Project Title	P.O.W.E.R.E.D. - **P**roject of **O**ffshore **W**ind **E**nergy: **R**esearch, **E**xperimentation, **D**evelopment
Project Code	087
Programme	IPA ADRIATIC CBC PROGRAMME 2007-2013
Priority	2 – Natural and Cultural Resources and risk Prevention
Measure	2.3 – Energy saving and renewable energy resources

Programme co-funded by the EUROPEAN UNION

Report

WP5 – Analysis and experimental evaluation of the environmental, infrastructural and technological issues

Authors	*Dissemination Level*	*Delivery Date*	*Version*
Data provided by the whole POWERED partnership **Final Report compiled by: Polytechnic University of Marche, Veneto Agricoltura and CETMA**	**RE**	**15/12/2014**	**3.0**

Table of Contents

List of Figures

CHAPTER 1

CHAPTER 2

CHAPTER 3

CHAPTER 4

CHAPTER 5

CHAPTER 6

List of Tables

CHAPTER 7

1. INTRODUCTION AND RATIONALE

1. INTRODUCTION AND RATIONALE

The actual energy request in the world increases greatly every year, in contrast with the decreasing availability of fossil fuels, which, to date, are still the basic resource to face current industrial activities and capacities of developing technology. Though a real and not promising picture, the reality is that the still large use of fossil fuels, besides their decrease by exploitation and corruption, is the main reason for which the climate is changing rapidly, with all consequences well delineated and quantitatively foreseen by the Intergovernmental Panel on Climate Change. On the other hand, under an utilitaristic vision, this condition has allowed promoting the study and increasingly use of green and blue energy as alternatives to fossil fuels resources.

The increasing consciousness of the human impacts on the environment, together with the will to reduce consumptions and conserve what is left in our environments, has been progressively growing in the last 30 years. Although nowadays the human population is, in general, much more conscious of the consequences of their actions, this does still not mean that we, as human beings, are sustainable for the Planet survivorship. Indeed, there are still lots of compartments of the Earth's human population that intends, egoistically, to exploit the natural resources up until their extinction.

The innovation and the technological capacities have taken us to create, model, destroy, use, accommodate many structures, machines and tools that we would have never imagined. In the actual times, since less than 20 years, these technologies have evolved rapidly and the use of wind, wave and solar energy is present in many countries. Depending on the will of the governments and of their economic conditions as well as of their natural characteristics, solar plants or wind farms are more or less abundant, and linked mainly to land. It is however only in the last decade that the wind industry is pushing harder. Great Britain, France and several Scandinavian countries have fastly established sustainable offshore wind farms, at least in the beginning to aid in the reduction of fossil fuels and increase the use of green and blue energies, as ratified by most countries in the Kyoto Protocol (first established in 1997) and, more recently, during the last Rio di Janeiro Summit (2012).

The interest of industry and governments, normally is in contrast with conservation and natural resources protection, and certainly the option of installation of offshore wind farms is not exempted of this contrast. To avoid or mitigate the contrast and to reduce to the maximum the impacts, spatial planning of these farms is a crucial and urgent need and should be the first part of the installation process together with an objective, impartial and science-based analysis of the potential impacts at all phases of plant installation and at all levels of stakeholding: environmental, social and economical. In addition, and requested by law, any project should have an associated Environmental Impact Assessment (EIA) concerning all the elements and establishing monitoring activities to be carried out before, during and after the life span of the wind farm to evaluate the real consequences and environmental effects of these alternative energy sources.

The latest aim of the wind energy industry is to promote the access to and the use of a non-fossil based energy resource, economically and ecologically competitive with the actual increasing energy demand from the world industry (Libert 2009; Elkinton et al. 2009; Henderson and Witch 2010; Lee et al. 2010; Perveen et al. 2014) but also in consonance with the environmental laws and in the respect of humans, their social issues and respecting the landscapes they have in the heart.

In this context, some governments have defined laws to compile and the engineers have started to elaborate measures to reduce the impacts of the different phases of the construction of the farms and to avoid negative opinions on the landscape and environmental issues. Among these crucial societal needs, an important part of the work deals with the acquisition of a positive (or at least not negative) public opinion. In principle it can be foreseen that if the population is contrary to the installation of large structures, possibly with some environmental effects and large visual impacts, like offshore wind farms, the procedures of public awareness building, on the one side, and of society convincing on the other one, are far more complicated (Walker et al. 2003; Ladenburg 2008; Walker and Judd 2010). A possible, relatively new, approach, also determined by law, is the preparation of Environmental Impact Assessments (EIAs) based on rigorous experimental designs to identify real effects and levels of eventual impact during all the phases of infrastructure construction, together with the identification of possible control, mitigation and, eventually, restoration measures (Chang and Jeng 2012; Lippert et al. 2013). Besides the increase in knowledge in specific fields related to wind energy and the increased number of wind farms deployed in the environment (including the sea), information and studies on the real effects of the installation of offshore wind farms are still at their infancy (Gill 2005; Gill et al. 2005; Fox et al. 2006; EnergiE2 2006; Inger et al. 2009; CEFAS 2010; Bergstrom et al. 2012; Mangi 2013; MMO

2013 and annexes). Such gaps of knowledge basically determine the difficultness to achieve the validation and weighting of the foreseen impacts.

In the last decade, the main issue, at least when dealing with environmental consequences of human activities, has moved from knowing the individual effects on each of the ecosystem(s) components towards the definition of the cumulative (and possibly synergistic) effects on the whole ecosystem (ecosystem approach). Another important step in assessing environmental effects of human activities is also to identify possible "tele-connected" effects, to prevent the so-called “butterfly effect” (if a butterfly beats it’s wings in one part of the planet, it could become a tornado in another part). Defining cumulative (additive, opposite or synergistic) effects implies having a lot of accessible and good quality data, lots of time, realistic maps, concise information, experimental measured results, and some good inferring instruments or predictive models. Unfortunately, it’s rare to find such complex and multivariate information and, more importantly, how to infer predictions on non-complete databases and non-reliable data is still a matter of scientific experiments and subjective approaches. As a result, the literature information on these procedures is still scarce, spatially and temporall fragmented, and scattered within hundreds of scientific journals and thousands of grey literature. Moreover, a large amount of data is likely "hidden" in private species-specific studies or site-specific studies.

There is an important matter of fact, highlighted already in the past (Gill and Kimber 2005; EnergiE2 2006; Madsen et al. 2010; De Decker et al. 2009; Jay 2010; Burger and Gochfeld 2012; Schumchemia et al. 2012; Bergstrom et al. 2012; MMO 2013 and annexes; Grilli et al. 2013) that the amount of gaps in knowledge is greater than the actual capacities (or wills to) of filling them.

Up to date, the existing offshore wind farms are typically placed within the territorial waters of one single country, and -besides some pilot projects- within the 12 nm national jurisdiction marine waters, using technologies that allow pales to be located at depths not exceeding 40 meters. The near future view of this industry foresees floating devices that can be settled up in waters with depths as high as 200 meters and, thus, further from the coast. As far as the marine environment is concerned, however, one of the most stricking issues resides in the still large lack of knowledge about the environmental characteristics of areas potentially usable for wind farm installations. This, in principle because of the poorly affordable and expensive technologies to study these environments on very large spatial scales, higlights the pressing need of undertaking in the incoming few years large documental and field investigations to fill up the gaps of knowledge about the ecologically sustainable marine environments receptivity for wind farms.

The possibility by the Adriatic sea to host wind farming activites, therefore, must be preceded by an accurate analysis of infrastructural and environmental conditions which could favor or impede offshore wind farm installations, to avoid conflicts among different marine uses and eventual environmental no-return impacts.

In this regard, the IPA Project POWERED (Project of Offshore Wind Energy: Research, Experimentation, Development) aims to define a set of strategies and methods common to the countries overlooking the Adriatic Sea valuable for the development of off-shore wind farms. The IPA-POWERED project aims to asses and validate the possibility, accounting all the factors that could influence the work, of the installation of offshore wind farms in the Adriatic Sea. At this aim the project is organized in six work packages (WP):

WP1 – Management and coordination
WP2 – Communication and dissemination
WP3 – Technological, normative, of energetic and environmental policy state of the art
WP4 – Numerical and experimental evaluation of wind energy resources in the Adriatic basin
WP5 – Analysis and experimental evaluation of environmental, infrastructural, energetic and technological issues
WP6 – Definition of Guidelines for the realization of off-shore wind parks in the Adriatic Sea

This report is the final output of the work carried out within the WP5 by a team of experts with expertise and skills in different fields (spanning from environmental analysis and impact assessment, landscape assessment, acoustic analysis, mapping techniques, infrastructures and OWF engeneering), aided in coordination with the documents and results previously provided by the Workpackage 3 (Technological, normative, of energetic and environmental policy) and Workpackage 4 (Numerical and experimental evaluation of wind energy resources in the Adriatic basin).

This report has profited of data and information provided, at different levels, by all institutional and scientific partners involved in the project. The final report, representing the rationalization of a huge amount of punctual and documental information collected over the entire duration of the project, has been compiled by all partners and finally summarised by an interdisciplinary team of experts including:

- Prof. Renato Ricci, Department of Energetics, Polytechnic University of Marche, Expertise: off-shore wind farm engineering
- Dr. Sergio Montelpare, Department of Energetics, Polytechnic University of Marche, Expertise: off-shore wind farm engineering
- Dr. Valter Lori, Department of Energetics, Polytechnic University of Marche,Expertise: acoustic
- Prof. Antonio Dell'Anno, Department of Life and Environmental Sciences, Polytechnic University of Marche, Expertise: marine biology and ecology
- Prof. Antonio Pusceddu, Department of Life and Environmental Sciences, Polytechnic University of Marche, Expertise: marine biology and ecology
- Dr. Carla Huete Stauffer, Expertise: marine biology and ecology, marine GIS
- Dr. Francesca Marcellini, Expertise: marine biology and ecology
- Dr. Daniela Moderini, Expertise: landscape architecture

Chapter 2.5 has been entirely compiled by Dr. Valter Lori

Chapters 3 and 4 have been mostly provided by Veneto Agricoltura and implemented by UNIVPM

Chapter 6 has been entirely compiled by CETMA.

2. OFFSHORE WIND FARM IMPACT ANALYSYS

2. OFFSHORE WIND FARM IMPACT ANALYSIS

2.1 Literature search

Within the WP5, the literature research for the bio-ecological analysis of the Adriatic basin aimed at the identification of the possible impacts of OWFs was based on published literature, grey literature, official websites, EIAs, VIAs, EEA reports and projects, and even internet blogs. The searching approach was intended as more holistic as possible since the information searched for included infrastructures, protected zones, naval issues, coastal environments and offshore environments, environmental risk issues and all the components that could interfere in the installation and operation of an offshore wind farm in the Adriatic Sea.

2.2 Rationale for the impact analysis

As briefly anticipated above, the goal of the WP5 is to collect the greatest amount of information on the (environmental) effects of the installation of a putative offshore wind farm in the Adriatic Sea. After collecting and reporting all the obtained data the objective is to weight this information and map it, to have a spatial weighted analysis on which to identify the environmental constrains associated with the energetic basins identified by WP4.

The final objective of WP5 is thus to elaborate a semi-quantitative and qualitative analysis of the constraining environmental and infrastructural conditions and their location in the Adriatic space, in order to give each constrain a weight to be assigned and to create a spatial conflict analysis for each area and constrain (Figure 2.1).

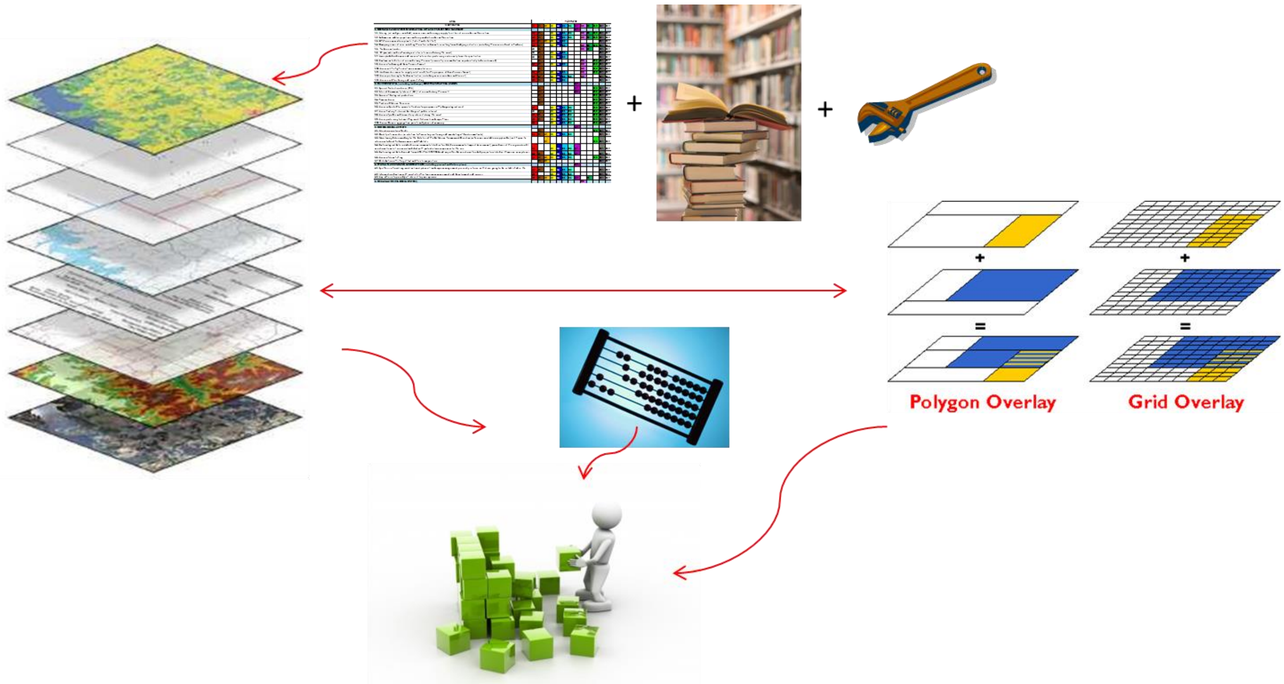


Figure 2.1. Workflow for environmental constrains for WP5

All the material regarding the impacts of offshore wind farms, the effects of offshore installed structures at sea, the biocoenosis of the Adriatic Sea, the ecological aspects of this enclosed sea, the environmental constrains, the protected areas, the EIAs of other countries as Great Britain or Denmark, which account with a long history of offshore wind farms, was collected and settled in a database with hyperlinks to retrieve the bibliography in a semi-automatic way. The origin of the material included in this database was mainly obtained from ISI or Scientific Journal publications, partly from grey literature and EIA Reports, partly from congress proceedings and a limited amount of the documents used for the WP5 purposes from other sources. The research on bibliography used primarily Google Scholar, ISI, Scopus and Wiley repositories to search the publications of use for the goal, and to download the content in a semi-economic way.

2.3 Method for the impact analysis

All the retrieved information was used to create a matrix of potential impacts during all the phases of the installation and their effects on the various elements of the marine environment (fauna, flora, currents, etc.) based on the levels of change in behavior of each element. For each putatively affected bio-ecological component (e.g. mammals, birds, currents), for each phase of the installation (pre-installation and design, construction, operation, decommissioning)[1], and divided by levels of the turbines (air level over blades, blade level, air fraction of pile, water surface, underwater fraction of pile, settling structure-bottom level and settling structure-sub-bottom level) we assigned a qualitative value of impact (Table 1).

Table 2.1. Conceptual framework for the qualitative validation of impacts and their weighting

Does it have an effect? Which degree?	What temporal extension of the effect?	Symbols for cells effect degree	Basis for assignment of degree	Weighted values of effects	Basis for assignment of weight
Yes	Long-term	Y	Demonstrated	9	Radically changes behaviour
No	Medium-term	N	Demonstrated or conditions do not allow "interaction"	1	No behavioural change
Very high	Short-term	Vh	Demonstrated or conditions allow "interaction"	10	Radically changes behaviour
High	All times	H	Demonstrated or conditions allow "interaction"	9	Changes behaviour
Medium		M	Demonstrated or conditions allow "interaction"	8	Could affect behaviour
Low		L	Demonstrated or conditions allow "interaction"	5	Behaviour change won't affect life style
Possible		Pr	Depends on conditions, components	6	Not assessed change but putatively
Probable		R	Close to demonstrated	7	Probabilities on behaviour change are high
Improbable		I	Depends on conditions, components	2	Improbable behaviour change
Unknown		U	No studies found		
Suspected		S	Hypothetically yes	3	
No available info		Nai	No available data-information	-	

Once the matrix was completed each qualitative value was substituted with a numeric value (10 to 1): very behavior "high change" was ranked 10, whereas "improbable" behavior change ranked 1. With the weighted matrix we analyzed the level of **expected effects** of each phase of wind farm operation on the marine community and bio-ecological characteristics.

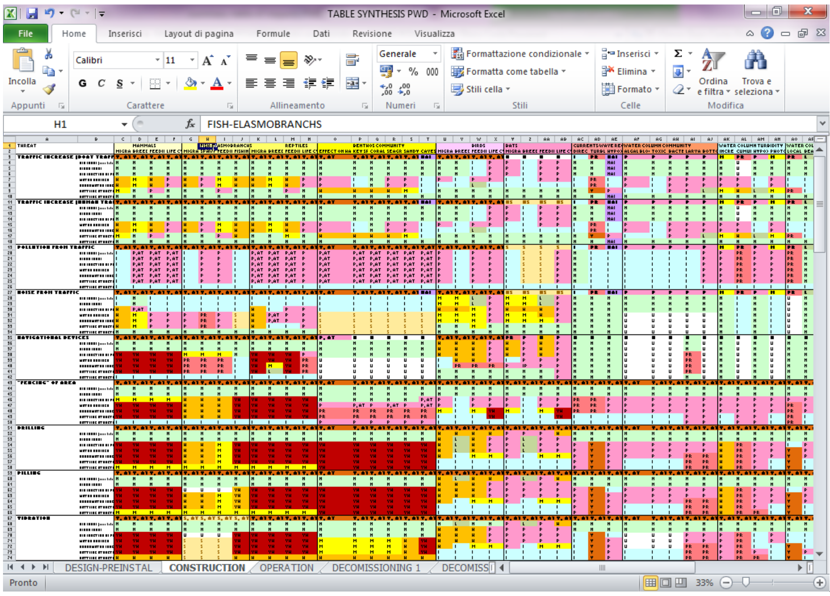
All the data used during this phase are updated to 1st July 2014, and concern information collected from the literature, open access EIAs documents and some experimental studies that have in some or other way studied the considered issue. The data collected was reported in the matrix as potential change of behavior, with no subjective validation. The various behaviors were lienked to the various phases of the installation and at the various

[1] NOTE: Decommissioning 1 considers decommissioning with total or subtotal removal of piles and Decommissioning 2 considers decommissioning with the removal of only aerial parts of piles.

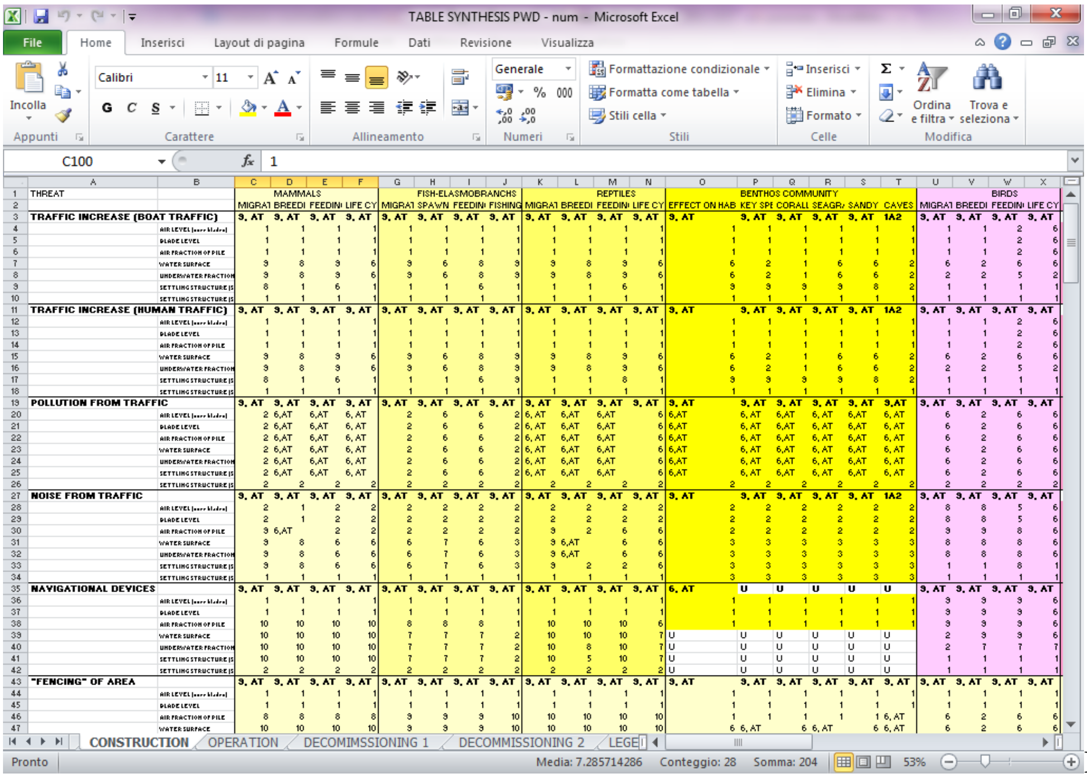
levels of the turbines. Some examples: a shark improbably will change its behavior by the presence of the air fraction of the turbine, but if birds do change their behavior due to the presence of the turnies, that shark can change its route of hunting superficial birds for feeding; benthic communities will not be affected by the turbine operation, but since the destruction of the bottom does affect them, the result is that thay are very vulnerable to change behavior; transport of boats and turbines will disturb (changing their behavior) most of the pelagic community, thus this change is probably lower in the benthic community.

2.4 Results of the behavioral impact analysis

A direct and indirect research of publications related with biocoenosis, ecological characteristics as protected areas (SIC, ZPS, Natura 2000, Ramsar sites, EMERALD sites. etc.), bird migration routes, mammal sensitive areas, currents, environmentally at risk areas, sedimentation rates and all the possible effects on the various communities and habitats of the installation of offshore wind farms, considering monopiles or tripode turbine farms (up to 40m depth) or floating turbine farms (up to 100m depth) was carried out. All of the retreated publications were included in a database for the metadata on publications and summarized in a review on the putative effects of offshore wind farms. The matrix created showed a sort of heat-map of the effects of the different phases of construction and elevation levels (see the example in Figure 2.3).



A



B

Figure 2.2. Example of a compiled matrix for the OWF construction phase. A) is the qualitative matrix shown as a heat-map where dark orange=YES, green=NO, red =VERY HIGH, orange=HIGH, yellow=MEDIUM, light green=LOW, pink=POSSIBLE, salmon=PROBABLE, blue=IMPROBABLE, white=UNKNOWN, light yellow=SUSPECTED and violet=NO AVAILABLE INFORMATION. B) is the weighted matrix, where each of the qualitative values corresponds to a number as orange=YES=9, green=NO=1, red =VERY HIGH=10, orange=HIGH=9, yellow=MEDIUM=8, light green=LOW=5, pink=POSSIBLE=6, salmon=PROBABLE=7, blue=IMPROBABLE=2, white=UNKNOWN=blank, light yellow=SUSPECTED=3 and violet=NO AVAILABLE INFORMATION=blank.

With the weighted heat-map as a basis, we then calculated the cumulative values per phase by summing all the values in the matrix for a defined environmental condition. Besides, we calculated the average values for the same conditions. Our results, as expected, show how the **construction phase** is the one of highest impact followed by Decommission 1; the least impact occurs during the pre-installation phase (Figure 2.3)

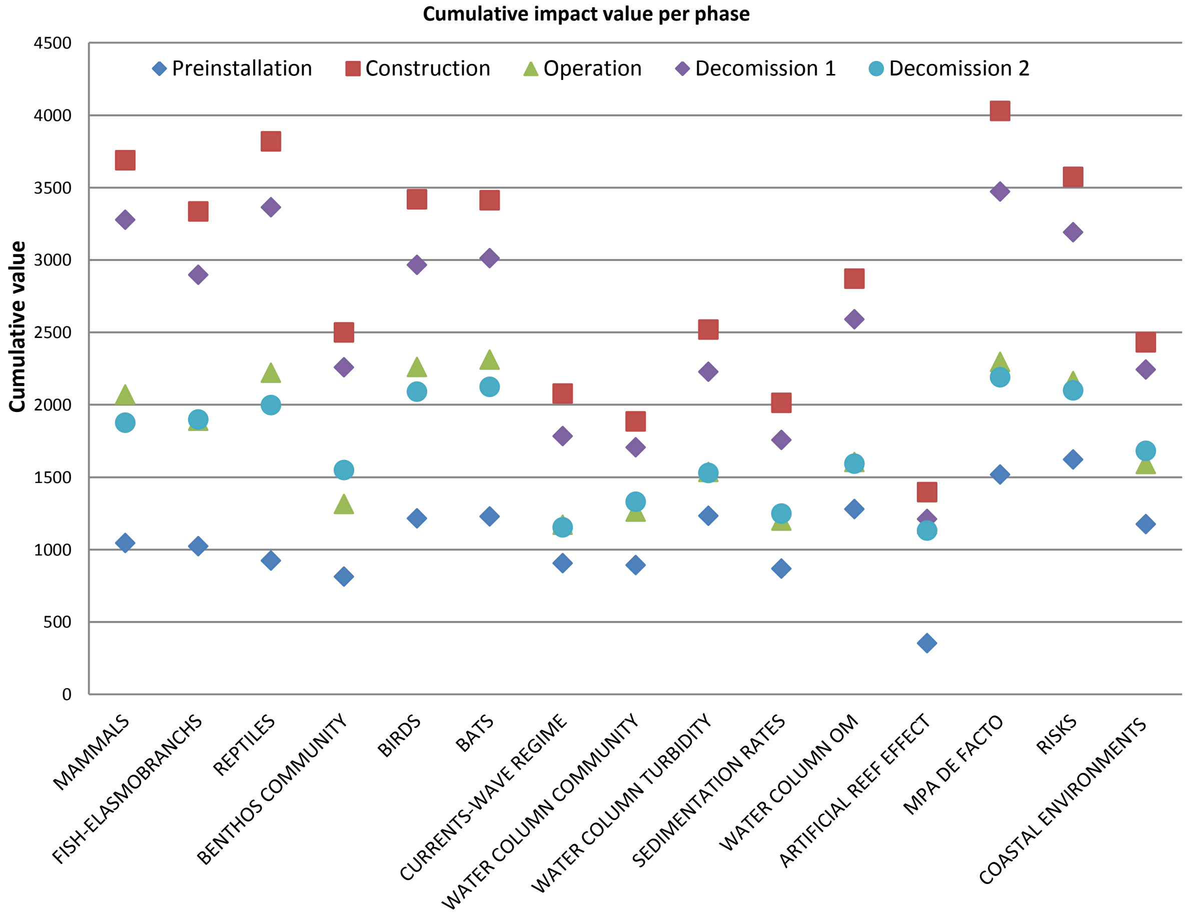


Figure 2.3. Cumulative impact value for each bio-ecological component for each phase of the life of the farm.

2.5 Offshore wind farm noise emission: impacts on marine life and mitigation procedures

2.5.1 Introduction

The Marine Strategy Framework Directive (MSFD, Directive 2008/56/EC of the European Parliament and of the Council), whose goal is to achieve and/or maintain a "Good Environmental Status" of the marine environment by 2020, introduced underwater noise as a descriptor of the environmental status. Marine fauna exposed to anthropogenic sound may indeed experience detrimental effects that include, behavioral disturbance and displacement, masking of biologically important signals, and other indirect effects. The potential effects depend on a number of factors, including duration, nature and frequency content of the sound, received noise level (sound level at the animals), overlap in space and time with the organism and sound source, and context of exposure (e.g., animals may be more sensitive to sound during critical times like feeding, breeding/spawning/, or nursing/rearing young). The highest powered sounds can entail physiological responses causing injuries or even leading to death. Extensive investigation mainly over the last fifteen years by academia, industry, government agencies and international bodies has resulted in a number of reviews of the effects of sound on marine fauna. Negative impacts for many marine species have been reported in scientific studies until today.

There is a great need for knowledge concerning the noise impacts of offshore wind power on marine life Incomplete studies of these impacts could give a reduced view of the effects which could lead to deficiencies in the processes surrounding the establishment of new wind farms. Since the beginning of the planning and installation of offshore wind farms, the possible noise impacts on the marine life have been discussed intensively. In fact one of the most important possible adverse effect of offshore wind farms relates to the underwater noise generated during the construction and operation of wind turbines. Quantifying the extent of the effect is a difficult task given the high variability of the characteristics of noise sources, of the sensitivity of different marine species and of the spatial scale of noise-produced. Knowledge of the effects, on marine life, of noise generated during the different phases of the wind farms lifecycle is limited and mainly based on data from monitoring at specific sites, similar industrial activities, researches sponsored by governments, and predictions provided from environmental impact assessments (EIAs) for proposed wind farms.

This chapter provides some basic element of underwater noise in the first section. The second section analyzes the key elements needed to assess the effect on marine life of the noise produced by wind farms: the wind farm lifecycle in relation with the main noisy activities connected and the technologies used, the background sea noise and the influence of the choice of the noise propagation model. The known and potential effects on marine mammals and on fishes are provided in the third section, on the base of the hearing sensitivities and the available threshold criteria for the different species. The fourth section gives a summary of the best practice and mitigation procedures for underwater noise produced by wind farms.

2.5.2 Basic elements of Underwater Noise

This section introduces some basic elements of underwater acoustic. A basic understanding of the terms, of the units and of some concepts used to describe underwater sound is required when assessing and interpreting the potential impact on marine life arising from wind farm produced underwater noise.

2.5.2.1 Nature of sound

Sound is a mechanical disturbance that travels through an elastic medium (e.g. air, water or solids). Sound is created if particles in such a medium are displaced by an external force and start oscillating around their original position. These oscillating particles will also set neighboring particles in motion as the original disturbance travels through the medium. Sound waves, in water as in air, are therefore compressional (longitudinal) waves that propagate through the interior of the medium as pressure fluctuations. The rate of change of these pressure fluctuations determines the frequency of the sound which is measured in hertz (Hz); defined as the number of complete vibration cycles per second. Sound wave amplitude is commonly measured as the difference between equilibrium and maximum positive pressure (peak) or as the difference between maximum positive and maximum negative pressure (peak to peak) of the waveform. The RMS pressure value of the waveform, is calculated as the square-root of the mean-squared pressure of the waveform over a period of time (Figure 2.4). RMS values are often used since the intensity of the sound is averaged over its duration.

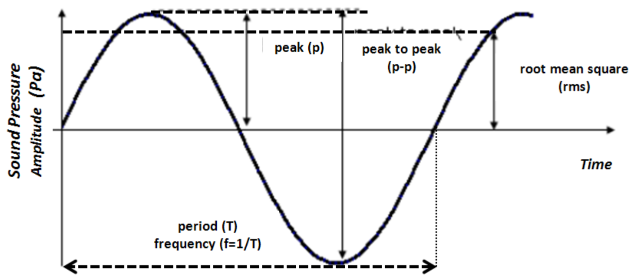


Figure 2.4 Spatial pressure variation of an acoustic sinusoidal wave

2.5.2.2 dB unit

Sound measurements are usually expressed using the decibel (dB) scale, which is a logarithmic measure of sound. This due to the fact that the ears of many animals are able to detect sounds over a vast range of amplitudes, sound pressure is rarely directly reported. Therefore, to compress this dynamic range into a convenient range of values, a logarithmic scale is used. This scale is also useful to approximate human hearing, since the human ear judges perceived "loudness" on a logarithmic scale. Any quantity expressed in this scale is termed a "level". If the unit is sound pressure, expressed on the dB scale it will be termed the "Sound Pressure Level". The fundamental definition of the dB scale is:

$$dB = 10\log10(X/X_{ref})$$

where X is the quantity being expressed on the scale, and X_{ref} is the reference quantity. The dB scale represents a ratio and is therefore used with a reference unit, which expresses the base from which the ratio is expressed.

For instance, a reference quantity of 20 µPa is usually used for sound in air, since this is the threshold of human hearing. For underwater sound typically a unit of 1 µPa is used as the reference unit.

Comparing the sound pressure levels in air and water is not straight forward as the reference pressures are different. This difference can be calculated as follows:

Difference* (dB) = 20log10 (air reference pressure/water reference pressure) = 26 dB

*in the numerical value to the same RMS pressure

Moreover, when comparing sound measurements in air and in water, the sound velocity and density of the medium (acoustic impedance) must also be considered. For two sources of equal intensity in air and water the sound pressure levels produced in water will be 62 dB than in air. 26 dB will be add due to the difference between the reference pressure and 36 dB will be added due to the difference of the acoustic impedance.

2.5.2.3 SPL_{RMS} - Sound Pressure Level

The more common convention in underwater acoustics for expressing Sound Pressure Level (SPL) is for it to be expressed as a root mean square (RMS) value.

The RMS Sound Pressure Level is normally used to characterize noise and vibration of a continuous nature such as drilling, turbine operational noise or background sea noise levels. To calculate the SPL, the variation in sound pressure is measured over a specific time period to determine the Root Mean Square (RMS) level of the time varying sound. The SPL_{RMS} is so related to the time averaged acoustic power and can therefore be considered to be a measure of the average unweighted level of the sound over the measurement period.

$$p_{RMS} = \frac{1}{T}\int_0^T p(t)^2 \, dt$$

$$Lp = SPL_{RMS} = 10\log\frac{p_{RMS}^2}{p_{ref}^2} = 20\log\frac{p_{RMS}}{p_{ref}} \mathrm{dB}$$

where:

If P_{ref}= 20 µPa in air	SPLRMS [dBre20 µPa]
If P_{ref}= 1 µPa in water	SPLRMS [dBre1 µPa]

2.5.2.4 Peak Level

Pulse sounds are all characterized by a relatively rapid rise from ambient pressure to a maximal pressure value followed by a decay period that may include a period of diminishing, oscillating maximal and minimal pressures. Pile driving using an impact hammer during construction of the foundations of an offshore wind farm is an example of underwater noise that is characterized as pulsed sound.

Impulse sounds may be characterized by peak level. Lpeak, which is the maximum level of the acoustic pressure. Is used as a measure for maximum sound pressure peaks without time or frequency weighting and without averaging.

$$\mathrm{Lpeak} = 20\log\frac{p_{peak}}{p_{ref}} \qquad [\text{dB re } 1\ \mu\text{Pa}]$$

Here, p_{ref} is the reference sound pressure in 1 µPa and ppeak the maximum positive or negative sound pressure ppeak.

$$p_{peak} = \max|p(t)| \qquad [\text{ Pa}]$$

2.5.2.5 Peak-to-peak Level

The peak-to-peak level is usually calculated using the maximum variation of the pressure from positive to negative within the wave. This represents the maximum change in pressure (differential pressure from positive to negative) as the transient pressure wave propagates.

$$L_{peak\ \ peak} = 20\log\frac{\max|p(t)| - \min|p(t)|}{p_{ref}} \qquad [\text{dB re } 1\ \mu\text{Pa}]$$

Here, p_{ref} is the reference sound pressure in 1 µPa.

Where the transient pressure wave, generated by an impulsive noise source, is symmetrically distributed in positive and negative pressure, the peak to peak level will be twice the peak level, and hence 6 dB higher.

2.5.2.6 Sound Exposure Level SEL

The Sound Exposure Level (SEL) is a measure of the energy of a sound; therefore it depends on both amplitude and duration. The sound exposure level SEL (LE) characterizes impulsive noise:

$$SEL = L_E = 10\log\frac{\int_0^T p^2(t)dt}{p_{ref}{}^2 T_0} \qquad \text{[dB re 1 µPa2 s]}$$

where T_0 is the reference time in 1 s and T the averaging time [dB re 1µPa^{2}s]. For the evaluation of single sound events, the averaging time corresponds to the duration of the event [dB re 1µPa^2 over pulse duration].

The Sound Exposure Level sums the acoustic energy over a measurement period, and effectively takes account of both the SPL of the sound and the length of time the sound is present in the acoustic environment.

The corresponding SPL_{RMS} values could be derived from the SEL-values using following equation:

$$SEL = SPL_{RMS} + 10\log T$$

where T is the time (duration expressed in seconds).

Therefore, for continuous sounds of duration less than one second, the SEL will be numerically lower than the RMS. For periods greater than one second the SEL will be numerically greater than the RMS.

2.5.2.7 SEL cumulative

In an evaluation of pile driving impacts on marine life, it may be necessary to estimate the cumulative SEL ($SEL_{cumulative}$) associated with a series of pile strike events. $SEL_{cumulative}$ may be estimated from a representative single-strike SEL value (e.g. expressed as [dB re 1µPa^{2}over pulse duration]) and the number of strikes that likely would be required to place the pile at its final depth by using the following expression:

$$SEL_{cumulative} = SEL_{single\ strike} + 10 \log (n° \text{ of pile strikes})$$

This equation assumes that all strikes have the same SEL value and that an animal would continuously be exposed to pulses with the same SEL, which is never actually the case. The equation, however, provides a reasonable estimation of the cumulative SEL value, given a representative single-strike SEL value and an estimate of the number of strikes.

2.5.2.8 Spectrum analysis

The spectrum of a sound, provides information on the distribution of the energy contained in the signal or the 'frequency content' of a sound. The term bandwidth describes the way the frequency range of sound is analyzed. A normalized bandwidth of 1 Hz is standard practice in mathematical analysis of sound, while 1/3 octave bandwidths are most common in physical analysis.

This choice allows to express the sound level as a function of frequency, where each band is, commonly, one third of an octave. In most cases it could be expressed as spectral density levels in third octave bands, in units of dB re 1 $\mu Pa^2/Hz$, where the values of each third octave band must be divided by the bandwidths. This is different from third octave band power spectra [dB re 1 μPa^2]. The spectra analysis of measured underwater noise therefore needs some indication of the analysis bandwidth and of the displaying units.

2.5.2.10 The speed of underwater sound

The speed of sound underwater varies significantly from speed of sound in air as the two mediums have very different properties. The sound travels faster through medium with higher incompressibility and/or lower density. The water has higher density than air but is harder to compress (higher bulk modulus) making the sound speed around 4.3 times higher in water than air. If the medium is more compressible more sound energy is used up for compressions and rarefaction and this results in lower sound speed .

In fresh water, sound travels at about 1497 m/s at 25 °C, while at the same temperature the speed of sound in air at sea level is 346 m/s. In sea water the speed of sound has a nominal value of 1500 m/s. The speed is also influenced by the temperature of water and furthermore in seawater, which is a non-homogeneous medium, there are other factors that affect the speed of sound namely salinity and water depth (pressure).

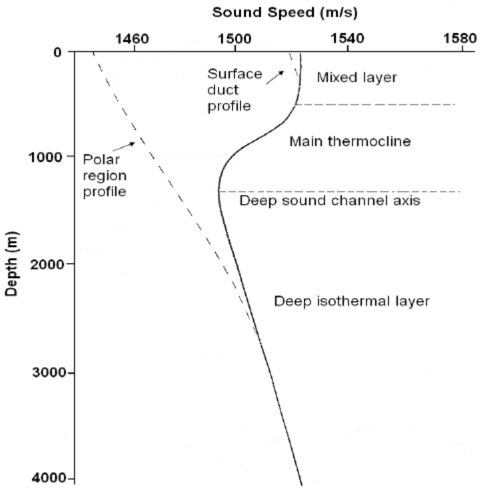


Figure 2.5 Sound speed profile in deep ocean

The approximate sound speed variations as a function of depth are given in Figure 2.5 for a layered deep ocean. Sound speed profile may be divided in several layers. Just below the surface the speed is susceptible to daily changes due to heating, cooling and wind action (mixed layer); main thermocline layer is a region where speed is by a negative gradient due to the decrease of temperature with depth; below. Below the main thermocline layer, the sound speed increases with depth, due to the increasing hydrostatic pressure, down to the deep ocean (deep isothermal layer). Between main thermocline layer and the deep isothermal layer there is the deep sound channel axis, where sounds from sources placed in this region may be caught within the channel and travel to great distances without appreciable losses, due to surface or bottom reflections.

Sound speed profile in shallow water is downward refracting or nearly constant over depth due to the shallow depth conditions. Typical shallow water are water depths down to 200 m. In shallow water, the surface volume and the bottom properties are all important.

A common feature of shallow water is the existence of a low frequency cut-off. Hence there is a critical frequency below which the shallow water channel ceases to act as a waveguide, causing that energy radiated by the source propagates itself directly into the bottom. For rigid bottoms the cut off frequency occurs at Depth = $\lambda/4$ where λ is the acoustic wave length (Urick 1983).

2.5.2.10 Sound propagation model

The generation and propagation of underwater noise is affected by the geography and geology of the windfarm location.

Underwater noise propagation models predict the spreading of sound from a noise source throughout the marine environment. An underwater noise model can predict the sound transmission loss (TL) between the source and a receiver. Given the source level (SL) of the considered noise source, the predicted TL across the transmission path is used to predict the sound pressure level (SPL) at the receiver location (RL) as:

$$RL = SL - TL$$

Factors that determine the transmission loss are discussed below.

2.5.2.10.1 Source Level SL

The source level SL is metric used frequently in underwater acoustics to describe the source output amplitude, a term not commonly used in airborne acoustic where the acoustic power level is used. SL might be expressed as dB re 1 µPa at 1m [dBre1 µPa•m]. It is often designated,, in literature, as the sound pressure level which is ideally "measured" at 1 m distance from an isotropic radiator. SL could be also expressed in term of sound exposure level [dBre1 $\mu Pa^2 \cdot m^2$]

In practice, for real sources, the Source Level is calculated by measuring the received level at a distance from source which is in the acoustic far-field and propagating the acoustic pressure back to the reference distance of 1m from the acoustic center of the source using an appropriate propagation model. It is necessary to point out that in most case for real sources the reference distance of 1m might be in acoustic near-field region where the acoustic energy amplitude oscillate due to the constructive and destructive interference of the acoustic pressure waves. For that reason the source level value is a virtual size which cannot be metrological determined at 1 m distance.

2.5.2.10.2 Received Level RL

Sound pressure level which is recorded at a measuring place (distance r from a source). It could be also considered as the sound pressure level which arrive at the receptors exposed to the noise/sound sources. This could be composed of contributions of several sound sources and/or contributions from various interactions/reflections of the sound with sea surface, sea bed, etc. RL could be expressed as a sound pressure level, dB re 1 μPa, but also as a sound exposure level, dB re 1 $\mu Pa^2 s$.

In case it is necessary to predict received level from estimated source level for evaluate the zone of impact, the received level (RL) could be determined by subtracting a transmission loss value from the source level:

$$RL=Lp(r)= SL-TL$$

In case the source level (SL) is evaluated from measured received levels (RL) at different distances from the source, SL could be determined by addicting the received level with a transmission loss value:

$$SL=RL+TL$$

2.5.10.3 Transmission Loss TL

Transmission loss TL is the term used to describe the reduction of the sound level, in dB, as a function of distance from an acoustics source. This reduction is mainly due to the geometrical spreading (i.e. the distribution of sound energy on a large enveloping surface), especially along the direct propagation path between the source and the receiver. Other important factors to consider, especially in order to evaluate the influence of multiple transmission paths which can occur due to reflections from sea surface and seabed, are reflection, absorption, scattering and refraction phenomena. A rough surface or seafloor causes scattering of the source noise, and some of the noise impacting on the seafloor is absorbed. Temperature variations in the water column cause refraction of sound. These transmission loss mechanisms are generally frequency dependent, and depend on the seafloor geo-acoustic properties and the surface and seafloor roughness.

The combination of the various transmission loss mechanisms give a total transmission loss. Frequently a simplification is made by assuming that the Transmission Loss may be approximated due to spreading and absorption losses such that:

$$TL = N\log(r) + \alpha r$$

where r is the distance from the source in metres, N is the constant coefficient for attenuation due to geometric spreading, and α is a factor for the absorption of sound in water and at boundaries in dB/m (Urick, 1983). The absorption coefficient is frequency-dependent: absorption of sound by seawater increases with increasing frequency with energy loss being proportional to the square of frequency (Urick 1983; Richardson et al. 1995).

Several mathematical models exist which estimate Transmission Loss for given water column properties. As wind turbines are currently planned in relatively shallow waters up to 50 m water depth, geometric spreading might be described by cylindrical spreading, with N= 10 (Richardson et al. 1995). However, several field studies indicated a higher geometric spreading in shallow waters, sometimes being higher than 20 log(r), depending on local conditions (Nedwell et al. 2003; Nedwell et al 2004; Madsen et al. 2006) as often assumed near to a source in deep water.

Thiele (2002) developed a formula that is applicable for coastal North Sea and Baltic waters with water depths up to 100 m, a sandy bottom and wind-speeds < 20 knots, where geometric spreading is intermediate between spherical and cylindrical spreading for 100 Hz (N= 15), closer to spherical spreading for 2 and 10 kHz, higher to spherical spreading over 10kHz. However, the limitations of these simplified models should be considered carefully.

2.5.3 Underwater noise of off shore wind farms, pre-existing noise and choice of propagation model

A complete understanding of offshore wind farms is required for any assessment of their environmental effect. The technology, duration and noise produced by events related to the development of a wind farm will have an influence on their effect on local marine wildlife. Also the location of the wind farm will have important influences on the environmental impact especially in term of pre-existing noise and underwater sound propagation.

2.5.3.1 The offshore wind farms lifecycle

The activities likely to occur during the complete life of a typical off shore wind energy project constitute the wind farm's lifecycle. The wind farm's lifecycle can be split into four different phases:

- the pre-construction/exploration phase,
- the construction phase,
- the operational phase
- the decommissioning phase.

Each phase is characterized by different marine activities (noise sources) and different length of time. Knowing the characteristics of the main noise sources and the length of time the marine environment is exposed to an underwater noise source is useful to assess environmental effect on marine life.

2.5.3.2 Pre-Construction - Construction phase's noise sources

Pre-construction phase and construction phase of an offshore wind farm may have similar characteristics in term of length of time and noise sources involved.

Both phases could take approximately one year each, however the exploration phase could be longer. Activities that occur during the pre-construction phase might include geophysical and geotechnical survey, meteorological mast installation and an increase in vessel traffic. Vessel traffic will increase in the vicinity of wind farm before its construction and continue through to decommissioning.

One of the most significant activities during wind farm construction, in term of noise produced and length of time taken, is represented by the foundation installation.

At present due to economic and technological reasons, the preferred foundation type is a driven mono pile, however other options are available including gravity foundations and multi pile foundations. Impact pile driving is the prevailing installation method for offshore wind turbines in shallow water (<40m).

Literature provides many measurements of sound pressure levels made during pile installation with impact hammer and different studies have pointed out physical and behavioral effects on marine life during this activity.

Drilling might be required during piled foundation installation. Dredging and rock laying may be also undertaken during wind farm construction.

Table Errore. Nel documento non esiste testo dello stile specificato..**2**. Noise levels and acoustic parameters related to main activities involved in the construction phase

Source	Source Level [dB re. 1 µPa 1m]	Unit	Frequency Range [Hz]	Major Amplitude Range [Hz]	Duration [ms] /Type of noise
Pile Driving	190-250 230 peak / 243-257 peak to peak	SPL RMS SPL	20 -20000	100 -500	Impulsive 50/100 ms
Vibro Driving	160-190	SPL RMS	20 -20000	< 2000	Continuous
Drilling	145-190	SPL RMS	10 - 10000	< 100	Continuous
Dradging	168 - 188	SPL RMS	30- 20000	100 - 500	Continuous
Rock Laying	whithin background noise				Continuous
Shipping	150 - 190	SPL	function of ship type		Continuous

Table 2.2 shows the measured noise levels and some acoustic parameters related of some of the anthropogenic sources that are required during the exploration and construction phase of the offshore wind farms.

Other construction activities include cable laying, turbine and turbine tower installation, and ancillary structure (e.g. offshore transformers) installation, but no measurements of the noise produced from these processes are available in literature.

2.5.3.2.1Impact Pile Driving Noise

Piling, for offshore installations, is one of the strongest sources of underwater noise. Mono pile foundation used for offshore wind farms is basically a cylindrical tube, usually made of steel, which is directly installed into the seabed using hammering. Impact pile driving is the prevailing installation method for offshore wind turbines. This technique can be used for several soil types and, since its introduction in the offshore projects, the mono pile has become larger and heavier. It has been applied to water depths up to 40 m. The diameter of the pile varies, depending on foundation type (mono pile 4-8 m, tripod 3-4 m, jacket 1-2 m). There is a great need of knowledge on the real mechanism of underwater noise generation and propagation during impact pile driving. Analyzing the different noise transmission paths it is believed that, the sound transmitted by the mono pile (structure-borne radiated path, generated at the interface between the pile and the water), is the dominant path in most cases. The seismic path (sea floor) it is believed to be less important for the overall underwater sound; however, in a few cases, it could be the main path at few frequencies, if sound isolation technologies (e.g. bubble screen or compliant layer treatments) are being applied. The airborne path is not a significant contributor to underwater sound (Stokes et al., 2010) because the majority of airborne transmission of pile hammering noise will be reflected at the sea surface due to the difference in acoustic impedance for air and water, and due to the angle of incidence (if greater than 13°).

The single impact pile driving noise is a relatively short and loud impulsive sound. Peak levels and sound exposure levels of pile driving are very high. The single pulses (Figure 2 1) are between 50 and 100 ms in duration with app. 30 - 60 beats per minute (Nedwell et al. 2003; Nedwell et al. 2004; ITAP 2005; Madsen et al. 2006).

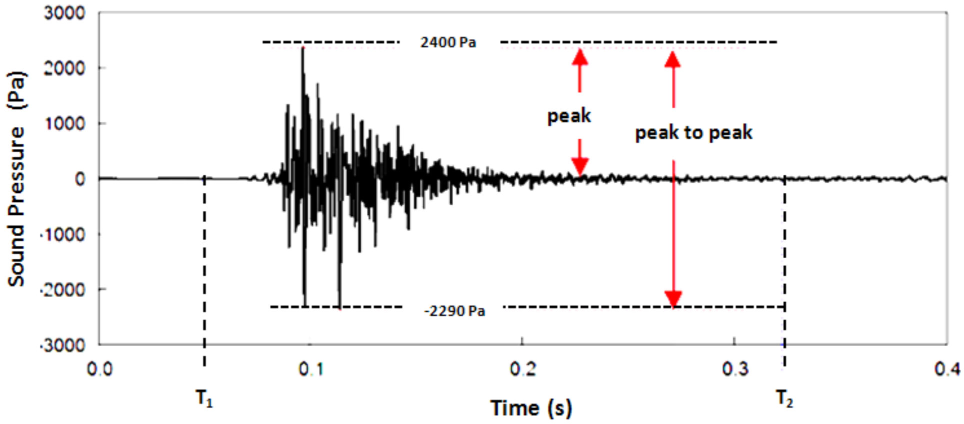


Figure 2.6. Time history of the Sound Pressure of a single typical impulse pile drive noise (Nehls et al 2007)

Typical source levels range from SEL 170–225 dB re 1 μPa^2•s for a single pulse, and peak level 190–260 dB re 1 μPa. Nedwell has estimated a source level as high as 262 dB re 1μPa (SL 1m) for piling associated with the construction of the North Hoyle and Scroby Sands wind farms (Nedwell et al. 2004). In Table 2.3 are synthetized some literature measurements of piling noise during the construction of mono pile foundations.

Table 2.3 Piling noise during installation of few mono pile foundation

Park	Pile diameter [m]	Measuring distance [m]	Peak Level [dB re. 1 µPa]	SEL [dB re. 1 µPa^{2}s]	References
Fino 1, Germany	1.6	750	192	162	Ainslie et al. 2009
Fino 2, Germany	3.3	530	190	170	Ainslie et al. 2009
Amrunbank West, Germany	3.5	850	196	174	Ainslie et al. 2009
Q7 Park, Netherlands	4	890 - 1200	195	172	Ainslie et al. 2009
Utgrunden	3	30 320	203 183	184	ØDS. 2000
North Hoyle	4	955 1881	192 185		Nedwell et al. 2004
Horns Rev	4	230 930	185 178		Tougaard et al 2008

The results of measurements during pile driving at various offshore locations show a positive correlation between the used blow energy, the pile diameter and the resulting sound pressure level. Other parameters which influence the sound pressure level are the soil structure, the water depth and the length, material and shape of the pile.

The spectrum analysis of a single stroke of pile driving noise shows broad-band noise levels (20 Hz - 20 kHz) with main energy concentrated at lower frequencies, < 1000 Hz, and the maxima of the spectral distribution in the frequency range between 100 Hz and 300 Hz (Ainslie et al., 2009).

The impact pile driving technique is of special concern for the marine environment as it generates very high noise levels, that have the potential to harm marine organisms like marine mammals or fish also over considerable distances (Nedwell et al. 2004a; Madsen et al 2006).

Due to the high sound pressure levels produced by impact pile driving activity and its potential impact on marine life, in Germany dual threshold values have been defined for the approval process of offshore wind farms in the EEZ by the approving authority BSH. During pile driving, the underwater noise sound pressure levels must not exceed 160 dB re 1 µPa^2•s

(SEL) or 190 dB re 1 μPa (Lpeak-to-peak) at 750 m from the piling source (UMWELTBUNDESAMT 2011, BSH 2012).

2.5.3.3 Operational phase's noise sources

The operational phase is recognized as the period of longest disturbance. The operational noise will occur over a number of years (currently windfarms are designed to have a 20 to 25 year life-span) and thus the marine environment will suffer a longer period of exposure to operational noise than any other noise source connected to the lifecycle of the project.

During this phase the main noise source is represent by the wind turbines noise. The underwater noise of a wind farm in operation depends both on the type of wind turbines installed, both on the type of their foundation.

Ship-traffic noise will also increase in the area of wind farm due to maintenance operations during the operation phase.

2.5.3.3.1 Wind turbines' operational noise

Noise from wind turbines comes in two forms: the first is aerodynamic noise mainly radiated from the blades and associated with the interaction of turbulence with the blade surface; the second is mechanical noise associated with machinery housed in the nacelle of the turbine(Wagner et al. 1996).

Mechanical noise is created by imbalances of the rotating components, the teeth in the gearbox coming into contact with each other (referred to as gear meshing), and electro-magnetic interaction between the spinning poles and stationary stators in the generator. Each of these sources occurs in discrete frequency bands related to the rotation speed of each component. Rotational imbalances tend to occur at very low frequencies (< 50 Hz), while gear meshing and electro-magnetic interactions tend to occur at low to moderate frequencies (50 Hz to 2 kHz). Other mechanical noises produced by wind turbines during normal operation tend to be of a limited temporal nature due to the pumping of hydraulic fluid, the cooling systems and the yawing of the nacelle followed by the braking.

Mechanical noise from modern wind turbines has been reduced to half of its level compare to the turbines of 1980s. The main reason is that the gearbox has been carefully designed and machined and the steel wheels of the gearbox have a semi-soft core, but a hard surface to ensure strength and longtime wear. Moreover some of the largest wind turbine currently available and therefore especially suited for off-shore applications are built using the direct-drive synchronous generator technology: rotor and generator shafts are mounted to the same shaft without gear-box. Other techniques to reduce the mechanical noise could be to apply anti-vibration mountings and couplings to reduce the structure borne noise, the use of acoustic damping of the nacelle and the use of oil-cooler (instead of using the fan-cooler) for the generator.

The various aerodynamic noise mechanism are mainly divided into three types: low-frequency noise, inflow turbulence noise and airfoil self-noise (Wagner et al. 1996).

Low frequency noise from wind turbine is originated when the rotating blade encounters localized flow deficiencies/discontinuities due to the flow around the tower, wind speed changes, or wakes shed from other blades. The noise spectrum is determined by the blade-passing frequencies and the frequencies range between 1Hz to 20Hz depending on the blade numbers and the rotation speed. Inflow turbulence noise depends on the amount of the natural atmospheric turbulence and is typically a broadband noise. The atmospheric turbulence, results in local forces or local pressure fluctuations around the blade. Airfoil self-noise includes the noise generated by the air flow right along the surface of the airfoil. This type of noise is typically of a broadband nature, but tonal components may occur due to blunt trailing edges, or flow over slits and holes.

Aerodynamic noise will increase with increasing rotational velocity of the turbine.

Aerodynamic noise originated by modern wind turbines has been reduced by: lower tip speed, modifying pitch control law in order to reduce noise emission and specially modified blade trailing edges .

Mechanical noise has a two different propagation paths:

• airborne path when the noise generated inside the nacelle is directly propagated into the air through the external structure
• strong structural path between the drive train (where the vibration is created), through the nacelle support frame, tower, into the foundation and finally from the foundation into the surrounding water where it is released as noise.

Aerodynamic noise propagates through an airborne path. The movement of air over the whole structure including the turbine blades and the hydrodynamic forces from passing waves will also induce structural vibrations.

All the structural vibrations that are transmitted to the turbine's foundation will encounter the turbine's foundation-water interface. Here, the structural vibrations will directly induce waterborne sound waves and it is thought that this will contribute the most to underwater wind turbine noise. The amplitude of vibration of the turbine increases with the square of wind speed at the hub height. It is likely, therefore, that the noise radiated at the interface between turbine's foundation and water will also rise with wind speed.

Many underwater acoustic measurements relating to operational noise of offshore wind turbines, have been carried out (Westerberg 1994, Degn 2000, Ingemansson Technology 2003, Betke et al 2004, Thomsen 2006, Nedwell 2011). Typical source levels range from 100–150 dB re 1 μPa RMS. Measurements reported in literature are mainly relative to single turbines with different design parameters, such as foundation type, water depth, turbine size, sediment type and wind speeds (Table 2.4).

Table 2.4 Operational noise measurements (reproduced from Marmo et al. (2013)), maximum noise levels recorded with their corresponding frequencies

Park	Foundation Type	Power [MW]	Wind Speed [m/s]	Distance [m]	Frequency [Hz]	Received Noise Level
Nogersund	Tripod	0.2	12	100	16	113 dB re. 1 μPa
Vindeby	Concrete Gravity Base	0.5	13	14	150	100 dB re. 1 $\mu Pa^2/Hz$
Bockstigen	Monopile	0.6	13	20	160	95 dB re. 1 $\mu Pa^2/Hz$
Middlegrunden	Concrete Gravity Base	2	13	Converted to SL (1m)	125	115 dB re. 1 $\mu Pa^2/Hz$
Utgrunden	Monopile	1.5	13	Converted to SL (1m)	180	151 dB re. 1 μPa
Utgrunden	Monopile	1.5	12	110	160	115 dB re. 1 μPa
UK	Monopile	3-3,6	3,9 -7,2	20	100	112 dB re. 1 $\mu Pa^2/Hz$

Carrying out a direct comparison is very difficult due to the different measurement techniques, due to the inherent variability in transmission conditions, for the measured sound levels, and also due to the different averaging time (measurement units). For various wind turbines, different sound spectral characteristics may be observed, probably related to wind speeds (rotational speeds) and mechanical properties of the turbine (e.g. Madsen et al., 2006, Betke, 2004). The measured noise levels are also likely to depend on the foundation type and, potentially, on the sea bed type.

However, noise related to operational phase of off-shore wind turbines have common features; specifically, the sound intensity is dominated by pure tones, probably originate from rotating machinery in the nacelle, with frequencies mostly below 700 Hz. Noise produced during operation has been found to be of much lower intensity than the noise produced during construction phase. Reported levels are low and the spatial extent of the potential impact of the operational wind farm noise on marine receptors is generally estimated to be small.

2.5.3.4 Decommissioning phase's noise sources

The last phase of a wind farm's lifecycle comes when it has finished its energy producing life and must be decommissioned. The majority of the activities and noise's sources involved in wind farm decommissioning are a reversal of the installation process, except for foundation removal, which is currently a grey area. The methods used will depend on the type of foundation to be dismantled. The mono pile foundation is usually cut one or a few meters below the ground surface. The column can then be lifted up as a whole on a transport barge. The time scale for windfarm decommissioning may be similar to that of windfarm construction.

The noise impact of this phase could be consider similar to the construction phase but there is a general lack of knowledge due to the young life of the off shore wind farms.
Considerations on the effect of decommissioning noise to the marine environment should be done at the time of decommissioning on the basis of the technology used and when local marine life will be known and understood.

2.5.3.5 Influence of foundation type on underwater noise

Currently in shallow water (d<30m) there are two main options for foundation design: monopile foundation and gravity bases foundation. In the transitional depth (30 < d < 60), new technologies are being created, or adapted from the oil and gas industry, including jacket substructures and multi-pile foundations, which also extend to the sea floor (Figure 2.7). So far the mono pile foundation technology is the most popular support structure used for the construction of wind farms. It is estimated that 75% of all installed offshore wind turbines use the mono pile foundation.

Figure 2.7. Different foundation type (source: NREL U.S. Department of Energy)

The design of the turbine foundation will have an important impact on the efficiency of both the transmission of vibration from the turbine tower to the foundation, both from the foundation to the surrounding water.

In terms of construction noise mono pile foundation technology produces the higher SPL noise levels during the impact pile driving activity. The tripod/tri pile foundations use 3 smaller piles rather than one huge mono pile, this implies that the construction phase could take longer. Therefore the noise levels are lower but the sound is produced for a longer duration of time and the accumulative noise reduction is minimal. Using vibratory hammers instead of hydraulic hammers could mitigate a huge amount of construction noise.

Gravity based foundation and jackets foundation (combined with vibro-piling) are certainly the best foundation types in terms of construction noise produced, as will be pointed out in the mitigation procedures section.

The design of foundation type also has an impact on the noise produced during the operation phase.

Even if making a direct comparison is very difficult, literature measurements have shown that noise levels during the operational phase are lower for gravity based foundation. As will be pointed out in the mitigation procedures section of this work, in case the gravity based foundation protrudes beyond sea level, it could reduced the operational noise of the turbine due to the fact that the steel mast of the turbine is acoustically decoupled from the water body.

Recent studies (Marmo et al. 2013) have confirmed this results comparing the effect of three foundation types (monopile, gravity base and jacket) on operational noise. Each foundation type has been modelled using the same input forces from the wind turbine and the same environmental conditions with the exception of water depth. The process of modelling involved the use of a finite elements method to determine the near-field noise levels (<40m) produced by a single wind turbine; then a beam trace model has been used to estimate the cumulative far-field noise level emitted in different wind condition by wind farms consisting of 16 wind turbines.

The results of the work show that generally the mono pile foundations could produce higher SPL, especially at low frequencies, with peaks up to 10 dB higher than those produced by gravity bases and up to 50 dB higher than those produce by jackets. The jacket foundation could produce higher SPL at high frequencies (>500 Hz), with noise levels strongly localized to volumes very close to the truss; these noise levels will dissipate rapidly moving away from the foundation due to the fact that the sound absorption caused by seawater, increases with increasing frequency .

2.5.36 Offshore Wind Farm's airborne noise

The generation of airborne noise during the construction and operation phases of the wind farms can affect sensitive on receptors in the vicinity. Although the airborne noise typically propagates itself over shorter distances than it does underwater, high noise levels produced at source means that there is still the potential for significant noise impacts, especially when the wind farm is relatively close to shore as in coastal applications.

Therefore, the noise impact on land-based receptors should be considered.

Typically on the land, the receptors of concern are humans but also sea birds and other animal species. Physical injuries as a consequence of the airborne noise from offshore wind farm are very unlikely; however noise impact in term of disturbance, to both humans and animals should be estimated.

The method to be used for the assess impact on humans is predefined by relevant local authorities or standards and the appropriate approach must be selected for the situation, which will depend on the type of noise introduced and the types of receptors in the vicinity.
It is however necessary to highlight that the modelling of the propagation of noise over water is a difficult task due to many physical parameters involved: wind direction and speed, vertical temperature profile, roughness of the sea, etc.

The method proposed by ISO 9613-2 (Acoustics — Attenuation of sound during propagation outdoors — Part 2: General method of calculation) is commonly adopted for the impact assessments of noise produced by onshore wind turbine.

However the ISO 9613-2 also cautions that: “inversion conditions over water surfaces are not covered and may result in higher sound pressure levels than predicted from this part of ISO 9613.” For this reason many models of propagation of sound over the sea have been developed in recent years and the For example in 2001, Naturvårdsverket (Environmental Protection Agency) in Sweden suggested a hemispherical propagation model with spherical propagation up to 200 m and cylindrical beyond. This was later revised in 2010, Report 5933 ‘Ljud från vindkraftverk’ (‘Noise from wind turbines’) (Naturvårdsverket 2010), suggesting spherical propagation up to 700 m and cylindrical beyond.

The choice of the propagation model could represents a key point of the noise impact assessment.

2.5.3.7 Pre-existing noise and background noise

The knowledge of the pre-existing underwater ambient noise is critically important when assessing the impact of noise from an industrial activity like wind farms. Underwater noise can be highly variable and usually comprises a broad range of individual sound sources, some of which are natural and some are man-made. The noise sources may be distant to the receiver, such as shipping, or may be close to the receiver, such as waves breaking. These sounds combine and produce an overall pre-existing noise in which marine animals live.

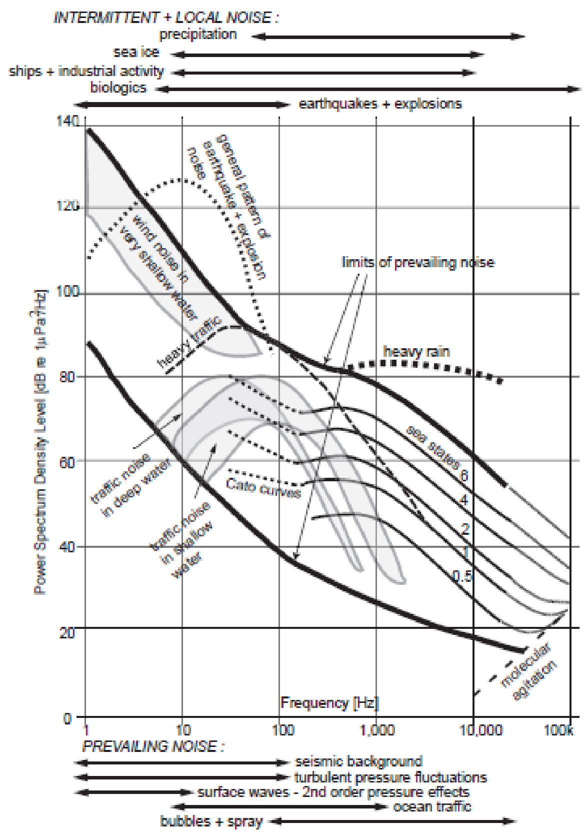


Figure 2.8 Ambient noise and anthropogenic source after by Wenz (1962) and Cato (2008) reproduced from Jasco (2011)

Ambient noise in oceans is the sound always present and cannot be attributed to an identifiable localized ambient noise is relatively well understood. source. As a result of military research, oceanic and deep water ambient noise is relatively well understood.

Figure 2.8 provides a summary of the range of the ocean ambient noise as given from Wenz (1962), for ocean deep water. Figure 2-3 also include the similar relationships which have been observed by Cato (2008) around Australian water. The “Cato curves” were joined to the “Wenz curves”. Low frequency ambient noise, from 1 to 10 Hz, exhibits a dependence on both wind strength and water currents. Distant anthropogenic noise begins to dominate between 10 and 100 Hz, with its greatest contribution between 20 Hz and 80 Hz. The noise in this frequencies range is not attributable to one specific source, but a collection of not identified sources at distance from the receiver. For frequencies higher to 100 Hz, the ambient noise level depends on weather conditions, with wind and wave related effects creating sound (Nedwell et al. 2004a). Spectrum levels of ambient noise exhibit a local minimum at about 100-200 Hz and rise up for $f<100$ Hz.

In shallow waters (commonly considered any water depth less than 200 m) ambient noise is less well understood and extremely variable. Sources of noise is typically dominated by shipping, wind, waves and biological sources. Wenz states that ambient noise is 5 dB higher in shallow waters than in deep, but this is considered an oversimplification.

In addition to ambient noise (which includes distant shipping traffic), in shallow coastal areas, local shipping traffic, pleasure craft, oil and gas platforms, other mechanical installations and local wildlife, all together contribute to the level of noise received at a location.

The combination of ambient noise, which cannot be attributed to a particular source, and these easily identifiable local sources is termed background noise. This is all the noise received at a particular time and location that is in addition to the source of interest.

The contributions of anthropogenic noise sources to the ambient level, in the shallow waters, are difficult to quantify but many literature study highlight that there was a trend of increasing in the last years. In shallow costal water, overall unweighted sound pressure level (SPL_{RMS}) are generally between 85 and 120 dB re 1 μPa with a sound power spectrum that shows main energies below 1000 HZ. This great variability in overall sound pressure level of the background noise could depend on the distance to shipping lines, on distance to ports, on distance to dredging or other activity areas.

The knowledge of the background noise is essential for a valid assessment of the potential effect from the introduction of a wind farm. More measurements in shallow coastal water are needed to allow a reliable assessment of their impact on the average underwater noise level in these regions. For this reason background noise measurements have to be carried out before construction phase of the wind farm starts for each project area.

An acoustic measure procedure of background noise has been proposed from a report (Müller-BBM GmbH, 2011) drawn up within the scope of the research project "Ecological research at the Alpha Ventus offshore test field" to evaluate the BSH German Standard for the Environmental Impact Assessment.

The procedure requires that the measurements of background noise have to be carried out for three classes of wind (on the Beaufort scale), corresponding to sea state 1 (without rainfall) and to the wind farm's power output range "medium" and "nominal capacity", and have to provide a sufficient statistical basis for the results.

At least three hours of evaluable measuring time are required for every wind class. Seasonal and diurnal peculiarities have to be documented. The hydro-acoustic background noise levels has to be measured at not less than three hydrophone positions simultaneously with at least one measuring station in the project area. One measuring station has to be placed in the nearest nature conservation reserve and a third measuring station has to be located at a distance of 5000 m.

2.5.3.8 Choice of the propagation model

To assess the potential impact on marine life associated with the activities involved in lifecycle offshore wind farms, a underwater sound propagation model must be adopted; the propagation model, allows to estimate the acoustic field at ranges and locations other than those where measurements have been made after modelled the noise sources and considered the measured background (pre-existing) noise.

In the case of the shallow coastal waters, where offshore wind farms are at present mainly designed and where the depth may rapidly fluctuate between shallow water of a few meters and deeper water, the limitations of TL (Transmission Loss) simplified models, briefly described in the first section of this work, should be considered carefully. In shallow costal water the transmission loss becomes a more complex function of depth that depends heavily on the local bathymetry and hence must be calculated using a more sophisticated model. The transmission of sound in shallow water also show a strong dependence on frequency due to the modal nature of the propagation and the frequency-dependent absorption in the water and in the sediment.

It is also important to point out that the accuracy of the results that can be obtained using a propagation model strictly depend on the choices made to model the noise sources.

The simplified SL (Source Level) model often used to describe uniquely the noise source is not suitable for different reasons. A source is spatially extended and cannot be accepted as a point source at 1 m distance; at 1 m distance the near-field is not separable from the radiating capable far field; a spatially extended source usually exhibits directional characteristics.

There is a great variety of acoustic models for the estimation of underwater noise propagation in coastal and offshore regions, mainly developed as a result of military interests. In addition to the TL simplified models some of the most used approaches are based on ray tracing theory/beam tracing theory and on modal expansion. There are also some propagation models that use the finite elements method to better model the noise sources and determine the spatial variation and intensity of the sound levels in near field (30/40 m) produced by underwater sources. These models may then use the results from the near-field model as source terms for ray tracing or beam tracing far-field models.

Some of this propagation model are implemented in commercial software.

The suitable modelling method to be choice should be determined based on the properties of the marine environment, including the bathymetry of the site, the acoustic properties of the sea bottom, the speed of sound profile within the water column, and the frequency characteristics of the noise source.

Müller-BBM GmbH (2013) have described the general procedure for the documentation of the forecasts of underwater sound associated with the construction and operation of offshore wind farms. In this document the authors point out that currently there is a worldwide lack of validated experience with regard to underwater noise recording from the construction and operation of offshore wind farms due to the lack of standardized measurement methods and validated distribution/propagation models. The forecast quality essentially depends on the accuracy of the input data and of the model used. It is therefore essential, related to forecast in each project phase, to describe the origin and quality of source data and of the propagation model used.

2.5.4 Known and potential impact of underwater noise produced by wind farms

Underwater sound is an extremely important constituent of the marine environment and plays an integral part of the lives of most marine fauna. Marine fauna exposed to anthropogenic sound may experience detrimental effects that include physical injury, behavioral disturbance and displacement, masking of biologically important signals, and other indirect effects. The potential effects depend on a number of factors, including duration, nature and frequency content of the sound, received noise level (sound level at the animals), overlap in space and time with the organism and sound source, and context of exposure (e.g., animals may be more sensitive to sound during critical times like feeding, breeding/spawning/, or nursing/rearing young) (Tasker, M.L et al , 2010).

The hearing sensitivities of marine species cover a broad frequency range and as such the same sound source may elicit different behavioral and physiological effects in different species. In addition, within-species, the responses may vary depending on individual traits of exposed animals and the context in which they are exposed. Nevertheless, based on published studies and defined noise threshold, predictions of how different species may be impacted by certain noise sources are possible. The key potential impacts of underwater noise, produced by wind farms on different marine species, may be analyzed and evaluated in relation to the different phases of the wind farm lifecycle.

2.5.4.1 Impacts on marine mammals

The theoretical zones of underwater noise influence on marine mammals have been defined from Richardson et al. (1995) and are mainly based on the distance between the source of the sound and the receiver (Figure 2.9).

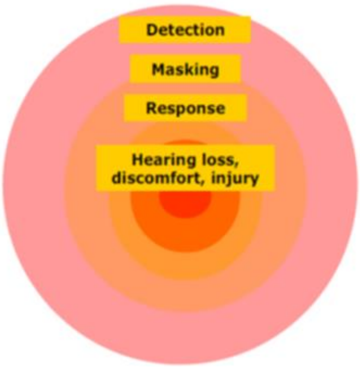


Figure 2.9. Theoretical zones of noise influence (after Richardson et al. 1995)

The zone of detection/audibility is defined as the area within which the animal is able to detect the sound. The zone of responsiveness is the region in which the animal reacts behaviorally or physiologically. This zone is usually smaller than the zone of audibility. The zone of masking is highly variable, usually somewhere between audibility and responsiveness and defines the region within which noise is strong enough to interfere with detection of other sounds, such communication signals or echolocation clicks. The zone of hearing loss is the area near the noise source where the received sound level is high enough to cause tissue damage resulting in either temporary threshold shift (TTS) or permanent threshold shift (PTS) or even more severe damage. A review of this theoretical zones from Prins t. et al. (2008) splits the zone of hearing loss in more four different zones: death, physical injury, TTS and PTS.

To give a representation of how the noise produced from the offshore wind farms may affect marine mammals, is necessary to analyze the hearing ability of marine mammals which are commonly described using audiograms.

To estimate behavioral or audiological effects of noise, caused by "loudness", it is also necessary to consider the dB_{ht}(Species) metric and the marine mammal auditory weighting functions.

2.5.4.1.1 Hearing sensitivity of marine mammals

The hearing ability of marine mammals is commonly described using audiograms. The audiogram is a representation of the hearing sensitivity of a specie/subject as a function of different frequencies; it indicates the range of frequencies detectable by a species and can highlight frequencies at which hearing is most sensitive. The hearing threshold can be defined as the received sound level in the vicinity of the ear that is just audible to an animal. Hearing thresholds depend on the frequency of the sounds and can vary strongly across species. .Hearing studies on marine mammals are conducted in three different ways:

- behavioral studies
- electro-physiological studies
- anatomical studies.

Behavioral studies have been conducted to determine the lowest noise levels that an animal can hear at different frequencies. These studies have been often performed in captivity with trained animals. Electro-physiological studies have also been used to determine the hearing threshold in many animals. The response of the nervous system to sound can be recorded from the change of electric charge, or voltage, in nerve cells. During these non-invasive studies, small electrodes placed on the surface of the animal's head record the voltages produced by nerve cells in the central auditory nervous system. The auditory brainstem response (ABR) is the voltage produced by the brainstem in response to a sound stimulus.

The hearing capabilities of marine mammals have been also studied by conducting anatomical examinations of dead animals. Scientists have been able to learn about hearing capabilities from the dissection of the animal body and ear. By examining the air-filled middle ear and fluid-filled inner ear, researchers have been able to estimate the range of frequencies that an animal could be able to hear. Much of the current knowledge of mysticete hearing has come from these anatomical studies. Audiograms for a number of marine mammals species derived from the literature are given in Figures 2.10-2.12.

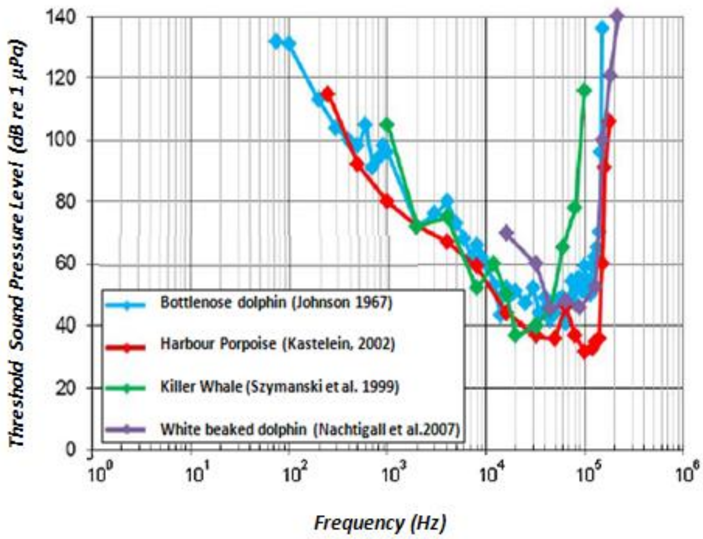


Figure 2.10. Odontocetes species hearing threshold data

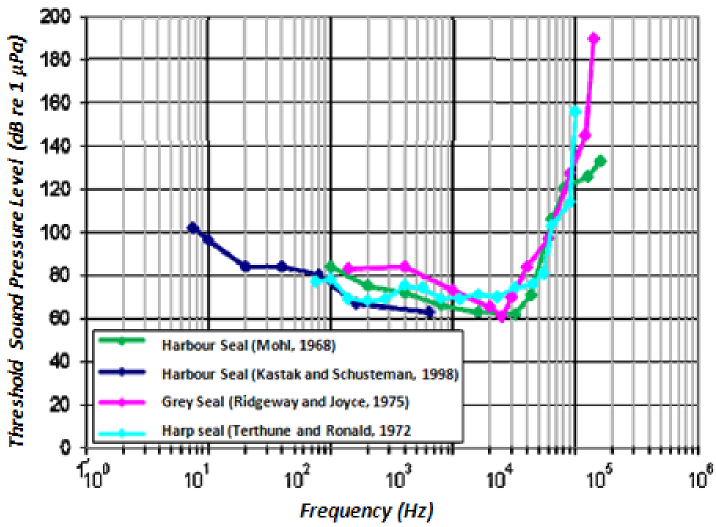


Figure 2.11. Pinniped species hearing threshold data

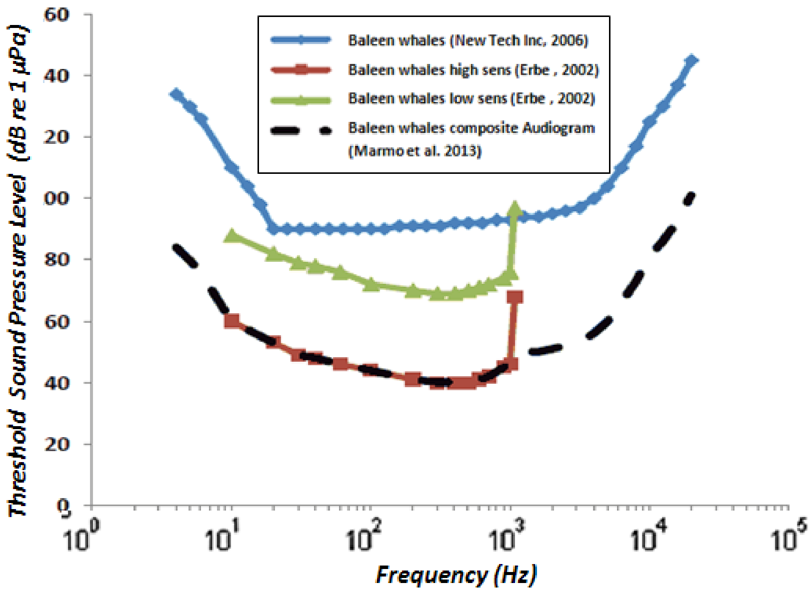


Figure 2.12. Mysticete species hearing threshold data

Generally, small-to medium-sized odontocetes (e.g. dolphin species) have good hearing across a broad range of frequencies (4-100 kHz) and are most sensitive to sounds above 10 kHz (Richardson et al. 1995), but can hear sounds below this level (Figure 3 2).
Harbour porpoises have excellent mid-high frequency hearing (Goodson & Sturtivant, 1996) and have good hearing down to ~4 kHz (Andersen, 1970; Kastelein, et al. 2002); below this frequency species hearing capability is predicted to be low. The hearing range extends over a very wide frequency range, including the ultrasonic spectrum (Figure 3 2).
Harbour seals hearing limits (Figure 3 3) are estimated to be 100 Hz – 50 kHz in water, the area of best hearing is between 8 and 16 kHz, with acute hearing also at lower frequencies (Kastak and Schusterman, 1998).

Data on hearing abilities of all mysticetes is lacking. However minke whales produce sounds in the low frequency range (100-200 Hz) and higher (up to 9 kHz) with regional variation across populations (Richardson et al. 1995; Gedamke et al. 2001) and it is very likely that they have their best range of hearing at lower frequencies compared to odontocetes (Figure 3 4).

2.5.4.1.2 dB_{ht} metric

The dB_{ht} (Species) metric (Nedwell et al (2007a) has been developed as a means for quantifying the potential for a behavioral impact of a sound on a species in underwater environment. The dB_{ht}(Species) provides a measurement of sound that allows the comparison of the effects of noise on a wide range of species. The metric incorporates hearing ability by referring the sound to the species' hearing threshold, and hence evaluates the level of sound a species can perceive. The loudness of a sound for a given species may be assessed by passing the sound through a filter that mimics the hearing ability of that species.

The behavior that is required for the filter is defined in terms of the measured hearing threshold of the animal. The metric therefore resembles the dB(A) scale that is used for the behavioral effects of noise on humans, and may be regarded as a generalization of the approach to other species. It is a dB scale where the simple fixed reference is replaced by the threshold of hearing of an animal, so the level is in "dBs referenced to hearing threshold", hence the "ht" suffix. It should be noted, however, that since the hearing threshold will vary with frequency, the weighting will also be frequency dependent and the dBht must be calculated as an integral over the frequencies. The dB_{ht}(Species) level, therefore, corresponds to the likely loudness of the sound perceived by that species. Therefore, the animal the level is calculated for (for a given noise source) must be specified as well as the corresponding level. It is important to note that the application of the dB_{ht}(Species) metric can be as good as the audiogram for the species that it is based on.

2.5.4.1.3 Marine mammal auditory weighting functions

The first broadly applied marine mammal weighting functions were developed by Southall et al.(2007). He has proposed the use of generalized frequency weighting functions, to filter underwater noise data to better represent the levels of underwater noise which various marine species are likely to be able to hear. Cetaceans and pinnipeds were divided into five functional hearing groups: LF (low frequency) cetaceans, MF (mid f.) cetaceans, HF (High f.) cetaceans, pinnipeds in air, and pinnipeds in water (Table 3 1). For each group an approximate frequency range of hearing was proposed, based on known audiograms data, where available, or inferred from other information such as auditory morphology.

The group of resulting weighting functions was referred to as the "M-weighting" functions (Figure 2.10). These weighting functions are applied in much the same way as the "A-weighting" is applied in airborne acoustics when considering the perceived response of a human receptor.

Table 2.5 Functional marine mammal groups, the assumed auditory bandwidth of hearing and genera presented in each group (reproduced from Southall et al. 2007)

Functional hearing group	Estimated auditory bandwidth	Genera represented	Example species
Low frequency cetaceans	7 Hz to 22 kHz	Balaena, Caperea, Eschrichtius, Megaptera, Balenoptera (13 species/subspecies)	Grey whale, Right whale, Humpback wale, Minke whale
Mid frequency cetaceans	150 Hz to 160 kHz	Steno,Sousa, Sotalia, Tursiops, Stenella, Delphinus, Lagernodelphis, Lagemorhynchus, Lissodelphis, Grampus, Peponocephala, Faresa, Pseudorca, Orcinus, Globicephala, Orcaella, Physeter, Delphinapterus, Monodon, Ziphius, Berardius, Tasmacetus, Hyperoodon, Mesoplodon (57species/subspecies)	Bottlenose dolphin, Striped dolphin, Killer whale, Sperm whale
High frequency cetaceans	200 Hz to 180 kHz	Phocoena, Neophocaena, Phocoenoides, Platanista, Inia, Kogia, Lipotes, Pontoporia, Cephalorynchus (20 species/subspecies)	Habour porpoise, river dolphins, Hector's dolphin
Pinniped (in water)	75 Hz to 75 kHz	Arctocephalus, Callorhinus, Zalophus, Eumetopias, Neophoca, Phocarctos, Otaria, Erignathus, Phoca, Pusa, Halichoerus, Histriophoca, Pagophilus, Cystophora, Monachus, Mirounga, Leptonychotes, Omnatophoca, Lobodon, Hydryrga, Odobenus (41 species/subspecies)	Fur seal, harbour (common) seal, grey seal

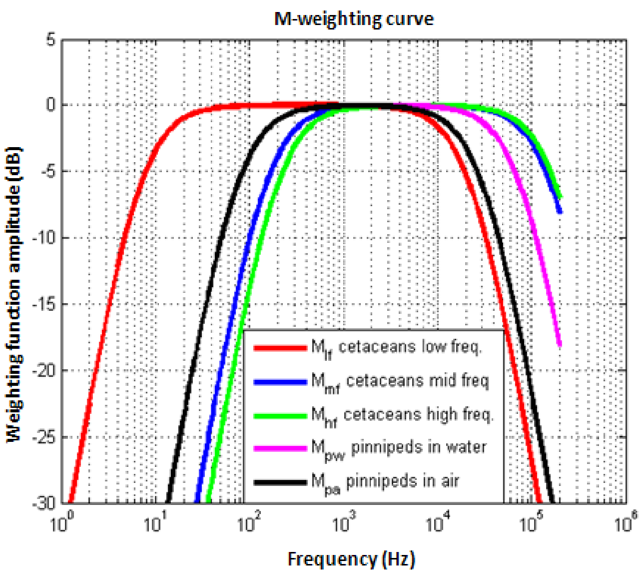


Figure 2.10. “M-weighting” functions reproduced from Southall et al.(2007)

It is important to highlight that Southall et al. (2007) have recognized that the proposed M-weighting functions are probably quite precautionary, especially in the regions of best hearing sensitivity for most species which are likely to be considerably narrower that the M-weighting functions. The next advancement of marine mammal weighting functions occurred when subjective loudness measurements were made with a bottlenose dolphin, the first time such an experiment has been conducted with a non-human animal (Finneran and Schlundt, 2011). The experiment allowed to determine weighting functions based on equal loudness contours (the "EQL weighting functions").

New auditory weighting functions have recently been proposed for marine mammals (NOAA 2013) taking into account what is known about marine mammal hearing. NOAA have proposed the modification of the original Southall et al. (2007) auditory weighting functions with the incorporation of more recent data (Finneran et al. 2012) on frequencies with a relatively increased susceptibility to noise-induced threshold shifts (Figure 2.11). NOAA also modified (NOAA 2013) the functional hearing groups proposed by Southall et al. (2007). It has proposed the division of pinnipeds group into Phocids (true seals) and Otariid (sea lions and fur seals); it has also proposed the extension of upper end of low-frequency cetacean hearing from 22 kHz to 30 kHz.

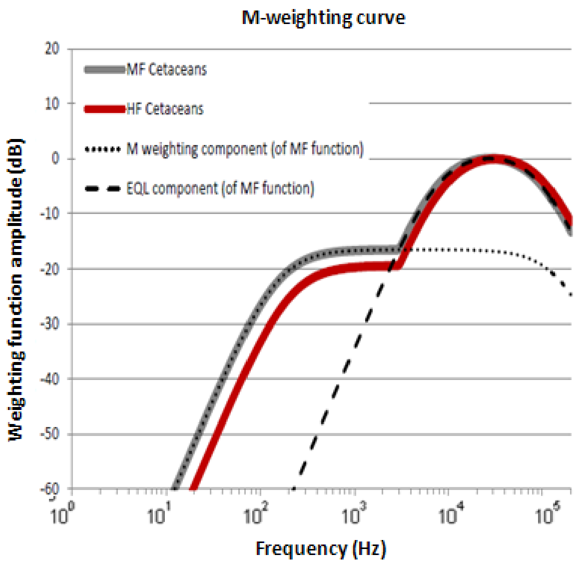


Figure 2.11. Example of the proposed weighting functions from NOAA (2013)

It is important to point out that the "M-weighting" functions allows to characterize noise sources in terms of biologically important frequencies (e.g., frequencies used for environmental awareness, communication or the detection of predators or prey). If the frequencies produced by a sound source are outside the range of a functional hearing group's best hearing sensitivity (where the weighting function amplitude is 0), sounds must be louder in order to produce a similar to noise-induced hearing loss/behavioral effect.

This approach involves that the measured or estimated underwater noise levels produced by different sound sources at the receiver (RL), are first filtered relative to hearing abilities of species under test and the sound exposure level, SEL, or the accumulated SEL is then calculated. When the measured or estimated SPL is considered as a peak level is not subjected to a weighted response.

2.5.4.1.4 Criteria used for evaluate underwater noise impact on marine mammals

Detection/Audibility

The detection/audibility distance is the physical range over which marine species can hear the noise produced during the construction phase or the operational phase of a wind farm. It will extend to the distance that the sound either falls below the ambient perceived sea noise level or the auditory threshold of the animal. Whether the sound is audible to an animal is not usually a consideration used to evaluate the noise impact on an animal since impact is usually judged in terms of physical or behavioral effects. These effects are triggered at levels that exceed audibility thresholds, which may already be within the ambient noise levels especially for low sensitivity animals or for high ambient noise levels. Estimate the detection/audibility zone however, could serve as an upper precaution limit of the range of influence.

Masking

Auditory masking occurs when an unwanted sound or noise may partially, or entirely, reduce the audibility of a signal which occurs in the same critical hearing band, even if the signal level is above the absolute hearing threshold.

Auditory masking can reduce the ability of an animal to communicate or detect predators. For sonar equipped animals, masking can also reduce their ability to hunt and navigate.

The masking in the marine environment is regarded as a key concern for marine mammals, especially for those that communicate using low frequencies such as baleen whales, seals and sea lions and also some of the vocalizations of toothed whales.

In Figure 2.12 are summarized the known typical frequency ranges of the sound produced by marine mammals and fish.

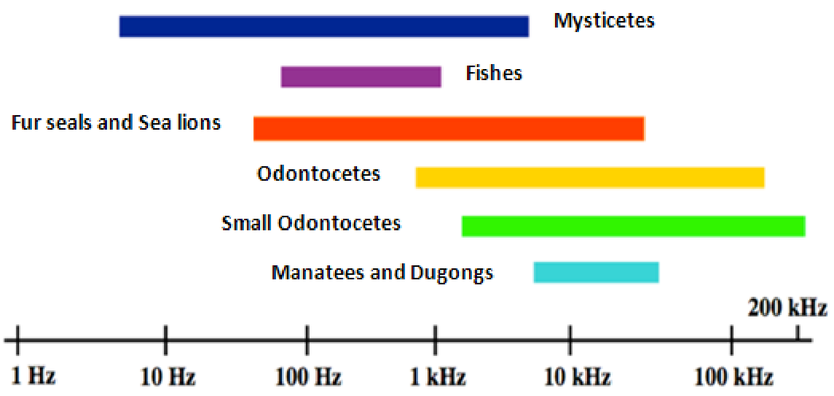


Figure 2.12. Typical frequency sound bands produced by marine mammals (and fish)

Responsiveness / Behavioral response

Behavioral reactions due to noise exposure are generally more variable, context-dependent, and less predictable than effects on hearing or on physiology. Behavioral responses may range from changes in surfacing rates and breathing patterns to active avoidance or escape from the region of highest sound levels. Responses may be conditioned by many factors such as auditory sensitivity, behavioral state (e.g., resting, feeding, migrating), nutritional or reproductive condition, habit or desensitization, age, sex, presence of young, proximity to exposure and distance from the coast. Therefore, the extent of behavioral disturbance for any given acoustic signal can vary both within a population as well as within the same individual. For this reason a general consensus for numeric criteria required to assess behavioral response to underwater noise on marine fauna has very slow to emerge. Different studies have proposed different criteria based on different metrics.

Nedwell et al. (2007a) have published assessment criteria to assess the potential impact of the underwater noise on marine species using the dBht metric. They postulate that sound pressure levels 75 dB_{ht} (Species) and 90 dB_{ht} (Species) above hearing threshold should lead to mild and strong behavioral reactions in cetaceans, respectively:

- 75 dB_{ht} (species) Significant avoidance (50% of individuals will react)
- 90 and above dB_{ht} (species) Strong avoidance reaction by virtually all individuals

Southall et al. (2007), highlighting the absence of an overarching meaning, of quantifying the biological significance of an effect, have used two different approaches to define criteria to assessing the range of possible responses and the severity of behavioral response.

A set of single pulse noise behavioral disturbance criteria and a behavioral response severity scaling for multiple pulse and nonpulses noise have been defined. The single pulse criteria are based on the temporary threshold shift (TTS) onset and are expressed in term of both SPL peak and SEL; these criteria are generally used to evaluate the instantaneous fleeing behavior/response in marine mammals exposed to a single pulse noise and do not take into account the potential disturbance associated with the duration of the noisy activity. The behavioral response severity scale, for multiple pulse noise, considers the duration of the noisy activity and ranks the behavioral response from 0 (no response) to 9 (Outright panic, flight, stampede, attack of conspecifics, stranding events, avoidance behavior related to predator detection). Noise levels that cause a behavioral response to with a severity scale of 5/6 are considered to represent a disturbance for the animals which can show possible avoidance reactions of the area.In recent investigations into the reactions of marine mammals (seals and harbour porpoises) to loud introduced noise sources (Brandt et al, 2011), received noise levels of 150 dB re 1 μPa^2s SEL (unweighted) were found to be high enough to cause a behavioral disturbance. At 145 dB re 1 μPa^2s SEL (unweighted), minor behavioral reactions might be expected.

Finneran et al. (2012), after defined the Navy mammals weighting functions, have proposed two new types of criteria/thresholds to estimate behavioral effects of noise:

- a single sound pressure level (SPL) threshold has been provided to predict the number of behavioral disturbances in cases where a specific taxonomic group's behavioral responses to noise have been well documented.
- a probabilistic function (BRF), Figure 2.13, that relates the probability of a behavioral response to the received SPL for all other taxa. The BRF is used to estimate the percentage of an exposed population that is likely to exhibit altered behaviors or behavioral disturbance at a given exposure SPL. Above a basement exposure SPL, the probability of a response increases with increasing SPL.

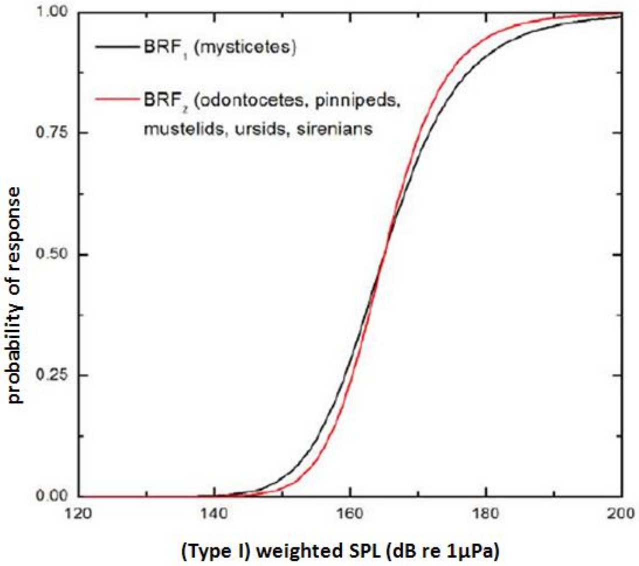


Figure 2.13. Navy Behavioral response (BRFs) from Finneran et al. (2012)

A summary of some of the available and adopted criteria for behavioral response for marine mammals is give in Table 2.6.

Species	***Exposure limit***	***unit***	***Source/ Type of Sound***	***behavioral response***	***Reference***
Hf, LF, MF Cetaceans	224 dB re. 1 μPa (peak) 183 dB re. 1 μPa^2 s (M)	*SPL* *SEL (M)*	Single Pulse	fleeing response	after Sauthall et al. 2007
Pinnipeds (in water)	212 dB re. 1 μPa (peak) 171 dB re. 1 μPa^2 s (M)	*SPL* *SEL (M)*	Single Pulse	fleeing response	after Sauthall et al. 2007
Lf Cetaceans	120-160 dB re. 1 μPa 100-120 dB re. 1 μPa	RMS (over pulse duraton)	Multiple pulse Non pulses	avoidance reactions	after Sauthall et al. 2007
Mf Cetaceans	120-180 dB re. 1 μPa 100-120 dB re. 1 μPa	RMS (over pulse duraton)	Multiple pulse Non pulses	avoidance reactions	after Sauthall et al. 2007
Hf Cetaceans	not applicable 120-150 dB re. 1 μPa	RMS (over pulse duraton)	Multiple pulse Non pulses	avoidance reactions	after Sauthall et al. 2007
Pinnipeds (in water)	160-170 dB re. 1 μPa 120-160 dB re. 1 μPa	RMS (over pulse duraton)	Multiple pulse Non pulses		after Sauthall et al. 2007
all	75 dBht(species) 90 dBht(species)	SPL		significant avoidance strong avoidance	Nedwell et al. 2007
seals/harbour porpoise	145 dB re. 1 μPa^2 s 150 dB re. 1 μPa^2 s	SEL unweighted		minor reactions disturbance	Brandt et al. 2011
Cetacean pinnipeds	160 dB re. 1 μPa 120 dB re. 1 μPa	RMS	impact piling vibro piling		NOAA 2011
Lf Cetaceans	BRF1	SPL (M, type 1)	sonar/other active sources	distrurbance	Finneran and Jenkins, 2012
Mf Cetaceans	BRF2	SPL (M)	sonar/other active sources	distrurbance	Finneran and Jenkins, 2012
Baked Whales	140 dB re. 1 μPa	SPL unweighted	sonar/other active sources	distrurbance	Finneran and Jenkins, 2012
Hf Cetaceans	BRF2	SPL (M)	sonar/other active sources	distrurbance	Finneran and Jenkins, 2012
Harbour porpoise	120 dB re. 1 μPa	SPL unweighted	sonar/other active sources	distrurbance	Finneran and Jenkins, 2012
Phocid Pinnipeds (in water)	BRF2	SPL (M)	sonar/other active sources	distrurbance	Finneran and Jenkins, 2012
Otariid Pinnipeds (in water)	BRF2	SPL (M)	sonar/other active sources	distrurbance	Finneran and Jenkins, 2012

Table 2.6 Literature summary of Behavior response criteria for marine mammals

Hearing loss/injury

At the highest sound pressure levels, typically during underwater blasts from explosives, sound has the ability to cause injury and, in extreme cases, the death of exposed animals.

Extended exposure to high levels of continuous noise, and/or of impulsive sounds, can lead to injuries of the hearing structures in marine mammals, resulting in hearing losses and other injuries (Richardson et al. 1995).

Hearing losses are classified as either temporary threshold shifts (TTS) or permanent threshold shifts (PTS), where threshold shift refers to the raising of the minimum sound level needed for audibility.

At some level and duration, sound can cause fatigue to hair cells of the inner ear, yielding an increase in auditory threshold by an amount called the temporary threshold shift (TTS). The amount of the TTS depends on many noise characteristics: sound pressure levels, the rise time, duration, duty cycle, spectral distribution, etc. The temporary threshold shift (TTS) is recoverable from over a period of time greater, the greater are the sound exposure level and the time exposure. However prolonged exposure to noise levels sufficient to cause TTS, could cause the destruction of the sensory hair cells of the ear. TTS is thus thought to be symptomatic of hearing damage. If hearing does not fully return to normal after noise exposure, the remaining threshold shift is called a permanent threshold shift. PTS is considered auditory injury. Nevertheless PTS has never been measured in any marine mammals, while a temporary threshold shift (TTS) has actually been measured on some species of pinnipeds and odontocetes (Finneran et al. 2010, Kastak and Schusterman 1996; Kastak et al. 2005; Lucke et al. 2009, Popov et al. 2011, Schlundt et al. 2000).

Increasing research has been undertaken recently to investigate the impact of noise on marine mammals and to define numeric criteria .

Parvin et al (2007) present a comprehensive review of information on lethal and physical impacts of underwater noise on marine receptors previously studied and propose the following criteria to assess the likelihood of these effects occurring:

- Lethal effect may occur where peak to peak noise levels exceed 240 dB re 1 μPa;
- Physical trauma may occur where peak to peak noise levels exceed 220 dB re 1 μPa.

Southall et al (2007) have presented a complete set of criteria for the levels of underwater noise that may lead to auditory injury (onset of permanent threshold shift -PTS) and to temporary threshold shift (TTS) on marine mammals; these criteria are based on the M-weighted Sound Exposure Level (SEL-M) and peak Sound Pressure Level (SPLpeak). In order to obtain the weighted sound exposure levels the data are first filtered using the proposed M-weighting functions then the sound exposure level is calculated. The PTS criteria, as PTS has not been measured in marine mammals, are based on TTS-onset measurements on marine mammals species and on researches on other mammals species, where it was found that onset of permanent threshold shift (PTS), or an irrecoverable reduction in hearing acuity, was caused at a SEL level of 15 dB above the level that led to onset of TTS.

The noise exposure criteria for marine mammals presented by Southall et al (2007) consider three different sound types (i.e. single pulses, multiple pulses, non pulses) in relation with noise produced from the different marine noise sources.

A study by Lucke et al. (2009) noted the onset of a temporary threshold shift (TTS), or short term reduction in hearing capability, in a captive harbour porpoise when it was exposed to a noise level of 164 dB re 1 µPa.s SEL, or 194 dB re 1 µPa SPL_{peak}. Danish research by Tougaard (2013) suggests that 165 dB re 1 µPa.s SEL may be a more suitable criteria to use for the onset of TTS for harbour purpoise.

The most recent set of criteria have been proposed by National Marine Fisheries Service (NMFS) and the National Oceanic and Atmospheric Administration (NOAA) in the Draft Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammals (NMFS 2013). The work proposed a variety of thresholds for the onset TTS and PTS according to auditory characteristics of marine mammals and to noise sources . It proposes also new weighting functions to calculate thresholds, based on recent research on acoustic biology.

The threshold value for PTS and TTS for each functional hearing group is defined in terms of the weighted SELcum and unweighted peak pressure level

In order to use the cumulative sound exposure level metric (SELcum metric) two different accumulation times may be use depending on the different models used to predict the sound exposure. An accumulation time of 24-hours (or the length of the activity whichever is less) if the prediction model used has the ability to consider moving animals and or sources. An accumulation time of 1 hour for models that do not incorporate animal movement . The 1 hour accumulation time may be used to calculate the "SEL threshold distance" (NMFS 2013). The peak sound pressure level metric takes into account the risk of causing direct mechanical fatigue by sound exposure to transient noise (e.g. single piling impulse sound).

A summary of some of the available criteria for the onset of permanent threshold shift, PTS, to marine mammals is give in Table 2.7.

Table 2.7 Literature summary of PTS criteria for marine mammals

Species	*Exposure limit*	*unit*	*Source/ Type of Sound*	*Reference*
Hf, LF, MF Cetaceans	230 dB re. 1 μPa (peak) 198 dB re. 1 μPa^2 s (M)	*SPL* *SEL*	Single Pulse / Multiple Pulse	after Sauthall et al. 2007
Pinnipeds (in water)	218 dB re. 1 μPa (peak) 186 dB re. 1 μPa^2 s (M)	*SPL* *SEL*	Single Pulse / Multiple Pulse	after Sauthall et al. 2007
Hf, LF, MF Cetaceans	230 dB re. 1 μPa (peak) 215 dB re. 1 μPa^2 (M)	*SPL* *SEL*	Non pulse	after Sauthall et al. 2007
Pinnipeds (in water)	218 dB re. 1 μPa (peak) 203 dB re. 1 μPa^2 s (M)	*SPL* *SEL*	Non pulse	after Sauthall et al. 2007
Harbour porpoise	200 dB re. 1 μPa (peak) 180 dB re. 1 μPa^2 (M)	*SPL* *SEL*		after Toungard 2013
LF, MF Cetaceans	230 dB re. 1 μPa (peak) 187 dB re. 1 μPa^2 s (M)	*SPL* *SELCUM*	Impulsive	after NMFS 2013
HF Cetaceans	201 dB re. 1 μPa (peak) 161 dB re. 1 μPa^2 s (M)	*SPL* *SELCUM*	Impulsive	after NMFS 2013
Phocid Pinnipeds (in water)	235 dB re. 1 μPa (peak) 192 dB re. 1 μPa^2 s (M)	*SPL* *SELCUM*	Impulsive	after NMFS 2013
Otariid Pinnipeds (in water)	235 dB re. 1 μPa (peak) 215 dB re. 1 μPa^2 s (M)	*SPL* *SELCUM*	Impulsive	after NMFS 2013
LF, MF Cetaceans	230 dB re. 1 μPa (peak) 198 dB re. 1 μPa^2 s (M)	*SPL* *SELCUM*	Non impulsive	after NMFS 2013
HF Cetaceans	201 dB re. 1 μPa (peak) 180 dB re. 1 μPa^2 s (M)	*SPL* *SELCUM*	Non impulsive	after NMFS 2013
Phocid Pinnipeds (in water)	235 dB re. 1 μPa (peak) 197 dB re. 1 μPa^2 s (M)	*SPL* *SELCUM*	Non impulsive	after NMFS 2013
Otariid Pinnipeds (in water)	235 dB re. 1 μPa (peak) 220 dB re. 1 μPa^2 s (M)	*SPL* *SELCUM*	Non impulsive	after NMFS 2013

A summary of some of the available criteria for the onset of temporary threshold shift, TTS, to marine mammals is give in Table 2.8.

Species	Exposure limit	unit	Source/ Type of Sound	Reference
Hf, LF, MF Cetaceans	224 dB re. 1 μPa (peak) 183 dB re. 1 μPa² s (M)	*SPL* *SEL*	Single Pulse / Multiple Pulse	after Sauthall et al. 2007
Pinnipeds (in water)	212 dB re. 1 μPa (peak) 171 dB re. 1 μPa² s (M)	*SPL* *SEL*	Single Pulse / Multiple Pulse	after Sauthall et al. 2007
Hf, LF, MF Cetaceans	212dB re. 1 μPa (peak) 183 dB re. 1 μPa² s (M)	*SPL* *SEL*	Non pulse	after Sauthall et al. 2007
Pinnipeds (in water)	224 dB re. 1 μPa (peak) 195 dB re. 1 μPa² s (M)	*SPL* *SEL*	Non pulse	after Sauthall et al. 2007
Harbour porpoise	194 dB re. 1 μPa (peak) 165 dB re. 1 μPa² (M)	*SPL* *SEL*		after Toungard 2013
LF, MF Cetaceans	224 dB re. 1 μPa (peak) 172 dB re. 1 μPa² s (M)	*SPL* *SELCUM*	Impulsive	after NMFS 2013
HF Cetaceans	195 dB re. 1 μPa (peak) 146 dB re. 1 μPa² s (M)	*SPL* *SELCUM*	Impulsive	after NMFS 2013
Phocid Pinnipeds (in water)	229dB re. 1 μPa (peak) 177 dB re. 1 μPa² s (M)	*SPL* *SELCUM*	Impulsive	after NMFS 2013
Otariid Pinnipeds (in water)	229 dB re. 1 μPa (peak) 200dB re. 1 μPa² s (M)	*SPL* *SELCUM*	Impulsive	after NMFS 2013
LF, MF Cetaceans	224 dB re. 1 μPa (peak) 178 dB re. 1 μPa² s (M)	*SPL* *SELCUM*	Non impulsive	after NMFS 2013
HF Cetaceans	195 dB re. 1 μPa (peak) 160 dB re. 1 μPa² s (M))	*SPL* *SELCUM*	Non impulsive	after NMFS 2013
Phocid Pinnipeds (in water)	229 dB re. 1 μPa (peak) 183dB re. 1 μPa² s (M)	*SPL* *SELCUM*	Non impulsive	after NMFS 2013
Otariid Pinnipeds (in water)	229 dB re. 1 μPa (peak) 206 dB re. 1 μPa² s (M)	*SPL* *SELCUM*	Non impulsive	after NMFS 2013

Table 2.8 Literature summary of TTS criteria for marine mammals

2.5.4.1.5 Known and potential effects of construction noise

Underwater noise from impact piling is known to result in significant peak pressure levels and sound exposure levels and will be distinguishable above ambient noise over distances of several tens of kilometers from the source (Thomsen et al. 2006; Nedwell et al. 2007). Foundation types which required the use of impact pile driving activities are considered the worst case in terms of the underwater noise produced during the construction phase.

Reviewing literature studies and comparing the impact piling noise levels, produced during the installation of wind turbine foundations, with the measured sea background noise levels, and with the different available criteria for the marine mammals it is possible to determine or estimate the amplitude of the impact areas.

Detection/Audibility zone

The zone of audibility for the different marine mammals species might be estimated, with the choice of a sound propagation model, evaluating the piling noise levels at different distances from the source. Thomsen et al. (2006) have estimated the theoretical audibility zone for impact pile driving noise for different marine mammals considering North-Sea background noise realistic conditions. The study has highlight that piling noise can be detected by harbour porpoises (HF cetaceans) and seals (pinniped) over huge distances: the radius of detectability might be at least 80 km and perhaps more. Odontocetes (MF cetaceans) as bottlenose dolphins and killer whales could detect piling noise at very large distances too, in some cases more than 80 km. Mysticetes as minke whale (LF Cetaceans), which have their best hearing range at lower frequencies compare to odontocetes, could probably detect piling noise over many tens of km. The zone of audibility for LF cetaceans would be probably limited by sea background noise and not by the hearing threshold. David (2006) estimated a detection distance of 40 km for pile driving noise for bottlenose dolphins.

Masking zone

Literature studies (Madsen et al. 2006) argue that due to short signal duration and due to low duty cycle of the pile driving noise, significant masking problems should not occur. However, they also admit that due to the high sound pressure levels involved, reception of signals may be impaired by indirect effects. Moreover repetition rates of 30-60 beats per second might hinder communication of social signals with relatively long durations and over long distances. Harbour seals (pinnipeds) use signals between 0.2 and 3.5 kHz for communication between mother and calf and as territorial signals among males (Richardson et al. 1995). Pile driving noise has the main energy at frequencies < 1000 Hz, and the maxima of the spectral distribution in the frequency range between 125 Hz and 300 Hz. For that reason some studies assume that the zone of masking for harbor seals extends well beyond 80km from the pile driving source. Most delphinids (MF cetaceans) are highly vocal, producing a wide-array of burst-pulsed sounds an whistles known or suspected to be used in communication (Richardson et al. 1995). For whistles of bottlenose dolphins, the area in which another individual can perceive the signals of a conspecific is 20-25 km at maximum source. This space will be reduced when the sound level of the masking sound, equals the ambient noise in the frequency of the signal (David, 2006). Different studies agree in estimating a masking zone extended up to 40 km for MF cetaceans. For LF cetaceans it is possible that impact pile driving noise could mask biological relevant signals within a zone at least as wide as that for MF cetaceans.

Responsiveness zone

The zone of behavioral response is particularly difficult to assess due to the many factors affect responsiveness in marine mammals (Richardson et al. 1995).

Theoretical assumptions and some empirical data suggest a rather wide zone of responsiveness in cetaceans for impulsive noise as impact piling noise.

Using the broadband values of pile-driving derived from the literature, calculating transmission loss and considering the available criteria it is possible to estimate that mild behavioral reactions in harbour porpoises could occur between 7 and 25 km distance from the pile-driving source. Strong behavioral reactions (i.e. fleeing response and/or strong avoidance) could occur up to 5 km from the source. This estimated responsiveness zone for harbor porpoise is confirmed by experimental studies conducted at different wind farm locations (i.e. Nysted, Horns Reef, Horns Rev, Horn Rev2) Experimental studies have monitored the activities of porpoise in the area before, during and after construction of wind turbine foundations in comparison to a control area (Tougaard et al. 2003, 2004, 2005, Brandt et al. 2011). All these studies reported that the porpoises either have decreased their acoustic activity or have left the area during pile-driving periods in the direct vicinity of the construction site but also at distance up to 18 Km.

When the installation phase was over the porpoise abundance, in some case, has returned to baseline levels (i.e. Horns Rev) and in other case no (Nysted). Recent studies have demonstrated that the zone of behavioral reaction for harbor porpoise might be also wider (Dähne et al. 2013). Aerial surveys at the Alpha Ventus wind farm (Germany), carried out during piling operations, show the avoidance behavior by porpoises for a 40 km diameter area, around the construction site.

Concerning harbour seals (pinniped), considering that the zone of audibility for pile-driving noise will probably be as wide as for harbor porpoise, empirical studies evaluate that potential behavioral reactions might be expected in distances comparable to porpoises.

Estimate the zone of responsiveness to offshore wind farm construction noise for other odontocetes (MF cetaceans) is very difficult due to fact that empirical studies on this topic are lacking. Some studies of responsiveness in odontocetes to other underwater noise sources are available in literature (e.g. Richardson et al. 1995; Würsig and Richardson 2002; Gordon et al. 2004; Nowacek et al., 2007; David 2006). However, looking at the principally large zones of audibility for pile-driving noise, it might be expected that behavioral reactions occur at considerable distance from the source, depending on species in question (Thonsen et al. 2007). Considering the available criteria, different noise assessment studies for proposed wind farms have estimated that, for a hammer blow energy of 3000 kJ, the mild behavioral reactions zone, for MF cetaceans, might extend up to 10 km; the strong behavioral reactions zone should be less wide.

The zone of responsiveness to pile-driving can't be reliably assessed for mysticetes (Thomsen et al. 2006). However, minke whales produce sounds in the low frequency range (100-200 Hz) and higher (up to 9 kHz) with regional variation across populations and it is very likely that they have their best range of hearing at lower frequencies (<2000 Hz) compared to odontocetes. Responsiveness to impulsive sounds occurs in mysticetes, sometimes at considerable distances (McCauley et al. 2000; Richardson et al. 1995 and Madsen et al. 2006), and the potential of pile-driving noise to alter the behavior of the species can't be ruled out. Considering the available criteria, different noise assessment studies for proposed wind farms have estimated that mild behavioral reactions zone (i.e. possible avoidance) might extend up to 20 -50 km.

<u>Hearing loss/injury zone</u>

There is no documented case of hearing injury caused by pile driving noise for marine mammals although experimental studies in captivity using simulated source levels (Mooney.et al 2009, Kastak, et al 2005) suggest that the levels of intense sound produced during pile driving are strong enough to cause noise induced hearing loss in some species. Moreover in the immediate vicinity of piling activities severe injuries cannot be excluded. Current researches indicates that sound from pile driving has the potential to induce hearing loss, in marine mammals, if they remain within a certain distance of the source which has been estimated between 100 and 500 m for PTS (Bailey, H., 2010).

