Environmental aspects in establishing Wind Energy networks in off-shore conditions - A multi-functional approach

Some INS and OUTS on off-shore wind farms!

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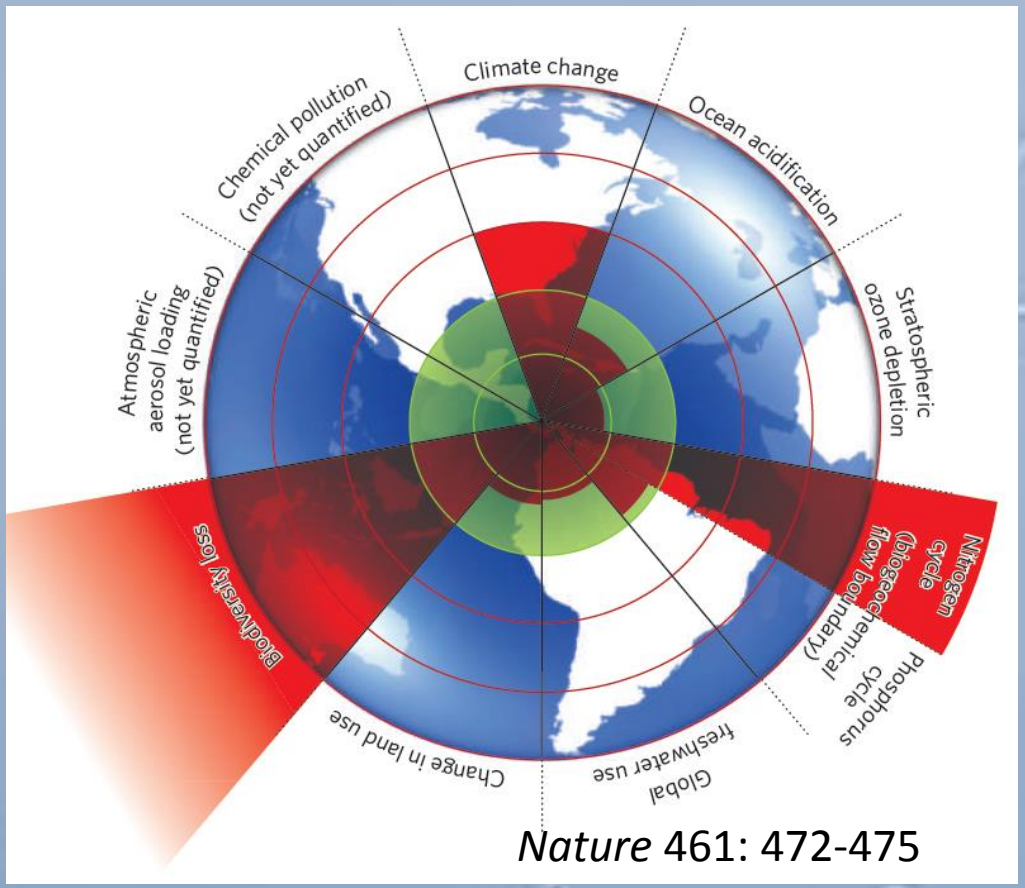
green energy in Adriatic sea
POWERED

A safe operating space for humanity

Identifying and quantifying planetary boundaries that must not be transgressed could help prevent human activities from causing unacceptable environmental change, argue Johan Rockström and colleagues.



