The Deep Sea Conservation Coalition, an alliance of over 40 international organizations, representing millions of people in countries around the world, is calling for a moratorium on high seas bottom trawling.

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Why the world needs a time-out on high-seas bottom trawling

L.E. Morgan
Marine Conservation Biology Institute, USA

E.A. Norse
Marine Conservation Biology Institute, USA

A.D. Rogers
British Antarctic Survey, Cambridge, UK

R.L. Haedrich
Memorial University of Newfoundland, St. John's, Canada

S.M. Maxwell
Marine Conservation Biology Institute, USA

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Introduction

Fishing on the high seas far from land is dangerous and expensive, and it consumes large amounts of fossil fuel. Fishermen would be unlikely to venture out on the high seas if fish were still abundant in more productive nearshore waters. High-seas bottom trawling (HSBT) is a relatively new industry, having begun in the 1950s when an increasing number of nations over-fished their coastal fisheries. They built larger and more powerful vessels and developed fishing gears that were more robust, such as rockhopper trawls, huge nets and stronger cables. Governments further fueled this move with grants and subsidies.[1]

Now fishermen are increasingly trawling in the least-known and least-protected place on Earth, the deep sea beyond nations' Exclusive Economic Zones (EEZs). Sixty-four percent of the world's oceans fall outside the boundaries of EEZs and few agreements exist to manage deep-sea fish stocks in this vast realm. Deep-sea environments are particularly vulnerable to bottom trawling, because conditions there are typically stable and unchanging. When changes or disturbances come (as with trawling), the organisms are poorly equipped to adapt or respond to them.[2] It is especially unfortunate that nearshore over-fishing and habitat destruction have shifted fishing to the last places on Earth where marketable fish with firm white flesh are found: seamounts, mid-ocean ridges, continental slopes and banks in the deep sea. Populations of deep-sea fish that are targeted by bottom trawlers and populations of those caught incidentally as bycatch, are especially vulnerable to trawling damage.[3] Crucial habitat-forming animals in the deep sea are similarly vulnerable but are often overlooked. In addition, many of these seamounts, and other hard, rocky surfaces which rise above the muddy seafloor, are thought to host a richness of species rivaling that of tropical rainforests, with many species restricted in range to a single geographic region, a seamount chain, or even a single seamount location.[4]

There are clear and increasing signs that high-seas bottom-trawl fisheries are causing unprecedented damage to some of the most vulnerable ecosystems on our planet. In this paper, we present the arguments that have motivated 1,136 scientists from 69 nations to publicly call for an immediate worldwide moratorium – a time-out – on the most destructive fishing method (deep-sea bottom trawling) in the least protected place on Earth (the high seas).

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[1] Roberts, C.M. (2002). Deep impact: the rising toll of fishing in the deep sea. *Trends In Ecology and Evolution* 17(5): 242-245

[2] NRC (National Research Council) (2002). *Effects of trawling and dredging on seafloor habitat*. National Academy of Sciences, Washington DC

[3] Gordon, J.D.M., et al (1995). Environmental and biological aspects of slope-dwelling fish. pp.1-30 in A.G. Hopper ed., *Deep Water Fisheries of the North Atlantic Oceanic Slope*, Kluwer Academic Publishers, Dordrecht

[4] Richer de Forges, B., et al. (2000). Diversity and endemism of the benthic seamount fauna in the southwest Pacific. *Nature* 405: 944-947

Six reasons why high-seas bottom trawling needs an immediate time-out

Scientists tend to be reluctant to prescribe actions unless there is an overwhelming need to do so. We would not be calling for an immediate moratorium on high-seas bottom trawling if there were significant uncertainty about the effectiveness of this course of action or if there were time to examine the issue at a more leisurely pace. There are six major reasons why we believe an immediate moratorium on high-seas bottom trawling is in order:

1. Although high-seas bottom trawling has spread rapidly, it is of minor economic importance

The former USSR was one of the first nations to initiate high-seas bottom trawling, beginning in the Pacific in the late 1950s and in the Atlantic in the early 1970s.[5] The discovery of substantial orange roughy populations around New Zealand brought bottom-trawl fishing to the deeper slopes and seamounts of the Southeast Pacific in the late 1970s.[6] Elsewhere, other countries started fishing on slopes and seamounts in the 1980s and '90s, and today they are continuing to fish even more deeply.[7] Rather than fishing deep-sea fish sustainably, commercial bottom trawlers reflect a typical pattern of serial over-fishing that is best summarized as "plunder and push on". High-seas bottom trawling – as currently practiced– quickly renders localized deep-sea fish populations commercially extinct, whereupon fishing vessels move on to the next fishing ground. Glover and Smith predict that all deep-sea fisheries present in 2003 will be commercially extinct by 2025.[8] Furthermore, because of the high level of unique species found on many seamounts, the potential for extinction through trawl damage is high.[9]

Across the globe, from the North Atlantic to Namibia, and from the Southwest Indian Ocean to the international waters surrounding New Zealand and Australia, HSBT has expanded in the last two decades, driven by the depletion of coastal resources and shelf-fisheries and by the resulting increased restrictiveness of fisheries regulations within national waters. At the same time, demand for fish in developed countries has increased whilst effective regulation on the high seas is lacking.[10] Exploratory fishing is now occurring in all oceans – sponsored by a variety of nations – to such an extent that it is likely that commercial fishing has had an impact on nearly all of the known seamounts with summits shallower than 1,000 meters.[11] In the New Zealand region alone, the number of fished seamounts has increased by almost 250 percent in just 20 years.[12]

In recent years, 95 percent of HSBT landings-by-weight have come from just a few species (listed here in order of approximate highest to lowest landings): northern prawns (*Pandalus borealis*), roundnose grenadier (*Coryphaenoides rupestris*), Greenland halibut (*Reinhardtius hippoglossoides*), rockfish (*Sebastes* spp.), smoothheads (*Alepocephalus* spp.), orange roughy (*Hoplostethus atlanticus*), blue ling (*Molva dypterygia*), alfonsinos (*Beryx* spp.), American plaice (*Hippoglossoides platessoides*) and roughhead grenadier (*Macrourus berglax*).[13] Landings from HSBT make up 80 percent of high-seas bottom fishing, yet the habitats on which bottom trawling occurs – the rocky substrates of mid-oceanic ridges, seamounts, and submarine canyons – are rare, occupying less than four percent of the seafloor.[14]

Globally, the market impact of HSBT is tiny: it constituted only a fraction of one percent of the reported total marine fish catch in 2001 by volume and value. The world's high-seas bottom-trawling fleet consists of several hundred vessels at most. The catch level in 2001 would at best support between 100 and 200 vessels operating on a year-round equivalent basis. This compares to a global fishing fleet of approximately 3.1 million vessels.[15] In 2001, HSBT contributed roughly 200 thousand tons[16] to the worldwide 80-million-ton marine fish catch. Just 11 countries accounted for 95 percent of the reported high-seas bottom-trawl catch: Spain, Russia, Portugal, Norway, Estonia, Denmark/Faroe Islands, Japan, Lithuania, Iceland, New Zealand, and Latvia.[17] European Union (EU) countries[18] took approximately 60 percent of the reported HSBT catch, with Spain accounting for over 65 percent of the reported EU catch and 40 percent of the global HSBT catch in 2001.[19] To put this in perspective, the combined value of the reported HSBT catch in the Atlantic, Pacific, and Indian Oceans in 2001 was roughly US$300-400 million,[20] equivalent to the revenue from one blockbuster movie (for example, Mel Gibson's *The Passion of the Christ*) or to the value of the State of Florida's annual commercial seafood imports.

