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Understanding Overfishing: A Literature Review

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Fishery resources are in danger due to the increase in the world's population, which has led to overfishing, manifested in several ways but very little noticeable and apprehensive. So, to reveal the characteristics of overfishing, a bibliographical synthesis was made. Thus, a typology, manifestations and drawbacks with some methods of overfishing are presented. It is an excessive fishery that leads to a decrease in the average size of individuals caught, a decrease in their reproductive capacity, in their number until their disappearance, and even negative impact on the income of the fishermen. This definition includes: i- growth overfishing, which occurs when juveniles are caught before they have a chance to grow ($Lc_{50} < Lm_{50}$); ii- recruitment or reproduction overfishing, when adult fish are fished in large numbers affecting their reproduction, hence the overfishing of reproduction ($Lm_{50} < L_{opt}$ and % of sexually mature fish in catches below the target reference point; iii- ecosystem overfishing, where the decline of a previously abundant fish stock is not offset by an increase in stocks of other species; iv- economic overfishing, where fishing effort exceeds that necessary to maximize economic rent; v- Malthusian overfishing, which manifests itself in the overpopulation of fishermen making a great effort to maintain their income and sources of animal protein.

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1. INTRODUCTION

Food and economic dependence on fishery resources existed since the dawn of time as a source of food, employment and income [1,2,3,4,5]. For these reasons, human settlements are often established in areas where fish catches are relatively good [6].

Fishing provides more than 3.2 billion people with almost 20% of their average animal protein intake. According to FAO (2022), global capture fisheries should recover and grow by 6% compared to 2020, reaching 96 million tonnes in 2030 [7].

UNEP [8] estimated that 47% of global fish stocks are fully exploited, while 18% are overexploited, leaving no opportunity for replenishment. The remaining stock could also come under pressure from the growing population of the world. According to Somma [9], 47 to 57% of global fish stocks are fully exploited, 15 to 18% overexploited or depleted, and 9 to 10% in recovery. Inland fishing statistics remain unknown, due to the unavailability of data and the fact that the FAO does not have a monitoring system comparable to that used in the marine environment. However, some authors, such as Rurangwa et al. [10], have estimated that inland fishing has already far exceeded its production capacity, given the small size of the fish caught and the small volume of catches, reflecting the overexploitation of rivers and lakes. This overexploitation of fishery resources is expressed through overfishing, which refers to excessive fishing by humans of certain fish or shellfish [11].

Overfishing takes the form of increased catching capacity, leading to a reduction in the number of catches, a drop in the average size and age of catches, a reduction in the average weight of catches and a decline in the stock of individuals able to reproduce. It has become a disruptive factor for stocks and resource replenishment, increasing the vulnerability and loss of productivity of aquatic environments and leading to the decline of certain local economies [11,12] Thus, overfishing manifests in several ways that remain barely perceptible and understandable. Therefore, it is important to do this literature review to provide a better understanding of the phenomenon of overfishing.

2. METHODOLOGY

The search engines used for this bibliographic synthesis are: Google, Google Scholar, Scopus, https://link.springer.com, www.science.gov, www.bioline.org.br, www.pdfdrive.com, www.Base-search.net, www.fao.org. The words or groups of words introduced in these different search engines were fishing, sustainable fishing, overfishing, fisheries, fish stocks, fishery resources, sustainable management of fishery resources.

3. RESULTS AND DISCUSSION

3.1 Typology of Overfishing

Three major considerations can be taken into account to make a typology of the forms of overfishing. These are (i)- the development phenomenon in fish (growth and maturation), (ii)- the ecosystem and (iii)- the level of exploitation of fishery resources in relation to the fishermen.

With regard to the phenomenon of development in fish, it seems important to emphasize that the development of an organism is based on growth and maturation (differentiation). Growth is the increase in size of the organism. It is a quantitative data that can be accessed by measurement, which enables us to appreciate the increase in weight, length or size of an organ or organism over a given period. Maturation means that, at certain periods of development, a tissue or organ changes and/or acquires its function. It is therefore a qualitative data of factor. This is an important phenomenon that can affect the genital organs during puberty, for example. The two processes are actually interrelated with some form of growth being necessary for differentiation to take place. These are two categories of phenomena: quantitative and qualitative. Excessive exploitation of fish during the growth phase corresponds to growth overfishing. Excessive exploitation of mature fish corresponds to recruitment overfishing [13].

Fish generally grow very fast when they are young and then their growth slows down. Theoretically, the best time to catch them is when their growth rate is exactly the same as their probability of dying of natural causes. Several authors [14,15,16] have argued that when small fish that are still growing fast are caught, growth overfishing occurs and the growth potential of each small fish caught is wasted. According to Troadec [17], premature exploitation of young age classes of fish by the use of too small mesh size, for example, reduces the productivity of the stock and the overall exploitation rate.