Nature 461: 472-475

PLANETARY BOUNDARIES

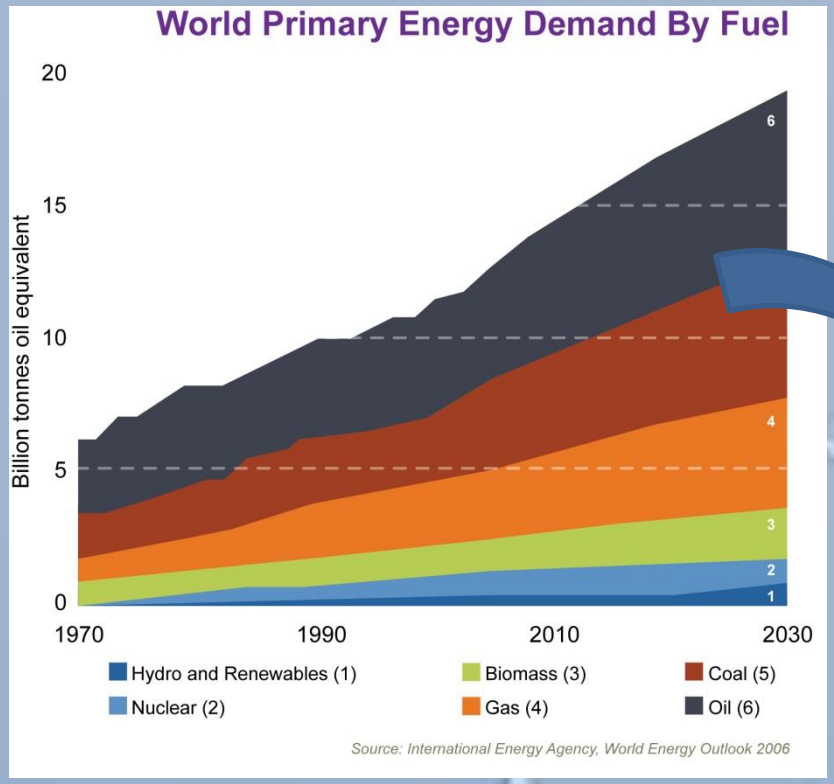
Earth-system process	Parameters	Proposed boundary	Current status	Pre-industrial value
Climate change	(i) Atmospheric carbon dioxide concentration (parts per million by volume)	350	387	280
	(ii) Change in radiative forcing (watts per metre squared)	1	1.5	0
Rate of biodiversity loss	Extinction rate (number of species per million species per year)	10	>100	0.1–1
Nitrogen cycle (part of a boundary with the phosphorus cycle)	Amount of N_2 removed from the atmosphere for human use (millions of tonnes per year)	35	121	0
Phosphorus cycle (part of a boundary with the nitrogen cycle)	Quantity of P flowing into the oceans (millions of tonnes per year)	11	8.5–9.5	~1
Stratospheric ozone depletion	Concentration of ozone (Dobson unit)	276	283	290
Ocean acidification	Global mean saturation state of aragonite in surface sea water	2.75	2.90	3.44
Global freshwater use	Consumption of freshwater by humans (km^3 per year)	4,000	2,600	415
Change in land use	Percentage of global land cover converted to cropland	15	11.7	Low
Atmospheric aerosol loading	Overall particulate concentration in the atmosphere, on a regional basis		To be determined	
Chemical pollution	For example, amount emitted to, or concentration of persistent organic pollutants, plastics, endocrine disrupters, heavy metals and nuclear waste in, the global environment, or the effects on ecosystem and functioning of Earth system thereof		To be determined	

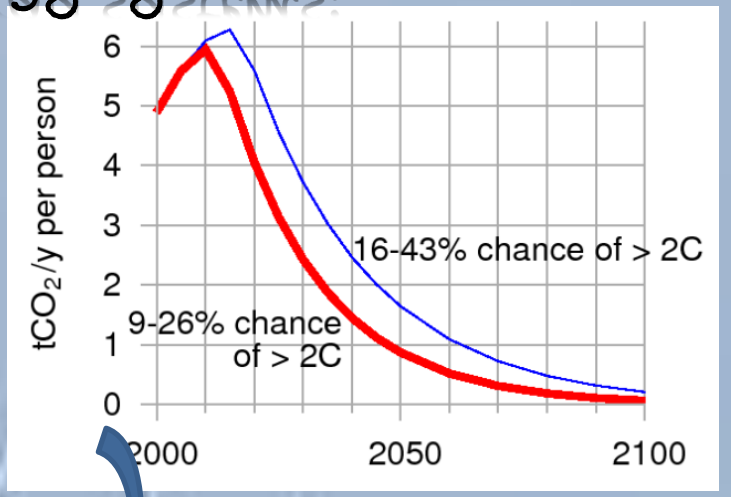
9 processi planetari per mantenere la soglia di sostenibilità:

