Chapter 6.2 Fisheries Indicators for Open Ocean Areas: Catch from Bottom Impacting Gear, Marine Trophic Index, Fishing-In-Balance Index and Demersal Fishing Effort

Lead Authors:

V.W.Y. Lam[1] and D. Pauly[1]

[1]Sea Around Us, Fisheries Centre, University of British Columbia, Canada.

Chapter Citation:

Lam, V.W.Y., Pauly, D. (2016). Chapter 6.2: Fisheries Indicators for Open Ocean Areas: Catch from Bottom Impacting Gear, Marine Trophic Index, Fishing-In-Balance Index and Demersal Fishing Effort. In UNESCO IOC and UNEP (2016). The Open Ocean: Status and Trends. United Nations Environment Programme, Nairobi, pp. 237-245.

6.2 Fisheries Indicators for Open Ocean Areas: Catch from Bottom Impacting Gear, Marine Trophic Index, Fishing-In-Balance Index and Demersal Fishing Effort

6.2.1 Summary and Key Messages

A set of indicators including catch from bottom impacting gear, Marine Trophic Index (MTI), Fishing-in-Balance index (FiB) and demersal fishing effort are used to quantify risks in different regions of the open ocean, for example: areas beyond Exclusive Economic Zones (EEZ). The percentage of global catch from bottom impacting gear to the total global catch in the open ocean reached its peak at 13 per cent in 1955 and then declined to 4.8 per cent in 1963 and fluctuated between 5 per cent and 11 per cent in the following 30 years. The MTI fluctuated between 3.5 and 3.8 in the past 60 years in the open ocean, whereas the mean FiB kept increasing since 1950 and became stable in the recent 10 years. The increasing trend in the FiB represents an expansion of the ecosystem exploited by fisheries due to a geographic expansion of fisheries to new grounds. However, FiB should be interpreted in conjunction with MTI. The total effective effort of demersal catch in the open ocean reached its peak at 25 million kilowatts in 1979 and then declined. The effective demersal effort fluctuated between 1 and 11 kilowatts in the most recent 30 years.

Key messages

- Though the proportion of the global fish landings in the open ocean coming from bottom impacting gear has stabilised in the last 60 years, some regions of the open ocean – in particular the southwestern and northwestern parts of the Atlantic Ocean – have very high proportions of fish landings coming from bottom impacting gear in the past decade;
- The mean Fishing-in-Balance (FiB) index has increased steadily since the 1950s, suggesting both a geographical expansion of the fisheries and, jointly with the trends of Marine Trophic Index (MTI), a decline of the mean trophic level of the catch, (for example: the phenomenon known as 'fishing down' marine food webs), in some areas, notably the Southwest Atlantic Ocean; and
- Substantial increase in the use of bottom trawls in the Antarctic Ocean in the early 1980s led to a sharp peak of global effective effort of demersal catch in this period. However, some regions of the open ocean, for example: the southwestern part of the Atlantic Ocean (FAO 41) shows increasing trends of effective effort and demersal catches since the 1950s.

6.2.2 Main Findings, Discussion and Conclusions

Proper management of the open ocean, here defined as the oceanic areas beyond countries' Exclusive Economic Znes (EEZs), is required as fishing has expanded into this area in the wake of overexploitation of coastal waters, increasing demand for fish driven by increasing world population and higher incomes, provision of government subsidies, and technological advances (Pauly et al. 2002; Swartz et al. 2010). Here, a set of indicators including catch from bottom impacting gear, Marine Trophic Index (MTI), Fishing-in-Balance index (FiB) and demersal fishing effort are used to quantify risks in different regions of the open ocean.

Catch from bottom impacting gear

Bottom impacting gear are overwhelmingly bottom trawls (with some 'pelagic' trawls operating near the sea floor), although dredges are used in some shallow areas, for example: off New England and in the English Channel. The fraction of the spatialized FAO catches derived from these gear were estimated by Watson et al. (2006a, 2006b); in the open ocean, where shallow waters (where dredges could be used) are extremely rare. The catch of bottom impacting gear is essentially the catch of deep-sea trawlers. This is particularly the case in the North Atlantic, where long-lived deep sea fish species are exploited that are extremely hard, if not impossible to fish sustainably (Norse et al. 2012).

The time series catch from bottom impacting gear types in the open ocean is shown in Figure 6.4. The annual trend of the percentages of catch from bottom impacting gear to the total catch in the open ocean is shown in Figure 6.5. This percentage reached its peak at 13 per cent in 1955 and then declined to 4.8 per cent in 1963 and fluctuated between 5 per cent and 11 per cent in the following 30 years. The percentage reached another peak at 13 per cent in 1999 and then declined again. The percentage has fluctuated between 7 per cent and 11 per cent in the recent 5 years.

Figure 6.4. Annual catch from bottom impacting gear in the open ocean from 1950 to 2010.

