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Chapter 21

Biomass from the Sea

Ernesto A. Chávez and Alejandra Chávez-Hidalgo

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1. Introduction

In the world oceans there is large amount of biomass suspended in the photic zone of water column. Part of the living part is of plant origin, the phytoplankton and other is the animal component or zooplankton. There is also large proportion of particulate organic matter composed by remains of dead animals and feces. They represent the basis of the food webs with three or four trophic levels where all the consumers are animals in whose top the carnivores or top predators, are found. In all aquatic trophic webs, many species are exploited.

2. The primary producers

Nearly 0.3% of solar energy incident on the sea surface is fixed by phytoplankton the tiny plant organisms suspended in natural waters, over the 40-60 meters of the upper water column, accounts to 75% of primary productivity of an area of the word oceans near to $3.5 \cdot 10^{14}$ square meters; the remaining 25% is produced by macro algae. The amount of biomass of all the consumers is based upon primary production by phytoplankton, which range between 0.05 – 0.5 $gCm^{-2}d^{-1}$, but in some very productive upwelling zones or in some grass beds, it can be as high as 5 $gCm^{-2}d^{-1}$ (Russell-Hunter 1970; Margalef 1974; Cushing and Walsh 1976). As a result of this photosynthetic process, the carbon gross production of the sea amounts to 15.5 x 10^{10} mt of Carbon per year, equivalent to a net production of 1.5 x 10^{10} mt, most of it in shore waters. By having in mind the energetic efficiency, these figures amount to 8 per cent of global aquatic primary production (Pauly and Christensen 1995; Friedland et al. 2012), meaning that there is a maximum limit to fisheries production.

Biological production through the fixation of light is a process interacting with the degradation or dissipation of energy by all organisms; in other words, the persistence of life as we know it, depends on a permanent input of energy, which after being fixed and transformed in chemical energy by the plants, is dissipated constantly by all organisms on Earth. Human beings have been able to simplify the food webs channelizing the production

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of a few species which are exploited by man; agriculture systems are a typical example of this process. However, this implies a limit to the maximum potential production of biomass by organisms (Pauly and Christensen 1995; Friedland et al. 2012; Botsford 2012).

3. The secondary producers and food webs

The thermodynamics of the biomass flow and secondary production indicates that the transfer efficiency of carbon in the sea webs may approach to 15 per cent; however, many other authors (in Christensen and Pauly 1993; Pauly and Christensen 1995) adopted the value of 10 per cent. All of the consumers depend from the chemical energy to subsist; this energy is synthesized by the primary producers and transferred to other trophic levels trough consumption by herbivores and then passed to several levels of animals through predation.

Zooplankton, the free-living animals suspended at the water column, are the kind or organisms which make use of the primary production. The main component of this food webs is the group of copepods. Apart o being composed mostly by herbivores, zooplankton also contains many predators of first order, like jelly fish and other crustaceans as larval stages of benthic organisms spending in most cases, from a few days to several months suspended in the water column as predators of micro zooplankton, then being recruited to the benthic communities as they grow.

Caloric value of organisms indicates very uniform qualities through the food web, being higher in those animals storing lipids in their bodies. In sugars and proteins, the caloric value is 4,100 cal g^{-1}, whilst in lipids this value amounts to 9,300 cal g^{-1}, but when these substances are not totally oxidized, the calories available are nearly 90% of their total caloric values. A high production of biomass from the primary producers would be uptaken by the herbivores and transferred to upper levels of the food web. This means that a high primary production will imply high biomass of consumers in proportion following the rule of 10 per cent; this is, for each ton of top predators, there will be 10 mt of predators of first order, and 100 mt of herbivores. The biomass of the carnivores ranges between 0.5 and 2 g C m^{-2} and follows the 10% rule respecting to the lower level. The biomass of primary producers, mainly phytoplankton, may be lower than the herbivores because of their high turnover rate. It is pertinent to mention that upwelling zones of the sea, like in Peru on the west coast of America and West Africa, significant amounts of nutrients are flowing up from the deep sea enriching the surface waters in the photic zone and stimulating the primary productivity. In these zones, the process of evolution has allowed the organization of short food chains, where the sardine and anchovies take advantage exploiting much of this production, allowing the growth of large schools which are exploited by human beings, with levels of exploitation of more than 12 Million mt, as occurred in Peru in the early seventies.