Per 3 di questi siamo oltre la soglia: CO_2, biodiversità e ciclo dell'azoto

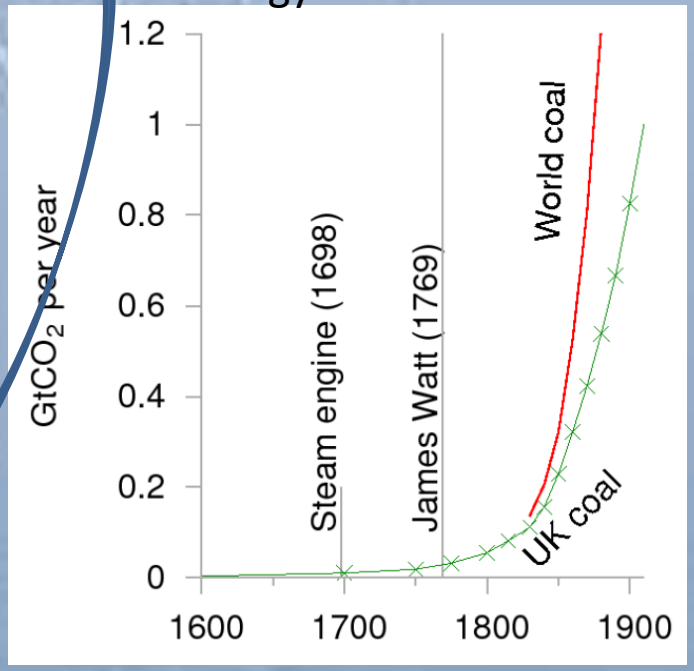
2 di questi 3 hanno rilevanza per la compatibilità ambientale dell'eolico offshore

The reason of renewable energy systems:





Energyforum.com

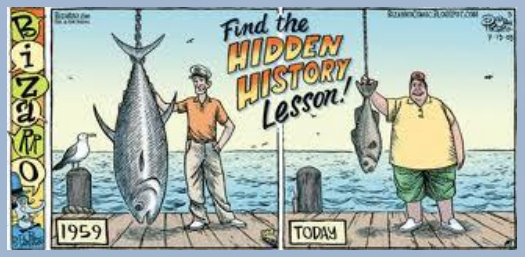


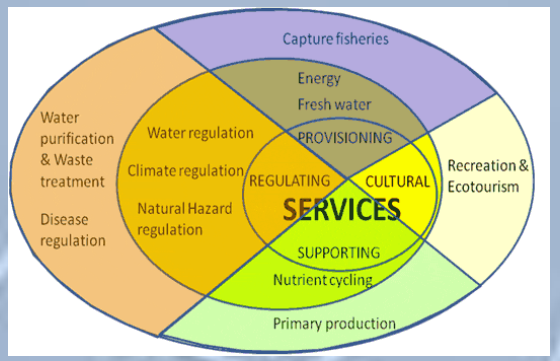
Something doesn't work properly:

- oil and coal are the main sources of energy, and there is a
- worldwide target to reduce CO_2 emissions by 2020

how can we aim for reduction if the main sources (oil and coal) are the most CO_2 consuming?

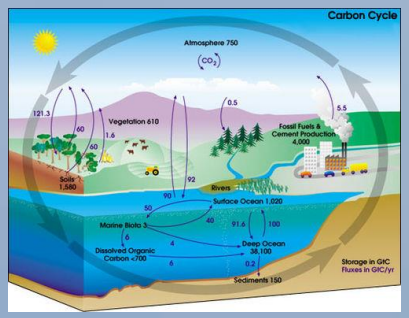
The reason of conservation (especially marine):