Different literature studies have estimated that, considering the instantaneous injury criteria and a blow hammer energy of 3000kJ, auditory injury (PTS) could only occur up to 150-300 meters from the piling noise source for all marine mammals except for harbour porpoise which could suffer of PTS up to 500-1000 meters. Considering the whole piling period and using the available cumulative SEL exposure criteria, other studies (i.e. Nedwell, 2014) have estimated that, for impact piling, ranges of up to 1 km are predicted for the PTS zone in LF cetaceans, and up to 3-5 km for harbour porpoise, during the installation of a 9.5 m diameter mono pile, assuming animal fleeing from the noise source at a rate of 1.5 ms-1. Using a stationary animal model, (i.e. it is assumed that the receptor stays in the same location relative to the noise source) the study have estimated that the extension of injury zone for piling noise impact should be far greater.

Mortality of marine mammals is very unlikely to occur during the construction phase of a wind farm except in very close proximity to the pile (<10m). This latter case can be almost certainly excluded because of the fleeing response of the animal.

2.5.4.1.6 Known and potential effects of operational noise

The nature of the underwater noise generated by an operational wind farm, as previously discussed, tends to be relatively broadband in nature with a few dominant tonal noise components mostly below 700 Hz. Measurements reported in literature have often related of single turbines with different design parameters, such as foundation type, water depth, turbine size, sediment type and wind speeds. In general, the measured underwater noise level of operational wind farms has been found to be significantly lower than the construction noise. However, the construction noise generally lasts for a limited period of time (from months to 1 year), while operational noise is produced throughout the lifetime of the wind farm (more than 20 years) and may therefore have a chronic impact on the marine ecosystem.

The effect of increased boat traffic, in the wind farm area, during operational phase, may be negligible in comparison with the overall boat traffic in the surrounding waters due to the fact that boat traffic in the area of the wind farm is prohibited.

Nedwell et al. (2007), Boesen C. & Kjaer J. (2005) and Betke (2006) all demonstrated that operational noise represents a light SPL increase of few dB re 1 μPa over the background levels.

Different studies (i.e. Betke 2006, Nedwell et al. 2007, Ward et al. 2006, Nedwell 2014) have concluded that operational noise emitted by wind farms cannot be detected by harbor porpoises, common seals (pinniped) and bottlenose dolphins (MF cetacean) beyond few hundred meters and is very unlikely to cause any behavioral response. Ward et al. (2006) have indicated that bottlenose dolphins and harbour porpoises would be aware of the operational noise at a distance of 200 m from the North Hoyle Offshore wind farm.

Teilmann et al. (2006) have monitored harbour porpoises activity around the Horns Rev and Nysted wind farms, located respectively in the North Sea and the south western Baltic Sea off the coast of Denmark. After have detected and recorded porpoise clicks before, during and after the construction of the wind farms, they have concluded that there was no reduction of porpoise activity at Horns Reef in its operational phase, while there was some reduction at Nysted when it was in operation, but that it was recovered to pre-construction levels after about two years.

Nevertheless caution is needed because of the actual limited knowledge on this topic. Recent studies (Marmo et al. 2013), comparing the effect of three foundation types (monopile, gravity base and jacket) on operational noise of a modelled 16 wind turbines wind farm, have estimated that minke whales (LF cetaceans) and seal species (pinniped) could be able to detect the wind farm (with mono pile or gravity foundations) at least 18 km in all wind speed condition. Bottlenose dolphins (MF cetaceans) and harbour porpoises, less sensitive to low frequency sound than either minke whales or the seals species, could still detect the operating wind farm under different foundation and wind speed scenarios.

Harbour porpoises could detect the gravity and monopole foundations out to at least 18 km while the jacket foundation at lower distance. Bottlenose dolphins could detect a wind farm mounted on a gravity base 4 km away in wind speeds of 10 ms-1 and 15 km at 15 ms-1; but it could detect jackets and mono piles only at close ranges of ~1 km.

The same modelling study has also estimated the behavioral response zone to operational noise. Neither seal species nor bottlenose dolphins were predicted to exhibit a behavioral response to the sounds generated under any of the operational wind turbine scenarios.

Only the harbour porpoises were predicted to exhibit an aversive behavioral response using the available criteria and the M-weighting metric, where 10% of animals encountering the noise field were expected to move away. Strong behavioral response were not predicted. Based on the available literature knowledge, and considering the available criteria it is unlikely that the sound levels during operation of wind turbines will be sufficient to cause physical injury or deafness to the marine mammals. Nevertheless it is important to point out that a lot of measurements in literature are related to rather small turbines. Furthermore, more and detailed measurements of whole wind farms in operation are needed to assess possible interference of sound waves coming from several turbines. As this might not be an important issue for smaller turbines, it might become relevant for the 4-5 MW class.

2.5.4.2 Effect/Impact on fish

In comparison to marine mammals, research into the effects of wind farm noise on marine fish have drawn less attention and there are less information available so far. Most of the material available is contained in technical reports or 'grey literature'. Generally, studies investigating sound induced effects on fish are numerically limited and the results are variable (Hastings and Popper 2005).

It is often difficult to extrapolate the results gained in specific investigations or in fundamental research in different conditions, basically as a result of the different hearing systems of the species analyzed and the differences in the physical properties of the sound stimulus used.

Marine fish are susceptible to the same range of effects as those which has been discussed previously for marine mammals although the principles of hearing differ somewhat between the two groups and these differences could influence how noise impact assessments should be conducted.

2.5.4.2.1 Hearing sensitivity of fish

There is an extraordinary diversity in auditory system among fishes, resulting in different auditory capabilities across species.

Most fish species hear in the range of about 30 Hz to 1 kHz but specific species have showed hearing capabilities in the infrasonic range, below 20 Hz, and ultrasonic range, above 20 kHz.

The underwater noise generated during the wind farms' lifecycle, including shipping, pile driving and operational noise of wind turbines exhibits major energy below 1,000 Hz and is thus within the frequency range of hearing of most fishes (Richardson et al. 1995; Popper et al. 2003). Fishes have developed sensory mechanisms for detecting, localizing, and interpreting of sounds. Two independent but related sensory systems, used by fish to detect sound, are the inner ear (the auditory system) and, to a lesser extent, the mechanosensory lateral line system, which is generally used to detect vibration and water flow.

The lateral line system is stimulated by low frequency (generally below 150 Hz) water flow relative to the fish body (Sand 1984; Enger et al. 1989; Coombs and Montgomery 1999; Wahlberg and Westerberg 2005).

Very close to the sound source, the lateral line system can detect the acoustic field. The inner ear includes three semicircular canals with associated sensory regions and three otolith end organs, the saccule, utricle, and lagena (Popper et al. 2003). The perception of sound pressure is restricted to those fish species containing air-filled swim bladders.

Therefore, hearing capabilities among species vary greatly. For classification purposes, the terms hearing specialist and hearing generalist are commonly used (Fay and Popper 1999):

- hearing specialists have high sound pressure sensitivity and generally low hearing thresholds when compared to generalists. They can detect sounds to over 3 kHz with best sensitivity from about 300 to 1,000 Hz (Popper et al. 2003).
- hearing generalists, the majority of fish species, can only detect sounds up to 500 - 1,000 Hz, with best hearing generally from 100 - 400 Hz (Popper et al. 2003).

Moreover, even at the lowest frequencies that both types of fish can hear, the specialists can detect lower intensity sounds than the generalists, so that the specialists can hear better in the frequency range that they share with the generalists and also hear over a wider frequency range. Audiograms for a number of fish species are given in Figure 2.13.

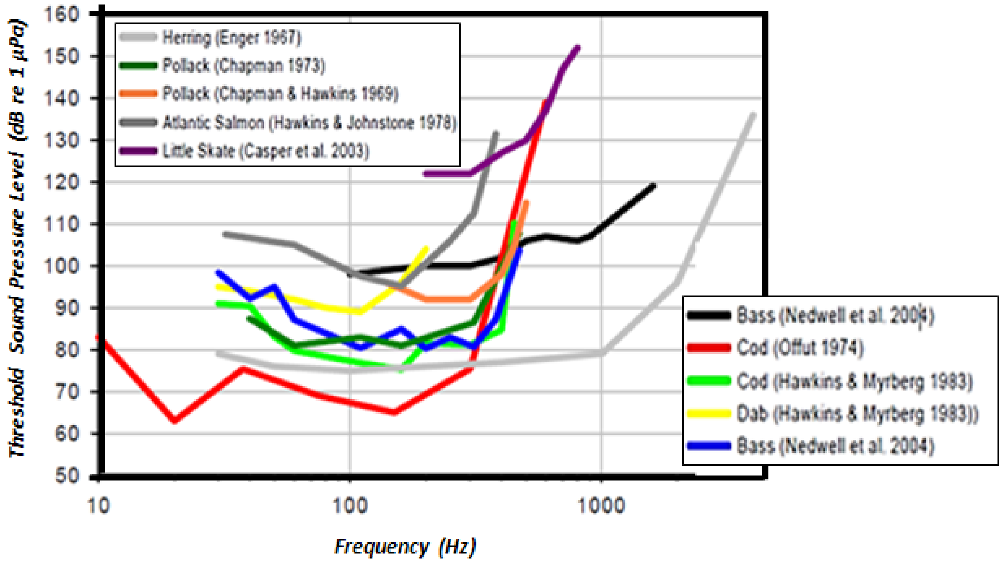


Figure 2.13. Audiograms for different fish species

Herrings show a low threshold and wider frequency sensitivity compared to other species with a hearing threshold of 75 dB re 1 µPa at 100 Hz and a good sound pressure sensitivity between 30 Hz and 4 kHz. This specie has a swim bladder and inner ear structures which explain their special hearing capabilities.

Cod, having a gas filled swim bladder, but no direct connection between swim bladder and ear, is more sensitive to sound than species without swim bladder. The best sensitivity have been determined, for cod, at 150 and 160 Hz with a hearing threshold of 75 dB re 1 µPa. Fish species without swim bladder, as dab, show a very restricted range of hearing frequencies between 30 and 300 Hz with a hearing threshold of almost 90 dB re 1 µPa.

Audiograms have generally been determined by behavioral experiments, by cardio-conditioning technique or neurophysiological investigation. Hearing threshold for generalists species (dab, pollack, salmon) may be only qualitatively valid, because some of them probably do not respond to sound pressure but only to particle motion. Hearing threshold for specialist species (cod, herring), may be also considered appropriately in terms of dB values.

2.5.4.2.2 Criteria used for evaluate underwater noise impact on fish

<u>Detection/Audibility and Masking</u>

Noise detection from fishes is to be expected when the sound overlaps in frequency and level with the hearing capability of the species under consideration, and when the signal exceeds the ambient noise. As previously highlighted for marine mammals whether the sound is audible to fishes is not usually a consideration used to evaluate the noise impact on the animals since impact is usually judged in terms of physical or behavioral effects.

Masking by anthropogenic noise can affect fish in two main ways, by interfering with acoustic communication or through the masking of important environmental auditory cues. Most communication signals in fish fall within a frequency band between 100 Hz and 1kHz (Figure 2.12).

Responsiveness / Behavioral response

The behavior response to sounds by fish can range from mild "awareness" to the sound induced avoidance of the area.

As previously discussed analyzing the responsiveness criteria of marine mammals, Nedwell et al (2007a) proposed two different criteria, based on the dBht metric, to assess the potential impact of the underwater noise on marine species: 75 dB_{ht} (Species) above hearing threshold for significant avoidance reactions and 90 dBht for strong avoidance reactions respectively. It is however important to highlight that the drawback of using a criterion based on the threshold of hearing of fish (dB_{ht}) is that this threshold is usually based on the measured hearing response of a limited number of fish of a particular species; moreover the measured audiograms, for given individuals of the same specie, may vary substantially. In coastal waters where ambient noise levels are generally above the hearing threshold for fish it is perhaps the level of the sound above ambient noise, and not the threshold of hearing, which is more important. It is therefore probably preferable to state a criterion as an absolute sound level.

Although no behavioral disturbance criteria has been established, evaluating pile driving noise, NOAA Fisheries and other Bodies currently recognize a 150 dB RMS re 1µPa level as the threshold for disturbance to ESA-listed fish species (e.g. salmon and bull trout) (Normandeau Associates, Inc. 2012) Based on their assessment, sound pressure levels in excess of 150 dB re1µPa are expected to cause temporary behavioral changes, such as elicitation of a startle response or avoidance of an area.

Even if it is not technically correct to convert RMS level to peak pressure level units, as pointed out by McCauley et al. (2000), an approximate conversion of the 150 dB RMS re 1µPa criterion is available in literature, resulting in peak pressure level disturbance threshold of around 168 to 173dB re 1 µPa. This peak criterion originates from the analysis of measured sound pulses from marine impact piling in shallow water, where the RMS level is several dB (10 to 12dB) lower than the acoustic peak pressure level measured for the same pulse. It should be noted that this correlation between peak pressure level and RMS levels depends on the propagation distance and so the peak pressure level can only be used as an approximate indicator.

Pearson et al. (1992) have investigated the effects of seismic airgun sound on the behavior of captive rockfishes, exposed to the sound of a single stationary airgun. They have highlighted that rockfishes react to the airgun sounds by exhibiting startle response behaviors and strong avoidance of the area, at a received peak pressure level of 200 dB re 1µPa.

A summary of some adopted and available criteria for assess behavioral response on fishes is given in Table 2.9.

Table 2.9 Literature summary of Behavior response criteria for fish

Species	***Exposure limit***	***unit***	***Source/ Type of Sound***	***behavioral response***	***Reference***
all	75 dB_{ht}(species) 90 dB_{ht}(species)	SPL		significant avoidance strong avoidance	Nedwell et al. 2007
ESA-listed	150 dB re. 1 µPa	RMS	Pile driving	temporary behavioral changes (startle and stress)	Normandeau Associates, Inc. 2012
all	168-173 dB re. 1 µPa	SPL peak	Pile driving	temporary behavioral changes (startle and stress)	McCauley et al. (2000)
all	200 dB re. 1 µPa	SPL peak	airgun	strong avoidance of the area- C-turn response	Pearson et al. (1992)

Hearing loss/injury zone

Most of the studies investigating hearing loss in fish have been laboratory-based using different types of sound (e.g., pure tones or white noise) and exposure durations with mixed results. Thomsen et al. (2006) analyzed these studies and pointed out that TTS was induced in hearing specialist from exposure to both white noise and pure tone (SPL= 140-170 dB re 1 µPa), whereas hearing generalist usually were no affected.

Two different criteria/levels were proposed by Parvin et al (2007) to assess the physical effects caused by noise on marine species as previously discussed analyzing injury zone for marine mammals:

- Lethal effect may occur where peak to peak noise levels exceed 240 dB re 1 μPa;
- Physical trauma may occur where peak to peak noise levels exceed 220 dB re 1 μPa.

Fisheries Hydroacoustic Working Group in the USA (2008) have advised the use of interim injury criteria, commonly adopted for assessing the impact of impact piling noise on fishes, based on unweighted noise levels: a peak sound pressure level, an accumulated sound exposure level over a period of time and an additional noise criterion or fish less than 2 grams in weight. A summary of some available criteria for assess injury on fishes is given in Table 2.10.

Table 2.10. Literature summary of injury criteria for fish

Species	***Exposure limit***	***unit***	***Source/ Type of Sound***	***Effect***	***Reference***
all fish	220 dB re 1 μPa (peak tp peak)) 240 dB re 1 μPa (peak to peak)	SPL p-p		injury phisical trauma lethal effect	Nedwell et al. 2007
all fish	206 dB re. 1 μPa (peak)	RMS	piling noise Single strike	injury	FHWG. 2008
all fish	187 dB re. 1 μPa^2 s	SEL cumulative unweighted	piling noise	injury	FHWG. 2008
fish < 2 g	183 dB re. 1 μPa^2 s	SEL cumulative unweighted	piling noise	injury	FHWG. 2008

2.5.4.2.3 Known and potential effects of construction noise on fish

Whilst there is limited knowledge on the impacts of construction noise of wind farm on fish, there are a number of studies and reports available in literature (Hastings et al. 2005; Nedwell et al. 2003, 2004, 2007; 2014, Thomsen et al. 2006; Wahlberg et al. 2005). The approaches to the measurement and assessment of noise differ in the different studies and the results and predictions are not always directly comparable. The different assessments have been based on an amalgam of the available data, on the choice of an underwater propagation model, all combined with knowledge of how fishes hear and react to sound.

Detection/Audibility and Masking zone

The zone of audibility is linked to the individual species' hearing threshold and sensitivity. Thomsen et al. (2006) have considered that herring and cod are likely to perceive noise caused by impact pile-driving up to 80 km away, while salmon and dab could detect piling noise up to a few kilometers from the source. They also highlighted that, to evaluate the audibility zone of piling noise for demersal species as dab, another important aspect to consider is the sound propagation through the sediment.

As previously discussed for marine mammals, masking might be a less important issue considering pile driving noise due to the intermittent nature of the sound. However fishes are very sensitive to low frequencies and pile-driving might affect communication indirectly due to stress induced by the noise. Pile driving noise can affect fish orientation and localization of prey negatively. The effect is probably greatest if it occurs during the fish's spawning period, or if their foraging is prevented during growth periods of early life stages.

Thomsen et al. (2006) have concluded that, for some fish species, zone of masking might be quite large; this has been estimated considering both hearing threshold of specialist species both the signal to noise ratio of piling noise vs background noise at great distances from the source. However the current base of knowledge cannot give enough information about the extension of the masking zone.

Responsiveness zone

The responsiveness zone is the area where fish might react to noise, with a behavior reaction or physiological reaction.

There have been very few experimental studies to determine the effects of wind farm noise on marine fish behavior to date and too little is known about the long-term effects of exposure to sound or about the effects of cumulative exposure to loud sounds.

A recent study on behalf of COWRIE (Mueller-Blenkle et al., 2010) investigated the reaction of various fish species (code and sole) in two large net, to recordings of impact pile driving noise played back on an underwater loudspeaker. The results of the study pointed out a behavior response of the selecting species. Cod have showed higher swimming speed, significant freezing response and initial avoidance. Sole have showed significant increase in swimming speed and initial avoidance. The results also suggested that piling noise could affect fish distribution within the range of some hundred meters up to several kilometers.

Based on the proposed 75 dB_{ht} criteria, Nedwell et al. (2003) have estimated zones, at the North Hoyle wind farm, where significant avoidance reactions to piling noise were to be expected as 1.4 km for salmon, 5.5 km for cod and 1.6 km for dab.

Nedwell et al. (2014a) have also estimated the zone out of 90 dBht, where a behavioral reaction could occur from impact piling of a 10 m diameter pile, using a blow energy of 3000 kJ, at Horns Rev 3 wind farm.

The level of underwater noise from the installation has been estimated using a proprietary underwater sound propagation model that enables to evaluate the level of noise from the piling at different distances and for varying tidal conditions, varying water depths and varying piling locations. The study has pointed out that the greatest behavioral response was expected from herring up to 12.2 and 24.7 km from the piling. The range for cod was between 11,4 and 23.7 km. Dab, could exhibit a strong aversive reaction up to 6.9 km.

Considering the 200 dB re 1 μPa peak criteria for strong avoidance of the area, different studies have estimated that C-turn reaction on fish is unlikely to occur at range beyond 600-1000 m from the pile during impact pile driving noise.

Hearing loss/injury zone

Reports in literature highlight that impact pile driving noise could kill fish of several different species if they are sufficiently close to the source (Hastings et al. 2005). Mortalities were observed after pile driving in the course of the San Francisco-Oakland Bay Bridge Demonstration Project, USA. Sound levels at a distance of 100 and 200 m from the pile were between 160 and 196 dB re 1 μPa RMS (Caltrans, 2001). Fish have been found dead primarily within a range of some meters. The external and internal injuries, which have been observed, have gave reason to assume that there might have been further mortalities, especially of species with swim bladders. The zone of direct mortality was about 10 - 12 m from piling, the zone of delayed mortality was assumed to extend out at least to 150 m to approx.1,000 m from piling. Tests on caged fish have also revealed greater effects when using a larger impact hammer (1700 kJ, as compared with 500 kJ). The results of the study have also indicated an increasing damage rates to the fishes together with extended exposure times (Caltrans, 2001).

Considering the single strike peak to peak proposed criteria (Table 3-6) Nedwell et al. (2014a) have estimated the distances where lethal and physical injury could occur from impact piling of a 10 m diameter pile using a blow energy of 3000 kJ at Horns Rev 3 wind farm. They have concluded that risk of lethal and physical injury (internal organ trauma), could occur at ranges of less than 10 m and less than 100 m, respectively, for any fish species. They also estimated the range where hearing injury could occur for fish using the criteria proposed by the FHWG in the USA (Table 3-6). Based on the 206 dB re 1 μPa SPLpeak criterion, injury to fish could occur at distances up to 250 m. Using the 187 dB re 1 μPa2s SEL criterion, and assuming the fish do not flee, the fish would receive the noise exposure within a distance of 9.5 km to 14.6 km from the piling, depending on the piling and the fish location. For small fish, under 2 grams, this range extends to 19.4 km at its maximum.

It is assumed that high noise levels could kill the eggs and larvae in the immediate surroundings due to the fact that, unlike adult fish, they are not able to swim away from the sound source. Nevertheless a recent study, investigating the impact of piling noise to larvae of sole (Damme, et.al., 2011) has concluded that there was no evidence of additional mortality of the larvae caused by the piling noise. However, the impact of piling noise on eggs of other fish species is not yet known.

2.5.4.2.4 Known and potential effects of operational noise on fish

As highlighted in the same section on marine mammals many studies have demonstrated that noise generated by an operational wind farm often determines a low SPL increase over the background noise and it is much lower than the construction noise.

Only few studies give some preliminary values about the audibility zone for some fishes species. Thomsen et al. (2006) estimated that hearing specialist species might detect operational noise perhaps 4-5 km from the source. The zone of audibility for hearing generalist species will be narrower, it will be less than 1 km.

A recent study (Marmo et al. 2013), with the aim of compare the effect different foundation types, has modelled the operational noise for a wind farm of 16 wind turbines and has evaluated that European eels, most sensitive to low frequency (<300 Hz), might detect the wind turbines founded on monopiles or mounted on gravity base at great distance (15-18 km), especially at high wind speed but are unable to detect turbines mounted on jackets.

Other species with higher hearing threshold (i.e. less sensitive to the noise), especially at low frequency, may detect operational noise at closer distances (2-3 km) only at high wind speed and only for wind turbines with jackets foundation or gravity based foundation.

The area of masking might extend as far as the zone of audibility for some species, especially if the frequency of the communication signals fall in the range of the low frequency. Thomsen et al. (2006) concluded that for herring, which use mid frequency signal, masking from operational noise should occur at very close distances.

Only few data are available to evaluate the responsiveness zone but it seems to be of negligible extension. Wahlberg et al. (2005) estimate the distance to which fish might be scared away from a wind turbine in less of 10 m. Nedwell et al. (2014) have concluded that the ranges of behavioural reaction, estimated considering the 90dBht(Species) criterion are negligible for the four target fishes species (Cod, Dab, Herring and Salmon).

Based on the available literature knowledge, it is unlikely that the sound levels during operation of wind turbines will cause physical damage to the fish fauna.

2.5.4.3 Potential cumulative impact

The potential impacts of sound on marine mammals and fish also need to be considered in a wider context, through addressing the consequences of acoustic disturbance on populations in conjunction with other stressors such as by catch mortality, overfishing leading to reduced prey availability and other forms of pollution such as persistent organic pollutants.

These various stressors may also act synergistically or cumulatively. For example underwater noise could interact with by catch or collision issues in that the individual is less able to detect the presence of fishing nets or nearby vessels .

Multiple sources of anthropogenic sound may also interact cumulatively or synergistically.

The greatest risk of impact resulting from underwater noise has been clearly identified by impact piling noise during the construction phase of a wind farm. Therefore potential cumulative effects on marine fauna exist as a consequence of the underwater noise produced during the construction phase of a wind farm overlapping temporally with construction noise produced from development of nearby offshore projects and marine activities.

Anthropogenic noise sources, as commercial shipping, fishing and dredging vessels, produce lower noise levels compared to impact piling noise and it is very unlikely that could increase the risk of injury on marine fauna during the construction phase of a wind farm. There might be an increase of the risk of behavioral effect on some species of marine mammal and fish in case of temporally overlapping with the construction phase.

It is very important to evaluate the potential cumulative impacts especially in relation to the proximity (considering the impact zones of the piling noise) of other offshore projects which may utilize the impact piling technology like oil and gas platform as well as other wind farms. In this case there might be a significant increase of the risk of injury and behavioral reactions for marine fauna which need to be evaluate.

2.5.5 Best practice and mitigation procedures for underwater noise

The aim of noise mitigation measures is to control and minimize environmental impact, and in general comprises of controlling the source of the impact factor, of reducing the impact by use of engineering solutions, of altering timing of the exposure to the impact factor and other methods, followed by monitoring of the effects. The most extreme mitigation measure is to avoid carrying out the activity altogether, but in the case of offshore wind turbine construction and operation is not possible.

However, quantifying the extent of the impacts is a difficult task given the high variability of the characteristics of sounds, of the sensitivity of different species and of the spatial scale of noise-producing human activities. In recent years several international organizations, such as the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention - OSPAR,), or the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS) and the Agreement on Conservation of Cetaceans of the Black Sea, the Mediterranean Sea and contiguous Atlantic Area (ACCOBAMS), have proposed guidelines on best environmental practices and on best available techniques to be implemented so as to mitigate the impact of noise on the marine environment.

In particular. recently the French Maritime Cluster (2014) has published a document to present a state of the art on anthropogenic noise in the marine environment, on mitigation measures and on constraints to their implementation, evoking also the best practices already used by offshore operators. Moreover ACCOBAMS (ACCOBAMS-MOP5/2013/Doc24) published a “Guidance on underwater noise mitigation measures” to improve and facilitate the use of the Guidelines to Address the Impact of Anthropogenic Noise on Cetaceans in the ACCOBAMS Area.

As pointed out from the French Maritime Cluster (CMF, 2014), guidelines from different organizations mainly consist of three common elements:

- Best practices, a range of procedures that are applied according to defined protocols and decision trees.
- Noise reduction technologies, either able to reduce the noise produced by conventional sources, or technical solutions having lower noise emissions than conventional techniques.
- Software, conceived for biological risk assessment and for the real-time detection of the presence of marine mammals. Besides, web platforms storing wide biological and ecological databases can be used as a complementary tool, useful to carry out a preliminary environmental assessment.

This section, on the base of these documents, summarizes some important elements about available mitigation procedures for underwater noise produced by wind farm.

2.5.5.1 Best Practices

Best practices consist in general procedures to apply during each phases of a project to reduce the noise impact on marine life of any offshore industrial activity. The French Maritime Cluster (CMF, 2014) analyzing the recommendations of international organizations has proposed a detailed list of the best available practice valid for any industry that could be adapted to offshore wind farm. The best practices of the list are assigned to three different phases of a project:

- planning phase of the project
- real-time mitigation during operational phase
- post activity monitoring and reporting.

During the planning phase of the project is very important to:

- consider the species that might be present, especially presence of marine mammals, the population density for these species and their sensitivity to the noise. The risks belonging to noise emission are taken into consideration in the impact assessments carried out prior to the beginning of works. In accord to ACCOBAMS resolution 4.17 (2010) it is necessary to model the generated sound field by the different wind farm noise sources in relation to geological and oceanographic features (depth/temperature profile, water depth, coastal and seafloor characteristics). In addition verification in the field need to be done and existing noise levels need to be extensively monitored before any activity begins. The area where animals could receive harmful noise levels (Exclusion Zone) should be defined
- select low sensitivity periods (avoid peak periods where the organisms are feeding or breeding) and areas; this practice probably represent the most effective mitigation measure. However CMF (2014) points out the most suitable periods for works at sea overlap very often with sensitive periods for animals;
- define biologically important zones as the Areas of Special Concern for Beaked whales or marine sanctuaries where eventually avoid pile driving activities or strict measures need to be applied as consider alternative technologies;
- use a noise propagation modelling outputs to estimate the extent of an Exclusion Zone (EZ) and in case of no modelling result available use a radius of 750 m for construction work as pile driving. CMF (2014) underlines that even though this measure is not widely implemented today it can be put in practice for marine mammals and turtles without major constraints. Conversely, its use for other marine fauna, such as fish, is considered as not feasible. Further, criteria for selecting the extent of the ZE are not clearly defined at present;
- plan the lowest practicable source power in pile driving and other construction activities (i.e. plan the minimum hammer energy required to penetrate the pile into the seabed).
- If, after have undertaken a site specific acoustic assessment, the piling work will have, or is likely to have, a significant impact on marine species eventually consider alternative technologies to the impact pile driving (i.e. vibro piling) and plan Noise Mitigation Technologies in case no alternatives are possible. During the operational

phase of the project several real time mitigation protocols and procedures are recommended by international bodies. All these mitigation protocols could be applied during the construction phase of an offshore wind farm to reduce the noise impact on marine species of different construction activities as drive piling, drilling and dredging. The list below includes the general guidance of the document prepared by CMF (2014) together with the information of the guidelines drawn up by ACCOBAMS (2013);

- use of Acoustic Mitigation Devices (AMD). The approach here is to use sound signals to warn the sensitive species, such as marine mammals so that they could move away from potential danger activities like piling activities. An acoustic mitigation device produces a high sound level in a specific frequency range depending on the hearing sensitivity of the species which it needs to deter (from very low frequency for fish to high frequency for porpoise). Prior to the beginning of the noisy work, AMD should be used to drive away groups or individuals of marine fauna. The efficacy of the AMD should be tested on all species of concern and is very difficult to predict how animals react to the device. In any case, the method is not suitable for slow-moving animals as fish larvae. Even if is quite commonly used it is important to point out that the use of acoustic deterrents increases the total amount of sound energy in the water, and frequent use might cause temporary loss of habitat and other injury risks if the sound of an acoustic deterrent is too loud for an animal at a short distance. The ACCOBAMS Resolution for cetacean device (2010) listed the AMDs allowed to be employed in the ACCOBAMS area.
- Use the Soft Start protocol. If marine mammals have not been sighted in the Exclusion Zone but are likely to enter during the pre-start procedure of a noisy marine activity, the noise emission should begin at low power, increasing gradually until full power is reached. For example piling impact energy should be gradually increased over a period of time to alert marine mammals to the presence of the piling rig and enable animals to move away to distances where injury is unlikely. This procedure should have a minimum duration of 20 minutes. Soft start procedure should be delayed if cetaceans enter the Exclusion Zone;
- use of the Visual Monitoring Protocol. This protocol includes that Dedicated and independent Marine Mammal Observers (MMO) should watch the Exclusion Zone for

30 min before the beginning the soft start procedure (120 min for highly sensitive species). In case of cetaceans enter the EZ the soft start procedure should be delayed Continuous watch should be kept for the entire duration of noise emission and the activity should be stopped (or powered down) if cetaceans enter the EZ. In case of a stop in noise the procedure need to be restart. If possible at least two dedicated MMOs should continuously observe the Exclusion Zone. It is important to points out that Visual Monitoring Protocol, on the basis of the recommendation for sensitive species (120 minute watch) could create troubles in the scheduling of works, entailing substantial additional costs (CMF,2014). For that reason a pre-search of more than 30 minutes should be justified by the existence of proven risks and the use of anticipatory solutions (e.g. spatial planning or the use of effective acoustic mitigation devises) should be preferred (CMF,2014);

- use of the Passive Acoustic Monitoring Procedure/Protocol. Passive Acoustic Monitoring (PAM) is an emerging technology that may be used to complement visual observations for the presence of marine mammals. PAM consists of listening to marine mammal's underwater vocalizations using hydrophones, and aims to identify and locate a variety of vocal marine mammals. Continuous acoustic monitoring could be performed for the entire duration of the noise emission and could be used to alert the observers (MMO) to the presence of cetaceans. If activities are carried out at night or during bad weather conditions, acoustic monitoring could be used as the main monitoring tool and noise emissions should be stopped, or powered down, if acoustic detections of cetaceans occur (ACCOBAMS 2013). Several configurations exist to set up a PAM system but PAM equipment should be able at least to detect and localize cetaceans. PAM operators should have experience of bio-acousticians and should have familiar with the vocalizations of cetaceans in a determined area. ACCOBAMS (2013) also suggest some commercial software to implement PAM system.

Finally, after completion of the risk mitigation mission, all the international organizations made two key recommendation (CMF, 2014):

- draft a detail report, including the procedures that were implemented, the sightings, behavioral observations, etc;

- make the report publicly available in order to contribute to deepen available knowledge and improve mitigation frameworks.

2.5.5.2 Noise Reduction Technologies

When we speak of noise reduction technologies we refer to those technologies and solutions that enable a mitigation of noise emission during the different lifecycle phases of an offshore wind farm. These technologies, also defined Source-based noise-reduction technologies, can be divide in two main different categories:

- Noise mitigation technologies employed to reduce the noise emission during the conventional noisy activity. They also could divide in reduction solutions of source level and reduction solutions of noise transmission (isolation);
- Alternative construction technologies that lower the noise emitted during conventional noisy operations.

The majority of these technologies are designed to be applied to mitigate the most impact activities associated with the construction phase of an offshore wind farm (impulsive noise generating activities) as mainly the drive piling activity but also other activities as drilling or dredging. All the Guidelines produced from the four different Bodies of the European Union waters (ACCOBAMS 2010/2013, ASCOBANS 2009, ICES 2010, and OSPAR 2008,2009, 2014) on the impact of underwater noise have highlighted that, during the construction phase of a wind farm, alternative technologies should be used or considered (instead of pile drivers or jackhammers). Additionally, the use of source-based mitigating technologies should be strongly recommended.

Regarding the operational phase of an offshore wind farm some alternative construction technologies (e.g. jacket foundation or gravity base foundation) could also have a positive impact on the noise emission during the operational phase (continuous sound mitigation) of a wind farm (Marmo et al. 2013).

2.5.5.2.1 Reduction technologies of source level

Impact pile driving is vastly used in offshore wind farm construction in shallow costal water as reported in previous sections. Measures to mitigate the source level of a driving mono pile, require modification of the blows applied by the driver to the top of the pile.

Possible options and techniques of reducing noise generation during pile driving activities consist of different solutions (The North Sea Foundation, 2012).

Some of these solutions however show important disadvantage as changing the pile-toe shape (e.g. beveled pile), solution which has not yet been tested on a large scale, or as using a contact damping between the pile and the hammer, solution which however will probably increase the time required to hammer the pile.

A tested solution with no disadvantage is instead represented by changing the parameter for pile stroke.

The sound pressure generated during the pile driving depends on the velocity of the vertical pile vibrations. Numerical investigations have revealed that prolonging the pulse duration and so the contact time of the hammer, reduces the corresponding sound emission (ELMER et al. 2007a, b) as a consequence of the reduced amplitude of the pile vibration. Prolonging the impulse not only reduces the sound level, but also shifts the maximum of the acoustic spectrum to lower frequencies, which are less harmful to marine mammals. Studies at the FINO 2 platform with a prolongation of the pulse duration by a factor greater than 2 revealed a noise reduction by up to 7 dB for the initial hammer strikes (ELMER et al. 2007b). Theoretically this method could mitigate noise by 10-13 dB, mostly at high frequencies, and have virtually no impact on the installation time.

2.5.5.2.2 Reduction solutions of noise transmission

These methods reduce the transmission path of the noise immission into the water, isolating the source (e.g. mono pile) from the water. The solutions mainly consist of placing a barrier around the pile to attenuate sound from hammering. The barrier can be a solid casing that is drained or filled with a layer of bubbles or other absorptive materials, or a curtain of bubbles. Different techniques can be used as cofferdam, hydro sound damper, bubble curtain and pile screen (isolation casings). A great number of these mitigation solutions have been developed and tested to attenuate noise from activities that generate impulsive sound, particularly pile driving, in the marine environment. The list below summarizes the main available information on these solutions on the bases of the technical literature, where considerable further detail can be found (North Sea Foundation 2012, CSA 2013, Koschinski, S. and Lüdemann, K. 2013, ACCOBAMS 2013 and OSPAR 2014):

- Cofferdam

The cofferdam is a rigid steel tube surrounding the pile from seabed to surface and centered using wedges. Once the pile in inserted into the cofferdam the water between the tube and pile is pumped out. The air space between the pile and the water column attenuates sound – acoustic decoupling of the pile driving noise within the cofferdam. The noise from the pile is radiated into the cofferdam rather than the water. This solution would ensure a reduction in the noise emission during pile driving activity up to 22 dB (SEL) and 18 dB (peak).
It was tested in many commercial projects in shallow waters (<15 m) but it is currently at the pilot stage for deeper offshore waters and proposed for depths of at least 45 m. It is necessary to point out that Installation probably require more time than other solution (e.g. bubble curtains) and specialist equipment will needed for offshore developments but may be considered where significant impacts are likely to
occur.

- Bubble curtain

A bubble curtain is a sheet of air bubbles that are produced around the location where the piling activity occurs. The bubbles in the bubble curtain create an acoustic impedance mismatch between the water and air trapped in the bubble, which results
in sound attenuation across the bubble curtain. The noise reduction is based on the physical phenomenon of sound scattering and on the resonance of vibrating air bubbles. Bubble curtains are currently one of the options which are considered as a useful and applicable mitigation measure and several technical realizations are possible:

  - Big Air Bubble curtain

  A large bubble curtain usually consists of a pipe with drilled holes placed around the whole foundation on the seabed. Compressed air escaping from the holes forms the bubble curtain which screens the environment from the noise source. This solution ensure a reduction in noise of 11-15 dB (SEL) and 8-14 dB (peak) for a single bubble curtain; double bubble curtain ensures a reduction in noise of 17 dB (SEL) and 21 dB (peak).

Bubble curtains are being successfully tested and represent a proven technology and potential for optimization in terms of handling and of system effectiveness (air supply, bubble sizes and distance from source). This solution can be also used to reduce the soil propagation path due to the large diameter of the system.

- Little air bubble curtain

It consists of smaller curtain placed around the noise source in a close fit. There are several variations of this solution with different noise reduction ability.: Layered ring system of perforated pipes (11-15 dB (SEL) and 14 dB (peak)). Confined bubble curtain using additional casing (4-5 dB (SEL)). Little bubble curtain of vertical hoses (14 dB (SEL) and 20 dB (peak)).

For this solution pilot stage with full-scale tests have been completed and so practical application is possible. Tidal currents can cause bubble drift and sound leakage but effect can be minimized in more recent designs. All designs do not affect seismic path propagation.

The use of bubble curtains may be limited by the water depth and practical or cost reasons, but may be considered when piling activities are expected to produce high noise levels and marine mammals are likely to be present within the area.

- Hydro Sound Damper (HSD)

The concept of hydro sound dampers is based on the same principle as bubble curtains but, instead of air bubbles, gas filled latex balloons are used. The balloons are attached to a frame or a network and completely surround the noise source. The resonance frequency of the balloons is adjustable,, by varying the balloon size, even to low-frequency ranges.

This solution would ensure a reduction in noise of 4-14 dB (SEL).

HSD solution is less affected by tidal currents than the bubble curtain, it is quite simple to assembly and it is easily adaptable to different activity (piling, drilling, dredging).

For this solution the pilot stage have not been concluded even if it has been used as mitigation procedure during the construction of Borkum wind farm in Germany.

- IHC Noise mitigation System (NMS)

It is a physical sound barrier placed around the mono pile constituted by two steel layers with air inside. Between the pile and the barrier a confined bubble screen totally adjustable is applied. Noise reduction by NMS was estimated to could exceed that of a bubble curtain (5-20 dB (SEL)). NMS was been successfully tested for activity up to 23 m of depth but insufficient information are available to make final conclusions.

- BEKA Shell

It is a combined system based on the principle of an isolation casing. It consist in a double steel made case, with a polymer filling, combined with an inner and outer bubble curtain and acoustic decoupling (vibration absorber). Multiple layers create shielding, reflection and absorption effects. This solution has a high theoretical noise reduction potential, that is assumed to significantly exceed that of a bubble curtain . However, proof of the estimated high potential noise reduction, in an offshore field test, is still absent. The only available noise emission reduction data show a 6-8 dB (SEL) reduction.

2.5.5.2.3 Alternative construction technologies

Alternative construction technologies are those that have the potential to replace existing commonly used technologies under certain conditions. The low noise levels virtually achieved through the use of such technologies theoretically means that no further mitigation systems would be required. However, the effectiveness of most of them has not been definitely proven and many of the alternative technologies are in various stages of development and are currently not commercially available for use.

In recent years sensible progress has been made, especially in the development of alternatives technologies to those used during pile driving for offshore wind turbines. There are also a number of alternative foundation types in existence or currently being developed.

These alternative construction technologies include vibratory pile driving, drilling foundation, floating wind turbines, jacket foundation and gravity-based or bucket foundations. A summary of alternative noise quietening technologies especially for impulsive noise generating activities, are summarized in the list below with information provided on their known effectiveness and current state of development. Information was mainly derived from two recent reviews (CSA, 2014; Koschinski, S. and Lüdemann, K. 2013) where considerable further detail can be found on the technologies, and also from the ACCOBAMS methodological summary (ACCOBAMS, 2013).

- Pile driving using vibratory hammers

Vibratory pile hammers are directly clamped to the pile, making the pile handling much more efficient, and contain a system of rotating eccentric weights, powered by hydraulic motors, able to cancel out the horizontal vibrations trasmitted, while only the vertical oscillations are transmitted into the pile at a low frequency of about 20-40 Hz. These vibrating movements enable penetration into the seabed. This solution is often used in combination with impact pile driving but the number of impact piling strikes required to reach the final mounting would still be reduced; in this way this solution might diminish the impact zones for marine mammals and fishes, due to the fact that the adverse effect of impulsive sound on marine fauna increases with the number of blows.

Employing vibratory hammers to install monopoles it is possible to reduce the noise produced during driving of 15-20 dB (peak) even if some broadband noises could be emitted at higher frequencies, between 500 Hz and several KHz.

This solution represent a proven technology commonly used on small piles. The total energy consumed can be considered comparable to that required for impact pile driving as more time is required for installation. Technology for larger piles and deeper water have been recently developed, but impact driving would still be required at the start/end of the process.

- Vibro-drilling foundation

Combination of a vibrator tandem PVE and a drill head in one unit. Pile is driven into the seabed by vibration, drilling is applied when there is resistance to vibration. This solution have been estimated to ensure less than 130 dB @ at 750 m from the source but no field tests have been done yet and the development stage of this technology is still not known.

- Gravity-base Foundations

Gravity base foundations are steel-reinforced concrete structures whose stability is achieved by the self-weight of the structure and increased by additional ballast. The models could differ in shape and production details, however the excavation of the seabed by suction hopper dredging, for most designs is required .

In term of noise reduction, no specific sound measurements are available but noise impact from pile driving/impulsive noise during the construction phase is eliminated. The main noise emission during the construction phase would be only represent by ships noise and dredging noise.

It is also important to points out that gravity-based foundations could also have a positive impact on the noise emission during the operational phase (continuous sound). In case the foundation protrudes beyond sea level, it possibly reduces the operational noise of the turbine due to the fact that the steel mast of the turbine is acoustically decoupled from the water body.

This solution represent a proven technology used in shallow waters (< 20 m depth) but developments are planned for up to 45 m. It is generally not economically competitive with other types of structures up to depths of 10 m at the present time.

- Jacket Foundation

The jacket foundations use the basic truss structure to give stability and strength. The support structures are a combination of small components.

Jacket foundations can be use especially in transition water (30 to 60 m) but the price of a this foundation is up to 10-15 times higher than a mono pile foundation. The jacket foundations are fixed to the sea bed using pinpiles, that are driven by impact hammers or vibratory hammers through pile sleeves into the sea bed. Generally, the pinpiles for jackets foundations will be much smaller than mono piles.

Marmo et al. (2013), evaluating the noise emission of a wind farm during the operational phase, has estimated that the jacket foundation produces the highest SPL at high frequencies (>500 Hz) which is however strongly localized to volumes very close to the jacket structure and which dissipates rapidly moving away from the foundation. This result could determine a positive impact on the noise emission produced during the operational phase (continuous sound) compared to the operational noise produced by wind farms with mono pile foundations.

Relating to the impact piling noise even if it would be expected that the piling of the smaller pins should be less noisy, a recent study in Belgium by Norro (2012) showed no significant differences between mono and pinpiling. The piling of at least four small piles for each wind turbine require 2,5 more times, than monopiling and so could have a more prolonged impact onto the marine fauna.

- Floating Foundations

At the present various research companies and institutes are developing floating wind turbines based on different types of floating foundations. Most developments aim at making larger depths (>60m) accessible to wind energy use in which standard fixed foundations are either too expensive or impossible to realized.

Even if this technology is in the early phase of development and will take some time before it will become commercially available, it seems to could provide many advantages especially in terms of construction, repair, transport and installation.

On the other hand the main disadvantage is represented by not yet financial feasibility in shallow waters.

In term of noise reduction, the underwater noise produced during the installation phase is only constituted of the noise of the transport and anchoring procedures, especially if the turbines are onshore pre-assembly. For this reason for the use of gravity based anchorages, noise emissions will be similar to those for gravity based foundations and so with a significant reductions compared to mono pile foundation. In case of pile driving is required for anchoring installation no significant reduction in noise emissions is expected.

No information are available to evaluate possible noise reduction during the operation of floating wind turbines.

2.5.5.3 Software

The acoustic monitoring and modelling are essential elements of noise mitigation for the marine environment both for the assessment of impulsive and continuous sound levels in an area but also for predicting and determining the presence of some marine species in the vicinity of noise generating activities. A varied range of tools are used or could be used, as a part of a strategy to minimize the impact in the upstream phase of a project (impact assessment/planning) and in the operational phase (real-time mitigation).

The development of acoustic mapping tools has made considerable progress in recent years and these tools are being put together to describe average human-induced noise fields over extended periods of time or over large areas of coastline or open ocean. They can provide powerful visualizations of low frequency noise contributions from anthropogenic sources and their extent, and also begin to address the ranges at which many marine animals operate. In combination with tools to characterize the distribution and density of marine they can provide important information for risk assessment. A list of some of the available software tools for the planning phase may be found in ACCOBAMS (MOP5/2013/Doc22). Two important tools that are currently being developed in the United States by working groups convened by NOAA National Ocean and Atmospheric Administration and presented at a symposium in 2012 (NOAA 2012).

There are also a great number of acoustic propagation and modelling tools, available for assessing the underwater noise impacts in coastal waters and, if necessary, for planning the mitigation procedures; these tools, which are implemented in commercial softwares, could be used during the environmental impact assessments.

Concerning the operational phase of the project, real-time monitoring software is mainly used during passive acoustic monitoring (PAM). By using these tools, PAM operators support marine mammal observers during daylight hours and good weather conditions whilst they become the most important resource during night-time and bad weather conditions. Passive monitoring tools have become popular in the last decade; however the correct implementation under real operative conditions is often problematic. A list of some of the available software tools for the operational phase may be found in ACCOBAMS (MOP5/2013/Doc22) and in CMF (2014).

It should be emphasized that all these tools are evolving rapidly in recent years with the emergence of an increasing number of new software.

3. ENVIRONMENTAL CHARACTERISTICS OF THE ADRIATIC SEA

3. ENVIRONMENTAL CHARACTERISTICS OF THE ADRIATIC SEA

3.1 General features

The Adriatic Sea has its own typical features, both at land and sea. Representing a relatively small fraction of the wider Mediterranean Sea basin, it is a semi-enclosed, narrow sea area solely connected to the rest of the Mediterranean through the Strait of Otranto, which is the narrowest part of the Adriatic Sea. The northern and northwestern coastlines are characterized by shallow waters and sandy beaches. The eastern part of the Adriatic Sea is typically deeper, rocky and hosts many islands and islets. The deepest parts of the Adriatic Sea are located in the south. The Adriatic Sea is bordered by six coastal states including Albania, Bosnia and Herzegovina, Croatia, Italy, Slovenia, and Montenegro (Figure 3.1).

Figure 3.1. Adriatic basin and its countries (*source: Image LandSat - Data SIO, NOAA, U.S. Navy, NGA, GEBCO, US Dept. of State Geographer ©Google 2013*).

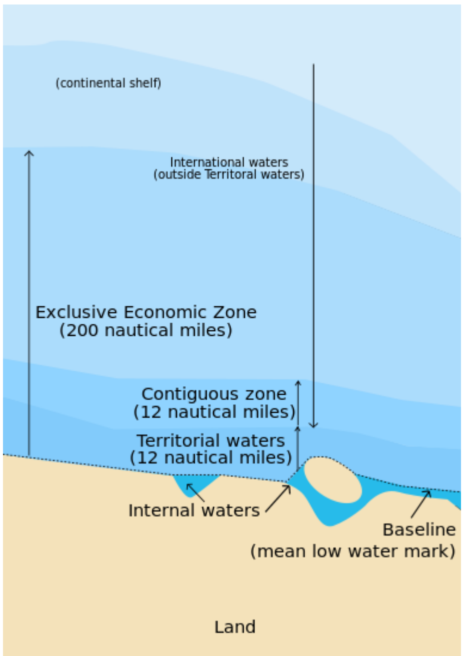
Croatia has by far the longest coastline among the six Adriatic countries (Table 3.1). Including more than 1000 islands, the Croatian coastline amounts to almost 6000 km, which is approximately 75% of the total length of the Adriatic coastline. The Italian coastline accounts for 15% of the total Adriatic coastline length, while the remaining countries of the Adriatic are characterized by shorter coastlines. Slovenia and Bosnia and Herzegovina have the shortest coastlines in the Adriatic Sea basin, respectively 47 and 23 km (*Vidas, 2008; The Network of Managers of Marine Protected Areas in the Mediterranean, www.medpan.org.*).

Table 3.1. Adriatic countries: coastline main features (n/a = not available or applicable)

Country	Coastline (km)	Islands and islets (n)
Albania	362	n/a
Bosnia-Herzegovina	23	n/a
Croatia	5835	1185
Italy	1300	n/a
Montenegro	294	n/a
Slovenia	47	n/a

3.2 Maritime jurisdictions

International Rights describe and set the boundaries of several water bodies: territorial waters, contiguous zone, exclusive economic zone, international waters and continental shelf (Figure 3.2). Those boundaries are established starting from the “baseline”, a line that divides the internal waters from the other water bodies.



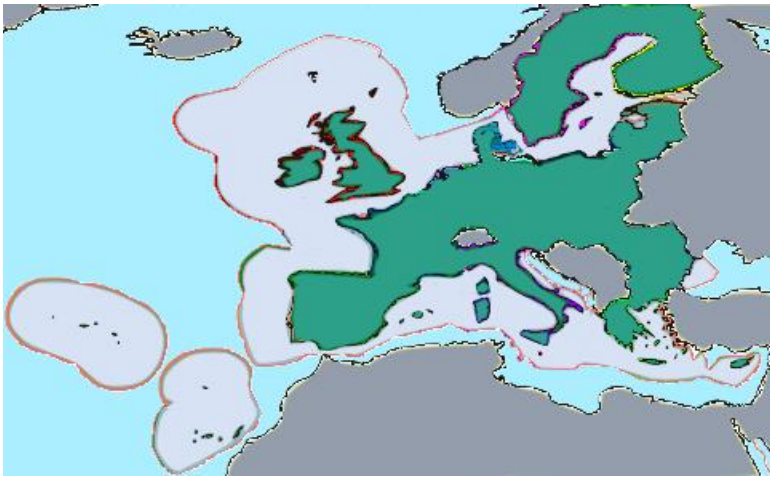


Figure 3.2. Sea areas in International Rights (left panel) and European boundaries of the EEZ (upper panel). (*http://en.wikipedia.org/wiki/Economic_exclusive_zone*)

As the width of the Adriatic Sea basin does not amount to 400 nautical miles (the average width is only 85 nm), the establishment of maritime zones implies either an agreement amongst neighboring States on a delimitation boundary or, if no agreement is reached, the submission of a dispute to a third party dispute resolution body. The countries that have set boundary agreements among them are shown in Table 3.1.

Table 3.1. Boundary agreements among Adriatic states (*source: Suárez de Vivero J.L. "EEZs in Europe",* in *http://www.eurocean.org/np4/80.html*)

Country	**Agreements with**	**To be agreed**
Albania	Italy	Montenegro
Bosnia-Herzegovina	Croatia	Montenegro
Croatia	Italy, Bosnia-Herzegovina	Slovenia
Italy	Albania, Croatia, Slovenia, Montenegro	Bosnia-Herzegovina
Montenegro	Italy	Albania
Slovenia	Italy	Croatia

Croatia and Italy established a territorial sea of 12 nm along their coasts[2]. In principal, Slovenia is also entitled to a territorial sea. However, the country has not yet reached an agreement with Croatia on the exact delimitation of the area along the bay of Piran (Figure 3.3).

Figure 3.3. Slovenian territorial waters and the contended area with Croatia (*source: Policy Research Corporation, 2008, based on: Vidas, 2008*).

Croatia and Slovenia recently agreed to set up an Arbitral Tribunal to reach agreement on their maritime border[3]. Regarding the maritime border between Croatia and Bosnia and

[2] In case a law is adopted for the establishment of a certain maritime zone, the zone is considered to be 'established'. If a country is intending to establish a maritime zone, but does not have such legislation in place, the maritime zone is considered to be 'claimed'

[3] An Arbitration Agreement between the Government of the Republic of Slovenia and the Government of the Republic of Croatia was signed, which in Article 3 stipulates the tasks of the Arbitration Tribunal. The Arbitration Tribunal shall,

Herzegovina, a treaty on the maritime borders of Bosnia and Herzegovina's territorial sea was signed in 1999. At present, the situation of water boundaries in the Adriatic basin is shown in Fig. 4.

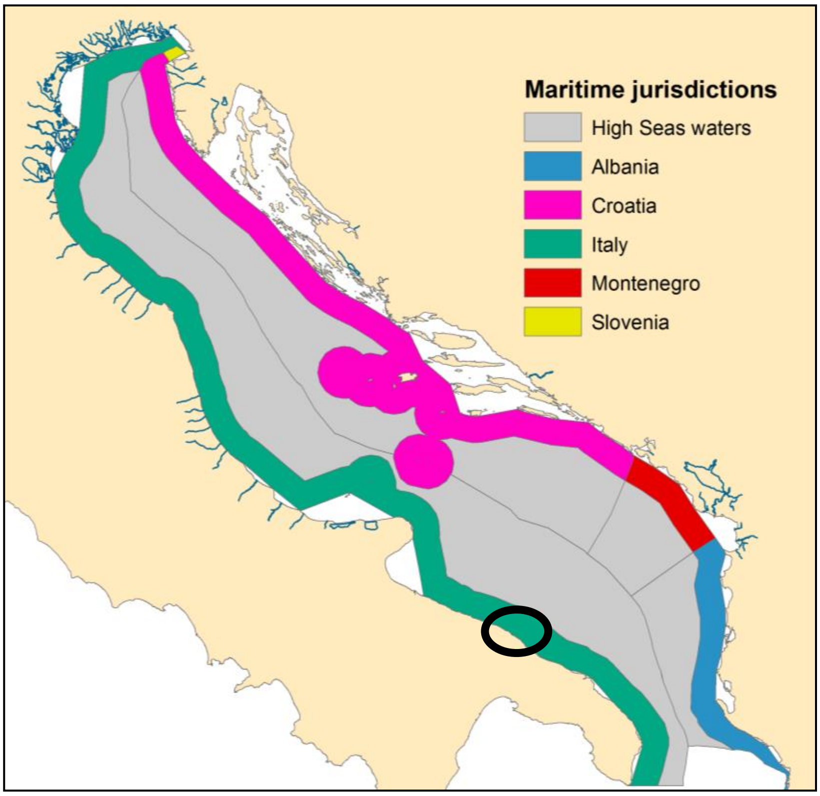


Figure 3.4. Limits of national and high seas waters in the Adriatic basin. Black ellipse: too small to be represented at this scale, the national waters of Bosnia-Herzegovina are completely surrounded by that of Croatia (*source: Suárez de Vivero J.L. "EEZs in Europe" in http://www.eurocean.org/np4/80.html*).

Besides the establishment of territorial seas, a number of special zones have been established by Croatia, Italy and Slovenia, implying an extension of their national jurisdiction beyond territorial waters. These zones incorporate a number of specific topics like fisheries and ecological protection. In 2003, Croatia established an Ecological and Fishery Protection Zone (EFPZ) in order to mitigate the negative impacts on marine resources (Figure 3.5). However, in 2004 the Croatian Parliament decided that the implementation of the zone regime for the EU Member States would only begin after signing a fishery partnership agreement with the EU. Since no such agreement was signed, in 2006 the Croatian Parliament decided

among other, determine the course of the maritime boundary between the Republic of Slovenia and the Republic of Croatia, Slovenia's junction to the High Seas and the regime for the use of the relevant maritime areas that the legal regime of the EFPZ with regard to the EU Member States was to commence as of 1 January 2008 at the latest. Subsequently, a new decision was adopted by which the EFPZ was provisionally not to apply to EU Member States “until a common agreement in the EU spirit was reached”. Consequently, so far, the EFPZ only applies to non-EU Member States.

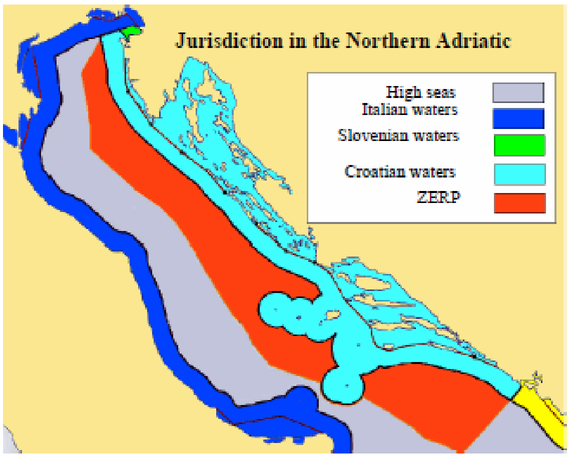


Figure 3.5. The boundaries of the Croatian EFPZ (red) coincides with those of the High Seas Croatian waters (from 12 nm to midline) (*source: Iborra Martín, 2008*).

In 2005, Slovenia established an Ecological Protection Zone. However, delimitation agreements with neighboring coastal States are still pending[4]. Italy has passed legislation empowering the establishment of an Ecological Protection Zone (one zone for the whole country) in 2006. The effective establishment of single portions of the EPZ will be acted by agreement with neighboring countries, or, pending the negotiations of the same agreements, by unilateral decree adopting provisionally the method of geometric equidistance. The Italian EPZ has been established in 2011 (Figure 3.6).

[4] UN, Maritime Space: Maritime Zones and Maritime Delimitation, Ecological Protection Zone and Continental Shelf of the Republic of Slovenia Act, 22 October 2005

Figure 3.6. Italian EPZ established in 2011 (*Source: http://www.ciesm.org/news/mscience/020412.htm*).

The southern Adriatic countries – Albania and Montenegro – did not establish any special zone. Therefore, their national jurisdiction is limited to their territorial waters. Table 3.2 sums up the basic facts of the maritime jurisdiction in the Adriatic Sea.

Table 3.2. Coastal length and maritime zones of the Adriatic Nations (*source: Policy Research Corporation, 2008*);
n/a: not applicable or not available

	Albania	Bosnia and Herzegovina	Croatia	Italy	Montenegro	Slovenia
Territorial Sea (width)	12 nm	Treaty signed; not ratified	12 nm	12 nm	12 nm	Established, but no agreement
Territorial Sea (area km²)	6 210		31710	n/a	n/a	n/a
Continental shelf (width)	North: 25 nm South: 2-4 4 nm	n/a	Extends outside of Croatia's territorial waters to the median line	Extends outside of Italy's territorial waters to the median line	n/a	n/a
Continental shelf (area km²)	n/a	2.4	44850	n/a	3079	n/a
Ecological and Fishery Protection Zone	-	-	In force, but does not apply to EU Member States	-	-	-
Ecological Protection Zone	-	-	-	Framework legislation was passed in 2006; up until today, no EPZ	-	Established in 2005 (no agreement)

Although a number of Adriatic countries have established special zones, a considerable part of the Adriatic Sea basin is not or partially managed or controlled, since only a limited number of zones have been established or management is limited to certain aspects (i.e. EPFZ/EPZ).

3.3 Essential oceanographic traits

The Adriatic is one of the sub-basins in which the Mediterranean Sea is conventionally divided. Despite its geographical location and relatively small surface (when compared with other sectors of the whole Mediterranean basins), it plays a fundamental role as regards the dynamics of its water masses. In fact, the Adriatic Sea is one of the main sources of the bottom waters for the eastern sector of the Mediterranean Sea. Through the Strait of Otranto the Adriatic pours into the Ionian Sea surface waters with a current flowing along the western Italian coast, as well as bottom waters formed in the northern and southern Adriatic (especially in winter as the result of event of dense shelf water formation). At the same time it receives, along the east coast, surface inputs from the Ionian Sea and, in the intermediate layer, Levantine waters that were formed in the far eastern basin of the Mediterranean.

The Adriatic Sea is the most continental basin of the Mediterranean (apart from the Black Sea), located between the mountain ranges of the Apennines, on the west side, and the Dinaric Alps, on the east. It is characterized by an elongated shape, with the major axis 800 km long and the minor axis less than 200 km, so its dynamics are strongly influenced by meteorology. Is a semi-closed sea, of about 138.000 km^2, conventionally divided into 3 basins (northern, central and southern), characterized by increasing depth from north to south (Figure 3.7).

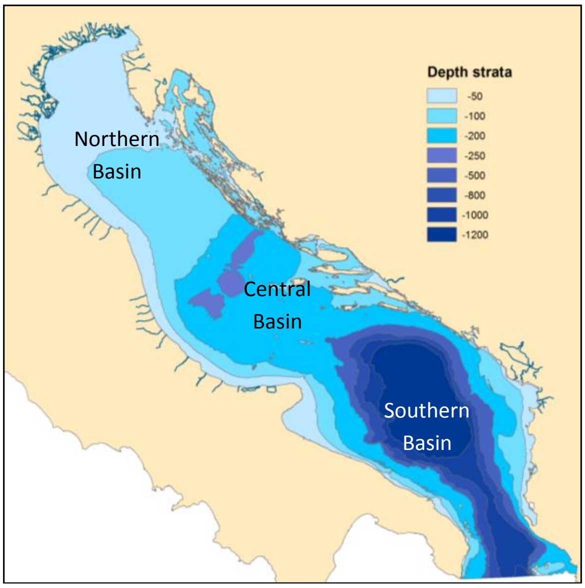


Figure 3.7. Adriatic Sea: basins' boundaries and bathymetric features (*source: ancona.ismar.cnr.it/IPO/PPT/ Adriatico.ppt*; modified)

The morphology of the seabed and the peculiar physiographical characteristics make the Northern Basin considerably different from the remaining two basins of the Adriatic Sea. In particular, the hydrological features of the North Adriatic are markedly affected both by meteorology and the input of freshwater due to the presence of its numerous rivers (Buljan and Zore-Armanda, 1979; Franco, 1973; 1983; Franco *et al*., 1982). The continental freshwaters determine a salinity considerably lower in the northern than the other Adriatic basins; the large inputs of nutrients associated with river outflow in the northern basin generate high levels of primary productivity and, consequently, fishing resources relatively more abundant than in other Mediterranean Sea sectors. The riverine inputs play also a direct role in the shaping of sea bottom morphology and exert a strong influence on water density of the basin itself. The presence of water masses with reduced salinity (and therefore density) in the northern basin, together with the winds and the rotational motion of the Earth, determine the entrance from the South Adriatic basin through the Strait of Otranto of higher-density deep waters, which flow along the eastern coasts of the basin and give birth to a cyclonic (counterclockwise) current. As a consequence, continental waters are driven southeast along the Italian (western) side of the basin (Franco, 1970). Those inputs are counterbalanced by an outflow of colder and denser water masses, which in the end constitute the bottom layer typically observed in the Eastern Mediterranean basin. In the northern basin are therefore present three water layers at different densities: a surface layer (influenced by low salinity continental waters), an intermediate layer of Ionic origin (with higher temperatures and salinity) and finally a deep layer, characterized by dense and cold water, which laps the Italian shores and gets into the Ionian Sea. On yearly basis two main circulation patterns, the first present during the spring, summer and autumn, and the second during the winter, can be described (Franco, 1986; Fonda-Umani *et al*., 1992) (Figure 3.8).

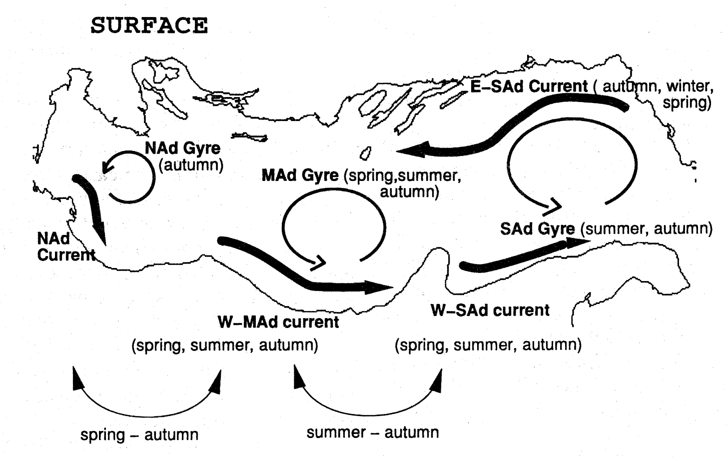


Figure 3.8. Main current models of the Adriatic Sea basin. *(Source:* Artegiani *et al., 1997a)*

With the increase of the surface temperature, in fact, a strong thermocline (with maximum in summer) is established, which is followed by a halocline in autumn. During fall, a process of cooling of the surface layer begins and the bottom layer at the same time reaches the maximum value of temperature, probably accentuated by the intrusion of mid-Adriatic deep waters. This marked stratification, which identifies three areas separated by strong density gradients, changes the circulation of the basin: the Gulf of Venice, in particular, is home to a cyclonic vortex that welcomes the masses of surface water, diluted by the Po river, at the same time separating it from a second cyclonic circulation zone, located in the south-eastern part of the basin (Franco, 1970). This general situation is influenced by tidal currents and wind in a variable manner; in the presence of a marked stratification and high stability of the water column it appears that the effect of mixing is limited to the surface layers, while the action of surface transportation on less dense water could be considerable (Franco, 1970). In winter the cooling process affects the entire water column and both the thermal and the density stratification disappear completely; due to the gradual cooling of shallow coastal waters, along the west coast two distinct water bodies can be identified, that is a strip of low-density water - originated by the mixing with riverine inputs - and high density and salinity waters offshore, separated by a sharp transition zone (front system) (Franco, 1986; Fonda-Umani et al., 1992). In particular, the coastal waters (up to 6-7 miles from the coast) are characterized by temperatures up to 5-6° C and salinity below 37‰, while those offshore have higher temperatures and salinity values (10-12° C and >38‰) (Franco, 1986; Artegiani, 1997a-b).

Under these conditions, the circulation of the basin is characterized by intense southward coastal currents in the diluted western area, by an intermittent flow of dense water, commencing in the western front outside the system and directed towards the deeper Adriatic waters, as well as by equalizing northern currents directed to the eastern and central part of the basin (Franco, 1986; Fonda-Umani et al., 1992). In coastal areas, at the mouth of many rivers of the Veneto and Emilia-Romagna, counter flows along the coast can be observed, while offshore takes over the main Adriatic current (Tomadin, 1979; U.O.L.G.M.B., 1980).

3.4 Main geological and sedimentological features

The Adriatic Sea was formed after the onset, at the end of the Cretaceous period (about 70 million years ago), of a compressive regime between the African and European plates. The compression has also given rise to the Alpine orogenesis leading to the formation of the Alps, the Dinaric and the Apennine systems. These compressive and converging forces also induced high subsidence that allowed the accumulation in this basin of enormous volumes of terrigenous sediments, mainly Plio-Quaternary (about 5 million years ago to the present), coming from the opposite Apennine and Dinaric chains.

The most recent Quaternary geological history has been strongly influenced by significant eustatic variations that led the northern part of the Adriatic Sea to emerge from water one last time approximately 15-18 thousand years ago, when sea level was about 120 m lower than the actual (Trincardi et al., 1994; Lambeck et al., 2004) (Figure 3.9).

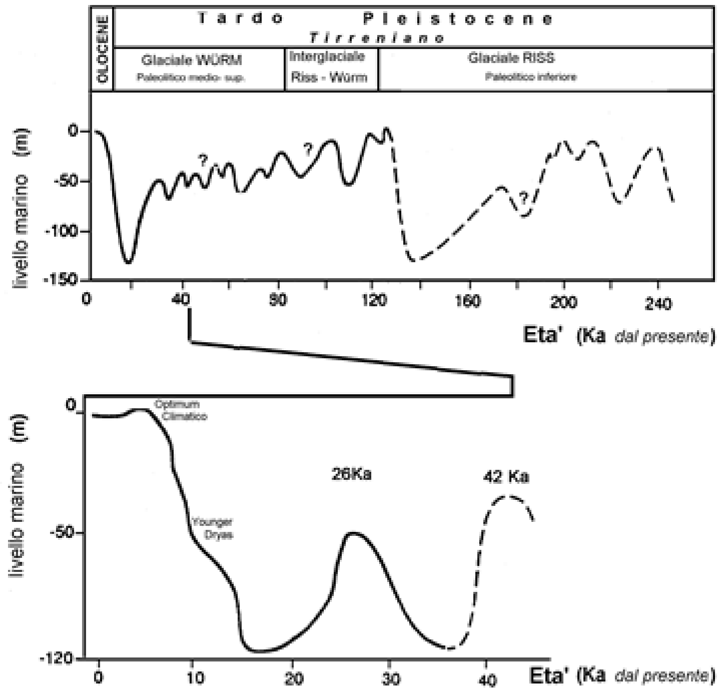


Figure 3.9. Timescale curve and glacio-eustatic sea level rise of late Quaternary (from Ricci Lucchi, 1992; mod.).

During the peak of Würmian glaciation the northern Adriatic was an extended floodplain with swamp and marshes, and the Po Valley reached the height of Pescara, where the delta of the paleo-Po was placed (Figure 3.10).

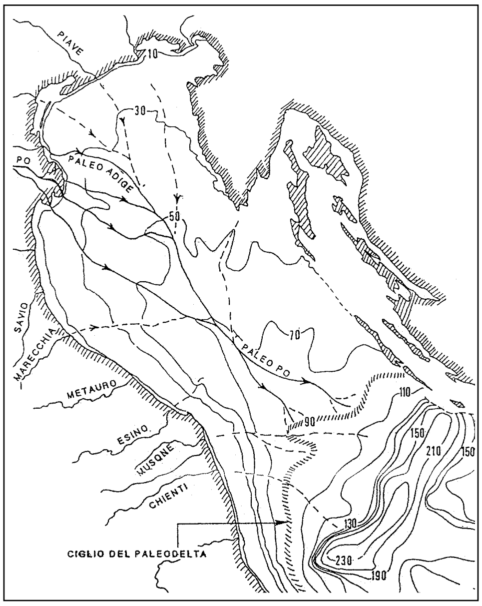


Figure 3.10. Würmian northern Adriatic Sea during the ice age (15-18 thousand years ago). The edge of the Po paleo-delta was located along the present isobath of 90 m (from Ricci Lucchi, 1992; mod.).

This plain was drained by the paleo-river beds of the actual rivers; because of the lowering of the base level and the consequent increase in the erosive power, the rivers were able to give rise to sandy flooding events, while in the intermediate zones there were marshy areas characterized by typical sedimentary successions with intercalations of clayey silt and peat (Colantoni et al., 1980). The continental deposits of the Würmian period form thick sedimentary layers of about 40-50 m that can be identified at more than 30 km off the actual coasts of Romagna (Brambati, 1992). The sea invaded this plane as a result of Flandrian transgression, who had two major episodes: the first led to a general arrest occurred about 6-8000 years ago, the formation of a shoreline approximately along the current depth of -25 m, and the second gave rise to the maximum Holocene marine ingression occurred about 3-4000 years ago (Figure 3.11).

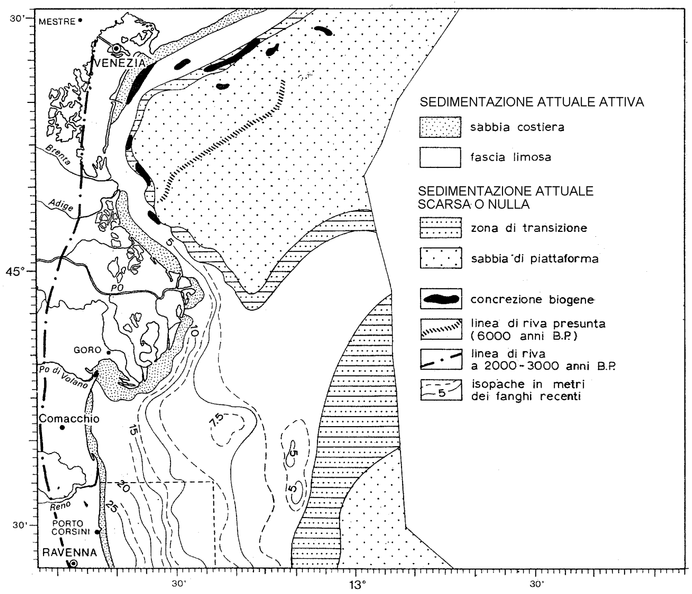


Figure 3.11. Schematic distribution of sediments in the coastal northern Adriatic area and presumed Holocene shorelines (from Colantoni et al., 1980; mod.).

Low frequency ultrasound profiles, run perpendicular to the coast, show a sharp discontinuity of the layers ("reflectors"), attributable to the Flandrian transgression and its coastal sand deposits. On this discontinuity the later depositional phase (still in progress) gave rise to the so-called Holocene wedge, made prevalently of silt (Figure 3.12).

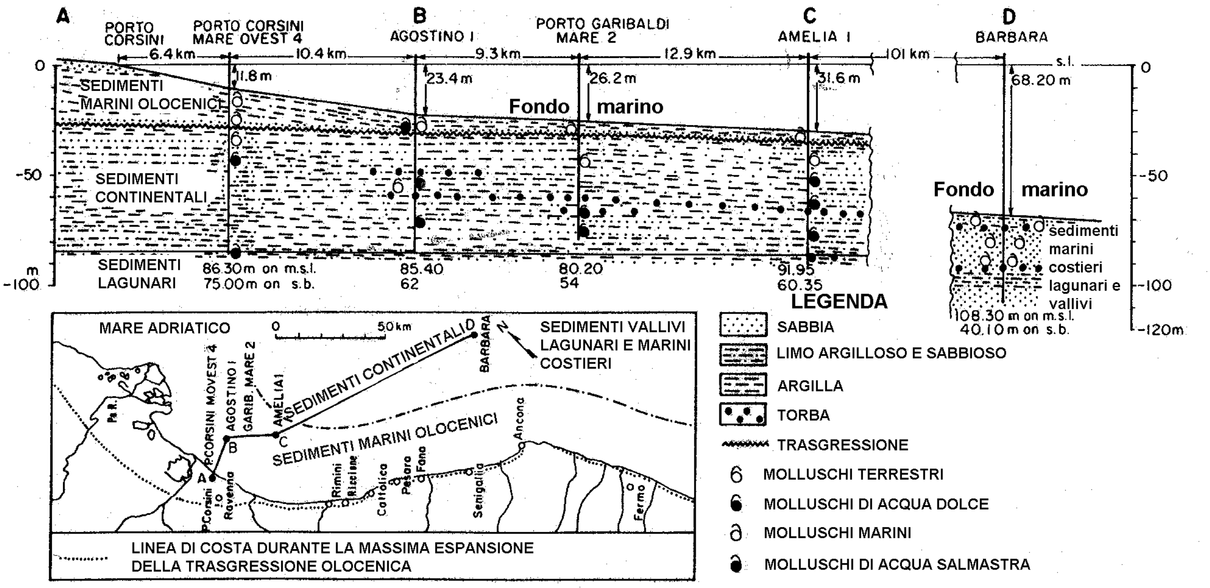


Figure 3.12. Correlations of lithostratigraphic depositional surfaces of the platform overlooking the Adriatic coast of Romagna and Marche (from Veggiani and De Francesco, 1972; mod.).

Below the Holocene wedge - which ends far offshore, and the layer of coastal sands, lie the Würmian continental deposits (predominantly clayey) containing also layers of peat formed in the swamp and fluvial environments previously described. Here sonographic profiles sometimes show areas acoustically transparent attributable to pockets of gassy sediments, whose containment is not, however, linked to particular geological structures but only to some changes in the porosity of the sediment itself. These pockets can be extremely shallow (ca. 5 m below the seabed) offshore, where the wedge is tapered or non-existent (Figure 3.13), and despite the relatively weak pressure may lead to uncontrollable and dangerous emissions, detectable even with echo sounders or similar equipment in the form of “pockmarks”.

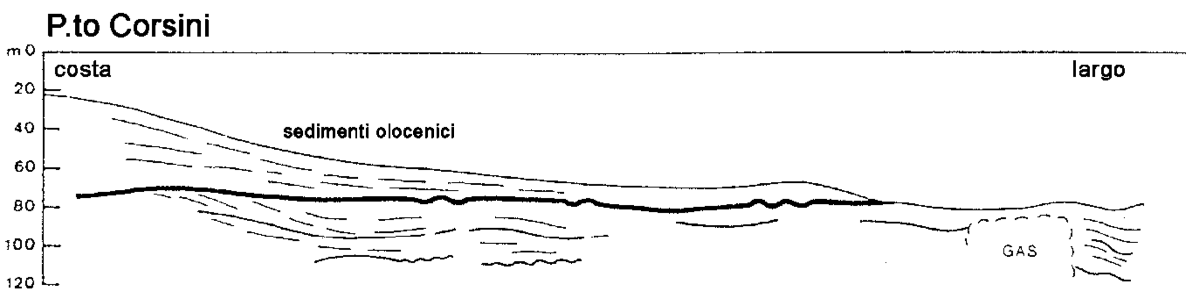


Figure 3.13. Schematic cross-section of sea bottom and sub-bottom obtained from low-frequency ultrasound: Holocene wedge and gas pockets are highlighted (from Colantoni et al., 1978; mod.).

The terrigenous contribution of various rivers entering the Adriatic and the transportation mechanisms that affect current sedimentation led to the formation of several well-defined and distinct sedimentary provinces on the basis of mineralogical composition. Within these is then identified a net size distribution.

The northern Adriatic includes: a coastal province along the Italian coasts; the Veneto province (north of the Po river delta); the much more extended Po province, which is limited by the Istrian-Dalmatian province (east) and the South-Augitica (south) (Figure 3.14).

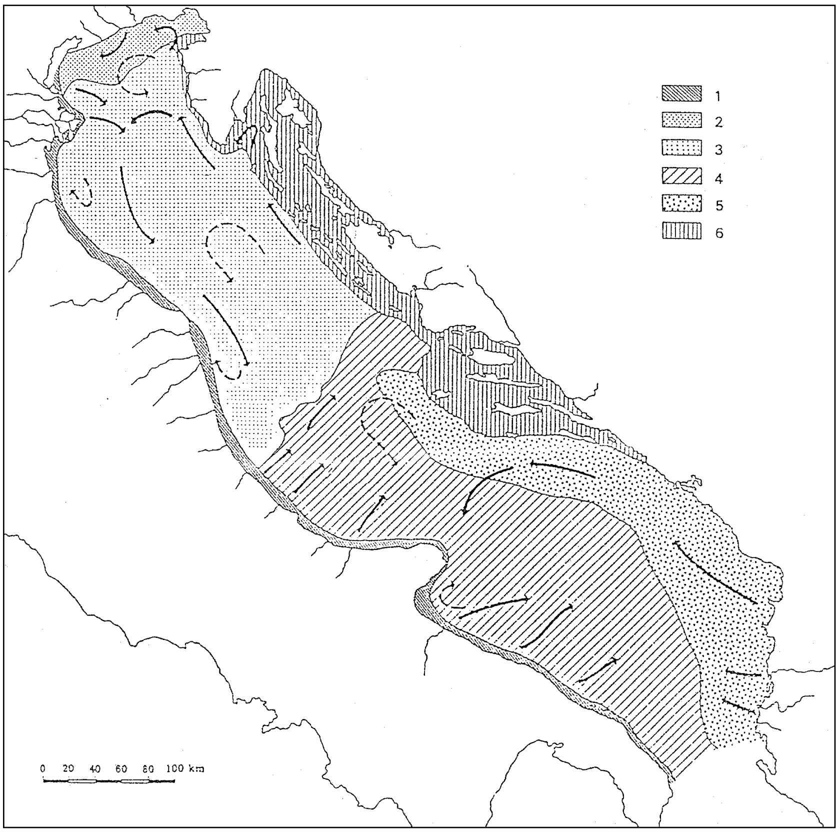


Figure 3.14. Sedimentary provinces and main directions of sediment transport: 1) Coastal province; 2) Veneto province; 3) Po province; 4) South-Augitica province; 5) Albanian province; 6) Istria-Dalmatia province (from Colantoni, 1986; mod.).

The coastal province begins with the submerged beach sands that reach a depth of 5-7 m on average. This province is followed by strips of finer sediments, from silty sands to clayey silt up to silty clay, derived from current sedimentation and covering part of the Po province. Offshore, after a transition zone composed by “loam” (sand, silt and clay) and clayey sands, platform relict sands can be found, dating back to the last post-glacial transgression (Flandrian transgression). This transgression, in its first phase, must have been fast enough for not allowing the waves to rework the sediment and place them in balance with the current sedimentation (Colantoni, 1986). The most terrigenous contribution is provided by the river Po, which has an average annual sediment transport estimated at 14 million tones consisting in a 77% of silt/clay and 23% of sand, approximately (Colantoni, 1986). Once at sea, the coarser sediment load (sand) is deposited almost immediately because of the strong decrease in speed. His fate is to be distributed along the coasts and then reworked by waves and coastal transport phenomena. The finer material remains instead in suspension and can be transported to the south from the typical currents of the Adriatic circulation (Figure 3.15).

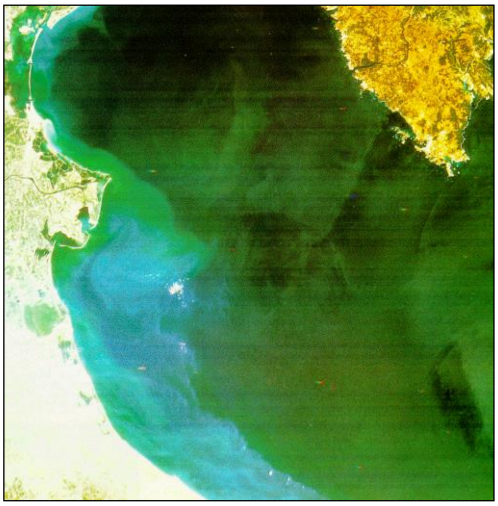


Figure 3.15. Satellite image of the northern Adriatic: it is possible to observe the "plume" of the Po river along the coasts of Emilia-Romagna because of the Adriatic circulation (*source: Telespazio, 1992*; mod).

The contribution of sediments, but also of nutrients and pollutants, is therefore very low in the more central areas of the basin, preventing the relict sand to be buried (Figures 3.16-3.17).

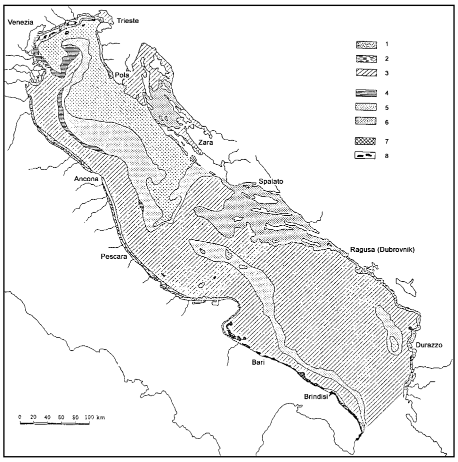


Figure 3.16. Sedimentological Chart of the Adriatic. Active sedimentation: 1) coastal sand; 2) silty sand and sandy silt; 3) clayey silt and silty clay (silt). Transition zone: 4) loam (sand, silt and clay); 5) clayey sand; 6) coastal and platform sands. Scarce or null sedimentation: 7) "relict" platform sands. Hard substrata: 8) calcarenites and biogenic concretions (from Colantoni, 1986; mod.).

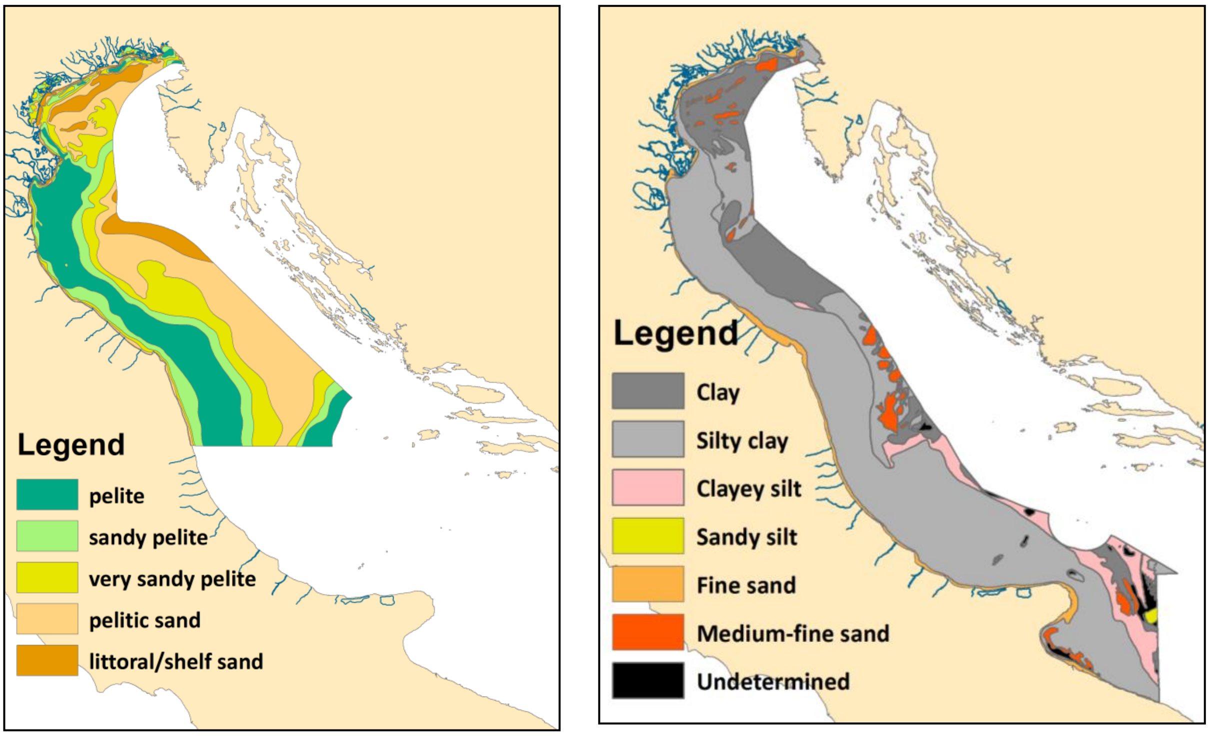


Figure 3.17. Maps of sea bottom main features in the Adriatic basin. Left panel: sedimentological chart of the Adriatic (from Brambati et al., 1988; mod.). Right panel: geological chart of Italy (from CARG, 2011; sheets NL 33-7, NL 33-10, NK 33-1-2, NK 33-5, NK 33-6, NK 33-8-9, mod.).

The sedimentary dynamics is actually much more complex and is strongly affected by seasonal and annual variations either of river transport and energy level of marine processes, higher on average during winter. In this way fine sediments, temporarily located near the coast, can be reworked and resuspended by gales and storms. These meteorological phenomena are also important from the biological and ecological point of view. In fact, together with the fine sediments also nutrients and pollutants can be re-suspended and released depending on the concentration differences between water and sediment, remaining in solution for days before being re-absorbed. By contrast, in the case of high concentrations in water, is possible that adsorption phenomena will be established on part of the re-suspended particulate, such as to produce a certain depuration (Colantoni, 1986). According to Brambati (1992), the current prevailing coastal erosion that is actually measured in the Adriatic basin, caused by the hydrodynamic features, the general reduction of riverine inputs, the increase in winter storms, the subsidence and the positive eustatism, is expected to continue for several decades at least.

3.5 Benthos and distribution of main benthic communities

Over 2300 species of benthic macro-invertebrates are known to the Adriatic Sea, together with 550 species of macroalgae (Ott, 1992) and 5 species of seagrasses, but as far as the Italian coasts are concerned, information is concentrated mainly on flora and fauna that inhabits soft bottoms (sediments). Aristocle Vatova in 1949 accurately described the faunal associations of soft bottoms in the northern Adriatic (Vatova, 1949), grouping them into biocoenoses and representing their distribution through maps. The associations of Vatova were reviewed almost twenty years later by Helena Gamulin - Brida (1967, 1974) using the methodology proposed in those years by Pérès and Picard (1964) and subsequently confirmed by Ott (1992).

The biocenotic structure of the Italian coasts has been updated following the completion of the mapping of the main coastal marine biotic communities based on literature and using the classification of Pérès and Picard (1964): this mapping, at the scale 1:250.000, relates to range within three miles from the coast but extends to 12 miles in the northern Adriatic Sea (Relini et al., 2004). Although the definition of biotic communities is not sufficient to adequately represent the high spatial heterogeneity and temporal variability of the populations of the seabed, it is nevertheless useful for a general characterization on a large-scale.

The biotic communities of the Adriatic Sea are roughly distributed in bands parallel to the coast, starting from the western sandy beaches that give way to the predominantly muddy bottoms offshore that stretch to the rocky coast of Istria, while in the Gulf of Kvarner and in the Dalmatian Archipelago we find a more patchy (mosaic) structure of the seabed and of the inhabiting communities (Figure 3.18).

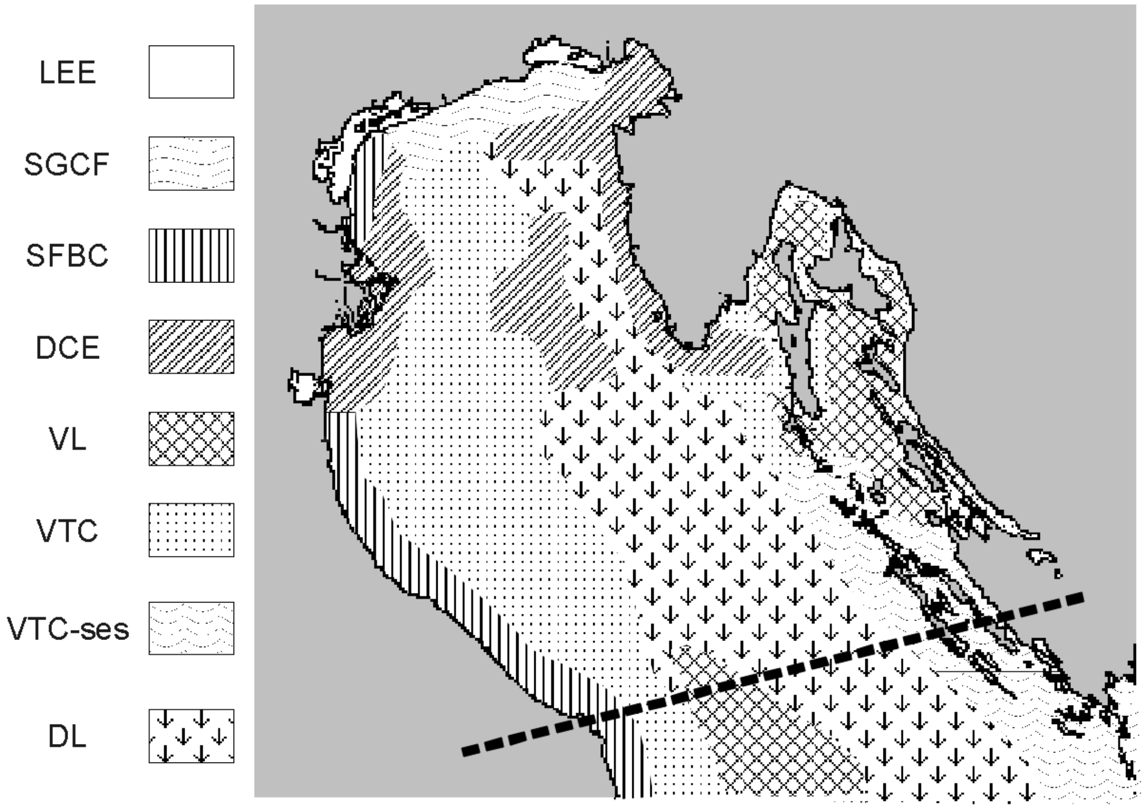


Figure 3.18. Main benthic communities of the Upper Adriatic seafloor. LEE: euryhaline and eurythermal lagoon; SGCF: coarse sands and fine gravels; SFBC: well-sorted fine sands; DCE: coastal muddy debris; VL: offshore muds; VTC: coastal terrigenous muds; VTC-ses: *facies* of sessile forms; DL: offshore debris (from Tagliapietra et al., 2008; modified).

The shallow sandy or sandy-mud bottoms allow bivalves to develop high biodiversity and reach considerable biomass as can easily be seen by looking at the shells stranded along the coasts of Friuli, Veneto and Emilia-Romagna. The lagoons are dominated by euryhaline and eurythermal lagoon (LEE) biocoenoses, characterized by organisms that can tolerate large variations in salinity and temperature, typical of shallow lagoon. These associations are characterized by the presence of seagrass meadows (*Zostera marina, Nanozostera noltii, Cymodocea nodosa, Ruppia marittima*), plants with true roots, stems and leaves that contribute greatly to the biodiversity of these areas. These transitional environments have been subjected to remediation and management by humans since ancient times, but especially in the last century the anthropogenic impact has led to profound modifications of the original populations: eutrophication, and the resulting dystrophic and anoxic conditions, has led to a drastic reduction in seagrass beds, favoring the development of nitrophilous phytoplankton and macroalgae (*Ulva spp.*, *Enteromorpha spp.*). Practices in aquaculture, maritime traffic and pollution (chemical and thermal) have facilitated the introduction and proliferation of invasive alien species such as the mussel *Musculista senhousia*, which alters the structure of the original populations, and the Manila clam (*Ruditapes philippinarum*) that almost everywhere replaced the native species, *Ruditapes decussatus*.

Along the sandy shores the biocoenosis of fine surface sands (SFS) can be find; on some shallow Northern Adriatic bottoms there were once lush meadows of the seagrass *Posidonia oceanica*, now reduced to only a few appearances.

Starting from the Conero promontory (close to the city of Ancona) and proceeding clockwise, the infralittoral and circalittoral bottoms are populated by the biocoenoses of the well-sorted fine sands (SFBC), characterized by the massive presence of several species of bivalves, such as *Chamaelea gallina* (zoocoenoses *Chione gallina*, *sensu* Vatova) and those belonging to the genera *Donax*, *Tellina* and *Cardium*.

Proceeding from coastline to offshore grounds, in the area of the Adige river mouth, this biocoenosis is followed by the biocoenosis of muddy coastal debris (DCE) (the zoocoenosis *Schizaster chiajei* of Vatova), characterized by the presence of the irregular sea urchin *Schizaster canaliferus* and of the brittlestar *Amphiura chiajei*; in this communities commercial bivalves like *Aequipecten opercularis* (queen scallop) and *Pecten jacobaeus* (scallop) are often found. Vatova described two facies of the zoocoenoses *Chione gallina* (*Owenia fusiformis* near the coast and *Schizaster chiajei* more offshore) in front of the Venice Lagoon while Gamulin-Brida proposed a SFBC - DCE sequence.

Off the coast of Friuli are the biotic communities of coarse sands and fine gravels (SGCF), which were defined by Vatova as zoocoenosis Amphioxus (*Branchiostoma lanceolatum*), accompanied by the bivalves *Phaxas adriaticus* (=*Cultellus adriaticus*), *Ensis ensis* and *Tellina distorta*. In the Gulf of Trieste, along the coasts of Istria to Kvarner, the biocoenosis of DCE can be found again, while in the Kvarner Gulf - due to the complex topography of the area - there is an alternance of offshore muds (VL, characterized by the presence of the Norway lobster, *Nephrops norvegicus*) and coastal terrigenous muds (VTC) biocoenosis (zoocoenosis *Turritella* of Vatova), which would be substituted by a facies of sessile forms in the Dalmatian Archipelago. The offshore bottoms of the eastern sector host for almost their total extension the *Turritella communis* facies of the VTC, accompanied by the bivalves *Corbula gibba*, *Nucula nucleus* and *Tellina donacina*; this biocoenosis is flanked to the east by that of the offshore debris (DL) (zoocoenosis of *Tellina*, sensu Vatova), whose sandy sediments are characterized by the presence of *Tellina distorta* and where the scarcity of organic matter in sediments generates a species-rich community but poor in individuals. In the central- eastern part of the Gulf of Venice, a DCE biocoenosis is found between the last two.

Ott (1992) presented a general view on large scale of the soft bottoms biocoenosis distribution (Fig. 20), which integrated and reviewed that of Gamulin-Brida (1974). A synthetic graphical description of the difference biocoenoses in the Adriatic Sea is illustrated in Figure 3.19.

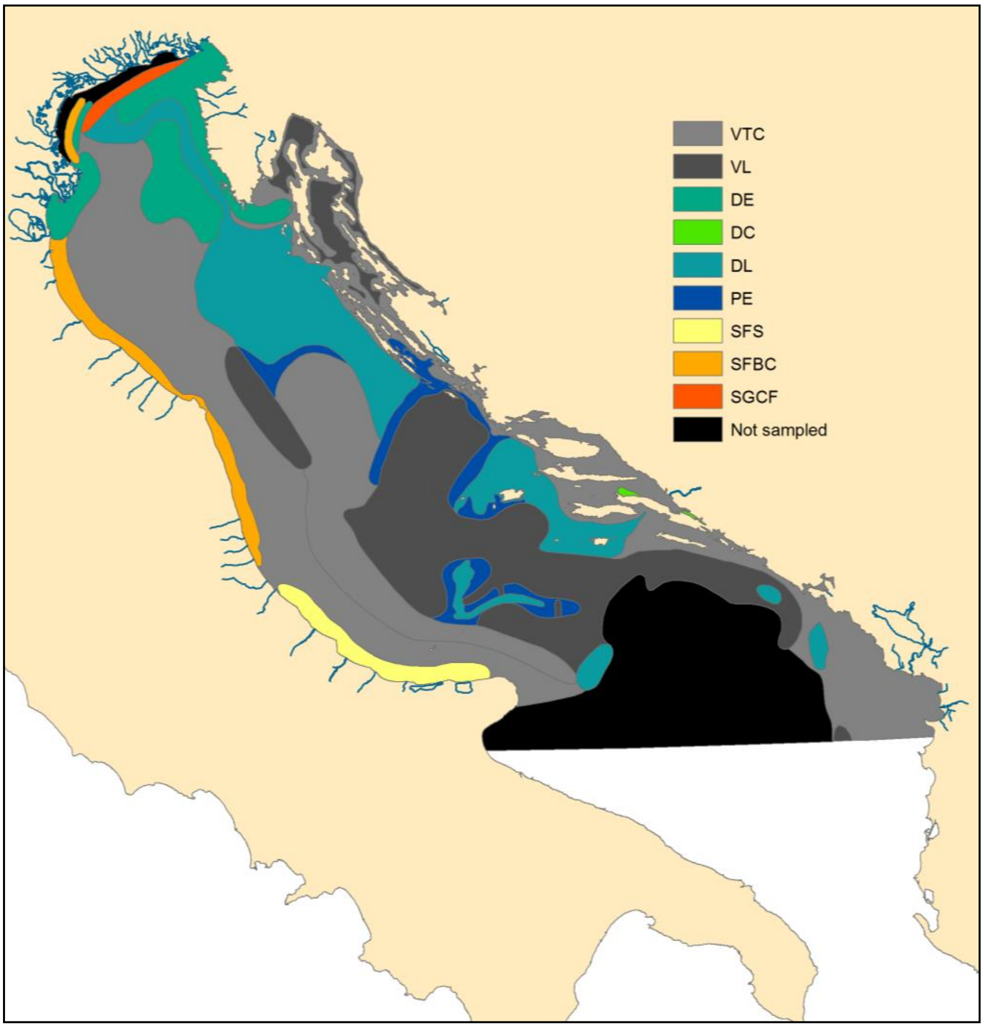
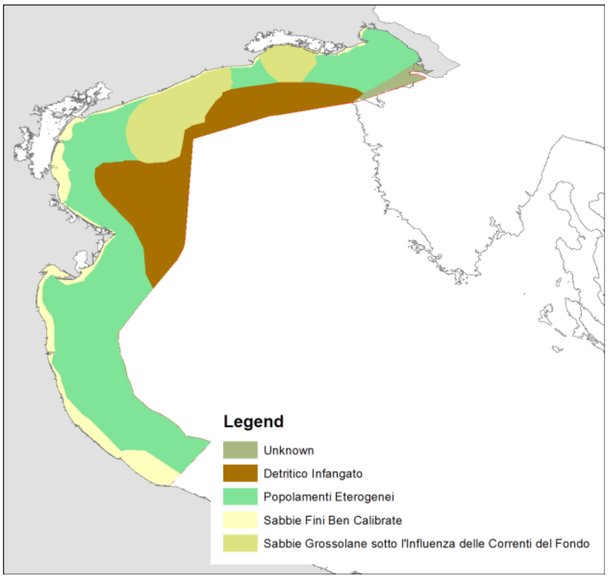


Figure 3.19. Main soft-bottoms benthic communities of the northern and central Adriatic basins (source: Ott, 1992; mod.). SFS: surficial fine sands; SFBC: well-sorted fine sands; SGCF: coarse sands and fine gravels; DC: coastal debris; DE: muddy debris; DL: offshore debris; VTC: coastal terrigenous muds; VL: offshore muds; PE: heterogeneous communities.

More recently, data on benthic biocoenoses distribution in the Adriatic basin have been collected by the Institute for the Protection and Environmental Research (ISPRA), in the framework of the activities related with the Marine Strategy Framework Directive (MSFD, 2008/56/CE) (Figure 3.20).



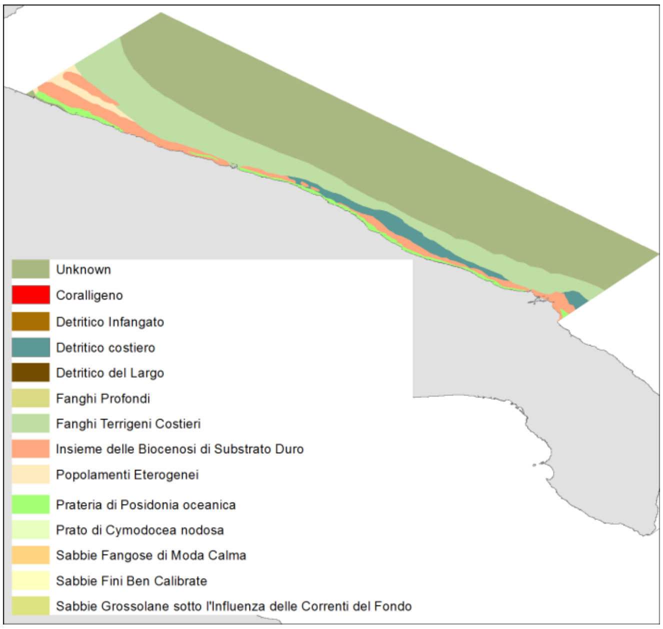


Figure 3.20. Main soft-bottoms benthic communities inside the Italian national waters in two areas of the Adriatic sea: in the northern basin (left panel) and along part of the Apulia coasts (right panel) (source: ISPRA, 2012).

The rocky eastern shores are characterized in the supralittoral and mediolittoral zones by the erosion of biological origin that shape the limestone, as a consequence of the penetration into the substrate mainly of lichens (*Verrucaria*) and algae (endolithic *Cyanophyceae*) jointly to the action of herbivorous animal that "scratch" the stone while grazing (Tagliapietra et al., 2008).

The infralittoral zone is characterized mainly by the photophilic algae (AP) biocoenosis whose facies with *Padina pavonica*, *Acetabularia sp.*, *Cystoseira* spp. and *Sargassum* sp. since the ‘60s and the ‘70s years of the last century have decreased substantially, probably due to eutrophic phenomena (Ott, 1992).

In the deeper areas extends the biocoenosis of the Coralligenous, which owes its name to the calcareous algae that encrust rocks and is the home of a rich community dominated by suspension feeders. Shoals of both yellow (*Eunicella cavolinii*) and red (*Paramuricea clavata*) gorgonians can be found, under which the red coral (*Corallium rubrum*) can be retrieved. This biocoenosis can be preceded in shallow waters by that of “pre-coralligenous”, where the non-calcified (or less calcified) algae such as *Halimeda tuna* and *Udotea petiolata* may be abundant (Tagliapietra et al., 2008).

3.6 Sensitive habitats and protection levels

Sensitive areas are places of a country, either terrestrial and aquatic, where special measures may be given to protect the natural habitats which present a high level of vulnerability (definition source: http://www.eionet.europa.eu). Vulnerability has to be intended as the degree to which a systems is susceptible to, and unable to cope with, injury damage or harm (definition source: http://glossary.eea.europa.eu). In this view, the main sensitive habitats in the Adriatic basin are represented by marine protected habitats, seagrass beds, coralligenous and mäerl beds, nursery and spawning grounds of small pelagic and demersal fish.

3.6.1. Marine protected habitats

The levels of protection in the Adriatic marine environment can be restricted to two “classes”: marine protected areas (MPAs) and no-take zones (NTZs).

3.6.1.1 Marine protected areas (MPAs)

Marine biodiversity in the Adriatic Sea is high, but at the same time a considerable number of species (both vegetation and animals) are endangered. In order to preserve biodiversity and maintain stocks of species, countries surrounding the Adriatic Sea have established marine protected areas. This section gives an overview of the MPAs in these countries.

1) Slovenia. Slovenia’s MPAs are illustrated in Figure 3.21.

Figure 3.21. Marine Protected Areas of Slovenia (s*ource: Policy Research Corporation, 2008, based on The Network of Managers of Marine Protected Areas in the Mediterranean, www.medpan.org*).

2) Italy. The Ministry of Environment has established 27 marine protected areas and 2 submerged parks (Figure 3.20) that protect a total of about 228.000 ha of sea and 700 km of coastline.

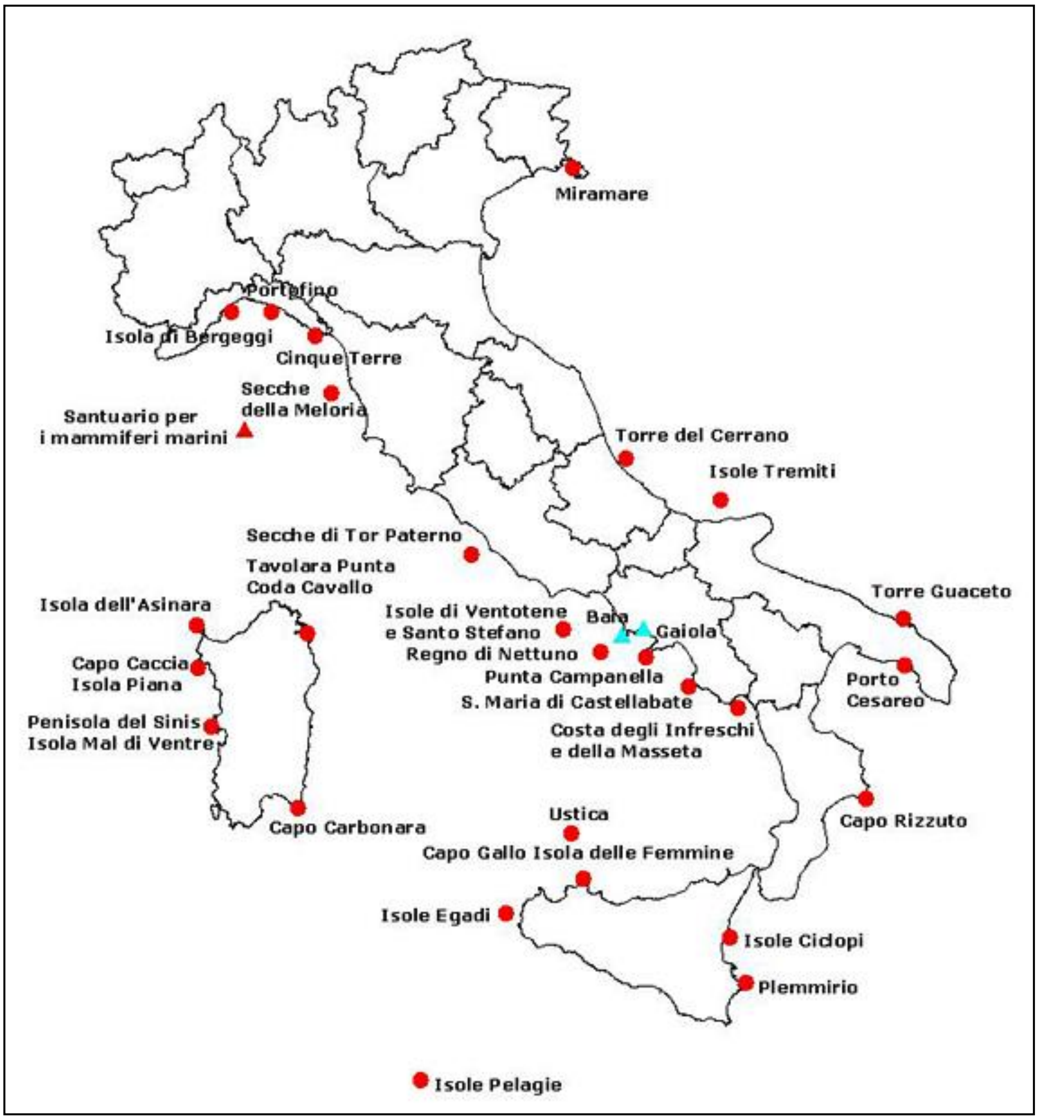


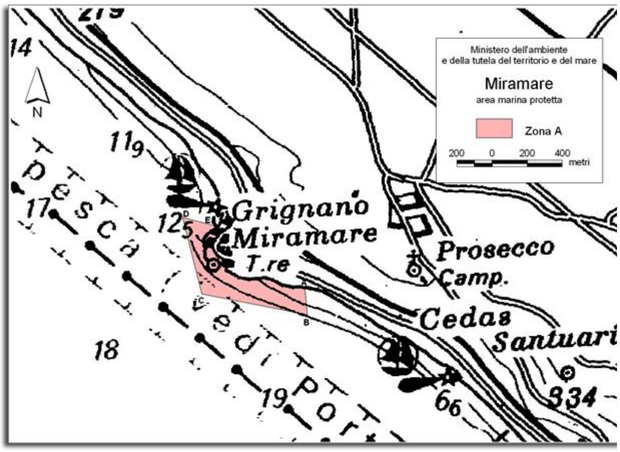
Figure 3.22. Italian Marine Protected Areas (*source: http://www.minambiente.it/pagina/aree-marine-istituite*).

In Italy, each area is divided generally into three types of zones with different degrees of protection. They consist of marine environments, i.e. water, sea bottom and stretches of coastline, that have significant relevance in natural, geomorphological, physical and biochemical traits, especially with regard to flora and fauna, either marine or coastal, and their scientific, ecological, cultural, educational and economic importance.

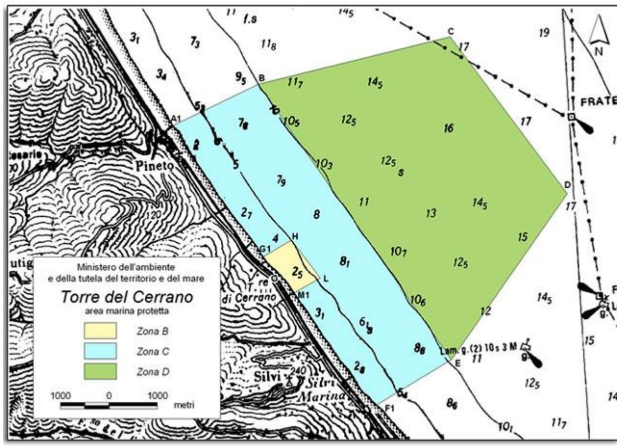
In the Adriatic Sea there are only 4 in MPAs in force (from north to south): Miramare, Torre del Cerrano, Isole Tremiti and Torre Guaceto (Table 3.2; Figure 3.23).

Table 3.2. Main features of the Adriatic MPAs (*source: http://www.minambiente.it/pagina/aree-marine-istituite*).

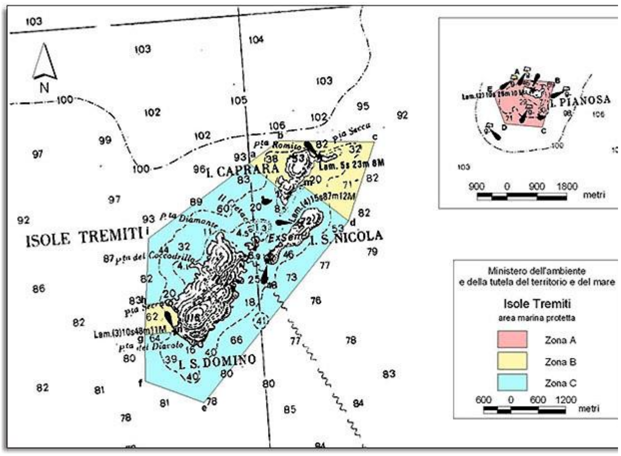
MPA	Established	Surface (ha)	Coastline (Km)
Miramare	12/11/1986	30	1.1
Torre del Cerrano	21/10/2009	3.430	7.1
Isole Tremiti	14/07/1989	1.466	20.4
Torre Guaceto	04/12/1991	2.227	8.4



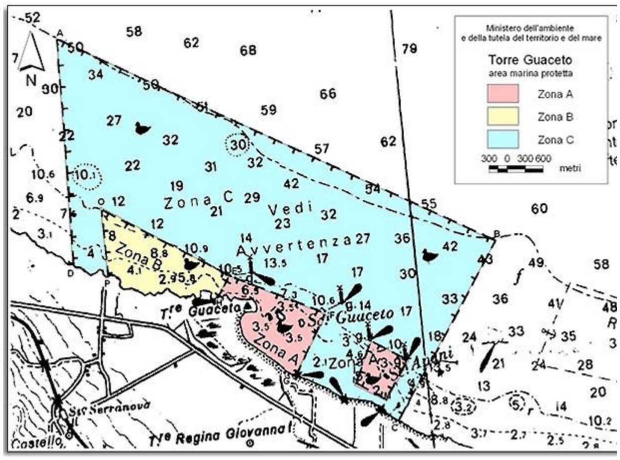
Miramare



Torre del Cerrano



Isole Tremiti



Torre Guaceto

Figure 3.23. Maps of the Italian Adriatic MPAs *(Source: http://www.minambiente.it/pagina/aree-marine-istituite)*

3) Croatia. In Croatia seven MPAs are present. Geographic location and main details about these areas are presented in Figure 3.24.

	Marine area surface (km²)	Legal status	International recognistion
Brijuni	27	National Park	Data not available
Kornati	166	National Park	Important Bird Area (IBA)
Lastovo	n/a	National Park	Data not available
Limski Zaljev	6	Special Marine Reserve	Data not available
Malostonski Zaljev	48	Special Marine Reserve	Data not available
Mljet	24	National Park	Data not available
Telascica	40	Nature Park	Important Bird Area (IBA)

Figure 3.24. Marine Protected Areas of Croatia (*source: Policy Research Corporation, 2008, based on The Network of Managers of Marine Protected Areas in the Mediterranean, www.medpan.org*)

According to the Network of Managers of Marine Protected Areas in the Mediterranean (MedPAN), Albania is establishing one Marine Protected Area – Karaburuni – which is located in its territorial sea and which will include the existing fisheries reserve. Two additional MPAs – Kepi i Rodonit and Porto Palermo – are planned in the Albanian territorial sea. Both Montenegro and Bosnia and Herzegovina do not have MPAs, but the former is planning to establish the MPA of "Katic" (source: www.medpan.org).

3.6.1.2 No take zones (NTZs)

The no-take zones in the Adriatic basin were enforced mainly by the Italian government (i.e. the Italian Ministry of Agriculture and Forestry). It's the "simplest" conservation measure, as the enforcing decree just bans all kind of fishing activities, either professional or not, in a certain area.

