Ecological and Economic Impacts of Distant Water Fishing:

Three Empirical Studies

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Chapter 1.

Introduction

1.1 Background and motivation

Fishery products today belong to the most extensively traded products in the world, with a trading volume that has been constantly growing and today represents almost 40 percent of global production. The bulk part of this originates from developing countries (FAO 2012a). This increase in international trade went along with a shift of per capita fish consumption from resource-rich "southern" countries to economically stronger, "northern" countries, and with an enhanced globalization of harvest operations. In addition to a shift of supply from south to north, demand for fish products has been rising considerably in emerging economies over past decades. These developments not only increased the pressure on fish populations but also evoked conflicts at political, legal and economic scales (Béné, Lawton, and Allison 2010; CEA 2011; Munro 1989; Taylor, Schechter, and Wolfson 2007). This thesis is concerned with one example of the sketched trend, namely the interplay between industrialized distant water fleets and the often highly vulnerable regions where they fish. This involves analyzing both marine and associated terrestrial regions and how these are affected by current and alternative developments of fishing activity and processing industries in terms of economic, ecological, political and social implications.

The research reported here falls within the broader field of "fisheries science". Main themes addressed by it include biological and ecological dynamics of marine and freshwater fish populations, human impacts on these populations and their regulation, and the trade-off between often incompatible sustainability and economic objectives – including economic yield, employment, ecosystem integrity, and biodiversity conservation. Fisheries science is multidisciplinary in approach, involving applied mathematics (formal modelling), biology, economics, political science and anthropology.

Research in this field can be classified in various ways. On a very high level, one can identify marine vs. freshwater fisheries and capture vs. aquaculture. These categories are commonly used by national fisheries ministries and international organizations, such as the Food and Agriculture Organization (FAO), to broadly divide sources of fisheries production. Most of the literature in fisheries science, including this thesis, is concerned with marine capture fisheries, i.e. catches of wild fish in the ocean.

When productivity, ecological impacts or vulnerability to overfishing are the subject of an analysis, relevant classifications of "fisheries" tend to be based on ecosystem types. This may focus on habitats (e.g. benthic vs. pelagic) or ecosystem attributes (e.g. low energy systems, such as coral reefs, versus high energy systems such as upwelling regions). In addition, categorization of fishing gears (trawlers, longlines, gillnets, spears, traps etc.) or type and scale of fishing (e.g., subsistence, artisanal, small-scale, industrial) are relevant (Pauly and Christensen 1995; Jackson 2001; Halpern et al. 2008).

When bioeconomic or ecological modelling are the main focus, specific functional groups (phytoplankton, zooplankton, planktivorous fish, small predators etc.) and commodity types (white fish, tuna, flat fish, crustaceans, invertebrates) are often focused on. Such a distinction is at the basis, for example, of the software packages *Ecopath* and *Ecosim* that were developed to model trophic chain interactions and human impacts on ecosystems (Christensen and Walters 2004). This distinction is also used in the international database on fisheries landings *FishstatJ,* published by the Food and Agriculture Organization (FAO 2012b).

For the purpose of this thesis another categorization is relevant. It has its basis in international maritime legislation. Through the coming into force of the 1982 United Nations Convention on the Law of the Sea (UNCLOS), and the 1995 United Nations "Fish Stocks Agreement", rights and responsibilities of marine capture fisheries were dramatically restructured (Munro 1989; Munro 2000). On the one hand, every coastal country was granted property rights over so-called exclusive economic zones (EEZs), ocean areas stretching 200 nautical miles from the coast into the ocean. On the other hand, the responsibility of fisheries management concerning all major areas in the high seas was assigned to so-called regional fisheries management organizations (RFMOs).

The latter are composed of delegates from all countries expressing interest in the management and exploitation of specific areas in the high seas. RFMOs also often have a mandate to manage highly migratory and straddling fish stocks (moving between EEZs or between EEZs and the high seas), including most of the economically relevant tuna species.

Based on this legal framework, every fishing activity can be either called domestic (where a vessel carries the flag of EEZ) or distant water fishing (where it does not). In this thesis we are particularly interested in distant water fishing. More specifically, the thesis is concerned with the challenges emerging from the interaction between distant water fleets and the regions in which they fish, in terms of both ecological and socio-economic effects. Section 1.2 will elaborate this problem statement, contextualizing challenges associated with distant water fishing, and accentuating idiosyncratic vulnerabilities of those areas where distant water fishing is most intense.

1.2 Ecological and economic interactions of Distant Water Fishing Nations with their fishing areas

Fisheries are intrinsically difficult to manage. Scientific stock assessments are expensive and prone to uncertainty because of complex and poorly understood ecosystem dynamics, as well as stochastic impacts of environmental fluctuations on stock recruitment and natural mortality (Hilborn 1987; Ludwig, Hilborn, and Walters 1993). Information on stock status is therefore often unavailable or of limited reliability. Even when information is available, management plans are, in many cases, absent or ineffective (CEA 2011; Mora et al. 2009). Despite technical improvements in surveillance and control, financial and human capacities are often insufficient to deal with the opaqueness of fishing operations. Sustainable management is further hampered by severe vessel overcapacity and overfishing, stimulated in many cases by subsidies (Sumaila et al. 2010).

In the case of distant water fishing (DWF), additional difficulties can arise. On the one hand this relates to the specific characteristics of distant water fleets, and on the other hand to the vulnerabilities of the fishing areas where distant water fleets are active. Below we discuss both aspects.

1.2.1 Characteristics of DWF

Distant water fleets generally are large scale, high-technology fleets that enjoy protection by economically and politically powerful nations and have well established connections throughout global seafood supply chains and trade organizations.

Political protection: Distant water fleets fly the flags of either industrialized nations or rising economies with traditionally strong fishing sectors. Due to politically active and well-established lobby groups, as well as the economic importance of the fisheries sector to national economies, distant water fleets often receive considerable political backing from home governments. This is reflected in strong diplomatic pressure of distant water fishing nations (DWFNs) on both third countries and RFMOs. In the former case, control over fishing grounds is exerted through fishing agreements which are often tied to trade agreements or foreign aid programs (Petersen 2003; Mbithi Mwikya 2006). In the latter case, both governments (through ministries) and the industry influence policy making through RFMO delegates (CEA 2011).

Distortion of economic competition: Some of the powerful DWFNs control the economically most important fish markets, including those of the EU, the United States, Japan and, more recently, Hongkong. As fish prices are considerably higher here than they are in tropical, developing countries, the control over access to these markets provides substantial leverage for DWFNs to negotiate with third countries, as well as to curtail domestic fisheries development in source countries. Instruments actively used by DWFNs in this context are tariffs and non-tariff trade barriers. The latter are sometimes referred to as "disguised protectionism" (Henson and Loader 2001; Runge 1990) and include sanitary and phytosanitary measures, environmental guidelines, work conditions and traceability requirements. Subsidies provided by national governments are an additional factor granting DWFNs a competitive advantage over economically weaker source countries. All major distant water fleets receive direct or indirect financial support to cover their fishing costs or access (Sumaila et al. 2010).

Technological superiority: Vessels fit for trips that last for several months are, by definition, large-scale, industrial vessels featuring modern technology and storage capacity that by far exceeds those of most near-shore, domestically fishing fleets. These industrial vessels allow for a greater ease at detecting, hauling in, and preserving fish without returning to the harbor. As a result, catchability is increased and cost per unit of effort decreased (Villasante and Sumaila 2010; Anticamara et al. 2011), adding to DWFN's competitive advantage in global fisheries.

Information and know-how: Given their long-standing presence and experience, distant water fishing fleets today are the key players in the global seafood industry. In many cases they are vertically integrated in multi-national corporations that dominate the fisheries value chains from harvest to retail (Hamilton et al. 2011). As such, they have a clear head-start concerning valuable technical know-how and information. This information relates to fluctuations of stock abundance and associated catch per unit of effort, population dynamics and behavioral patterns of fish schools. In addition, it includes a better understanding of the economic and financial aspects of the fishing industry, concerning operational cost and revenue streams as well as market dynamics of global fisheries commodities. This means that DWFNs are strong competitors in fisheries and fishery markets.

Overcapacity: Arguably the most severe problem of distant water fishing is overcapacity. On a global level, fishing capacity would have to be reduced by approximately 50% to reach a maximum economic yield (World Bank 2009) and slightly less to reach maximum sustainable yield (landing volume per year). Virtually every country with a distant water fleet has to accommodate more vessels than are compatible with the productivity of their fishing areas. In view of the DWFN characteristics above (highly competitive and technologized fleets that are heavily subsidized), and given the finite nature of marine resources, this suggests two possible scenarios. If fishing areas are well-managed by effective limits of input (fishing capacity or total effort) or output (fishing quotas), then increased competition among DWFNs can be expected both in high seas and in the EEZs of third countries. As a result, the value of a fishing quota or access to fishing grounds may rise. If management is poor, overcapacity can lead to a "race to fish", where too many boats eventually hunt too few fish, resulting in declining stock densities and the risk of collapse (Clark 1976; Costello, Gaines, and Lynham 2008; Hilborn, Orensanz, and Parma 2005).

1.2.2 Economic and ecological vulnerabilities of DWFN fishing areas

Distant water fleets are operative in areas where fisheries management has shown to be particularly weak and which are therefore especially vulnerable to overfishing and economic exploitation. This includes high seas areas and EEZs of tropical developing countries (our geographical focus).

High seas: Effective fisheries management in the high seas today stands and falls with the managerial devotion and skill of regional fisheries management organizations (RFMOs). These multi-national management bodies replaced open access regimes in the high seas that prevailed until the early 1990s and meant an important step towards the management of highly valued predatory pelagic fish (Munro 2000). Unfortunately, the inception of this concept of cooperative management between countries went along with numerous difficulties and disappointments. Most importantly, a consensus decision-making process has allowed RFMOs to systematically overrule scientific advice and ignore international agreements and conservation proposals. The main reason for the weak performance of RFMOs can be explained by a lack of commitment to their mandates. This, in turn, relates to the fact that almost 90 percent of delegates are affiliated with either ministries (fisheries, trade, foreign affairs) or fishing corporations, and that all but one RFMO (the CCAMLR) financially heavily depend on one or two select member countries (Cullis-Suzuki and Pauly 2010; CEA 2011).

EEZs of tropical developing countries: Structural vulnerabilities are even more pronounced in EEZs of tropical developing countries than they are in the high seas. Many EEZs are connected to countries that are politically unstable and economically weak. They are often characterized by feeble institutions, corruption and lack of information , which gives rise to myopic decision-making about natural resource management (CEA 2011). Outcomes are even worsened through the loss of traditional resource management and the influence of formal markets (Johannes 1978). Marine resources are not given a high status in political decision-making in many tropical developing countries but continue to be regarded as a means to the end of closing budget gaps or even self-enrichment of those in power. Adding to this, marine ecosystems in the tropics tend to be rather complex and delicate, including high species diversity and low nutrient levels, which demands much caution in management.

1.3 Aims and outline of this thesis

This thesis adopts three different perspectives to shed light on the previously sketched problems and associated challenges. The methodological approaches range from literature review through empirical data analysis to mathematical modelling. The connecting factor of the resulting studies, reported in chapters 2 to 4, is integrated ecological-economic impact assessment of distant water fishing on their fishing areas, and identifying strategies and policies aimed at sustainable fishing activities. Below we briefly summarize the approach and contents of each chapter.

In *Chapter 2* we critically review the development of distant water fishing in the tropical world over the past 50 years. This involves three steps. We first provide a thorough appraisal of trends concerning stock health, maritime law and fisheries management. We then introduce and categorize the concept of fishing agreements. These were initially thought to assist in smoothly triggering the phase-out of distant water fishing from the tropical developing world while simultaneously creating income for coastal states that then might be reinvested into domestic industries. Beyond being merely remunerable concessions, agreements have often been accompanied by partnerships for management and trade. However, today many fishing agreements run a serious risk of undermining sustainable resource management and have not lived up to the expectations that developing countries had when, several decades ago, governance of EEZs was legally transferred to coastal states. We examine global trends in distant water fishing and identify reasons for the often unaccomplished aspirations of existing agreements. This comprises two elements: identifying major distant water fleets, quantifying their contribution to global distant water fishing and highlighting their handling of fishing agreements; highlighting those "host" countries most dependent on distant water fishing and discussing their motives for granting access to distant water fishing nations.

Chapter 3 addresses an important question raised in Chapter 2, namely whether tropical host countries should continue granting access to distant water fishing nations or whether they should rather attempt to develop an own domestic fishing industry. Our case study for this question is a set of Pacific Island Countries (the 17 member countries to the Forum Fisheries Agency) that together control access to the largest tuna fisheries (by volume and value) in the world. Interestingly, despite this control, these countries remain to benefit only marginally from this natural resource, being strongly dependent on distant water fishing, as explained in detail in Chapter 2. We develop a multi-player bioeconomic optimization model to maximize fishing rents for this set of Island countries. The model accounts for multiple fishing gears, fish species and fishing areas. Particular attention is given to the trade-off that PICs face in their policy-making between access fees from distant water nations and income from developing domestic fishing and fish processing industries that create value added. In addition, we consider the potential political consequences of, and barriers to, replacing distant water fleets with domestic vessels.

Chapter 4 is concerned with the second aspect of distant water fishing, namely the challenges faced by RFMOs to manage high seas areas and highly migratory fish species. In this context, a much cited case is the overfishing of Eastern Atlantic and Mediterranean stock of Bluefin tuna Thunnus thynnus (BFTE). This species is one of the most extensively traded and highly valued fish species. A large part of it is earmarked for the high-grade sashimi market in Japan and other "Western" economies. Its high value has stimulated overcapacity not only in the harvest sector but also in other segments of the associated value chain. Motivated by industry interests, fishing quotas set by ICCAT (International Commission for the Conservation of Atlantic Tunas) have exceeded those suggested by its scientific committee for many years, resulting in structural overfishing which has driven the stock to near collapse. Although ICCAT has decreased allowable fishing quotas considerably in past years, uncertainty exists about illegal catches that persists beyond this quota. The size of this catch is an important input to stock assessment models as well as an indicator of the effectiveness of fisheries management. In this chapter we challenge ICCAT's view that no illegal catch has been taking place anymore since 2007 (ICCAT 2012a). For this purpose, we develop a model using monthly Bluefin tuna trade data of 25 countries involved in BFTE trade between 2005 and 2011 to infer actual catches and thus estimate the extent of illegal catch.

Chapter 5 concludes and draws general lessons for analysis, modeling, policy and management of DWFN fisheries.

Chapter 2.

A Critical Review of Fishing Agreements with Tropical Developing Countries

2.1 Introduction

The past decades show a dramatic increase of global fishing effort. The diffusion of advanced fishing technology in developed countries and the drastic increases of fishing effort in lower latitudes (notably in Asia) have resulted in ever-growing global fishing capacity that has gradually shifted to tropical regions (Anticamara et al. 2011; Swartz et al. 2010; Villasante and Sumaila 2010; FAO 2010). This has increased the pressure on tropical marine ecosystems, systems for which knowledge about the health of fish stocks is poor and fisheries management is weak (Worm et al. 2009; Mora et al. 2009). In addition to a rise in local fishing efforts in African, Carribbean and Pacific (ACP) countries, fishing access agreements signed between these countries and distant water fishing nations (DWFN) have further contributed to intensify fishing pressure. It has been argued that fishing agreements have considerable potential to help developing "host" countries profit from their otherwise unutilized fisheries resources while domestic industries are being built up. Unfortunately, such agreements have mostly failed to benefit host countries in the long run. The main criticisms are that coastal states become dependent on access fees, that the wealth captured through agreements is only a fraction of the resource's value, that value-added activities are exported to DWFNs and that stock health suffers from the lack of control of local institutions over the exploitation of the resource (Petersen 2002; Alder and Sumaila 2004; Mbithi Mwikya 2006; Walmsley et al. 2007).

This paper offers a critical review of international fishing agreements and some of their impacts on host countries. This involves analyzing historical trends of distant water fishing and better understanding the motives of host countries to sign agreements. Since agreements are very heterogeneous, a typology of agreements will be developed here. The resulting analysis of fishing agreements, trends and impacts can provide information about how to improve the fisheries sector of ACP countries and its management given the constraints, or opportunities, created by the fishing agreement. The formulation and implementation of fisheries management is often influenced by uncertainty about fish population dynamics (G. Sethi et al. 2005). This is partly due to problems of measurement and lack of adequate indicators. This issue will also receive attention here.

The remainder of the paper is structured as follows. Section 2 reviews the literature with respect to fish stock health as well as trends in fisheries management and fishing pressure, all with a focus on tropical developing countries. Section 3 provides a typology of international fisheries interactions and illustrates the development of distant water fishing since 1960. Section 4 looks at two sets of host nations, namely countries that contribute most to DWFN landings and countries with weak domestic fisheries as compared to foreign catches. Section 5 presents the major conclusions to be drawn from the analysis in this paper, including policy suggestions.

2.2 Context: global fisheries, international policies and ACP countries

2.2.1 The health of fish stocks

Opinions of fisheries scientists on the health of the oceans seem to be diverging considerably at first sight; a closer look however reveals that they mostly agree on the trends thereof: Due to a very limited number of scientifically assessed stocks, different views have emerged over the past decade about the proper interpretation of available data concerning the impact of fisheries on targeted stocks as well as on ecosystems and biodiversity.

At one extreme, extrapolation of available stock assessments suggests that most major fish stocks are either close to healthy levels of exploitation or slowly getting there (Worm et al. 2009). However, the assessed stocks make up a mere 20 – 25 percent of global landings in weight (Ricard et al. 2012) and only 0.15 percent of global fisheries in stock numbers.[1] In addition, all available surveys stem from waters under the jurisdiction of developed countries (with the exception of South Africa and Peru, both of which have highly productive upwelling systems and industrialized fisheries). Finally, available assessments are heavily biased towards Clupeidae and Gadidae. The first family includes anchovies, sardines and herrings and is characterized by fast-growing and resilient species. The second family includes cods, haddocks, whitings and other "white fish". Virtually all commercially relevant catches of this family are certified by ecolabels such as the *Marine Stewardship Council.* This indicates a willingness to pay for sustainably fished products and hence a higher degree of caution at the supplier's end.

At the other extreme, the so-called catch-based method derives the state of a fish stock from its current landing weight as compared to maximum historic catches or similar historic reference values. Any change in landing is thus attributed to actual changes in the ecosystem, disregarding other factors that might influence catches such as a reduction in fishing effort due to management or demand fluctuations (Grainger and Garcia 1996; Pauly et al. 2003). Although contradictory results have been produced over past years (mainly due to improvements in the methodology), catch-based analyses paint a much darker picture of global stock health than scientific stock assessments. Similar disagreement exists about the health of food chains involving commercially caught fish (Pauly et al. 1998; Branch et al. 2010). However, despite a broad range of possible interpretations of existing data, there seems to be consensus on the following statements:

At the global level, the status of fish stocks is worsening rather than improving. One clear indication is globally stagnating or even declining catch weights despite an increase in total fishing effort (Anticamara et al. 2011; FAO 2011). Although stock health in many developed countries of the western hemisphere is improving due to more effective fisheries management, biomass levels tend to be below BMSY[2] in ACP countries while fishing mortality remains above FMSY[3] (FAO 2005; Worm et al. 2009; Costello et al. 2012). This trend is exacerbated in areas of high human population growth rates and

[1] Fisheries are defined here as species per FAO fishing area ((FAO 2012b).
[2] BMSY: Biomass at maximum sustainable yield.
[3] FMSY: Fishing mortality at maximum sustainable yield.

by the presence of foreign fishing fleets (Alder and Sumaila 2004; Cinner and McCLANAHAN 2006; Béné, Hersoug, and Allison 2010).

2.2.2 Trends in global fishing pressure

The international fishing fleet has continuously grown over the past decades (Anticamara et al. 2011; Gelchu and Pauly 2007). Simultaneously, case studies reveal that the technological efficiency tends to increase at an annual rate of 4 to 5 percent (FAO 2010; Villasante and Sumaila 2010; Gascuel, Fontenau, and Foucher 1993). One way to demonstrate the potential ecological impact of these combined developments is by calculating the primary productivity required (PPR) to sustain the catch of a given species in a given area (Pauly and Christensen 1995). Applying this indicator to historic catches of a wide range of species groups, Schwartz et al. (2010) show that the overall increase in global fishing effort in the past 60 years was accompanied by a southward expansion of effort (catches corresponding to at least 10 percent of PPR) at a rate of almost one degree latitude per year. This increase in fishing effort was so significant that, by 2005, catches in most parts of the Western Central Pacific- and Indian Ocean, as well as along wide stretches of Western Africa corresponded to 30 percent of PPR, as opposed to less than 10 percent of PPR only few decades earlier. As a result, by the mid-1990s only unproductive or economically unattractive fishing areas were left unexploited, an argument suggested by S.A. Sethi et al. (2010), who show that changes in catch compositions between 1950 and 2004 were driven by economically motivated behavior of fishermen rather than by trophic changes. In other words, species that yielded the highest profits were caught first, after which effort shifted to catching less profitable species. Another example of expanding fishing operations to less profitable areas is given by Morato et al. (2006) who demonstrate that marine fish are increasingly caught in deeper waters despite associated diminishing returns due to high operational costs of deep water fishing. Today, all major fish stocks in the world have been drawn into the scope of international fisheries and only few stocks of minor economic interest to the industry have been left unexploited. So it seems that “We are running out of new stocks by 2020” (Personal communication with Rainer Froese, senior scientist at the Leibniz Institute of Marine Sciences (IFM-GEOMAR).

2.2.3 International fisheries policy and the legal basis of fishing agreements

By 1949, with the establishment of the United Nations' International Law Commission (ILC) it soon became clear that questions pertaining to high seas and territorial seas were among the topics ripe for codification (Treves 2008). This was no simple task. For centuries, the concept of the freedom of the sea, *Mare Liberum,* proposed in 1609 by the Dutch lawyer Hugo Grotius, and suggesting that all oceans should be accessible and open to exploitation, was contrasted by John Seiden's concept of *Mare Clausum* in 1635. The latter claimed that at least parts of the sea should belong to specific countries. Considering that these concepts continue to fuel debates today, it is little wonder that after the first UN conference on the law of the sea held in Geneva in 1958, it took 36 years and three conferences to fully ratify, in 1992, the United Nations Convention on the Law of the Sea (UNCLOS). Until 1992 there was not a unified legal instrument applicable globally to preclude foreign fishing vessels from exploiting coastal resources. Especially for economically weak countries in the tropical south, this implied a yet unquantified loss of potential economic benefits as their own fishing industry had hardly been developed. UNCLOS implied a complete restructuring of marine property rights. In combination with the 1995 United Nations "Fish Stocks Agreement",[4] UNCLOS legally assigned rights and responsibilities over all marine areas. UNCLOS established exclusive economic zones (EEZ), maritime zones stretching up to 200 nautical miles into the ocean, over which coastal states gained sovereign rights for the purpose of exploring, exploiting, conserving, and managing natural resources. Although many countries had declared EEZs since the 70s, all coastal states now received *de facto* sovereign rights over the utilization of the living and non-living resources in their EEZs. Today, these areas cover 40 percent of the ocean's surface and contribute about 85 percent of global catch

[4] The "Fish Stock Agreement" (United Nations Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (in force as from 11 December 2001) relates to the management of high seas areas and straddling, and of highly migratory fish stocks and assigns regional fisheries management organizations (RFMOs) the responsibility to sustainably manage these stocks.

weight (Munro 1989; Mbithi Mwikya 2006; "Sea Around Us Project" 2013) and www.seaaroundus.com).[5]

Despite the adoption of EEZs since the 70s and the coming into force of UNCLOS in 1992, the expected decline of distant water fishing did not occur. Rather, the distant water fleet size increased until the late 1980s and only declined in the early 90s due in large part to the withdrawal of the previously "subsidized" fleet of the Former Soviet Union (FSU) (Johnstone 1996). Fishing countries started negotiating access agreements with the new owners of their old fishing grounds to absorb their distant water fleet capacity and enable them to continue to fish in areas where they had historically done so. Later on, agreements were signed also with governments of new fishing areas (IFREMER 1999; Mbithi Mwikya 2006; Walmsley et al. 2007).

2.2.4 Management of fish stocks in ACP countries

Although UNCLOS draws attention to countries' responsibility to sustainably manage the living resources of their EEZs, levels of accountability, and as a result enforcement, have been, and still are, extremely low. In fact, current international law makes it impossible for one state to sanction another for mismanaging its marine resources because such mismanagement primarily affects the resource owner itself. This low accountability is reflected in wide-spread deterioration of fish stocks as a result of failing fisheries management. This is especially true in low latitudes: Mora et al. (2009) find that practically all tropical and subtropical coastal states have highly ineffective measures in place to identify and enforce meaningful biological reference points for harvest. RFMOs do not seem to perform any better; Cullis-Suzuki and Pauly (2010) find that they are structurally vulnerable and institutionally weak, and have consistently failed to manage shared stocks. It is curious to see that fisheries are mismanaged at this scale given the immense financial losses induced by mismanagement (World Bank 2009). However, the open access nature of marine resources, the diversity of stakeholders, the complexity of

[5] Since near-shore waters have significantly higher levels of nutrients and primary productivity as compared to off-shore areas, the highest densities of fish is found in waters close to the coast, i.e. along the shelf. Therefore, the geographic expansion of fishing effort since the 1950s first and foremost implied the exploitation of shelf areas.

underlying biological and ecological dynamics, and myopic economic interests do not make it an easy task to steer a given fish stock towards ecological sustainability or even towards its maximum economic yield. Depending on the type of resource, the institutional strength of the management body, the economic stimuli, and social heterogeneity of the fishing community, among others, the effectiveness of possible approaches can be very distinct (Costello, Gaines, and Lynham 2008; Gutiérrez, Hilborn, and Defeo 2011).

When focusing on management weaknesses in ACP countries, two developments seem to be the most decisive, namely the collapse of traditional tenure systems and the incompatibility of tropical fisheries with western management approaches. Customary marine tenure systems included input and output controls as well as sophisticated ownership systems to exclude neighboring villages from fishing and often provided flexible mechanisms of risk-sharing among villages (Johannes 1978; Johannes, Ruddle, and Hviding 1991). These community-based laws and regulations were often intrinsically tied with religious systems as well as village laws and family structures (Ruddle 1994; Mcclanahan et al. 1997). Local management regimes require a high degree of leadership, social cohesion, collective action and exclusive access to resources (Gutiérrez, Hilborn, and Defeo 2011; Ostrom 1990). These requirements are directly or indirectly undermined by external pressure on the resource (distant water fishing), access to formal markets, population growth, poverty, and changes in social structures. Today, hardly any purely community-based fisheries management can withstand the pressure of altered circumstances (Johannes 1978; Toloa, Gillett, and Pelasio 1991; Alder and Sumaila 2004).