Ecosystem services

Fish and food stock



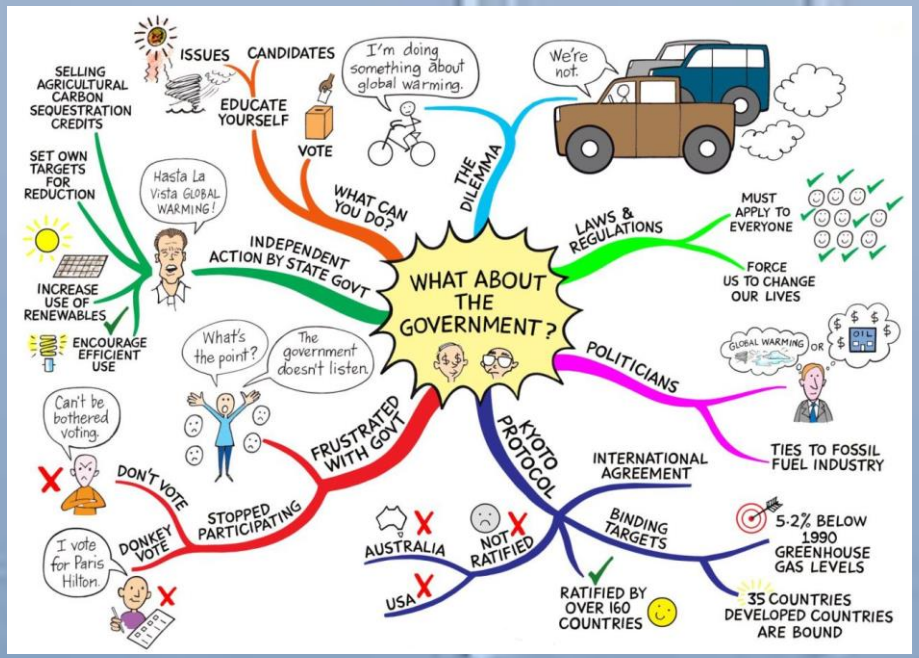
Main CO_2 sink (and others) and basic part of carbon cycle

