The challenge of sustainability for Pacific Island village fisheries, a historical perspective

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Introduction

The World Wide Fund (WWF) paints an extremely alarming picture of the state of marine populations exploited by fisheries in the most recent Living Blue Planet report (Tanzer et al. 2015). Fish stocks have fallen by 50% between 1970 and 2012. This information is consistent with a 2006 Science paper written by a group of biologists and economists announcing that 29% of fish and shellfish species were nearing extinction, their catches having decreased by 90% between 1950 and 2000. If this trend continues, Boris Worm et al. (2006) conclude that it is highly probable that all of the world's fish and shellfish stocks will disappear. This catastrophic view is not shared by all (Hilborn 2007). The Food and Agriculture Organization of the United Nations (FAO 2010) emphasizes that the maximum annual catch that fishers have taken from the ocean (74.7 million tonnes in 1996) is below the potential catch, estimated at between 80 and 100 million tonnes (Gulland 1971). The fact remains that many stocks are overexploited, and with the human population continuing to grow, demand for marine protein will rise accordingly, putting increased pressure on fish stocks.

Within this bleak picture of global fisheries, the Pacific Islands are relatively better off than other regions in the world because the development of their fisheries took place comparatively later, both with regard to commercial tuna fisheries (Cillaurren 1991) and artisanal fishing (David 1991). However, the situation is evolving rapidly and there is a strong risk that the status of stocks will deteriorate in the near future if the governance of fisheries is not improved. With the widespread adoption of the ecosystem approach to fisheries (Garcia 1996; Garcia et al. 2003), marine protected areas (MPAs) have become a fisheries management tool in their own right (FAO 2011; Lauck et al. 1998) and environmental NGOs now present them as being the principle means to save endangered fish stocks (Tanzer et al. 2015).

Over the past few years, large MPAs in particular have been created in the Pacific Islands: the Phoenix Islands protected area (408,250 km^2) in 2008; the Coral Sea Marine Park (1,292,967 km^2) and the Coral Sea Commonwealth Marine Reserve (989,842 km^2) in 2012; the extension of the Pacific Remote Islands Marine National Monument, which was created in 2009 and extended in 2014 to cover 1,271,500 km^2. The British government plans to establish a 834,000 km^2 MPA around Pitcairn in the near future, while the Chilean government has decided to extend the MPA around Rapa Nui (Eastern Island) to 631,368 km^2 (see the chapters by Giron and by

Cornier and Leblic in this volume). Will these MPAs resolve the growing problem of overfishing in the Pacific Island region? There is reason to doubt. As Tundi Agardy et al. (2003) already demonstrated over 10 years ago, an increase in the number of MPAs often increases the risk that these MPAs will be ineffective if the required human and financial resources are unavailable.

This chapter argues that setting up MPAs in no way constitutes a panacea for fisheries management in the Pacific Islands, and that a holistic approach is needed to break from the ecosystem approach to fisheries and return to a fisheries system paradigm (Chaboud and Fontana 1992; Charles 1995; Quensière 1993; Rey et al. 1997) in order to establish responsible fisheries at the level of each state and territory.

Rationale and methodology

This chapter discusses Pacific Island village fisheries. Although generally less well known than the industrial fisheries exploiting tuna stocks in the region's exclusive economic zones, village fisheries play a vital role in island coastal economies in terms of both employment and food security. This fishery also is characteristic of Pacific fisheries because throughout the islands of Melanesia, Micronesia and Polynesia, the village is the geographic unit on which fish production, fisheries management — referred to as community-based fisheries management (SPC 2010) — and a good part of the distribution and consumption of fishery products is organized. Coastal communities have a land territory, which provides villagers with a large portion of their carbohydrates and fats, and a maritime territory, which provides the majority of their protein intake (Bell et al. 2009).

Until quite recently, this village maritime territory was composed exclusively of the *nearshore*, which comprises shallow areas such as mangroves, beaches, seagrass beds,[1] coral reefs,[2] and surface water inhabited by small pelagic species (see below). This space holds a wide range of fisheries resources: fish, shellfish, crustaceans, holothurians (sea cucumbers).[3] Four thousand species of reef fish have been recorded

1. The seagrass beds are composed of marine phanerogams. Specific to sandy and sandy-muddy zones, these herbaceous plants with roots are unique in marine ecosystems. They are clearly distinguished from algae which, equipped with clamps but no roots, attach to rocky substrates.

2. Coral reefs are bioconstructions created by colonies of scleractinar corals, micro-animals belonging to the phylum Cnidaria (like sea anemones and jellyfish) known as "polyps", which use carbonates and calcium in seawater to construct a coral skeleton in which they take refuge. Polyps live in symbiosis with dinoflagellates, single-celled micro-algae belonging to the genus *Symbiodinium*, which provide 70 to 80% of their food through photosynthesis. Scleractinar coral therefore need light to survive and are not found at depths below 50-75 metres. This ecosystem plays a leading role in global biodiversity. It holds one quarter of all known marine species (Moberg and Rönnbäck 2003).

3. The fisheries resources which live on the seafloor are known as benthic organisms and include fixed shellfish and holothurians; those living near to but with some independence from the seafloor are

in the region (Meyers 1989). This nearshore is the territory of subsistence fishing. Subsistence fishing refers to all fishing activity in which most of the production is destined to be consumed by the fishers and their families, or is given to other village households. Subsistence fishers fix their production objectives according to their needs and home-consumption capacities. Once this objective is achieved, they cease their fishing effort except when they face exceptional cash needs, for example, to pay for their children's school fees. There are thus two types of subsistence fishing: self-consumption fishing, where all the fishing production is consumed in the fishers' household or village (one might also call this home-consumption fishing), and subsistence fishing with trade, where surplus production (e.g., production surpassing a fisher's home-consumption capacities) is sold.

With the development of artisanal fishing (meaning professional commercial fishing) and motorized vessels, two new fishing grounds became accessible to village fishers:

- the *outer slope*, which is the island equivalent of the continental slope. Its upper section begins with the end of the euphotic zone and is composed of dead coral constructions, sometimes covering hundreds of metres [4] (as such, it is often described as the outer reef slope). This space is associated with demersal resources known as deepwater species because they generally live at depths of between 100 and 800 metres, and sometimes deeper. These species are mainly fish. There are some shrimp stocks, but these stocks generally are too small to be the object of sustainable commercial fishing;

- the *offshore pelagic space*, which extends to the 1,000 metre isobaths and sometimes deeper. The furthest reaches see little activity except when near fish aggregating devices (FADs) are anchored to aggregate tuna resources.

In contrast with subsistence fishing, artisanal fishing is motivated by a sustained desire to fish in order to sell. Earning income from fishing is the main motivation of the fisher's activity and the fishing effort [5] is continued until the income objectives have been reached.

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known as demersal species; and those living in the open water are called pelagic species. In shallow water, the pelagic species are small in size (sardines, mackerel, anchovies) and therefore are described as small pelagic fish, distinguishing them from the large pelagic fish (tuna, dolphinfish, etc.) living further offshore.

4. The volcanic Pacific islands on which the coral develop are slowly sinking by subsidence under their weight.

5. Fishing effort refers to "the ensemble of means used by fishers to capture a stock of aquatic animals during a given period of time", the stock being a capturable resource associated with a fishing zone (Laurec and Le Guen 1981). In Pacific Island village fisheries, fishing effort is measured in number of trips or number of fishing hours per unit of time. The amount of effort spent depends on two main factors: what fishers hope to catch and fishing yield (catch per unit of time or per unit of effort).

The combination of the type of fishing ground, effort type, target species and market components leads to the identification of three types of village fisheries: outer slope artisanal fishery, artisanal fishery around FADs, and nearshore subsistence fishery.

Due to a rising demand for fishery products generated in part by population growth (Bell et al. 2009; Bell et al. 2011; UNFPA 2014), the fishing pressure on nearshore and coastal marine resources will intensify. Climate change is leading to increasing degradation of habitats due to more violent cyclones, ocean acidification (Anthony et al. 2011; Guinotte and Fabry 2008) and temperature peaks inducing increasingly severe coral bleaching (Hoegh-Guldberg 1999). The sustainability of Pacific Island village fisheries is thus a pressing question which should be addressed with regard to these three types of fisheries.