At the same time, western-type fisheries management does not take much effect in most ACP countries. Already in the late 70s it became clear that the western influence had hardly had any positive effect on resource management in tropical developing countries. Johannes (1978, 356) writes that, if “there is an island somewhere in Oceania where marine resources are conserved more effectively today than they were before European contact, I have not heard of it”. Reasons include the following. (i) The biological data required to estimate total allowable catches (TAC) are lacking and little or no capacity exists to enforce fishing regulations (Silvestre and Pauly 1997;

Mcclanahan et al. 1997); (ii) Small-scale artisanal fisheries are inherently difficult to manage as vessels cast off and land along the whole stretch of the coast as depicted by Salas et al. (2007) and personal communication with Matthieu Ducrocq (Marine programme coordinator, IUCN West Africa);[6] (iii) Fisheries in ACP countries is often more than just an occupation. It is a lifestyle, an integral component of social cohesion and represents a safety net (Béné, Hersoug, and Allison 2010). As a result, typical aspects of western-type fisheries management including catch share systems meet with resistance.

As a response to the negative effect of "westernization" on tropical fisheries management and the small effect that western, port-based fisheries management has in these areas, over the last decades, so-called co-management regimes[7] have been proposed as representing the most promising solutions to such areas: "The revival and rejuvenation of traditional customary systems with limited but crucial government involvement is one of the most promising policy options for upgrading and managing artisanal fisheries" (Panayotou 1982, 48) in (Johannes, Ruddle, and Hviding 1991). Although co-management is considered the most effective management approach in small-scale coastal fisheries, its success seems to be highly correlated with species of low mobility and homogeneous resource users displaying high social cohesion and strong leadership (Gutiérrez, Hilborn, and Defeo 2011).

For interactions between DWFNs and host countries, low effectiveness of fisheries management in the tropics signifies a high degree of uncertainty for both resource owners and distant water fleets about the state and trajectory of stock health. This in turn undermines alleged commitments of sustainable fishing. This is further aggravated when small-scale operators compete with industrial vessels so that the impact of distant water fleets cannot be distinguished from that of domestic fisheries.

[6] These fisheries often involve one or few fishing methods that simultaneously target various species with different biological life traits such as growth and recruitment patterns or size at first maturity. Optimal fishing efforts of one species might hence be suboptimal for others leading to a dilemma in effort selection.

[7] Co-management can be defined as an "arrangement where responsibility for resource management is shared between the government and user groups" (Sen and Raakjaer Nielsen 1996, 406).

2.3 Fishing agreements and trends in distant water fishing

At the broadest level, fishing agreements can be classified into three typologies. First, they can be reciprocal or unidirectional agreements; second, they may be bilateral or multilateral; and third, signatory parties may either be governments or companies. Table 2.1 summarizes the resulting possible types of agreements and gives examples where relevant.

Table 2.1: Typology of fishing agreements

		Government-Government	Government-Private	Private-Private
Reciprocal	Bilateral	*Description*: Governments of two countries sign agreements that grant permission to both signatories to fish in each other's EEZs. This is usualy combined with management cooperation. *Examples*: Reciprocal agreement between China and Japan or China and Vietnam	N.A.	N.A.
	Multilateral	*Description*: Governments of three or more countries sign agreements that grant permission to all signatories to fish in each other's EEZs. This is usualy combined with management cooperation. *Examples*: Trilateral agreement between Iceland, Norway and Russia	N.A.	N.A.
Unidirectional	Bilateral	*Description*: Governments of two countries sign agreements that grant fishing permission to of the DWFN in the host countries' EEZ *Examples*: Fisheries partnership agreements between the EU and ACP countries.	*Description*: Fishing companies of DWFNs sign access agreements with governments of host countries. *Examples*: South Korean, Taiwanese and Chinese fishing agreements with ACP countries in Asia and Africa	*Description*: Joint ventures between foreign investors and fishing companies in host countries as well as reflagging of foreign vessels to local vessels. *Examples*: After the termination of the EU-Senegal FPA, many Spanish operators either reflagged their vessels or went into joint ventures with local operators.

	Multilateral	**Description:** Governments of one DWFN and two or more host countries sign agreements that grant fishing permission to of the DWFN in the host countries' EEZs **Examples:** Multilateral Treaty on Fisheries between certain governments of the Pacific Island States and the government of the United States of America	**Description:** Fishing companies of DWFNs sign access agreements with governments of two or more host countries. **Examples:** All fishing agreements with countries of the Nauru-agreement are *per se* multilateral as the agreement requires uniform terms and conditions for the licensing of foreign vessels.	N.A.

Note: N.A. = not available.

For the purpose of this paper, only agreements will be considered that include host countries of tropical developing countries (or ACP countries), all of which belong to the category “unidirectional”.

2.3.1 Agreements by Major DWFNs

The most important DWFNs sourcing their landings from southern fishing areas are, by catch weight, the EU, Japan, the ex-Soviet countries and Asian and South East Asian countries. This section presents the core features of the major DWFNs’ fishing agreements.

2.3.1.1 EU agreements

Besides reciprocal “Northern” agreements with countries in the Northern Atlantic, the EU currently has, strictly bilateral, non-reciprocal `Southern agreements with 15 ACP countries in place, 10 of which are in Africa (mainly Western African countries). During the past decade, the EU has put much effort into improving fishing agreements, most importantly by replacing the highly criticized old generation of fishing agreements by the new, so-called “Fisheries partnership agreements” following the reform of the CFP in 2002. Since then, agreements have, at least on paper, increased the degree of technical support and transfer of know-how granted to the host country, as well as the amount of financial contributions to the host country. Today’s fix payments of €100/ton of fish represents between 10-15 % of landed value of the resource. What is more, access fees paid to host countries have increasingly been earmarked to specific investments pertaining to fisheries management or domestic fisheries infrastructure to help host countries develop their own fishing industry in a sustainable manner. In addition, European external fleets have started to abide by the FAO Code of Conduct for Responsible Fisheries more strictly[8], as a result of which agreements cannot be signed anymore if the state of the resources is beyond sustainable limits (Mbithi Mwikya 2006; Walmsley et al. 2007). In their aspiration to reach these goals, two main trends could be observed. First, a trend away from problematic mixed fisheries agreements towards tuna agreements that are less ambiguous than mixed fisheries agreements as they target fewer species and biomass estimates are subject to less uncertainty. Second, an overall reduction of FPAs (European Commission). Possible explanations for this fact include the withdrawal of several host countries from FPAs (including Senegal and Morocco) but might furthermore be explained by stricter political constraints on the part of the EU.

However, although on paper ambitious goals have made their way into legal documents, in practice major difficulties remain unsolved: (i) The EU continues to agree on targeting stocks for which biological surplus production cannot be ascertained scientifically; (ii) European regulations pertaining to technical measures (for example minimum mesh size) are not applied in foreign EEZs. Rather, less rigorous local regulations are followed; (iii) the transparency of contracts is high, underlying reasoning and evaluations however, as well as detailed reporting on landings and values of landings, are not disclosed; (iv) FPAs are not coherent with their objectives to enhance fisheries management in host countries nor does the EU make sure that the money is spent as foreseen in the contract (see for example Le Manach et al. (2013)); (v) the partnership dimension in FPAs often is far from reaching its goals: One of several evaluations concerning FPAs summarizes that "this aspect of partnership is an illusion. Funds do not reach the intended purposes, fish stocks are decreasing and the lives of fish workers[9] in contracting states are harder than ever"(SSNC 2011, 60).

The currently developed 2012 CFP reform will most probably include a stronger alignment of EU's external policies with the internal policy of the CFP. This includes strict

[8] The CCRF (Code of Conduct for Responsible Fisheries) is a non-binding collection of principles, goals and elements for action, adopted by over 170 UN-members in 1995.

[9] The term "fish workers" refers to local men and women who directly or indirectly depend on (mostly small-scale) fisheries. Declining fish stocks negatively affect their livelihoods while compensation payments by distant water fleets virtually never trickle down to the fish worker level to make up for their economic (or other) losses.

ex-ante assessments assuring that a biological ‘surplus’ is available as well as more rigorous annual joint scientific committees.

2.3.1.2 US agreements

Although the US foreign fishing industry is not a major DWFN in terms of catch weights, it is worth considering their agreements here as they are the only multilateral fishing treaties with ACP countries. The “Treaty on Fisheries Between the Governments of Certain Pacific Island States and the Government of the United States of America” or “South Pacific Tuna Treaty” (SPTT) grants access to 40 tuna purse seiners within the joint EEZs of 17 Pacific Island Countries (PIC). It was first signed in 1988 and was last renewed in 2003, for a period of 10 years. In return for access rights, the US tuna industry pays an annual fee of US$ 3 million to the Forum Fisheries Agency (FFA). This amount can vary with tuna prices. 15 percent of access fees are distributed equally among the 17 PICs, while 85 percent are distributed on a pro rata basis depending on the weight of tuna landed in each EEZ. Besides the actual fees however, $18 million is annually raised in form of an economic assistance agreement between the U.S. government and the FFA, which can be freely spent on development projects unrelated to military purposes (NOAA 2009).

The US agreement allows for cooperation between neighboring host countries, as opposed to, for example, EU agreements. Such cooperation considerably increases the negotiating power of host countries, especially when the migratory behavior of tuna stocks can be used as leverage in negotiations by DWFNs. Despite their progressive agreements, the US agreement has also been criticized for not respecting local conservation efforts, reflagging less responsible Taiwanese vessels as US-vessels (i.e. reselling some of their unused concessions) and underpaying the PICs (Pala 2011). What is more, $18 million of US development aid is closely tied to the agreement. William Gibbons-Fly, the chief negotiator to the current SPTT, made it abundantly clear that the whole package, including foreign aid to the PICs, is “dependent on the extension of the treaty” (US Congress 2011, 3). This has driven a wedge between the PICs. While resource poor islands see great profit in the US- development aid, resource rich parties to the

Nauru agreement (PNA) [10] value their fish higher than their current share of the US agreement and have established a scheme allowing them to capture relatively high payments from other DWFNs[11]. As a response to the inflexible position of the US representatives, Papua New Guinea, which is one of the 17 PICs, in early 2011 announced to repudiate the treaty as they consider it outdated. Although the US government asserts that their access payments outcompete every other DWF in the region, local sources contend that US-payments represents at most one quarter of fees paid by Asian DWFs for tuna (Pala 2011).

2.3.1.3 Japanese agreements

Japan was one of the very first countries to conclude fisheries agreements in the pacific area. Japanese industry associations negotiate with ACP governments in the presence of the Japanese government. The far-stretched network of Japanese distant water fleets has been decreasing over the last three decades as a result of high fuel prices, stagnating fish prices and nationalized EEZ areas around the world. As a result, fish caught outside the Japanese EEZs dropped from over 5 million tons in the mid-80s to less than half a million tons in the late 90s. The figure has stabilized to around 1 million tons over the last few years (Sea Around Us project).

At present, Japan has agreements with nine Pacific Island Countries for which the terms of agreements are not publically available. It is known, however, that access fees are generally fixed at 5 percent of the export value of captured fish, a rule that has been criticized as it creates incentives to underreport and distort landing data (Grynberg 2003). The once dominating DWFN in the pacific region has become only one player among many. Similar to treaties between ACP countries and the US or EU fleets, the Japanese agreements are tied to foreign aid: While their access fees in the region amount to around US$ 8 million per year, Japanese foreign aid programs add up to around US$150 million per year (Petersen 2002). The unquestionably high competition with other Asian, European and US-DWFs, as well as a growing self-consciousness of

[10] The PNA consists of eight PICs that hold an estimated 85% of all tuna resources within their EEZs.
[11] This scheme, known as the “vessel day scheme”, allows vessel owners to purchase and trade days fishing at sea in places subject to the PNA (www.ffa.int).

coastal states in the Pacific, has recently made Japan agree to revise the conditions of the agreement in favor of host countries (Havice 2010).

2.3.1.4 Russian, Chinese, Korean, Taiwanese and Philippine agreements

All remaining fishing agreements between major distant water fleets and tropical host countries are entirely opaque. A small amount of unverifiable and mainly anecdotal knowledge suggests the following:

- Prevalence of simple "pay, fish and go" agreements that merely specify the number of vessels allowed per year (Mbithi Mwikya 2006; Walmsley et al. 2007).
- Low payment. Van Santen and Muller (2000) estimate that access fees from Taiwan and South Korea represent less than 4 percent of landed value for agreements in the Pacific. Based on few historic and some more recent agreements, Walmsley et al. (2007) assert that EU and US-agreements yield higher pay-offs for host countries than non-EU agreements.
- No transparency. To the outsider, the details of agreements are entirely unknown. This weakens the negotiation power of other host countries since comparability is made impossible.
- High rates of illegal, unregulated and unreported (IUU) fishing. IUU fishing seems to be more prominent in East Asian and ex-Soviet fleets than it is in EU-and US-fleets. As an example, the IUU black list compiled by Greenpeace (2012) suggests that 60 percent of IUU vessels are of East Asian and Russian origin while 15 percent are European and no US-vessels have been blacklisted. It has to be noted of course that this does not provide a measure on the quantity of illegally landed fish.

2.3.2 A shift in distant water powers

In order to quantitatively and historically track the changes of distant water fishing, as well as to detect current trends in power shifts, the only viable data source are landing weights as reported by fishing nations to the Food and Agriculture Organization (FAO). In its quality as a UN-body, the FAO is not permitted to officially challenge the quality of the data, which can be imprecise, biased and often misleading. In fact, at every step in the chain of reporting, incentives to over- or underreport exist, leading to severe information failures in up to 58 percent of total catches See for example Agnew et al. (2009). As opposed to the FAO, the "Sea Around Us" (SAUP) project at the University of British Colombia has been working on modifying and enhancing FAO data, adjusting them to obvious under-or over-reporting as well as increasing the precision of geographic attributes, among others. In this section, SAUP- data are used to conduct the following two assessments:

1. Spatio-temporal development of four major (sets of) traditional fishing countries namely EU, Japan, the ex- Soviet countries and China, Taiwan and South Korea (Figure 2.1);
2. Identification of the major distant water fleets by the relative weight that each nations extract from foreign, tropical and subtropical exclusive economic zones (Table 2.2),

2.3.2.1 Spatio-temporal development of major DWFNs

Figure 2.1 shows three main developments of international distant water fisheries in 'Southern' waters[12]. Underlying data include catch weights per EEZ and catches per high seas region by fishing country, aggregated into corresponding FAO fishing areas. Data was extracted from the SAUP-website[13]. The following three developments are, perhaps, most noteworthy:

First, an expansion of fishing grounds and an increase in catches for all parties involved can be observed between 1961 and 1985; second, a drop of distant water landings as well as a reduction of fishing areas for Japan, EU and the former soviet countries thereafter; and third, a further increase of Chinese, Taiwanese and South Korean catches and fishing areas up until 2006. Some of the most important reasons for this development include (i) the collapse of the Soviet regime in 1990 leading to sudden reductions of subsidized distant water fleets (Milazzo 1998), (ii) the oil crisis and

[12] 'Southern waters' are all ocean areas adjacent to Africa, South- and Central America and South East Asia, as well as the Indian Ocean. Landing data include catches made in both open oceans and EEZs.

[13] The Sea Around Us webpage www.saup.org contains FAO fisheries statistics that are modified to correct for Chinese over reporting as well as to increase the geographic precision of the data. Spatial information on catches follows an algorithm based on taxonomic distributions, a fishing access database compiled by SAUP (not public) and Spatial references of landings as provided by the FAO. Also, in few cases catch weights might have been lost as SAUP only shows the 10 most prominent fishing countries per EEZ.

stagnating fish prices in Japan in the 70s, (iii) The increased development of national fisheries as in the cases of Namibia, South Africa, Argentina, Peru and Chile (see for example Gelchu and Pauly (2007)) and (iv) higher competitiveness of Asian fleets ((US Congress 2011 and personal communication with Dominique Greboval, Senior Fishery Planning Officer FAO).

2.3.2.2 Major distant water fleets

Table 2.2 elaborates on Figure 2.1 by identifying those countries that have contributed to over 90 percent of foreign fishing in tropical EEZs between 2002 and 2006. For the preparation of Table 2.2, landing weights of every EEZ per fishing country (as extracted from the SAUP-webpage) were divided into domestic (caught by adjacent country) and non-domestic catches (caught by others). The table shows that only very few DWFNs dominate distant water fishing in tropical regions. As opposed to Figure 2.1, Table 2.2 does not present China, South Korea and Taiwan as major distant water nations, at least not in tropical EEZs. We assume that this discrepancy is due to inaccuracies in the SAUP-algorithms as pertaining to the importance that they attach to existing knowledge on fishing agreements.

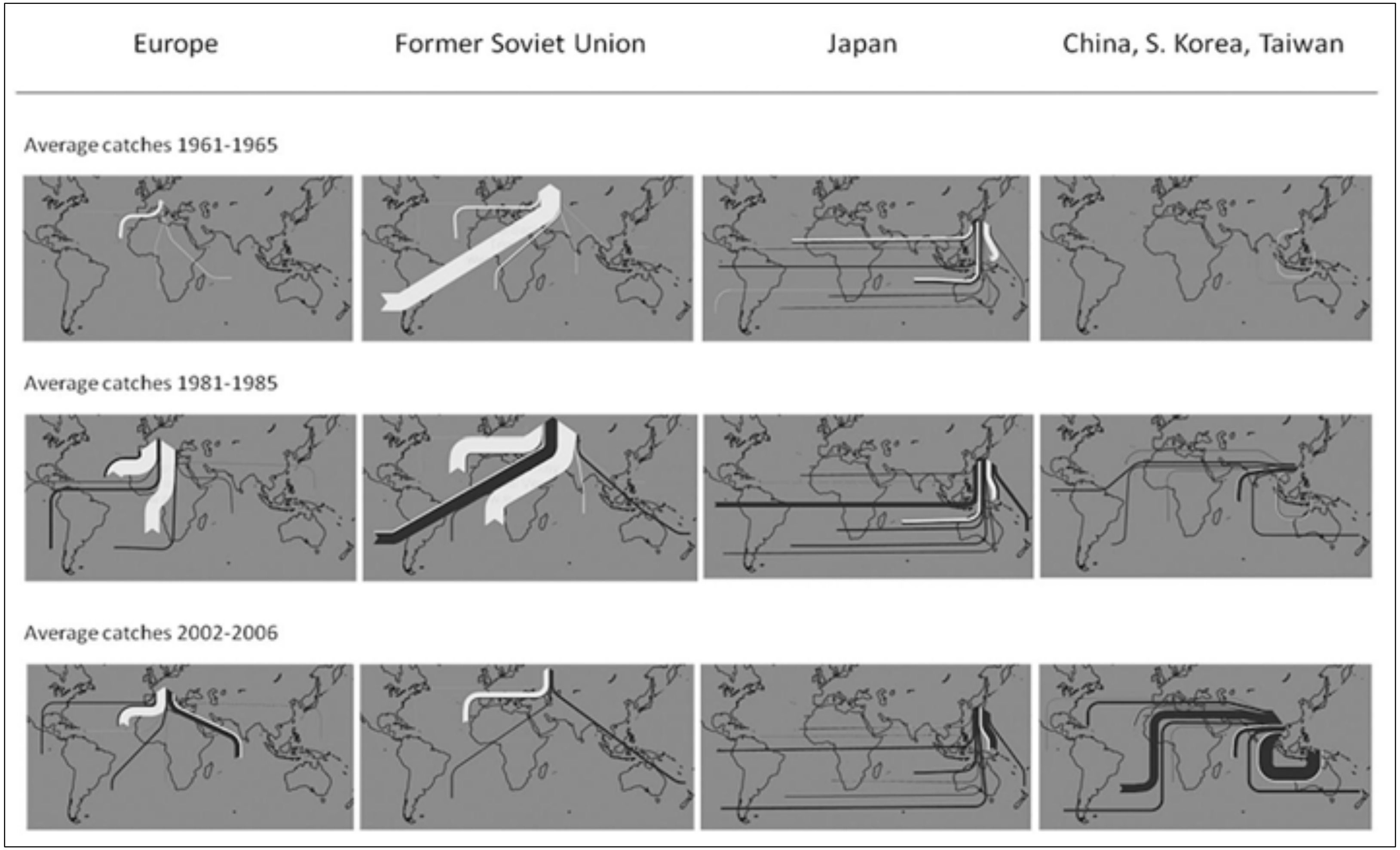

Figure 2.1: Spatio-temporal development of distant water fishing fluxes between 1961 and 2006. Black fluxes indicate open ocean fisheries while white fluxes are fish caught in national EEZs.
Note: underlying data extracted from www.seaaroundus.org

Table 2.2: Major DWFNs in ACP regions and their main fisheries

Fishing Country	Financial compensation to host country	Source country (only ACP)	Average catch weight 2002-2006	Contribution to total DWF-catches in ACP countries	Contribution of fishing country to overall distant water catches in source country	Contribution of fishing country to overall catches in source country	Type of fishery
Thailand	**N.A.**	Malaysia	763852,8	35,4%	100,0%	51%	Mixed fishery
		Myanmar	248536	11,5%	99,7%	18%	Mixed fishery
		Somalia	216	0,0%	4,2%	1%	Mixed fishery
		Total	**1012604,8**	**46,9%**			
European Union	**€100/tonne; for most agreements this amounts to 13 % of landed value**	Morocco	225044,4	10,4%	48,9%	16%	Demersal, Pelagic,Tuna
		Mauritania	60670,8	2,8%	58,8%	20%	Crustaceans, Demersals, Pelagics, Tuna
		Senegal	19274,2	0,9%	25,7%	4%	N.A.
		Mauritius	17539,4	0,8%	59,0%	44%	Tuna
		Seychelles	17246,2	0,8%	79,6%	57%	Tuna
		Madagascar	15122,6	0,7%	57,9%	11%	Tuna
		Cape Verde	5886,4	0,3%	84,9%	49%	Tuna
		Guinea	5251,8	0,2%	86,4%	5%	Shrimp, Pelagic finfish, Cephalopods, Tuna
		Mozambique	4775	0,2%	59,5%	21%	Tuna
		Kiribati	4413,8	0,2%	20,0%	13%	Tuna
		Guinea-Bissau	4225,2	0,2%	87,0%	39%	Shrimp, Pelagic finfish, Cephalopods, Tuna
		Cote d''ivoire	2663	0,1%	83,6%	7%	Tuna
		Namibia	2533,4	0,1%	100,0%	1%	N.A.
		Angola	2435,6	0,1%	18,4%	1%	N.A.
		Dominica	2381,6	0,1%	100,0%	74%	N.A.
		Comoros	2247,8	0,1%	84,1%	48%	Tuna
		Gabon	1367,6	0,1%	11,8%	3%	Tuna
		Sao T. & Principe	1328	0,1%	78,2%	24%	Tuna
		Total	**394406,8**	**18,3%**			
Russia	**N.A.**	Morocco	96119,2	4,4%	20,9%	16%	Small Pelagic species
		Senegal	27337,8	1,3%	36,4%	4%	
		Angola	3414	0,2%	25,8%	1%	
		Total	**126871**	**5,9%**			
Philippines	**N.A.**	Indonesia	102062,6	4,7%	99,6%	3%	Tuna
		Total	**102062,6**	**4,7%**			
Japan	**Generally 5 - 6 % of landed value**	Solomon Isl.	57415,2	2,7%	88,4%	74%	Tuna
		Kiribati	13179	0,6%	59,6%	13%	
		Fiji	7627	0,4%	100,0%	34%	
		Mauritius	2833,2	0,1%	9,5%	44%	
		Madagascar	2528,8	0,1%	9,7%	11%	
		Morocco	545	0,0%	0,1%	16%	
		South Africa	435,8	0,0%	21,1%	0%	
		Cote d'ivoire	309,4	0,0%	9,7%	7%	
Japan (contd.)	**Generally 5 - 6 % of landed value**	Sao T. & Principe	211	0,0%	12,4%	24%	Tuna
		Gabon	198,8	0,0%	1,7%	3%	

		Tanzania	145	0,0%	10,3%	1%	
		Mozambique	99,6	0,0%	1,2%	21%	
		Bahrain	58,6	0,0%	0,4%	0%	
		Total	**85586,4**	**4,0%**			
Ukraine	**N.A.**	Morocco	63239,4	2,9%	13,7%	16%	Small Pelagic species
		Senegal	2404	0,1%	3,2%	4%	
		Total	**65643,4**	**3,0%**			
Sri Lanka	**N.A.**	India	51362,4	2,4%	95,6%	1%	Tuna, Crustaceans
		Total	**51362,4**	**2,4%**			
Nigeria	**N.A.**	Cameroon	27637	1,3%	100,0%	30%	Pelagic finfish, small pelagic species, Shrimps
		Gabon	9784,4	0,5%	84,8%	3%	
		Total	**37421,4**	**1,7%**			
Taiwan	**Literature disagrees, fees vary between 2-6% of landed value**	Nauru	6141,8	0,3%	77,0%	77%	Tuna
		Mauritius	5660,4	0,3%	19,0%	44%	
		Madagascar	5226,8	0,2%	20,0%	11%	
		Maldives	3306,6	0,2%	58,0%	2%	
		Somalia	2907,8	0,1%	56,8%	1%	
		Brazil	2211,8	0,1%	91,5%	1%	
		Mozambique	1820,2	0,1%	22,7%	21%	
		Tanzania	761,2	0,0%	54,3%	1%	
		Myanmar	695,8	0,0%	0,3%	18%	
		Bahrain	193,6	0,0%	1,4%	0%	
		Total	**28926**	**1,3%**			
Marshall Isl.	**N.A.**	Micronesia	9433,8	0,4%	56,1%	42%	Tuna
		Papua New Guinea	7654	0,4%	44,5%	3%	
		Solomon Isl.	4855,8	0,2%	7,5%	74%	
		Palau	2047,4	0,1%	43,3%	41%	
		Kiribati	1340,2	0,1%	6,1%	13%	
		Nauru	756,2	0,0%	9,5%	77%	
		Tuvalu	549,8	0,0%	31,2%	25%	
		Total	**26637,2**	**1,2%**			
Korea South	**Literature disagrees, fees vary between 3-6% of landed value**	Senegal	13550,4	0,6%	18,1%	4%	Tuna and pelagic finfish
		Angola	7367,6	0,3%	55,7%	1%	
		Morocco	477,4	0,0%	0,1%	16%	
		Bahrain	432,2	0,0%	3,2%	0%	
		Jordan	6,2	0,0%	41,3%	4%	
		Total	**21833,8**	**1,0%**			
Total general (including all DWF countries)			**2160636,4**	**90,4%**			

Notes: Underlying landing data extracted from www.seaaroundus.org; compensation payments from [7], [9] and [10]; "Type of fishery" from fishstat+ (www.fao.org) and [10]. N.A. = not available

2.3.3 The rise of South-east Asian fishing countries

Data on global fisheries catches show a steady rise until the late 1980s and a plateau thereafter. This however masks the underlying dynamics of global fisheries. One interesting way of looking at the data is to geographically distinguish between fishing countries. As figure 2.2 shows, this yields a very different picture. While the "traditional north" countries (Japan, EU, North America and the FSU) show dramatic declines in their fish catches since the 90s, Low-middle income countries and emerging economies in Asia and Africa are buffering this downward trend. China, Taiwan and South Korea seem to have reached a plateau in catches, whereas Southeast Asian countries continue to increase catches.