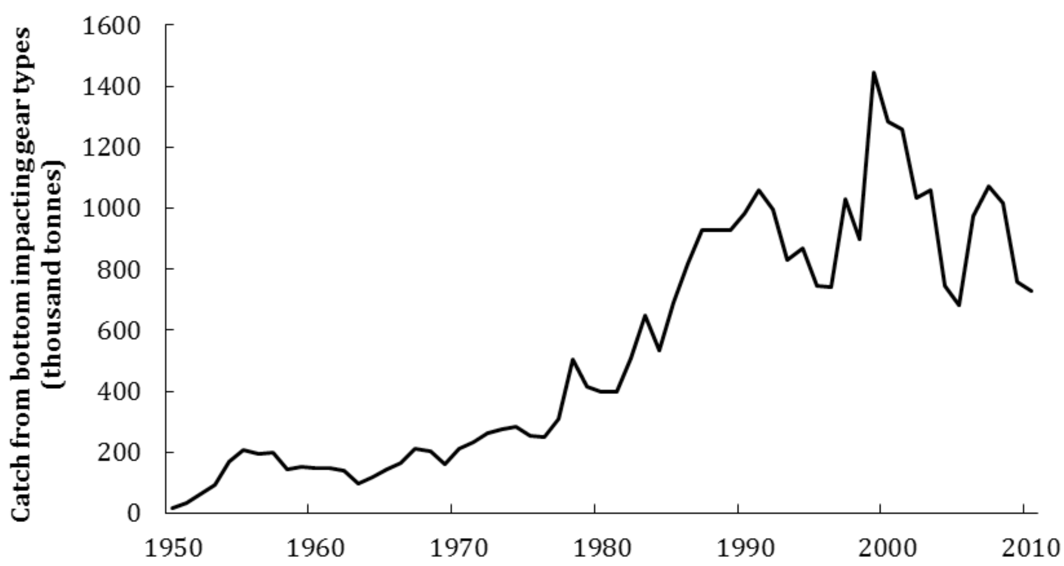
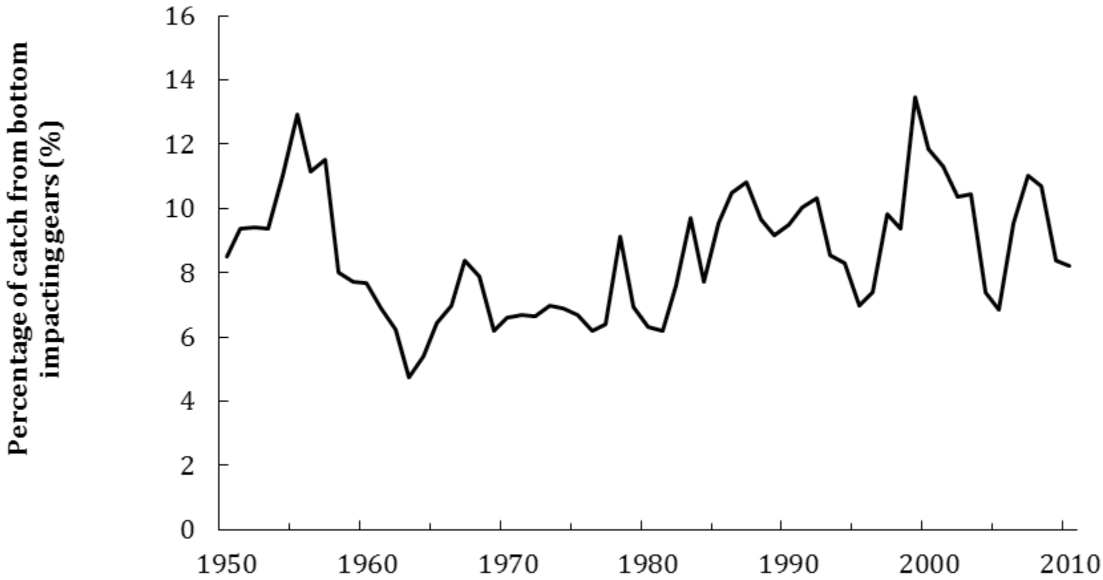
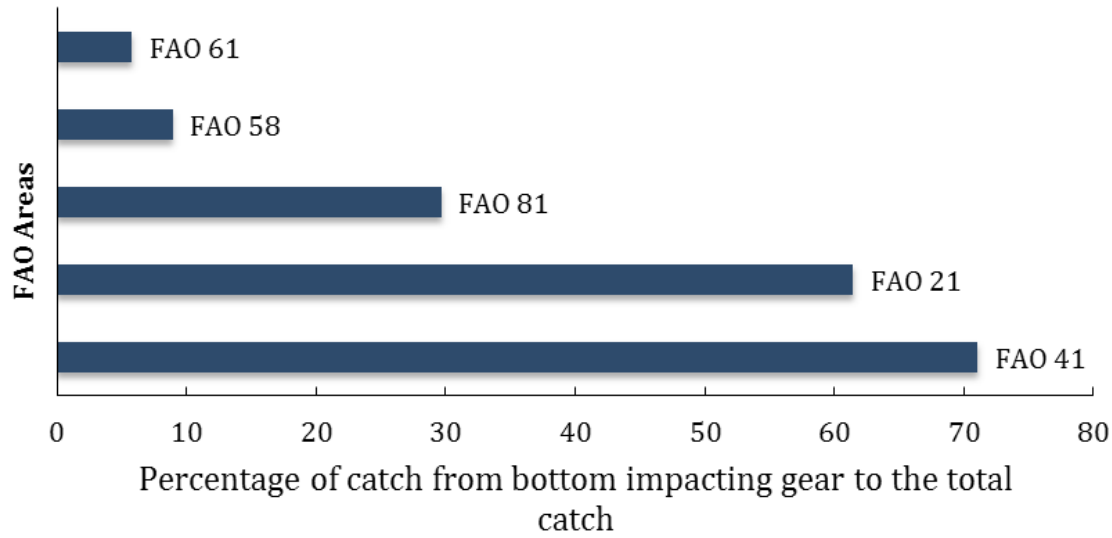