Compensatory programs and programs

Eco-Tourism

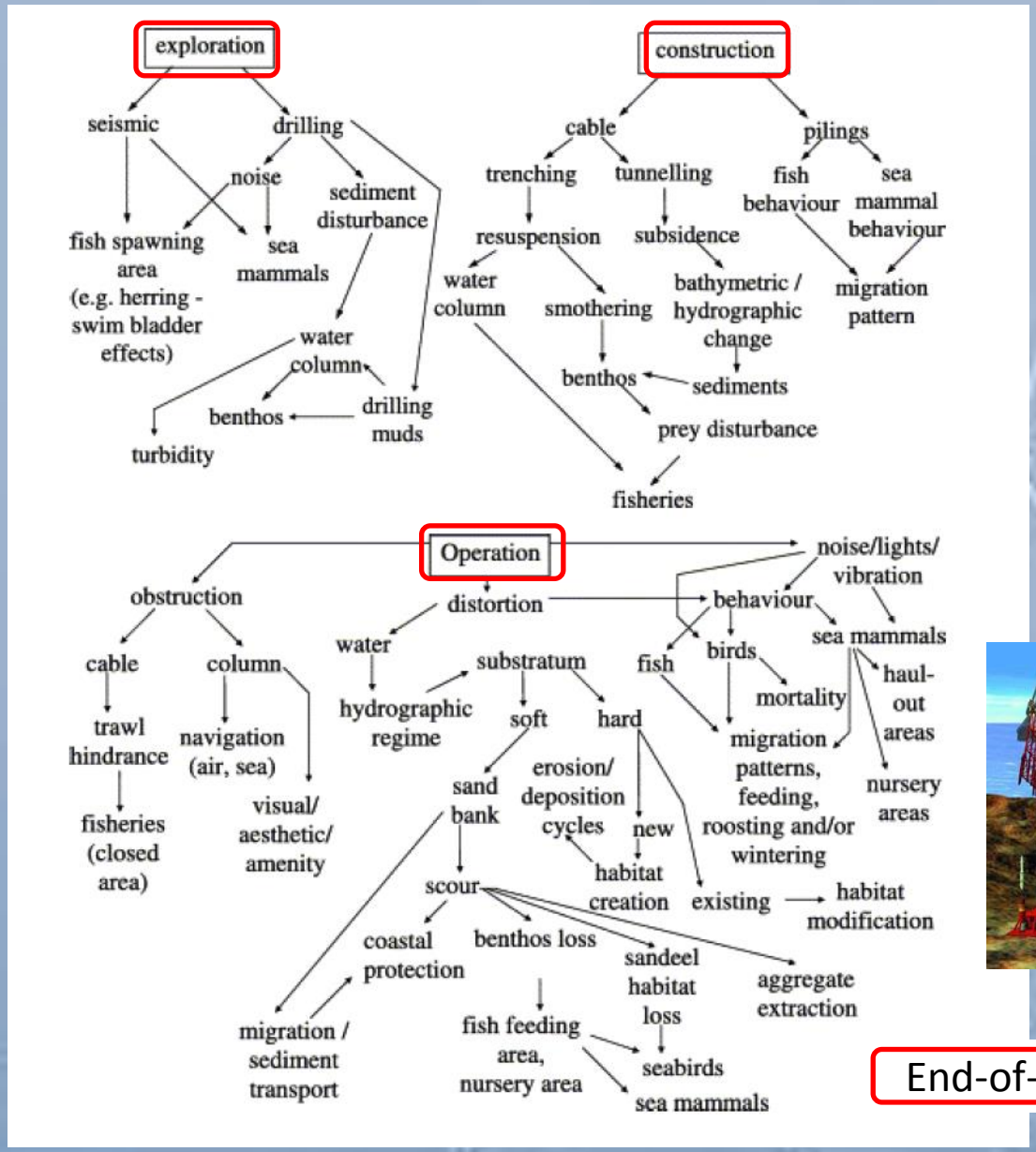
Ecosystem restoration

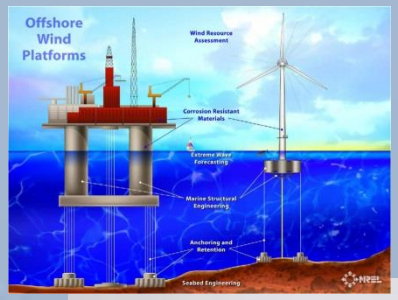
Renewal energy development + conservation?



Off-shore wind farms have a huge potential in coping renewal energy systems with conservation approaches (*de facto* MPAs), reducing the general negative view of the involved/local communities

Attention! Off-shore wind farms are not free of environmental impacts





End-of-life impact→ with/without removal

Wilson (2011) InTech, ISBN: 978-953-307-237-1

Exploration and Pre-installation phase:

- **Increased boat and vessel traffic→** increased local emissions, effect on the pelagic community (from fish to cetaceans), possible oil spills, increased collision probabilities, local increased electromagnetic waves…

- **Installation of variety of instruments for wind and current measurements→** fix or mobile, drilling and dredging, electromagnetic effects of sensors, noise (disturbing or lethal)…

- **Terrain sampling→** dredging (physical bottom destruction), increased water turbidity…

- **Increased economic entries in the designated area**

Evaluation of multiplier environmental impacts/benefits has to further consider:

- Type of turbine (piles, tripodes, floating, other)
- Size, number and height of turbines
- Siting (pristine or devastated area)
- Surface of wind farm
- Distance to power converter and/or to shore
- The instruments used during and post construction

Ideally this phase would have a biocenosis/water quality/benthic monitoring phase T_0

Construction and Installation phase:

Construction phase:

- Inland construction→ material obtaining (mining, extracting), effects on inland ecosystems, elevated CO_2 emissions during construction of turbine pieces
- Off-shore mounting→ siting, transportation (land-port-off-shore assemblage (all based on high Carbon energy sources), noise

Installation phase:

- Increased boat traffic and big vessel (heavy transport, collisions)
- Dredging, trawling, drilling, pile-driving
- Sediment movement (up-welling and anoxic sediments surface)
- Increased turbidity
- Direct habitat destruction or fragmentation
- Depletion of scour protection (habitat change)
- Noise (vessels, drilling)
- Visual impact
- Increased possibility of accidental oil spills
- Commercial and recreational activities decrease