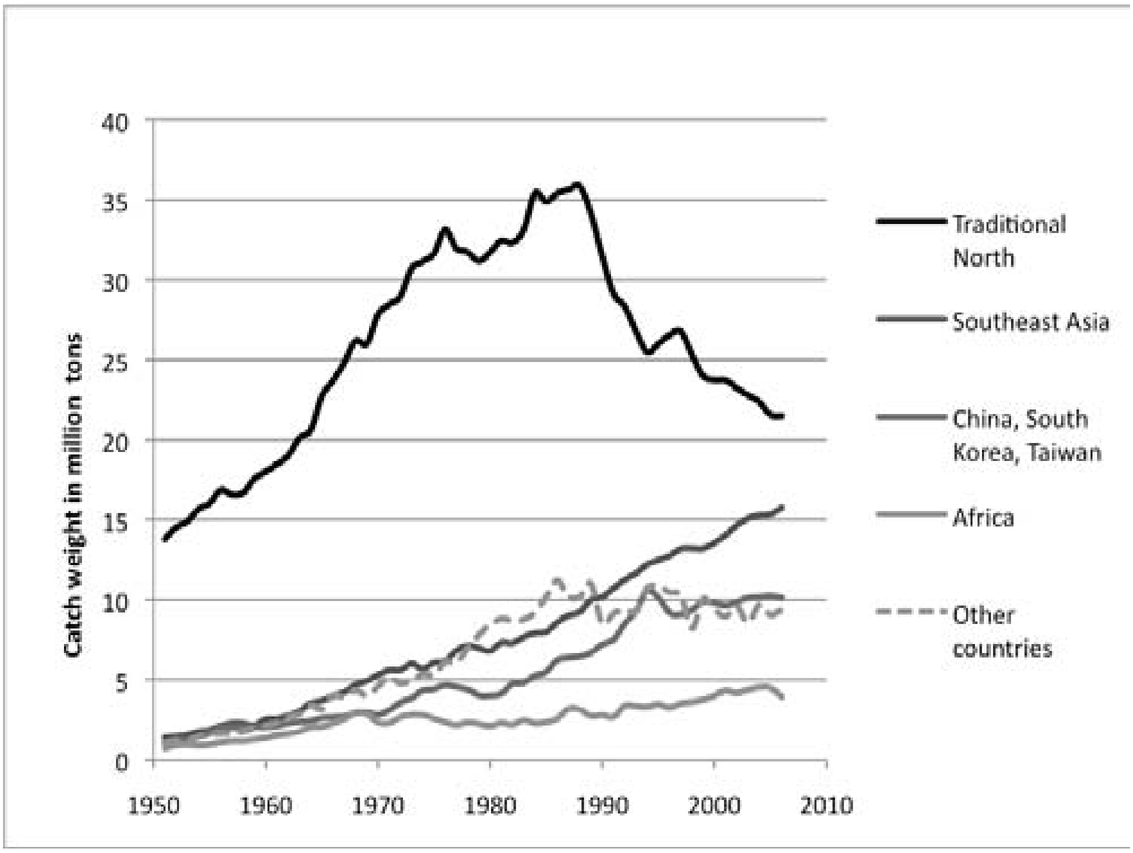

Figure 2.2: Landings of marine fisheries for five clusters of countries. ("other countries" excludes Peru)

2.4 The host countries' perspective

2.4.1 Major tropical host countries

The SAUP-data used beforehand also allowed us to distinguish between domestic and foreign catches in each EEZ. These data are presented in two forms. In Figure 2.3, it is shown which tropical EEZs contribute to the majority (96 percent) of global distant water landings. Table 2.3 lists all host countries in whose EEZs domestic fishing accounts for less landings than fishing by DWFNs. It is interesting to note that the highest foreign catches are taken from host countries that mostly fall into one of the three categories: (i) highly productive waters (Western Africa, PIC countries), (ii) large EEZs (Islands of the Western Indian Ocean, PICs) and (iii) proximity to rising, Asian fishing nations (Malaysia, Myanmar, PICs). Table 2.3 on the other hand shows that almost all host countries whose domestic catches contribute to less than half of their EEZ's catches are economically weak, small island states for which fishing represents a significant contribution to national GDP.

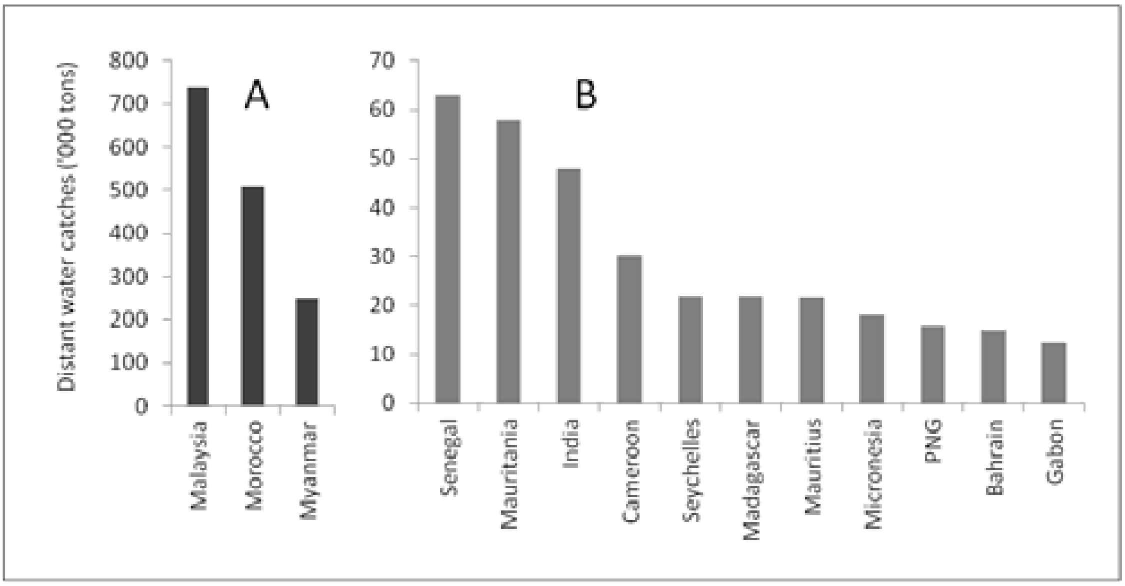

Figure 2.3: Highest distant water fishing in ACP countries (2006)
Note: A includes countries with considerably higher catches than those under B.

Table 2.3: Tropical developing countries with the lowest proportion of domestic fisheries (sorted by column 3)

ACP host countries with lowest share in catch of own EEZ	Average annual catch (2002-2006, in metric tons) made in EEZ	Percentage of EEZ catch taken by host country	Contribution of fisheries sector to GDP	Access fees as percentage of total government revenues	GDP/capita ('000 US $)
Guinea-Bissau	10.875	55%	4%	N.A.	0,137
Malaysia	1.492.694	49%	2%	N.A.	6,29
Bahrain	26.805	49%	0%	N.A.	6,915
Comoros	4.682	43%	15%	2%	0,214
Cape Verde	12.002	42%	1%	N.A.	3,18
Kiribati	35.258	37%	22%	41%	1,35
Seychelles	30.022	28%	30%	N.A.	7,678
Dominica	3.221	26%	2%	N.A.	3,655
Mauritius	39.714	25%	1%	N.A.	4,804
Micronesia	22.490	25%	10%	10%	2,308
Tuvalu	2.169	19%	8%	13%	1,909
Solomon Isl.	77.328	16%	6%	4%	0,879
American Samoa	1.495	13%	0%	0%	8,0
Palau	4.965	5%	6%	3%	7,473
Nauru	7.981	0%	10%	17%	2,263

Sources: Underlying Landing weights data: www.seaaroundus.org; column 3: data courtesy Kieran Kelleher, the World Bank; columns 4 and 5: www.fao.org; column 6: www.cia.gov.

2.4.2 The logic behind host countries' contracting strategies

From a social welfare perspective it would seem rational if host countries were to sign agreements with DWFNs whose fishing agreements would be likely to result in socially desirable, ecological sustainable and the most economically profitable outcomes. At first sight, characteristics of agreements leading to these outcomes seem to include (i) Sharing fisheries' technical information in order to appraise population dynamics and set appropriate TACs (SPTT 1994; Mbithi Mwikya 2006); (ii) Assistance of DWFNs in fisheries management of host countries to offset capacity constraints (Walmsley et al. 2007); (iii) Collaboration in the development of national fisheries infrastructure in order to help host countries undergo a transition from external exploitation of national resources to capturing the full wealth of resources themselves, including the integration of EEZ fisheries as well as developing value-adding processes in national economies. Walmsley et al. (2007) report that over 90 % of profits for developing host countries can be derived from value-added processes such as canning, smoking and packing, as the examples of the Seychelles and Côte d'hivoire (the Ivory Coast) show. Similar results are presented in Gudmundsson and Asche (2006) who note that developing countries control a relatively small share of the overall value chain in fisheries compared to developed countries. As an example, Tanzanian and Moroccan companies control less than 50 percent of the entire value chain of Nile perch and anchovy respectively (as compared to over 70 percent in Iceland for example); (iv) Facilitating market access. Foreign markets allow higher profits for both raw and processed seafood but higher hygiene standards as well as import tariffs impede access to such markets for small entrepreneurs in developing countries (Doherty 2010). Any investment into domestic fisheries and fisheries infrastructure thus needs to be proceeded by meaningful trade partnerships facilitating the access to profitable markets; and above all (v) payment of high access fees.

Despite the difficult access to attractive markets, which remains a serious obstacle for many tropical countries, the characteristics described above are best represented by the agreements from European and US-governments (Walmsley et al. 2007; IFREMER 1999). Nonetheless, these are among the DWFNs that are losing most ground in distant water fishing. Meanwhile, Asian DWFNs – which have received most criticism from environmentalist organizations concerning IUU fishing and noncompliance with the CCRF – are quickly growing their share in international fisheries. This could be for one of three reasons.

First, characteristics that we assumed to be beneficial to host countries in the long run might not entirely overlap with the short-term imperatives that these countries face. As a result, the patronizing character of EU agreements (and to some extent US and Japanese agreements), as exemplified by earmarked access fees, potentially conflicts with the necessity of economically weak host countries to flexibly spend concession payments as gaps arise in the public budget. Such flexible spending is facilitated in the case of other DWFNs, that "pay, fish and go" and see access agreements more as a business than as a development partnership.

Second, negotiators and decision makers in developing countries might abuse fishing agreements for personal, political or financial ends. As an example, it has been reported that in contrast to Western interests of poverty-reduction, negotiators representing Asian distant water fleets tend to accommodate decision makers of African host countries with financing “grand and prestigious buildings […] that African leaders highly appreciate for their own political reasons” (Tull 2006, 467).

Third, in many cases it seems to be the case that host countries indiscriminately sell licenses to all potential buyers. Due to the little biological information on the stocks and due to a general lack of fisheries technical- and economic data, fishing rights are handed out at least as long as no striking signs of collapsing stocks are observed.

In general, decision-making in tropical developing countries often is governed by high uncertainty of market development and severe budgetary deficits, as well as structural debilities of the national economy. Given high discount rates and political priorities that need immediate attention, the primary interest is often plug immediate deficits today rather than hoping for some fish stock to pay-off tomorrow. This rent-seeking behavior with resulting low GDP growth is a typical symptom of resource-rich countries and generally referred to as “the resource curse” (see for example Sachs and Warner (2001)). Although the resource curse tends to be more obvious for non-renewable point resources such as minerals and oil, four factors influencing the magnitude of the “curse” suggest that fisheries in general and fishing agreements in specific can be characterized as a case of a resource curse: weak property rights, unstable institutions and the capital-intensive nature of resource extraction (Tompson 2006), as well as the foreign-aid character of government fees (Djankov, Montalvo, and Reynal-Querol 2008).

The tendency to sell off natural resources is exacerbated by high uncertainty about the stock biomass: Both the migratory behavior of many fish stocks and the open access nature of fisheries in coastal developing countries discourage efforts of precautionary fisheries conduct: Neither on the fishermen level nor on the country level does the investment into non-fishing promise to render secure payoffs to the “investors”. On a regional level it has long been suggested (and is legally binding since 2001 through the UN “Fish Stocks Agreement”) that the problematic management of shared resources be addressed via cooperative management between countries and DWFNs sharing access to straddling and highly migratory fish stocks (Munro 2009). In a situation of uncertain amortization, “investing” into the fish stock by decreasing fishing effort often is politically unfeasible. This is exacerbated by the ecological dynamics of fish stocks that often allow consistent landing weights while masking weakening fish populations. In fact, landing weights can long cover dramatic biomass declines; Sen and Raakjaer Nielsen (1996) estimate that 21% of global stock collapses can be defined as 'plateau-shaped' collapses, denoting sudden falls of persistently high levels of catches.

2.5 Conclusions

Whilst the limits of productivity in our oceans are becoming more clear-cut every year, meaningful plans to ensure high, sustainable yields continue to lack vigor. This is especially true in tropical developing countries where poor fisheries technical data and the resulting uncertainty about stock biomass cannot "compete" against the daily imperative of generating income and resulting myopic decision making. Next to the uncontrollable nature of open access in local small-sale fisheries, many coastal ACP countries therefore grant foreign fleets access to national EEZs, a fast and secure source of foreign exchange earnings. Meanwhile, the rent seeking strategy of selling fishing rights rather than domesticating its inherent wealth through own exploitation and value-added mechanisms has isolated developing countries in the lowest levels of the value chain, where they capture far less of overall wealth than would be possible if processing, wholesale and possibly even retailing was integrated into the national economy. In addition to potential economic losses, this strategy deprives host countries from valuable data that are required for sustainable fisheries management and for improving negotiation power in signing agreements in the first place.

Given the common negative impacts of foreign fishing on local ecosystems and communities, the clear "shift of powers" in distant water fishing is alarming. While European, US- and Japanese distant water operations have contributed to overfishing in many occasions, their distant-water politics are gradually moving towards more responsible fishing. This, however, is not yet the case for the rising Asian distant water fleets. It is important to note that the positive trend especially in the EU and US has been significantly driven by civil society. In contrast, NGOs in the respective Asian countries "typically are poorly funded, have little access to information, and often lack a visible presence or audible voice in international governance processes" (Gemmill and

Bamidele-Izu 2002, 16–17). The commitment of "Western" fishing powers towards improved standards of security and comfort on board, proper wages and insurances, compliance with port measures as well as with UN-agreements and conventions has led to a significant decrease in their distant water operations. This is clearing the space (both in terms of fishing capacity and supply) for rising fishing powers many of which lead the lists of IUU infringements (Greenpeace 2007) and are characterized by non-transparent fishing agreements as well as high growth rates of distant water operations.

The threat of distant water fishing and the state of dependence that developing countries are caught in is not easily reverted. They might make a transition to domestic fisheries or invest into local value-added infrastructure, but it is not certain that this will increase the control over, and wealth gained from, national fisheries resources. Such a transition deserves, however, more attention than it currently receives. Promising policy adjustments to realize a transition would aim at the following changes:

(i) A higher involvement in the value chains of key fish commodities originating from domestic EEZs in order to increase local employment. This requires a good understanding of the dynamics of supply of and demand for such goods. Whether or not, for example, the establishment of processing plants will be profitable, might depend on a variety of factors, including the degree of vertical integration in respective supply chains, the volatility of prices, the distance to markets, or the scale of production that is possible in a given ACP country.

(ii) A stepwise reduction of foreign fishing effort in exchange of well-controlled increases in domestic harvest. Ending fishing agreements, paired with effective fisheries management plans, can result in a higher intensity of domestic harvest. This has the potential to increase the control over marine fisheries resources, among others, as data collection procedures can be better controlled and standardized. This, in turn, is the basis for an ecologically more sustainable exploitation and thus promises higher payoffs in the long run. Whether or not making a transition to domestic harvest is generally desirable has to be decided on a case-by case basis. Of course, such transition will often be limited by the lack of investment funds in the host country.

(iii) An increase in negotiation power in order to gain higher payments for resources harvested by distant water fleets. One of the main reasons for a meager financial compensation in fishing agreements is the small negotiation power of many developing countries. Intensified cooperation between ACP countries, through coordinated or even joint negotiations, and a higher degree of transparency concerning contracts of similar host countries (with respect to volume of harvest, species composition and state of stocks) will help these countries to strengthen their position in negotiations. In addition, this requires a good knowledge about the state of stocks, which can benefit from a higher involvement of domestic fisheries.

Chapter 3.

A Multi-player Bioeconomic Model Maximizing Fisheries Rents of Pacific Island Countries

3.1 Introduction

Tuna fisheries in the Western and Central Pacific Ocean (WCPO) dominate global tuna fisheries in terms of both volume and value. A very productive ecosystem, located around relatively poor Pacific Island Countries (PICs), supplies all major global fish markets with both canned and fresh products. These represent an ex-vessel value of approximately US$ 5 billion in recent years (WCPFC 2012). The island countries have, however, not succeeded in adequately profiting from fisheries resources that, by international law, are theirs to govern. As a result, PICs currently play only a marginal role in the harvest of tuna fished in their waters. This certainly is not for a lack of trying. On the contrary, over past decades PICs have attempted to scale-up domestic fisheries but failed, over and over again, resulting in losses of well over US$ 100 million in public investments (Schurman 1998). Intimidated by the scale of losses and the difficulty to compete with well-established industrial fishing countries, PICs have largely left the arena to distant water fishing nations (DWFNs) who compensate host countries with access payments (Barclay and Cartwright 2007; Parris 2010).

However, the ambition to increase domestic participation in harvest and value-adding activities (mainly fish processing plants) remains very much alive (Gillett 2008). This discrepancy between PIC's low participation in tuna fisheries and their unchanged and high aspirations to gain greater benefits from it have extensively been discussed in a growing body of literature (Schurman 1998; Petersen 2002; Barclay and Cartwright 2007; Gillett 2003; Gillett 2008). It identifies and categorizes aspirations, as well as factors that have hindered the realization of such endeavors in the past. On the one hand, these studies suggest that various constraints of a political, financial and infrastructural nature persist that explain the low participation of PICs in tuna fisheries but could, in some cases, be addressed by host governments through relatively simple policy changes. On the other hand, the literature concludes that, at least for some PICs, such aspirations are difficult to attain unilaterally, thus calling for regionally coordinated approaches.

While these studies are concerned with the feasibility of upscaling domestic harvest and processing industries, they do not, in enough detail, discuss whether such endeavors are economically desirable. Another, more technical body of literature has emerged that addresses the question whether Pacific tuna fisheries in general are economically optimal, i.e. if efforts correspond to maximum possible rent (Bertignac, Campbell, and Hand; Kompas and Che 2006; Reid, Bertignac, and Hampton 2006; Hannesson and Kennedy 2008; Bailey, Sumaila, and Martell 2013). The focus of analysis here has been to maximize total economic rents of all fisheries involved for defined ocean areas. We instead are interested in identifying solutions of effort utilization that maximize rents of specific (groups of) fishing countries. In particular, we here seek to address the question how PICs can maximize their total rent from fisheries if they would cooperate in fishing policies. To address this question we develop a bioeconomic model.

The remainder of this paper is structured as follows. In Section 2 ("Current state of WCPO tuna fisheries") we sketch the current state of tuna fisheries in the WCPO. Section 3 ("Previous modeling studies" reviews earlier bioeconomic models of Pacific tuna fisheries and motivates our approach. In Section 4 ("The model") we develop the model. Section 5 presents results and discusses implications for strategies and policies. Section 6 concludes.

3.2 Current state of WCPO tuna fisheries

Over the past two decades, tuna fisheries in the Western and Central Pacific Ocean (WCPO) have concentrated on four species, namely Albacore (*Thunnus alalunga*), Bigeye (*Thunnus obesus*), Skipjack (*Katsuwonus pelamis*) and Yellowfin (*Thunnus albacores*). Globally, these four species make up 65 percent of all tuna landings by volume, a little over half of it originating from the WCPO. Within this area, 57 percent of the catch is taken in the exclusive economic zones (EEZs) of 17 Pacific Island Countries, which together form the Forum Fisheries Agency (FFA) Figure 3.1. This intergovernmental advisory body guides the management of tuna fisheries within the EEZs of its members. FFA countries therefore have control over the access to fishing grounds currently providing 35 percent of landings from these species.

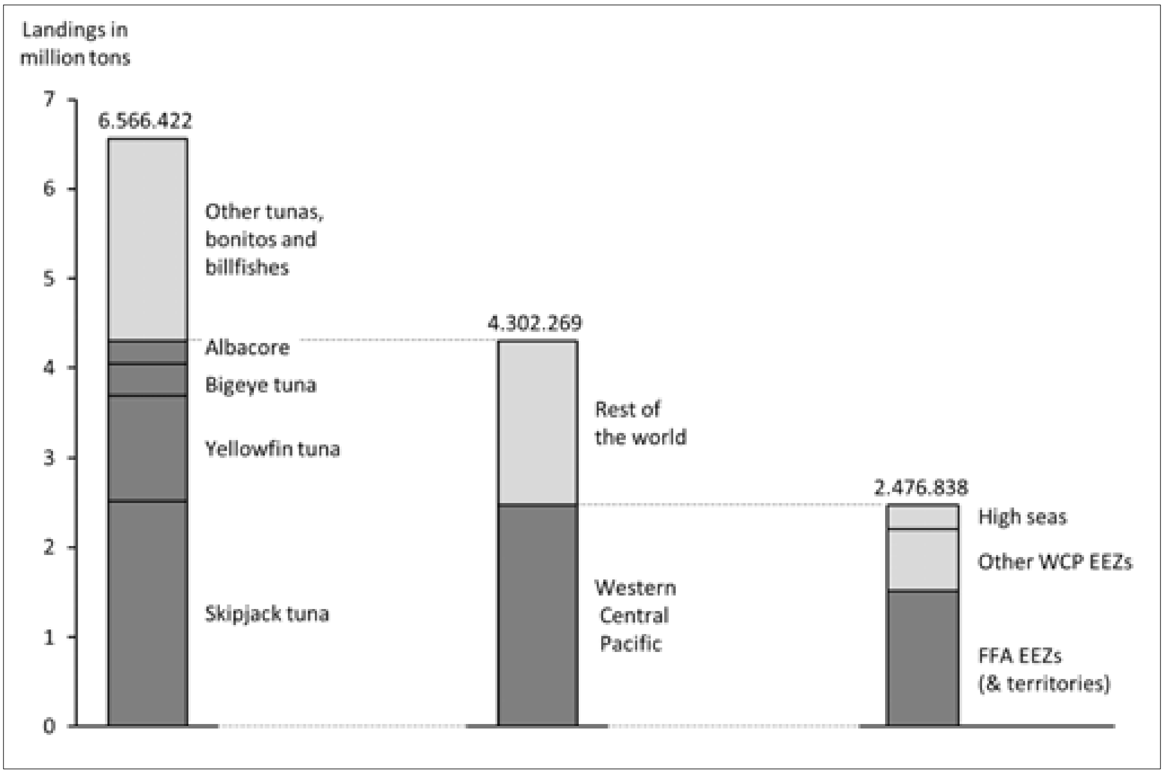

Figure 3.1: Average annual tuna catches between 2009-2011
Data source: (WCPFC 2012; FAO 2012b)

In spite of the legal mandate giving FFA control over such a massive portion of global tuna, FFA countries play an almost marginal role in actual tuna harvesting within their own waters. Figure 3.2 shows the major players in the tuna fishery, by volume of landed species. It indicates that distant water fishing nations (DWFNs) currently land around three quarters of all catch taken within EEZs of FFA countries.[14] Although DWFNs compensate FFA countries through access fees, such compensation schemes have long been criticized to not represent the true value of access, nor to economically justify the slow development of a domestic fishing sector in FFA countries (Schurman 1998; Petersen 2002). Recent changes in regional policies have helped turn an important page for resource-rich Pacific Island Countries. These included most prominently the "amalgamation" of the most productive EEZs in the region for management purposes, the closure of some high seas areas to purse seine fishing, the cap-and-trade nature of fishing licenses and a benchmark price for purse seine effort (through the so-called vessel

[14] Due to the relatively low importance of Albacore, especially to Pacific Island countries, we will focus only on Skipjack (SKJ), Yellowfin (YFT) and Bigeye (BET)

day scheme).[15] These changes significantly increased the economic benefits from distant water fishing, especially from purse seining, the most prominent fishing gear in the WCPO. Distant water purse seiners that paid only US$ 1,350 per day in 2004 are now paying US$ 6,000 per day (Havice 2013; Campling and Havice 2013). Beyond this quantum leap in capturing wealth from access fees over past years, a further rise in effort costs has already been agreed to by PNA members (Parties to the Nauru agreement, see footnote 15). The new daily fee of US$ 6,500 will be implemented by 2014 (PNA 2013). Access fees of other fishing gears are a fixed percentage of fishing revenue instead of a fee per unit of effort.