4. The fisheries

The exploitation of aquatic populations by human beings through fisheries, leads to a change in the trophic structure of ecosystems, allowing that opportunistic species, formerly infrequent, to become abundant and reducing the biodiversity; this seems to be the case of squids and jellyfishes. This process determines an increase of the primary production/biomass ratio in the ecosystem. The most productive ecosystems are those associated to upwelling, where the fast growing predators with short life spans, plankton feeders determining the existence of short food chains, allow the existence of very productive fisheries as in the case of anchovy and sardine fisheries. In other natural communities, where the ecosystem usually imposes high environmental stability, top predators usually are animals with long life span in relatively long food chains; in this case, the potential biomass production is low, because the evolutionary forces are oriented towards the density dependent processes, leading to the organization of ecosystems with high biodiversity as occurs in coral reefs. In this kind of communities, the surplus production is almost nule, because the production/consumption ratio approaches zero, severely reducing the capacity of commercial exploitation.

4.1. The logistic curve approach

According to Graham (1939), the maximum yield that can be extracted from a wild stock is found at the half of the virgin size of that population, as seen in Fig. 1A, B. A similar view is commented by Zabel et al. (2003). After this premise, a simplistic approach can be adopted by assuming that when the catch trend shows a maximum, followed by a decline, then that

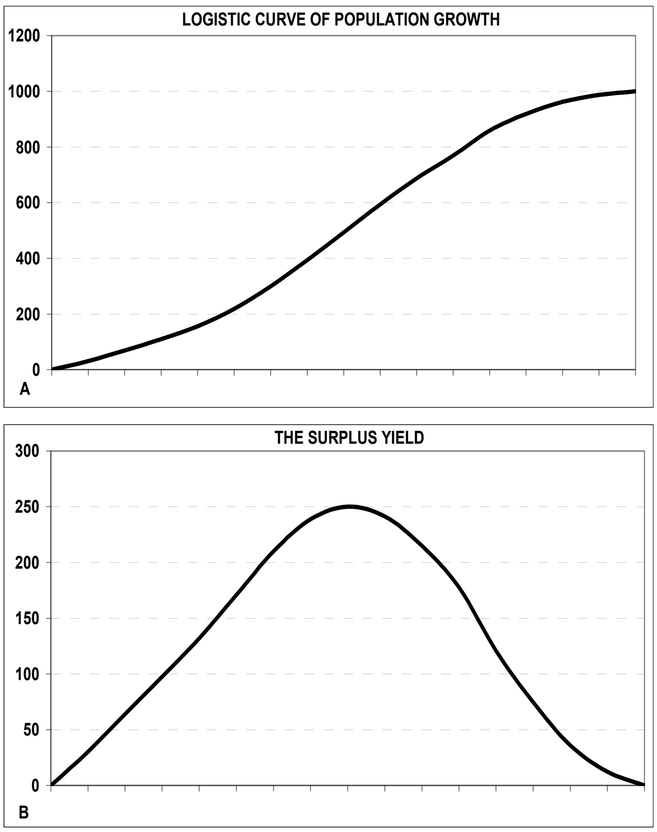

Figure 1. Principles of the logistic growth of a population (A) and the surplus yield of an exploited stock (B). Horizontal scale of Fig. A is time and in Fig. B indicates population size.

maximum yield corresponds to the half of the population size at the virgin stock. Stock assessment based upon this approach is very limited and despite that its ecological principles as background are valid, there are many factors constraining the validity of this procedure and therefore other approaches more accurate and based upon age structure have been adopted over time.

By following the former statements, a simple approach to roughly estimate the stock biomass is by just fitting a parabola to the catch records of some fisheries or regions, even deliberately ignoring a relationship of the stock density of populations, just by usually using the catch per unit of effort as an indicator of stock density. In this case, time was used as an indirect indicator of fishing effort, because the information on this variable is not easily available and because it is beyond the scope of this paper. Therefore, second degree regressions were used to several fisheries and regions just to have an idea on when the maximum yields, presumably equivalent to the Maximum Sustainable Yields (MSY), were attained. It is assumed that the stock biomass is at least twice bigger than the maximum yield attained in a certain time, and in that point is supposed that the exploitation rate E, is 50 per cent. This approach is conservative, because the intrinsic growth rate is not provided, given that many populations are involved. In the stock assessment process, the E value is usually lower than 0.5; however, by considering that many species are involved in the procedure is analysis, is likely to expect that in this collection there may be species which are overexploited, as well as others which may be underexploited. For this reason, it is reasonable to adopt a conservative criterion instead of being too optimistic assuming that the biomass could reach higher values. It is pertinent to mention that most of the regressions applied and described in the following paragraphs excepting three, provided high and significant R^2 coefficients.

On being consistent with this idea, estimations of the MSY by applying a parabola were fitted to catch data of the world fisheries exploited and recorded for different regions as shown in Fig. 2 (A - F) and in Table 1. The time scale of catch extracted from FAO (2010), data goes from 1950 to 2010. It is evident that in most cases the catch has attained a maximum yield, which for practical purposes; it can be considered as equivalent to the MSY level.