Figure 6.5. Percentage of annual catch from bottom impacting gear to the total catch in open ocean from 1950 to 2010.



The average annual percentage of catch from bottom impacting gears to the total catch in each of the top 5 FAO areas[31] with the highest percentages in the past 10 years (2001 to 2010) is shown in Figure 6.6. The southwestern part of the Atlantic Ocean (FAO 41) had the highest average percentage of catch from bottom impacting gears (for example: 71 per cent) in the past decade. The northwestern part of the Atlantic Ocean (FAO 21) had the second highest percentage of catch from bottom impacting gears (for example: 61 per cent). The high percentage in Southwest Atlantic (FAO 41) is due to the intensive use of bottom trawling in this area, whereas the extensive use of dredge in Northwest Atlantic (FAO 21) contributes to the high percentage in this area. The Arctic Ocean (FAO 18) and Southeast Pacific (FAO 87) and Eastern Central Pacific (FAO 77) have the lowest percentage of catch from bottom impacting gears (for example: less than 1 per cent respectively).

Figure 6.6. The average annual percentage of catch from bottom impacting gears to the total catch in each of the top 5 FAO areas[32] with the highest percentages in the past 10 years (2001 to 2010).



Marine Trophic Index (MTI)

The MTI is an indicator used by the Convention on Biological Diversity (CBD) and it expresses the mean trophic level (mTL) of the fisheries catch in an area. When a fishery begins in a given area, it usually targets the largest among the accessible fish, which are also intrinsically most vulnerable to fishing (Cheung et al. 2007). Once these are depleted, the fisheries then turn to less desirable, smaller fish. This pattern has been repeated innumerable times in the history of humans (Jackson et al. 2001) and also since the 1950s, when landing statistics began to be collected systematically and globally by the FAO.

The mTL (and hence the MTI) for all fisheries landings in the open ocean has been calculated. Figure 6.7 shows the change in mTL from 1950 to 2010. The MTI fluctuated between 3.5 and 3.8 in the past 60 years in the high seas. The MTI for all fisheries landings in each FAO in the high seas has also been calculated. Here, we used FAO 41 (Southwestern Atlantic Ocean) to illustrate changes in marine trophic level through time (Figure 6.8). The mTL in this FAO area fluctuated between 3.7 and 4.2 between 1950 to the mid-1980s; then, this index remained around 3.8.