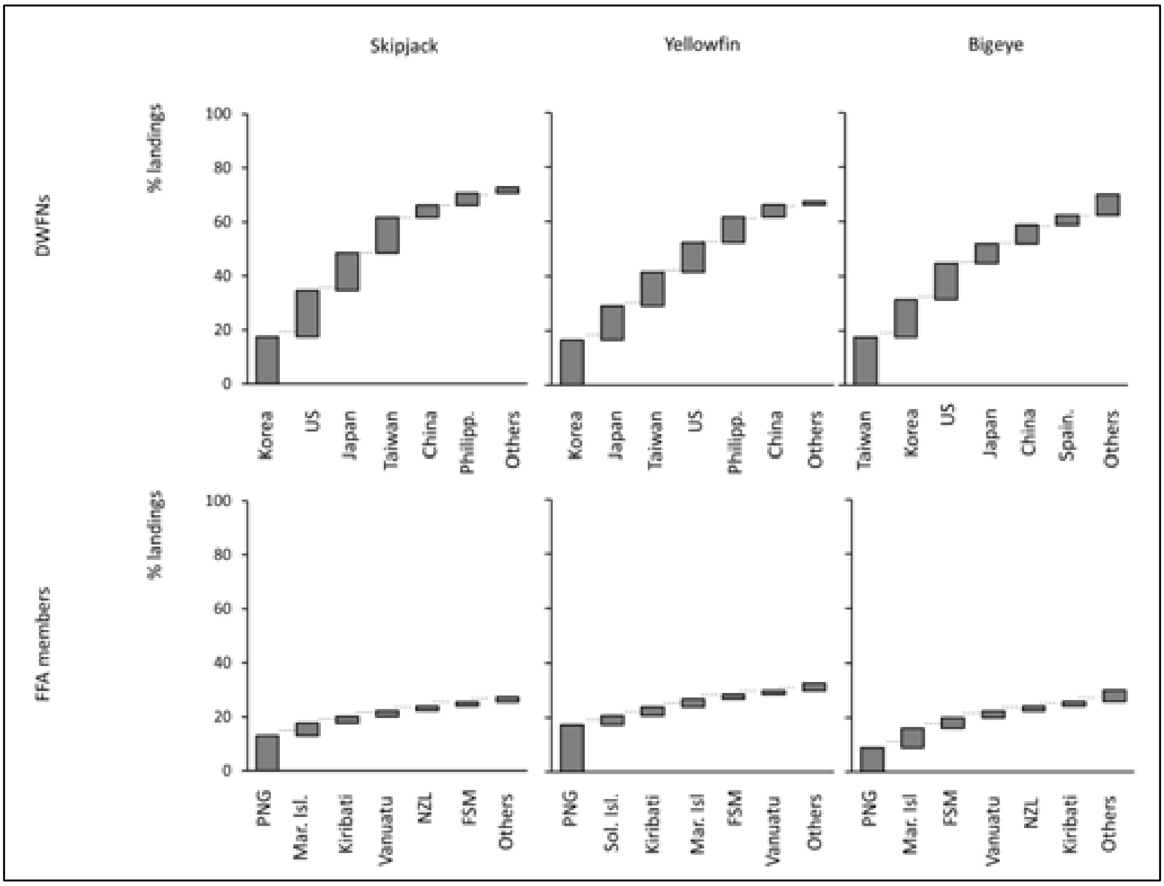

Figure 3.2: Average annual catches between 2009-2011 in the EEZs of FFA countries, by fishing country

[15] These policies are restricted to the parties to the Nauru agreement (PNA). These concern eight of the 17 FFA members. Since 97% of purse seine catch within FFA waters is taken in the EEZs of PNA countries, we do not need to make a distinction between FFA and in our study.

One of the most important features of WCPO tuna fisheries is its multi-gear nature. Three gear types jointly harvest the bulk part of tuna, namely purse seine (PS), long line (LL) and pole and line (PL). Detailed descriptions of all gear types can be found in Barclay et al. (2007) and Williams et al. (2011). We briefly summarize here the most relevant technical aspects of each gear type. Figure 3.3 provides an overview of historical catches and their composition.

“Purse seining” involves strong vessels that pull large nets behind them, usually close to the surface, targeting Skipjack (SKJ) and Yellowfin (YFT), with juvenile YFT and Bigeye tuna (BET) as non-target by-catch. Landings are earmarked for canned products, thus providing raw material to major fish processing industries. Tuna purse seiners are the most capital intensive of all vessel types and include technologically sophisticated machinery. These vessels are mainly operated by distant water fishing nations within 5 degrees of the equator.

“Long line” fishing consists of pulling lines behind a boat (sometimes several kilometers long with thousands of baited hooks) or fixing these to buoys for later collection. Vessels come in all sizes, are generally less capital intense than purse seiners, and target more sparsely distributed, larger tuna that are generally found at greater depths than the schooling tuna targeted by purse seining. Main target species are YFT and BET, both earmarked for fresh consumption or the high-value Sashimi market.

The “pole and line” technique is fairly simple and consists of short, hooked lines at the end of rigid 2-3 meter poles, with bait being thrown overboard to attract skipjack to the surface (chumming). Vessels are medium sized, often equipped with special platforms at the rear part of the vessel on which fishermen stand and fish while the vessel is moving. The main target species is SKJ. Most catch is earmarked for local consumption and canned products.

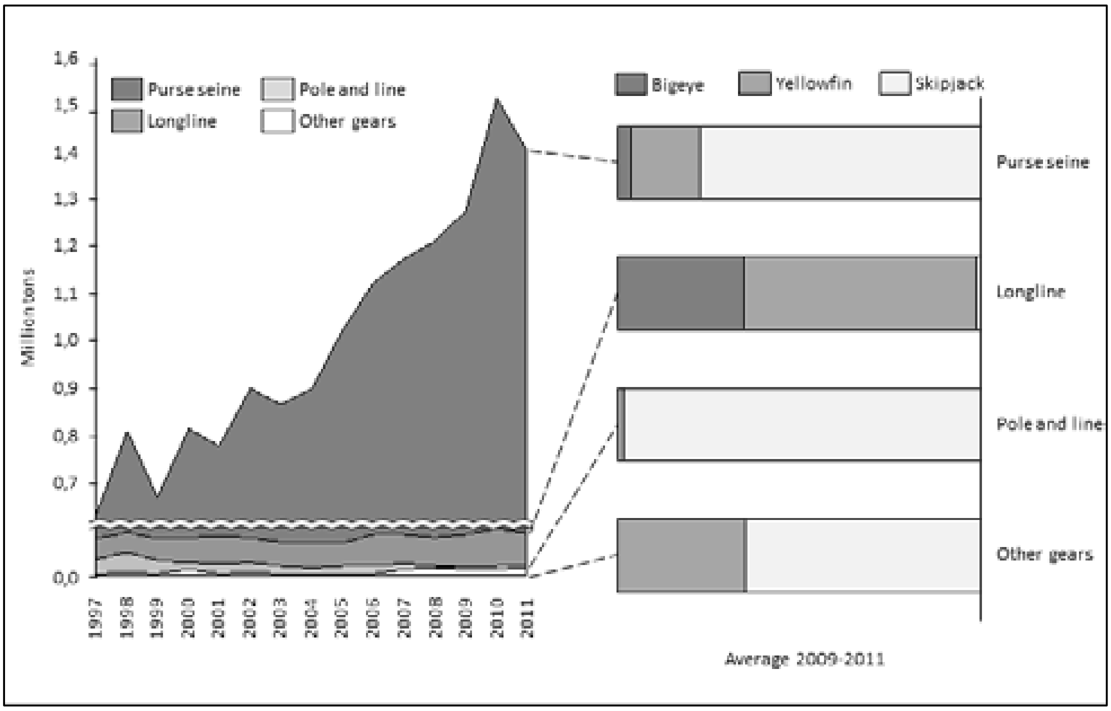

Figure 3.3: Historical development of major gear types in the WCPO tuna fishery, and corresponding species composition

As a result of the relatively low participation of PICs in WCPO tuna fisheries, aspirations to increase domestic rent from what is perceived as national resources remain high. Several recent studies therefore have investigated the potential of, and difficulty to develop a domestic fishing industry (Schurman 1998; Petersen 2002; Gillett 2003; Gillett, Preston, and Walton 2008; Barclay and Cartwright 2007; Barclay 2010; Parris 2010; Hanich, Parris, and Tsamenyi 2010; Hamilton et al. 2011; Havice 2010; Havice 2013). These studies adopt a variety of perspectives, ranging from examining "institutional maturity" and political economy aspects to detailed analyses of the potential of economic developing a domestic tuna industry in PICs. They nevertheless agree on major issues and collectively yield the following picture. After frustration over the inability to raise access fees in the 1970s and 1980s (as a result of low negotiation power), public money was heavily invested into domestic fleets, which dramatically failed. Reasons for this are poor planning, lack of knowhow, high costs of fishing and marketing, sinking fish prices, poor port infrastructure and unfavorable policies to attract private capital. Instead of establishing a solid commercial fishing and processing sector, investments lead to dramatic boom-and-bust cycles of the tuna industry in the past. Yet, past disappointment has in no way weakened aspirations to develop domestic fishing and processing industries.

Most FFA members continue with high hopes to gradually replace DWFN effort by domestic fishing effort and to increase their global share in fish processing capacity, most prominently canning. Having struggled with similar aspirations for several decades now it is no secret that they are challenging. The main challenges can be categorized into six types.

First, the multi-player, multi-gear, multi species nature of this fishery implies complex bioeconomic dynamics. As a result, the economic rationale of DWFN-replacement through domestic fleets is not self-apparent. Besides the trade-off between access fees and domestic revenues through fishing, optimal gear utilization is non-trivial.

Second, most of the tuna value chain is in the hands of few powerful DWFN countries, and to some extent vertically integrated (from harvest through processing to distribution, wholesale and retail). Banning foreign vessels from FFA waters could theoretically complicate the sale of domestic raw tuna.

Third, fishing agreements are often tied to foreign aid, and part of trade agreements with DWFNs, or (loosely) connected to strategic or diplomatic interests of FFA members; discontinuing permits might have economic and political repercussions.

Fourth, even if profitability seems apparent on paper, large capital investments, especially by foreign investors, will also depend on transparency of tax- and legal conditions and regulatory consistency.

Fifth, the rationale of rent maximization might not coincide with socio-economic goals of FFA countries. Optimal effort utilization greatly varies depending on whether the objective is economic yield, food security or job creation.

Sixth, the upscale of annual processing capacity stands and falls with the creation of economies of scale that allow competition with established processing centers such as Thailand and the Philippines. Realizing such economies of scale requires a high degree of regional cooperation among the Pacific Island countries.

Each one of these issues deserves attention and must be carefully pondered when making decisions about fisheries development policies. In the remainder of this document, we focus mainly on the first issue, i.e. the question whether, from an economic point of view, FFA countries do well to continue with attempts to develop domestic fisheries industries. After reviewing earlier studies with similar objectives in Section 3, we will, in sections 4 to 6, develop and discuss a new rent-maximizing bioeconomic model that explores how changes in fishing effort affect revenues and costs of the different fleets and fishing countries involved (FFA and DWFNs).

3.3 Previous modeling studies

The literature on bioeconomic modeling in WCPO fisheries includes numerous approaches to determine optimal effort. The bioeconomic model underlying most recent studies is the *Western and Central Pacific Ocean Bioeconomic Tuna Model* (WCPOBTM), a dynamic, spatially disaggregated multi-gear and multi-species model of WCPO tuna fisheries (Bertignac, Campbell, and Hand). This model, as well as models based on it (Kompas and Che 2006; Reid, Bertignac, and Hampton 2006; Hannesson and Kennedy 2008; Bailey, Sumaila, and Martell 2013), explore under which circumstances economic rent (aggregated over all fishing countries) of WCPO tuna fisheries can be maximized. The main output of these studies is that total rent of the fishing sector could be increased if purse seine effort were to be reduced considerably while long line effort remained at current levels or were to be increased. Increased net benefits of effort adjustments are estimated to lie between US$ 75m-350m per year. The underlying bioeconomic arguments are threefold.

Most importantly, different gears target the same species and thus compete with one another. The by far most used gear, purse seine, mainly targets the fast-growing and abundant SKJ but has a significant impact on juveniles of the less abundant and slower-growing YFT and BET, especially when fishing in the vicinity of Fish Aggregating Devices. This hampers the development of an abundant adult stock of these species. While PS catch is earmarked for cheap canned products, LL vessels target older age classes of YFT and BET, which are earmarked for the expensive Sashimi market (purse seine products are earmarked for significantly cheaper canned products). Furthermore, stock density increases with decreased fishing effort and associated economic losses are offset by increased catch per unit effort (CPUE). Finally, prices on consumer markets rise when supply is decreased. As a result, effort reductions are rewarded by increased raw material prices.

The studies discussed above elucidate important aspects of the WCPO tuna fishery. They tend to focus on the question to what extent each fishing gear should be utilized in order to gain highest overall economic rents, for all fishing countries of FFA and DWFNs jointly, from the tuna resource. However, several crucial concerns are not properly addressed. On the one hand, existing rent maximization models solve for aggregate rent of all players and not for specific (groups of) fishing countries. This allows to detect solutions of highest economic efficiency for the entire tuna fishery and to identify associated winners and losers. Yet, it does not provide optimal solutions to specific (groups of) fishing countries. In other words, the existing models do not sufficiently reflect that FFA members have legal competence to rule over fishing effort employed in their Exclusive Economic Zones. Different fishing countries have different stakes in the various fisheries. For example, decreased purse seine catches would make FFA members worse-off while making distant water fleets better-off, as noted by Bailey et al. (2013). Although cooperative game theory suggests that such deficiencies can be solved through side-payments (Bailey, Rashid Sumaila, and Lindroos 2010), adequate mechanisms for such compensation schemes are lacking to date and associated transaction costs might outweigh the benefits.

In addition, existing models do not properly include access fees, capital costs and potential benefits from fish processing industries. Concerning capital costs, an exception is Bertignac et al. (2000), who include the long-run opportunity costs of capital. When analyzing the potential economic benefits of tuna fisheries to FFA countries, existing approaches thus have to be extended to better represent the current system.

3.4 The model

Similar to Hannesson et al. (2008) we develop an age-structured steady-state yield-per-recruit model with two types of players (DWFNs and FFA members) and three gears (PS, LL, PL) that target three species (SKJ, YFT, BET) in two fishing areas (inside and outside of FFA EEZs). We adopt WCPOBTM values for gear selectivity and biological parameters. Main differences with previous studies are as follows:

- The central focus shifts from whole-of-region rent maximization (aggregate over all players) to rent maximization of two groups of players (distant water fishing nations and members of the FFA)
- Access fees are included as a source of income to FFA and as costs to DWFNs. FFA license fees appear as a costs to FFA countries.
- Capital expenses for newly invested fishing vessels are included as fixed costs. While Bertignac et al. (2000) include long-term opportunity costs in the variable costs of effort, we treat capital costs as an exogenous variable that is increased when effort exceeds current levels.
- Increased domestic PS catch is translated into increased benefits of value-adding fish processing industries.
- Rents are defined as the sum of discounted cash flows (net present value) within a period of 25 years in order to address the capital-intensive nature of tuna fisheries and the associated opportunity costs to investors.

The model is divided into four modules, namely i) biological module, ii) harvest module, iii) revenue module, and iv) cost module. Values and units of all model parameters as well as sources for these are provided in Table 3.3.

3.4.1 Biological module

We formulate an age-structured, steady-state yield-per recruit model, which divides species-specific fishing mortality into 12 sub-mortalities, resulting from two fishing areas (inside and outside EEZs of FFA members), three fishing gear types (PS, LL, PL) and two groups of fishing countries (FFA and DWFNs), hereafter referred to as "players". Throughout the model presentation we consistently use subindices i, s, j, k, l to denote age, species, fishing area, fishing gear and fishing country ("player") respectively:

- Age $i \epsilon \{0,1,2..I_s\}$, where the species-specific life span $\mathrm{I_s}$ of the stocks is considered to be 12 quarters for Skipjack, 24 quarters for Yellowfin and 28 quarters for Bigeye;
- species $s \epsilon \{1,2,3\}$, with the numbers denoting SKJ, YFT and BET, respectively;
- Fishing area $j \epsilon \{1,2\}$, with the numbers denoting inside and outside of FFA's EEZ, respectively;

- Fishing gear $k \epsilon \{1,2,3\}$, with the numbers denoting PS, LL and PL respectively;
- "Player" $l \epsilon \{1,2\}$, with the numbers denoting DWFNs and FFA members, respectively.

We use letters as subindices to denote fishing gear and players as this makes equations more easily readable.

We establish the individual age-length relationship based on a van Bertalanffy exponential growth curve. In (1), $L_{i,s}$ is the length at age *i* for species *s* and $L_{inf,s}$ is the mean asymptotic length per species. The van Bertalanffy curvature parameter is denoted by k_s, and i_0 *is* the age at which $L_{i,s}$ = 0. For notational simplicity the time index is omitted in the presentation hereafter.

$$L_{i,s} = L_{inf,s} * \left(1 - e^{-k_s*(i-i_0)}\right) \quad (1)$$

Conversion from individual body length to individual weight $w_{i,s}$ in each age class is based on species-specific length-weight conversion factors *A* and *B* as shown in (2)

$$w_{i,s} = A_s * {L_{i,s}}^{B_s} \quad (2)$$

In (3) fishing mortality $F_{i,s}$ is defined based on age-specific selectivity $v_{i,s,j,k,l}$, catchability $q_{i,s,kj,k,l}$ and fishing effort $E_{j,k,l}$.

$$F_{i,s,j,k,l} = v_{i,s,j,k,l} * q_{i,s,j,k,l} * E_{j,k,l} \quad (3)$$

The size of the stock, in numbers of individual fish per age class and species $x_{i,s}$ is calculated based on fishing mortality $F_{i,s}$ (summed over all fishing areas, gears and players) and natural mortality $M_{i,s}$ (4). The initial number of fish recruited into the first age class $x_{1,s}$ differs for each species (5) and results from calibrating the model as explained later on. Stock recruitment relationship is simplified by including a "steepness" parameter of recruitment: Whenever spawning stock biomass is reduced to less than 75 percent of original size, recruitment into the first age class is reduced by 30 percent[16].

$$x_{i,s} = x_{i-1,s} * \ e^{-F_{i,s}+M_{i,s}} \tag{4}$$

$$x_{1,s} = x_{0,s} \tag{5}$$

3.4.2 Harvest module

Species-specific harvest is established as a function of fishing mortality and based on a Ricker-type Yield-per-recruit model following Hannesson et al. (2008), resulting in landing data that are divided into fishing country (players), fishing gear and fishing area. In (6), harvest $h_{i,s,j,k,l}$ is a function of fishing mortality, natural mortality and stock size.

$$h_{i,s,j,k,l} = \frac{F_{i,s,j,k,l} * x_{i,s} * w_{i,s}}{F_{i,s,j,k,l} + M_{i,s}} * \left(1 - e^{-\left(F_{i,s,j,k,l}+M_{i,s}\right)}\right) \tag{6}$$

3.4.3 Cost module

For each player, cost is divided into fixed and variable costs. Fixed costs consist of new capital investments, variable costs consist of operational costs and access fees. Fixed costs are up-front payments charged in year one, variable costs accrue on an annual basis.

Whenever the effort of a specific gear is increased, fishing vessels are added to the fleet. Equations (8) – (10) show how we calculate costs of new Capital investment $C_{k,l}^{K}$. Current levels of effort are based on WCPFC Public Domain Catch and Effort data (WCPFC 2013a). These data are disaggregated temporally (per year) and geographically (per 5° squares) but are aggregated over all fishing countries. We therefore use spatially disaggregated, country-specific catch data (WCPFC 2012) as a proxy to infer player-

[16] Although steepness belongs to the most influential parameters in stock assessments, it is of little relevance in this study as rent maximization of fully exploited fisheries tends to imply a reduction of effort and not an increase.

specific efforts per year and 5° square. Average values between 2009 and 2011 are used. Current vessel capacity is based on Hampton et al. (2012).

In (7), the average effort employed by one vessel $E^{v}_{k,l}$ is calculated dividing current, area-specific, gear specific and player specific effort $E_{j,k,l}$ by the number of vessels currently available $v_{j,k,l}$ and summing over fishing areas.

$$E^{v}_{k,l} = \sum_{j=1}^{2} E_{j,k,l}/v_{j,k,l} \tag{7}$$

In (8) the number of vessels invested in $I^{v}_{k,l}$ corresponds to the difference between current effort and "optimal" effort $E^{*}_{k,l}$ divided by average effort employed by one vessel. Optimal effort results from solving the model for highest economic rents of specific players.

$$I^{v}_{k,l} = \sum_{j=1}^{2} (E^{*}_{k,l} - E_{k,l}) * \frac{1}{E^{v}_{k,l}} \tag{8}$$

In (9) capital costs $C^{K}_{k,l}$ are defined as the product of vessel numbers invested and vessel price $p^{v}_{k,l}$.

$$C^{K}_{k,l} = I^{v}_{k,l} * p^{v}_{k,l} \tag{9}$$

Variable fishing costs per player and gear $C^{f}_{k,l}$ in (10) are based on the effort utilized inside and outside of the Exclusive Economic Zones of FFA members. This effort is then multiplied by the cost per unit of effort $C^{E}_{k,l}$ of the corresponding fleet.

$$C^{f}_{k,l} = \sum_{j=1}^{2} E_{j,k,l} * C^{E}_{k,l} \tag{10}$$

The calculation of access fees as well as revenues from fishing involves market prices of landed tuna. Since market prices tend to change with supply, equation (11) includes an elasticity of demand determining fish price dependence on supply. Here $p^{f}_{s,k,l}$ is the current product price of landed catch, dependent on species, gear type and fishing country, $p^{f,opt}_{s,k,l}$ is the product price corrected for the new harvest quantity $h^{opt}_{s,k,l}$, $h_{s,k,l}$ is the harvest under current effort levels, and $e_{s,k,l}$ the price elasticity based on Bailey et al. (2013). All values are listed in Table 3.3.

$$p^{f,opt}_{s,k,l} = p^{f}_{s,k,l} + p^{f}_{s,k,l} * \frac{\left(h^{opt}_{s,k,l} - h_{s,k,l}\right)}{h_{s,k,l}} * \frac{1}{e_{s,k,l}} \qquad (11)$$

Access fees differ between players and gear types. In (12), $C^{a}_{1,PS,DWFN}$ is the cost of purse seine access born by DWFNs fishing in the EEZs of FFA countries, $E_{1,PS,DWFN}$ is the corresponding effort and p^{vds} the access fees of purse seining for DWFNs. In (13), $C^{lf}_{PS,FFA}$ represents the license fees payable by FFA countries for all PS effort, $E_{j,PS,FFA}$ the corresponding effort and p^{lf} the assumed daily license fee of PS effort (See Table 3.3 for values). The subscript *k* can adopt the values “PS” and “LL+PL”

$$C^{a}_{1,PS,DWFN} = E_{1,PS,DWFN} * p^{vds} \qquad (12)$$

$$C^{lf}_{PS,FFA} = \sum_{j=1}^{2} E_{j,PS,FFA} * p^{lf}_{PS} \qquad (13)$$

Long line- and pole and line fees for both players correspond to a fixed percentage of the landed value of in (14), $C^{a}_{1,LL+PL,DWFN}$ is the access fee paid by LL and PL vessels of DWFNs, $h_{s,1,LL+PL,DWFN}$ is the corresponding harvest, $p^{f,opt}_{s,PL+LL,DWFN}$ the product Price of the catch and $r^{a}_{LL+PL,DWFN}$ a fixed percentage to estimate fees corresponding to this catch. In (15), $C^{lf}_{LL+PL,FFA}$ are the license fees paid by FFA countries for long lining and pole and line fishing, $h_{s,j,LL+PL,FFA}$ is the corresponding harvest, $p^{f,opt}_{s,LL+PL,FFA}$ the product price of the catch and $r^{a}_{LL+PL,FFA}$ a fixed percentage to estimate fees corresponding to this catch. Access fees for gears other than purse seine have been estimated to lie between 2-6 percent of landed value (Gagern and van den Bergh 2013) license fees for domestic fishing is a rough estimate, listed in Table 3.3.

$$C^{a}_{1,LL+PL,DWFN} = \sum_{s=1}^{3} \sum_{k \in \{LL,PL\}} h_{s,1,k,DWFN} * p^{f,opt}_{s,k,DWFN} * r^{a}_{k,DWFN} \tag{14}$$

$$C^{lf}_{LL+PL,FFA} = \sum_{s=1}^{3} \sum_{j=1}^{2} \sum_{k \in \{LL,PL\}} h_{s,j,LL+PL,FFA} * p^{f,opt}_{s,k,FFA} * r^{lf}_{k,FFA} \tag{15}$$

Total costs of access for DWFNs $C^{a}_{1,k,DWFN}$ and license fees for FFA countries $C^{lf}_{j,k,FFA}$ can thus be summarized as shown in (16) and (17) respectively.

$$C^{a}_{1,PS+LL+PL,DWFN} = C^{a}_{1,PS,DWFN} + C^{a}_{1,LL+PL,DWFN} \tag{16}$$

$$C^{lf}_{j,PS+LL+PL,FFA} = C^{lf}_{PS,FFA} + C^{lf}_{LL+PL,FFA} \tag{17}$$

Total costs for DWFNs (18) and FFA countries (19) thus are the sum of all costs listed above.

$$C^{Tot}_{DWFN} = \sum_{k=1}^{3} (C^{K}_{k,DWFN} + C^{f}_{k,DWFN} + C^{a}_{1,k,DWFN}) \tag{18}$$

$$C^{Tot}_{FFA} = \sum_{j=1}^{2} \sum_{k=1}^{3} (C^{K}_{k,FFA} + C^{f}_{k,FFA} + C^{lf}_{j,k,FFA}) \tag{19}$$

3.4.4 Revenue module

While revenue for DWFNs is restricted to revenues from fishing, FFA countries also earn from access fees paid by DWFNs and from fish processing industries. As formalized in (20) for DWFNs and in (21) for FFA members, revenue from fishing $R^{f}_{k,l}$ is the product of harvest $h_{s,j,k,l}$ and fish prices $p^{f,opt}_{s,k}$. Revenue from fishing is summed over species and fishing areas. FFA revenue from access fees is equal to DWFN costs of access fees.

$$R^{f}_{k,DWFN} = \sum_{j=1}^{2}\sum_{s=1}^{3} h_{s,j,k,DWFN} * p^{f,opt}_{s,k,DWFN} \tag{20}$$

$$R^{f}_{k,FFA} = \sum_{j=1}^{2}\sum_{s=1}^{3} h_{s,j,k,FFA} * p^{f,opt}_{s,k,FFA} \tag{21}$$

We estimate the benefits of the processing industry accruing to FFA countries based on domestic catch value. Almost all purse seine catches made in the WCPFC are earmarked for processing. Although foreign processing hubs (notably Thailand) remain highly competitive, Pacific Island Countries have over the past years been very active in scaling up processing capacities. Current investments in Papua New Guinea alone indicate that canning and loining processes will more and more take place in FFA member countries estimated to reach 200-400.000 tons per year in 2018 (Blomeyer & Sanz 2012), while canneries in various other islands are either already functional or planned. We here assume a total FFA processing capacity of 400.000 tons and establish that all purse seine landings of FFA members are landed for processing in domestic canneries.[17] Literature on profit margins in fisheries processing operations is scarce but suggest these to be

[17] Currently, both FFA countries and DWFNs contribute to the raw material input of domestic processing plants. The assumption that only FFA catch ends up in domestic plants is a simplification. However, if DWFN effort were to decrease, domestic plants would be supplied only by domestic fishing operators.

above 20% (Gudmundsson and Asche 2006). We here assume conservative profit margins at 10% of domestic PS landed value. This is formalized in (22), where $R^{va}_{k,FFA}$ denote revenues from value-adding processes (fish processing industries), $h_{s,j,k,FFA}$ is harvest, $p_{s,k,FFA}$ is product price (ex-vessel) and B^{va} is the benefit from value adding industries, expressed as a percentage (10% as mentioned).

$$R^{va}_{k,FFA} = \sum_{j=1}^{2}\sum_{s=1}^{3} h_{s,j,k,FFA} * p_{s,k,FFA} * B^{va} \quad (22)$$

The total revenue accruing to DWFNs $R^{Tot}_{k,DWFN}$ and FFA countries $R^{Tot}_{k,FFA}$ becomes the sum of all applicable revenue streams as shown in (23) and (24).

$$R^{Tot}_{DWFN} = \sum_{k\in\{LL,PL\}} R^{f}_{k,DWFN} \quad (23)$$

$$R^{Tot}_{FFA} = \sum_{k\in\{LL,PL\}} R^{f}_{k,FFA} + C^{a}_{1,k,DWFN} + R^{va}_{k,FFA} \quad (24)$$

3.4.5 Objective functions

The sum of annual rents accruing to DWFNs $\pi_{DWFN,t}$ and FFA countries $\pi_{FFA,t}$, equals total annual revenues minus total annual costs as formalized in (25). The sub-index t (time in years) is now introduced as we need to add yearly values into a Net Present Value (NPV).

$$\pi_{l,t} = R^{Tot}_{l,t} - C^{Tot}_{j,t} \quad (25)$$

Based on these cash flows NPV is determined over a time period T (25 years) and subject to a discount rate δ (=10 %).[18] In (26a) and (26b) we establish the equation for NPV of DWFNs and FFA members respectively.

$$NPV_{DWFN} = \sum_{t=1}^{T} \frac{\pi_{DWFN,t}}{(1+\delta)^{t-1}} \tag{26a}$$

$$NPV_{FFA} = \sum_{t=1}^{T} \frac{\pi_{FFA,t}}{(1+\delta)^{t-1}} \tag{26b}$$

Aggregating NPV over both groups of fishing countries into NPV_{ALL} is formalized in (27).

$$NPV_{ALL} = NPV_{DWFN} + NPV_{FFA} \tag{27}$$

3.4.6 Control variables in the maximization procedure

The decision vector $\vec{E}$ is composed of 12 effort types (2 players fishing in 2 areas with 3 different gears). Alternative values of this vector lead to changes in all model components, thereby affecting the NPV of different players. We are here interested in the change of efforts required to maximize the NPV for specific players or their aggregate NPV. The complexity of the problem is high due to many effort choices and the problem taking the form of a constrained non-linear optimization. We therefore apply an evolutionary algorithm that iteratively searches for a global maximum. The maximization objective can be expressed as follows for FFA members (28a), DWFNs (28b) and all fishing countries (29).

