IDDRI

DÉVELOPPEMENT DURABLE &
RELATIONS INTERNATIONALES

Sustainable management of tuna fisheries: a synthesis report

Marie Lecomte, Julien Rochette, Renaud Lapeyre, Yann Laurans (IDDRI)

September 2017

Context of the report

This report has been prepared in the context of the project “Diagnosis of the tuna industry in the Indian Ocean”, co-funded by the Institute for Sustainable Development and International Relations (IDDRI) and the French government in the framework of the programme “Investissements d’avenir”, managed by ANR (the French National Research Agency) under the reference ANR-10-LABX-01. It is a synthesis of 3 comprehensive reports,[1] which have been elaborated through a review of the scientific and grey literature, as well as interviews with numerous experts and stakeholders at the global, regional and national level.

The authors would like to thank all those who kindly contributed to the preparation of this report by providing information and insights. Special thanks go to the Steering Committee members of this project who contributed significantly with their guidance: Selim Azzi (WWF France), Pascal Bach (IRD), Norbert Billet (IRD), Thomas Binet (Vertigo Lab), Jacques Bruhlet (Eurothon), Christian Chaboud (IRD), François Chartier (Greenpeace France), Pierre Commere (Association des entreprises de produits alimentaires élaborés), Sylvain Cuperlier (Thai Union Europe), Elisabeth Druel (Client Earth), Margaux Favet (MSC), Marc Ghiglia (Union des armateurs à la pêche), Michel Goujon (Orthongel), Patrice Guillotreau (Université de Nantes), François Henry (AFD), Edina Ifticene (WWF France), Joséphine Labat (WWF France), Edouard Le Bart (MSC), Francisco Leotte (MW Brands), Frederic Le Manach (Bloom Association), Yvon Riva (Union des armateurs à la pêche), Thomas Roche (Ministère chargé de l’écologie), Cécile Schneider (Conservation International), Pauline Soudier (WWF France), Yvan Yvergniaux (Smart Fish).

For more information: lecomtemarie12@gmail.com / julien.rochette@iddri.org

[1] Lecomte M., Rochette J., Lapeyre R., Laurans Y. (2017). Tuna: fish and fisheries, markets and sustainability; Lecomte M., Rochette J., Lapeyre R., Laurans Y. (2017). Indian Ocean tuna fisheries: between development opportunities and sustainability issues; Dueri S., (2017). Impacts of climate change and ocean acidification on Indian Ocean tunas.

List of acronyms

EEZ	Exclusive Economic Zone
EU	European Union
FAD	Fishing Aggregating Device
FAO	United Nations Food and Agriculture Organisation
FPA	Fisheries Partnership Agreement
GDP	Gross domestic product
GT	Gross tonnage
IOTC	Indian Ocean Tuna Commission
MSC	Marine Stewardship Council
MSY	Maximum Sustainable Yield
RCP	Representative Concentration Pathway
RFMO	Regional Fisheries Management Organisation
T	Tonne
US	United States of America