As an example, the decree of 22/01/2009 prohibits:

1) the fishing of juveniles of all species of fish throughout the year and in all no-take zones;

2) the exercise of all forms of commercial fishing, sport fishing and recreation, including fishing underwater unless explicitly permitted.

The same decree leaves the possibility to use some fishing gears, detailed area by area, so in the NTZ "Miramare" the use of static nets and pots by professionals is allowed unless the target species are mantis shrimp (*Squilla mantis*) and cuttlefish (*Sepia* spp.), while gamers are allowed to use only 5 hooks each person; in the NTZ "Porto Falconera-Caorle" fishing is strictly forbidden in every way; in the NTZ "Fuori Ravenna" pots and static gears are permitted to professionals; etc.
In the Adriatic sea there are 8 No-Take Zones: Miramare, Porto Falconera-Caorle, Tenue, Off Ravenna, Barbare, Fossa di Pomo-Jabuka Pit, Tremiti, Offshore Apulia coasts (Figure 3.25).

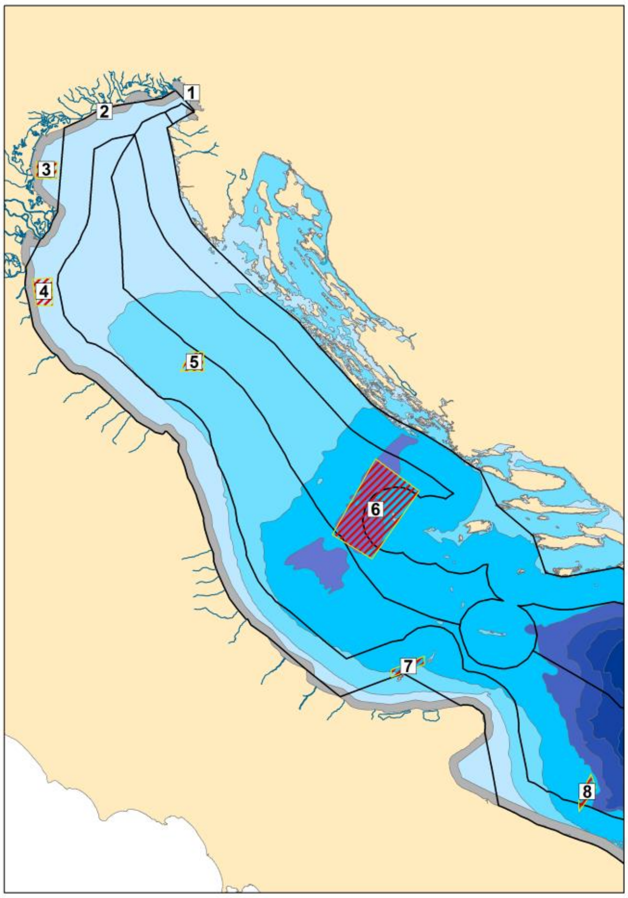


Figure 3.25. Italian No-Take Zones. 1) Miramare; 2) Porto Falconera - Caorle, 3) Tenue; 4) Off Ravenna; 5) Barbare; 6) Fossa di Pomo-Jabuka Pit; 7) Tremiti; 8) Offshore Apulia coasts. Jurisdictional limits are also reported, as well as the 3 nautical miles limit (grey area along the Italian coasts). Only NTZ 1 and 2 are completely inside the 3 nm boundary.

Apart from all the legal measures put in place by each Adriatic country to protect their marine habitats, when we take into account the work of international organizations (at

European and global level) we find that there are lots of plans and proposals that regard the entire Mediterranean basin, hence the Adriatic area. Micheli et al. (2013) recently reviewed the existing and proposed regional conservation plans, giving a general idea of the actual situation (Figure 3.26). From this survey it appears that the Adriatic Sea represents an undoubtable priority area for the conservation of the marine environment.

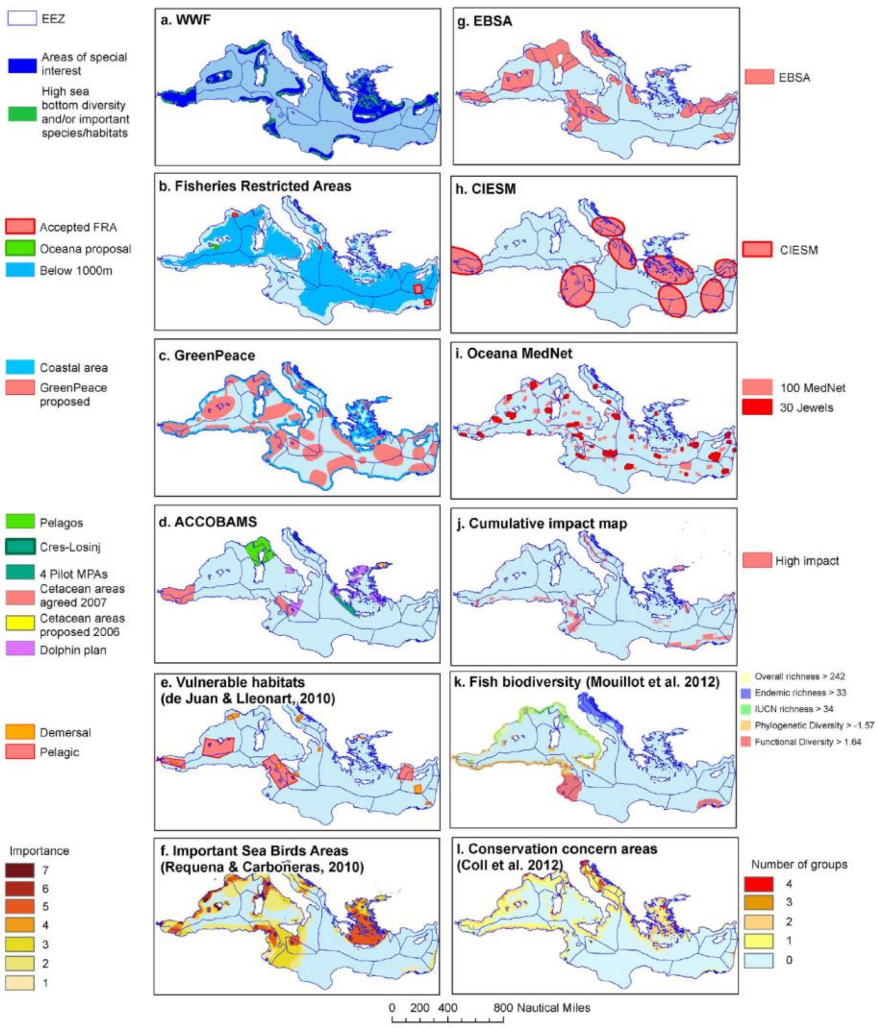


Figure 3.26. Proposed conservation priority areas in the Mediterranean Sea (from Micheli et al., 2013).

3.6.2. Seagrass beds and coralligenous and mäerl beds

In this section the main source of information about the distribution of seagrass and coralligenous/mäerl beds has been extrapolated from the final report of the EU funded project "MEDISEH - MEDIterranean SEnsitive Habitats" (MEDISEH, 2013) and, more in general, from Belluscio *et al.* (2013) (coralligenous) and from Fraschetti *et al.* (2013) (mäerl beds).

3.6.2.1 Seagrass beds

In the Mediterranean Sea, "seagrass" is a collective term for the species *Posidonia oceanica*, *Cymodocea nodosa*, *Zostera marina* and *Zostera noltii*. Other seagrasses species in the area are *Ruppia cirrhosa*, *Ruppia maritima* and *Halophila stipulacea*.

Posidonia oceanica is the only species that makes meadows, similar to the forest habitat for the terrestrial environment, which are are the most diverse, complex and productive stratocoenosis existing along the coastline of the Mediterranean Sea (Buia *et al.*, 2003). The distribution of *P. oceanica* and the other seagrass species in the Adriatic is shown in Figures 3.27-3.29.

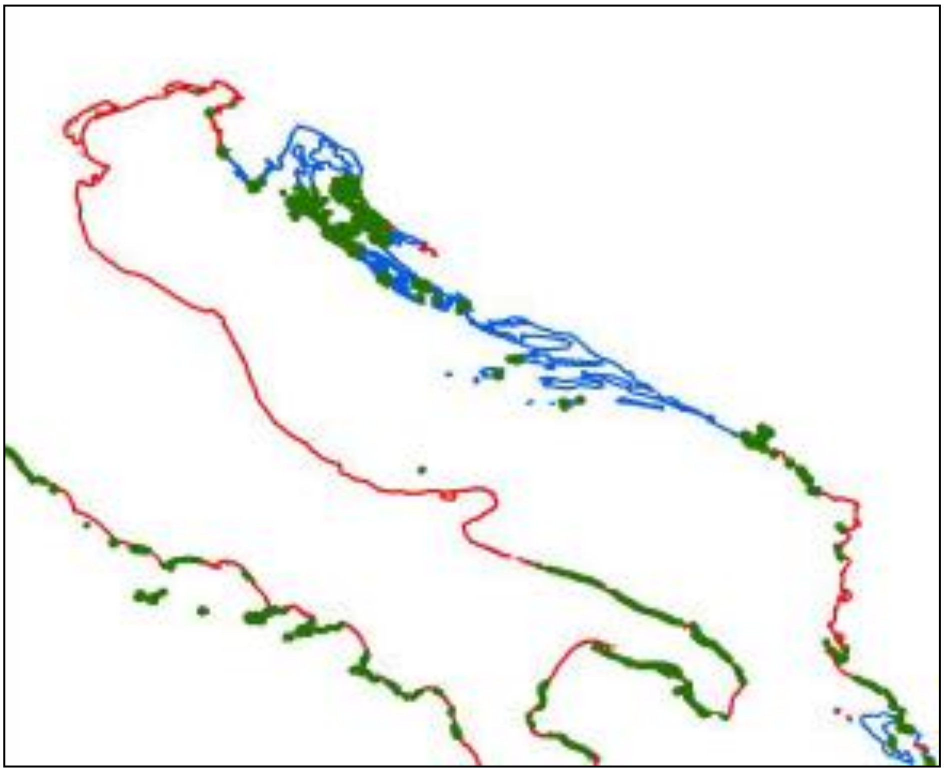
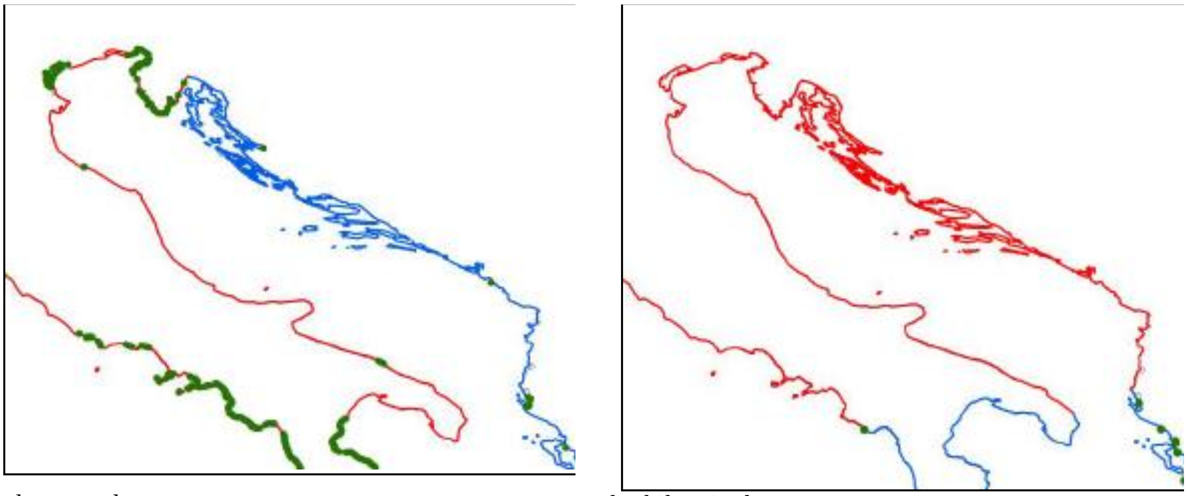
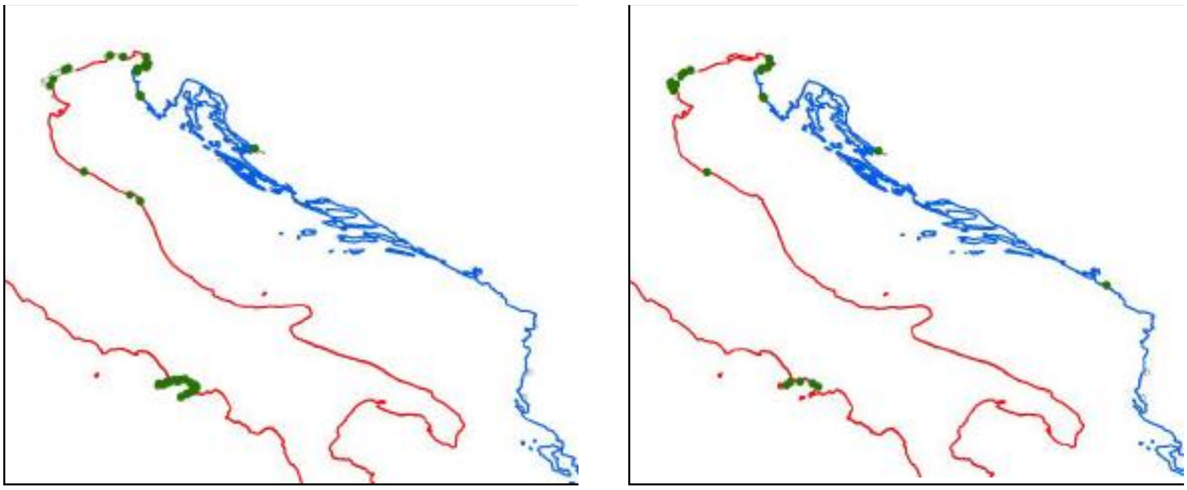


Figure 3.27. Current distribution of *P. oceanica* in the Adriatic (green: presence; red: absence; blue: no data) (source: Belluscio *et al.*, 2013; mod.).



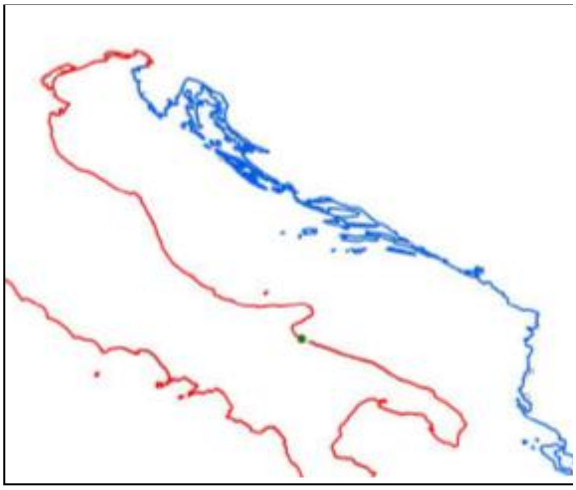
Cymodocea nodosa *Halophila stipulacea*

Figure 3.28. Current distribution of *C. nodosa* and *H. stipulacea* in the Adriatic (green: presence; red: absence; blue: no data) (source: Belluscio *et al.*, 2013; mod.).

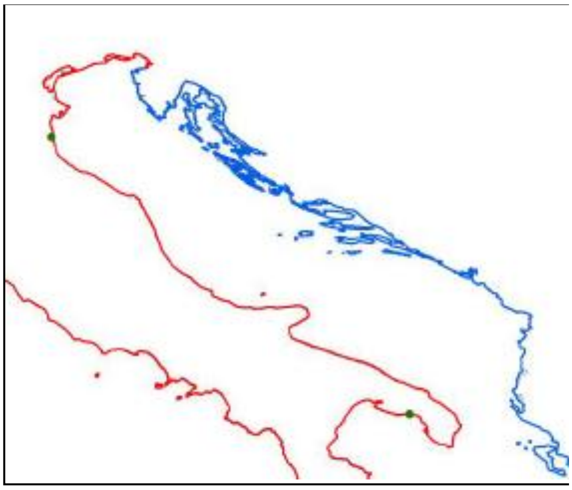


Zostera marina *Zostera noltii*

Figure 3.29. Current distribution of *Z. marina* and *Z. noltii* in the Adriatic (green: presence; red: absence; blue: no data) (source: Belluscio *et al.*, 2013; mod.).



Ruppia marittima



Ruppia cirrhosa

Figure 30. Current distribution of *R. marittima* and *R. cirrhosa* in the Adriatic (green: presence; red: absence; blue: no data) (source: Belluscio *et al.*, 2013; mod.).

As it can be seen, *C. nodosa* and *Z. noltii* are relatively common, whereas *Z. marina* and *P. oceanica* are quite rare. The latter is listed in the Red Data List of Threatened Vascular Plants in Slovenia, where its only natural habitat is about 50 m wide and 1 km long and is protected as a natural monument.

3.6.2.2 Bioconstructors (Coralligenous and Mäerl)

Bioconstructors like coralligenous formations and mäerl beds are considered as a typical Mediterranean underwater seascape comprising coralline algal frameworks that grow in dim light conditions and in relatively calm waters (Ballesteros, 2006). They are the result of the building activities of algal and animal builders and the physical as well as biological eroding processes. Coralligenous is considered of great significance both for fisheries and CO_2 regulation. At present, results are showing that mechanical disturbance (Coma et al., 2004), sedimentation increase (Balata et al., 2005), species invasion (Baldacconi and Corriero, 2009), temperature increase (Garrabou et al., 2001) and water degradation (Giuliani et al., 2005) have all negative effects on species assemblages associated to coralligenous habitats. Those stressors can drive a decrease in species density and/or increase in mortality rates.

Mäerl beds are biodiversity 'hot-spots' as they enhance biological and functional diversity of coastal sediments (Bordehore et al. 2003; Steller et al. 2007). The same stressors potentially affecting coralligenous formations can be drivers of change of mäerl.

One of the Countries where knowledge is quite good is Italy, where maps of bioconstructions are available in shapefiles for several Italian coasts; Apulia, in particular, is so far among the regions where research activities have been carried out more systematically. Distribution of coralligenous habitats and mäerl beds in the northern Adriatic is shown in Figure 3.31.

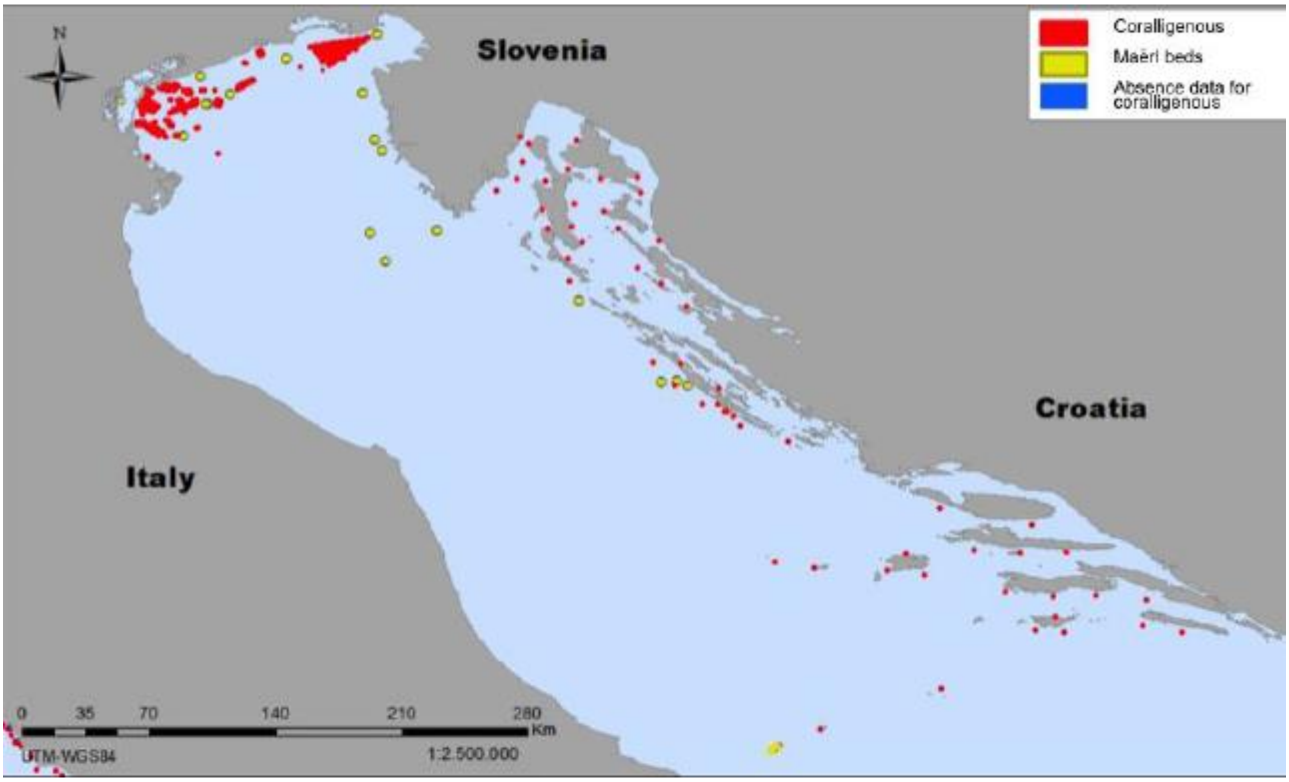


Figure 3.31. Distribution of Coralligenous and mäerl beds in the northern and central Adriatic basin (source: Fraschetti *et al.*, 2013).

In the northern Adriatic Sea several "points" of coralligenous-maërl are available for the coasts of Italy. In this area, an effort has been carried out to map peculiar formations called *tegnùe*, *trezze*, *presùre* or *grebeni*, submerged rocky substrates of biogenic concretions irregularly scattered in the sandy or muddy seabed and containing extraordinary zoobenthic assemblages (Casellato and Stefanon, 2008). For Croatia only point data sources are available, even though it is clearly evident that coralligenous might be largely present in this area. Very few data refer to maërl. Some information is available for Albania but no information is officially available for Montenegro, even though there are internal reports referring to the presence of bioconstructions (Figure 3.32).

Figure 3.32. Distribution of Coralligenous and mäerl beds in the southern Adriatic basin (source: Fraschetti *et al.*, 2013).

In the Apulia region , there are a lot of data on the presence of bioconstructions (as the above map shows); the continuous distribution suggested by this map is just a rough assessment of the real distribution. Good quality data are also available for the three Marine Protected Areas (Isole Tremiti, Torre Guaceto, Porto Cesareo) where the available resolution is at 1:5000 (data not shown).

3.7 Land scape and infrastructures at sea (MODERINI)

4. CONSTRAINS ASSESSMENT

4. CONSTRAINS ASSESSMENT

4.1 Data collection and gaps of knowledge analysis

The aim of WP5 is to analyze and experimentally evaluate environmental, infrastructural, energetic and technological constrains to the installation of offshore wind farms. To this scope, all partners, based on a commitment grid, were requested to compile a descriptive report that consisted in listing the critical environmental issues and landscape details for each region or area, possibly providing geo-referenced information. Partners were also requested to create a synthetic report of the issues that could concern their territory or competences. The compilation of this section of the WP5 report is thus based on the huge amount of data and a few reports provided, in very heterogeneous shapes and formats, by the Partners.

In addition to such partnership-source material, additional data from the literature was retrieved, reported, transformed or modified to obtain maps that referred to the information on each of the potentially constraining elements considered (birds, mammals, benthos, etc.…) and for each country, when available. It is important to consider that, in many cases, even after the strong data mining effort paid by the whole partnership, some data remained missing or insufficiently reliable to be used for mapping. We nevertheless pinpoint that in the thematic analysis there are no areas with no information, at least when considering the marine and related wildlife, but there are areas where the information is very scant, spatially fragmented or temporally scattered. **We stress here that these missing data represent one of the most important issues to be considered under operational procedures of wind farm siting**.

All the collected information, no matter derived from reliable or "grey-literature" sources, has not been experimentally verified. It is reminded that this work has been based on information retrieved from the literature or submitted by the partners until 31 July 2014, so that any data produced or made available around that date is not included in this report.

Beside this, it must be took into consideration that part of the information gathered from the literature does not derive from studies carried out exclusively in the Adriatic Sea (actually in a few cases not even in the Mediterranean Sea). Nevertheless, wherever the experimental conditions were applicable to the Adriatic Sea and the putative impacts were of similar effect, the analysis of constrains for OWFs installation and operation was included the theme. As an example, it is obvious that the collision of a marine mammal could exert similar effects in any sea, with the main difference being the mammalian species that collided.

4.2 Research institutions

4.2.1 Italy

The monitoring of sea water quality started around 10 years ago by the Italian Sea Protection Department and the 15 coastal regions in order to (PAP/RAC, 2008b):

- Improve knowledge on sea water quality;
- Protect sea and marine ecosystems;
- Identify possible degradation situations;
- Prevent and reduce water pollution.

The regions carry out the monitoring tasks through environmental agencies, universities and research institutes. One of these agencies is ARPA (Agenzia Regionale per la Prevenzione e Protezione Ambientale). It is an environmental control and technical support body to the regional, district and local authorities and is administratively and technically independent. ARPA has dedicated offices in each one of the Italian regions. Its functions cover all aspects concerning environmental control, including:

- Monitoring of the various environmental components;
- Management and surveillance of human activities and their territorial impacts;
- Activities in support of the environmental impact assessment of plans and projects;
- Creation and management of a regional environmental information system.

The agencies also have a water department that monitors the marine and coastal habitat in a variety of ways. The following activities are carried out:

- Checks on bathing waters;
- Checks on the ecological quality of the marine and coastal environment;
- Studying and monitoring anomalous phenomena such as sea bloom and eutrophication;
- Studies and applies research into areas of particular environmental value.

The agency's activities are aimed at local, regional and national institutional customers, the business world and private citizens. In addition, ARPA collaborates with the Italian Agency for the Environment and Territory, the European Environmental Agency and Italian, European and International institutes and research centres.

ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale) is another Italian research institute. The Italian Institute for Environmental Protection and Research has been established by Decree no. 112 of 25 June 2008 and converted into Law no. 133 (with amendments) on 21 August 2008. ISPRA performs the following tasks:

- Ex-APAT, Italian Environment Protection and Technical Services Agency (article 38 of Legislative Decree no. 300, July 30, 1999, and subsequently amended);
- Ex-INFS, National Institute for Wildlife (Law no. 157 of February 11, 1992, and subsequently amended);
- Ex-ICRAM, Central Institute for Scientific and Technological Research applied to the Sea (Decree no. 496, article 1-bis, December 4, 1993, converted into Law no. 61, Article 1, January 21, 1994, with amendments).

The Institute acts under the vigilance and policy guidance of the Italian Ministry for the Environment and the Protection of Land and Sea.

CNR-ISMAR is an institute of marine sciences. The research themes of the institute include:

- The evolution of oceans and their continental margins, studying submarine volcanoes, faults and slides and their potential impacts onshore;
- The influence of climate change on oceanic circulation, acidification, bio-geochemical cycles and marine productivity;
- Submarine habitats and ecology, and the increasing pollution of coastal and deep-sea environments;
- The evolution of fish stocks with a view to keep commercial fishing within sustainable limits and improve mariculture and aquaculture practices;
- Natural and anthropogenic factors that economically and socially impact coastal systems from pre-history to the industrial epoch.

These themes show a strong link to the issues relevant for MSP and the institute is therefore highly relevant for data collection and knowledge building.

4.2.2 Slovenia

Within the framework of the PlanCoast project a map illustrating the current maritime uses in the Slovenian internal and territorial waters was developed, showing that information on the different maritime activities currently taking place in Slovenian waters is available (PRC, 2011).

In addition, the 'Institute of the Republic of Slovenia for Nature Conservation' has as main objective to conserve the nature (including the sea) with a special care devoted to its most valuable and most threatened parts. Some of the institute's key tasks are:

- Collection of data on plant and animal species, their habitats and ecosystems (in cooperation with the implementers of public works in the sphere of direction of natural resources management);
- Registration and evaluation of separate nature's parts;
- Management of databases concerning natural riches and biodiversity components;
- Monitoring of the state of nature preservation, biodiversity and the state of natural riches;
- Development of models for various purposes.

Furthermore, the Inspectorate for the Environment and Spatial Planning of the Ministry of the Environment and Spatial Planning maintains the 'Spatial Information System'. The system is used to facilitate the implementation and monitoring of national and municipal tasks in the area of spatial planning, including the preparation of spatial planning documents. Nevertheless, this information system mainly focuses on onshore development rather than on offshore development (PAP/RAC, 2008a).

4.2.3 Croatia

In Croatia, in 2004, all responsibilities for protected areas and nature conservation initiatives (including marine areas) were transferred from the Ministry of Environmental Protection, Physical Planning and Construction to the Ministry of Culture, Administration for the Protection of Nature. The scientific work connected to among others data collection, Natura 2000, background documents for the proclamation of protected areas and the revision of management plans is the responsibility of the State Institute for Nature Protection (i.e. Agency for the protection of the environment). The Institute of Oceanography and Fisheries is a scientific institution established for the investigation of the sea. Its activities encompass virtually all aspects concerned with sea exploration: physical, chemical, geological, biological aspects and fisheries. Papers have been written concerning expedition reports, hydrographic studies, dynamic properties of the marine eco-system, description of flora and fauna, ecological research (in particular, primary and secondary production), fisheries research, advancements in fishing and artificial breeding (in relation to the Adriatic and Mediterranean, including coastal and open seas), as well as the impact of human activities on the sea. The Centre for Marine Research, part of the Ruđer Bošković Institute in Zagreb, is an interdisciplinary research centre where activities are focused on basic and applied oceanographic research, including among others the following activities: ecological, physiological and genetic studies of marine organisms and the effects of pollution; Monitoring of pollution and sea water quality.

4.2.4 Cross-border/international efforts

A Croatian Vessel Traffic Monitoring System (VTMIS) is currently being implemented in order to avoid accident risks and to monitor the density of the international traffic. International cooperation is considered needed in this respect since countries cannot tackle major accidents on their own (PRC, 2011). Therefore, Italy, Slovenia and Croatia have the intention to cooperate on this topic. Furthermore, the national institutes from the different countries maintain good relations with each other and cooperate frequently on various projects.

4.3 Thematic maps

The thematic maps were created using a combination of ArcGis 10.2, MapInfo and Autocad platforms, to be then reunited in the cumulative constrains mapping (shown later).

4.3.1 Birdlife

The data from migrating birdlife has been collected mosdtly from Spina and Voltori (2008a-b), who provide a sufficiently detailed analysis of the areas subjected to migration of passerines and non-passerines birds. The data on Important Bird Areas (IBAs) is available from the European Environmental Agency (EEA) and on the Ramsar Convention website all the shape files from the various sites are available. On the other hand, we included as well data on SCIs and ZPS concerning wetlands and marshes, which are the ideal environments for birds and normally protected with some sort of regulation.

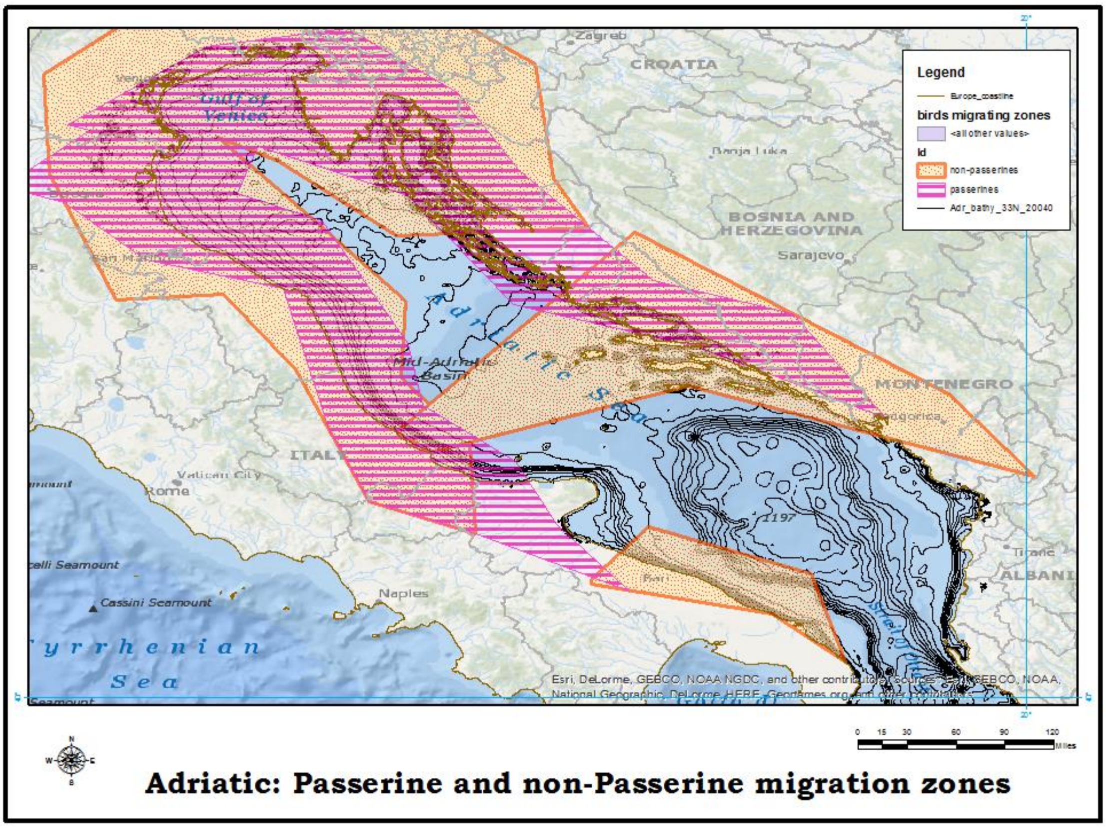


Figure 4.1 Birdlife migration areas in the Adriatic Sea

4.3.2 Marine Mammals

Data from mammal presence or evidences were collected by the NETCET project, then considered in the MEdtSeH and MEDITS projects, where some of those data are available only as jpeg images. NETCET intended to fill in the gap of knowledge in vivo of the cetacean and reptile communities in the Adriatic Sea applying air and video analysis in a grid designed for the basin. Data from the literature, the report given by Veneto Agricoltura, together with reports from Protect Planet, the Cetacean report of RAC/SPA (2014) and the cetacean sightings websites (NOAA, Instituto della marina militare, Fondazione cetacei) were useful to update and create polygons related to the areas of sightings and populations. As a corollary note the main cetaceans present in the Adriatic Sea are *Tursiops truncatus*, *Stenella* *coeruleoalba* and some ramdomly reported individuals of *Grampus griseus* and *Ziphius cavirostris*. Monk seals are meant to be present in some sparce areas near Slovenia and Croatia, though considered very rare.

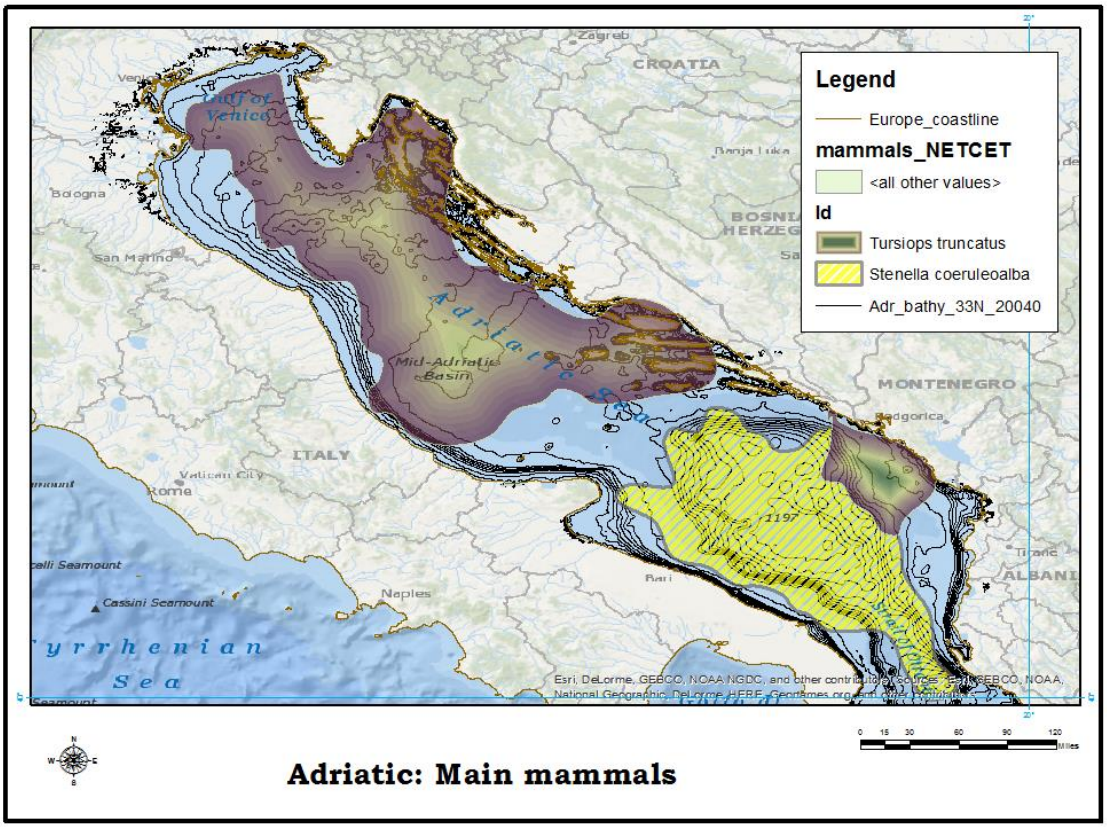


Figure 4.2 Main marine mammals distribution in the Adriatic Sea

4.3.3 Marine Reptiles

For the Adriatic Sea there is not much information on reptiles, besides the declared by-catches and accidents created, where in most of the cases the animal perishes. NETCET, along with the mammal analysis intended as well to collect data on reptiles and their posiible nesting zones. Unfortunately, in the Adriatic Sea, the common thoughts are orientated to the belief that there are no more turtles in the basin and this has increased the urbanism and the construction on the beaches suitable for nesting or forage. On the contrary, very recently, Schoefiled et al. (2013) showed that the migrating routes of turtles in the Adriatic Sea exist and they are different for males and females. We used the data provided in this publication and other data from the literature to compile the following map of turtles migration routes in the Adriatic Sea.

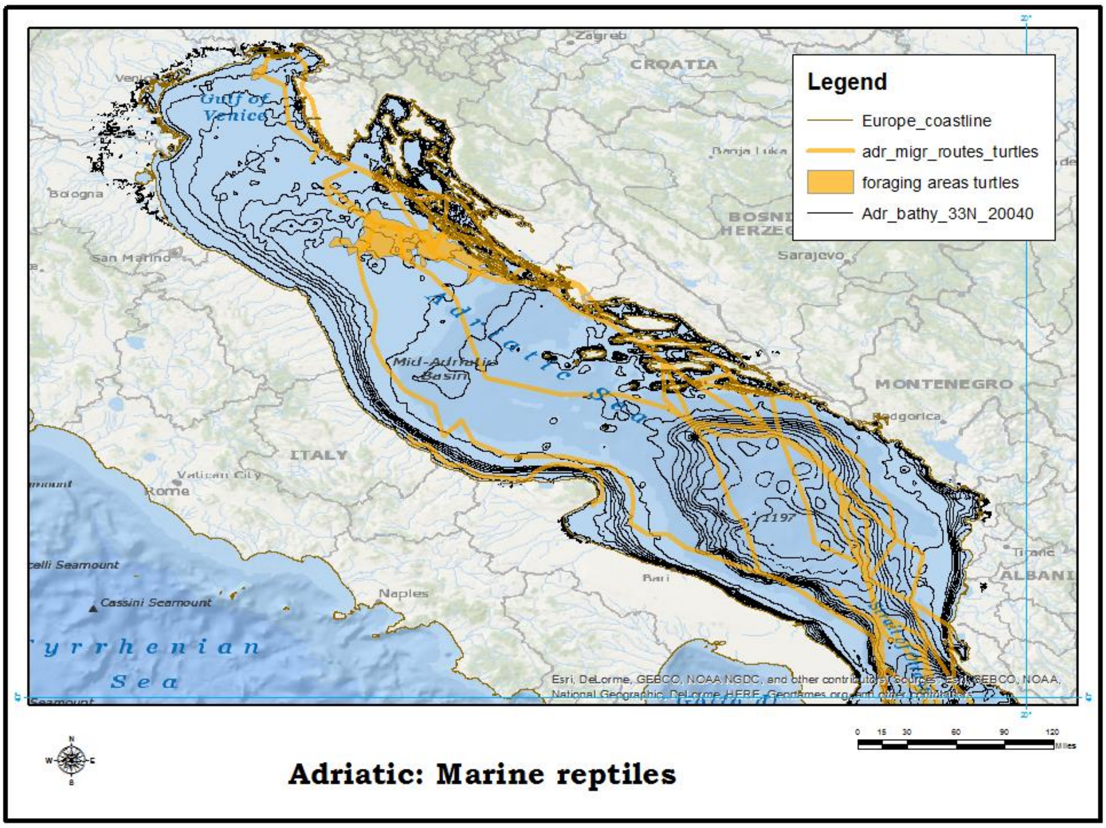


Figure 4.3 Marine reptiles (turtles) foraging and migration areas in the Adriatic Sea

4.3.4 Elasmobranchs (sharks and rays)

As for cetaceans, sharks and rays were considered almost extint in the Adriatic Sea and the only traces were given by those rare fishermen that declare their by-catch. Data for this group of fish has been retrieved from the CIESM sighting and monitoring website for elamsobranches. We also profited of data collected within the NETCET project. Overall the analysis of those data indicate that i) most of the sharks and rays sighted or by-catches remain unidentified and ii) there are still abundant populations of *Mobula mobula* in the Adriatic Sea

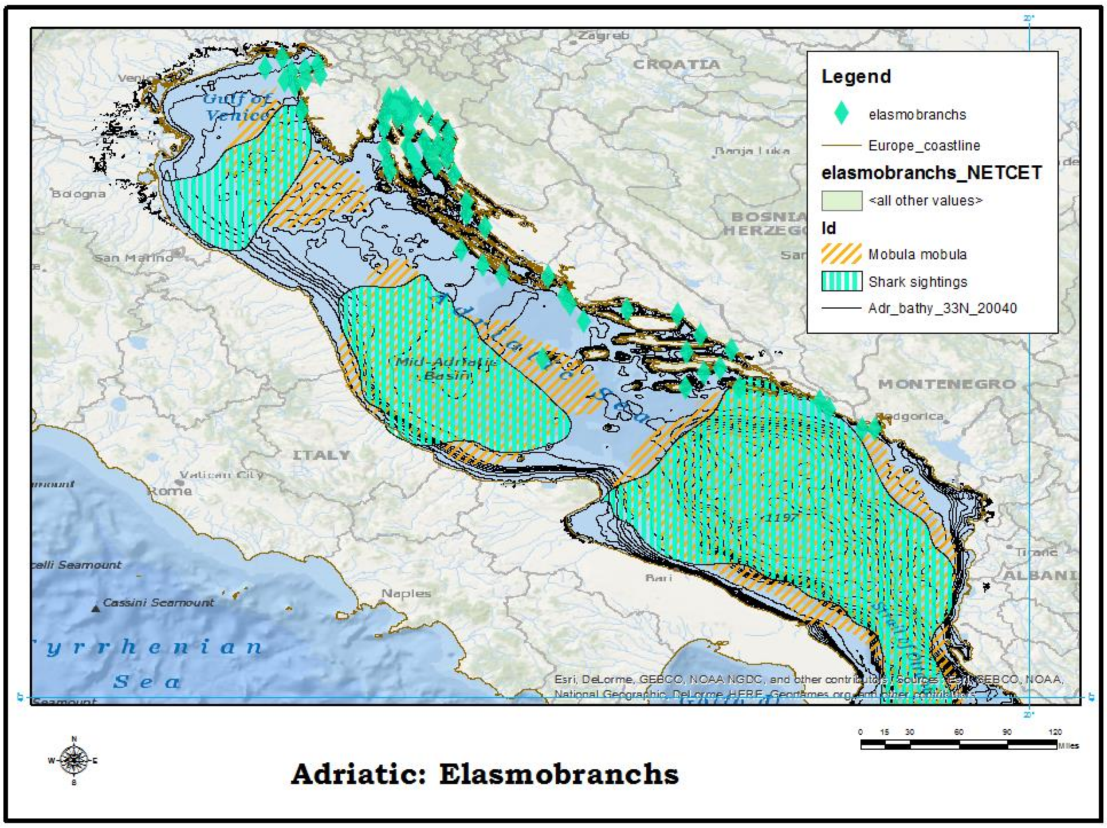


Figure 4.4 Elasmobranchs (sharks and rays) distribution in the Adriatic Sea

4.3.5 Benthic communities

The information about the benthic communities in the Adriatic Sea is sparce, mixed, difficult to manage and not always available. This issue has created important issues in finding reliable data on the benthos, because the only complete data set available during the compilation of the present report deals with seagrass (*Posidonia oceanica*) meadows, maerls and coralligenous assemblages, because they have been identified in the context of EUNIS, Natura 2000 and RAC/SPA. The lack of apparent interest about sandy and muddy communities has as undesirable consequence the lack of knowledge and the limited possibility of identifying areas of particular interest, for instance because the existence of Pennatulaceans or other deep communities whose presence has been known by by-catches inspections and only recently confirmed with the use of ROVs and other innovative technologies.

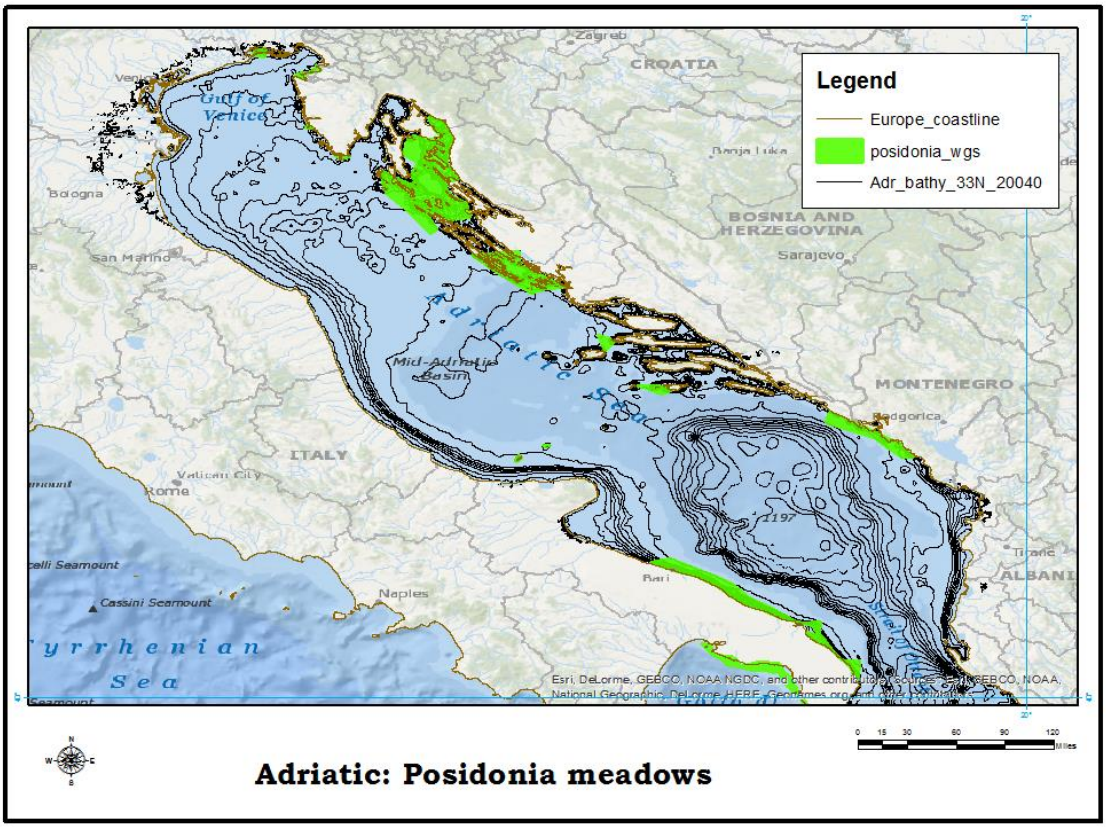


Figure 4.5 *Posidonia oceanica* meadows distribution in the Adriatic Sea.

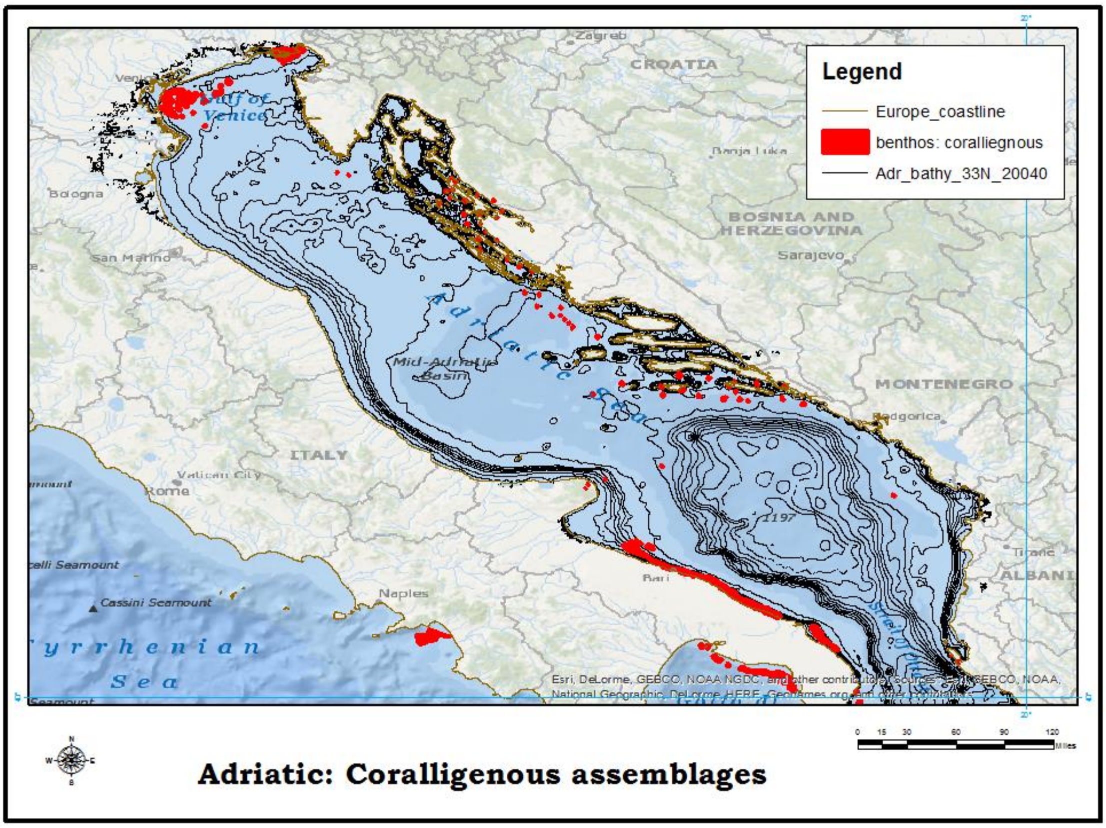


Figure 4.6 Coralligenous distribution in the Adriatic Sea

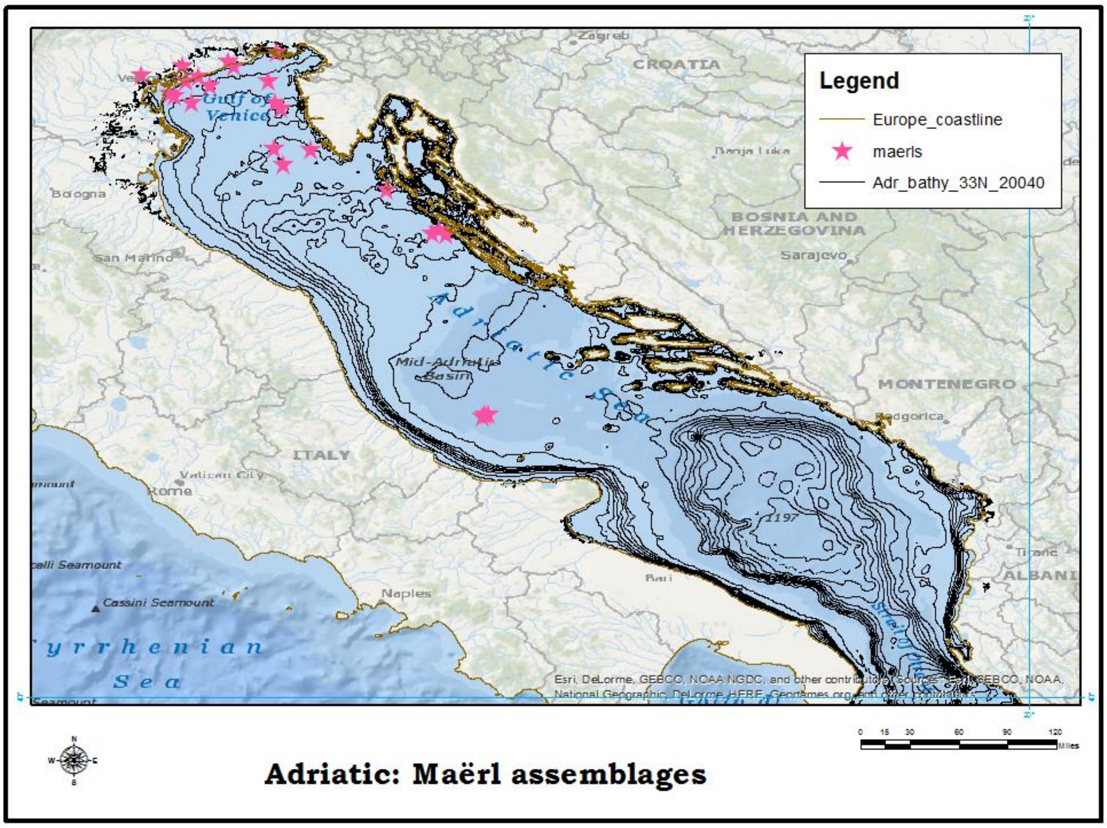


Figure 4.7 Maerls distribution in the Adriatic Sea

4.3.6 Biological resources, fish stock and fisheries

4.3.6.1 Fish stocks

This section deals with the distribution and consistency of the most relevant commercial species obtained through trawl fishing data, the distribution of clams, the distribution of mussel or other mollusks farms and spatial data on protected species (mammals). Fishing in the Adriatic Sea is characterized by multi-gear fishing activities, ranging from small-scale artisanal fishery[5] and hydraulic dredging to demersal[6] trawling and pelagic[7] mid-water

[5] Artisanal fisheries: traditional fisheries involving fishing households (as opposed to commercial companies), using relatively small amounts of capital and energy, relatively small fishing vessels, making short fishing trips, close to shore, mainly for local consumption. In practice, definition varies between countries (e.g. from gleaning or a one-man canoe in poor developing countries, to more than 20 m trawlers, seiners, or long-liners in developed ones). Artisanal fisheries can be subsistence or commercial fisheries, providing for local consumption or export. Sometimes referred to as small-scale fisheries (glossary FAO). Trawling is a harvesting method that involves dragging a net behind a boat

[6] Demersal = near the seabed

trawling and recreational fishing. In Croatia fishing is primarily artisanal, whereas in Italy trawling is the most common fishing method[8]. The most caught fish species in the Adriatic Sea are small pelagic species, such as anchovies and sardines. The Adriatic Sea is also a productive area for molluscs; the most frequently caught mollusks species in the sea are clams, cuttlefish and octopus. Crustacean species are caught as well, but in smaller numbers. The shrimp is the most represented crustacean[9].

4.3.6.1.1 Commercial species: most common fish, cephalopods and crustaceans

Differently from the hydrological subdivision, when it comes down to commercial stocks management the Adriatic basin is typically split in two major sectors (GSAs: Geographical Sub-Areas), established by GFCM (General Fisheries Commission for the Mediterranean) at its 26th session in 2001 (Figure 4.8).

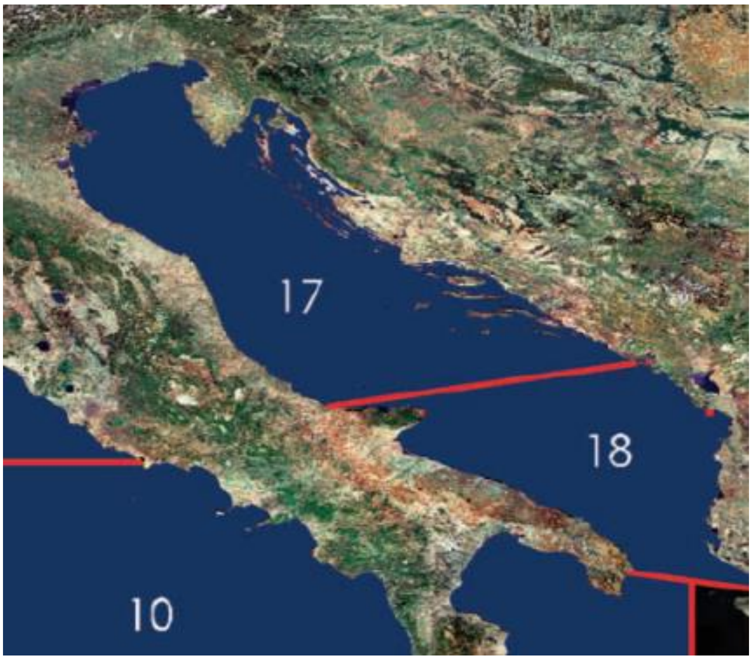


Figure 4.8 Adriatic basin GSAs (Geographical Sub-Areas). 17: Northern Adriatic; 18: Southern Adriatic (Source: Dall'Aquila *et al.*, 2008)

---

[7] Pelagic = water column neither close to the bottom nor close to the surface

[8] Raicevich, S. (ISPRA), *Spatio-temporal distribution of fishing effort and biological resources in the Northern Adriatic Sea (case study for the GAP project)*

[9] Landing statistics for 2004 from Italian, Slovenian and Croatian Ministries

The main sources of information from the point of view of spatial distribution of resources are represented by scientific, trawl-fishing based, monitoring surveys.

In Italy the first program on fish stocks data collection was the GRUND (National Group on Demersal resources) project, conducted in national and international waters from 1985 to 2007. The programme was an assessment of demersal resources through experimental fishing campaigns (direct methods) and use of commercial fishing boats and gear, with a progressive inter-calibration of the tools used. Since 1994 the Mediterranean area (Figure 4.9) was interested by the MEDITS survey programme (International bottom trawl survey in the Mediterranean), to collect and analyze data on the biological community interested by fishery in the bathymetric interval from 10 to 800 meters of depth carrying out an experimental fishing survey in late spring–summer.

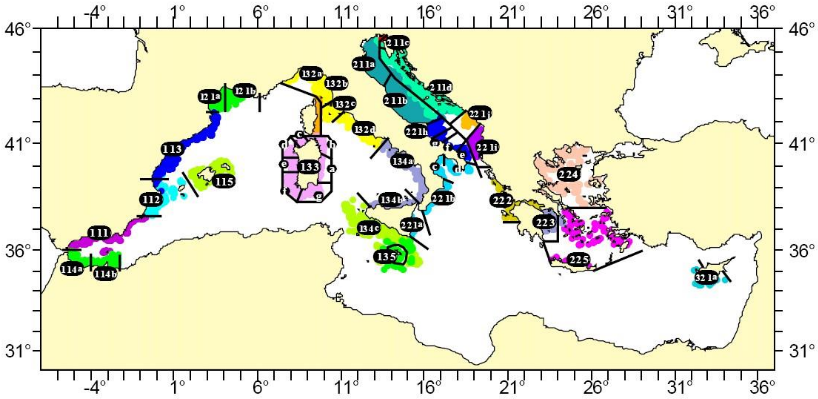
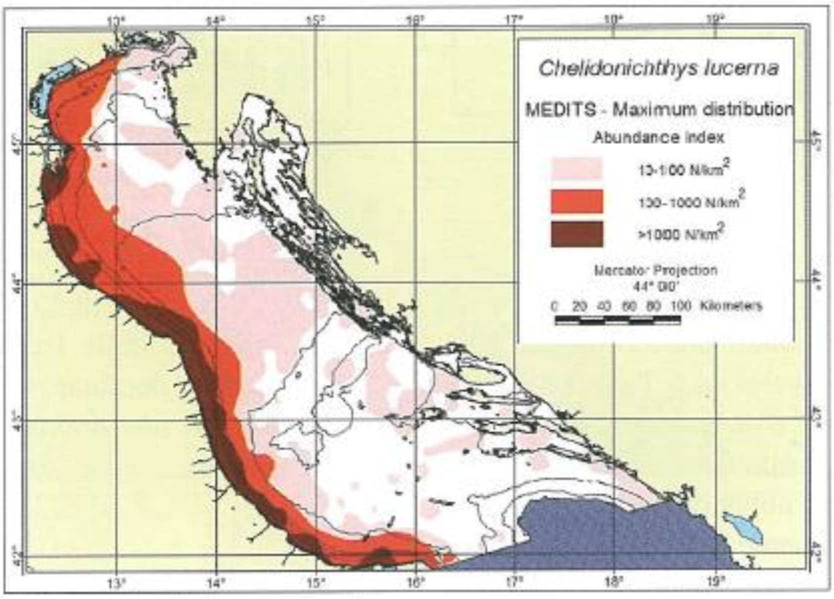


Figure 4.9. MEDITS programme: the areas covered by the surveys are represents by different colours (Source: http://www.sibm.it/SITO%20MEDITS/principaleprogramme.htm)

The first two surveys (1994 and 1995) had been conducted only along the coast of Spain, France, Italy and Greece. In 1996 the area was enlarged to cover almost all the Adriatic Sea (including Slovenian, Croatian and Albanian waters). The MEDITS survey is included in the European DCF regulation related to the collection of fishery data (Anonymous, 2000).

Recently, a synthesis of the results obtained in the period 1996-2010 by MEDITS in terms of maximal distribution and persistence area of relevant commercial species in the Adriatic basin (GSA 17) has been published by Piccinetti *et al*. (2012). The following maps, regarding 18 commercial species (11 bony fish, 5 mollusks and 2 crustacean), are all taken from that paper.



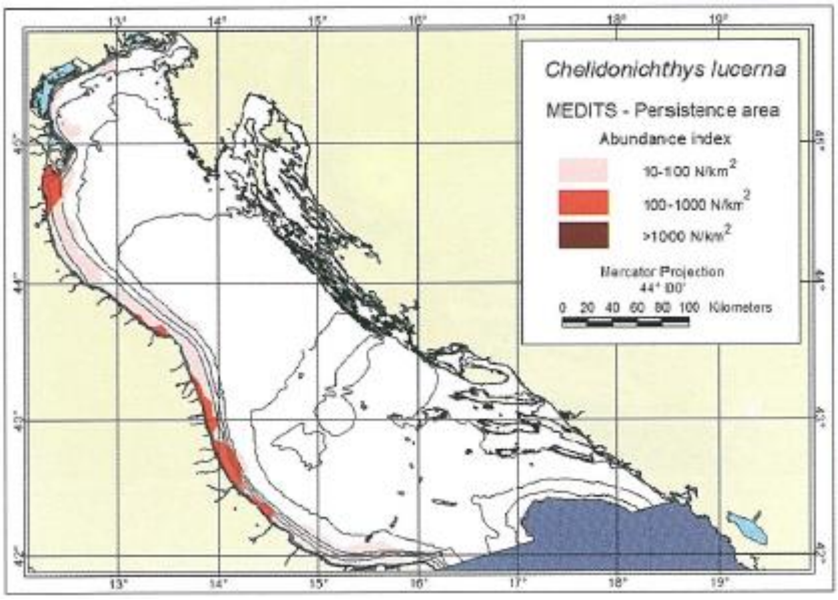
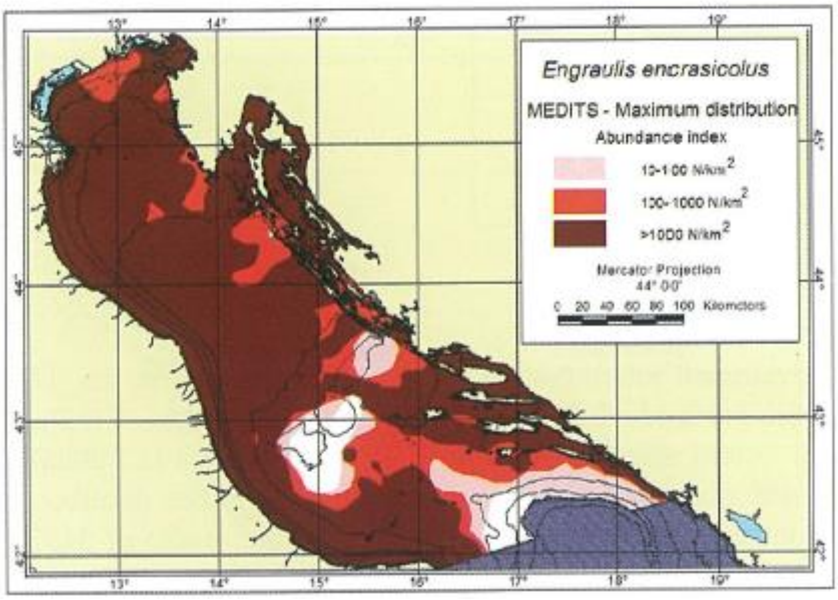


Figure 4.10. Maximum distribution (upper panel) and persistence area (lower panel) of *Chelidonichthys lucerna* (tub gurnard) in the GSA 17 (Piccinetti et al. 2012)



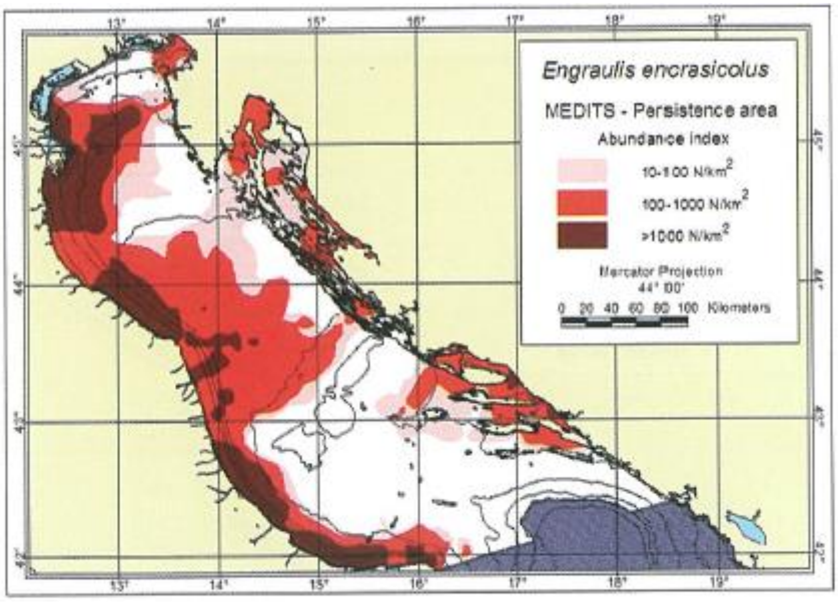
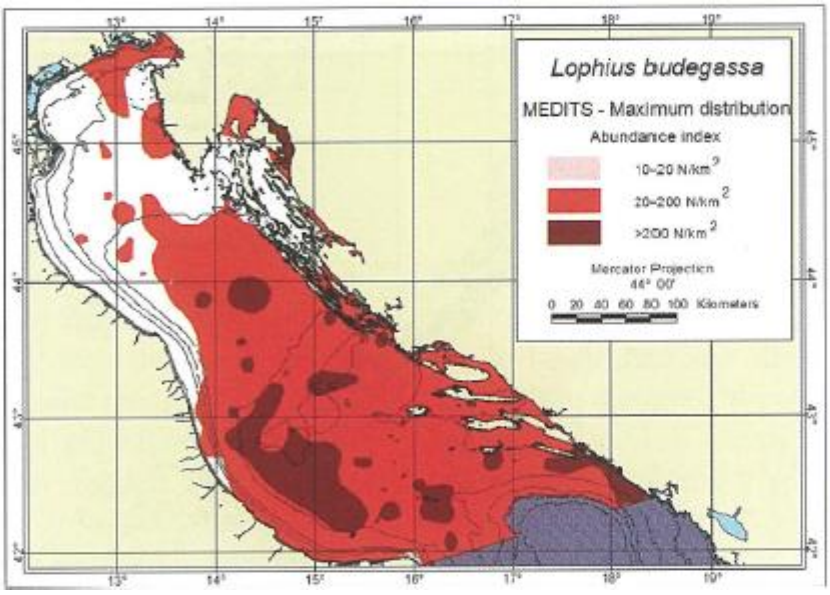


Figure 4.11. Maximum distribution (upper panel) and persistence area (lower panel) of *Engraulis encrasicolus* (European anchovy) in the GSA 17. (Piccinetti et al. 2012)



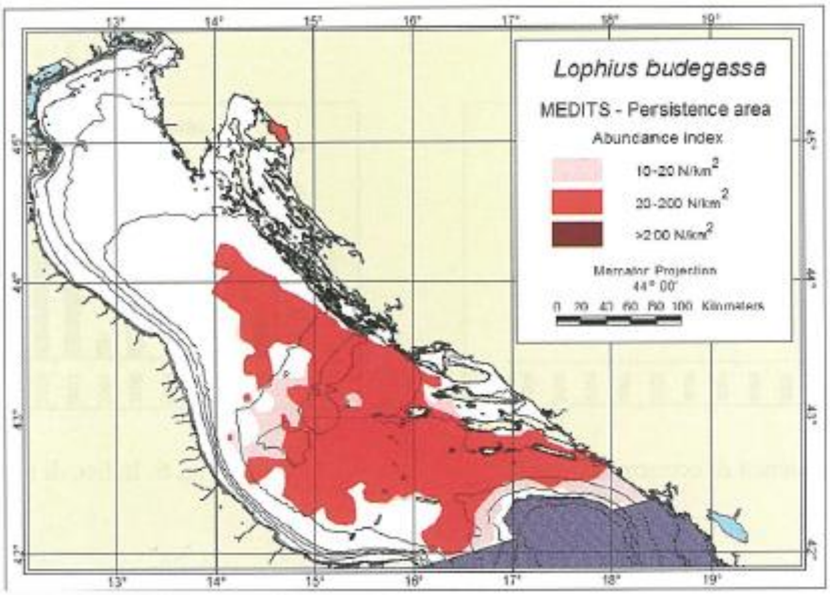
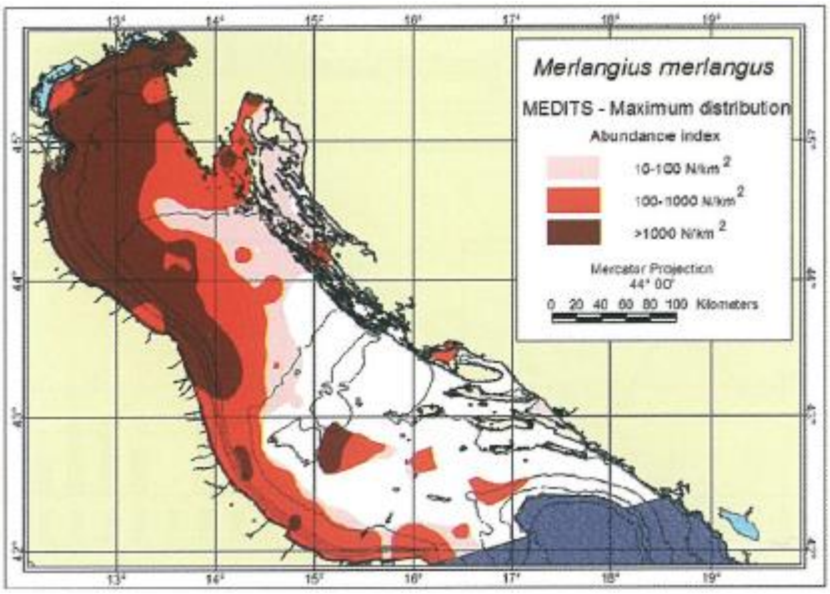


Figure 4.12. Maximum distribution (upper panel) and persistence area (lower panel) of *Lophius budegassa* (blackbellied angler) in the GSA 17 (Source:



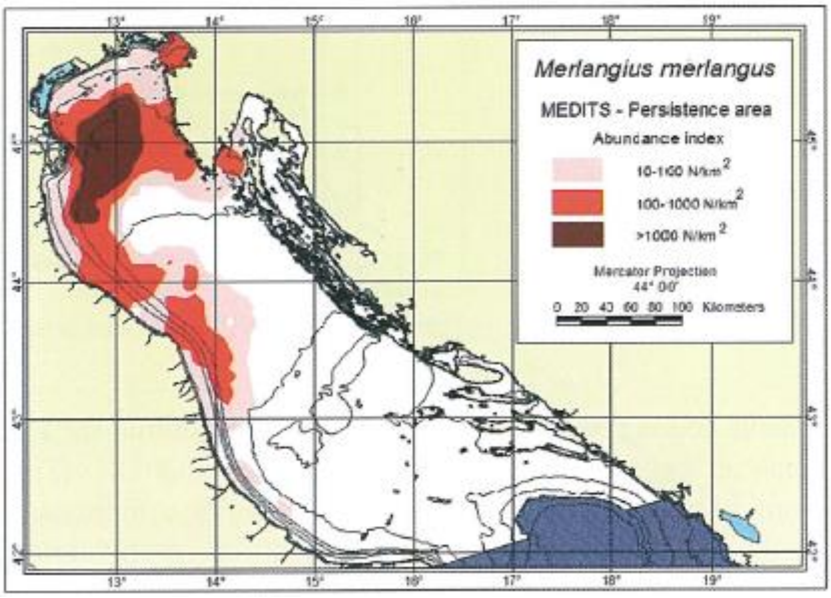


Figure 4.13. Maximum distribution (upper panel) and persistence area (lower panel) of *Merlangius merlangus* (whiting fish) in the GSA 17 (Piccinetti et al. 2012)

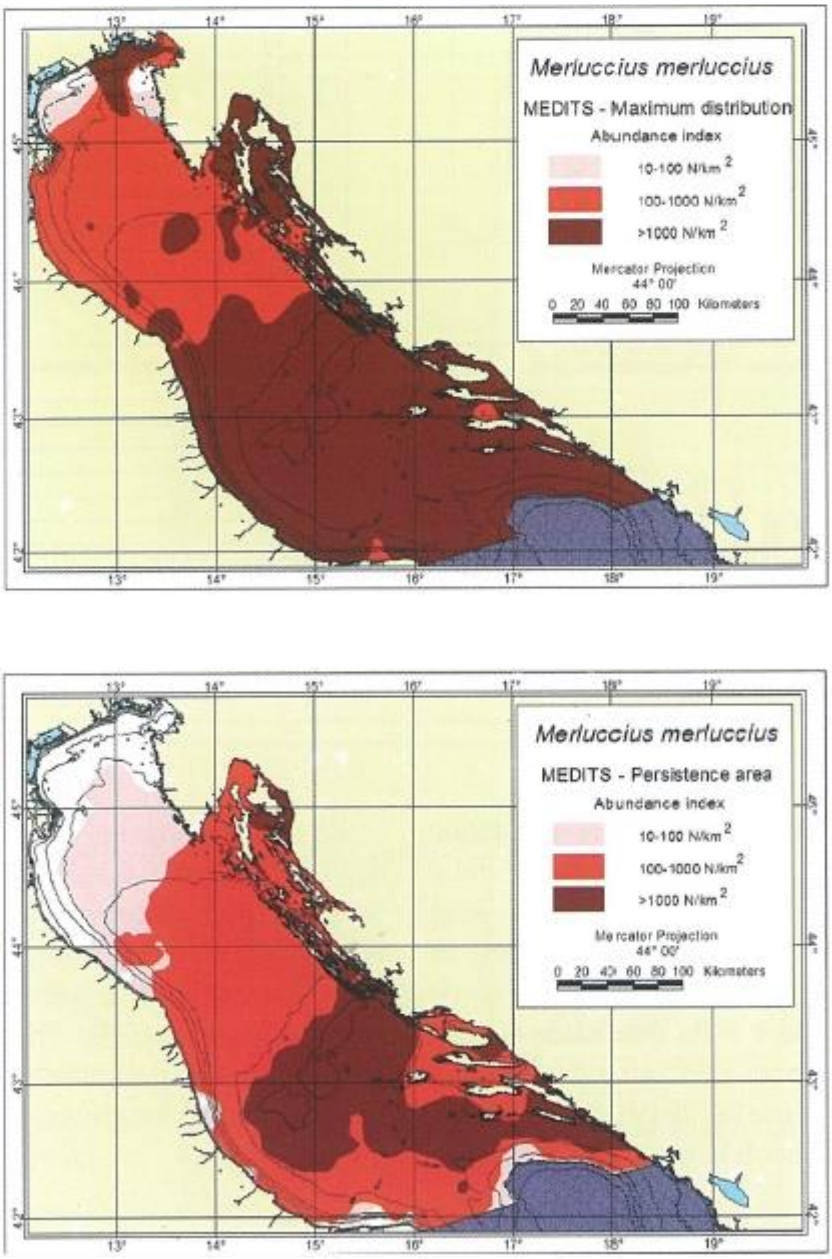
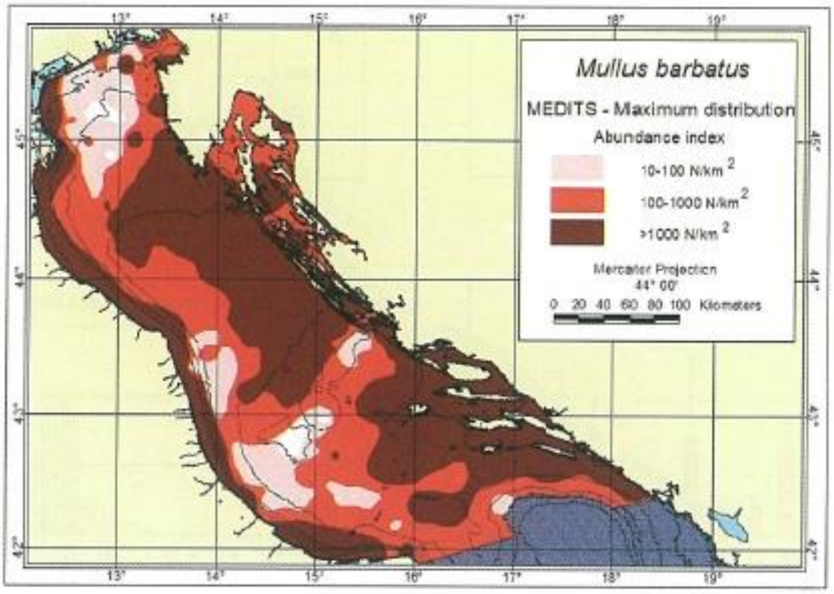


Figure 4.14. Maximum distribution (upper panel) and persistence area (lower panel) of *Merluccius merluccius* (european hake) in the GSA 17 (Piccinetti et al. 2012)



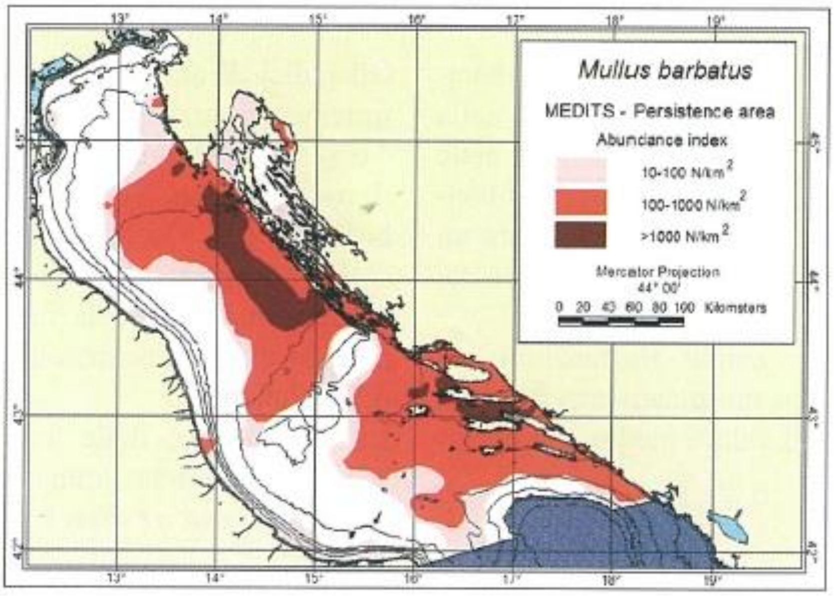
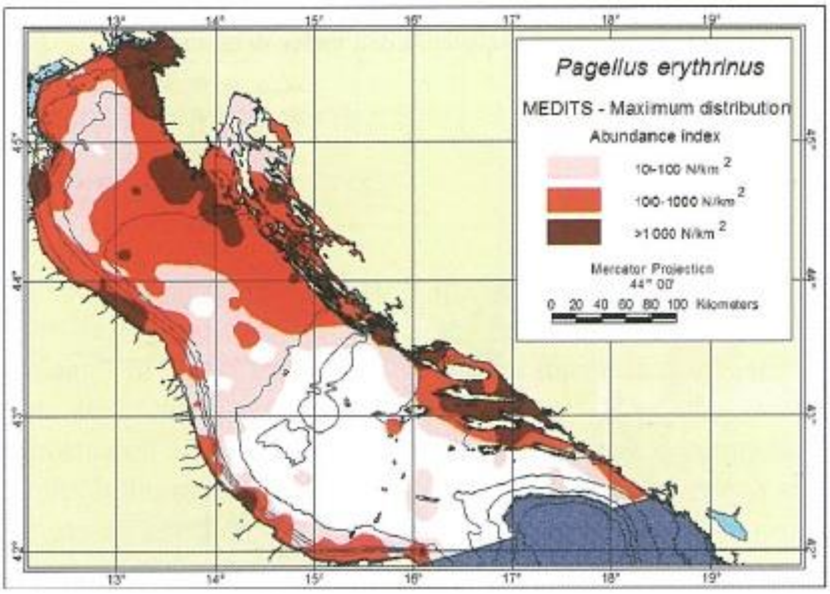


Figure 4.15. Maximum distribution (upper panel) and persistence area (lower panel) of *Mullus barbatus* (red mullet) in the GSA 17 (Piccinetti et al. 2012)



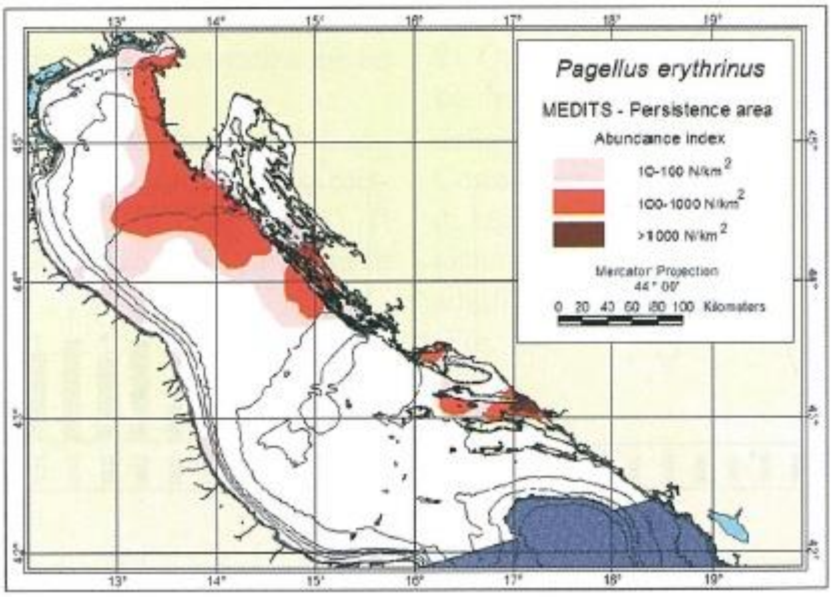
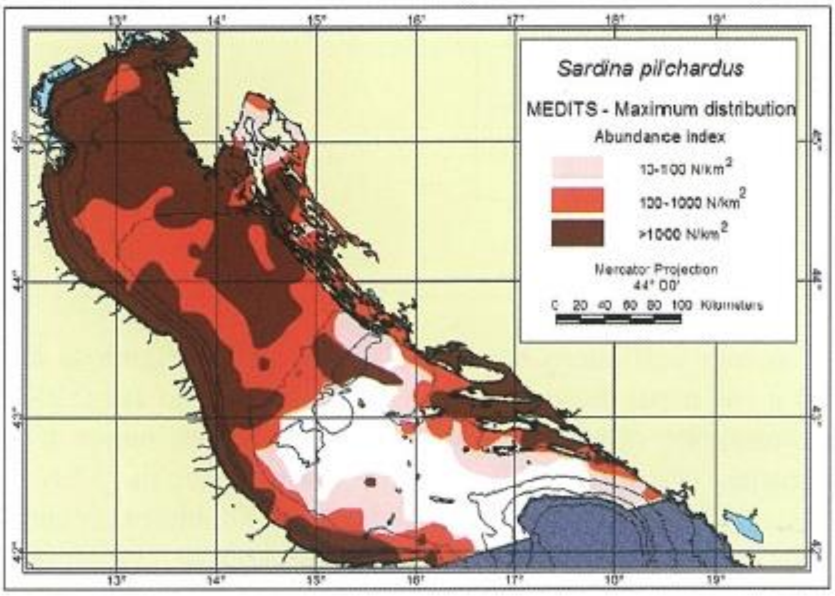


Figure 4.16. Maximum distribution (upper panel) and persistence area (lower panel) of *Pagellus erythrinus* (common Pandora) in the GSA 17 (Piccinetti et al. 2012)



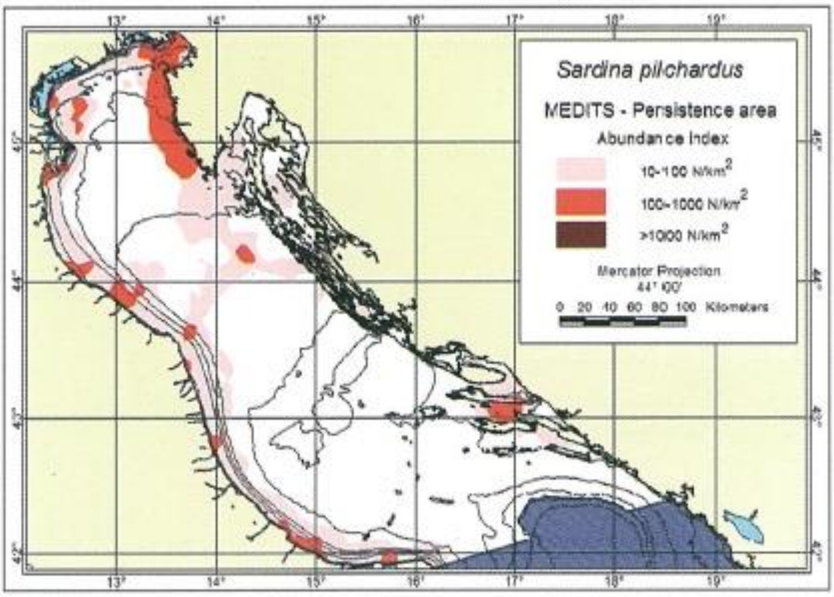


Figure 4.17. Maximum distribution (upper panel) and persistence area (lower panel) of *Sardina pilchardus* (European pilchard) in the GSA 17 (Piccinetti et al. 2012)

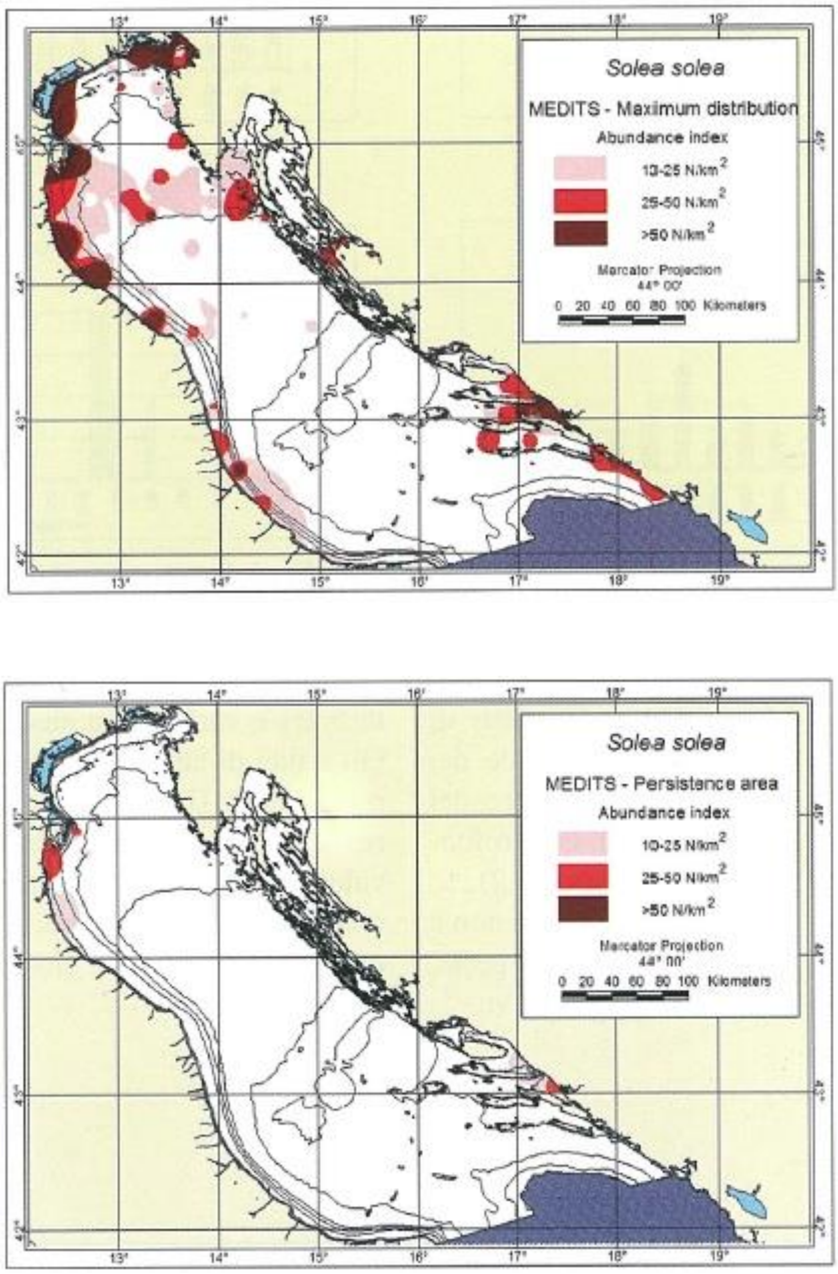


Figure 4.18. Maximum distribution (upper panel) and persistence area (lower panel) of *Solea solea* (common sole) in the GSA 17 (Piccinetti et al. 2012)

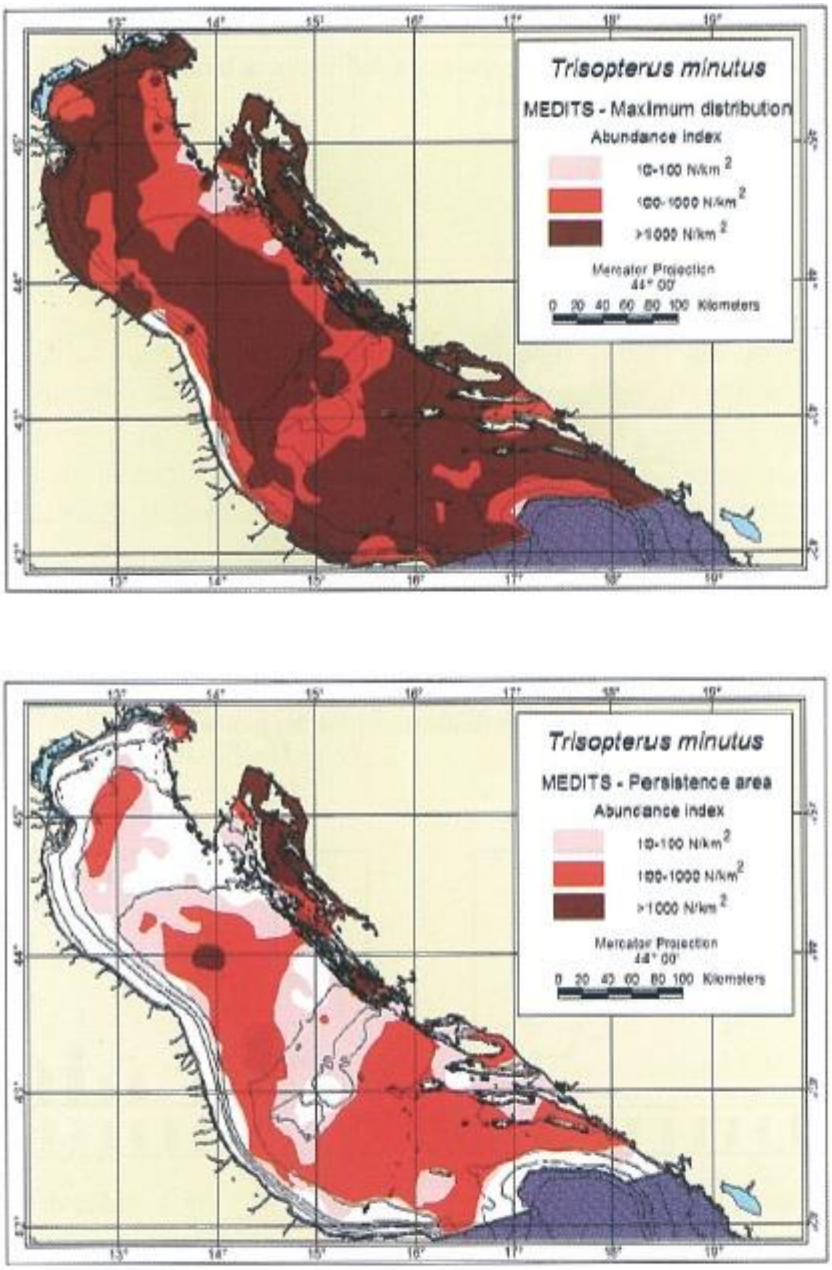
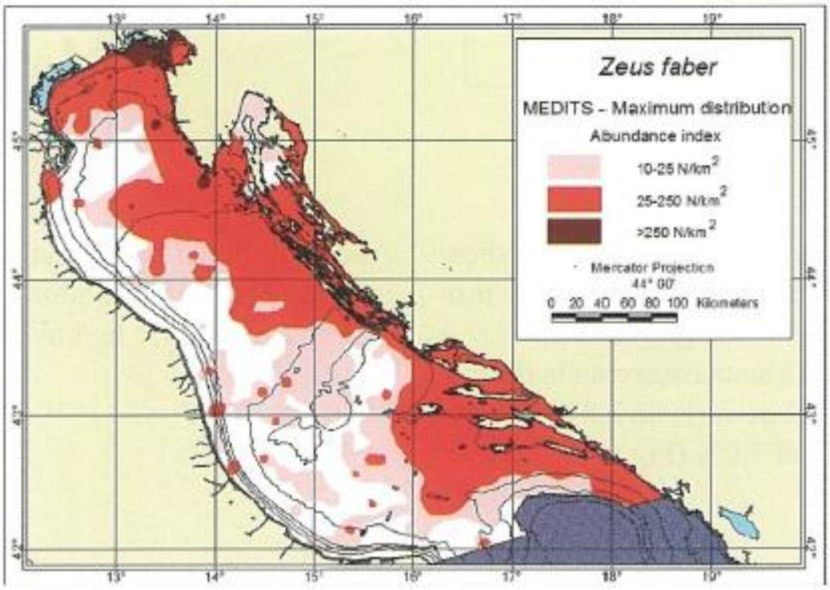


Figure 4.19. Maximum distribution (upper panel) and persistence area (lower panel) of *Trisopterus minutus* (poor cod) in the GSA 17 (Piccinetti et al. 2012)



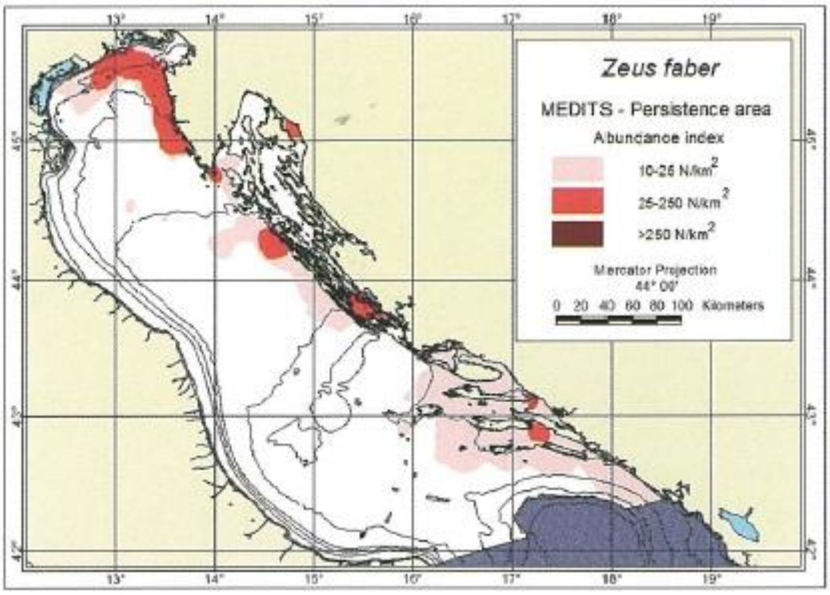


Figure 4.20. Maximum distribution (above) and persistence area (below) of *Zeus faber* (john dory) in the GSA 17 (Piccinetti et al. 2012)

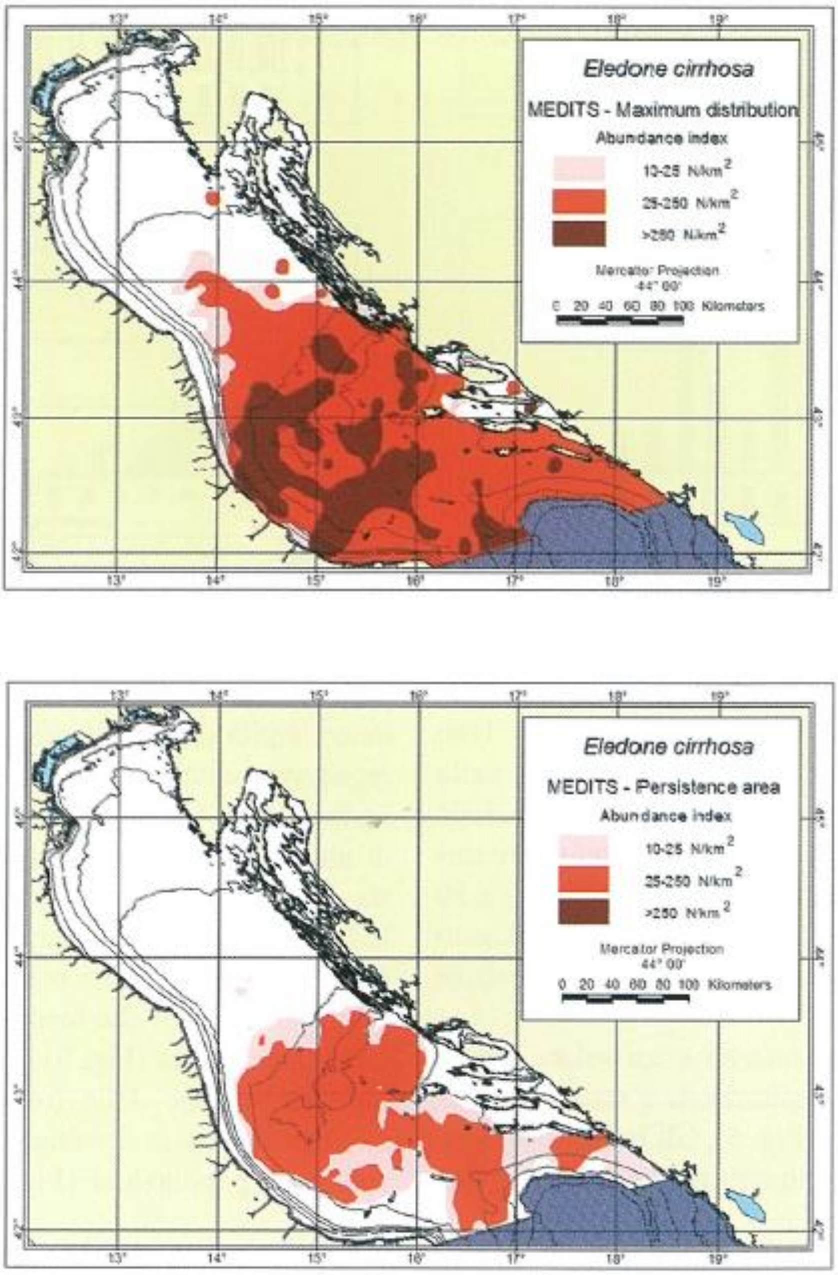
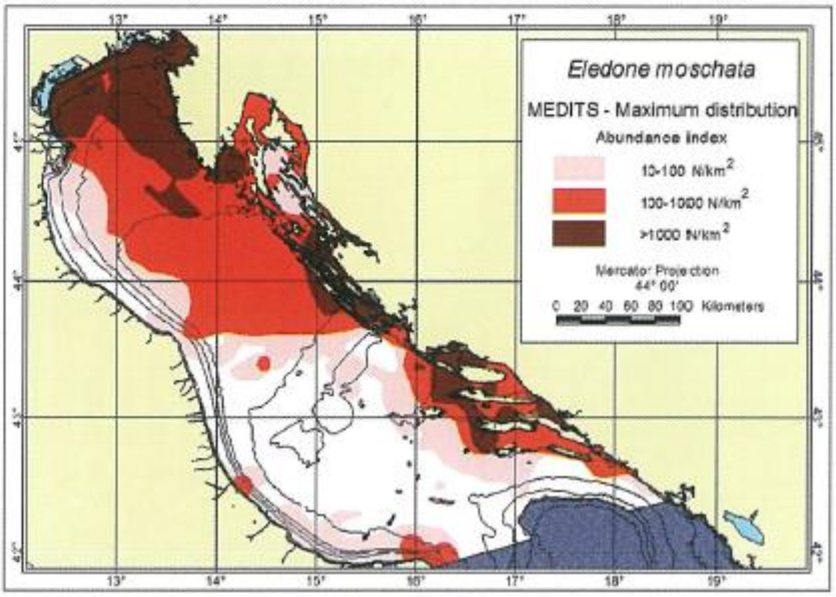


Figure 4.21. Maximum distribution (upper panel) and persistence area (lower panel) of *Eledone cirrhosa* (hornet octopus) in the GSA 17 (Piccinetti et al. 2012)



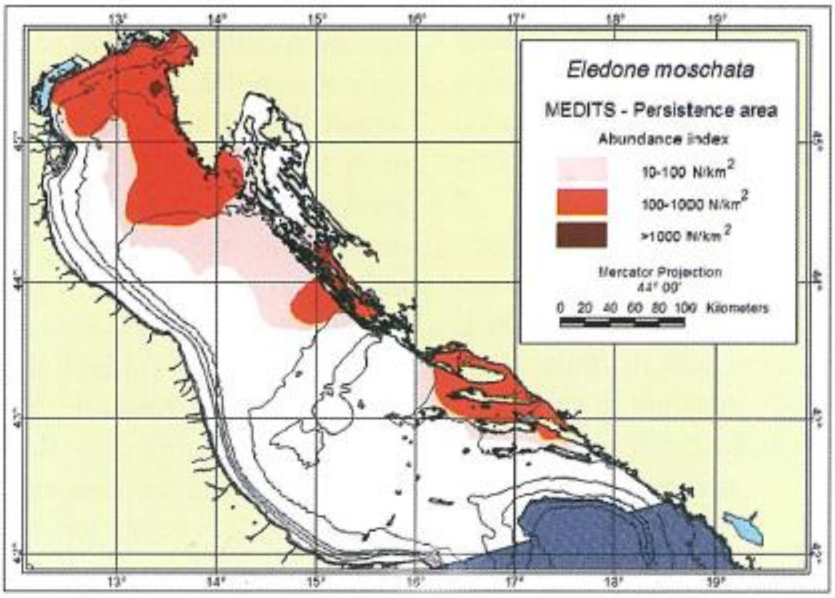


Figure 4.22. Maximum distribution (upper panel) and persistence area (lower panel) of *Eledone moschata* (musky octopus) in the GSA 17 (Piccinetti et al. 2012)

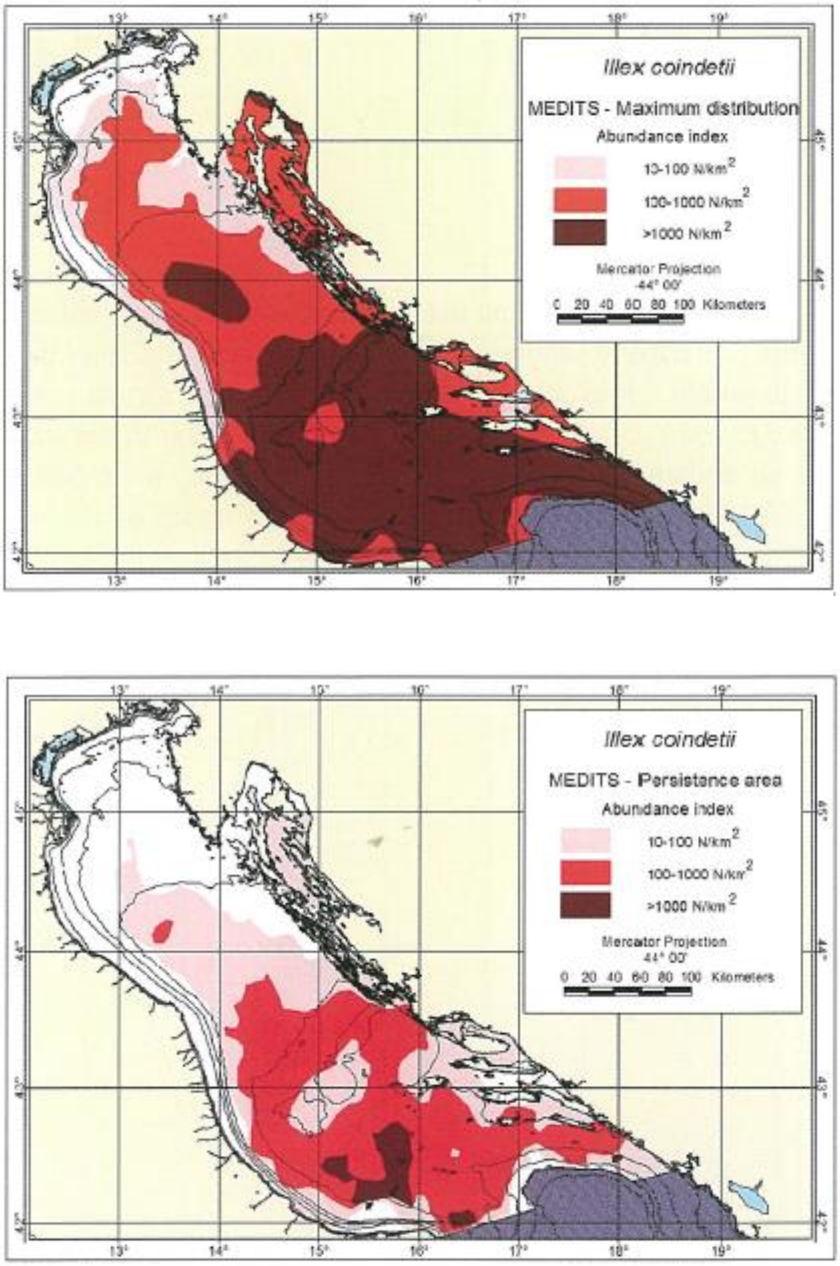
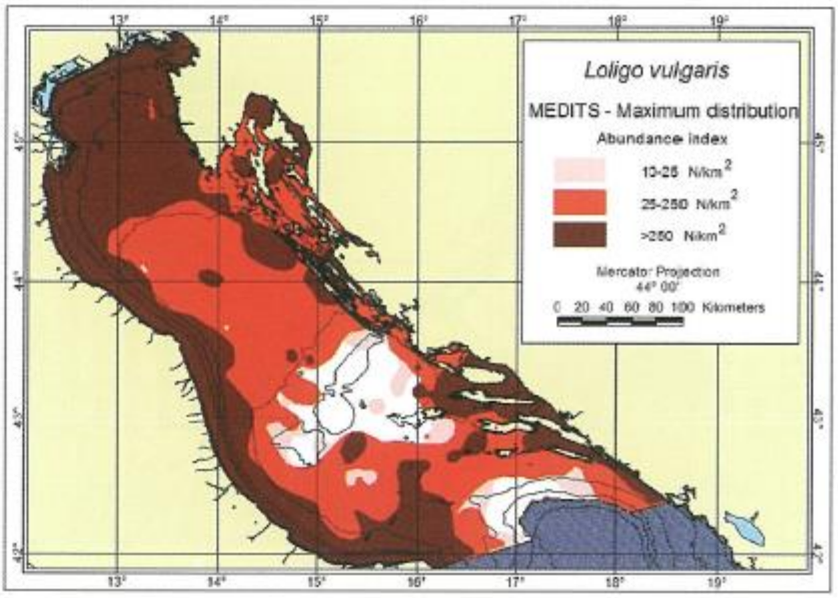


Figure 4.23. Maximum distribution (upper panel) and persistence area (lower panel) of *Illex coindetii* (broadtail shortfin squid) in the GSA 17 (Piccinetti et al. 2012)



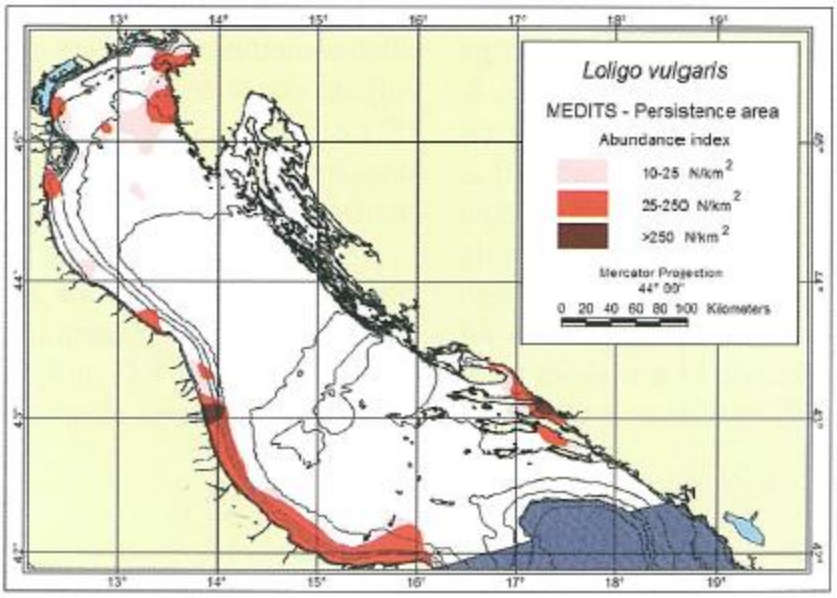
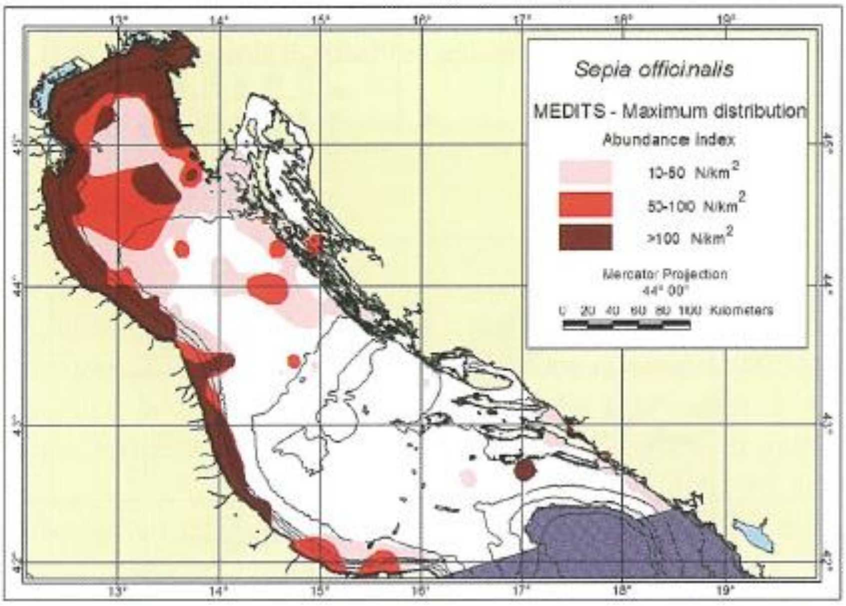


Figure 4.24. Maximum distribution (upper panel) and persistence area (lower panel) of *Loligo vulgaris* (european squid) in the GSA 17 (Piccinetti et al. 2012)



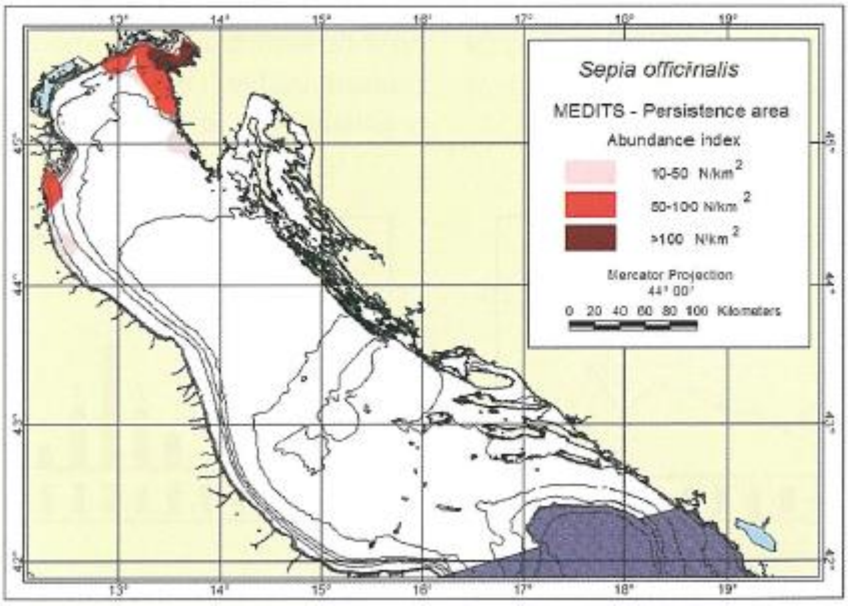
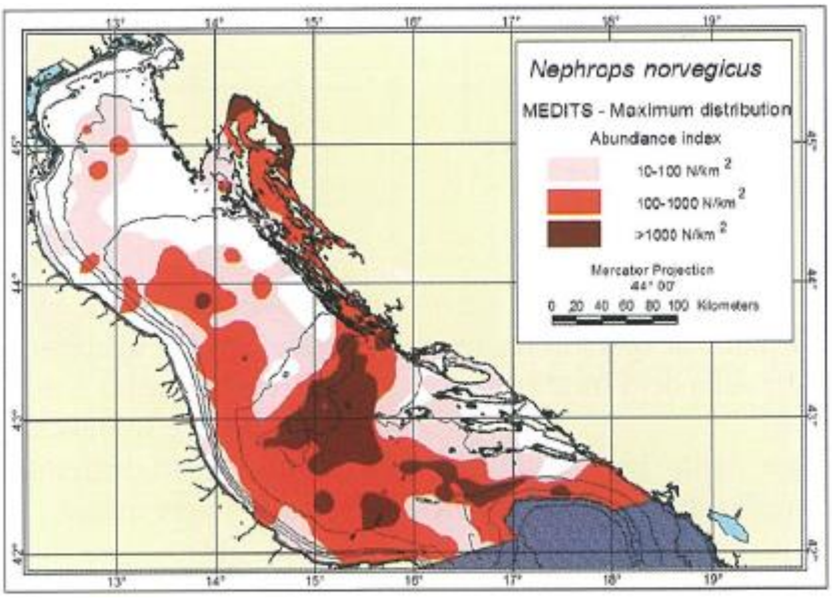


Figure 4.25. Maximum distribution (upper panel) and persistence area (lower panel) of *Sepia officinalis* (common cuttlefish) in the GSA 17 (Piccinetti et al. 2012)



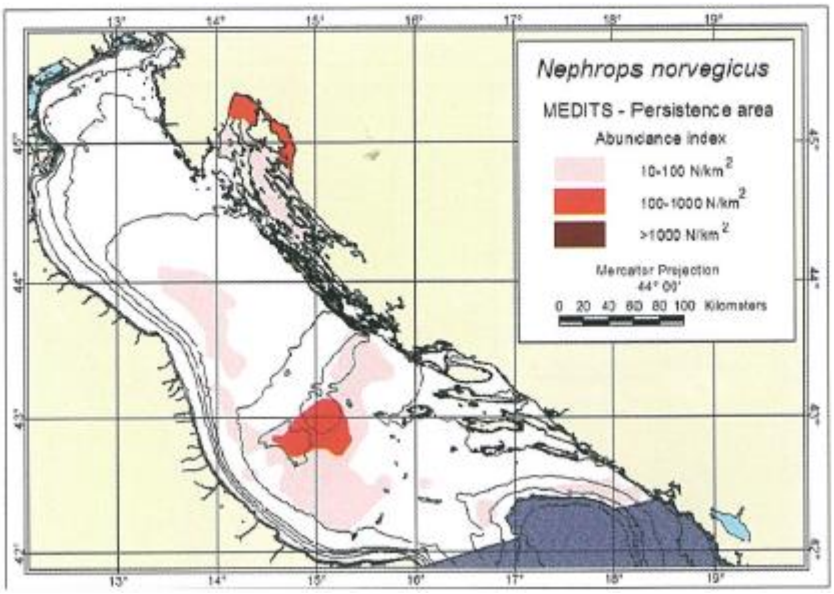


Figure 4.26. Maximum distribution (upper panel) and persistence area (lower panel) of *Nephrops norvegicus* (norway lobster) in the GSA 17 (Piccinetti et al. 2012)

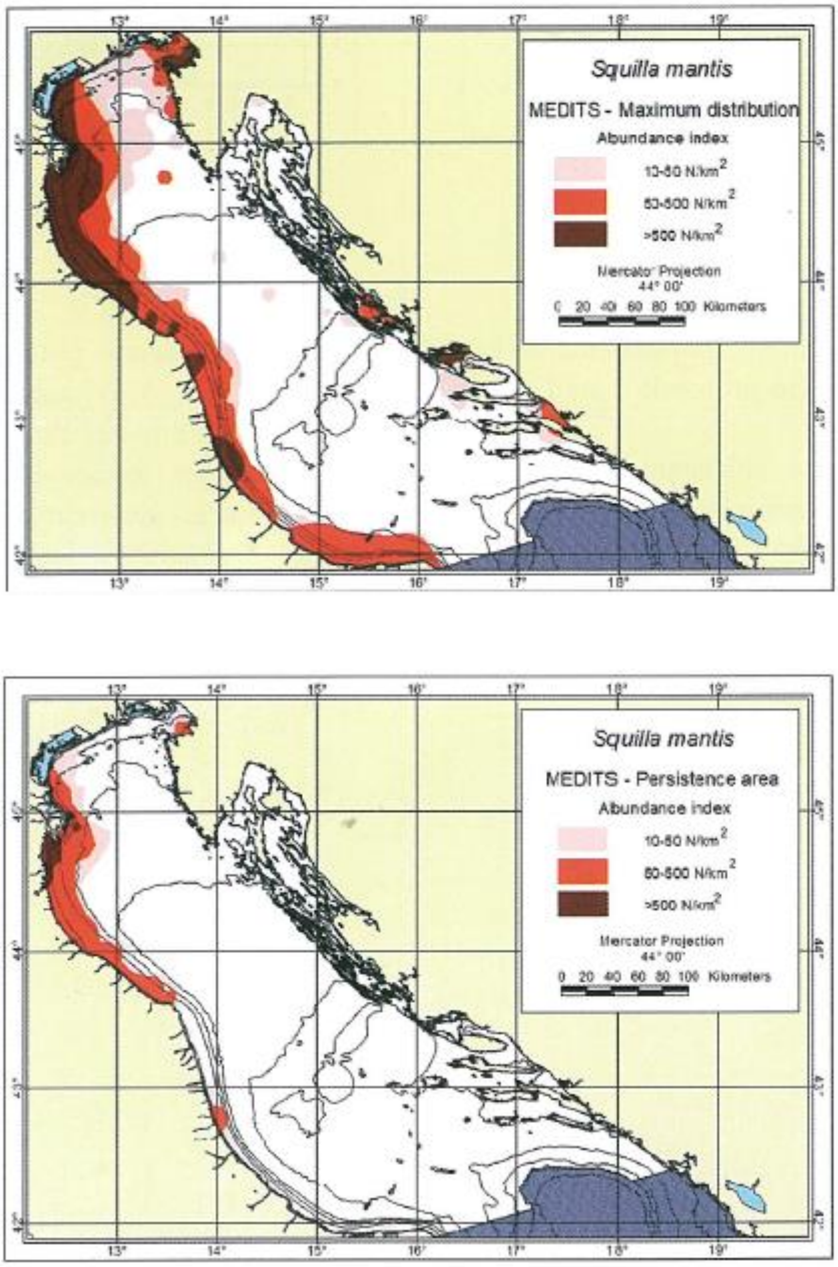


Figure 4.27. Maximum distribution (upper panel) and persistence area (lower panel) of *Squilla mantis* (mantis shrimp) in the GSA 17 (Piccinetti et al. 2012)

4.3.6.2 Bivalves stocks

The venus clam *Chamelea gallina* (Linnaeus, 1758) is a bivalve mollusc, filter feeder. Its distribution includes the Mediterranean Sea, the Caspian Sea and the Eastern Atlantic. *C. gallina* can reach the size of 45-50 mm at an age of 8 years, but it commonly has a size of 25-30 mm (25 mm is the minimum landing size). The venus clam is fished on industrial basis by a fishing gear called "hydraulic dredge". As the clam is found in aggregates of high density on sandy and sandy-muddy coastal zones, to depths of 15 m and/or within 3 Km from the coast, in the Adriatic Sea these distributional features limit the distribution of this clam to the western side (Italian shores), where natural beds of *C. gallina* can be found along 530 Km of coasts out of a total (from Monfalcone to Molfetta) of 875 Km (Romanelli *et al*., 2009). There is not a comprehensive study that shows at a glance the distribution of *C. gallina* in the whole Mediterranean Sea, so we collected several studies carried out on local basis (Figure 4.28) to illustrate where the venus clam is fished by means of hydraulic dredges.