Significantly, the majority of the high-seas bottom-trawl catch is destined for markets in the most affluent nations, namely the USA, Europe, and Japan, negating claims that HSBT contributes to global food security.[21] HSBT fishing is a boutique fishery, *temporarily* benefiting only wealthy nations and wealthy consumers while trashing the global *environment for a very long time* (decades to centuries). Restrictions on these fisheries will have no major social impact but will have very important environmental benefits.

2. Bottom trawling is the world's most destructive type of fishing

The idea that dragging huge, heavily-weighted nets across vast areas of seafloor might be harmful to seafloor ecosystems appears obvious. Indeed, as early as 1376, long before there were marine scientists, fishermen from the Thames Estuary asked King Edward III of England to ban primitive trawl nets that they recognized were causing "great damage of the common's realm and the destruction of the fisheries."[22] Unfortunately for the United Kingdom today, that did not happen, and the Thames Estuary has long since ceased being a biodiversity and fishery hotspot. However, in the twenty-first century, at a time when commonsense is no longer common and irrefutable, and when quantitative scientific proof is increasingly demanded to test the validity of even the obvious,

5 Pechenik, L.N., and F.M. Troyanovsky (1970). *Trawling resources of the North-Atlantic continental slope.* Murmanskoe Knihnoe Izdatel'stvo, Murmansk. Israel Program for Scientific Translations, 1971(5977):1-66; Koslow, J.A., et al (2000). Continental slope and deep-seas fisheries: Implications for a fragile ecosystem. *ICES Journal of Marine Science* 57:548-557

6 Zeldis, J.R. (1993). Applicability of egg surveys for spawning-stock biomass estimation of snapper, orange roughy and hoki in New Zealand. *Bulletin of Marine Science* 53 (2):864-890

7 Roberts 2002, see note 1; Pauly, D., et al (2003). The future for fisheries. *Science* 302 (5649):1359-1361

8 Glover, A.G., and C.R. Smith (2003). The deep-sea floor ecosystem: current status and prospects of anthropogenic change by the year 2025. *Environmental Conservation* 30(3): 219-241

9 Roberts, C.M., and J.P. Hawkins (1999). Extinction risk in the sea. *Trends in Ecology and Evolution* 14(6): 241-246

10 WWF/IUCN (2001) *The Status of Natural Resources on the High-seas.* World Wide Fund for Nature and World Conservation Union; Gianni, M. (2004). *High-seas bottom fisheries and their impact on the biodiversity of vulnerable deep-seas ecosystems: options for international action.* IUCN

11 Stone et al (2004). Seamount biodiversity, exploitation and conservation. pp. 41-70 in L.K. Glover and S.A. Earle, eds. *Defying Ocean's End: An Agenda for Action.* Island Press, Washington, DC

12 Clark, M., and R. O'Driscoll (2003). Deep-water fisheries and aspects of their impact on seamount habitat in New Zealand. *Journal of Northwest Atlantic Fisheries Science* 31: 441-458

13 Gianni 2004, see note 10 (landings information compiled from various sources)

14 Gordon et al 1995, see note 3; Glover and Smith 2003, see note 8

15 FAO (2002). *The state of the world fisheries and aquaculture 2002.* United Nations Food and Agriculture Organization, Rome; Gianni 2004, see note 10

16 Gianni 2004, see note 10, estimates roughly 170 to 215 thousand tons

17 Gianni 2004, see note 10

18 including Latvia, Lithuania, and Estonia which became EU members in May 2004

19 Gianni 2004, see note 10

20 *ibid.*

21 *ibid.*

22 FAO 2002, see note 15

there is overwhelming scientific evidence that bottom trawling causes terrible damage to seafloor ecosystems and even more terrible damage to the fragile and slow growing ecosystems of the deep sea. Perhaps the combination of simple logic and scientific observations will help us to avoid making the same mistakes that governments have been making for centuries.

The huge bottom trawls are dragged across the seafloor to catch fish and shrimp that live in, on, or just above the bottom. Because more than *98 percent* of marine animal species live in, on, or immediately above the seafloor,[23] anything that causes significant harm to the seafloor profoundly damages the health of ocean ecosystems as a whole. Both logic and the large, and rapidly growing, number of scientific studies documenting trawling-impacts lead to the unmistakable conclusion that bottom trawling is the world's most harmful method of fishing.[24]

Bottom trawlers range from eight-meter boats that fish in nearshore water to 100-meter ships that fish in the deep sea thousands of kilometers from home ports. Large bottom trawlers use 4,000-horsepower engines to haul 40-ton catches.[25] Weighted with massive bobbins, rollers, or rockhoppers, the trawl nets stretch up to 40 meters in width and are held open by pairs of seven-ton steel trawl doors. Trawler footropes can roll 18-ton seafloor rocks.[26] Both rolled-boulders and trawl doors can plow deep gouges in soft sediments. A trawler towing at three to four knots for a period of four hours directly impacts an area of 2.5 km^2.[27] Trawling trips can last as long as four to six weeks with fishing around the clock. Trawlers sweep a vast area of seafloor, crushing corals, sponges and most of the other living things that they hit. The estimated total area swept annually by trawl nets

23 Thurman, H.V., and E.A. Burton (2001). *Introductory Oceanography*. 9th ed. Prentice-Hall, Upper Saddle River, New Jersey (USA)