Recruitment overfishing occurs when adult or mature fish are caught in large numbers, impairing their potential reproductive rate. The number of newly spawned fish that survive at least the first year to become part of the spawning group is known as the recruit. Once there are no longer enough spawning fish to generate sufficient recruitment, we speak of recruitment overfishing. In addition, when the parental stock is severely depleted, the average recruitment and productivity of the stock may weaken; this reduction in average recruitment through overexploitation of the parental stock is then referred to as reproductive overfishing. Thus, recruitment overfishing and reproductive overfishing are equivalent.

Ecosystem overfishing occurs when the decline of a once abundant fish stock is not offset by an increase in stocks of other species. This presupposes that this form of overfishing occurs in a multi-species stock, and strikes a blow against the normal functioning of the food web within the ecosystem.

Economic overfishing occurs when increased fishing effort leads to profit levels below the maximum desired. According to Pauly [13], of the various types of overfishing, economic overfishing appears to be the most interesting to fishery managers and planners. Its appearance, coinciding with falling economic profits, makes it possible to draw up fishery management plans.

By combination of overfishing, according to Hilborn and Hilborn [14], there is a so-called yield overfishing whose two components are: recruitment overfishing and growth overfishing. Therefore, FAO [18] estimated that overfishing results from a combination of growth overfishing and recruitment overfishing, and most often occurs in conjunction with ecosystem overfishing and economic overfishing.

Overfishing has a negative impact on fish resources and their environment. According to Berkowitz [19], overfishing is the intensification of fishing activity that leads to a decline in the number of individuals caught until they disappear, a drop in their average weight and a reduction in the ability of individuals to reproduce. This definition seems to include growth, recruitment and ecosystem overfishing, the sum of which could lead to economic overfishing. In any case, the unsustainable exploitation of fishery resources today is encouraged by the fact that oceans, rivers and water bodies belong to no one, and so their exploitation is non-exclusive or free to all [20]. In contrast to marine areas under the sovereignty (territorial sea) or jurisdiction of the coastal state (exclusive economic zone), the freedom of fish in international waters is legally enshrined [21]. Although four types of overfishing affect fishery resources in specific ways, [22] believes that growth overfishing is one of the main causes of declining yields in many fisheries. This overfishing affects very small fish that have not yet reached sexual maturity. Indeed, the fight against overexploitation of fishery resources presupposes that fish are caught at a relatively larger size, i.e. the size (length) of first capture Lc_{50} must be greater than the size (length) of first sexual maturity L_{50} [23,24,25,26,27]. Selectivity, which aims to select only what we want to catch in order to spare small fish or unwanted species, remains one of the means of sustainable management of fish in the sea, rivers and bodies of water. Although this selectivity can be intraspecific (size selection within the same species) or interspecific (separation between species), it must also be improved by closing areas, for example, during a season when juvenile or spawning fish are abundant: "spatio-temporal" selectivity [28].

3.2 Manifestations and Consequences of Overfishing

Fishing is a threat, not only to resources but also to the ecosystem [29]. Fishing has a direct impact on specifically targeted populations, on long-lived species with low reproductive rates [30]. It also has repercussions on community structure, trophic interactions, benthic fauna and habitat [31,32,33]. Nowadays, improved fishing techniques, larger and more powerful vessels, the manufacture of increasingly resistant nets (synthetic fibers) of larger size, the use of GPS to locate shoals of fish, and the emergence of better conditions for preserving and processing fish products have all contributed to overfishing. Aside from these technology-related aspects, the increase in the population of world, open access, overcapacity, bycatch and the rise in purchasing power in emerging countries have all contributed significantly to the rise in overfishing [8,34,35]. The consequences of overfishing are numerous and can be broken down according to the type of overfishing.

3.3 Growth Overfishing

Growth overfishing occurs when juveniles, which make up the bulk of the stock and are destined to become spawners, are caught before they have a chance to grow [36]. Fishing this age class of fish leads to a reduction in size and premature maturation [27]. Worldwide, 72% of the global fishery resources were being exploited faster than they could reproduce; and industrial fishing has contributed enormously to a rapid decline in fish populations [8]. Fishing for juvenile freshwater pearl mussels in Russia's Baltic Sea basin has led to a collapse in their stock, although the condition of their habitats appears to be quite good [37]. According to Berkowitz [19], one of the consequences of growth overfishing is a drop in the number of individuals fished to extinction, a drop in their average size and age, and a drop in their average weight. This overfishing also occurs on the high seas, where large quantities of juvenile shrimp are either discarded or kept on board for reasons of non-target species.

3.4 Recruitment Overfishing

In a population, any individual that has reached the given size to enter the fishery or the exploitable fish stock. This fish become vulnerable to fishing gear. Thus, in fishery, recruitment overfishing occurs when adult fish are caught in large numbers, impairing their reproduction [13]. When recruitment overfishing persists in an ecosystem, it leads to the disappearance of large individuals and super-reproducers [19].