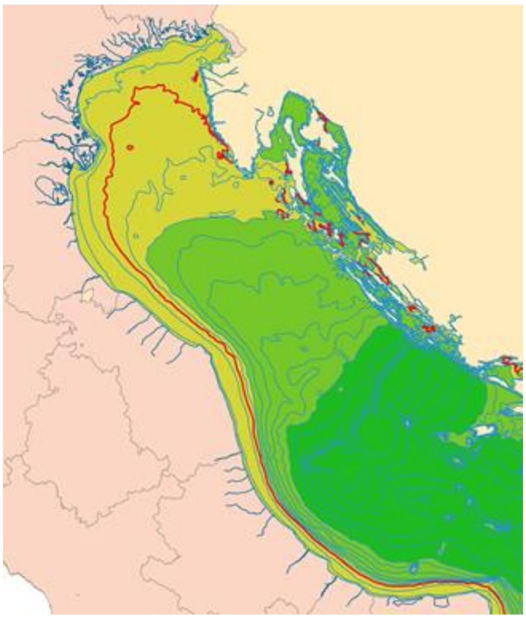


Figure 4.28. Local reports on the presence of the venus clam natural beds. From north to south: Emilia-Romagna and Rimini compartment, Marche and Abruzzo. Red line: 30 m depth isobath.

Along the coasts of the Emilia-Romagna region the natural beds of *C. gallina* are all distributed witihn the 10 m depth isobath, which stands between 0.5 (near Cattolica) and 7 Km away (Ravenna) from the coastline (Figure 4.29).

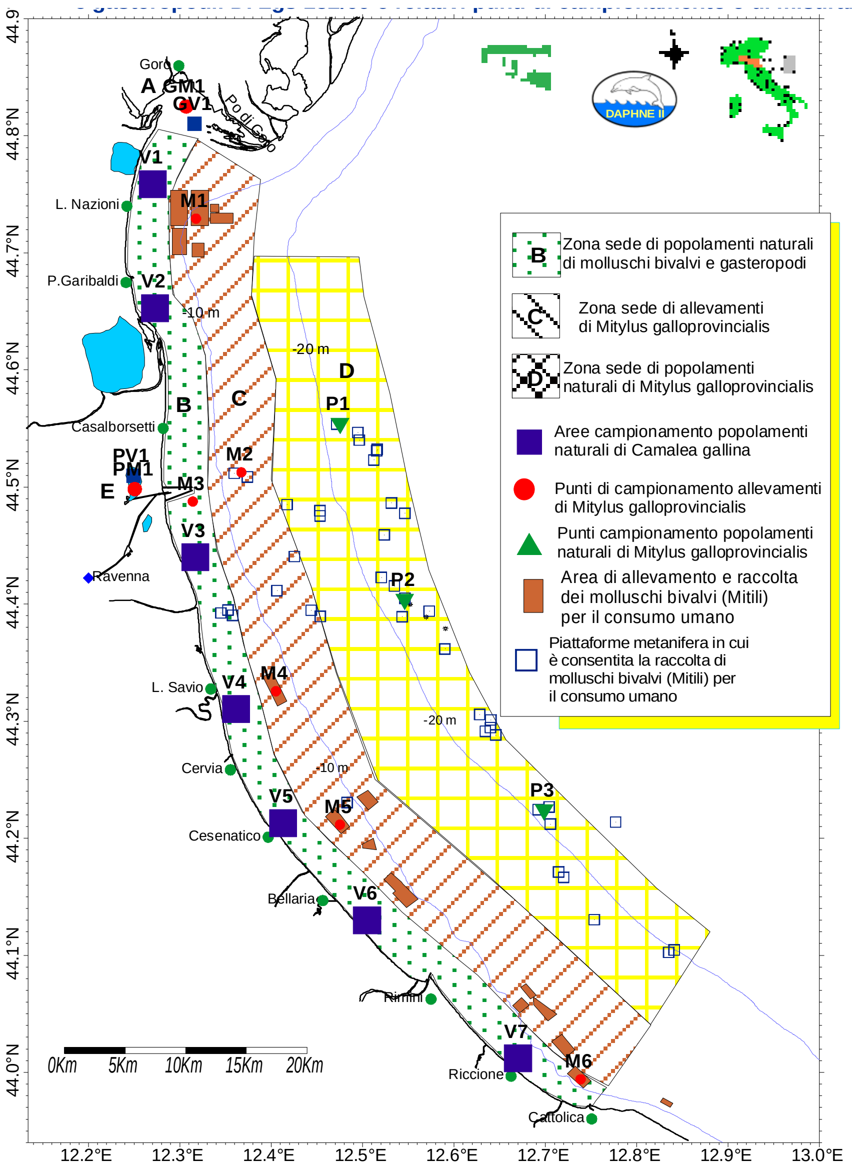


Figure 4.29. Emilia-Romagna coasts: map showing the sampling points (blue squares) on natural beds of *C. gallina* established by the Regional Agency for Environmental Protection (source: *www.mo-mar.net/documents/Ferrari_1.ppt)*

Focusing on the Maritime Compartment of Rimini, some indications on natural densities of venus clam come from experimental trials on seed and adults transferring techniques applied to management issues of this biological resource (Figure 4.30).

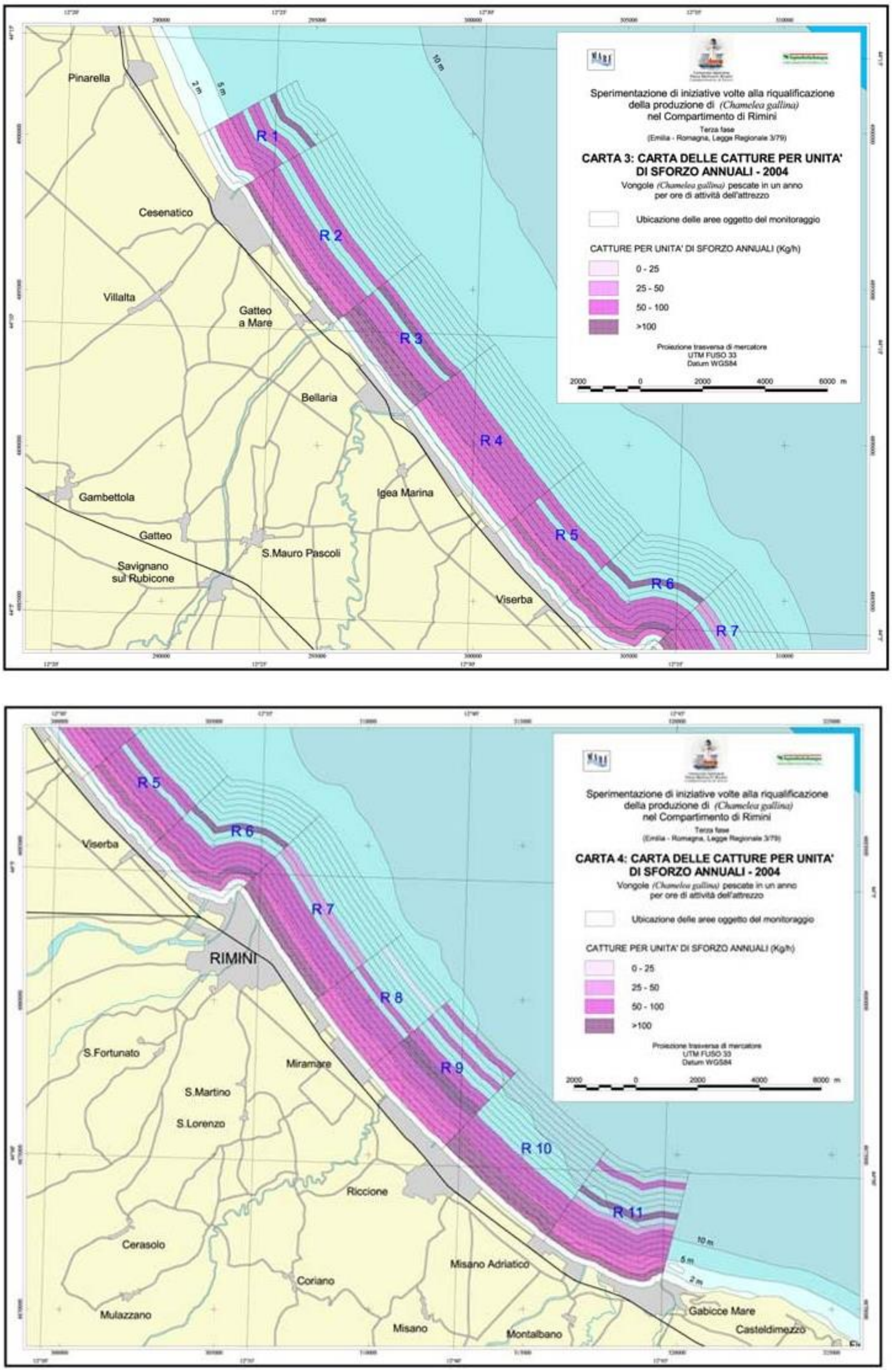
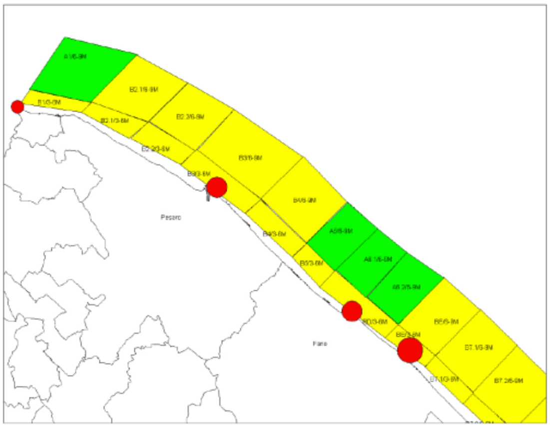
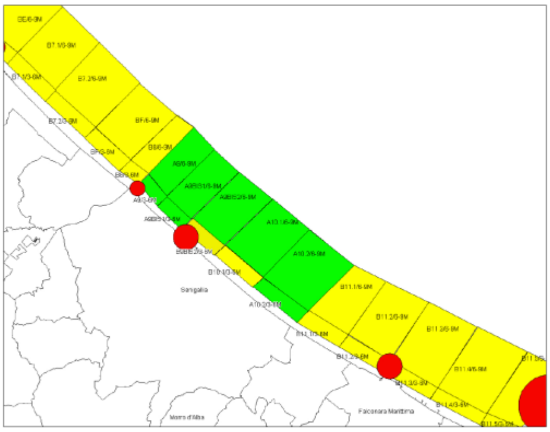


Figure 4.30. Annual catch per unit effort (Kg h^{-1}) of *C. gallina* in the Rimini Compartment in the year 2004.

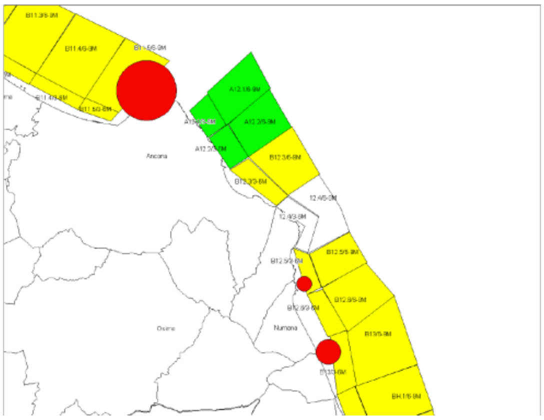
In the Marche region a recent decree of the regional council (nr 136, 18/02/2013) reviewed the health classification of production areas for bivalve molluscs and set new zones where *C. gallina* can be collected by hydraulic dredging and brought to the market (Figure 4.31).



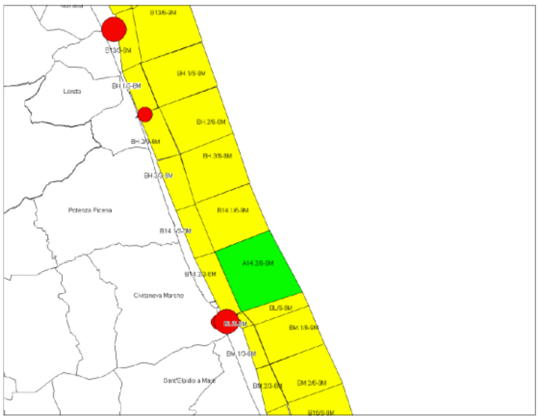
1) Fano - Pesaro province



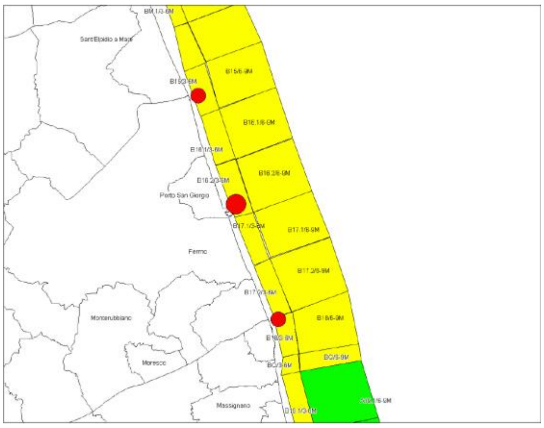
2) Senigallia - Falconara Marittima province



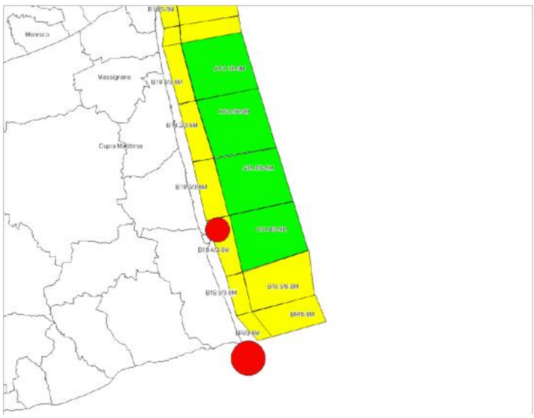
3) Ancona - Numana province



4) Loreto - Sant'Elpidio a Mare province



5) Porto San Giorgio - Massignano province



6) Cupra Marittima province

Figure 4.31. Production areas of *C. gallina* (green) (Regione Marche, regional council, resolution 136, 18th February 2013).

In 2006 a study was conducted in the framework of the European funds to manage fisheries and preserve the natural beds of the Venus clam along the Abruzzo region coasts (Figures 4.32-4.33).

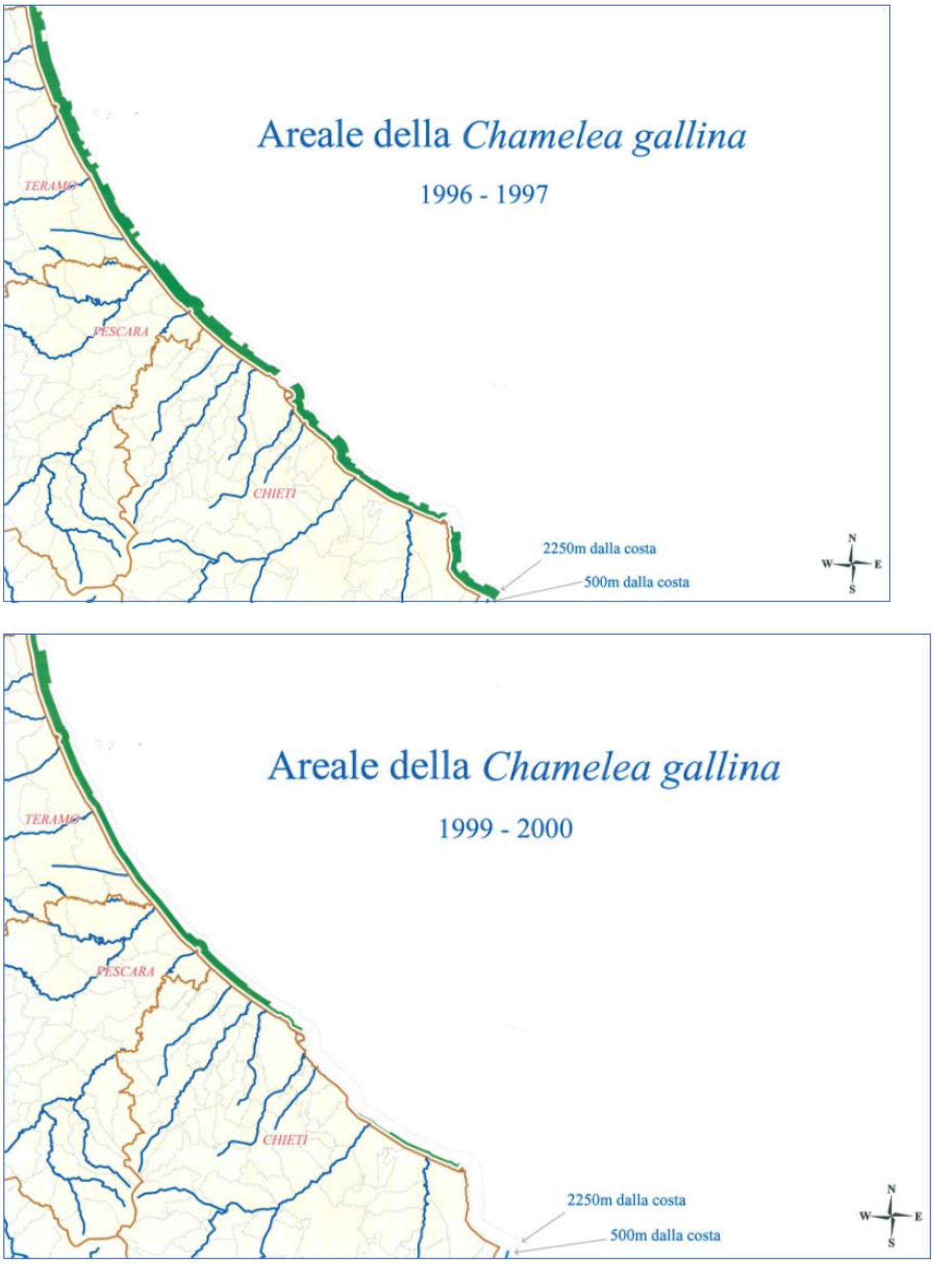


Figure 4.32. Spatial distribution of *C. gallina* natural beds (green) along the Abruzzo coasts in years '96-'97 and '99-2000 (AA. VV., 2006).

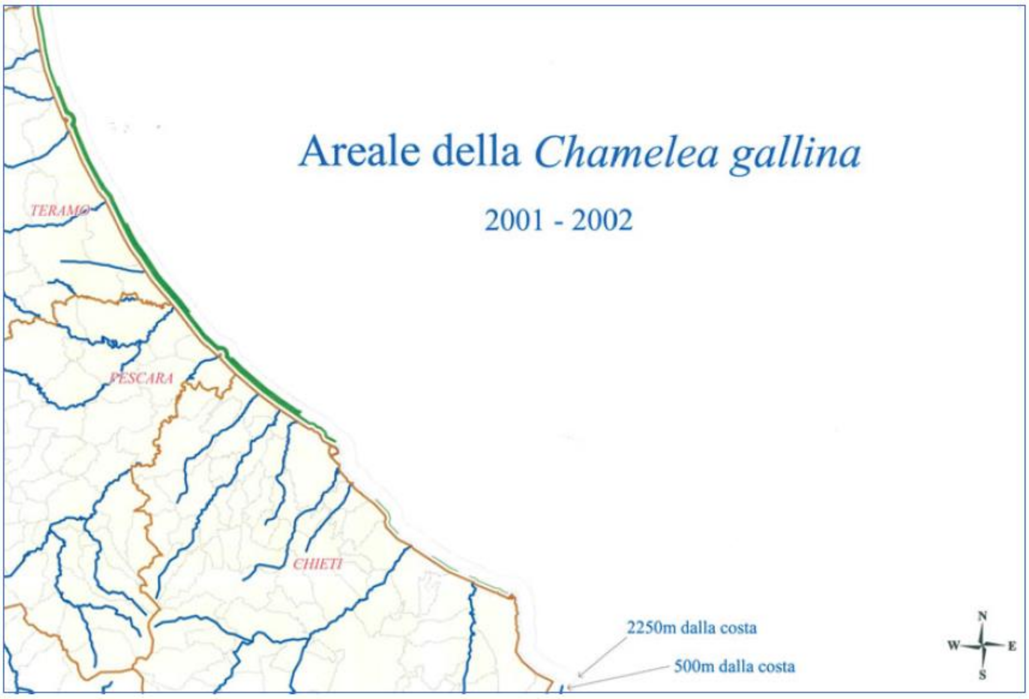


Figure 4.33. Spatial distribution of *C. gallina* natural beds (green) along the Abruzzo coasts in years '01-'03 (AA. VV., 2006).

It seems clear from the maps that in the years 1996-1997 the distribution of the venus clam's natural beds was quite uniform along the entire coast of the Abruzzo region and often reached depths of about 10-12 m (2-2.5 Km distance from the coast). Just two years later (1999-2000) the production areas were significantly reduced, especially in the province of Chieti where, in some areas, the clams even almost disappeared. In the years following the resource depauperation has become more and more evident, and the lower limit of the natural banks climbed back up to depth of about 6-7 m (less than 1.5 Km from the coast).

4.3.6.3 Bivalves mariculture

The share of the fisheries sector in the national economies is decreasing in the whole Mediterranean Sea. Fish stocks have suffered from overfishing and/or pollution, especially in the Italian part of the Northern Adriatic Sea. Pollution is caused by water discharges of industrial activities, agriculture and urbanised areas, but also by river discharges (e.g. the Po) in the Adriatic Sea, containing pollutants due to discharges along the river (PRC, 2011).

A shift towards mariculture has been experienced in recent years, although the sector is facing environmental and spatial constraints. Not all locations are indeed suited for the installation of offshore farms nor are all suitable locations in compliance with other activities. Mariculture activities mainly involve the production of mussels[10].

Mariculture locations in the Italian Adriatic counterpart are mainly distributed along the coasts of Friuli Venezia Giulia, Veneto, Emilia-Romagna, Marche, Abruzzo, Molise and Apulia regions (Figure 4.34). The distribution of mussel farms is generally restricted to coastal areas inside the 3 mn limit (Prioli, 2001).

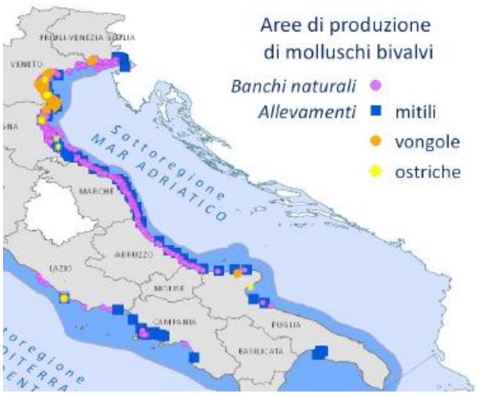
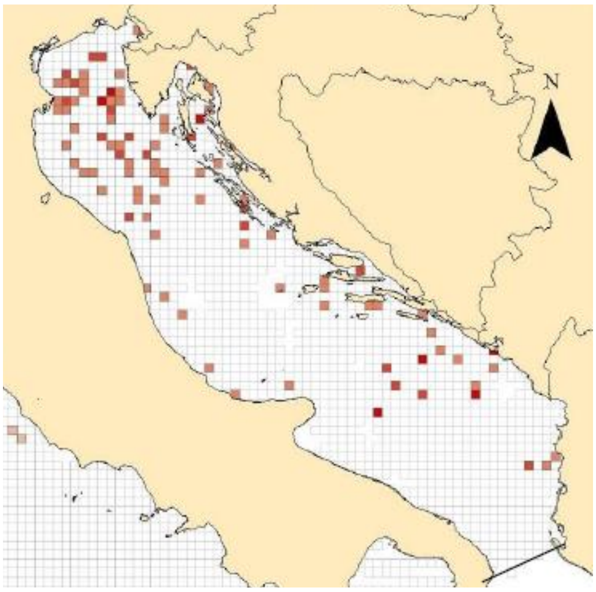


Figure 4.34. Italian bivalves' production areas in the Adriatic (pink dots: natural beds; blue squares: mussel farms; orange dots: clams; yellow dots: oysters) (source: Petochi et al., 2013)

[10] *Veneto Agricoltura, 2008, La Pesca in Numeri: raccolta 2007 – 2008.*

4.3.6.4 Protected species

Thanks to the effort promoted by the Marine Strategy Framework Directive (MSFD, 2008/56/CE), ISPRA summarized, among the others, the current knowledge on the descriptors at the national level in a report entitled “Valutazione iniziale per la Strategia Marina”. Among the other descriptors, the report provides also information about marine mammals distribution in the Adriatic Sea (namely: *Tursiops truncatus*, *Stenella coeruleoalba*, *Grampus griseus* and *Monachus monachus*), from which the following maps (Figures 4.34-4.37) were extracted (ISPRA, 2012). Maps are referred to an aerial survey carried out during 2010.



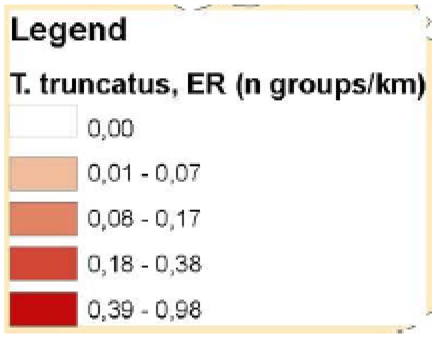
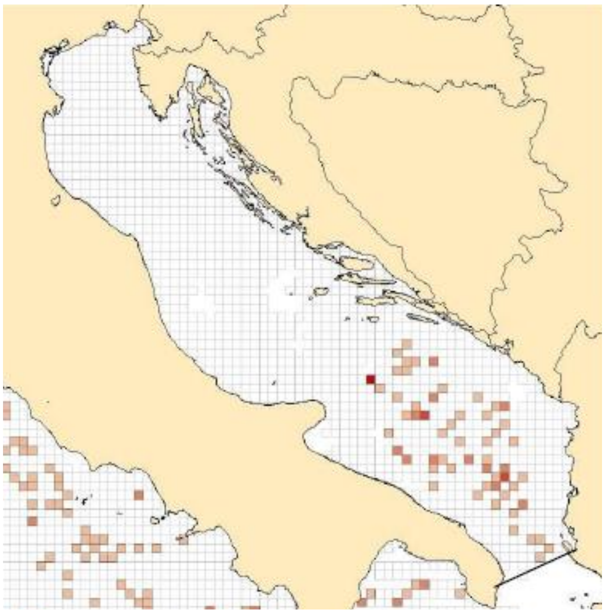


Figure 4.35. Distribution of bottlenose dolphins in the 3 subregions MSFD: rate of encounter (ER) groups/km traveled per cell. Note: the white cells present a research effort > 0 km, but a zero rate meeting



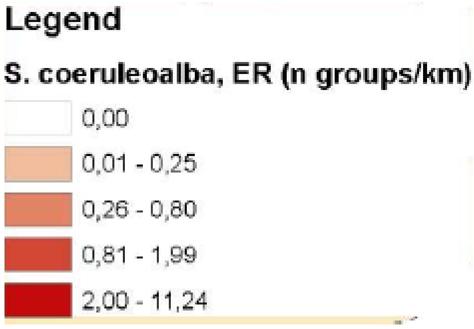


Figure 4.36. Distribution of striped dolphins in the 3 subregions MSFD: rate of encounter (ER) groups/km traveled per cell. Note: the white cells present a research effort > 0 km, but a zero rate meeting (Source:

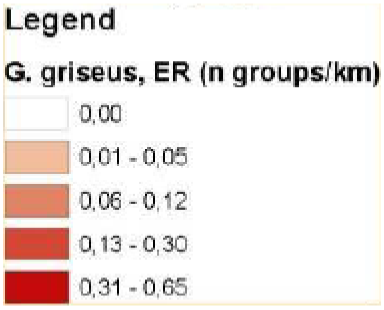


Figure 4.37. Distribution of Risso's dolphins in the 3 subregions MSFD: rate of encounter (ER) groups/km traveled per cell. Note: the white cells present a research effort > 0 km, but a zero rate meeting

From these data, it seems that the bottlenose dolphin is distributed mainly in the GSA 17, wherease the striped dolphin is sighted almost exclusively in the GSA 18. This was clearly seen in the most recent aerial survey carried out in the Adriatic Sea in 2013, whose results are shown in Figure 4.38.

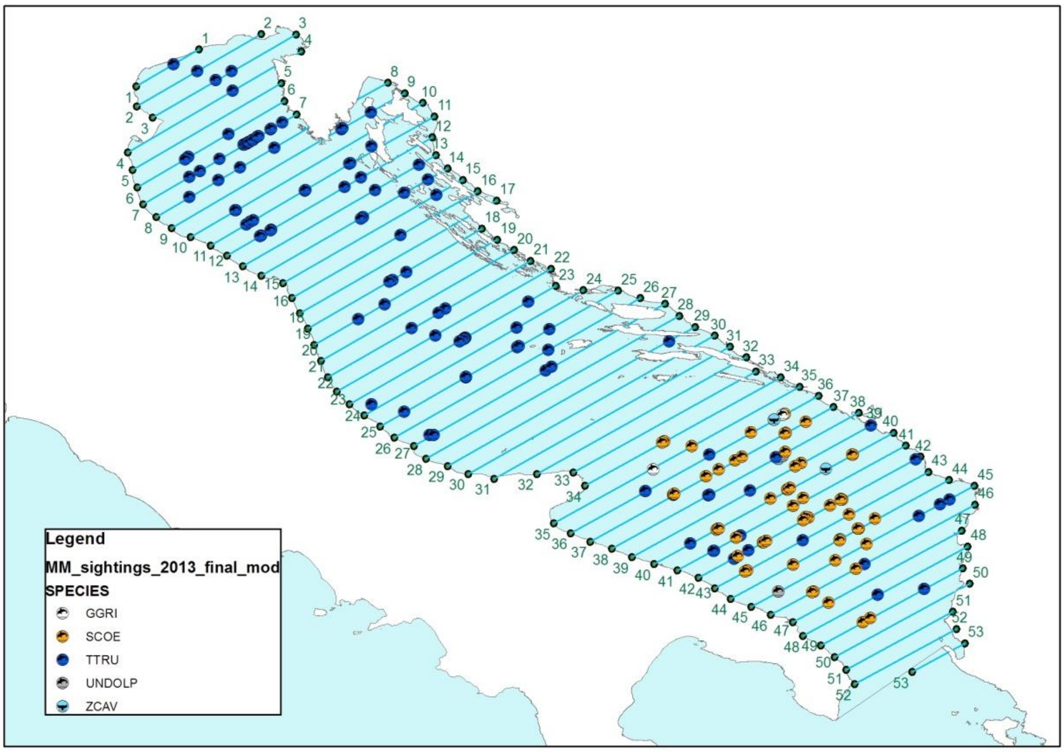


Figure 4.38. Sea mammals sightings in the Adriatic during the aerial survey of 2013 (july-september). Legend: GGRI = *Grampus griseus* = Risso's dolphin; SCOE = *Stenella coeruleoalba* = Striped dolphin; TTRU = *Tursiops truncatus* = Common bottlenose dolphin; UNDOLP = Unidentified dolphin species; ZCAV = *Ziphius cavirostris* = Cuvier's beaked whale (source: Project NETCET - Network for the conservation of sea Turtles and Cetaceans in the Adriatic, IPA Adriatic Cross Border Cooperation 2012-2015; data owners: ISPRA - Italy, Blue World Institute - Croatia).

Risso’s dolphin (Figures 4.37-4.38) and Mediterranean monk seal (Figure 4.39) can be found in the GSA 18, but their abundance is scarce if compared to the other mammal species.

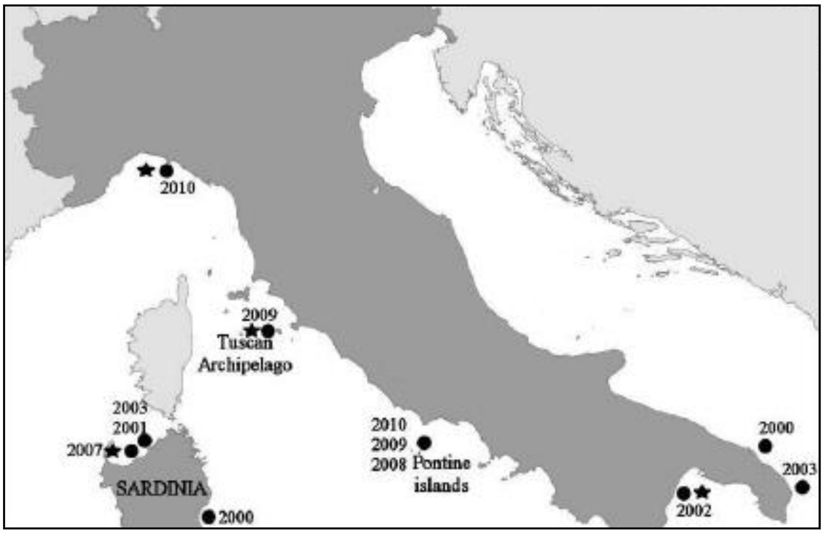


Figure 4.39. Validated sightings of the Mediterranean monk seals in the period 1998-2010 (circles indicate locations blacks, stars indicate the presence of photographic documentation, numbers in parentheses indicate the number of times that an event of sighting occurred in a year) (source: Mo *et al.* 2007; Mo, 2011).

During the same survey an accurate observation of elasmobranchs was also performed (Figure 4.40).

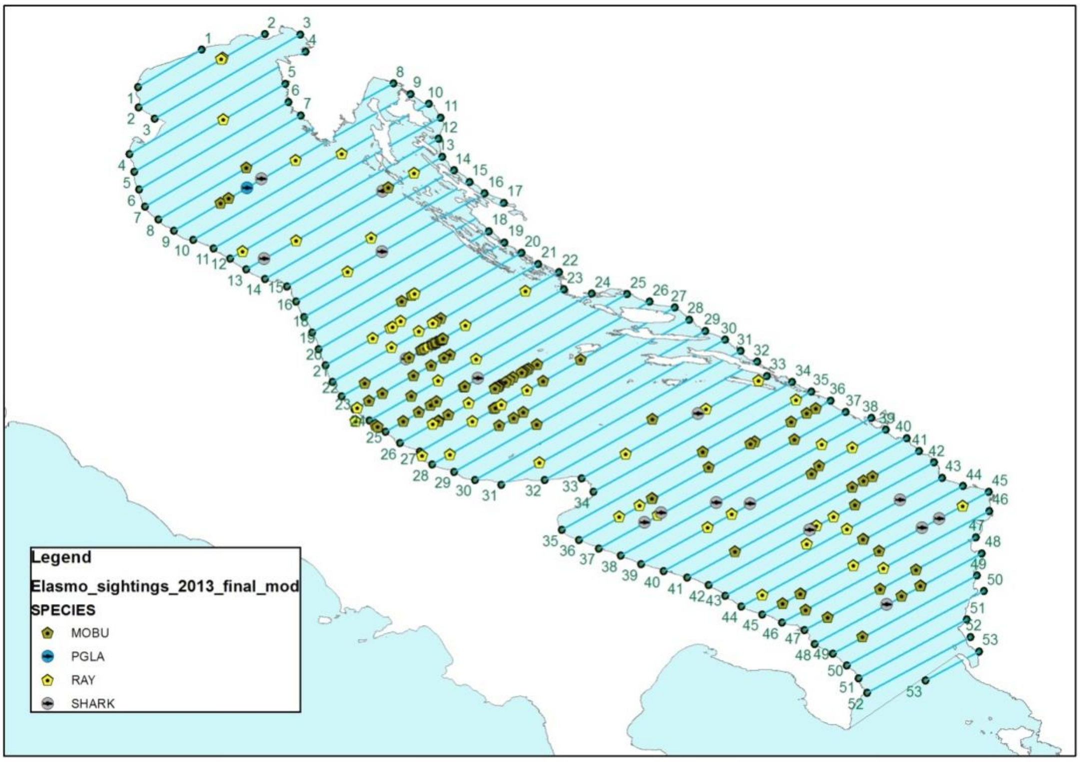


Figure 4.40. Elasmobranchs sightings in the Adriatic during the aerial survey of 2013 (july-september). Legend: MOBU = *Mobula mobular* = Giant devil ray; PGLA = *Prionace glauca* = Blue shark; RAY/SHARK = Unidentified specimen (source: Project NETCET - Network for the conservation of sea Turtles and Cetaceans in the Adriatic, IPA Adriatic Cross Border Cooperation 2012-2015; data owners: ISPRA - Italy, Blue World Institute - Croatia).

4.3.7 Fisheries

The approval procedure for wind farm proposals should considers site-specific conflict analysis between the wind farm and fisheries. Due to the relatively small spatial coverage of wind farms, potential opportunity losses to the fisheries are always considered as low or negligible. In fact, this effect could vary according to the location of the wind farm, in particular the opportunities to catch such valuable species could be considerably reduced if the location of these industrial plants is located in an area in which there is also a high biomass of these resources.

For this reason, in this section we try to describe the spatial distribution of biological resources subject of fishing activities in order to provide some basic information for planning the location of wind farms in the Adriatic sea considering two different biological information on stocks:

- the spatial distribution of biomass and abundance index that can be considered an estimation of the distribution of fishing potential production;
- the spatial distribution of spawning and nursery areas that can be considered a subject of fishery planning.

4.3.7.1 Data sources

Since the 80's sampling surveys were carried out systematically in the Adriatic Sea, at first conducted only in Italian waters and in the international ones, and then in the entire basin. Those surveys served for the collection of information on catches, fishing effort, and more generally on the biology of the Mediterranean fish stocks (so-called "demersal") which have been caught pre-eminently by trawling. The information gathered was used to provide a summary of knowledges on key benthic and necto- benthic species fished in the Adriatic basin.

The first program carried out with this objective was the GRUND (National Group on Demersal Resources), financed by the Italian Government and then carried out only in the Italian and international waters (occasionally in the early 80's during few surveys were covered also the jugoslavian waters). The data collected in GRUND surveys have been used, in 1997, to produce a series of maps representing the distribution of the main demersal species in all the Italian waters and therefore also in the Adriatic Sea (Ardizzone et al., 1997). GRUND surveys stopped in the Adriatic Sea in the 2007.

Since 1994 an international research program named MEDITS began. Its main, still running, objective is the study of the demersal resources along the Mediterranean coasts of four EU countries (Spain, France, Italy and Greece) and, since 1996, also some Balkan countries on the Adriatic Sea (Albania, Croatia, Slovenia and later Montenegro). The program collects and analyzes data on the biological communities interested by fishery in the bathymetric interval from 10 to 800 meters of depth carrying out an experimental fishing survey in late spring–summer.

Both the above mentioned survey programs have collected information on demersal species of high commercial value but it is important to specify that the two programs have used different sampling methods:

- Different geographical coverage and sampling station number as shown in Figure 4.41 (MEDITS has covered the entire area of the Adriatic sea with a more optimized number of sampling points, while GRUND has covered only the area of the Italian national waters and international ones with a larger number of sampling points);
- Different types of fishing gear were used (MEDITS sampling trawl net has a vertical opening more than 2 meters with the codend of 20 mm mesh size, whereas GRUND sampling trawl net is less than 1 meter with codend mesh of 40 mm). The difference mesh also causes a substantial difference in the sizes caught being the catch of MEDITS more representative for small size individuals;
- Different sampling season (MEDITS survey carried out during late spring-summer while GRUND in the first period, when MEDITS program was not operating both during late autumn-winter and during summer, then only during autumn-winter.

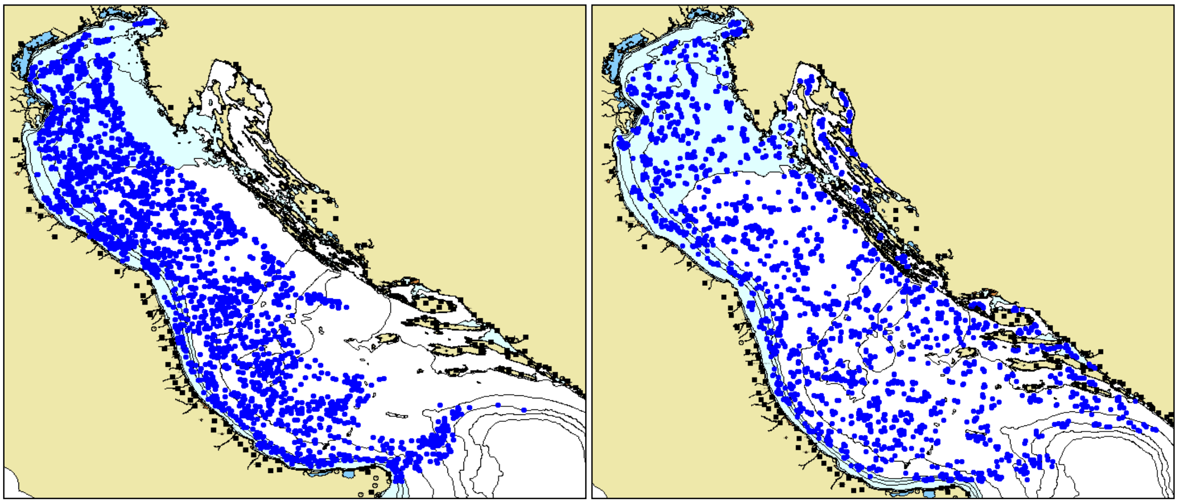


Figure 4.41.Spatial distribution of all the sampling points carried out during the GRUND (left panel), and MEDITS (right panel) programs.

MEDITS data have recently been the subject of a series of analysis carried out by the research Institutes who collected them in order to determine the spatial distribution of fish stocks. A recent publication by Acta Adriatica (the International Journal of Marine Sciences published by the Institute of Oceanography and Fisheries of Split) has provided a series of maps with spatial distribution of 78 different species produced by means of MEDITS data. The area represented in these maps covers the entire FAO GSA17 that means Northern and central Adriatic sea (2/3 of the entire Adriatic extension). For brevity, these maps are not reported in the present report.

More recently, a specific project named MEDISEH (Mediterranean Sensitive Habitats - 2013) used MEDITS data to identify and locate nursery areas (juveniles in their first and, if appropriate, second year of life) and spawning aggregations of commercially valuable species.

In this report we decided to use these two recent studies and in particular their maps in order to describe the distribution of the main fishing grounds in the Adriatic and identify areas of particular interest for fishery management, such as spawning and nursery areas.

4.3.7.2 Mapping method

As mentioned above, in the present report the maps published in Acta Adriatica and MEDISEH report were used as a basis. These maps can be divided into three main groups taking into account the data representing:

- the spatial distribution of abundance index (number of individuals/km^2);
- the spatial distribution of the biomass index (kg/km^2);
- the spatial distribution of probability to be a nursery or a spawning area.

The maps published in the Acta Adriatica monograph belong to the first two groups whereas the maps reported in the MEDISEH documents belong to the last one.

Both publications present a series of maps describing the above mentioned data for several species. In this report these maps were combined together in order to obtain summary maps that take into account all the species considered in a single map.

Acta Adriatica maps were used to identify the main fishing grounds, whereas the MEDISEH maps to find out areas in which several species have theirs spawning events and where these species spend their juvenile stage of life.

4.3.7.3 Identification of main fishing grounds

In Acta Adriatica monograph, for each of the 78 considered species, a map with the extension of the maximum spatial distribution is presented (Piccinetti et al, 2012). These maps are obtained using all the sample points collected during the MEDITS survey from 1994 to 2009. Three different values of abundance index were chosen to identify three different spatial extents: 1) to identify the maximum extent of the area of presence for the species all over the entire period covered by the survey program; 2) to identify an area (less extensive then the previous one) in which the presence is characterized by a moderate value of the index considered; 3) to border a smaller area with high values. These values are species dependent and represent low, medium and high values of abundance index. Each value was used to produce a different map using Universal Kriging technique with linear drift (Piccinetti et al., 2012). Then the three maps obtained for each of the species were superimposed to produce a final map with the three different spatial extents associated to the low, medium and high values represented together (Figure 4.42-4.43).

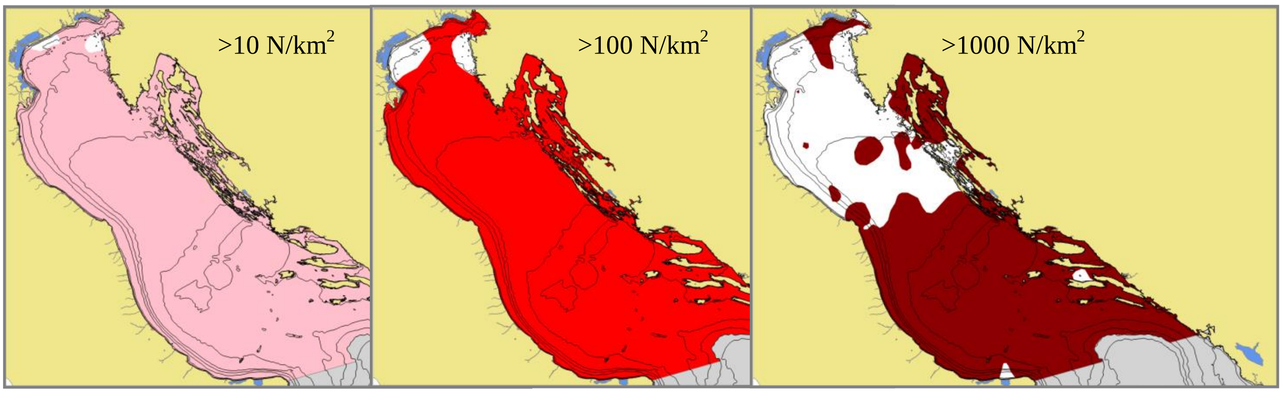


Figure 4.42. Spatial distribution of different classes of abundance index.

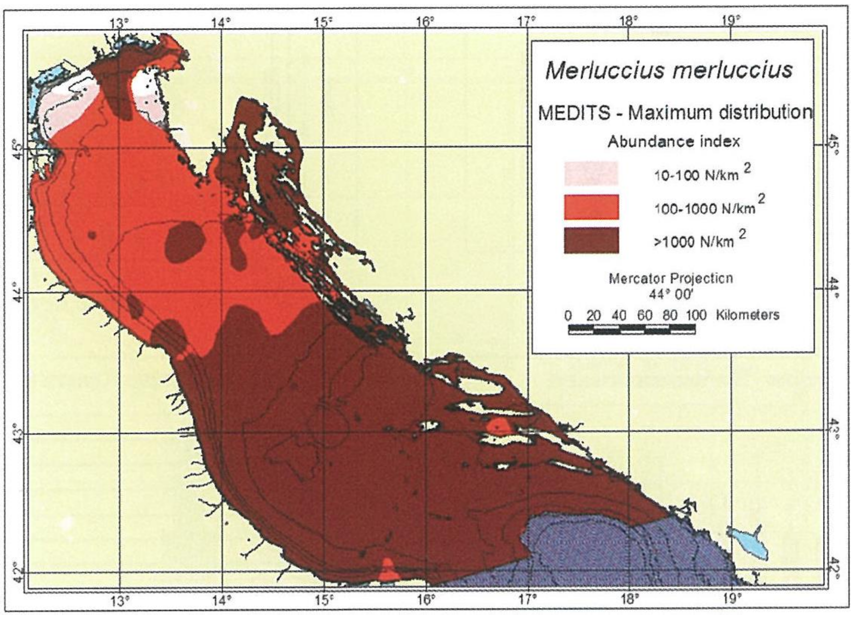


Figure 4.43. Example of spatial distribution of different abundance index for one speceies. Superimposition of the 3 layers produces the final map (Piccinetti et al. 2012)

For 15 species of particular commercial interest were presented also the maps with biomass index. These maps were obtained with the same technique described above for abundance index. In this case appropriate values of biomass index were identified for each of the 15 species trying to border areas with low, medium and high value of this index. This report uses the maps of these 15 species to produce the fishing grounds final map. The list of the species is reported in the following Table 4.1.

Table 4.1. List of species considered in the present report for the identification of fishing grounds

Eledone cirrhosa (Lamarck, 1798)	Horned octopus
Eledone moschata (Lamarck, 1798)	Musky octopus
Illex coindetii (Vérany, 1839)	Broadtail shortfin squid
Loligo vulgaris (Lamarck, 1798)	European squid
Lophius budegassa (Spinola, 1807)	Black-bellied angler
Merlangius merlangus (Linnaeus, 1758)	Whiting
Merluccius merluccius (Linnaeus, 1758)	European hake
Mullus barbatus (Linnaeus, 1758)	Red mullet
Nephrops norvegicus (Linnaeus, 1758)	Norway lobster
Pagellus erythrinus (Linnaeus, 1758)	Pandora
Scyliorhinus canicula (Linnaeus, 1758)	Smallspotted catshark
Sepia officinalis (Linnaeus, 1758)	Common cuttlefish
Squilla mantis (Linnaeus, 1758)	Spottail mantis shrimp
Trisopterus minutus (Linnaeus, 1758)	Poor cod
Zeus faber (Linnaeus, 1758)	John dory

For each species, the boundaries of the area representing the high value for values of abundance and biomass index were digitized. The maps obtained from digitized boundaries for abundance index are reported in Figure 4.44, whereas the maps with boundaries for biomass index are reported in Figure 4.45.

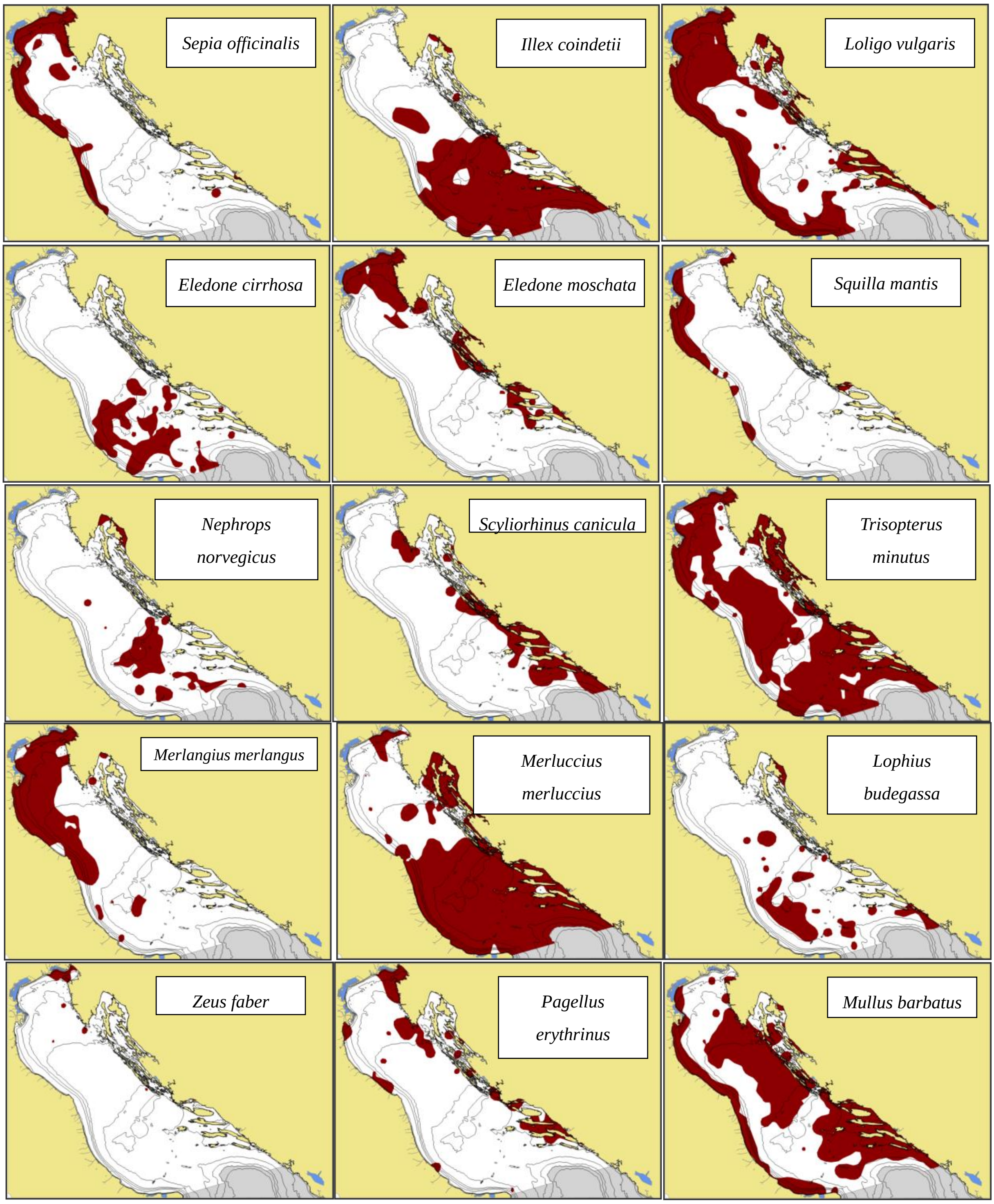


Figure 4.44. Abundance index distribution maps for 15 commercially valuable species of the Adriatic Sea (source :Acta Adriatica)

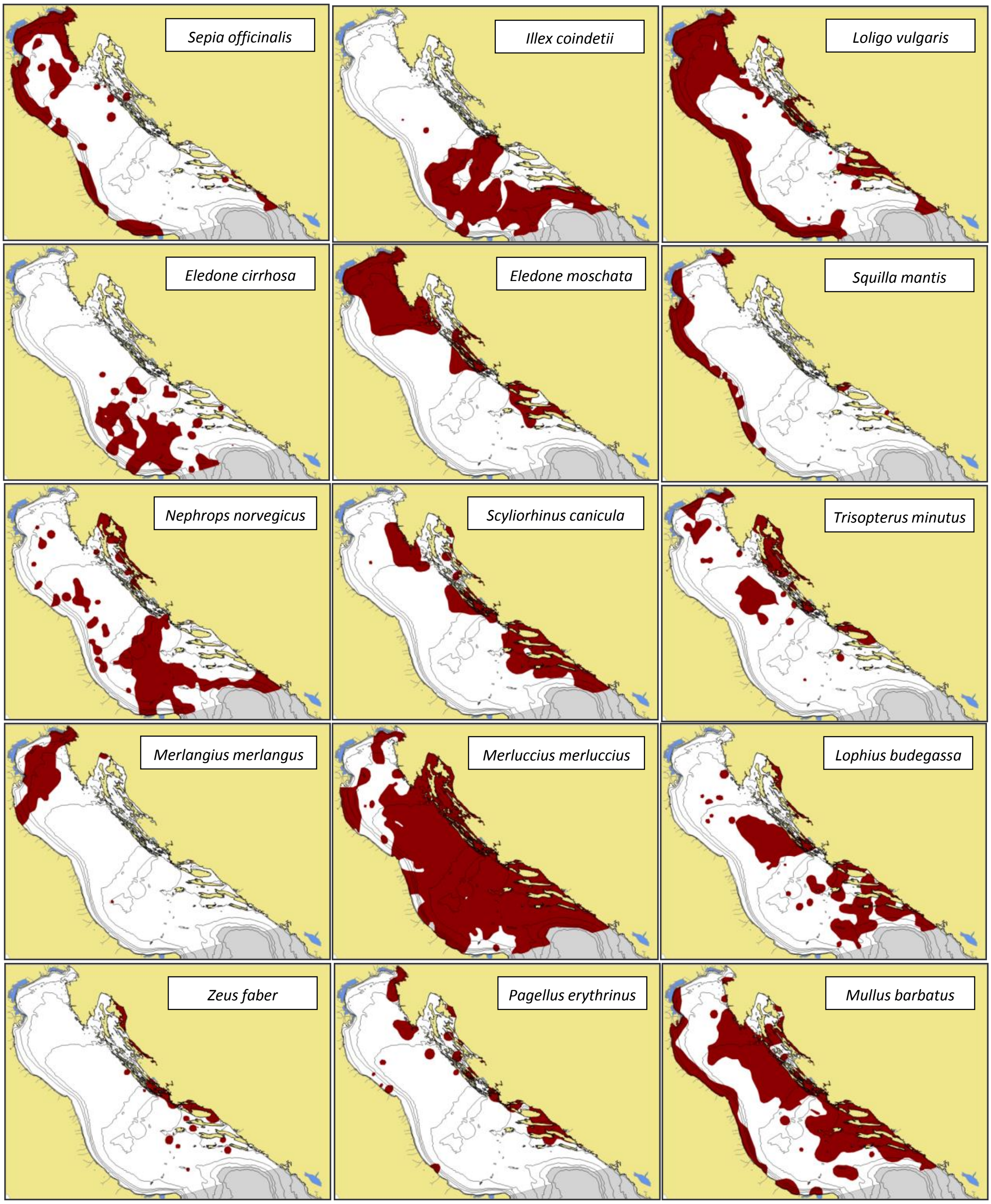


Figure 4.45. Biomass index distribution maps for 15 commercially valuable species of the Adriatic Sea (source: Acta Adriatica).

In order to consider all the 15 species together in a single map the following procedure was used. A matrix layer was defined covering the entire area represented in the abundance and biomass maps. The matrix is composed by square elements with a 5 km side. The matrix was superimposed as a layer to all maps which represent the spatial extension of abundance/biomass index. Then, for each element of the matrix, the number of species whose area covers at least a part of the element was calculated. Finally this number was subdivided by the total number of species. The procedure is graphically described in Figure 4.46.

The Presence Index (PI) calculated for each element of the matrix can be obtained as follow:

$$PI(i) = \frac{N}{S}$$

where PI(i) is the Presence Index referred to the i element of the matrix, N the number of species whose spatial distribution intersect the i element of the matrix and S is the total number of species considered in the analysis.

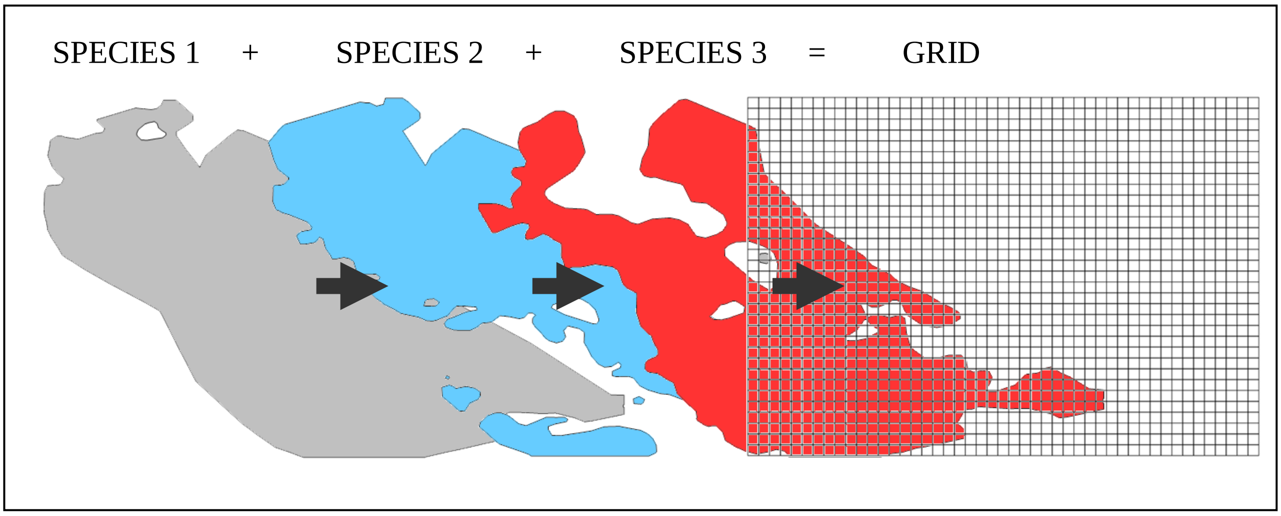


Figure 4.46. Graphic representation of the method used to combine several species in a summary map

The final map obtained with this method emphasizes the areas in which several species can be caught and then can be considered as representing their potential fishing grounds. A bias of this method is that it gives the same importance to all species considered even if some fishing activities have a specific target species and then their fishing grounds are influenced only by the distribution of that species. Nevertheless, for bottom otter trawlers (the most important fishery typology in the Adriatic sea) the target species list (defined in the protocol of the survey) overlaps with the one used in the present post-elaboration. Then, the final maps could be considered a good image of the distribution of fishing grounds available in the Adriatic Sea.

The final maps obtained with the method described above are reported in the following two figures (Figure 4.47-4.48). The first map (Figure 4.47) considers the abundance index distribution maps and the second one (Figure 4.48) the biomass index distribution maps. Both maps show that fishing grounds are practically distributed in all the considered area. If we look at the areas with more then 30% of species considered, they are located in the shallow waters of the northern part of the basin, along the western coast, in the area of the Dalmatian islands and in the off-shore area of the middle Adriatic sea from Dalmatia to Abruzzo and Molise coastline. This last off-shore area seems to be populated by a large number of individuals but not corresponding to high values of biomass as revealed by the comparison of the two result maps. The same consideration can be done also for the western coast. The reason for this difference between the result maps could be identified in the fact that the above mentioned areas are populated by juveniles of some species which number could be considerable high but does not correspond to high values of biomass. This fact is confirmed by the results obtained analyzing the data presented in the MEDISEH report, which are summarised in the next session.

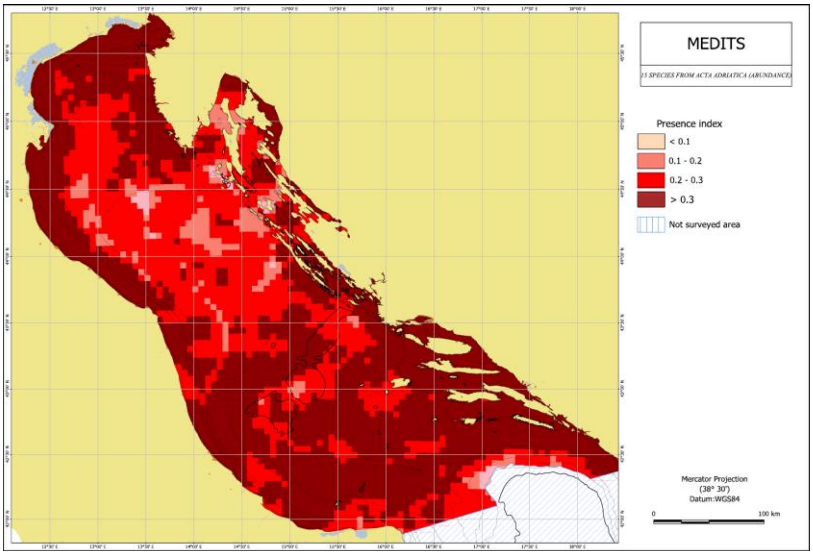


Figure 4.47. Map of Presence Index obtained using abundance index maps (Piccinetti et al. 2012)

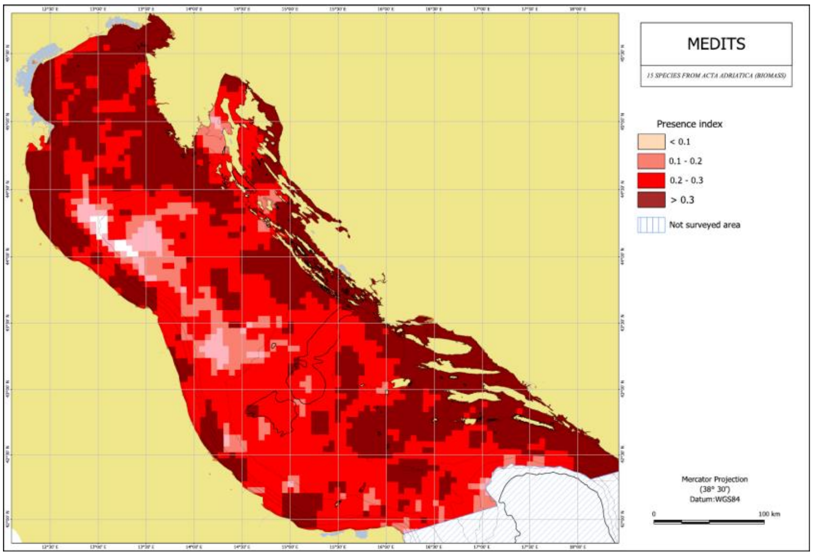


Figure 4.48. Map of Presence Index using Biomass index maps (Piccinetti et al. 2012)

4.3.7.4 Identification of main nursery and spawning areas

In the MEDISEH report nursery and spawning maps were published. From the whole set of species investigated under the MEDISEH umbrella, in this report only species that are present in the Adriatic Sea were considered. The list of the considered species for the purposes of the present report is reported in Table 4.2.

Table 4.2. List of species considered in the present report for identification of spawning and nursery areas

Aristaeomorpha foliacea (Risso, 1827)	Giant red shrimp
Aristeus antennatus (Risso, 1816)	Blue and red shrimp
Eledone cirrhosa (Lamarck, 1798)	Horned octopus
Engraulis encrasicolus (Linnaeus, 1758)	Anchovy
Galeus melastomus (Rafinesque, 1810)	Blackmouth catshark
Illex coindetii (Vérany, 1839)	Broadtail shortfin squid
Merluccius merluccius (Linnaeus, 1758)	European hake
Mullus barbatus (Linnaeus, 1758)	Red mullet
Nephrops norvegicus (Linnaeus, 1758)	Norway lobster
Pagellus erythrinus (Linnaeus, 1758)	Pandora
Parapenaeus longirostris (Lucas, 1846)	Deep-water rose shrimp
Sardina pilchardus (Walbaum, 1792)	Sardine
Solea solea (Linnaeus, 1758)	Common sole

The difference between this list and the one presented in the previous section used to identify fishing grounds is due to the fact that the species array considered by the Acta Adriatica monograph is larger than the one used in the MEDISEH project. Moreover, the different extent of the area covered by the MEDISEH project (i.e. the entire Adriatic sea basin instead of only the Northern and Central part of it considered in the Acta Adraitica paper) makes it possible to consider some species whose distribution is confined only in the Southern part of Adriatic sea basin. Another element that should be emphasized analysing the list reported above is the presence of anchovy and sardine. These two species, that were neglected in the previous section, are the main target species of the mid-water pair trawlers, another important fishing gear largely used in the Adriatic Sea. These "small pelagic" species were not considered to identify fishing grounds because Acta Adriatica maps were generated using MEDITS data that are collected using a bottom trawl. In the MEDISEH maps these data were integrated using data coming from specific designed survey for small pelagic species like the "MEDIAS" surveys.

For each species the spawning and nursery areas were digitized from the maps published in the report (see Fig 4.49 and Fig. 4.50 for examples).

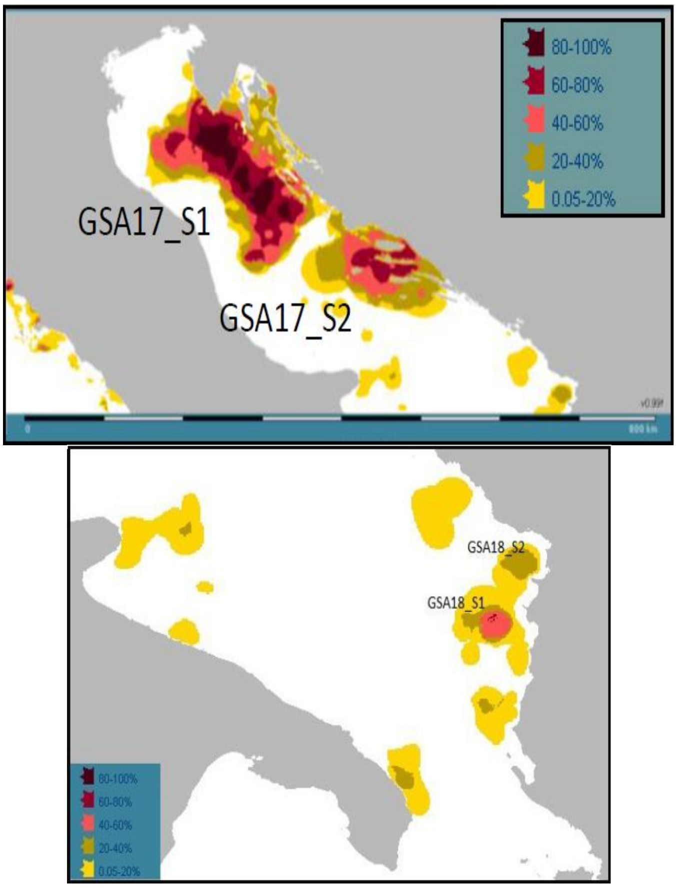


Figure 4.49. Example of map of spawning grounds (ed Mullet) in the Northern and Central (left panel) and in Southern sectors (right panel) of the Adriatic Sea.

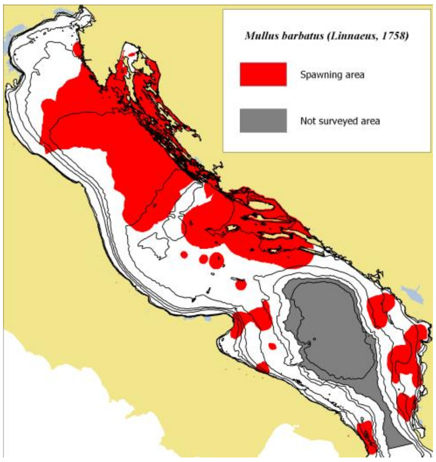
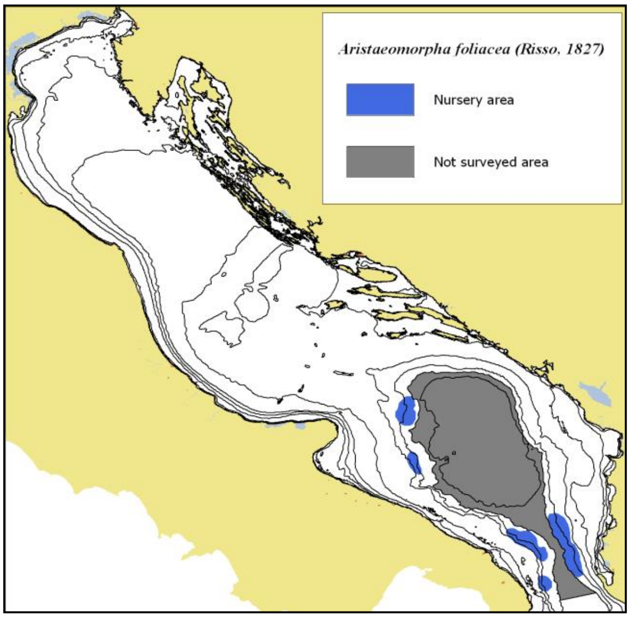
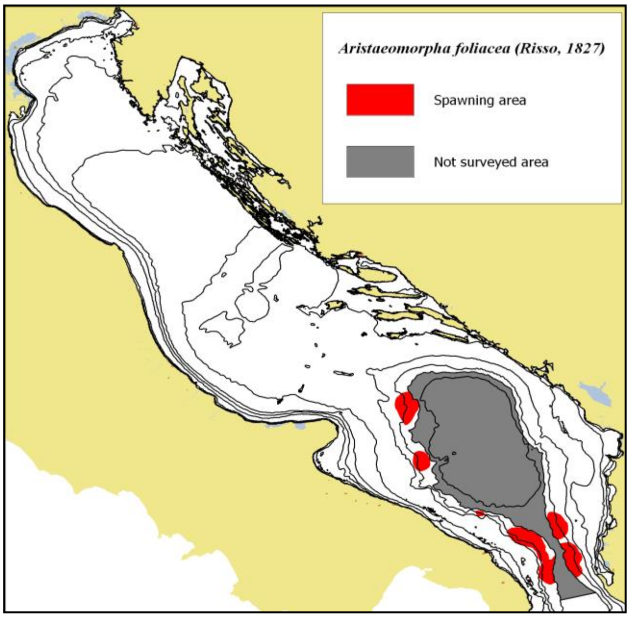


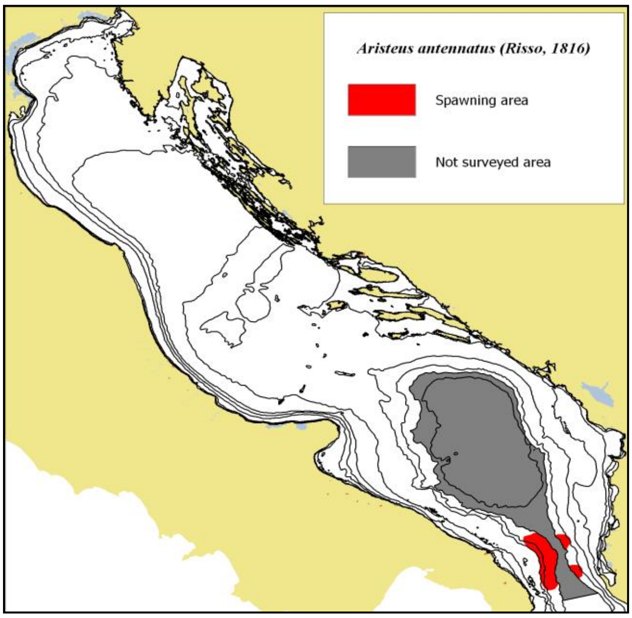
Figure 4.50. Digitized version of the maps shown in Figure 4.49. (Piccinetti et al. 2012)

In the following panels under the caption of Figure 4.51 all the nursery (blue) and spawning (red) areas for the 13 species considered are reported.

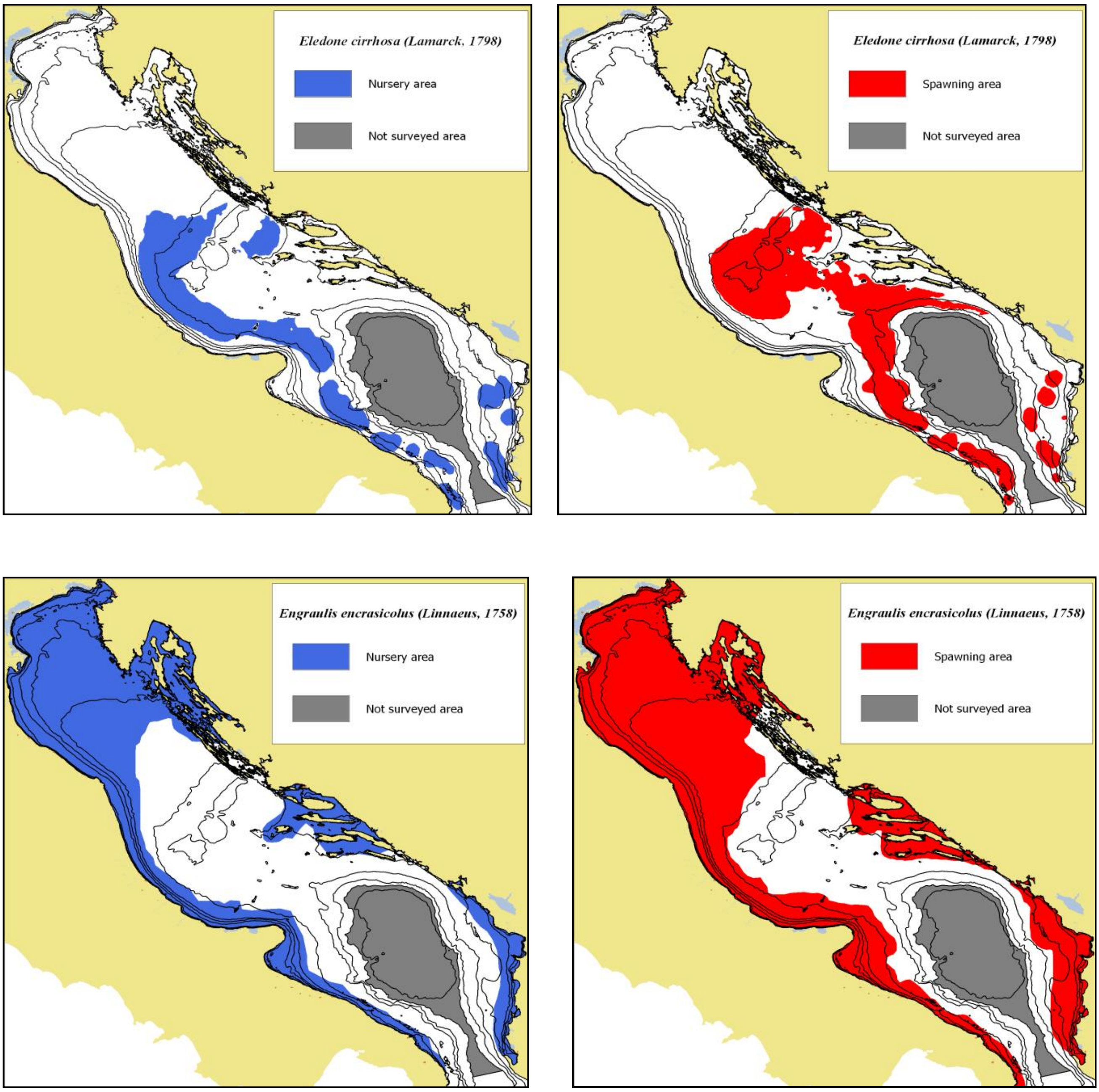




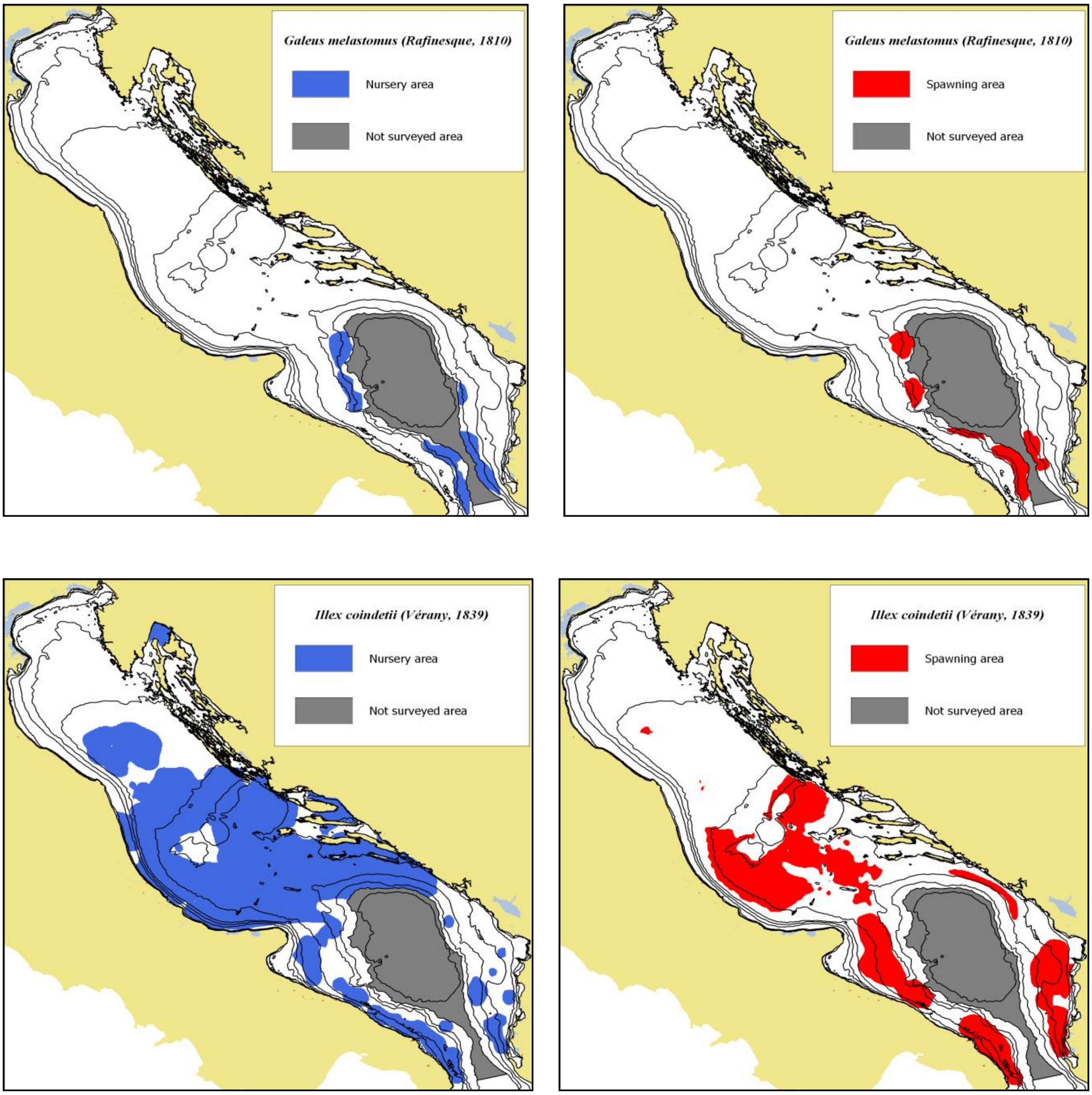
Not available



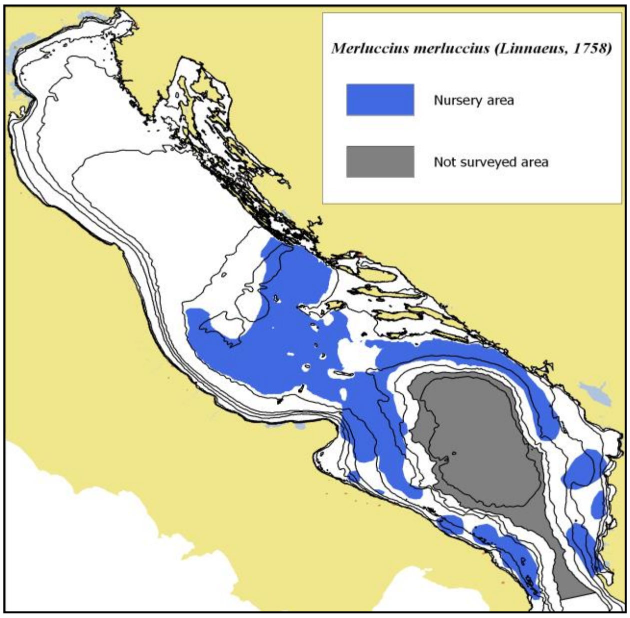
(Piccinetti et al. 2012)

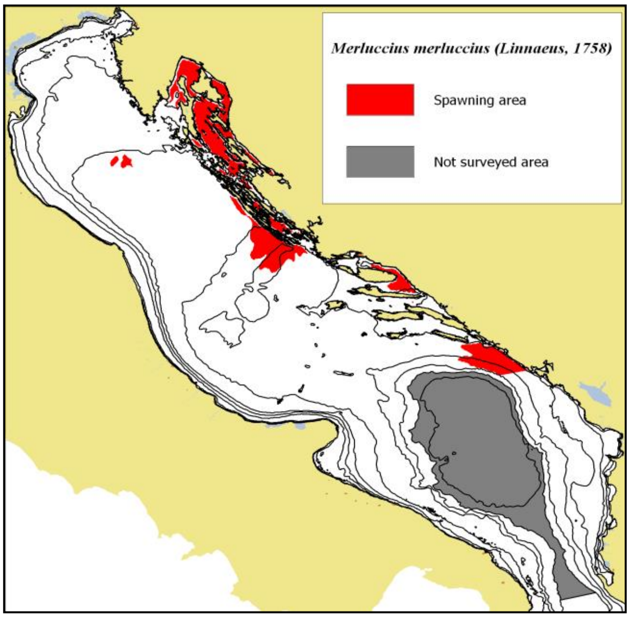


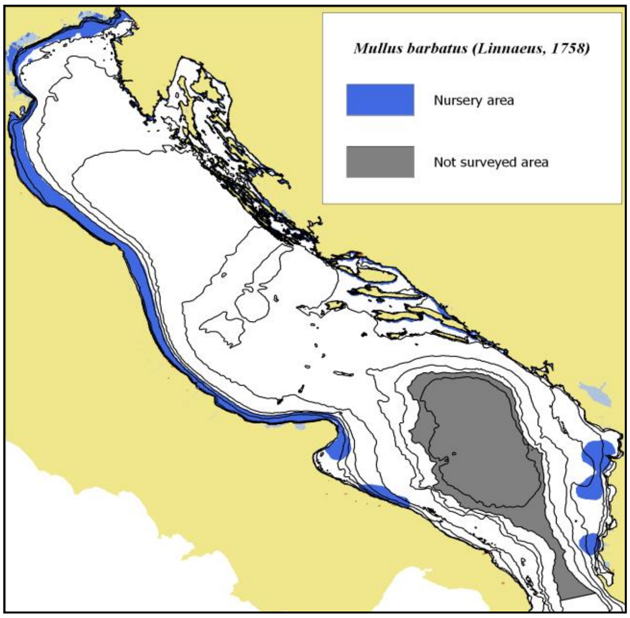
(Piccinetti et al. 2012)

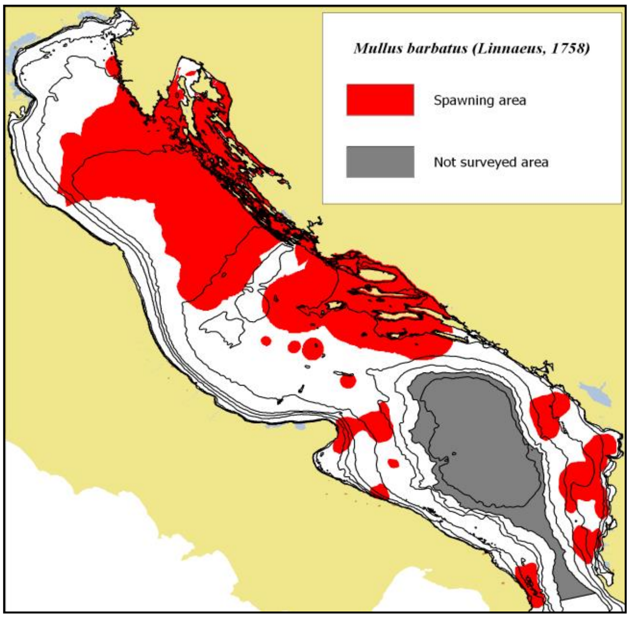


(Piccinetti et al. 2012)

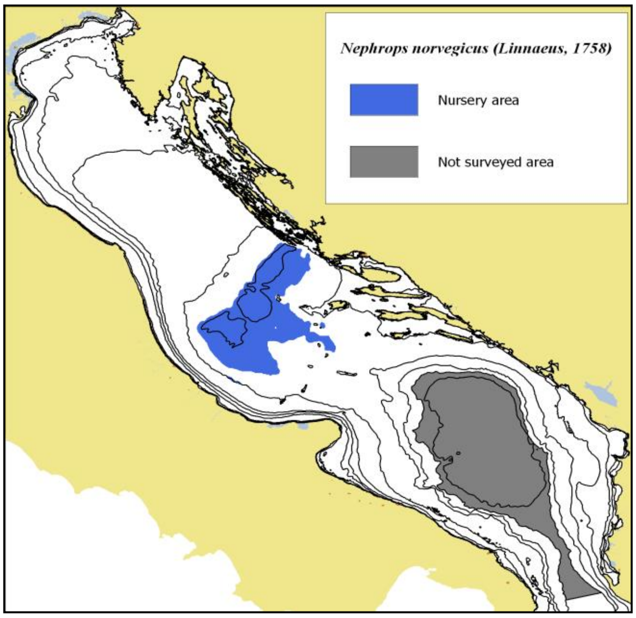


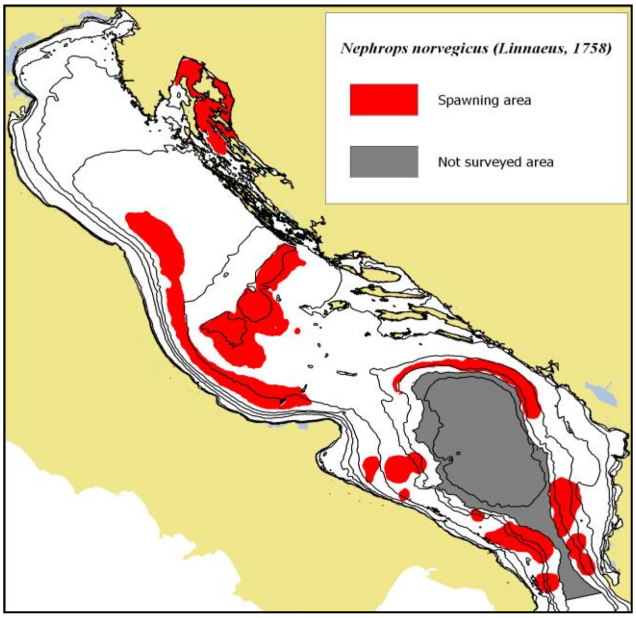


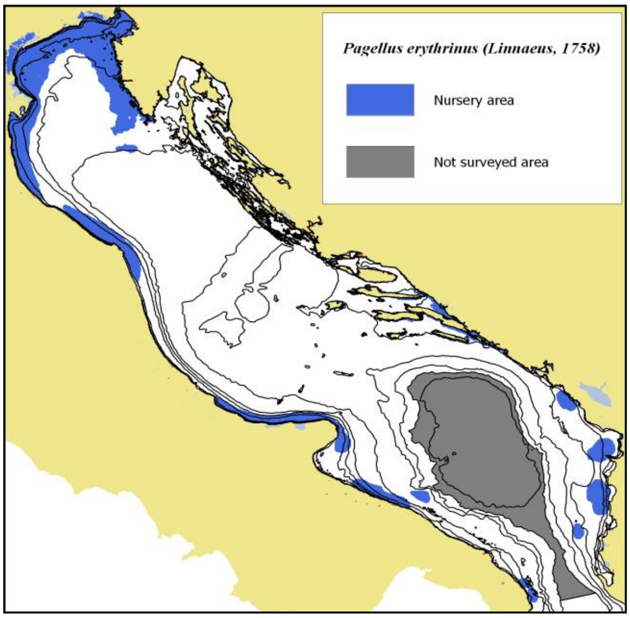


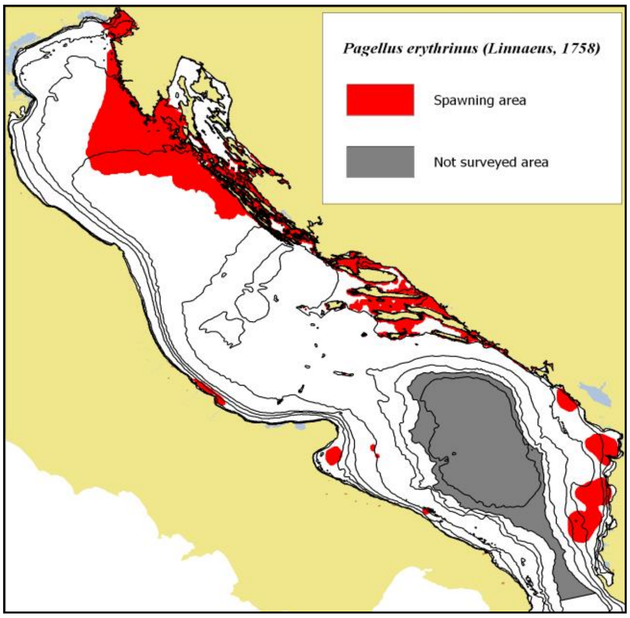


(Piccinetti et al. 2012)

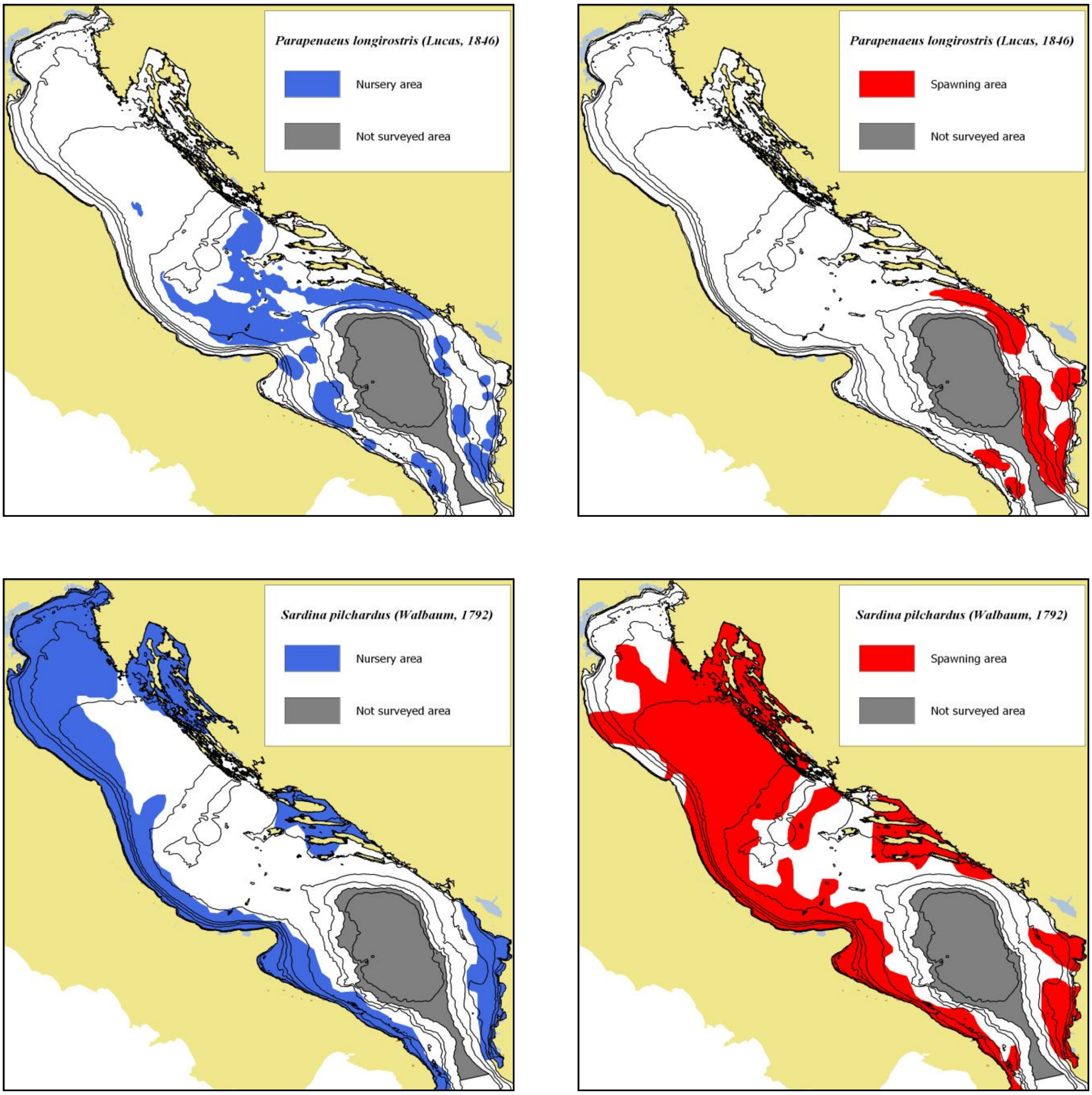




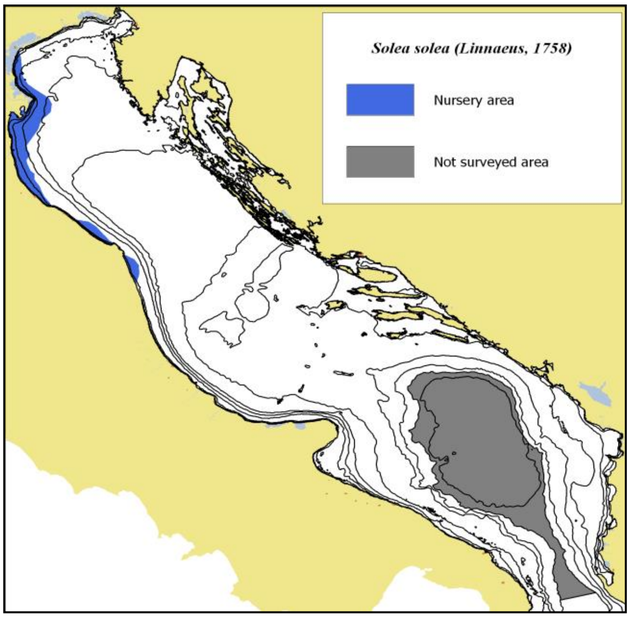




(Piccinetti et al. 2012)



(Piccinetti et al. 2012)



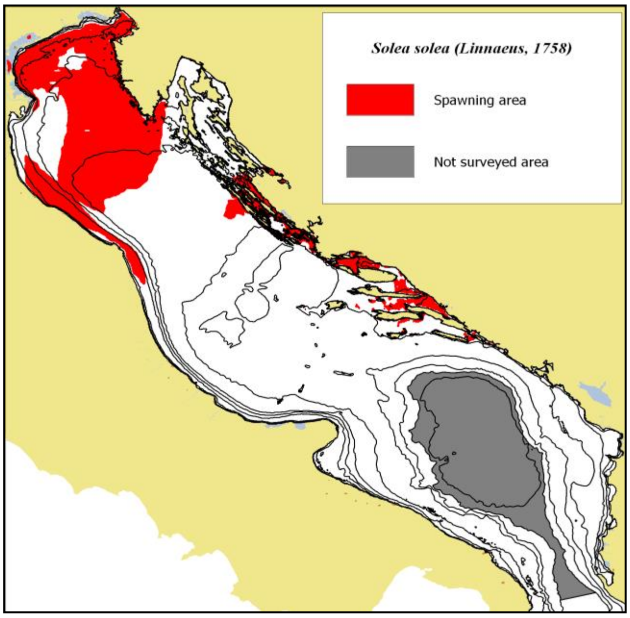
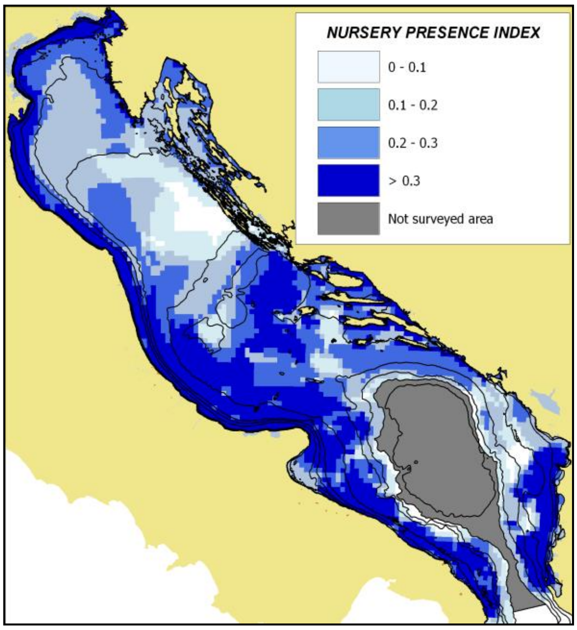


Figure 4.51. Nursery (left panels) and spawning (right panels) areas as obtained after MEDISEH report. Note that for the red shrimp (*Aristeus antennatus*) only the spawning area was identified. (Source:

The final maps with presence index of species both for nursery and spawning areas are reported in the following panels included in Figure 4.52.



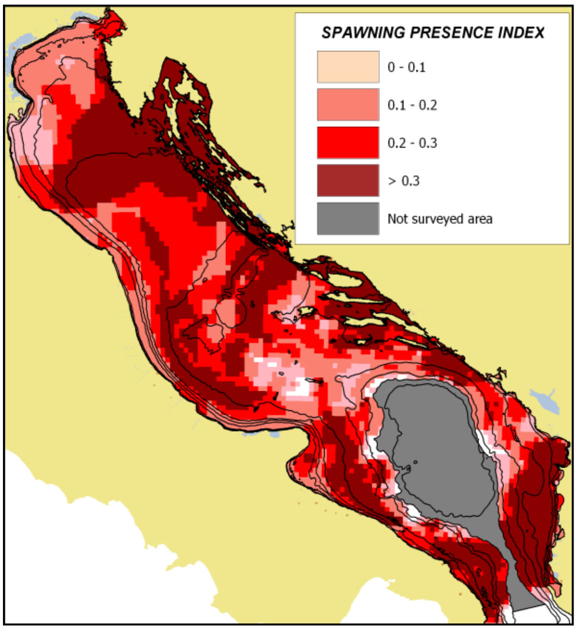


Figure 4.52. Presence Index for Nursery (left panel) and Spawning (right panel) areas. (Source:

The comparison between the two final maps allows delineating the following generalities. The western coast is better characterized by the presence of nurseries whereas the eastern one by the presence of spawning areas. More in details, in the Northern part of the basin there is an evident disjunction between the main nursery grounds and spawning ones, whereas in the central and southern parts of the basin an overlap between nursery and spawning grounds is clearly evident. In particular, in the Southern sector of the basin there is a virtual complete overlap between the two areas.

4.3.7.5 Concluding remarks on fisheries

The results of this analysis represent an attempt to characterize the Adriatic sea in terms of spatial distributions of species subject of fishing activity and relying on them to identify the main fishing grounds. Moreover, to identify sensitive areas because of their role in some key stage of life crucial for the sustainable exploiting of fishing resources. These data have been used together with data on the fishing effort data in the GRID application to evaluate different scenarios as described in the following session.

4.3.8 Spatial distribution of fishing effort

To potentially evaluate the interactions between an offshore wind farm and the fishing activities, information about the spatial distribution of the fishing effort are definitely relevant. This kind of information provides an image of the main fishing grounds used by fishing vessels during their activity and is definitely needed because installing a wind farm at sea will remove some areas previously available for fisheries.

4.3.8.1 VMS data to characterize the spatial distribution of the fishing effort

The Vessel Monitoring System (VMS) is a mandatory tool, widely used in Europe, North America, South America and Africa, for fishing vessels having a length over all (LOA) exceeding a threshold set by each state or organization between states. In Italy, this length threshold corresponds to a LOA equal to 12 m. Because of a large number of exemptions for fishing vessels with LOA ranging between 12 and 15 m, this limit in fact could be reasonably considered equal to 15 m.

The system is composed by a transmitter, known as Blue-Box, installed on board each fishing unit. This tool provides both the geographic localization of the fishing unit (being generally attached to the INMARSAT network) and the transmission of information (via a satellite network for telecommunications) to the control center. For Italy, the center corresponds to the network Coast Guard stations and, ultimately, to the General Command of

Coast Guard sited in Rome. The data transmitted by each Blue-Box comprise: latitude and longitude, speed and course.

Born as a control tool and safety system (each Blue-Box is equipped with various sensors and will warn the Coast Guard in case of collision, damage or sinking), since 2006 the VMS is a powerful tool effectively used also for monitoring the fishing fleets. It indeed allows tracking the position of the fishing units and:

- when combined with the Logbook, it allows to identify the fishery activity;
- when analyzed with respect to speed and compared with the general behaviour of fishing units it allows to identify each haul.

The ability to extract all the useful information from the raw VMS data depends largely on the application of appropriate algorithms for filtering, analyzing and combining data. For the present report we have applied the algorithms and methods reported in Bastardie et al., 2010 (combination of VMS and logbook); Russo et al., 2011a (interpolation of the signals in order to increase artificially the frequency) and Russo et al. 2011b (use of neural networks for the characterization of the activity in the absence of an abutment on the given Logbook). All procedures were conducted in the R environment (Development Core Team, R., 2009).

It is important to point out that the VMS derived information are not representative of the entire fleet, having excluded the small scale fishery due to the fact that their vessel length is smaller than the law threshold. However, it is reasonable to assume that VMS derived data represents more than 80% of the overall effort because of the larger fishing vessels are responsible of most of the fishing/exploitation of resources in the investigated basin.

The following Figure 4.53 shows the percentage of the total Italian fishing fleet covered by the VMS in the 7 GSA (FAO Geographical Sub Areas) interested by fishing activity of the above mentioned fleet.

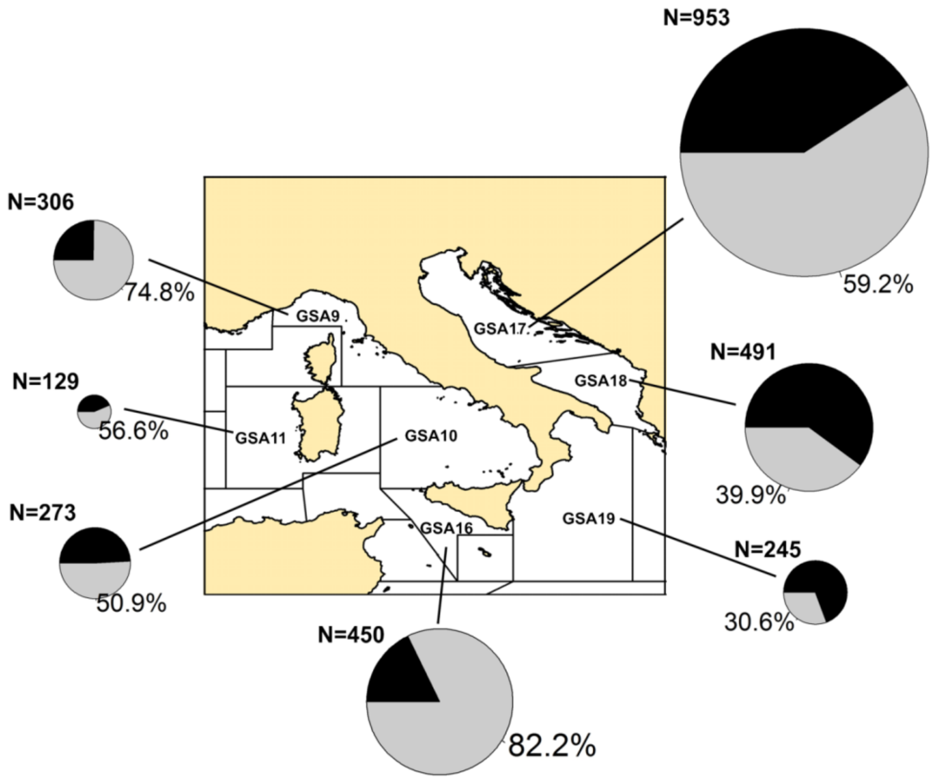


Figure 4.53. Percentage of Italian fishing fleet covered by VMS in the 7 FAO GSA interested by the Italian fishing activities. (Source:

4.3.8.2 List of maps produced from VMS data

The analysis of VMS data was conducted in order to characterize the spatial distribution of the fishing effort of several fishing fleet segments including: bottom otter trawls, boat dredge, beam trawl, pelagic pair trawl, purse seine, set gillnet, drifting long-lines. Furthermore the data were analyzed considering seasonal variability and splitting the fleet on the basis of vessels base port. Four different groups of maps were then produced as described below:

1. maps with spatial distribution of effort for the different fishing segments and for GSA17 and GSA18 considering all data available from 2006 to 2011;
2. maps with seasonal spatial distribution of fishing effort for each of the fishing segments for the years 2010 and 2011;
3. maps described above considering also the vessel base ports;

The dimension of each cell that belongs to the grid is 1 km^2. The coordinate system used for the maps was the Geographical coordinate system referred to the WGS 84 ellipsoid. For each cell the specific data calculated during the elaboration is represented using different colors.

As far as the first group is concerned, a total of 14 maps were generated. In detail, 7 maps for each fishing segment for the two GSA considered. The following three panels included cumulatively in Figure 4.54 report the maps for 3 of the 7 fishing segments of larger importance in the Adriatic sea, namely bottom trawl, beam trawl, and pelagic pair trawl. These data were used also in the application of the GRID system described in the next chapter of this report.