24 Auster, P.J., and R.W. Langton (1999). The effects of fishing on fish habitat. pp 150-187 in L.R. Benaka, ed. *Fish habitat: essential fish habitat and rehabilitation.* American Fisheries Society, Bethesda, Maryland (USA); Barnette, M.C. (1999). Gulf of Mexico fishing gear and their potential impacts on essential fish habitat. NMFS, NMFS-SEFSC-432, St Petersburg, FL; Berkeley et al (1985). *Bait shrimp fishery of Biscayne Bay.* Florida Sea Grant College Program Technical Paper No. 40; Bradstock, M., and D.P. Gordon (1983). Coral-like bryozoan growths in Tasman Bay, and their protection to conserve commercial fish stocks. *New Zealand Journal of Marine and Freshwater Research* 17: 159-163; Bridger, J.P. (1970). Some effects of the passage of a trawl over the seabed. Gear and Behavior Committee, ICES C.M.: 254-259; Collie et al (2000) Photographic evaluation of the impacts of bottom fishing in benthic epifauna. *ICES Journal of Marine Science* 57: 987-1001; de Groot, S.J. (1984). The impact of bottom trawling on benthic fauna of the North Sea. *Ocean Management* 9: 177-190; Engel, J., and R. Kvitek (1998). Effects of otter trawling on a benthic community in Monterey Bay National Marine Sanctuary. *Conservation Biology* 12: 1204-1214; Freese et al (1999). Effects of trawling on seafloor habitat and associated invertebrate taxa in the Gulf of Alaska. *Marine Ecology Progress Series* 182: 119-126; Guillen et al (1994). Anti-trawling reefs and the protection of *Posidonia oceanica* (L.) delile meadows in the western Mediterranean Sea: Demand and aims. *Bulletin of Marine Science* 55: 645-650; Jennings, S., and M.J. Kaiser (1998). The effects of fishing on marine ecosystems. pp 201-352 in Blaxter et al, eds. *Advances in Marine Biology.* Academic Press Limited, London; Jennings et al (2001). Impacts of trawling disturbance on the trophic structure of benthic invertebrate communities. *Marine Ecology Progress Series* 213: 127-142; Kaiser, M.J., and B.E. Spencer (1996). The effects of beam-trawl disturbance on infaunal communities in different habitats. *Journal of Animal Ecology* 65: 348-358; Kaiser et al (2000). Chronic fishing disturbance has changed shelf sea benthic community structure. *Journal of Animal Ecology* 69: 494-503; Kenchington et al (2001). Effects of experimental otter trawling on the macrofauna of a sandy bottom ecosystem on the Grand Banks of Newfoundland. *Canadian Journal of Fisheries and Aquatic Sciences* 58: 1043-1057; Meyer et al (1999). Effects of live-bait shrimp trawling on seagrass beds and fish bycatch in Tampa Bay, Florida. *Fishery Bulletin* 97: 193-199; Moore, D.R., and H.R. Bullis (1960). A deep-water coral reef in the Gulf of Mexico. *Bulletin of Marine Science of the Gulf and Caribbean* 10: 125-128; Sainsbury, K.J., and R.A. Campbell (1997). Experimental management of an Australian multispecies fishery: Examining the possibility of trawl induced habitat modifications. pp 107-112 in Pikitch et al, eds. *Global Trends: Fisheries Management.* American Fisheries Society, Bethesda, MD; Schwinghamer et al (1998). Effects of experimental otter trawling on surficial sediment properties of a sandy-bottom ecosystem on the Grand Banks of Newfoundland. *Conservation Biology* 12: 1215-1222; Smith, E.M., and L.L. Stewart (1985). *A study of lobster fisheries in the Connecticut waters of Long Island Sound with special reference to the effects of trawling on lobsters.* Connecticut Department of Environmental Protection Marine Fisheries Program, University of Connecticut, Hartford, CT; Thrush et al (1998). Disturbance of the marine benthic habitat by commercial fishing: Impacts at the scale of the fishery. *Ecological Applications* 8: 866-879; Tilmant, J. (1979). *Observations on the impact of shrimp roller frame trawls operated over hard bottom communities, Biscayne Bay, Florida.* National Park Service, Biscayne National Monument, Series No. P-553, Homestead; Tuck et al (1998). Effects of physical trawling disturbance in a previously unfished sheltered Scottish sea loch. *Marine Ecology Progress Series* 162: 227-242; Van Dolah et al (1987). Effects of a research trawl on a hard bottom assemblage of sponges and corals. *Fisheries Research* 5: 39-54; Watling, L., and E.A. Norse (1998). Disturbance of the seabed by mobile fishing gear: a comparison with forest clear-cutting. *Conservation Biology* 12: 1189-1197

25 Merrett, N., and R. Haedrich (1997). *Deep-Sea Demersal Fish and Fisheries.* Chapman and Hall, London

26 Risk, M.J., et al. (1998). Conservation of cold- and warm-water seafans: threatened ancient gorgonian groves. *Sea Wind* 12(1): 2-21

27 Merrett and Haedrich 1997, see note 25

(the same area is often trawled many times a year) is equivalent to about 50 percent of the world's continental shelf area, or approximately 150 times the area of forest that is clearcut worldwide.[28]

The International Council for the Exploration of the Seas (ICES) reviewed available information on the impacts of gillnets, longlines and bottom trawl gear on deep-water habitats. They concluded that while all deep-water fishing gear has some impact on the seabed, bottom-trawl fishing is by far the most damaging to deep-water corals and other vulnerable species. ICES concluded by advising that "*the most effective way of mitigating the effect of trawling on these habitats is to close such areas to [bottom-trawl] fishing" and "the only proven method of preventing damage to deep-water biogenic reefs from fishing activities is through spatial closures to towed gear that potentially impacts the bottom.*"[29]

The United States National Academy of Sciences' National Research Council[30] comprehensively analyzed the ecological impacts of trawling. In summarizing dozens of peer-reviewed scientific papers, it concluded that trawling diminishes seafloor species diversity, habitat complexity, and productivity. Morgan and Chuenpagdee and Chuenpagdee and colleagues polled fishery professionals including fishermen, managers, conservationists and scientists for their assessment of the ecological impact of 10 major fishing gears used in United States waters, and found that experts from all sectors agree that bottom trawling is the most damaging fishing method of all.[31]

Because fishing has depleted fish from the nearshore, including the continental shelves,[32] 40 percent of the world's trawling grounds are now in deeper waters on slopes or seamounts.[33] Today, most commercially important deep-sea species are found on seamounts. However, some 'seamount species' were originally caught on continental slopes before fishing operations drove them to such low population levels that seamounts became their last refuges.[34] Most HSBT occurs at depths below 400 meters on slopes, seamounts, banks, ridges, plateaus, and other bathymetric rises from the seafloor,[35] and the majority of it occurs in the 600 to 1,000 meters range.[36] Relatively few vessels currently fish below 1,000 meters, although this will change as fish are eliminated at shallower depths.[37] The deepest trawling currently occurs up to a depth of 2,000 meters.[38]

Most deep-sea bottom trawling appears to occur within national waters, but firm evidence is lacking because UN Food and Agriculture Organization (FAO) data do not distinguish between high seas and EEZ waters or between different gear types.[39] Recent attempts to analyze the best statistics available indicate that the great majority of HSBT fishing occurs in the North Atlantic, Southern Indian, and Southwest Pacific (adjacent to Australian and New Zealand EEZs) Oceans. It is estimated that 60 percent of the world's HSBT catch comes from the Northwest Atlantic.[40]

28 Watling and Norse, see note 24; Norse, E.A., and L. Watling (1999). *Impacts of mobile fishing gear: The biodiversity perspective.* American Fisheries Society Symposium

29 ICES (2002). Report of the ICES Advisory Committee on Ecosystems, 2002. ICES Cooperative Research Report No. 254. International Council for the Exploration of the Sea, December 2002. pgs 28-33.