4.2. Biomass and fish production

The FAO (1995, 2005) is involved in the task of recording the world statistics of food production and often publishes assessments accounting for the status of world fisheries (FAO 1995, 2005; Froese and Pauly 2012). The catch records are grouped by statistical regions subdivided in 17 sub regions and in the following paragraphs, some highlights on the current status of the fisheries of these regions and sub regions is given, as well as some rough estimations of the biomass on which the exploitation of fish resources is based.

4.2.1. The Atlantic

In the Atlantic North-eastern, the MSY level was attained in the middle eighties (Fig. 2A), with 11.6 million (M) mt; this catch implies a biomass of 23.2 M mt with a significant

REGION	MSY	BIOMASS	Mean 2008 - 10 YIELD	BIOMASS
ATLANTIC NORTHEASTERN	11,600,000	23,200,000	8,600,000	17,200,000
ATLANTIC EASTERN CENTRAL	3,700,000	7,400,000	3,750,000	7,500,000
ATLANTIC SOUTHEASTERN	2,700,000	5,400,000	1,300,000	2,600,000
ATLANTIC NORTHWESTERN	3,500,000	7,000,000	2,400,000	4,800,000
ATLANTIC SOUTHWESTERN	2,650,000	5,300,000	1,840,000	3,680,000
GULF OF MEXICO*	800,000	1,600,000	550,000	1,100,000
TOTAL ATLANTIC	**24,150,000**	**48,300,000**	**17,890,000**	**35,780,000**
PACIFIC NORTHEASTERN	2,950,000	5,900,000	2,440,000	4,880,000
PACIFIC NORTHWESTERN	22,550,000	45,100,000	20,900,000	41,800,000
PACIFIC WESTERN CENTRAL	12,000,000	24,000,000	12,000,000	24,000,000
PACIFIC EASTERN CENTRAL	2,000,000	4,000,000	2,000,000	4,000,000
PACIFIC SOUTHEASTERN	14,500,000	29,000,000	10,900,000	21,800,000
PACIFIC SOUTHWESTERN	800,000	1,600,000	600,000	1,200,000
TOTAL PACIFIC	**54,800,000**	**109,600,000**	**48,840,000**	**97,680,000**
ANTARCTIC INDIAN OCEAN	90,000	180,000	10,000	20,000
INDIAN OCEAN EASTERN	7,000,000	14,000,000	6,800,000	13,600,000
INDIAN OCEAN WESTERN	4,500,000	9,000,000	4,500,000	9,000,000
TOTAL INDIAN OCEAN	**11,590,000**	**23,180,000**	**11,310,000**	**22,620,000**
ANTARCTIC TOTAL	40,000	80,000	5,000	10,000
MEDITERRANEAN & BLACK SEA	1,700,000	3,400,000	1,500,000	3,000,000
OUTSIDE THE ANTARCTIC	80,000	160,000	20,000	40,000
TOTAL MARINE REGIONS	**99,710,000**	**199,420,000**	**79,565,000**	**159,130,000**

*Included in the Atlantic Southwestern region

Table 1. Maximum yields, equivalent to the MSY, of catch data recorded in FAO statistics for the seventeen statistical areas. Biomass estimates of total yields per area within a region and the total for the whole region are indicated. Current average yields, for the years 2008-2010 and their corresponding biomass are also shown on the two right side columns. Values are rounded, in mt.

decrease in biomass of 6 million mt in the last three years (Table 1). In Fig. 2B, the maximum catch of the Atlantic Eastern Central is displayed, and corresponds to 3.7 M mt, attained in the year 2000; this figure corresponds to a biomass of 7.4 M mt, but at the end of the period displays an increase of 100,000 mt. In the Atlantic South eastern, the maximum yield was obtained in the early eighties, with 2.7 M mt (Fig. 2C); the corresponding biomass is 5.4 M mt, with a significant decrease in biomass during the last three years to only 2.6 M mt. The catch trend of the Atlantic North western (Fig. 2D) is declining, with a maximum of 3.5 M mt attained in the early seventies; to this figure corresponds a biomass of 7 M mt (Table 1). The low biomass estimated for the years 2008-2010, with somewhat more than 4.8 M mt, is something to be concerned. The catch trend of the Atlantic South western (Fig. 2E) is not very clear, because it seems to attain a maximum followed by a decline, but the projection of the regression line suggests that the maximum yield will be reached until the year 2030 with