31 See Chapter 6.1 Figure 1 for Map of FAO Fishing Areas
32 See Chapter 6.1 Figure 1 for Map of FAO Fishing Areas

Figure 6.7. Marine trophic level in the open ocean

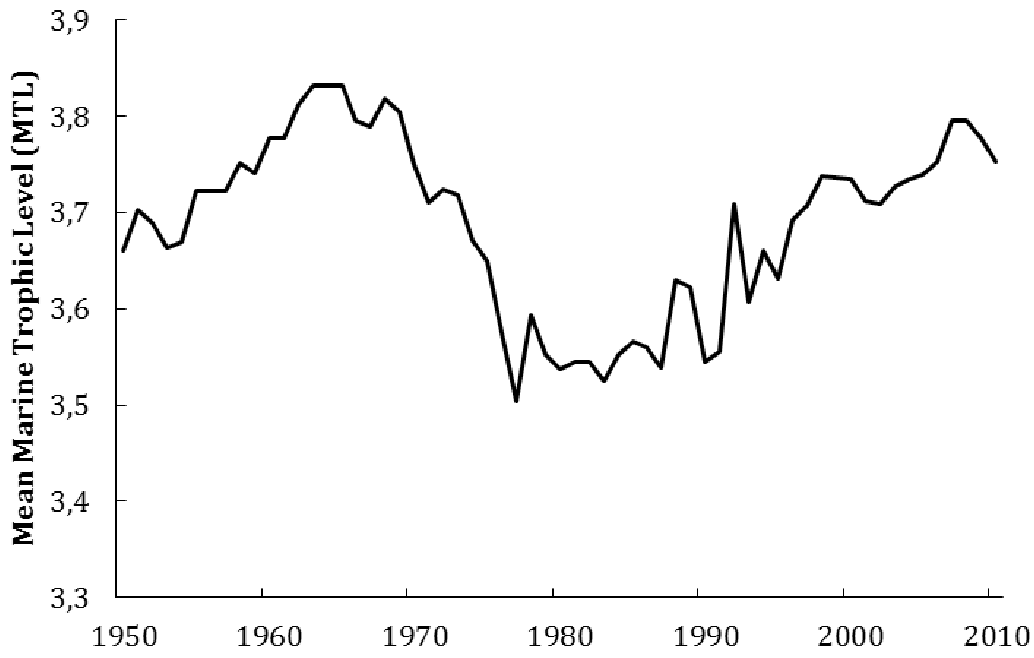
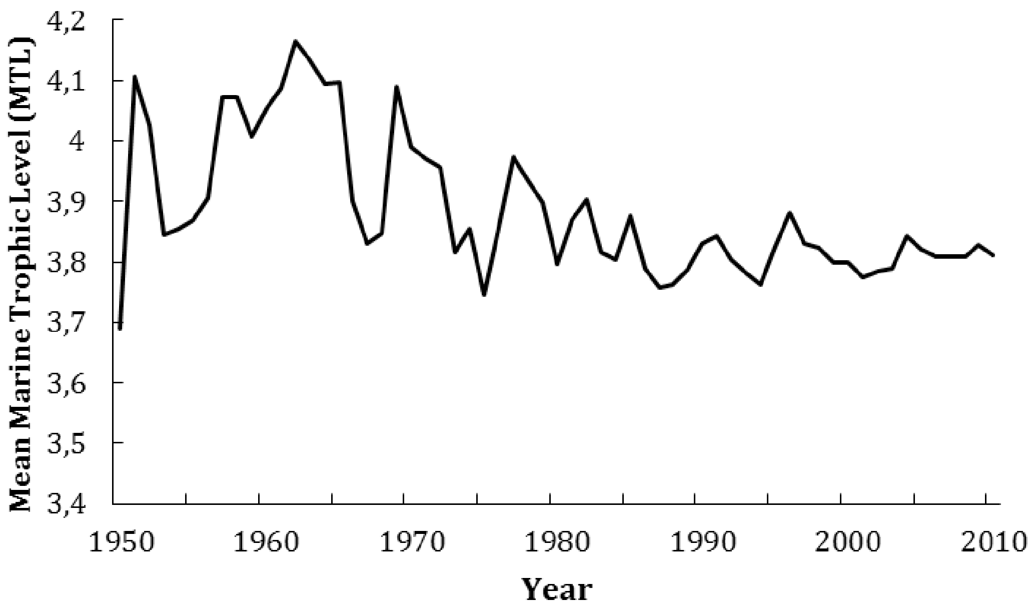


Figure 6.8. Marine trophic level in the open ocean of FAO 41 (Southwestern Atlantic Ocean).



Fishing-in-Balance Index (FiB)

The Fishing-in-Balance (FiB) index measures a geographic expansion, showing an increase when a fisheries expands. It is best analysed jointly with the Marine Trophic Index (MTI) – for which both indexes allow an understanding of the status of socks and an assessment of the changes in the ecosystem and potential impacts on human wellbeing. The trend of Fishing in Balance (FiB) index in the open ocean is shown in Figure 6.9, and should be interpreted

Figure 6.9. Fishing-in-Balance (FiB) index in the open ocean. The increasing trend of the FiB index suggests that the fisheries have expanded their area of operations.

