

HABITAT QUESTIONNAIRE

1. Could you please send us a short bio (less than 20 lines)?

These answers have been produced by a small cross section of scientists from the HERMIONE project.

The HERMIONE (Hotspot Ecosystem Research and Man's Impact on European Seas) project is a Collaborative Project funded under the European Commission's Framework 7 programme (<http://www.eu-hermione.net/>). It is designed to make a major advance in our knowledge of the functioning of deep-sea ecosystems and their contribution to the production of goods and services.

2. Are deep-sea habitats more vulnerable to trawling disturbance than shallow water habitats?

Technically all seafloor habitats within range (e.g. water depths <2,000m) are vulnerable to commercial trawling disturbance. The passage of a trawl over any seafloor habitat, regardless of its water depth, will modify / damage / degrade that habitat. Vulnerability is a measure of risk of trawling. A shallow water tropical reef is as vulnerable to trawling as a deep-water reef.

Deep-water fishes have life histories that are very different to pelagic shoaling fish. They reach maturity at a later age, have low natural mortality, grow much slower and live much longer (Morato, T., Cheung, W.W.L., Pitcher, T.J. (2006) Vulnerability of seamount fish to fishing: fuzzy analysis of life history attributes. *Journal of Fish Biology*, 68, 209-221). Hence stocks cannot recover from fishing impact in the same way as pelagic shoaling fish, and may take hundreds of years to do so. In addition, deep-sea habitats take a very long time to establish (hundreds to thousands of years) and thus cannot regenerate following bottom impact fishing (Nellemann, C., Hain, S., and Alder, J. (Eds). February 2008. In *Dead Water – Merging of climate change with pollution, over-harvest, and infestations in the world's fishing grounds*. United Nations Environment Programme, GRID-Arendal, Norway, www.grida.no; Koslow et al., 2000. Continental slope and deep-sea fisheries: implications for a fragile ecosystem. *ICES Journal of Marine Science*. 57,548-557).

3. Are there deep-sea habitats that are more vulnerable than others? What can you say about the likelihood of trawling disturbance on muddy bottoms? On hard substrate?

Habitats listed in the OSPAR list of threatened or declining habitats that occur in the deep sea:

- Carbonate mounds
- Coral gardens
- Deep sea sponge aggregations
- Lophelia pertusa* reefs
- Oceanic ridges with hydrothermal vents/fields
- Seamounts
- Seapen and burrowing megafauna communities

Many of these habitats have their own distinct, often endemic, associated fauna. Some ecosystems are less resilient than others and will take longer to recover - and may never recover to their original state.

All deep-sea habitats within range (<2,000m) are vulnerable to trawling, and all trawled will be impacted.

On muddy bottoms: Hexactinellid sponges form aggregations in areas of open sediment creating a distinct habitat linked to increased macrofaunal abundance and richness. A study of the impact of trawling on deep-sea sponges found no evidence of repair of tissues and many individual died of tissue necrosis (Freese, 2001 Trawl-induced damage to sponges observed from a research submersible. *Marine Fisheries Review*, 63, pp7-13). Aggregations of xenophyophores, which in some locations are the dominant epifaunal organisms, increase habitat heterogeneity and are linked to increased meiofaunal and macrofaunal abundance in the surrounding sediments. Additionally, the tests of xenophyophores provide microhabitats for meiofaunal metazoans and foraminifera, and they are important for maintaining the biodiversity and hence functioning, of these ecosystems (Gubbay, 2002 *The Offshore Directory: Review of a selection of habitats, communities and species of the north-east Atlantic*. Available from: <http://www.ngo.grida.no/wwwneap/Projects/Reports/Offshore.pdf>; Hughes and Gooday, 2004. Associations between living benthic foraminifera and dead tests of *Syringammina fragilissima* (Xenophyophorea) in the Darwin Mounds region (NE Atlantic). *Deep-Sea Research I*, 51, pp1741–1758). There is no documented account of the effects of trawling on xenophyophores but their fragility makes them vulnerable to trawling.

On hard substrate: Damage to hard substrate is well documented, for example Freiwald, et al., 2004, *Cold-water Coral Reefs*. UNEP-WCMC, Cambridge, UK; Wheeler, et al., 2005, *The impact of demersal trawling on Northeast Atlantic deepwater coral habitats: The case of the Darwin Mounds, United Kingdom*. In: Barnes, P.W., Thomas, J.P. (Eds.), *Benthic Habitats and the Effects of Fishing*. American Fisheries Society, Bethesda, MD, pp. 807–817. Alteration to the character of the seabed by fishing gear may prevent recovery of cold-water coral reefs or octocorals in areas previously trawled. Recovery of cold-water coral ecosystems from fishing impacts is likely to be very slow and potentially impossible. Corals are extremely slow-growing and long-lived. Large reef-complexes, formed by stony corals, may be more than 8 000 years old. Freiwald et al. 2004 suggest that regeneration will lead to reduced species diversity.