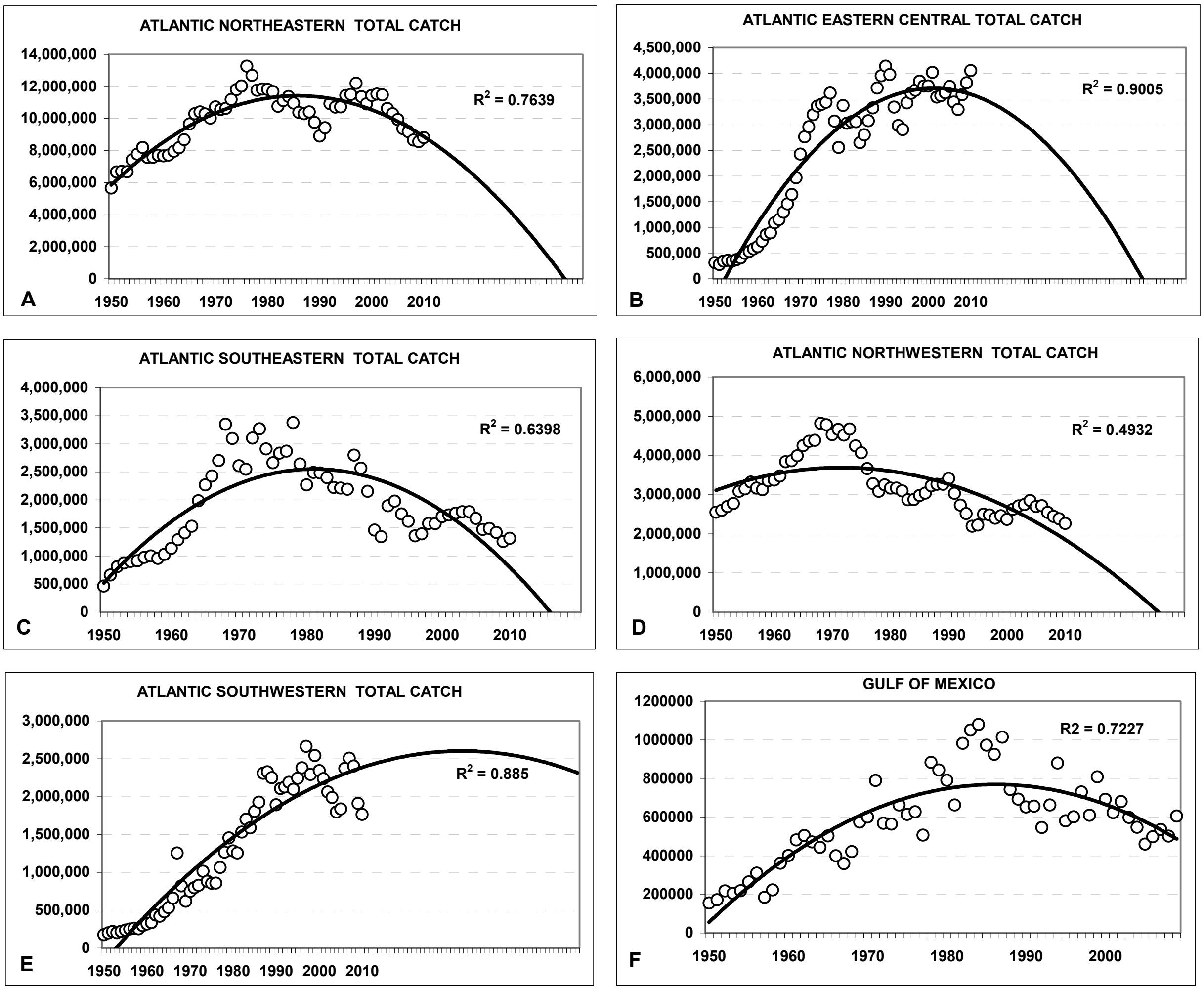

Figure 2. Trend of total catches extracted from several regions of the Atlantic in the period 1950 – 2010. A. Atlantic north eastern; in this region the maximum catches were obtained in the late eighties. B. Atlantic eastern central; the maximum yields were obtained around the year 2000. C. Atlantic south eastern; the maximum yield was obtained in the early eighties. D. Atlantic north western; the maximum yield was obtained by the year 1970, with a declining trend afterwards. E. Atlantic south western. It is not clear whether the maximum yield was attained by the early 2000´s, or it still may grow to a maximum near the year 2030. In the Gulf of Mexico, whose data are included in those of Fig. 2.E, more than 60 species caught and recorded in the statistics, are included in this analysis; here, the MSY was attained in the middle 80´s.

2.65 M mt. The corresponding biomass will be 5.3 M mt (Table 1); the stock current biomass is 3.68 M mt. It was possible to examine with some detail the catch trend of the Gulf of Mexico (Fig. 2F), whose values are part of those for the Atlantic South western; in this case, the maximum yield was obtained in the late eighties with 800,000 mt, with a corresponding biomass of 1.6 Million mt; the current biomass is only 1.1 M mt. The global MSY for the Atlantic Ocean is 24.15 M mt, corresponding to a biomass of 48.3 M mt but these values do not correspond to the same year; unfortunately in all cases but one, current yields were left behind and the current biomass is considerably lower than the figures provided. The current biomass estimated for the Atlantic Ocean amounts to 35.78 M mt (Table 1).