30 NRC 2002, see note 2

31 Chuenpagdee, R., et al (2003). Shifting Gears: Assessing collateral impacts of fishing methods in US waters. *Frontiers in Ecology and the Environment* 1: 517-524; Morgan, L.E., and R. Chuenpagdee (2003). *Shifting Gears: Addressing the Collateral Impacts of Fishing Methods in U.S. Waters.* Island Press, Washington, DC

32 Pauly et al 2003, see note 7

33 Roberts 2002, see note 1; Stone et al 2004, see note 11

34 Clark, M.R., et al (2000). The effects of commercial exploitation on orange roughy (*Hoplostethus atlanticus*) from the continental slope of the Chatham Rise, New Zealand, from 1979 to 1997. *Fisheries Research* 45:217-238; Watson, R., and T. Morato (2004). Exploitation patterns in seamount fisheries: a preliminary analysis. pp. 61-66 in T. Morato and D. Pauly, eds. *Seamounts: Biodiversity and Fisheries.* University of British Columbia, Vancouver

35 ICES Advisory Committee on Fisheries Management (2003). Deep-water fisheries resources south of 63°N, Overview. Available online at http://www.ices.dk/committe/acfm/comwork/report/2003/oct/o-3-13.pdf

36 Glover and Smith 2003, see note 8

37 *ibid.*

38 Gianni 2004, see note 10

39 *ibid.*

40 *ibid.*

3. Deep-sea fish are inherently vulnerable to over-fishing

To keep pace with exploitation, all fisheries depend on the reproductive capacity and growth rates of the target species, which in turn depend on the productivity of the ecosystem.[41] With the exception of hydrothermal vents, deep-sea ecosystems have much lower productivity than surface and coastal waters. Moreover, the deep sea is cold, often just above freezing. Low food availability and cold temperatures contribute to the very low reproduction and growth rates of deep-sea fish. For example, some of the rockfish (*Sebastes* spp.) that live on continental slopes and seamounts in the North Pacific may live to be as old as 200 years,[42] and take 10 to 39 years to reach maturity.

As a result of their slow growth and low reproductive rates, deep-sea fish are the most vulnerable of all fish to over-fishing.[43] For shallow-water species, a large body size and late age of maturity are reliable predictors of vulnerability to overexploitation,[44] and the same relationship appears to hold true for some deep-sea species. The pattern of sequential population depletion observed in many shallow-water fisheries is now being witnessed in deep-sea fisheries, but at a much faster pace and with even less chance of recovery.[45] Yet most studies of deep-sea fisheries begin only *after* intense fishing has sharply reduced their populations.[46] Annual sustainable levels of catch were estimated at only two percent of pre-exploitation biomass for orange roughy in New Zealand,[47] and model simulation studies show that the low population resilience of seamount fish species suggests exploitation rates greater than five percent annually will be unsustainable.[48] These are very low exploitation levels and may not be economically viable.[49]

Seamount fisheries have repeatedly devastated fish populations in just a few years. For example, pelagic armorheads (*Pseudopentaceros wheeleri*) on the Emperor Seamount chain in the north Pacific were severely over-fished in the 1960s and '70s by Soviet and Taiwanese trawlers, and have not recovered in the decades since.[50] Other deep-sea fisheries off New Zealand, Australia and Namibia, and in the North Atlantic and Southern Indian Oceans have all experienced similar rapid depletions of deep-sea fish populations.[51] In its recent review of deep-water fishing, the ICES Advisory Committee on Fisheries Management expressed concern that "deep-sea stocks can be depleted very quickly and that recovery will be slow."[52]

41 Merrett and Haedrich 1997, see note 25; Jennings and Kaiser 1998, see note 24
42 Caillet et al (2001). Age determination and validation studies of marine fish: do deep-dwellers live longer? *Experimental Gerontology* 36:739-764
43 Gordon et al 1995, see note 3; Morato et al (2004). Vulnerability of seamount fish to fishing: Fuzzy analysis of life-history attributes. pp. 51-60 in T. Morato and D. Pauly, eds. *Seamounts: Biodiversity and Fisheries*
44 Jennings et al 2001, see note 24
45 Clark, M.R. (1999). Fisheries for orange roughy (*Hoplostethus atlanticus*) on seamounts in New Zealand. *Oceanologica Acta* 22 (6):1-10; Roberts, C.M. (2000) Why does fishery management so often fail? pp. 170–192 in M. Huxham, D. Sumner, eds. *Science and Environmental Decision Making* Prentice Hall; Roberts 2002, see note 1
46 Haedrich, R.L., et al (2001). Can ecological knowledge catch up with deep-water fishing? A North Atlantic perspective. *Fisheries Research* 51:113-122; Glover and Smith 2003, see note 8
47 Francis, R., et al (1995). *Assessment of the ORH 3B orange roughy fishery for the 1994-1995 fishing year.* New Zealand Fishery Assessment Research Document 95/4, 43pp. Available at: NIWA, Wellington
48 Morato et al 2004, see note 43
49 *ibid.*
50 Humphreys, R.L. (2000). Otolith-based assessment of recruitment variation in a North Pacific seamount population of armorhead *Pseudopentaceros wheeleri. Marine Ecology Progress Series* 204:213-223
51 New Zealand orange roughy biomass reduced to 15-20% of pre-exploitation levels in 15 years, reported in Clark, M. (2001). Are deep-water fisheries sustainable?—the example of orange roughy (*Hoplostethus atlanticus*) in New Zealand. *Fisheries Research* 51(2-3): 123-135; Australian orange roughy biomass reduced to 7-13% of pre-exploitation levels in about 15 years, reported in Lack, M., et al (2003). *Managing risk and uncertainty in deep-sea fisheries: lessons from orange roughy.* A Joint Report by TRAFFIC, Oceana, and WWF Endangered Seas Programme; Namibian orange roughy biomass reduced to 10% of pre-exploitation levels in 6 years, reported in Branch, T.A. (2001). A review of orange roughy *Hoplostethus atlanticus* fisheries, estimation methods, biology and stock structure. *South African Journal of Marine Science* 23:181-203; North Atlantic Ocean, Atkinson, D.B. (1995) The biology and fishery of roundnose grenadier (*Coryphaenoides rupestris* Gunnerus, 1976) in the northwest Atlantic. pp 51-112 in A.G. Hopper, ed. *Deep-Water Fisheries of the North Atlantic Oceanic Slope.* Kluwer Academic Publishers, Dordrecht (Netherlands); Southern Indian Ocean, Gianni 2004, see note 10
52 Report of the ICES Advisory Committee on Fishery Management, 2003, ICES Report number 261

Targeting Spawning Aggregations

Because of the generally low food supply in the deep sea, fish are normally dispersed and come together in large groups only to spawn. From the perspective of HSBT, those aggregations provide the most profitable target. Targeting spawning aggregations is also the most effective way to rapidly deplete fisheries, but that is exactly what some HSBT operations do.