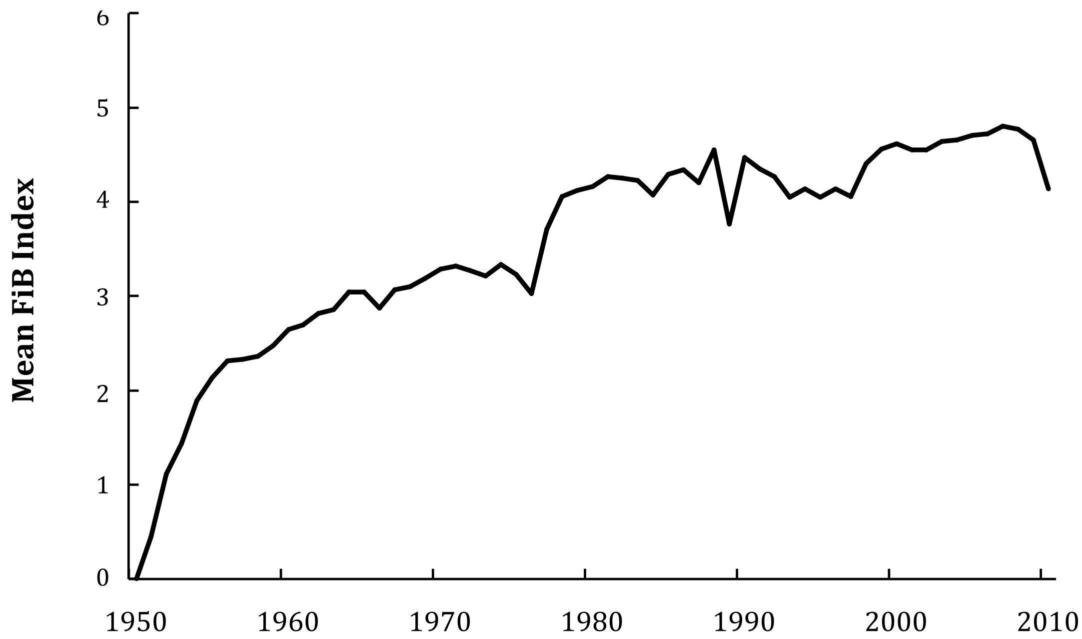
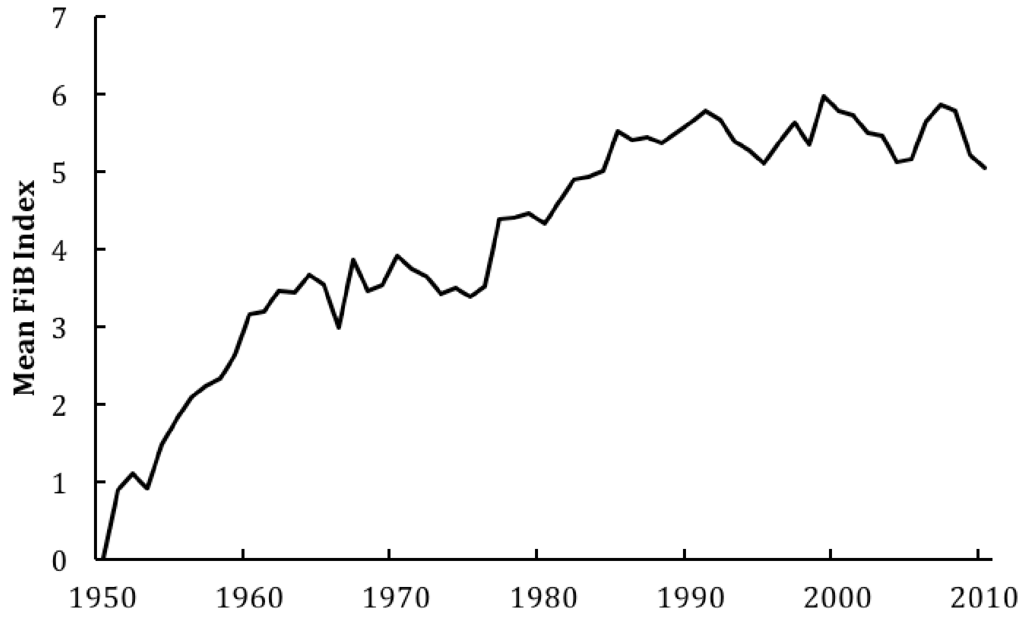


Figure 6.10. Fishing-in-Balance (FiB) index in FAO 41 (Southwestern Atlantic Ocean) in the open ocean.



in conjunction with Figure 4. Here, the increasing trend in FiB is probably due to a geographic expansion of the fisheries to new grounds, which in effect expands the size of the ecosystems they exploit (Kleisner et al. 2014). FAO 41 (Southwestern Atlantic Ocean) was used as an example of a trend of the FiB index in an FAO area (Figure 6.10). This graph should be interpreted in conjunction with Figure 6.8.

Demersal Effort

Fishing effort is any activity, such as the deployment of vessels, used to catch fish during a conventional period, for example: one year. Here, the cumulative power of the engine of fishing vessels is used as a measure of *nominal* effort, which is converted to *effective* effort through multiplication by an annual technological factor reflecting improvements in locating fish (for example: through echosounders and navigation (GPS)). The total effective effort of demersal catch reached its peak at 25 million kilowatts in 1979 and then declined to 3.8 million kilowatts in 1982 (See Figure 6.11). The effective demersal effort fluctuated between 1 and 11 kilowatts in the most recent 30 years. The peak in the early 1980s is mainly due to the substantial increase in the use of bottom trawls in the Antarctic Ocean during this period (Figure 6.12). Overall, there is an increase in effort from the 1950s to the recent years, for example: in the Southwest Atlantic (FAO 41) in Figure 6.13.

Figure 6.11. Effective fishing effort of demersal catch in the open ocean from 1950 to 2006.