4.2.2. The Pacific

The catch obtained from this region at the maximum yield level, accounts to 62 per cent of world catch, with 54.85M mt (Table 1). The biomass from which this catch was extracted is 109.6 M mt. The current biomass is 89 per cent of the one at the MSY level. In Fig. 3A the catch trend of the Pacific north eastern is displayed; here the maximum yield was recorded by the year 2000, with almost 3 M mt, extracted from a stock biomass of 5.9 M mt; current biomass is unfortunately one Million lower and the trend is declining. In the Pacific north western, a similar trend is displayed (Fig. 3B), the maximum yield was obtained also by the year 2000, with nearly 22.6 M mt corresponding to a biomass of 45.1 M mt. The current

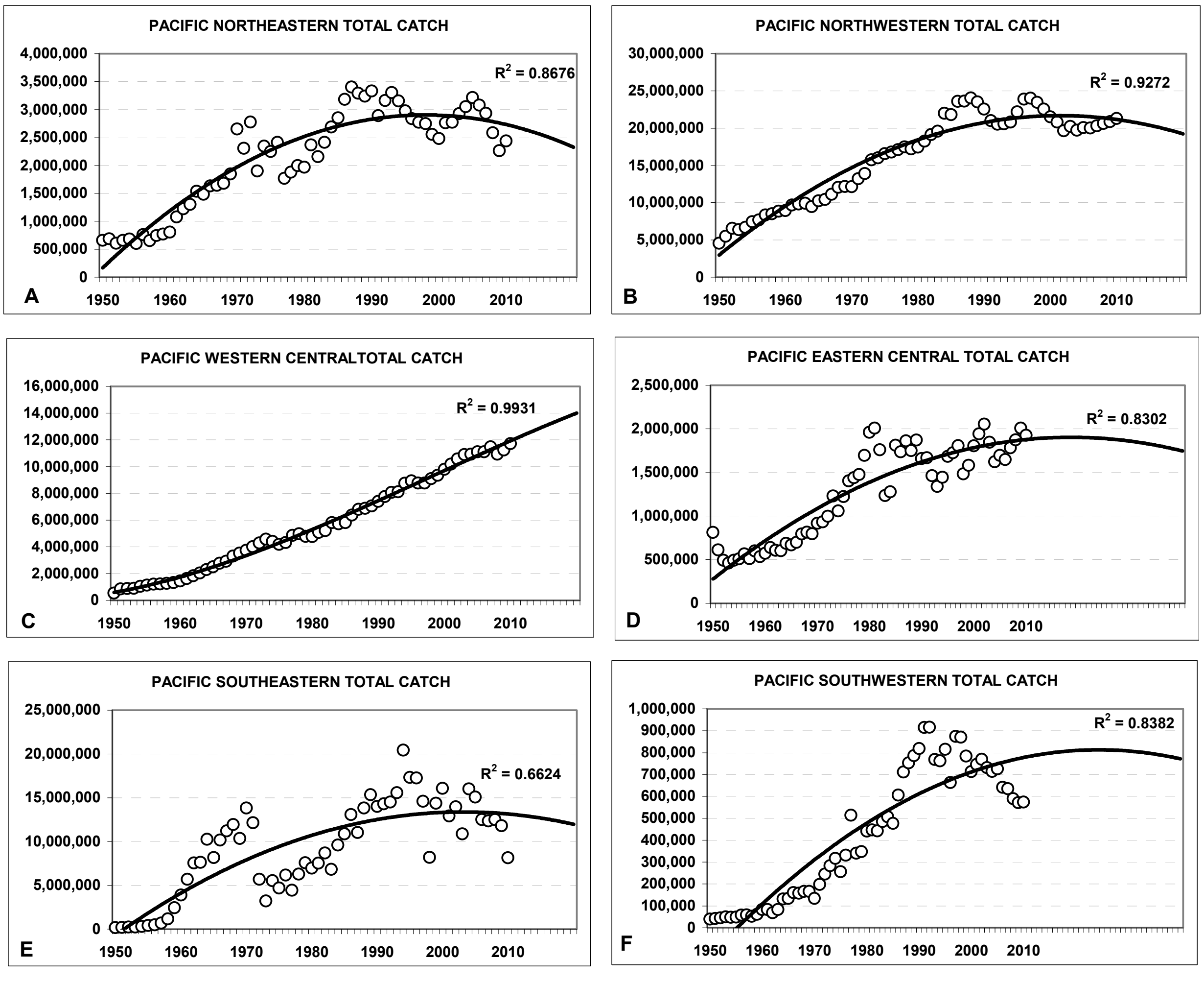

Figure 3. Trend of total catches extracted from several regions of the Pacific Ocean in the period 1950 – 2010. A. Pacific north eastern; in this region the maximum catches were obtained in the late nineties. B. Pacific north western; the maximum yields were obtained around the year 2000. C. Pacific western central; the maximum yield has not been reached and the fisheries seem to be in the eumetric phase. D. Pacific eastern central; the maximum yield seems that will be obtained in the near future. E. Pacific south eastern, the maximum yield was attained in the middle 2000´s, but the catch of the last three years suggests a decline. F. Pacific south western, the trend suggests that the maximum yield has not been reached yet, but the catch has been declining since the last fifteen years.