Indeed, super-reproducers are fish that have reached a length of more than 10% of the optimal size and play a vital role in the long-term survival of a population [38]. As a result of overfishing, 72% of the global fishery resources are exploited faster than they can reproduce [8]. Fish reproduction depends on the presence of spawning grounds, and one of the consequences of overfishing for reproduction is the destruction (reduction) of fish nests through the use of fishing gear, which causes turbulence and disrupts fish reproduction [39].

3.5 Ecosystem Overfishing

Ecosystem overfishing occurs when the decline of a once abundant fish stock is not offset by an increase in stocks of other species [13]. The stock represents the exploitable part of the population of a species in a given area. This stock does not include eggs, larvae or juveniles that have not reached a sufficient size to be caught. Ecosystem overfishing arises from the collapse of a stock that is not compensated by another stock (population of another species). The first stock collapse with worldwide repercussions was linked to the anchovy, *Engraulis ringens* [40]. However, the systematic harvesting of large predators such as tuna and cod, as well as the fishing of crustaceans and molluscs, has led to devastating changes [41]. The direct impact of this action in the oceans, for example, is that the collapse of populations of small fish living closer to the surface, such as sardines or anchovies, can reduce pressure on jellyfish while increasing their food sources. Ecosystem overfishing is also responsible for the disruption of food webs and thus the biomass of the various species in these webs [42,43]. The epipelagic zone being the upper aquatic zone where primary productivity takes place, as it is exposed to sufficient light for photosynthesis to take place, overfishing manifests itself up to 1600 m on the slopes of continental shelves inducing a decrease in fish stocks in the epipelagic zone [19]. These consequences are also felt at the level of benthic communities living on the seabed, whose stocks are declining. The consequences of ecosystem overfishing have affected several fish stocks in the Shire River in Malawi. Overfishing led to the decline of the *chambo* stock (*Oreochromis lodole*). This was replaced by the *kumbuzi* stock, a small fish which accounted for the bulk of catches after the collapse of the *chambo* stock. Later, the *kumbuzi* stock also declined [39].

3.6 Economic Overfishing

Economic overfishing occurs when fishing effort exceeds that required to maximize the economic rent of a fishery [13]. This overfishing leads to a reduction in revenues for both vessels and fishermen. Thus, the economic consequences of overfishing in terms of growth, recruitment and ecosystem are mainly related to the economic profit of fishermen and fishing industry manufacturers. Indeed, overcapacity linked to the presence of too many vessels in certain fishing zones generates this form of overfishing, which contributes to the degradation of resources. It promotes unsustainable fishing, creates a conflict between short- and long-term benefits, and reduces the potential for vital food production for a large number of developing countries [8]. As a result, the world would recover just under $50 million a year by reducing fishing effort and allowing depleted marine resources to be rebuilt to provide sustainably higher catches for a rapidly growing population in the future [44].

There is also a new form of overfishing known as Malthusian overfishing according to Pauly et al. [45], which describes the overpopulation of tropical coastal fisheries by poor fishermen who make great efforts to maintain their incomes and sources of animal protein. This form of overfishing remains widespread in the developing countries of Southeast Asia, where it is entrenched in many of the artisanal fisheries region [46,47]. Indeed, neo-Malthusians believe and argue that population growth, poverty, famine, environmental degradation and lack of alternative livelihoods are major factors in the overexploitation of fishery resources in Southeast Asia [45,48]. For Pauly [49], it is by trying to maintain their incomes that small-scale fishermen in developing countries cause massive destruction of fishery resources, thereby inducing Malthusian overexploitation. We therefore conclude that the way in which man exploits fishery resources for economic survival is at the root of economic and Malthusian overfishing. Yield-related overfishing has repercussions on juvenile and adult fish, affecting the renewal potential of fish stocks in aquatic ecosystems.

All analyses show that fishing activities have a direct impact on the resources they exploit, but also an indirect impact on other species, habitats and the way ecosystems function [50]. Beyond the different types of overfishing, it is inevitable that overfishing manifests itself almost today at all trophic compartments at the level of pelagic species [51]; deep-sea species [52,53]; low trophic levels [54] up to top predators [55,56,57]. Unfortunately, there isn't enough time for biodiversity to renew itself, and this increases its vulnerability, all of which is corroborated by the fact that knowledge of trophic flows within pelagic ecosystems is still too patchy to be able to draw any final, edifying conclusions [58].

3.7 Some Methods for Studying Overfishing

Overfishing occurs when the capacity to extract resources from rivers, lakes, seas and oceans exceeds the capacity to renew them. It implies a level of excessive capture of individuals from a population without taking into account the time it needs to renew itself. As a result, overfishing hampers population growth, reduces the number of spawners and transforms many mature, high-biomass ecosystems into unstable, low-biomass ones.

