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Review Article

Fisheries, Aquaculture and Coastal Water Developments

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Abstract

We propose the limitation of fisheries, the expansion of aquaculture, restocking and stock enhancement trough hatchery proliferation, to produce more aquatic food. Multiplication of artificial reefs, filter feeders and algae on long lines, of marine protected areas in coastal waters, allows also to reduce chemical and plastic pollutions and limit water acidification. All these improvements are sometimes better valued by tourism and leisure activities than by professional fishing and gives an increased economical value to all aspects to these environments.

Keywords: Aquaculture; Developments; Economy; Fisheries; Leisure

Introduction

Fisheries and Aquaculture are the two main forms of exploitation of marine resources resulting from the primary production of the ocean (estimated between 50 and 120 billion tons in dry weight by various authors). Fish biomass would be 1 to 2 billion tons dry weight (8 to 20 billion tons wet weight) according to the data reported by Irigoien et al. [1]. Fishing and aquaculture, primarily, exploit waters near continents and islands. The continental shelves cover 30 to 40 million km^2; coastal areas (≈ 40 km wide band) represent 8% of the ocean surface and produce 80% of the exploited marine resources: The coastal waters, agitated by winds and tides, are richer than those offshore.

Interference, synergy or competition between aquaculture and fisheries relate to the same living aquatic resources, but they are not the only way to value and exploit marine ecosystems. Ecological developments are the other way (maritime transport, marine energy and mineral resources been excluded).

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Fisheries and Aquaculture

Fisheries

In the 1960s-1970s, "Fishery theory" imposed its analytical models for exploiting marine fish populations, but fish stocks collapsed: In Canada, cod catches decreased from 500,000 tons in the 1980s to 50,000 tons in 1992 causing the closure of the fishery and 35,000 unemployed [2]. The forecasts for the year 2000 fisheries varies from 160 to 400 million tons, while the ceiling reached 86.7 million tons in 1996! In all these models, recruitment was considered constant from year to year. However, it is unpredictable in nature: The cross influences of climate and hydrology on the plank tonic larval stages of marine species constitute two unpredictable phenomena involved in a cascade [3-6]. The lack of information on actual stocks, "The inability to predict" is a serious handicap for an economic activity. Another approaches, "Ecosystem-based modeling" [7] or "Large marine ecosystem management" are no more successful in fisheries management, despite some thirty years of effort [8]. Progress towards fisheries reconstruction has been hampered by a lack of political will or by the inability to accept socio-economic consequences in the short term [9]. Added to the failure of science, these disabilities have been exploited by fishermen for widespread overexploitation of fish stocks: It ranges from 50% in the Atlantic to 91% in the Mediterranean for example. Total capture production in marine waters was 83.5 million tonnes in 2015 [10] but illegal fishing (11 to 26 million tons), by catch and discards (20 to 30 million tons), ghost fishing (by lost or forgotten gear), adds to this overfishing. The capacity of the global fishing fleet is two to three times the sustainable harvest threshold. Fisheries subsidies are estimated at between $14 and $35 billion, according to Hoegh-Guldberg et al. [11].

For some countries, such as Australia, Canada, New Zealand, the USA, the strategies are based on the concept of Maximum Sustainable Yield (MSY), i.e., the amount that can be harvested on a long term [12]. These modern fisheries management strategies are a precautionary approach to biomass [13]. Cod stocks are recovering in Canada after two decades of fishing bans [14], but this approach is far from being implemented everywhere. With a production of ≈ 91 million tons, fisheries can be compared to the primary production of the ocean (60 billion tons of C and 600 billion tons fresh weight, according to Irigoien et al. [1]: The fish caught represents less than 1/6,000 of primary production. According to the same work, the Lantern fish biomass (no catch) of the twilight zone (200-1000 m) must be multiplied by 10 and reach 10 billion tons, or 1.3 t of fish per human on Earth!

Aquaculture

The decline of fisheries contrasts with the progress of aquaculture (the art of multiplying and breeding aquatic animals and plants). "A milestone was reached in 2014 when the aquaculture sector's contribution to the supply of fish for human consumption overtook that of wild-caught fish for the first time" [10]. The number of cultivated species exceeds 500 including ≈ 350 fishes, ≈ 100 shellfishes, ≈ 50 crustaceans and ≈ 50 seaweeds. To produce offspring is to control the recruitment. It is necessary to reconstitute the whole life cycle and plank tonic food chain (for feeding the larvae) in the hatchery to obtain these juveniles. Hatcheries produce tens of billions of juveniles of shellfish, crustaceans, salmonids and marine fish which are then grown [15,16].

