Management and Sustainable Harvest of Deep-sea Trawl Resources

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Introduction

Fishing has been crucial to mankind right from the Palaeolithic period (Yellen, et al., 1995). At the beginning, it was a passive exercise, but nowadays, it has taken the form as an enterprise, in particular because of the motorization of crafts, which in turn has brought about the evolution of energetic fishing strategies which include trawling. The diverse fishing strategies have progressed step by step over the millennia. Marine fisheries play a crucial position in India's economy. The industry gives employment and profits to almost a million people. The boom in marine fisheries in the course of the Nineteen Fifties and Seventies has been quicker compared to the inland fisheries. However, in the Eighties and 1990s, the trend has been reversed because the capture fisheries have declined compared to the inland fisheries. During the nineties, the marine fisheries reached a plateau. The present trawling is restricted to 150m depth as 90% of craft operating in Indian water are of 15m OAL and cannot trawl in deeper waters. Most of the commercially important species that are being exploited are displaying symptoms of over-exploitation. The demand for sea food is growing day by day. The present scenario suggests that the current level of marine fish production from the exploited zone has to be sustained by closely monitoring the landings and the fishing effort and by strictly implementing scientific management measures and strategies.

Fishing efforts in coastal waters have begun to increase over the years, primarily due to increased demand and the introduction of new technologies. This eventually reduced the catch per boat. Perhaps, with the exception of some industries, the misconceptions about the inexhaustible nature of coastal fishing are largely over. The world's total catch has decreased by about 500,000 tonnes annually since 1988 (Bhathal, 2005). This threatens global food security, especially the supply of animal protein in developing countries. Here, alternative fish stocks appear in the scenario. Deep sea fishing is an alternative to animal protein. In the current situation, it is necessary to introduce deep-sea fishing vessels equipped with resource-specific fishing vessels such as tuna longline vessels, purse-seining vessels and squid jiggers. These vessels operate offshore only in the Exclusive Economic Zone (EEZ) and beyond on the high seas. There would be no scope of conflict with the traditional sector. However, such a deep-sea fishing fleet would be capital intensive and needs to be encouraged through foreign equity participation as well through technology transfer. The extent of sustainable exploitation of deep-sea resources is doubtful, since the deep-sea ecosystem is very fragile when compared to the coastal zone. Exploitation of offshore resources in the EEZ will have to be reconsidered in terms of not only the resources available, but also in terms of infrastructure. To avoid over capitalisation and ensure a cautious growth of the infrastructure and investments, a rationalised approach will be essential in determining the number and size of fishing vessels, their resource-specific gear as well as the technology to be made available. The development of the deep-sea fishery industry is of concern to the entire marine fishery sector because it would have considerable impact on the management of nearshore fisheries, shore-based infrastructure utilisation and postharvest activities, both for domestic marketing and export. With the pressure to expand world fisheries and exploitation of new stocks, attention off India has expanded into deeper waters, with additional species being added to our known fauna, especially those from deep waters off the Continental Slope (200-1200m) of Indian EEZ and central Indian Ocean. This article briefly describes deep-sea trawlable fishery resources, reviews aspects of their sustainability, and discusses alternative strategies for sustainable exploitation.

The Present Scenario

Deepsea fisheries are those that take place at great depths (up to 1600metres). Many deep-sea fisheries take place in waters beyond national jurisdiction (such as the exclusive economic zone [EEZ]), which is on the high seas. For some, the deep seas have become the iconic last frontier for the expansion of marine fisheries. The great depths and distances from the coast at which marine living resources are caught by deep-sea fisheries in the high seas pose scientific and technical challenges, particularly in providing scientific support for management. A number of governmental and non-governmental organizations with mandates relating to conservation of the environment, biodiversity and management of fisheries have expressed concerns about the likely, known or feared consequences of deep-sea fishing in terms of its effects and impacts on target stocks, associated species and habitats. These concerns are reflected in resolutions adopted by the United Nations General Assembly and led to the adoption of specific recommendations by the FAO Committee on Fisheries at its twenty-seventh session, in March 2007, which prompted the subsequent development and adoption (in August 2008) of the FAO International Guidelines for the Management of Deepsea Fisheries in the High Seas. The types of fishing gear and vessels used in deep-sea fisheries vary greatly, depending on the species targeted and their behaviour. In general, these fisheries are conducted at depths beyond 200 m, on continental slopes or isolated oceanic topographic structures such as seamounts, ridge systems and banks. Some vessels involved in deep-sea fisheries in the high seas may fish exclusively in the high seas, but others also operate within EEZs during the course of the year, either in deep seas or in shallower waters. Most vessels target various species throughout the year and some regularly change fishing gear. These fisheries are competitive and require a high level of investment.