Table of contents

List of figures

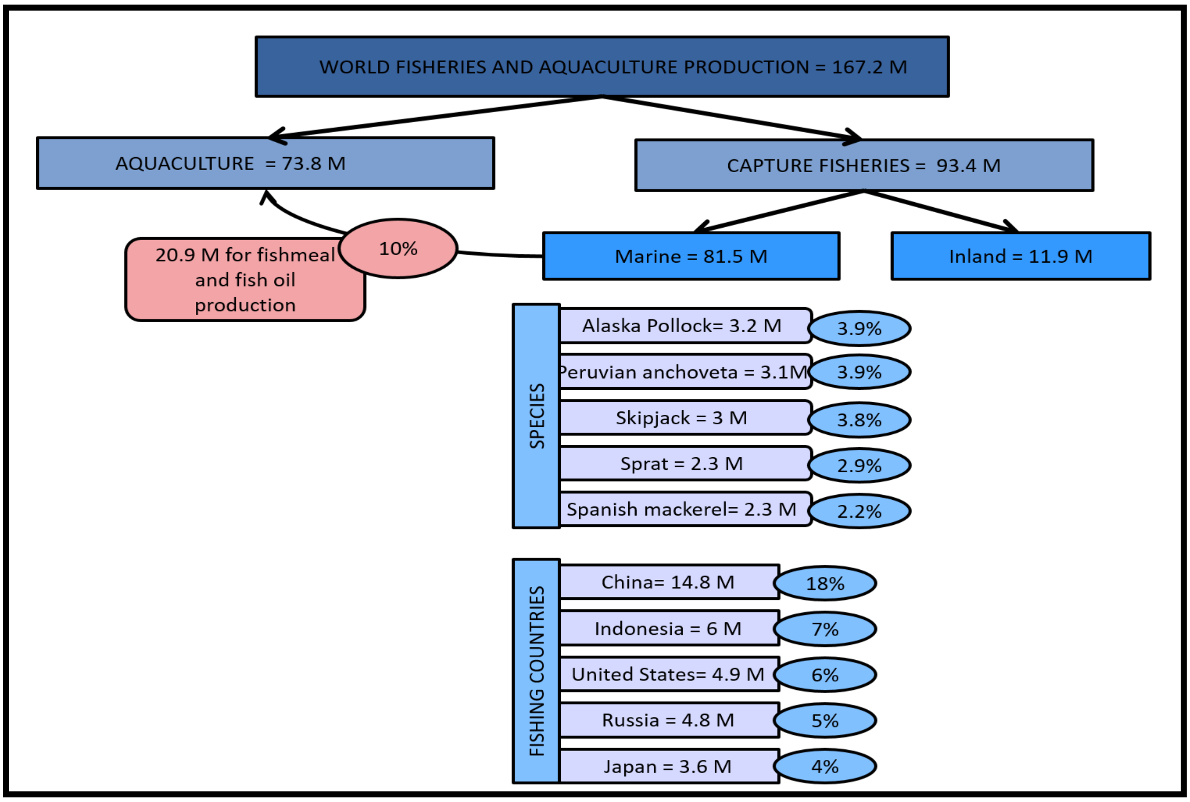
List of tables

1. Introduction

1.1 The global seafood industry

For fifty years, global fisheries production has been steadily increasing. While capture fisheries peaked in the 1990s and have since levelled off, aquaculture production has seen significant growth. In 2014, the contribution of the aquaculture sector to fish supply for human consumption exceeded supply from the wild-caught fish sector for the first time (Figure 1) (FAO 2016). This growth in aquaculture production has been driven by China, which accounts for 60% of world production (FAO 2016). In 2014, capture and aquaculture production stood at 167 million tonnes, 44% of which derived from aquaculture (FAO 2016). Capture fisheries, mainly marine catches, totalled some 93 million tonnes (FAO 2016).