[18] We here choose a relatively high discount rate to better reflect the generally myopic approach to natural resource management observed in developing countries.

$$\max_{\vec{E}^*_{j,k,l}} NPV_{FFA} \quad , \quad \vec{E}^*_{j,k,l} = \begin{pmatrix} E^*_{1,PS,DWFN} \\ E^*_{1,LL,DWFN} \\ E^*_{1,PL.DWFN} \\ E^*_{j,PS.FFA} \\ E^*_{j,LL,FFA} \\ E^*_{j,PL,FFA} \end{pmatrix} \tag{28a}$$

When solving (28a), the following constraints apply to DWFN effort: Outside of EEZs cannot be altered; within EEZs it can only be decreased. No constraints apply to FFA effort.[19]

$$\max_{\vec{E}^*_{j,k,l}} NPV_{DWFN} \quad , \quad \vec{E}^*_{j,k,l} = \begin{pmatrix} E^*_{j,PS,DWFN} \\ E^*_{j,LL,DWFN} \\ E^*_{j,PL.DWFN} \end{pmatrix} \tag{28b}$$

When solving (28b), the following constraints apply: Within EEZs DWFN effort can only be decreased; outside FFA's EEZs it can be changed without any constraint. Note that FFA effort is not part of the control variables, which means that it cannot be changed at all.

When solving for aggregate maximum rent of both players (29), no specific constraints apply to the effort vector. However, for all three optimization problems a general constraint applies, namely that effort can never exceed 300 percent, or drop below 20 percent, of current (i.e. reference) effort.

$$\max_{\vec{E}^*_{j,k,l}} NPV_l \quad , \quad \vec{E}^*_{j,k,l} = \begin{pmatrix} E^*_{PS,DWFN} \\ E^*_{LL,DWFN} \\ E^*_{PL.DWFN} \\ E^*_{PS.FFA} \\ E^*_{LL,FFA} \\ E^*_{PL,FFA} \end{pmatrix} \tag{29}$$

[19] Model constraints reflect EEZ legislature summarized in Munro (1989).

3.4.7 Model calibration

The harvest model is calibrated based on average landing data between 2009 and 2011 (WCPFC 2012) and estimates of fishing mortality (data courtesy of Simon Hoyle, Secretariat of the Pacific Community). We iteratively adjust initial recruitment numbers and catchability coefficients until fishing mortality and landings correspond to reference values. Costs per unit effort are chosen so as to yield profits equaling 10 percent of revenues for each player and gear type, as proposed by Hannesson et al. (2008).

3.4.8 Error estimation

We identified two sources of potential error that might influence the qualitative outcome of the model. First, capital costs used in the model (as detailed in Table 3.5) are educated guesses based on DEVFISH (2006) and WCPFC (2013b) and data provided by shipbrokers for vessels that are similar to those in use by the different parties (details see Table 3.3). However, prices vary with vessel size and quality and past decisions on investments might not be telling for future investment decisions. If, for example, the rules of admission for vessels operating in the WCPO change, capital costs will change with them.

Second, variable costs used in the model are selected so as to produce profits worth 10 percent of revenues for each player and gear type. This value is also used by Hannesson et al. (2008) who argue that previous, more detailed models produced rents equaling between nil and 30 percent of revenues and that the non-monopolistic nature of WCPO tuna fisheries is more likely to produce profits near a Nash equilibrium, i.e. close to zero.

We respond to these uncertainties by testing the sensitivity of model outcomes to variation in values for capital- and variable costs to see whether the results are qualitatively different at different levels of both costs types. For the sensitivity analysis around variable costs we also include literature values of Reid et al. (2003). As shown in Table 3.4, using literature values as variable costs in our model would imply that purse seining for both players is economically profitable while all other subsectors are operating at a loss.

3.5 Results

3.5.1 System response to aggregate and disaggregate gear effort

Before presenting the optimization analysis we examine the response of the model system to changes in effort. Following common practice in the literature, we do this with the help of a so-called effort multiplier. First, we examine how the two model outputs NPV and harvest volume vary for both players if effort of all gears is simultaneously altered. As seen in the right graph of Figure 3.4, catch does not significantly decrease with increased overall effort until current effort is more than doubled. Calculations are based on formulas (6) for harvest and (28a), (28b) and (29) for NPV. The “steepness” of stock-recruitment dynamics used in the model (i.e. recruitment is constant until spawning stock is decreased by 75 percent) explains non-decreasing catch per unit of effort until reaching effort levels of more than twice current ones. As shown in the left graph of Figure 3.4, current effort clearly exceeds levels at which rent is maximized. Profitability is highest for both FFA countries and DWFNs at effort levels that are approximately half the current values.

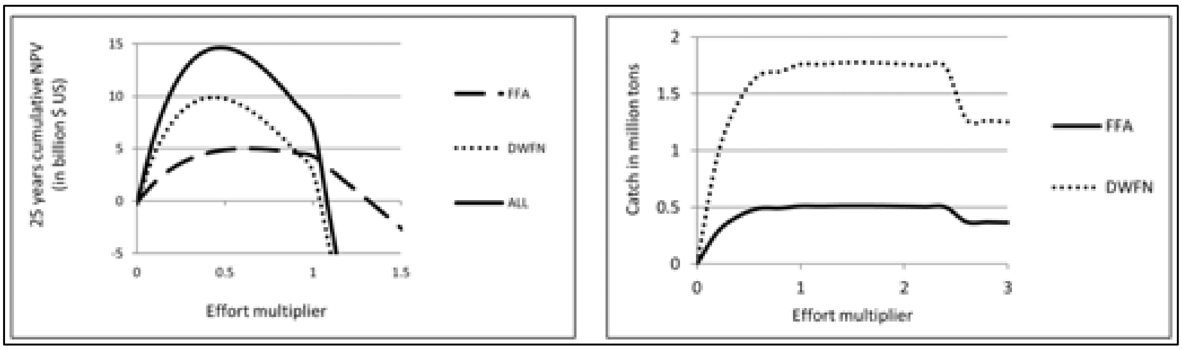

Figure 3.4: Yield per recruit for rent (left) and catch (right) as a function of a global effort multiplier

As fishing countries make effort choices on a gear level rather than simultaneously altering effort for all gears, we examine the sensitivity of costs and revenues to gear-specific effort using equations (18) and (19) for costs and (23) and (24) for revenues.

Figure 3.5 shows how costs and revenues change for all players and gears, assuming that all other efforts remain at current levels. If only one gear can be changed at a time, rent maximization always implies a decrease in effort of this gear. This means that no gear type of either player is lucrative enough to legitimate current levels of effort. Every single gear type would economically profit from decreasing the associated effort.

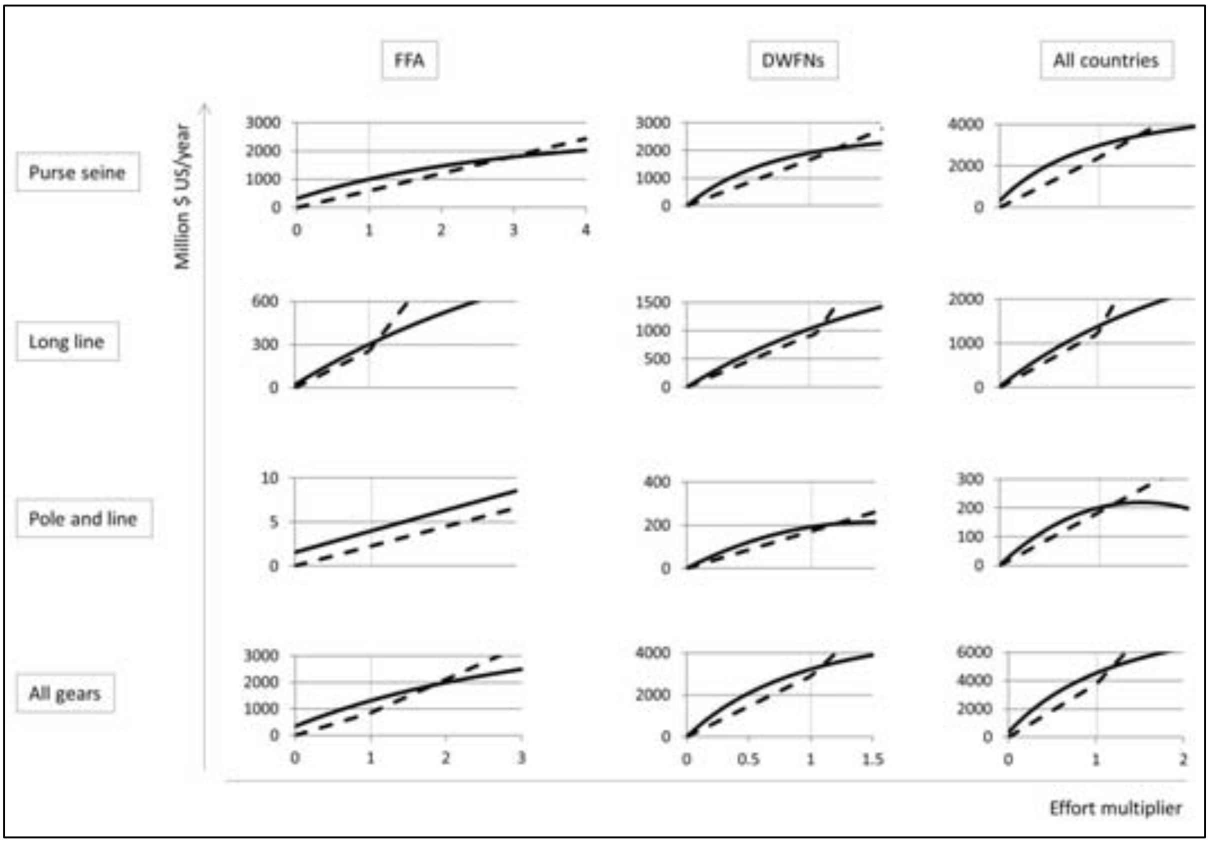

Figure 3.5: Graph shows the sensitivity of revenue (solid lines) and costs (dashed lines) to player-and gear-specific efforts. The vertical bars indicate current effort levels

3.5.2 System optimization using different objective functions

Here we examine outcomes of the three optimization exercises, namely solving for highest rents of FFA countries, DWFNs and "ALL" countries. Figure 3.6 presents effort changes required to maximize rents for aggregate players (left graphic) and disaggregated players (right graphic). Table 3.1 presents model outcomes including annual rent, effort changes and implications for fishing mortality in absolute and relative terms. Based on these results, the following observations can be made about the three optimization exercises:

(I) Solving problem (28a), maximizing for FFA implies the almost complete removal of DWFN effort from domestic waters and a 35 percent increase in domestic purse seine effort.[20] The removal alone creates a productivity surplus in the fish stocks that would drastically increase catch per unit of effort for the domestic fleet, increasing FFA rent by 50 percent (annually US$ 55 million). The created surplus is so significant that the investment in additional domestic capacity increases rent by another US$ 76 million/year to a total of US$ 302 million a year.

(II) Solving problem (28b), maximizing DWFN rent implies an even more drastic cut of DWFN effort as changes also include effort outside the EEZs of FFA countries. However, long line effort is cut significantly less than purse seining and pole and line operations, reflecting the high catchability of long line fishing for DWFNs and the high market value of related products. The optimal effort vector created increases current rents of DWFNs by 250 percent to US$ 384 million a year.

(III) Solving problem (29), when solving for aggregate rent, efforts of all players and gears are freely alternated. With these settings, rent maximization suggests an even higher effort cut than in both other cases, except for long line effort that stays almost unchanged. This reflects the often-cited gear rivalry of Pacific tuna fisheries. Purse seiners and, to a lesser extent, pole and line gears, harvest Yellowfin and Bigeye already in young age classes. Associated harvest is earmarked for low-cost canned products. On the other hand, long line harvest is earmarked for high-grade sashimi markets but is unselective for young age classes, i.e. depends on an abundant adult stock.

[20] Model constraints limit the reduction of DWFN effort to 20 percent of reference values.

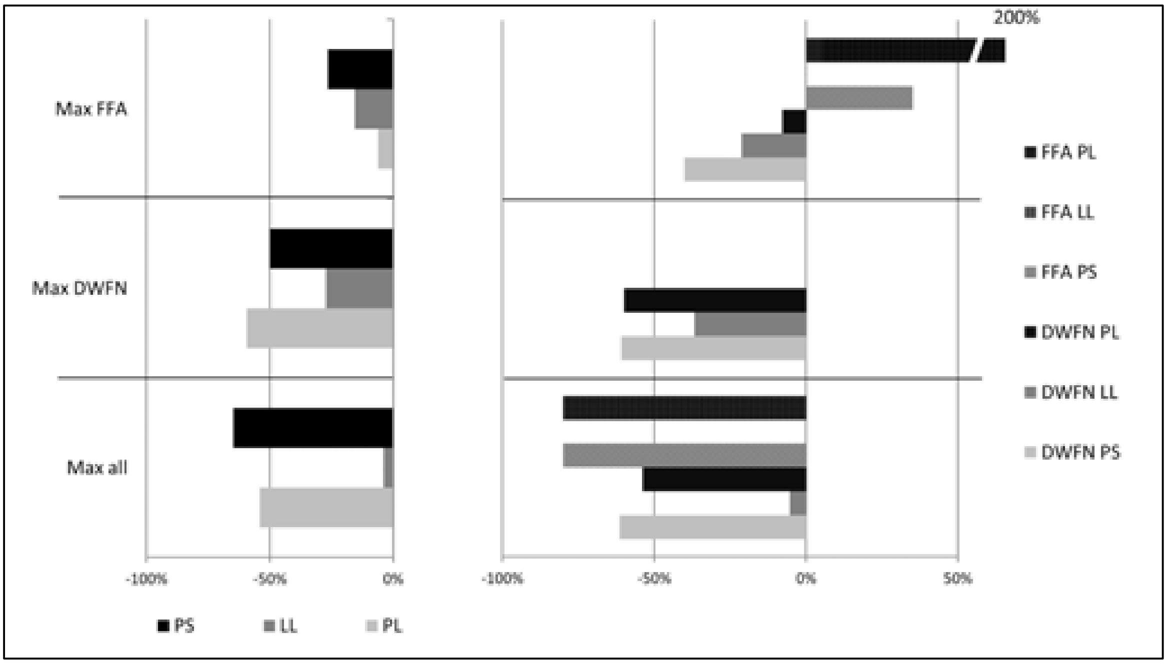

Figure 3.6: Required changes in the effort vector to maximize 25 years NPV for different (sets of) players. Left: Aggregated players; right: disaggregated players

Table 3.1: Model outcomes of the maximization exercises. The reference effort corresponds to average effort values between 2009 and 2011

		At reference effort	Maximized FFA rent	% change from reference	Maximized DWFN rent	% change from reference	Maximized aggregate rent	% change from reference
Million US$ / year	FFA rent	171	302	77%	259	51%	199	16%
	DWFN rent	110	89	-19%	384	250%	635	478%
	Aggregate rent	281	391	39%	643	129%	834	197%
Thousand vessel days	DWFN PS	79	47	-40%	31	-61%	31	-61%
	DWFN PL	20	19	-8%	8	-60%	9	-54%
	FFA PS	17	23	35%	17	0%	3	-80%
	FFA PL	0.2	0.5	199%	0.2	0%	0.0	-80%
Million hooks	DWFN LL	606	477	-21%	382	-37%	573	-5%
	FFA LL	213	213	0%	213	0%	213	0%
Fishing mortality F	F Skipjack	0.20	0.13	-36%	0.12	-39%	0.09	-56%
	F Yellowfin	0.10	0.07	-27%	0.07	-29%	0.07	-33%
	F Bigeye	0.04	0.03	-30%	0.03	-26%	0.04	1%
Landings ('000 tons)	Skipjack	1,332	1,024	-23%	995	-25%	772	-46%
	Yellowfin	398	350	-12%	346	-13%	311	-22%
	Bigeye	113	91	-19%	95	-16%	115	-2%

3.5.3 Sensitivity analysis

Here we present the sensitivity of effort choices to three important model parameters, namely capital costs, effort costs and costs of access fees to distant water fleets, as discussed above.

First, the sensitivity of optimized efforts to capital costs is absent when solving for DWFNs and aggregate rents, and negligible when solving for FFA countries (Figure 3.7). In the case of DWFNs this relates to the fact that optimization excludes effort increases within EEZs of FFA countries. FFA countries, however, generally optimize rents by banning DWFN effort. If capital costs then still permit to increase domestic effort, this is the favored solution. Although the total amount of new investments in domestic purse seiners and pole and line vessels varies with capital costs, they remain above zero until the multiplier value of 4. At this value, domestic purse seine vessel would cost US$ 40 million, which is an unrealistically high price. Whether one gear is increased or decreased as a result of maximizing rents thus does not depend on capital costs, meaning that the model outcomes are qualitatively insensitive to capital costs.

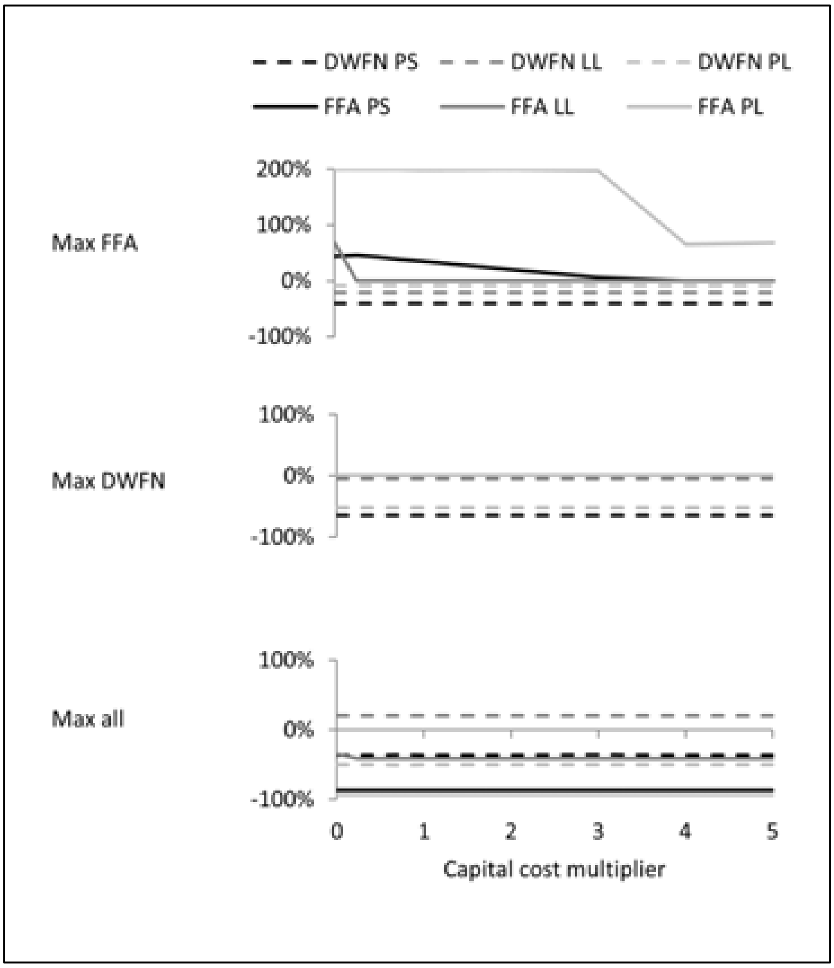

Figure 3.7: Sensitivity of optimized effort to capital costs

Second, sensitivity analysis of variable costs suggests that costs per unit effort do not qualitatively influence the model outcome as long as all subsectors of pacific tuna fisheries are operating at some economic profit (Figure 3.8). The only occasion in which model outcomes are qualitatively distinct is when literature values are used because these imply economic losses for fishing operations of several gears (Table 3.4).

Third, sensitivity of optimized effort and associated rent to access fees of DWFNs shows that FFA's strategy to ban foreign vessels is optimal for FFA countries until fees are doubled. In other words, FFA countries would favor current settings only if access fees were increased to approximately US$ 13,000 for purse seiners and a value equivalent to 10 % of landed value in the case of the two other gears.

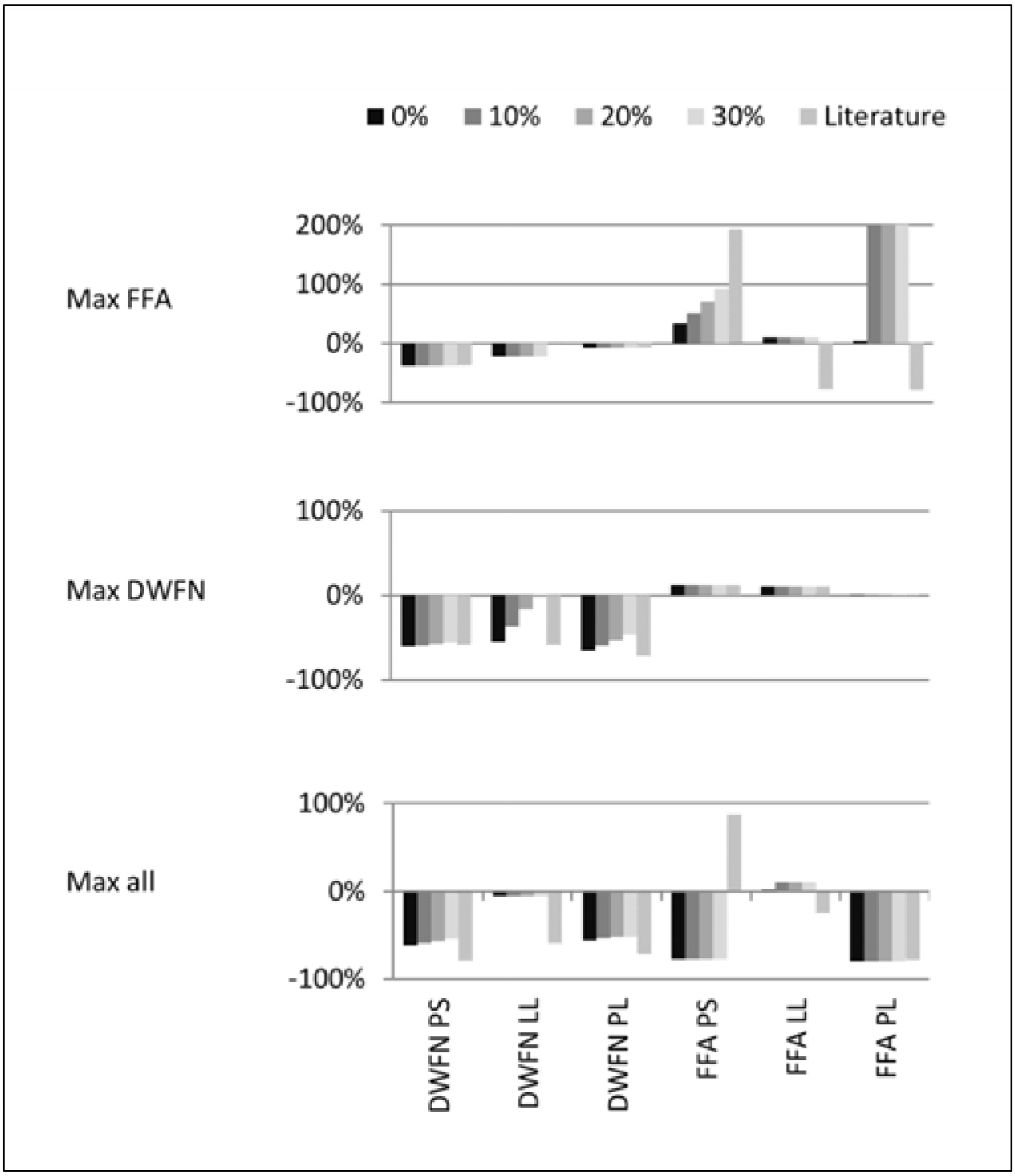

Figure 3.8: Sensitivity of optimized effort to variable costs

If our initial assumptions on variable costs are realistic, DWFNs would, with such fees, still be operating on a small positive profit margin (Figure 3.9). As long as access fees remain below this threshold, our maximization exercises suggest that the economically favorable solution for FFA countries is to phase out fishing agreements and to increase domestic harvest operations.