The Past

Small-scale deep-sea fishing using hooks and lines was developed in the early 18th century, and deep-sea trawl nets using factory frozen trawlers began in the mid-1950s. With the expansion of the EEZ since the 1970s, some fleets have lost access to coastal or near-coastal fishing grounds. Some simply stopped operations, while others started deep-sea fishing on the high seas. Since the mid-1990s, depletion of fish stocks within the EEZ, quota restrictions, and technological advances have led vessel operators to seek alternative fishing opportunities outside the EEZ. Until the last few decades, there was little activity or interest in the deep-sea, except for occasional adventures by scientists. For decades, deep-sea fishing has continued to have potential interest in countries where coastal fishing has been completed or overfished (Hopper, 1995). High has been developed on the upper continental shelf (up to 600 m) and is now an important part of commercial fishing in many countries. The industry thrives in developed countries and continents such as Europe, the Soviet Union, the United States, Canada, New Zealand and Australia (Moore, 1999; Koslow et al., 2000; Roberts, 2002). Some of the popular deep-sea fisheries across these nations are, orange roughy (*Hoplostethus atlanticus*), oreos (*Allocyttus niger*, *Pseudocyttus maculatus*), roundnose grenadier (*Coryphaenoides rupestris*), rough head grenadier (*Macrourus berglax*), blue ling (*Molva dypterygia*), black scabbard fish (*Aphanopus carbo*), redfish (*Sebastes mentella*, *S. marinus*), Greenland halibut (*Reinhardtius hippoglossoides*) and deep-water dogfish (*Centroscymnus coelolepis*) Norwegian long-line fishery for ling (*Molva molva*) and the Spanish deep-water long-line fisheries for forkbeard (*Phycis blennoides*) and common mora (*Mora moro*) (Hopper, 1995; Gordon, 2001; Pineiro et al., 2001). The commercially exploited deep-water crustaceans include species such as the red shrimp (*Aristeus antennatus*), the giant red shrimp (*Aristeomorpha foliacea*) and Norway lobster (*Nephrops norvegicus*) from the Mediterranean and adjacent seas (Maria et al., 2001). he situation on the Indian coast for deep ocean trawling has been terribly meagre. Excluding some trails by government vessels, it's virtually negligible.

Catching methods for Deep-sea fishery

Longlines, bottom trawls, bottom trawls, gillnets and traps/pots are employed for fishing in the high seas. Trawling is the predominant bottom fishing method, representing nearly 70 % of vessels on the high seas. Some fisheries, such as orange roughy (*Hoplostethus atlanticus*), usually use technologically advanced fish detection and net monitoring equipment: in these aimed-trawling fisheries, the trawl gear can hardly hit the bottom, whereas different deep-sea trawl fisheries need the trawl to form bottom contact for many hours.