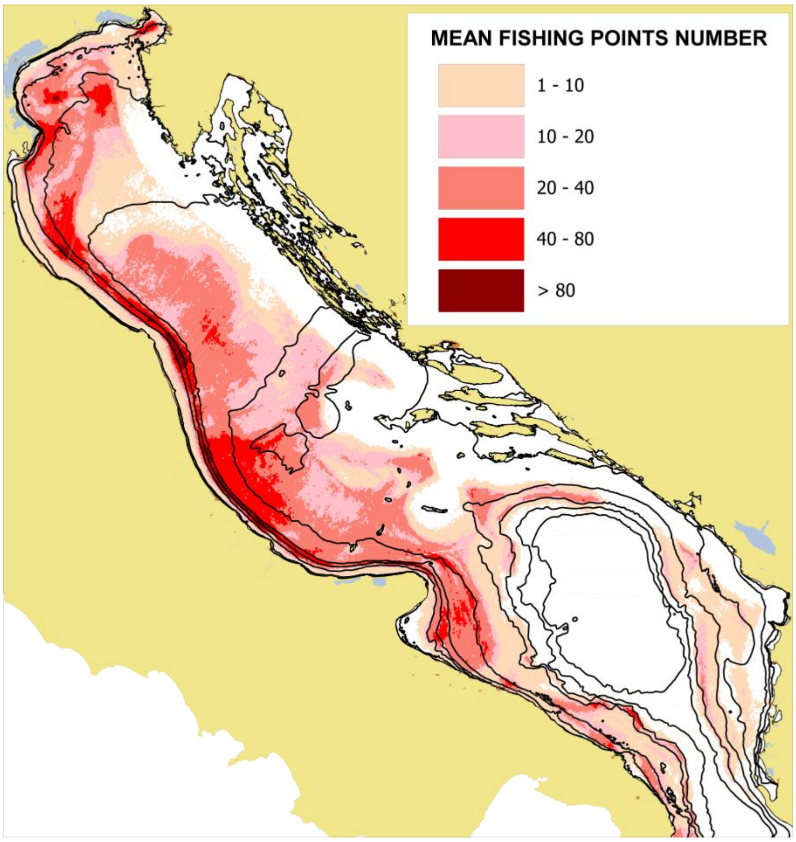


Figure 4.54a. Spatial distribution of bottom otter trawl effort calculated as mean fishing points number using data from 2006 to 2011. (Source:

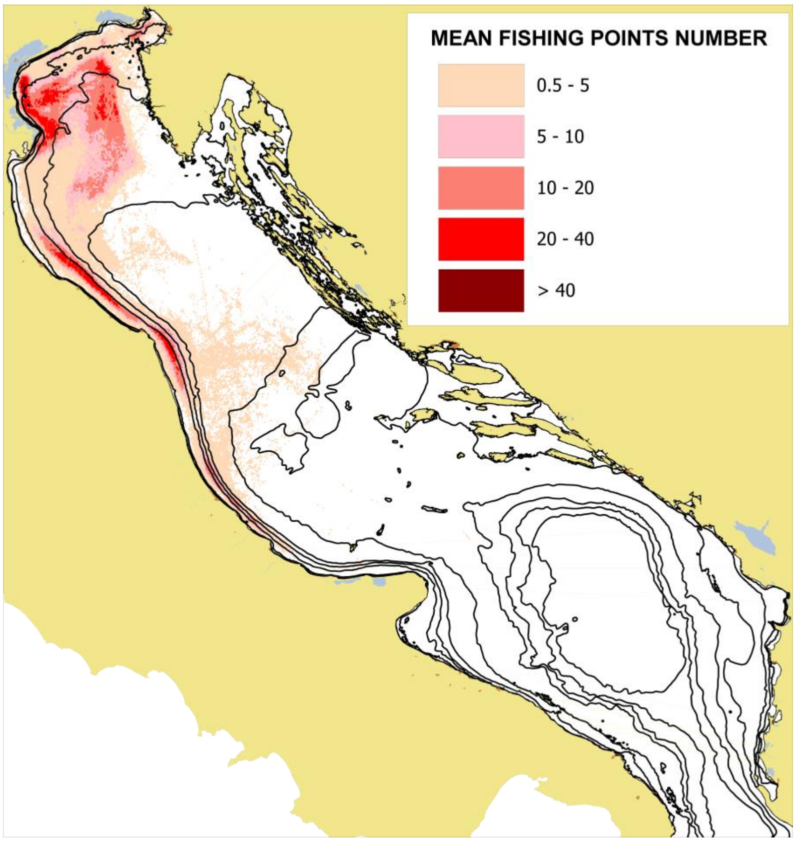


Figure 4.54b. Spatial distribution of beam trawl effort calculated as mean fishing points number using data from 2006 to 2011. (Source:

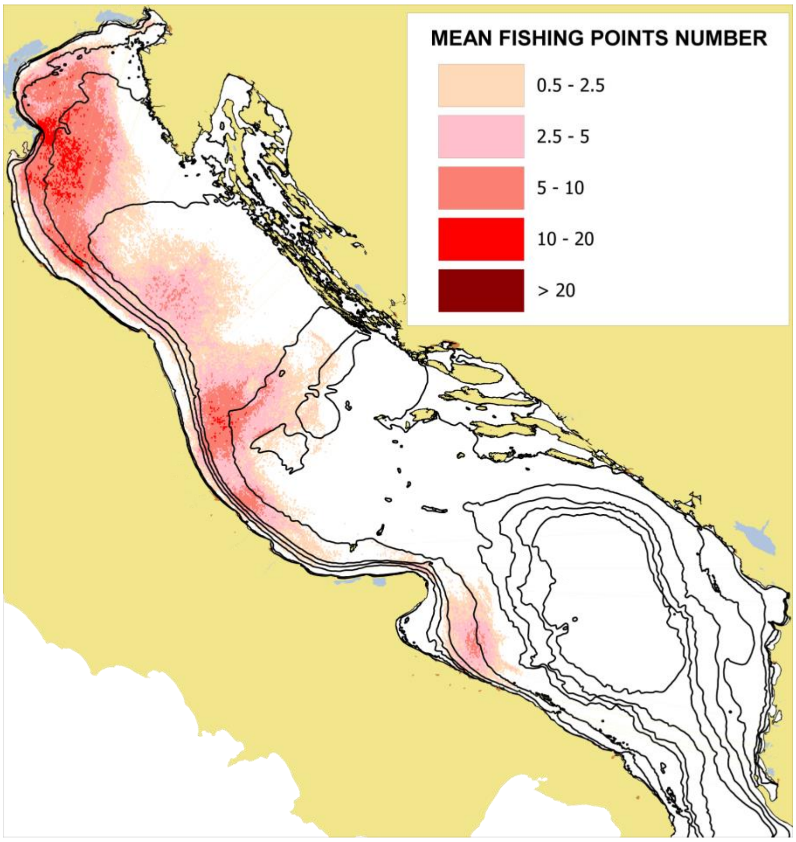


Figure 4.54c. Spatial distribution of pelagic pair trawl effort calculated as mean fishing points number using data from 2006 to 2011. (Source:

The second group of maps is composed by 112 shape files (56 for each GSA considered). An example map is reported in the Figure 4.55.

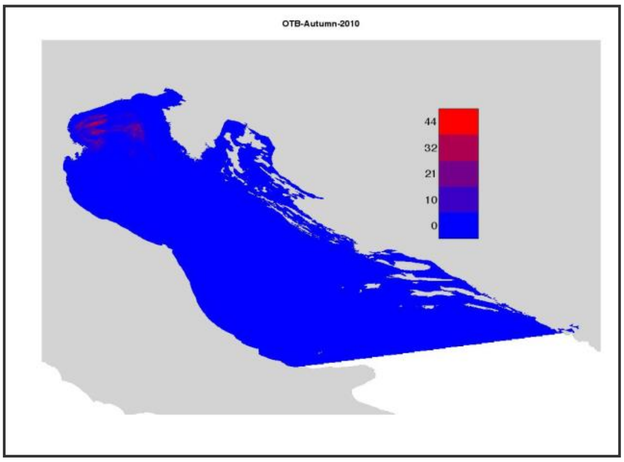


Figure 4.55. Example of spatial distribution of bottom otter trawl fishing effort during autumn 2010. (Source:

A total of 1554 maps was produced considering the vessel base ports. It is important to note that the information about the base port of each vessel used in that analysis was inferred from the archive available at the Italian Ministry for Agriculture and Fisheries (MiPAF). Some vessels could change their base port during the period considered and that could have generate some bias of the final results. The following Table shows the list of base ports considered during the analysis together with their codes.

Tab 4.3. List of base ports used in the analysis

PORT	CODE
Ancona	ANC
Bari	BAR
Bisceglie	BIS
Brindisi	BRI
Caorle	CAO
Castro Marina	CSM
Cattolica	CAT
Cervia	CER
Cesenatico	CES
Chioggia	CHI
Civitanova	CIV
Falconara	FAL
Fano	FAN
Giulianova	GIU
Goro	GOR
Grado	GRA
Igea Marina	IGM
Isole tremiti	ITR
Jesolo	JES
Lignano Sabbiadoro	LSD
Manfredonia	MAN
Margherita di Savoia	MDS
Marotta	MAR
Martinsicuro	MSC
Mola di Bari	MDB
Molfetta	MOL
Monfalcone	MFA
Monopoli	MPO

Muggia	MUG
Numana	NUM
Otranto	OTR
Pedaso	PED
Pesaro	PES
Pescara	PRA
Porto Garibaldi	PGA
Porto San Giorgio	PSG
Porto Tolle	PTO
Ravenna	RAV
Rimini	RIM
San Benedetto del Tronto	SBT
San Cataldo	SCT
Santa Maria di Leuca	SML
Savelletri	SAV
Scardovari	SCA
Senigallia	SEN
Sistiana	SIS
Termoli	TER
Trani	TRA
Trieste	TRI
Vasto	VAS
Venezia	VEN
Vieste	VIE
Others	ALT

The following figures are mere examples of the maps produced considering the vessel base ports (Chioggia in this case).

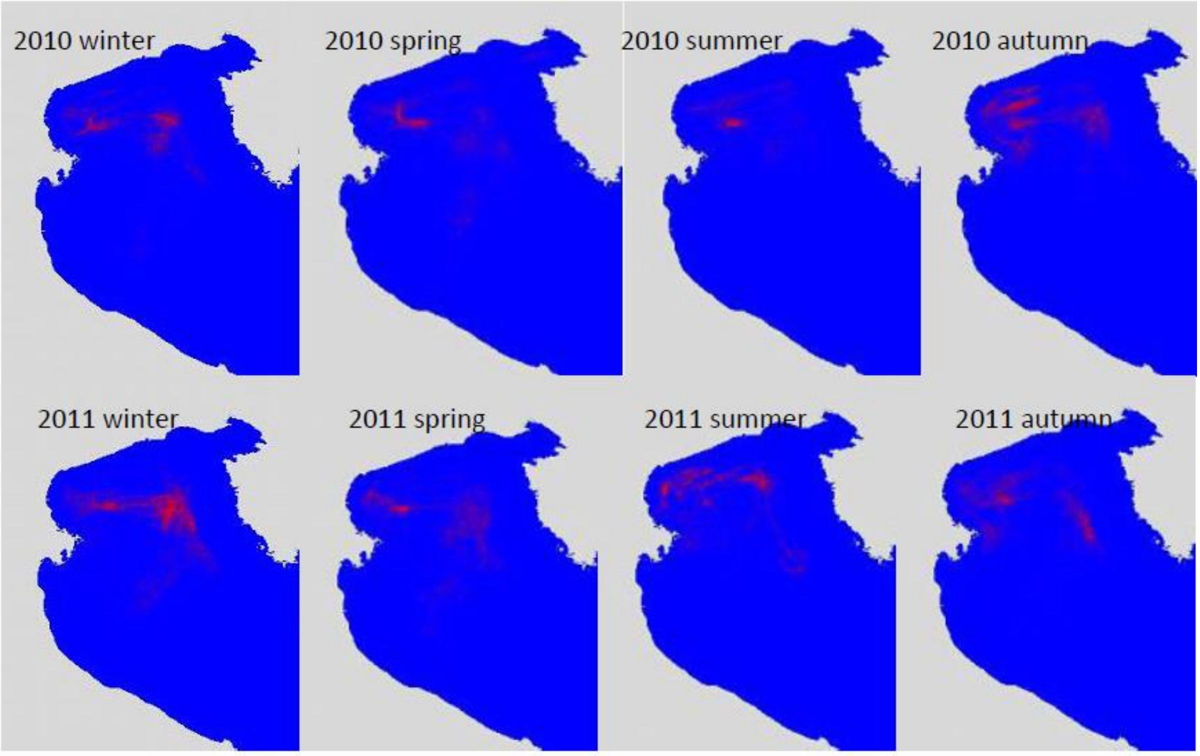


Figure 4.56a. Spatial distribution of bottom otter trawler fishing seasonal effort in Chioggia in 2010 and 2011.

(Source:

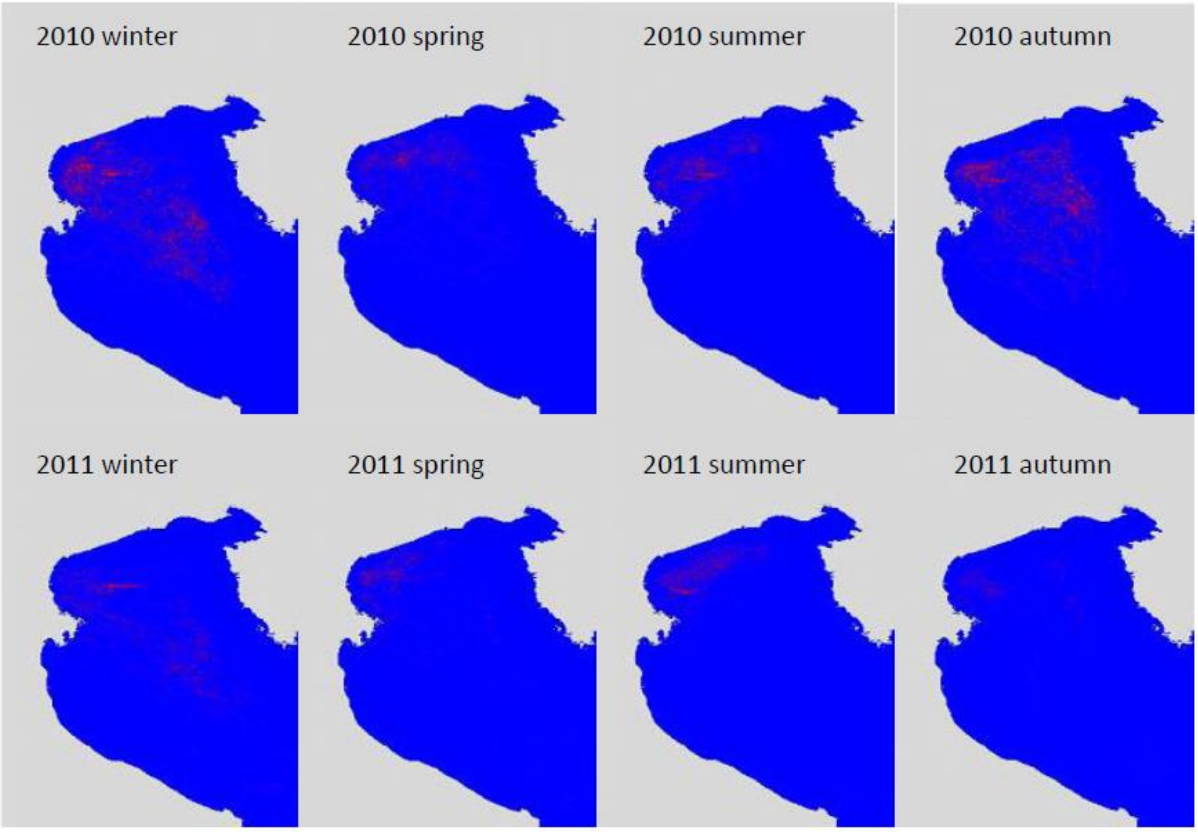


Figure 4.56b. Spatial distribution of fishing beam trawler seasonal effort in Chioggia in 2010 and 2011. (Source:

The analysis performed in the last elaboration produced the following Table with the estimation of fishing time and time spent (minutes) by vessels from Chioggia at sea.

Table 4.4. Total fishing time and time at sea of fishing vessels operating in Chioggia

Fleet	Total fishing Time (min. ± st.dev.)	Total time at sea (min. ± st.dev.)
12 m <= LOA < 18 m	743.8495 ± 686.6642	1219.771 ± 1035.98
18 m <= LOA < 24	1114.708 ± 973.7062	1736.889 ± 1324.767
LOA >= 24 m	733.8598 ± 895.0102	1378.188 ± 1168.889

Fig. 4.57 shows the box-plot obtained using the hauls extracted by the VMS data and the total time at sea get from the same origin.

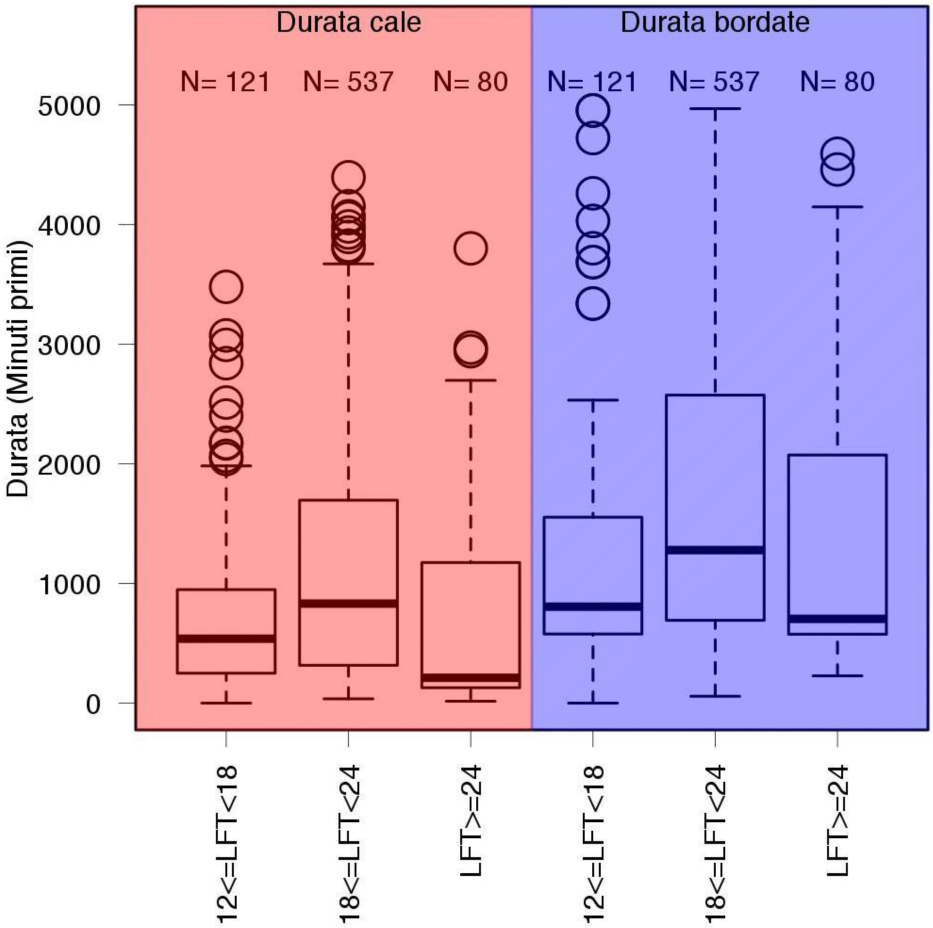


Figure 4.57. Duration of hauls as extracted from the VMS data**.**

(Source:

4.3.9 Protected Areas

Within the Adriatic Sea, and due to the laws' heterogeneity of its surrounding countries, there are many forms and names identifying protected areas. Adriatic countries within the EU have assumed a list of possibilities of protection: Marine Protected Areas (MPAs), Special Protected Areas (SPAs), Sites of Community Interest (SCIs), Zones of Biological Protecteion (ZPSs) and many other more. Several non-EU Adriatic countries, though having their own methods and laws for the protected areas, have shared regulations in what could be considered the Natura 2000 counterpart for the eastern countries: the EMERALD sites. Natura 2000 and EMERALD Sites represent networks of protected areas, where the guidelines for protection have been written, though no managing options are clearly defined: they only deal with the composition of protection and eventually the status of conservation of listed sites, eventually compiled with the collaboration of the managing groups.

The case of Croatia cannot be reported here, though a high percentage of its territory is protected, because of its recent entry in the EU: Croatia indeed has still not updated the ex-EMERALD sites to Natura 2000, and, at the same time, the EMERALD sites network does not report the Croatian protected areas any longer. To face this issue we considered at least those Croatian protected areas declared in ADRIAPAN and Protect Planet documents.

4.3.9.1 Natura 2000 sites.

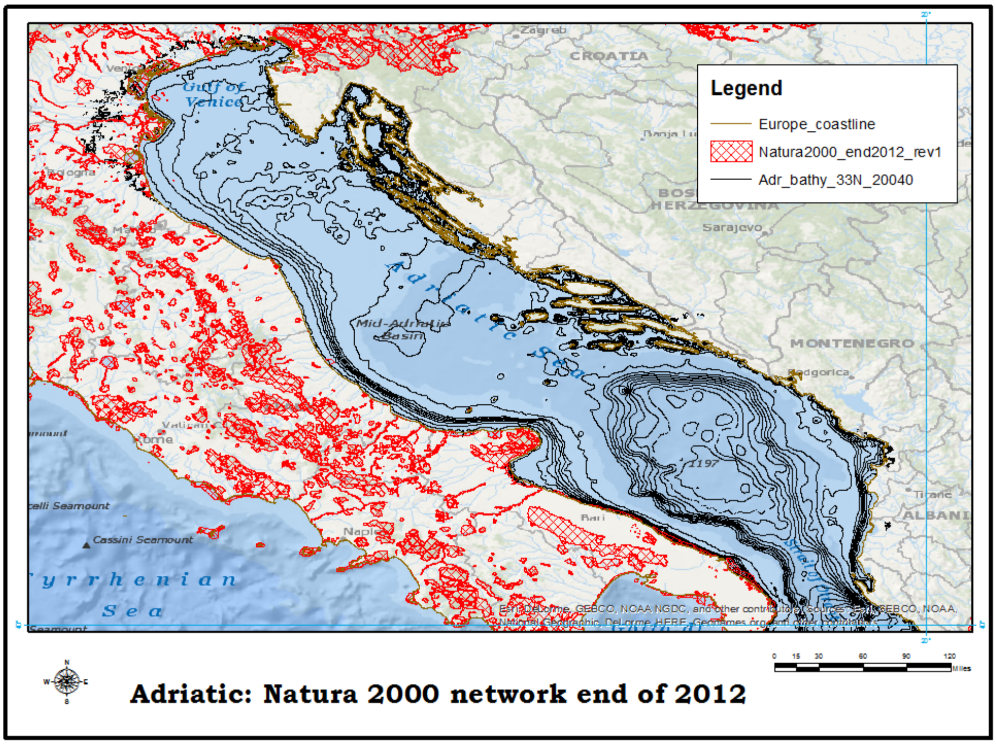


Figure 4.58 Natura 2000 network till 2012

4.3.9.2 EMERALD sites.

In late 2013, Croatia entered the EU, thus the EMERALD sites will become Natura 2000 sites. Up to date there is no official map showing the actual distribution of these which may suffer changes and is "in a sort of limbo" situation as they are not EMERALDS anymore and not yet Natura 2000. The percentage of protected territory covered by protected areas in Croatia is high, probably triple of most of the actual member countries.

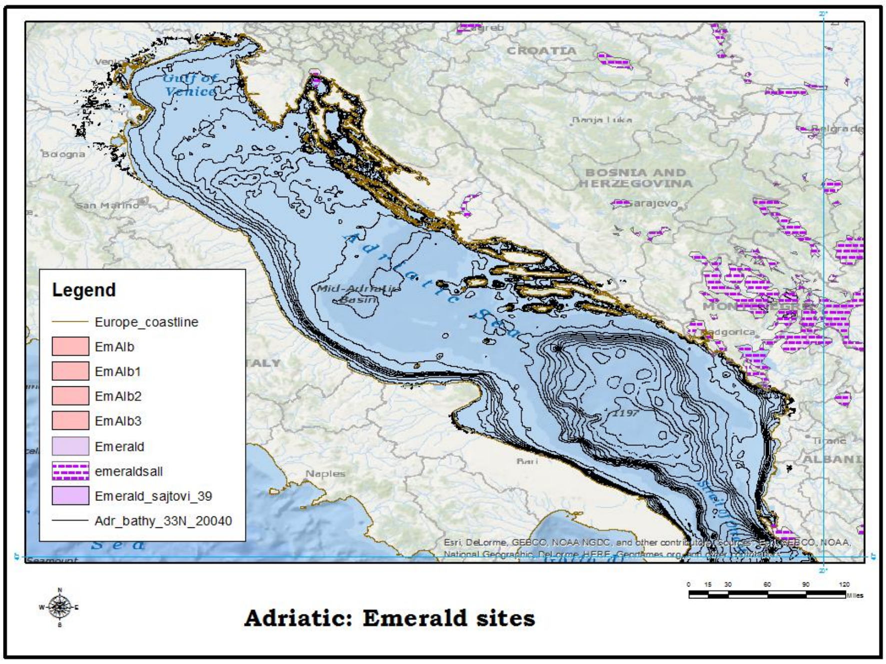


Figure 4.59 Emerald sites

4.3.9.3 Other protection relevant areas (RAMSAR, Corine Biotypes)

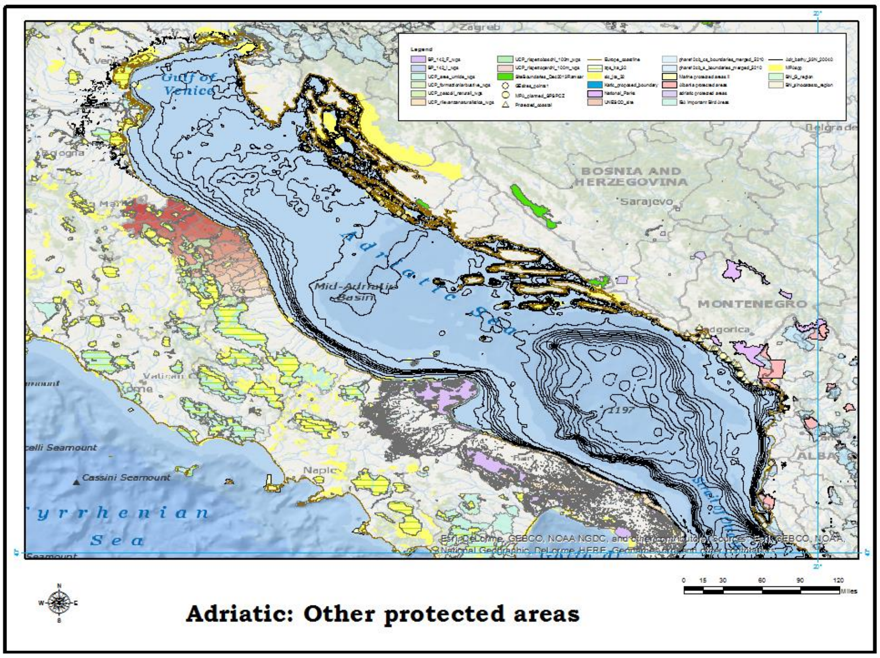


Figure 4.60 Other protection relevant areas

4.3.10 Tourism

Countries surrounding the Adriatic Sea are important touristic destinations. As their importance as tourist destinations clearly depends on the Adriatic Sea characteristics, it is very important to maintain the Adriatic Sea basin's status and undertake actions for the preservation of the region. As an example the Veneto region alone received 14.1 million arrivals in 2008 with 60.6 million overnight stays in the same year. Seaside tourism accounted for 3.7 million arrivals (25.8 million overnight stays) in 2007 (PRC, 2011). In the Friuli Venezia Giulia region 2 million arrivals took place in 2008 (8.9 million overnight stays) and in Emilia-Romagna 8.8 million arrivals (38.3 million overnight stays)[11]. A total of 11 million tourists arrived in Croatia in 2009. Tourist overnight stays amounted to 56 million[12]. Regarding marine tourism, Croatia expects an increase of the number of nautical ports and coastal moorings from 21.020 in 2007 to 33.655 in 2015. 'Marine' tourists are mostly attracted to areas under different categories of protection as they are characterised by a high natural value and biodiversity. Particularly attractive are the national parks of Brijuni, Kornati, Krka and Mljet and the nature parks of Telascica and Lastovo islands, whereas the largest number of marine tourists' visits is realised in the national park of Kornati[13]. Slovenian statistics show a total number of 2.8 million tourists arriving in Slovenia in 2008. Overnight stays in the same year amounted to 8.4 million[14]. Overnight stays in 2006 amounted to 17 million in Montenegro[15].

Intensive coastal tourism leads to pollution of the sea, especially when wastewater treatment plants lack the capacity to treat all wastewater and, as a result, discharge a certain (substantial) quantity directly into the sea. Coastal protection through beach nourishment instead of using protection barriers (due to unattractive sight) may have negative environmental effects as well. Although less significant, marine tourism activities may also affect the environment. For instance, diving and recreational bathing can damage marine vegetation.

[11] EUROSTAT, *regional tourism statistics NUTS 2*

[12] Ministry of tourism Croatia, 2009, *Tourist traffic in Croatia for the year 2009*

[13] Ministry of the Sea, Transport and Infrastructure, Ministry of Tourism, 2008, *Nautical tourism development strategy of the Republic of Croatia 2009 – 2019*

[14] Statistical Office of the Republic of Slovenia, www.stat.si

[15] Ministry of Tourism and Environment, Montenegro tourism development strategy to 2020

4.3.11 Maritime transport

The Adriatic Sea is an important maritime transport route used by merchant ships in international and national trade, by yachts, fishing vessels, war ships and other non-merchant ships. A significant number of important industrial centres are located along the western Adriatic coast and several mid-European – and in many cases landlocked – countries heavily depend on the Northern Adriatic ports (among others the port of Trieste, Venice, Koper and Rijeka) for the import of energy.

In addition, several of the eastern Adriatic ports are deep-water ports – especially in Croatia – which could host super-tankers. These ports could serve as a solution for today's bottlenecks with regard to oil export routes in Eurasia (Vidas, 2008). Consequently, the Adriatic countries believe that maritime transport will increase in the future. Existing routes will be used more intensively, new routes will be introduced and new south-eastern transit ports will gain importance (among others Ploce in Croatia, Bar in Montenegro and Vlorë in Albania) (Vidas, 2008).

An insight into the traffic routes/separation schemes in the Adriatic Sea basin and into the intensity of maritime traffic in the Adriatic Sea in 2008 is provided in Figure 4.61.

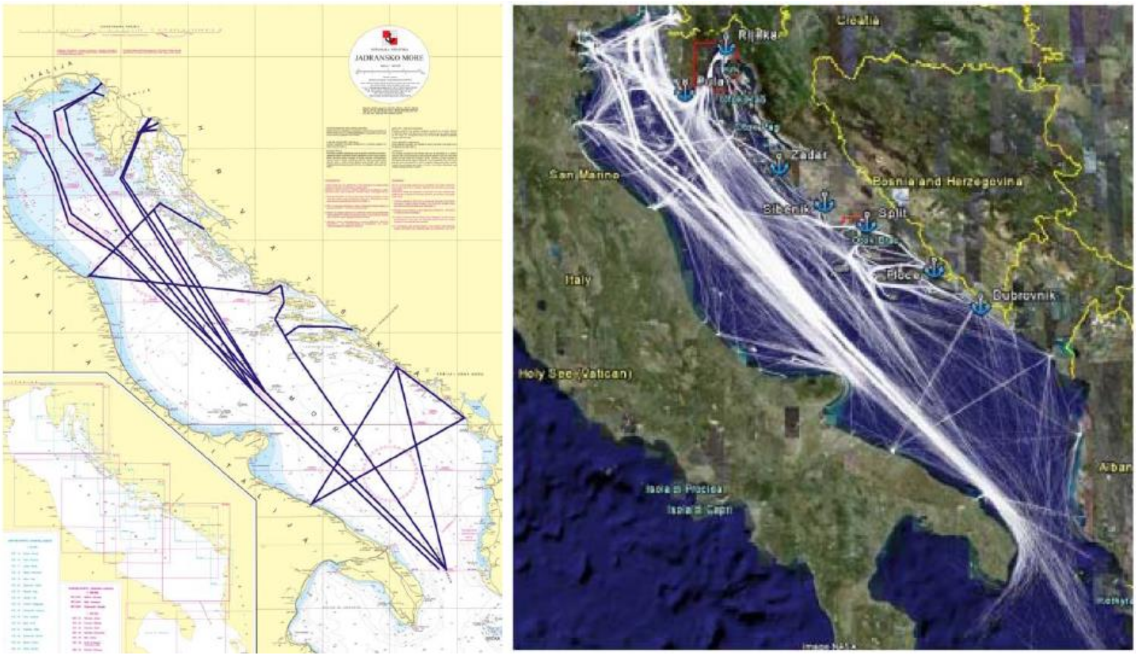


Figure 4.61. Traffic routes and maritime traffic intensity in the Adriatic Sea in 2008 (Source: PRC, 2011 based on Maglic *et al.*, 2009)

The Adriatic Sea is characterised by a large marine biodiversity and is home to some significant treasures of world heritage. This is recognised by the proposal of Adriatic countries (initiated by Croatia) to designate the whole Adriatic Sea as a ***Particularly Sensitive Sea Area (PSSA)***. A Particularly Sensitive Sea Area requires special protection through action by the International Maritime Organisation (IMO) because of its significance for recognised ecological, socio-economic or scientific reasons and because it may be vulnerable to damage by shipping. Once designated as a PSSA, specific measures can be approved by IMO to reduce the risk associated with shipping.

The intensive maritime transport in the Adriatic Sea implies a significant risk of accidents and consequently a potentially strong impact on the marine environment. Given the enclosed nature of the Adriatic Sea basin, the impact of a single accident – even though accidents are rare – can be highly disastrous (Maglic et *al.*, 2009). The areas of increased risk of sinking, collision and grounding are shown in Figures 4.58-4.59.

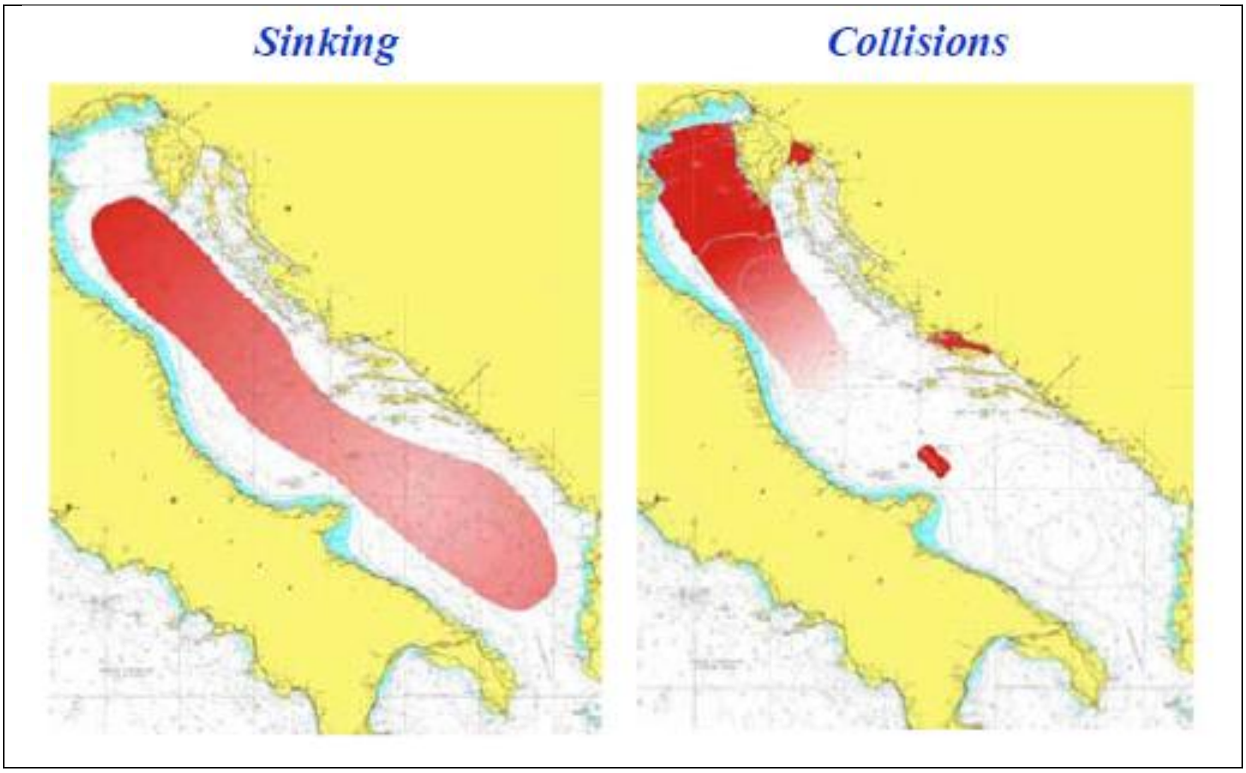


Figure 4.58. Areas of increased risk of sinking and collisions (Source: PRC, 2011 based on Maglic *et al.*, 2009).

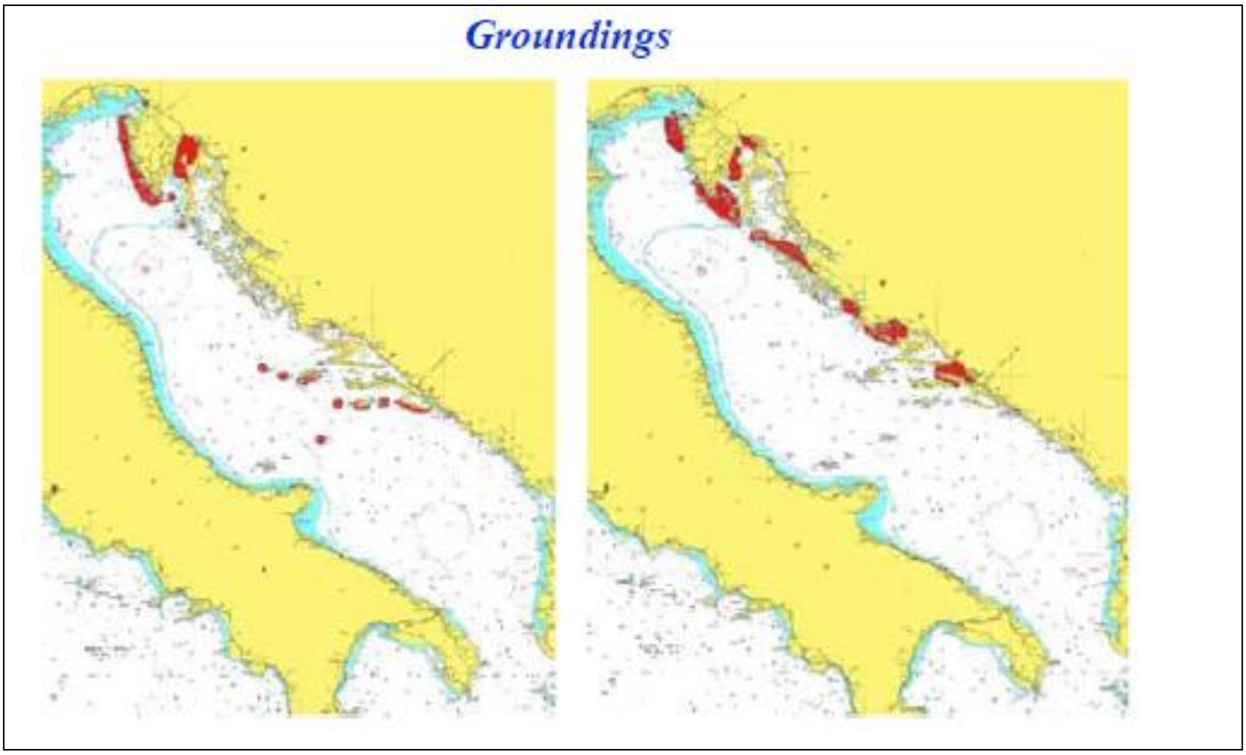


Figure 4.59. Areas of increased risk of groundings (Source: PRC, 2011 based on Maglic *et al*., 2009)

Moreover, Figure 4.60 illustrates the impact on the environment of a collision near the entrance of the Kvarner Gulf in Croatia. Given the effects of accidents on the Adriatic environment, continuous monitoring of the sea area is considered a necessity (Maglic *et al.*, 2009).

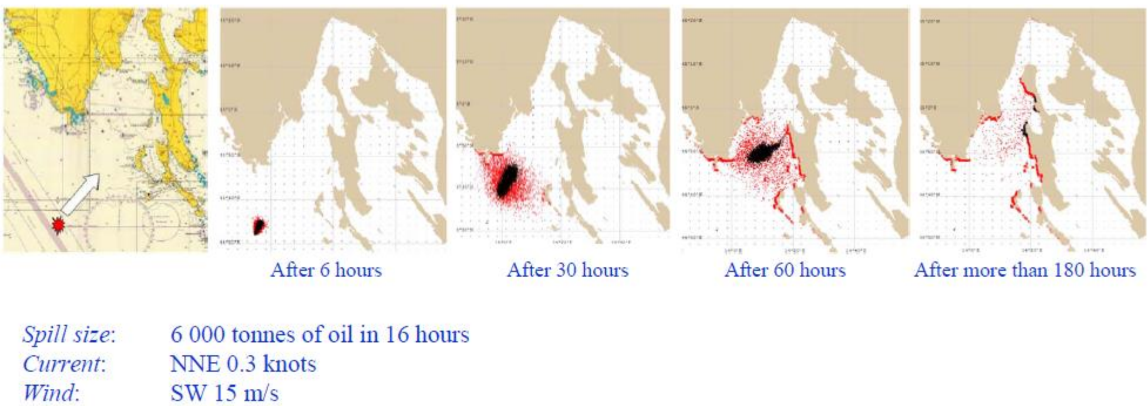


Figure 4.60. Impact collision near the entrance of the Kvarner Gulf in Croatia (Source: PRC, 2011 based on Maglic *et al*., 2009)

Italy and Slovenia already have a Vessel Traffic Monitoring and Information System (VTMIS) implemented to increase safety. Croatia is currently developing VTMIS. The Twinning Project PHARE 2006 'Institutional Capacity Building for VTMIS and Flag State Implementation (FSI) is coming to an end[16]. This project covered institutional co-operation of the Croatian maritime administration with Finland, Italy and Sweden concerning the organisation of the Croatian VTMIS, as well as the training of future employees. This project ensured the transfer of know-how from Finland and Italy regarding navigation management and control. Furthermore, Italy, Croatia and Slovenia cooperate in the Northern Adriatic with VTMIS (PRC, 2011). An indication of the density of oil spills in the Adriatic Sea is illustrated in Figure 4.61. This density is based on satellite images that recorded oil spills and is normalised for the number of images taken for specific parts of the sea.

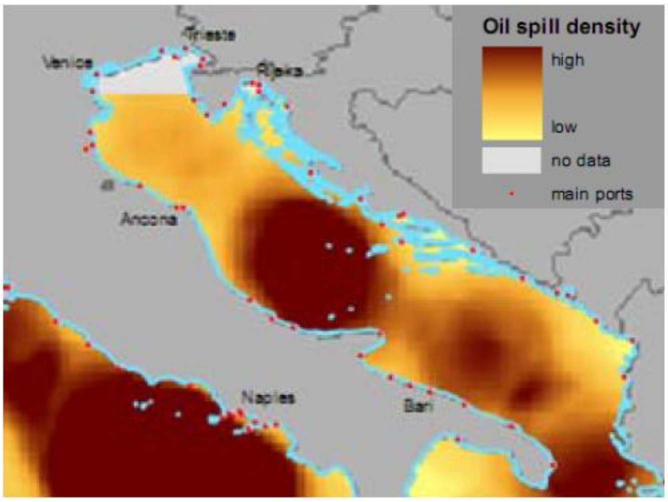


Figure 4.61. Oil spill density in the Adriatic Sea (Source: PRC, 2011 based on Joint Research Centre of European Commission, http://serac.jrc.it)

The ballast water of ships can lead to another effect on the marine environment. Ballast water is used by ships to reach a certain draft for stability purposes. When a ship is not (fully) loaded, water is added in the port of departure. When the ship is subsequently loaded with cargo in another port, the water is discharged because the cargo will provide the necessary weight. In ballast water, invasive species may be present, which can have an impact on the flora and fauna of the sea if it is discharged into the sea[17].

[16] Croatian Business & Finance Weekly, May 18, 2010

[17] International Union for Conservation of Nature (IUCN), *Marine Menace: alien invasive species in the marine environment*

4.3.12 Extraction activities: offshore oil and gas platforms and LNG terminals

Some Adriatic regions are suitable for the installation of offshore Liquefied Natural Gas (LNG) terminals. The first offshore LNG terminal in the world has been built in the Northern Adriatic Sea in the proximity of Porto Levante (Veneto Region) and it went into operation in 2009. Several other companies have proposed plans for developing new offshore LNG terminals. For instance, an offshore terminal is proposed in the Gulf of Trieste (Terminal Alpi Adriatico, by Endesa Europa) in the Italian territorial sea, near Slovenia[18]. The presence of such terminals leads to competition with other maritime activities within the Adriatic Sea basin. For example, fishing will be prohibited around the terminal and around the pipeline that connects the terminal with the shore.

Offshore platforms also involve a certain risk of strong pressure on the environment; if accidents happen, and the effects on the marine environment can be very high.

In the Adriatic Sea offshore gas production is taking place through various projects. ENI (Italian) and INA (Croatian) have created a joint venture that started producing gas by platform Annamaria A in six wells in Croatian waters in 2009. The Annamaria B platform (located in Italian waters) started production in 2010[19]. A substantial number of offshore platforms is located in the Emilia-Romagna region (Figure 4.62).

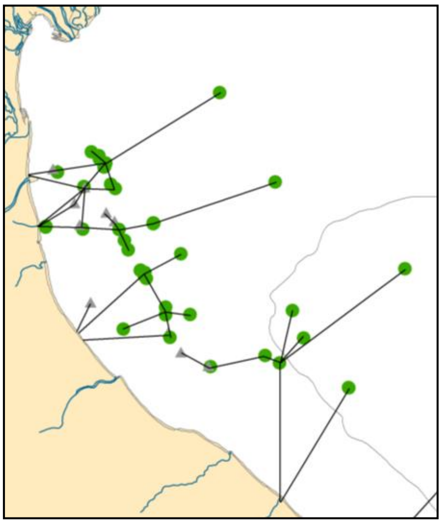


Figure 4.62. Gas platforms (green dots) and other productions (grey triangles) along the coasts of Emilia-Romagna. The pipes and connections are also shown (black lines) (source: Ministero dello Sviluppo Economico, http://unmig.sviluppoeconomico.gov.it/ unmig/strutturemarine/completo.asp; modified)

[18] Reuters, www.reuters.com/article/idUSL1186435520080311

[19] www.upstreamonline.com

An overview of extraction platforms location in the Adriatic Sea is given in Figure 4.63.

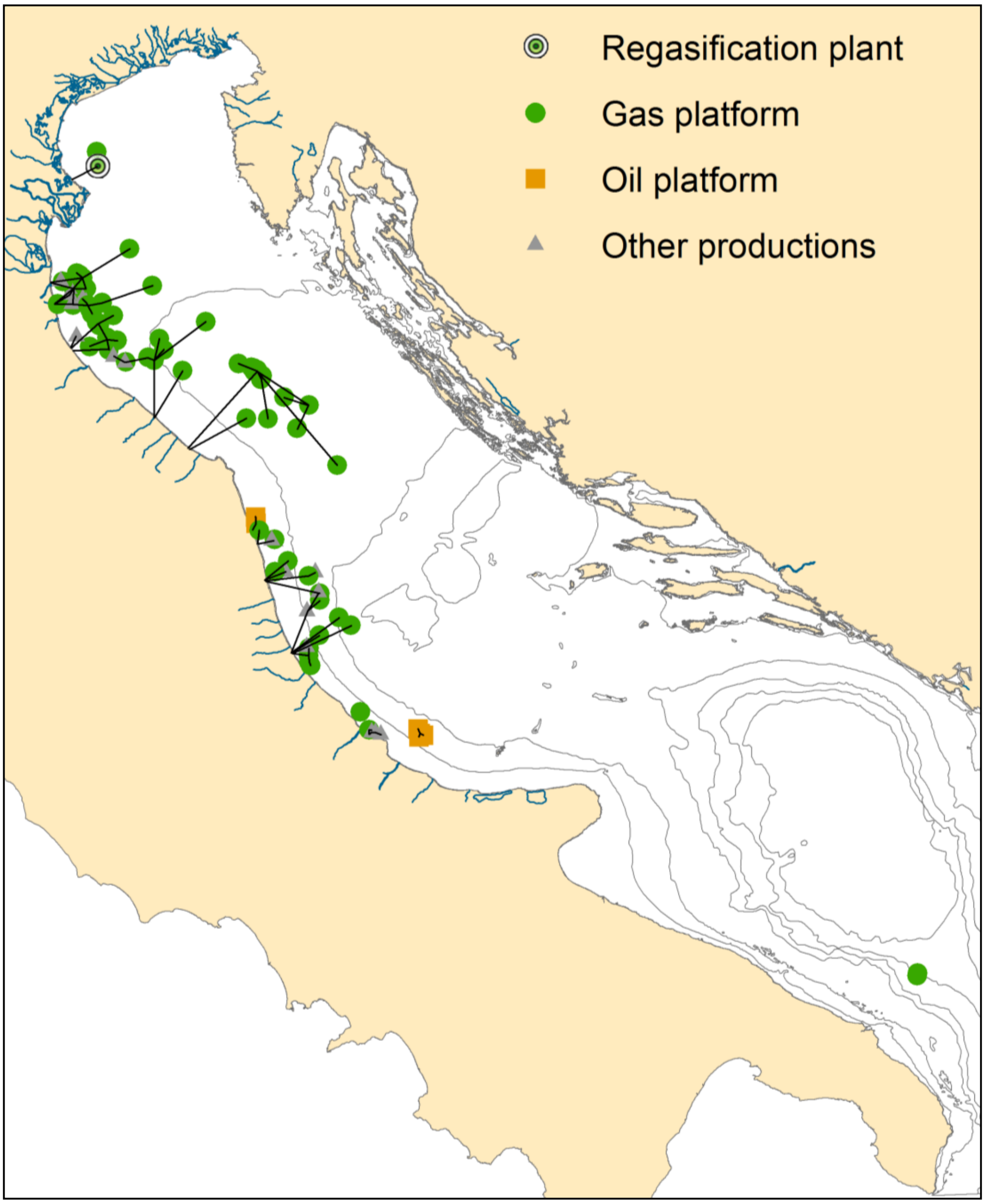


Figure 4.63. Gas and oil platforms in the Adriatic basin. Regasification plant and other productions are also shown (source: Ministero dello Sviluppo Economico, http://unmig.sviluppoeconomico.gov.it/unmig/strutturemarine/completo.asp; modified)

4.4 Territorial analysis

The general idea that the Adriatic Sea is a small shallow basin, overexploited and thus with "nothing left in it", and with no special interest at an environmental level, except maybe for the Croatian coasts, has unfortunately pervaded many stakeholders. But this vision is indeed far away from the reality. The environmental complexity within the basin is high and changes from zone to zone and from country to country; the characteristics of the basin, even if it is small, change drastically from North to South and from East to West. The northwestern basin is mainly influenced by the Po river discharge giving the area its shallow and highly productive conditions, while moving eastern ward the conditions around Slovenia change towards less river discharge and the presence of some coralligenous and maerls beds. Southward, while approaching Croatia, the Adriatic Sea is characterized by the presence of a complex network of islands, fairly rare in the rest of the basin, with a high percentage of karstic geology, and completely different benthic communities. Albania and Montenegro have a combination between the deep and transparent waters with hard bottoms of the Southern Adriatic and the sandy and muddy communities of the central Western basin. The southern Adriatic is the deepest zone, with elevated presence of hard bottoms and rocky shoals, compared to the central and northern areas. All these environmental changes have determined the activities of each country based on their environment. Besides the fisheries, and due to the great amount of economic and social agreements and coalitions within the basin countries, the amount of maritime transport, fossil fuels extraction, naval and maritime activities is enormous. Together with the actual situation, it is important to add the accumulation of military areas and of unexploded war discharged bombs and structures still active since the Kosovo war in the early 90's.

In this chapter, the reports dealing with the territorial analysis submitted by each partner have been summarized in a table per country, showing if information was existing or not available for the area. In the cases of the Eastern Adriatic Basin, no data from Croatia, Slovenia, Bosnia-Herzegovina and Greece were provided, so that for each of these countries we were obliged to provide a summary of information gathered from the literature. Other partners of the project, with not exclusive territorial competence, gave as well their contributions, for instance with data on oil and gas lines.

The information collected for each territory -together with the obtained information on impacts and vulnerabilities, biocoenoses and bio-ecological data, and any other useful record -

were used to fulfill the impact assessment and the vulnerability matrix based on the putative changes in behavior of each of the elements that could be threatened during the various processes of the installation of an offshore wind farm in the Adriatic mainly within the 12 nm.

In this part of the report a summary of the knowledge and main issues that could appear in each country in the case of OWF installations is also provided.

4.4.1 Albania

THEME	Information: Yes, No, Not applicable, Not declared, Not available
1. OBSTACLES AND INTERFERENCES AT SEA WITHIN 12 MILES FROM THE COAST	
1.1. Mining (oil and gas included) concessions and energy supply facilities at sea under authorization	Yes
1.2. Submarine cables, pipelines and any conduit under authorization	In prospect
1.3. Offshore aquaculture plants (finfish and shellfish)	Yes
1.4. Dumping areas at sea, including those for sediments resulting from dredging activities (including those carried out in harbors)	ND
1.5. Trade naval routes	Yes
1.6. Shipwrecks and archaeological sites (at sea and along the coast)	Yes
1.7. Unexploded ordnance and areas of interest or pertaining exclusively to military activities	Possible
1.8. Contaminated sites at sea and along the coast (currently in remediation or potentially to be reclaimed)	Yes
1.9. Areas of submerged beach nourishment	Yes
1.10. Areas with a high risk of environmental crisis	Yes
1.11. Underwater caves to supply relict sand (for the purpose of beach nourishment)	No
1.12. Areas pertaining to harbor activities (including access corridors and transit)	Yes
1.13. Areas used for diving and spearfishing	No
2. ENVIRONMENTAL (including landscape) CONSTRAINS	
2.1. Special Protection Areas (SPA)	No
2.2. Sites of Community Interest (SCI) [at sea and along the coast]	No, Emerald sites
2.3. Zones of biological protection	No, Emerald sites
2.4. Ramsar Areas	Yes, Emerald sites

2.5. Parks and Marine Reserves	Yes, Emerald sites
2.6. Areas subjected to special attention for purposes of hydrogeological asset	
2.7. Areas hosting historical buildings of public interest	
2.8. Areas of public and/or military interest along the coast	
2.9. Areas pertaining to Local/Regional/National Landscape Plans	
2.10. Scenic Drives, aggregation points and places of memory	
3. BIOECOLOGICAL ASPECTS	
3.1. Migration routes of birds	Yes
3.2. Quality of sea water (in relation to harvesting, culturing and marketing of bivalve mollusks)	NA
3.3. Monitoring data according to the dictates of the EU Marine Framework Directive (wherever available or applicable), with specific reference to benthic biocoenosis and habitats	National Biodiversity Strategy and Action Plan
3.4. Bio-ecological data included in environmental studies for EIA (Environmental Impact Assessment) procedures at the regional and / or national level at sea or on land, but with potential consequences to the sea	In progress
3.5. Bio-ecological data derived from LIFE, IPA, INTERREG and any other EU or national funded projects, related with marine ecosystems	ND
3.6. Areas of clam fishing	Possible
3.7. Distribution of fishing effort and fleet composition	ND
4. SPATIAL PLANNING AND LANDSCAPE USE	
4.1. Synthesis of local/regional/national plans of landscape management presently in force or that are going to be established in the near future	ND
4.2. Information dealing with coastal traffic, tourism management and development and so on…	Ministry of Economy
4.3. Any other info possibly of interest to your opinion	

From the report, it is clear that Albania has stopped its energetic development during the period of time between the 70's and the last couple of years. It certainly has been a high industrial objective for European countries since the costs of production were low, and this has encouraged the adaption of the technology in the last decade. Three long submarine pipelines are projected between Albania and Italy, mainly for gas transport. Four main ports are allocated along the coast, and have increased traffic each year. There are numerous contaminated spots, mainly due to mining activities and discharges. The Albanian coasts suffer from natural and anthropogenic coastal erosion, and thus nourishing from beaches, damming of the rivers, and dredging events are common. Environmental risk areas are identified and divided in reasons, those interesting the coastal fraction are flooding and landslides. Pertaining fisheries, finfish and shellfish are cultivated and list of IUCN-Red List species are present in Albania inlands or coasts. At the moment, the natural parks and reserves are mostly proposed and not yet effectively declared or managed. These protection and proposed areas are at the moment linked to the EMERALD network, important since the application in 2009 to enter the EU of the country. Monitoring of water quality has only been done during 2010-12, and revealed an important chemical contamination of heavy metals together with low values of dissolved oxygen, and physical pollution of total suspended particles and high nutrient values. Since the entry of the country in the global market the natural resources have been damaged and, still, the industrial and urban discharges occur directly into the rivers and from there to the sea, with no pre-treatments. The abundance of water in the country is evident, but unfortunately most of the hydric resources are in some way polluted.

Shipwrecks are located and archeological sites are abundant on land but little is known in the sea. In accordance with MedPAN, Albania should activate a Marine Protected Area in Karaburuni and two more are planned in Kepi i Rodonit and Porto Palermo. The coastal fraction of Albania is highly diverse in geology and biotopes: wetlands, dunes, lagoons and scattered reef structures in immediate coastline. These habitats are known and more or less described in Albania, as well as a consciousness to be protected but reality is that the level of protection of the habitats and species in Albania is very low or null. The Albania ministries have identified this problem, and have the intention of resolving the issue before the natural resources are doomed: the main issue is that with no adequate management of discharges, litter, agriculture remains, industrial outflows and little control on the spatial planning for urban sites and coasts the aim remains difficult to achieve. Part of the initiatives for this purpose is the list of parks and reserves named in the last decade, besides the agreements held with UNESCO, Birds Directive and Habitat Directive and Biodiversity Strategy. From the MTKRS 2011 it arises that the majority of tourists choose Albania due to the natural coastal environment.

Some of the critical elements in this region include:

Pollution and discharges: Albania has an enormous problem with litter and discharge management, since mainly they are not managed at all. This issue is not only concerning the Albania coasts but all the rest of the Adriatic countries and from there the whole Mediterranean. The main issue applied to the rest of the Adriatic with marine litter is 1) the accumulation on the Croatian "worm-like" coasts on behalf of the current transportation, 2) the feeding of turtles during migration and thus the lethal or sub-lethal consequences and 3) the chemicals and solid particles this country is inputting in an already overexploited and over populated small basin.

Threatened species and habitats: The list of present species in Albania, as a result of some of the requisites imposed by the Marine Strategy and the management of putative Natura 2000 sites, has been updated. The list considerers *Acipenser naccarii*, *Acipenser sturio*, *Caretta caretta*, *Dermochelys coriacea*, *Chelonia mydas*, *Testudo hermanni*, *Emys orbicularis*, *Delphinus delphis*, *Lutra lutra*, *Monachus monachus*, *Tursiops truncatus* which are mainly all threatened or vulnerable species. *Delphinus* dolphin was not found in the NETCET report, but the project was not considering nearby coastal areas. The main issue with these threatened species, that migrate or live in the vicinities of Albanian coasts is the marine transport but more importantly the risk of contamination through the untreated discharges. Heavy metals are present in the area, thus bio-accumulation is a great issue. Sturgeon are actually important for the Albanian economy, but due to illegal fishing and exploitation of the resources are severely threatened. Reefs are present in great extension in the peninsula Gjari I Ariut near Orikum, concentrating as well turtles zones, dunes and special habitats. Other areas have more scattered reefs and dune formations. Other important and threatened species, that need protection at a local level are *Posidonia oceanica* meadows and Fucal forests.

Illegal fishing: Is probably not that much accounted as discharge management but also increasing and abundant. The licensed fishermen are about 300 but the unlicensed and illegal fishermen are possibly around 900. Mainly the arrivals at port are from trawlers, between 12-24m and longer than >24m. Unbalanced licensed vs. illegal fisheries provokes, besides an uncontrolled overexploitation of the resources and stock, an important gap when managing fisheries. The initiatives applied to licensed fishermen escape illegal fisheries, thus in consequences means that the effort carried to manage the stock is half lost. Illegal fishing, normally has no consideration on the stocks, on the by-catches, on the resources or on the environmental consequences; all the risks concerning marine mammals, reptiles and special habitats are increased in the Albanian coasts, since it is not easy to fine, punish or educate illegal fishing into conservation.

4.4.2 Montenegro

Theme	**Information**: Yes, No, Not applicable, Not declared, Not available
1. OBSTACLES AND INTERFERENCES AT SEA WITHIN 12 MILES FROM THE COAST	
1.1. Mining (oil and gas included) concessions and energy supply facilities at sea under authorization	Yes
1.2. Submarine cables, pipelines and any conduit under authorization	Yes
1.3. Offshore aquaculture plants (finfish and shellfish)	Yes
1.4. Dumping areas at sea, including those for sediments resulting from dredging activities (including those carried out in harbors)	Yes
1.5. Trade naval routes	Yes
1.6. Shipwrecks and archaeological sites (at sea and along the coast)	Yes
1.7. Unexploded ordnance and areas of interest or pertaining exclusively to military activities	Yes
1.8. Contaminated sites at sea and along the coast (currently in remediation or potentially to be reclaimed)	Yes
1.9. Areas of submerged beach nourishment	No
1.10. Areas with a high risk of environmental crisis	Yes
1.11. Underwater caves to supply relict sand (for the purpose of beach nourishment)	No
1.12. Areas pertaining to harbor activities (including access corridors and transit)	Yes
1.13. Areas used for diving and spearfishing	Yes
2. ENVIRONMENTAL (including landscape) CONSTRAINTS	
2.1. Special Protection Areas (SPA)	No, Emerald sites
2.2. Sites of Community Interest (SCI) [at sea and along the coast]	Yes
2.3. Zones of biological protection	No
2.4. Ramsar Areas	Yes, 1
2.5. Parks and Marine Reserves	Yes
2.6. Areas subjected to special attention for purposes of hydrogeological asset	ND
2.7. Areas hosting historical buildings of public interest	Yes

2.8. Areas of public and/or military interest along the coast	Yes
2.9. Areas pertaining to Local/Regional/National Landscape Plans	Yes
2.10. Scenic Drives, aggregation points and places of memory	Yes
3. BIOECOLOGICAL ASPECTS	
3.1. Migration routes of birds	Yes
3.2. Quality of sea water (in relation to harvesting, culturing and marketing of bivalve mollusks)	Yes, scattered
3.3. Monitoring data according to the dictates of the EU Marine Framework Directive (wherever available or applicable), with specific reference to benthic biocoenoses and habitats	No
3.4. Bio-ecological data included in environmental studies for EIA (Environmental Impact Assessment) procedures at the regional and / or national level at sea or on land, but with potential consequences to the sea	No
3.5. Bio-ecological data derived from LIFE, IPA, INTERREG and any other EU or national funded projects, related with marine ecosystems	No
3.6. Areas of clam fishing	Yes
3.7. Distribution of fishing effort and fleet composition	Yes, 22 vessels
4. SPATIAL PLANNING AND LANDSCAPE USE	
4.1. Synthesis of local/regional/national plans of landscape management presently in force or that are going to be established in the near future	Yes
4.2. Information dealing with coastal traffic, tourism management and develoment and so on…	Yes
4.3. Any other info possibly of interest to your opinion	

As evidenced in the report provided by Montenegro partners, the coastal fraction of Montenegro is fairly exploited by concessions, dumping zones, contaminated areas, shipwrecks and aquaculture. In summary it appears that the Montenegrin coasts are endangered and polluted. There are naval routes that depart across the Adriatic. Probably due to the war during the early 90's a considerable amount of unexploded ordinances are present and the war consequence has brought metal contaminated areas. In concrete, Bay of BokaKotorska is considered under environmental risk. Protected natural zones are limited mostly to land, and those pertaining coastal fractions are small and under the control of the Montenegrin authorities. Enclosed in the EMERALD network and the only marine parks are under consideration. Bio-ecologically, Montenegrin authorities control water quality for bathing and recreational issues but no further monitoring activities are declared. Some of the work carried out have been achieved in collaboration with the Apulia region in the context of the EU-funded COCONET project (http://www.coconet-fp7.eu/). NETCET and MeditSeH projects have shown in front of the Montenegrin coasts, though beyond the 12nm, the presence of *Stenella coeruleoalba* (striped dolphin), less common *Tursiops truncates* (bottlenose dolphin), rare *Grampus griseus* (Risso's dolphin) and *Ziphius cavirostris* (Cuvier's beaked whale). The Montenegrin coasts are also important as nurseries for commercial fish. It has been verified the presence of *Posidonia oceanica* beds along the coasts, together with other threatened seagrasses with considerably large populations of *Pinna nobilis*. Scattered points of coralligenous assemblages are present, in the northern frontier. Sharks and rays are common, and meaningfully by-catch. Fishing fleets are well documented and clam fishing is popular among all its coast line.

Some of the critical elements in this region are:

Posidonia oceanica: it is a protected species, though apparently in Montenegro there are no protected zones dedicated to *Posidonia* and/or *Pinna nobilis*. This species is at risk, and any disturbing-altering process can deplete the whole patch or habitat, including the disturbance by global warming (Macic, 2012). The only benthic habitat comprehensive study is the Kotor report from RACSPA with the scope of establishing an MPA where coralligenous patches have been identified within the bay.

Turtle migration and putative nesting: From Schoechime et al (YEAR), it is evident that turtles use the Montenegrin corridor for migration. Due to the characteristic of the area, a mix of cliffs and sandy beaches, it could be possible that turtles nest also in Bosnia-Herzegovina and Croatia. The main threat for these animals is the habitat loss, the food availability and the maritime activities that may harm them (dune alteration, urbanization, gas ducts…).

Pollution: Montenegro has been established as an "environmental state" by its constitution, but far it is from obtaining such a goal; partially due to the economic crisis and the impossibility of entering widely in the market, practical aims and goals in environmental issues have been difficult to date. In any case, Montenegro has adhered to the International Agreements of Air Pollution, Biodiversity, Climate Change, Climate Change-Kyoto Protocol, Desertification, Hazardous Wastes, Law of the Sea, Marine Dumping, Marine Life Conservation, Ozone Layer Protection, and Ship Pollution. On the other hand, Croatia claims that most of the litter arriving on their coasts arrives especially from Albania but also from Montenegro; if this is the reality, it is easy to presume that the litter and othere discharges are not well regulated or controlled with consequences of finding not only litter but also dangerous substances in the water, for example from non-treated industrial discharges.

Marine mammals, reptiles and elasmobranchs: the presence and abundances of these animals were evidenced by NETCET and the cetacean observatories, besides those reported by civilians. The main threat to these animals is collisions with ships and loss of habitat or food. Sharks have always been considered a problem for fisheries, since always considered dangerous for the catch and a great loss when by-catches occur; only recent initiaves are starting to sensibilize the community that these animals are actually important for the environment and thus merit to be considered. The CIESM has created a group of sighting reports and verification that has as well evidenced, together with NETCET and other projects, that there is residual community of sharks in the Adriatic Sea that are, however, in clear decline. Referring to mammals and reptiles, collisions are the greatest threats, and thus movimentation of boats and maritime activities have to be carried in care and if possible introducing new technologies to avoid noise, EMFs and collisions that can alter the behavior of these animals and disorientate them with fatal consequences (see above for the acoustic impacts analysis).

Military material at sea: Probably the Kosovo war is the main responsible for the threat posed by unexploded ordinances, heavy metals pollution, and chemical alteration of the waters surrounding these events. The risk inherited for humans and any practice carried out in these areas is evident, since underwater vibration, digging, dredging etc could activate bombs or mix the settled contaminants. For the environment, the consequences depend on the ordinance or pollutant itself, but could certainly alter the whole community or even doom it definitely. There are current vortices posed in front of the Montenegro coast which could spread into the Southern pit all the effect of a potential disaster.

Rocky shoals and cliffs: the characteristic landscape of Montenegro alternates sandy and muddy substrates with hard rocky bottoms; this alternating geology is also reflected underwater, in the immediate coastal waters where a variety of rocky outcrops emerge in great extensions of sandy bottoms. The altering of these geological-biological formations presupposes rich and diverse underwater communities, but little is known and/or published. Alteration of cliffs for anthropogenic big scale purposes is expensive and dangerous, so presumably these areas would be avoided for offshore cabling, for example. Sandy areas, on the contrary, are more feasible and comfortable to manage, and thus a good pathway to disturb the rest of the environment surrounding or near.

Reduced, or at least up to our knowledge, protection laws and surveillance: it is not clear, from the reports of the partners involved and the research done for this report, if the Montenegro proposal as environmental state is just a "political position" or if there is a real intention to achieve their objectives but resources are limited considering a reconstruction of a country or just that the information is not published or it is but though not easily accessible channels. This issue could have consequences in the near future since all the concessions and labors at sea, and presumably on land, have little or no control, increasing the possibility of destroying environments even before they are even considered to be protected and losing the whole goal of the state.

4.4.3 Veneto-Friuli-Venezia Giulia

Theme	**Information**: Yes, No, Not applicable, Not declared, Not available
1. OBSTACLES AND INTERFERENCES AT SEA WITHIN 12 MILES FROM THE COAST	
1.1. Mining (oil and gas included) concessions and energy supply facilities at sea under authorization	ND, Yes
1.2. Submarine cables, pipelines and any conduit under authorization	ND, Yes
1.3. Offshore aquaculture plants (finfish and shellfish)	Yes
1.4. Dumping areas at sea, including those for sediments resulting from dredging activities (including those carried out in harbors)	ND
1.5. Trade naval routes	ND, Yes
1.6. Shipwrecks and archaeological sites (at sea and along the coast)	Yes
1.7. Unexploded ordnance and areas of interest or pertaining exclusively to military activities	ND
1.8. Contaminated sites at sea and along the coast (currently in remediation or potentially to be reclaimed)	Yes
1.9. Areas of submerged beach nourishment	ND
1.10. Areas with a high risk of environmental crisis	ND, Yes
1.11. Underwater caves to supply relict sand (for the purpose of beach nourishment)	ND

1.12. Areas pertaining to harbor activities (including access corridors and transit)	Yes
1.13. Areas used for diving and spearfishing	Yes
2. ENVIRONMENTAL (including landscape) CONSTRAINS	
2.1. Special Protection Areas (SPA)	Yes
2.2. Sites of Community Interest (SCI) [at sea and along the coast]	Yes
2.3. Zones of biological protection	Yes
2.4. Ramsar Areas	Yes
2.5. Parks and Marine Reserves	Yes
2.6. Areas subjected to special attention for purposes of hydrogeological asset	ND
2.7. Areas hosting historical buildings of public interest	ND
2.8. Areas of public and/or military interest along the coast	ND
2.9. Areas pertaining to Local/Regional/National Landscape Plans	ND
2.10. Scenic Drives, aggregation points and places of memory	ND
3. BIOECOLOGICAL ASPECTS	
3.1. Migration routes of birds	ND
3.2. Quality of sea water (in relation to harvesting, culturing and marketing of bivalve mollusks)	Yes
3.3. Monitoring data according to the dictates of the EU Marine Framework Directive (wherever available or applicable), with specific reference to benthic biocoenoses and habitats	Yes-In collaboration
3.4. Bio-ecological data included in environmental studies for EIA (Environmental Impact Assessment) procedures at the regional and / or national level at sea or on land, but with potential consequences to the sea	Yes-In collaboration
3.5. Bio-ecological data derived from LIFE, IPA, INTERREG and any other EU or national funded projects, related with marine ecosystems	Yes- In collaboration
3.6. Areas of clam fishing	Yes
3.7. Distribution of fishing effort and fleet composition	Yes
4. SPATIAL PLANNING AND LANDSCAPE USE	
4.1. Synthesis of local/regional/national plans of landscape management presently in force or that are going to be established in the near future	
4.2. Information dealing with coastal traffic, tourism management and development and so on…	
4.3. Any other info possibly of interest to your opinion	

Some of the critical elements in this region are:

*Sensitive habitats :*There is a very precise community living within the Venice Lagoon and surroundings. The natural community has co-lived with humans for the last 20 centuries, but lately (last 50 years), it is highly threatened by global change, variations in the charge/discharge of the Po river, contaminants and fertilizers, antibiotics…that are increasing in concentration rapidly. This increase is terribly important when dealing with shallow waters and vertical rapid change and transfer. All the habitats, including those far from the Lagoon are threatened, and under constant disturbs.

Aquaculture and breeding zones: when looking at a detailed satellite image it s clear how populated of fish and seafood aquaculture or breeding plants exist in the Venetian and Friulian waters. This, if not well controlled and "cleaned" can become an excessive organic matter input in an already nutritious basin as well a antibiotics used to protect the breed. The cascade of effects from this over-nutritional/drug inputs could have terrible effects on the actual community (if they are already not perceiving them), even for the aquaculture plants themselves.

Intense maritime traffic: beside increasing the possibilities of collision and accidents, in these shallow waters there is a constant need of re-excavating the channels and thus constant movement of sediments (with "doubtable" concentrations of metals or pollutants), local increase of CO2 and changes in the current regime.

Hypoxia: the whole northern basin shows numerous spots with natural or induced hypoxia.. This means that probably any sort of activities within those areas should be well studied: from the chemical issues to the effects that moving or altering those areas could have. Surprisingly, even if catalogued as hypoxic areas there is a reasonable number of fishermen registering fishing activities there.

4.4.4 Emilia-Romagna

Theme	**Information**: Yes, No, Not applicable, Not declared, Not available
1. OBSTACLES AND INTERFERENCES AT SEA WITHIN 12 MILES FROM THE COAST	
1.1. Mining (oil and gas included) concessions and energy supply facilities at sea	Yes

under authorization	
1.2. Submarine cables, pipelines and any conduit under authorization	Yes
1.3. Offshore aquaculture plants (finfish and shellfish)	Yes
1.4. Dumping areas at sea, including those for sediments resulting from dredging activities (including those carried out in harbors)	NA
1.5. Trade naval routes	Yes
1.6. Shipwrecks and archaeological sites (at sea and along the coast)	ND
1.7. Unexploded ordnance and areas of interest or pertaining exclusively to military activities	ND
1.8. Contaminated sites at sea and along the coast (currently in remediation or potentially to be reclaimed)	Yes
1.9. Areas of submerged beach nourishment	ND
1.10. Areas with a high risk of environmental crisis	Yes
1.11. Underwater caves to supply relict sand (for the purpose of beach nourishment)	ND
1.12. Areas pertaining to harbor activities (including access corridors and transit)	ND, Yes
1.13. Areas used for diving and spearfishing	ND
2. ENVIRONMENTAL (including landscape) CONSTRAINS	
2.1. Special Protection Areas (SPA)	Yes
2.2. Sites of Community Interest (SCI) [at sea and along the coast]	Yes
2.3. Zones of biological protection	ND
2.4. Ramsar Areas	Yes
2.5. Parks and Marine Reserves	Yes, 1
2.6. Areas subjected to special attention for purposes of hydrogeological asset	
2.7. Areas hosting historical buildings of public interest	
2.8. Areas of public and/or military interest along the coast	
2.9. Areas pertaining to Local/Regional/National Landscape Plans	
2.10. Scenic Drives, aggregation points and places of memory	
3. BIOECOLOGICAL ASPECTS	
3.1. Migration routes of birds	Yes
3.2. Quality of sea water (in relation to harvesting, culturing and marketing of bivalve mollusks)	ND
3.3. Monitoring data according to the dictates of the EU Marine Framework Directive (wherever available or applicable), with specific reference to benthic biocoenoses and habitats	ND
3.4. Bio-ecological data included in environmental studies for EIA (Environmental Impact Assessment) procedures at the regional and / or national level at sea or on land, but with potential consequences to the sea	ND
3.5. Bio-ecological data derived from LIFE, IPA, INTERREG and any other EU or	ND

national funded projects, related with marine ecosystems	
3.6. Areas of clam fishing	Yes
3.7. Distribution of fishing effort and fleet composition	ND
4. SPATIAL PLANNING AND LANDSCAPE USE	
4.1. Synthesis of local/regional/national plans of landscape management presently in force or that are going to be established in the near future	
4.2. Information dealing with coastal traffic, tourism management and develoment and so on…	
4.3. Any other info possibly of interest to your opinion	

Emilia Romagna regions shares some characteristics of the Northerne basin and some from the Cnetral basin, in terms of sttructure and environemens, but the afluence if tourism, especially in summer, is massive throughout all the coast. Industrial maritime transport is not excessivley intense, besides Ravenna port, which is the main inustrial landing point of the region.

The underwater environemant is particular, showing Tegnue formations, which are a sort f isolated coralligenous like blocks in snady bottoms. These environemants are protected and actually under threat due to tourism, trawling and other uncontrolled uses. aquaculture is also high, but less that the Veneto region but there is an intense fishing effort in the immediate shore. the greta population increase during the summer season creates punctual contamination events that spread out to the sea and transported to already polluted or nutritios areas of the southern regions.

The Emilia-Romagna region is an important partof the Italian economy due to the amount of industries and enterprises that have bease here. In consequence, pollution levels in water and air are higher that the surrounding regions. Besides the industrial income, there is also an important economic entry that exports an important amount of food: fishing and seaffod dealing.

Protected areas in this region are many, especially onland, but the river mouths and the marshs for bird wildlife are also protected beign these the conection between land and sea. The marine protected areas are few.

Some of the critical elements in this region are:

Water pollution: water monitoring is fairly constant in this area due to the great exportation of mollusks and to tourism, unfortunately, as in most Italy there is a lack of monitoring of what occurs prior to arrival at sea, the depuration plants are mostly out of work or in neglected functioning and they over charge during the summer season. These events occur yearly and as consequence some beaches are closed to bathing, during the summer season.

Coastal erosion: as in all the eastern Italian coast from the north to central Adriatic there is an important issue: coastal erosion and beach loss. in the late 60's some communes decide to "protect" their beaches with breakwaters that were partially exposed. The construction of these breakwaters was not planned or consulted by scientists and the result has been an increase in certain areas of the advancement of the sea. this problem follows along the whole coast of Marche, Abruzzi and part of Apulia with differnet intensity and with differnet types of breakwaters, but more or less the effect is the same in all areas, as they change the natural current regime changing completely the beach natural nourishment and destruction.

Overfishing and trawling: from pelagics to crustaceans and mollusks, the Emilian fleet that is considered within the fishing industry is big and has the capacity (as a region) to fish and export huge amounts of fished sources. Unfortunately, there is still little control on. biological parameters that could assure a sustainable fishing fleet

Migration routes of birds and some specially protected birds: as shown in the ISPRA report, coastal Abruzzi region is not one of the most targeted migration stops, but there are certain species of special protection. There are some Ramsar zones near the coast, though probably not influencing directly the coastal-dependent communities.

Ever more common dolphin sightings: From the last report of NETCET and MeditSeH apparently there are more species in the Adriatic Sea of cetacean than initially thought and they are distributed along the whole Adriatic with special zoning per species. It is not rare, especially during the summer when the beaches are populated by tourists, to observe herds of dolphins close to the coast.

Dune communities and habitats: the dune communities have mainly disappeared due to massive constructions, habitat destruction and tourism. This is one of the reasons that have majorly influenced the increase in coastal erosion, since there are no more natural plant communities that "hold" the sand.

4.4.5 Marche

Theme	**Information**: Yes, No, Not applicable (Nap), Not declared-defined (ND), Not available(NA)
1. OBSTACLES AND INTERFERENCES AT SEA WITHIN 12 MILES FROM THE COAST	
1.1. Mining (oil and gas included) concessions and energy supply facilities at sea under authorization	No
1.2. Submarine cables, pipelines and any conduit under authorization	No
1.3. Offshore aquaculture plants (finfish and shellfish)	25
1.4. Dumping areas at sea, including those for sediments resulting from dredging activities (including those carried out in harbors)	Scattered, not in use
1.5. Trade naval routes	ND
1.6. Shipwrecks and archaeological sites (at sea and along the coast)	NA-MiBAC
1.7. Unexploded ordnance and areas of interest or pertaining exclusively to military activities	NA
1.8. Contaminated sites at sea and along the coast (currently in remediation or potentially to be reclaimed)	Yes, between 200-550
1.9. Areas of submerged beach nourishment	Yes
1.10. Areas with a high risk of environmental crisis	Yes
1.11. Underwater caves to supply relict sand (for the purpose of beach nourishment)	No
1.12. Areas pertaining to harbor activities (including access corridors and transit)	Yes, 9
1.13. Areas used for diving and spearfishing	ND, 7
2. ENVIRONMENTAL (including landscape) CONSTRAINS	
2.1. Special Protection Areas (SPA)	Yes, 29
2.2. Sites of Community Interest (SCI) [at sea and along the coast]	Yes, 80
2.3. Zones of biological protection	Yes, 10
2.4. Ramsar Areas	Yes, 1
2.5. Parks and Marine Reserves	Yes, 3
2.6. Areas subjected to special attention for purposes of hydrogeological asset	Yes
2.7. Areas hosting historical buildings of public interest	Yes, PPAR
2.8. Areas of public and/or military interest along the coast	NA
2.9. Areas pertaining to Local/Regional/National Landscape Plans	Yes, PPAr
2.10. Scenic Drives, aggregation points and places of memory	Yes, PPAR

3. BIOECOLOGICAL ASPECTS	
3.1. Migration routes of birds	Yes
3.2. Quality of sea water (in relation to harvesting, culturing and marketing of bivalve mollusks)	ND
3.3. Monitoring data according to the dictates of the EU Marine Framework Directive (wherever available or applicable), with specific reference to benthic biocoenoses and habitats	ND.Yes
3.4. Bio-ecological data included in environmental studies for EIA (Environmental Impact Assessment) procedures at the regional and / or national level at sea or on land, but with potential consequences to the sea	ND
3.5. Bio-ecological data derived from LIFE, IPA, INTERREG and any other EU or national funded projects, related with marine ecosystems	NAp
3.6. Areas of clam fishing	Yes
3.7. Distribution of fishing effort and fleet composition	Yes
4. SPATIAL PLANNING AND LANDSCAPE USE	
4.1. Synthesis of local/regional/national plans of landscape management presently in force or that are going to be established in the near future	Yes
4.2. Information dealing with coastal traffic, tourism management and develoment and so on…	Yes
4.3. Any other info possibly of interest to your opinion	

The Marche Region is actually in a changing phase, where some municipalities have adhered to a common aim of becoming environmentally smart. This is still a process, and will take time to achieve but there are some elements can be already seen. In first place there is a good database, under update, of spatial planning and critical issues of the region, there is a good number of SIC, ZPS, Ramsar areas, parks and Reserves, etc. Of course after the disasters in the past concerning the gas plants at sea, there is general high conscious of the possible consequences and thus, as Marche is also a big fishing area, measures have been implemented in the management of the plants and their surroundings.

Some of the critical elements in this region are:

Water pollution: water monitoring is fairly constant in this area due to the great exportation of mollusks and to tourism, and less neglected, as it seems in the last years, that the neighbor Abrizzu region.

Overfishing: Probably one of the most critical and common issues considering the Veneto, Molise, Abruzzi and Apulia regions. The fleets and aquaculture plants and areas are truly under risk of over carrying the system capacity, there is no effective surveillance on what, when and where legal and illegal fishing activities are carried out. There is a general denial approach for introducing protected or more managed areas for fishing, and thus fishermen are still convinced that the introduction of newly managed area has the only aim of reducing or denying their work, when in reality the managed fishing areas intend, amongst other objectives, to maintain the already deemed ecosystem to have spill out for the fisheries.
There is an absolute denial of fishermen and population to implement a Marine Protected area in the Conero.

Seasonal and not sustainable tourism: there is an intent of transforming the actual Marche tourism slowly into a more sustainable and effective tourism, but this process is long and surely has not got all the community in favor. The Parks pertaining the coastal areas (Conero, Sentina and San Bartolo), try to limit and control massive tourism floods, but it is difficult to achieve the whole territory.

4.4.5 Molise

Theme	**Information**: Yes, No, Not applicable, Not declared, Not available
1. OBSTACLES AND INTERFERENCES AT SEA WITHIN 12 MILES FROM THE COAST	
1.1. Mining (oil and gas included) concessions and energy supply facilities at sea under authorization	Yes
1.2. Submarine cables, pipelines and any conduit under authorization	Yes
1.3. Offshore aquaculture plants (finfish and shellfish)	Yes
1.4. Dumping areas at sea, including those for sediments resulting from dredging activities (including those carried out in harbors)	No
1.5. Trade naval routes	ND
1.6. Shipwrecks and archaeological sites (at sea and along the coast)	Yes, 1
1.7. Unexploded ordnance and areas of interest or pertaining exclusively to military activities	No

1.8. Contaminated sites at sea and along the coast (currently in remediation or potentially to be reclaimed)	ND
1.9. Areas of submerged beach nourishment	Yes
1.10. Areas with a high risk of environmental crisis	ND
1.11. Underwater caves to supply relict sand (for the purpose of beach nourishment)	No
1.12. Areas pertaining to harbor activities (including access corridors and transit)	Yes
1.13. Areas used for diving and spearfishing	No
2. ENVIRONMENTAL (including landscape) CONSTRAINS	
2.1. Special Protection Areas (SPA)	Yes
2.2. Sites of Community Interest (SCI) [at sea and along the coast]	Yes
2.3. Zones of biological protection	Yes
2.4. Ramsar Areas	No
2.5. Parks and Marine Reserves	No
2.6. Areas subjected to special attention for purposes of hydrogeological asset	Yes
2.7. Areas hosting historical buildings of public interest	ND
2.8. Areas of public and/or military interest along the coast	No
2.9. Areas pertaining to Local/Regional/National Landscape Plans	ND
2.10. Scenic Drives, aggregation points and places of memory	ND
3. BIOECOLOGICAL ASPECTS	
3.1. Migration routes of birds	ND
3.2. Quality of sea water (in relation to harvesting, culturing and marketing of bivalve mollusks)	Yes
3.3. Monitoring data according to the dictates of the EU Marine Framework Directive (wherever available or applicable), with specific reference to benthic biocoenoses and habitats	Yes
3.4. Bio-ecological data included in environmental studies for EIA (Environmental Impact Assessment) procedures at the regional and / or national level at sea or on land, but with potential consequences to the sea	ND
3.5. Bio-ecological data derived from LIFE, IPA, INTERREG and any other EU or national funded projects, related with marine ecosystems	ND
3.6. Areas of clam fishing	Yes
3.7. Distribution of fishing effort and fleet composition	ND
4. SPATIAL PLANNING AND LANDSCAPE USE	
4.1. Synthesis of local/regional/national plans of landscape management presently in force or that are going to be established in the near future	
4.2. Information dealing with coastal traffic, tourism management and develoment and so on…	
4.3. Any other info possibly of interest to your opinion	

Molise Region concerns a small trait of coast, with similar characteristics of the confining regions: sandy banks and dunes and occasional rocky shoals as special areas to protect or under protection with an important mollusk fishing activity. besides the natural values of these types of environments the Molise coast counts a as well on extraction plants of gas and constant beach loss due to, partially natural events and to the presence of the containing walls introduced in the last decades. As for the whole area pertaining Marche, Apulia and Molise regions the issues vary slightly. Most of the SIC and ZPS are contained in the interior, and only 2 concern strictly a marine portion. Upon the Molise region we find an important area for elasmobranch sightings and in the route of migrating birds and turtles.

Some of the critical elements in this region are:

Water pollution: water monitoring is fairly constant in this area due to the great exportation of mollusks and to tourism, unfortunately, as in most Italy there is a lack of monitoring of what occurs prior to arrival at sea, the depuration plants are mostly out of work or in neglected functioning and they over charge during the summer season. These events occur yearly and as consequence some beaches are closed to bathing.

Overfishing: Probably one of the most critical and common issues considering the Veneto, Marche, Abruzzi and Apulia regions. The fleets and aquaculture plants and areas are truly under risk of over carrying capacity, there is no effective surveillance on what, when and where legal and illegal fishing activities are carried out. There is a general denial approach for introducing protected or more managed areas for fishing, and thus fishermen are still convinced that the introduction of newly managed area has the only aim of reducing or denying their work, when in reality the managed fishing areas intend, amongst other objectives, to maintain the already deemed ecosystem to have spill out for the fisheries.

Seasonal and not sustainable tourism: as for the land part sustainable tourism is increasing, there is no real consciousness about the marine sustainable activities. Hotels with pools and drain directly on the beaches, fully clean and organized beaches, no respect for the natural environment of the coast or the dune systems "because it is ugly" and the beaches are "full of grass", besides consuming with no criteria food and accommodation. All together, become a great issue during the summer seasons but their consequences pertain during the whole year.

4.4.6 Abruzzo

Theme	Information: Yes, No, Not applicable, Not declared, Not available
1. OBSTACLES AND INTERFERENCES AT SEA WITHIN 12 MILES FROM THE COAST	
1.1. Mining (oil and gas included) concessions and energy supply facilities at sea under authorization	Yes
1.2. Submarine cables, pipelines and any conduit under authorization	Yes
1.3. Offshore aquaculture plants (finfish and shellfish)	Yes
1.4. Dumping areas at sea, including those for sediments resulting from dredging activities (including those carried out in harbors)	ND
1.5. Trade naval routes	Nd
1.6. Shipwrecks and archaeological sites (at sea and along the coast)	ND
1.7. Unexploded ordnance and areas of interest or pertaining exclusively to military activities	ND
1.8. Contaminated sites at sea and along the coast (currently in remediation or potentially to be reclaimed)	Yes
1.9. Areas of submerged beach nourishment	ND
1.10. Areas with a high risk of environmental crisis	ND
1.11. Underwater caves to supply relict sand (for the purpose of beach nourishment)	Yes
1.12. Areas pertaining to harbor activities (including access corridors and transit)	Yes
1.13. Areas used for diving and spearfishing	ND
2. ENVIRONMENTAL (including landscape) CONSTRAINS	
2.1. Special Protection Areas (SPA)	Yes
2.2. Sites of Community Interest (SCI) [at sea and along the coast]	Yes
2.3. Zones of biological protection	Yes
2.4. Ramsar Areas	Yes
2.5. Parks and Marine Reserves	Yes
2.6. Areas subjected to special attention for purposes of hydrogeological asset	Yes
2.7. Areas hosting historical buildings of public interest	Yes
2.8. Areas of public and/or military interest along the coast	Yes
2.9. Areas pertaining to Local/Regional/National Landscape Plans	Yes
2.10. Scenic Drives, aggregation points and places of memory	Yes

3. BIOECOLOGICAL ASPECTS	
3.1. Migration routes of birds	ND
3.2. Quality of sea water (in relation to harvesting, culturing and marketing of bivalve mollusks)	ND
3.3. Monitoring data according to the dictates of the EU Marine Framework Directive (wherever available or applicable), with specific reference to benthic biocoenoses and habitats	ND
3.4. Bio-ecological data included in environmental studies for EIA (Environmental Impact Assessment) procedures at the regional and / or national level at sea or on land, but with potential consequences to the sea	ND
3.5. Bio-ecological data derived from LIFE, IPA, INTERREG and any other EU or national funded projects, related with marine ecosystems	ND
3.6. Areas of clam fishing	Yes
3.7. Distribution of fishing effort and fleet composition	ND
4. SPATIAL PLANNING AND LANDSCAPE USE	
4.1. Synthesis of local/regional/national plans of landscape management presently in force or that are going to be established in the near future	Yes
4.2. Information dealing with coastal traffic, tourism management and develoment and so on…	ND
4.3. Any other info possibly of interest to your opinion	

Abruzzo region, is actually and has been for the last years renewing their databases on territorial spatial planning, including urban, coastal and "any sort" of protected areas in their geo-referenced updates. Most of the data submitted is available online (http://opendata.regione.abruzzo.it/) , and the report submitted identified the main issues at a technical level when considering the port structure and requirements for the operations required by/ for the offshore wind farms.

Abruzzi region considers a large fraction of dunes or semi-dune environment along all its coasts, from which a considerable number are listed as SIC or ZPS. The marine and strictly coastal environments are mostly not enlisted as protected, but a large amount of these SIC-ZPS have a terrestrial-marine fraction. Along the coast, only the Torre del Cerrano Marine Protected Area is present, concerning a small fraction of coast (about 7 Km^2). Some of the recurrent threats in the region are commercial fishing, dredging-nourishing, polluted river inputs, and the mining concessions at sea. Commercial fishing is mainly for clams, mussels and small fish within the first nautical miles from the coast, then industrial trawling and netting occurs beyond the 3-6 nm line. There are abundant seasonal rivers along the coast, and about 10 perennial ones, that support with sediment the near basins, which due to the numerous coastal modifications (breakwaters, villages, hotels, ports, rafts,…) are not able to define their normal sedimentation/erosion rates. These coastal modification have "provoked" an abnormal sedimentation rating creating the human need to dredge and nourish beaches to avoid "loosing" the beach and for security reasons. Beyond the sediment issue from the rivers, there are serious issues with the pollution coming from inland: non-working depuration plants, seasonal over-tourism, illegal dumps (ex Bussi), coastal hyper-urbanized areas, agriculture, altogether with the mining, oil and gas concessions, which are scattered along the coast and most of them visible from land picture the Abruzzi Region l as highly exploited and not virgin. In spite of this, there is a growing interest on protecting, or at least maintaining the environment and a great amount of sustainable tourism activities are developing: cycling routes, nature walks, certifications and some political pressures on advertising the region as the lungs of Italy. Tourism offshore is reduced, mainly circumstanced to the first 1 nm and within the first 5nm there are few naval routes different from those for fishing.

Some of the critical elements in this region are:

<u>Turtles nesting (2013):</u> Last year, maybe by accident or by coincidence, or because she was really born in that beach, a female turtle nested in a very popular beach in Roseto degli Abruzzi, surrounded by umbrellas and bathers. This particular fact, not only gives good marketing to the area but means that eventually the Abruzzi coasts, if protected, could be a new cull for turtle nesting in the Adriatic Sea.

<u>Migration routes of turtles:</u> As shown in Schoefield et al. (2013) and NETCET the migration routes vary amongst females and males, as well as foraging areas and nesting zones, but their presences has been highly underestimated in this basin. The protection of turtles in the Mediterranean is imposed and is part of the RED LIST, the RAC/SPA and the Barcelona Convention.

<u>Migration routes of birds and some specially protected birds:</u> as shown in the ISPRA report, coastal Abruzzi region is not one of the most targeted migration stops, but there are certain species of special protection like the Kentish plover (*Charadrius alexandrinus) that nest in the dunes. There are some Ramsar zones near the coast, though probably not influencing directly the coastal-dependent communities.*

Ever more common dolphin sightings: From the last report of NETCET and MeditSeH apparently there are more species in the Adriatic Sea of cetacean than initially thought and they are distributed along the whole Adriatic with special zoning per species. It is not rare, especially during the summer when the beaches are populated by tourists, to observe herds of dolphins close to the coast.

Dune communities and habitats: vegetation as the Sea Daffodil (*Pancratium maritimum*), Mullein of the Gargano (*Verbascum niveum subsp. Garganicum*), Sea Bindweed (*Calystegia soldanella*) and Purple Spurge (*Euphorbia peplis*) are just some of the examples of the precious sand dune vegetation. Towards the south of the Abruzzi region wetlands and well developed dunes. Towards Vasto area there a series of SIC that consider dunes and the associated marine area.

Sandy bottoms with not attractive protected species: Sandy bottoms are usually considered “boring” and with no interest; thus they can be modified and exploited with no consideration. This is a wrong approach since most of the filtering organism that live in the sand are responsible for the water quality and, in disturbed conditions, this function is totally lost. Besides the ecological function of the sandy communities, there are species like *Chamalea gallina* with high commercial value and *Sabellaria halckoki* that create important reef structures that increase the complexity on the sand banks; in the southern Abruzzi region some punctual “trottoir” of vermetides are present which function similarly as *Sabellaria* sp. Besides the sand bottoms there are scattered hard bottoms that utterly increase biodiversity and importance of the marine resources, natural and commercial values along the Abruzzi coast.

Existing concessions at sea: The numerous gas and oil platforms along the coast, installed in the last 20-30 years, besides their initial disruption of the habitats, have at the moment created a sort of *de facto* MPA as it is not allowed to fish or other activities in the surroundings; besides this fact the introduction of new structures have given the possibility of new colonizers and increased biological complexity. Certainly, the potentiality of these shore structures of being dangerous is not banal, as happened in the Ancona surroundings in 2007, can have consequences still observable today: direct pollution, indirect effect on the community and total loss of the underlying populations.

Overfishing, especially coastal: The eastern coast of the Adriatic is the most exploited area in the basin, from Trieste gulf with numerous fleets of pelagic fishing, to all the Marche and Abruzzi seafood fishing (clams and mussels, mostly), to the Apulia region famous for sea urchin fishing. Throughout the Abruzzi region mainly all the coastal line is overexploited and the bottom trawling and clam fishing gear are mainly destroying the whole ecosystem, not allowing these fairly fast growing animals to recover and depleting year by year the amount fished.

4.4.7 Apulia

Theme	**Information**: Yes, No, Not applicable, Not declared, Not available
1. OBSTACLES AND INTERFERENCES AT SEA WITHIN 12 MILES FROM THE COAST	
1.1. Mining (oil and gas included) concessions and energy supply facilities at sea under authorization	ND, Yes
1.2. Submarine cables, pipelines and any conduit under authorization	ND, Yes
1.3. Offshore aquaculture plants (finfish and shellfish)	Yes?
1.4. Dumping areas at sea, including those for sediments resulting from dredging activities (including those carried out in harbors)	ND, Yes
1.5. Trade naval routes	ND, Yes
1.6. Shipwrecks and archaeological sites (at sea and along the coast)	ND
1.7. Unexploded ordnance and areas of interest or pertaining exclusively to military activities	ND
1.8. Contaminated sites at sea and along the coast (currently in remediation or potentially to be reclaimed)	ND, Yes
1.9. Areas of submerged beach nourishment	ND
1.10. Areas with a high risk of environmental crisis	Yes
1.11. Underwater caves to supply relict sand (for the purpose of beach nourishment)	ND
1.12. Areas pertaining to harbor activities (including access corridors and transit)	Yes
1.13. Areas used for diving and spearfishing	ND
2. ENVIRONMENTAL (including landscape) CONSTRAINS	
2.1. Special Protection Areas (SPA)	ND
2.2. Sites of Community Interest (SCI) [at sea and along the coast]	Yes
2.3. Zones of biological protection	Yes
2.4. Ramsar Areas	ND, IBA yes

2.5. Parks and Marine Reserves	Yes
2.6. Areas subjected to special attention for purposes of hydrogeological asset	Yes
2.7. Areas hosting historical buildings of public interest	Yes
2.8. Areas of public and/or military interest along the coast	Yes
2.9. Areas pertaining to Local/Regional/National Landscape Plans	Yes
2.10. Scenic Drives, aggregation points and places of memory	Yes
3. BIOECOLOGICAL ASPECTS	
3.1. Migration routes of birds	Yes
3.2. Quality of sea water (in relation to harvesting, culturing and marketing of bivalve mollusks)	ND
3.3. Monitoring data according to the dictates of the EU Marine Framework Directive (wherever available or applicable), with specific reference to benthic biocoenoses and habitats	ND
3.4. Bio-ecological data included in environmental studies for EIA (Environmental Impact Assessment) procedures at the regional and / or national level at sea or on land, but with potential consequences to the sea	ND
3.5. Bio-ecological data derived from LIFE, IPA, INTERREG and any other EU or national funded projects, related with marine ecosystems	ND
3.6. Areas of clam fishing	ND
3.7. Distribution of fishing effort and fleet composition	ND
4. SPATIAL PLANNING AND LANDSCAPE USE	
4.1. Synthesis of local/regional/national plans of landscape management presently in force or that are going to be established in the near future	
4.2. Information dealing with coastal traffic, tourism management and develoment and so on…	
4.3. Any other info possibly of interest to your opinion	

The Apulia region, as the Marche Region, in the last years has officially declared to become more environmentally smart. To obtain their goal they have set up numerous projects to describe the actual situation (Shape project, accessible database of PPTR, submersed environments characterization, etc.) and to be able to plan the future situation. Besides POWERED, the EU-funded project COCONET works as well in the environment of offshore wind farm installation in the Adriatic Sea but with a focus more oriented to the biological effects and (even positive) consequences. The Apulia effort in updating all their databases, and rendering them public, has ensured an invaluable smart support to the activities of environmental analysis carried out in the WP5 for the Apulian coasts.

Apulia region, is probably up to date, the only Italian region with projects of offshore or semi-offshore wind farms under evaluation, whereas the extraction of gas and concession for prospection is going to be highly reduced.

This region, compared to the northern neighbors, has a more reduced fishing effort on mollusks and aquaculture, whereas the pelagic fishing efforts are moved on to the Southern Adriatic Pit.

Protected areas in Apulia are vast and numerous, including Ramsar, IBAs, MPAs, SICs, ZPSs, National Parks and SPAs, all of which concern more or less a marine or coastal portion. The Tremiti Islands and the Gargano Park are the most emblematic ones, but there is also the Torre Guaceto MPA which represents an example of good environmental management of nature and resources exploitation.

Due to the change in the natural characteristics of the Apulian coasts and the offshore zones on the Adriatic coastline, the depth increases rapidly, so that the sandy communities are partially substituted by hard bottoms, the currents and the trophic levels change abruptly and the general characteristics result much different from those of the to the Northern and Central Adriatic Sea.

Some of the critical elements in this region are:

Old and new industrial discharge: Apulia region has been, for a long time an important area for coal and blast furnace plants, that, at time, were not regulated and for years have discharged and contaminated the air and waters around them. Traditional links and connections with the eastern Adriatic countries have been from Bari and Brindisi ports, which still today transport, besides passengers, numerous dangerous and polluting substances.

Natural resources exploitation, lack of rigid regulations: due to the special importance of the ecosystems in this region, it is important to maintain these for conservation and for the future generations; unfortunately there is still a reduced management, especially when environment protection and stakeholders come together. In concrete, the installation of certain SICs appears to be the result of rush considerations. This, as in most of the Mediterranean Sea countries, attains as well the non-regulated fishing activities, which apparently have increased with the global crisis.

4.4.8 Croatia

The information made available in the present report is exclusively derived from the literature, as the Croatian partner did not provide any synthetic report.

Croatia has recently entered in the EU and is updating lots of the databases and information under jurisdiction of the country. For this reason some of the information on concessions and fisheries, as well as managements of certain resources could most likely change in the near future.

Croatia is an emblematic area of the Adriatic Sea, will more than 1000 islands with a characteristic northern Mediterranean climate. The environment is highly heterogeneous and diverse, with a low population (ca. 90 habitants per square km) that considers their natural resources not only as goods and services but also as the best tourism resource, and thus highly protected. The management of the protected areas is controlled by public institutions from each of the counties, which allows to have common approaches and initiatives for the whole counties. From the recent entry of Croatia in the EU, the absolute protected percentage of protected areas in the EU as object Horizon 2020 grew up to 19%.

Amongst the islands and Peninsulas, we find key marine habitats like coralligenous, various types of sea grass meadows, sandy and muddy bottoms which are all under some sort of protection. The habitats allow nursing and spawning spots for fish that out spill to all the Adriatic Sea. In addition turtles are more common that in the rest of the Adriatic, as most of their migrating routes and north basin foraging zones consider the Croatian coasts. Sharks are, apparently, more abundant in this area but it is not clear if the reason of this larger abundance is due to the numerous islands from where to observe these animals is easier that the open seas, or because there is a focused research on elasmobranchs in the area or if it is actually true that sharks and rays prefer these coasts. In any case, the biodiversity of the Croatian waters and coastal areas is high and, at least as declared, in a good or fairly good status. Croatia is mainly populated by Croatians that love and are proud of their natural resources, which aids in the conservation of their patrimony.

On behalf of the threats, the main one lately is the litter accumulated on the beaches that arrive from the southern countries mostly. This issue, should be approached by the whole Adriatic countries, since they are not all included in the EU the initiative should approached in an ecosystem functioning way. The Adriatic is already eutrophic and nutritious, shallow, overexploited and less oxygenated that other Mediterranean regions so eventual increased inputs on discharges and litter could augment and determine environmental crisis.

The fishing fleets in Croatia are small and mostly artisanal, claiming this way maybe the less exploited area in the basin. Not the least, even if it concerns deeper water the diverse and complex context in which it is situated does not allow certain machinery to work, so creating a sort of protected zones against destructive fishing practices.

At the moment, physical parameters like the number of islands and the geology, allow little high scale disturbances like big ports or submarine cables or big industrial zones. Erosion, compared to the rest of the Adriatic basin is low since is less disturbed in terms of urbanization and because all the islands protect partially the continental coast.

Some of the critical elements in this region are described below.

Pollution and discharges: the main issue applied to marine litter is the accumulation on the Croatian "worm-like" coasts on behalf of the current transportation, that can affect the feeding of turtles during migration and thus the lethal or sub-lethal consequences and increase the chemicals and solid particles in the sea.

Threatened species and habitats: Tourism to Croatia has increased due in part to the crisis since remain convenient and offers great variety of choices. The increase in tourism brings as well the increase of maritime activities: transport, sports, increased demand on services, etc… that all have a cost on the environment. When considering pelagic animals, as turtles for example, the main threat is the collision and the use of putative nesting/ nursing zones. Increased tourism, though a good economic resource if not well managed could decline the actual status of the environmental conditions.

4.4.9 Slovenia, Bosnia Herzegovina and Greece

Slovenia, Bosnia-Herzegovina and Greece did not provide reports, thus they were not included as direct partners. Partially Slovenian and Croatian information request was given by Veneto Agricoltura in their synthetic report. On the other hand the Greek part of the Adriatic Sea is almost out of the limits of the project.

Bosnia-Herzegovina has only 27km of coast from which little is known. Slovenia, in some way, is included as study area for the Italians in the Trieste Gulf and by the Croatians in the Istria Peninsula. In reality, the Slovenian coast accounts an important number of special habitats and species, and within a relatively low coastal territory it accounts a large diversity.

Coralligenous, sea grass meadows and an important fish nurseries; bottoms are mostly snady and muddy with differen grain sizes and there is presence of typical of sandy and muddy bottom communities, where aquaculture has not modified the conditions. The same issues apply for the whole gulf when regarding turtles, sharks and mammals: collisions, loss of habitat and by-catch. In addition, Schoefield et al. (2013) identified this area to be an important foraging zone for turtles. The reality on Slovenia is very similar to the Trieste area: frequent and abundant maritime activities, intense fishing and fishing fleets as well as developed aquaculture practices. Most of the activities are controlled and managed by the surveillance system for security and safety, since the Trieste Gulf is one of the high risk for collision in the Adriatic. As in the whole North Adriatic, seasonal and permanent hypoxia events occur, due to algal blooms or over-limiting nutrient introduction from the Po river that determines drastically the ecosystem in the whole gulf. Added to the nutrients used in aquaculture hypoxia is becoming more frequent; presumably hypoxia events would eliminate the whole community in the area, but the populations seem to be adapting to this "unnatural" condition. This is also one of the reasons why the Gulf of Trieste has very low incidence of alien species. Slovenia and Italy, together with other countries in the basin have ratified a series of agreements within economic, safety and environmental contexts to share data and knowledge. Up to date, this collaboration is occurring but still no official database is in act.

4.4.10 Transnational territorial constrains referring to sea uses

While carrying out the country-by-country analyses, differences have been observed between the northern part of the Adriatic and the central and southern part with regard to experienced and/or expected competition between maritime activities. The northern part of the Adriatic Sea has more potential for the application of Maritime Spatial Planning (MSP) than the other parts of the Adriatic. Consequently, the remainder of this chapter focuses on the northern part of the basin. After detailing the area and the type and density of the activities taking place in the region, stakeholder involvement and the legal and institutional framework are analyzed with the aim of providing a procedural scheme for extending the analysis to other Adriatic Sea areas and including offshore wind farms as causal agents of maritime use conflicts. Next the cross-border/international cooperation and consultation is discussed, followed by the data collection, monitoring and evaluation of marine/maritime-related topics. This chapter ends with a coherence analysis of terrestrial and marine spatial planning.

4.4.10.1 Area and type of activities

The Northern Adriatic is an intensively used area. Besides maritime transport, the area is characterized by a significant number of other maritime activities, likely leading to competition between the different maritime uses in the area. Moreover, the intensity of the different maritime activities is expected to increase. Given the crowdedness of the area and the involvement of several countries in the region, cross-border/international MSP could be considered a more efficient tool in order to resolve competition in terms of maritime space compared to national MSP. Certain activities taking place at the national/local level have transboundary impacts on the surrounding areas. These issues can be addressed in cross-border/international MSP.

In this section information is provided about the competition taking place in a number of regions in the Northern Adriatic Sea.

These areas are (Figure 4.64): **(**1) Slovenian territorial waters, (2) waters under Italian jurisdiction, (3) waters under Croatian jurisdiction. Besides competition at the national level, competition is experienced across the Northern Adriatic, as the migration loop of fish (4) shows.

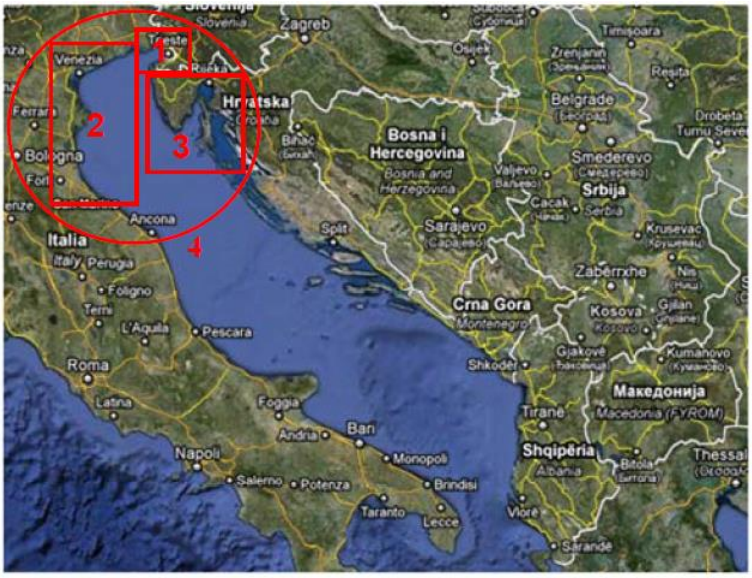


Figure 4.64. Area covered by the Northern Adriatic (including: Friuli Venezia Giulia, Veneto and Emilia Romagna for the Italian side; Slovenia; Northern Croatia) (source: Policy Research Corporation, 2011)

(1) Waters under Slovenian jurisdiction

Within the framework of the PlanCoast project, a map was developed to obtain awareness of the current situation on marine uses in Slovenia. During the process information was gathered on established uses and regimes, possible competition between the different maritime uses and assessments of the arguments in favour or against the implementation of MSP in Slovenia. Moreover, through the development of this map, the major stakeholders related to maritime uses were identified (PRC, 2011). Figure 4.65 shows the current maritime uses in the internal and territorial waters in Slovenia (as part of the Gulf of Trieste) as prepared during the PlanCoast project[1][20]. The activities shown include among others corridors for navigation, bathing waters, fishery sites, salt pans and nature conservation sites. The maps can be consulted in more detail on the website of the Regional Development Centre in Koper[21].

The Slovenian internal and coastal waters are intensively used and competition between maritime uses - both at the national/regional as well as on the cross-border/international level - is present. The fact that Slovenia has a relatively small coastal / marine area limits the space available for maritime activities and thus increases the possibility of competition for space. At present, competition between tourism, maritime transport and fisheries is already experienced at the national/local level. One example of currently existing cross-border/international competition concerns a plan for an Italian offshore gas terminal in the Gulf of Trieste as it is regarded as competing with tourism (which is an important sector in Slovenia). The LNG terminal would be placed 300 meters from the Slovenian coast. Slovenian stakeholders foresee negative effects for the Slovenian tourism sector (PRC, 2011).

[20] Although the border with Croatia is not correctly displayed, this figure is useful since it indicates the activities taking place and the presence of knowledge and technology

[21] Regional Development Centre Koper, www.rrc-kp.si

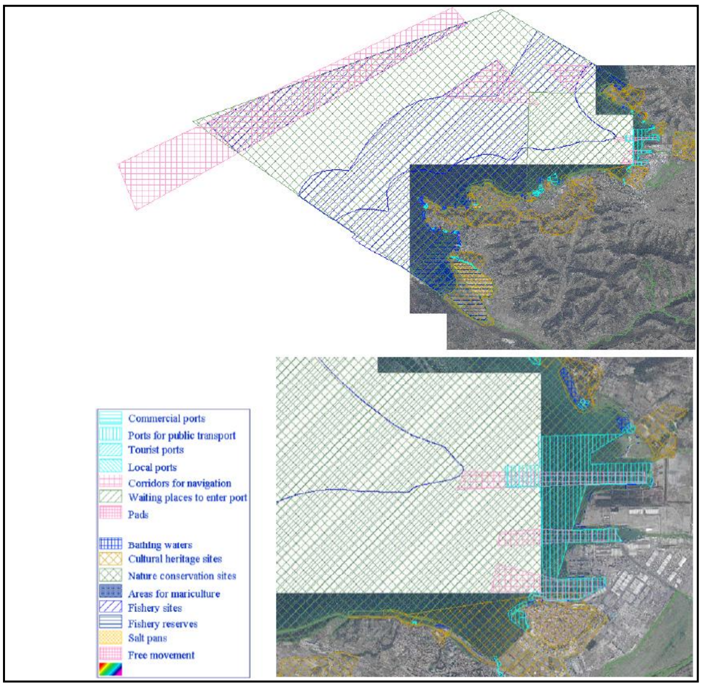


Figure 4.65. Maps of sea-uses in the Slovenian marine area (as part of the Gulf of Trieste) (Source: Policy Research Corporation based on Regional Development Centre Koper, www.rrc-kp.si)

Given the crowdedness of the Slovenian marine area and the presence of more than one country in a relatively small sea area/region (which is likely to lead to cross-border/international competition next to the existing national competition), the concept of cross-border/international Maritime Spatial Planning could provide a solution to solve spatial issues at sea. However, the willingness of the involved governments to cooperate in establishing a cross-border/international Maritime Spatial Plan has to be kept in mind.

(2) Waters under Italian jurisdiction

The waters under Emilia-Romagna, Veneto and Friuli-Venezia Giulia jurisdiction are intensively used by coastal and marine tourism, maritime transport, fishing, mariculture, offshore platforms and sand extraction. Maritime transport is an important activity and Italy possesses a significant number of large ports in the Northern Adriatic Sea (i.e. Ravenna, Venice, Chioggia, Porto Levante, Trieste and Monfalcone). These ports are important for the transportation of goods as well as passengers (PRC, 2011). Different maritime activities compete with each other in northern Italian waters. For instance, sand extraction competes primarily with fishing. After sand is extracted from the sea bed, the composition of the seabed changes, which may lead to damage to fishing gear since fishermen cannot estimate the new depth of the sea. Sand extraction, fishing and other activities experience competition from offshore platforms and pipelines. Around platforms safety zones are in place, in which activities are prohibited. Safety zones around pipelines are also in place, prohibiting fishing and dredging but not affecting shipping. Competition among different types of fishing is experienced as well. Trawlers tend to fish illegally within the 3 nautical miles limit or within the 50 meters depth limit. Due to the higher capacity of trawlers, this poses a threat to the artisanal fishermen. Maritime activities in the northern Italian part of the Adriatic Sea also impact the environment. Illegal clam fishing in the Venice lagoon for example has an impact on the sediment. Competition between fishing and the environment is also experienced in rocky outcrops so called "Tegnúe" (PRC, 2011), because (illegal) fishing in this area damages the protected soil and affects fish stocks in an unsustainable way. Other maritime activities with an impact are sand extraction (damages the soil) and shipping (pollution). Land-based activities also have a negative impact on the marine environment because non-purified wastewater is discharged into the sea, leading to water pollution.

(3) Waters under Croatian jurisdiction

The most important maritime activities in Croatia are maritime transport, marine and coastal tourism and fisheries. Competition between maritime uses is experienced at the national level mainly around port cities such as Rijeka, Zadar and Split. As a rise in maritime transport is expected, competition in the port regions is also likely to increase. Furthermore, competition between maritime uses at the local level is experienced between the tourism sector, the fisheries sector and the upcoming mariculture sector (PRC, 2011). Maritime transport towards ports in Croatian waters is expected to increase as several of the Croatian ports are deep-water ports which could accommodate super-tankers. Consequently, Croatian ports are believed to provide a solution for today's bottlenecks in oil export routes in Eurasia (Vidas, 2008). In this respect, the set-up of the pre-accession maritime transport strategy of the republic of Croatia is relevant. Furthermore, fishing has always been an important economic activity for the Croatian population. The country's coastline combined with its numerous islands, bays, coves and cliffs provides good conditions for fishing. Nevertheless, compared to other parts of the Mediterranean, the Croatian part of the Adriatic has limited fisheries resources. Therefore, steps have been taken to preserve this specific kind of resources, through (1) the establishment of the Ecological and Fisheries Protection Zone and (2) the division of the Croatian territorial waters into seven fishing zones according to fishery legislation. Each zone has particular restrictions regarding the possible timeframe for and type of fishing activities (PAP/RAC, 2007b). Division of the Croatian territorial sea into seven fishing areas is illustrated in Figure 4.66.