Diagnosing the state of the stock then enables us to evaluate the intensification of fishing activity on a fish stock. According to Bouvet [59], the stock represents the exploitable part of a fish population made up of adults from several cohorts, where the youngest are the recruits who have just reproduced. This stock evolves as a function of the number of recruits entering it, natural mortality and harvesting by fishing. Reproductive age and life expectancy also influence stock size. In fisheries science, therefore, the assessment of fishing pressure on aquatic resources must take into account a number of biological indicators based on a living component of the ecosystem, whose fluctuations will be studied in order to account for the state of the environment and ecological impacts [60]. Several authors [61,62,63] have suggested that these biological indicators must be: 1) easily measurable; 2) abundant, easy to sample and identify; 3) sensitive to the forcing imposed on the system; 4) respond to the forcing in a predictable and specific way; 5) vary little; 6) generate an understandable and interpretable response; 7) give a representative picture of the environmental condition; and 8) be affordable to monitor and assess.

For all these reasons, Rochet and Trenkel [62] have identified three indicators that can be classified according to their level in the hierarchy of biological organization. Population indicators include intrinsic growth rate, total mortality coefficient (Z), exploitation rate (F/Z) and mean catch size. They also suggest assemblage or settlement indicators that trace the characteristics of populations that could be impacted by fishing, through diversity, dominance and specific composition. Community indicators focus on interaction networks between populations or individuals (total biomass, trophic composition, food web). With this explanatory phase in mind, we describe in detail the method used to study overfishing. The choice of indicators to be assessed: indicators must be linked to the study of population dynamics, and must evolve or diminish as a function of fishing activity. Indicators must be predictable, sensitive to reference points, measurable (total weight, length classes, abundance indices, etc.) and exclusive to fishing. They must not be influenced by other factors extrinsic to the fishing activity. In this way, in the study of overfishing for growth, recruitment, ecosystem and economic reasons, the estimation of mortality remains essential to diagnose the state of a population, since it represents the rate of individuals lost in relation to a population [64].

To assess overfishing for growth, we will look at the sizes of first capture and first sexual maturity of individuals in the population. The size of first sexual maturity (Lm_{50}) is the size at which 50% of individuals of both sexes of a species become mature [23, 24,25,26,27]. The size of first capture (Lc_{50}) represents the total length at which 50% of fish are caught by fishing [23,24,25,26,27]. When $Lc_{50}<Lm_{50}$, the vast majority of a stock of juveniles are caught, and growth overfishing occurs.

Assessment of recruitment (spawning) overfishing will be based on biological indicators such as the size of first sexual maturity (Lm_{50}) and the optimum size (L_{opt}), which represents the size at which the maximum number of fish should be caught to obtain a very high yield. Its formula is: $L_{opt} = L\infty \frac{3}{3+M/K}$ Froese [65], where L∞ and K are parameters of the von Bertalanffy growth function and M is the instantaneous natural mortality rate.

The percentage of sexually mature fish determined by the formula: $L_{90\text{-}100\%} = Lm_{50} \times 1.14$. Where 1.14 = standard value of the ratio Lm_{50} / $L_{90\text{-}100\%}$ [38].

When $Lm_{50} < L_{opt}$ and the % of sexually mature fish in the catch is below the target reference point (100%) the fishery is experiencing recruitment overfishing [65].

The assessment of ecosystem (stock) overfishing will take into account biological indicators including:

- percentage of super-spawners in the catch. These are fish that have reached a length of more than 10% of the optimal size and play a vital role in the long-term survival of a population [38,65];
- fishing yield expressed in kg/ha/year;
- population biomass (B), which corresponds to the total mass (kg) of the available stock, the total weight of existing living matter;
- fishing mortality (F) according to the formula F = Z-M;
- Biomass at Maximum Sustained Yield B_{RMS};
- fishing mortality at Maximum Sustained Yield F_{RMS} and exploitation rate $E = \frac{F}{M+F} = \frac{F}{Z}$ [13]

Eventually, the yield curve takes the shape of a dome and is a function of the fishing exploitation rate (Fig. 1), which is defined by the population biomass (B) and fishing mortality (F). The maximum value of the yield curve (RMS) gives a reference point that determines the critical values of biomass (B_{RMS}) and fishing mortality (F_{RMS}) for a given population. The equilibrium biomass of a population decreases as fishing mortality increases (Fig. 1). Once a critical threshold is exceeded (F_{RMS}, B_{RMS}), increased exploitation leads to the extinction of the population (F_{EXT}), of the stock. This also assumes that the % of super-reproducers in the catch (individuals whose size is greater than the optimal size by at least 10% will be below 20%; this would indicate an endangered stock, and an overexploitation that relates to the extinction of a fish stock is ecosystem overfishing [65].

The assessment of economic overfishing will take into account biological indicators such as:

- Catch per unit effort (CPUE), which represents the ratio between catch (kg) and fishing time;
- Economic Profit (EP) = RT- CT where RT = Total Revenue and CT = Total Cost.

All this will require knowledge of the costs of preparing fishing trips and the selling prices of fish according to different catch sizes.