The ecological condition of deep-sea

Ecologically, the word 'deep-sea' will be outlined as part of the ocean deeper than 200m. However, deep-sea trawl fishing is usually about fishing conducted for bottom habitation species below 400 m on the continental slope, seamounts, deep-sea ridges and plateaus and associated underwater features. With current technologies and other fishing methods, fishing has manifested itself right down to depths of roughly 2,000 meters. The ocean floor is roofed by huge plains of sediment created from fine detritus and particles that drift down from the surface. It's the biggest surroundings on earth wherever deep-demersal fish comprise regarding 6.4% of the overall variety of species of fishes that are well-known (Merrett and Haedrich, 1997). The sea atmosphere is dark, cold and less productive. The distribution, habits and physiology of deep-sea organisms are influenced by the everyday environmental conditions of the habitat. The chief physical factors that have an effect on the ichthyofauna within the deep-sea are temperature, light, pressure, seabed and therefore the currents (Fujita et al., 1995; Jacob et al., 1998). Salinity and the quantity of dissolved gas are the most chemical factors that will influence the distribution of fishes (Jacob et al., 1998). On the far side, physical and chemical factors, biological factors conjointly play a key role within the distribution of various faunal assemblages, that embody resource availability, predator-prey relationships, and interspecies competition (Moranta et al., 1998). Fish that live in this advanced atmosphere sometimes develop different physical and physiological adaptations. The oversized portion of deep-sea catch is taken in the North Atlantic., within the East Atlantic, for example, vessels can typically target a spread of species, resembling ling (*Molva dypterygia*), Kalaallit Nunaat halibut (*Reinhardtius hippoglossoides*), roundnose grenadier (*Coryphaenoides rupestris*), black scabbardfish (*Aphanopus carbo*), many species of sharks and additional recently exploited species such as Baird's slickhead (*Alepocephalus bairdii*) and sea red crab (*Chaceon affinis*). The bulk of deep-sea fisheries in this space involve bottom trawlers which can operate deeper water trawls as well, but longliners are smaller in numbers. In other regions, the vessels target a much more limited number of species. For example, in the Southern Ocean, where the fisheries (using longlines) are mainly targeting toothfish (*Dissostichus eleginoides* and *D. mawsoni*). In the South Pacific and the Indian Ocean, many of the bottom fisheries take place over rough geological features (e.g., seamounts and ridges). Bottom trawling for orange roughy is generally done as aimed trawling. Mid-water trawlers, which may operate nets close to the seabed, mainly target alfonsino (*Beryx splendens*). Longliners in the South Pacific typically target species such as hapuka (*Polyprion* spp.), bluenose warehou (*Hyperoglyphe antarctica*) and morwongs (*Nemadactylus* spp.).