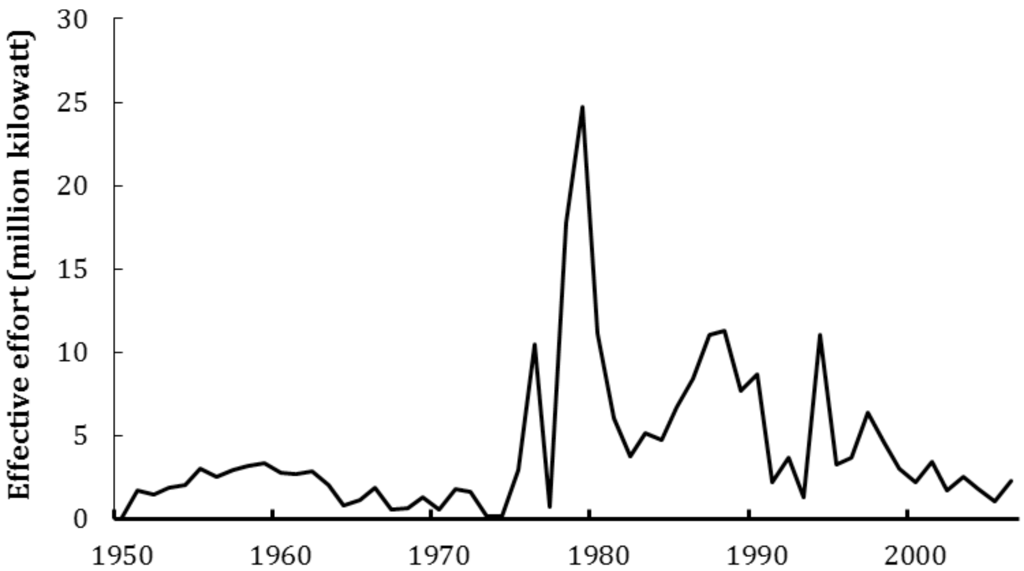


Figure 6.12. Effective effort of demersal catch of the open ocean waters of the Antarctic Ocean (FAO 48) from 1950 to 2006.

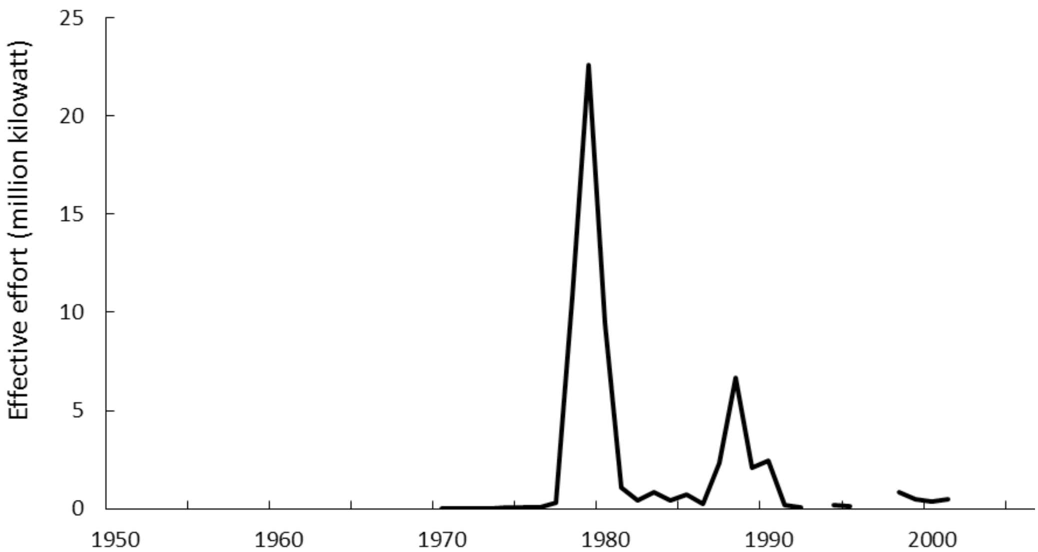
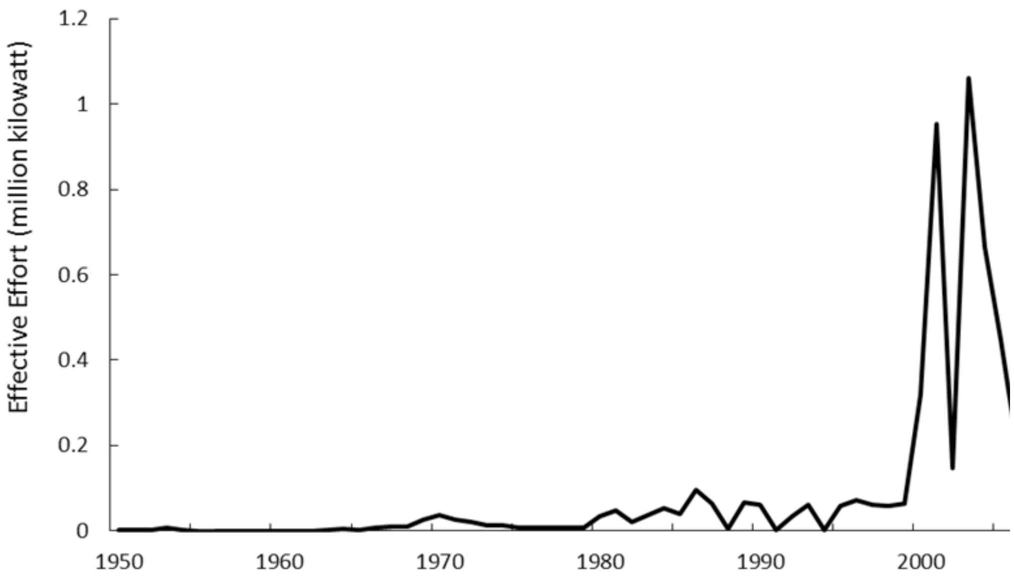