Four main rationales drive this chapter:

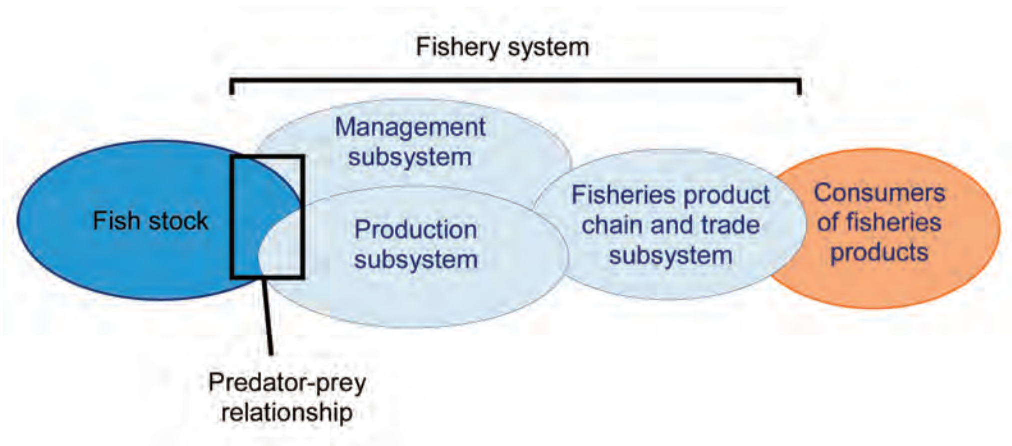
a) Outer slope artisanal fishery, artisanal fishery around FADs and nearshore subsistence fishery work as a fishery system composed of three subsystems which form the link between exploitable fish stocks and fish-consuming populations: the production subsystem, the management subsystem, and the fisheries product chain and trade subsystem (fig. 1).

b) The predator-prey relationship stands at the interface between the fish stock, the production subsystem and the management subsystem (fig. 1). It requires the presence on the fishing grounds of both fishers and the species they target (which must be available to be capturable). This relationship is expressed by both fishing effort and catches. The fisheries resource management aims to regulate this relationship by acting in a direct and indirect manner on the fishing effort.

c) The development of artisanal fisheries at the village level has been strongly driven by the Pacific Community (SPC), a regional technical support development organization based in Noumea, New Caledonia. Through the provision of scientific and technical assistance, the SPC has introduced the same fisheries development model throughout the Pacific Island region. The model is based on artisanal fishery of pelagic species around FADs and the exploitation of deep sea demersal species. In this context, detailed knowledge of the development of artisanal fisheries at the country level can contribute essential elements that should be considered to build sustainable fisheries at the village scale and across all Pacific Island countries and territories. This chapter uses Vanuatu as an example. Vanuatu is one of the Pacific countries with well-documented fisheries resources and fisheries. Since achieving independence in 1980, the government of this young country has developed an ambitious fisheries development policy. It has done so based on a complete inventory of its fisheries resources. ORSTOM (now known as IRD) was extensively involved in this inventory and the analysis of fisheries development. The author of this chapter contributed to this research, notably through the 2001 publication of the coastal fisheries atlas of Vanuatu, which as yet has no equivalent in the Pacific Island area (Cillaurren et al. 2001).

d) The near future of outer slope artisanal fishery, artisanal fishery around FADs and nearshore subsistence fishery is driven by dynamics which are anchored in the past and which meet new constraints. An understanding of the recent past of these three types of fisheries is thus needed to assess their present and future sustainability in order to move towards sustainable village fisheries.

Figure 1: The fishery system and its three subsystems



In the interest of simplification, commercial fisheries of the outer slope and around FADs will be studied together as both fall under artisanal fishing and are recent creations, unlike nearshore subsistence fishery. They date back to the independence period in Oceania when new resource management frameworks emerged, first in the context of artisanal fisheries of the outer slope and around FADs, and then in the context of subsistence fisheries.

Fisheries on the outer slope and around fish aggregating devices

In Oceania, artisanal fishery focuses on two types of resources. The first are large pelagic fish (notably tuna and dolphinfish) which gather around FADs. FADs are anchored to the sea floor at depths of 500 to 1,200 metres in territorial sea water, meaning no more than 12 miles off the coast (Cillaurren 1999; Désurmont and Chapman 2000). The second are deep sea demersal species living at depths of 100 to

800 metres on the outer slopes of islands. This artisanal fishery aims at commercialization. Distribution networks sometimes go all the way up to the capitals and main urban centres of the countries concerned and rely on air transportation.

The production system

The resources

Mainly composed of Lutjanidae (snappers) and Serranidae (groupers), deep sea demersal species present the advantage of being sedentary and available throughout the year and are untainted by ichtyosarcotoxism,[6] which facilitates their commercialization. On the other hand, their abundance is closely related to underwater topography and morphology. Their spatial distribution therefore is not homogeneous, and fishing yields can vary sharply according to the fisher's experience and know-how.

Numerous pelagic species swim in the surface and subsurface waters of the Pacific Islands. They are mainly skipjack tuna (*Katsuwonus pelamis*), yellow tuna (*Thunnus albacares*), dolphinfish (*Coryphaena hyppurus*), frigate tuna (*Auxis thazard*), wahoo (*Acanthocybium solandri*), tuna (*Euthynnus afinis*), and black and striped marlin (*Makaira indica* and *Teraptems audax*). These fish are highly mobile and the probability of a fisher coming across them while randomly moving across the water is low. FADs are deployed to significantly increase this probability by aggregating the fishery resource. FADs are rafts floating on the surface which are tied to an anchor by a mooring line that is frequently over 1,000 metre long, and on which strap bands are fixed, near to the surface, to attract small prey which serve in turn to attract tuna. In general, skipjack tuna are the first pelagic species to concentrate around FADs. It takes between two to five weeks for them to appear (Cillaurren 1994). The species then swim regularly around the FADs. Skipjack and yellow tuna form mixed schools on the surface and subsurface. However, these schools do not always remain around the rafts. In Vanuatu, they are reported to be most abundant at sunrise; catches also are reported in the middle of the day while the tuna move away from the raft at night (Cillaurren 1988). In general, pelagic resources are subject to marked seasonality, notably skipjack tuna, with the exception of latitudes around the Equator, from 10° north to 10° south, where Papua New Guinea, Palau, the Solomon Islands, Federated States of Micronesia, Kiribati and Tuvalu are located.

The first FADs were installed in 1977 in the Pacific for "troll" fishing of surface pelagic species. At the end of the 1980s, French Polynesian fishers were the first to

6. Widely known as ciguatera, ichtyosarchotoxism is caused by a toxin (ciguatoxin) produced by a microalgae of dinoflagellates, *Gambierdiscus toxicus*. This dinoflagellate stands as epiphyte of macroscopic algae living in coral reefs, notably branched, fan-shaped ones. The ingestion of *Gambierdiscus toxicus* by fish grazing on the coral contaminates their flesh and organs, with the poison transmitted to their predators (fish and humans). In people, ciguatoxin mainly affects the nervous system and disturbs the assimilation of sodium ions at the level of synapses (Laurent et al. 1993).

try to catch pelagic fish under the surface using vertical lines. They then noticed that new resources were available: large yellow tuna at depths of 40 to 100 metres, long finned tuna (*Thunnus alalunga*) and bigeye tuna (*Thunnus obesus*) from 100 to 200 metres (Leproux et al. 1990).

From fisheries development to overexploitation

In most Oceania countries, the fisheries development programs set up by the national fisheries departments during the 1980s to develop artisanal fisheries represented a veritable "blue revolution". Loans, subsidies and technical assistance were used systematically across the entire region to equip subsistence fishers with modern material (motorized boats equipped with wooden reels) so that they could become professional fishers, enabling yields unlike any possible using traditional fishing practices (see for instance the "FADIL" boat project in New Caledonia presented by Cornier and Leblic in this volume). The strategies implemented were driven by both economic and scientific rationales. They aimed to increase fish production without surpassing the optimal level of exploitation, the estimate of which was based on fishing experiments conducted by SPC master fishers (Dalzell and Preston 1992). The uniformity of the artisanal fleets [7] in the Pacific Islands and of the species targeted (pelagic resources aggregated by FADs and deep sea demersal species) is due to the major role played by the SPC in promoting artisanal fisheries (Preston et al. 1999).