Conversely, juveniles from the wild can be grown in cages (capture based aquaculture) for tuna and mullets for example in the Mediterranean [17]. These interactions between fisheries and aquaculture have been summarized [18]. Fishmeal from industrial fishing is used for growing caged fish, but this dependence decreases by incorporating soymeal. Trujillo et al., [19] lists 20,976 sea bass and gilthead sea-bream cages on the Mediterranean coast, using data from Google Earth. About 90% of the algae and oysters, 80% of the mussel's world productions are of aquaculture origin. Here again, the offspring caught at sea are often used.

Coastal Waters Developments

For Michael [20] the term "management ... implies the meaning to handle, wield, guide, direct, conduct or control". In the ecological domain "aménagement" (in French) is defined as the "organization of a space by the modification of an ecosystem for the purpose of exploitation or the creation of habitats with a view to promoting the reproduction or implantation of species" [21]. For us, "aménagement" can be translated by developments or improvements of coastal waters aims, to enhance the resources and services of nature while avoiding disturbing ecosystems.

This compromise between human use and the conservation of natural ecosystems joins the concept of sustainable development. Such developments have already existed for a long time: Salt marshes, "Claires" for oysters from Marennes-Oléron (France), "Valli" in Italy, "Tambaks" in Asia, etc. Marine Protected Areas (MPAs) are a form of development. They are not synonymous with integrity or maintenance and should be seen as a form of economic development [22].

Economic value of coastal waters and oceans

The existence of fishing limits or rights, aquaculture concessions in coastal waters, suggest that these users of the sea are the owners, but many other human activities are involved, whose purpose is no longer the production of living resources. Coastal waters become both a capital and an economic resource. Inspired by Böhnke-Henrichs et al., [23] and Rogers et al., [24] we will summarize the main services provided by marine ecosystems:

- Provisioning services: Sea food- Sea water- Raw materials- Biodiversity- Medical- Ornamental
- Regulatory services: Air purification (50% of O^2 production, 30% CO_2 absorption)- Climate regulation (thermal, rains, clouds…)- Waste and pollution removal (dust, dimethyl sulfide, breakdown of pollutants, filtering of water…)- Disturbance prevention
- Habitat Services: Life cycle maintenance- Recreation (SCUBA diving, spear fishing, recreational fishing, beach- Combing, coastal tourism
- Cultural & Amenity Services: Inspiration- Cultural heritage and identity- Sea-scape (like open blue water, reef- scape) etc.,

Hoegh-Guldberg et al., [11] estimate the capital value of the oceans at $24 trillion and they would bring in $2420 billion/year via:

- Direct production (fishing, reefs, algae, etc.): $690 billion
- Trade and maritime transport: $520 billion
- Indirect production (tourism, recreation): $780 billion
- Carbon absorption: $430 billion

Torres and Hanley [25] conducted a comprehensive review of these economic evaluations. We learn both the estimated value of a fish taken by the amateur fisherman (£13), the value of a dive (£70) and that of a beautiful point of view on a port: It increases the value of a 2.95% property in Hong Kong ($15,000); for a small point of view the loss will be 2.18%. The role of climate in the oceans is not evaluated, but can it be?

If coastal waters concentrate 80% of the marine production, the ports are there, and these richer waters absorb more carbon, but now, coastal tourism and leisure constitute the 1st activity of the world economy providing 9 to 12% of the world's population with 1 in 10 jobs worldwide [26]. Along with fisheries and aquaculture, one of UNWTO's goals is "life below water… to sustainably manage and protect marine and coastal ecosystems from pollution, as well as address the impacts of ocean acidification."

Proposals for ecological developments in coastal waters

Thousands of researchers and aquaculturists are at the base of current productions; impossible to name them all. We made our modest contribution to this collective work, but also practiced other activities such as spear fishing for fun (Figure 1) or competition, studied biology of fish, open sea aquaculture (Figure 2), artificial reefs (Figure 3). With the contribution and help of many colleagues, we have editéd or writen books in the field of aquaculture or développements [15,18,27-30].