Orange roughy (*Hoplostethus atlanticus*) fisheries deliberately target spawning aggregations. Other fisheries that have used this strategy, such as the Nassau grouper (*Epinephelus striatus*) fisheries throughout the Caribbean, have eliminated their target fish in just a few years, allowing little opportunity for recovery.[53] But orange roughy and other deep-sea fish are more vulnerable because of their longer lifespan and lower reproductive rates. Exploiting spawning aggregations is more like mining than fishing because it reduces the chance of recovery so severely.[54]

Because it is the target of one of the most important deep-sea fisheries, orange roughy is one of the best studied deep-sea fish and provides a good case study concerning the vulnerability of deep-sea fish to fishing. This species occurs on deep banks, mid-ocean ridges, and seamounts in most oceans but is especially abundant near New Zealand and Tasmania,[55] typically at depths of 700 to 1,800 m.[56] Orange roughy live to 150 years, and their average age at sexual maturity is 24, making this fish extremely slow to recover from fishing.[57]

The New Zealand fishery for roughy took off in the 1980s with the discovery of spawning grounds around deep New Zealand and southern Australian seamounts, where catches for the fish could be as high as 60 metric tons from a 20-minute tow.[58] New Zealand instituted total allowable catch levels that were considered prudent in the early years of the fishery – but populations and landings had declined by the 1990s.[59] In just over a decade, populations collapsed to less than 20 percent of pre-exploitation abundance because the fishery targeted spawning aggregations.[60] As with most fisheries where spawning aggregations are targeted, these declines were not recognized until it was too late to mitigate them. Even in a small population, when all the adults aggregate for spawning they give the appearance of a healthy population because catches are still high – even with low fishing effort.[61]

In Namibia, four orange roughy spawning aggregations were discovered in 1994. Only five vessels fished them, but in just six years, these populations were overexploited to around 10 percent of their original biomass.[62] The targeting of these most vulnerable groups of deep-sea fish species and the inherent vulnerability of all deep-sea *fish makes HSBT fisheries one of the least sustainable fisheries on Earth*. Worse still, the impact of these fisheries is not limited to the species they target.

Impacts of bottom trawling on non-target fish species

One key measure of the efficiency or 'cleanness' of a fishery is the amount of bycatch, defined as the catch of non-target species or individuals that are discarded, usually dead or fatally injured. By this measure, too, bottom trawling is by far the worst of all fishing methods. The FAO's latest compilation of world fishery statistics reports that trawl fisheries for shrimp and demersal finfish constitute about 22 percent of the world's fish landings but account for more than 50 percent of the

53 Sadovy, Y. (1993). The Nassau grouper, endangered or just unlucky? Reef Encounters 13:10–12
54 Johannes, R.E. (1998). The case for data-less marine resource management: examples from tropical nearshore fin fisheries. *Trends in Ecology and Evolution* 13:243–246
55 Koslow et al 2000, see note 5; Koslow, J.A., et al (2001) Seamount benthic macrofauna off southern Tasmania: community structure and impacts of trawling. *Marine Ecology Progress Series* 213:111-125
56 Rogers, A.D. (1994). The biology of seamounts. *Advances in Marine Biology* 30:305-350
57 Clark, M.R., and D.M. Tracey (1994). Changes in a population of orange roughy, *Hoplostethus atlanticus*, with commercial exploitation on the Challenger Plateau, New-Zealand. *Fishery Bulletin* 92(2): 236-253
58 Batson, P. (2003). *Deep New Zealand: blue water black abyss.* The Canterbury University Press, Christchurch ; Roberts 2002, see note 1
59 Merrett and Haedrich 1997, see note 25
60 Clark 1999, see note 45; Koslow et al 2000, see note 5
61 Cheung, W.W.L. et al (2004). A fuzzy logic expert system for estimating the intrinsic extinction vulnerabilities of seamount fish to fishing. pp. 33-50 in T. Morato and D. Pauly, eds. *Seamounts: Biodiversity and Fisheries.* University of British Columbia, Vancouver
62 Branch 2001, see note 51

world's bycatch. In addition, while overall world discards have decreased (in large part due to greater retention of non-target species), deep-water fisheries discards have increased.[63]

Many deep-sea fisheries are also multi-species fisheries or have a large bycatch of non-commercial fish species.[64] As a result, they can be at least as devastating to non-target species as to their intended targets. After ten years of the orange roughy fishery on the Chatham Rise, off New Zealand, 13 out of 17 bycatch species showed lower biomasses. Populations of Plunket's shark (*Centroscymnus plunketi*) and black cardinal fish (*Epigonus telescopus*) decreased to only six percent of their original biomass.[65] The orange roughy fishery on the South Tasman Rise also captured large quantities of oreos (fish in the family *Oreosomatidae*). Between the 1997-1998 and 2000-2001 fishing seasons, oreo bycatch decreased from 7,400 to 350 tons, indicating a substantial population decline.[66] Atlantic wolffish, *Anarhichas lupus*, may be on the road to becoming an endangered species in the northwest Atlantic largely due to mortality relating to bycatch.[67]

A non-expert might ask whether some of these bycatch animals could be returned to the sea unharmed. Inedible scavengers such as starfish and hermit crabs trawled in shallower waters do survive being caught and thrown back,[68] but probably 100 percent of fish caught by HSBT die because of external damage to the skin from the fishing gear or internal damage caused by distension of the swim bladder owing to pressure changes from the great depths from which they are brought up.[69] Some fish that are too small to catch can squeeze through the net meshes of the trawls and escape without being brought to the surface, but deep-sea fish have large scales and weak skin and lack the mucus coating of shallow water fish. As a result, they are stripped of scales and skin by the tremendous forces in trawl nets, so that even if they are able to pass through the trawl-net mesh alive, they suffer heavy mortality from their injuries.[70]

4. Deep-sea ecosystems are severely damaged by bottom trawling

Myriad living organisms, such as corals, sponges, tube worms, and mussels form complex structures in and on the seafloor, thereby providing crucial food and refuge for marine species and enhancing fish survivorship.[71] Trawling gear removes these complex structures,[72] and