A key to this revolution was the training of fishers. This involved taking subsistence fishers attracted by potential profits, and more rarely small entrepreneurs attracted by fishing, to create a core group of professional fishers able to create and sustain their own small fishing businesses. This training focused first on the use of fishing gear and the preparation of fish for sale, [8] and second on business management and resource-related knowledge. This strategy is well illustrated by Vanuatu's implementation of a Village Fisheries Development Project (VFDP) in 1983 which sought to train 25 fishing enterprises [9] with support from European or Canadian marine fishers working

7. Most fishing boats are less than 10 m long and are equipped with three to four lines mounted on wooden reels which can be used both to troll for large pelagic fish and for vertical line fishing of deep sea species. French Polynesia escaped this schema with the development of "Poti Marara", very rapid vessels initially meant for harpoon fishing of large pelagic fish (Blanchet et al. 1987).

8. All countries in the region chose cold storage, setting up ice block or ice chip production units in the islands to supply ice to fishing companies so that they could keep fish in chests of sea water chilled to 4/5° from the moment of their capture to their commercialization (Preston and Vincent 1986).

9. Each enterprise was made up of five to six fishers and sometimes a manager. In 1984, the price of a "Alia" type catamaran, 8.6 m in length, delivered with a 25hp engine, a spare 5hp engine and fishing gear was US$9,000; the price of a monohull boat 5 m in length with the same engines and gears was US$5,400. Fifty-one percent of the cost was covered by a European grant, 47% was loaned by the Development Bank of Vanuatu at a rate of 4%, leaving only 7% to be covered by the fishers (Cillaurren and David 1995).

with the fisheries extension service of the Vanuatu fisheries department. By fishing intensively, these fishers were expected to defray their production costs and generate substantial cash income through the sale of their catch. Their professional success was also expected to inspire subsistence fishers to take up commercial fishing. This was a classic scheme for the diffusion of innovation in which a massive injection of capital and sustained technical assistance are required to take a population which was not, or only slightly, integrated into a market economy and transform the members into production professionals whose success would ensure a growing number of participants.

The scheme initially far surpassed the hopes of its designers. As the deep sea fish had not been previously exploited, the first catches proved to be "miraculous", with some of the red snappers (*Etelis coruscans*) measuring over 1.5 metres in length. Press coverage led new village groups to apply to be equipped with a boat and fishing gear. Electoral clientelism enabled a large number to receive positive responses. However, the number of fishery extension service agents in charge of providing technical assistance remained unchanged. The agents consequently became overloaded with enterprises to support and the quality of their technical assistance rapidly deteriorated. In the end, the know-how acquired by the new artisanal fishers proved insufficient to achieve the results required to reimburse the loans granted for the purchase of the fishing gear. Three-quarters of the artisanal fishing enterprises ceased operations within the first two years, 53% of them folded during their first year (Cillaurren and David 1995), notably those located too far from the home villages of the fishery extension service agents to benefit from regular technical assistance.

The sensitivity of deep sea species to intensive exploitation due to their slow growth and the low productivity of the deep sea environment are other reasons for the failure of Vanuatu's artisanal fishery development program. Fishers rapidly were confronted with a drastic reduction in the average size of their catch and in their incomes. Another reason is the low purchasing power of the rural communities living in the vicinity of the fishing enterprises and potential consumers of their production. In the face of insufficient local demand, these companies should have exported their production to urban centres and rural centres with developed cash economies. However, this would have required ice making and chilling facilities and equipment and effective fishery product distribution chains, which were unavailable on most of the islands of Vanuatu (David and Cillaurren 1992).

These market access problems are not specific to Vanuatu; they are encountered in most of the Pacific Island countries and territories. Fishers have adapted themselves to this constraint. They now operate out of urban centres with markets where their production can be sold. This concentration of the fishing effort on limited areas inevitably will lead to the overexploitation of stocks if drastic management measures are not taken (see below). When yields drop, fishers with the necessary capital respond in two ways. They buy longer-range boats in order to move their fishing effort to areas which have not been or are scarcely exploited. They also replace their vertical lines with much more productive bottom longlines, raising the risk that this intensification of the fishing effort will lead to a geographic extension of the over-exploitation of deep sea fish stocks. The sustainability of this type of fishery thus depends on good management (see below).

Trolling for pelagic fish around FADs requires less know-how than deepwater fishing. Moreover, large pelagic resources (tuna, dolphinfish, etc.) are much less abundant than the demersal stocks and much less vulnerable to any intensive exploitation. When the aggregating raft is productive, any fisher operating nearby is certain to obtain numerous catches.[10] This form of fishing logically is more profitable than demersal fishing, but two constraints and mistakes could dramatically affect this profitability. The first is to locate FADs too far away from boat launch sites for the fishing to be profitable given the vessels used (Cillaurren 1988, 1990, 1999). The vulnerability of FADs to hydroclimatic hazards is the second. The most promising sites, such as passageways between two islands used by tuna, often are exposed to high wind and currents, leading to the FADs positioned there to be short-lived.

From 1990 to 2015, artisanal fishery around FADs underwent two important changes. First, there was increasing competition between artisanal fishery and industrial fishery over young yellow tuna and skipjacks, which aggregate around FADs but also can be exploited by canners and seiners hundreds of kilometres away due to the great mobility of tuna.[11] Second, a negative image of FADs was propagated by international NGOs, which blamed them for encouraging the overfishing of tuna and the incidental capture of turtles and dolphins by purse seine fishery.[12] Meanwhile, the (high) cost of installing and maintaining an anchored FAD in relation to the life expectancy (often low) and financial resources of Pacific Small Islands Developing States (Pacific SIDS) remained unchanged. All of the FADs set up between 1985 and 1995 in the Pacific SIDS were funded by international donors, notably Europe and Japan through the Japan International Cooperation Agency (JICA). When donors did not renew their financial support to set up new ones, at the end of several years Pacific Island artisanal fishers were left without FADs to aggregate the pelagic resources and only a memory

10. The presence of a large number of sea birds flying over a FAD attests to the effectiveness of the device in attracting pelagic species, notably tuna.

11. Tuna in the Pacific migrate over long distances, as has been shown since 1977 through successive tuna tagging programs organized by SPC at a regional level (see http://www.spc.int/tagging/en, Accessed on November 23, 2015).

12. The two following sites are indicative of the "anti-FAD" movement. What are involved here are drifting FADs used for industrial fishing which are very different from the anchored FADs used for artisanal fishing, but which are often considered to be similar by the general public:
http://www.seableue.fr/limpact-des-dcp-aborde-lors-de-la-commission-des-peches-du-pacifique-ouest-et-central-du-2-au-9-decembre/ (Accessed on November 23, 2015),
http://www.greenpeace.org/france/fr/campagnes/oceans/arrethon/?petition&codespec=N15AW&gclid=CNWN66vO5MQCFSr3wgodKjcAoA (Accessed on November 23, 2015).

of "miraculous" fishing. Recurring requests to fund the deployment of new FADs are made, but donors have little inclination to fund equipment likely to disappear within a few months, or even weeks, even though the FADs built in 2015 are much more solid than those anchored 20 years ago. Nevertheless, a few FADs remain in the region. The last ones deployed were in Kosrae in the Federated States of Micronesia (3), the Cook Islands (3), American Samoa (2) and Vanuatu (4) (Sokimi 2012). A new type of FAD, known as a nearshore FAD because it is anchored at depths of 500 to 300 metres or less, are tending to replace FADs located far offshore, anchored at depths of over 1,000 metres. Although they are less productive, nearshore FADs have the advantages of being much less expensive — US$2,000 in 2011 (Tacquet 2011), compared to US$3,000 for an offshore FAD in 1983 (Cillaurren 1988, 1990) — and of not being visited by industrial fishers.