From these practices we have extracted the propositions below.

Figure 1: Spear fishing of grouper (*Epinephelus marginatus*) in the eighties, near Alméria, South of Spain.

Figure 2: Mussel suspended culture in the open sea (Sète, France). Each 10 m long rope produces ≈ 100 kg in nine months [18].

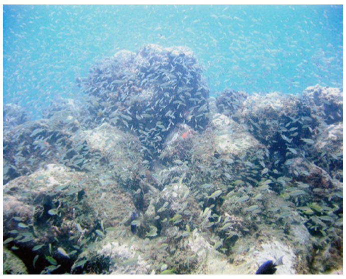

Figure 3: School of young fish above an artificial reef (7 m deep) of rock blocks in Martinique (WFI) [18].

Limitation of Fisheries

Sometimes, fishing for food is not the best way to value fish: An approach has been taken with regard to groupers around the island of Port-Cros (France). A simplified approach is reported by Briquet-Laugier et al. [31]: At 20 € per kilo, a grouper of 15 kg is worth 300 euros. This actualized value of the 280 groupers inventoried is around € 80,000, but they attract tens of thousands of divers a year. With a dive at € 40 and groupers living several tens of years, they constitute a capital one thousand bigger than food value! It is the same at Islas Médas MPA, in Spain (€ 70 diving). The State of The Bahamas has banned shark fishing, and divers participate in impressive feeding sequences [32]. The price of each live shark has been estimated at $250,000! It is the same in French Polynesia, and so on, even if these feedings are not very ecological! With the expenses of transport, residence, boat, fish is very expensive for the recreational fishermen. Currently, in tourist areas, and for some species, the time of the no-kill (take and release) removes to fishing its food function, to refocus on the play activity.

Pisanty [33] reports drastic measures (restriction of the right of access, hight taxes, mesh nets of 70 mm, etc.) set up for the successful rehabilitation of fishing in the Bardawil lagoon (Mediterranea).

Positive interventions are proposed as part of the ecosystem approach to fisheries [7]:

- Limitation of fleet capacity
- Limitation of fishing effort
- Avoid habitat degradation and build new ones
- Repopulation and development of stocks of fingerlings
- Reduction of some populations
- Introduction of species (e.g., top snail and scallops)

So, depending on the local economic context, fishing for food should be limited or even prohibited in some coastal waters, for respect for fish and the environment, when tourism and leisure can enhance the economic value of this ecosystem by snorkeling, diving, recreational fishing or water sports. Damages of trawling on the benthos and pelagic life imposes its total abolition in coastal waters.

To date, only 0.6% of the ocean surface is non-capture areas. Hoegh-Guldberg O [11], reports that the expected benefits for ecosystem services with a 10% expansion of no-capture MPAs in the oceans are estimated at between $622 and $923 billion over the 2015-2050 period. The economic rate of return would be between 9 and 24% [34]. Among other reported examples [18], the estimate of the benefits associated with the use of the Baltic Sea in current environmental conditions is close to $15 billion/year. For the Great Barrier Reef they ranged from US $700 million to US $1.6 billion and the recreational value associated with is worth US $18 to US $40 billion. White and Costello [35], proposed to close the high seas to fishing, but it would be better to close the coastal waters where many species breed.

The hatchery and the mastery of recruitment

The cohorts of hatchery juveniles, produced by hundreds of billions allow the expansion of aquaculture and are also used for restocking, stock enhancement (Figure 4), sea ranching, and transplantation of new species. The Science Consortium for Ocean Replenishment [36] has published numerous studies on these topics.

Estimates of aquaculture turnover are around 160$ billion [10]. Aquaculture production has outpaced fisheries and forecasts for 2050 are around 140 million tons. The value of hatcheries production has not been estimated. Their multiplication is the basis of increases in aquatic productions.

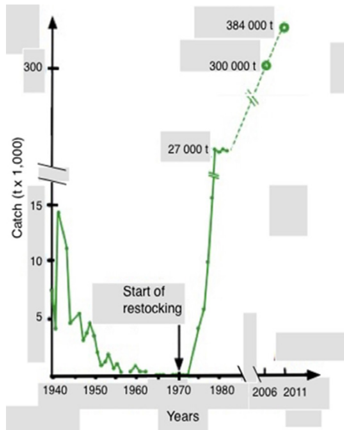

Figure 4: Evolution of scallop catches in the Sarufutsu Coastal Sea (Japan) from 1940 to 2011 (adapted from Anon [37], completed with Seafish [38].