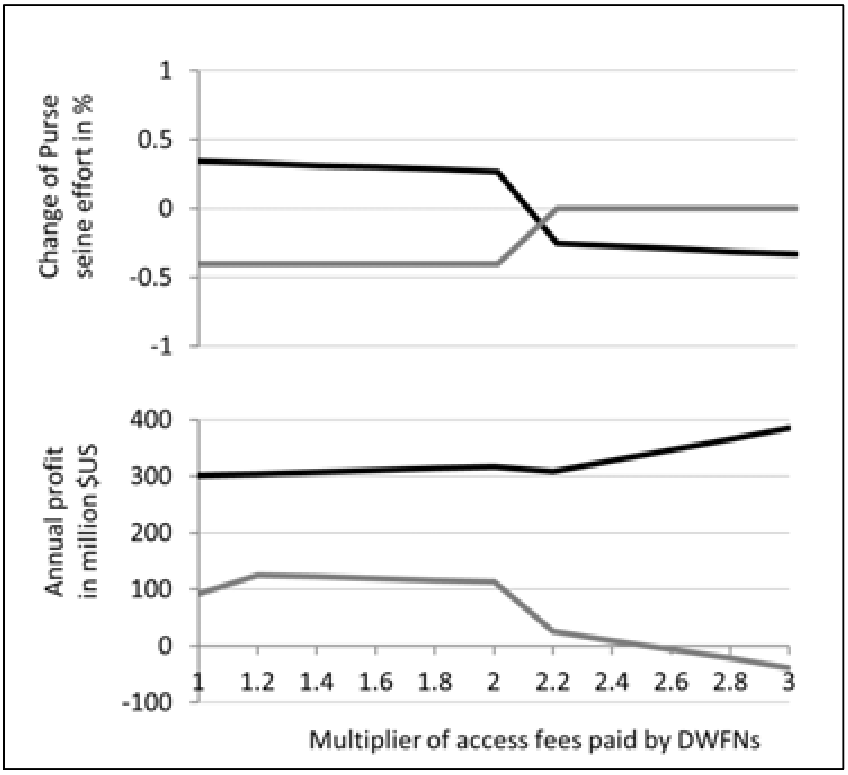

Figure 3.91: Sensitivity of effort utilization and rent to access fees

3.6 Discussion

3.6.1 Model outcomes

Our results suggest that, irrespective of the objective function (solving for DWFNs, FFA or both players), fisheries rent is maximized by reducing overall effort. Importantly however, they also suggest that individually optimal strategies to maximize rents diverge considerably for DWFNs and for FFA countries.

Due to the relative dominance of DWFN catches in all tuna fisheries, strategies for DWFNs and “all countries” are very similar, involving sizable reductions in purse seine and pole and line effort, thereby increasing catch per unit effort for the more lucrative long line fishery. This finding is much in line with earlier studies, as summarized in Table 3.2.

More striking is the strategy chosen by FFA countries, entailing the complete ban of all distant water effort in national EEZs (to the extent allowed by model constraints) while simultaneously increasing domestic purse seine effort by 35%. These outcomes indicate that access fees paid by DWFNs do not justify the cautious domestic fisheries development currently observed and that FFA countries fare better replacing foreign with domestic capacity. In fact, according to Figure 3.9, access fees could rise to more than twice their current level before economically justifying DWFN presence in FFA waters.

What is more, our model suggests that the mere removal of DWFN capacity from FFA waters boosts stock productivity and increases CPUE of the existing FFA fleet so significantly that the latter sees a 50 percent increase in annual rent amounting to US$ 55 million, without even investing in one new vessel.[21] This means that current access fees by DWFNs do not even offset the "costs" that FFA members incur in terms of reduced stock productivity through DWFN effort. However, as shown in Figure 3.6, FFA rent will decrease with every increase in domestic fleet capacity as long as existing DWFN effort remains in place.

3.6.2 Transition to more profitable solutions

Considering these results, an important question remains unanswered, namely why have FFA countries not yet made a transition to optimal solutions so as to capture higher economic benefits from their resources? As highlighted in the introduction, bioeconomic effects are only one of various aspects that have to be taken into consideration when making decisions of this magnitude. We will here shortly discuss the most important other aspects.

Politics and power are central concerns. When solving for the highest rent of FFA countries the model assumes that FFA countries are a homogeneous set of fishing countries that coordinate policies in a quasi-monopolistic manner, while DWFNs are heterogeneous and competitive. While the latter probably holds true, the former most likely does not, at least at the moment. FFA countries are highly heterogeneous and have divergent interests concerning access agreements and fisheries development. Almost every island country is, in a different way, dependent on financial, structural or military support by at least one large distant water nation. Some of the large DWFNs

[21] To some extent this is also an effect of the price elasticity to demand included in the model. As harvest goes down, market prices are increased.

explicitly tie foreign aid (or trade agreements) to fisheries agreements, including the EU, the USA and Japan.

A second issue is information and uncertainty. One of the central pillars of sound resource management is reliable and authoritative information. In the case of WCPO tuna fisheries, crucial information is often missing or highly uncertain. This pertains to both future geographic distribution of tuna and economic data.

A third concern is transition costs and myopia. The present analysis is based on a steady-state model simulating average annual outcomes once new strategies have been in place for some time, possibly several years. However, this excludes the cost of a transition towards equilibrium.

Finally, there are various issues related to the lack of coordination in FFA countries and the difficulty to establish economies of scale. Pacific Island countries are formally grouped in various umbrella bodies including the FFA, the PNA (Parties to the Nauru agreement) and the SPC (Secretariat of the Pacific Community), all of which have been very successful in promoting PIC's interests and coordinating research, management and negotiations associated with tuna fisheries and processing industries. However, economic development on a country level remains at the discretion of national governments and is not centrally coordinated. As pointed out in Barclay et al. (2007), PIC fisheries development is often hampered by the inability of single countries to set up economies of scale in fishing operations and fish processing industries in order to compete on an international level. Strong regional coordination of fisheries development would be a logical next step.

3.6.3 Comparison with earlier studies

Of the three optimization problems studied here, the maximization of aggregate rent is the only one that can be compared with earlier studies as they do not solve for specific (groups of) fishing countries. As summarized in Table 3.2, reference rent and maximized aggregate rent, as well as the associated effort implications, are comparable with the findings of earlier studies. The relative increase in rent is slightly larger in our study. Likely reasons for this include value-adding benefits that we consider in the model and slightly lower effort costs (in line with the assumption that all gear types are profitable) compared to earlier studies.

Table 3.2: Comparison of aggregate optimization results with findings of earlier studies

Model	Rent at reference effort (million $ US)	Maximized aggregate annual rent (million $ US)	Percentage increase in rent	Main implications of aggregate optimization for effort
Bertignac et al. (2000)	158	311	96%	Reduction of all gears but increase of LL
Hannesson and Kennedy (2008)	238	570	140%	Almost elimination of PS, stark increase of LL effort
Bailey et al. (2013)	1,536	1,631	n.a.	Shift from PS to LL effort
Current study	281	834	196%	Shift from PS to LL and shift from DWFN to FFA effort.

3.7 Conclusions

In this study we have developed a steady-state bioeconomic model to explore the potential of FFA member countries to increase their profits from pacific tuna fisheries. The model is disaggregated into two fishing areas, two groups of fishing countries (FFA members and DWFNs), three fishing gears and three tuna species. The study distinguishes itself from earlier ones in that it seeks to optimize the rent of the FFA member countries under a number of constraints. Moreover, it accounts for the effects of access fees, capital costs and value-adding activities (processing industry), all of which are crucial factors that have to be taken into account when maximizing rents of FFA members.

Our findings suggest that the current scenario, by which 75 percent of total catch is outsourced to distant water fishing nations, is not economically rational from FFA's perspective. The results of the optimization exercises allow for three important conclusions. First, current effort of all gears has to be significantly reduced to achieve the highest economic rents. Second, strategies favored by distant water fishing nations are not compatible with strategies favored by FFA countries. The latter involves a heavy reduction of DWFN effort in FFA waters and a slight increase of domestic fishing capacity. These changes would imply additional rent to the FFA community of approximately US$ 130 million per year. Third, access fees of distant water fishing nations have to be doubled before FFA countries economically can derive more rent from DWFN dominance than from domestic fisheries development. The outcomes, i.e. suggested directions of policy adjustments, are qualitatively robust to changing levels of variable and capital costs. All solutions leading to maximum rents of one or both players lead to decreased fishing mortalities. In addition to outcomes of the modeling exercise presented here, any decision about changes in fishing access must take into consideration other relevant dimensions, notably of a political and social nature.

Acknowledgements:

Valuable advice on the WCPO tuna fisheries, on data and on modelling was provided by Bob Gillette, Elizabeth Havice, Chris Reid, Adam Baske, Christopher Costello, John Hampton, Simon Hoyle and Peter Williams.

Appendix to Chapter 3

Table 3.3: Values of parameters used in the model.

Biological parameters				
	Skipjack	**Yellowfin**	**Bigeye**	**Reference**
recruitment number in first age category (millions)	2.299.376	189.155	64.100	Model calibration
Linf (cm)	62.5	190	214	(Bertignac, Campbell, and Hand)
K (per quarter)	0.50	0.08	0.05	Ibid.
M (per quarter)	0.36	0.21	0.15	Ibid.
to	0	0	0.12	Ibid.
Weight-length A	4.8E-06	2.5E-05	2.0E-05	Ibid.
Weight-length B	3.37	2.94	3.02	Ibid.
Fisheries- technical parameters				
	Purse seine	**Long line**	**Pole and line**	**Reference**
Effort	60000 fishing days	400 million hooks	5400 fishing days	For PS and LL: (Hampton, Harley, and Williams 2012) figures 2 and 9 For PL, effort is not comprehensively reported. 5400 days represents 9% of PS effort, reflecting relative PL catch values in (WCPFC 2012).
Effort utilization of a typical vessel	300 days/year	-	300 days/year	Own estimate
Catch made within EEZs of FFAs	71%	28%	6%	(WCPFC 2012)
Catch made by DWFNs	79%	89%	95%	Ibid.
Catchability coefficients				
FFA Skipjack	3.09E-06	0.00E+00	2.28E-05	Model calibration
FFA Yellowfin	3.97E-07	6.68E-05	2.84E-06	Ibid.
FFA Bigeye	2.33E-07	2.21E-04	9.55E-06	Ibid.
DWFN Skipjack	3.31E-06	0.00E+00	4.56E-06	Ibid.
DWFN Yellowfin	4.32E-07	3.45E-05	7.85E-07	Ibid.
DWFN Bigeye	2.38E-07	1.17E-04	2.89E-07	Ibid.
Selectivity all species all gears	See reference	See reference	See reference	(Bertignac, Campbell, and Hand)
Economic parameters				
	Skipjack	**Yellowfin**	**Bigeye**	**Reference**
Fish prices ($ US/ton)				
Purse seine	800	1000	1000	(Hannesson and Kennedy 2008)
Long line	-	6000	7000	Ibid.
Pole and line	1700	1700	1700	Ibid.
Price elasticity of demand	**Purse seine**	**Long line**	**Pole and line**	
	-1.9	-9.97	-1.9	(Bailey, Sumaila, and Martell 2013)
Effort costs (crating profit equal to 10% of revenue)				
DWFN	$ US 18,946/ day	$ US 1.56 / hook	$ US 8,455/ day	(Reid, Bertignac, and Hampton 2006)
FFA	$ US 31,424/ day	$ US 1.16/ hook	$ US 12,137/ day	Ibid.

Access fees				
DWFN	$ US 6,500/ day (*vds*)	5% of landing value	5% of landing value	(PNA 2013; Grynberg 2003; Gagern and van den Bergh 2013)
FFA	$ US 1,500/ day (*lf*)	2% of landing value	2% of landing value	Own estimate
Value adding benefit	10% of domestic PS catch value			
Average age of fleet (years)				
DWFN	17	31	24 (average PS, LL)	(WCPFC 2013b) and ("Maritime Connector" 2013)
FFA	15	17	16 (average PS, LL)	Ibid.
Vessel numbers				
DWFN	158	4323	1	Derived from WCPFC (2012), Bailey et al. (2013) and Hampton et al. (2012)
FFA	42	546	17	Ibid.
Vessel price (in million $ US)				
DWFN	15	4	1	Educated guesses based on (DEVFISH 2006), the WCPFC vessel database (WCPFC 2013b), and shipbroker webpages including 'atlanticshipbroakers.com' 'and maritimesales.com'
FFA	10	2	1	Ibid.

Table 3.4: Values used in the sensitivity analysis of variable costs.

Gear and player	Unit	Profit = 0% of revenue	Profit = 10% of revenue	Profit = 20% of revenue	Profit = 30% of revenue	Literature costs based on (Reid et al. 2003)	Profit as % of revenue for literature values
DWFN PS	$ US/ day	21,414	18,946	16,478	14,011	20,812	2%
FFA PS	$ US/ day	35,059	31,424	27,788	24,153	10,339	68%
DWFN LL	$ US/ hook	1.69	1.56	1.38	1.21	1.94	-11%
FFA LL	$ US/ hook	1.33	1.16	1.03	0.90	1.56	-20%
DWFN PL	$ US/ day	9,403	8,455	7,507	6,559	15,000	-59%
FFA PL	$ US/ day	13,516	12,137	10,758	9,379	15,000	-11%

Table 3.5: Capital costs for different vessel types in million US$

	FFA	**DWFN**
Long line	2.0	4.0
Purse seine	10.0	15.00
Pole and line	1.0	1.0

Chapter 4.

Trade-based Estimation of Bluefin Tuna Catches in the Eastern Atlantic and Mediterranean, 2005-2011

4.1 Introduction

Over the past decade, the Eastern Atlantic and Mediterranean Bluefin tuna stock (Thunnus thynnus, hereafter BFTE) has been brought to near collapse (MacKenzie, Mosegaard, and Rosenberg 2009). Reasons for this overexploitation are of both biological and anthropogenic nature. On the one hand, scientific understanding of population dynamics and stock recruitment has been limited. For example, we are only now starting to appreciate the degree of mixing between Western Atlantic and Eastern Atlantic stocks, as well as the possibility of a genetically distinct subpopulation in the Mediterranean (Taylor, Schechter, and Wolfson 2007). Population assessments are therefore characterized by considerable uncertainty, particularly about estimates of spawning stock biomass. In addition to this scientific uncertainty, management has been unable to control fishing mortality, allowing this stock to fall to biologically precarious levels. Especially in the years leading up to 2007, the International Commission for the Conservation of Atlantic Tunas (ICCAT) routinely set quotas above the scientifically recommended ones, which were associated with maximum sustainable yield and instituted only weak enforcement of those quotas (MacKenzie, Mosegaard, and Rosenberg 2009; ICCAT 2012a; Sumaila and Huang 2012).

With increased international pressure to improve management, in 2007 ICCAT started to put into place a set of more promising management measures. Since 2007, allowable quotas have been cut substantially, from 36,000 tons in 2006 to less than 13,000 tons in 2011. In addition, surveillance has improved and the Bluefin catch documentation (BCD) scheme was put in place to track BFTE along the entire supply chain and mitigate illegal catches.

Although these measures are promising as a means to help the stock recover, one major obstacle to successfully managing this species is the possibility of illegal catch, here defined as landings over and above allowable quotas. When setting a yearly quota, ICCAT bases its decision on the stock's probability of recovery. Currently, the harvest control rule requires that the probability of recovery by 2022 is at least 60 percent (ICCAT 2012b). However, the probability of recovery fundamentally changes with the assumption on excess catches, which, in the main model, is currently assumed to be zero. This assumption has been challenged in various studies basing their analysis on different indicators on illegal catch:

Basing calculations on vessel capacity and economic viability of the fleet, illegal catches were estimated to be up to 107 percent above allowable quotas in 2007 (ICCAT 2012a), and up to 60 percent between 2008-2010 (Tudela and Quilez-Badia 2012). Although based on solid extrapolations of available data, these estimates are indicators rather than direct measurements of illegal fishing. Since most BFTE is internationally traded, another promising approach has been to estimate catches through import and export data. The "Mind the Gap" report (Pew 2011) is the latest study in this vein: Based on this study, illegal catches appear to have exceeded allowable quotas by 31, 75 and 141 percent for the years 2008, 2009 and 2010, respectively. On the other hand, while ICCAT's Standing Committee on Research and Statistics (SCRS) acknowledges the significant catches beyond quota before 2007, it is the "Committee's interpretation […] that a substantial decrease in the catch occurred in the Eastern Atlantic and Mediterranean Sea in 2008 and 2009" as a result of a more stringent TAC (total allowable catch) setting process since 2008 and that overfishing after 2007 has dropped to negligible (SCRS 2012, 82).

In this report, we build on, revise and update Pew (2011) to estimate illegal catches of BFTE between 2005 and 2011. We modify the various steps of the methodology used in this earlier study, perform a sensitivity analysis, and present the findings in a form which is relevant to ICCAT's pending decision making about the future management of Atlantic Bluefin tuna.

4.2 Data used

4.2.1 Trade data

All countries involved in legal BFTE trade keep detailed records of imported and exported goods, both in terms of quantity and value. The competent body for data collection usually is the customs agency or the national statistics agency, which in most cases makes trade data publically available, although often against payment. Beyond national statistical services, some intergovernmental organizations collect, and make available, regional statistical data.

For the purpose of the present paper, monthly trade data for BFTE (between January 2005 and March 2012) were accessed through three sources: Eurostat, the official platform of European trade statistics provides all EU27 import-and export data in value and volume ("Eurostat, Your Key to European Statistics. European Commission" 2012); the Japanese customs agency; and GTIS (Global Trade Information Service), a provider of official national trade statistics. Trade data from all reporting countries specified by Eurostat and the Japanese customs data were included in the analysis. GTIS data was limited to the top trading countries representing 97.5 percent of both imports and exports of BFT. While Eurostat always reports data as provided by national statistical agencies, GTIS in addition contains customs data for some of the most important producing countries including Spain and France.

All raw trade data analyzed in this paper are publically available. Although we used the service of GTIS for a subset of trade data, GTIS obtain its data uniquely from official, publically available sources of each reporting country. Import and export data are categorized into internationally harmonized 6-digit codes (HS codes) by statistical agencies, referring to specific commodities (e.g. "030345, Bluefin tunas Thunnus thynnus, Frozen) that may or may not be further itemized into nationally applicable subcategories based on 2- to 4-digit statistical codes. These 2- to 4-digit codes sometimes vary among countries and therefore cannot be directly compared between countries. These include, for example, the exact "presentation" of a traded product and allow distinguishing between fillets, gilled and gutted fish or unmodified, whole fish (e.g. for the United States "0303450000, Bluefin Tunas (Thunnus Thynnus), Frozen, Except

Fillets, Livers And Roes”). In important importing countries, statistical codes are also used to distinguish between BFTE and other, similar Bluefin species (e.g. for the United States “Thunnus Orientalis (Pacific Bluefin Tuna), Frozen, Except Fillets, Livers And Roes”). In order to minimize the error resulting from inconsistencies between country-specific statistical codes, our data collection was conducted as follows:

i) All trade flows corresponding to HS codes including “Thunnus thynnus” were selected.
ii) Whenever it was unclear whether a given trade-flow exclusively referred to *Thunnus thynnus* we dropped this trade flow entry, thereby underestimating overall catches by a probably small but unknown amount.
iii) Finally, based on trade statistics, Mexico and Panama apparently contribute to a significant part of BFTE export. However, these exports are likely to refer mostly to Western Atlantic Bluefin tuna or Pacific Bluefin tuna. We therefore dropped flows from Mexico and Panama.

The raw data fed into the model (described below) finally covers 25 countries that exported and/or imported BFTE between the first quarter of 2005 and the second quarter of 2012. Just a few countries dominate this trade. Figure 4.1 shows the relative trade volumes of those countries that cumulatively account for 98% of import (10 countries) and export volume (12 countries).

Almost all countries report their trade data on a monthly basis (over 95 percent in volume). The rest is reported annually or quarterly. All trade flows were aggregated into quarterly imports and exports, in order to minimize the error in the crosscheck exercises (Section 3.2), while still allowing for the highest possible accuracy in adjusting time at trade to time at catch (Section 3.6).

4.2.2 Additional data

The computation of fattening rates, corresponding to weight increase during a given fattening period (Section 3.5), required information on fishing gear, for which we consulted the ICCAT Task I database. The two main gears used in the BFTE fishery are Purse seine and Longline. While the latter is employed throughout the year, the former is limited to several weeks in late spring and early summer Purse seine catch (live BFTE) is transferred to fattening ranches (see Section 3.5). We therefore used the relative amount of catches harvested by purse seiners as the fraction of total catch that entered the fattening process each year. Formulas are given in Section 3.5. The ICCAT Task I database was further used as reference for recreational catches. Finally, we also use ICCAT conversion factors for round weight (ICCAT 2006).

4.3 Methods

Following a sequence of conversion calculations, the traded product weights as retrieved from the databases were transformed into live round weight at the time of catch and compared to annual allowable catch quotas. In the following subsections each step of the conversion is described in detail, from raw trade data to estimated weight at time of catch. A graphical overview of the calculation approach is provided in Figure 4.2.

4.3.1 Combining data sources

The three sources of data consulted cover distinct but overlapping sets of countries that report import from or export to partner countries. Together they represent the widest possible range of publically available data on BFTE trade. Following Pew (2011). We combined these data sets by comparing corresponding quarterly trade flows to avoid double counting. Whenever two overlapping data entries of distinct data sources conflicted, we picked the larger value in order to obtain the most complete data set and to detect inconsistencies between data sources. Anecdotal evidence suggests, for example, that the customs agencies of several European countries have underreported BFTE exports to the national statistics agencies and hence to Eurostat. As a result, one would expect Eurostat data to include lower values than GTIS data, which also include original customs data. In fact, while import data are very consistent across data sources, export data conflict in various occasions. However, conflicting overlaps yield minimal differences in total export weight (<4 percent).

4.3.2 Comparing reported imports with corresponding reported exports

Traded freight logged by one country as export to a specific partner country should be consistent with reported associated imports by the partner country. For example, if Italy reports exporting 1 ton of Bluefin fillets to Japan in February 2009, Japan should report importing 1 ton of Bluefin tuna fillets from Italy in the same month. This consistency is often absent, for which there are five possible explanations:

- Most traded BFTE is transported by sea, from the Mediterranean to as far away as Japan, South Korea, or the United States. The time lag between logging a particular freight as an export upon departure and as import upon arrival might result in seemingly inconsistent data, if the exports are recorded in a different month or even quarter or year than the imports, i.e. if reference timing is used inconsistently. The EC user guide on statistics (EC 2006, 12) notes that "… the reference period in theory is again the calendar month in which the goods are imported or exported. In practice, information is generally assigned to the month in which the customs authority accepts the declaration". The definition of "reference timing" as the change of ownership is, however, impractical for "… those interested in the transport aspects of the data" because "it is believed that the definitions used generally coincide with the timing of ownership changes, although by no means always."
- In principle, incentives to under-report trade flows exist for both importers and exporters. At the exporters' end, under-reporting can mask the trade of catch that exceeds the national allowable quotas and would, if reported, lead to a cut in quotas for the subsequent year. At the importers' end, customs agencies might collaborate illegally with cargo agencies and introduce part of the shipment into the black market, or seek to avoid tariffs.
- During shipment, freight can get lost, spoiled, or otherwise damaged (Pew 2011). If, as a result, freight is discarded in transit to avoid customs fees upon arrival for a good that cannot be sold, importing countries will report a lower weight than exporting countries.
- There are also measurement and logging inaccuracies. Sloppiness during measurement, logging, and extrapolation of product weight at the customs agencies can lead to differences in reported data.

• Different levels of detail in reporting of BFTE products might lead to underreporting (never over reporting) in some countries. One example is Bluefin fillets, which might be traded as "fish fillets" in one country (thereby escaping our filter) and as "BFTE fillets" in another country.

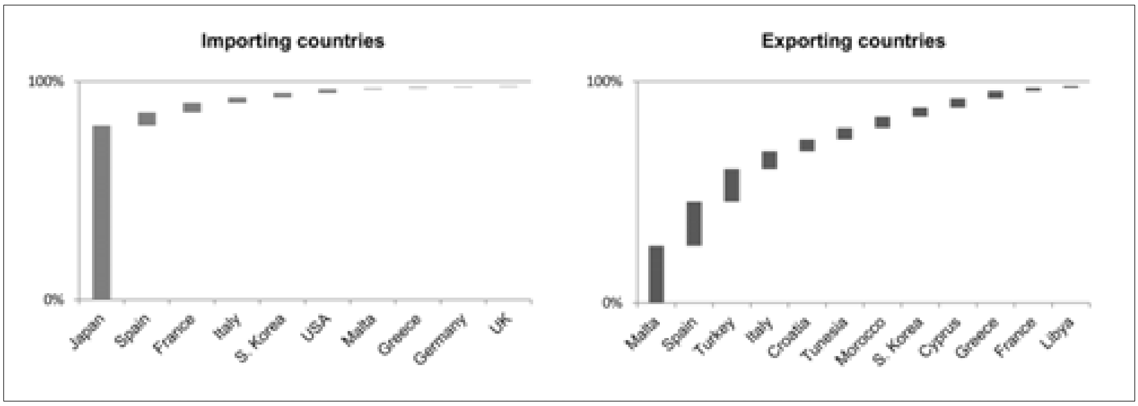

Figure 4.1: Main exporters and main importers of BFTE as reflected in trade data (traded product weight)

We established three scenarios (hereafter "input scenarios") that estimate total trade flow. These scenarios are as follows:

• The maximum scenario: If two corresponding trade flows conflict, the larger value is adopted. This scenario allows us to eliminate intentional under-reporting to a large extent. However, this procedure introduces two biases, namely overestimation because of time lag of logging and overestimation through always favoring the positive error of measurement inaccuracies. If the identical freight is reported in different quartiles by exporters and importers, the "max" scenario might overestimate overall catches because the model picks the higher value (reported by exporters) in one quartile and the higher value (reported by importers) in the subsequent quartile.