Today, in 2015, artisanal fishers remain multiskilled. They fish around FADs when these are deployed; otherwise, they target deep sea demersal species. The experience of the past 25 years shows that the sustainability of a production subsystem is not only governed by the abundance of the fishery resource. To be able to continue their activity, fishers must above all have access to a nearby market where they can sell their production and earn a sufficient income. A sustainable market outlet is thus the first condition to be able to sustainably produce. The second condition is to have a sustainable access to the fisheries resources required for this production. When fishers have the necessary capital, they purchase vessels that allow them to explore areas beyond the field of action of most boats operating out of urban centres. The largest (15 to 25 metres) then can set down bottom longlines to target export markets. This very productive gear must be deployed carefully so as not to overexploit deep sea fish stocks. This risk also is high around urban centres where most artisanal fishers are concentrated. All exploitation of deep sea demersal fish must therefore be accompanied by rigorous resource management to be sustainable.

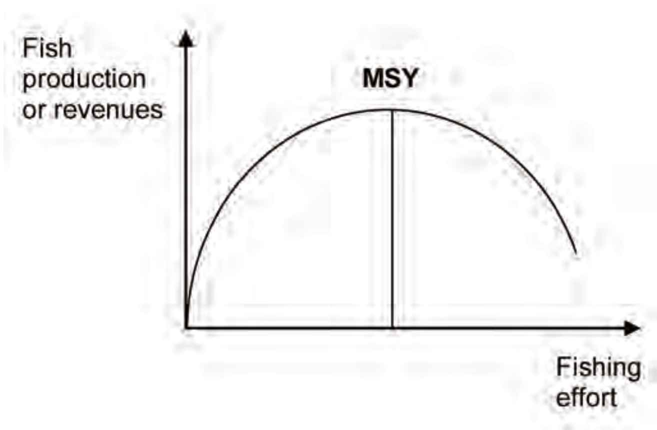
Resource management

Fish management is characterized by two features, resource dynamics and fishing activities, which are responsible for the fishing mortality of this resource. Managing fishing involves determining an acceptable level of fishing mortality (Brêthes 2000) and controlling the fishing effort. The growth of this management is closely related to the development of a scientific approach to fisheries based on the application of predictive mathematical models.

Global models, the most famous of which being that of Milner B. Schaeffer (1954), rely on data regarding catches and effort; analytic models (Gulland 1983) use demographic indicators drawn from catch lengths and weight measurements. Focused on the "predator-prey" relationship, this approach introduced the concept of overexploitation of stock and made resource conservation the main objective of fishery management, which relies on the dynamics of the populations exploited (Laurec and Le Guen 1981).

Between the 1950s and the 1980s, these quantitative models became increasingly complex. Applied to multispecies stocks, they integrated biological parameters (recruitment, growth, mortality) of each species in an attempt to provide an estimation of the sustainable exploitation rate based on the optimal capture of each species. However, this type of modelling requires relevant and reliable data sets which are extremely difficult to collect regularly in the Pacific Islands. The fisheries scientists working with Pacific Island fishing departments therefore opted for a pragmatic solution: to consider all of the target species in the same resource space as belonging to the same stock unit, to which is applied a Schaeffer type of global model in order to estimate a maximal sustainable yield (MSY). A critical parameter in the management of a fish stock, MSY is the maximum quantity of fish that can be captured each year without altering stock renewal capacities, a term fisheries scientists use to refer to the exploitable marine population. MSY is represented graphically (fig. 2), with the peak of the parabola indicating the relationship between the fishing effort (along the x-axis) and the fish production (along the y-axis).

Figure 2: The Schaeffer model



When national fisheries departments are staffed correctly (Govan 2015), the management of deep sea commercial fishing relies on the regular collection and computer processing of statistics on fishing effort and the weight and size of captures (Moffit 1993; Polovina and Ralston 1987) in order to assess the MSY at the national level, and more rarely, region by region. With MSY and average boat yield, fisheries departments can manage the resource through the simple management of the inputs and outputs of the fishing fleet. When fishing pressure is well under the MSY, financial and technical assistance is given to fishers to increase the number of boats and the fishing effort. When the opposite is true, fishers are invited to apply their effort to other resources, notably pelagic fish aggregated by FADs. Ultimately, although based on scientific knowledge of the resource and the use of mathematical models, these management measures are too generalized to manage demersal fishing across a vast archipelago. Optimal management requires MSY to be assessed island by island (Cillaurren et al. 2001). However, few fisheries departments are able to collect the yearly data on catches and effort needed for this assessment, particularly when boats are leaving from scattered villages (Cillaurren and David 2000).

In this context, one might reasonably wonder whether the scientific effort applied is not disproportionate to the outputs expected. This was the opinion expressed by T. Adams in 2002 while director of the SPC marine resources department: "*there is no point in trying to set up western style management models that only can function if they have an immense volume of scientific data and can only be applied to western style commercial fisheries*." Noting "*the enormous gap between the cost of data collection programs conducted in most developing countries and the more modest means which would suffice to take effective decisions, both in terms of surveillance and management*," he advocates for a minimal data management mode, emphasizing that, "*we are in desperate need of solutions that are invulnerable to possible system failures, solutions that will allow us to deal with the consequences of inexact stock assessments due to a lack of fundamental environmental data or an overly optimistic distribution of the fishing effort*" (Johannes et al. 2002).

A simple solution consists of using average catch size as the principal indicator of the status of a stock. The method, which was applied in Vanuatu during the 1990s, consists of providing each fishing enterprise with a board to measure fish that indicates the minimum size of each targeted species. Once catches fall under this minimum size, an agreement is reached with fishers to move the fishing effort to other fishing zones to allow time for the stock to reconstitute itself, or at least to allow juveniles to become adults and reproduce at least once. This method involves co-management by fishers and the fisheries departments. The cost is low: all that is required are boards to measure the fish and some visits by agents from the fisheries departments to fishing villages. It therefore should be able to be implemented in most Pacific Island countries and territories.

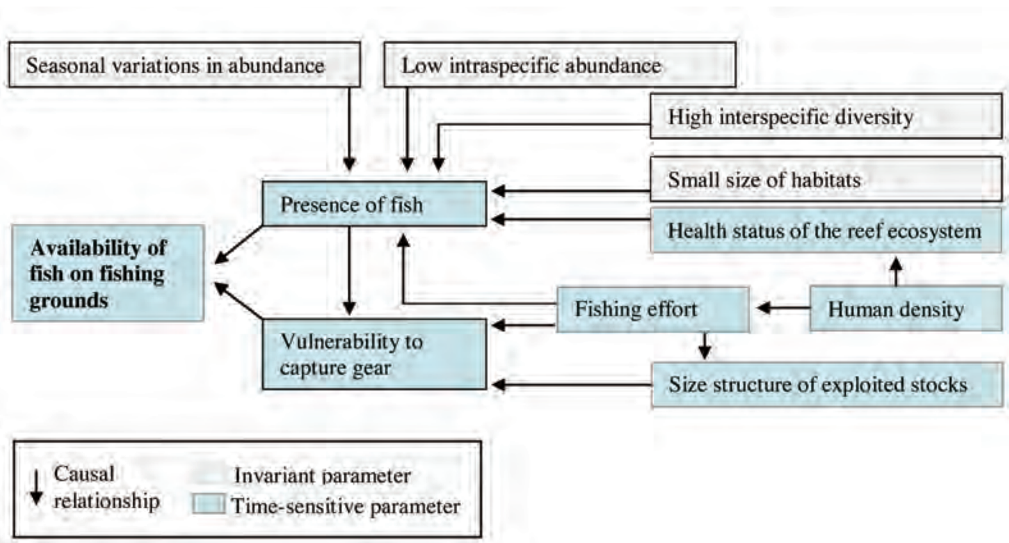
Subsistence fisheries

The production system

Availability of fish on the fishing grounds

Subsistence fisheries are always shallow water fisheries. The main characteristic of shallow waters is the extreme diversity of the fish living in them. It is common to find over one hundred fish species on a single hectare of reef. During an inventory of Vanuatu's marine resources carried out by the Australian Institute of Marine Science in 1988, a total of 469 species of fish were visually identified (Williams 1990). Coral reefs form the ecosystem with the highest diversity of fauna but the coral biotope is very restrictive for the populations living in it. The habitat favourable to each species is quite small: one refers to microbiotopes, generally scattered from each other. The ensemble of these microbiotopes form in the space a kind of three-dimensional mosaic where each element harbours a micropopulation composed of a small number of fish of the same species. This low intraspecific diversity is accompanied by strong specialisation, as much from the perspective of diet as habitat (Kulbicki 1992). Due to their small size, these micropopulations are sensitive to all intensive exploitation on the part of fishers and their abundance per hectare is low. These two factors, combined with the rich species diversity of the fish biomass, constitutes the primary constraints on the fishing activity; added to them are seasonal variations in fish abundance, which are particularly sharp in the case of small pelagic fish (Conand 1987). These constraints are prohibitive for fishers; they cannot circumvent them and have no other choice than to integrate them into their capture strategies and techniques. One is faced here with the invariants inherent in the structure of coral habitats and in the ecology of fish that heavily impact the availability of fish on the capture sites (fig. 3).