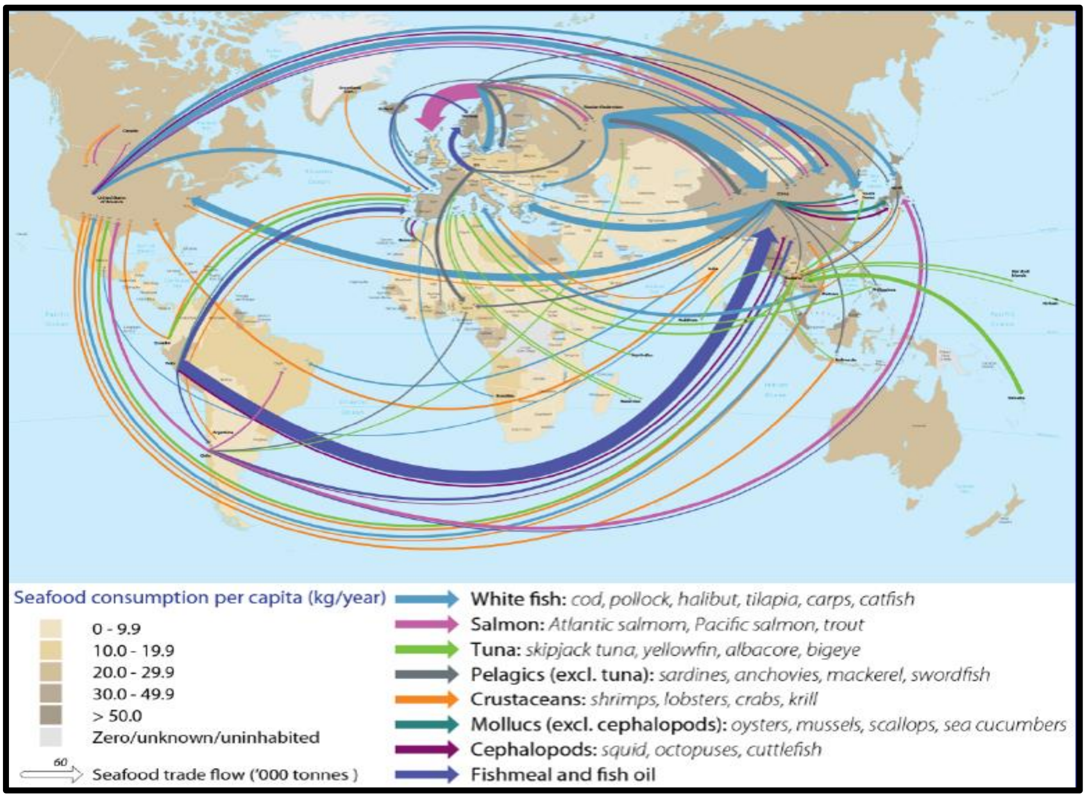
Figure 1: World fisheries and aquaculture production in 2014 (Source: M. Lecomte, based on FAO, 2016b).



At the global level, fish consumption has more than doubled in recent decades, rising from an average of 9.9 kg per capita per year (kg/cap/year) in the 1960s to 20.1 kg in 2014 (including 9.5 kg from capture fisheries)(FAO 2014; FAO 2014; GLOBEFISH 2016b; FAO 2016). This increase is partly linked to the sharp rise in per capita fish consumption in developing countries (from 5.2 kg in 1961 to 17.8 kg in 2010), although the highest levels of consumption are still found in developed countries (23 kg in 2013) (FAO 2014; FAO 2016).

Fish and fish products are among the most traded commodities in the world: in 2012, some 200 countries reported exporting fish and fishery products (FAO 2014). In 2014, fish and fishery products accounted for 9% of total agricultural exports and 1% of world merchandise trade in terms of value (FAO 2016), with exports worth US$148 billion (FAO 2016). The main fish and fishery products traded internationally are shrimp (15% of exports), salmon (14%), whitefish (e.g., hake and cod, 10%), tuna (9%) and fishmeal (3%). Together, these products represent 51% of global fish and fishery product exports (Potts *et al.*, 2016). Figure 2 depicts the main flows of this trade.

Figure 2: Main global seafood trade flows (Source: Nikolik, 2015)



1.2 The major place of the tuna sector in the seafood industry

The term “tuna” includes several species of ocean fish in the *Thunnini* tribe. Within this tribe, 14 species are divided into 4 genus: *Auxis*, *Katsuwonus*, *Euthynnus* and *Thunnus*. Among these fourteen species, seven are of major importance for trade (Table 1). Present in the three oceans (except for the Atlantic and Pacific Bluefin tunas), these species are highly migratory, gregarious and predatory (GOUJON 2013).