4. What aspects of deep-sea habitats make them especially vulnerable to trawling disturbance?

The deep-sea is a stable environment in which habitats develop great complexity with time. This is clearly demonstrated by the cold-water coral reefs. A paper by Jensen and Fredericson described 4625 individual organisms from an 18 kg sample of coral from the Faroe Islands. These organisms belonged to 256 different species. The organisms were found to be particularly abundant in dead coral structures that form part of many deep-sea coral reefs. Such complex reefs with living and dead coral structures and a wealth of other species take hundreds to thousands of years to develop and similar times to regenerate after trawling activity. (Jensen, A. & Frederiksen, R., 1992. The fauna associated with the bank-forming deepwater coral *Lophelia pertusa* (Scleractinaria) on the Faroe Shelf. *Sarsia*, 77, 53-69). The impacts of trawling have been

described in many papers – for example Clarke and O’Driscoll describe trawled areas on the Chatham Rise off New Zealand as barren landscapes in contrast to adjacent areas untouched by trawling that have some dense coral patches and much more invertebrate life. (Clark M, O’Driscoll FR 2001, Deepwater fisheries and aspects of their impact on seamount habitat in New Zealand. *J Northw Atl Fish Sci* 31:441–458). Hall-Spencer et al. document widespread trawling damage to cold-water coral reefs along the West Ireland continental shelf break (Hall-Spencer, J. M., Allain, V., Fosså, J. H., 2002. Trawling damage to Northeast Atlantic ancient coral reefs. *Proc. R. Soc. London Ser. B* 269, 507). In the past such impacts were poorly known, but more extensive use of Remotely Operated Vehicles by scientists and others is beginning to show widespread impacts in many areas.

5. Do we have any way to estimate the possibility of recovery of deep-sea habitats after trawling ceases?

Targeted field observations and experiments such as those carried out in the Pacific Ocean in connection with manganese nodule mining - the DISCOL project (see <http://www.drbluhm.de/discolpubl.html> for DISCOL publications).

Regular photographic/video surveys of areas previously trawled would provide a method of assessing if and when any recovery occurred (e.g. Roberts et al., 2000. Seabed photography, environmental assessment and evidence for deep-water trawling on the continental margin west of the Hebrides. *Hydrobiologia*, 441, 173-183).

6. Is it possible that deep-sea communities can withstand trawling impacts if they happen only once? Many times?

All evidence suggests that deep sea ecosystems take a far longer time to regenerate than those in shallow water. Certain ecosystems, such as deep-sea corals and sponge assemblages are certainly very slow growing, so that they are unlikely to withstand trawling impacts even if they happen once. However much more research needs to be done.

7. Which are the dominant life forms in deep-sea habitats? What do we know about their life history and habitat requirements? Are there particular aspects of their life history that would cause them to be especially vulnerable to physical impacts of trawling? What do we know of their growth rates and reproduction cycles?

The deep sea is thought to contain more species than any habitat on earth, including representatives of all major phyla. Dominant life forms in the deep-sea benthic habitats vary with location, and are dependent on a number of factors, such as water depth, organic inputs, currents, sediment type, and biogeographic factors

Relatively little is known about many deep sea species but evidence indicates that low temperatures and a limited supply of food results in low rates of growth, respiration, reproduction, recruitment and bioturbation in comparison to shallow-water ecosystems.

Many deep water fisheries have developed very quickly and, because most deep-water species are long-lived, have low fecundity and a slow growth rate, combined with a late age at maturity, stocks can become rapidly depleted and recovery will be slow. Deep water fish caught and subsequently discarded on deck will almost certainly die and as most species are very vulnerable to injury. Immature fish encountering fishing gear then escaping through the nets are unlikely to survive.

8. Is there a way to estimate the extent of damage to deep-sea ecosystems so far?

Everywhere a trawl has been dragged across the seafloor the local ecosystem has been damaged. Given open access to logbooks, satellite tracking data and full and complete records of trawl deployments by the fishing industry an impact map could be readily produced.

A simpler question perhaps would be has deep-water fishing already caused the destruction / loss of target fish stocks? The answer to this is already proven, yes, and the losses have had wider impacts on seafloor and water column communities (e.g. Bailey, D.M., Collins, M.A., Gordon, J.D.M., Zuur, A.F and Priede, I.G., 2009. Long-term changes in deep-water fish populations in the northeast Atlantic: a deeper reaching effect of fisheries? Proceedings of the Royal Society; Morato et al., Fishing down the deep. Fish and Fisheries, 7, 24–34).

9. Can you estimate the area already affected by trawling worldwide? Or locally?

Yes, provided the fishing industry is subject to full and frank disclosure of its activities. All areas with water depths <2,000m are vulnerable and many have already been impacted. As the shelf edge and upper slope trawl fisheries have been in operation for >100-years it is likely that all of Europe's Atlantic margin has already been affected.