Figure 3: The availability of fish on subsistence fishing grounds, a process associating invariance and temporality



The availability of fish on fishing grounds is also sensitive to two parameters which evolve over time. These are the health of marine ecosystems and the density of human populations on the coast. For the past thirty years, the health of mangroves, seagrass beds and coral reefs has deteriorated in peri-urban areas, around mines, and close to intensive agriculture (Chin et al. 2011; Salvat 1987). Chemical and organic pollution as well as heavy siltation of the water are the main factors behind this negative development. It has led to a heavy reduction in the biodiversity and number of species targeted by fishing as the number of fish species capable of thriving in these degraded areas has been reduced. As a general rule, high human population densities contribute to this degradation, to which can be added the mechanical destruction of coral as it is trampled under fishers' feet, and the cutting of wood in the mangroves for domestic (notably firewood) and professional activities.

The past thirty years have been marked by a growing integration of the Pacific Island countries and territories with a globalized world. This has been translated into a division within the national space between densely populated areas linked to the global system and outlying areas where the population is tending to turn in on itself due to a lack of commercial outlets (David 2003; Ward 1993). For the latter, if fishing pressure remains moderate and the habitats in good health, the abundance and availability of fish on the fishing grounds should remain high with the exception of sea cucumbers and mother-of-pearl shellfish, which already are and will continue to be the focus of important fishing pressure. These resources effectively can be sold at high prices on international markets and can be conserved for several weeks (sea cucumbers in dried form, trochus and green turban snails as empty shells) while awaiting buyers. Sparsely populated areas can thus suffer from severe overexploitation of these resources due to the level of demand on international markets. The same situation holds for densely populated areas, although the reasons are different. There, demand is strictly local and is part of the home-consumption of fish production by families with low cash resources. The sea is thus called upon to cover families' nutritional needs. It therefore is possible to establish a relationship between population density and fishing effort. In the short and medium term, Pacific Island towns will be called on to grow and densify, and the fishing effort around them will therefore increase and the availability of fish will continue to decrease, a dynamic which involves predator-prey relations.

The predator-prey relation

This relationship depends first on the availability of the fisheries resource on the fishing grounds and the presence of fishers.[13] This refers back to social and economic considerations such as access rights to the fishing grounds, belonging to a fishing clan (Leblic 1989), and family or village demand for seafood products. It also is dependent on climate-related constraints: sea state and weather, in particular wind

13. One considers that a fisher collects from a stock, the effects of which are determined by the fishing effort used and its productivity, comparable to the production of a fisher in one unit of time. This productivity depends on both the abundance of the resource and the effectiveness of the gear used, meaning the relationship between the number of animals present on the fishing grounds and the captures.

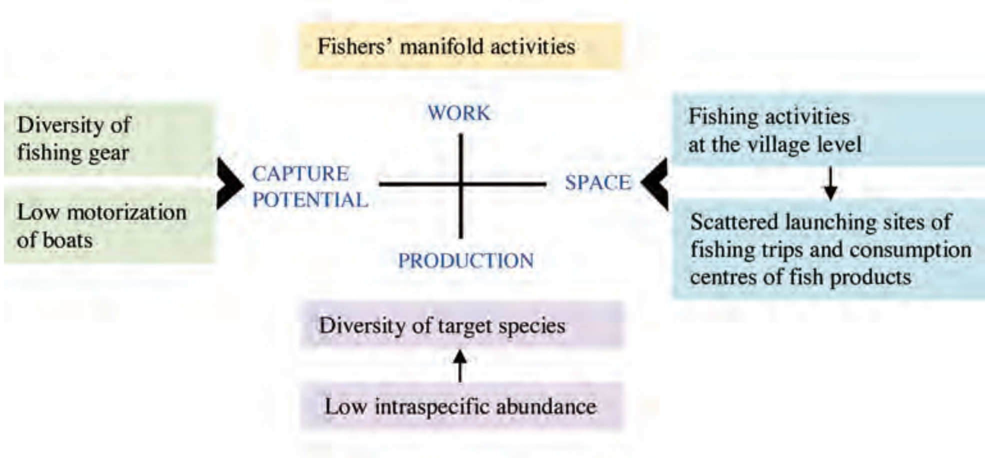
speeds and rainfall. These constraints determine the work conditions on the fishing grounds and affect the decision of fishers to go fishing or not. In this regard, the question is posed differently depending on whether fishing is conducted by boat, on foot, or diving. Most boat fishing trips are made in dugout canoes, which generally are small. Their poor nautical performance[14] does not permit fishing trips on high seas and restricts them to areas sheltered from the wind as soon as there are heavy seas. Widespread before the colonial period (Haddon and Hornell 1975), sailing canoes are now rare. Motorized canoes also are rare, although motorization is spreading; the latter remains largely reserved for commercial fishing, for which fishers favour boats over canoes.

In general, the further fishers move away from shore, and the smaller their vessel, the greater is their vulnerability to the sea state. This is minimal in intertidal zones and in shallow waters such as river mouths, frequently protected by sand and pebble shoals, and the long stretches of beach generally located at the end of bays. As for mangroves and seagrass beds, they only grow on fine sediments whose deposits are found solely in areas sheltered from the swells and waves of the sea created by the prevailing winds. The rain and cold rather than the sea state and wind speed thus determine when fishing grounds are frequented. In general, Pacific Island fishers know how to adapt themselves to downturns in the weather by changing their fishing grounds. When rough sea conditions forbid canoe expeditions, it always is possible to take refuge in river mouths, sheltered bays, or mangroves, and to redeploy the fishing effort on one or several target species according to the abundance of the resource and its species diversity.

A diversity in the means of production is the logical consequence of this diversity of the targeted species and of the biotopes exploited by subsistence fishers (fig. 4). The most common gear are hand lines because they can be used for multiple purposes. They are used for trolling and as vertical drop lines when fishing from canoes or on foot on the reef crest. The other are release gear (spears, bows and arrows, darts, cast-nets, underwater guns) and passive gear (fish traps, gillnets, fish fences). This gear is generally owned by the fisher. Although the materials used to make them are increasingly manufactured industrially, their design and use remain largely traditional. As a rule, this gear is not very cumbersome. It can be easily carried by the fisher and is inexpensive. Fish fences are the one exception; these are fixed fisheries largely used on inner reef slopes and Polynesian lagoon passes (Blanchet et al. 1985). In addition to the materials which are incontestably fishing gear given that the capture of aquatic animals is their main function, there are also multipurpose tools which are applied to fishing as well as other uses. The main one is the machete, at least one of which is owned by all rural households. Iron rods are also commonly used to capture octopus at low tide on the flats and to hunt for shellfish.

14. In the early 1980s in Vanuatu, most expeditions were made in outrigger canoes paddled with oars that were no longer than five metres (Cillaurren et al. 2001).

Figure 4: Main features of subsistence fisheries production system



A study (unpublished) that I conducted at the end of 1984 in collaboration with the National Planning and Statistics Office of Vanuatu demonstrated the extreme diversity of coastal fishing activities in the context of subsistence fisheries. A total of 943 fishing trips were analyzed over the entire archipelago. They resulted in the capture of over 100 species of fish belonging to 32 families. Ten types of gear were identified. Seven were used either alone or in association with one or several other types of gear; three always were used with other gear. In total, 39 types of gear or combinations of gear were identified (22 combinations of two types of gear, 9 combinations of 3 types of gear, one combination of 4 types of gear and 7 uses of a single type of gear), which correspond to 82 different modes of use.[15] For the same type of gear, there can be several capture techniques[16] which vary depending on whether the fisherman uses a boat or not and on the type of biotope exploited. On this basis, these 39 types of gear and combinations of gear generated 97 capture techniques.