Ideally this phase would have, besides the ordinary monitoring, a biocenosis/water quality/benthic monitoring phase T_{1-2}

Operational phase:

- Noise→ decreased after construction to about 1kHz; depends on number of turbines and decreases with distance

- Electromagnetic waves→ effect on migrating and pelagic animals, nursing effect on fish, communication disturbance amongst animals by disturbing frequencies

- Scour protection→ artificial reef effects (www.towers of life.com, http://www.renewableenergymagazine.com/article/dong-energy-to-build-artificial-reefs-at), cost-effective *de facto* Marine Protected Areas, stepping-stones in colonization (native and non-native species)

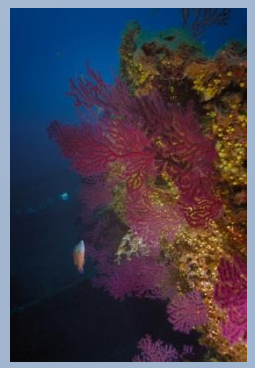
- Turbine presence→ bird mortality?, migration disruption/attraction (reptiles, fish, mammals and birds), light disturbances, coastal settlement/protection, temperaure increase?

- Farms presence as a network→ *de facto* Marine Protected Areas, no-fishing zones, ecotourism zones, environment recovery or creation

- Renewable energy functioning for up to 50 years

Ideally this phase would have, besides ordinary monitorings a biocenosis/water quality/benthic monitoring phase T_3 (yearly or biannual)

End-of-life and decommissioning phase:



With removal:

- New created/recovered habitat destruction
- Construction phase impacts→ instead of construction of turbines, dismantling has to be considered
- Return to original conditions→ back to fishing (trawling, dredging, nets)

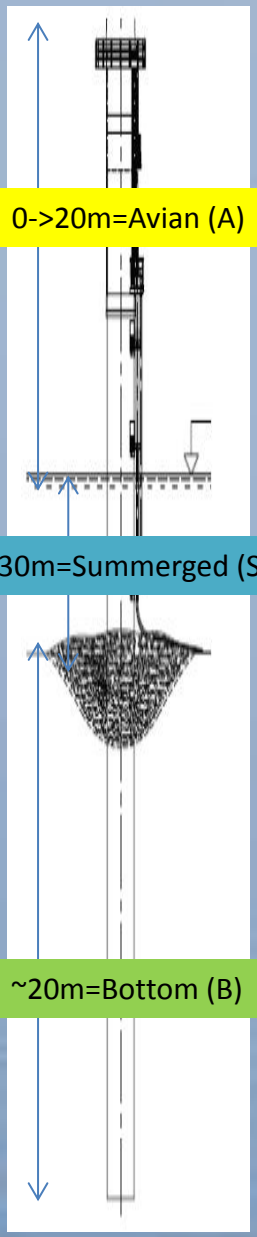
Without removal (after tempering):

- New niche creation after disturbance effects (construction, electromagnetic waves, corrosion)
- Maintenance of recovered or created ecosystem
- Maintenance of a de facto MPA→ no-fishing, eco-recreational activities, nursery with spill-out of recruits

Anholt wind farm, Denmark

Ideally this phase would have a biocenosis/water quality/benthic monitoring phase T_4 (yearly or biannual)

General environmental impacts and benefits of an off-shore wind farm:



NOTE: for most of the considered aspects, there is a great lack of knowledge/evidence to assume if a certain event is a benefit or an impact!