[63] FAO (2004). *The state of the world fisheries and aquaculture 2004.* United Nations Food and Agriculture Organization, Rome
[64] Piñeiro, C.G., and M.C.R. Bañón (2001). The deep-water fisheries exploited by Spanish fleets in the Northeast Atlantic: a review of the current status. *Fisheries Research* 51:311-320
[65] Clark et al 2000, see note 34
[66] Anderson O.F., and M.R. Clark (2003). Analysis of bycatch in the fishery for orange roughy, *Hoplostethus atlanticus*, on the South Tasman Rise. *Marine and Freshwater Research* 54 (5):643-652
[67] O'Dea, N.R., and R.L. Haedrich (2002). A review of the status of the Atlantic Wolffish, *Anarhichas lupus*, in Canada. *Canadian Field Naturalist* 116(3):423-432
[68] Kaiser, M.J., and B.E. Spencer (1996). The effects of beam-trawl disturbance on infaunal communities in different habitats. *Journal of Animal Ecology* 65: 348-358.
[69] Gordon, J.D.M. (2001). Deep-water fisheries at the Atlantic Frontier. Continental Shelf Research 21:987–1003
[70] Connolly, P.L., and C.J. Kelly (1996). Catch and discards from experimental trawl and longline fishing in deep-water of the Rockall Trough. *Journal of Fish Biology* 49 (Supplement A): 132--144
[71] Auster, P.J.M., et al (1995). *Management implications of mobile fishing gear alterations to benthic habitats in the Gulf of Maine: science program summary.* Groton,CT., NOAA's National Undersea Research Center; Auster, P.J. (1998). A conceptual model of the impacts of fishing gear on the integrity of fish habitats. *Conservation Biology* 12: 1198-1202; Langton, R.W., et al (1995). A spatial and temporal perspective on research and management of groundfish in the Northwest Atlantic. *Reviews in Fisheries Science* 3(3):201-229; Stein, D.L., et al (1992). Fish-habitat associations on a deep reef at the edge of the Oregon continental shelf. *Fishery Bulletin* 90:540-551; Tupper, M., and R.G. Boutilier (1995). Effects of habitat on settlement, growth, and postsettlement survival of Atlantic cod (*Gadus morhua*). *Canadian Journal of Fisheries and Aquatic Sciences* 52:1834-1841; Yoklavich, M.M., et al (2000). Habitat associations of deep-water rockfish in a submarine canyon: an example of a natural refuge. *Fishery Bulletin* 98:625-641
[72] Auster, P., et al (1996). The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (Northwest Atlantic): Implications for conservation of fish populations. *Reviews in Fisheries Science* 4:185-202; Koenig, C.C., et al (2000). Protection of fish spawning habitat for the conservation of warm-temperate reef-fish fisheries of shelf-edge reefs of Florida. *Bulletin of Marine Science* 66:593-616; Koslow et al 2001, see note 55; Brown, E.J., et al (2005). Effects of commercial otter trawling on benthic communities in the southeastern Bering Sea. *American Fisheries Society Symposium* 41: in press; Stone, R.P., et al (2005). Effects of bottom trawling on soft-sediment epibenthic communities in the Gulf of Alaska. *American Fisheries Society Symposium* 41: in press

young fish that cannot take refuge in complex structures suffer higher rates of predation.[73] Trawling also greatly reduces the biomass of benthic species[74] and alters the composition of the marine community.[75] By any measure, on a worldwide basis, bottom trawling is the most harmful fishing method to seafloor habitats.

As with fish, habitat-forming animals are vulnerable to bottom trawling because of their extreme longevity.[76] Individual gold corals from seamounts have been estimated to live up to 1,800 years,[77] making them the oldest known animals on Earth, while deep-sea, cold-water coral *Lophelia* reefs are estimated to persist for over 8,000 years.[78] By comparison, the oldest living terrestrial animals are thought to be land tortoises, which live to approximately 170 years of age.[79] Because so many bottom-dwelling deep-sea organisms are extremely slow growing, even a single trawl causes damage that cannot be reversed for decades or even centuries.[80] This is particularly true on seamounts, which have an exceptionally high proportion of endemic species (species that are found in one place and nowhere else).[81] Endemism on seamounts may range as high as 30 to 50 percent.[82] For endemic species, there are no sources for recolonization after a seamount is trawled, so endemism makes seamounts especially vulnerable to trawling.

Bottom trawling can strip seamounts bald. Off Tasmania, Australia, some trawled seamounts are 95 percent bare rock.[83] One comparison of trawled and untrawled seamounts on the Chatham Rise off New Zealand showed that coral habitat covered 52 percent of the seafloor on untrawled seamounts as opposed to two percent on trawled seamounts.[84] On Northwest Challenger Plateau in the Tasman Sea and on the Graveyard seamount complex on Northwest Chatham rise, coral cover on untrawled seamounts was close to 100 percent as opposed to two to three percent on trawled seamounts.[85] Another study found that untrawled seamounts had double the benthic biomass as well as 46 percent more species than trawled seamounts.[86]

[73] Lindholm, J., et al (1999). Habitat-mediated survivorship of juvenile (0-year) Atlantic cod (*Gadus morhua*). *Marine Ecology Progress Series* 180:247-255; Stone et al 2005, see note 72
[74] Jennings et al 2001, see note 24; Koslow et al 2001, see note 55; Kenchington et al 2001, see note 24; Brown et al 2005, see note 72; Collie, J.S., et al (2005). Effects of fishing on gravel habitats: assessment and recovery of benthic megafauna on Georges Bank. *American Fisheries Society Symposium* 41: in press; Gordon, D.C., et al (2005). Summary of the Grand Banks otter trawling experiment (1993–1995): effects on benthic habitat and macrobenthic communities. *American Fisheries Society Symposium* 41: in press
[75] Sainsbury, K.J. (1988). The ecological basis of multispecies fisheries and management of a demersal fishery in tropical Australia. pp. 349-382 in J.A. Gulland, ed. *Fish Population Dynamics.* John Wiley & Sons, Ltd.; Gage, J.D., et al (2005). Potential impacts of deep-sea trawling on the benthic ecosystem along the northern European continental margin: a review. *American Fisheries Society Symposium* 41: in press
[76] Andrews, A.H., et al (2002). Age, growth and radiometric age validation of a deep-sea, habitat-forming gorgonian (*Primnoa resedaeformis*) from the Gulf of Alaska. *Hydrobiologia* 471:101-110; Risk, M.J., et al (2002) Lifespans and growth patterns of two deep-sea corals: *Primnoa resedaeformis* and *Desmophyllum cristagalli. Hydrobiologia* 471:125-131
[77] Druffel, E.R.M., et al (1995). Gerardia: Bristlecone pine of the deep-sea? *Geochemica et Cosmochimica Acta* 59: 5031-5036
[78] Mikkelsen, N., et al (1982). Norwegian corals:radiocarbon and stable isotopes in *Lophelia pertusa. Boreas* 11:163-171; Hovland, M., et al (1998). Ahermatypic coral banks off mid-Norway: evidence for a link with seepage of light hydrocarbons. *Palaios* 13:189-200; Andrews et al 2002, see note 76; Risk et al 2002, see note 76
[79] Stocks, K. (2004). Seamount invertebrates: composition and vulnerability to fishing. pp. 17-25 in T. Morato and D. Pauly D, eds. *Seamounts: Biodiversity and Fisheries.* University of British Columbia, Vancouver
[80] Freiwald, A., et al (2004). *Cold Water Coral Reefs: Out of sight- No longer out of mind.* UNEP World Conservation Monitoring Center, Cambridge (UK)
[81] Koslow et al 2001, see note 55
[82] Stone et al 2004, see note 11; estimate of 30-50% from Richer de Forges et al (2000). Diversity and endemism of the benthic seamount fauna in the southwest Pacific. *Nature* 405: 944-947
[83] Koslow et al 2001, see note 55
[84] Rowden, A.A., et al (2004). *The influence of deep-water coral habitat and fishing on benthic faunal assemblages of seamounts on the Chatham Rise, New Zealand.* ICES paper CM2004/AA:09
[85] Anderson and Clark 2003, see note 66
[86] Koslow et al 2001, see note 55

