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**The fisheries in the South-Western Indian
Ocean, with emphasis on reconstructed
catches**

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The fisheries in the South-Western Indian Ocean, with emphasis on reconstructed catches

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Abstract

Following a brief description of the evolution of marine fisheries since the Second World War, the major trends in the domestic and foreign fisheries in the Exclusive Economic Zones (EEZs) of the Comoros, Madagascar, Mozambique, the Seychelles and Tanzania are reviewed, with emphasis on the actual ('reconstructed') catches (as opposed to officially reported catches) of the domestic fisheries for the 61 year period from 1950 to 2010. The discrepancies between these two catch types have policy implication which leads to a discussion of what the governance of these fisheries should emphasize, besides

having to be ecosystem-based, and increasingly account for demographic pressure and climate change. The resource managers to be trained for facing these challenges will have to have to be versatile, conservation-orientated, and adept at making use of generic online resources that allow bypassing time-consuming and costly local replications.

Résumé

Suite à une brève description de l'évolution de la pêche maritime depuis la Seconde Guerre mondiale, les principales tendances de la pêche intérieure et étrangère dans les zones économiques exclusives (ZEE) des Comores, Madagascar, le Mozambique, les Seychelles et la Tanzanie sont examinées, l'accent étant mis sur les captures ('reconstruites') réelles (par rapport à les captures déclarées officiellement) des pêches intérieures pour la période de 61 ans allant de 1950 à 2010. Ces divergences ont une implication politique qui conduit à une discussion sur ce que la gouvernance de ces pêcheries devrait souligner, en plus d'avoir à être fondée sur les écosystèmes, et de plus en plus tenir compte de la pression démographique et le changement climatique. Les gestionnaires des ressources formés pour faire face à ces défis devront être polyvalents, orientées vers la conservation et doués pour utiliser des ressources en ligne génériques per-

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mettant de contourner les reproductions locales coûteuses en temps et laborieuses.

Introduction

The period following the Second World War saw a massive increase in fishing effort, particularly in the 1960s. However, crashes due to this overfishing began to be reflected in global catch trends in the 1970s, and intensified in the 1980s and 1990s. In response, the industrialized countries of the Northern Hemisphere (where overfishing-induced catch declines appeared first) moved their effort offshore (Kleisner et al. 2014), toward deeper waters (Morato et al. 2006), and toward the south, i.e., to the coasts off developing countries, and beyond into the southern hemisphere, all the way to Antarctica (Swartz et al. 2010a). Now, in the second decade of the 21st century, the global expansion of fisheries is completed, and the real global catch, which is much higher than officially reported, peaked in the mid 1990s and is now rapidly declining (see www.seaaroundus.org). In parallel, the collateral damage to marine ecosystems and biodiversity continues to increase. Several factors act to prevent the public in developed countries from realizing the depth of the crisis fisheries are in, notably the increased imports by developed countries, of seafood from developing countries (Swartz et al.

Figure 1. Map of the Southwestern Indian Ocean, emphasizing the Exclusive Economic Zones of the Comoros, Madagascar, Mozambique, the Seychelles and Tanzania.

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2010b). Also, the misleading perception that aquaculture can substitute for declining catches is widespread. In some countries, notably the US, stocks are being rebuilt, but elsewhere, the failure to respond creatively to these clear trends bodes ill for the next decades. Indeed, the projected effects of global warming (productivity declines in the tropics, widespread disruptions at high latitudes; Cheung et al. 2010), which have already begun to be felt in the last decades (Cheung et al 2013), will strongly impact fisheries and global seafood supply.

The area of the South-Western Indian Ocean covered by the **FisherMan** Project (<http://www.fisherman-project.eu/>) covers the Exclusive Economic Zones (EEZs) of the Comoros, Madagascar, Mozambique, the Seychelles and Tanzania (Figure 1). In the following, a brief account of major domestic and foreign marine fisheries from 1950 to 2010 is given for each of these countries, capped by a general discussion of the governance of these fisheries, and of the research that is required for their management, along with some thought on the university education required by fisheries managers and similar personnel in the region.