• The average scenario: If two corresponding trade flows conflict, their nonzero-average is taken. This scenario mitigates the error of inaccurate measurement, as well as the error introduced through time lags, but it assumes that no intentional under-reporting exists.

• The import data scenario: Only import data are taken into consideration. This scenario assumes that there might be under-reporting at the exporters' end, but that neither under-reporting at the importers' end nor losses during the shipping process occur. As in the average scenario, the errors introduced due to time lag of logging are eliminated, and no under reporting is assumed. In addition, freight discarded before arrival is ignored.

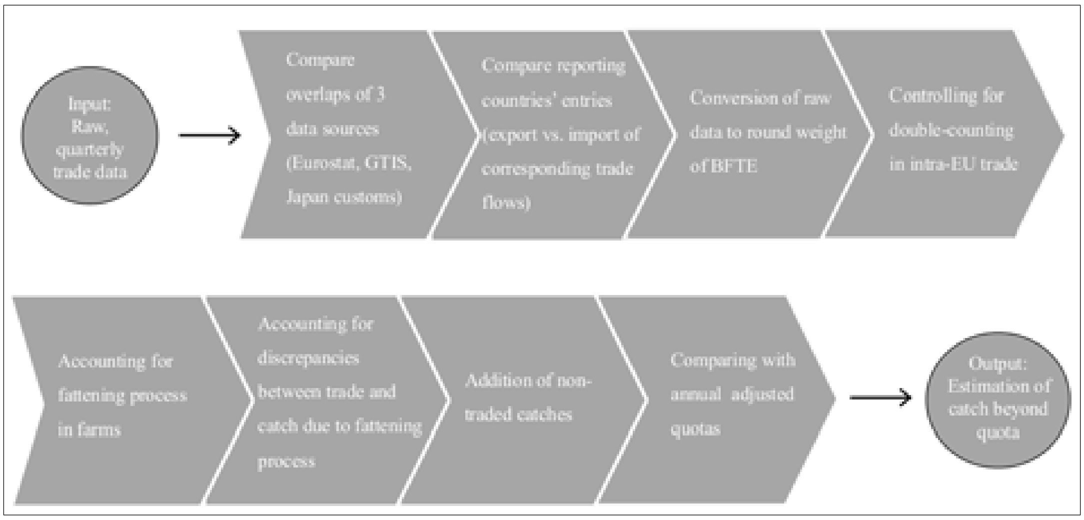

Figure 4.2: Graphical overview of the calculation approach

4.3.3 Conversion to round weight

Between harvest and trade, BFTE is gutted, gilled, dressed, and/or filleted. These different types of fish products are called "presentations." To make up for the weight loss during these steps, we have to convert product weight to round weight. This step requires two types of information, namely suitable conversion factors for each type of presentation and the relative composition of product presentations in the trade data. While conversion factors to round weight are readily available from ICCAT (2006), composition of presentation in most national trade data is not detailed enough to directly apply conversion factors to raw trade data. Fortunately, the main importer of BFTE, Japan (around 80 percent of all imports), provides the highest level of detail for BFTE product type. We therefore calculate and apply a weighted average conversion factor to all traded BFTE based on the relative appearance of "presentations" (product types) in Japanese import data (Customs Japan). This is formalized in equation 1. In all formulas, variables are written in capital letters while parameters are written in lowercase. Exogenous variables are labeled with an over line. To simplify notation, time indices are omitted.

$$RW = \sum_{i=1}^{N} cf_i * rp_i * \overline{TW} \quad (1)$$

<u>where</u>

RW Round weight, which is the weight of the fish when taken out of the water, regardless of whether it has been ranched or not;

cf_i Specific conversion factor to round weight for "presentation" (ICCAT 2006). These factors are applied to traded product weight to make up for weight loss during the processing. The subindex *i* indicates that these factors are presentation-specific (i.e. *i* denotes presentation);

rp_i Relative contribution of a given "presentation" in the Japanese import data;

TW Traded product weight as specified in raw trade data.

Basing the conversion factor to round weight solely on Japanese import data might introduce an error if product types for Japanese markets significantly differ from those earmarked for other import markets. We therefore establish three values around the calculated weighted average as possible conversion factors.

4.3.4 Elimination of double counting within EU trade and estimation of EU consumption

Two major constraints to the analysis apply to catch and trade within some of the main quota countries. First, it is not possible to capture locally caught and consumed BFTE through trade data as these catches are not reflected in trade data; second, it is not possible to distinguish exports from re-exports (for example, if Spain ships to France, which subsequently re-exports the product to Japan).

While this double counting problem caused by exports and re-exports applies mainly to France, Spain, and Italy (making up a "circular" trade representing around 13 percent of global imports, Figure 4.1), an inability to account for local consumption applies to all Eastern Atlantic and Mediterranean fishing countries (hereafter EU fishing countries) with BFTE quotas. We simultaneously controlled for both errors by replacing import entries of the EU block Spain, France and Italy with an estimate of BFTE consumed in all EU fishing countries. We do so by introducing a parameter ("EU consumption") that represents a consumption ratio between the EU fishing countries and the three end markets of Japan, USA and South Korea, which together make up 85 percent of BFTE import between 2005 and 2011. The introduction of this parameter hence does two things: It eliminates all potential double counting due to re-export and it includes an estimate of consumption in Eastern Atlantic and Mediterranean fishing countries. Unfortunately, the scientific literature does not offer recent estimates on BFTE consumption that are independent of trade data. We therefore base our range of values on two types of information. First, we consulted online newspaper articles and NGO statements; second, we conducted five interviews with industry representatives, BFTE scientists and NGO representatives. Interviewees spoke to us under the premise not to be cited due to the politically tenuous nature of BFTE management in the past. These sources rather consistently point out that i) Consumption in Japan, the US and South Korea makes up about 80-90% and that the rising demand of high-grade sushi products in the EU has led to a higher presence of BFTE into local markets. In the model, we thus use 10, 15, and 20 percent (corresponding to 80-90% of consumption in the main end-markets) as possible values but select the most conservative value (10 percent) for a scenario that we highlight as the "preferred scenario" (see Section 4.6). The steps presented in (2) (defining end markets) and (3) (applying the "EU consumption" parameter) only change round weight entries for Spain, France and Italy, while other countries' trade data entries remain unchanged.

$$RW_E = \sum_{i=1}^{3} RW_i \quad (2)$$

$$RW_{EU} = RW_E * cons_{EU} \quad (3)$$

<u>where</u>

RW_E Round weight of the main non-European end markets (Japan, South Korea and USA);

RW_i Individual round weight per non-EU end market country (Japan, South Korea and USA, denoted by subindex *i*);

RW_{EU} be — Round weight of the EU countries where circular trade and re-export can be expected (France, Italy and Spain);

$cons_{EU}$ the — Consumption in France, Italy and Spain as a fraction of import going to the block Japan, South Korea and USA.

4.3.5 Conversion to catch weight

Net round weight does not always correspond to weight at catch. Some of the caught BFTE are transferred live into tuna ranches where fish are kept to reach the ideal fat content and meat color. During this process, BFTE also gain weight. To compare estimated catches with the allowable quotas, we must take such weight increases into consideration. This is addressed in two steps. First, trade flows are split into those with an origin in Croatia and those with another origin. Croatia is the main country entitled to catch BFTE at the minimum individual weight of 8 kilograms (As allowed for Adriatic catches), while the quotas of all other areas require a catch limit of 30 kilograms. This difference in catch weight fundamentally changes the assumptions related to fattening processes, given that wild juvenile fish have higher growth rates. Second, fattening rates are established to account for the weight increase during the ranching process.

4.3.5.1 Non-Croatian fattening

BFTE fattening in non-Croatian farms usually takes place between July and April. Although meat quality increases towards the winter, some fish are harvested throughout the rest of the fattening period in response to market dynamics and to avoid over-supply in the winter months. The best publically available set of data on non-Croatian fattening rates is presented by Galaz et al. (2011), spanning the period between 1995 and 2005, and including observations on more than 12,000 BFTE individuals. In this study, length frequency distributions (LFD, relative frequencies per size class) are presented, as well as cumulative size-specific fattening rates (weight increase per month and per size class between August and April) over the entire fattening period. LFD is crucial for the computation of fattening rates since different size classes have different growth patterns. Note, as opposed to natural conditions, young individuals in captivity can display high growth and fattening rates as long as they are the dominant size class in the pen; otherwise they seem to suffer from being underrepresented and grow even slower than mature, older fish (Galaz 2011). We adapted the findings to calculate a weighted average fattening rate, which is then multiplied by the calculated *net* weight. Equation (4) yields the average monthly fattening rate, based on which equation (5) calculates the overall weighted average fattening rate. Equation (6) then applies this fattening rate to the purse seined fraction of non-Croatian net weight, to calculate catch weight before the ranching. Equation (7) is merely an auxiliary equation defining RW_G, which is a variable appearing in (6).

$$AIW_m = \sum_{s=1}^{S} rw_{s,m} * \overline{IW}_{s,m} \quad (4)$$

$$AIW = \sum_{m=1}^{M} AIW_m * rh_m$$

(5)

$$CW_c = AIW * ps_c * RW_G \quad (6)$$

$$RW_G = RW_E + RW_{EU} + RW_R \quad (7)$$

<u>where</u>

AIW_m Average monthly (cumulative) increase of weight during the non-Croatian fattening process;

$rw_{s,m}$ Relative weight of size class *s* in month *m* as compared to total weight in month *m;*

$IW_{s,m}$ Increase in weight per size class *s* in month *m;*

AIW Average increase in weight during the entire fattening process

rh_m Relative harvest per month *m* during fattening process;

CW_c Estimated catch weight of non-Croatian fishing countries before any fattening process;

ps_c The country-specific fraction of purse-seined catch as specified by the ICCAT Task I data base;

RW_G Global round weight excluding Croatia;

RW_R Round weight exported by countries not included in RW_E or RW_{EU} and excluding Croatia.

4.3.5.2 Croatian fattening

Croatian BFTE ranching is focused on smaller individuals, making the ranching time longer and fattening rates higher than in non-Croatian ranching. The studies (Katavić, Tičina, and Franièeviæ 2002; Katavić, Tičina, and Franièeviæ; Tičina, Katavić, and Grubišić 2007) report a weight increase of over 500 percent for individuals that entered the pens between 6 and 8 kg (very small specimen) over a time period of almost 2 years, and weight increase of 220 – 320 percent for larger individuals. As none of these studies discloses LFD or even mean sizes of ranched BFT, it is difficult to make an assertion about Croatian weight increases during fattening processes. Furthermore, Tičina et al. (2007, 542) states that "since the rearing conditions are not fully controlled but depend on environmental changes, these indications should not be used for back-calculations [inferring from round weight to catch weight before fattening] to determine the initial quantity of fish stocked into cages." Finally, some of the ranched fish in Croatia originates from other countries including Italy and France, where legal catch sizes start at individuals > 30 kg and whose ranching yields similar weight increases as non-Croatian fattening rates. We therefore propose three estimates (2, 2.5 and 3) of Croatian fattening rates (CFR) so that the formula applied to Croatian exports becomes equation (8):

$$RW_{Croatia} = AIW_{Croatia} * ps_{Croatia} * RW_{Croatia} \qquad (8)$$

<u>where</u>

$RW_{croatia}$ Round weight exported by Croatia;

$AIW_{croatia}$ Average cumulative increase of weight during the Croatian fattening process;

$ps_{croatia}$ The Croatian fraction of purse-seined catch as specified by the ICCAT Task I data base;

$RW_{croatia}$ Round weight exported by Croatia.

4.3.6 Weight at time of catch

Allowable quotas have greatly varied over the past years. When comparing trade data with quotas we therefore must correct for the time lag introduced by ranching. Bearing in mind that the main fishing season takes place between June and July and the fattening process stretches at least into April, we attributed all trade between January and June (quarter 1 and quarter 2) to catches from the previous year. Beyond that, we date all exports coming from Croatia back another 2 years, acknowledging the longer duration of the fattening process in that country.

In order not to underestimate Croatian catches in 2010 and 2011, an auxiliary set of export data was created for Croatia covering the years 2012 and 2013, as well as the first two quarters of the year 2014, based on average Croatian exports of the past 3 years. This might slightly overestimate the fraction of Croatian catches between 2009 and 2011 since quotas have been falling over past years. Similarly, we created a set of data for non-Croatian trade data for the second quarter of 2012, based on average values on the second quarter of 2009, 2010 and 2011. This again might lead to a slight overestimation of landings if catches have fallen as much as quotas have been falling in this time period.

4.3.7 Addition of non-traded catches

Part of the allowable quotas is earmarked for recreational fishing but cannot be traded and is thus not captured by the trade analysis (Pew 2011). This recreational fishing data were added without modifying weight. Landing figures are assumed to reflect round weight.

4.3.8 Sensitivity analysis

Based on the different values of each variable that we considered in the model, a simple linear sensitivity analysis of all uncertain parameters was conducted. To do this, a total of 243 gaps (illegal catch as a percentage of allowable quotas, hereafter referred to as "gaps"; three input scenarios and four variables with three values each = 3^5 = 243 gaps) were calculated. These gaps refer to cumulative estimated illegal catch as a percentage of cumulative allowable quotas over the period 2008-2011, the period for which SCRS believes there is no fishing beyond the allowable quota.

Table 4.1 summarizes the gaps that were calculated based on the three input scenarios (maximum, average, or import data) and the different values that we attributed to the variables (fattening rates, EU consumption, and conversion factors) of the model.

4.4 Results

4.4.1 Comparing reported imports with corresponding reported exports

The choice of the input method is a decisive step in this methodology. Using the Maximum scenario shows markedly higher overall catch estimates than the *import* or *average* scenarios (Figure 4.3A). This indicates the magnitude of inconsistencies in the reported trade data. It should be noted that Figure 4.3C through 4.3E always adopt the middle value and ignore the upper and lower bound of the previous step. This is with the exception of Figure 4.3D which adopts the lower bound scenario of Figure 4.3C (10% EU consumption). Together, these choices lead to our "preferred scenario" (Figure 4.3E).

4.4.2 Conversion to round weight

Table 4.2 summarizes the commodity-specific round weight conversion factors as used by ICCAT, as well as the composition of commodity types to the highest possible detail, as presented by the Japanese customs data. While the conversion factor of 1.67 for fillets (representing 65 percent of product weight entering Japan) is uncontroversial, it is less clear what round weight conversion factor to apply to the remaining 35 percent of product weight, which is solely designated as fresh or frozen Bluefin tuna (the descriptions in Japanese customs data offer slightly more detail, but they do not allow for more precise interpretation of the products' presentation). Table 4.2 therefore also presents a set of weighted average conversion factors that are based on different assumptions pertaining to the presentation of the 35 percent of product weight that is unspecified.

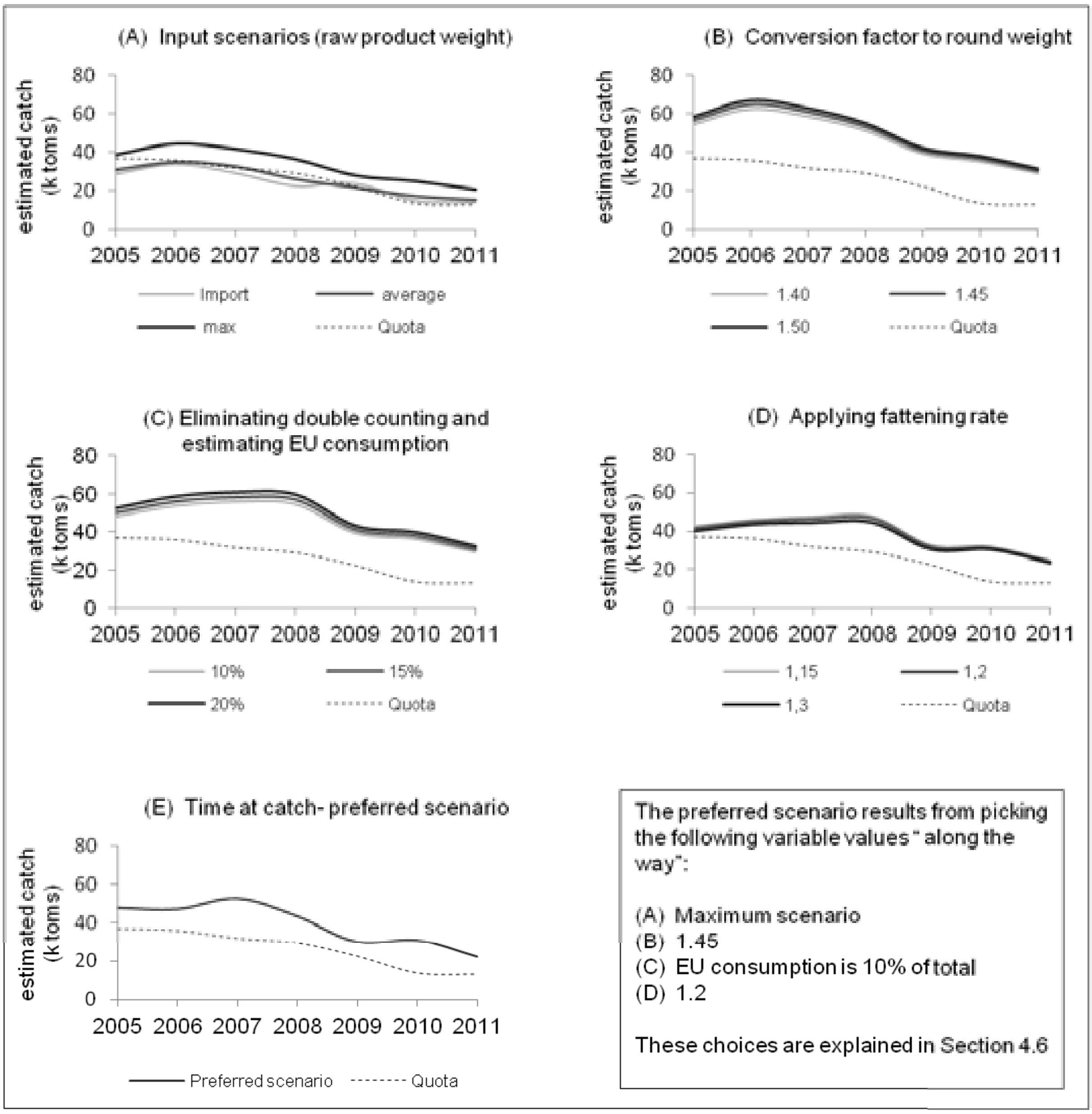

Figure 4.3: The development of estimated catch over the various stages of the methodology. B is based on maximum scenario, C through E are based on middle value of previous step

If we assume that all tuna of unspecified presentations have been neither gilled nor gutted, nor otherwise modified, we get to an overall conversion factor of 1.43. If we assume that all such unspecified products are in fact fully "dressed" (gilled, gutted, partly beheaded and some of the fins missing), an overall conversion factor of 1.52 is calculated. Basing our conversion factor solely on Japanese import data we hence calculate conversion factors ranging from 1.43 to 1.52., whereby the lower bound is improbable given the unlikelihood of BFTE being exported without modification. As the 20 percent of remaining trade data might have slightly different presentation patterns than is favored in the Japanese market we have used three values (1.4, 1.45, and 1.5) as conversion factors in the model. Figure 4.3B illustrates the change in estimated catch as a function of these three values. This figure is based on calculations for which the maximum input scenario is adopted.

Table 4.1: Weighted average conversion factors (to round weight) calculated based on different assumptions on product presentation

Commodity type	**Japanese import weight in percentage (2005-2011)**
Fillet, fresh or frozen	0.0001%
Fresh Fillet	0.0087%
Frozen Fillet	64.7%
Fresh unspecified	17.0%
Frozen unspecified	18.2%
Weight type	**ICCAT conversion factor**
Dressed weight (DWT)	1.25
Gilled and Gutted weight (GWT)	1.16
Fillet weight (FIL)	1.67
Hypothetical presentation of "fresh" and "frozen" BFT	**Weighted average calculated**
All whole (conversion factor 1)	1.43
All GWT	1.49
All DWT	1.52
One half GWT, one half DWT	1.51
One third GWT, one third DWT, one third unmodified	1.48

4.4.3 Elimination of double counting within EU trade and estimation of EU consumption

Based on the assumptions made on EU consumption, compared to *round weight* the calculated catch values are slightly lower until 2007 and slightly higher thereafter (Figure

4.3C). The reason for this is that French, Spanish and Italian imports of BFTE greatly decreased over the past years (Figure 4.4). Recalling our model specification on assumed EU consumption, this means that estimated round weight is corrected downwards as long as imports by France, Spain and Italy are higher than 10, 15 or 20 percent of global imports respectively, and upwards if the opposite is true. Interestingly, compared to *round weight*, the overall picture does not change much, suggesting that the positive bias of double counting is of similar magnitude as the negative bias induced by missing data on internal EU consumption.

4.4.4 Conversion to catch weight

Combining the length frequency distribution (Figure 4.5) and size-specific cumulative rates of weight increase over the period of fattening (Figure 4.6), both based on Galaz (2011), we calculated a weighted average fattening rate for non-Croatian BFTE farming of 1.16. Next to the LFD presented in Galaz (2011), Figure 4.5 includes the LFD based on the purse seine catches (2004-2011) presented in the 'ICCAT Task II size' data base. As these LFD are fundamentally different from those presented in Galaz (2011) we chose to include three values as possible non-Croatian fattening rates, namely 1.15, 1.2 and 1.3. However, contrary to our expectations, the choice of fattening rates has only a small effect on the estimated overall catch (Figure 4.3D).

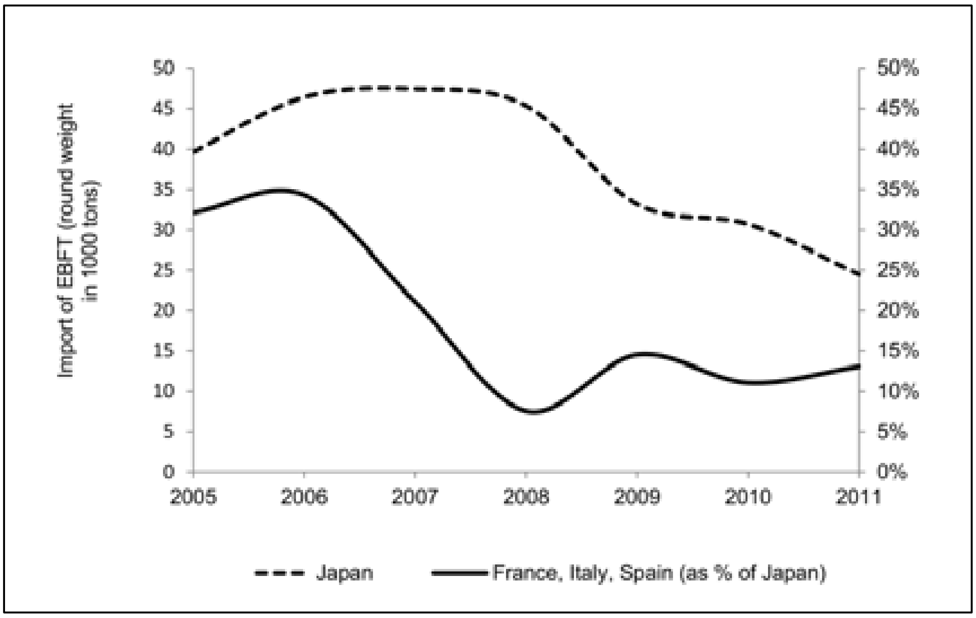

Figure 4.4: Import by main EU importers as a percentage of Japanese imports

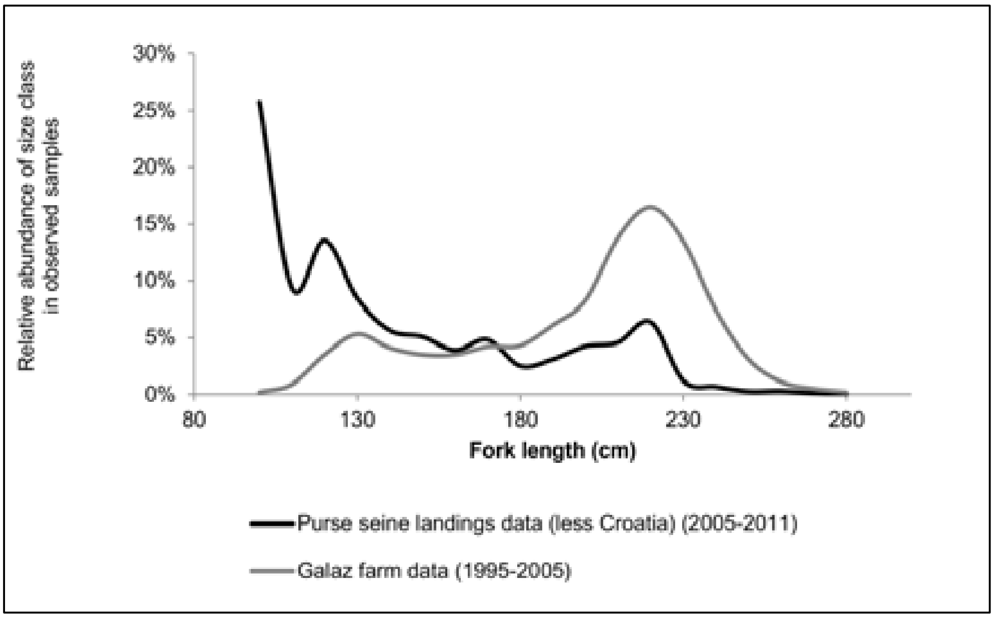

Figure 4.5: Length-frequency distributions based on different sources

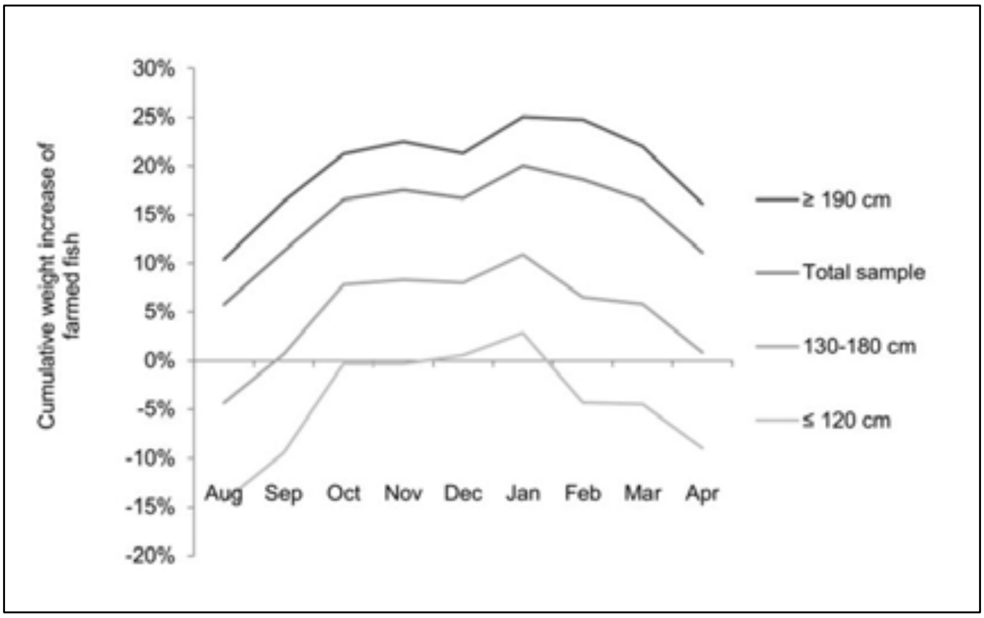

Figure 4.6 Size-specific cumulative weight increase during the period of non-Croatian fattening

4.4.5 Catch weight at time of catch and addition of non-traded catches

The reassignment of trade dates to catch dates pronounces the differences between catch seasons. The decline of estimated catch in 2009, followed by its sharp rise in 2010 (despite sinking quotas) suggests another dynamic being captured here, namely short term business decisions by ranchers (Figure 4.3E). Although we do not have specific data supporting this conclusion, it is reasonable to assume that the observed behavior is a consequence of rapidly sinking tuna prices in 2009, which caused tuna ranchers to keep their tuna in pens, waiting for the prices to stabilize again before selling (personal communication with an industry representative who prefers not to be cited here).