Use of artificial reefs

Artificial reefs have many functions that focus on physical protection (coastal protection, trawling protection) and biological function (recruitment and habitat for algae, invertebrates, fish, upwelling, MPA, etc.). They can also serve as a substrate for filter feeding benthos. To compensate for habitat loss in estuaries and coastal areas, artificial reefs were set up and monitored for five years in the interior of Delaware Bay (United States); the reefs increase the global benthic biomass by a factor between 147 and 895 fold, compared to the initial biomass of the sandy site [39]. The average annual value of services provided by these reefs is $10,325 to $99,421/ha, more than the commercial value derived from harvesting the oysters from a depleted reef.

In Asia, Achoi [40] calculates that they increase fish production from 60 to 2000%.

Japan has 20 million m^3 on 6400 sites covering 1800 km^2 to create new fishing grounds. The catch would vary from 5 to 20 kg/m^3/year (with aggregation).

The wrecks of boats, planes, metro, immersed by the United States are only a fraction of their artificial reefs. The submerged part of the oil platforms has been estimated at 180 million m^3. The highest known annual production of fish biomass was showed on these oil platform by Claisse et al., [41], 27 times greater than for coral reefs. North Carolina (United States) boasts of the number of sunken shipwrecks: "There are so many fish that you can hardly see the wreck through the fish".

The economic impact (recreation and tourism) of the reefs is enormous. There are 2,878 artificial reefs in Florida generating economic activity of $3.1 billion [42]. For Texas, this activity generated revenue of $3.7 billion in 2011 [43]. For comparison, the French professional maritime fishery posted total sales of $1.054 billion in 2012 [44].

Installing filter feeders

Populations of mussels, oysters and other bivalves dominate in coastal waters. Their filtering capacities are as extraordinary as the fineness of the filtration (1 to 2 µm): Smaal and Prins [45] calculate the theoretical filtration times of the waters of some large ecosystems:

- San Francisco Bay: 0.7 day (various species)
- Asko area (Baltic Sea): 0.3 day (mussels)
- Eastern part of the Wadden Sea: 0.5 day (mussels)
- Brest harbor: 2.8 days (various species)
- Thau pond: 2.8 days (suspended oysters and mussels) for 340 million m^3

Bivalves are used for bottom culture (mussels, oysters, scallops) even in rough waters and constitute a "living bottom". Alongside Atlantic states, empty oyster shells are spread on soft bottom [46] and seeded with oyster seed *Crassostrea virginica* to restore exploited oyster stocks and habitats. They filter water for clarity, limiting erosion and being the only hard substrates for flora and fauna (ecosystem services).

Suspended mussel production reaches 250 t/ha/yr (highest livestock production) in the sheltered Rias of Galicia (Spain), but 20 to 40 t/ha/yr on average elsewhere. The filtered plankton is brought by tides and currents, but what a practical advantage! The use of flexible long lines has allowed the cultivation of oyster, mussels and scallops on ropes 10 to 15 m long, on a very large scale. The water depth can exceed 60 m. We have skimmed these aspects of coastal zone aquaculture and open sea [18]. Ögmundarson et al., [47] reviewed the types of long line and anchors used at open sea in 32 countries.

These filterers are also purifiers: The filtering capacity of the mussels is used to clear the Mersey estuary in Liverpool [48], the tropical mussels to purify the discharges of shrimp ponds in South- East Asia, etc. Richards et al., [49] point out that mussel growth is one of the highest in the world on the Gulf of Mexico (50 mm long in 6 to 8 months) where they sometimes form clusters 1.2 m thick.

We propose to use mussel larvae, barnacles larvae or other fouling species to sink the plastics of the great "garbage" patches of the oceans. These invertebrates can spawn under natural factors that stimulate ovulation and spawning. A simple thermal shock in controlled conditions, a strong shaking, triggers for example the spawning of the mussels. Some tons of mussels taken by expedition vessels or installed under drifting rafts (like in rias) will produce hundreds of billions of larvae. These larvae will settle on the only solid substrates available in open water: Plastics. Even with slow growth (poor waters), the apparent weight of these filter feeders will sink the plastic particles to the abyss.