Material and Methods

The fisheries catch reconstructions whose results are presented below were based on the ideas (in Pauly 1998) that (i) there is no fishery with 'no data', because fisheries, as social activities, throw a 'shadow' unto other sectors of the economy in which they are embedded, and (ii) it is always worse to put a value of 'zero' (or 'no data', which will be translated into a zero) for the catch of a poorly documented fishery than to estimate its catch, even roughly, because subsequent users of one's statistics will interpret the zeroes as 'no catches', rather than 'catches unknown'. This was operationalized by Zeller et al. (2007) as a six-step approach, as follows:

1. Identification, sourcing and comparison of baseline catch times series, i.e., a) FAO (or other international reporting entities) reported landings data by FAO statistical areas, taxon and year; and b) national data series by area, taxon and year;
2. Identification of sectors (e.g. subsistence, recreational), time periods, species, gears etc., not covered by (1), i.e., missing data components. This is conducted via extensive literature searches and in collaboration with local experts;

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3. Sourcing of available alternative information on missing data identified in (2), via extensive searches of the literature (peer-reviewed and grey, both online and in hard copies) and in consultations with local experts. Information sources include social science studies (anthropology, economics, etc.), reports, data sets and expert knowledge;
4. Development of data 'anchor points' in time for each missing data item, and expansion of anchor point data to country-wide catch estimates;
5. Interpolation for time periods between data anchor points, either linearly or assumption-based for commercial fisheries, and generally via per capita (or per fisher) catch rates for non-commercial sectors; and
6. Estimation of total catch times series by combining the reported catches in (1) and the interpolated, country-wide expanded missing data series in (5).

There is obviously more to reconstruction than this (notably for making uncertainties explicit, see, e.g., Zeller et al. 2014), but this summary should suffice for the five country accounts presented below. Le Manach and Pauly (2015) should be consulted for reconstructions covering the entire western Indian Ocean region, and Pauly and Zeller (2016; see also

www.seaaroundus.org) for reconstructions covering all the EEZs of the world.

Results

Comoros (based on Doherty *et al.* 2015a)

The Union of the Comoros is an archipelago in the Western Indian Ocean, composed of three main islands, which have a combined land area of 1,670 km² and an EEZ of 165,000 km² (Figure 1). The domestic fisheries consist of a small-scale boat fleet of pirogues and motor boats operated by men, and shore-based fishing by women. Small-scale catches from the artisanal and subsistence sectors compose the bulk of the domestic in the Comoros' EEZ (Figure 2A). Doherty *et al.* (2015a), based on these and other reports, reconstructed domestic catches of 1,200 t·year⁻¹ in the early 1950s, which increased to 10,000 t by the mid-1980s, and around 18,500 t·year⁻¹ from 2005 to 2010. The rapid increase in later years was due to the increasing number of motorized vessels, more efficient gear, and the use of fish aggregating devices (FADs) offshore. Overall, reconstructed catches are 1.4 times the data reported by FAO for the Comoros; the discrepancy is mainly due to an increase in catches since 1995, which is not reflected in the FAO data. Figure 2B shows that while do-

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mestic catches dominate the total removals, foreign fishing by Spain, France and Japan also occurs. The reconstructed catch consists primarily of skipjack tuna (*Katsuwonus pelamis*) and yellowfin (*Thunnus albacares*) offshore, and sardinellas (*Sardinella* spp.) and anchovies (Family Engraulidae) closer inshore (Figure 2C).

Figure 2. Domestic and foreign catches taken in the EEZ of Comoros. A) by sector; B): by fishing country (note that foreign catches are very uncertain); C): by taxon.