Figure 4.65. Fishing zones in Croatia (Source: PRC, 2011 on based on PAP/RAC, 2007b)

As indicated, fishing activities (and recently developed mariculture) are experiencing more and more competition with other activities. The Zadar county developed maps of suitable zones for fish farming, shell-fish farming and zones for demersal fish within the framework of the 'study of use and protection of the sea and underwater area in the Zadar County'. This study mainly focused on Maritime Spatial Planning in terms of mariculture (PAP/RAC, 2007b). The exact zones are specified in Figure 4.66, also illustrating the potential competition between mariculture and marine and coastal tourism activities in those specific regions.

Figure 4.66. Zones suitable for fish farming, for shell-fish farming and demersal fish zones in Croatia(Source: PRC, 2011 on based on PAP/RAC, 2007b)

(4) Migration loop of fish

In the Adriatic Sea fishery resources are shared between different countries (Figure 4.67).

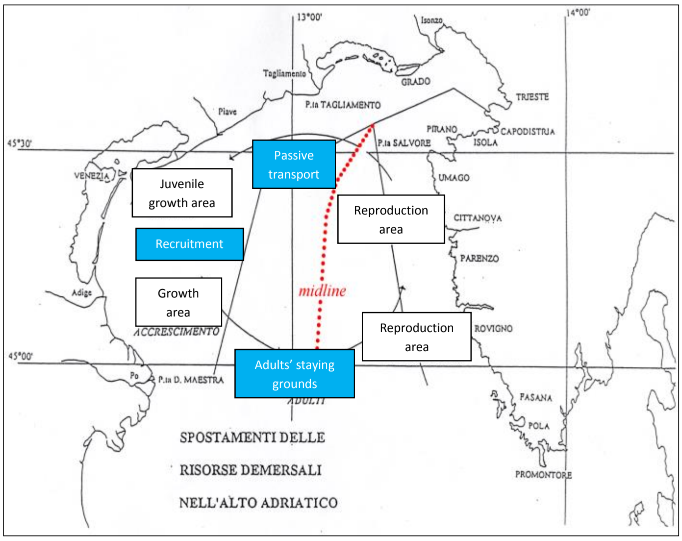


Figure 4.67. Migration loop of demersal resources in the Northern Adriatic basin (in red passive transport routes).

Usually nursery areas are situated at the western side (Italy), while at the eastern side, spawning areas can be found. For instance, the common sole fish species moves in the winter to the south-west of Istria to spawn. After the eggs have come out, the juveniles subsequently reach the lagoons in the early spring in the north-west of Italy. In the lagoon, they grow further and during fall these fish leave the lagoon to reach the Italian coastal area and later on, the high seas. The stocks of fish species have decreased as a result of human activities, also along this migration loop. Unsustainable fishing is carried out in the hotspots along the migration loop. Also pollution in lagoons (which is a part of the migration loop), resulting from port activities and land-based activities, is affecting the health of fish and the fish stocks. This means that for the protection and sustainable use of marine resources, it is necessary to take into account the biological cycle of species, and thus manage the whole ecosystem (i.e. protect spawning and nursery areas permanently or temporarily) (PRC, 2011).

4.4.10.2 Potential stakeholders (out of the fisheries activities)

The stakeholders listed in Table 4.55 are included based on their competences in the field of (maritime) spatial planning, maritime activities/policy and environmental protection. Research centers and other stakeholders providing information for the implementation of maritime policy are also listed.

Table 4.5. Relevant stakeholders in the marine Adriatic area (Source: PRC, 2011)

		Italy	*Slovenia*	*Croatia*
Public authorities	*National*	Ministry of the Environment, Land and Sea Ministry of Infrastructure and Transport Ministry of Agriculture and Fisheries Ministry of Defence	Ministry of the Environment and Spatial Planning, Spatial Planning Directorate Ministry of Agriculture, Forestry and Food Ministry of Economy Slovenian Maritime Administration Ministry of Transport	Ministry of Environmental Protection, Physical Planning and Construction Ministry of the Sea, Transport and Infrastructure Ministry of Economy, Labour and Entrepreneurship Ministry of Agriculture, Fisheries and Rural Development
	Regional / local	Ordinary regions (i.e. Emilia-Romagna, Veneto) Special regions (i.e. Friuli Venezia Giulia) (Coastal) Provinces (e.g. Provincia di Venezia) (Coastal) Municipalities	(Coastal) municipalities: Koper, Izola and Piran	(Coastal) regions / counties: Istrian, Primorje-Gorski Kotar, Lika-Senj, Zadar, Sibenik-Knin, Split-Dalmatia and Dubrovnik-Neretva
Other stakeholders		ISPRA ARPA	Regional development agency South Primorska Institute of the Republic of Slovenia for Nature Conservation	Institute for Oceanography and Fisheries Centre for Marine Research Agency for the protection of the environment (AZO)

Italy

Stakeholder involvement in territorial management is mandatory. All the territory management tools have to be developed through (PAP/RAC, 2007a): 1) Institutional agreement phases; 2) Stakeholders consultation; 3) Face-to-face conversations with directly involved people and participation of people who are interested. The abovementioned required involvement of stakeholders shows that authorities should include stakeholders in territorial management plans and thus incorporate their opinions in an early stage. Consequently, if MSP would be developed, a similar approach is likely to be adopted. Formally, the involvement of different levels of authorities is common given the division of responsibilities between national and regional authorities. For example, the Ministry of Environment, Protection of the Territory and the Sea (Directorate for Sea Protection) activated a consultation process with the coastal regions in order to define a national ICZM strategy as well as related planning and implementing projects (such as a CAMP project). However, up until today no national ICZM strategy has been developed.

Slovenia

The Spatial Planning Act (2007) details the spatial planning process and lays down the stipulations for coordination and involvement of stakeholders at the national level. The following steps ensure a coordinated and transparent approach at all planning levels (PAP/RAC, 2008a):

- The producer of a plan (Ministry of the Environment and Spatial Planning or municipality)[22] prepares a draft (national) spatial plan;
- The spatial planning stakeholders provide the guidelines within their competences on this basis of which the producer complements the draft;
- The producer must acquaint the public with the draft (national) spatial plan through public exhibition (lasting 30 days) and ensure a public debate; amended (national) spatial plan is put on a public exhibition, followed by a public debate;
- The producer prepares an amended (national) spatial plan and asks for the opinions of the spatial planning stakeholders;

[22] Whether the Ministry of the Environment and Spatial Planning or the municipalities draft spatial plans depends on the type of spatial plans

- The producer finalizes the draft (national) spatial plan and submits this to the Government[23] or the Municipal Council[24] for adoption.

During the PlanCoast project, it was proposed to develop the Marine Spatial Plan as a separate 'national strategic spatial plan'(PRC, 2011). In this case, it would be the Ministry of the Environment and Spatial Planning who would draft the Marine Spatial Plan and the Government who would finally adopt the Marine Spatial Plan. The procedure would ensure coordination between stakeholders and involvement of the public and local communities when new spatial arrangements at sea are being developed. Consequently, new developments at sea would be planned in a participatory and transparent manner. Such a procedure is also used when Environmental Impact Assessments are carried out.

Croatia

A certain level of integration and coordination among competent authorities with respect to spatial planning has been achieved in Croatia. Spatial plans are being coordinated at various levels (national, municipal and county level) to avoid conflicts between objectives, strategies and uses of land. Nevertheless, this applies almost exclusively to onshore spatial planning and the first 300 metres seawards. For the remaining part of the marine area, coordination among stakeholders is limited and a sectoral approach dominates (PRC, 2011).

4.4.10.3 Institutional and legal framework

An overview of the institutional and legal framework is presented in Table 4.6.

Table 4.6. Institutional and legal framework in the Northern Adriatic (Source: PRC, 2011).

	Italy	***Slovenia***	***Croatia***
Level of responsibility for coastal planning	State69	Municipalities	State Counties /
Responsible ministry for coastal planning	Ministry of the Environment, Land and Sea	Ministry for the Environment and Spatial Planning	Ministry of Environmental Protection, Physical Planning and

[23] In case the Ministry of the Environment and Spatial Planning was the producer of the plan

[24] In case the municipality was the producer of the plan

Legal basis for coastal planning	Regional Coastal Plans	National Spatial Planning Act (2007)	Act of Physical Planning and Construction (1994) Governmental Regulation on Development and Protection of Coastal
Level of responsibility for maritime planning	State Region	State	State
Responsible ministry for maritime planning	Sectoral ministries	Mainly the Ministry for the Environment and Spatial Planning	Sectoral ministries
Legal basis for Maritime Spatial		National Spatial Planning Act (2007)	

<u>Italy</u>

In 1982, following the fast development of human activities on the Italian coast, the Law on General Rules for Sea Protection was established. The law foresaw the creation of a sea and coastal defense plan for the whole national territory to be defined in agreement with the regions. Such national plan has not been elaborated so far. Instead, the government decided in 1998 to shift the main coastal competences from the state to the regions as the regions were considered more suited to implement planning policies and Integrated Coastal Zone Management. The regions have the commitment to evaluate the state of the environment, especially in inland and coastal areas. Moreover, they have to coordinate aquaculture and fishing activities although they depend on different ministries in relation to the coordination at national level. Consequently, there is no dedicated national legal framework for ICZM or MSP but some Italian coastal regions took the opportunity to develop their own Regional Coastal Plans and adequate laws which serve as regional planning instruments. In addition, the following national legislation is relevant to consider:

- The Urban Planning Law (N°1150/1942) regulates the building implementation and development in urban centers as well as in the territory; Italy has three levels of spatial planning, namely the regions, the provinces and the communes;
- Law on Marine Protected Areas (N° 394 of 1991) identifies and defines the activities in MPAs in order to ban those activities that could jeopardize the protection of the environment;
- Environmental Consolidated Act (N°152/06) foresees that the regions develop, in compliance with the European Water Framework Directive 2000/60, a Water

Protection Plan as this is a necessary regional instrument to achieve environmental targets as regards the environmental quality of superficial and sea water.

To date, however, the situation of coastal planning still seems to be characterized by fragmentation between the different levels of authority, namely the state, the regions and the communes (PAP/RAC, 2007a). With regard to Maritime Spatial Planning, the following ministries have related competences:

- The Ministry of the Environment, Land and Sea[1][25]: responsible for the management and protection of inland waters, the prevention of pollution and the protection of the sea and coastal environment;
- The Ministry of Infrastructure and Transport (MIT)[26]: responsible for all transport infrastructure and general transport planning and logistics; in addition, MIT governs maritime properties of national interest (e.g. sea defenses);
- The Ministry of Agricultural, Food and Forestry Policies (MIPAAF)[27]: responsible for the coordination of policies on aquaculture and fisheries; in addition, the Ministry manages fisheries resources;
- The Ministry of Defence[28]: responsible for the defence of the Italian territory, including the marine areas.

Table 4.7 provides insight into the competences of the regions related to MSP.

[25] Ministry of the Environment, Land and Sea, www.minambiente.it, art. 36, DLGS 300/1999

[26] Ministry of Infrastructure and Transport, www.mit.gov.it, art. 42, DLGS 300/1999

[27] Ministry of Agricultural, Food and Forestry Policies, www.politicheagricole.it, art. 33, DLGS 300/1999

[28] Ministry of Defence, www.difesa.it, art. 19 – 20, DLGS 3000/1999

Table 4.7. Responsibilities regarding Italian regions (Source: PRC, 2011).

Public body	*Responsibilities (related to maritime*	*Related legislation*
Ordinary regions (e.g. Emilia-Romagna and Veneto)	Maritime networks and ports (only small ports) Administration of maritime (e.g. sea defences) and riverine / lake properties (when used for tourist purposes) Protection of environment, establishment and management of reserves at regional level Management and protection of inland waters Navigation in inland waters	Art. 117 Constitutional Law, as modified in art. 3 Constitutional Law 18 October 2001 n. 3 Art. 59 of DPR 616/1977 Art. 83 of DPR 616/1977 Art. 91 of DPR 616/1977
Special regions (e.g. Friuli Venezia Giulia)	Responsibilities listed above Fisheries, aquaculture and	Art. 4 Constitutional Law January

Slovenia

In Slovenia, spatial plans are being developed at the national and municipality level. Coastal as well as Maritime Spatial Planning has always been the responsibility of the municipalities. In their spatial plans, the municipalities covered both coastal and a number of sea uses. Following the adoption of the Spatial Planning Act of 2007, the responsibility for Spatial Planning was shifted from the municipalities to the state, more specifically the Ministry of Environment and Spatial Planning, the Spatial Planning Directorate. Although the act does not specifically address Maritime Spatial Planning, its regulations may also be applied to the entire Slovenian marine area. Consequently, substantial legislative changes are not necessary to enhance Maritime Spatial Planning in Slovenia (PAP/RAC, 2008a).

The Spatial Planning Act provides for three types of spatial plans: national, municipal and inter- municipal[29] plans. At all levels, a strategic as well as a detailed plan can be established. The coastal zone has not been defined in Slovenia; part of South Primorska, covering the municipalities of Koper, Izola and Piran, is considered as the coastal area. As a result, planning of the coastal area forms part of the (inter-)municipal plans of Koper, Izola and Piran in accordance with the objectives and directives of the national strategic master plan. On the basis of the Spatial Planning Act, a Maritime Spatial Plan could form part of the overall national strategic spatial plan or being undertaken in the form of a separate national strategic maritime plan (PAP/RAC, 2008a). Besides the Spatial Planning Act, the following Slovenian legislation is relevant to consider in the framework of applying Maritime Spatial Planning (PAP/RAC, 2008a):

- Spatial planning of arrangements of national significance Act[30] (Zakon o umeščanju prostorskih ureditev državnega pomena v prostor (ZUPUDPP) - Official gazette of the Republic of Slovenia, nr. 80/10). The spatial arrangements at the sea are recognized as spatial arrangements of national significance.
- Waters Act ("Zakon o vodah" (ZV-1) - Official gazette of the Republic of Slovenia, nr. 67/02, amendments: Official gazette of the Republic of Slovenia, nr.110/02-ZGO-1, 2/04-ZZdrI-A, 41/04-ZVO-1, and 57/08) - Governs the management of marine, inland and ground waters, and the management of water and waterside land; this comprises the protection of waters, the regulation of waters and decision-making on the use of waters;
- Environmental Protection Act ("Zakon o varstvu okolja" (ZVO-1 UPB1) - Official gazette of the Republic of Slovenia, nr. 41/04, amendments: Official gazette of the Republic of Slovenia, nr.17/06, 20/06, 28/06 Skl.US: U-I-51/06-5, 39/06-UPB1, 49/06-ZMetD, 66/06 Odl.US: U-I- 51/06-10, 112/06 Odl.US: U-I-40/06-10, 33/07-ZPNačrt, 57/08-ZFO-1A, 70/08, and 108/09)

[29] Regions have not been established in Slovenia; the 2007 Spatial Planning Act does not encourage a regional spatial planning approach but only inter-municipal cooperation in the field of spatial planning and environmental infrastructure in particular

[30] Official translation of Act is not yet available

- Nature Conservation Act ("Zakon o ohranjanju narave" (ZON-UPB2) - Official gazette of the Republic of Slovenia, nr. 56/99 (31/00) amendments: Official gazette of the Republic of Slovenia, nr.110/02-ZGO-1, 119/02, 22/03-UPB1, 41/04, 96/04-UPB2, 61/06-ZDru-1, 63/07 Odl.US: Up- 395/06-24, U-I-64/07-13, 117/07 Odl.US: U-I-76/07-9, 32/08 Odl.US: U-I-386/06-32, and 8/10-ZSKZ-B): Provides the measures for the preservation of biotic diversity and the system of valuable natural features protection with the aim to contribute to the conservation of nature;
- Maritime code ("Pomorski zakonik" (PZ- UPB2) – Official gazette of the Republic of Slovenia, nr. 26/01, amendments: Official gazette of the Republic of Slovenia, nr. 21/02, 110/02-ZGO-1, 2/04, 37/04-UPB1, 98/05, 49/06, 120/06-UPB2); Regulates the sovereignty, jurisdiction and control of the Republic of Slovenia over the sea, navigational safety in territorial waters and internal waters, protection of the sea against pollution from vessels and legal regime of ports;
- Marine Fisheries Act ("Zakon o morskem ribištvu" (ZMR-2) - Official gazette of the Republic of Slovenia, nr. 115/06): Lays down goals and measures in marine fishery.

For spatial planning, the Ministry of the Environment and Spatial planning, Spatial planning Directorate is responsible at the national level, the municipalities at the local level:

- The state is competent to determine the objectives of spatial development, determine the policies and guidelines for spatial planning at all levels, plan spatial arrangements of national significance and supervise the legality of spatial planning at the municipal level;
- Municipalities are competent to determine the objectives and guidelines for spatial development at local level, determine the land-use and set the conditions for spatial development and plan spatial arrangements of local importance at terrestrial level.

As regards Maritime Spatial Planning, the competence lies with the state and not with the municipalities. The sea is defined as national public good. All proposed spatial interventions are therefore a matter of national spatial planning according to the Governmental Decree on the types of spatial arrangement of national significance issued on the basis of the Spatial

Planning Act 2007. Besides the Ministry of the Environment and Spatial Planning, the following ministries have competences related to Maritime Spatial Planning[31]:

- Ministry of the Environment and Spatial Planning: policy making and implementation with regard to nature conservation and spatial planning; the ministry conducts the spatial planning procedures and strategic environmental assessment of plans and programmes;
- Ministry of Agriculture, Forestry and Food: policy making, implementation and licensing concerning fisheries and aquaculture; the ministry also takes a role as stakeholder in the spatial planning processes, responsible for natural resources (land, soil, forest);
- Ministry of Economy: policy making, implementation and licensing concerning offshore oil and gas; the ministry also takes a role as stakeholder in the spatial planning processes (energy);

- Slovenian Maritime Administration: licensing with regard to shipping and cruise tourism;
- Ministry of Transport: policy making and implementation with regard to cruise tourism and shipping; the ministry also takes a role as stakeholder in the spatial planning processes (road, rail, air and marine transport).

At regional level, the Regional Development Centre Koper (RDC Koper) should also be taken into account. It aims at promoting business and economy development in the region. It performs the role of regional coordinator of interests on local as well as national level in the fields of regional development, economy, human resources and environment protection. RDC Koper gained the status of leading organisation of the Regional Development Agency South Primorska for the municipalities of Divača, Hrpelje-Kozina, Ilirska Bistrica, Izola, Komen, Koper, Piran and Sežana in 2001. Consequently, RDC Koper became a permanent

[31] Slovenian Maritime Administration, www.up.gov.si/en; Slovenian Ministry of Agriculture, Forestry and Food, www.mkgp.gov.si/en; Slovenian Ministry of the Economy, www.mg.gov.si/en; Slovenian Ministry of the Environment and Spatial Planning, www.mpo.gov.si/en; Slovenian Ministry of Transport, www.mzp.gov.si/en

representative of ministries, governmental organisations, chambers of commerce and craft, companies and other institutions.

Croatia

MSP and coastal spatial planning is at present mainly a national affair. Although the Ministry of Environmental Protection, Physical Planning and Construction prepared the National Spatial Planning Strategy (1997) and the National Spatial Planning Programme (1999)[32] and monitors the implementation of physical planning and coordinates the licensing of development permits, the regulatory system that governs the sea area is still characterised by a sectoral approach. This is the consequence of the absence of a legal framework for MSP (PAP/RAC, 2007b). The following ministries should be taken into account with regard to MSP:

- Ministry of Economy, Labour and Entrepreneurship, Directorate for Energy;
- Ministry of the Sea, Transport and Infrastructure;
- Ministry of Agriculture, Fisheries and Rural Development;
- Ministry of Tourism.

In Croatia, there is no direct MSP legislation, nor any spatial planning or coastal law which can also be applied to the sea. Existing laws and regulations relevant in the framework of MSP are limited to a number of sectoral laws and regulations.

Important laws in this respect include the Maritime Code (1994 and 1996), the Shoreline and Marine Harbours Law (2003), the Law on Marine Fishery (1994) and the Law on the Protection of Nature (2005) which regulated the establishment of MPAs (PAP/RAC, 2007b).

One exception is the 300 m marine belt which is protected under the Act on Physical Planning and Construction (1994) and the Government Regulation on Development and Protection of the Protected Coastal Area (2004). The coastal zone of 1 km landwards and 300 m seawards is considered as Protected Coastal Area in which restrictive conditions for construction apply as well as clear planning requirements (PAP/RAC, 2007b).

[32] The National Spatial Planning Strategy defines long-term objectives of the physical development and planning harmonised with the overall economic, social and cultural development; the Spatial Planning Programme defines measures and activities towards the implementation of the Spatial Planning Strategy

4.4.10.4 Cross-border/international cooperation and consultation

The Adriatic countries are involved in a number of initiatives/projects which could help facilitate the dissemination of the concept of Maritime Spatial Planning as a cross-border/international tool to solve competition between maritime activities (and their environmental impact).

a) Trilateral Commission for the protection of the Adriatic[33]

The Trilateral Commission for the protection of the Adriatic originates from the bilateral commission between Italy and Yugoslavia (1974), which was re-launched in 1992, including Italy, Croatia and Slovenia. Montenegro has recently become a member of the initiative. Even though the other Adriatic countries – Albania and Bosnia and Herzegovina – do not form part of the Trilateral Commission, their interest in activities conducted by the Trilateral Commission was expressed. They were invited for – and attended – the last meetings of the Trilateral Commission. The main goal of the Trilateral Commission is the protection of the Adriatic Sea and coastal areas against pollution. Therefore, the Commission: 1) studies all problems related to the pollution of the Adriatic Sea waters and coastal areas; 2) does propositions and recommendations to the government related to the research needed; 3) is engaged in introducing measures required to eliminate the current pollution and prevent new causes of pollution. The Trilateral Commission presents the adequate institutional framework for the cooperation of the Adriatic states in the field of marine environmental protection. Moreover, the work of the Trilateral Commission has proved to be an efficient model, housing different aspects of marine environmental issues and providing for appropriate response to new challenges. Consequently, the Trilateral Commission is believed to be the instrument to come to a common vision – a long-term Maritime Spatial Planning strategy – with regard to cross-border/international Maritime Spatial Planning in the (Northern) Adriatic. The 10th meeting of the Trilateral Commission in June 2009 discussed:

- The current marine environment protection topics;
- Ballast water management in the Adriatic Sea;

[33] Ministry of Environmental Protection, Physical Planning and Construction, www.mzopu.hr; Organization for Security and Co-operation in Europe, 2008; The Organisation for Security and Co-operation in Europe, 2008, Plenary Session III – Experiences in maritime co-operation in the Mediterranean Region

- Implementation of the Sub-Regional Intervention Plan for Cases of Sudden Adriatic Sea Pollution;
- EU Marine Strategy Directive;
- The integrated management of coastal areas and safe harbours.

The members emphasized the importance of coordination and synergy of all activities in the Adriatic for the purpose of its efficient protection and sustainable development.

b) Adriatic-Ionian Initiative[34]

The Adriatic-Ionian Initiative (AII) was established as a political initiative at the Conference on Safety and Development of the Adriatic and Ionian Sea, held in Ancona (Italy) in May 2000. This platform for cross-border/international cooperation includes representatives of Albania, Bosnia and Herzegovina, Croatia, Greece, Italy, Montenegro, Serbia and Slovenia.

The AII links the coastal countries of the two seas (Adriatic and Ionian) for the purpose of cooperation in the development and safety of the whole area. Its objectives are achieved by cooperation in different fields: tourism, transport, maritime affairs, culture, education as well as environmental protection and sustainable development. The issues of environmental protection and maritime safety (e.g. high sensitivity of the maritime and coastal areas of the enclosed Adriatic Sea) are central for socio-economic development in the sub-region.

Its organizational structure consists of the Adriatic-Ionian Council, the Council of Senior Officials and round table meetings. It could provide a good basis for high-level dissemination of the advantages and benefits of cross-border/international Maritime Spatial Planning and for the development of strategies and actions in the region.

The Adriatic-Ionian Initiative dealt and deals with among others:

- The Adriatic Action Plan, adopted in 2003;
- Contingency plan for the Adriatic, including a Sub-regional Contingency Plan for the Northern Adriatic (Slovenia, Italy and Croatia), to be coordinated by the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC);

[34] Ministry of Environmental Protection, Physical Planning and Construction, www.mzopu.hr; The Adriatic Sea Partnership, http://asp.rec.org

- Proposal for the designation of the Adriatic Sea as a Particularly Sensitive Sea Area (PSSA)[35];
- Strategic Environmental Assessment of Maritime Activities including Ballast Water Issue[36];
- Integrated Coastal Zone Management.

c) Adriatic Euroregion[37]

The Adriatic Euroregion (AE) was founded on June 30, 2006 in Pula, Region of Istria, Croatia for transnational and interregional cooperation between regions of the Adriatic coastline. The Adriatic Euroregion is the institutional framework for jointly defining and solving important issues in the Adriatic area. It consists of 26 members - regional and local governments from Albania, Bosnia and Herzegovina, Croatia, Greece, Italy, Montenegro and Slovenia.

The aims of the AE are the following:

- Forming an area of peace, stability and co-operation;
- Protection of the cultural heritage;
- Protection of the environment;
- Sustainable economic development in particular of tourism, fishery and agriculture;
- Solution of transport and other infrastructure issues.

The Adriatic Euroregion is divided in 6 technical Commissions, namely for:

- Tourism and culture;
- Fisheries;
- Transport and infrastructure;
- Environment;
- Economic affairs;
- Welfare.

[35] A Particularly Sensitive Sea Area (PSSA) is an area that needs special protection through action by IMO because of its ecological or socio-economic or scientific significance and which may be vulnerable to damage by international maritime activities

[36] The introduction of invasive marine species into new environments by ships ballast water, attached to ships hulls or via other vectors was identified as one of the four greatest threats to the seas

[37] Regione Emilia-Romagna, 2009, Shape (Shaping an Holistic Approach to Protect the Adriatic Environment: between coast and sea), Bologna

The Commission for Environment is led by the Emilia-Romagna region and aims to identify common policies and joint projects to promote the sustainable development of the Adriatic area. In 2008 the Commission adopted an Integrated Strategy for the environmental protection of the Adriatic Region where Coastal Zone Management and Maritime Spatial Planning are defined as strategic objectives.

The following reasons for the need of ICZM and MSP in the Adriatic region have been expressed by the AE:

- Coasts and sea are strategic for the well-being and prosperity of the Adriatic Countries;
- Human activities tend to develop in coastal and marine areas competing with each other and with protection needs of habitats and landscapes;
- Many issues transcend national borders; sharing a common approach to the management of marine space in the same sea basin will make it easier to meet global challenges.

The Trilateral Commission and the Adriatic Ionian initiative – given the good relationships between the different member and non-member countries and their fields of action/expertise – could be deemed important drivers for the establishment of cross-border/international MSP in the Adriatic region. The Adriatic Euroregion also seems to be a qualified initiative through which MSP could be applied to the Adriatic Sea. This initiative is sector-neutral and includes both environmental and economic objectives. MSP initiatives should be neutral, meaning that the initiative should not only target at environmental protection or the development of one or more particular economic activities. Instead, it should have a holistic ecosystem-based approach that aims at sustainable development of maritime activities. In that respect, the Trilateral Commission is primarily focused on protection of the marine environment and therefore seems less qualified. A disadvantage of AE is that only coastal regions are members; there are no participants from national authorities. Since national authorities are also responsible for maritime affairs, they need to be involved in cross-border/international initiatives for the application of MSP.

Other cross-border/international projects are being proposed in the framework of the IPA (Instrument for Pre-Accession Assistance) Adriatic Cross-border Cooperation Programme.

The following section provides information about this programme and some of the project proposals with relevance to MSP.

d) IPA (Instrument for Pre-Accession Assistance) Adriatic Cross-border Cooperation Programme[38]

The IPA instrument seeks to provide targeted assistance to countries which are candidates or potential candidates for membership of the EU rationalising Pre-Accession Assistance by replacing the various instruments which previously existed for the assistance. IPA prepares, inter alia, candidates for the implementation of Structural and Cohesion Funds and Rural Development on accession, by specifically supporting institution building and introducing procedures as close as possible to the Structural Funds. Cross-border cooperation between candidate countries/potential candidate countries and between them and the Member States is supported by the IPA Component II (the Cross- border cooperation component). Within this programme, the proposals Shape, COAS and IMaGe have been submitted. The Shape project has been approved and selected provisionally as a funded project. Although the other project proposals have not (yet) been adopted, they show that initiatives with relevance for MSP are undertaken.

A. Shape

The Emilia-Romagna region has submitted a project proposal called 'Shape' (Shaping a Holistic Approach to Protect the Adriatic Environment) under the first call of the IPA (Instrument for Pre-Accession Assistance) Adriatic Cross-border Cooperation Programme (2007-2013). The Shape 'project' is to be a cross-border/international cooperation project aiming at the sustainable development of the Adriatic Maritime Region and consequently aims to promote the rational use of the sea and its resources through an integrated approach. The project furthermore aims at creating a multilevel cross-sector governance system, able to solve competition between different uses. In addition, the project focuses on ICZM and MSP and offers the opportunity to develop adequate tools supporting spatial planning in the whole Adriatic Basin.

[38] Annual Report on the implementation of the IPA Adriatic Cross-Border Cooperation Programme (www.adriaticipacbc.org)

According to the project proposal, the objectives/tasks of an Adriatic project on MSP ('Shape') are:

- To make human activities in coastal and marine areas more sustainable;
- To manage competition between different uses and support the decision-making process;
- To improve the institutional framework, the stakeholders involvement and the public awareness;
- To strengthen the role of ICZM in the Adriatic Sea basin and to prepare the ground for national and local strategies;
- To promote MSP in the Adriatic Sea basin according to the MSP key principles;
- To reach a high level of coherence between planning in coastal areas and planning in maritime spaces, binding ICZM and MSP;
- To share data and experience as a common base of knowledge allowing the coherent and conscious governance of the coastal and marine environment;
- To develop a coherent picture of the Adriatic Sea and contribute to EMODNET (European Marine Observation and Data Network).

B. CAOS (Coordinated Adriatic Observing System)

Within the IPA Adriatic Cross-border Cooperation Programme (2007-2013), the CAOS project has been proposed. The CAOS project is a cross-border/international initiative between Italy (Emilia Romagna, Veneto, Friuli Venezia Giulia), Slovenia and Croatia. The aim is the creation of an Observatory for the protection of the marine and coastal environments in the Adriatic-Ionic basin, which will support decision makers. The North Adriatic Coastal Observatory will be a permanent network between public authorities, aimed at providing timely and continuous information to all bordering countries on the state of the sea. The final aim of the Observatory is to guarantee integration of all activities and initiatives at local and cross-border level in order to provide a homogeneous and coherent action on the Northern Adriatic.

C. IMaGe

This project proposal involves 31 parties representing national environmental ministries, public institutions, research institutes, universities and regional authorities from Italy, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Albania and Corfu (Greece). The objectives are:

- To share data and experiences as a common base of knowledge, thus allowing a coherent and conscious governance of the coastal-marine environment;
- To enhance the sustainability of the activities occurring in the Adriatic coastal and marine areas by improving institutional building and public awareness in the Adriatic area;
- To promote a model of governance of the marine and coastal environment through the application of Integrated Coastal Zone Management (ICZM) in the Adriatic Region;
- To promote a new instrument of Maritime Spatial Planning in the Adriatic Sea as a tool for achieving international consensus on the future use of maritime and coastal surfaces, bearing in mind growing pressures and related conflicts;
- To contrast damaging phenomena, both natural and caused by human actions, as eutrophication, coastal erosion, salt-intrusion, diffusion of invasive species, subsidence and sea level raising.

4.4.10.5 Coherence between terrestrial and maritime spatial planning

Italy

According to the Constitutional Law, regions are responsible for spatial planning of the coast. Since there is no national ICZM strategy, several regions (Liguria, Marche, Tuscany and Emilia-Romagna) have developed their own Coastal Plan, examining the present condition of their coasts. All this has been realized based on the awareness that coastal governance required a methodological planning instrument, instead of the ‘urgent measures’ adopted in the past. At present, the Italian regions have not yet developed any Maritime Spatial Plan. Nevertheless, the Coastal Plan involves several sectors: coastal protection, beach nourishment, marinas, coastal traffic issues, recovery and re-organization of urbanized tracts and development of public and tourist facilities in the coastal area. Emilia-Romagna Region has developed and adopted, by Council Act n. 645 of 20 January 2005, the ICZM Regional Strategy that represents the tool to address all activities affecting the coastal area towards economic, social and environmental sustainability.

The ICZM Plan is based on an integrated and multi-sector approach considering nine thematic areas (PAP/RAC, 2007a):

- Physical system, defense strategy;
- Integrated water management at basin scale;
- Port, transport, navigation related risks and management;
- Enlargements of natural habitats and improvement of biodiversity;
- Sustainable tourism;
- Fishing and aquaculture;
- Sustainable agriculture;
- Energy policy;
- Coastal urbanization and transport.

This specific ICZM strategy shows that maritime activities are included and therefore coherence between strategies for land and sea is present in a number of cases. Nevertheless, awareness of the importance of coherence between terrestrial and marine planning needs to be increased in the other Italian regions as well.

Slovenia

In Slovenia, legislation provides for the integration of the management of land and sea areas. Concrete examples towards such an attempt exist, indicating the government's will to achieve coherence between terrestrial and Maritime Spatial Planning (PRC, 2011). The most prominent example of land-sea integration in Slovenia is related to the requirements of the EU Water Framework Directive. Under this Directive, it is required to put in place River Basin Management Plans by 2013. The Waters Act – which provides for the implementation of the EU Water Framework Directive in Slovenia – prescribes the Water Management Plan for Aquatic Areas (or detailed water management plans). The Minister must provide its consent on each draft detailed water management plan that is submitted in order to ensure co-ordination with spatial planning and other sectoral plans[39]. Moreover, the Water Council – which consists of the representatives of local communities, the holders of water rights and non-governmental organizations – ensures the participation of public and stakeholders (PRC,

[39] The Minister's consent ensures that the spatial plan is in compliance with river basin management plans and with the Water Act

2011). In addition, the Ministry of Environment and Spatial Planning indicated to be in favor of approaching the different EU directives' requirements in an integrated (cross-border/international) manner, together with Italy and Croatia. In that case, the Trilateral Commission is seen as a platform through which such an approach could be introduced (PRC, 2011).

Croatia

In Croatia, integration between terrestrial and maritime planning is likely to be existent (theoretically) for the 300 meter marine belt as this forms part of the Protected Coastal Area. For the remaining parts of the marine area, it is the sectoral approach that dominates. The Act on Physical Planning and Construction (1994) and the Government Regulation on Development and Protection of the Protected Coastal Area (2004) prescribe cooperation between coastal stakeholders and thus different sectors. These acts however do not apply to the marine area, which implicates that integration between land and sea in terms of development and planning remains limited (PRC, 2011).

5. CUMULATIVE CONSTRAINS ASSESSMENT IN THE ADRIATIC SEA

5. CUMULATIVE CONSTRAINS ASSESSMENT IN THE ADRIATIC SEA

5.1 Cumulative value assessment method

The thematic maps were created on the ArcGis 10.2 platform, when and how much as possible using geo-referenced data or custom referenced using the literature data and partner reports (in particular Albania, Montenegro, CETMA, Veneto Agricoltura, Emilia-Romagna, Marche Region, Abruzzi Region, Molise Region, Apulia Region). Some of these maps concerned birds, mammals, reptiles, protected areas (Natura2000, EMERALDS, SCIs etc.), (when possible) benthic communities under some sort of protection, ports, fisheries, naval routes, contaminated areas, cables and underwater structures, and any sort of information available or "obtainable" from the literature that could influence the installation of offshore wind farms. Data in literature or reports with no way of geo-referencing was not included.

For the assessment exercise, each impact, limitation or penalty was scored 1 and strengths or positive weights were assigned 0; eventual impacts that were time or scale or spatial dependent (e.g. noise, depth, migration) were scored 0.5 or scaled up or down depending on the distribution and if necessary.

The maps were transformed as necessary to adapt the data to the tools that would be used, then framed and turned into raster files (with 0.01 size cells) to be able to apply spatial analysis tools (overlay). Raster coversion was based on a created integer in the Attribute Table named "CV" (cumulative value with 1 and 0 values) to extract the information useful for the weighted sum of the cumulative values (1/0) to identify the areas with higher cumulative values. As a result a higher number of critical issues to consider means a higher value in the weighted map and thus, potentially, larger and more difficult procedural cautions for offshore wind farms.

The initial rasters that were overlaid were 75 but the maximun overlay of raster layers was 22 with a minimum of 4. We stress here that for certain areas we were not able to get information so that we pinpoint that using a greater database with less NODATA areas would result in an increase of the potential limitations. We note also that those areas with high weighted sum value and a maximum score of 25 must be considered critical *per se*, as more than a third of the critical elements considered with this approach are currently occurring.

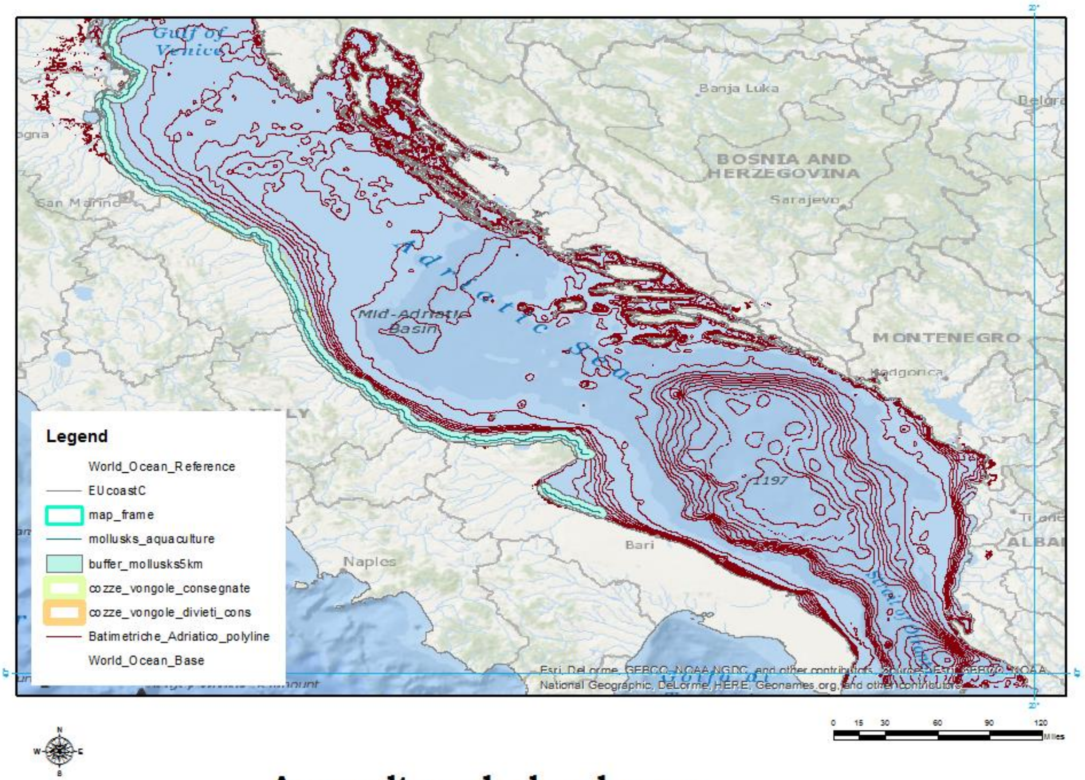
As we decided to avoid weighting the relative importance of the different issues considered, considering the limitedness of some layers and the lack of some information, **the condensed map provided in this report should not be interpreted rigorously as a tool to**

locate areas where offshore wind farms could be established. On the other hand, such map represents a preliminary tool to identify the cumulative number of (known and available) constrains that are present in a 1/0 validation in a determined pixel size (cells of 0.01).

5.2 Maps created under the cumulative value assessment process

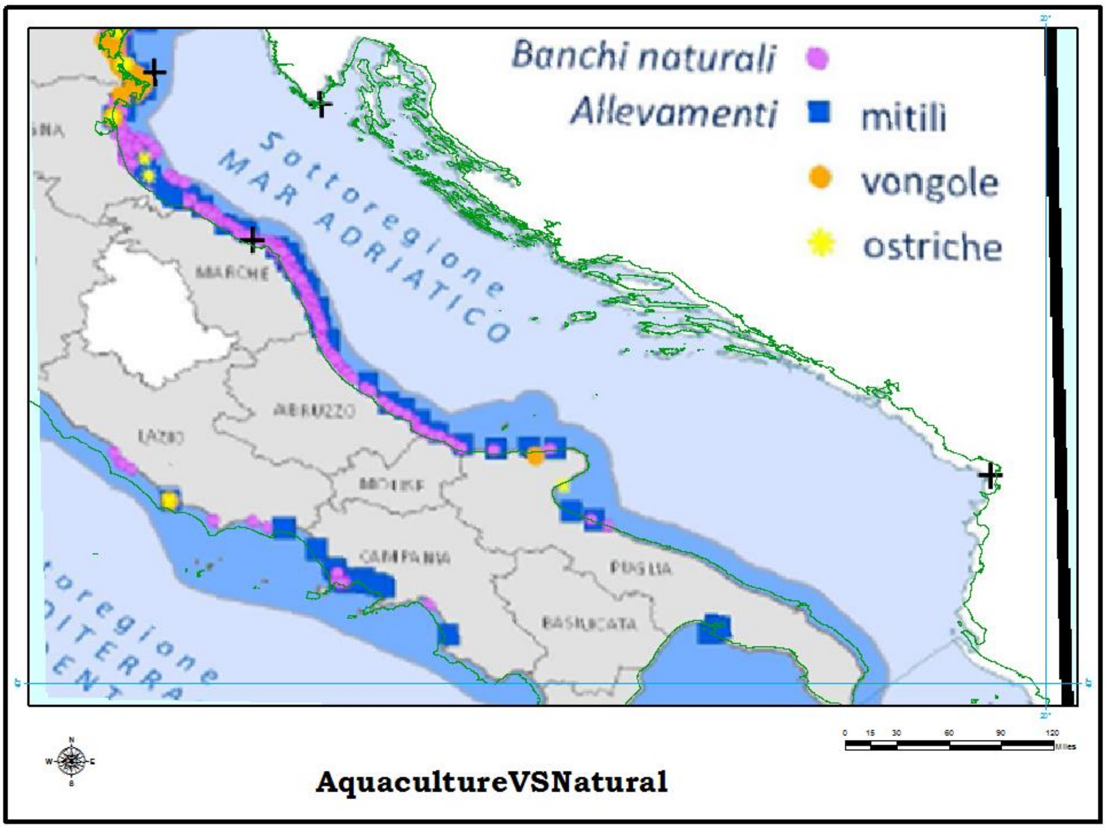
Maps considered for the overlapping exercise are reported below (Maps 1-16) and include information about: i) aquaculture, natural banks of edible mollusks, critical benthic habitats (coralligenous and *Posidonia oceanica*), birds, protected areas (at any level), elasmobranchs (sharks and rays), Emerald sites, oil exploration areas, fishing intensity, spawning fish, fish nurseries, turtles, mammals, existing platforms, ports plus and additive map with a number of *per se* critical areas.

Map 1 - Aquaculture

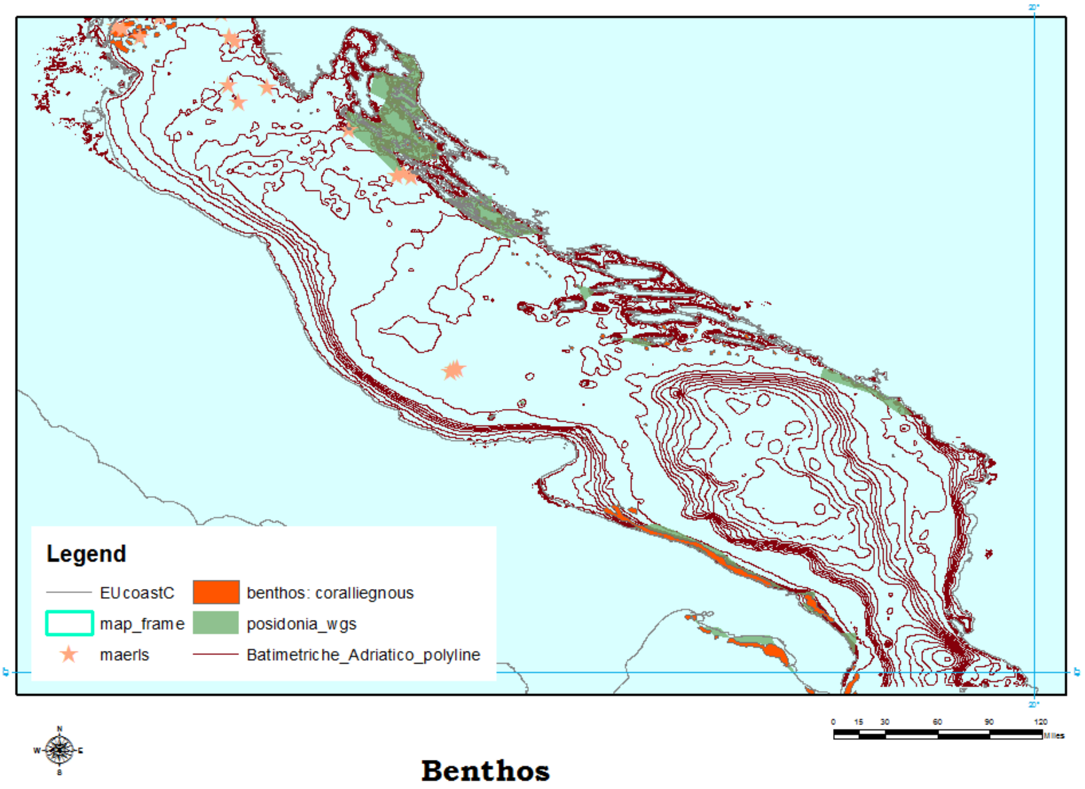


Aquaculture declared zones

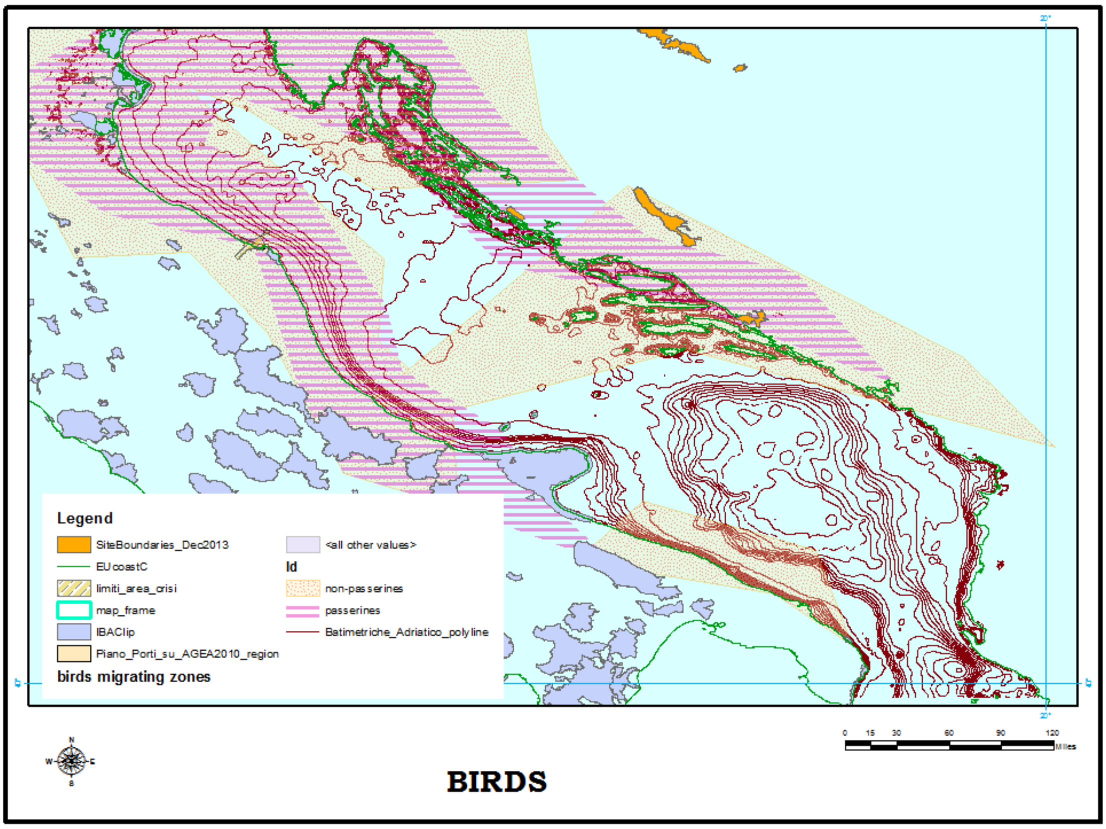
Map 2 - Aquaculture vs. natural banks



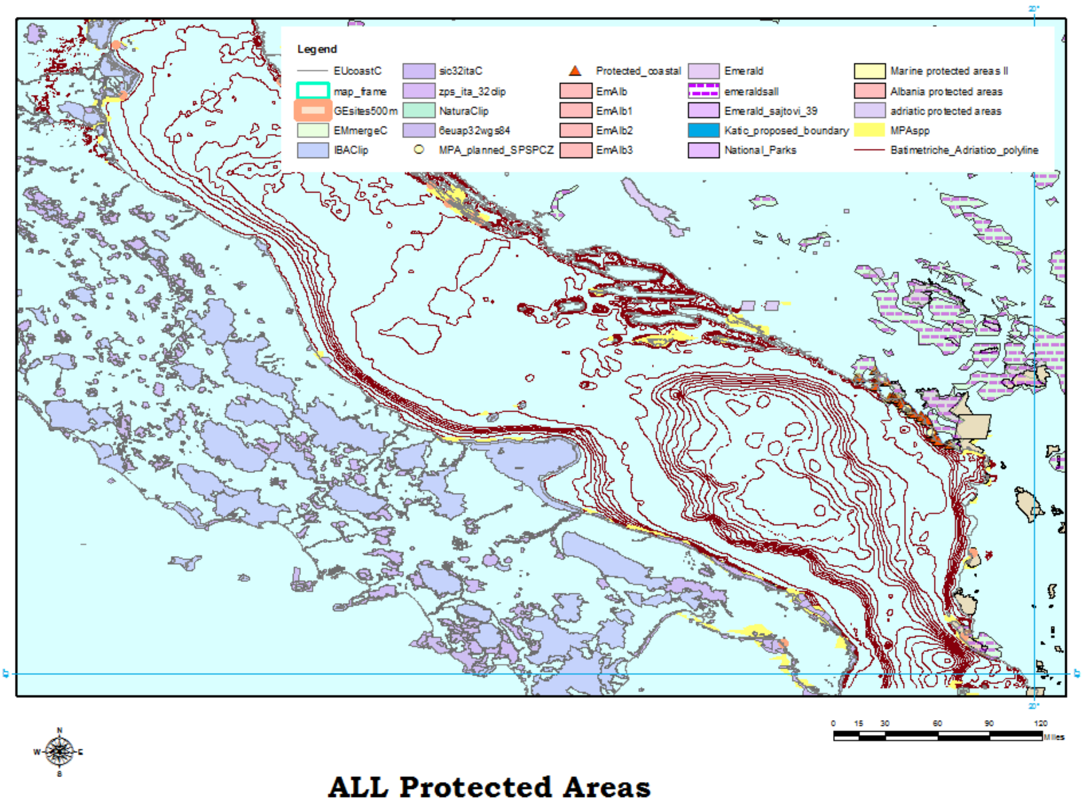
Map 3 - Critical benthic habitats



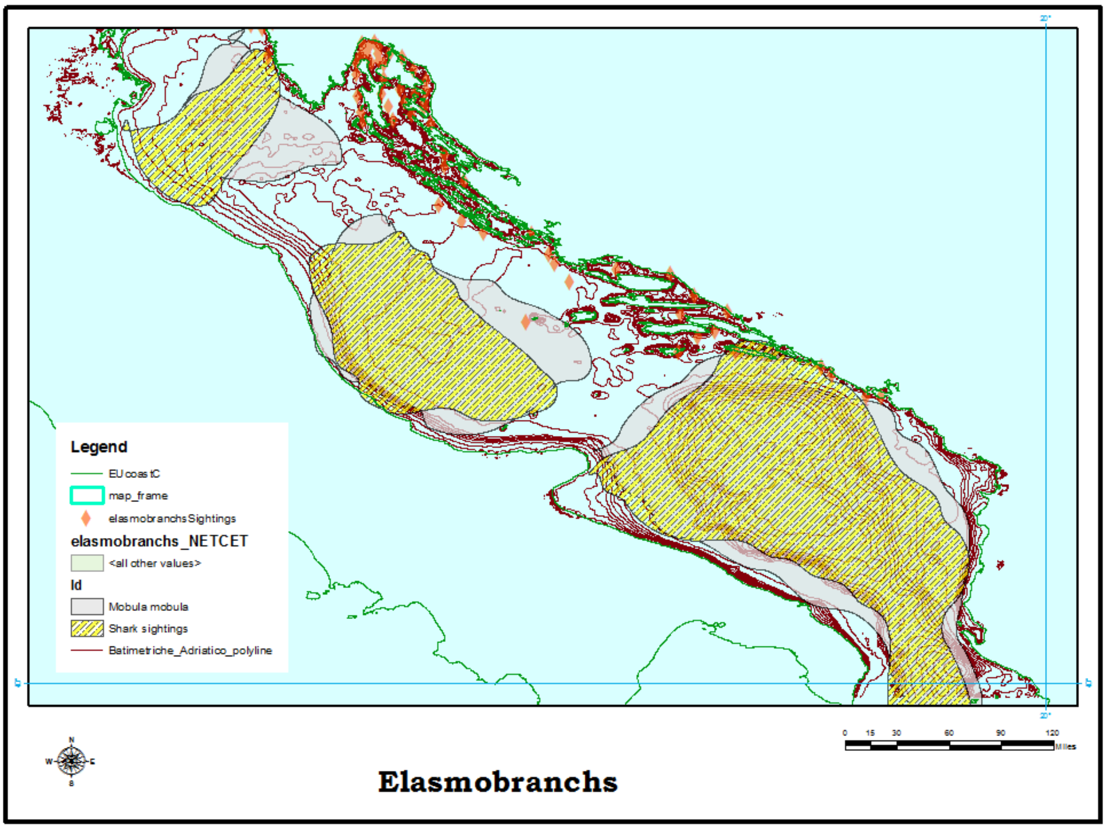
Map 4 - Birds


Legend
SiteBoundaries_Dec2013
EUcoastC
limiti_area_crisi
map_frame
IBAClip
Piano_Porti_su_AGEA2010_region
birds migrating zones
<all other values>
Id
non-passerines
passerines
Batimetriche_Adriatico_polyline
0 15 30 60 90 120
Miles
BIRDS

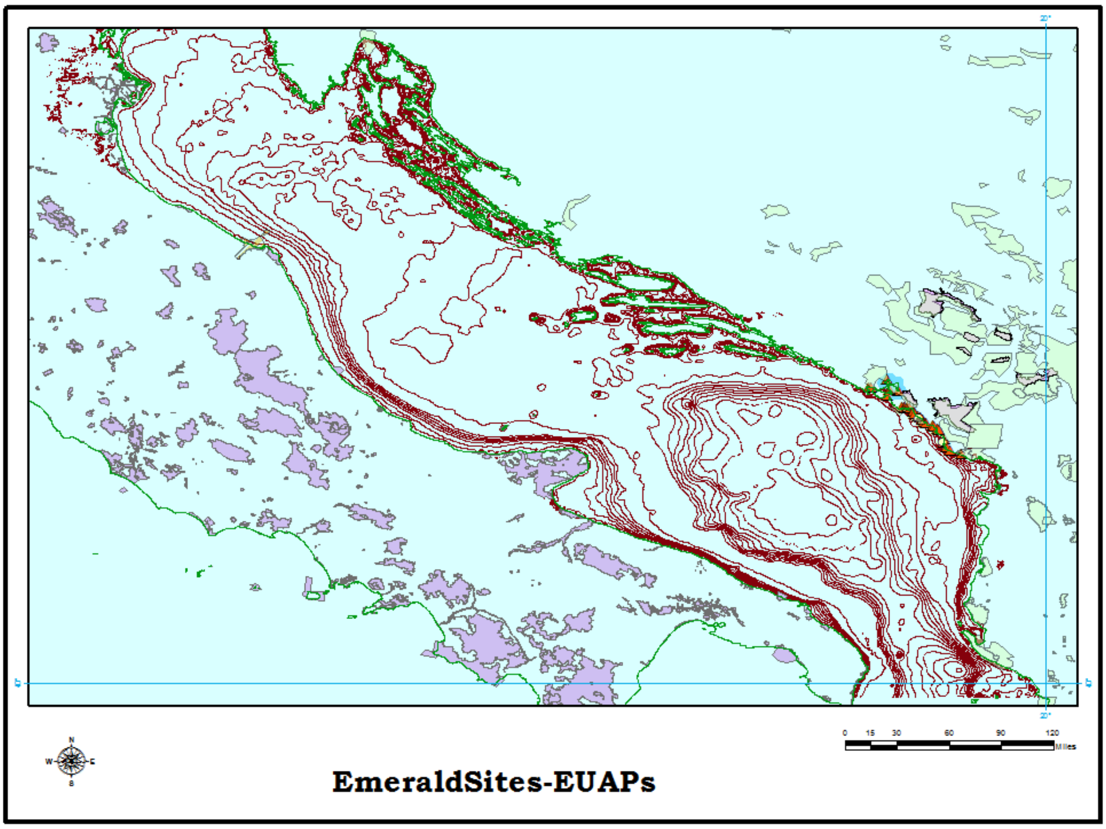
Map 5 - All protected areas in the Adriatic



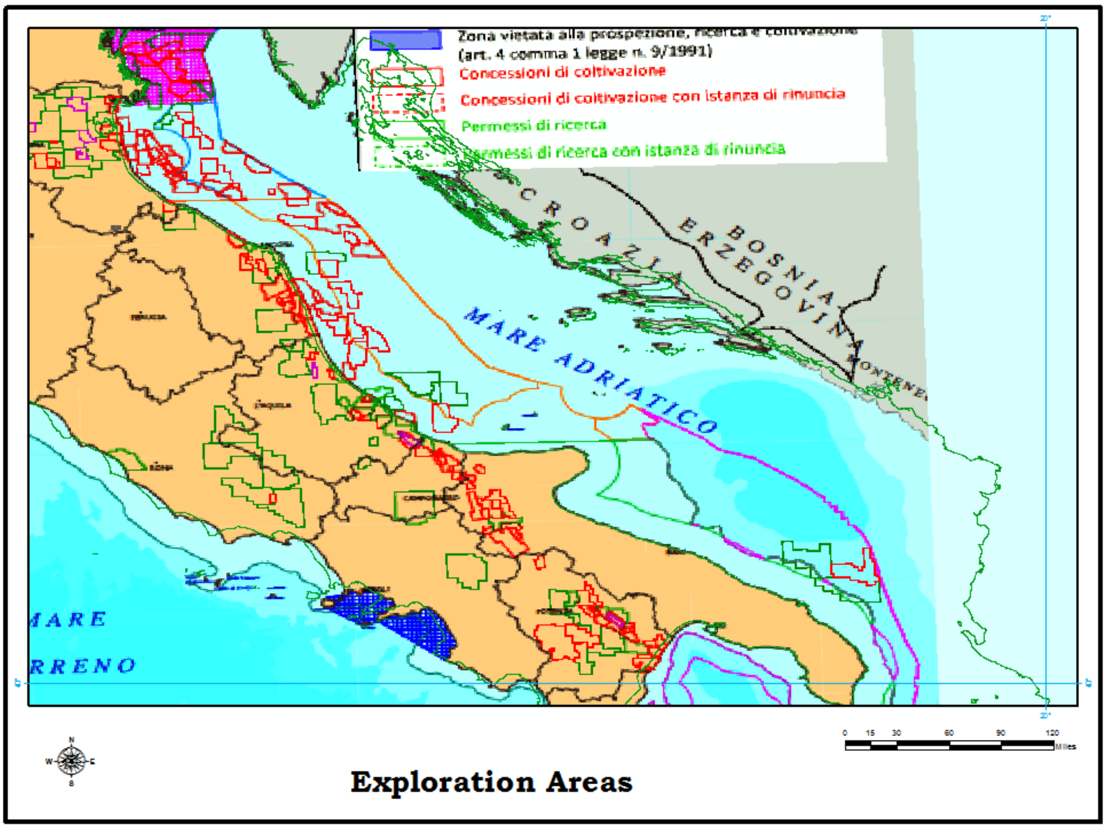
Map 6 - Elasmobranchs



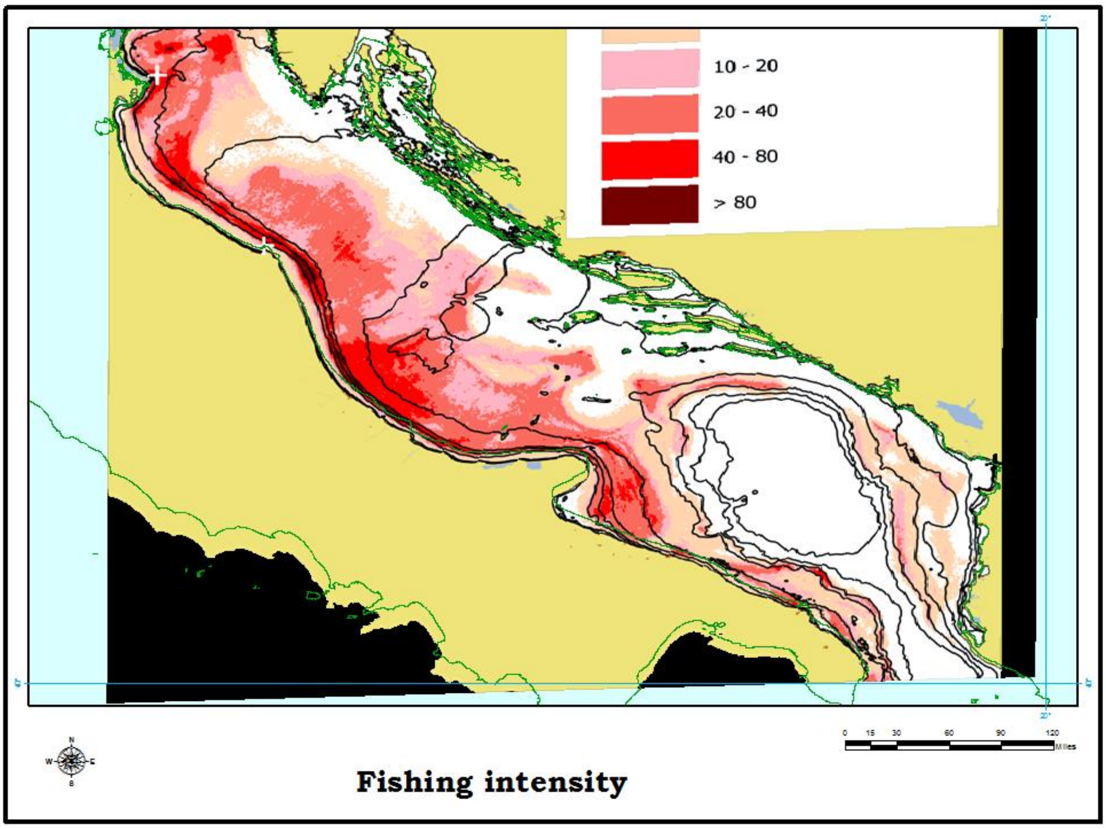
Map 7 - EUAP-Emerald Sites



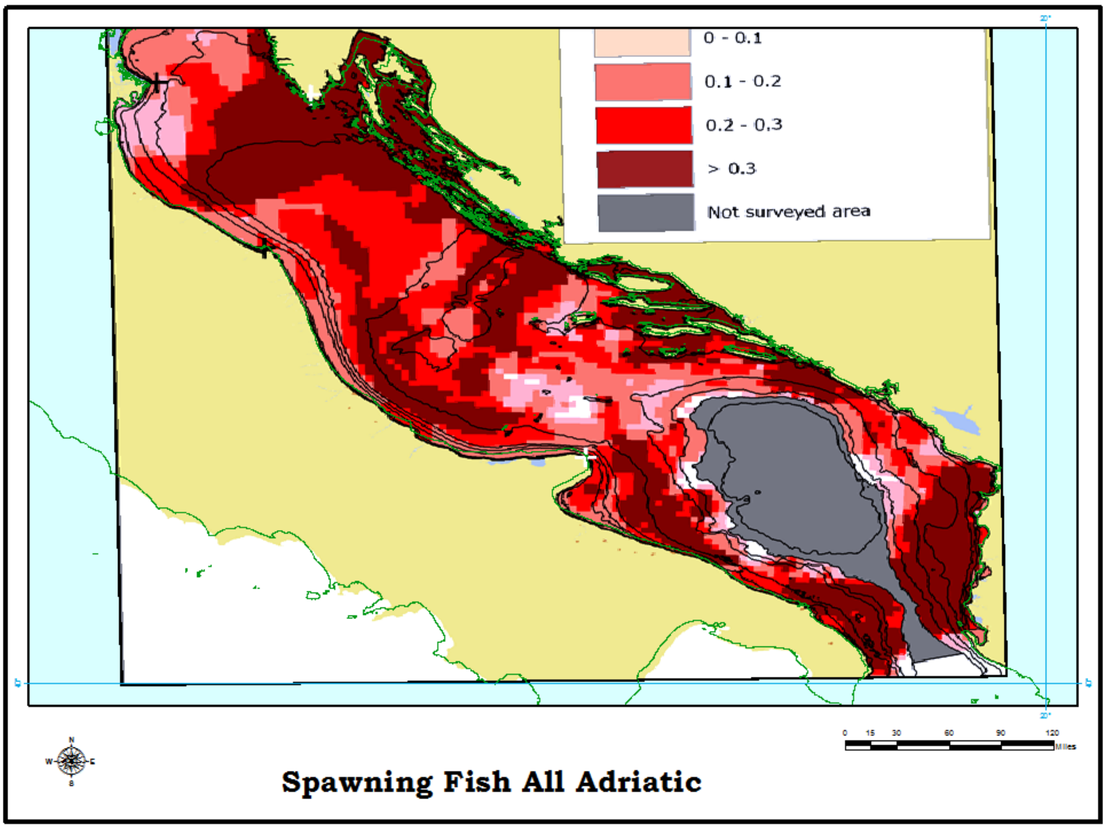
Map 8 - Exploration Areas



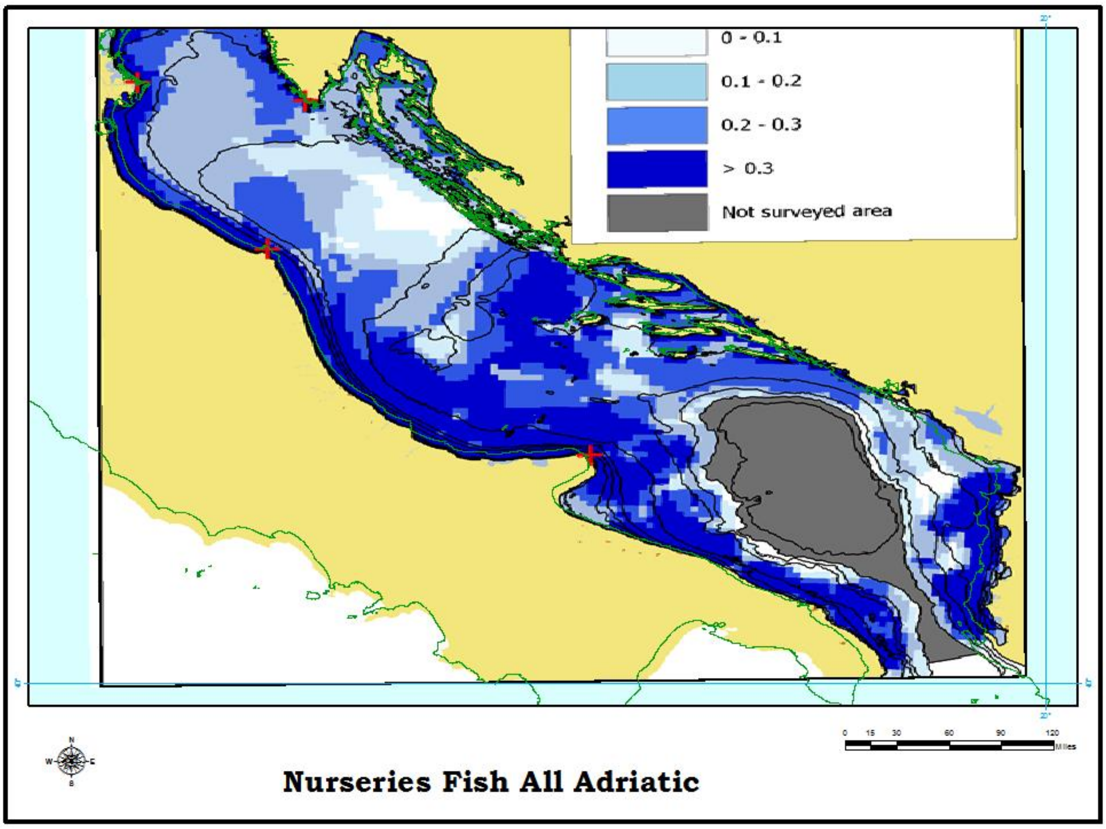
Map 9 - Fishing intensity



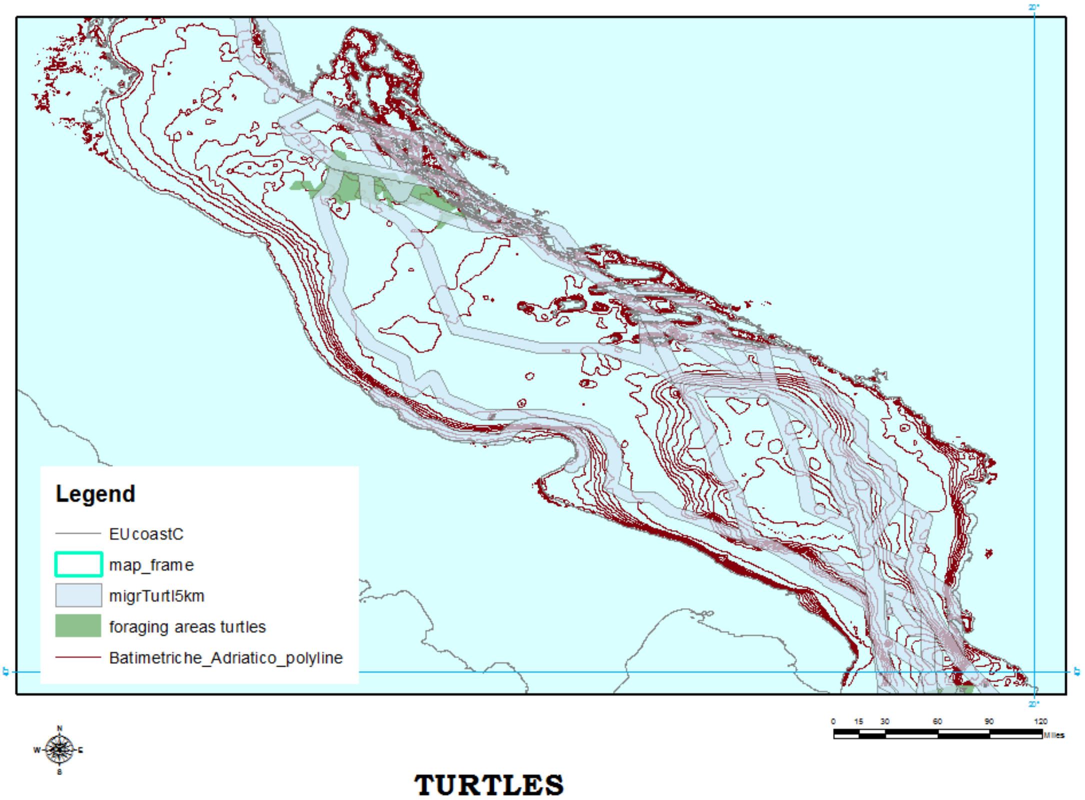
Map 10 - Spawning areas



Map 11 - Fish nurseries

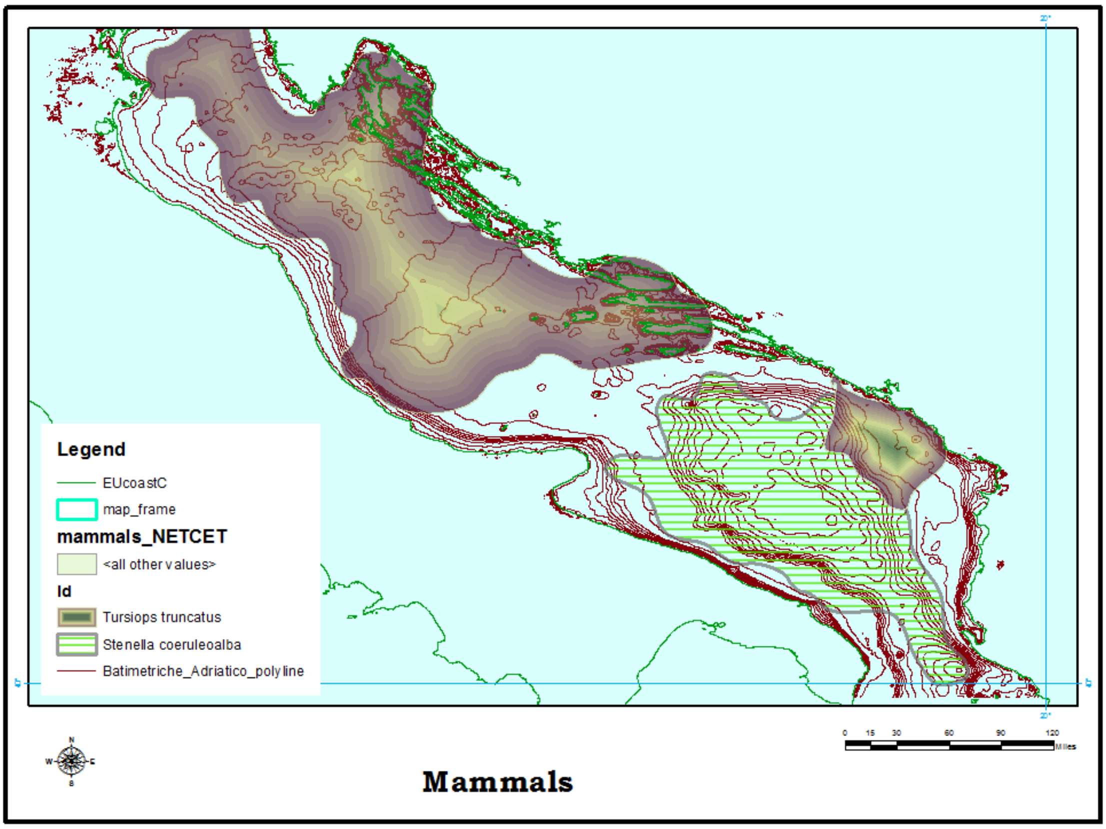


Map 12 - Marine turtles

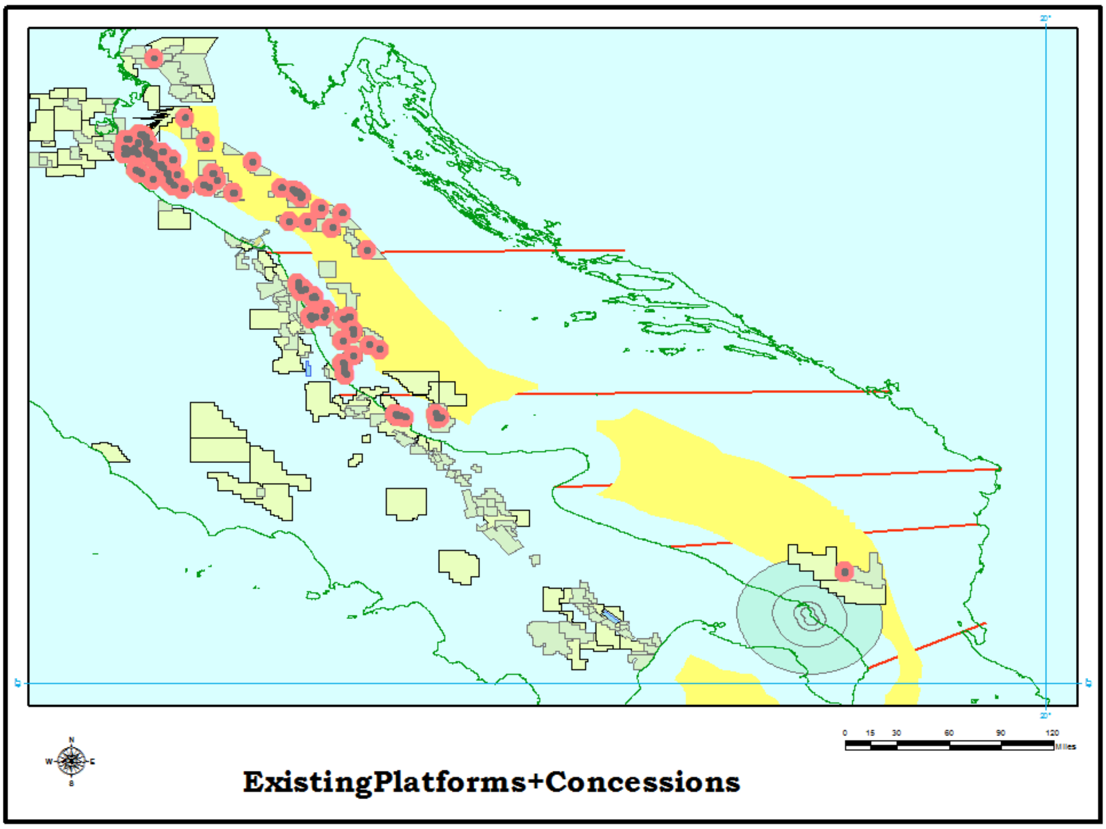


TURTLES

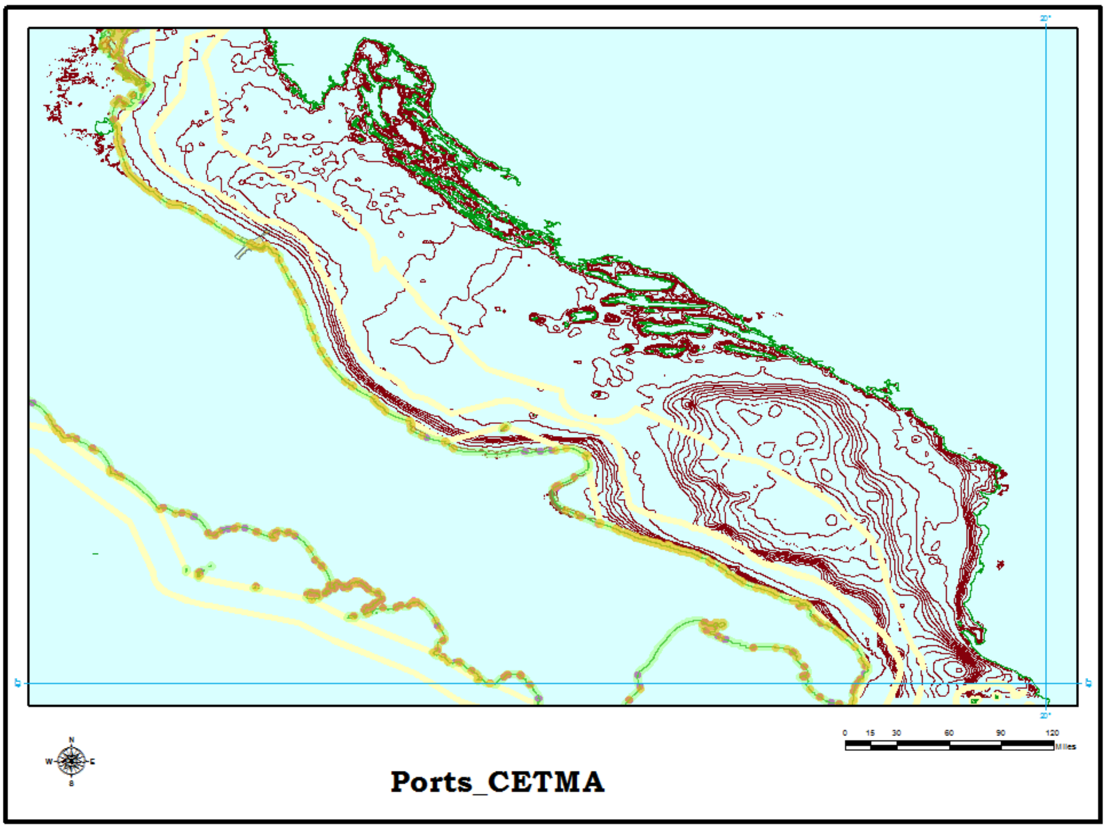
Map 13 - Marine mammals



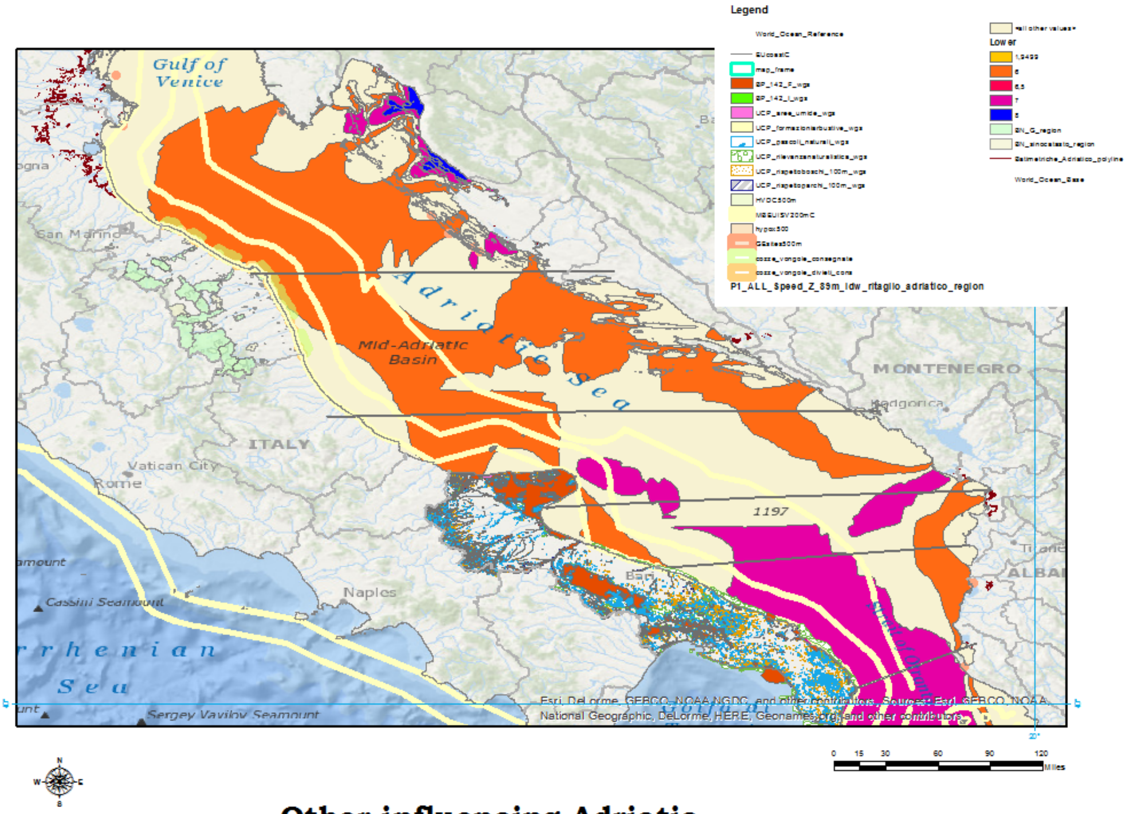
Map 14 - Existing platforms



Map 15 - Ports



Map 16 - Other influencing areas



Other influencing Adriatic

5.3 Synthesis of the cumulative constrains assessment: significance and biases

The results of the cumulative constrains assessment evidence clearly the presence of **large differences among the different areas within the Adriatic Sea**. The number of reliable and useful data for this assessment from Eastern countries is relatively low, as well as it is in other few Western areas where the available data are relatively older than those from other areas. Therefore, we can here anticipate that **a certain amount of heterogeneity among areas also depends upon the fragmentation of the data and the high variability in the quality of the data**.

The results of this exercise, together with those derived from the analysis of expected impacts describe above (see Chapter 2), evidence, at a very first glance that:

i) the Adriatic Sea is highly exploited at the basin scale;

ii) in almost all of the basin, those areas that could be suitable for the installation of offshore wind farms with the actual technology and in accordance with the availability of fruitful wind speeds (see WP4 report) are to some extent already exploited for other activities or under protection.

The approach adopted in this exercise, based on 1/0 ranks of any critical issue considered, though relatively too weak - at this stage - to indicate definitely where OWFs could be fruitfully installed, provides **a basis for identifying those areas where the space exploitation is already large or several (cumulated) critical issues are present**.

With the maps presented below, once taken into account wind needs and technological possibilities, stakeholders/investors and policy/decision-makers can have a picture of the areas, if not more suitable, at least less critical to host possibly an offshore wind farm.

Basically the maps should be read considering those areas with an elevated number of cumulative issues (highest scores) as the most problematic for OWFs installation, whereas areas with a low number of concurrent critical issues (lowest score), at a very first sight, as those possibly more suitable/less problematic. A few considerations, though, are important to be underlined:

1. cumulative values reported in this report are updated to July 2014 and with the available data at the time; since then, we acknowledge that other data obtained through other regional and international projects have been produced, but, have not been included here;

2. low cumulative values do not imply definitely optimal or preferential characteristics for OWFs installation, due to the fact that, in certain areas, data is null, low-quality, spatially fragmented or temporally scattered;
3. the working scale of the maps and reports used to create these cointingency maps is generally broad and mostly given at a basin-scale level, which implies that more precise local critical issues should be present indeed and should therefore accurately identified during the EIA and the planning phase of the OWFs;
4. the cumulative values must not be interpreted as a judgment, rather they are a validation accounting on all the information available where, for example, the presence of a naval route counts the same as a protected area; the decision of the relative importance of each of the critical aspects encountered is a mansion that does not occupy the rationale of this report or, in a broader sense, of the Workpackage 5, that was designed to give a scientific analysis of the possible environmental impacts and constraints of an OWFs in the Adriatic basin.

When overlapping wind maps created after WP4 to those created by WP5 it appears evident that, at the stage of the current technology (OWFs on fixed poles at depths <40m), **only few coastal areas show to have the wind constancy and strength required**. Among these, the area upon the Croatian shore and one of the zones in the southern area of Albania, have been excluded due to the impossibility of fixed installations in deep waters. The remaining areas include three areas:

i. in between Albania and Montenegro
ii. in the Southern area of the Gargano Promontory in the Apulian Region
iii. the zone closest to Brindisi, again in the Apulian Region.

We stress here that the results obtained uniquely in terms of wind characteristics (see WP4 report) and other installation needs (e.g., water depth up to -40m, or in the future -200m when using floating devices, plus turbine capacity limitations, nearby ports) **are not to be definitely interpreted as a preeminent vocation of the Apulian coasts as the most suitable area for OWFs installations**.

As a matter of fact, in spite of the great and appreciable interest of the Apulia region in searching for and investing in current years on the development of alternative "green" energies, some (if not many) key environmental issues stand out when looking at environmentally safe areas where installing offshore wind farms in this region: **<u>most of the Apulian coasts are indeed already protected</u>** some way. The Apulian coasts indeed are characterized by peculiar and highly vulnerable environmental characteristics and habitats including highly valuable sand dunes, seagrass (*Posidonia oceanica*) meadows, extended and vulnerable coralligenous and maërl habitats, marine turtles nesting beaches, wetlands and salt-marshes critical in bird migration routes and nesting.

<u>Altogether, given the potential impacts generated during the different operational phases (see above Chapter 2), the presence of these environmental constraints should in principle avoid considering almost the entire coastal sea in the Apulian Region as an affordable area for the installation of OWFs</u>.

Nevertheless, in this context, it could be also hypothesized that the installation of OWFs could serve, in areas critically exploited and characterized by an unusual concentration of highly impacting activities, as a potential tool to limit further degradation and, to a certain extent, to smooth a certain number of local conflicts in the use of the coastal sea. For instance, in spite of the elevated levels of environmental impairment, the ports and accessibility in the Brindisi area *per se* could represent an element of suitability for the construction and operation of OWfs in the neighbors. The coastal area neighboring the town of Brindisi is, however, highly contaminated by the intense and continuiing activities of coal and heavy metals industries, and counts on various squares of military practices zones, together with the presence of mining prospection concessions. The concurrent presence of all of these critical issues in principle avoids just thinking about adding another one, because of the potential effects of multiple stressors on the marine environment (Claudet and Fraschetti, 2010).

On the other hand, the "green" characteristics of wind power production along with the possibility to avoid any other use in the proximity of the wind farms could altogether provide elements for thinking about the Brindisi neighbors as a "restoration" site based on the presence of an OWF. In this regard, it is worth noting that another FP7-EU-funded project (COCONET) is indeed currently individuating *"areas where Offshore Wind Farms might become established, avoiding too sensitive habitats but acting as stepping stones through marine protected areas"*... also investigating in a socioeconomic perspective how to create a *"knowledge-based environmental management aiming at both environmental protection (MPAs) and clean energy production (OFW)"* (http://www.coconet-fp7.eu/index.php/about-coconet).

In addition, it must be pointed out that one of the environmentally most critical phases of offshore wind farm operativity is the installation phase, which, among the other actions, includes also the electric connection of the wind farm(s) with land. This operation (and more specifically the phase of cables deployment on the seafloor) could indeed interfere severely with the structure and functioning of delicate and vulnerable ecosystems like seagrass meadows, coralligenous and maërl habitats and sandbanks. In this sense, it can be anticipated that the presence of multiple landward connections along a spatially limited coastline would imply a higher number of local environmental impacts; at larger spatial scales, these multiple connections would result in the occurrence of undesirable consequences, because of the synergistic effects of environmental disturbance generated by multiple cables landing in multiple locations. It is, indeed, now recognized that many of the present undesirable changes of the integrity of marine ecosystems are actually the result of effects produced by multiple stressors (Claudet and Fraschetti, 2010), which, often acting synergistically, can determine impacts, whose consequences are much higher than those determined by each single factor separately. It is a matter of fact, therefore, that the use of marine stations that connect multiple wind farms offshore with a single hub on land could concentrate the impacts in single marine area and on one (or only a few) point on land, thus limiting to a great extent the multiplicative negative effects of multiple connections.

Nevertheless, we stress here that **whether the Brindisi area is realistically eligible or not for OWFs installations is not a matter of solution in the framework of this report/project, and will need local/regional and deeper assessment of the environmental cost/benefit paths as well as further accurate considerations directly linked to the sociopolitical acceptance of eventual installations.**

On the other (eastern) side of the Adriatic Sea, the zone located between the Albania and Montenegro borders could be suitable for OWFs, as, apparently, the marine bottom conditions could allow their installation as well as because of the relative vicinity of ports and infrastructures. Based on the available information, the main emerging issue in this area could be uniquely related with the protection of the marine environment, since - to the best knowledge available so far - there are only limited coastal areas currently under protection in these countries. It is worth noting, however, that the scant quantitative information about some environmental characteristics of the area, **the estimated low number of constrains here reported for this area could be simply an underestimation of the actual environmental criticalities**. Nevertheless, besides the possibly unknown yet critical issues in the area, the suitable zone for OWFs installation is fairly small, but could be considered for a more reduced implant.

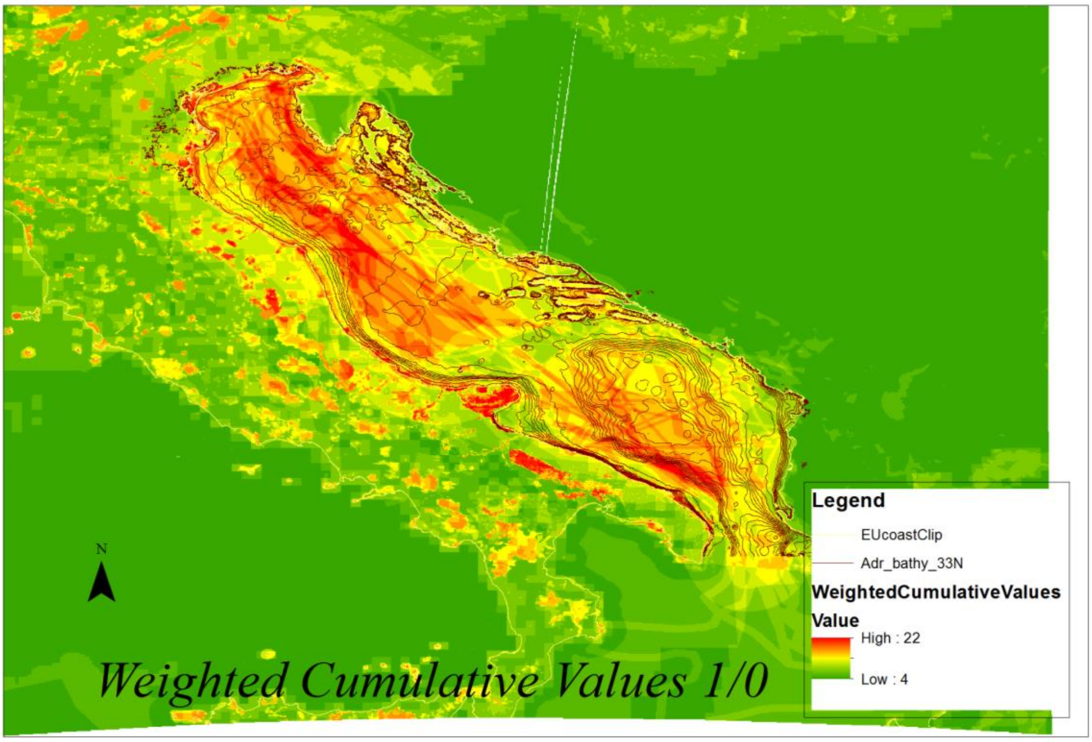


Figure 5.1 All Adriatic view with the cumulative values scaled to low and high.

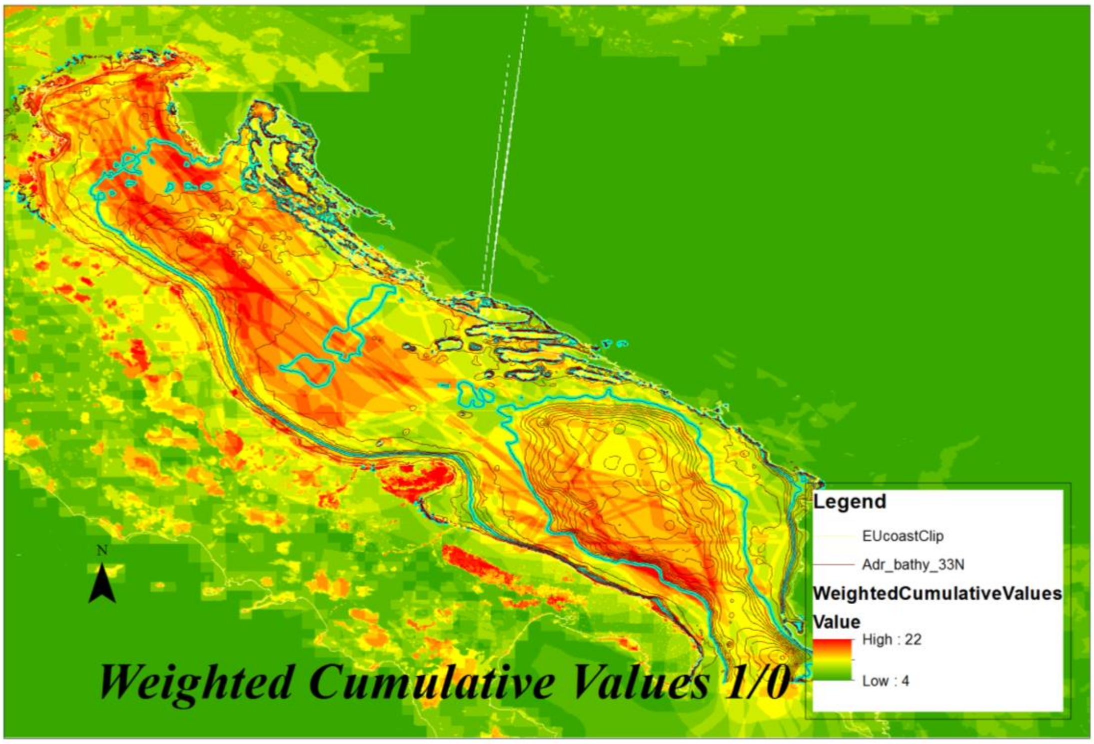


Figure 5.2 All Adriatic view with the cumulative values scaled to low and high with the critical bathymetry highlighted in blue

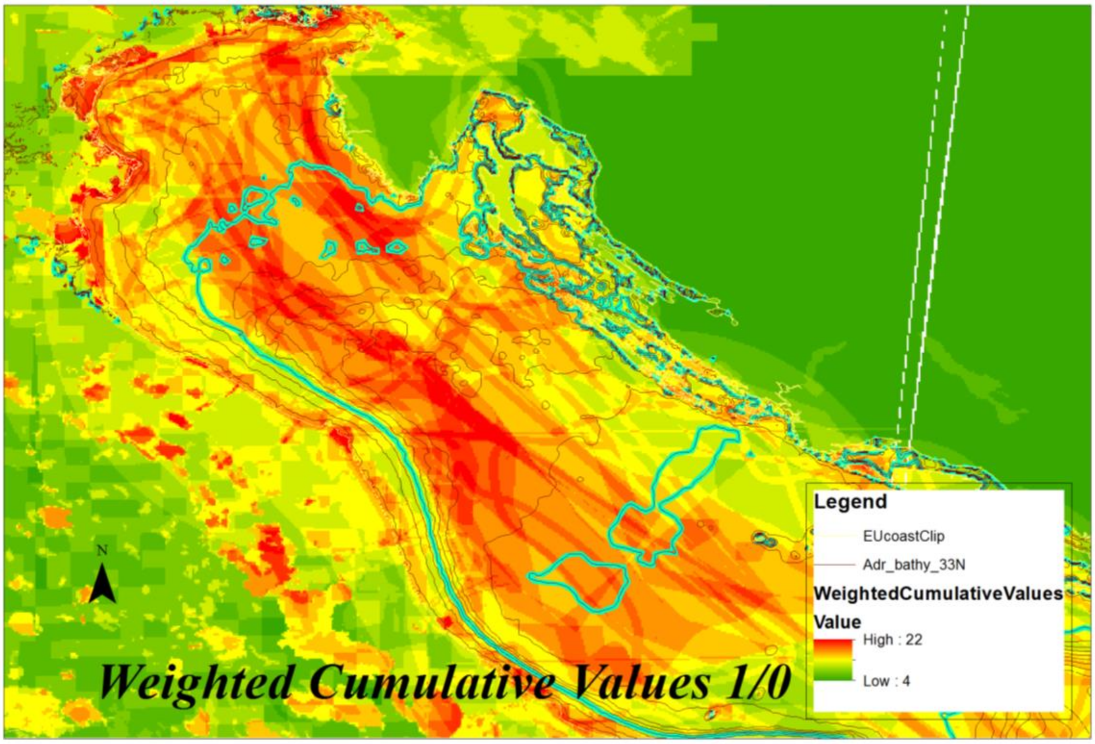


Figure 5.3 Northern Adriatic in the weighted cumulative value analysis and with the critical bathymetry highlighted in blue.

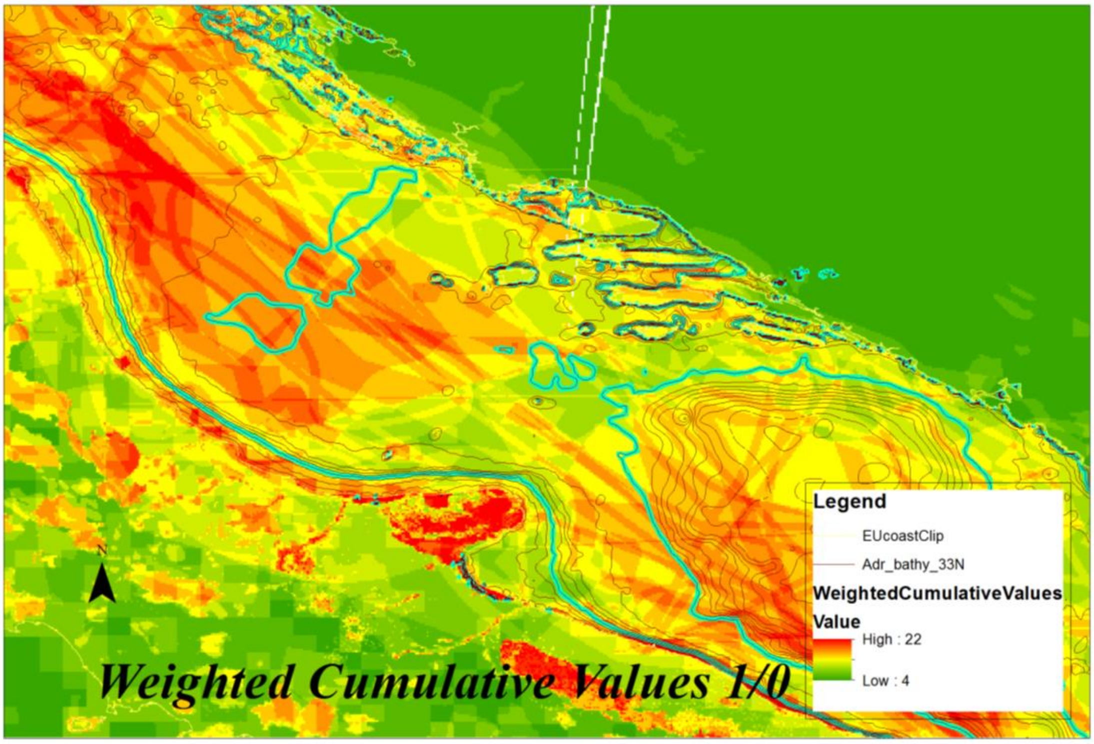


Figure 5.4 Central Adriatic in the weighted cumulative value analysis and with the critical bathymetry highlighted in blue.

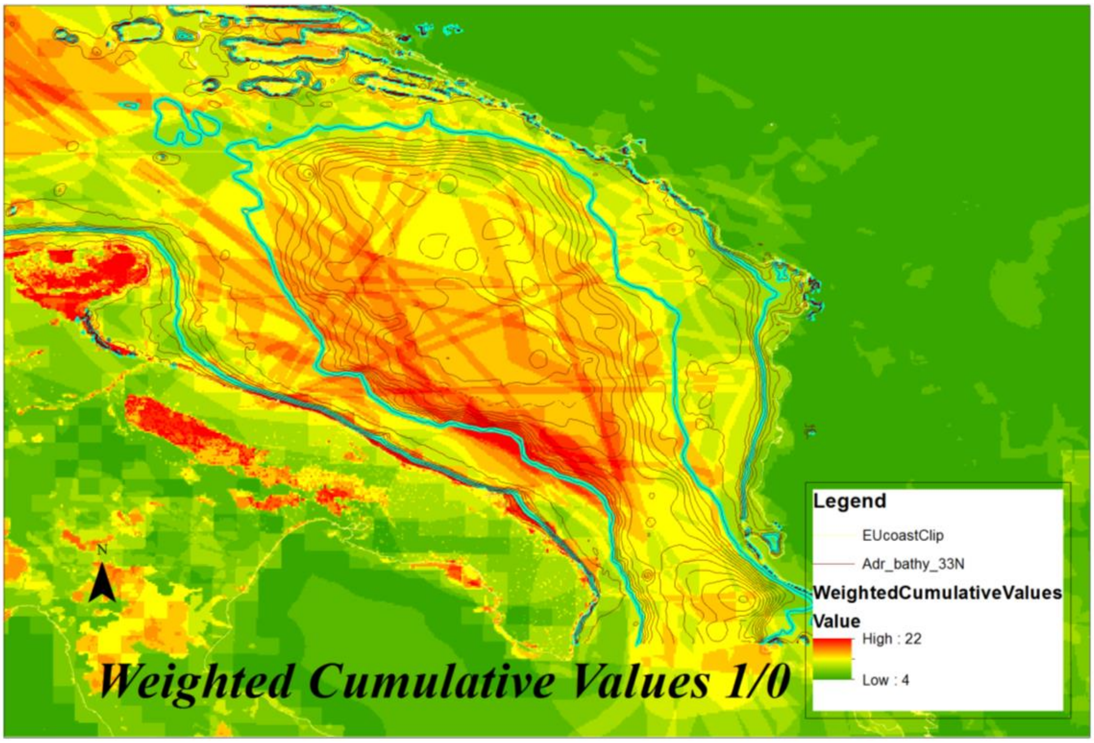


Figure 5.5 Southern Adriatic in the weighted cumulative value analysis and with the critical bathymetry highlighted in blue.

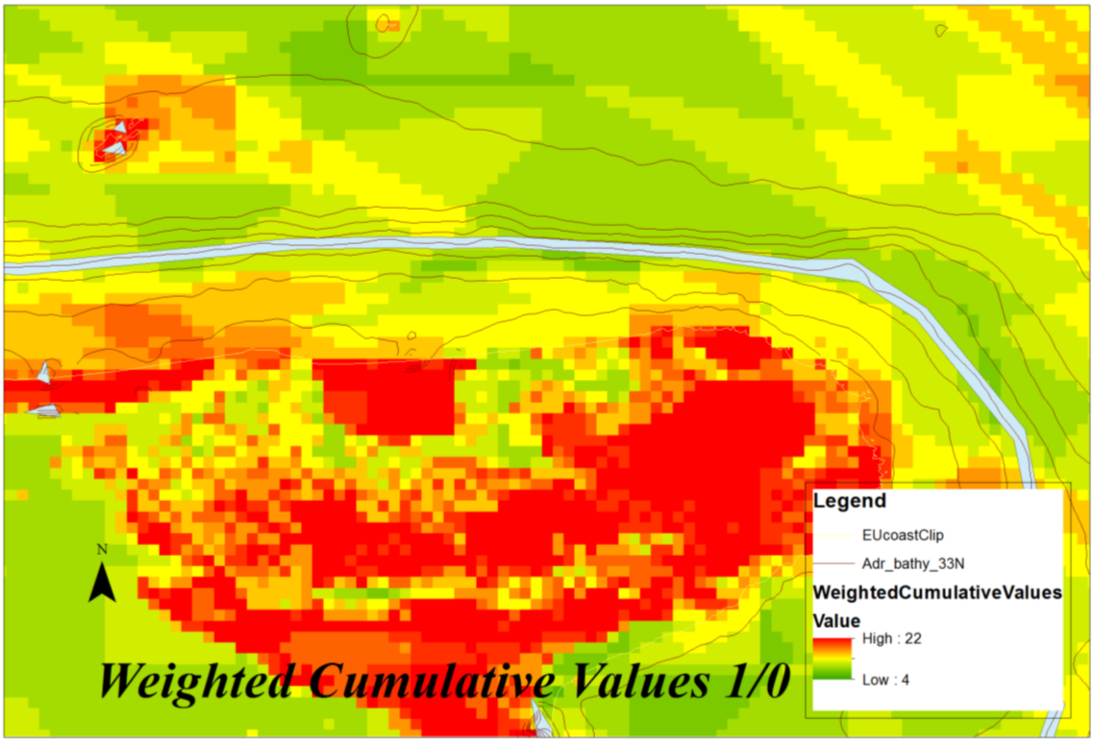


Figure 5.6 A scaled up detail of the Gargano area and the different colored cells showing how critical it could be to set any sort of plants or contrsution in this area, as the majority of the area shows a high cumulative value.

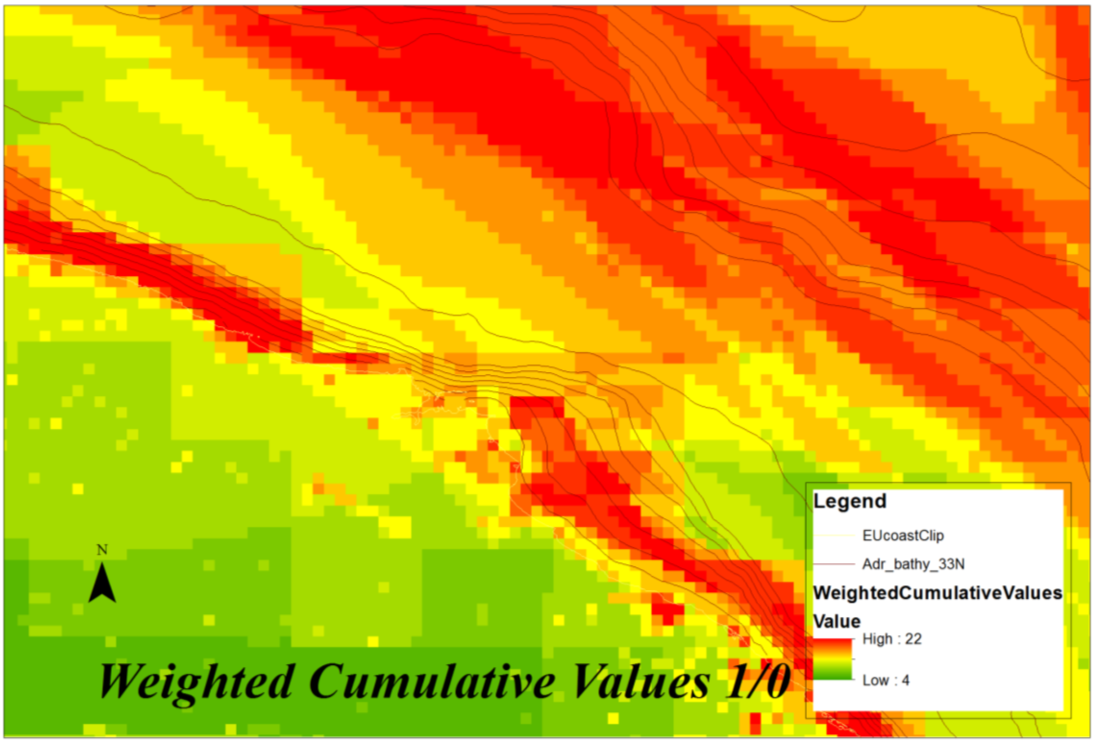


Figure 5.7 Deeper detail of the Brindisi Port zone, In this area the cumulative value is high as most of the coastal zone shows high values, so any possible work to be done has to consider a large number of elements.

6. IDENTIFICATION OF MAIN RISKS RELEVANT TO OFFSHORE WIND FARMS DEVELOPMENT AND SAFETY AND CONTINGENCY RESPONSE RECOMMENDATIONS (Provided by CETMA)

6. IDENTIFICATION OF MAIN RISKS RELEVANT TO OFFSHORE WIND FARMS DEVELOPMENT AND SAFETY AND CONTINGENCY RESPONSE RECOMMENDATIONS

6.1 Abbreviations and acronyms used in this chapter

AIS	Automatic Identification System
ALARP	As Low As Reasonably Practicable
ASMS	Active Safety Management System
CCFA	Common Cause Failure Analysis
CCTV	Closed Circuit Television
COLREG	Convention on the International Regulations for Preventing Collisions at Sea
DSC	Digital Selective Calling
DfT	UK Department for Transport
DTI	UK Department of Trade and Industry
EIA	Environmental Impact Assessment
ETA	Event Tree Analysis
FMEA	Failure Modes and Effects Analysis
FSA	Formal Safety Assessment
FTA	Fault Tree Analysis
GPS	Global Positioning System
HAZID	Hazard Identification Technique
HAZOP	Hazard and Operability Analysis
HFE	Human Factors Engineering
HSE	Health, Safety and Environment
IMO	International Maritime Organization
MCA	UK's Marine and Coastguard Agency
MRCC	Maritime Rescue Co-ordination Centre
OREI	Offshore Renewable Energy Installations

POB	Persons on Board
QRA	Quantified risk assessment
SAR	search and rescue
RRPP	Reducing Risk, Protecting People (UK HSE Document)
SCADA	Supervisory Control And Data Acquisition
SOLAS	International Convention for the Safety Of Life At Sea
SQ	Semi-quantitative
UNCLOS	United Nations Convention on the Law of the Sea
VHF	Very High Frequency
WTG	Wind Turbine Generator

6.2 Introduction and rationale

This chapter has the objective to show the main risks relevant to offshore wind farms development in the Adriatic sea, and to propose safety and contingency response recommendations and methodologies.

Technically, a wind farm is composed of windmills mounted on foundation piles and of submarine connection cables, sometimes linked to offshore transforming substations.

The aerial part of the windmills poses the same problems of onshore windmills, related to noise during operation, risk of impact with birds and other flying animals and of risks of impacts with airplanes and helicopters, although in the sea these problems are less important than onshore (in open sea usually there are less people hearing noise, less birds and flying animals, less airplanes and helicopters).

The foundation structures of offshore windmills pose the same problems than those of other offshore platforms, although less important: windmills are installed on shallow waters (to date, nearly never with depths exceeding 30 meters), and in case of contingencies (collision, fires etc.) the risks are much less limited: a wind mill is mostly composed of inert materials, the potentially polluting materials are limited amounts of oils in the generator and some batteries.

These consideration must not, however, bring to the conclusion that no specific risk analysis, safety and contingency plans are needed: offshore wind farms pose the real problem of occupying large portions of sea, and their impact and interference with navigation, fishery and other marine activities can be significant.

The cables, finally, pose the same problems of any other type of submarine electric cable.

Risks and hazards are, however, more differentiated and critical to assess during construction (and for some important maintenance operations and during decommissioning/repowering) rather than during operation, as it occurs for many other offshore structures.

These factors, together with the broad extension of offshore wind farms, the enormous size of wind turbines components to be handled in the middle of the sea by cranes and vessels and some other specificities, require extensive activities of risk analysis and the development of sound safety and contingency response plans.

Nonetheless, Adriatic sea is not the first area of the world being interested by offshore: offshore wind energy started being developed in the Northern and Baltic seas, which offer better wind conditions and shallower seabed, and diffused then to other seas with even more striking conditions, like the Atlantic shores of Ireland and of North-Eastern USA.

Due to this evolution risk, safety and contingency response analyses were already produced since the installation of the first offshore wind farms in the Nineties and are currently well coded by maritime regulation in several countries. Denmark pioneered offshore wind energy development, and developed the first guidelines and coded recommendations for risk analysis, safety and contingency response in the field. Denmark guidelines were then used and adapted to local conditions (and to the different regulations and maritime control and administrative organizations) in the other countries and are to date quite similar each other.

Today, the Country leading offshore wind energy is UK: the United Kingdom has the largest installed capacity of offshore wind in the world, with 3.68 GW installed by the end of 2013, 56% of total offshore installed in Europe [1].

Regulations and guidelines of UK were used as the main reference for this study. The changes needed in the adaptation of these documents from UK to the Adriatic countries are limited due to the many points in common between the seas surrounding UK:

- Typically, sea depths are low;
- Both North Sea and Adriatic Sea are crossed by intense maritime and aerial traffic (although in the Adriatic traffics are less intense);

- Both North Sea and Adriatic Sea host gas and oil offshore platforms and are crossed by a network of pipelines and electric underground cables (although in the Adriatic infrastructures are relatively less developed), and regulations in the fields of offshore infrastructure are well developed (although in the Adriatic traffics are less intense);
- Both North Sea and Adriatic Sea waters are shared among several Countries.

The differences among the two situations are smaller, and to a large extent they are limited to aspects which pose more stringent constraints in the UK than in the Adriatic:

- Storms in the Adriatic are sensibly less intense;
- Tides in the Adriatic are much lower (few centimetres or tens of centimetres compared to several meters in the Atlantic and North Sea) and tidal currents are consequently less intense.

Finally, the maritime control and regulation Authorities are of course different from UK to the Adriatic countries, especially for those countries not yet included within the European Union.

