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Mini Review

Past, Present and Future of Deep-Sea Fisheries in the Global Oceans

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Introduction

In recent years, the intensive study of deep-sea ecosystems (continental slopes, seamounts, depressions and troughs) of the world ocean has received increased attention due to the high level of endemism of their biota and extreme vulnerability to any impacts, especially from humans [1,2]. While in the past, researchers aimed to obtain knowledge, mainly on the qualitative and quantitative composition of the population of deep-sea ecosystems, at the present stage it is becoming increasingly important to assess the human impact on them, to ensure the conservation of biological and genetic diversity, the safe and sustainable use of biological resources and their protection from destruction in the course of human economic activities (fishing, mining, shipping, etc.).

There is no agreed world-wide definition of deep-water species. Setting a depth limit above and under which species would be considered demersal or deep-water dwellers would therefore be arbitrary. In the Atlantic waters, the shelf break occurs around 200 m and International Council for the Exploration of the Sea (ICES) considers deep-sea waters as all waters below 200 m depth. This is in line with the limits used by Food and Agriculture Organization (FAO). ICES uses the following definition of deep-sea fish species: "Deep-sea fish species occur in deep-sea waters and are characterized by one or a combination of the following factors: slow growth, low natural mortality, high longevity, no annual continuous recruitment or spawning season" (http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2015/Special_Requests/EU_deep_waters_stock.pdf).

According to the FAO (http://www.fao.org/fishery/topic/4440/en) deep-sea fisheries might be characterized by following features:

a. Deep-sea fisheries take place at great depths (between 200-2000 meters);

b. Fishing grounds are on continental slopes, oceanic seamounts, ridge systems, and banks;

c. Targets are demersal or benthic species;

d. Deep-sea fisheries use a range of gears including bottom and mid-water trawls, traps, gill nets, and longlines;

e. Deep-sea fisheries take place in both exclusive economic zones (EEZs) and in areas beyond national jurisdiction (ABNJ);

f. Most of these fisheries require significant investment;

g. The types of fishing gear, vessels and people employed in these fisheries vary greatly;

h. They include small-scale deep-sea fisheries though the majority are commercial with technologically advanced operations using a variety of gears.

Small-scale deep-sea fisheries using hooks and lines developed in the early 1800s while trawl fisheries for deep-sea species using factory freezer trawlers started in the mid-1950s. With the extension of EEZs, starting in the 1970s, several fleets no longer had access to coastal or near-shore fishing grounds; some simply ceased operations while others began developing deep-sea fisheries in the high seas. Since the mid-1990s, the reduction of fish stocks inside EEZs, quota limits and technological advances have increasingly led vessel operators to seek alternative fishing opportunities outside EEZs. The first large-scale deep-sea fishery catches are from 1956 by the Soviet Union. From here onwards, catches steadily increased through the 1960s, after which there were three major periods

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of peak catches. These peaks represent sudden increases in catch of one or two species, such as Greenland halibut *Reinhardtius hippoglossoides* and longfin codling *Laemonema longipes*, whose populations were newly discovered and rapidly exploited. While the early catches were dominated by just a few species from one or two areas, the deep-sea fisheries history becomes more complex, adding more species and regions, with large estimated unreported catches between 1985 and 2010 and an estimated about 600,000 t of fish being caught in the mid-1970s, late 1980s and early 2000s [3].

Comparisons between the FAO records and the reconstructed catches by the project "Sea Around Us" [3] show a steady increase in both data series for the number of species being caught, or at least recorded. This can be expected in the FAO data series, as a large number of species were not reported in the past, because of different regulation or the species were often grouped under a category of "nei." However, the reconstructions also show an increase in the diversity of species being caught, with an increase of up to 30 species from the 1950s to the modern period. The analysis showed that the average depth of the catch increased continuously between 1950 and 2006, revealing a trend of fishing for deeper water species [4]. When presenting the results for deep-sea species only, the analysis shows an increase in the average depth of catches in the same period of about 128 m (from 407 m in 1950 to 535 m in 2006). Fishing deeper water species means fishing for increasingly longer-lived and thus more vulnerable species. The mean longevity of species reported by the EU fleet catch increased with depth from about 13 years for shallow water species to about 25 years for intermediate species and about 60 years for deep-sea species [4].