The relationship between fishing effort and catch level is illustrated by the effort yield curve. In this logic, we assume a linear relationship between effort and cost. The economic rent from fishing is maximized at that level of effort where the difference between total revenue and total cost is greatest, i.e. at effort level Ex in Fig. 2. For this reason, the greatest economic rent is accumulated at A1, or what is considered maximum economic yield (MEY). When effort exceeds this point, economic overfishing is claimed. In other words, the catch per unit effort is increasing and is not proportional to the economic rent, i.e. the difference between gross revenues and fishing costs [48]. This situation, favored by the fishing of small-sized individuals at low selling prices, puts fishermen at an economic disadvantage, making it difficult for them to survive on fishing alone. An overexploited fishery is characterized by low catch rates, low economic returns and over-allocation of resources to industrialists [66,67].

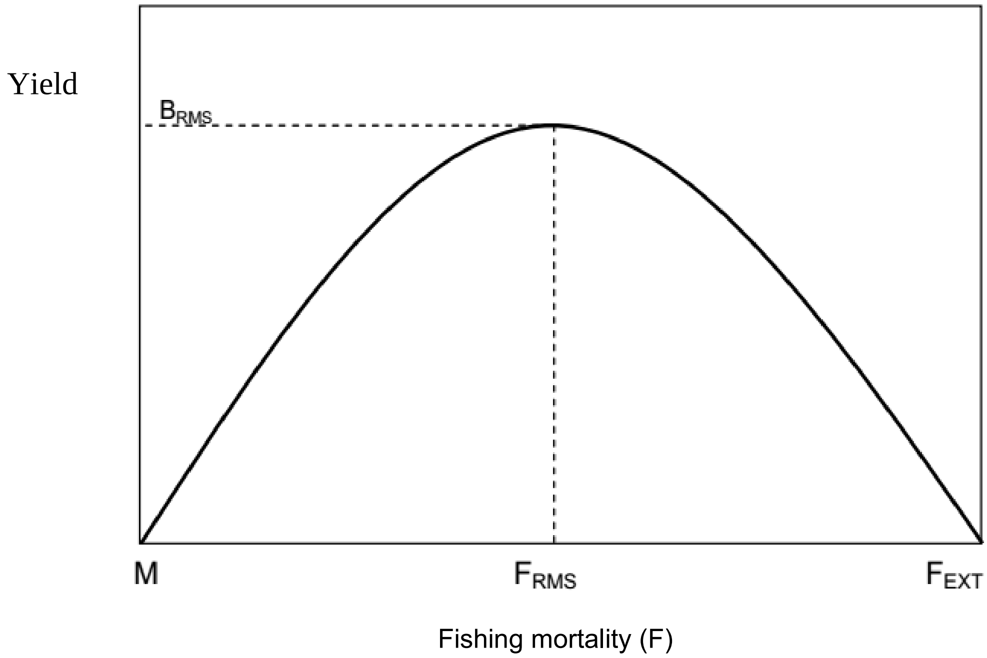

Fig. 1. Resulting equilibrium relationship between yield and fishing mortality [64]

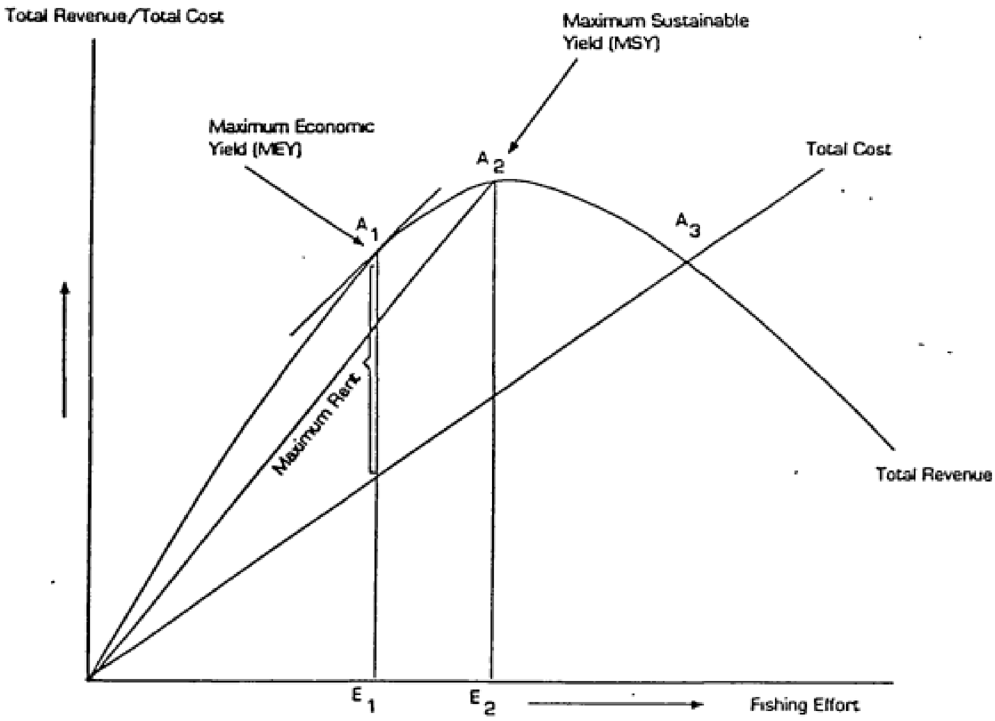

Fig. 2. Long-term yield curve and fishing effort curve [68]

Every instance of overfishing has repercussions on fishery resources, and in turn on people in general, and on fishermen in particular. A number of direct and indirect techniques can be used to regulate fishing effort. These include techniques based on the use of total allowable catches (TACs), spatial and temporal bans, gear restrictions, licenses, territorial use rights and moratoria [69]. Some indirect techniques will be royalties (taxes) on factors of production or consumption and alternative employment schemes for fishermen [69,70].