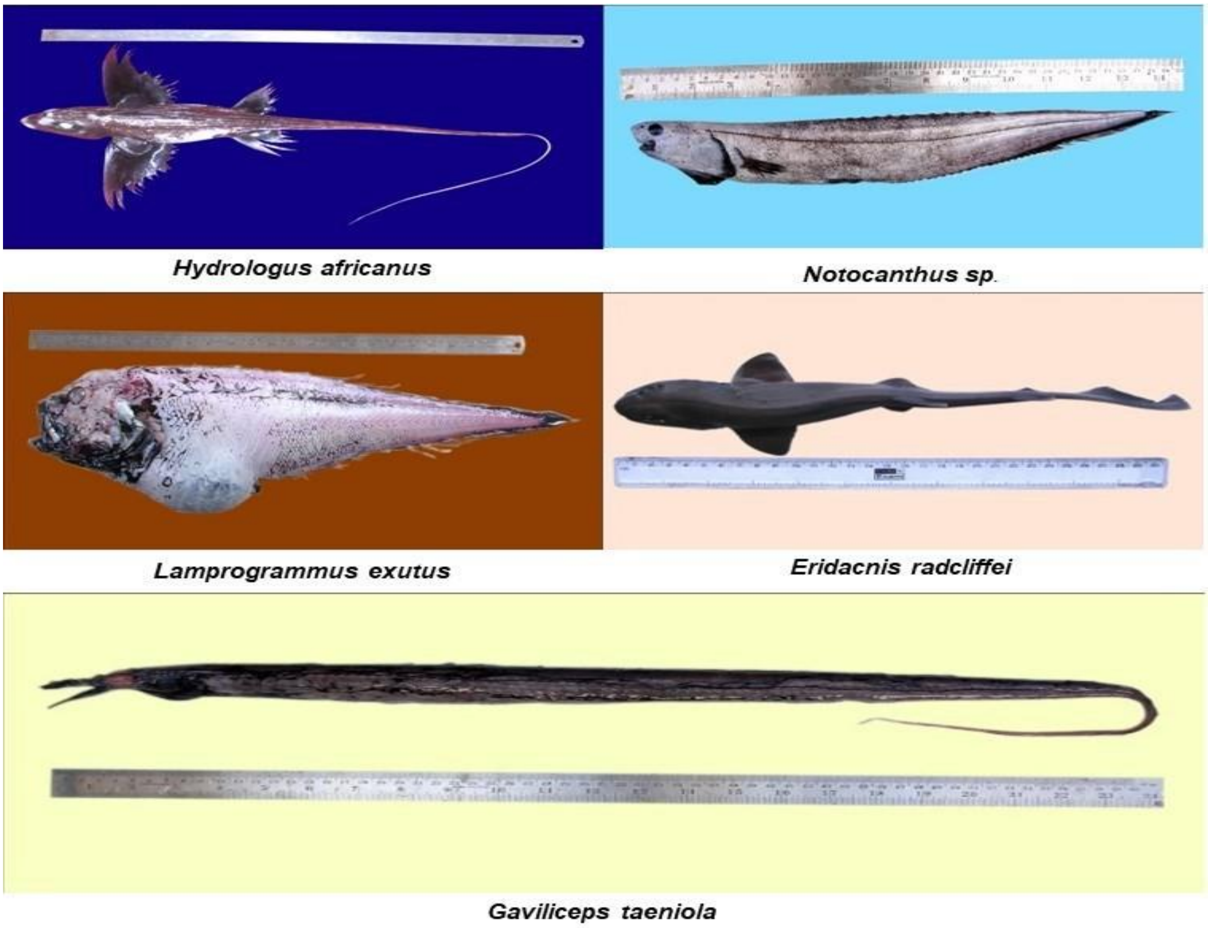

Fig. 1. Deep Sea fishes from Indian waters

Efforts to study deep-sea resources by ICAR-CIFT

Studies have been undertaken via various means by ICAR-CIFT on diverse cruises of FORV Sagar Sampada. Sampling was mainly executed using the EXPO version of fish trawl and ICAR-CIFT's HSDT (Fish & Crustacean Versions). Stocks had been envisioned longitude wise, depth wise and intensity wise alongside the continental slope of the East and West coast of the

Indian EEZ. Eels inclusive of *Bathyuroconger braueri*, *Coloconger rancieps*, *Gavialiceps taeniola* and *Evermannell indica* ruled the catches. Next to the eels were *Echinorhinus brucus* (Bramble shark) and the broad nose cat shark (*Apristurus investigatoris*). Other reasonably considerable resources were Moridae and Chlorophthalamidae. Chlorophthalamidae consisted of *Chlorophthalamus bicornis* and *C. punctatus*. The species that had been recovered past 700m in good intensity were *Lamprogrammus exutus*, *Gaviliceps taeniola*, *Echinorhinus brucus* and *Hydrologus africanus*. Some of the deep-sea non-traditional fish species which figure within the regular catches include *Priacanthus hamrur*, *Chlorophthalamus agassizi*, *Neopenula orientalis* and *Rexea prometheoides* are recognized as capable of unconventional food resources, but value-added products need to be made from those resources. Certain species landed predominantly beyond 500m in Indian territorial waters are *Myctophum* spp., *B. vicinus*, *Halielutaea* sp., *B. moresbyi*, *C. macrolophus*, *A. bicolor*, *Lophiomus* sp., *B. caudimaculata*, *C. raniceps*, *Uranoscopus* sp., *N. pinnata*, *P. cyanea*, *E. radclifei* and *Luciobrotula* spp.