This chapter is organized as follows:

- Chapter 6.3 provides an overview of the development phases of a wind farm, starting from the site selection, the design, construction, grid connection and commissioning phases, operation and maintenance during its operative life and final decommissioning (or repowering);
- Chapter 6.4 provides an overview of the main international agreements and conventions regarding obligations and regulations maritime safety;
- Chapter 6.5 describes the common features and techniques for the individuation and the assessment of hazards, consequences and risk;
- Chapter 6.6 indicates the main features of the methodology proposed for risk assessment on wind farms and illustrates the scope and the depth of it;
- Chapter 6.7 includes the recommendations on navigation safety;
- Chapter 6.8 provides the general guidance and proposes some techniques on navigational safety issues, based on the case of UK.

6.3 Offshore Wind Farm Development Phases – General Overview

This chapter describes the main development phases of the development of an offshore wind farm:

1. Site selection;
2. Preliminary activities and design;
3. Wind farm construction, grid connection and commissioning;
4. Wind farm operation;
5. Repowering and decommissioning.

6.3.1 Site Selection

The selection of a site is determined by several aspects, and is an issue which is often not determined by the sole wind farm developer. Today's offshore wind farms tend to be quite large (respect to onshore plants), involving several tens to hundreds of large, multi-megawatt windmills, thus achieving an installed power for the whole wind farm that is rarely below 50 MW and that can reach the GW scale. This is due to several aspects: from one side, costs for preparatory activities are pretty elevated, requiring several preparatory studies, wind measurement campaigns whose cost – mostly in terms of equipment – is higher than onshore –, the need to rely on the use of expensive, specific equipment and the need to equip and use an harbour area in the neighbourhood for preparing windmills' components (mainly foundations, junction elements and the windmills themselves) before shipping and installation on site. From the other side, the constraints to wind farm dimensions are much less limited than in the onshore case.

A consequence of the large size (a 1 GW wind farm occupies a sea surface in the 1,000 km^2 scale) is that the suitable sites are not a large number – even in case of Countries with very large economic exploitation zones like the UK. Thus very often the governments make preliminary studies regarding wind speed, conditions of the seabed and interference of wind farms with other activities and define the areas where wind farms can be built. What occurred in all the countries where offshore wind energy is developing is that the very first offshore wind farms where installed on sites individuated by the developer, going to ask for a concession for that area to the government. The phase with a strong government involvement in planning the location of wind farms usually came after some years of unregulated development, during which several projects were proposed (in some cases in the same location) but only very few were realized.

Selecting the proper location of an offshore wind farm is a crucial issue. The determining factors are many. Those having an impact on economic feasibility of a wind farm are listed here:

- Wind speed, first of all, determines the amount of producible energy and, therefore, the profitability of investment. Measuring wind speed in the sea has higher costs than onshore, however the spatial variability of wind speed in the sea is much lower and the number of anemometric masts can be more limited;
- Depth and consistency of the seabed determine the type and cost of foundations to be used;
- Distance from the shore determines the cost of energy transportation infrastructures (and, to a lesser extent, of construction operations), which may imply the need of transforming stations and/or AC/DC and DA/AC converters. The need of such components depends on the distance from the shore and on the size of the wind park;
- The availability of a port area for onshore mounting activities and the availability of construction equipment (most of which – jackup ships, special cranes... – has to be leased and has waiting lists that may exceed the year).

Aside these main constraints, impacting on the economic features of a wind farm, there are other aspects that may impact on the layout – and, in some cases – that may prevent the use of some areas for wind farms installation. These constraints are related to fish breeding areas, fishing areas, harbours, shipping routes, military areas etc.

Aim of the whole POWERED project is to provide useful guidance to the Governments and to investors in defining the areas most suitable and less impactant for wind power development in the Adriatic Sea.

6.3.2 Preparatory Activities at Site

After a company acquires the lease on the area, the next step in development is to determine (or verify, if previous measurements are available) the wind potential at site and conduct the technical studies and the environmental impact assessment (EIA), whose main features are evaluated in the POWERED deliverable “Regulatory, Environmental and Energy Policies State of the Art”. The technical studies and the EIA occur along the design phase, and are aimed at driving the design of the plant in finding the best compromise among economical, technical and environmental aspects.

6.3.3 Technical Studies

A range of technical surveys and studies is also required to project development, and these can also support the EIA ([2][3]). In particular, a Geotechnical survey is performed for seabed (Figure 6.1) and its results are at the basis of the design of the wind turbines foundations. These analyses often involve a jack-up barge with a drilling platform to take core samples of material from the seabed. Figure 1 shows the underwater equipment for drilling operation. The equipment is able to work efficiently and to collect high quality samples which are safely stored on the unit until recovery of the drill to the surface.

The seabed and subsoil samples are analyzed by accredited laboratories and the results are used in the design phase of the wind farm. Figure 6.2 shows an example of stratigraphy of core of material with the description of its physical characteristics (lithology) such as color, texture, grain size, or composition.

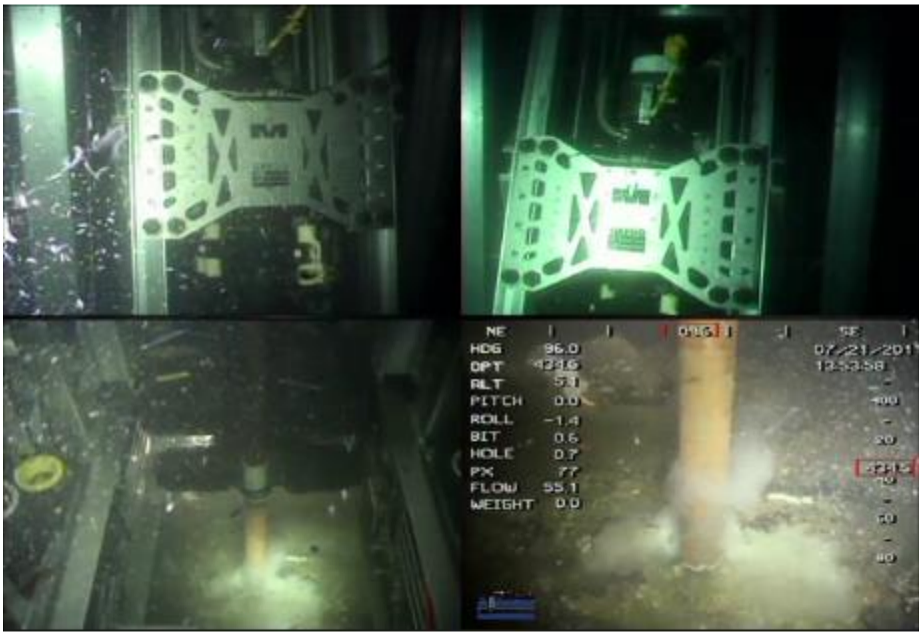


Figure 6.1. Geotechnical survey: underwater drilling operation to take soil samples

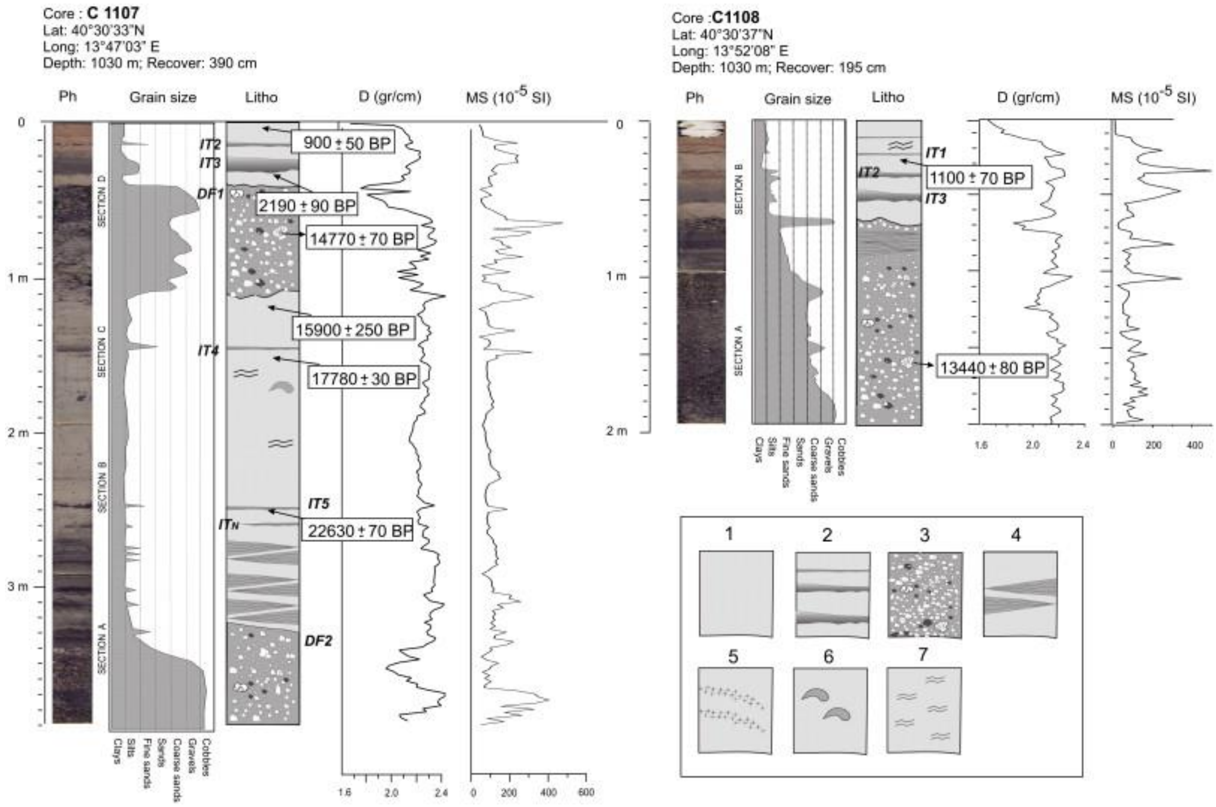


Figure 6.2. Core stratigraphy and lithology description

In this phase a monitoring mast is installed at the site to perform measurements of wind speed and direction. This structure, which can be up to 100m tall, comprises a lattice mast that is supported by a steel pile foundation fixed to the seabed. Installation of the mast is usually performed within one week by a jack-up barge similar to that described above. The mast is instrumented with anemometers, wind vanes, warning lights to make it visible to both boats and aircraft and sometimes a foghorn.

A non-intrusive geophysical survey is also required to investigate the seabed topography or the seabed stratigraphy by using an acoustic instrument (Figure 6.3). The acoustic investigation yields greater detail of localized sub-surface stratigraphy and provides a much larger data volume compared to the soil samples used in the geotechnical survey. The acoustic cores have a diameter of about 14 meters as against the diameter of 0,1 meters of the soil samples. In Figure 6.4 a comparison between the acoustic core analysis results and the soil samples analysis results (borehole data) is shown.

Figure 6.3. Acoustic instrument for non-intrusive geophysical survey

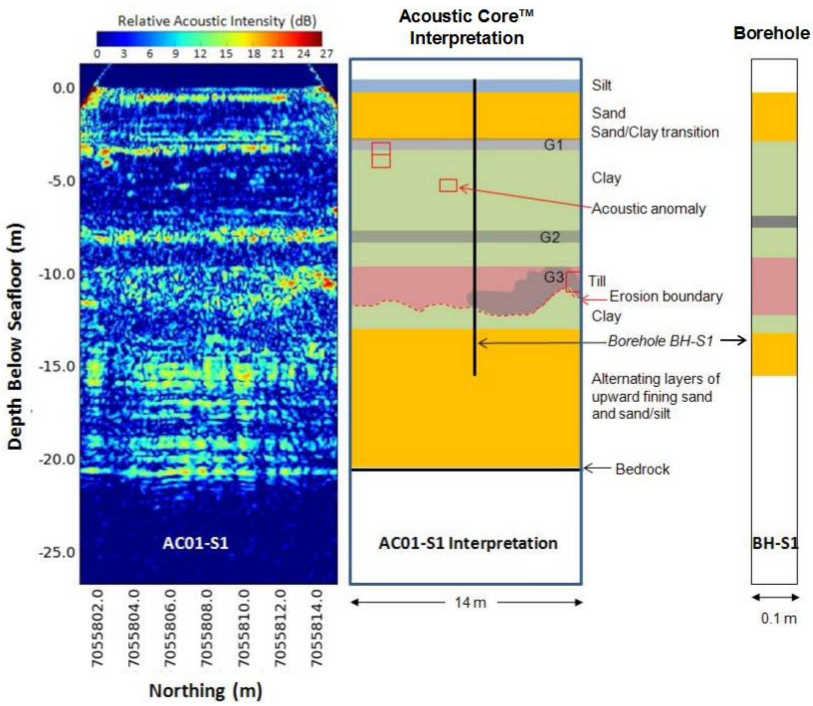


Figure 6.4. Comparison between acoustic core investigation and borehole data (core of material)

The survey of the wind farm area and cable route to shore is performed from small vessels with a measurement equipment below the water surface. Objective of this survey is the collection of data necessary for the engineering and installation of the foundations and of the cables connecting the wind turbine to the shore. The on-site investigation employs remote sensing technology, often multi-beam sonar and/or high-resolution seismic reflection. This investigation, known as hydrographic surveying, generally provides a detailed bathymetric map (Figure 6.5) of the sea bottom as well as general soil characteristics. Both techniques rely on an array of energy emitters and receivers that can carry out the site investigation in a relatively short period of time. The results acquired are also fundamental for marine ecology and coastal processes assessments, as well as for the site layout of the wind farm. In addition to the measurements performed at the site, the oceanographic data are used as the basis for understanding the existing physical environment within the site and its surroundings. These data concern wind and wave measurements, current velocity, tidal elevations, seabed sediment and water quality.

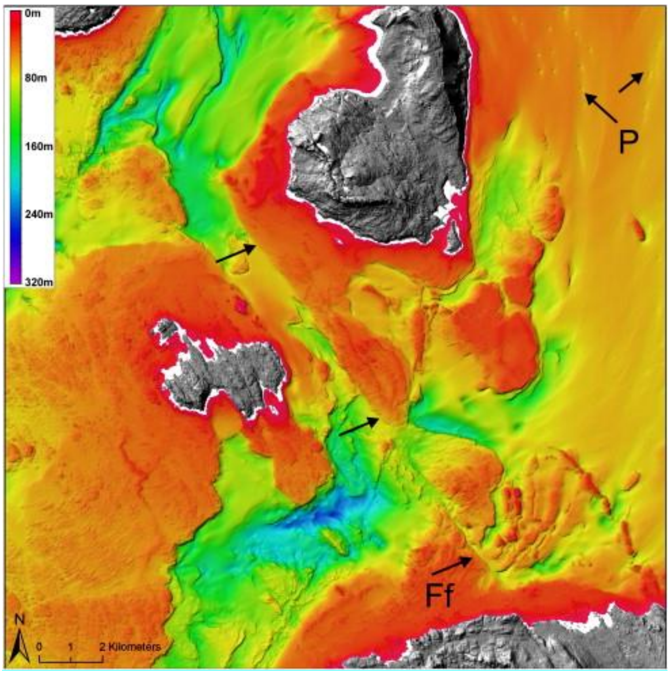


Figure 6.5. Multibeam bathymetry analysis results

Another aspect to be take into account, which is the core of the following Chapters 5, 6 and 7 is the Safety of Navigation to ensure that the wind farm is properly located, designed, lit and marked. In particular, a detailed Navigational Risk Assessment is performed using on-site traffic surveys and input from the navigation community. The possible effects of offshore wind farms on commercial fisheries are also investigated using analysis of catch records and consultations with local and national fishing organizations and individual fishermen.

6.3.4 Environmental Impact Assessment

An Environmental Impact Assessment (EIA) is an assessment of the likely positive and/or negative influence that a project may have on the environment. The EIA is a detailed process involving many different disciplines and can take from one to two-and-a-half years [2][3].

Figure 6.6. Marine ecological surveys: benthic sampling

A range of marine ecological surveys is undertaken within the EIA process, from fish trawls and marine mammal surveys to benthic sampling, organisms living in and on the sea floor (Figure 6.6). Determining the likely effects of the wind farm on the marine ecology of the area is a fundamental part of the EIA process and is undertaken by skilled companies in this field.

In the EIA process an Ornithological Assessment is performed to investigate the effects of the proposed wind farm on birds species in and around the site. In addition, the effect of the wind farm on the visual environment is determined in a Land and Seascape Visual Assessment. This assessment involves the characterization of the seascape in the vicinity of the wind farm, the representation of the wind farm using techniques as photomontages and finally the assessment of the effects of the development site on the visual environment.

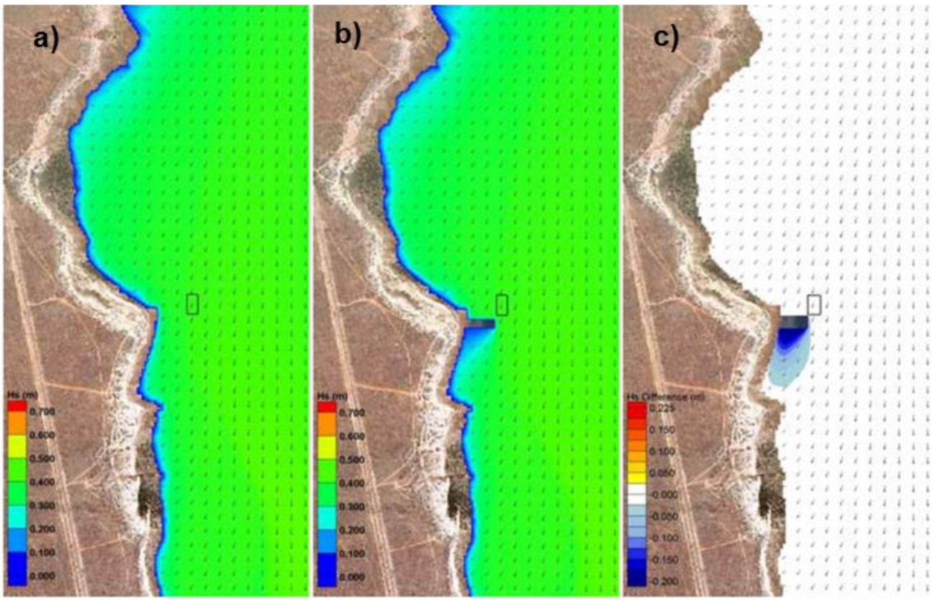


Figure 6.7. Numerical Analysis Results of Wave Field during a 25 knot Wind from the North: a) Existing; b) Causeway Landing Facility; c) Difference Due to Causeway Landing Facility

The likely effects of background noise from the wind farm, during both construction and operation, are often assessed. In such cases, background noise monitoring is undertaken at several locations for two to four weeks and predictions on the likely environmental effects are investigated.

The coastal processes assessment is also an important aspect to be included in the EIA process. The assessment studies the effects of the wind farm (especially the turbine foundations) on the wind, waves and currents in the area in order to determine its influence on nearby coastal erosion. This analysis may require specialist numerical modelling techniques; often it is also necessary to collect specific wave and current measurements at the site for a period of about a year in order to increase the accuracy of the numerical model. Figure 6.7

shows an example of coastal processes modelling performed to investigate the impacts that a pier would have on the near shore wave field due to a 25 knot wind from the North.

6.3.5 Construction

The wind farm construction is the most intensive phase of the development project which includes the procurement of goods, fabrication & assembly and installation ([4]). Procurement is the largest cost category followed by fabrication, assembly and installation.

Figure 6.8. Fabrication and assembly park

Construction normally includes the raw material cost and the cost to fabricate piling, transition pieces and jacket structures, as well as the cost to assemble turbines. Fabrication may occur at the staging area or at another location.

Procurement and delivery involves acquiring of equipment and delivering it to the staging area. Equipment includes meteorological instruments, turbines (towers, nacelles, hub, blades), cables, transformers, control and data acquisition (SCADA) system and other goods that do not require fabrication. Turbines are the primary capital expenditure and are delivered to the staging area where they are assembled according to the installation strategy.

Fabrication of foundations and transition pieces is performed near or at site (in the harbor, close to the offshore site, selected for these operations), or may be delivered to site via road, rail, or – more frequently – by barge. Typically, the foundation of each turbine is installed on it on site and, subsequently, the turbine is mounted on it.

Assembly of the turbine may occur onshore or offshore and the degree of onshore assembly impacts installation costs. A complete offshore turbine assembly requires a heavy-lift jack-up vessel. Figure 6.8 shows a fabrication and assembly park and Figure 6.9 a heavy-lift vessel used for offshore foundation activities.

Figure 6.9. Heavy-Lift Vessel

Installation is defined as all activities to transport and install wind farm components. After a suitable number of turbines and/or foundations are available at the staging area, offshore installation may begin. Installation occurs over three primary stages: foundation, turbines and cables. The basic work flow is:

1. Installation of the foundation, transition piece, and scour protection;
2. Erection of the tower and turbine (Figure 6.10);
3. Installation of the electric service platform (if applicable).
4. Installation of the cables (Figure 6.11)

Installation activities costs include the cost to load the foundations, transition pieces, tower, turbines, substation, and cables from port; the cost to transport and install/erect individual elements; and cost of all the support vessels directly associated with the operation (e.g., crew boats, tugs, and supply vessels).

Figure 6.10. Installation of Tower (Left) and Rotor Blades (Right)

6.3.6 Grid Connection and Commissioning

Every offshore wind farm requires a connection to either the electricity distribution or the transmission system ([5][6]). Submarine cables are required to supply the energy produced by the offshore wind farms to the transmission network and ultimately to the users. These connections must transport considerable power capacities over distances of up to 200 km.

Normally, the transport of large amounts of energy implies the need of elevating voltage to reduce resistive losses, thus if the park includes several turbines and distances are long an offshore medium voltage to high voltage substation is needed.

The need of using submarine cables under long distances also implies the need of converting electricity from AC to DC, since alternating current implies the need of more expensive cables and faces sensible losses due to capacity and inductance (this conversion is not necessary if the length of the cable is limited to few kilometers). Thus, in large offshore wind farms the plant is provided with its own transformer platform to which all wind energy plants are connected in bundles (Figure 6.12). The offshore transformer platform elevates voltage and often, as explained, converts the Alternating Current (AC) in Direct Current (DC). For transmission, a submarine cable is used to transport the power from offshore transformer platform to the nearest coupling point onshore (Figure 6.13).

Figure 6.11. Cables installation

Usually substations are almost completely mounted onshore and then transported to their offshore respective position (Figure 6.14). Arrived at the correct position, the transformer platform is installed on the seabed by means of jacket foundations.

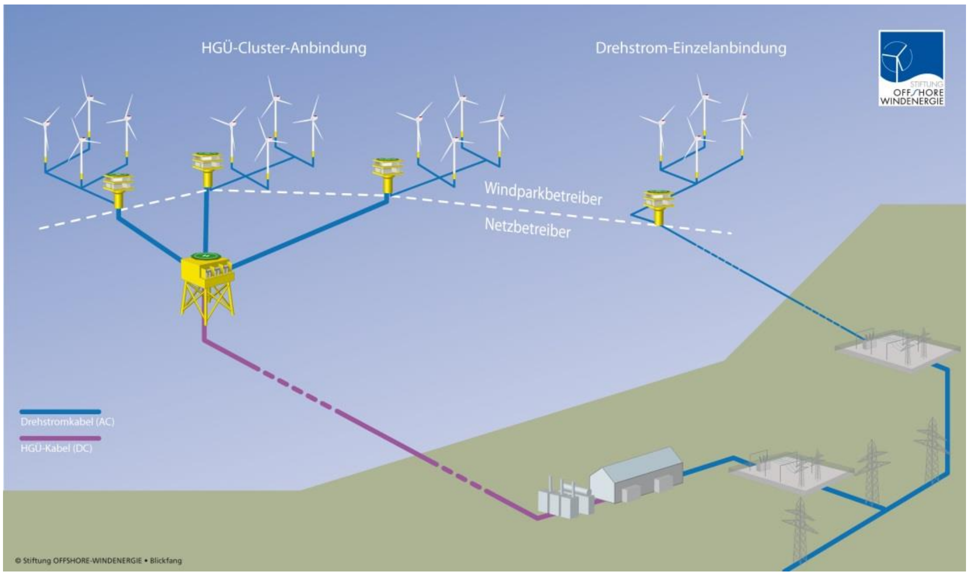


Figure 6.12. Grid Connection

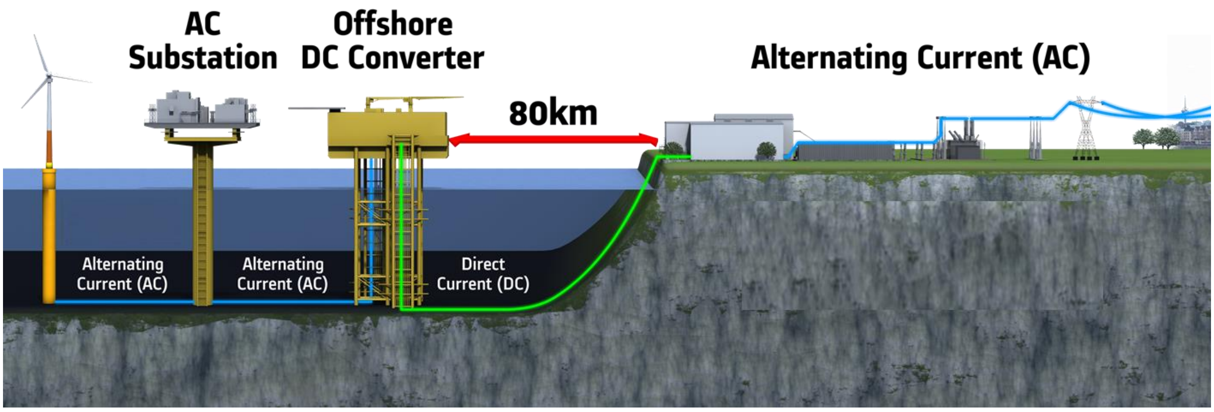


Figure 6.13. Transformer Platform and Power Transmission

Figure 6.14. Construction and Installation of a Wind Farm Transformer Station

The submarine cables are laid in the sea ground at a depth of at least 1.5 meters. The laying is carried out with special ships using different technologies. The cable must then be run to the next substation of the onshore transmission grid, where the power is transformed and supplied.

After grid connection, the next step is the turbines commissioning. Commissioning is the process of safely putting all systems to work before handover. The key steps in commissioning include visual inspection, mechanical testing, protection testing, electrical insulation testing, pre-energisation checks, trip tests and load checks [6].

After a wind farm is tested and commissioned, it is ready for commercial production and power injection into the grid.

6.3.7 Operation and Maintenance

Operation and Maintenance activities aim to optimise the availability and capacity factor of a wind farm keeping costs to an acceptable level. The "Availability" is the measure of the percentage of time during which the wind turbine is able to produce power if the wind is blowing. Modern onshore turbines have availability of around 98%. Many offshore wind turbines have availability of around 90% due to lost time due to access limitations.

The "Capacity factor" is the measure of the energy (MWh) produced as a percentage of the theoretical maximum that could be produced. For offshore turbines the capacity factor may be of around 40-50% compared with 20-30% of onshore turbines [6].

During the operation and maintenance phase, regular inspection of turbines, foundations, cables etc and any necessary repair work are performed. The work falls into three categories:

- Periodic overhauls;
- Scheduled maintenance;
- Unscheduled maintenance.

Periodic overhauls are carried out in accordance with the turbine manufacturer's warranty. They are planned for execution in the periods of the year with the best access conditions, preferably in summer.

Scheduled maintenance refers primarily to inspections of components wear, parts susceptible to fail or deterioration between the periodic overhauls. A scheduled inspection of each turbine is likely to take place every six or twelve months. It requires the intervention of small boat for maintenance (Figure 6.15).

Unscheduled maintenance takes place in the case of any sudden defects. The scope of such maintenance ranges from small defects to complete failure or breakdown of main components. It may require the intervention of construction vessels similar to those used for wind farm construction [3].

Figure 6.15. Small Boat for Operation and Maintenance Services (Left) and Access to Pile (Right)

6.3.8 Re-powering and Decommissioning

During the operational life of the wind farm, the client may decide to re-power the wind farm using new turbines. This decision will be based on the performance of the wind farm to date, and the likely returns of re-powering versus full decommissioning and removal of the project components [3].

It may be possible to reuse some infrastructure from the first phase to reduce the capital cost for the second (re-powered) phase.

The decommissioning of the wind farm is the final phase of the project. The aim of this phase should be to return the seabed to its original state as far as practicable [3].

Depending on the national regulations, prior to the construction of the wind farm the developer must submit to the relevant regulatory authority a decommissioning statement, including the scope and method of decommissioning and considerations of health and safety and environmental protection issues. It is likely that decommissioning will mean the removal (and potential reuse, recycling or scrapping) of the wind turbines and also of foundations and ancillary structures. It may also potentially mean the removal of subsea cables, though it may be judged more environmentally sound to leave the buried cables undisturbed.

The environmental obligations of the wind farm operator may potentially continue after decommissioning if any latent issues should come to light after this time.

6.4 Maritime Safety Issues – Obligations and Regulations

This section is focused on the regulations concerning the maritime safety issues. The most important treaties, conventions and regulation bodies are: the convention regulating the rights and responsibilities of nations in their use of the world's oceans (UNCLOS); the navigation rules to be followed by ships to prevent collisions between two or more vessels (COLREGs); an international maritime safety treaty (SOLAS) aimed at specifying minimum standards for the construction, equipment and operation of ships, compatible with their safety; and the International Maritime Organization (IMO) responsible for measures to improve the safety and security of international shipping.

6.4.1 United Nations Convention on the Law of the Sea (UNCLOS)

The United Nations Convention on the Law of the Sea (UNCLOS), also called the Law of the Sea Convention, is the international agreement that resulted from the third United Nations Conference on the Law of the Sea (UNCLOS III), which took place between 1973 and 1982. The Law of the Sea Convention defines the rights and responsibilities of nations in their use of the world's oceans, establishing guidelines for businesses, the environment, and the management of marine natural resources. The Convention, concluded in 1982, replaced four 1958 treaties. UNCLOS came into force in 1994, a year after Guyana became the 60th nation to sign the treaty. As of August 2013, 165 countries and the European Union have joined in the Convention. The European Community has signed and ratified the Convention; although the United States recognizes the UNCLOS as a codification of customary international law, the U.S. Senate has not ratified it yet. Italy has ratified the Convention by the law of 2 December 1994, n. 689.

6.4.2 International Maritime Organization (IMO) Conventions on Maritime Safety

The International Maritime Organization (IMO) is a specialized agency of the United Nations which is responsible for measures to improve the safety and security of international shipping and to prevent marine pollution from ships. The IMO's primary purpose is to develop and maintain a comprehensive regulatory framework for shipping and its remit today includes safety, environmental concerns, technical co-operation, maritime security and the efficiency of shipping. It is also involved in legal matters, including liability and compensation issues and the facilitation of international maritime traffic.

It was established by means of a Convention adopted under the auspices of the United Nations in Geneva on 17 March 1948 and met for the first time in January 1959. It currently has 170 Member States. IMO's governing body is the Assembly which is made up of all 170

Member States and meets normally once every two years. The IMO slogan sums up its objectives: safe, secure and efficient shipping on clean oceans.

6.4.3 Convention on the International Regulations for Preventing Collisions at Sea (COLREG)

The 1972 Convention was designed to update and replace the Collision Regulations of 1960 which were adopted at the same time as the 1960 SOLAS Convention. The convention was adopted on October 20, 1972 and entered into force on July 15, 1977.

The International Regulations for Preventing Collisions at Sea (COLREGs) are published by the International Maritime Organization (IMO) and set out, among other things, the "rules of the road" or navigation rules to be followed by ships and other vessels at sea to prevent collisions between two or more vessels.

The COLREGs are derived from a multilateral treaty called the Convention on the International Regulations for Preventing Collisions at Sea.

6.4.4 International Convention for the Safety Of Life At Sea (SOLAS)

The International Convention for the Safety Of Life At Sea (SOLAS) is an international maritime safety treaty. The main objective of the SOLAS Convention is to specify minimum standards for the construction, equipment and operation of ships, compatible with their safety. Flag States are responsible for ensuring that ships under their flag comply with its requirements, and a number of certificates are prescribed in the Convention as proof that this has been done. Control provisions also allow Contracting Governments to inspect ships of other Contracting States if there are clear grounds for believing that the ship and its equipment do not substantially comply with the requirements of the Convention - this procedure is known as “port State control”.

The SOLAS Convention in its successive forms is generally regarded as the most important of all international treaties concerning the safety of merchant ships. The first version was adopted in 1914, in response to the Titanic disaster, the second in 1929, the third in 1948, and the fourth in 1960.

A new Convention was adopted in 1974 which included not only the amendments agreed up until that date but a new amendment procedure - the tacit acceptance procedure - designed to ensure that changes could be made within a specified (and acceptably short) period of time.

Instead of requiring that an amendment shall enter into force after being accepted by, for example, two thirds of the Parties, the tacit acceptance procedure provides that an amendment shall enter into force on a specified date unless, before that date, objections to the amendment are received from an agreed number of Parties. As a result, the 1974 Convention has been updated and amended on numerous occasions. The Convention in force today is sometimes referred to as SOLAS, 1974, as amended.

6.5 Identification of the Main Hazards, Consequences and Risk evaluation

This chapter provides an overview of the risk assessment, with particular reference to Offshore installations. In particular, it describes the main steps in the process of risk assessment and the techniques and models that have been developed to conduct a proper risk assessment.

Risk assessment is typically used to support the decision-making process. In fact, the primary objectives of risk assessment are to identify and rank the risks so that they can be adequately managed and to examine associated risk reduction measures to determine those most suitable for implementation.

Risk analysis can address financial risks, health risks, safety risks, environmental risks and other types of business risks. This report focuses on health and safety risks related to navigation: the largest risks and contingencies related to wind farms are related to collision with vessels.

6.5.1 Risk Assessment Definitions

Before analyzing the risk assessment process, it is important to provide a clear definition of the term "risk" and of the other terms used in the risk assessment. In particular, we will refer to the risk of unintended accidents which may threaten the safety of individuals, the environment or a facility. The main terms are the following [11.]:

- **Hazards** or **Threats:** *Hazards* or *threats* are conditions which may potentially lead to an undesirable event.
- **Controls:** *Controls* are the measures taken to prevent hazards from causing undesirable events. Controls can be physical (safety shutdowns, redundant controls, conservative designs, etc.), procedural (written operating procedures), and can address human factors (employee selection, training, supervision).
- **Event:** An *event* is an occurrence that has an associated outcome which may range in severity from trivial to catastrophic, depending upon other conditions and events.

- **Risk:** *Risk* is composed of two elements, frequency and consequence. Risk is defined as the product of the frequency with which an event is anticipated to occur and the consequence of the event's outcome:
    - $Risk = Frequency \times Consequence$

- **Frequency:** The *frequency* of a potential undesirable event is expressed as events per unit time, usually per year. The frequency should be determined from historical data if a significant number of events have occurred in the past. Often, however, risk analyses focus on events with more severe consequences (and low frequencies) for which little historical data exist. In such cases, the event frequency is calculated using risk assessment models.
- **Consequence:** *Consequence* can be expressed as the number of people affected (injured or killed), property damaged, amount of spill, area affected, outage time, mission delay, economic loss, etc. Regardless of the measure chosen, the consequences are expressed "per event". Thus the risk equation has the units "events/year" times "consequences/event", which equals "consequences/year", the most typical quantitative risk measure.

6.5.2 Approaches to Risk Assessment

The risk assessment methodology applied should be efficient and should enable the ranking of risks in order to identify the measures for risk reduction. The care and the attention to be taken in the risk assessment process should be proportionate to the complexity of the problem and the magnitude of risk.

In some cases, qualitative methods to assess frequency and consequence are satisfactory to enable the risk evaluation. In other cases, a more detailed quantitative analysis is required. In general, the risk assessment take place through the following stages [7]:

- **Qualitative** (Q), in which frequency and severity are determined purely qualitatively.
- **Semi-quantitative** (SQ), in which frequency and severity are approximately quantified within ranges.
- **Quantified risk assessment** (QRA), in which full quantification occurs.

The approaches to risk assessment described above are characterized by a different level of assessment from Q (lowest) to full QRA (highest) (see Figure 6.16). One efficient method to decide the appropriate level of detail is to make an initial assessment to identify the likely minimum approach to risk assessment.

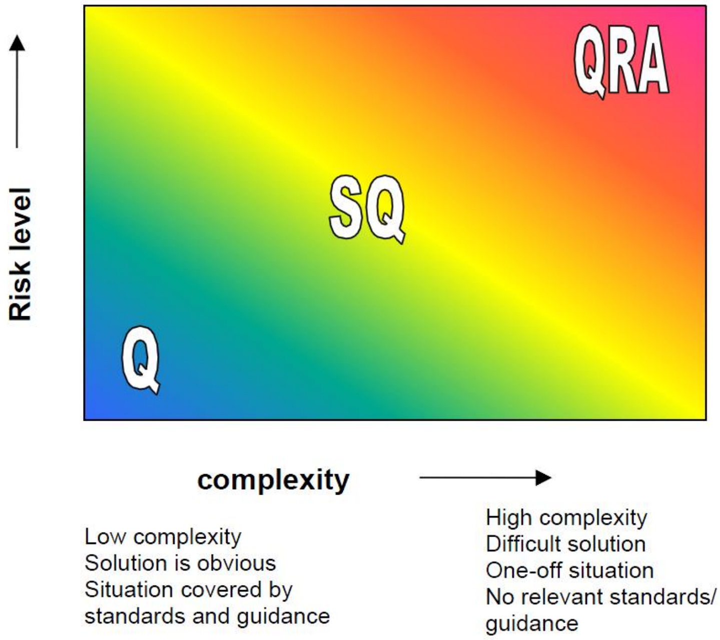


Figure 6.16. Risk Assessment as a Function of Risk Level and Complexity

This initial assessment defines the starting approach and it may be necessary to upgrade the approach whenever it is unable to offer the required understanding of the risk and not adequate for decision making. Some of the factors that should be taken into account when deciding the initial approach to risk assessment in offshore structures are indicated in Table 1 [7].

6.5.3 The risk assessment process

The risk assessment process consists of three main steps:

a. Hazard Identification;
b. Risk Estimation, consisting of:
    i. Frequency Assessment and
    ii. Consequence Assessment;
c. Risk Evaluation.

The level of information needed to make a decision varies widely. In some cases, after identifying the hazards, qualitative methods of assessing frequency and consequence are satisfactory to enable the risk evaluation. In other cases, a more detailed quantitative analysis is required [11.].

Table 6.1. Initial Risk Assessment Approach

Issue	Factors tending towards more detailed risk assessment approach	Factors tending towards less detailed approaches
Stage in life-cycle	• Design • Initial operation • Significant modifications	• Combined operations • Abandonment/ decommissioning • Minor modifications
Process conditions	• High pressure/ temperature • Well fluids containing gas/ condensate	• Low pressure/ temperature • Well fluid is oil/ water with no gas or condensate
Degree of standardisation	• Novel concepts and designs • High complexity	• Standardised designs and controls available
Complexity	• Integrated platforms • Processing of well fluids	• Drilling • Export of well fluids only • Storage • Accommodation
Persons on Board (POB)	• High POB • Permanent presence	• Low POB • Occasional manning

Figure 6.17 illustrates the iterative process of risk assessment and risk reduction as described in [8] and [9]. This is considered a fairly good representation of the risk assessment process, applicable for both qualitative and quantitative assessments.

Figure 6.18 shows the risk estimation, analysis and evaluation as described in [10]. This description of a quantitative risk assessments fits very well with a typical offshore QRA.

There are many different analysis techniques and models that have been developed to aid in conducting risk assessments. Some of these methods are summarized in Figure 6.19 [11]

A key to any successful risk analysis is choosing the right method (or combination of methods) for the situation at hand. It should be noted that some of these methods (or slight variations) can be used for more than one step in the risk assessment process. For example, every tree analysis can be used for frequency assessment as well as for consequence assessment. Figure 6.19 lists the methods only under the most common step to avoid repetitions [11].

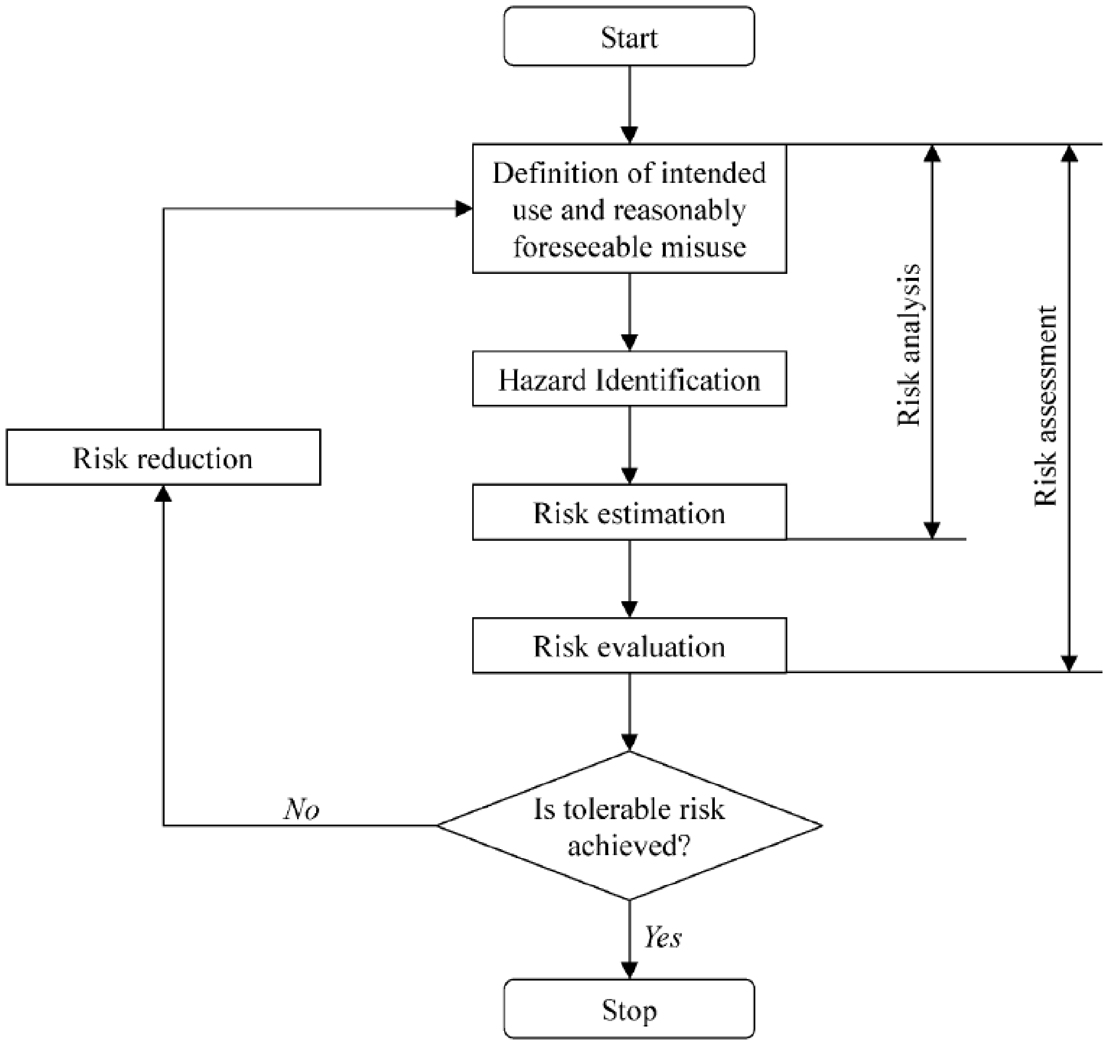


Figure 6.17. Iterative Process of Risk Assessment and Risk Reduction

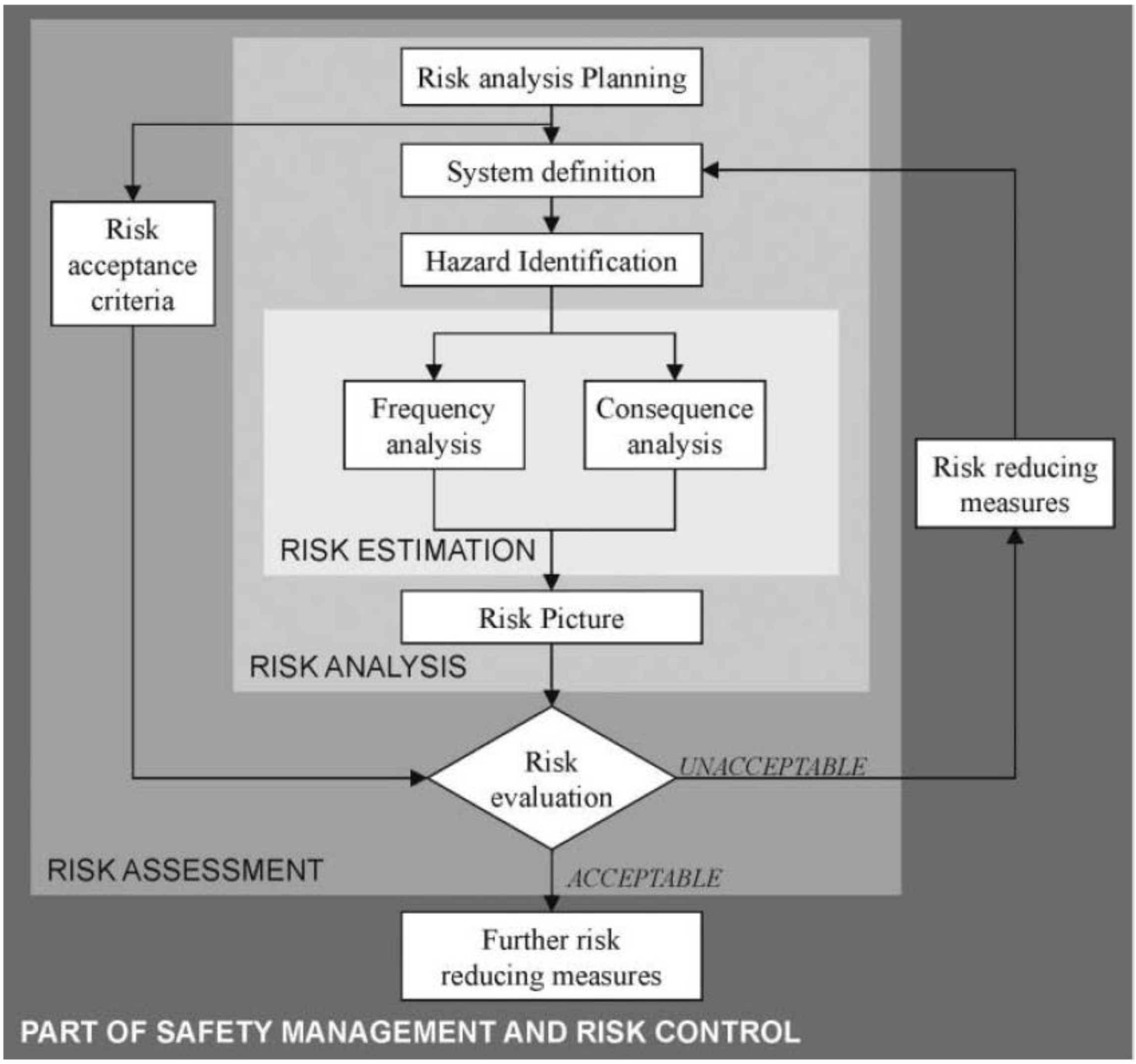


Figure 6.18. Risk estimation, analysis and evaluation

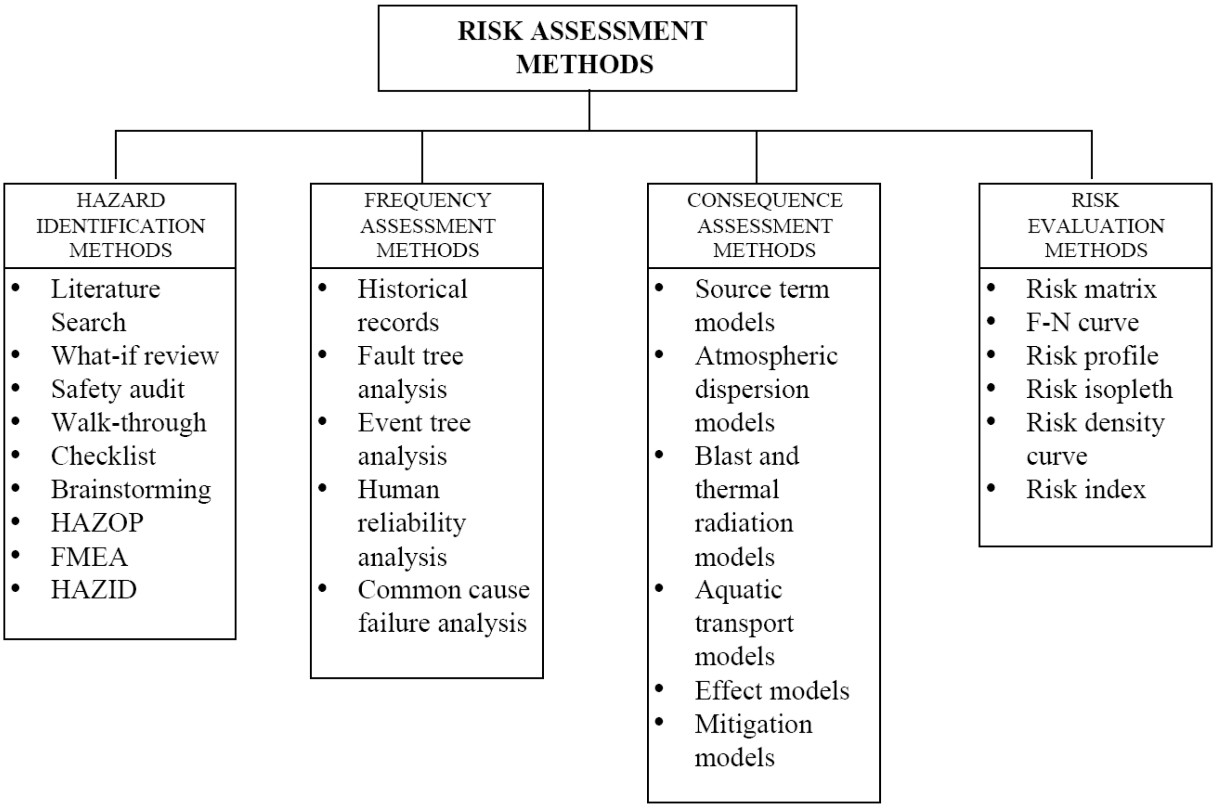


Figure 6.19. Overview of Risk Assessment Methods

6.5.4 Hazards Identification

Because hazards are the source of events that can lead to undesirable consequences, analyses to understand risk exposures must begin by understanding the hazards present. Although hazard identification seldom provides information directly needed for decision making, it is a critical step.

Sometimes hazard identification is explicitly performed using structured techniques. Other times (generally when the hazards of interest are well known), hazard identification is more of an implicit step that is not systematically performed. Overall, hazard identification focuses a risk analysis on key hazards of interest and the types of mishaps that these hazards may create. The following are some of the commonly used techniques to identify hazards [11].

6.5.4.1 Hazard Identification (HAZID) Technique

HAZID is a general term used to describe an exercise whose goal is to identify hazards and associated events that have the potential to result in a significant consequence. For example, a HAZID of an offshore facility may be conducted to identify potential hazards which could result in consequences to personnel (e.g., injuries and fatalities), environment (spills and pollution), and financial assets (e.g., production loss/delay). The HAZID technique can be applied to all or part of a facility or vessel or it can be applied to analyze operational procedures.

Typically, the system being evaluated is divided into manageable parts, and a team is led through a brainstorming session (often with the use of checklists) to identify potential hazards associated with each part of the system. This process is usually performed with a team experienced in the design and operation of the facility, and the hazards that are considered significant are prioritized for further evaluation.

6.5.4.2 What-if Analysis

What-if analysis is a brainstorming approach that uses broad, loosely structured questioning to:

- postulate potential upsets that may result in mishaps or system performance problems;
- ensure that appropriate safeguards against those problems are in place.

This technique relies upon a team of experts brainstorming to generate a comprehensive review and can be used for any activity or system.

Table 6.2. What-if Evaluation Example

Summary of the What-if Review of the Vessel's Compressed Air System				
What if …?	*Immediate System Condition*	*Ultimate Consequences*	*Safeguards*	*Recommendations*
1. The intake air filter begins to plug	Reduced air flow through the compressor affecting its performance	Inefficient compressor operation, leading to excessive energy use and possible compressor damage Low/no air flow to equipment, leading to functional inefficiencies and possibly outages	Pressure/vacuum gauge between the compressor and the intake filter Annual replacement of the filter Rain cap and screen at the air intake	Make checking the pressure gauge reading part of someone's daily rounds OR Replace the local gauge with a low pressure switch that alarms in a manned area
2. Someone leaves a drain valve open on the compressor discharge	High air flow rate through the open valve to the atmosphere	Low/no air flow to equipment, leading to functional inefficiencies and possibly outages Potential for personnel injury from escaping air and/or blown debris	Small drain line would divert only a portion of the air flow, but maintaining pressure would be difficult	—

What-if analysis generates qualitative descriptions of potential problems (in the form of questions and responses) as well as lists of recommendations for preventing problems. It is applicable for almost every type of analysis application, especially those dominated by relatively simple failure scenarios.

It can occasionally be used alone, but most often is used to supplement other, more structured techniques (especially checklist analysis).

Table 6.2 is an example of a portion of a what-if analysis of a vessel's compressed air system [11].

6.5.4.3 Checklist Analysis

Checklist analysis is a systematic evaluation against pre-established criteria in the form of one or more checklists. It is applicable for high-level or detailed-level analysis and is used primarily to provide structure for interviews, documentation reviews and field inspections of the system being analyzed. The technique generates qualitative lists of conformance and non-conformance determinations with recommendations for correcting non-conformances. Checklist analysis is frequently used as a supplement to or integral part of another method (especially what-if analysis) to address specific requirements. Table 6.3 is an example of a portion of a checklist analysis of a vessel's compressed air system [11].

6.5.4.4 Hazard and Operability (HAZOP) Analysis

The HAZOP analysis technique uses special guidewords to prompt an experienced group of individuals to identify potential hazards or operability concerns relating to pieces of equipment or systems. Guidewords describing potential deviations from design intent are created by applying a predefined set of adjectives (i.e. high, low, no, etc.) to a pre-defined set of process parameters (flow, pressure, composition, etc.). The group then brainstorms potential consequences of these deviations and if a legitimate concern is identified, they ensure that appropriate safeguards are in place to help prevent the deviation from occurring. This type of analysis is generally used on a system level and generates primarily qualitative results, although some simple quantification is possible.

Table 6.3. Checklist Analysis Example

Responses to Checklist Questions for the Vessel's Compressed Air System		
Questions	*Responses*	*Recommendations*
Piping	*Piping*	*Piping*
Have thermal relief valves been installed in piping runs (e.g., cargo loading/unloading lines) where thermal expansion of trapped fluids would separate flanges or damage gaskets?	Not applicable	—
• • •	• • •	• • •
Cargo Tanks	*Cargo Tanks*	*Cargo Tanks*
Is a vacuum relief system needed to protect the vessel's cargo tanks during liquid withdrawal?	Yes, the cargo tanks will be damaged if vacuum relief is not provided. A vacuum relief system is installed on each cargo tank	—
• • •	• • •	• • •
Compressors	*Compressors*	*Compressors*
Are air compressor intakes protected against contaminants (rain, birds, flammable gases, etc.)?	Yes, except for intake of flammable gases. There is a nearby cargo tank vent	Consider routing the cargo tank vent to a different location
• • •	• • •	• • •

The primary use of the HAZOP methodology is identification of safety hazards and operability problems of continuous process systems (especially fluid and thermal systems). For example, this technique would be applicable for an oil transfer system consisting of multiple pumps, tanks, and process lines. The HAZOP analysis can also be used to review procedures and sequential operations. Table 6.4 is an example of a portion of a HAZOP analysis performed on a compressed air system onboard a vessel [11].

6.5.4.5 Failure Modes and Effects Analysis (FMEA)

FMEA is an inductive reasoning approach that is best suited for reviews of mechanical and electrical hardware systems. This technique is not appropriate to broader marine issues such as harbor transit or overall vessel safety.

Table 6.4. Example of a HAZOP Analysis

Hazard and Operability Analysis of the Vessel's Compressed Air System					
Item	*Deviation*	*Causes*	*Mishaps*	*Safeguards*	*Recommendations*
1. Intel Line for the Compressor					
1.1	High flow		No mishaps of interest		
1.2	Low/no flow	Plugging of filter or piping (especially at air intake) Rainwater accumulation in the line and potential for freeze-up	Inefficient compressor operation, leading to excessive energy use and possible compressor damage Low/no air flow to equipment and tools, leading to production inefficiencies and possibly outages	Pressure/vacuum gauge between the compressor and the intake filter Periodic replacement of the filter Rain cap and screen at the air intake	Make checking the pressure gauge reading part of someone's daily rounds OR Replace the local gauge with a low pressure switch that alarms in a manned area
1.3	Misdirected flow	No credible cause			
• • •	• • •	• • •	• • •	• • •	• • •

The FMEA technique:

- considers how the failure mode of each system component can result in system performance problems;
- ensures that appropriate safeguards against such problems are in place.

This technique is applicable to any well-defined system, but the primary use is for reviews of mechanical and electrical systems (e.g., fire suppression systems, vessel steering/propulsion systems). It is also used as the basis for defining and optimizing planned maintenance for equipment because the method systematically focuses directly and individually on equipment failure modes. FMEA generates qualitative descriptions of potential performance problems (failure modes, root causes, effects, and safeguards) and can be expanded to include quantitative failure frequency and/or consequence estimates. Table 6.5 is an example of a portion of a FMEA performed on a compressed air system onboard a vessel [11.].

6.5.4.6 Contribution of "Human Factors" Issues

In any effort to identify hazards and assess their associated risks, there must be full consideration of the interface between the human operators and the systems they operate. Human Factors Engineering (HFE) issues can be integrated into the methods used to identify hazards, assess risks, and determine the reliability of safety measures. For instance, hazard identification guidewords have been developed to prompt a review team to consider human factor design issues like access, control interfaces, etc.

Table 6.5. FMEA Evaluation Example

Example from a Hardware-based FMEA

Machine/Process:	Onboard Compressed air system
Subject:	1.2.2 Compressor control loop
Description:	Pressure-sensing control loop that automatically starts/stops the compressor based on system pressure (starts at 95 psig and stops at 105 psig)
Next higher level:	1.2 Compressor subsystem

Failure Mode	*Effects*			*Causes*	*Indications*	*Safeguards*	*Recommendations/ Remarks*
	Local	*Higher Level*	*End*				
A. No start signal when the system pressure is low	Open control circuit	Low pressure and air flow in the system	Interruption of the systems supported by compressed air	Sensor failure or miscalibrated Controller failure or set incorrectly Wiring fault Control circuit relay failure Loss of power for the control circuit	Low pressure indicated on air receiver pressure gauge Compressor not operating (but has power and no other obvious failure)	Rapid detection because of quick interruption of the supported systems	Consider a redundant compressor with separate controls Calibrate sensors periodically in accordance with written procedure
B. No stop signal when the system pressure is high	• • •	• • •	• • •	• • •	• • •	• • •	• • •
• • •	• • •	• • •	• • •	• • •	• • •	• • •	• • •

An understanding of human psychology is essential in estimating the effectiveness of procedural controls and emergency response systems.

Persons performing risk assessments need to be aware of the human factors impact, and training for such persons can improve their ability to spot the potential for human contributions to risk. Risk analysts can easily learn to spot the potential for human error any time human interaction is an explicit mode of risk control. However, it is equally important to recognize human contributions to risk when the human activity is implicit in the risk control measure. For example, a risk assessment of a boiler would soon identify "overpressure" as a hazard that can lead to risk of rupture and explosion. The risk assessment might conclude that the combination of two pressure control measures will result in an acceptably low level of risk. The two measures:

a. have a high pressure alarm that will tell the operator to shut down the boiler and vent the steam, and
b. provide an adequately sized pressure relief valve.

The first risk control measure involves explicit human interaction. Any such control measure should immediately trigger evaluation of human error scenarios that could negate the effectiveness of the control measure. The second risk control measure involves implicit human interaction (i.e., a functioning pressure relief valve does not appear on the boiler all by itself but must be installed by maintenance personnel).

A checklist of common errors or an audit of the management system for operator training are examples of methods used to address the human error potential and ensure that it also is controlled.

The purpose of any tool would be to identify the potential for error and identify how the error is prevented [11.]. Does the operator know what the alarm means? Does he know how to shut down the boiler? What if the overpressure event is one of a series of events (e.g. what if the operator has five alarms sounding simultaneously)? Did the engineer properly size and specify the relief valve? Was it installed correctly? Has it been tested or maintained to ensure its function? A corollary to each of the above questions is required in the analysis: "How do you know?" The answer to that last question is most often found in the management system, thus "Human Factors" is the glue that ties risk assessment from a technology standpoint to risk assessment from an overall quality management standpoint.

6.5.5 Risk Estimation - Frequency Assessment

The risk estimation is constituted by the frequency and consequences analysis.

After the hazards of a system or process have been identified, the next step in performing a risk assessment is to estimate the frequency at which the hazardous events may occur. In the following, some of the techniques and tools available for frequency assessment [11.] are presented.

6.5.5.1 Analysis of Historical Data

The best way to assign a frequency to an event is to research industry databases and locate good historical frequency data which relates to the event being analyzed. Before applying historical frequency data, a thoughtful analysis of the data should be performed to determine its applicability to the event being evaluated. The analyst needs to consider the source of the data, the statistical quality of the data (reporting accuracy, size of data set, etc.) and the relevance of the data to the event being analyzed. For example, transportation data relating to helicopter crashes in the North Sea may not be directly applicable to operations in the Adriatic Sea due to significant differences in atmospheric conditions and the nature of helicopter operating practices. In another cases, frequency data for a certain type of vessel navigation equipment failure may be found to be based on a very small sample of reported failures, resulting in a number which is not statistically valid.

When good quality, applicable frequency data cannot be found, it may be necessary to estimate the frequency of an event using one of the analytical methods described below.

6.5.5.2 Event Tree Analysis (ETA)

Event tree analysis utilizes decision trees to graphically model the possible outcomes of an initiating event capable of producing an end event of interest. This type of analysis can provide (1) qualitative descriptions of potential problems (combinations of events producing various types of problems from initiating events) and (2) quantitative estimates of event frequencies or likelihoods, which assist in demonstrating the relative importance of various failure sequences. Event tree analysis may be used to analyze almost any sequence of events, but is most effectively used to address possible outcomes of initiating events for which multiple safeguards are in line as protective features.

The following example event tree (Figure 6.20) illustrates the range of outcomes for a tanker having redundant steering and propulsion systems. In this particular example, the tanker can be steered using the redundant propulsion systems even if the vessel loses both steering systems [11.].

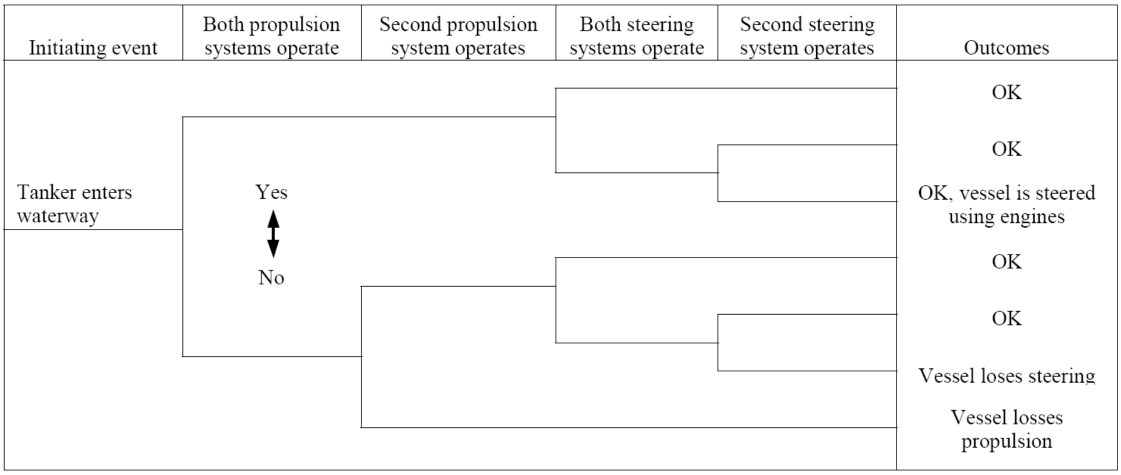


Figure 6.20. Example Event Tree Analysis

6.5.5.3 Fault Tree Analysis (FTA)

Fault Tree Analysis (FTA) is a deductive analysis that graphically models (using Boolean logic) how logical relationships among equipment failures, human errors and external events can combine to cause specific mishaps of interest. Similar to event tree analysis, this type of analysis can provide (1) qualitative descriptions of potential problems (combinations of events causing specific problems of interest) and (2) quantitative estimates of failure frequencies/likelihoods and the relative importance of various failure sequences/contributing events. This methodology can also be applied to many types of applications, but is most effectively used to analyze system failures caused by relatively complex combinations of events.

The following example illustrates a very simple fault tree analysis of a loss of propulsion event for a vessel (Figure 6.21) [11].

6.5.5.4 Common Cause Failure Analysis (CCFA)

CCFA is a systematic approach for examining sequences of events stemming from multiple failures that occur due to the same root cause. Since these multiple failures or errors result from the same root causes, they can defeat multiple layers of protection simultaneously.

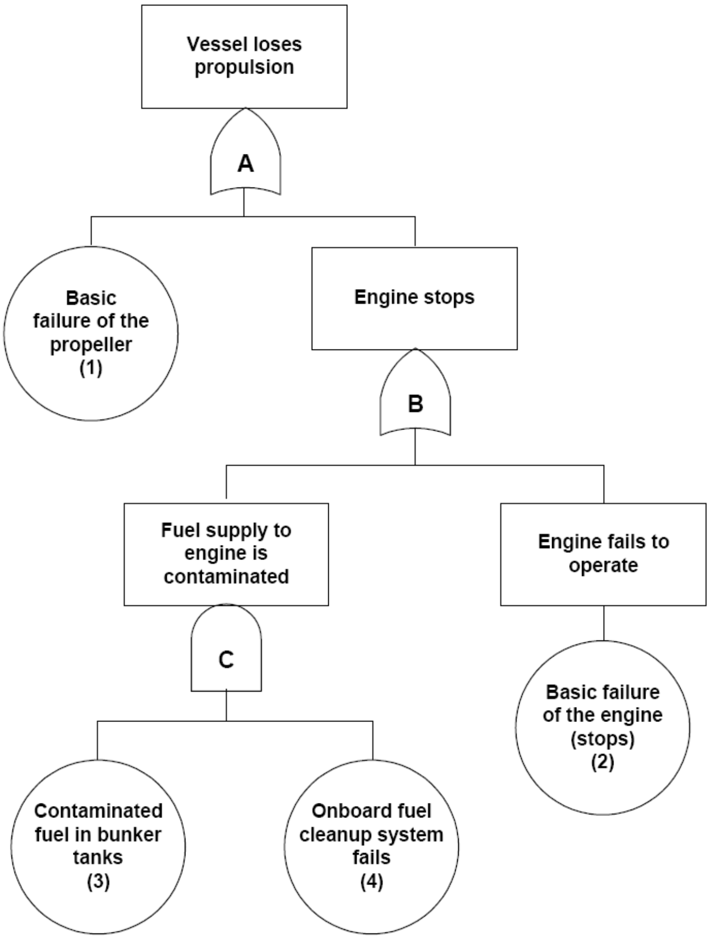


Figure 6.21. Example Fault Tree Analysis

CCFA has the following characteristics:

a. systematic, structured assessment relying on the analyst's experience and guidelines for identifying potential dependencies among failure events to generate a comprehensive review and ensure that appropriate safeguards against common cause failure events are in place;
b. used most commonly as a system-level analysis technique;
c. primarily performed by an individual working with system experts through interviews and field inspections;
d. generates:
   i. qualitative descriptions of possible dependencies among events;
   ii. quantitative estimates of dependent failure frequencies/likelihoods;
   iii. lists of recommendations for reducing dependencies among failure events;

e. quality of the evaluation depends on the quality of the system documentation, the training of the analyst and the experience of the SMEs assisting the analyst.

CCFA is used exclusively as a supplement to a broader analysis using another technique, especially fault tree and event tree analyses. It is best suited for situations in which complex combinations of errors/equipment failures are necessary for undesirable events to occur.

6.5.5.5 Human Reliability Analysis

Where human performance issues contribute to the likelihood of an end event occurring, methods for estimating human reliability are needed. For instance, an event tree could be constructed which includes a branch titled "*Operator responds to alarm and takes appropriate corrective action*". In order to estimate a numerical frequency with which this occurs, human reliability analysis can be applied.

Human Reliability Analysis is a general term for methods by which human errors can be identified, and their probability estimated for those actions that can contribute to the scenario being studied, be it personnel safety, loss of the system, environmental damage, etc.

The estimate can be either qualitative or quantitative, depending on the information available and the degree of detail required.

Regardless of the approach used, the basic steps that an assessor would undertake for a human reliability analysis would be the same. Figure 6.22 graphically depicts the steps of the human reliability assessment process and their order.

In case that high-risk scenarios were identified during the risk assessment, these scenarios would be re-examined as to the impact the individual could have while completing a task related to the scenario. The assessor would then conduct some sort of task analysis to determine what an individual would do to successfully complete the task [11.].

Once the successful steps were identified, then the assessor could determine what the person might do wrong at each step to reach the undesirable result. Some examples of potential problems areas are:

- Written procedures not complete or hard to understand;
- Instrumentation inoperative or inadequate;
- Lack of knowledge by the operator;
- Conflicting priorities;
- Labeling inadequacies;

- Policy versus practice discrepancies;
- Equipment not operating according to design specifications;
- Communication difficulties;
- Poor ergonomics;
- Oral versus written procedures;
- Making a repair or performing maintenance with a wrong tool.

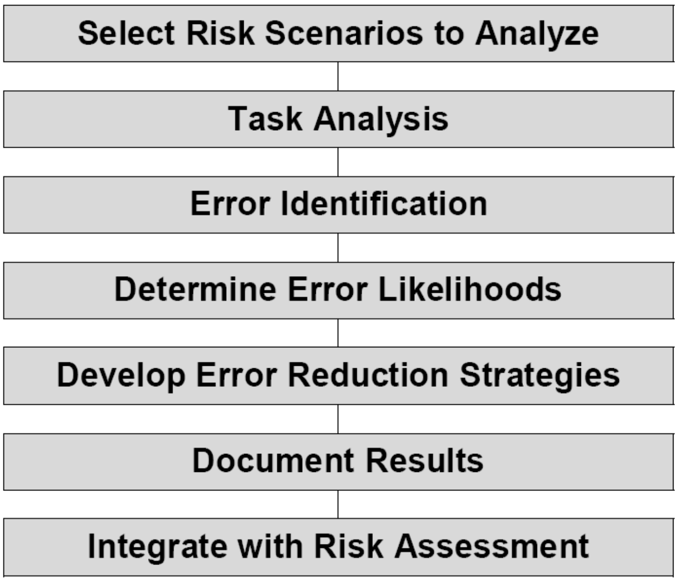


Figure 6.22. Human Reliability Assessment Process

Each of the above situations increases the probability that an individual will err in the performance of a task. This is important since the following stage in human reliability analysis is assigning likelihood estimates to human errors. When examining each of the potential human errors in the context of a scenario, the analysis must systematically look at each step and each potential error identified. If there are a large number of potential errors, the assessor may decide to conduct a preliminary screening to determine which errors are less or more likely to occur and then choose to only assign values to the more likely errors. For determining likelihood, the assessor can produce qualitative estimates, (e.g., low, medium or high) or quantitative estimates (e.g., 0.003) using existing human failure databases. These estimates allow to determine what individual errors are the most likely to cause an individual's performance to fall short of the desired result. Upon reviewing the estimates, error reduction strategies can be developed to minimize the frequency of human error. Minimizing the human error will also reduce the likelihood of the overall scenario itself from occurring. After the human reliability analysis is complete, the following information will be available:

- List of tasks;
- List of potential errors;
- Human error probabilities;
- Error reduction strategies;
- Information related to training and procedures;
- Information related to safety management system.

The listing of tasks relating to the scenario, the list of human errors and their probabilities, the error reduction strategies and the other information generated as a part of the human reliability study can all be integrated into the risk assessment study. The human reliability information should also be used for defining risk reduction measures [11].

6.5.6 Risk Estimation - Consequence Assessment

Consequence modeling typically involves the use of analytical models to predict the effect of a particular event of concern. Examples of consequence models include source term models, atmospheric dispersion models, blast and thermal radiation models, aquatic transport models and mitigation models. Most consequence modeling today makes use of computerized analytical models.

Use of these models in the performance of a risk assessment typically involves four activities:

- Characterizing the source of the material or energy associated with the hazard being analyzed;
- Measuring (through costly experiments) or estimating (using models and correlations) the transport of the material and/or the propagation of the energy in the environment to the target of interest;
- Identifying the effects of the propagation of energy or material on the target of interest;
- Quantifying the health, safety, environmental, or economic impacts on the target of interest.

Many sophisticated models and correlations have been developed for consequence analysis. Millions of dollars have been spent researching the effects of exposure to toxic materials on the health of animals. The effects are extrapolated to predict effects on human health.

A considerable empirical database exists on the effects of fires and explosions on structures and equipment, and large, sophisticated experiments are sometimes performed to validate computer algorithms for predicting the atmospheric dispersion of toxic materials.

All of these resources can be used to help predict the consequences of accidents. However, only those consequence assessment steps needed to provide the information necessary for decision making should be performed.

The result from the consequence assessment step is an estimate of the statistically expected exposure of the target population to the hazard of interest and the safety/health effects related to that level of exposure.

For example:

- One hundred people will be exposed to air concentrations above the emergency response planning guidelines;
- Ten fatalities are expected if this explosion occurs;
- If this event occurs, 1,200 lb. of material are expected to be released to the environment.

The form of consequence estimate generated should be determined by the objectives and scope of the study. Consequences are usually stated in the expected number of injuries or casualties or, in some cases, exposure to certain levels of energy or material release. These estimates customarily account for average meteorological conditions and population distribution and may include mitigating factors, such as evacuation and sheltering.

In some cases, simply assessing the quantity of material or energy released will provide an adequate basis for decision making.

Like frequency estimates, consequence estimates may have very large uncertainties.

Estimates that vary by a factor of up to two orders of magnitude can result from (1) basic uncertainties in chemical/physical properties, (2) differences in average versus time-dependent meteorological conditions, and/or (3) modeling uncertainties [11.].

6.5.7 Risk Evaluation - Comparison Between the Risk Estimated and Risk Acceptance Criteria

Once the hazards and potential mishaps or events have been identified for a system or process and the frequencies and consequences associated with these events have been estimated, the relative risks associated with the events can be evaluated. There are a variety of qualitative and quantitative techniques used to do this [11.].

6.5.7.1 Subjective Prioritization

Perhaps the simplest qualitative form of risk characterization is subjective prioritization. In this technique, the analysis team identifies potential mishap scenarios using structured hazard analysis techniques (e.g., HAZOP, FMEA). The analysis team subjectively assigns each scenario a priority category based on the perceived level of risk.

Priority categories can be:

- Low, medium, high;
- Numerical assignments;
- Priority levels.

6.5.7.2 Risk Categorization/Risk Matrix

Another method to characterize risk is categorization. In this case, the analyst must (1) define the likelihood and consequence categories to be used in evaluating each scenario and (2) define the level of risk associated with likelihood/consequence category combination.

Frequency and consequence categories can be developed in a qualitative or quantitative manner. Qualitative schemes (i.e., low, medium, or high) typically use qualitative criteria and examples of each category to ensure consistent event classification. Multiple consequence classification criteria may be required to address safety, environmental, operability and other types of consequences. Table 6.6 and Table 6.7 provide examples of criteria for categorization of consequences and likelihood [11.].

Table 6.6. Consequence Criteria

Category	*Description*	*Definition*
1	Negligible	Passenger inconvenience, minor damage
2	Marginal	Marine injuries treated by first aid, significant damage not affecting seaworthiness, less than 25K
3	Critical	Reportable marine casualty (46 CFR 4.05-1)
4	Catastrophic	Death, loss of vessel, serious marine incident (46 CFR 4.03-2)

Table 6.7. Likelihood (e.g. Frequency) Criteria

*Likelihood**	*Description*
Low	The mishap scenario is considered highly unlikely.
Low to Medium	The mishap scenario is considered unlikely. It could happen, but it would be surprising if it did.
Medium to High	The mishap scenario might occur. It would not be too surprising if it did.
High	The mishap scenario has occurred in the past and/or is expected to occur in the future.

* Likelihood assessments are for the remaining life of the system, assuming normal maintenance and repair.

Once the assignment of consequences and likelihoods is complete, a risk matrix can be used as a mechanism for assigning risk (and making risk acceptance decisions), using a risk categorization approach.

Likelihood of occurrence	Negligible	Marginal	Critical	Catastrophic
High	A	M	U	U
Med. to High	A	M	U	U
Low to Med.	A	A	M	U
Low	A	A	A	M

A = Acceptable
M = Marginal
U = Unacceptable

Figure 6.23. Example Risk Matrix

Each cell in the matrix corresponds to a specific combination of likelihood and consequence and can be assigned a priority number or some other risk descriptor (as shown in Figure 6.23). An organization must define the categories that it will use to score risks and, more importantly, how it will prioritize and respond to the various levels of risks associated with cells in the matrix.

6.5.7.3 Risk Sensitivity

When presenting quantitative risk assessment results, it is often desirable to demonstrate the sensitivity of the risk estimates to changes in critical assumptions made within the analysis. This can help illustrate the range of uncertainty associated with the exercise.

Risk sensitivity analyses can also be used to demonstrate the effectiveness of certain risk mitigation approaches. For example, if by increasing inspection frequency on a piece of equipment, the failure rate could be reduced, a sensitivity analysis could be used to demonstrate the difference in estimated risk levels when inspection frequencies are varied.

6.6 Proposed Methodology, Scope and Depth of Risk Assessment in the Offshore Wind Field

In the following, a risk assessment methodology is proposed, to be used by wind farm developers for preparing their marine navigation safety risk assessments. Methodology will be useful to identify the level of information that a developer shall provide in an application. This methodology is mutuated with the risk assessment methodology implemented in the UK, where it must be mandatorily followed by developers.

The risk assessment methodology covers the marine navigational safety risks for navigation and operations taking place within and around the wind farm. Important topics are:

a. Formal Safety Assessment, supported by
b. Navigation risk assessment, including:
    i. Search and rescue overview;
    ii. Emergency response overview.

The Marine Navigational Safety Risk Assessment, produced by applying this methodology, should form part of the Environmental Impact Assessment.

6.6.1 Areas Covered

The key risk areas covered by the methodology include:

a. Risks associated with a development;
b. Cumulative risks associated with the development and the other wind farm developments in the strategic wind farm area;
c. In-combination effects on the risk of the development with other economic developments over the operational life of the wind farm.

6.6.2 Proportionality and Depth of the Risk Assessment

When developers carry out a risk assessment, they should take into account that the scope and depth of the assessment, together with the tools and techniques used, should be proportionate to the:

a. Scale of the development;
b. Magnitude of the risks.

In particular, developers should:

a. Inform the relevant Maritime Authority of their proposals and seek guidance;
b. Carry out a preliminary hazard analysis;
c. Define an appropriate programme of work;
d. Define the tools and techniques to be used;
e. Be prepared to change scope, depth, tools and techniques resulting from the assessed risk as the full assessment progresses.

Within this process, the Maritime Authority should:

a. Give guidance if asked;
b. Be prepared, in principle, to accept a change in scope, depth, tools and techniques resulting from the assessed risk as the full assessment progresses.

In the following, some examples clarifying the idea of proportionality are provided.

6.6.3 High Risk or Large Scale Development

In case the development is carried out in an area with high potential risks or if it is a large scale development, the assessment should include a:

a. Comprehensive Hazard Log;
b. Detailed and quantified Navigation Risk Assessment;
c. Preliminary search and rescue assessment or overview, to agreed the local authorities requirements;
d. Preliminary emergency response assessment or overview, to agreed local authorities requirements;
e. Comprehensive Risk control log.

6.6.4 Low Risk or Small Scale Development

In case the development is carried out in an area with low potential risks or if it is a small scale development, the assessment should include a:

a. Hazard list;
b. Navigation risk assessment based on qualitative techniques such as “expert judgement”;
c. Search and rescue overview, to agreed maritime authorities requirements;
d. Emergency response overview, to agreed maritime authorities requirements;
e. Risk Control List.

6.6.5 Preliminary Search and Rescue Operations Assessment or Overview

As mentioned above, a preliminary assessment or overview should be proportionate to the scale of development and the magnitude of the risks. When developers carry out a risk assessment, they should seek guidance from the local authorities as to the scope to be followed.

It is noteworthy to highlight a twofold characteristic of a wind farm. On the one hand, it may present risks to marine safety thus generating the need for search and rescue operations; on the other hand, it may hinder search and rescue operations not connected to the development itself.

Therefore, the preliminary assessment should firstly consider all those features that could present problems for the emergency services.

In the assessment, it is of particular importance to include the detection and positioning of casualties within and near to the wind farm by other vessels, maritime authorities, maritime rescue bodies, military authorities (navy and air forces). It is also important providing compliance of turbines with maritime and air regulation codes, in respect of an active safety management system (ASMS).

Another important feature concerns the developer’s contingency plans related to personnel working on turbines or operating within and close to the wind farm; such plans should form part of the Environmental Statement submission. It is recommended that any marine safety aspects will be discussed and agreed with the maritime authority.

In general, since surface vessels are the most likely means of rescue from/within wind farms, the assessment should give details on the position of lifeboat stations and lifeboats type near to the site, and of any appropriate training which will be given to lifeboat crews.

6.6.6 Requirements for more detailed Search and Rescue Operation Assessments

In case of areas of high traffic density, where any type of marine safety hazards are seen to be significant, or where passenger vessel operations are common, authorities may require a more detailed Search and Rescue Response Assessment to be undertaken later as a condition of a granted consent.

However, where the frequency or the consequences of such incidents gives rise for even greater concern, a full assessment may be required before consent is granted.

This assessment may, if deemed appropriate by the maritime authority, include:

a. Resource planning assessment
b. Response planning assessment

The maritime authority should inform developers of their specific requirements in this respect.

6.6.7 Preliminary Assessment or Overview of the Required Emergency Response to the Spills of Hazardous and Polluting Substances

Developers should become familiar with the Governments' national contingency plans for marine pollution from shipping and offshore installations, where adopted. Pollution contingencies may result from incidents occurring within or close to offshore wind farms. Such plans consider pollution from oil and a variety of hazardous substances.

The preliminary assessment should determine the likelihood of any such incidents occurring; such assessment should be based on the general navigation risk assessment and the types of vessel expected to be found in the vicinity. Furthermore, the potential consequences of such an incident, with respect to seafarers, the environment, and the shore population should be considered.

Any circumstance created by the wind farm development, which may adversely affect counter pollution operations undertaken by the appropriate authorities, should be specified. These circumstances should include counter pollution operations relating to incidents not caused by the wind farm development, but into whose area the resulting pollution may drift.

6.6.8 Requirements for more detailed Emergency Response Assessments

Depending on the above assessment, the competent authority may require a more detailed emergency response assessment to be undertaken later, as a granted consent. However, where the frequency, or the consequences, of such incidents give rise for even greater concern, a full assessment may be required before consent is granted.

It is fundamental that the maritime authority will inform developers of their specific requirements in this respect.

6.7 Recommendations on Navigation Safety

This chapter is built on the experience gained by North European Countries and in particular to UK. The main reference is the document "Guidance on the Assessment of the Impact of Offshore Wind Farms: Methodology for Assessing the Marine Navigational Safety Risks of Offshore Wind Farms", developed by the UK Department of Trade and Industry (DTI) in cooperation with UK's Marine and Coastguard Agency (MCA) and the UK Department for Transport (DfT) [14.].

The recommendations contained therein apply to all sites, whether within the jurisdiction of port limits or in open sea areas. However, port authorities may require developers to comply with their own specific criteria (this occur both in the UK as in the Adriatic countries). In addition, where proposals within port limits could affect navigation or emergency planning, there will be the need to review the port's safety management system (an aspect that is up to the port's authorities, although the costs for this review may be reverted to the project developer), in accordance with the relevant port marine safety code.

Developers should comply with the recommendations during all phases of their planning, construction, operation and decommissioning. Information concerning their navigational impact during these four phases should be promulgated in ample time to all relevant mariners, organizations and authorities.

Contingency arrangements to deal with marine casualties in, or adjacent to sites, including responses to environmental pollution, should be planned and practised to test their efficiency.

6.8 Considerations on Site Position and Structure

6.8.1 Traffic Survey

An up to date traffic survey of the area concerned should be undertaken. This should include all vessel types and it is likely to total at least four weeks duration but also taking account of seasonal variations in traffic patterns. These variations should be determined in consultation with representative recreational and fishing vessel organisations, and, where appropriate, port and navigation authorities. Whilst recognising that site-specific factors need to be taken into consideration, any survey should, in general, assess:

a. Proposed wind farm site relative to areas used by any type of marine craft;
b. Numbers, types and sizes of vessels presently using such areas;
c. Non-transit uses of the areas, e.g. fishing, day cruising of leisure craft, racing, aggregate dredging, etc;
d. Whether these areas contain transit routes used by coastal or deep-draught vessels on passage;
e. Alignment and proximity of the site relative to adjacent shipping lanes;
f. Whether the nearby area contains prescribed routeing schemes or precautionary areas;
g. Whether the site lies on or near a prescribed or conventionally accepted separation zone between two opposing routes;
h. Proximity of the site to areas used for anchorage, safe haven, port approaches and pilot boarding or landing areas;
i. Whether the site lies within the limits of jurisdiction of a port and/or navigation authority;
j. Proximity of the site to existing fishing grounds, or to routes used by fishing vessels to such grounds;
k. Proximity of the site to offshore firing/bombing ranges and areas used for any marine military purposes;
l. Proximity of the site to existing or proposed offshore oil/gas platform, marine aggregate dredging, marine archaeological sites or wrecks, or other exploration/exploitation sites;
m. Proximity of the site relative to any designated areas for the disposal of dredging spoil;
n. Proximity of the site to aids to navigation and/or Vessel Traffic Services in or adjacent to the area and any impact thereon;

o. Researched opinion using computer simulation techniques with respect to the displacement of traffic and, in particular, the creation of 'choke points' in areas with high traffic density.

6.8.2 Wind Farm Structure

There are different wind farm structures that could affect the navigation activities, such as:

a. Turbine:
   i. Foundation type;
   ii. Transition Piece;
   iii. Tower;
   iv. Nacelle;
   v. Blades;
   vi. Platforms and superstructure fittings.
b. Offshore Installations (if appropriate):
   i. Offshore Substation;
   ii. Offshore Service Bases;
   iii. Offshore Accommodation Bases;
c. Cable:
   i. Export Cable;
   ii. Inter-turbine Cabling;
d. Subsea Installations, including anti-scour material.

In particular, it should be determined:

a. Whether any features of the wind farm, including auxiliary platforms outside the main generator site and cabling to the shore, could pose any type of difficulty or danger to vessels underway, performing normal operations, or anchoring. Such dangers would include clearances of wind turbine blades above the sea surface, the burial depth of cabling, etc[40];
b. Whether any feature of the installation could create problems for emergency rescue services, including the use of lifeboats, helicopters and emergency towing vessels;

[40] Recommended minimum safe (air) clearances between sea level conditions at mean high water springs (MHWS) and wind turbine rotors are that they should be suitable for the vessels types identified in the traffic survey but generally not less than 22 meters.

c. How rotor blade rotation and power transmission will be controlled by the designated services when this is required in an emergency[41].

6.8.3 Assessment of Access to and Navigation Within or Close to the Wind Farm

This evaluation should be carried out to determine the extent to which navigation would be feasible within the wind farm site itself, by assessing whether:

a. Navigation within the site would be safe :
    i. by all vessels, or
    ii. by specified vessel types, operations and/or sizes,
    iii. in all directions or areas, or iv. in specified directions or areas,
    iv. in specified tidal, weather or other conditions.
b. Navigation in and/or near the site should be:
    i. prohibited by specified vessels types, operations and/or sizes,
    ii. prohibited in respect of specific activities,
    iii. prohibited in all areas or directions, or
    iv. prohibited in specified areas or directions, or
    v. prohibited in specified tidal or weather conditions, or simply
    vi. recommended to be avoided.
c. Exclusion from the site could cause navigational, safety or routeing problems for vessels operating in the area.

Relevant information concerning a decision to seek a "safety zone" for a particular site in any point during its construction, operation or decommissioning, should be promulgated and shared with the relevant institutions.

6.9 Navigation, Collision Avoidance and Communications

6.9.1 Effect of Tides, Tidal Streams and Other Underwater Currents

Possible impact on tidal hydrodynamics is considered a primary issue in Northern seas. In the Adriatic Sea this problem is much less important due to the limited tidal excursion, although some other phenomena determining strong currents (e.g. close to river and coastal lakes

[41] See paragraph 6.4.

mouths, or close to capes in locations close to the coast) are possible in limited areas. In these cases only, it should be determined whether or not:

a. Current maritime traffic flows and operations in the general area are affected by the depth of water in which the proposed installation is situated at various states of the tide i.e. whether the installation could pose problems at high water which do not exist at low water conditions (this problem is much less important for the Adriatic Sea in respect to the northern seas, due to limited tidal excursion), and vice versa;
b. Set and rate of the tidal (or similar) stream, at any state of the tide, has a significant effect on vessels in the area of the wind farm site;
c. Maximum rate tidal (or similar) stream runs parallel to the major axis of the proposed site layout, and, if so, its effect;
d. The set is across the major axis of the layout at any time, and, if so, at what rate.
e. In general, whether engine failure or other circumstance could cause vessels to be set into danger by the tidal (or other current) stream;
f. Structures themselves could cause changes in the set and rate of the tidal (or other current) stream;
g. Structures in the tidal stream could be such as to produce deposition of sediment or scouring, affecting navigable water depths in the wind farm area or adjacent to the area.

In situations where important tidal (or similar) phenomena occurred a hydrographic survey of the site and its immediate environs should be carried out for establishing a baseline.

6.9.2 Effect of Weather

It should be determined if:

a. The site, in normal, bad weather, or restricted visibility conditions, could present difficulties or dangers to craft, including sailing vessels, which might pass in close proximity to the wind farm;
b. The structures could create problems in the area for vessels under sail, such as wind masking, turbulence or sheer.

6.9.3 Visual Navigation and Collision Avoidance

It should be assessed if:

a. Structures could block or hinder the view of other vessels under way on any route.
b. Structures could block or hinder the view of the coastline or of any other navigational feature such as aids to navigation, landmarks, promontories, etc.

6.9.4 Communications, Radar and Positioning Systems

The farm developer should provide researched opinion of generic and, where appropriate, site specific nature concerning whether or not:

a. Structures could produce radio interference such as shadowing, reflections or phase changes, with respect to any frequencies used for marine positioning, navigation or communications, including Automatic Identification Systems;
b. Structures could produce radar reflections, blind spots, shadow areas or other adverse effects:
   i. Vessel to vessel;
   ii. Vessel to shore;
   iii. VTS radar to vessel;
   iv. Racon to/from vessel. Racons, also called radar responders, or radar transponder beacons, are receiver/transmitter transponder devices used as a navigation aid, identifying landmarks or buoys on a shipboard marine radar display.
c. Wind farms, in general, would comply with current recommendations concerning electromagnetic interference;
d. Structures and generators might produce sonar interference affecting fishing, industrial or military systems used in the area;
e. Site might produce acoustic noise which could mask prescribed sound signals;
f. Generators and the seabed cabling within the site and onshore might produce electromagnetic fields affecting compasses and other navigation systems.

6.9.5 Maritime and Navigational Marking

The following aspects should be determined:

a. How the overall site would be marked by day and by night taking into account that there may be an ongoing requirement for marking on completion of decommissioning, depending on individual circumstances;

b. How individual structures on the perimeter of and within the site, both above and below the sea surface, would be marked by day and by night;
c. If the site would be marked by one or more racons and/or,
d. If the site would be marked by an Automatic Identification System (AIS) transceiver, and if so, the data it would transmit;
e. If the site would be fitted with a sound signal, and where the signal or signals would be sited;
f. Whether the proposed site and/or its individual generators would comply in general with markings for such structures, as required by the relevant authorities;
g. The aids to navigation specified by the relevant authorities are being maintained such as established by national and international regulations;
h. The procedures that need to be put in place to respond to casualties to the aids to navigation specified by the relevant authorities within the proper timescales.

6.9.6 Safety and Mitigation Measures during Construction, Operation and Decommissioning

Mitigation and safety measures should be applied to the wind farm development appropriate to the level and type of risk determined during the Environmental Impact Assessment (EIA). The specific measures to be employed should be selected in consultation with the Maritime Authority. These measures will be consistent with international standards contained in, for example, the Safety of Life at Sea (SOLAS, see Chapter 3) Convention (SOLAS, see Chapter 3) - Chapter V, IMO Resolution A.572 (14)3 and Resolution A.671(16)4 and could include any or all of the following:

a. Promulgation of information and warnings through notices to mariners and other appropriate media;
b. Continuous watch by multichannel VHF, including Digital Selective Calling (DSC);
c. Safety zones of appropriate configuration, extent and application to specified vessels;
d. Designation of the site as an area to be avoided;
e. Implementation of routeing measures within or near to the development;
f. Monitoring by radar, AIS and/or closed circuit television (CCTV);
g. Appropriate means to notify and provide evidence of the infringement of safety zones;
h. Any other measures and procedures considered appropriate in consultation with other stakeholders.

6.10 Standards and Procedures for Emergency Wind Turbine Generator Shutdown

This paragraph contains some recommendations regarding the shutdown in the event of a search and rescue, counter pollution or salvage incident in or around a wind farm.

6.10.1 Design Requirements

The wind farm should be designed and constructed to satisfy the following design requirements for emergency rotor shut-down in the event of a search and rescue (SAR), counter pollution or salvage operation in or around a wind farm:

a. All wind turbine generators (WTGs) will be marked with clearly visible unique identification characters. The identification characters shall be illuminated by a low-intensity light visible from a vessel, thus enabling the structure to be detected at a suitable distance to avoid a collision with it. The size of the identification characters in combination with the lighting should be such that, under normal conditions of visibility, they are clearly readable by an observer, stationed 3 metres above sea level, and at a distance of at least 150 metres from the turbine. It is recommended that lighting for this purpose be hooded or baffled so as to avoid unnecessary light pollution or confusion with navigation marks. (Precise dimensions to be determined by the height of lights and necessary range of visibility of the identification numbers);
b. All wind turbine generators (WTG) should be equipped with control mechanisms that can be operated from the Central Control Room of the wind farm;
c. Throughout the design process for a wind farm, appropriate assessments and methods for safe shutdown should be established and agreed, through consultation with the relevant maritime authorities and other emergency support services;
d. The WTG control mechanisms should allow the Control Room Operator to fix and maintain the position of the WTG blades as determined by the relevant Maritime Rescue Co-ordination Centre (MRCC)[42];

[42] The maritime rescue is organized and managed differently from Country to Country. In Italy the Coast Guard (Guardia Costiera) is responsible for it, in Croatia the responsible body is the National Maritime Rescue Coordination Center Rijeka (MRCC RIJEKA), in Montenegro the Maritime Rescue Coordination Center Bar (MRCC Bar) etc.

e. Nacelle hatches should be capable of being opened from the outside. This will allow rescuers (e.g. helicopter winch-man) to gain access to the tower if tower occupants are unable to assist and when sea-borne approach is not possible.
f. Access ladders, although designed for entry by trained personnel using specialised equipment and procedures for turbine maintenance in calm weather, could conceivably be used, in an emergency situation, to provide refuge on the turbine structure for distressed mariners. This scenario should therefore be considered when identifying the optimum position of such ladders and take into account the prevailing wind, wave and tidal conditions.

6.10.2 Operational Requirements

a. The Central Control Room should be manned 24 hours a day;
b. The Central Control Room operator should have a chart indicating the Global Positioning System (GPS) position and unique identification numbers of each of the WTGs in the wind farm;
c. All relevant MRCCs will be advised of the contact telephone number of the Central Control Room;
d. All relevant MRCCs will have a chart indicating the GPS position and unique identification number of each of the WTGs in all wind farms.

6.10.3 Operational Procedures

a. Upon receiving a distress call or other emergency alert from a vessel which is concerned about possible collision with a WTG or is already close to or within the wind farm, the MRCC will establish the position of the vessel and the identification numbers of any WTGs which are visible to the vessel. The position of the vessel and identification numbers of the WTGs will be passed immediately to the Central Control Room by the MRCC.
b. The control room operator should immediately initiate the shutdown procedure for those WTGs as requested by the MRCC and maintain the WTG in the appropriate shut-down position, again as requested by the MRCC, until receiving notification from the MRCC that it is safe to restart the WTG;

c. Communication and shutdown procedures should be tested satisfactorily at least twice a year.

6.11 General Guidance and Proposed Techniques on Navigational Safety Issues

This chapter is built on the experience gained by North European Countries and in particular UK. Also for this Chapter is mainly based on the document "Guidance on the Assessment of the Impact of Offshore Wind Farms: Methodology for Assessing the Marine Navigational Safety Risks of Offshore Wind Farms" [14.], developed by the UK Department of Trade and Industry (DTI) in cooperation with UK's Marine and Coastguard Agency and the UK Department for Transport. A further useful source of technical information is the UK's Marine Guidance Note 371 (M+F) "Offshore Renewable Energy Installations (OREIs) - Guidance on UK Navigational Practice, Safety and Emergency Response". This chapter considers several aspects important to assess navigation safety around offshore wind farms (rules on navigation, effect of COLREGs, formal safety assessment, present and future traffic density assessment, assessment of marine activities, risk assessment, creation of an hazard log, measure of risk levels, influences on risk levels and tolerability of residual risks), but it is not meant to be an exhaustive manual for risk assessment on offshore wind (for such a guide, [14] is an excellent reference): developing a similar manual needs to have a whole regulatory framework developed specifically for offshore wind energy in each of the Adriatic Countries, which is still under development. This Chapter (and this whole Report), as well as the other outcomes of Powered Project, are parts of this development and it is hoped they will provide a useful reference for building this framework.

6.11.1 Rules on Maritime Navigation Safety Issues

The main rules to be taken into account are: the navigation rules to be followed by ships to prevent collisions between two or more vessels (COLREGs); the International Maritime Organization (IMO) responsible for measures to improve the safety and security of international shipping; a law which defines the rights and responsibilities of nations in their use of the world's oceans (UNCLOS); an international maritime safety treaty (SOLAS) aimed at specifying minimum standards for the construction, equipment and operation of ships, compatible with their safety.

6.11.2 The Prevention of Collision Regulations – COLREGs

COLREGs have already been introduced earlier in this chapter. The assessment tools and techniques used in the navigational risk assessment must be such that all of the regulations are applied to the vessel types and operations that make up the traffic in the sea area under consideration.

Assessments using numerical modelling and simulation tools that are not able to meet this requirement will need to be supplemented by other techniques. The assessment should particularly address Rules 1 to 19: these do not only affect the probability of collision and contact between vessels and with wind farm structures, but may also influence that of grounding when in restricted water depths. Additionally, any potential interference by the development with the vessel lights and shapes or light and sound signals defined in Rules 20 to 38 should be addressed. The positioning and technical details of such lights and shapes, additional signals for fishing vessels, sound signals and distress signals are included in Annexes I to IV of the Collision Regulations.

6.11.3 Formal Safety Assessment (FSA)

FSA is a structured and systematic methodology, aimed at enhancing maritime safety, including protection of life, health, the marine environment and property, by using risk analysis and cost benefit assessment to facilitate decision making. FSA evaluates not only that a particular measure will improve maritime safety or pollution prevention but also by how much and at what cost. FSA can be used as a tool to help in the evaluation of new regulations for maritime safety and protection of the marine environment or in making a comparison between existing and possibly improved regulations, with a view to achieving a balance between the various technical and operational issues, including the human element, and between maritime safety or protection of the marine environment and costs. FSA consists of five steps (Figure 6.24) aimed at producing decision-making recommendations:

a. identification of hazards (a list of all relevant accident scenarios with potential causes and outcomes);
b. assessment of risks (evaluation of risk factors);
c. risk control options (devising regulatory measures to control and reduce the identified risks);
d. cost benefit assessment (determining cost effectiveness of each risk control option);

e. recommendations for decision-making (information about the hazards, their associated risks and the cost effectiveness of alternative risk control options is provided).

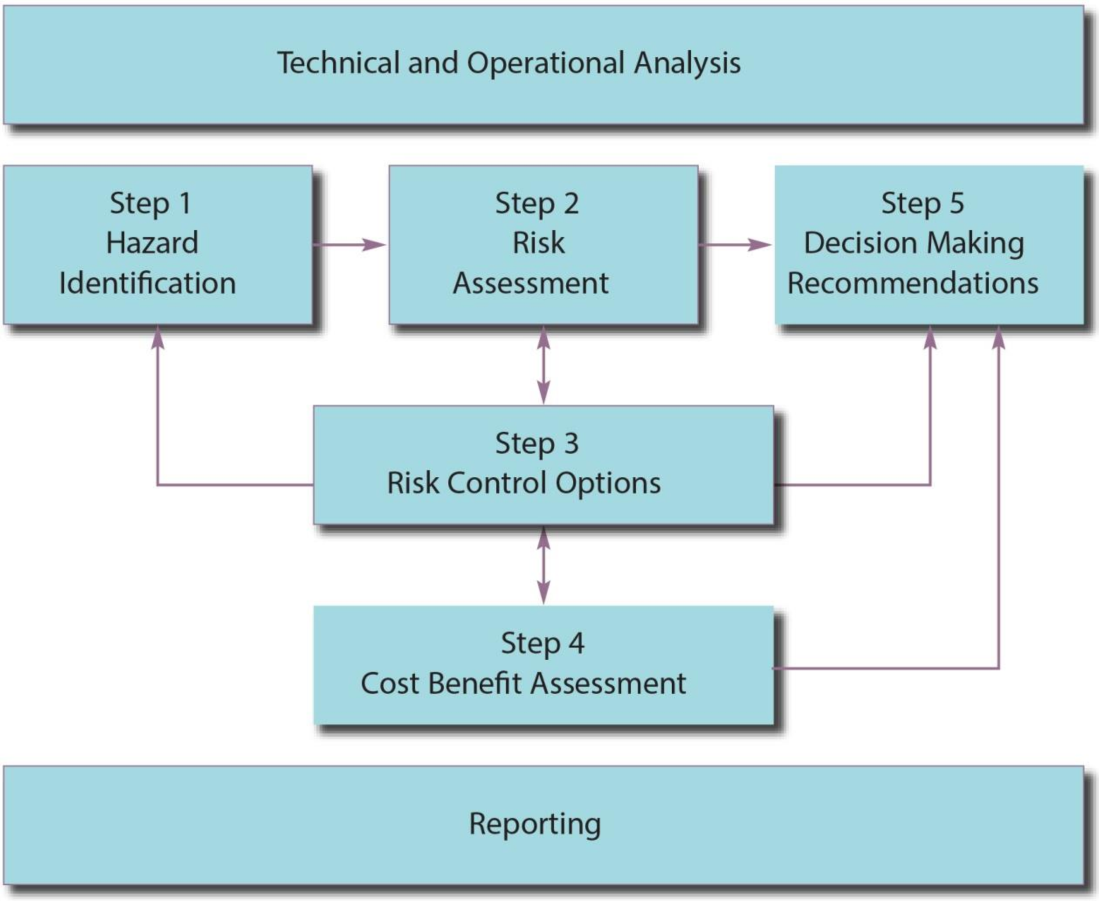


Figure 6.24. Formal Safety Assessment (FSA)

6.11.4 Guidance on Understanding the Base Case Traffic Densities and Types

The risk assessment needs to be based on a sound knowledge of the traffic densities and types. This is one of the key inputs to assessing proportionality.

As regards the boundary of the survey area, it is important that further boundary extension would not considerably impact the results of the assessment, thus minimizing the boundary effects. However, the analyst is responsible for demonstrating that the survey area is appropriate.

6.11.5 Traffic Data Requirements

Assessment of data on traffic densities and types is fundamental for a proper risk assessment; in fact, important navigation safety issues within and close to offshore wind farms can occur, in particular due to high traffic levels, vessel operations and constrained water spaces. All these aspects are connected with offshore wind farms.

Navigation safety issues and risks are also related to the type, size and nature of the vessels and their operations within the survey area. For this reason, the classification of the traffic density, types, operations, sizes, drafts, speeds and routes is basic for an accurate representation of the current safety regime and future impacts.

Generally, an up to date traffic survey of the target area should be undertaken within 12 months prior to the submission of the Environmental Statement. This survey should include all vessel types and take into account seasonal variations in traffic patterns. These variations should be determined with representative recreational and fishing vessel organizations, and, where appropriate, with port and navigation authorities.

6.11.6 Extracting Information from the Data

Traffic surveys vary for each location. However, the outcomes must provide basic traffic information for the overall traffic and for each class of vessel. Data required may vary depending on the type of modelling or other technique used in the risk assessment; at least, the following parameters must be included:

a. The centrelines and excursion limits of representative routes and operations through and within the Study Area;
b. The average hourly traffic volume and types of vessels passing along key routes;
c. Key seasonal variations in traffic activity.

In this context “class of vessel” means a grouping of vessels of a common type, in terms of operation and/or cargo, etc., size, and navigation characteristics.

6.11.7 Design Traffic Densities and Types

A key issue following collection and collation of data is the accurate representation of “Design Traffic Densities and Types” in the risk assessment.

At this aim, it might be important to identify the daily traffic densities average, the representative routes or operations and survey area. In particular, routes and operational areas associated with and used by leisure craft, fishing vessels, aggregate dredging and other marine activities should be identified. Furthermore, the seasonal variation of such traffic, if appropriate, should be closely examined.

6.12 Guidance on Predicting Future Densities and Types of Traffic

The methodology requires an assessment of a "Future Case" levels of risk with and without the wind farm. Therefore, it is necessary to carry out a prediction of the future densities and types of traffic.

6.12.1 Traffic Forecasting

A forecast of future traffic activity at 10-year intervals over the expected life of the wind farm should be made. The following main features have to be considered:

a. Macro drivers (national/regional marine growth predictions) and local conditions (reasonably foreseeable developments, i.e. port & marine growth plans, etc);
b. Changes in vessel size over the forecast period shall be taken into account. For example, if a local container port is set to improve its throughput by 50% in the next 20 years, but the vessels serving this facility will grow at a similar rate the traffic volumes will stay the same;
c. Future change for all marine activities, such as fishing, recreational craft, off-shore exploitation shall be taken into account.

6.12.2 Techniques of Traffic Forecasting

A number of techniques may be used to forecast future traffic volume, routes and vessel types. As regards the choice of the appropriate techniques for predicting future densities and types of traffic, developers should discuss with the Maritime Authority at the commencement of the risk assessment.

Many techniques may be used in the risk assessment, for example, to evaluate if the growth of maritime traffic, of vessel size, draft, etc. might imply the non-viability of traffic routes or operations due to the wind farm location.

Important features in traffic forecasting are the knowledge of the international trade, of fishing operations and all other activities potentially affecting the sea area. Such knowledge may be used to determine if non-viability of main traffic routes is a credible possibility. It should also be remembered that traffic, within a particular area, may reduce as well as increase due to a variety of controlling circumstances.

6.12.3 Stochastic Forecasting

In addition to the techniques mentioned above, some techniques may use a stochastic, or probabilistic, approach. This method, which may be appropriate for some development sites, consists in the reviews of historic traffic trends for the previous ten years or more and identifies the variability of relevant factors. This variability is then introduced into the forecast model to create various viable future scenarios.

6.12.4 Indications on Describing the Marine Activities Environment

Developers should use the following analysis as a starting point for a site specific technical and operational analysis including any extra site specific information and excluding (with a justification) information that is not applicable.

6.12.4.1 Description of a Technical and Operational Analysis

The developer's technical and operational analysis and the navigational safety risk assessment will both be expected to include a description of:

a. The technical scope of the development and how this relates to maritime safety;
b. The structural details of turbines, platforms and cabling;
c. The positioning, configuration and proposed structure of the development as a whole;
d. How the development will be built, commissioned, operated and decommissioned and how this relates to maritime safety.

The developer's analysis will be expected to cover navigational risks; it will include appropriate search and rescue and emergency response overviews and how these will be assessed and managed over all phases of the wind farm development. The analysis will be expected to include an identification of:

a. Potential accidents resulting from navigation activities;
b. Navigation activities affected by offshore wind farm;
c. Wind farm structures that could affect navigation activities;
d. Wind farm development phases that could affect navigation activities;
e. Other structures and features that could affect navigation activities;
f. Vessel types involved in navigation activities;
g. Conditions affecting navigation activities;
h. Human actions related to navigation activities for use in hazard identification.

6.12.4.2 Generic Technical and Operational Analysis

The following, lists from Table 6.8 to Table 6.15 describe a generic technical and operational analysis. In the specific real case, site specific items might be added, as well as some of the items herein included might be removed if inappropriate.

Table 6.8. Wind Farm Structures that could affect Navigation Activities

H3	Wind Farm Structures
1	Turbines
	a. Foundation type
	b. Transition Piece
	c. Tower
	d. Nacelle
	e. Blades
	f. Platforms and superstructure fittings
2	Offshore Installations (if appropriate)
	a. Offshore Substation
	a. Offshore Service Bases
	a. Offshore Accommodation Bases
3	Cable
	a. Export Cable
	a. Inter-turbine Cabling
4	Subsea Installations, including antiscour material

Table 6.9. Wind Farm Development Phases that Could affect Navigation Activities

H4	Development Phase
1	*All*
2	Pre-construction
3	Construction
4	Operation
5	Maintenance
6	Decommissioning

Table 6.10. Potential Accidents resulting from Navigation Activities

H1	Accident Category
	All
1	General Navigation Safety Risks
	1. Collision
	2. Contact
	3. Grounding and Stranding
2	Other Navigation Safety Risks
	1. Foundering
	2. Capsizing
	3. Fire
	4. Explosion
	5. Loss of Hull Integrity
	6. Flooding
	7. Machinery Related Accidents
	8. Payload Related Accidents
	9. Hazardous Substance Accidents
	10. Accidents to Personnel
	11. Accidents to the General Public and Shore Populations
	12. Electrocution
3	Aviation Safety Risks[14]
	1. Aviation Accidents
4	Other Safety Risks
	1. High Probability Events
	2. High Severity Outcomes
	Low Confidence / High Uncertainty Events
	Note: Although not "accident categories" themselves, the following search and rescue and emergency response activities may result from one or more of the above incident categories
5	Search and Rescue
	1. Overall
	2. External to Internal
	3. Internal to Internal
	4. Internal to External
	5. External to External
	6. Worst Case
6	Emergency Response
	1. Overall
	2. External to Internal
	3. Internal to Internal
	4. Internal to External
	5. External to External
	6. Worst Case

Table 6.11. Navigation Activities affected by an Offshore Wind Farm

H2	Navigation Activity
1	*All*
2	Navigation on Passage
	1. Navigating or operating near a wind farm
	2. Navigating or operating around a wind farm
	3. Navigating or operating through a wind farm
	4. Navigating or operating within a wind farm
	5. International traffic
	6. National traffic
	7. Coastal traffic
	8. Short sea shipping traffic
	9. Fishing vessels
	10. Recreational craft
	11. All other traffic listed in section 6 below
3	Fishing operations
	1. Single vessels
	2. Paired vessels & others fishing in close proximity
	3. Crabbing
	4. Trawling
	5. Drift Nets
4	Recreational activities
	1. Sail and power cruising
	2. Sail and power day sailing
	3. Sail and power racing
	4. Personal watercraft use (e.g. Jet Skiing)
	5. Windsurfing
	6. Kite Surfing and Kite Boarding
	7. Leisure or Sport Diving
5	Anchoring
	1. Routine Anchoring
	2. Emergency Anchoring
6	Other Marine Operations close to or within a wind farm
	1. Aggregate Dredging, Dredging or Spoil Dumping
	2. Commercial Diving
	3. Construction Operations
	4. Servicing Operations
	5. Decommissioning Operations
	6. Oil and Gas Operations
	7. Salvage Operations
	8. Cable Laying
	9. Pipeline Installation
	10. Boarding and Landing of Pilots
7	Special Events
	1. Regattas and Competitions
8	*None*

Table 6.12. Other Structures and Features that could affect Navigation Activities

H5	Other Structures and Features
1	Wrecks
2	Oil & Gas Installations (Existing and projected)
3	Other Wind Farms (Existing and projected)
4	Other Offshore Renewable Energy Installations (Existing and projected)
5	Other Exclusion or Safety Zones including Areas to be avoided (ATBA)
6	Fishing Grounds
7	Dredging and Dumping Areas
8	Diving Areas

Table 6.13. Vessel Types involved in Navigation Activities

H6	Types of Vessel
1	*All*
2a	Large Vessels
	1. Bulk Carriers
	2. Bulk/Oil Carriers
	3. Chemical Tankers
	4. Container Vessels
	5. Cruise Vessels
	6. Liquefied Gas Carriers
	7. Oil Tankers
2b	Medium Vessels
	1. General Cargo
	2. Specialised Carriers
	3. Passenger
	4. Passenger Ferries
2c	High Speed Craft (HSC's)
	1. High speed ferries
	2. Other high speed recreational and commercial craft
3	Fishing Vessels
	1. Fish Processing
	2. Fishing Vessels (Various types and operations)
4	Recreational Vessels
	1. Sailing dinghies and Yachts
	2. Motor Boats
	3. Small Personal Watercraft
	4. Rowing boats
	5. Sports Fishing
	6. Windsurfer
	7. Kite Boards
	8. Tall Ships
	9. Recreational Submarines and dive support craft
5	Anchored Vessels
	All
6	Other Operational Vessels
	1. Barges
	2. Dredgers
	3. Dry Cargo Barge
	4. Offshore Production and Support
	5. Salvage
	6. Tank Barges
	7. Tugs and Tows
7	Military Vessels
	1. Warships
	2. Submarines
	3. Royal Fleet Auxiliaries
8	Other Vessels
	1. Seaplanes
	2. Wing-In-Ground Craft (WIG)
	3. Hovercraft

Table 6.14. Conditions affecting Navigation Activities

H7	Conditions
1	*All*
1	Weather
	1. Restricted visibility (Fog, mist, haze, precipitation)
	2. Wind strength and direction
	3. Sea State
	4. Icing
	5. Light conditions
2	Tides and local currents
	1. Local Currents
	2. Tidal Streams and heights
3	Time of Day
	1. Night
	2. Dawn
	3. Day
	4. Dusk
3	Circumstances
	1. Planning access to shelter
	2. Vessel constrained by her draft
	3. Vessel engaged in fishing
	4. Vessel not under command
	5. Vessel restricted in her ability to manoeuvre
	6. Scheduled/Shuttling vessels
4	Electronics
	1. Vessels underway with no AIS (i.e. non SOLAS craft) or with AIS switched off
	2. Interference to Marine Radar, Navigation and Communications
5	Other
	1. Overfalls and other local conditions.

Table 6.15. Human Actions related to Navigation Activities

H8	Human Actions
1	Violation
2	Mistakes
3	Lapse
4	Slip

6.13 Overview of Hazard Identification

Developers should include a Hazard Identification based on analysis of the causal chain of an accident, including human error.

6.13.1 Causal Chains used in Navigation Hazard Identification

Causal Chains, also called are **Event Sequences** or **Accident Sequences**, are useful in risk assessment as many risks will are the result of complex chains of events, with a diversity of causes and a range of consequences.

The causal chain scheme starts from a **cause**, inducing an **accident**, causing the **consequences**.

6.13.2 Human Element

The human element is one of the most contributory aspects to the causation and avoidance of accidents. Human element issues should be systematically treated within the FSA framework. Figure 6.25 lists the main causes of “Human Error”, here defined as examples of the active cause of an unsafe act recognizing that some acts are intentional while others are not.