4. CONCLUSION

Overfishing is proved and remarked in several ways that remain barely perceptible and understandable. This literature review is done to help understanding clearly the phenomenon of overfishing. A compilation of articles and scientific documents dealing with fisheries, sustainable fisheries, overfishing, fish stocks, fisheries resources, sustainable management of fisheries resources are created. It helps in defining the concept, to make the typology and to present the characteristics and overfishing evaluation methods. Thus, overfishing consists in fishing all fish resources available, juveniles (growth overfishing, Lc_{50} < Lm_{50}), adults or mature (recruitment or reproduction overfishing, Lm_{50} < L_{opt} and that the percentage of sexually mature fish in catches is below the target reference point (100%). It can lead to the depletion of a stock (ecosystem overfishing, critical threshold exceedance (F_{RMS}, B_{RMS}), the decrease in the income of fishermen (economic overfishing, fishing effort exceeding that necessary to maximize economic rent) or an increase in fishing effort by an overpopulation of fishermen making a great effort to maintain their income and sources of animal protein (Malthusian overfishing, fishing effort exceeding the maximum economic yield (MEY). The next step would be to consider the biological indicators and to apply the method of study of each type of overfishing stated to assess them.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAO. Food and Organization of the United Nations. Introduction to tropical fish stock assessment. Fisheries technical paper. Rev.2. Rome. 1998;407.
2. Welcomme R, Naeve H. An international symposium on fisheries and society Budapest, Hungary, 01-03 June, 2000. Fish. Mnag. Ecol. 2001;85:283-462.
3. Arlinghaus R, Mehner T, Cowx IG. Reconciling traditional inland fisheries management and sustainability in industrialized countries, with emphasis on Europ. Fish Fish. 2002;3:261-316.
4. Smith DR, Villela RF, Lemarié DP (2003) Application of adaptive cluster sampling to low-density populations of freshwater mussels. Environ. Ecol. Stat. 2003;10:7-15.
5. Njiru M, Kazungu J, Ngugi CC, Gichuki J, Muhoozi L. An overview of the current status of Lake Victoria fisheries: Opportunities, challenges and management strategies. 2008;12.
6. Arnason R. Some Elementary ModelingIdeas. The Management of High Seas Fisheries. 1977;1-97.
7. FAO. Food and Organization of the United Nations. The global situation of fisheries and aquaculture. Towards a blue transformation. 2022;294.
8. UNEP. Overfishing is the main threat to the word's maritime ecology. Environmental Alert Bulletin. 2004;4.
9. Somma A. The ecological consequences and economic costs of the depletion of fish stocks. Economic Outlook: Overexploitation of fishing grounds around the world. Electronic journal of the United States Department of State. 2003;8:16-18.
10. Rurangwa E, Van Den Berg J, Lalèyè PA, A.P, Van Duijn AP, Rothuis A. Exploratory mission on fishing, fish farming and aquaculture in Benin. A quick scan of the sector for possible interventions. 2014;70.
    Stavins RN. The Problem of the Commons: Still Unsettled after 100 Years. Am Econ Rev. 2011;101:81-108.
11. Ekouala L. Sustainable development and the fisheries and aquaculture sector in Gabon: a study of the sustainable