This diversity of fishing activity is not specific to Vanuatu but corresponds well to the ecological, physical, and economic constraints shaping the subsistence fisher (predator) — fish (prey) relationship in Pacific Island countries and territories. With the growth of a cash economy, there has been a gradual transformation of fishing material, with homemade gear such as bows and spears being replaced by much more high-yielding gear, notably gillnets and cast-nets.

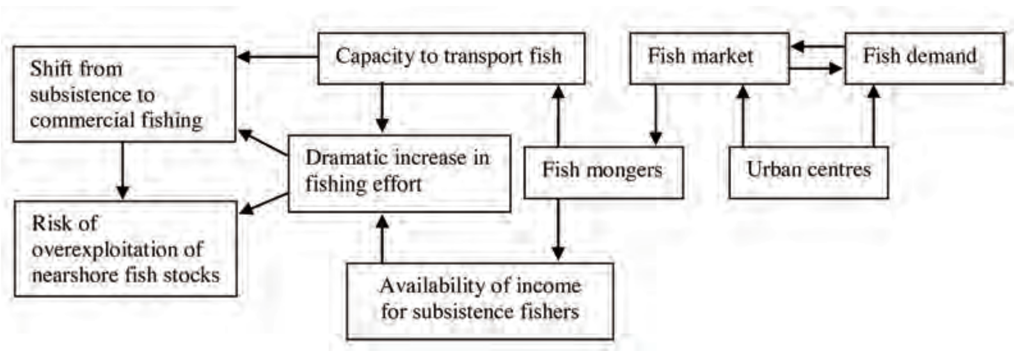
15. (7 x 1) + (22 x 2) + (9 x 3) + (1 x 4) = 82 modes of use of capture gear.

16. The capture technique is defined as the conjuncture of a mode of use of fishing gear (alone or in combination), a motion vector (on foot, diving, boat) and a biotope exploited.

In contrast, the framework in which fishing is practiced has not changed. The village continues to occupy a central place both as the fisher's habitat, the launching site of fishing trips, and the main consumption centre of fish products. Fishing grounds border villages and in numerous regions they form a veritable fishing territory with access reserved to the villagers (Carrier 1981; Dahl 1988). Fishers generally maintain multiple activities (fig. 4) and agriculture often remains the main source of income, with the majority of fishing trips undertaken within a framework of subsistence fishing. Home consumption at the village level remains the main use of fish products; only surpluses are marketed. Commercial fishing, characterized by the desire of the fisherman to sell, only concerns a minority of fishers in rural areas except when there is a need of cash for exceptional expenses (taxes, school fees, festivities) leading numerous fishers to sell their production to balance their budgets. The limited development of commercial fishing is due to the weakness of distribution channels (on many high islands, inland consumption of seafood is impossible) and the poverty of potential consumers. The situation is completely different around urban centres, which provide regular commercial outlets for fishers, particularly when wholesalers assume the task of transporting the fish from the fishers' villages to the sales points.

The presence of a profitable market is a powerful vehicle for the development of the commercial fishing of reef species. Subsistence fishers can then become genuine commercial fishers, even if their fishing gear and target species remain unchanged. As emphasized by Tom D. Brewer (2011) in the case of the Solomon Islands, this shift from subsistence fishing to marked-based fishing can deeply affect the reef fish stocks. The overfished areas in mangroves, meadows, and coral reefs then widen depending on how often fish mongers pass, a parameter determined by consumer demand and the distance to the market (fig. 5).

Figure 5: The possible effects of urbanization on nearshore fish abundance



The introduction of trade in fisheries products in villages dominated by subsistence fishing is not a new phenomenon. Mother-of-pearl shellfish and sea cucumbers have been commercially exploited in Oceania since the first half of the 19th century (Doumenge 1966). Like whales, they contributed to the insertion of this region into the global economy, to such a degree that the vehicular languages spoken in Vanuatu, the Solomon Islands and Papua New Guinea (Bislama, Pijin, Tok Pisin) were developed to facilitate their trade. This exploitation is practiced within a mining economy framework,[17] with beach-combers, often sailors who have deserted, working for a merchant adventurer whose vessel sweeps an area until its holds are full, combing one zone before moving to another (Shineberg 1967). In the past, trade was too infrequent for subsistence fishers to become commercial fishers, as some of their descendants have become in the 21st century with the development of local markets (fig. 5). Trade only allowed them to derive value from products that were little used or not used at all. Sea cucumbers thus were not fished probably because they were deemed inedible. Mother-of-pearl shellfish were consumed for their flesh and their shells were used to make jewellery and hooks (Conte 2010). These were replaced with metal hooks purchased from the beach-combers to whom the sea cucumbers and mother-of-pearl shells were sold.

This mining economy model has changed little over time. To satisfy increasing international demand, notably due to the concurrent increase in the consumer population and their purchasing power in China (Conand 1986), buyers working for large global import companies (often Chinese) travel through the coastal inter-tropical zone organizing the collection of sea cucumbers at the national scale (Kinch et al. 2008). They venture to the most remote Pacific Islands, offering local communities considerable amounts of money in relation to their purchasing power to collect the maximum amount of trochus and sea cucumbers. How can traditional leaders resist this windfall when governments are cutting back their financial commitments, including for the maintenance of health, education and transportation infrastructure? The overexploitation of part of their fish stock has a minimal cost compared to the expected benefits: the renovation of a school or dispensary, or improving a road network which contributes to increasing the viability of their territory.

This type of predator-prey relationship, which involves a chain of decisions reaching up to the global level to plan local and national collections, is part of a mining economy that has no equivalent in coastal fisheries. At the world scale, at any given moment five to ten countries are full-time producers of sea cucumbers, but they

17. When applied to renewable resources, the expression, "mining economy" means a form of exploitation that is unconcerned with the renewal of the resource. Exploitation continues as long as profits are generated, with no concern for the overexploitation of the resource. Once the resource is exhausted, the exploitation moves to another resource which has not yet been exploited.

occupy this role for only a short period — two to three years — before ceding their place to other countries, their stocks having been seriously depleted. A "fallow" period then follows, with several years needed before stocks are reconstituted and these countries can resume their role as leading sea cucumber producers (Carlton et al. 2013). For example, from 1984 to 1988, sea cucumber exports from Fiji went from 50 tons to over 700 tons, only to fall back to less than 300 tons in 1990 (Bettencourt 1995). In 2003, sea cucumbers once again represented a significant part of seafood exports (11% of their value), yet four years later, they were no longer listed among the country's exports (Gillett 2009). This succession of highs and lows also is illustrated by the case of the Solomon Islands, where sea cucumber exports, after stagnating between 100 and 150 tons between 1986 and 1990, exceeded 600 tons in 1991 to culminate at 715 tons in 1992, only to then collapse due to the overexploitation of stocks. In 2005, sea cucumber exports were again at high levels. They generated a value of US$766,000 only to dive down to US$33,000 the following year (Bettencourt 1995; Gillett 2009).

Traditional regulation of fishing activities

Due to the limited size of fishing grounds in some localities, "traditional" solutions for regulating fishing pressure are practiced by some groups (clan or tribe) which consist of controlling access to the resource through temporary fishing bans covering part or all of a fishing grounds (Carrier 1981; Foale et al. 2011; Johannes 1978, 1994; Ruddle and Akimichi 1984; Ruddle and Johannes 1989; South et al. 1994). The objective is to be able to harvest at specific times the resource needed for feasts and customary exchanges or for the survival of the group after a natural catastrophe has destroyed the agricultural resources on which their daily diet depends. These bans are directed at all members of the village community with a fishing ground and to non-resident populations, or sometimes only to the latter, and cover either all of the exploitable species, or only the species most threatened. Their effectiveness depends on two factors. The first is the growth rate of the species present in the protected area, the "record" belonging to the octopus, which can reconstitute its population in six months. The second is the "sink" situation of the fishing ground in relation to the currents carrying the flow of eggs or larvae of fish, molluscs, and shellfish emitted by the reefs called the "sources", which can be located several dozen, or even several hundred, kilometres away. In this way, habitats which have been in part depopulated by overfishing can be gradually recolonized.