biomass is 41.8 M mt. The catch of the Pacific western central displays a growing trend with 12 M mt in the last three years (Fig. 3C). To this catch corresponds a stock biomass of 24 M mt; no signs of stabilization of the catch are perceived, which is encouraging. In the Eastern central region, the yield seems to be attaining a maximum with around 2 M mt and a biomass of 4 M mt (Fig. 3D). These values are considered the current ones. The catch of the Pacific western central displays a growing trend with 12 M mt in the last three years (Fig. 3C). To this catch corresponds a stock biomass of 24 M mt; no signs of stabilization of the catch are perceived, which is encouraging. In the Eastern central region, the yield seems to be attaining a maximum with around 2 M mt and a biomass of 4 M mt (Fig. 3D). These values are considered the current ones. The south eastern region displays large variability, and the trend suggests that the maximum was attained a few years before, with a catch of 14.5 M mt corresponding to a biomass of 29 M mt. The mean catch of the last three years indicates a biomass decline to 21.8 M mt. The south western region suggests that the maximum was already attained, but the trend indicates that it will be reached within 15 years or so, with a catch of 800,000 mt and a biomass of 1.6 M mt; the current biomass is only 1.2 M mt.

4.2.3. The Indian Ocean, the Antarctic and the Mediterranean-Black Sea

These regions hardly attain a yield of 14 M mt at the MSY level, being the Indian Ocean the most productive of this group with 12 M mt caught in the whole area. The stock biomass approaches to 24 M mt at the MSY level but at the current exploitation level, this variable implies a reduction of almost 2 M mt, with almost 22 M mt.

The three regions in which it is divided show remarkable differences implying important characteristics in the fishing intensity applied; for instance, the Antarctic zone seems to have been completely overexploited and probably collapsed since 1992 (more recent catch data are not available) and the maximum catch was attained by the early eighties with nearly 100,000 mt as mean trend (Fig. 4A). The same as the Pacific western central, in the Indian ocean eastern the yield describes an increasing trend, with nearly 7 M mt in the last three years, with no signs of stabilization in the near future, which is also encouraging (Fig. 4B). The catch in the western region is also growing, but it seems to be stabilizing currently; the catch is 4.5 M mt corresponding to a maximum stock biomass of 9 M mt (Fig. 4C).

The catch at the Antarctic shows a declining trend, with a maximum yield of nearly 40,000 mt recorded in the middle fifties (Fig. 4D) and a stock biomass of 80,000 mt. Same as the Antarctic Indian Ocean, these fisheries seem to be completely collapsed since the late eighties.

The Mediterranean and Black sea display a quite stable catch trend through the last 30 years and the MSY was attained by the year 1990 with 1.6 M mt, from a biomass of 3.2 M mt. After that year there has been a slow declining trend, such that the current stock biomass is no higher than 3 M mt (Fig. 4E).