management of fishery resources and their ecosystem in the Estuary and Ogooé Maritime provinces. Doctoral thesis, Université du Littoral Côte d'Opale. 2013; 408.
12. Etoga G. The Governance of Marine and Coastal Biodiversity in the Gulf of Guinea. Thesis and dissertation, University of Nice-Sophia Antipolis. 2009;175.
13. Pauly D. Theory and Practice of Overfishing. A Southeast Asian Perspective. Proceedings of Marine Fisheries Resources in Southeast Asia. Indo-Pacific Fisheries Commission, Darwin, Australia. 1987;146-163.
14. Hilborn R, Hilborn WU. Overfishing, What everyone needs to know. Oxford University Press.1947;169.
15. Pauly D, Christensen C, Dalsgaard J, Froese R, Torres F; Fishing down the food webs. Science. 1998;279:860-863.
16. Christensen V, Guenette S, Heymans JJ, Walters CJ, Watson R, Zeller D, Pauly D. Hundred years decline of North Atlantic predatory fishes. Fish Fish. 2003;4:1-24.
17. Troadec JP. Man and fisheries resources. Essay on the use of a renewable common resource. IFREMER. 1989;817.
18. FAO. Food and Organization of the United Nations. Use of wild fisheries resources for capture-based aquaculture. FAO Technical Guidelines for Responsible Fisheries. 2013;105.
19. Berkowitz H. The problem of overfishing and its management. The Libellio of Aegis. 2014;37-42.
20. Stavins RN. The Problem of the Commons: Still Unsettled after 100 Years. American Economic Review. 2011;101:81-108.
21. Koumga Wanda FJ. The exploitation of fisheries resources in international waters: equity and environmental protection. Master's degree in international law, University of Montreal. 2017;174.
22. Petersen CJ. What is Overfshing? J. Mar. Biolog. Assoc.1903;6:587-595.
23. Tweddle D, Turner JL. Age, growth and natural mortality rates of some cichlid fishes of Lake Malawi. J.Fish Biol. 1997; 10:385-398.
24. Chikou A, Lalèyè PA, Bonou CA, Vandewalle P, Phillipart J-C. First maturity and capture size of six species of catfish in the Ouémé delta in Benin (West Africa). Int. J. biol. chem. Sci. 2011; 5(4):1527-1537.
25. Ahouansou Montcho S, Adjihouede H, Montchowui E, Laleye PA, Moreau J. Population parameters of *Oreochromis niloticus* (Cichlidae) recently introduced in lake Toho (Benin, West Africa. Int. j. fish. aquat. sci. 2015;2(3):141-145.
26. Bédia AT, N'doua ER, Goore GI, Essetchi kouamelan KP, N'douba V. Growth and exploitation parameters of *Chrysichthys nigrodigitatus* (Lecepede, 1803) (Siluriformes, Bagridae) in a tropical lagoon: Ebrié lagoon (Sector I: Potou lagoon, Ivory Coast). Tropicultura. 2017;35 (4):253-261.
27. Koffi KM, Ouattara NI, Bodji IM, Joanny TGT. Parameters of growth and exploitation of stocks of *Trichiurus lepturus* Linnaeus, 1758 (Perciformes, Trichiuridae) living off the Ivorian coast. J Appl Sci. 2020;150:15434-15447.
28. Delporte C. Selectivity of fishing gear and their ecological impact, towards sustainable fishing. BTSM 2nd year, Specialty Fishing and marine environment management. Boulogne/Le Portel maritime professional high school. 2016;32.
29. Cury P, Miserey Y. A sea without fish. Paris, Calmann-Levy. 2008;283.
30. Jenning S, Greenstreet SPR, Reynolds JD. Structural change in an exploited fish community: a sequence of differential fishing effects on species with contrasting life histories. J Anim Ecol. 1999;68:617-627.
31. Jennings S, Kaiser MJ. The effects of fishing on marine ecosystems. Adv. Mar. Biol. 1998;34:203-302.
32. Hall SJ. The effects of fishing on marine ecosystems and communities. Fish Biology and Aquatic Resources Series 1. Oxford Blackwell Science. 1999;274.
33. [33] Gislason H, Sinclair MM, Sainsbury K, O'Boyle R. Symposium overview: incorporating ecosystem objectives within fisheries management. ICES J. Mar. Sci. 2000;57:468-475.
34. UNID. World fisheries: facts and figures. 2010;3.
35. WWF- World Wide Fund for NatureD. Online: <www.wwf.be>, consulted on 03/28/22.
36. Banzon CP, Danilo IC. Overfishing in the Philippine Commercial Marine Fisheries Sector. Philipine Institute for Development Studies. 1997;26.
37. Popov IY. Overfishing in the Baltic Sea Basin in Russia, Its Impact on the Pearl

