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Case Study 1 – Annex

Trade-offs in ecosystem-based fisheries management in the North Sea aimed at achieving Biodiversity Strategy targets[1]

[1] *See full case study report for author and project information. Further information at https://aquacross.eu/content/case-study-1-trade-offs-ecosystem-based-fisheries-management-north-sea-aimed-achieving*

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Annex 1

Knowledge base applied to determine for each societal goal the extent to which the management measures implemented to achieve that goal are expected to reduce impact risk for the impact chains (human activity–pressure–ecosystem component) involved. The management measures to achieve the sustainable food supply all target the fishing sector as the main human activity, those aimed to achieve the clean energy goal target OWFs. The pressure " Physical disturbance" represents three pressures as they occur in the focal SES (table 1), i.e. Abrasion/Damage, Smothering and Changes in Siltation.

Goal	MM#	Pressure(s)	Ecosystem component(s)	Estimated degree to which specific impact chains are reduced in terms of impact risk
Sustainable food supply	1.1	Physical disturbance Changes in input of organic matter Death or Injury by Collision Litter	Mammals Birds Coastal (A1, A5) Shelf (A4, A5)	Several of the main commercial fish stocks are still overexploited suggesting that a (further) reduction in effort (or capacity) of the fishing fleet, and hence all its main pressures, could contribute to the long-term goal of a sustainable food supply. Based on (ICES, 2017b) we found that several stocks, i.e. cod, haddock, whiting and megrim, caught using otter trawl and seine fisheries are still exploited above MSY levels. For these we assumed a 10% reduction in effort or capacity is possible. Also several sole stocks caught using beam trawl were exploited only just above MSY levels. For this type of fishery we therefore assumed a 5% reduction was feasible. Based on (ICES, 2017b) showing beam trawls make up approximately half of the nominal effort deploying benthic trawls we assume an average reduction of 7.5% for all fishing-induced pressures other than catch.
		Extraction of flora and/or fauna	Fish & Cephalopods Coastal (A5) Shelf (A5)	We assume the impact risk caused by the extraction of fish and benthic invertebrates is reduced by 40% as this management measure should achieve the societal goal of a sustainable food supply (i.e. a "good" status of the commercial fish species) but not for a healthy marine ecosystem as several of the sensitive non-target species will not achieve a "good" status.
	1.2	Extraction of flora and/or fauna	Fish & Cephalopods Coastal (A5) Shelf (A5)	This alternative represents more precautionary fisheries management which sacrifices the achievement of a sustainable maximum food supply in order to achieve more of a healthy ecosystem. In addition to the conventional single species advice (ICES, 2018a) provides a more precautionary management mixed fisheries advice where fishing stops if the most limiting of the stock shares of a fleet has been caught up (i.e. the "Minimum" scenario determined by choke species). This causes underutilization of the single-stock advice possibilities of all other stocks. This scenario shows a reduction in total fish catch of 50% while benthic invertebrate catch (i.e. Norway lobster) was reduced by 73%. As fishing grounds of Norway lobster only make up a relatively small part of the habitat we assume for all these ecosystem components a reduction in impact risk of 50%
		Physical disturbance	Mammals Birds Coastal (A1, A5) Shelf (A4, A5)	For all other fishing-induced pressures we assume a reduction in impact risk equal to that of the fish catch, i.e. 50%.