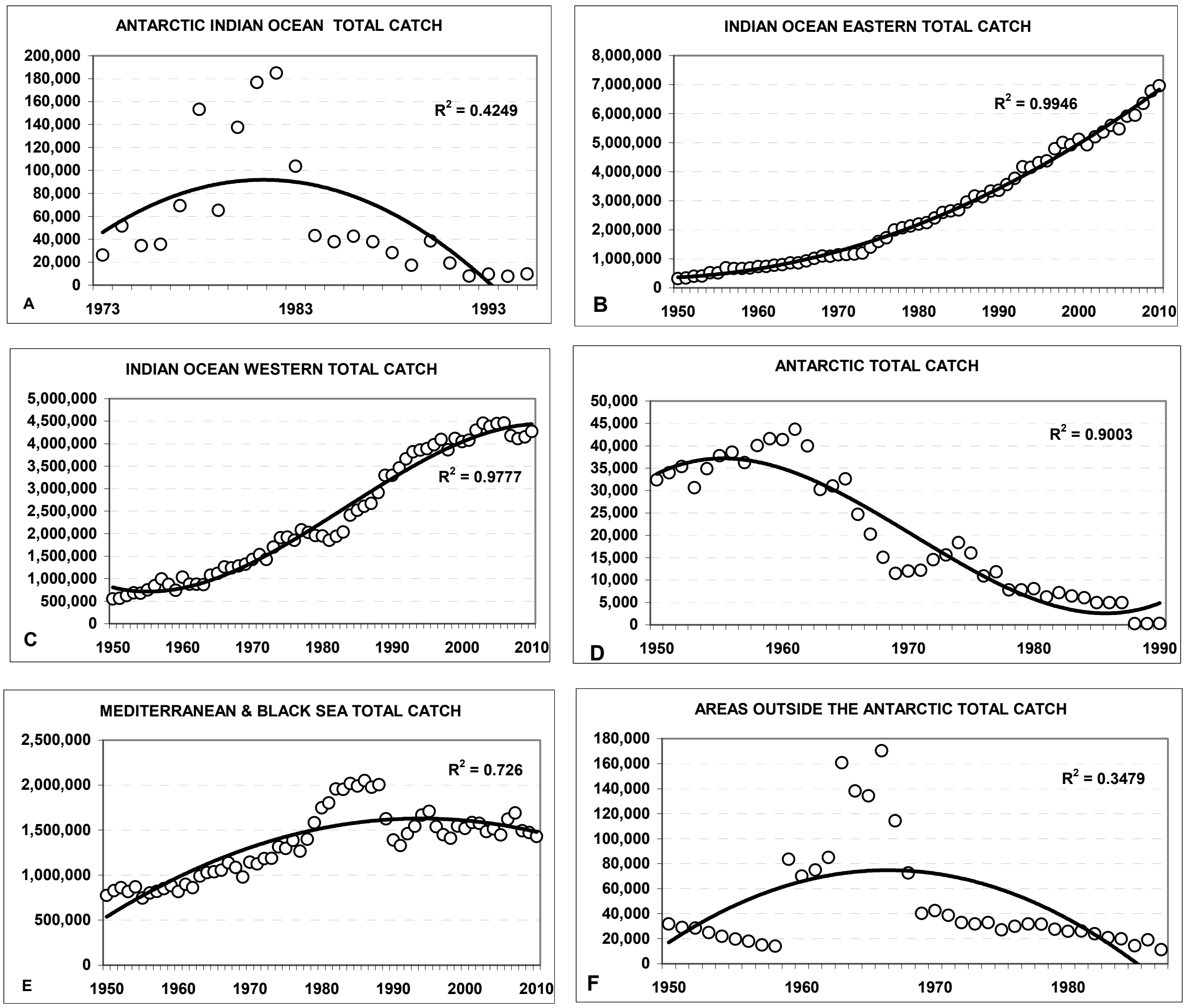

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Figure 4. Trend of total catches extracted from several regions of the Indian Ocean, Antarctic, and Mediterranean-Black Sea in the period 1950 - 2010. A. Antarctic Indian ocean; the maximum yield was obtained in the year 1980 and the fisheries collapsed by the early nineties. B. Indian Ocean eastern; the fisheries are in a eumetric stage of growth nowadays. C. Indian Ocean western; after a sustained growth since the fifties, these fisheries appear to be approaching their MSY level nowadays. D. Antarctic ocean; all information related to this ocean confirms a collapse of its fisheries, as occurred in this case. E. Mediterranean-Black sea; after a period of slow but consistent growth, the MSY appears to have attained the MSY level in the late nineties, followed but a slow decline nowadays. F. The areas outside the Antarctic show the same trend as the Antarctic itself, with an apparent collapse nowadays.

Finally, the areas outside the Antarctic, apart from a peak of the catch in the middle sixties, display low yields that currently are above 11,000 mt from a stock biomass of 40,000 mt. This fishing region appears to be collapsed too.

5. Concluding remarks

The use of surplus yield models for assessment of exploited fish stocks, has becoming an tool hardly used nowadays, because the use of age structured methods with the aid of computing techniques, allow more powerful and more accuracy in the assessments. There were times when fisheries researchers devoted their efforts into that approach and more sophisticated variations of the original statements were made (Walter 1975, 1978; Csirke and Caddy 1983; Arreguín-Sánchez and Chávez 1986; Polacheck et al. 1993; Fréon and Yáñez 1995); however, this approach has became obsolete over time, despite its background ecological principles are still valid. However, the large variance implicit in the estimations caused by several factors, contributed in a great deal to its current lack of use. Despite this consideration, it was decided to adopt that approach in this paper, for several reasons, the first one is it accessibility and easy way to just fitting a second degree curve in the spreadsheet where a bunch of catch data involving as many species as they are exploited in the world oceans, just to have a guideline on the maximum yield level and the year when it was reached. It also provided a minimum basic requirement for the estimation the stock biomass on which fisheries of each region were based.