Mussel, and Possibilities for the Conservation of Riverine Ecosystems in Conditions of High Anthropogenic Pressure. Biology Bulletin. 2017;44:39-44.
38. Ndour I, Diadhiou DH, Le Loc'h F, Ecoutin J-M, Thiaw OT, Titos de Morais L. Diagnosis of the exploitation status of *Mugil cephalus* and *Pomatomus saltatrix* stocks using indicators based on size frequencies on the northern coast of Senegal. Journal of Fisheries and Aquatic Sciences. 2013;6:194-206.
39. Hishamunda N, Thomas M, Brown D, Engle C, Jolly C. Small-Scale Fish Farming in Rwanda: Data Report. Sustainable aquaculture for secure future. 1998;27.
40. Mullon C, Fréon P, Cury P. The dynamics of collapse in world fisheries. Fish Fish. 2005;6:111-120.
41. Ocean. Overfishing: what consequences for us? Transforming European fisheries. 2012;5.
42. Miro Pina V, Penillard A, Postic M, Quévreux P. Impacts of fishing on marine biodiversity. CERES Biodiversity. 2012;15.
43. Claudet J, Cury P, Gascuel D, Hubard R. The impacts of fishing and climate change on fishery resources: what are the challenges for tomorrow. 2020;9.
Accessed on April 12, 2022.
Available:https://hal-agrocampus-ouest.archive-ouverte.fr/hal-03307681.
44. FAO. Food and Organization of the United Nations. The state of food and agriculture. Movingforward on food loss and waste reduction. 2019;182.
45. Pauly D, Silvestre G, Smith IR. On development fisheries and dynamite: brief review of tropical fisheries management. Natural Resource Modeling. 1989;3:307-329.
46. Pauly D. Small-Scale Fisheries in the Tropics: Marginality, Marginalization, and Some Implications for Fisheries Management. In Global Trends: Fisheries Management.1997;40-49.
47. McManus JW. Tropical marine fisheries and the future of coral reefs: brief review with emphasis on Southeast Asia. Coral Reefs. 1997;16:121-127.
48. Pauly D, Chua TE.The overfishing of marine resources: socioeconomic background in Southeast Asia. Ambio. 1988;17(3):200-206.
49. Pauly D. From growth to Malthusian overfishing: stages of fisheries resources misuse. Traditional Marine Resource Management and Knowledge Information Bulletin, South Pacific Commission. 1993; 3:7-14.
50. Moullec F. Impacts of global change on biodiversity in the Mediterranean Sea: an End-to-End modeling approach. Thesis, University of Montpellier. 2019;346.
51. Fromentin JM, Powers JE. Atlantic Bluefin tuna: population dynamics, ecology, fisheries and management. Fish Fish. 2005;6:281-306.
52. Roberts CM. Deep impact: the rising toll of fishing in the deep sea. Trends in Ecology and Evolution. 2002;17:242–245.
53. Clark MR. Deep-sea seamount fisheries: a review of global status and future prospects. LAJAR. 2009;37:501-512
54. White JM, Buhle ER, Ruesink JL, Trimble AC. Evaluation of Olympia Oyster (Osrealurida, Carpenter 1864) Status and Restoration Techniques in Puget Sound, Washington, United States. J. Shellfish R. 2009;28:107-112.
55. Baum JK, Myers RA. Shifting baselines and the decline of pelagic sharks in the Gulf of Mexico: Pelagic sharks declines. Ecol Lett. 2004;7:135-145.
56. Collette BB, Carpenter KE, Polidoro BA, Juan-Jord, MJ, Boustany A, Die DJ, et al. High Value and Long Life-Double Jeopardy for Tunas and Billfishes. Science. 2011; 333:291-292.
57. Ferretti F, Myers RA, Serena F, Lotze HK. Loss of Large Predatory Sharks from the Mediterranean Sea: Large Sharks in the Mediterranean. Conserve Biol. 2008;22: 952-964.
58. Cassiopea CD. International fisheries governance through the case of tunas in the West Central Atlantic. Thesis for obtaining the degrees of master in environment and master in international ecology, University of Sherbrooke. 2015; 122.
59. Bouvet Y. From the sea to the plate: presentation of the fishing industry in the world. Geoconfluences. 2014;22.
60. Linton DM, Warner FG. Biological indicators in the Caribbean coastal zone and their role in integrated coastal management. Ocean Coast. Manag. 2003; 46:261-276.
61. Duquesne S, Riddle M, Schulz R, Liess M. Effects of contaminants in the Antarctic environment potential of the gammarid amphipod crustacean *Paramorea walkeri* as a biological indicator for Antarctic

ecosystems based on toxicity and bioaccumulation of copper and cadmium. Aquati Toxicol. 2000;49:131-143.

62. Rochet M-J, Trenkel MV. Which community indicators can measure the impact of fishing? A review and proposals. Can. J.Fish. Aquat. Sci. 2003;60:86-99.
63. Rice JM, Tochet M-J. A framework for selecting a suite of indicators for fisheries management. ICES J. Mar. Sci. 2005; 62:516-527.
64. Arvisais M, Legault M, Fournier H, Nadeau D. Establishment of pointse biological references to diagnose the state of lake trout (*Salvelinus namaycush*) populations in Quebec. Ministry of Natural Resources and Wildlife, General Directorate of Expertise on Wildlife and its Habitats. Department of aquatic fauna. 2012;27.
65. Froese R. Keep it simple three indicators to deal with overfishing. Fish Fish. 2004; 5:86-91.
66. Anderson LG. The Economics of Fisheries Management John Hopkins Press. Baltimore; 1977.
67. Lawson RM. Economics of fisheries development: Francis Pinter (Publishers). London. 1984;283.
68. Yahaya J, Abdullah NMR. Fisheries Resources Under Stress: The Malaysian Experience. Paper presented at the international Association for the Study of Common Property Fourth Annual Common Property Resource Conference, Manila, Philippines.1993;27.
69. Aguero M. Economic consequences of excessive effort, in Indo Pacific Fishery Commission Symposium on the Commission Symposium on the Exploitation and Management of Marine Fishery Resources in Southeast Asia, IPFC/87/Symp/IV/WP. 1978;3:164-169.
70. Gauthier J-F, Rakotomanana FR, Oubaud F. Is the tax on production factors a solution for taxing informal businesses? Work document. Development and international integration. 1999;32.

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