Madagascar (adapted from Le Manach *et al.* 2011, 2012)

Madagascar, which has a land area of 587,000 km² and an EEZ of 1.2 million km² (Figure 1), is one of the world's poorest developing countries, and its people depend heavily on marine resources for their livelihood (Barnes-Mauthe *et al.* 2013). Exports of these resources and foreign fishing access agreements are important economically. In recent years, concerns have been voiced amongst local fishers and industry groups, yet knowledge of Malagasy fisheries remains poor (Le Manach *et al.* 2012). Unfortunately, fisheries legislations, management plans and foreign fishing access agreements are often decided on based on very incomplete data (Le Manach *et al.* 2012). As presented in Figure 3A, total catches allocated to Madagascar's EEZ are dominated by the industrial sector, followed closely by the artisanal sector. The catch reconstruction of all Malagasy fisheries sectors performed by Le Manach *et al.* (2011) suggests that domestic catches increase from 15,000 t·year⁻¹ in the early 1950s to 137,000 t·year⁻¹ from 2000 to 2010. Overall, this was about twice as high as officially reported, due in part to the subsistence sector, which is missing in the national statistics. A large component of the allocated catches originate from domestic fisheries; however, varying catches by Spain, France

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and Yemen, among others, have been documented (Figure 3B). This catch consists mainly of halfbeaks (Family Hemiramphidae), skipjack tuna (*Katsuwonus pelamis*), Indian white prawn (*Fenneropenaeus indicus*) and grunts (Family Haemulidae; Figure 3C). Signs of stock decline have been observed, suggesting that the current fishing pressure is excessive.

Figure 3. Domestic and foreign catches taken in the EEZ of Madagascar. A) by sector; B): by fishing country (note that foreign catches are very uncertain); C): by taxon.

Mozambique (adapted from Jacquet *et al.* 2007, 2010)

Mozambique stretches along the coast of East Africa, between South Africa and Tanzania (Figure 1), has an EEZ of 571,000 km² with a shelf of 85,300 km², and is relatively rich in marine resources (see contributions in Pauly 1992). However, Mozambique underreports its marine catches (Jacquet *et al.* 2010). Small-scale fisheries, including subsistence fishing by women, account for most marine fisheries landings within Mozambique's EEZ (Figure 4A). Foreign fishing occurs, but is not prominent (Figure 4B). Doherty *et al.* (2015) reconstructed catches (including discards) between 55,000 and 64,000 t·year⁻¹ in the 1950s, and which peaked at over 200,000 t·year⁻¹ in the mid-1980s, but were affected by the war of independence from Portugal, followed by a long civil war. By the late 2000s, catches were between 120,000-130,000 t·year⁻¹. Between 1950-2010, the fishing sector is estimated to have caught 4.6 times the landings reported by FAO on behalf of Mozambique. However, since 2003, annual catches reported to FAO have increased due to substantial improvements in national data reporting systems, and the total reconstructed catches are only 1.6 times the statistics reported by FAO. Figure 4C, based on Doherty *et al.* (2015), summarizes the taxonomic composition of the catch, which includes her-

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rings, shads and sardines (Family Clupeidae) and anchovies (Engraulidae). Although globally Mozambique has a low (if increasing) per capita GDP, the country is demonstrating that this should not be a reason for inaccurate fisheries statistics. Hopefully, this example will be followed elsewhere.

Figure 4. Domestic and foreign catches taken in the EEZ of Mozambique. A) by sector; B): by fishing country (note that foreign catches are very uncertain); C): by taxon.

Seychelles (*adapted from Le Manach et al. 2015*)

The Seychelles is an archipelago located north of Madagascar, composed of 115 islands; it has a land area of 459 km² and an EEZ of 1.33 million km² (Figure 1). With around 15% of the available formal jobs, the fisheries sector is the main pillar of the national economy, the second being tourism. The domestic fisheries sector is small-scale, with a fleet of small boats targeting demersal and small pelagics in and around the coral reefs (SFA 2014). Since the early 1990s, though, an expansion towards offshore waters has occurred, with a fleet of longliners targeting primarily swordfish. Total domestic catches were estimated to have increased from 3,100 t·year⁻¹ in the 1950s to around 20,000 t·year⁻¹ in the 2000s (of which around 5,000 t·year⁻¹ are artisanal, Le Manach *et al.* 2015), with reconstructed domestic catches being around 1.3 times the figures reported to FAO. Overall, catches within the EEZ are dominated by industrial fleets (Figure 5A), mostly foreign (Figure 5B). Due to the predominance of foreign industrial fleets, catches are dominated by large pelagics (Figure 5C). A large sector contributing to the national economy is foreign owned: the large fleets of Spanish purse seiners and Taiwanese and Japanese longliners are often Seychelles flagged and operate throughout the western Indian Ocean. A

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portion of their catch is landed in Victoria on Mahé (Figure 1), the largest tuna hub in the Indian Ocean, and processed at the national cannery.