The addition of non-traded recreational catch increases the overall estimated catch by around 1 percent for the period of 2005-2011.

4.4.6 Defining a preferred scenario

The wide range of results of the sensitivity analysis (Table 4.2) does not represent equally probable outcomes. It reflects the model's reaction to different values of the model parameters. Within the obtained range we would like to define a "preferred scenario" that we believe is the most likely. This scenario is based on the following assumptions and associated motivations:

- Given the high incentives to under-report trade data, as well as other dynamics favoring under-reporting, it seems legitimate to pick the maximum import scenario (Section 4.1).
- Basing the conversion factor for round weight on calculated weighted average values, a factor of 1.45 appears to be the most appropriate conversion factor while still permitting for some degree of conservatism (Section 4.2).
- Given the dearth of information on consumption and double counting, the value of 10 percent EU-consumption of BFTE was used as a conservative estimate (Section 4.3).
- The weighted average fattening rate calculated based on data from Galaz (2011) suggests a rate of weight increase of 1.16 for non-Croatian ranches. Nonetheless, we favor the more conservative rate of 1.2 for two reasons. First, data used in that study cover the period from 1995-2005 and we can assume that fattening processes have improved since then. Second, although in Galaz (2011) it is shown that small

individuals increase in weight at a lower rate than large individuals, the difference in LFDs between Galaz et al. (2011) and the ICCAT data might suggest higher rates of weight increase given that ICCAT data show a predominance of small fish, a decisive factor for fish BFTE growth in fattening ranches (Galaz 2011). Thus, factor 1.2 is used as a more realistic value. Given the shortage in publically available data on Croatian ranching, we prefer to choose the most conservative factor of 3 (Section 3.5 and 4.4).

Applying these assumptions, the model calculations suggest that between 2008 and 2011, total BFTE catches exceeded allowable quotas by 57 percent. The exceedance calculated for the years 2005-2007 is somewhat lower, namely 44 percent, because despite falling catches over past years, fishing quotas have fallen more rapidly than our estimates of catches. Figure 4.7 shows the upper and lower model bounds, highlights our "preferred scenario" and indicates the catch beyond quota (in percent) that is calculated based on this scenario.

4.4.7 Sensitivity analysis

Table 4.2 shows that the highest sensitivity of the model is due to the choice of input scenarios (maximum, average, or import data). All other variables only lead to minor changes in estimated gaps.

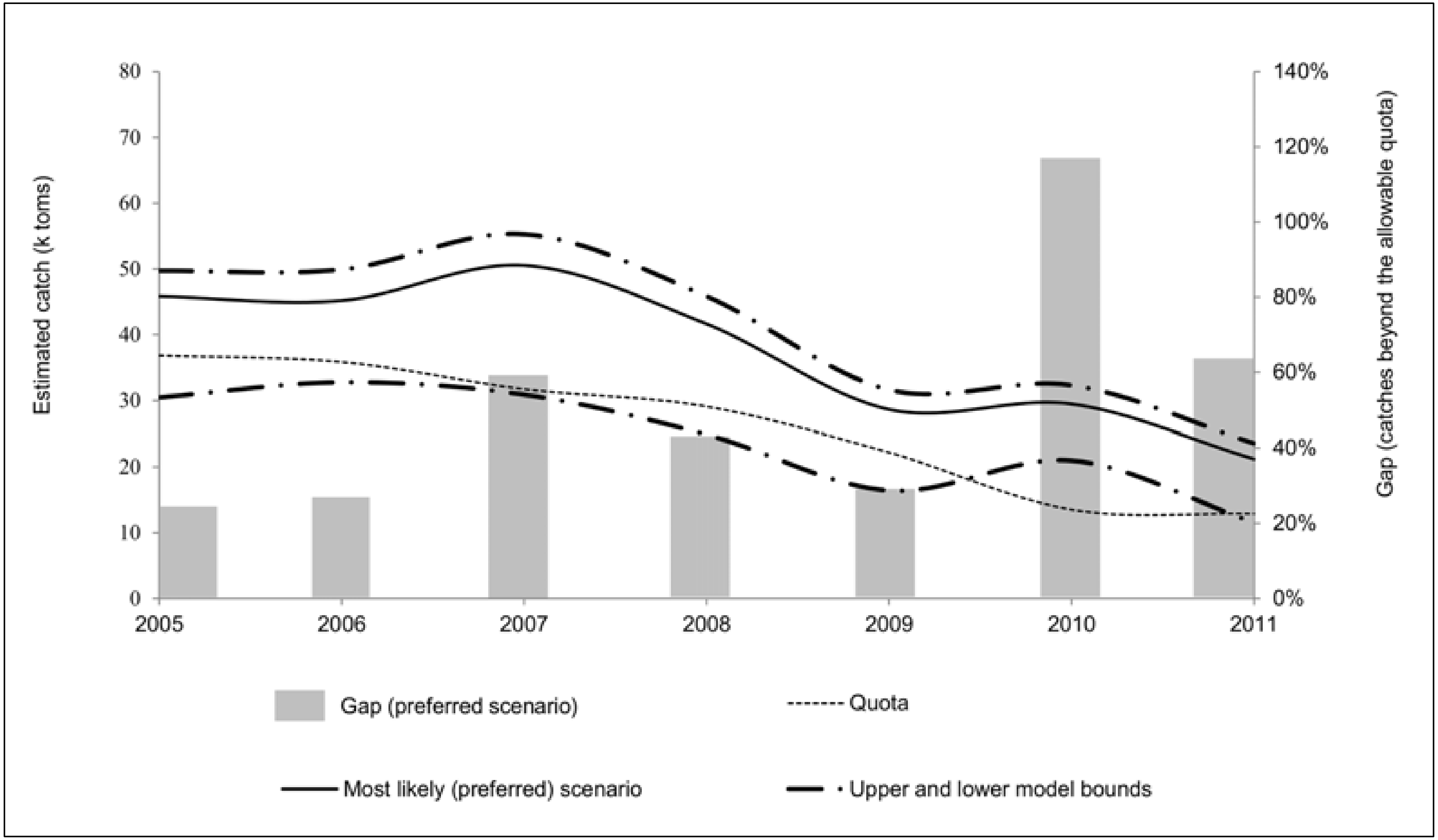

Figure 4.7: Estimated catches and corresponding gap (catches beyond quota)

Table 4.2: Calculated gaps based on all possible combinations of variables used in the model; FR = fattening rate, Rwt = round weight

Maximum scenario			10% EU consumption			15 % EU consumption			20 % EU consumption	
FR Med	FR Croatia	Conversion to Rwt 1.4	Conversion to Rwt 1.45	Conversion to Rwt 1.5	Conversion to Rwt 1.4	Conversion to Rwt 1.45	Conversion to Rwt 1.5	Conversion to Rwt 1.4	Conversion to Rwt 1.45	Conversion to Rwt 1.5
	2	57%	63%	69%	64%	70%	76%	72%	78%	84%
1.15	2.5	55%	60%	66%	62%	67%	73%	69%	75%	81%
	3	53%	58%	64%	60%	65%	71%	67%	73%	78%
	2	55%	60%	66%	62%	68%	73%	69%	75%	81%
1.2	2.5	52%	**57%**	63%	59%	65%	70%	66%	72%	78%
	3	50%	56%	61%	57%	63%	68%	64%	70%	75%
	2	50%	56%	61%	57%	63%	68%	64%	70%	75%
1.3	2.5	48%	53%	58%	54%	60%	65%	61%	66%	72%
	3	46%	51%	56%	52%	58%	63%	59%	64%	70%
Average scenario			10%			15%			20%	
FR Med	FR Croatia	1.4	1.45	1.5	1.4	1.45	1.5	1.4	1.45	1.5
	2	10%	14%	18%	15%	19%	23%	20%	24%	29%
1.15	2.5	8%	12%	16%	13%	17%	21%	18%	22%	27%
	3	7%	11%	15%	12%	16%	20%	17%	21%	25%
	2	8%	12%	16%	13%	17%	21%	18%	22%	26%
1.2	2.5	7%	10%	14%	11%	15%	19%	16%	20%	24%
	3	5%	9%	13%	10%	14%	18%	15%	19%	23%
	2	5%	9%	12%	10%	14%	18%	15%	19%	23%
1.3	2.5	3%	7%	11%	8%	12%	15%	13%	16%	20%
	3	2%	6%	9%	7%	10%	14%	11%	15%	19%
Imports scenario			10%			15%			20%	
FR Med	FR Croatia	1.4	1.45	1.5	1.4	1.45	1.5	1.4	1.45	1.5
	2	-5%	-1%	2%	-1%	3%	6%	4%	7%	11%
1.15	2.5	-6%	-3%	0%	-2%	2%	5%	2%	6%	9%
	3	-7%	-4%	0%	-3%	1%	4%	1%	5%	8%
	2	-6%	-3%	0%	-2%	1%	5%	2%	6%	9%
1.2	2.5	-8%	-4%	-1%	-4%	0%	3%	1%	4%	8%
	3	-9%	-5%	-2%	-4%	-1%	2%	0%	3%	7%
	2	-9%	-6%	-3%	-5%	-2%	2%	-1%	3%	6%
1.3	2.5	-10%	-7%	-4%	-6%	-3%	0%	-2%	1%	5%
	3	-11%	-8%	-5%	-7%	-4%	-1%	-3%	0%	4%

Note that this table consists of three identically arranged sub-tables differing only with respect to input scenario: Maximum, Average and Imports. Percentages indicate the extent by which allowable quota have been over- or under fished between 2008 and 2011.The bold number (57%) is the gap calculated based on the preferred scenario, that is, values we regard as being most probable

4.5 Discussion

Our study highlights significant levels of excess catch in the Eastern Atlantic and Mediterranean Bluefin tuna fishery. Providing a wide range of values for variables around which uncertainties exist, our findings show that one would have to take a range of highly questionable assumptions for granted to assume that no fishing beyond allowable catches has occurred between 2008 and 2011. These assumptions include that (i) no under reporting exists at the importers' end, (ii) overall conversion factors from product weight to round weight are as low as 1.4, (iii) EU consumption of BFTE is merely 10 percent of overall consumption, and (iv) the highest fattening rates presented for both the Mediterranean farms and for Croatia are true.

Using the, in our view, most realistic values around each variable, cumulative illegal catch has exceeded allowable catch by 44 percent since 2005. As allowable quotas decreased over past years, and illegal catch did not decrease at the same pace, this figure rises to 57 percent of excess fishing for the period 2008-2011.

4.5.1 Possible sources of error

4.5.1.1 Data-related errors

We identified five potential sources of data-related errors, three of which would imply that we underestimate our final catch value and two of which would imply overestimating this value. First, the complete exclusion of non-quota countries can lead to some underestimation. WWF (2012), for example, suggests that between 2000 and 2010, 18,704 tons of Bluefin tuna (life weight equivalent) were traded via Panama without being reported to ICCAT. Second, our analysis does not capture catches that have been traded in black markets. This includes, but is not limited to, mislabeling, which can potentially take the form of downgrading (labeling BFTE as less costly fish to avoid citations of excess catch) and upgrading (labeling other tuna as BFTE to yield higher prices at end markets). Given the strict rules at customs agencies, the high price of BFTE, and the 'connoisseur'-nature of end markets, upgrading can be expected to be minimal. Downgrading, on the other hand, is a common problem that has often been reported. The latest example includes the uncovering of 40 tons of BFTE labeled as yellowfin tuna and shipped from Italy to Spain in May 2012, representing 4 percent of Italian quotas for 2012 (De Sabata 2012). Third, the exclusion of trade entries containing other species than BFTE might lead to some underestimation. To the extent that data-related errors are concerned we are therefore confident that estimated excess catches presented in this study (the preferred scenario) are conservative. Fourth, Japanese Import data only poorly distinguish between Atlantic and Pacific Bluefin tuna. However, the countries considered as exporters do not, or only to a very small extent fish and trade Pacific tuna (See Figure 4.1 for reference). Fifth, before 2007, Inter-EU trade of life BFTE was poorly coded, potentially being partly included in the processed BFTE data. This error is not relevant for our main results, as these apply to the years 2008-2011.

4.5.1.2 Methodological errors

Such errors include the crosschecking both between sources and between reporting countries, the creation of auxiliary data sets to make up for recent years' catch that has not yet been traded and, to a lesser extent, variable assumptions of our preferred scenario.

In our preferred scenario we always pick the larger of two values when conflicting entries arise. Although we believe that this is necessary to deal with under reporting, it unavoidably leads to overestimates. These have two origins. First, whenever a random deviation occurs in two corresponding entries, the positive deviation is favored and the negative error is dropped. Second, if there is a time lag between reporting export and reporting import, an error might be introduced if data entry is not identical to the date at which the product changes ownership. Since both errors are decreased at a higher degree of temporal aggregation of trade data, we used quarterly aggregation of data instead of monthly data.

The creation of auxiliary data sets for 2012, 2013 and 2014 is likely to overestimate total catches. This overestimation however is less severe than the one resulting from our crosschecking methodology. First, this overestimate only applies to Croatian exports, and within these exports only to the purse seined fraction of catches. Second, although quotas have decreased between 2009 and 2010, they stayed constant thereafter. Taking averages over the three-year period 2009-2011 thus leads to very low levels of overestimation.

Variable definition is a justified source of concern regarding the selection of our preferred scenario. However, as opposed to other errors herein presented, it is difficult to judge whether they tend to overestimate or underestimate the final results. On one hand, wherever data were poor we chose a more conservative variable value. On the other hand, extrapolations from Japanese import data could be misleading. This mainly pertains to the calculation of the conversion factor to round weight, which is a sensitive variable.

4.5.2 Comparison with previous studies

Similar to previous studies, this analysis confirms that illegal catch has been responsible for large parts of overall BFTE catches in past years. Although taking an alternative and significantly altered approach to calculate catches from trade data and despite fully independent data collection between the studies, our analysis largely supports the overall outcome of Tudela et al. (2012) and Pew (2011): Illegal catch significantly and persistently surpasses current allowable quotas and this gap has been slightly increasing over past years in relative terms. This study adds three important dimensions to existing, published tuna trade analyses. First, we provide a mathematical model which converts raw trade data into catch estimates and presents each computational step in detail, thereby making the analysis transparent and reproducible. Second, we use monthly data aggregated into quarterly data instead of using annual data. This allows us to more accurately assign trade data to catch data and still avoid overestimations through time lags induced by shipment to distant destinations. Third, our model contains a detailed sensitivity analysis: We present estimates on illegal catch as a function of those variables in the model, around which some uncertainty exists; we then justify the use of a specific set of values for each variable both quantitatively and qualitatively, and define the in our view most realistic outcome for yearly excess catch.

4.5.3 Policy implications and recommendations

4.5.3.1 ICCAT quota

Currently, ICCAT uses size-structured population models to calculate the probability that, at a given catch, the stock recovers to MSY levels by the year 2022 (ICCAT 2012a). Quotas are set at the highest level of catch that would still allow a 60 percent (or higher) probability of recovery. Using reported landings to estimate the levels of catch neglects illegal catch which, when included in the stock assessment models, is likely to result in incorrect quota levels. Although managers are provided with model outputs that include potential illegal catch, the main calculations are based on the assumption of zero illegal fishing. Including excess fishing in the model considerably decreases the probability of recovery at current quotas. We therefore urge ICCAT to include the estimates of 57 percent illegal fishing beyond actual allowable quotas when making decisions about future quotas.

4.5.3.2 Management at sea and in farms

Management of the Eastern Atlantic and Mediterranean Bluefin tuna keeps failing its objectives. Although quotas have been decreased, catch has not fallen anywhere close to desired values. As pointed out by previous research, insufficient enforcement of existing measures might have several reasons, most importantly weakly implemented BCD schemes (ICIJ 2010), insufficient observer programs and low levels of cooperation among BFTE fishing countries (Sumaila and Huang 2012). To effectively tackle the problem of BFTE overfishing, these management tools must hence be strengthened and member states' cooperation and accountability must be increased. However, as an important tool for successful management, a better understanding on the main source of incompliance must be fostered. Our analysis highlights that, smoothing the fluctuations of estimated catch between 2008 and 2011, excess fishing tends to adapt to allowable quotas. This might suggest that excess fishing is closely linked to unreported landings by vessels with quotas, and to a lesser extent with entirely illegal vessels. If this was the case, an increase of observer programs on vessels would have a significant effect on the mitigation of illegal catches. Although we cannot conclude this assertion based on available data, this represents one important question around illegal fishing and should receive more attention in future research.

Another weakness in the chain of management seems to be that some farms accept live BFTE from vessels not entitled to quotas (or only to a lesser extent than they supply). As farm operators are ultimately trading the BFTE, a swift improvement of the electronic version of the BCD scheme implemented should continue to be a high priority for ICCAT to allow effective and real-time tracking of all BFTE catches and to hamper black markets.

Acknowledgements:
This paper has benefitted from thorough and constructive comments by Mary Lack and Luis Ambrosio Blásquez. We further thank California Environmental Associates for coordinating this analysis.

Chapter 5

Conclusions

In this thesis we have looked at different aspects of distant water fishing in relation to ecological and economic vulnerabilities of its main fishing areas. These include both exclusive economic zones of tropical developing states and the high seas. We adopted different perspectives and applied a variety of approaches to address this general issue. This involved identifying and interpreting characteristics and trends of distant water fishing in the wider context of global fisheries, evaluating opportunities for tropical developing states to increase economic benefits from fisheries resources, and examining management options that embrace the challenges associated with overexploitation of particular high seas fisheries, notably tuna. In this chapter we recapitulate the insights drawn from our studies and provide a final, overarching conclusion.

Chapter 2 dealt with the ecological, economic and political challenges arising from the interplay of distant water fleets with tropical developing countries that are generally institutionally and economically relatively weak. This entailed three steps. First, drawing on literature in the fields of fisheries biology, fisheries management and maritime law, the chapter highlighted the specific vulnerabilities of tropical developing countries in the context of globalizing fisheries operations and trade. We showed that ecological, institutional and diplomatic weaknesses undermine the handling of fisheries in a way that would guarantee healthy stocks and provide the states with adequate economic remuneration from their resources. Second, we provided a categorization of fishing agreements between distant water fleets and "host countries" and identified major distant water fishing nations (DWFNs), their fishing grounds and the development of their landings since 1960. Based on global landings data we showed that a limited number of industrialized nations is responsible for the main part of international distant water fishing. Moreover, traditional fishing countries, such as the EU, Japan and the former Soviet Union, are gradually being replaced by newcomers like China, South Korea and Taiwan. We argue that this shift in effort is potentially problematic for the sustainability of fishing grounds as the newcomers have a poorer record in accountability and responsible fishing than the traditional distant water fleets. Third, we identified those African, Caribbean and Pacific (ACP) countries in whose exclusive economic zones the landings from DWFNs exceed domestic catches. We find that these countries are relatively small coastal or island states with a low GDP per capita, in which the fisheries sector and access fees contribute up to 30 and 40 percent to GDP and government revenues, respectively. We argue that the economically weak status of host countries, paired with a built-up dependence on fees from fisheries agreements, has the potential to erode already meagre sustainability objectives of host governments and stimulates myopic decisions regarding marine resource management. In addition, the sustainability practices of some traditional DWFNs are undercut by the need to compete with less virtuous "newcomers". We postulate that a higher involvement in the value chains of key fish commodities would increase the host countries' ability to economically benefit from, and improve control over its fisheries resources, which in turn would provide a better guarantee for their long-run sustainability.

Chapter 3 addressed the question whether the Forum Fisheries Agency (FFA), a group of seventeen Pacific Island Countries, can increase economic rents from tuna fisheries occurring in their exclusive economic zones. To this end, we presented a bio-economic model that reflects the nature of this fishery in as much detail as necessary. Earlier, related models addressed the overall economic efficiency of the pacific tuna fishery, that is, jointly for all countries involved, without solving for sub-groups. Learning from their approaches and insights, we developed a new model to determine player- and gear-specific effort changes required to maximize aggregate FFA rents. Because of the international law of the sea, the respective island states control the most productive tuna fishery in the world. Similar to earlier models, we accounted for multiple fishing countries, fishing areas, fishing gears and fish species. Our model distinguishes itself from the earlier ones through the inclusion of capital costs, access fees from distant water nations, and potential benefits from fish processing activities. We find that overall rent from the Western and Central pacific tuna fishery would be maximized by drastically decreasing fishing effort for all gears except for long line, as this specializes in the catch of high-grade sashimi fish that offers the highest profit margins. When maximizing economic rent of FFA members we find that, given current access fees, policy changes must involve the phasing out of access agreements with distant water fishing nations, replacing them with domestic catches, notably of purse seine effort. The latter provides additional benefits to FFA countries in the form of processing activities. We argue that potential economic gains suggested by model outcomes have to be carefully pondered against political obstacles and the difficulty of developing economies of scale in small, geographically scattered island states that are remote from major international fish markets. The political dimension cannot be overstated as fishing agreements often represent one of many diplomatic ties that FFA countries maintain with distant water nations. Discontinuity of fishing access to distant nations could result in negative repercussions in other areas including the cessation of foreign aid programs and trade agreements that are, in some cases, explicitly tied to fishing agreements. A replacement of distant water fleets with domestic fleets would only be conceivable provided a high degree of regional political cooperation and infrastructural coordination (for example, in the design and development of fish processing and marketing activities) would be realized.

Chapter 4 was concerned with the second type of “impact area” of distant water fleets, namely stocks managed by regional fisheries management organizations (RFMOs). We challenged here the assumption of the International commission for the conservation of Atlantic Tuna (ICCAT), responsible for the management of the Eastern Atlantic and Mediterranean Bluefin tuna (EBFT), that no overfishing of this species is occurring since 2007. We constructed a model that allows deducting life catch weight from monthly trade data for all major countries involved in EBFT trade between 2005 and 2011. This includes conversion of traded product weight to life round weight, taking into account the fattening process in tuna farms, and the elimination of double-counting for re-export within the EU. The resulting estimates were then compared with allowable fishing quotas to infer annual illegal catch during the period considered. We found that EBFT has persistently been overfished, throughout the entire period. In a scenario with most likely values of uncertain parameters, allowable quotas were exceeded by 44 percent between 2005 and 2011 and by 57 percent between 2008 and 2011. A sensitivity analysis shows that potential errors in the parameters used for conversion calculations and for the elimination of double-counting in inner-EU trade, has only minor implications for the results. The range of parameter values used in the model yields estimated catches beyond allowable quota of 46 percent to 84 percent for the period of 2008-2011. These values are based on the assumption that conflicting trade volumes between importers and exporters for the same trade flow result from underreporting. To correct for this, we always adopt the larger value. Our findings are relevant for future management of this species. They suggest that the models employed by ICCAT to compute fishing quotas are based on catch estimates that are likely too low. Underestimating catch by ignoring illegal landings leads to fishing quotas that are too high to reach management goals. Our research indicates that, despite considerable improvements in ICCAT policies over past years, monitoring and control of tuna fisheries have to be considerably improved still. Notably, it is recommendable to swiftly implement the electronic version of the Bluefin Tuna Catch Documentation Scheme, an electronic logbook allowing traceability of all catch.

This thesis has highlighted a number of important aspects concerning the expansion of distant water fishing over past decades. The picture we draw depicts distant water fishing as an important factor, if not the driver, of the globalization of harvest operations and trade. We show that this process is ongoing and threatening ecosystem preservation and wealth distribution. This suggests the need for a clear perspective on political responses by both distant water fishing nations and host countries. On the one hand, distant water nations must adjust accountability standards of external fleets to the codes of conduct pursued in domestic waters. On the other hand, host countries must design strategies – as studied here – that embrace long-term opportunities of their resource-rich EEZs in order to capture maximum wealth from their fish stocks.

This study has contributed to the literature on distant water fishing, its impacts on fish stock health in the high seas and tropical EEZs, and the welfare of resource-rich developing countries. Studies of this type are scarce. More research in this field could help to develop transparent, accountable, equitable and reciprocal partnerships between distant water fishing nations and tropical developing countries. This would permit the latter to profit from international trade while simultaneously mitigating negative impacts on vulnerable resource users and delicate marine ecosystems within their national boundaries.

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