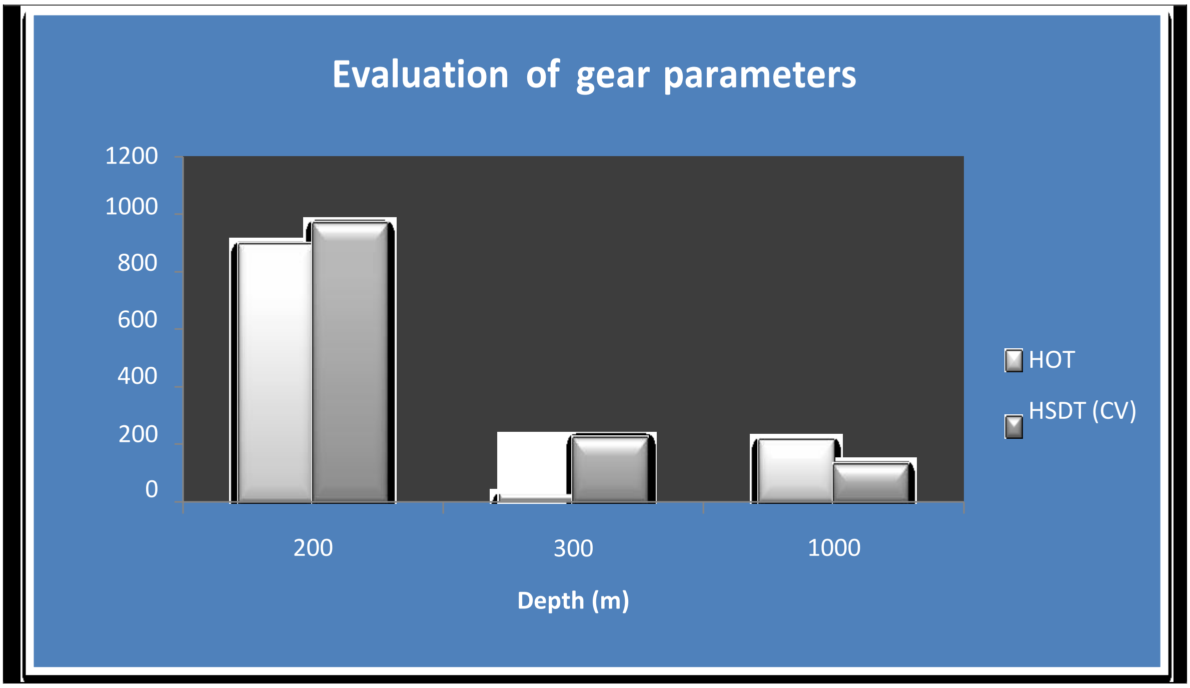

Fig 2. Comparison in catch between High Speed Demersal Trawl Crustacean Version High Opening Trawl

Trawl	No. of fishing operations	Depth	Average of CPUE (Kg/hr)
HSDT (CV)	10	200	968.708
	2	300	222.685
	9	1000	132.393
HOT	3	200	896.639
	8	300	24.1878
	1	1000	214.5

Table 1. Catch details of HDST CV and HOT

Trawl efficiency and performance can be affected by various aspects of gear design and construction and the size of the vessel, which cause selectivity to be size and/or species dependent. Comparison of gear geometry measured during surveys with the HSDT CV (High Speed Demersal Trawl Crustacean Version) trawl and HOT (High Opening Trawl). A total of 38 fishing operations were covered during the four cruises, 26 fishing operations were conducted with HSDT (CV) and 12 fishing operations were conducted with HOT nets.