To generalize the use of the long lines in the coastal waters would make possible harvesting the tiny phytoplankton (primary production). This harvest can be used either for the food production or to clean up the waters or fix the CO_2 in the shells [50]. This technique can also be used in the context of climate engineering to limit water acidification.

Installation of seaweeds

With superior nutritional qualities and ten times faster growth than terrestrial plants, algae absorb CO_2, phosphorus and nitrogen. One percent of the ocean surface (3.1 million km^2) would produce an amount equal to that of plants grown on land. They would extend the human life of 4 to 7 years [51]. They have also multiple uses: Carbon sink, bio fuel, animal food, molecules like EPA DHA, pigments, absorption of nitrogen, phosphorus, toxic metals.

Production in dry weight ranges from 10 to 50 t/ha/year, but 100 t/ha/year for the Ulva. Crops are grown on long lines, on horizontal nets (but just below the surface and in shallow waters) or on hard bottom. *Sargassum*, often considered as pests are cultured in South Korea [52]. Algae installation downstream of fish cages allows multitrophic aquaculture.

Production (wet weight) was 28.5 million tonnes of seaweeds and other crops grown (99% in Asia), according to the FAO [10]. The potential of culture is enormous in the West, but limited by several problems (low value because no tradition of culture and consumption, administrative problems, access to sites…)

Extension of Marine Protected Areas (MPAs)

Their extension requires only political will and compliance: Nature will ensure the restoration of biodiversity and stocks. MPAs are numerous and sometimes large, but some are only "paper parks" because there is no control or sanction. We have seen that 10% expansion of no-capture MPAs in the oceans was estimated at between $622 and $923 billion over the years 2015-2050.

Discussion

Hatchery techniques have allowed the production of many marine species by billion. To be able to raise in captivity or restock marine species with hatcheries offspring is a new stage in the history of humanity. These hatcheries, but also fisheries and intensive aquaculture require continuous work and monitoring, while others improvements are more like episodic crop care (long lines for filter feeders, algae culture). After their installation, the artificial reefs, the MPAs need less care, and sometimes only monitoring. These amenities, are integrated into the functioning of ecosystems and allow regulation or changes in natural production.

Increased production of aquaculture and fisheries, conservation and improvement of ecosystems and increased economic values are just one aspect of coastal water management: The cultivation of filtering species and algae, can also reduce chemical and plastics pollutions, fix the CO_2 to limit water acidification. Artificial reefs have been used to allow the natural fixation of filterers that purify the waters [53]. Capacities for water treatment against pollution are as gigantic as their biological potential. Oceans are also the great thermal controller of the climate (physical pump but also biological pump of carbon).

Depending on the economic context, these improvements can be valued by tourism and recreation or fisheries or both at the same time, but all users of these ecosystems insist on the need to eliminate pollution.

Many problems still remains: Ramade [54] clearly expresses the opinion of many ecologists: "The demographic (human) explosion is, in fact, the most gigantic ecological disaster that our species is facing; it is the source of most of the others". The collapse of our civilization is predicted by Oreskes and Conway [55]. They explain that the causes are known (CO_2 and pollution), but that we are unable to act on what we know and stop it. The authors show that the know- how and technological capacity of a transition exist, but that the available technologies will not be implemented in time. The cause would be the compartmentalization of sciences, incapacitating scientists locked in their specialties.

But all the old predictions have not been verified (fishery production, ozone hole, infinite human population, disasters, etc.). Scientific ecology must extend its findings from proposals to action, to protect and value the ocean. Action becomes the missing dimension of ocean research.

Conclusion

What other amenities than those in coastal waters can both produce more food, fight pollution, absorb carbon, regulate the climate, while providing man with the largest spaces for tourism and recreation on the planet? What are we waiting for to develop without end these coastal ecosystems?