Figure 5. Domestic and foreign catches taken in the EEZ of the Seychelles. A) by sector B): by fishing country (note that foreign catches are very uncertain); C): by taxon.

Tanzania (adapted from Bultel *et al.* 2015; Doherty *et al.* 2015b and Jacquet *et al.* 2007, 2010)

Tanzania (Figure 1) has a shelf area of 19,000 km² and an EEZ of 241,000 km². The Tanzanian coastline is coastline dotted by numerous islands (Figure 1), of which Pemba and Zanzibar form the 'Zanzibar Region', previously separate, now joined with the mainland ('Tanganyika') into the United Republic of *Tan-zan-ia*. Until a few years ago, Zanzibar's catches, although relatively large, were not included in landings reported by FAO on behalf of Tanzania. Also, the mainland catches were underestimated due to incomplete country-wide expansion of locally sampled catch data. Thus, a reconstruction of Tanzania catches was undertaken (Jacquet and Zeller 2007; Jacquet *et al.* 2010; updated by Bultel *et al.* 2015) which addressed these issues, and estimated domestic catches of 18,000 t·year⁻¹ in the early 1950s and 110,000 t in 2010. Small-scale fisheries, especially artisanal, dominate catches in this EEZ (Figure 6A), with little foreign fishing presently documented (Figure 6B). This highlights the often neglected role of artisanal and subsistence fisheries (see, e.g., Nakamura 2011), another reason why the reconstructed catches are 1.8 times the FAO catches for Tanzania, even after Zanzibar is taken into account. These catches were dominated

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by emperors (Family Lethrinidae), sardine (*Sardinella* spp.), shark and rays, jacks (Carangidae), rabbitfishes (Siganidae) and mackerels and tuna (Scombridae; Figure 6C). The number of taxa reported to FAO has increased in recent years, thus decreasing the amount of miscellaneous ‘marine fishes nei’, a positive development also noted in other countries of the region.

Figure 6. Domestic and foreign catches taken in the EEZ of Tanzania. A) by sector; B) by fishing country (note that foreign catches are very uncertain); C) by taxon.

Discussion

For the period from 1950 to 2010, the reconstructed domestic catches for the Comoros, Madagascar, Mozambique, the Seychelles and Tanzania ranged from 1.3 (Seychelles) to 4.6 (Mozambique) times as much as the data reported by the FAO on behalf of these countries, with a median value of 1.8 (Tanzania). These discrepancies, which fortunately exhibit a declining trend, but which do not account for the catch of foreign fleets, are predominantly due to two sources of unreported catches:

- i. The discards of industrial fisheries, mainly from bottom trawling for penaeid shrimps;
- ii. The widespread neglect of small-scale fisheries, here artisanal and subsistence fisheries.

Item (i) reflects a practice – the wholesale discarding of the perfectly edible fish that is caught along with targeted shrimps – that is wasteful and arguably immoral, and which ought to be banned in the South-western Indian Ocean region, whose countries – notably Madagascar – suffer from food insecurity. Even the European Parliament has now passed legislation to gradually ban discarding, following the example of Norway, where discarding was phased out starting in the mid-1980s.

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Item (ii) refers to a widespread phenomenon in developing countries, i.e., for politicians and fisheries managers to focus on industrial export fisheries – notably because they generate foreign exchange (and also, it must be said) opportunities for corruption – while paying scant attention, if any, to the artisanal and subsistence fisheries yielding the animal protein that rural people eat, and thus contribute to their food security in a way that export-orientated industrial fisheries cannot match (Pauly 2006).