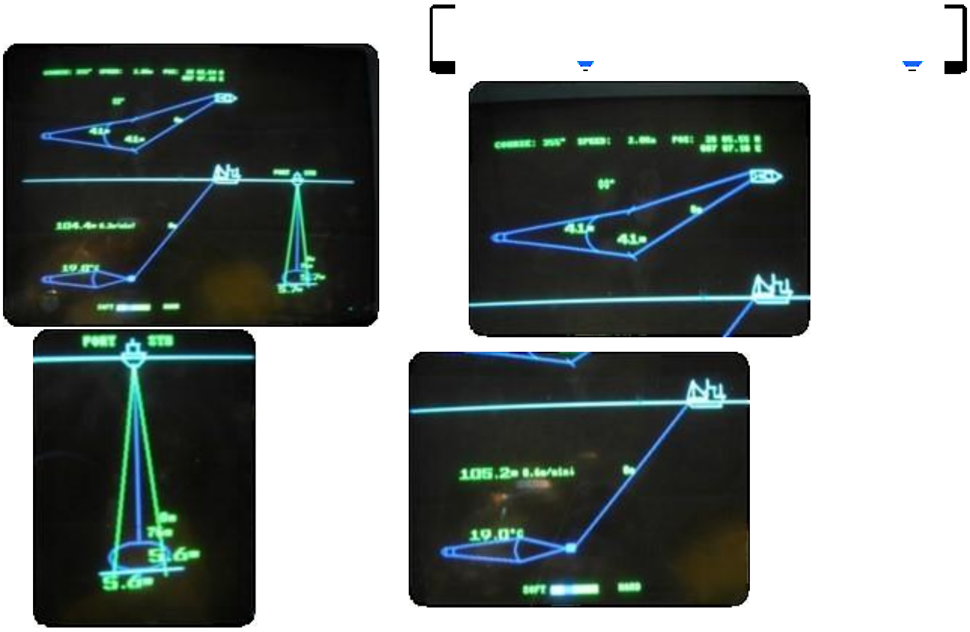

Fig. 3. Gear Parameter study

Vulnerability of the habitat

Human activities, such as fishing, can have a negative impact not only on living marine resources but also on related ecosystems. Species groups, communities or habitats that are easily damaged and take a long time to recover are considered vulnerable. The vulnerability of an ecosystem is related to the vulnerability of its constituent populations, communities or habitats. Features of an ecosystem may be physically vulnerable (i.e. structural elements of the ecosystem may be damaged through direct contact by fishing gear) or functionally vulnerable (i.e. selective removal of a species may change the manner in which the ecosystem functions). The most vulnerable ecosystems are those that are both easily disturbed and slow to recover. Examples of species groups and communities that are considered sensitive and potentially vulnerable include certain coldwater corals and hydroids, some types of sponge-dominated communities and seep or vent communities comprised of unique invertebrate and microbial species. These species and communities may be associated with submerged edges and slopes of the continental shelf, summits and flanks of seamounts, guyots, banks, knolls, and hills, canyons and trenches, hydrothermal vents and cold seeps. The ecological characteristics of deep water fishes can make them vulnerable to over-exploitation, and slow to recover from it. The deep-sea species often have a slow growth rate, high longevity, low fecundity, and hence low productivity. The history of orange roughy fisheries in New Zealand and Australia illustrates the rapid development to a relatively high level, and then an equally dramatic decline (Clark, 2001). The black scabbard fish (*Aphanopus carbo*) is the target of the oldest deep-sea fishery in the world, which takes place off the island of Madeira, Portugal (Merret and Haedrich, 1997; Haedrich et al., 2001). For centuries, this fishery, which only supplied the local markets, seemed to be sustainable. However, since the onset of export, the fishery expanded and the landings have decreased considerably (Merrett and Haedrich, 1997). However, it is not possible to generalize about biological characteristics, as rubyfish (*Plagiogeneion rubiginosum*) are relatively short-lived and fast growing compared with orange roughy. But, it is widely recognized that this deep-sea species is less productive and more vulnerable to fishing pressure than shelf species (Japp & Wilkinson, 2007; Sissenwine & Mace, 2007).

In a global review of deep-water fisheries, Koslow et al. (2000) concluded that deep-water fish stocks are "typically fished down, often within 5-10 years, to the point of commercial extinction or very low levels". Rogers (1994), in reviewing data on fisheries on seamounts worldwide over the previous two decades, concluded that fish stocks associated with seamounts/deep-seas have been consistently exploited at unsustainable levels. The most common reasons given are that there is often little or no understanding of the biology of the target and by-catch fish populations; management measures, where they exist, are often based on poor data; and highly efficient trawl fishing on aggregations of fish on or just above seamounts results in intensive fishing pressure. A common additional problem is the fact that the management regime is either weak or non-existent, a problem which continues today.