References

1. Irigoien X, Klevjer TA, Rostad A, Martinez U, Boyra G et al. (2014). Large mesopelagic fishes biomass and trophic efficiency in the open ocean. Nat Commun 5: 3271.
2. https://en.wikipedia.org/wiki/Collapse_of_the_Atlantic_northwest_cod_fishery
3. Hartline BK (1980) Coastal upwelling: Physical factors feed fish. Science 208: 38-40.
4. Barnabé G (1996) L'exploitation des ressources vivantes marines; changer de stratégie. I Halieutique et Aquaculture. L'Année biologique, 4e série, 35: 163-183.
5. Barnabé G (1996) L'exploitation des ressources vivantes marines; changer de stratégie: II L'aménagement des ressources aquatiques. L'Année biologique , 4e série, 35: 184-202.
6. GLOBEC (2010) Global Ocean Ecosystem Dynamics, GLOBEC International, Plymouth, UK.
7. FAO (2010) Gestion des pêches. FAO Directives techniques pour une pêche responsable. FAO Rome, Italy.
8. http://www.lme.noaa.gov/images/Content/Downloads/DigitalMaps/LME66_watersheds.pdf
9. Ye Y, Cochrane K, Bianchi G, Willmann R, Majkowski J. et al. (2013) Rebuilding global fisheries: The world summit goal, costs and benefits. Fish and Fisheries 14: 174-185.
10. FAO (2016) The state of World Fisheries and Aquaculture. FAO, Rome, Italy.
11. Hoegh-Guldberg O (2015) Reviving the ocean economy: The case for action. WWF, Gland, Switzerland.
12. NOAA (2006) Fishery glossary. National Marine Fisheries Service, NOAA, Maryland, USA.
13. Future Ocean (2013) Getting stock management right. In: The future of fish-The fisheries of the Future. World Ocean Review 5: 94-129.
14. Rose GA, Rowe S (2015) Northern cod comeback. Canadian Journal of Fisheries and Aquatic Sciences 72: 1789-1798.
15. Barnabé G (1990) Rearing bass and gilthead bream. In: Barnabé G (ed.). Aquaculture. Ellis Horwood Publishing Limited, New York, USA. Pg no: 647-683.
16. Nash CE, Novotny AJ (1995) Production of aquatic animals. Elsevier, Amsterdam, USA.
17. Barnabé G, Dewavrin G (2015) Mediterranean Mariculture. Reference Module in Earth Systems and Environmental Sciences. Pg no: 532-536.
18. Barnabé G (2016) Ecologie et aménagement des eaux marines. Editions Lavoisier, Paris, France.
19. Trujillo P, Piroddi C, Jacquet J (2012) Fish farms at sea: The ground truth from Google earth. PLoS One 7: 30546.
20. Michael RG (1987) Managed aquatic ecosystems. Ecosystems of the World, Elsevier, Amsterdam, USA.
21. Parent S (1990) Dictionnaire de l'environnement. Broquet Inc, Ottawa, Canada.
22. UICN (1980) Stratégie mondiale de la conservation. La conservation des ressources vivantes au serviced développement durable. IUCN, Gland, Switzerland.
23. Böhnke-Henrichs A, Baulcomb C, Koss R, Hussain SS, de Groot RS (2013) Typology and indicators of ecosystem services for marine spatial planning and management. J Environ Manage 130: 135-145.
24. Rogers AD, Sumaila UR, Hussain SS, Baulcomb C (2014) The high seas and us: Understanding the value of high-seas ecosystems. Global Ocean Commission.
25. Torres C, Hanley N (2016) Economic valuation of coastal and marine ecosystem services in the 21st century: An overview from a management perspective. Universitat de les Illes Balears 75: 1-218.
26. UNWTO (2017) Annual Report 2016. The World Tourism Organization (UNWTO), Madrid, Spain.
27. Barnabé G (1990) Aquaculture. Ellis Horwood, New York, USA.
28. Barnabé G (1994) Aquaculture, biology and ecology of cultured species. Ellis Horwood Limited, New York, USA.
29. Barnabé G, Marinaro JY, Charbonnel E, Francour P, Ody D (2000) Artificial reefs in France: Analysis, assessments and prospects. In: Jensen A, Collins K, Lockwood A (eds.). Artificials Reefs in European Seas. Chapman and Hall, London. Pg no: 167-184.

30. Barnabé G, Barnabé-Quet R (2000) Ecology and management of coastal waters. The Aquatic Environnment. Springer, London, UK.

31. Briquet-Laugier JC, Chancollon O, Cottalorda JM, Francour P (2007) Vers une évaluation économique du mérou en Méditerranée? In: Francour P, Gratiot J. (eds). 2nd Symposium on Mediterranean Groupers. Nice, France.