This regeneration potential of fish stock held by reef environments is a considerable advantage which compensates for their high sensitivity to all intensive exploitation. All of the species present do not have the same potential to recolonize an environment. Those whose larvae live on open water are at a clear advantage compared to species which spend most of their larval stage fixed to the sea bottom. Moving with the currents, the former can cover great distances; in contrast, the latter have a very limited distribution area and only recolonize the environment around where they were laid. To respond to the introduction over the past thirty years of spear guns and gillnets, which are more efficient than "traditional" capture gear, temporary fishing bans have been accompanied by a ban on the use of this gear on the fisheries resources. On the atolls of Tonga, Tuvalu, and southern Kiribati, it has been observed that commercial fishery can be banned and only home-consumption fishery allowed when there is heavy fishing pressure on the environment (Bataille-Benguigui 1994; Zann 1990).[18]

Lastly, these temporary fishing bans are a means to manage the village maritime territory of a coastal community and have a dual objective, both social — involving the affirmation that a fishing ground belongs to the community — and economic. The economic objective can be broken down into three subobjectives which can only all be fulfilled if the abundance of the reef fisheries resource is preserved or restored:

- the first is to consolidate the sustainability of subsistence fishing as a steady source of animal protein. This situation corresponds to coastal areas unsuitable for agriculture because fishing generally comes second after agriculture and is only practiced regularly when land is not sufficiently productive. With the increase of human population densities on some islands, this daily food function of fishing grounds is today becoming more commonplace, including on the large Melanesian islands where it was still marginal just thirty years ago.

- the second objective involves the reinforcement of the reef's food pantry function in difficult situations, notably after a cyclone has destroyed a large part of the gardens producing daily food items.

- the third objective aims to provide fish production sufficient to cover traditional and religious events which work to reinforce intra and inter-community social cohesion. This was the situation found by Edvard Hviding (1990) in the Marovo lagoon in New-Georgia (Solomon Islands).

These traditional forms of management have been given a fresh boost over the past twenty years with the establishment of locally managed marine areas (LMMAs) (Govan 2009; Ruddle 1998). Using "ancestral" fishing ground management rules to develop a fisheries resource management mode at both the village and national scale is an innovative idea compared to so-called modern fisheries management based on

18. We have only scanty knowledge of the current situation on these atolls.

the dynamics of the exploited resource. As emphasized by Philippa Cohen and Simon Foale (2011:5): "*Area closures are a useful tool for a holistic approach to management suited to multi-species fisheries; managing at the ecosystem level rather than species level*."

The focus is no longer on managing a resource, but rather the space where the resource lives. The management rules no longer rely on mathematical models but rather on collective decisions regarding the opening or closing of a fisheries resource space which are taken at the village level. In this way, fishers are transformed into managers of the resources that they exploit. In so doing, one avoids the jump in scales between the national level, where fisheries management decisions are taken by public authorities intending to exploit these resources for the good of the national community according to rules they have defined, and the local level, where fishing is practiced daily and where these management rules are generally applied poorly due to a desire to maintain full use of the fisheries resources on the territory. When the decision to set aside fishing grounds is taken in concertation or in agreement with national authorities, it is possible to speak of *co-management*, *collaborative management* or *community-based management* (Barrow et al. 2000; Nurse and Kabamba 2000; Sen and Nielsen 1996).

All the same, the Pacific today is not that of yesterday. Closed, self-sufficient systems have opened, and cash is circulating in even the most remote areas. Given these changes, it is logical to question whether traditional management modes will function correctly in the future just because they worked well in the past, especially if the species are targeted by commercial fishing and can attain a good price on international markets, such as sea cucumbers and mother-of-pearl shellfish. Higher global demand puts greater pressure on national stocks, raising the risk that they will not be able to reconstitute themselves. If sea cucumbers were managed in a "balanced" fashion within a village framework, such a development would be impossible. This is the reason that co-management efforts currently are being made between the fisheries departments and local communities in New Caledonia and Vanuatu (Léopold et al. 2013a) which are taking into account lessons learned from the LMMAs set up in the early 1990s to manage trochus stocks in Vanuatu.

The Port-Vila fisheries department was behind the first LMMAs in Vanuatu. These were set up to secure the development of juvenile trochus produced at the hatchery run by the Port-Vila fisheries department and released into the natural environment to attain the size of adults and become marketable. To keep down poaching and the collection of immature shellfish, agreements were reached between the fisheries department and village communities so that the shellfish would be not be collected during the months needed for their growth. It quickly became apparent that these initial LMMAs did not last long (David 1994), mainly because local political authorities were not strong enough to enforce a fishing ban on a resource which fetched very high prices on the international market (David 2006).

Nonetheless, interest in LMMAs grew in Vanuatu and throughout the Pacific Islands (Bartlett et al. 2009; Veitayaki et al. 2003). In 2009, Hugh Govan reported that 595 LMMAs had been established in the Pacific Islands, covering a total area of 1,107 km^2. This development is due to two phenomena acting in synergy. The first was international enthusiasm for MPAs, of which LMMAs represent one category. The precautionary approach to fisheries management and the ecosystem approach to fisheries [19] (FAO 1995; Garcia 1996) present these MPAs as effective fisheries management tools because they allow the complexity of marine ecosystems to be preserved and the gradual repopulation of zones damaged by fishing pressure (Pauly 1997). The second phenomenon stemmed from the distrust of large international NGOs and members of certain UN agencies regarding the capacity of governments to ensure "good governance". To promote sustainable development, they sought to bypass central authorities, which were deemed inefficient and often corrupt, and act directly at the local community level. Managed locally by users and beneficiaries, LMMAs were immediately met with enthusiasm by international conservation NGOs. Nevertheless, LMMAs remain fragile entities. Their longevity in Vanuatu during the 2000s was due in large part to the technical and financial support of NGOs. However, once the latter was withdrawn, the support of the coastal population dimmed in the face of conflicts and disputes between stakeholders (Léopold et al. 2013b). These problems should not *a priori* condemn the LMMA concept, but LMMAs should no longer be considered as a panacea for the management of nearshore resources. The creation of LMMAs also should be reserved to communities with sufficient power to effectively impose and enforce the rules of access to fishing grounds which are inherent to all MPAs (David 2006).

However, even when this political power exists, the effectiveness of LMMAs as a fisheries resource management tool depends on the logics within communities and the rationales of their political leaders, as illustrated by the example of "*Sasi lola*" on Kei Besar island in the Maluku Islands (an archipelago in the eastern part of Indonesia). To preserve trochus resources, traditional bans were renewed at the start of the 1980s. Fishing for them is now open only two to three days a year and is marked by a ceremony: the lifting of *Sasi*, or "the taboo". However, as shown in the thesis by Isabelle Antunès (2000), the conservation of the resource is not the objective of this LMMA. It is instead a means to ensure the viability of the territory and village community by "maximizing" the cash income earned from trochus exploitation because the village has few other marketable resources. As long as the

19. These approaches emerged from the major crisis which upset fisheries science following the collapse of Canadian cod fisheries. The mathematical models of exploited populations' dynamics on which modern fisheries management was based were revealed incapable of predicting the sustained collapse of stocks and the dynamics of exploited populations lost its "magical science" status, to quote Didier Gascuel (1995).

conservation of the fisheries resource furthers territorial viability, fishing is managed correctly. However, overfishing fish stocks which are highly sought after on international markets may also be considered rational when the income generated helps to strengthen the overall viability of the territory.

Conclusion

Given the importance of village fisheries for the food security of Pacific Island coastal populations, ensuring their sustainability should be a priority of government and village authorities across the ensemble of the Pacific Island countries and territories. The experience of the 1980s and 1990s has shown that national fisheries departments did not have the human and financial resources necessary to directly manage village fisheries. The landing sites are too dispersed to be regularly visited by fisheries officers. A bridge must be established between the national level, where fisheries management is planned and developed by national fisheries departments, and the local level, where fisheries resources are exploited. However, the challenge is considerable. In effect, it is not just a bridge between two geographic levels that is needed, but also a bridge between the reasoning of the actors operating on each of these levels. Villagers aspire to retain the full use of the natural resources in the waters of their village territory while public authorities (the fisheries departments) intend to exploit these resources for the good of the nation in accordance with the rules they have defined.