Management of Deep-Sea resources

Several renowned fisheries research institutions from the North Atlantic region have undertaken unsurpassed investigations into estimating the biological characteristics and maximum sustainable yields by following standard stock assessment techniques (Gianni, 2004). But, the outcome of basic statistics on catches and effort are of poor quality and in some cases lacking. There is often insufficient information on the general biology of these species, in particular on age and growth, seasonal behaviour, migration, and stock discrimination. These factors always lead to imprecise stock assessments, which ultimately affect the sustainability of the deep-sea fisheries. This concept was well described by Francis & Clark (2005) in the case of orange roughy based on the New Zealand experience. Punt (2005) and Sissenwine & Mace (2007) also discussed the difficulties of orange roughy and how uncertain such stock assessments are likely to be. This uncertainty in fisheries science has, at times, led to insufficient management of resources. The standard management strategies (estimating Maximum Sustainable Yields) applied in several deep-sea fisheries (e.g., orange roughy) has been proven risky and insufficiently conservative.

Future Directions

The ecosystem-based management (EBM) approach is a possible paramount to rescue the deep-sea resources immediately. Various EBM actions now include closed areas, fishing method or gear restrictions, depth limits, catch quotas, by-catch quotas (Probert et al., 2007). The closed areas can help protect, recover and maintain fish stocks, population size, distribution, trophic complexity, ecosystem resilience, habitat structure, biological diversity as well as species feeding, breeding, spawning and nursery grounds. In the management of deep-sea closed areas, there will be a need for science-based criteria and transparent processes for identifying areas appropriate for fishing as well as vulnerable marine ecosystems. Protection of vulnerable deep-sea living resources may require a combination of management tools, which includes complete abandon of bottom contacting trawls, using-off bottom trawls, modification of gears for size selective or species selective, use of much selective long lining, and trap fishing.

Although the North Atlantic deep-sea fisheries have been exploited for a century or more, new deep-sea fisheries are still developing on a global scale. In many countries, like India, the deep-sea fisheries are barely exploited. In recent years, scientists in India have attained interest in deep-sea fisheries as the coastal fisheries have been over exploited and the advancement of harvesting technologies. By considering the past experiences of vulnerability to readily over-exploitation of deep-sea fishes, the upcoming deep-sea fisheries (e.g., Indian deep-sea fisheries) have to adopt strategies combined from standard fisheries management methods as well ecosystem-based management approach.

References

Bhathal, B. 2005. Historical reconstruction of Indian marine fisheries catches, 1950-2000, as a basis for testing the 'Marine Trophic Index'. Fisheries Centre Research Reports 13(4). Fisheries Centre, University of British Columbia, Vancouver, Canada.

Clark, M. 2001. Are deepwater fisheries sustainable? - The example of orange roughy (*Hoplostethus atlanticus*) in New Zealand. *Fish. Res.*, 51: 123-135.

Francis, R. I. C. C. and M. R. Clark. 2005. Sustainability issues for orange roughy fisheries. *Bull. Mar. Sci.*, 76: 337-351.

Fujita, T., T. Inada, and Y. Ishito. 1995. Depth gradient structure of the demersal fish community on the continental shelf and upper slope off Sendai Bay, Japan. *Mar. Ecol. Prog. Ser.*, 118:13-23.

Gianni, M. 2004. High seas bottom trawl fisheries and their impacts on the biodiversity of vulnerable deep-sea ecosystems. Report prepared for IUCN/the World Conservation Union Natural Resources Defense Council WWF International Conservation International. 90 pp.

Gordon, J. 2001. Deep-water fisheries at the Atlantic Frontier. *Continental Shelf Research*, 21: 987-1003p.

Haedrich R.L., N.R. Merret, N.R. O'Dea. 2001. Can ecological knowledge catch up with deep-water fishing? A North Atlantic perspective. *Fish. Res.*, 51: 113-122p.

Hopper, A.G. 1995. Deepwater fisheries of the North Atlantic oceanic slope. In: Proceedings of the NATO Advanced Research Workshop on Deepwater Fisheries of the North Atlantic Oceanic Slope, Hull, UK, 1994. Kluwer Academic Publishers, Dordrecht, Netherlands, 421 pp.

Jacob, W., S. McClatchie, P. K. Probert, and P. J. Hurst. 1998. Demersal fish assemblages off Southern New Zealand in relation to depth and temperature. *Deep-Sea Research I,* 45: 2119-2155.