Deep-sea fishing is currently one of the most significant impacts of human activities on deep-sea ecosystems [5], which occurs on the continental slope (toothfishes *Dissostichus* spp., grenadiers Macrouridae, rockfishes *Sebastes* spp., Greenland halibut, thornyheads *Sebastolobus* spp., sablefish *Anoplopoma fimbria*, threadfin codling, skates Rajidae, Arhynchobatidae, etc.), seamounts (pelagic armorhead *Pseudopentaceros wheeleri*, orange roughy *Hoplostethus atlanticus*, alfonsinos *Beryx* spp., etc.) and in high seas (blue whitings *Micromesistius* spp., beaked redfish *Sebastes mentella*, etc.). The reduction of stocks of traditional fishery targets on the shelf of the world ocean in the middle of the last century was a powerful impetus for the development of deep-sea fishing on the continental slope and in remote ocean areas, which allowed to catch 0.8-1.0 million tons annually since the mid-1960s. Between 1950 and 2015, about 25 million tons were caught in deep-sea fisheries, accounting for only about 0.5% of the total catch [3]. The number of species involved in deep-sea fisheries has been growing steadily from year to year. Thus, if in 1950 there were about 30 of them, now it is more than 60 [3]. It should noted that deep-sea fishery targets, despite their relative scarcity, have great demand and high market value, which makes their fishery attractive and highly profitable.

However, deep-sea fishing also has a "reverse side". By the beginning of the new century, most deep-sea fish resources were overfished or depleted [1,6], which is related to the biology of most deep-sea fish species, such as late maturation, slow growth, low fecundity and long lifespan [5-9]. Such specific life history traits of deep-sea fishes define the rapid depletion of stocks under the impact of fishing with the subsequent very slow recovery, which often requires decades [1,10].

The distribution of global catches of deep-sea fisheries between 1950 and 2015 shows that there are four major areas: the North-East Atlantic (8.86 million tons), the North-West Pacific (5.64 million tons), the South-West Pacific (4.28 million tons) and the North-West Atlantic (3.75 million tons), which account for 90.5% of the global deep-sea catch [3]. In the North-East Atlantic prior to the mid-1980s, the catches were dominated by Greenland halibut, which subsequently began to be replaced by beaked redfish amounting in recent years the bulk of the catches. In the North-West Atlantic prior to 1980, a significant proportion of catches consisted of different grenadiers; at present, deep-sea fishing in this area completely dominated by Greenland halibut. In the North-West Pacific in the late 1960s - early 1970s, the catches were dominated by pelagic armorhead, which overfishing off the Emperor Seamounts led to a complete cessation of its fishery in the mid-1970s. From the mid-1970s to the mid-1990s, the catches were dominated by threadfin codling. From 1977 to 2008, a significant proportion of the catches were represented by Kamchatka flounder *Atheresthes evermanni*. Since the early 1980s the development of fisheries for grenadiers began; along with Greenland halibut they currently constitute the basis of deep-sea catches in the area.

Deep-sea fishing on seamounts dates back several decades and began to develop rapidly in the 1970s. The main targets were pelagic armorhead, orange roughy, roundnose grenadier *Coryphaenoides rupestris* and alfonsinos. Currently, this type of fishing has a very limited prospects for a number of reasons:

a. Seamounts are quite far from the coasts and in conditions of rising fuel cost, the profitability of fishing on the seamounts is greatly reduced;

b. Fishes inhabiting seamounts, tend to have long lifespan and low productivity making their stocks greatly affected by fishing, they are rapidly overfishied and very slow recover;

c. Ecosystems of seamounts have a high degree of endemism, marine protected areas or closed areas, where fishing activities are strictly regulated, are often created around them.

At present, stocks of mesopelagic fishes (lanternfishes Myctophidae, black smelts Bathylagidae, pearlsides *Maurolicus* spp., lightfishes *Vinciguerria* spp., etc.), which biomass according to recent estimates exceeds 1 billion tons [11], have the greatest prospect for deep-sea fisheries in the high seas. The development of this colossal resource is of undoubted interest due to the growing volume of aquaculture, which requires an increase of feed production. However, large-scale industrial exploitation of resources of mesopelagic fishes requires

a. An extensive research of the most productive regions of the world ocean, where sustainable and profitable fisheries for mesopelagic fish is possible;

b. Development of effective methods of their capture;

c. Technological research aimed at obtaining, first of all, high-quality feed for aquaculture.

Another problem on the way of exploitation of mesopelagic resources may be the climatic changes. If until recently the greatest stocks of mesopelagic resources were concentrated in the North Atlantic, the Mediterranean, the North-West Pacific and the North-West Indian Ocean, by 2100 in connection with climate change, the most of the biomass in the mesopelagial will be concentrated in the Central-Eastern Pacific, the Sub-Antarctic, the South-East Atlantic and the North-West Pacific [12]. Prospects for the development of deep-sea fishing are seen in the full use of by-catch, which is currently being discarded in most cases, the development of resource-saving technologies for processing of fish raw materials, the search for new and promising fishery targets, the development of new fishing and processing technologies.

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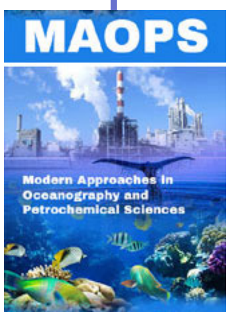

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