	Changes in input of organic matter Death or Injury by Collision Litter		
1.3	Physical disturbance	Fish & Cephalopods Coastal (A5) Shelf (A5)	Habitat credits provide an incentive to fishermen to avoid sensitive seabed habitats thereby contributing to the conservation of the seabed habitats. A study by (Batsleer et al., 2018) shows a shift from coarse (high credits) to soft (low credits). Assuming the credits are representative of the quality of the habitat and that the total amount of credits does not result in a reduction of effort and catch quota can still be fished, a reduction of 37% in physical damage was achieved.
1.4	Physical disturbance	Coastal (A5) Shelf (A5)	The implementation of the pulse trawls results in a decreased physical disturbance of the sublittoral sediment. (ICES, 2018b) considered several aspects of the trawling impact on the seabed habitats. An average disturbance depth of an experimentally trawled study site was reduced from 4.0 cm with the traditional beam trawl to 1.8 cm in the pulse trawl. Together with a lower trawling footprint the total reduction of the mechanical impact on seafloor and benthos was estimated at 50%.
	Death or Injury by Collision	Mammals	Pulse trawls are deployed at a lower towing speed than traditional beam trawls which should result in a reduced chance of death or injury by collision of marine mammals. (ICES, 2018b) shows that average towing speed is reduced by 22% from 6.3 to 4.9 knots in large vessels and by 15% from 5.4 to 4.6 in small vessels. Death or injury by collision for marine mammals is based on: 1) probability of encounter (Martin, 2015) and 2) probability of lethal injury from a vessel strike (Vanderlaan, 2007). The above reduction of speed will reduce this pressure by an average of 46%
	Changes in input of organic matter	Fish & Cephalopods Coastal (A5) Shelf (A5)	The pulse trawl results in less unwanted bycatch and should thus result in a lower input of organic matter affecting sublittoral sediment, fish and cephalopods. (ICES, 2018b) shows improved species selectivity when deploying a pulse trawl as opposed to the conventional beam trawl. An improved selectivity should result in less discarding and hence a lower input of organic matter. The discards negatively impact on the benthic community and scavenger fish species. A lower catch rate of 16% (small vessels) and 24% (large vessels) discarded fish in the pulse trawl was observed from discard monitoring programme. This was translated to a decrease of 20% of the organic matter input.
2.1	Physical disturbance Disturbance (visual) of species Extraction of flora and/or fauna	Fish & Cephalopods Mammals Birds Coastal (A1, A2, A3, A4, A5) Shelf (A4, A5)	The assumption is that all extractive activities are banned from the MPAs. The reduction in impact risk is assumed equal to the proportion surface area of the North Sea covered by the MPAs. Currently 18% of EU waters area in the North Sea within 200nm is covered by MPAs (https://www.eea.europa.eu/data-and-maps/figures/regional-seas-surrounding-europe-and-2).

Healthy marine ecosystem

		Selective Extraction of non-living resources: substrate e.g. gravel		
Clean energy	3.1	Death or Injury by Collision	Birds	Planning the OWFs in areas selected to minimize bird casualties. Moving from average bird casualties OWF areas to low bird casualties areas achieves a 90% reduction of death or injury by collision for the 5 most sensitive bird species (Leopold, 2014).
		Barrier to species movement Total Habitat Loss	Birds	Planning the OWFs in appropriate areas achieves a 91% reduction of Habitat loss and Barrier to species movement (Leopold, 2014).
	3.2	Barrier to species movement Death or Injury by Collision Total Habitat Loss	Birds	Optimising the turbines and wind park design to minimize casualties results in a reduction of bird collision rate. Using data from land based turbines where the death rate of birds was studied for different type of turbines, the collision rate is reduced by approx. 40% by doubling the capacity of wind turbines (Thaxter, 2017). Assuming collision chance at sea is similar to land based turbines (chosen due to lack of knowledge). The sensitivity for increasing windturbine capacity among seabird species varies.
	3.3	Physical disturbance Extraction of flora and/or fauna	Fish & Cephalopods Coastal (A5) Shelf (A5)	A ban on fishing (benthic trawling) inside the OWFs results in an assumed 25% decrease in impact risk (roughly the equivalent of a decrease in the exposure categories used in Culhane et al. (submitted) from widespread-even to widespread patchy) of all relevant fishing-induced pressures.
	3.4	Total Habitat Loss	Coastal (A5) Shelf (A5)	This represents a potential benefit of OWFs based on the assumption that the foundations, scour protection and other structures of the wind turbines provide additional hard substrate, i.e. habitat type A4, which is assumed to compensate 0.1% of the total impact risk experienced by this habitat. The assumed 0.1% is an arbitrary value but based on a recent estimate that OWFs make up 0.02% of natural substrate (Hyder, 2017). Further increases can be achieved by planning artificial reefs within the OWFs.

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