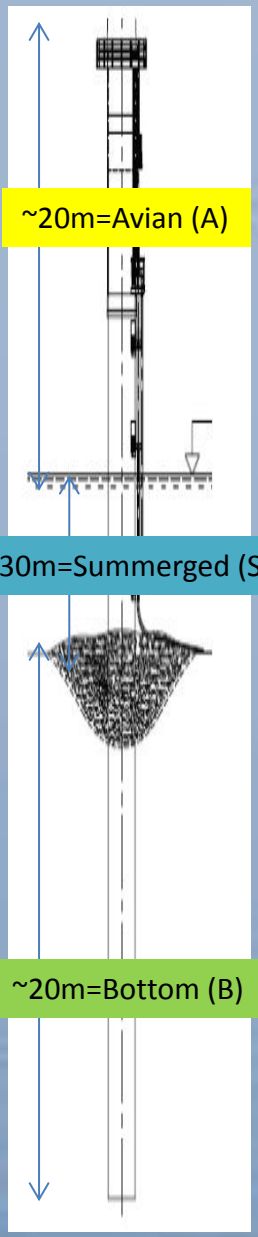
Exploration

- Most of disturbance is local and spontaneous vessel traffic), eventual introduction of instruments-see construction-; effect depends highly on underlying benthic/pelagic community (Affects A and S)

Installation

- Noise and drilling/dredging will probably be avoided by most animals (even up to 100km far)(Affects A, S and B)
- Upwelling and output of sediment/OM can be attractive as food source but also can become lethal for benthic communities (Affects S and B) because of noxious buried substances (including pollutants)
- Scour protection may utterly introduce a new habitat, a new disturb (Affects S and B)
- Vessel traffic increases the probabilities of collision, disorientation in migration, oil spills (Affects A and S)

General environmental impacts and benefits of an off-shore wind farm:



Operation

- Constant boat traffic for monitoring, less than during installation (Affects A)
- Electromagnetic waves can affect fish nurseries, mammal communication, migrators orientation (Affects A and B)
- Bird mortality by collision, but some have been seen nesting? (Affects A)
- Scour protection (affects A, S and B) can:
  - become an ideal artificial reef and promising (cost-effective) *de facto* MPA (reduced fishing, controlled recreational activities, aquaculture possibilities
  - act as stepping stones allowing colonization, including alien/non-native species
  - unite the fragmented habitats if predisposed as a network
- Floating turbines can become ideal FADs (Fish Aggregating Devices)
- Increased fish abundance/over-spill (Affects A, S and B)

Decommissioning (affects A, S and B)

- Idem construction and installation when removed
- Recovered or created ecosystem maintained and will remain as a de facto MPAs, even if not surveyed (no one want to lose their gear!!!)

	Impact/monitoring objective	Indicator
Benthic habitat and resources	Changes to seafloor morphology and structure (compared to preconstruction)	Increase or decrease in seabed volume
	Changes in median grain size, or organic content	(i) Deposition: decrease in median grain size, increase in organic content, increase in seabed volume (ii) Scour: increase in median grain size, decrease in organic content, decrease in seabed volume
	Turbidity during construction/decommissioning	Change in water column turbidity
	Change in target species abundance and distribution (e.g., species of importance)	Change in abundance, diversity, % cover, multivariate community composition
	Current speed/direction inside and outside farm	Change in residual flow rates
	Reef effects, colonization on foundations	Increase in % cover, biomass of epifaunal organisms; increase in presence of nonnative species
	Change in density, diversity, dominance structure of infauna	Change in abundance, diversity, % cover, multivariate community composition
Fish	Reef or aggregation effects	Increase in fish abundance around devices, shift in species composition, increase in presence of nonnative species
	Changes to abundance/distribution caused by disturbance or habitat alteration	Increase or decrease in fish abundance; increase or decrease in target species; shift in species composition; change in density, diversity, and dominance structure of fish species; increase in presence of nonnative species
	Blade strikes/pressure gradients (tidal power)	Observation of blade strike incidents
	EMF effects	Not feasible to monitor directly—changes in fish abundance, behavior, or species composition are indicators
	Installation or operational noise effects	Not feasible to monitor directly—changes in fish abundance, behavior, or species composition are indicators
Fisheries	Catchability (catch per unit effort) during construction	Catch per unit effort increases or decreases for target species
	Catchability (catch per unit effort) during operation	Catch per unit effort increases or decreases for target species
	Loss of access to grounds	Changes in numbers of vessels fishing near or inside of the renewable energy area, change in the presence of fixed fishing gear inside of or around a renewable energy installation
	Changes in species distribution	Shift in species composition, increase in presence of nonnative species
	Reef effects (aggregation)	Increase in fish abundance around devices; shift in species composition; increase in presence of nonnative species
Avian	Displacement/attraction	Increase or decrease in avian species-specific densities postconstruction in development area
	Barrier effects—effects on foraging, roosting, migratory movements	Migrating or commuting birds avoiding developed areas
	Collision mortality	Birds found dead or injured due to direct collision with infrastructure above the water
Marine mammals and sea turtles	Vessel strikes	Detection of dead or injured animals
	Noise generated during construction	Detection of dead or injured animals; changes in distribution, abundance, or behavior of populations
	Disturbance or injury during all stages of development, including from vessels	Detection of dead or injured animals; changes in distribution, abundance, or behavior of populations
	Noise generated during operation	Changes in distribution, abundance, or behavior of populations