The rapid disappearance of corals after trawling begins is evident even in fishery statistics. The first pass of a trawl inflicts the most disturbance on the benthic habitat.[87] On South Tasman Rise seamounts, orange roughy fisheries caught an estimated 1.6 tons of coral for each hour of towing a trawl net during the 1997-1998 season, the first year of this fishery. Indeed, the catch of 4,000 tons of orange roughy that first year is estimated to have resulted in a catch of more than 10,000 tons of coral – with presumably much more destroyed or damaged on the seabed below .[88] At the start of the New Zealand fishery that targeted spawning aggregations of orange roughy, bottom trawls brought up a great deal of benthic bycatch, but these levels decreased with repeated trawling.[89]

Trawling damage to deep-sea corals is by no means confined to the Pacific orange roughy fishery. In the North Atlantic, colonies and reefs of the cold-water coral *Lophelia pertusa* have been damaged or smashed to rubble by deep-sea bottom trawling.[90] Trawling has caused extensive coral damage all along the continental margin off Ireland, Scotland, and Norway to depths of 1,300 meters.[91] The Institute for Marine Research in Bergen, Norway, estimates that 30 to 50 percent of deep-sea corals in the Norwegian EEZ have already been damaged by bottom-trawl fishing.[92]

Deep-sea corals are especially vulnerable, not only because they are long-lived, but also because their branched physical forms – evolved so that the capture of drifting food by the individual polyps is at its most efficient – are fragile and easily snagged and cannot, therefore, resist deep-sea bottom trawling.[93] Almost nothing is known about the role played by coral structures in the life histories of deep-sea fish. From what is known about corals in shallower regions, however, it is very likely that this role is substantial, especially during the younger life stages of the fish.

Trawling ancient forests of deep-sea corals is analogous to forest clearcutting.[94] But despite measures taken by some countries within their EEZs, we have not yet even begun to establish refuges for the endemic animals that live on seamounts in international waters. An immediate moratorium on high-seas bottom trawling is needed to preserve these fragile animals while regulators determine how best to manage and protect them.

5. Scientific understanding is inadequate for sustainable deep-sea bottom-trawl fisheries

Without reliable data it is impossible for scientists to provide managers with sound advice. The extent of bottom-trawl fishing in international waters is still poorly known. The FAO states that "it is difficult to assess the development of fishing on the high seas because reports to the FAO of marine catches make no distinction between those taken within EEZs and those taken on the high seas," nor is gear type distinguished.[95] In general, with the exception of the Northwest Atlantic, which is managed by the Northwest Atlantic Fisheries Organization (NAFO), and the waters around Antarctica which are managed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), few data are consistently gathered on high-seas bottom-trawl landings.[96]

Attempts to regulate the exploitation of seamount species such as orange roughy have failed to prevent fishery collapse because these species are very different from shallow-water species in longevity, growth rate, and rate of reproduction.[97] This means that methods of fish stock assessment and fisheries management models developed for shallow-water species are often inappropriate for deep-sea species.[98] In addition, fundamental data about deep-sea fish populations are often lacking or are gathered long after the fish stock has been decimated. Such information for depleted stocks may not apply to populations in their more natural state.[99]

Deep-sea bottom-trawl fishing has generally commenced in the absence of basic biological information essential to sustainable fisheries management. For instance, there was little actually known about the basic biology of the roundnose grenadier (*Coryphaenoides rupestris*) prior to exploitation, and only in 1997 – 30 years after the start of commercial fishing – was it confirmed that this is a long-lived, slowly maturing fish vulnerable to exploitation.[100] Genetic studies have shown that although deep-sea fish apparently have wide geographic ranges, populations are genetically distinct at oceanic, regional, and sub-regional scales.[101] This means that rebuilding exploited stocks through immigration from other populations is unlikely.

It is much easier to kill huge numbers of deep-sea fish in trawls than it is to study these fish as living animals. One consequence of this fact is that scientists have almost no understanding of the roles that either target or bycatch species play in these deep-sea ecosystems. There are reports that some target species occur in the diets of whales,[102] but most deep-sea food webs are still a scientific mystery. And they are likely to remain so if we destroy seamount after seamount in pursuit of their fish. Impacts of trawling on deep-sea fish may have unforeseen consequences on other parts of deep-sea ecosystems about which we, as yet, have little understanding. But to judge from what has happened in shallower waters, selective removal of large fish through trawling will have profound, long-term and probably irreversible impacts on the entire ecosystem, especially on productivity and community structure.[103]

Despite the fact that seamounts are very large features (by definition, they extend upward more than 1,000 meters above the surrounding seafloor), their numbers are poorly known. The true number is in the range of 14,000 to 100,000,[104] but only 350 have been biologically explored, and only 90 of these have been the subjects of quantitative, taxonomically-broad surveys.[105] We only know enough about them to say that they are biologically very special, that their species are uniquely vulnerable, and that seamount ecosystems are rapidly being destroyed by bottom trawling.

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87 Dinmore, T.A., et al (2003). Impact of a large-scale area closure on patterns of fishing disturbance and the consequences for benthic communities. *Ices Journal Of Marine Science* 60(2): 371-380
88 Anderson and Clark 2003, see note 66
89 Probert, P.K., et al (1997). Benthic invertebrate bycatch from a deep-water trawl fishery, Chatham Rise, New Zealand. *Aquatic Conservation: Marine and Freshwater Ecosystems* 7: 27-40; Anderson and Clark 2003, see note 66
90 Rogers, A.D. (1999). The biology of *Lophelia pertusa* (LINNAEUS 1758) and other deep-water reef-forming corals and impacts from human activities. *International Review of Hydrobiology* 84: 315-406; Fosså, J.H., and P.B. Mortensen (2000). The deep-water coral *Lophelia pertusa* in Norwegian waters: distribution and fishery impacts. *Hydrobiologia* 417: 1-12
91 Hall-Spencer et al (2002). Trawling damage to Northeast Atlantic ancient coral reefs. *Proceedings of the Royal Society of London, Series B: Biological Sciences* 269:507-511
92 Fosså and Mortensen 2000, see note 90
93 Stocks 2004, see note 79
94 Watling and Norse 1998, see note 24; Norse and Watling 1999, see note 28
95 FAO 2002, see note 15