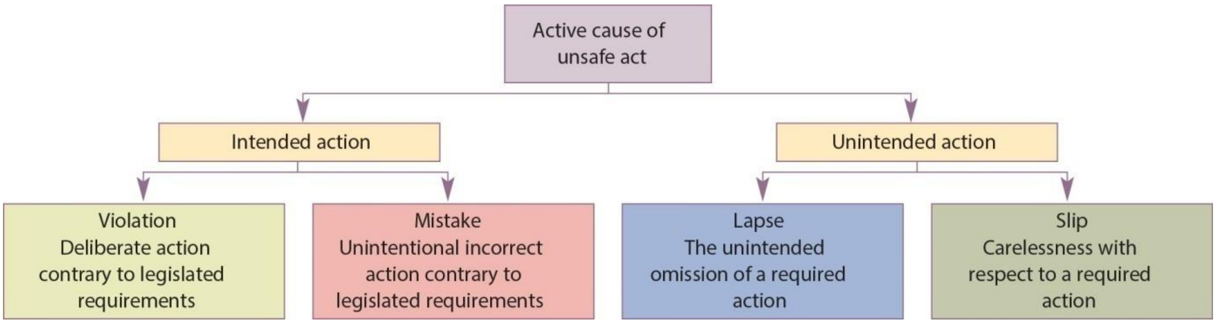


Figure 6.25. Causes of Human Error

Any analysis technique must be able to assess vessels’ compliance with the steering and sailing rules (1 to 19) of the International Regulations for Preventing Collisions at Sea (COLREGs); this classification of the cause of unsave action should be used for quantifying the effect of not being able to comply with casual random events.

The analysis should also take into account any effects on the lights and shapes to be carried by vessels (e.g. interference to the visibility of navigation lights), on navigation marks ashore and at sea and to the light and sound signals made by vessels and navigational aids in particular circumstances.

6.13.3 Special Circumstances

Some events may originate in any sea or coastal area and have an impact on the wind farm area, such as vessels not under command, oil pollution, chemical hazard, or casualties requiring search and rescue operations, being set or drifting from, into or through the wind farm, perhaps from a considerable distance.

6.14 Overview of Risk Assessment

As introduced earlier, risk is the combination of probability and consequence (Figure 6.26). Linking this to the Causal Chain requires an assessment of the probability of the cause and the magnitude of the consequence. FSA also encourages to take into account the influences on the causal chain as well as any direct effects, because in many marine accidents causal sequences not only affect the probability of the cause but also the magnitude of the consequence.

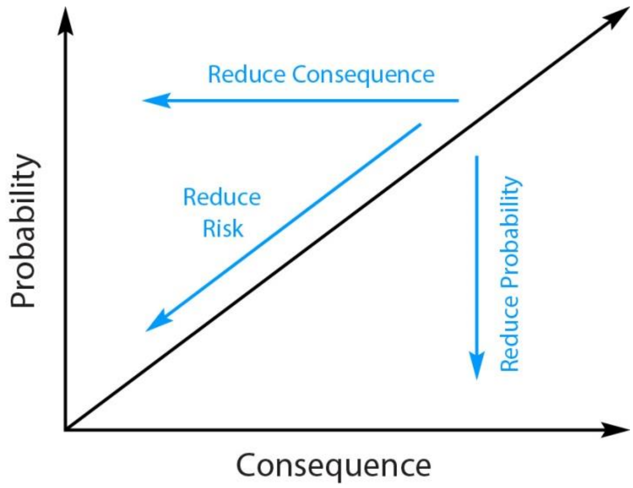


Figure 6.26. Definition of Risk

6.14.1 Creating a Hazard Log

The Hazard Log is a process covering:

a. Hazard Identification;
b. Risk Assessment;
c. Confidence Assessment;
d. Risk Control Assessment;
e. Tolerability Assessment;
f. Closure.

6.14.2 Hazard identification

a. Identify all the relevant hazards and describe them as Causal Chains. At this aim, the techniques used are:
    i. Hazard Identification brainstorming, checklists, etc. (HAZID),

    ii. Hazard and Operability Studies (HAZOP),
    iii. Failure Modes and Effects Analysis (FMEA).

b. Group the causal chains identified into risk groups. Suggested risk groups are:
    i. General navigation safety,
    ii. Other navigation safety.
c. Analyse aviation safety aspects related to navigation safety:
    i. Other safety including overviews of:
    ii. Search and rescue
    iii. Emergency response
d. Analyse each causal chain against marine environment lists (from the Technical and Operational Analysis) to understand it in detail and allow it to be risk assessed, adding extra causal chains as required. Suggested marine environment lists are:
    i. Accident category
    ii. Navigation activity
    iii. Wind farm structures
    iv. Phase of development
    v. Structures and features
    vi. Vessel types
    vii. Conditions
    viii. Human actions.

6.14.3 Risk Assessment

As regards the Risk assessment, the following steps shall be followed.

a. Analyse each causal chain against influences on the level of risk (from the influence analysis) to understand it in detail and allow it to be risk assessed, adding extra causal chains as required. Suggested influence lists are:
    i. Navigation risk factors
    ii. Influence on causes
    iii. Traffic types, densities and operations
    iv. Circumstances
    v. Influences on consequences

b. Assign a probability and consequence to each causal chain.
c. It is sometimes also useful, at this stage, to identify the non-marine navigational safety consequences, as these can be useful in deciding on risk controls (for example an asset to control a safety risk might not be justified by "As Low As Reasonably Practicable-ALARP" arguments but when combined with environmental, property or business arguments the asset may be justified).

6.14.4 Confidence Assessment

a. List the evidence supporting the risk assessment
b. Assess the quality of the evidence.

6.14.5 Risk Control Assessment

a. List the risk controls that are included in the risk assessment. Suggested categories for controls are:
   i. Assets
   ii. Rules
   iii. Good practices
b. List the risk control options still under consideration
c. Link the risk controls to the risk control log.

6.14.6 Risk Tolerability Assessment

The risk tolerability is a qualitative assessment. Suggested outcomes are:

a. Broadly acceptable
b. Tolerable with monitoring
c. Tolerable with additional controls
d. Tolerable with modifications
e. Unacceptable.

6.14.7 Closing the Hazard Log

Closing the hazard log is based on the individual closure of each hazard log entry.

Closing each hazard log entry is based on a judgement on the "Tolerability of the Risk", including in particular:

a. A justification that the risk has been adequately assessed, risk controls defined and/or put in place and that further risk control is grossly disproportionate
b. A declaration by a nominated and accountable person that agrees with each justification.

6.15 Guidance on Measuring the level of risk

The risk must be measured at two levels: one is the individual risk, and the other is the societal level.

6.15.1 Measuring Individual Risk

Qualitative risk assessment should be made on the basis of:

a. Frequency bands;
b. Consequence bands;
c. Criticality matrix;
d. Tolerability matrix;
e. Evidence matrix.

Criticality Matrix

Although there is no standardization for criticality matrixes, in general the criticality matrix is a matrix were frequency/probability and consequence of events is scaled in decades. This allows it to be used both for numerically and specifically defined risk criticality ranking.

Probability/Frequency (per year)	minor injuries	major injuries	1	10	100	1,000	10,000	100,000
100	0	1	2	3	4	5	6	7
10	-1	0	1	2	3	4	5	6
1	-2	-1	0	1	2	3	4	5
1/10	-3	-2	-1	0	1	2	3	4
1/100	-4	0	0	-1	0	1	2	3
1/1,000	-5	-4	-3	-2	-1	0	1	2
1/10,000	-6	-5	-4	-3	-2	-1	0	1
1/100,000	-7	-6	-5	-4	-3	-2	-1	0
1/1,000,000	-8	-7	-6	-5	-4	-3	-2	-1

Consequence (Fatalities)

Figure 6.27. Example of Criticality Matrix – Numerically Ranked

A *numerical risk criticality ranking* (Figure 6.27) is based on multiplying probability and consequence.

The advantage of this approach is that it can be fed directly into an FN curve, where "N" relates to the number of casualties per accident and "F" is the potential frequency per year of these occurring.

Figure 6.28. Example Criticality Matrix – Specifically Defined

Probability/Frequency (per year)									
	100	6	6	7	7	8	8	9	9
	10	5	6	6	7	7	8	8	9
	1	5	5	6	6	7	7	8	8
	1/10	4	5	5	6	6	7	7	8
	1/100	3	4	5	5	6	6	7	7
	1/1,000	3	3	4	5	5	6	6	7
	1/10,000	2	3	3	4	5	5	6	6
	1/100,000	1	2	3	3	4	5	5	6
	1/1,000,000	1	1	2	3	3	4	5	5
		minor injuries	major injuries	1	10	100	1,000	10,000	100,000
		Consequence (Fatalities)							

A specifically defined ranking (Figure 6.28) can be defined by the assessor in the way he prefers, but the disadvantage is that it cannot be fed into an FN curve.

The disadvantage of both approaches is that people prefer to judge:

a. Risk in a more qualitative way;
b. From fewer probability bands (often 5).

Therefore, it is suggested that the assessment is based on a criticality matrix that developers believe is appropriate for their needs, but that a mapping is made to a decade based risk matrix to allow a FN curve generation. Alternative representations for individual risk are the self-explaining frequency bands (Figure 6.29) and consequence bands (Figure 6.30). Their combination can provide a qualitative criticality matrix, such as that in Figure 6.31.

Frequency		
	Frequent	Likely to happen (to a wind farm) yearly or more frequently.
	Reasonably Probable	Likely to happen during the licence period of a wind farm (nominally 20 years).
	Remote	Unlikely (but not exceptional) to happen during the licence period.
	Extremely Remote	Only likely to happen in exceptional circumstances.

Figure 6.29. IMO Style Frequency Bands

Insignificant	Minor	Major	Catastropic
No significant harm to people	Injury to vessels crew Injury to turbine installation or maintenance crew Injury on the shore	Loss of a vessel crew member(s) (1 to 3) Loss of a turbine installation or maintenance crew member(s) (1 to 3) Fatality(ies) on the shore (1 to 3)	Total loss of a vessels crew Total loss of a turbine installation or maintenance crew Multiple fatalities on the shore
Consequence to People			

Figure 6.30. IMO Style Consequence Bands

Frequency	Insignificant	Minor	Major	Catastropic
Frequent	4	5	6	7
Reasonably Probable	3	4	5	6
Remote	2	3	4	5
Extremely Remote	1	2	3	4
	Consequence			

Figure 6.31. IMO Style Criticality Matrix

Tolerability Matrix

Although there is no general definition for it, the tolerability matrix combines the criticality bands with the risk experience, such as it is shown in Figure 6.32.

Evidence Matrix

The development in risk assessment techniques has defined risk as not just a combination of probability and consequence but as a combination of probability, consequence *and uncertainty in the assessment of probability and consequence*. In this way, it is possible to verify that risks ranked as “low” are truly so. This responds to the need of assessing the quality of the evidence used of supporting a probability and consequence assessment.

Figure 6.33 provides an example of a guide to assessing confidence for particular risks, in a particular wind farm and in a particular scenario, indicating how evidence quality, for this particular development or scenario, may be assessed in an Evidence Matrix.

Risk Criticality		Condition	Explanation
7	Unacceptable		Risk must be mitigated with design modification and/or engineering control to a Risk Class of 5 or lower before consent
6	Unacceptable		Risk must be mitigated with design modification and/or engineering control to a Risk Class of 5 or lower before consent
5	Tolerable with Modifications	with a commitment to further risk reduction before construction	Risk should be mitigated with design modification, engineering and/or administrative control to a Risk Class of 4 or below before construction
4	Tolerable with Additional Controls	with a commitment to further risk reduction before operation	Risk should be mitigated with design modification, engineering and/or administrative control to a Risk Class 3 or below before operation
3	Tolerable with Monitoring	with a commitment to risk monitoring and reduction during operation	Risk must be mitigated with engineering and/or administrative controls. Must verify that procedures and controls cited are in place and periodically checked
2	Broadly Acceptable		Technical review is required to confirm the risk assessment is reasonable. No further action is required
1	Broadly Acceptable		Technical review is required to confirm the risk assessment is reasonable. No further action is required

Figure 6.32. Example Risk Tolerability Matrix

6.15.2 Measuring Societal Concern

Societal concerns can arise when the realization of a risk impacts on society as a whole. The impact may produce an adverse socio-political response (which has its origins in the public aversion to certain characteristics of the hazards concerned). The harm which results is a loss of confidence by society in the provisions and arrangements in place for protecting people and, consequently, a loss of trust in the regulator and duty-holders with respect to control of the particular hazard and hazards more generally.

A way to measure societal concern is to assess, on an FN curve, the overall level of risk. Figure 6.34 provides an idea of such a curve, with fake values, for a wind farm.

The aggregate potential loss of lives for all the hazards in the wind farm itself and of those in the sea area that may result from an accident within or close to the wind farm is given by the area under the blue curve.

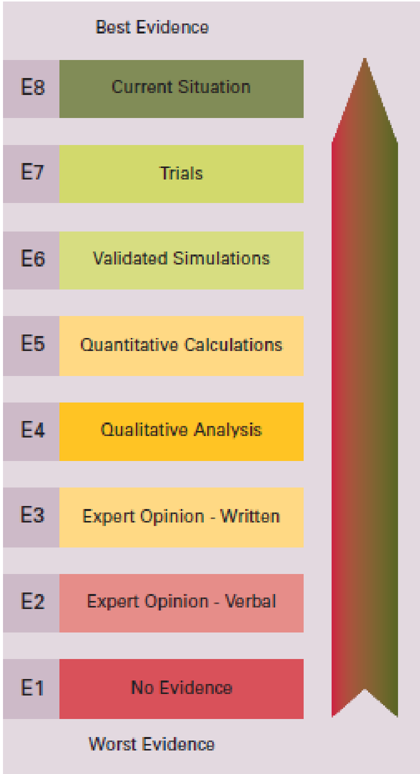


Figure 6.26. Example of Evidence Matrix

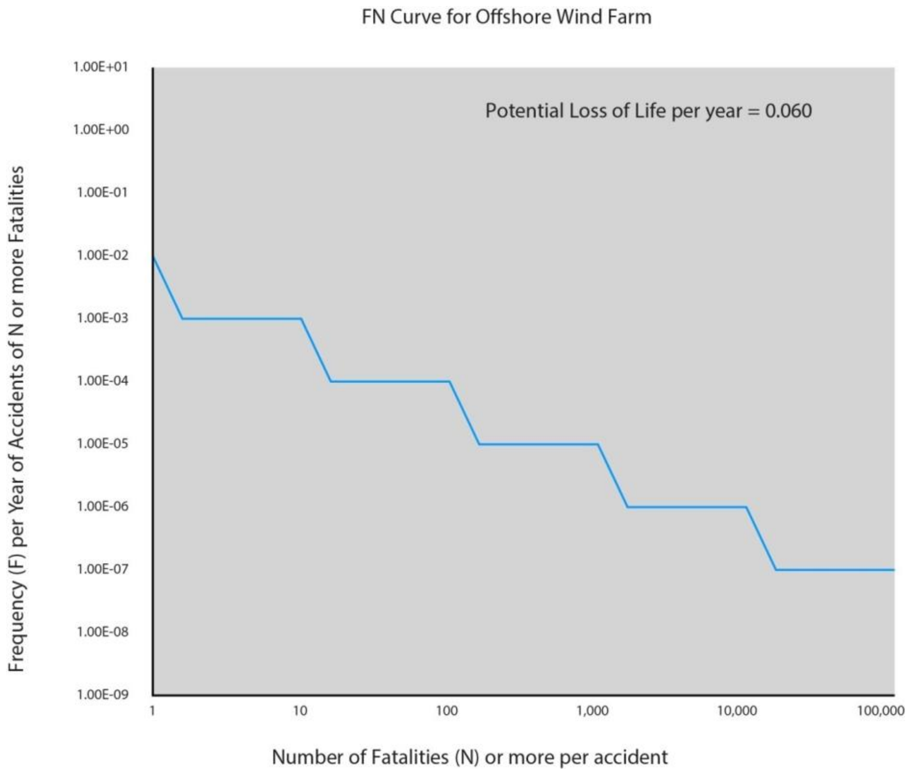


Figure 6.34. Example FN Curve

6.16 Influences on the Level of Risk

Several features of a wind farm and of the surrounding ambient may influence the levels of risk, producing situations where risks are lower or higher than without the wind farm – or different than those around another similar wind farm. Developers should use the analysis hints contained in the following from Table 6.16 to Table 6.20 as a starting point for a site specific Influence Analysis, including any extra site specific influences and excluding, where unrelevant, influences that are not applicable.

Table 6.16. Risk Factors - Example Checklist

Risk Factors	
Site	
1.	Location of wind farm.
2.	Alignment of wind farm.
3.	Layout of wind farm. (E.g. grid, scattered or other layouts)
Traffic	
1.	Traffic routes, density, type and operations.
2.	Potential growth or decline in traffic.
3.	Seasonal variation in traffic.
4.	Special traffic, e.g. dangerous goods, etc.
Interrelations Between Vessels	
1.	Blocking of escape routes or bad weather refuges
2.	Bunching
3.	Increase in "crossing" encounters
4.	Increase in "end-on" encounters
5.	Increase in "overtaking" encounters
6.	Increase in traffic volumes
7.	Loss of recreational cruising routes
8.	Pinching
9.	Reduction in sea room for manoeuvring
10.	Reduction in water depth for manoeuvring
11.	Blocking of routes to safe havens and inshore anchorages
12.	Redirection of recreational craft and fishing vessels into routes used by other vessels, particularly larger and faster vessels.
Navigator Behaviour	
1.	Lengthened navigation routes for leisure craft increase navigator fatigue (and hence error) and increase the criticality of weather windows.
2.	Enhanced navigational complexity and need for navigational awareness increase fatigue (and hence error)
Other single vessel factors	
1.	Collision with wind farm structures
2.	Fouling or contact with cables
3.	Grounding

Table 6.17. Influences on Causes – Example Checklist

Influence on Causes
Vessel Traffic Management
1. Availability of Vessel Traffic Services (VTS).
2. Availability of Pilot services.
Aids to Navigation
1. Compliance with requirements for Aids to Navigation. (site and vessel)
2. Failure (or non availability) of Aids to Navigation & other systems
3. Site-specific effects on aids to navigation. E.g. masking by background lights, masking by structures and the effects of rotating blades, control responsibility for foghorns, etc.)
4. AIS (Automatic Identification System) failure or not required to fit.
5. Marking on charts of wind farm structures and associated navigation aids
Bathymetry
1. Accuracy of and changes to bathymetry (e.g. navigable channels, shifting sandbanks, anti-scour material, seabed mobility, etc.)
Interference
1. Interference with vessel based communications.
2. Interference with shore based communications.
3. Interference with vessel based navigation. (E.g. GPS, radar, compasses etc.).
4. Interference to ship based radar e.g. shadowing and blind sectors and false echoes.
5. Interference with shore based navigation. (e.g. VTS services, MRCC services, etc.)
6. Interference to shore based radar e.g. shadowing and blind sectors and false echoes
7. Similar interference to helicopter and fixed wing aircraft radar used in SAR and emergency response.
8. Electromagnetic interference from turbine generators, transformers or cables
9. Acoustic interference to sonar, diver communications, echo sounders, fish finders and acoustic release systems
10. Helicopter radar contact in a wind farm interpreted as a vessel contact
Future Technical Change
1. Application of Radar Absorbing Material to towers and blades, etc.

Table 6.18. Traffic Levels – Example Checklist

Traffic Levels
Hindcast – ½ consent period (e.g. 10 years)
Current
Forecast – ½ consent period (e.g. 10 years)
Forecast – full consent period (e.g. 20 years)

Table 6.19. Circumstances - Example Checklist

Circumstance
Intentional Navigation
1. Intentionally navigating within a wind farm en route or to carry out activities.
Accidental Navigation
1. Unintentionally navigating within a wind farm or being forced to do so to avoid collision with another vessel, etc.
Emergency Navigation
1. Wind farm blocking passage to port of refuge, safe haven, inshore anchorage or inshore routes.
2. Wind farm restricting anchoring.
Forced Navigation
1. Wind farm forcing passage in more dangerous waters.
2. Wind farm forcing passage in more congested water.

Table 6.20. Consequences - Example Checklist

Influence on Consequence
Wind Turbine Design
1. Strength and robustness of wind turbine structure.
2. Collapse mode of impacted turbines after collision
Vessels
1. Vessel size.
2. Vessel cargo. (E.g. polluting cargoes, hazardous cargoes, etc.)
Search and Rescue
1. Adequacy of Search and Rescue provision. (E.g. equipment, equipment location, communication, etc.)
2. Availability of Search and Rescue resources. (E.g. currently in commercial use, multiple SAR operations, etc).
3. Ability to deploy Search and Rescue resources. (E.g. helicopter operations affected by blade rotation, aircraft operations affected by search height restrictions, etc.)
Emergency Response
1. Adequacy of Emergency Response provision. (E.g. tugs, oil spill equipment, communications, etc.)
2. Availability of Emergency Response resources. (E.g. currently in commercial use, multiple ER operations, etc).
3. Ability to deploy Emergency Response resources. (E.g. state of contingency planning)

6.17 Tolerability of Residual Risks

As a good HSE practice, the residual risk should kept as low as possible, following good engineering practice. Within the risk analysis, it is important to define if a risk is:

a. unacceptable; or

b. tolerable; or

c. broadly acceptable.

The framework for decision-making based "Tolerability of Risk" defines regions of unacceptable, tolerable and broadly acceptable risk as shown in the following diagram (Figure 6.35).

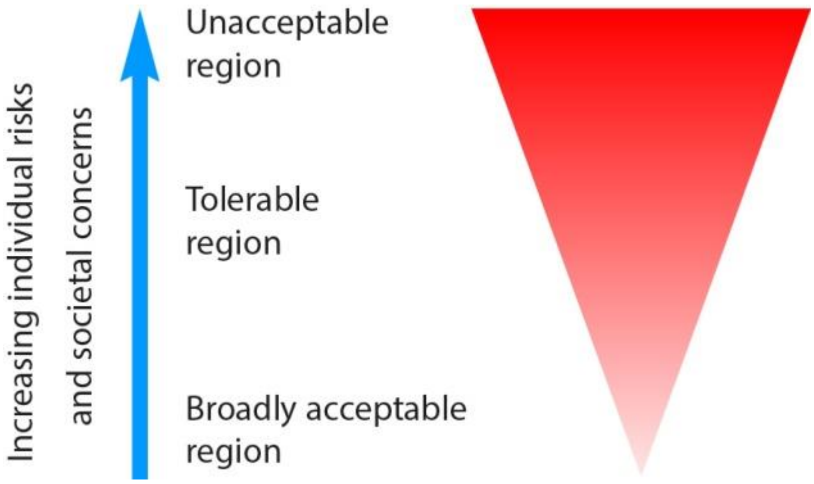


Figure 6.35. Framework for the Tolerability of Risk

The diagram indicates the high (normally unacceptable) risks at the top and the low (broadly acceptable) risks at the bottom. The region between top and bottom is called the 'Tolerable Region', because risks in this region can sometimes be tolerated, if they cannot practically be reduced, in return for the benefits provided by the system or installation that causes the risks.

From this, the following main issues emerge:

a. At what point does a risk become "Broadly Acceptable"?
b. What is included in "Relevant Good Practice"?

As a criterion, risks resulting from hazards may be classified as broadly acceptable when the expected loss is so small that it is not reasonable to implement any counter safety measure.

A definition of "broadly acceptable" risk stays in the perception of how they relate to people and the things they value, and for man-made hazards on how well the process (giving rise to the hazard) is considered understood, how equitable the danger is distributed, how well individuals can control their exposure and whether the risk is assumed voluntarily.

As a reference, UK's "Reducing Risk, Protecting People" (RRPP) Health and Safety Executive Document states that an individual risk of death of one in a million per annum for both workers and the public corresponds to a very low level of risk and should be used as a guideline for the boundary between the broadly acceptable and tolerable regions. It also notes that this level is extremely small when compared to the background level of risk.

As relevant references for good practice, important references are contained in the EU and national legislation, as well as standards produced by Standards-making organisations (e.g. CEN, CENELEC, ISO, IEC, etc.), as well as those standards and regulations adopted by Countries with a longer experience curve in offshore wind energy.

7. USAGE OF A GEOREFERENCE INTERACTIONS DATABASE (“GRID”) TO EVALUATE THE IMPACT OF DIFFERENT SCENARIOS OF OWF SITING

(Provided by Veneto Agricoltura)

7. USAGE OF A GEOREFERENCE INTERACTIONS DATABASE ("GRID") TO EVALUATE THE IMPACT OF DIFFERENT SCENARIOS OF OWF SITING

In this section the usage of a specific web based application to evaluate the impact of an hypothetic Offshore Wind Farm on the fishery activity (considering two different locations) is described. It is proposed this exercise as an operative example that, on the basis also of provided data on fishing effort and biological resources spatial distributions, could be extended to other areas of the Adriatic basin.

7.1 What is GRID

GRID (GeoReference Interactions Database) is a web-based flexible database and tool to analyse interactions (conflicts and synergies) in marine coastal areas. GRID has a GIS (Geographical Information System) module which allows to analyse spatial distribution of current and future activities (fisheries, aquaculture, energy etc.) and interactions (existing/ potential synergies and conflicts).

7.2 When and why GRID was developed

Grid was developed in the framework of the UE founded Project called COEXIST (see www.coexistproject.eu).

GRID was developed in order to visualize, quantify and summarize interactions between several activities which take place in a marine coastal area.

Another very important aim was also to provide stakeholders involved in marine spatial planning with a decision support and managing tool. For these reasons particular attention was given on sharing data between different players involved in the process.

The following basic ideas were followed during the development phase:

- to be flexible enough in order to be used in different Case Studies;
- to have an intuitive Graphic Interface in order to be also used by people without specific knowledge in database and GIS software;
- to allow data sharing between stakeholders;
- to model different situations such as the present one and/or future scenarios in a very easy way;
- to improve transparency in decision making process.

7.3 What the GRID application does and its users

The online version of GRID provides the following information about different activities in a specific marine coastal area:

- Characteristics (traits) of activities
- Spatial distribution
- Spatial overlapping between activities

Furthermore it could be able to describe their interactions performing the following analysis considering different scenarios:

- calculation of conflict scores;
- generation of Matrices of interactions;
- plot of maps;
- evaluation of spatial interactions existing in a specific marine coastal area;
- calculation of asymmetric spatial overlaps;
- calculation of stress levels.

For these reasons it was developed in order to be used by:

- Governmental agencies for:
    - Fisheries and aquaculture management
    - Environmental protection
    - Shipping
    - Spatial planning
- Coastal municipalities
- Industries
    - Fishing and aquaculture industry
    - Energy
    - Dredging and dumping
    - Shipping
- Non Governmental Organisations (NGOs)

7.4 Using GRID in the framework of POWERED project

Considering the previous mentioned features, we decided to use, for demonstration purposes, GRID application to assess its usefulness in a scenario of planning a wind farm in the Italian coastal area in the middle Adriatic sea along the Marche region coast-line. The area was identified according to the fact that the GRID application was applied in that area during the COEXIST project. It means that some data regarding activities carried out in the marine coastal area were already inserted and than can be immediately used in the scenarios provided by POWERED.

7.5 GRID Tools, an overview

Matrix of interactions. One of the first standardised tool which was implemented in GRID was the visualization of the interaction matrix which reflects the level and type of interactions (conflicts and synergies) between activities (Figure 7.1).

These matrices are produced with the help of experts' knowledge and comprise qualitative levels of conflicts ranging from "no" to "high". GRID tried to implement a good practice for the identification of interactions and their quantification. Therefore, a set of criteria should be applied to define a conflict and to quantify it in order to be represented on a matrix.

A particular section of the GRID database was implemented to manage the application of a series of rules that can be defined to quantify negative interactions or synergies for space, resources and socio-economic aspects. Rules are mainly based on the attributes associated to each activity and the conflict score is a result of a mathematical combination of them. For a detailed description of the rules you can refer to the deliverable 3.9 (D 3.9) of the COEXIST project (see www.coexistproject.eu).

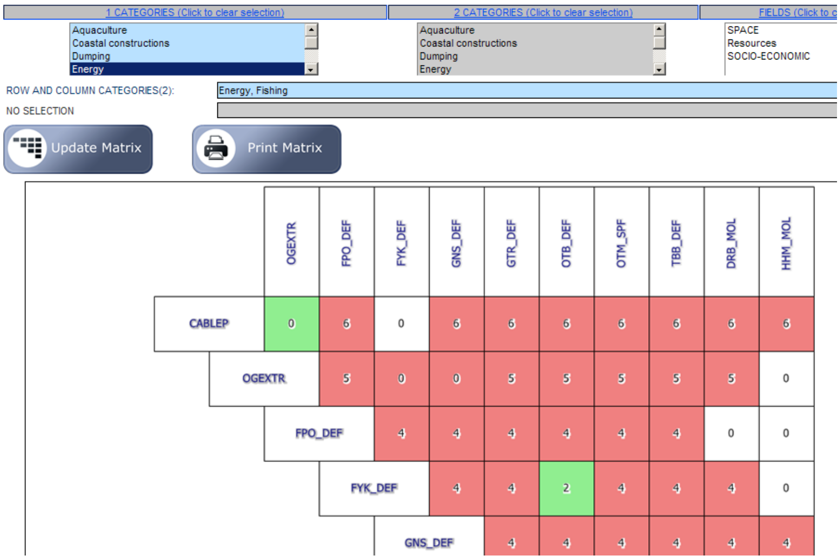


Figure 7.1 Example of Matrix of interactions.

Spatial analysis. A specific GIS module was inserted in the GRID application to produce maps (Figure 7.2) and to analyze spatial interactions.

The GIS module of GRID was developed in order to perform two main tasks:

1. producing maps with activities to visualize their spatial distribution and spatial extensions within the area of interest;
2. performing spatial analysis to evaluate interactions between activities that stand in a specific area.

Spatial analysis procedures cited at point 2) can be subdivided in two different categories:

1. spatial analysis procedures that combine two or more activities together;
2. spatial analysis procedures that compare two different activities at a time.

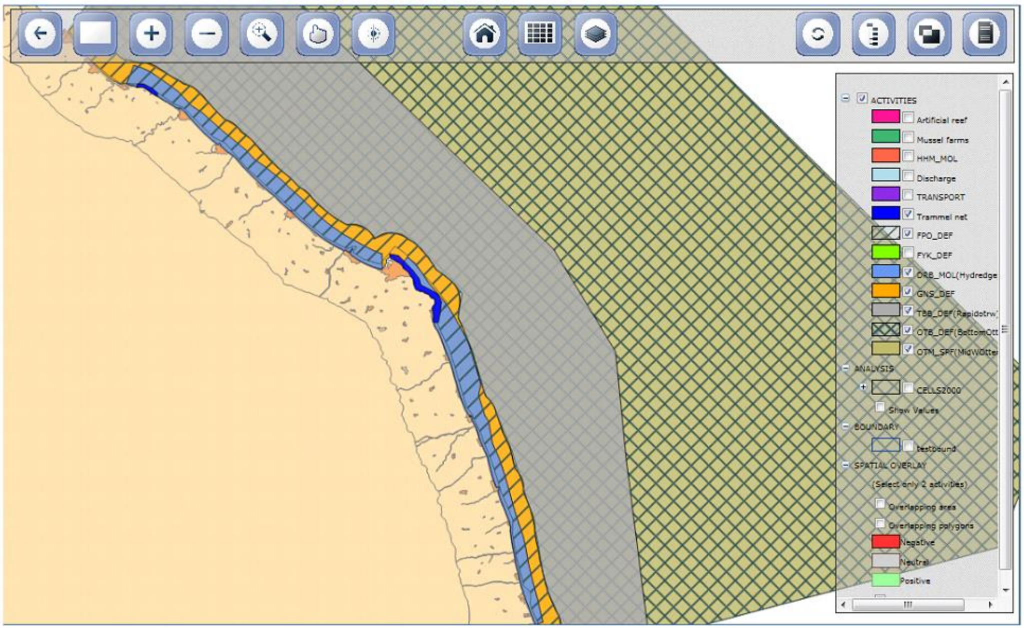


Figure7.2 Example of Map of activities.

Selecting two activities it is possible to visualize the overlapping area with the corresponding conflict score. The percentages of overlap on the total extent of each activity as well as the values for “revenues”, “production”, “effort” and “people” associated to the overlaps can be also calculated and represented (Figure 7.3).

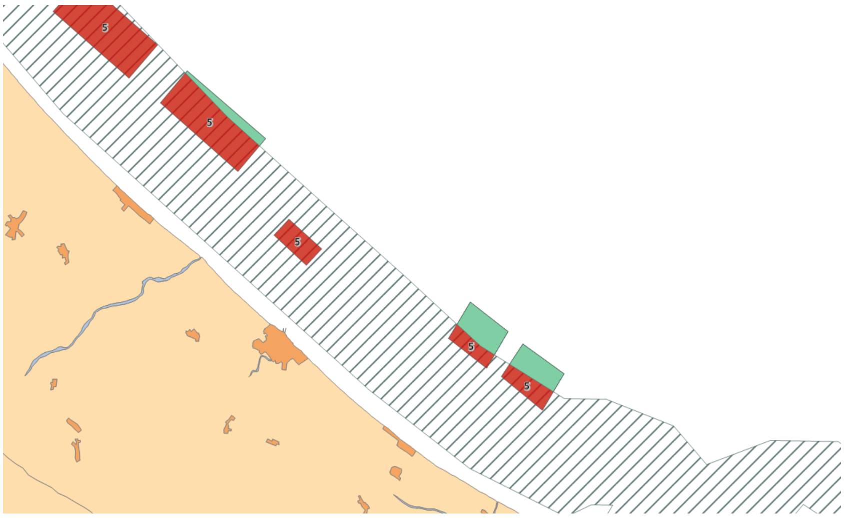


Figure 7.3. Example of Map with overlapping area (in red).

Selecting more than two activities it is possible to visualize the total conflict score associated to the area. This task is performed subdividing the area according to a grid and then calculating for each cell the sum of conflict scores of interactions that stand on it. Figure 7.4

shows the grid with the conflict scores in the different cells and the total conflict score. It represent a sort of summarized score for the entire area and its variation can give an idea of the impact of a planned management measure.

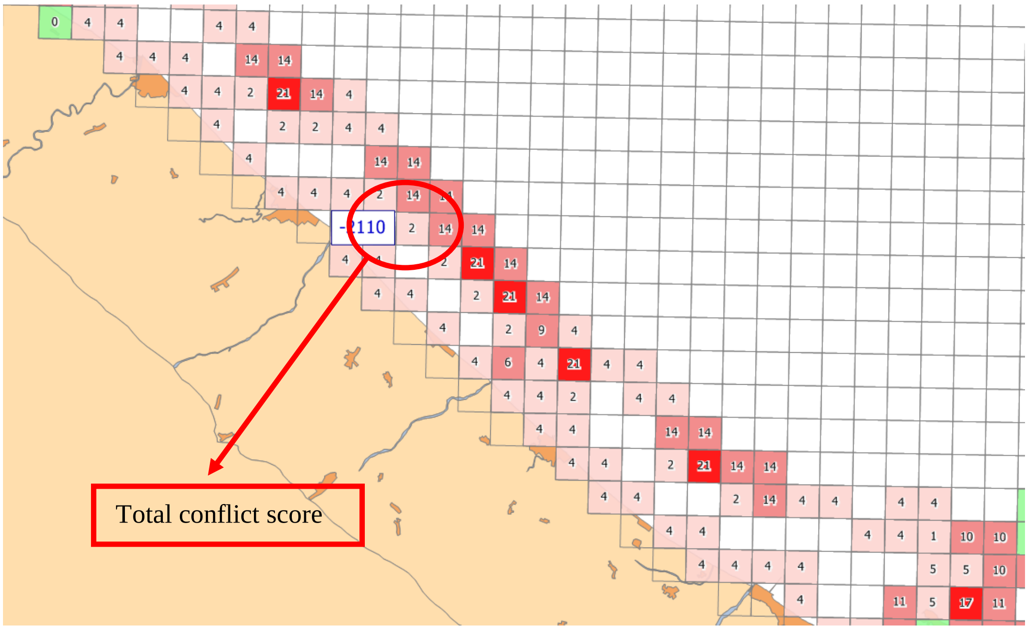


Figure 7.4. Example of Total conflict score calculation

7.6 Using GRID to asses different wind farm locations

Wind farm location. In our simulations we consider the installation of a wind farm in the northern part of the Marche Region coastal area. Two different scenarios have been taken into account. They differ for a different location of the wind farm. The first scenario provides a location of a wind farm at a distance of about 3 nautical miles from the coast line (called In-shore scenario) (Figure 7.5).

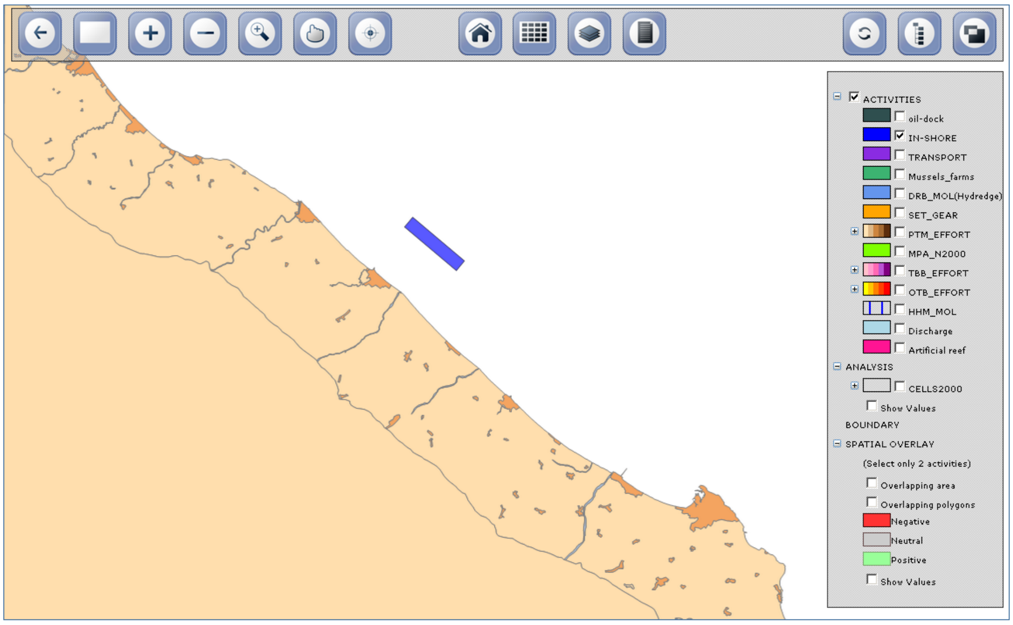


Figure 7.5 Location of the Wind Farm as established for the first scenario (In-shore).

The second one provide a location far from the coast line at a bathymetric interval of 35-40 m depth (called Off-shore scenario) (Figure 7.6).

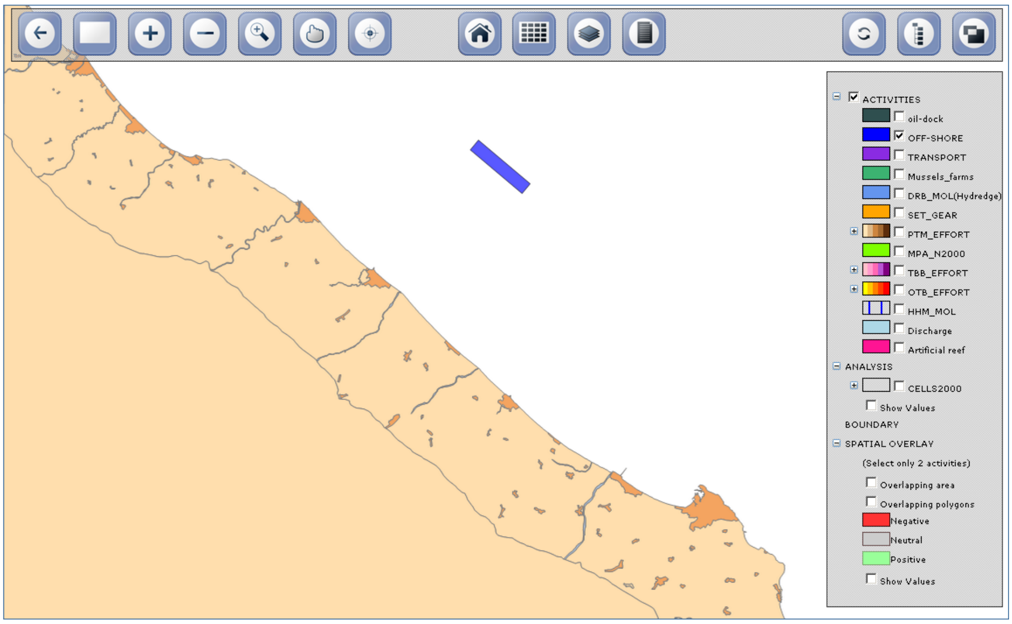


Figure 7.6 Location of the Wind Farm as established for the second scenario (Off-shore).

Conflict scores: After uploading the GRID application the location of the Wind farm we settled a conflict with this kind of activity with fishery. In detail we consider the "spatial conflict" between Wind farm and the most important fishing activity carried out in the area:

small scale fishery, bottom otter trawlers, beam (“rapido”) trawlers and Mid-water pelagic trawlers.

Due to the fact that in the area occupied from the Wind farm fishery is prohibited, the conflict score calculated by the GRID rules is equal to the maximum value of 6. In Figure 7.7 all the interactions between the Wind farm and fisheries are represented together with the activities attributes as settled in the database.

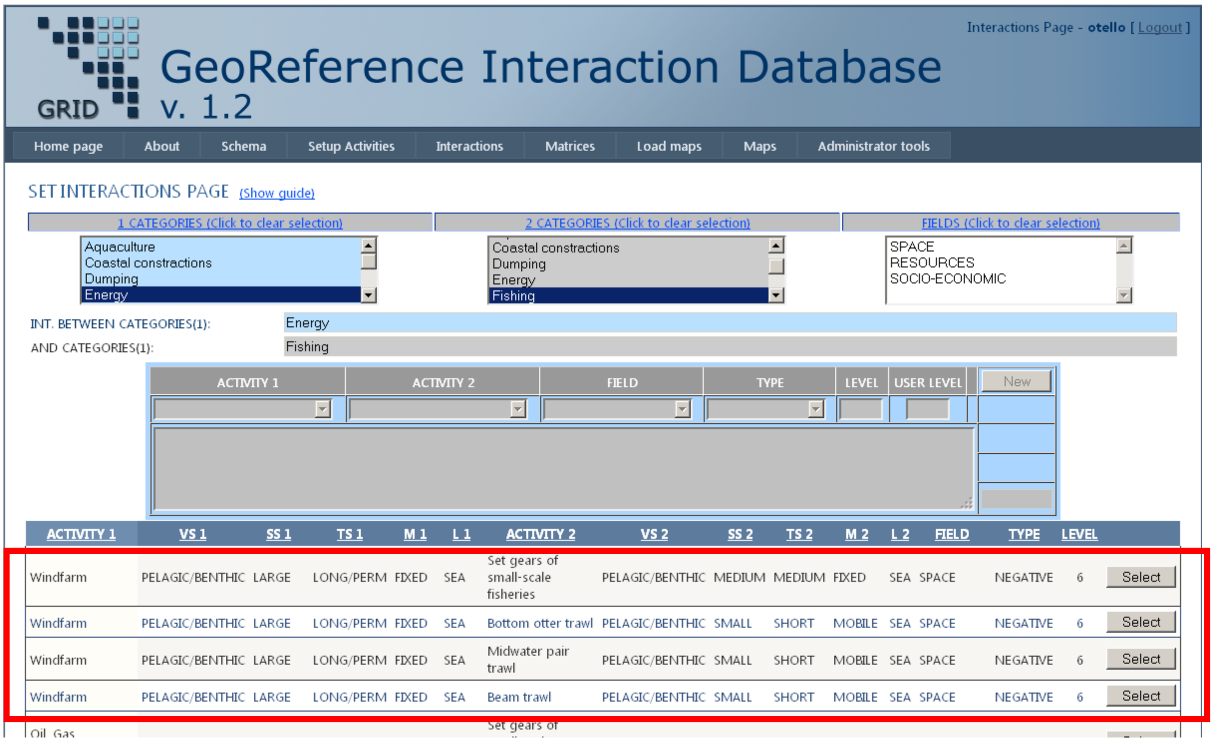
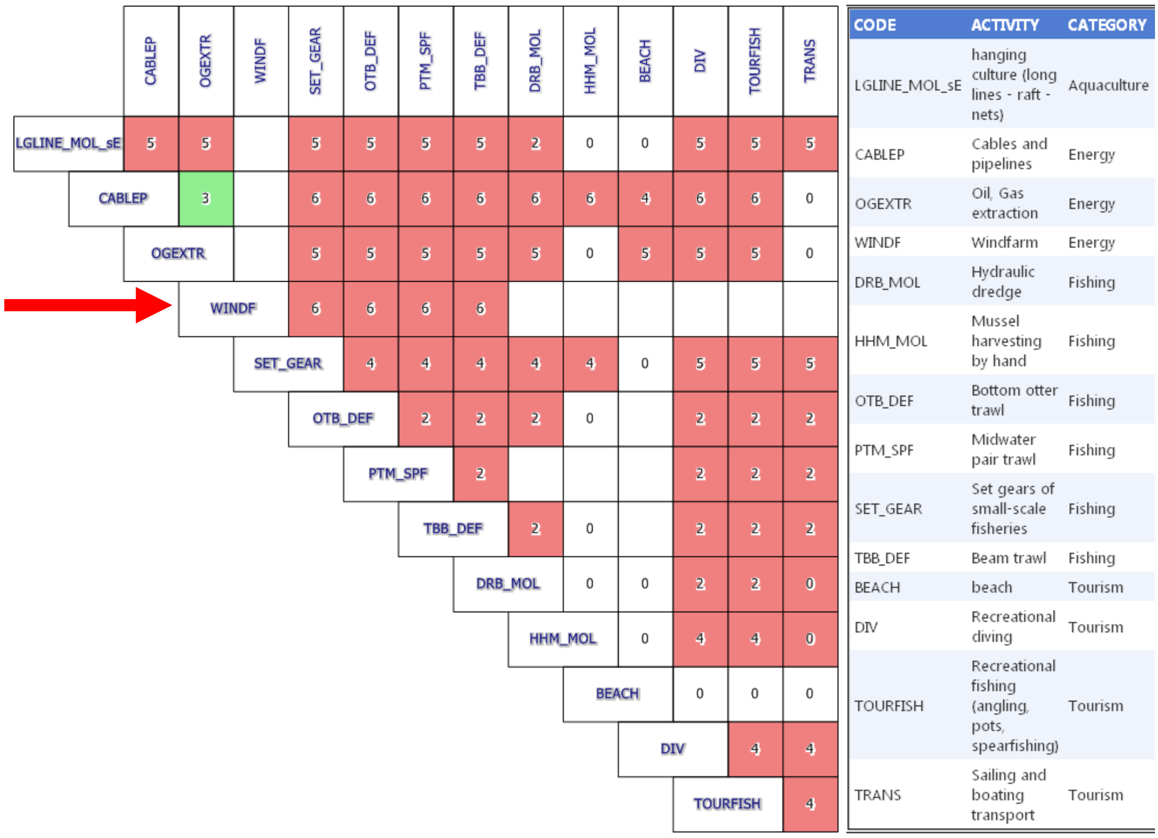


Figure 7.7 Interactions between Wind Farm and fisheries.

In Figure 7.8 is represented a Matrix of interactions considering several activities. Conflict scores due to the Wind farm are highlighted.



	CABLEP	OGEXTR	WINDF	SET_GEAR	OTB_DEF	PTM_SPF	TBB_DEF	DRB_MOL	HHM_MOL	BEACH	DIV	TOURFISH	TRANS
LGLINE_MOL_sE	5	5		5	5	5	5	2	0	0	5	5	5
CABLEP		3		6	6	6	6	6	6	4	6	6	0
OGEXTR				5	5	5	5	5	0	5	5	5	0
WINDF				6	6	6	6						
SET_GEAR					4	4	4	4	4	0	5	5	5
OTB_DEF						2	2	2	0		2	2	2
PTM_SPF							2				2	2	2
TBB_DEF								2	0		2	2	2
DRB_MOL									0	0	2	2	0
HHM_MOL										0	4	4	0
BEACH											0	0	0
DIV												4	4
TOURFISH													4

CODE	ACTIVITY	CATEGORY
LGLINE_MOL_sE	hanging culture (long lines - raft - nets)	Aquaculture
CABLEP	Cables and pipelines	Energy
OGEXTR	Oil, Gas extraction	Energy
WINDF	Windfarm	Energy
DRB_MOL	Hydraulic dredge	Fishing
HHM_MOL	Mussel harvesting by hand	Fishing
OTB_DEF	Bottom otter trawl	Fishing
PTM_SPF	Midwater pair trawl	Fishing
SET_GEAR	Set gears of small-scale fisheries	Fishing
TBB_DEF	Beam trawl	Fishing
BEACH	beach	Tourism
DIV	Recreational diving	Tourism
TOURFISH	Recreational fishing (angling, pots, spearfishing)	Tourism
TRANS	Sailing and boating transport	Tourism

Figure 7.8. Matrix of interactions with Wind Farm.

Spatial conflict analysis: To analyze spatial conflict between these activities, a distribution of fishing effort for each fishing segment considered were uploaded. For that concerning small scale fishery, we assumed that in both scenarios there are not spatial conflict between this fishing activity and the Wind Farm (Figure 7.9). The reason for that assumption is that small scale fishery is carried out in an area extended from the coast line to a maximum distance of 3 nautical miles, then there is no overlapping between this activity and the Wind farm as planned in the two different scenarios.

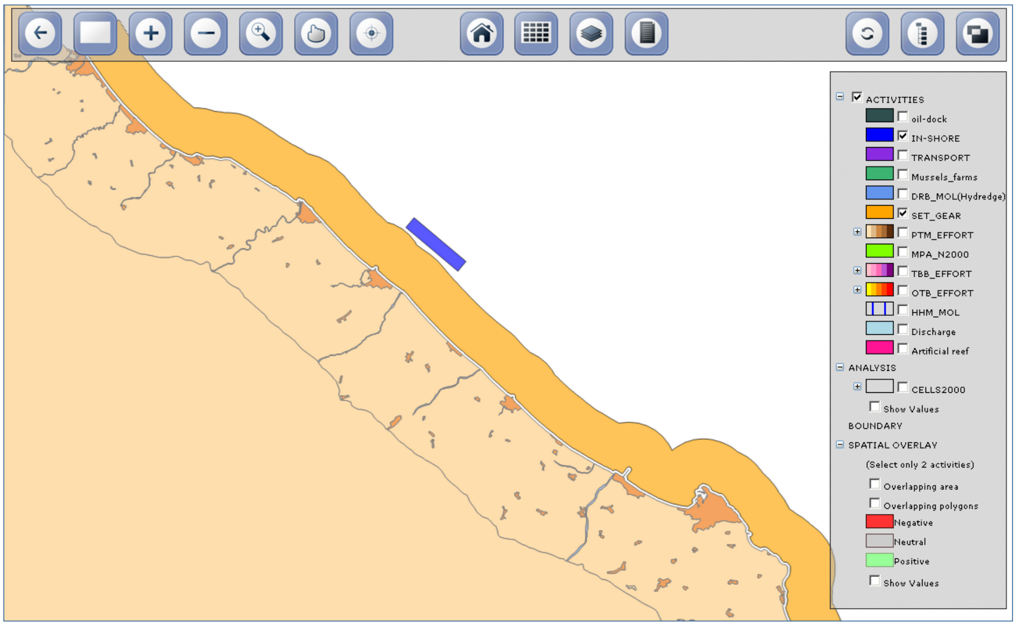


Figure 7.9 Wind Farm (in blue) and Small scale fishery area (in orange).

Spatial distribution of fishing effort for Otter trawlers, Beam trawlers and for Mid-water pair trawlers were uploaded in the GRID database in order to be mapped together with the two different Wind farm locations.

Figures 7.10-7.12 represent the comparison between wind farm locations in both scenarios and the spatial distribution of fishing efforts.

The map generated show that the impact of different scenarios with each fishing activity is quite different.

Even if the impact with Mid-water trawlers seems to be the same in the two different scenarios, we can not say the same for the other two fishing segments. In-shore scenario seems to affect most of all the Beam trawling activity, then the Off-shore one the Otter trawling activity.

We performed some numerical analysis in order to compare the different situation and to have a quantitative measure of the loss of effort if the wind farm is implemented.

A specific tool of GRID was used to calculate these parameters and to compare them together as discussed in the next paragraph.

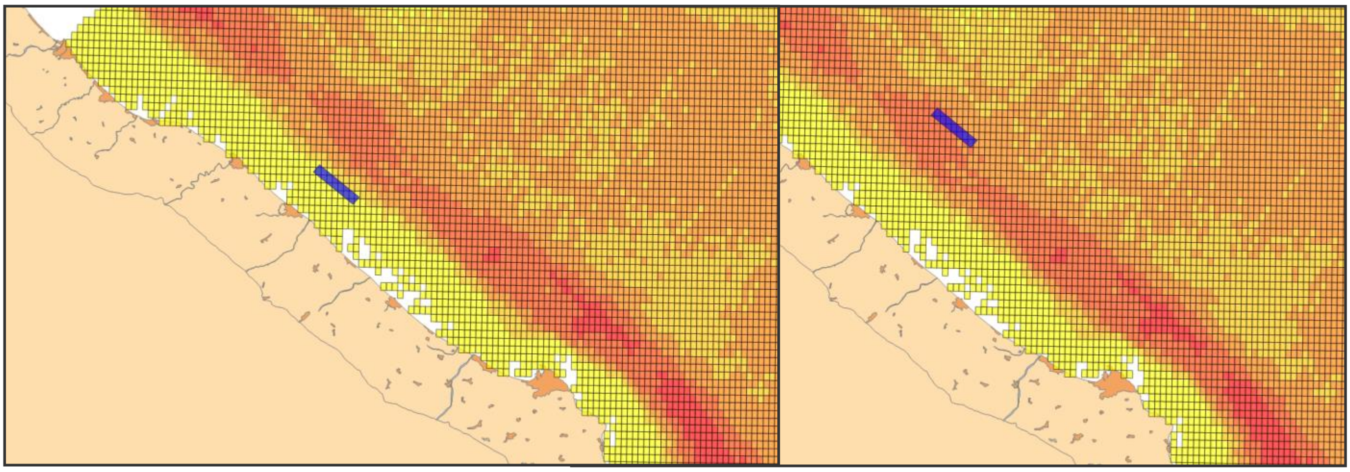


Figure 7.10. Spatial distribution of Otter bottom trawlers effort with Wind farm in scenario 1 (left) and scenario 2 (right).

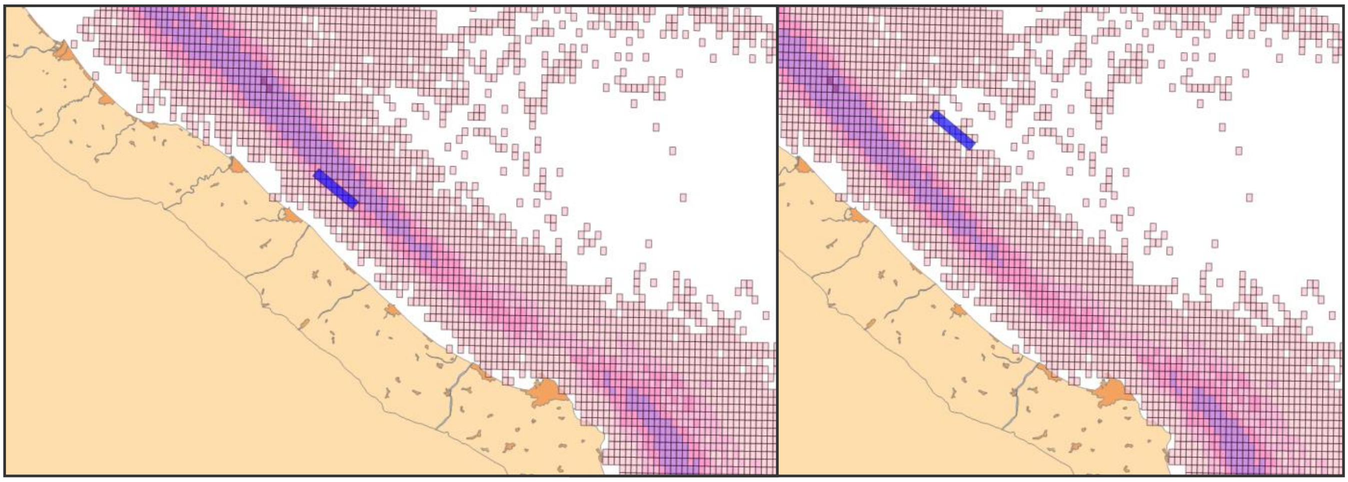


Figure 7.11 Spatial distribution of Beam trawlers effort with Wind farm in scenario 1 (left) and scenario 2 (right).

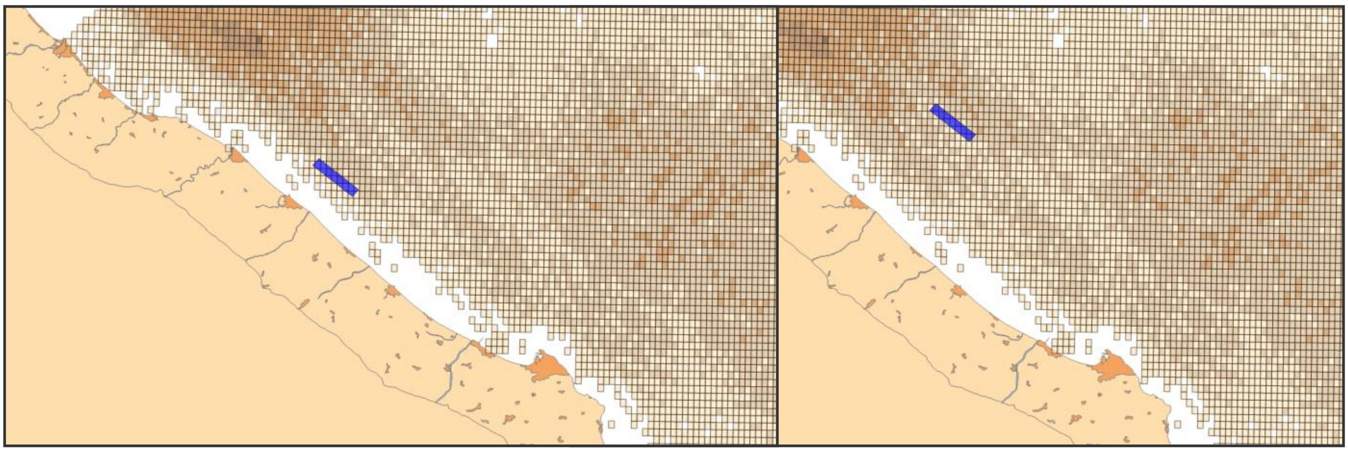


Figure 7.12. Spatial distribution of Mid-water pair trawlers effort with Wind farm in scenario 1 (left) and scenario 2 (right).

Stress level analysis. Each scenario was analyzed calculating the amount of effort for each segment that is associated with the area in which the Wind farm is placed. This data were then used to quantify and compare the impact of the two different scenarios on fishing activities.

The Table 7.1 shows the value calculated using GRID Spatial analysis tools.

Table 7.1 stress-level analysis results.

SCENARIO	ACTIVITY	AREA (%)	EFFORT	EFFORT (%)
IN-SHORE	OTB_EFFORT	0.143	216.99	0.059
IN-SHORE	PTM_EFFORT	0.166	49.68	0.116
IN-SHORE	TBB_EFFORT	0.32	379.84	1.288
OFF-SHORE	OTB_EFFORT	0.143	1169.16	0.317
OFF-SHORE	PTM_EFFORT	0.172	76.17	0.178
OFF-SHORE	TBB_EFFORT	0.222	14.5	0.049

Graphs that compare these values are represented in Figure 7.13-7.14.

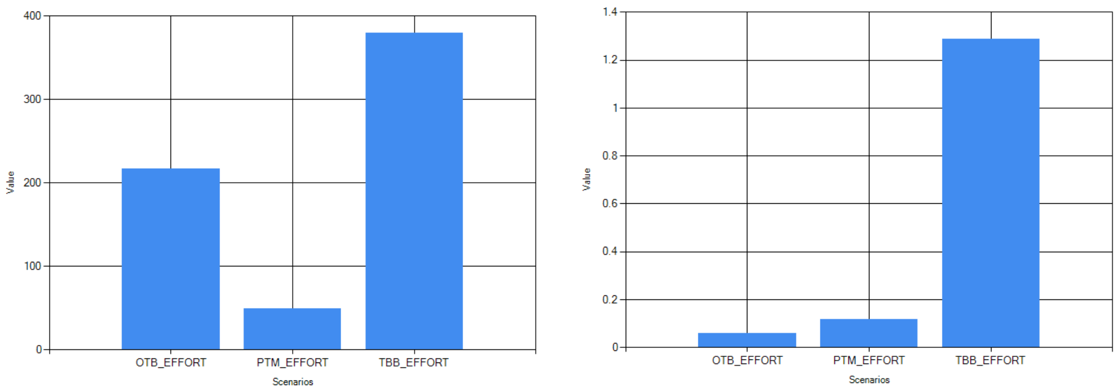
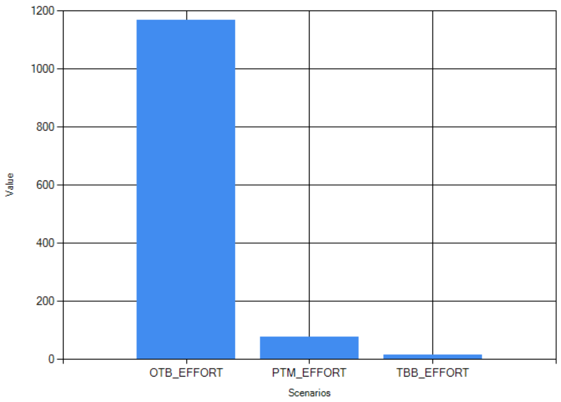


Figure 7.13. Effort loss in the scenario 1 (Total value on the left and percentage on the right).



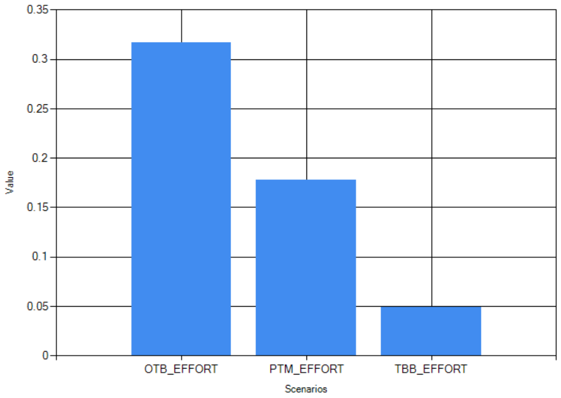


Figure 7.14 Effort loss in the scenario 2 (Total value on the left and percentage on the right).

As already highlighted in the maps, the impact on the Mid-water pair trawlers activity is not so different considering the two different scenarios. For Otter bottom trawlers and for Beam trawlers planning a Wind farm in-shore or off-shore has a completely different impact.

The In-shore scenario has a great impact on the Beam trawling considering the percentage of effort lost by Beam trawlers, that spent a lot of their fishing time in that zone. Comparing the impact between the activity in terms of total amount of effort, the difference between Beam trawlers and Otter trawlers is reduced because the number of vessel in the first segment mentioned is lower than in the second one.

On the other hand the analysis of the impact of the Off-shore scenario shows a completely different situation. In this second scenario the most important impact is on the Otter bottom trawling activity and the less important one is on Beam trawlers. In that case, as highlighted in the map, the Wind farm is located in the most exploited zone by the Otter bottom trawlers.

Comparing scenarios using the map of fishing grounds. In a previous section of this report a map of potential main fishing grounds for the Northern and Central Adriatic sea was produced. As explained in that section the map consider 15 target species for bottom otter trawlers. The map, uploaded in the GRID application was represented together with the two different scenarios. The output of GRID is reported in the Figure 7.15.

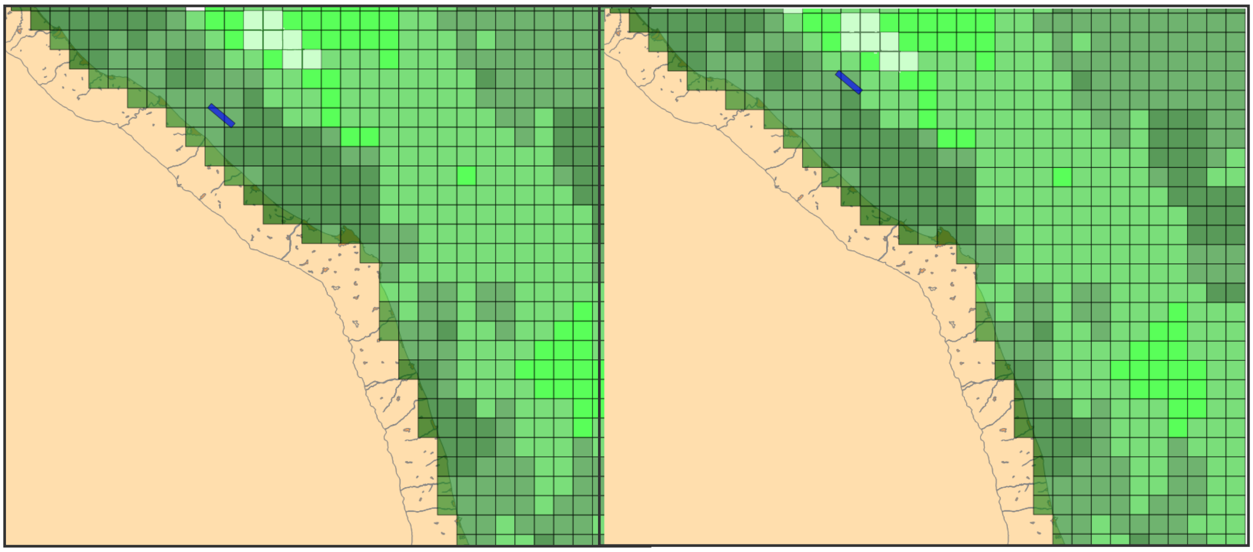


Figure 7.15 Different scenarios considering the main fishing grounds

In both the scenarios the wind farm is located in the coastal area in which the Presence Index results to be high. The off-shore solution puts the wind farm on the boundary of this main fishing area.

Comparing scenarios using the map of nursery and spawning areas. In a previous section of this report a map of main nursery and spawning grounds for the entire Adriatic sea was produced. The map, uploaded in the GRID application was represented together with the two different scenarios. The output of GRID is reported in the Figure 7.16-7.17.

As commented in the specific section of nursery and spawning areas, in the northern and central Adriatic sea there are no overlap between areas of recruitment and areas of reproduction, being the first on shore and the second off shore. In the first scenario the wind farm is placed in an area with a high value of presence index and then it means that the area is a nursery for several species. In the second scenario the distance of the wind farm from the coast is large enough to move out from the main nursery grounds. On the contrary for that concerning the reproduction areas, the first scenario does not overlap with main spawning grounds. In the second scenario the wind farm is placed in the boundary of an area with high value of presence index for spawners.

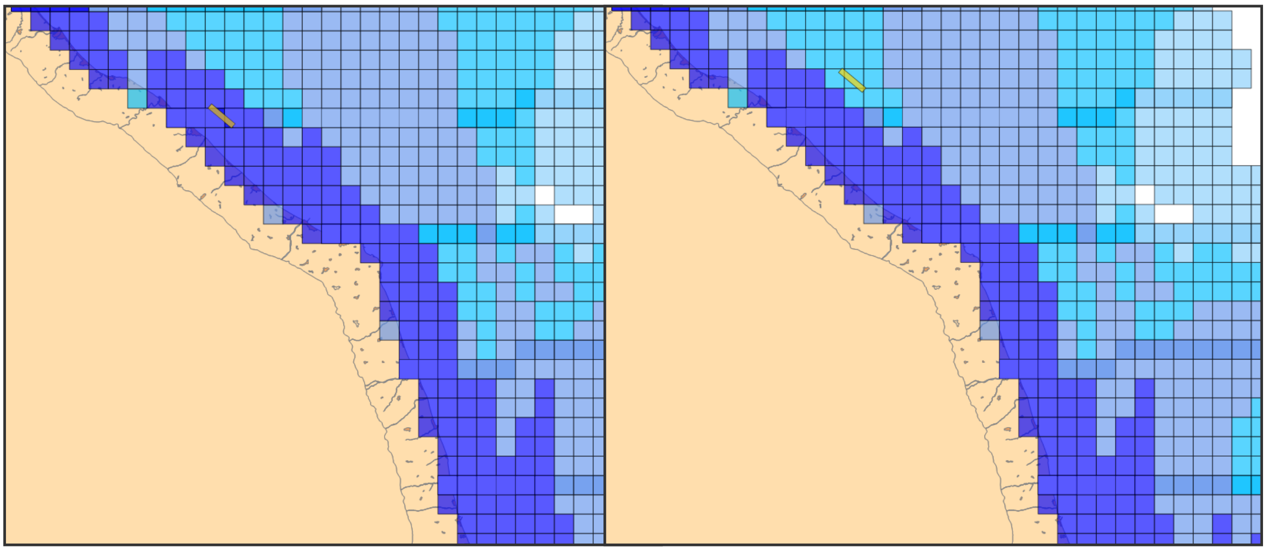


Figure 7.16 Different scenarios considering the main nursery grounds

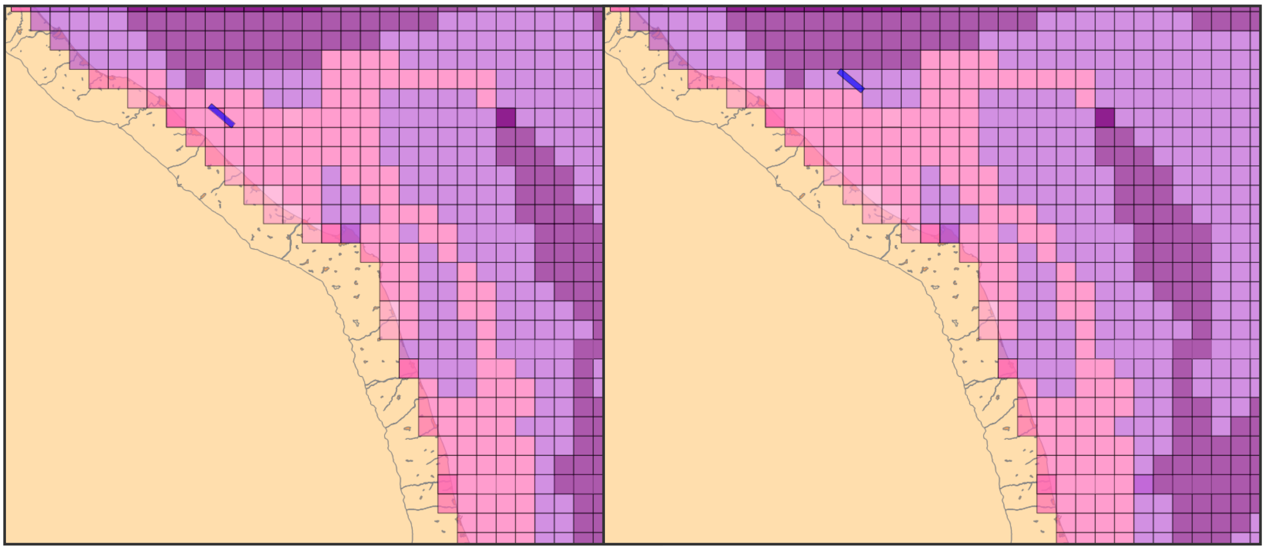


Figure 7.17 Different scenarios considering the main spawning grounds

Conclusions. GRID application shows all its potential in emphasizing the spatial conflict between the different activities carried out in the coastal zone. A wind farm placed not so far from the coast line will have an impact on other anthropic activities, especially with fishing. GRID application can be used to evaluate different scenarios, qualitatively through the production maps that show spatial interactions, but also quantitatively by quantifying some parameters, such as fishing effort associated to the area subtracted to the fishing activities by the wind farm.

8. REFERENCES

8. REFERENCES

AA. VV. (2006) Gestione e tutela dei banchi naturali di Chamelea gallina (vongola adriatica) nel Compartimento Marittimo di Pescara. Relazione finale. IZS Abruzzo e Molise "G. Caporale", Centro di Biologia delle Acque di Giulianova, 181 pp.

Abruzzi Region –Italy- Final Report for WP5 (2014) 376pp.

ACCOBAMS 2010. Resolution 4.17. Guidelines to Address the Impact of Anthropogenic noise on cetaceans in the ACCOBAMS area;

ACCOBAMS 2013. Methodological Guide: Guidance on underwater noise mitigation measures. ACCOBAMS-MOPS/2013/Doc24;

ACCOBAMS-MOP5/2013/Doc22. Anthropogenic noise and marine mammals: review of the effort in addressing the impact of anthropogenic underwater noise in the ACCOBAMS and ASCOBANS areas;

Ainslie, M., de Jong, C., Dol, H., Blacquière, G., & Marasini, C. (2009). Assessment of natural and anthropogenic sound sources and acoustic propagation in the North Sea. the Hague: TNO;

Albania Final Report for WP5 (2014) 28pp.

American Bureau of Shipping. 2000. Guidance notes on Risk Assessment Applications for the marine and offshore oil and gas industries", online at www.eagle.org

Anonimous (2000) Council Regulation (EC) No 1543/2000 of 29 June 2000 establishing a Community framework for the collection and management of the data needed to conduct the common fisheries policy. Official Journal of the European Communities (L 176/1 of 15.7.2000): 1-16.

Apulia region –Italy- Final Report for WP5 (2014) 76pp (sort of)

Ardizzone G.D., F.Corsi (editors) 1997. Atlante delle Risorse Ittiche Demersali Italiane. Atlas of Italian Demersal Fishery Resources - Trawl surveys 1985-1987. Biol. Mar. Medit . 4(2)

Ardizzone G.D., F.Corsi (editors) 1997. Atlante delle Risorse Ittiche Demersali Italiane. Atlas of Italian Demersal Fishery Resources - Trawl surveys 1985-1987. Biol. Mar. Medit . 4(2)

Artegiani A., Bregant D., Paschini E., Pinardi N., Raicich F., Russo A. (1997a) The Adriatic Sea general circulation. Part 1: air-sea interactions and water mass structure. Journal of Physical Oceanography 27 (8): 1492-1514

Artegiani A., Bregant D., Paschini E., Pinardi N., Raicich F., Russo A. (1997b) The Adriatic Sea general circulation. Part 2: baroclinic circulation structure. Journal of Physical Oceanography 27 (8): 1515-1532.

ASCOBANS (2009). Final Report of the ASCOBANS Intersessional Working Group on the Assessment of Acoustic Disturbance. Bonn, Germany;

Bailey, H., Senior, B., Simmons, D., Rusin, J., Picken, G. & Thompson, P. (2010) Assessing underwater noise levels during pile-driving at an offshore wind farm and its potential effects on marine mammals. Marine Pollution Bulletin 60: 888-897;

Balata D., Piazzi L., Cecchi E., Cinelli F. (2005) Variability of Mediterranean coralligenous assemblages subject to local variation in sediment deposition. Marine Environmental Research 60: 403–421.

Baldacconi R., Corriero G. (2009) Effects of the spread of the alga Caulerpa racemosa var. Cylindracea on the sponge assemblage from coralligenous concretions of the Apulian coast (Ionian Sea, Italy). Marine Ecology – An Evolutionary Perspective, 30: 337–345.

Ballesteros E. (2006) Mediterranean coralligenous assemblages: a synthesis of present knowledge. Oceanography and Marine Biology – An Annual Review, 44, 123 pp.

Bastardie, F., Nielsen, J.R., Ulrich, C., Egekvist, J., Degel, H., 2010. Detailed mapping of fishing effort and landings by coupling fishing logbooks with satellite-recorded vessel geo-location. Fish. Res. 106, 41–53.

Bastardie, F., Nielsen, J.R., Ulrich, C., Egekvist, J., Degel, H., 2010. Detailed mapping of fishing effort and landings by coupling fishing logbooks with satellite-recorded vessel geo-location. Fish. Res. 106, 41–53.

Bean D. 2011. Offshore Wind – The Development Process”, online at www.chinawind.org

Bearzi G., Holcer D., Notarbartolo di Sciara G. (2004) The role of historical dolphin takes and habitat degradation in shaping the present status of northern Adriatic cetaceans. Aquatic Conserv.: Mar. Freshw. Ecosyst., 14: 363–379.

Belluscio A., Panayiotidis P., Gristina M., Knittweis L., Pace M.L., Telesca L., Criscoli A., Apostolaki E.T., Gerakaris V., Fraschetti S., Spedicato M.T., Lembo G., Salomidi M., Mifsud R., Fabi G., Badalamenti F., Garofalo G., Alagna A., Ardizzone G.D., Martin C., Valavanis V. (2013) Seagrass beds distribution along the Mediterranean coasts. Mediterranean Sensitive Habitats (MEDISEH) Final Report, DG MARE Specific Contract SI2.600741.

BETKE, K. (2008): Minderung von Unterwassergeräuschen beim Bau von Offshore WEA - Schallschutz-hüllen und andere Verfahren. Presentation Workshop „Forschungsergebnisse der Begleitfor-schung zur Rammungsschallemission bei der Installation der Forschungsplattform FINO3“ FOWEUM, BSH Hamburg 8. Oktober 2008;

BETKE, K. & MATUSCHEK, R. (2010): Unterwassergeräusche beim Bau und beim Betrieb des Offshore-Windparks "alpha ventus" - Untersuchungen gemäß StUk3 – Presentation;

Betke, K., (2006). Measurement of underwater noise emitted by an offshore wind turbine at Horns Rev. ITAP report 13/02/2006;

Betke, K., Glahn, M. S-v. and Matuschek, R. (2004) Underwater noise emissions from offshore wind turbines. Proceedings of CFA/DAGA '04;

Boesen, C. & Kjaer, J., (2005). Review report 2004. The Danish Offshore Wind Farm Demonstration Project: Horns Rev and Nysted Offshore Wind Farms, Environmental impact assessment and monitoring. Elsam Engineering and ENERGI E2;

Bordehore C., Ramos-Esplá A.A., Riosmena-Rodríguez R. (2003) Comparative study of two mäerl beds with different otter trawling history, southeast Iberian Peninsula. Aquatic Conservation: Marine and Freshwater Ecosystems, 13 (SUPPL. 1): 43-54.

Brambati A. (1992). Origin and evolution of the Adriatic Sea. In: Colombo G., Ferrari I., Ceccherelli V.U., Rossi R. (eds) "Marine eutrophication and population dynamics. Proceedings of the 25th European Marine Biology Symposium, Ferrara, Italy, 10-15 September 1990", International Symposium Series, Olsen & Olsen, 394 pp.

Brambati A., Ciabatti M., Fanzutti G.P., Marabini F., Marocco R. (1988) Carta sedimentologica dell'Adriatico Settentrionale e Centrale. CNR, Ist. Geogr. De Agostini, Novara.

Brandt, M., Diederichs, A., Betke, K., & Nehls, G. (2011). Responses of harbour porpoises to pile driving at the Horns Rev II offshore wind farm in the Danish North Sea. Mar Ecol Prog Ser(421), pp. 205-216;

BS EN ISO 17776:2002. 2002. Petroleum and natural gas industries – Offshore production installations – Guidelines on tools and techniques for hazard identification and risk assessment.

BSH - BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE (2012): Änderungs- und Ergänzungsbescheid zu der Genehmigung „Albatros“ (Az. 511/Albatros/M5382);

Buia M.C., Gambi M.C., Dappiano M. (2003) I sistemi a Fanerogame marine. Biol. Mar. Medit., 10: 145-198.

Buljan M., Zore-Armanda M. (1979) Hydrographic properties of the Adriatic Sea in the period from 1965 through 1970. Acta Adriatica, 20(1-2): 1-368.

C Huete-Stauffer Report 2013-14 (2014) Report Huete-Stauffer Carla Grace Co.co.co IPA-POWERED (Project of Offshore Wind Energy: Research, Experimentation, Development) for: “Selezione per un incarico individuale con contratto di lavoro autonomo do collaborazione coordinate e continuative nell’ambito del progetto: “POWERED- Project of Offshore Wind Energy: Research, Experimentation, Development- IPA Adriatic Cross-border Cooperation Program 2007-2013 (scadenza il 28/02/2014)- codice CUP I31J10000700005” Attività di supporto alla ricerca intitolata: “Analisi dell principali caratteristiche bio-ecologiche del Mar Adriatico” Cod. 57”

C Huete-Stauffer, A Pusceddu, A Dell’Anno, R Ricci (2014) Environmental impacts of offshore wind farms in the Adriatic Sea: A review for consensus method application (in progress)

Caltrans, (2001). Fisheries Impact Assessment – San Francisco – Oakland Bay Bridge East Span Seismic Safety Project. PIPD EA 012081, Caltrans Contract 04A0148, Task Order 205.10.90, PIPD 04-ALA-800.0/0.5: 57 pp 51;

CARG (2011). Carta Geologica dei Mari Italiani (Trincardi F., Argnani A. and Correggiari A. eds). ISMAR-CNR Bologna, stamp. S.EL.CA. Firenze.

Casellato S., Stefanon A. (2008) Coralligenous habitat in the northern Adriatic sea: an overview. Marine Ecology, 29: 1-21.

Cato, D. H. (2008). Ocean ambient noise: Its measurement and its significance to marine animals. Proceedings of the Institute of Acoustics, 30(5);

CETMA Report (2014) Security and Risk Analysis for the installation of offshore wind farms.

Claudet J, Fraschetti S (2010) Human-driven impacts on marine habitats: a regional meta-analysis in the MEditerranean Sea. Biological Conservation 143:2195-2206.

Cluster Maritime Francais – CMF (2014). UNDERWATER NOISE : ECONOMIC AND ENVIRONMENTAL CHALLENGES IN THE MARINE ENVIRONMENT;

Colantoni P. (1986) Aspetti geologici e sedimentologici dell'Adriatico. In: AA. VV. "Eutrofizzazione, quali interventi?" Atti del convegno nazionale di Ancona. Ministero della Marina Mercantile, Regione Marche e Ente Autonomo Fiera di Ancona: 17-21.

Colantoni P., Curzi P., Gallignani P. (1978) Caratteristiche generali del fondo e del sottofondo della piattaforma continentale tra Ancona e la foce del fiume Reno. In: Colantoni P., Gallignani P. Ricerche sulla piattaforma continentale dell'Alto Adriatico. C.N.R. P.F. Oceanografia e Fondi marini 1, Bologna: 15-27.

Colantoni P., Gallignani P., Lenaz R. (1980) La piattaforma continentale dell'Alto Adriatico dalla foce del Reno a Venezia: evoluzione ed ambienti di sedimentazione tardo Pleistocenici ed Olocenici. In: Colantoni P., Gallignani P. Ricerche sulla piattaforma continentale dell'Alto Adriatico. C.N.R. P.F. Oceanografia e Fondi marini 2, Bologna: 11-28.

Coma R., Pola E., Ribes M., Zabala M. (2004) Long-term assessment of temperate octocoral mortality patterns, protected vs. unprotected areas. Ecological Applications, 14: 1466–1478.

Coombs, S. and Montgomery, J.C. (1999). The Enigmatic Lateral Line System. In: Fay, R.R. and Popper, A.N. (eds.). Comparative Hearing: Fish and Amphibians, 319-362;

Corbetta G., Pineda I., Moccia J., Guillet J. 2013. The European offshore wind industry - key trends and statistics 2014, EWEA, online at www.ewea.org

CSA Ocean Sciences Inc., 2013. Quieting Technologies for reducing noise during seismic surveying and pile driving. Information Synthesis. BOEM. 53 pp;

Dähne M, Gilles A, Lucke K, et al. (2013) Effects of pile- driving on harbour porpoises (Phocoena phocoena) at the first offshore wind farm in Germany. Environ Res Lett 8:025002. doi: 10.1088/1748- 9326/8/2/025002;

David, J.A. (2006). Likely sensitivity of bottlenose dolphins to pile-driving noise. Water and Environment Journal 20 , 48-54;

Dell'Aquila M., Mariani A., Ugolini R. (2008) GIS, the Sea and Fisheries. Geographical Information System Application Examples: towards a GIS-based Italian Fisheries' Information System. UNIMAR, Roma, 73 pp.

Development Core Team, R., 2009. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria, ISBN 3- 900051-07-0, http://www.Rproject. org.

Development Core Team, R., 2009. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria, ISBN 3- 900051-07-0, http://www.Rproject. org.

ELMER, K.-H., BETKE, K. & NEUMANN, T. (2007a): Standardverfahren zur Ermittlung und Bewertung der Belastung der Meeresumwelt durch die Schallimmission von Offshore-Windenergieanlagen: SCHALL2. - Project 0329947 final report. The German Federal Environment Ministry;

ELMER, K.-H., BETKE, K. & NEUMANN, T. (2007b): Standardverfahren zur Ermittlung und Bewertung der Belastung der Meeresumwelt durch die Schallimmission von Offshore-Windenergieanlagen: Untersuchung von Schallminderungsmaßnahmen an FINO 2. - Project 0329947 A final report. The German Federal Environment Ministry;

Emilia-Romagna region –Italy- Final Report for WP5 (2014) total of 62pp divided in 5 reports.

Enger, P.S., Kalmijn, A.D. and Sand, O. (1989). Behavioural investigations on the function of the lateral line and inner ear in predation. In: Coombs, S., Görner, P. and Münz, H. (eds.) The mechanosensory lateral line. Springer-Verlag, New York, 375-387;

European Commission – Commission staff working paper, Relationship between the initial assessment of marine waters and the criteria for good environmental status - Brussels, 14.10.2011 SEC(2011) 1255 final bridge.

European Commission – Commission staff working paper, Relationship between the initial assessment of marine waters and the criteria for good environmental status - Brussels, 14.10.2011 SEC(2011) 1255 final bridge.

Fay, R.R. and Popper, A.N. (1999). Hearing in Fishes and Amphibians: An Introduction. In: Fay, R.R. and Popper, A.N. (eds.). Comparative Hearing: Fish and Amphibians, 1-14;

Finneran JJ, Jenkins AK. (2012) Criteria and Thresholds for U . S . Navy Acoustic and Explosive Effects Analysis;

Finneran, J. J. and Schlundt, C. E. (2011). "Subjective loudness level measurements and equal loudness contours in a bottlenose dolphin (Tursiops truncatus)," Journal of the Acoustical Society of America 130, 3124-3136;

Finneran, J. J., Carder, D. A., Schlundt, C. E., and Dear, R. L. (2010). "Temporary threshold shift in a bottlenose dolphin (Tursiops truncatus) exposed to intermittent tones," J Acoust Soc Am 127, 3267–72;

Fonda-Umani S., Franco P., Ghirardelli E., Mallej A. (1992) Outline of oceanography and the plankton of the Adriatic Sea. In: Colombo G., Ferrari I., Ceccherelli V.U., Rossi R. (eds) "Marine eutrophication and population dynamics. Proceedings of the 25th European Marine Biology Symposium, Ferrara, Italy, 10-15 September 1990", International Symposium Series, Olsen & Olsen, 394 pp.

Franco P. (1970) Oceanography of Northern Adriatic Sea. I – Hydrologic features: cruises july-august and october-november 1965. Arch. Oceanogr. Limnol., 16 (Suppl.): 1 – 93.

Franco P. (1973) L'influenza del Po sui caratteri oceanografici e sulla distribuzione della biomassa planctonica dell'Adriatico Settentrionale. Da "Studi e Ricerche sul Delta del Po". Annali dell'Università di Ferrara: 95-117.

Franco P. (1983) L'Adriatico settentironale: caratteri oceanografici e problemi. In: Atti 5° congresso AIOL. Stresa: 1-27.

Franco P., Jeftic L., Malanotte Rizzoli P., Michelato A., Orlic M. (1982) Descriptive model of the Northern Adriatic. Oceanologica Acta 5 (3): 379-389.

Franco, P. (1986). Caratteristiche oceanografiche dell'Adriatico Settentrionale. Atti del Convegno "Eutrofizzazione: quali interventi?", Ancona, 4-5 Novembre 1985: 9 – 16.

Fraschetti S., Gristina M., Salomidi M., Knittweis L., Pace M.L., Punzo E., Belluscio A., Scarcella G., Grati F., De Leo F., Rizzo L., Cattaneo-Vietti R., Povero P., Cau A., Piccinetti C., Valavanis V., Martin C. (2013) Coralligenous and mäerl beds distribution along the Mediterranean coasts. Mediterranean Sensitive Habitats (MEDISEH) Final Report, DG MARE Specific Contract SI2.600741

G Schofield, VJ Hobson, S Fossette, MKS Lilley, KA Katselidis, GC Hays (2010) Fidelity to foraging sites, consistency of migration routes and habitat modulation of home range by sea turtles. Diversity and Distributions 16: 840–853

Gamulin-Brida H. (1967) The benthic fauna of the Adriatic Sea. Oceanography and Marine Biology: an Annual Review, 5: 535-568.

Gamulin-Brida H. (1974) Biocoenoses benthiques de la Mer Adriatique. Acta Adriatica 15 (9): 1-102.

Garrabou J., Perez T., Sartoretto S., Harmelin J. (2001) Mass mortality event in red coral Corallium rubrum populations in the Provence region (France, NW Mediterranean). Marine Ecology Progress Series, 217: 263–272.

Gerdes G., Tiedemann A., Zeelenberg S. 2008. European Offshore Wind Farms - A Survey for the Analysis of the Experiences and Lessons Learnt by Developers of Offshore Wind Farms. Online at www.tethys.pnnl.gov

Giannoulaki M., A. Belluscio, F. Colloca, S. Fraschetti, M. Scardi, C. Smith, P. Panayotidis, V. Valavanis M.T. Spedicato. 2013. Mediterranean Sensitive Habitats DG MARE Specific Contract SI2.600741, Final Report, 557 p.

Giannoulaki M., A. Belluscio, F. Colloca, S. Fraschetti, M. Scardi, C. Smith, P. Panayotidis, V. Valavanis M.T. Spedicato. 2013. Mediterranean Sensitive Habitats DG MARE Specific Contract SI2.600741, Final Report, 557 p.

Giuliani S., Virno Lamberti C., Sonni C., Pellegrini D. (2005) Mucilage impact on gorgonians in the Tyrrhenian Sea. Science of the Total Environment, 353: 340-349.

Goodson, A. D., and C. R. Sturtivant. “Sonar characteristics of the harbour porpoise (Phocoena phocoena): Source levels and spectrum.” ICES Journal of Marine Science, 1996: 53, 465-472;

Gramolini R., F. Grati, T. Schulze, G. Fabi 2013. Interaction in coastal waters (COEXIST) E.U. funded project number: 245178, Deliverable D3.9 GRID GeoReference Interactions Database, 30 p.

Gramolini R., F. Grati, T. Schulze, G. Fabi 2013. Interaction in coastal waters (COEXIST) E.U. funded project number: 245178, Deliverable D3.9 GRID GeoReference Interactions Database, 30 p.

Hastings, M. C. and Popper, A. N. (2005). Effects of sound on fish. California Department of Transportation Contract 43A0139 Task Order, 1. http://www.dot.ca.gov/hq/env/bio/files/Effects_of_Sound_on_Fish23Aug05.pdf;

HSE 2006. Guidance on Risk Assessment for Offshore Installations. Online at www.hse.gov.uk

Husum (2002), Germany. On behalf of COWRIE Ltd. 01;

Iborra Martín J. (2008) The Ecological and Fisheries Protection Zone (ZERP) in Coatia. Directorate General for Internal Policies of the Union, Policy Department – Structural and Cohesion Policy, Fisheries. IP/B/PECH/NT/2008-03, February 2008, 20 pp.

ICES (2010). Report of the Working Group on Marine Mammal Ecology (WGMME). Horta, The Azores; p. 10–35;

IPA-NETCET Reports and maps (2013) 11 pp in two reports.

ISO/IEC, 1999. Guide 51, Safety aspects — Guideline for their inclusion in standards.

ISO/TMB WG on Risk Management Terminology, 1999. The Third Working Draft of Risk Management Terminology'.

ISPRA, (2012) Valutazione iniziale per la strategia marina.

ITAP – Institut für technische und angewandte Physik GmbH (2005). Ermittlung der Schalldruck-Spitzenpegel aus Messungen der Unterwassergeräusche von Offshore-WEA und Offshore-Rammarbeiten. Report commissioned by biola (biologisch-landschaftsökologische Arbeitsgemeinschaft);

Jasco Applied Sciences (2011), Noise and the effects on marine mammals; A Pocket Handbook, 3rd edition;

JC Wilson (2010) The Potential for Habitat Creation around Offshore Wind Farms . AMEC "From Turbine to Wind Farms - Technical Requirements and Spin-Off Products" pp19.

Kaiser M.J., Snyder B.F. 2012. Offshore Wind Energy Cost Modeling - Installation and Decommissioning. Springer

Kastak, D., and R., J. Schusterman. (1998) "Low-frequency amphibious hearing in pinnipeds: Methods, measurements, noise, and ecology." Journal of the Acoustical Society of America, April, 1998: 103, 2216-2228§;

Kastak, D., and Schusterman, R. (1996). "Temporary threshold shift in a harbor seal (Phoca vitulina)," J Acoust Soc Am 100, 1905–1908;

Kastak, D., Southall, B. L., Schusterman, R. J. & Kastak, C. R. (2005) Underwater temporary threshold shift in pinnipeds: effects of noise level and duration. Journal of the Acoustical Society of America 118: 3154-3163;

Kastelein, R.A., P. Bunskoek, M. Hagedoorn, W.L.W. Au, and D. de Haan. "Audiogram of a harbor porpoise (Phocoena phocoena) measured with narrow-band frequency-modulated signals." JASA 112 (2002): 334;

Köller J., Köppel J., Peters W. 2006. Offshore Wind Energy - Research on Environmental Impacts

Koschinski, S. and Lüdemann, K. 2013. Development of noise mitigation measures in offshore wind farm construction. Federal Agency for Nature Conservation / Bundesamdt für Naturschutz (BfN). 97 pp;

Lambeck K., Antonioli F., Purcell A., Silenzi S. (2004) Sea-level change along the Italian coast for the past 10,000 yr. Quaternary Science Reviews, 23 (14-15): 1567-1598.

Lucke K, Lepper P.A. and Blanchet, M (2009). Temporary shift in masked hearing thresholds in a harbour porpoise (Phocoena phocoena) after exposure to seismic airgun stimuli. J. Acoust. Soc. Am. 125(6) 4060-4070;

Madsen, P.T., Wahlberg, M., Tougaard, J., Lucke, K. and Tyack, P. (2006). Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs. Mar. Ecol. Progr. Ser. 309, 279-295;

Maes J, Turnpenny A W H, Lambert D R, Nedwell J R, Parmentier A and Olivier F (2004). Field evaluation of a sound system to reduce estuarine fish intake rates at a power plant cooling water inlet. J.Fish.Biol. 64, pp938 – 946;

Maglic L., Simic Hlaca M., Zec D. (2009) Maritime Transport and Possible Accidents in the Adriatic Sea. Online at www.bib.irb.hr

Marche Region –Italy- Final report for WP5 (2014) 41pp.

Marmo, B., Roberts, I., Buckingham, M.P., King, S., Booth, C.(2013) Modelling of Noise Effects of Operational Offshore Wind Turbines including noise transmission through various foundation types (Edinburgh: Scottish Government) ;

McCauley, R.D., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner, M.-N., Penrose, J.D., Prince, R.I.T., Adhitya, A., Murdoch, J. and McCabe, C. (2000). Marine Seismic Surveys: Analysis and Propagation of Air Gun Signals; and Effects of Air-Gun Exposure on Humpback Whales, Sea Turtles, Fishes and Squid. Report on research conducted for The Australian Petroleum Production and Exploration Association;

MEDISEH - Mediterranean Sensitive Habitats (2013). Edited by Giannoulaki M., Belluscio A., Colloca F., Fraschetti S., Scardi M., Smith C., Panayotidis P., Valavanis V., Spedicato M.T. DG MARE Specific Contract SI2.600741, Final Report, 557 p.

Micheli F., Levin N., Giakoumi S., Katsanevakis S., Abdulla A., Coll M., Fraschetti S., Kark S., Koutsoubas D., Mackelworth P., Maiorano L., Possingham H.P. (2013) Setting Priorities for Regional Conservation Planning in the Mediterranean Sea. PLoS ONE 8(4): e59038. doi:10.1371/journal.pone.0059038

Mo G. (2011) Mediterranean Monk Seal (Monachus monachus) sightings in Italy (1998-2010) and implications for conservation. Aquatic Mammals, 37(3): 236-240. DOI 10.1578/AM.37.3.2011.236

Mo G., Agnesi S., Di Nora T., Tunesi L. (2007) Mediterranean monk seal sightings in Italy through interviews: validating the information (1998-2006). Comm. Int. Mer Medit., 38: 542.

Molise Region –Italy- Final Report for WP5 (2014) 35pp.

Montenegro Final report for WP5 (2014) 8pp.

Mooney, T.A., Nachtigall, P.E., Breese, M., Vlachos, S. & Au, W.L. (2009) Predicting temporary threshold shifts in a bottlenose dolphin (Tursiops truncatus): the effects of noise level and duration J. Acoust. Soc. Am. 125(3): 1816-1826;

Mueller-Blenkle C, McGregor P K, Gill A B, Andersson M H, Metcalfe J, Bendall V, Sigray P, Wood D and Thomsen F. (2010). Effects of pile-driving noise on the behaviour of marine fish. COWRIE Ref: Fish 06-08 / Cefas Ref: C3371. Technical Report 31st March 2010;

Müller-BBM GmbH - Hamburg branch (2013). Offshore Wind Farms Prediction of Underwater Sound Minimum Requirements on Documentation;

Müller-BBM GmbH (2011) Offshore wind farms Measuring instruction for underwater sound monitoring;

Naturvårdsverket (2010) Ljud från vindkraftverk ('Noise from wind turbines') Report 5933;

Nedwell J R, Turnpenny A W H, Lovell J, Parvin S J, Workman R, Spinks J A L and How-ell D. (2007a). A validation of the dBht as a measure of the behavioural and auditory effects of underwater noise. Subacoustech Report Reference: 534R1231, Published by Department for Business, Enterprise and Regulatory Reform;

Nedwell J., Langworthy J., Howell D. (2004) Assessment of sub-sea acoustic noise and vibration from offshore wind turbines and its impact on marine wildlife; initial measurements of underwater noise during the construction of offshore windfarms, and comparison with background noise. Subacoustech Ltd, 544 R 0424, Southampton;

Nedwell, J. R. and D. Howell (2004a). A review of offshore windfarm related underwater noise sources. –COWRI report No. 544 R 0308, 57 pp.

Nedwell, J. R., Langworthy, J. and Howell, D. (2003). Assessment of sub-sea acoustic noise and vibration from offshore wind turbines and its impact on marine wildlife; initial measurements of underwater noise during construction of offshore windfarms, and comparison with background noise. COWRIE report No. 544 R 0424, 68 pp;

Nedwell, J., Mason, T., Barham, R., (2014). Noise assessment for the proposed Rhiannon Wind Farm – Subacoustech;

Nedwell, J., Mason, T., Barham, R., (2014a). Horns Rev 3 Offshore Wind Farm ORBICOM-Subacoustech;

Nedwell, J.R., Parvin, S.J., Edwards, B., Workman, R., Brooker, A.G. & Kynoch, J.E., (2007). Measurements and interpretation of underwater noise during construction and operation of offshore wind farms in UK waters. COWRIES- Subacoustech. NOISE 03-2003. 80pp;

Nehls, G., Betke, K., Eckelmann, S., & Ros, M. (2007). Assessment and costs of potential engineering solutions for the mitigation of the impacts of underwater noise arising from the construction of offshore windfarms. Newbury: COWRIE Ltd;

NOAA National Oceanic and Atmospheric Administration, 2013. Draft Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammals-Acoustic Threshold Levels for Onset of Permanent and Temporary Threshold Shifts;

NOAA, National Ocean and Atmospheric Administration, 2012. Mapping Cetaceans and Sound: Modern Tools for Ocean Management. Final Symposium Report of a Technical Workshop held May 23-24 in Washington, D.C.;

Normandeau Associates, Inc. 2012. Effects of Noise on Fish, Fisheries, and Invertebrates in the U.S. Atlantic and Arctic from Energy Industry Sound-Generating Activities. A Workshop Report for the U.S. Dept. of the Interior, Bureau of Ocean Energy Management. Contract # M11PC00031;

Norro, A. et al. (2012). Differentiating between underwater construction noise of monopile and jacket foundation wind turbines: A case study from the Belgian part of the North Sea, in: Degraer, S. et al. (Ed.) (2012). Offshore wind farms in the Belgian part of the North Sea: Heading for an understanding of environmental impacts. pp. 145-155;

NORSOK Standard Z-013, Risk and Emergency Preparedness Analysis, Rev.1, online at www.standard.no

North Sea Foundation (2012). Sound Solutions - Construction of offshore wind farms without underwater noise. North Sea Foundation , BH Utrecht Netherlands;

ØDS. (2000). Offshore Wind-Turbine Construction – Offshore Pile-Driving Underwater and Above-water Noise Measurements and Analysis, Odegaard & Danneskiold-Samsoe A/S, Copenhagen.

OSPAR (2008). Guidance on Environmental Considerations for Offshore Wind Farm Development;

OSPAR (2009). Overview of the impacts of anthropogenic underwater sound in the marine environment. OSPAR;

OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic. 2014. Draft Inventory of noise mitigation measures for pile driving. Meeting of the Intersessional Correspondence Group on noise (ICG Noise), Gothenburg (Sweden): 29-30 January 2014. ICG Noise 14/6/2-E;

OSPAR, 2008. Guidance on Environmental Considerations for Offshore Wind Farm Development - Reference number: 2008-3.

Ott J.A. (1992) The Adriatic benthos: problems and perspectives. In: Colombo G., Ferrari I., Ceccherelli V.U., Rossi R. (eds) "Marine eutrophication and population dynamics. Proceedings of the 25th European Marine Biology Symposium, Ferrara, Italy, 10-15 September 1990", International Symposium Series, Olsen & Olsen, 394 pp.

PAP/RAC (2007a) National Report on Current Policy, Procedures, Legal Basis and Practice of Marine Spatial Planning in Emilia-Romagna Region, Italy. UNEP, Mediterranean Action Plan. Priority Actions Programme Regional Activity Centre (PAP/RAC), RAC Reports (PAP)

PAP/RAC (2007b) National Report on Current Policy, Procedures, Legal Basis and Practice of Marine Spatial Planning in Split. UNEP, Mediterranean Action Plan. Priority Actions Programme Regional Activity Centre (PAP/RAC), RAC Reports (PAP)

PAP/RAC (2008a) National Report on Current Policy, Procedures, Legal Basis and Practice of Marine Spatial Planning in Koper. UNEP, Mediterranean Action Plan. Priority Actions Programme Regional Activity Centre (PAP/RAC), RAC Reports (PAP)

PAP/RAC (2008b) State of the Art of Coastal and Maritime Planning in the Adriatic Region – Synthesis Report. UNEP, Mediterranean Action Plan. Priority Actions Programme Regional Activity Centre (PAP/RAC), RAC Reports (PAP)

Parvin S J, Nedwell J R and Harland E (2007). Lethal and physical injury of marine mammals, and requirements for Passive Acoustic Monitoring. Subacoustech Re-port 565R0212, report prepared for the UK Government Department for Business, Enterprise and Regulatory Reform;

Pérès J.M., Picard J. (1964). Nouveau manuel de bionomie benthique de la Mer Méditerranée. Rec. Trav. St. Mar. Endoume, 31, 47 pp.

Petochi T., Gazzea N., Di Marco P., Latini M., Barchiesi F., Conte A., Barile N.B., Caruso G., Zaccone R., Cavallo R.A., Croci L., Mancini L., Marino G. (2013) Il monitoraggio della qualità microbiologica delle aree di produzione dei molluschi bivalvi nell'ambito della Direttiva sulla Strategia Marina. Poster presentato al II° Convegno Nazionale della Società Italiana di Ricerca Applicata alla Molluschicoltura (SIRAM) "Trasparenza tra produttori autorità di controllo e consumatori", 29 novembre 2013, Cesenatico (FC).

Piccinetti C., Vrgoč N., Marčeta B., Manfredi C. (2012) La situazione delle risorse ittiche nel Mare Adriatico. Acta Adriatica, Monograph Series 5, Split, 220 pp.

Piccinetti, C., N. Vrgoč, Marčeta B. and C. Manfredi, (2012). Recent state of demersal resources in the Adriatic Sea. Acta Adriatica Monograph Series no. 5. Intitute of oceanography and fisheries, Split, Croatia, 220 pp.

Piccinetti, C., N. Vrgoč, Marčeta B. and C. Manfredi, (2012). Recent state of demersal resources in the Adriatic Sea. Acta Adriatica Monograph Series no. 5. Intitute of oceanography and fisheries, Split, Croatia, 220 pp.

Policy Research Corporation (2011). The potential of Maritime Spatial Planning in the Mediterranean Sea. Case study report: The Adriatic Sea. European Commission, Directorate-General for Maritime Affairs and Fisheries, 2011, 59 pp.

Popov, V. V, Supin, A. Y., Wang, D., Wang, K., Dong, L., and Wang, S. (2011). "Noise-induced temporary threshold shift and recovery in Yangtze finless porpoises Neophocaena phocaenoides asiaeorientalis," J Acoust Soc Am 130, 574–84;

Popper, A.N., Fay, R.R., Platt, C. and Sand, O. (2003). Sound Detection Mechanisms and Capabilities of Teleost Fishes. In: Collin, S.P. and Marshall, N.J. (eds.). Sensory Processing in Aquatic Environments. Springer Verlag, New York, 3-38;

Prins, T., Twisk, F., Van den Heuvel-Greve, M., Troost, T., & Van Beek, J. (2008). Development of a framework for Appropriate Assessment of Dutch offshire wind farms. Deltares;

Prioli G. (2001) Censimento nazionale sulla molluschicoltura del Consorzio UNIMAR. Osservatorio Tecnico-Biologico UNIMAR, 98 pp.

Relini G., Ardizzone G., Giaccone G. (2004) Descrizione delle biocenosi marine costiere. In: Blasi C., D'Antoni S., Dupré E., La Posta A. (eds), Atti del Convegno "La conoscenza botanica e zoologica in Italia: dagli inventari al monitoraggio". Min. Ambiente - Ist. Naz. Fauna Selvatica, Quad. Cons. Natura: 111-118.

Reports Pollution Brindisi (2006-2014): 1) http://www.asi.br.it/ws/consorzio/area-industriale-di-brindisi/; 2) http://www.eea.europa.eu/pressroom/newsreleases/industrial-air-pollution-cost-europe; 3) http://www.ecoblog.it/post/13885/eea-la-hit-delle-191-industrie-che-inquinano-di-piu-laria-in-europa; 4) ARPA report Apulia (2010 up to date) 3.3. Siti contaminati 12pp. www.arpa.puglia.it

Ricci Lucchi F. (1992) I ritmi del mare. Sedimenti e dinamica delle acque. NIS, Roma, 251 pp.

Richardson, W.J., Malme, C.I., Green, C.R.jr. and D.H. Thomson (1995). Marine Mammals and Noise. Academic Press, San Diego, CA ;

Romanelli M., Cordisco C.A., Giovanardi O. (2009) The long-term decline of the Chamelea gallina L. (Bivalvia: Veneridae) clam fishery in the Adriatic Sea: is a synthesis possible?ACTA ADRIATICA, 50 (2): 171 - 205.

Russo, T., Parisi, A., Cataudella, S. in press. Spatial indicators of fishing pressure: preliminary analyses and possible developments. Ecological indicators.

Russo, T., Parisi, A., Cataudella, S. in press. Spatial indicators of fishing pressure: preliminary analyses and possible developments. Ecological indicators.

Russo, T., Parisi, A., Cataudella, S., 2011a. New insights in interpolating fishing tracks from VMS data for different métiers. Fish. Res. 108, 184–194.

Russo, T., Parisi, A., Cataudella, S., 2011a. New insights in interpolating fishing tracks from VMS data for different métiers. Fish. Res. 108, 184–194.

Russo, T., Parisi, A., Prorgi M, Boccoli F., Cignini I., Tordoni M., Cataudella, S., 2011b. When behaviour reveals activity: Assigning fishing effort to métiers based on VMS data using artificial neural networks. Fisheries Research 111, 53– 64.

Russo, T., Parisi, A., Prorgi M, Boccoli F., Cignini I., Tordoni M., Cataudella, S., 2011b. When behaviour reveals activity: Assigning fishing effort to métiers based on VMS data using artificial neural networks. Fisheries Research 111, 53– 64.

Sand, O. (1984). Lateral line system. In Bolis, L. Keynes, R. and Maddress, S. (eds.), Comparative physiology of sensory systems. Cambridge University Press, Cambridge;

Schlundt, C.E.,Finneran, J.J.,Carder, D.A.,Ridgway, S.H.(2000). ”Temporary shift in masked hearing thresholds of bottlenose dolphins, Tursiops truncatus, and white whales, Delphinapterus leucas, after exposure to intense tones”, J Acoust Soc Am 107(6), 3496-3508;

Southall B L, Bowles A E, Ellison W T, Finneran J J, Gentry L, Greene C R (Jr), Kastak D, Ketten DR, Miller J H, Nachtigall P E, Richardson W J, Thomas J A and Tyack P L. (2007). Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. Aquatic Mammals, Vol. 33, No. 4;

Spina F. & Volponi S., 2008 - Atlante della Migrazione degli Uccelli in Italia. 1. Non-Passeriformi. Ministero dell’Ambiente e della Tutela del Territorio e del Mare, Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA). Tipografia SCR-Roma. 632 pp.

Spina F. & Volponi S., 2008 - Atlante della Migrazione degli Uccelli in Italia. 2. Passeriformi. Ministero dell’Ambiente e della Tutela del Territorio e del Mare, Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA). Tipografia SCR-Roma. 34 pp.

Steller D.L., Hernández-Ayón J.M., Riosmena-Rodríguez R. (2007) Effect of temperature on photosynthesis, growth and calcification rates of the free-living coralline alga Lithophyllum margaritae. Cienc. Mar., 33: 441–456.

Tagliapietra D., Bianchi F., Franceschini G., Ponti M. (2008). Caratteristiche dell’Adriatico Settentrionale. In: Ponti M., Mescalchin P. (eds) “Meraviglie sommerse delle “Tegnùe”. Guida alla scoperta degli organismi marini”. Associazione “Tegnùe di Chioggia”-onlus, Editrice “La Mandragora”, Imola (BO), 424 pp.

Tasker, M.L, M. Amundin, M. Andre, A. Hawkins, W. Lang, T. Merck, A. Scholik-Schlomer, J. Teilmann, F. Thomsen, S. Werner & M. Zakharia. (2010) Marine Strategy Framework Directive. Task Group 11. Report Underwater noise and other forms of energy;

Teilmann J, Tougaard J and Carstensen J. (2006a). Summary on harbour porpoise monitoring 1999- 2006 around Nysted and Horns Rev offshore wind farms. Report to Energi E2 A/S and Vattenfall A/S. Danish Ministry of the Environment;

Telespazio (1992) Progetto coste. Progetto pilota di telerilevamento delle coste italiane. Ministero dell'Ambiente, Roma.

The Crown Estate, 2010. A Guide to an Offshore Wind Farm. Online at www.thecrownestate.co.uk

Thiele, R. (2002). Propagation loss values for the North Sea. Handout Fachgespräch: Offshore-Windmillssound emissions and marine mammals. FTZ-Büsum, 15.01.2002;

Thomsen, F., Lüdemann, K., Kafemann, R. & Piper, W. (2006). Effects of offshore wind farm noise on marine mammals and fish. London, U.K.;

Tomadin L. (1979). Clay mineralogy of recent sediments around the Po river delta. Giornale di Geologia, XLIII (1): 249-275.

Tougaard, J. (2013). Test af LF sonar. Notat fra DCE - Nationalt Center for Miljø og Energi;

Tougaard, J., Carstensen, J., Henriksen, O.D., Teilmann, J. & Hansen, R.J. (2004). Harbour Porpoises on Horns Reef – Effects of the Horns Reef Wind Farm. Annual Status Report 2003. Roskilde, Department of Arctic Environment DDH-Consulting;

Tougaard, J., Carstensen, J., Teilmann, J. and Bech, N.I., Skov, H. and Henriksen, O.D. (2005). Effects of the Nysted Offshore wind farm on harbour porpoises. Technical Report to Energie E2 A/S. NERI, Roskilde;

Tougaard, J., Ebbesen, I., Tougaard, S., Jensen, T. & Teilmann, J. (2003). Satellite tracking of harbour seals on Horns Reef. Use of the Horns Reef wind farm area and the North Sea. Technical report to Techwise A/S, Biological Papers from the Fisheries and Maritime Museum, Esbjerg. No. 3. Roskilde;

Tougaard, J., Madsen, P. T. & Wahlberg, M. (2008). Underwater noise from construction and operation of offshore wind farms. Bioacoustics 17;

Trincardi F., Correggiari A., Roveri M. (1994) Late Quaternary transgressive erosion and deposition in a modern epicontinental shelf: the Adriatic semienclosed basin. Geo-Marine Letters 14: 41-51.

U.O.L.G.M.B. (Unità Operativa Laboratorio Geologia Marina CNR Bologna) (1980). Ricerche oceanografiche sulla piattaforma continentale Adriatica tra Ancona e la Laguna di Venezia. Lab. Geol. Mar. CNR, Pubblicazioni, 9: 1171-1186.

UK Department of Transport and Industry, 2005. Guidance on the Assessment of the Impact of Offshore Wind Farms: Methodology for Assessing the Marine Navigational Safety Risks of Offshore Wind Farms. Online at www.webarchive.nationalarchives.gov.uk

UK's Marine Guidance Note MGN 371 (M+F), Offshore Renewable Energy Installations (OREIs) - Guidance on UK Navigational Practice, Safety and Emergency Response Issues", Maritime and Coastal Agency (MCA). Online at www.gov.uk

UMWELTBUNDESAMT (2011): Empfehlung von Lärmschutzwerten bei der Errichtung von Offshore Windenergieanlagen (OWEA). Umweltbundesamt Dessau, Germany;

Urick, R. J. (1983) Principles of Underwater Sound, Peninsula Publishing, New York;

Vatova, A. (1949) La fauna bentonica dell'Alto e Medio Adriatico. Nuova Thalassia 1 (3): 1-110.

Veggiani A., De Francesco A. (1972) I terreni superficiali del fondo del Mare Adriatico al largo della costa romagnola. Bull. mens. Camera Comm. ind. artif. agric. 9-10-11, Forlì, 58 pp.

Veneto Agricoltura (2014) Final report for WP5. 172 pp in three reports.

Vidas D. (2008). The UN Convention on the Law of the Sea, the European Union and the Rule of Law: what is going on in the Adriatic? Fridtjof Nansen Institute, 2008, 75 pp.

Wagner, S., Bareib, R. and Guidati, G., Wind Turbine Noise, Springer, Berlin, 1996;

Wahlberg, M. and Westerberg, H. (2005). Hearing in fish and their reactions to sound from offshore wind farms. Mar. Ecol. Prog. Ser. 288, 295-309;

Ward, P.D., Harland, E. & Dovey, P., (2006). Measuring ambient noise in relation to offshore wind farm characterisation. QinetiQ 2006;

Wenz, G. M. (1962). Acoustic Ambient Noise in Ocean—Spectra and Sources. Journal of the Acoustical Society of America, 34(12), 1936-1956;

Wp3 Final Report 2012a. Task 3.1. deliverable: Technological State of the Art. 275pp.

Wp3 Final Report 2012b. Task 3.2, 3.3, 3.4. Deliverable: Regulatory, environmental and Energy Policies State of the Art. 16 pp.

Wp4 Final Report (in progress) Numerical and experimental evaluation of wind energy resources in the Adriatic basin