The *Sea Around Us* has recently completed the first pass of a global project devoted to help overcome this widespread policy bias against small scale fisheries, notably by ensuring that all national catch reconstruction, as here illustrated for five countries, disaggregate catch estimates by sector, with the catch of the small scale sectors (artisanal and subsistence, and recreational where possible) explicitly identified (see Pauly and Zeller 2016, and www.searoundus.org). I also believe, given that member countries of the Food and Agriculture Organization of the U.N. (FAO) must annually report their catch to FAO, that they should be asked to supply catches separately for large scale (industrial) and small-scale fisheries (Pauly and Charles 2015), as this would encourage the development of catch data recording systems that are less biased against small-scale fisheries. This would then serve as basis for a

re-evaluation of the role of coastal small scale fisheries, which ought to be encouraged and privileged, e.g., when they competes with industrial vessels operating inshore (Pauly 2006).

In contrast, the current emphasis of policy makers in the Western Indian Ocean region is to encourage the growth of offshore, export-orientated pelagic fisheries, i.e., to bank on fisheries resources whose catches are currently declining under an excessive multinational fishing pressure (Figure 7).

Figure 7. Industrial landing of large pelagic fishes from the Indian Ocean, 1950-2010, showing a) the total annual reported landings by area; b) percentage landing by country; c) percentage landing by gear; and d) percentage landing per species. (The grey color in panels B, C and D refers to 'Others'; source: Le Manach et al. 2014).

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Finally, the FisherMan project has, as one of its task, the development of (Msc.-level) courses/curricula for future fisheries managers in the South-Western Indian Ocean.

During my nearly 40 year career in fisheries, as I taught fisheries science courses on five continents in four languages, and supervised over 50 Master and PhD students from and in a multitude of countries, I also noted that fisheries resources and marine biodiversity have declined across the board, as have terrestrial resources and biodiversity. These declines have sometimes been subtle (Pauly 1995) and often contested (see www.fishingdown.org), but they occurred nevertheless. From this, and from the global fisheries reconstruction project that the *Sea Around Us* just concluded, I offer two recommendations regarding the training of fisheries managers:

My first recommendation is that a solid grounding in quantitative ecology and resource economics is needed for future fisheries managers, not only to understand how to optimally exploit marine resources, but to also understand the effects of relentless human population (and demand) growth on natural resources (see, e.g., Pauly 2006), combined with the effects of global warming on marine resource populations (Cheung et al. 2010, 2013). This requires that the cursus must focus on resource conservation, i.e., how to prevent the wholesale

liquidation of all natural resources in the next few decades, especially in developing countries. This is a major issue for the 21st Century, which is not going to be solved by ritual invocations of “sustainable development”, and the ill-founded notion that aquaculture can replace fisheries.

My second recommendation is that new courses for developing-country setting ought to be increasingly structured around the free, high quality resources that are available online, and which can replace costly books and foreign experts, and routine investigations. This ranges from Wikipedia, a unique multilingual encyclopedia, to domain-specific tools such as FishBase (www.fishbase.org), which can be not only used to teach ichthyology (via an online manual already tested in multiple course at several universities worldwide), but also used for fish identification, to document fish biodiversity, and to obtain estimates of parameters (growth, mortality, etc.) for use in stock assessments (e.g., Martell and Froese 2013) or ecosystem models (Christensen and Walters 2004). There is simply no more time for duplicative parameter estimations, especially when such estimations take the place of locally adapting and running resource optimization models.

Indeed, I believe that the ability to access and use such online resources will increasingly define good managers. However,

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at the same time, we ought to abandon the notion that these resources managers should be government agents. Thus, the community of environmental non-government organizations (e-NGOs) have become in both developed and developing countries a major employer of fisheries, ecology and resources management graduates (especially at the Master level), a trend that is likely to intensify in the future, and which neither governments, not the private sector are likely to match. A cur-sus for the fisheries managers of the future will thus have to consider the requirements of e-NGOs, which emphasize the ability to communicate with laypeople, and to use scientific and other knowledge to solve practical problems.

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Mahajanga, Madagascar, where the above material and ideas were originally presented.

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