96 Gianni 2004, see note 10
97 Morato et al 2004, see note 43
98 Boyer, D.C., et al (2001). The orange roughy fishery off Namibia: Lessons to be learned about managing a developing fishery. Pp205-211 in Paine, A.I.L., Pillar, S.C. and Crawford, R.J.M. (eds.). A decade of Namibian fisheries science. *South African Journal of Marine Science* 23
99 Haedrich et al 2001, see note 46
100 Kelly, C.J., et al (1997). Age estimation, growth, maturity and distribution of the roundnosed grenadier from the Rockall Trough. *Journal of Fish Biology* 50: 1-17
101 e.g., black-spot sea bream, Stockley, B., et al (2005). Genetic population structure in the black-spot sea bream (*Pagellus bogaraveo* Brünnich, 1768) from the NE Atlantic. *Marine Biology* 146:793-804; bluemouth (*Helicolenus dactylopterus*), Aboim, M.A., et al (2005). Genetic structure and history of populations of the deep-sea fish *Helicolenus dactylopterus* (Delaroche, 1809) inferred from mtDNA sequences. *Molecular Ecology*. 14:1343-1354
102 Best, P.B. (1999). Food and feeding of sperm whales *Physeter macrocephalus* off the west coast of South Africa. *South African Journal of Marine Science* 21:393-413; Chikuni 1970 in Humphreys 2000, see note 50
103 Jackson, J.B. et al (2001). Historical over-fishing and the recent collapse of coastal ecosystems. *Science* 293: 629-638
104 Stone et al 2004, see note 11
105 Madin, L.P., et al (2004). The Unknown Ocean. pp 213-236, in L.K. Glover and S.A. Earle, eds. *Defying Ocean's End* Island Press, Washington DC

6. Management and governance are inadequate for sustainable deep-sea bottom-trawl fisheries

On top of the inherent vulnerability of seamount species, the paucity of scientific information about them and the enormous impact of high-seas bottom-trawl fishing, existing mechanisms for protecting, recovering, and ensuring the sustainability of high-seas deep-water resources are extremely poor.[106] Unfortunately, the stark reality is that access to high-seas living resources is virtually unimpeded and unregulated.[107] As deep-sea bottom-trawling fleets have expanded into the high seas, few regional fisheries management organizations (RFMOs) have the competence to regulate deep-sea fisheries, and fewer still have adopted effective regulatory measures.[108]

Several international agreements, including the 1995 UN Fish Stocks Agreement and the UN FAO Code of Conduct for Responsible Fisheries dictate that fisheries should be managed in a sustainable, precautionary and ecosystem-based manner that protects biodiversity, non-target species and special habitats. However, there is little evidence that bottom-trawl fisheries on the high seas, with the exception of the exploratory fisheries regulated by the CCAMLR, are operating in a manner consistent with these requirements.

Vast areas of the oceans lack coverage by an RFMO with the legal competence to manage deep-sea fisheries on the high seas. The entire Indian and Pacific Oceans, as well as the Central and Southwest Atlantic are without effective regulatory mechanisms to mange deep-water fisheries or protect deep-sea biodiversity beyond national jurisdictions. The history of serial depletion and biodiversity destruction in most high-seas deep-water fisheries indicates an urgent need for action. In areas where a need for regulation arises due to the commencement of a deep-sea fishery, the rapidity with which bottom-trawl fleets deplete these populations is such that they may no longer exist once the international institutions are operational.[109]

For example, in the Southwest Indian Ocean ongoing efforts to create an RFMO since the discovery of fishable populations of orange roughy on the high seas in the late 1990s have not yet resulted in an agreement, although it is likely one will be reached in 2005. In the meantime most of the current bottom-trawl fisheries in this region peaked around 2000 and most appear to have been depleted or collapsed by 2002. Moreover, it is clear that current RFMOs with the competence to manage deep-sea fisheries on the high seas, again with the exception of the CCAMLR, have made very little or no effort to discourage harm to deep-sea ecosystems and biodiversity. Fortunately, it appears that at least two RFMOs (the General Fisheries Commission of the Mediterranean and the North-East Atlantic Fisheries Commission) are starting to wake up and take some measures, but these are small and slow steps compared to the urgency of the situation.[110]

Without a comprehensive governance structure for the management of high-seas deep-sea bottom fishing and the protection of seafloor habitats, commercial extinction of most targeted species and biological extinctions of vast numbers of other marine species are likely.

[106] Gjerde, K. and D. Freestone (eds.) (2004). Unfinished Business: Deep Sea Fisheries and the Conservation of Marine Biodiversity Beyond National Jurisdiction. *Special Issue of the International Journal of Marine and Coastal Law* 19(3): 209-364
[107] WWF/IUCN 2001, see note 10; Gorina-Ysern, M., et al (2004). Ocean governance: a new ethos through a world ocean public trust. pp 197-212 in L.K. Glover and S.A. Earle, eds. *Defying Ocean's End* Island Press, Washington DC
[108] Gianni 2004, see note 10
[109] Molenaar, EJ. (2004). Unregulated Deep Sea Fisheries: A need for a Multi-Level Approach. in Unfinished Business: Deep Sea Fisheries and the Conservation of Marine Biodiversity Beyond National Jurisdiction, Special Issue of the *International Journal of Marine and Coastal Law* 19(3): 209-364
[110] Matt Gianni, personal communication

Summary

Deep-sea fish and ecosystems are extremely fragile and highly vulnerable to disturbance from fishing. Deep-sea fish are too often treated by the fishing industry as a non-renewable resource, to be 'mined' until they are no longer economically viable.[111] We can say with near certainty that, given current management practices, all current deep-sea fisheries on the high seas are unsustainable.

Glover and Smith outline all of the potential impacts to the deep sea over the next 25 years. Deep-sea fishing is by far the most certain and intense threat to the most productive and diverse deep-sea ecosystems.[112] Scientists and fisheries managers agree that the greatest threat to biodiversity in the deep-sea is bottom trawling.

Two events in the last six months highlight our scant knowledge about the deep sea. First, in December 2004, a United States Navy nuclear submarine collided with a previously uncharted seamount in the western Pacific. Second, scientists recently described a newly discovered species of black coral that grows to be two meters tall. This was found in the waters just offshore of one of the largest cities in the world, Los Angeles, California. Clearly, humankind's capacity to harm the deep sea has greatly exceeded our knowledge of it. The headlong rush to exploit deep-sea fish on the high seas has, and will undoubtedly continue to, come at a very steep price to the world's biodiversity.

Deep-sea bottom trawling is the most destructive form of fishing and one of the most significant human impacts on the globe. Life-history characteristics of deep-sea fish and benthic invertebrates and the high species-endemism found on seamounts make these species and ecosystems exceptionally vulnerable to over-fishing and disturbance by bottom trawling. Bottom trawling on the high seas is not sustainable given the inadequacy of current management and may very well be unsustainable at even greatly reduced levels of fishing. That is why 1,136 scientists have called for a moratorium on high-seas bottom trawling until the nations of the world can establish strong management measures for deep-sea fisheries and biodiversity on the high seas. They should be heeded.

[111] Clark 2001, see note 51
[112] Glover and Smith, see note 8