Figure 6.13. Effective effort of demersal catch of the open ocean waters of the Southwest Atlantic (FAO Area 41) from 1950 to 2006.



Discussion and Conclusions

The different indicators and graphs presented here contribute to an overview of the general status of fisheries and ecosystems in the open ocean. It accounts for the characteristics of fisheries, ecology of the exploited species and ecosystems. The global status of fisheries in the open ocean is mixed and the indicators do not always give consistent messages. Even given these limitations, these indicators evaluated current catch and related fisheries data and provide some information for developing policies for ecosystem-based fisheries management, for example: by identifying areas where management and/or mitigation measures are particularly needed. Also, some studies (for example: White and Costello 2014, Sumaila et al. 2015) suggested that closing the high seas would benefit the world as a whole by generating net gains in both catch and landed value and even the distribution of benefits among coastal countries. Thus, the information provided here can be used to further more equitable and environmentally sound policy. This information can also provide guidance on information gaps (for example: spatial effort data) and areas for research (for example: large scale, fisheries-independent biomass estimation), so that ecosystem-based management of fisheries can be strengthened in the open ocean.

6.2.3 Notes on Methods

This chapter documents the application of some fisheries-related indicators to highlight the level of risk within the open ocean. This was based on catch data spatialized using an approach developed by Watson et al. (2004), which relies on splitting the world ocean into more than 180,000 spatial cells of ½ degree latitude-longitude and mapping onto these cells, by species and higher taxa, all catches that are extracted from the corresponding areas. The catches in these spatial cells were regrouped into higher spatial aggregates, for example: the open ocean areas in each of the 19 FAO statistical areas.

Given that aggregates of spatial cells were combined with other data (for example: the catch from bottom impacting gear types and demersal effort data), subsequently, other time series could be derived for example: of indicators of the degree to which FAO areas may be degraded. Here, a description of the methods used to calculate the indicators including the catch time series from bottom impacting gear type, Marine Trophic Index (MTI), Fishing-in-Balance (FiB) index and demersal effort are provided. It should be noted that there are no scientifically defined thresholds for the indicators included in this chapter. Thus, the indicators were interpreted by expert opinions.

Bottom Impacting Gear
Annual landings from bottom impacting gear types by each FAO statistical area in the open ocean were extracted from *Sea Around Us* global catch database from 1950 to 2010.

Marine Trophic Index (MTI)
With a trophic level assigned to each of the species in the FAO landings data set, Pauly et al. (1998) were able to identify a worldwide decline in the mean trophic level of fish landings, a phenomenon they called "fishing down marine food webs". This was replicated in numerous local studies (see www.fishingdown.org).

However, landings reflect abundances only crudely. A fishery that has overexploited its resource base, for example: on the inner shelf, will tend to move to the outer shelf and beyond (Morato et al. 2006; Watson and Morato 203). There, it accesses hitherto unexploited stocks of demersal or pelagic fish, and the MTI calculated for the whole shelf, which may have declined at first, increases again, especially if the 'new' landings are high (Kleisner et al. 2014). This is the reason why the diagnosis as to whether fishing down occurs or not depends on whether a geographic expansion of the fishery has taken place. This is more *likely* than not, given the observed global tendency toward expansion (Swartz et al. 2010).

Fishing-in-Balance
To facilitate the interpretation of MTI-trends, an index of Fishing-in-Balance (FiB) was developed by Pauly et al. (2000), who defined it such that its value remains the same when a downward trend in mean trophic level is compensated for by an increase in the volume of 'catch', as should happen given the pyramidal nature of ecosystems and transfer efficiency of about 10 per cent between trophic levels (Pauly and Christensen 1995). As defined, the FiB index increases if landing increases more than compensate for a declining MTI. In such cases (and obviously also in the case when landings increase and the MTI is stable or increases), the FiB index increases indicate that a geographic expansion of the fishery has taken place, for example: that another part of an ecosystem is being exploited (Bhathal and Pauly 2008; Kleisner et al. 2014).