Table 1: Major species of commercial tunas

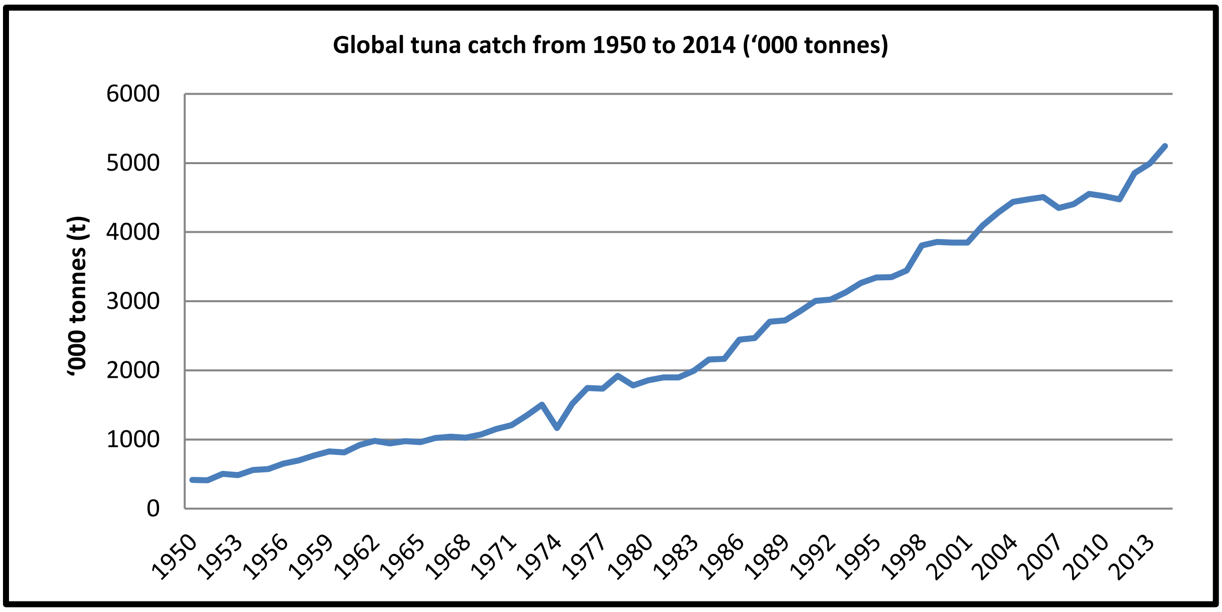
English name	Scientific name	FAO abbreviation
Skipjack tuna	*Katsuwonus pelamis*	SKJ
Yellowfin tuna	*Thunnus albacares*	YF
Bigeye tuna	*Thunnus obesus*	BE
Albacore tuna	*Thunnus alalunga*	ALB
Atlantic Bluefin	*Thunnus thynnus*	ABF
Pacific Bluefin	*Thunnus orientalis*	PBF
Southern Bluefin	*Thunnus maccoyii*	SBF

Global tuna catches have rapidly and steadily increased since the 1950s (Figure 3). From 1950 to 2015, the global catch rose from 500,000 to 5 million tonnes, representing a 1000 % increase. Tuna is indeed one of the most popular seafood products worldwide (GUILLOTREAU *et al.* 2016). World tuna consumption is estimated at 0.45 kg per capita per year, which represents 2.2 % of global fish consumption (GLITNIR 2007). This level of consumption is close to the global consumption of Nutella (0.51 kg per capita per year) (MITZMAN 2014), with canned tuna being the most frequently consumed form (CHEMERINSKI 2013). In 2014, the tuna industry was worth around US$33 billion, or 24% of the value of the global seafood industry, reflecting the high value of tuna compared to other seafood products (MACFADYEN 2016).

The main segment of the tuna industry is canned tuna, both in terms of volume and value. Canned tuna is the cheapest animal protein, representing an annual market of 1.7 million tonnes (8.5 billion tins). Tuna processing in canneries is a major industrial sector for some countries (Thailand, Spain, Ecuador) and represents a considerable source of employment. By contrast, the sashimi market is a high-end market, where tuna reaches one of the highest prices of any seafood. In 2016, a Japanese restaurateur bought a 200 kg tuna at a record price of €600,000.