It is remarkable to realize that the maximum yield of the world oceans approaches very close to 100 M mt and the biomass of all the exploited stocks is near to 200 M mt. Another important point to call the attention is that in most cases, the MSY was attained more than a decade ago and that the current yield and stock biomass are nearly 40 per cent below those maxima. This is something to concern and is a possible indicator of excessive pressure on the fish stocks and in this respect those on the Antarctic seem to be the most heavily impacted by fishing activities. Evidently the over exploited fisheries have passed by several stages (Pauly et al. 1998) already pointed by other authors (Harding 1968; Feeny et al. 1990; Myers and Worm 2003) and unfortunately the perspective suggests that other world oceans apart from the Antarctic, will follow the same steps if no action is taken by the nations to ensure exploiting the sea in a sustainable way (Jorgensen et al. 2007).

Author details

Ernesto A. Chávez* and Alejandra Chávez-Hidalgo
Centro Interdisciplinario de Ciencias Marinas, Instituto Politécnico Nacional, La Paz, México

6. References

Arreguín-Sánchez F. and Chávez E.A. 1986. Influencia del reclutamiento sobre el rendimiento pesquero. IOC Workshop Report No. 44:95-104

Botsford L.W., Castilla J.C., and Peterson C.H. 2012. The management of fisheries and marine ecosystems. Science 277:509-515

* Corresponding Author

Csirke J. and Caddy J.F. 1983. Production modeling using mortality estimates. Can. J. Fish. Aquat. Sci. 40: 43-51.

Christensen, V. and Pauly D. 1993. Trophic models of aquatic ecosystems. International Center for Living Aquatic Resources Management. Manila, Philippinnes.

Cushing D.H. and Walsh J.J. 1976. The ecology of the seas. Blackwell.

FAO. 1995. http://www.fao.org/docrep/006/ac442s/AC442s31.htm# (Declaration Kyoto Conference/Fisheries FAO Fisheries Department).

FAO. 2005. Review of the state of world marine fishery resources. Marine resource service. Fishery resource division. FAO Fisheries Department. Technical paper 457.

Feeny D., Berkes F., MacCay B.J., and Acheson J.M. 1990. The tragedy of the commons: twenty-two years later. Human Ecology, 1(18):1-19.

Fréon P. and Yáñez E. 1995. Influencia del medio ambiente en evaluación de stock: una aproximación con modelos globales de producción. Invest. Mar. Valparaíso, 23:25-47.

Friedland K.D., Stock C., Drinkwater K.F., Link, J.S., Leaf R.T., Shank B.V., Rose J.M., Pilskain C.H., and Fogarty M.J. 2012. Pathways between primary production and fisheries yields of large marine ecosystems. PloS One 7(1):e28945.

Froese, R. and D. Pauly Editors 2012. FishBase. World Wide Web electronic publication. http://www.fishbase.org, version (08/2011).

Graham M. 1939. The sigmoid curve and the overfishing problem. Rapp. Conseil. Explor. Mer. 110:15-20.

Harding G. 1968. The tragedy of the Commons: The population problem has no technical solution; it requires a fundamental extension in mortality. Science 162: 1243-1248.

Jorgensen C., Enberg K., Dunlop E.S., Arlinghaus R., Boukal D.S., Brander K., Ernande B., Gårdmark A., Johnston F., Matsumura S., Pardoe H., Raab K., Silvia A., Vainikka A., Dieckmann U., Heino M., and Rijnsdrop A.D. 2007. Managing evolving fish stocks. Science 318:1247.

Margalef R. 1974. Ecología. ed. Omega, 951 pp.

Myers R.A. and Worm B. 2003. Rapid worldwide depletion of predatory fish communities. Nature 423:280-283.

Pauly D. and Christensen, V. 1995. Primary production required to sustain global fisheries. Nature 376:255-279.

Pauly D, Christensen V., Dalsgaard J., Froese R., and Torres F.Jr. 1998. Fishing down marine food webs. Science 279:860-863.

Polacheck T., Hilborn R., and Punt A.E. 1993. Fitting surplus production models: comparing methods and measuring uncertainty. Can. J. Fish. Aquat. Sci. 50: 2597-2607.

Russell-Hunter W.D. 1970. Aquatic productivity. Macmillan Pub. Co., NY., 306 pp.

Walter G.G. 1975. Graphical method for estimating parameters in simple models of fisheries. J. Fish. Res. Board Can. 32: 2163-2168.

Walter G.G. 1978. A surplus yield model incorporating recruitment and applied to a stock of Atlantic mackerel (*Scomber scombrus*). J. Fish. Res. Board Can. 35:229-234.

Zabel R.W, Harvey C.J, Katz S.L, Good T.P., and Levin P.S. 2003. Ecologically sustainable yield. American Scientist. 91(2):150-157.

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