Demersal Effort
Demersal effort is quantified by multiplying the power of the vessels' engines and the numbers of days they are at sea in a year. A database of the nominal fishing effort deployed by the world's maritime countries was created by Anticamara et al. (2011) which was spatialized by Watson et al. (2013), and which was used to estimate demersal fishing effort from 1950 to 2006 (Figure 8). The 'nominal' effort estimated in this manner can be made to reflect gradual technological improvements in fish finding and catching, which are equivalent to increases of nominal effort of 1 – 3 per cent per year (Pauly et al. 2002; Pauly and Palomares 2010). Here, this technological improvement factor was set at 2.42 per cent per year, based on a meta-analysis of published efficiency increase (Pauly and Palomares 2010).

Acknowledgements

This is a contribution of the *Sea Around Us*, a scientific collaboration between the University of British Columbia and the Pew Charitable Trusts and the Paul G. Allen Family Foundation.

References:

Anticamara, J.A., R. Watson, A. Gelchu and D. Pauly. 2011. Global fishing effort (1950-2010): Trends, gaps, and implications. *Fisheries Research* 107: 131-136.

Bhathal, B., & Pauly, D. (2008). 'Fishing down marine food webs' and spatial expansion of coastal fisheries in India, 1950–2000. *Fisheries Research*, *91*(1), 26-34.

Cheung, W. W., Watson, R., Morato, T., Pitcher, T. J., & Pauly, D. (2007). Intrinsic vulnerability in the global fish catch. *MARINE ECOLOGY-PROGRESS SERIES-*, *333*, 1.

Jackson BC, Kirby MX, Berger WH, Bjorndal KA, Botsford LW, Bourque BJ, Bradbury RH, Cooke R, Erlandson J, Estes JA, Hughes TP, Kidwell S, Lange CB, Lenihan HS, Pandolfi JM, Peterson CH, Steneck RS, Tegner MJ, Warner RR (2001) Historical overfishing and the recent collapse of coastal ecosystems. Ecology 84:162-173.

Norse, E.A., S. Brooke, W.W.L. Cheung, M.R. Clark, I. Ekeland, R. Froese, K.M. Gjerde, R.L. Haedrich, S. S. Heppell, T. Morato, L.E. Morgan, D. Pauly, R. Sumaila, R. Watson. 2012. Sustainability of deep-sea fisheries. *Marine Policy* 36: 307-320.

Pauly, D., Christensen, V., Guénette, S., Pitcher, T. J., Sumaila, U. R., Walters, C. J., R. Watson and D. Zeller. (2002). Towards sustainability in world fisheries. *Nature*, *418*(6898), 689-695.

Pauly, D. and Palomares, M.L.D. (2010) An empirical equation to predict annual increases in fishing efficiency. Fisheries Centre University of British Columbia, Working Paper Series 2010-07.

Pauly, D. and V. Christensen. 1995. Primary production required to sustain global fisheries. Nature 374: 255-257.

Pauly, D., Christensen, V., and C. Walters. (2000). Ecopath, Ecosim, and Ecospace as tools for evaluating ecosystem impact of fisheries. ICES Journal of Marine Science, 57: 697-706.

Sumaila, U.R., Lam,V.W.Y., Miller, D.D., Teh, L., Watson, R.A., Zeller, D., Cheung, W.W.L., Côté, I.M., Rogers, A.D., Roberts, C., Sala, E., and Pauly, D. 2015. Winners and losers in a world where the high seas is closed to fishing. Nature Scientific Report. 5: 8481, doi: 10.1038/srep08481

Swartz, W., E. Sala, R. Watson and D. Pauly. 2010. The spatial expansion and ecological footprint of fisheries (1950 to present). *PLoS ONE* 5(12) e15143, 6 p.

Watson, R., Kitchingman, A., Gelchu, A. and Pauly, D. (2004) Mapping global fisheries: sharpening our focus. *Fish and Fisheries* 5(2), 168–177.

Watson, R., C. Revenga, and Y. Kura. 2006a. "Fishing gear associated with global marine catches: I. Database development." *Fisheries Research* 79(1): 97-102.

Watson, R., C. Revenga, and Y. Kura. 2006b. "Fishing gear associated with global marine catches: II. Trends in trawling and dredging." *Fisheries Research* 79(1): 103-111.

Watson, R., W.W.L. Cheung, J. Anticamara, R.U. Sumaila, D. Zeller and D. Pauly. 2013. Global marine yield halved as fishing intensity redoubles. *Fish and Fisheries*, 14: 493-503,

White C, Costello C (2014) Close the High Seas to Fishing? PLoS Biol 12(3): e1001826. doi:10.1371/journal.pbio.1001826