MPAs are not exempt from these constraints. While reef MPAs are widespread in the Pacific region, they are not all effective. Four main reasons for this lack of effectiveness may be noted:

- a poor location in relation to marine currents transporting the larvae of the species populating the reefs. A lack of recognition of connectivity is widespread in the region. The situation should improve in the future for the "classic" MPAs set up by public authorities in the Pacific Island countries and territories. In effect, to reduce MPAs' vulnerability to climate change, the conservation of coral reefs must now be planned within the framework of an MPA network. In this context, connectivity becomes a key parameter (David et al. 2015). In contrast, LMMAs follow purely local rationales; they respond exclusively to the needs of a village community and under this framework, connectivity is completely ignored;

- high vulnerability to polluting flows and runoff from watersheds that can severely degrade coral habitats; reducing this vulnerability involves setting up integrated watershed/downstream coastal management. This vulnerability only concerns the "classic" MPAs located along the coast of high islands. It results from an absence of integrated territory management, with the people managing watershed resources failing to take into account the negative impacts generated by their activities on the marine ecosystem, notably reefs. In contrast, LMMAs are not concerned because in principle the marine territory on which area closures are set up is an integral part of the village territory;

- high coastal population densities and severe income poverty ruling out the possibility of purchasing protein-rich food that could take the place of fresh fish products. This constraint is shared by classic MPAs and LMMAs. It is even stronger since fish mongers pass regularly in villages neighbouring MPAs to supply market demand for fresh fish products. The only solution is to develop other income generating activities besides fishing which are compatible with the objectives set for the MPAs;

- MPA managers and rangers, or political authorities in the case of LMMAs, are too weak to enforce fishing bans when all of the members of the village community do not share the logic that led to the imposition of the bans. This constraint raises the issue of the social acceptance of MPAs and the means to reinforce this acceptance.

In the case of LMMAs, establishing a bridge between village communities and national authorities takes place through co-management agreements. These should be understood by the national authorities as a form of recognition that the planning of fisheries management, and the setting up of MPAs and their management, are necessary, but village communities play a major role in marine conservation and management and are needed to ensure the success of these actions. On the side of village communities and NGOs, which often support these communities in setting up LMMAs, these agreements should be understood as a form of recognition that marine conservation and management, including fisheries management, cannot be done exclusively at a local level, and that planning at a national, indeed international level, is necessary. They therefore need to recognize the role played by public authorities as an interface with international organizations such as the SPC and as the designers of national marine conservation and management policy.

It is within this framework that LMMAs need to be organized into a network. Studies also need to be made on the coherence of this network with regard to the connectivity of reefs to maximize the reserve effect on the marine environment and to minimize the negative effects of the inadequacy of the area (about 2 km^2 each) protected under LMMAs to engender a significant spillover effect on surrounding fish stocks. Temporary fishing reserves set up for several weeks on spawning grounds during egg-laying periods also are a measure which could be taken at the local level to avoid the capture of spawners and consequently encourage the future recovery of fish populations.

It is also within this framework that deepwater MPAs, nearshore FADs and artificial reefs must be set up. Given the vulnerability of deep sea demersal species to fishing which is intensive or prolonged over time, such deepwater MPAs should be established to secure the future of these fisheries. As for nearshore FADs and artificial reefs, these are much less expensive than deeply moored FADs, which seem to have a limited future given their high purchase and maintenance costs. Their deployment in sedimentary zones should increase the fish biomass and reinforce the sustainability of nearshore fisheries.

Lastly, this brief panorama of the recent history of Pacific Island village fisheries shows that the sustainability of this fishery cannot be achieved if the focus is limited to a geographic dimension — the national level or the local level — or a sectoral view of the fishing system. Regardless of the geographic dimension (local or national) in which one positions oneself, one cannot address the production subsystem if one does not have a clear picture of the management subsystem, and one cannot address the management subsystem without a clear understanding of the production subsystem and the fisheries product chain and trade subsystem. The sustainability of Pacific Island village fisheries therefore must be organized at the level of each of the three subsystems forming the village fisheries system (fig. 1) and at each of the geographic dimensions.

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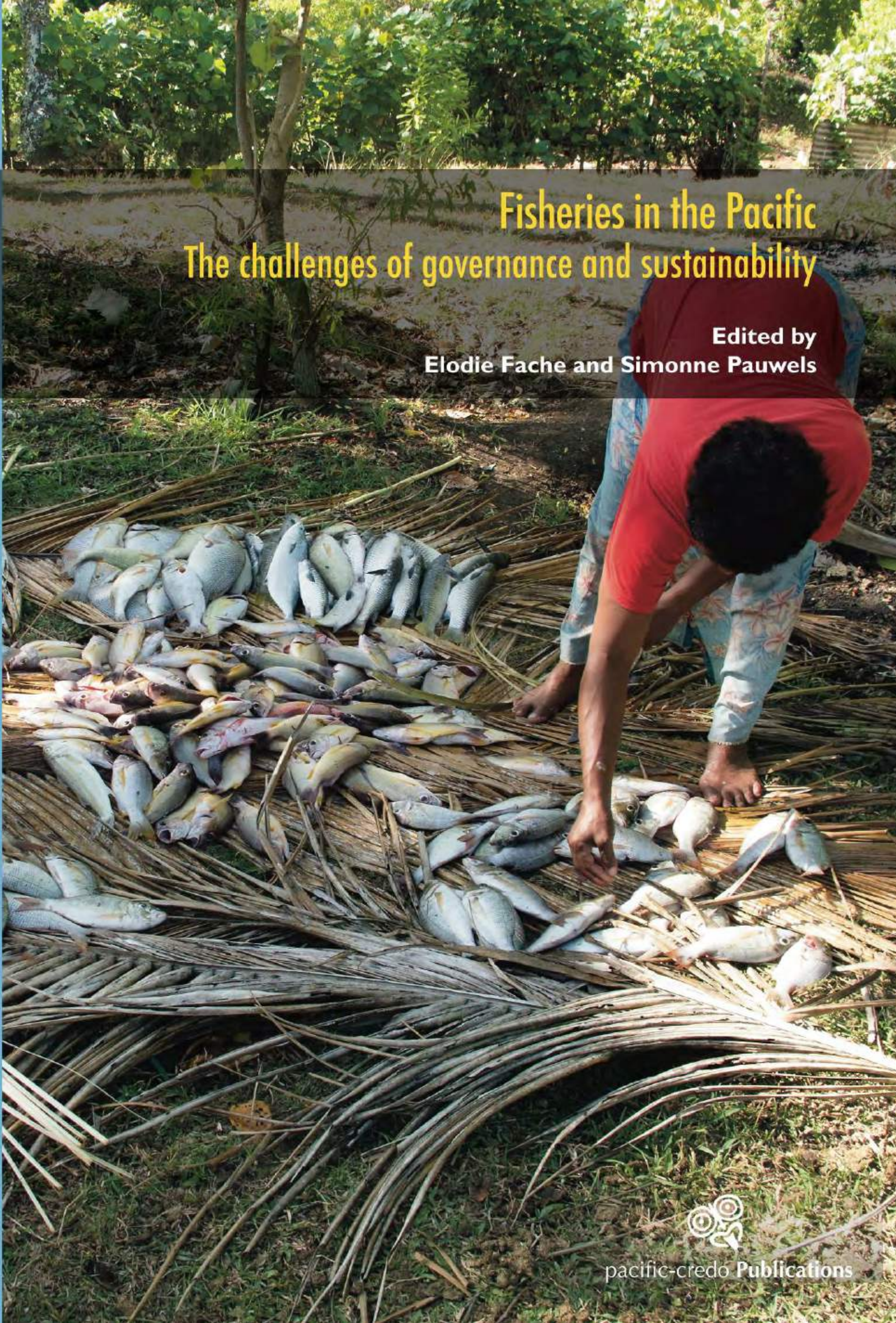

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Edited by
Elodie Fache and Simonne Pauwels

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