A preliminary estimate shows that the annual impact of bottom trawling is orders of magnitude greater than than all other human activities put together.

Studies of deep water trawling intensity have been carried out, for instance in the North Atlantic (e.g. Jennings et al, 1999. Fishing effects in northeast Atlantic shelf seas: patterns in fishing effort, diversity and community structure. III. International trawling effort in the North Sea: an analysis of spatial and temporal trends. Fisheries Research, 40, 125-134), which give indications of trawling effects on bottom habitats.

Studies of bottom trawl harvests, coupled with area and ocean productivity have been carried out (see the EU project INCOFISH <http://www.incofish.org/>), in order to give an impression of degree with which different oceans are affected by trawling.

10. The area of coral affected by trawling?

Probably most of it at water depths <2,000m (certainly in European waters) – published (catch) records indicate substantial coral impacts from the very early 1900s. Fosså et al. estimated that 30-50% of cold water coral reefs in Norwegian waters were damaged but an estimate of cold water coral loss or damage overall is not available (Fosså et al., 2002. The deep-water coral *Lophelia pertusa* in Norwegian waters: distribution and fishery impacts. *Hydrobiologia* 471: 1–12, 2002).

Today, the deep-water coral *Lophelia pertusa* is most readily found on giant carbonate mounds and oil field infrastructure – its apparent absence / rarity in suitable habitats on the upper slope on the European Atlantic Margin may well be the result of trawling – with carbonate mounds and oil field infrastructure providing physical refugia from trawling impacts.

11. Has anyone estimated the damage in terms of biodiversity loss? In economic terms (that is, in case some evaluation of the value of deep-sea ecosystem services has been done, at least tentatively)?

Not aware of any work estimating in economic terms the damage from deep-sea fishing in terms of biodiversity loss.

In terms of fisheries-related aspects of biodiversity loss/valuation deep sea species are characterised by high longevity, slow growth, late maturity and low fecundity, often leading to high vulnerability to exploitation. Depletion can be rapid, and recovery slow. This makes valuation difficult: even if we know what is coming out of the deep sea in any given year, we do not know to what extent this harvest is sustainable as an on-going flow of value, and to what extent it represents unsustainable stock depletion, giving only a short-term provisioning service, but with long-term costs in terms of reduced options for future provisioning, and perhaps reduced ecosystem function and biodiversity.

The report by the UN Secretary General, “Impacts of fishing on vulnerable marine ecosystems: actions taken by States and regional fisheries management organizations and arrangements to give effect to paragraphs 66 to 69 of General Assembly resolution 59/25 on sustainable fisheries, regarding the impacts of fishing on vulnerable marine ecosystems” (http://www.un.org/Depts/los/general_assembly/general_assembly_reports.htm#A/64/305) refers to impacts of fishing practices, including bottom trawling, on vulnerable marine ecosystems and biodiversity.

The impacts of trawling on biodiversity are discussed by, for example, Koslow et al, 2001; Clark and O’Driscoll, 2003; Gianni, 2004 (Koslow et al., 2001. Seamount benthic macrofauna off southern Tasmania: community structure and impacts of trawling. *Marine Ecology Progress Series*, 213, 111-125; Clark, M. & O’Driscoll, R. 2003. Deepwater Fisheries and Aspects of Their Impact on Seamount Habitat in New Zealand. *Journal of Northwest Atlantic Fishery Science*, 31, 441-458; Gianni, M. 2004. High Seas Bottom Trawl Fisheries and Their Impacts on the Biodiversity of Vulnerable Deep-Sea Ecosystems: Options for International Action. IUCN – The World Conservation Union).

12. What do you figure the future of deep-sea fisheries will be by year 2015 for example?

Local stocks will quickly collapse and can only be economically fished to destruction as has already been seen. Fishing to destruction (biological mining) or not fishing at all are the two economically viable options. Establishing economically viable sustainable fisheries seems unlikely. As this approach has failed with shallow-water species, its chance of success with deep-sea species is vanishingly small due to the higher cost of fishing and lower sustainable yields.

'Business as usual' will result in continued depletion of biodiversity and fishing down the marine food web will intensify leading ultimately to the transformation of marine ecosystems into dead zones (Pauly, D., 2009. Beyond duplicity and ignorance in global fisheries. *Scientia Marina* 73(2) 215-224). The serial depletion of deepwater fish stocks will continue as long as these species are targeted. Declines in abundance of target and non-target species will extend beyond the maximum depths of commercial fishing and may result in ecosystem-level changes (Bailey, D.M., Collins, M.A., Gordon, J.D.M., Zuur, A.F and Priede, I.G., 2009. Long-term changes in deep-water fish populations in the northeast Atlantic: a deeper reaching effect of fisheries? *Proceedings of the Royal Society, B*).