32. BBC (2011) Shark fishing banned in the Bahamas. BBC, London, UK.

33. Pisanty S (1981) The fishery and management of the hypersaline lagoon of Bardawil. In GFCM, Management of living resources in the Mediterranean coastal area. Stud Rev Fish Counc Mediterr, 58: 35-73

34. Reuchlin-Hugenholtz E, McKenzie E (2015) Aires marines protégées: Un bon investissement pourlasanté des océans. WWF, Gland, Switzerland.

35. White C, Costello C (2014). Close the High Seas to Fishing? PLoS Biol 12: 1001826.

36. SCORE (2016) Science consortium for ocean replenishment. SCORE.

37. Anon (1990) Working towards equalized income in a fishing village. Fishery Journal 34: 6-7.

38. Seafish (2013) Responsible sourcing guide: Scallops. SEAFISH 3: 1-13.

39. Foster KL, Steimle FW, Muir WC, Kropp RK, Conlin BE (1994) Mitigation potential of habitat replacement: Concrete artificial reef in delaware bay - preliminary results. Bulletin of Marine Science 55: 2-3.

40. Achoi J (2015) Super-men told to monitor fish resources closely. Borneo Post Online, Sabah, Malaysia.

41. Claisse JT, Pondella DJ, Love M, Zahn LA, Williams CM, et al. (2014) Oil platforms off california are among the most productive marine fish habitats globally. Proc Natl Acad Sci USA 111: 15462-15467.

42. Huth B, Morgan A, Burkart C (2015) Measuring Florida artificial reef economic benefits: A synthesis. Florida Artificial Reef Summit, Clearwater Beach, Florida.

43. Gaskill M (2014) Analyzing artificial reefs. Texas Parks and Wildlife, Austin, Texas, USA.

44. Ifremer (2014) Données économiques maritimes françaises. 1 Les produits de la mer. 1.1. Pêches maritimes. Ifremer, Issy-les-Moulineaux, France.

45. Smaal AC, Prins TC (1993) The uptake of organic matter and the release of inorganic nutrients by bivalve suspension feeder beds. In: Dame RF (ed.). Bivalve fillter feeders. Springer, Berlin, Germany. Pg no: 271-298.

46. Coen lD, Hadley N, Shervette V, Anderson B (2011) Managing oysters in South Carolina: A five year program to enhance/restore shellfish stocks and reef habitats through shell planting and technology improvements. Library of Congress, Washington DC, USA.

47. Ögmundarson O, Holmyard J, Pordarson G, Sigursson F, Gunnlaugsdottir H (2011) Offshore aquaculture farming - Report from the initial feasibility study and market requirements for the innovations from the project. Skýrsla Matís.

48. Phelps HL (2005) Use of freshwater mussels to improve water quality within the reflecting pool at constitution gardens. Report to the National Park Service, Washington DC, USA. Pg no: 8.

49. Richards JB, Culver CS, Fusaro C (2009) Shellfish Harvest as a Bio fouling Control. Strategy on Offshore Oil and Gas Platforms. The Ecology of Marine Wind Farms: Perspectives on Impact, Mitigation, Siting and Future Uses, 8th Annual Sea Grant Science Symposium, New Jersey, USA.

50. Filgueira R, Byron CJ, Comeau LA, Costa-Pierce B, Cranford PJ, et al. (2015) An integrated ecosystem approach for assessing the potential role of cultivated bivalve shells as part of the carbon trading system. Mar Ecol Prog Ser 518: 281-287.

51. Institute of Food Technologists (2015) Ocean holds the key to superior nutrition and sustainability. Science Daily, Maryland, USA.

52. Redmond S, Kim JK, Yarish M, Pietrak M, Bricknell I (2014) Culture of *Sargassum* in Korea: Techniques and potential for culture in the U.S. Maine Sea Grant Publications, Orono, Canada.

53. Bartol IK (1994) Intertidal oyster reef as a tool for enhancing settlement, growth, and survival of the oyster Crassostrea virginica. Shellfish Res 13: 280-281.

54. Ramade F (1994) Ecologie, démographie et développement. Plein sud 15: 6-7.

55. Oreskes N, Conway E (2014) The collapse of western civilization: A view from the future. Columbia University Press, New York, USA.