Japp, D. W., and S. Wilkinson. 2007. Deep-sea resources and fisheries. In: Report and documentation of the expert consultation on deep-sea fisheries in the high seas. *FAO Fish. Rep*., 838: 39-59.

Koslow, J. A., G.W. Boehlert, J. D. M. Gordon, R. L. Haedrich, P. Lorance, and N. Parin. 2000. Continental slope and deep-sea fisheries: implications for a fragile ecosystem. *ICES Journal of Marine Science*, 57: 548–557p.

Koslow, J.A., G. W. Boehlert, J. D. M. Gordon, R. L. Haedrich, P. Lorance, and N. Parin, 2000. Continental slope and deep-sea fisheries: implications for a fragile ecosystem. *ICES Journal of Marine Science*, 57: 548–557p.

Maria J., I. Figueiredo, P. Figueiredo, B. Machado. 2001. Deep-water penaeid shrimps (Crustacea: Decapoda) from off the Portuguese continental slope: an alternative future resource? *Fish. Res.,* 51: 321-326p.

Merrett, N. and R. Haedrich. 1997. Deep-sea demersal fish and fisheries. Chapman & Hall. 280pp.

Merrett, N. R., J. D. M. Gordon, M. Stehmann, R. L. Haedrich, 1991a. Deep demersal fish assemblage structure in the Porcupine Seabight (eastern North Atlantic): slope sampling by three different trawls compared. *J. Mar. Biol. Ass. U. K.,* 71:329-358.

Merrett, N. R., R. L. Haedrich, J. D. M. Gordon, M. Stehmann, 1991b. Deep demersal fish assemblage structure in the Porcupine Seabight (eastern North Atlantic): results of single warp trawling at lower slope to abyssal sounding. *J. Mar. Biol. Ass. U. K.,* 71:359-373.

Moore, J. A. 1999. Deep-sea finfish fisheries: lessons from history. *Fisheries*, 24: 16–21p.

Moranta, J., C. Stefanescu, E. Massuti, B. Morales-Nin and D. Lloris. 1998. Fish community structure and depth related trends on the continental slopes of the Balearic Islands (Algerian Basin, western Mediterranean). *Mar. Ecol. Prog. Ser.*, 171: 247-259.

Pineiro C., M. Casas and R. Banon. 2001 The deep-water exploited by Spanish fleets in the Northeast Atlantic: a review of the current status. *Fish. Res.*, 51: 311- 320.

Probert, P.K., S. Christiansen, K.M. Gjerde, S. Gubbay, and R.S. Santos. 2007. Management and conservation of seamounts. In: T.J. Pitcher, T. Morato, P.J.B. Hart, M.R. Clark, N. Haggan & R.S. Santos (eds.). Seamounts: ecology, fisheries, and conservation. Blackwell Fisheries and Aquatic Resources Series 12, Blackwell Publishing, Oxford, pp. 442-475.

Punt, A. E. 2005. The challenges of, and future prospects for, assessing deepwater marine resources: experience from Australia, New Zealand, Southern Africa and the United States. In: R. Shotton (ed.). Deep sea 2003: conference on the governance and management of deep-sea fisheries. Part 1. Conference papers. *FAO Fish. Proc.*, No. 3/1: 138-148.

Roberts, C. M. 2002. Deep Impact: The Rising Toll of Fishing in the Deep Sea. *Trends in Ecology and Evolution*. 17(5): 242-245.

Rogers, A. D. 1994. The Biology of Seamounts. Advances in Marine Biology Vol. 30, 305-350.

Sissenwine, M. P. and P. M. Mace. 2007. Can deep water fisheries be managed sustainably? In: Report and documentation of the expert consultation on deep-sea fisheries in the high seas. *FAO Fish. Rep.,* 838: 61-111.

Yellen, J. E., Brooks, A. S., Cornelissen, E., Mehlman, M. J and Stewart, K. 1995. A middle stone age worked bone industry from Katanda, Upper Semliki Valley, Zaire. *Science*, 268:553-556.