Table summary of **monitoring standards and indicators** for all renewable off-shore energies; from Shumchenia *et al.* (2012) *The Scientific World Journal* doi:10.1100/2012/450685

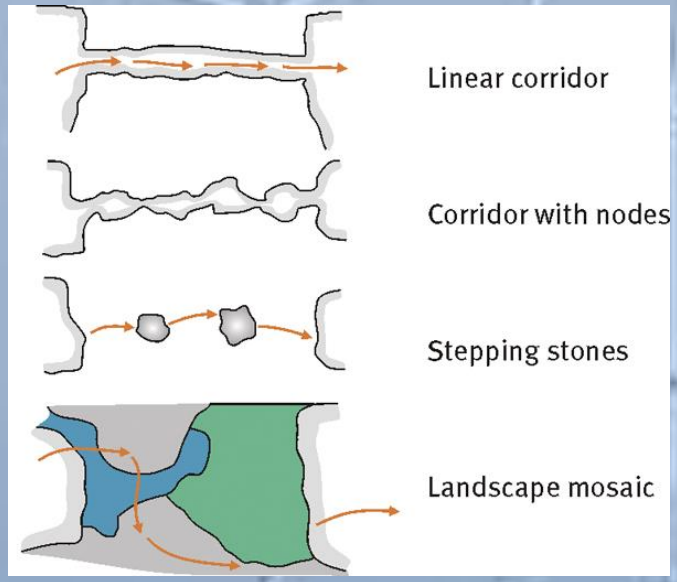
Scientific & Societal Opportunies from WIND farms

COCONET

Towards COast to COast NETworks
of Marine Protected Areas
Coupled With Sea-based Wind Energy Potential

SEVENTH FRAMEWORK PROGRAMME

The project is producing the guidelines to design, manage and monitor network of MPAs, and an enriched wind atlas for both the Mediterranean and the Black Seas



Socioeconomic studies are integrating to knowledge-based environmental management aiming at both environmental protection(MPAs) and clean energy production (Offshore Winffarms).

OFFSHORE WINDFARMS ARE NEW HOPES FOR ENVIRONMENTALLY FRIENDLY ENERGY CONSUMPTION IN EUROPE. Additional studies are needed for the offshore projects in order to achieve more knowledge regarding the environmental impacts, the effects on radars and the collision risks. An early and active involvement of the public could also help to increase the social acceptance of the projects.

Scientific & Societal Opportunies from WIND farms

The aim of the European Union's ambitious Marine Strategy Framework Directive (adopted in June 2008) is to protect more effectively the marine environment across Europe. It aims to achieve good environmental status of the EU's marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend.

DEVOTES

DEVelopment Of innovative Tools for understanding marine biodiversity and assessing good Environmental Status.

A major aim of DEVOTES is to **test the indicators proposed by the EC**, and develop new ones for assessment at species, habitats and ecosystems level, for the status classification of marine waters, **integrating the indicators** into a unified assessment of the biodiversity and the cost-effective implementation of the indicators (i.e. by defining monitoring and assessment strategies).