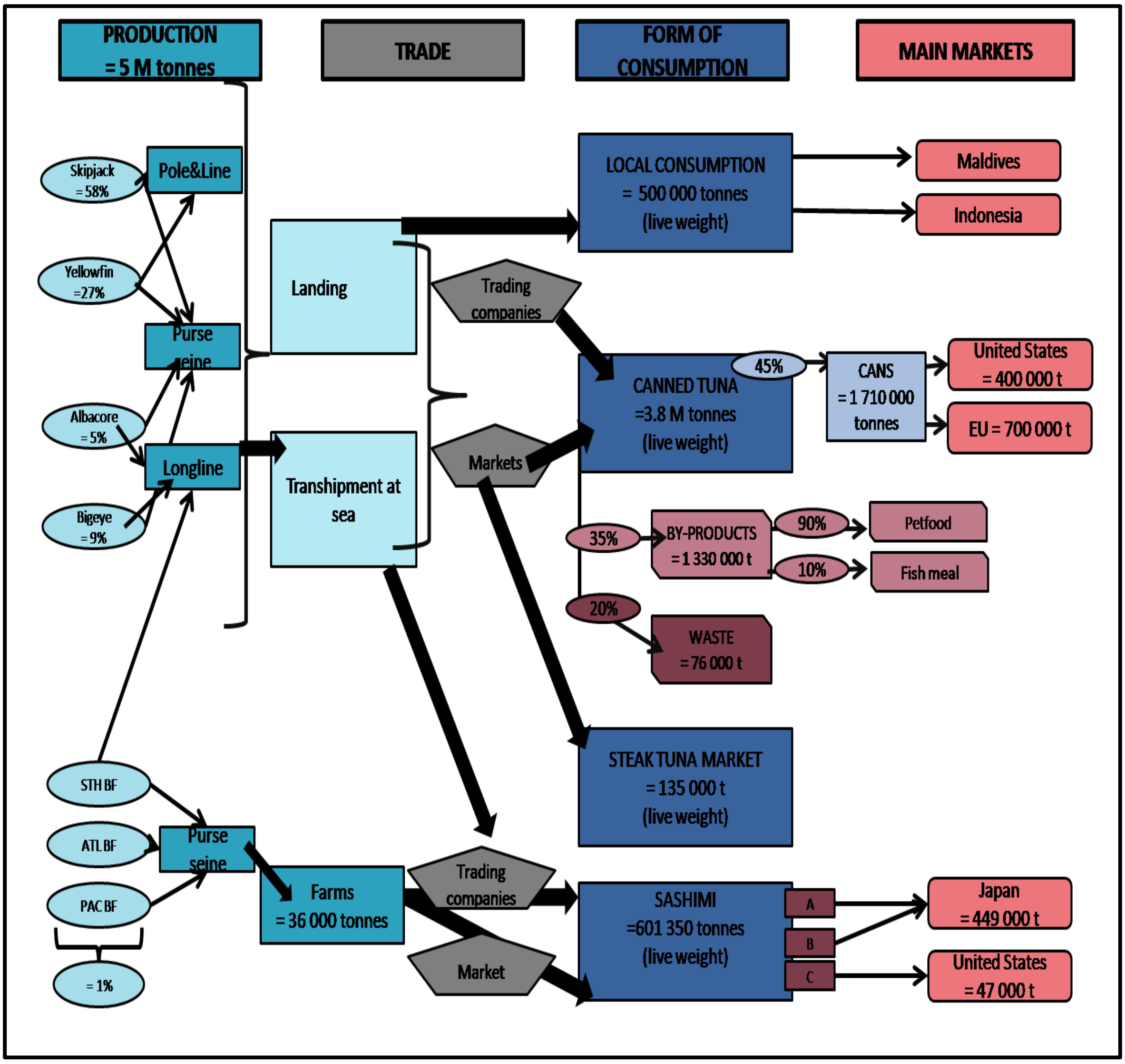
The tuna industry is particularly important for some island and coastal States. For some Pacific States, for example, tuna is a vital sector and represents a significant part of the Gross domestic product (GDP). For example, public revenues from the issuing of fishing licences represent 36% of Tuvalu’s GDP and 32 % of Kiribati’s GDP (VIRDIN 2016). Tuna fisheries are also a major source of export income: tuna accounts for 90% of exports from Kiribati, 84% of Maldivian exports and 60% of Seychellois exports (ITC Trade Map 2017). In some island countries, tuna is also the main source of protein and plays a major role in terms of food security. There are few fish species that are so vital to the economy of a country.

Figure 3: Global tuna catch from 1950 to 2014 (Source: FIGIS, 2016)



The tuna market is a global market. In 2013, almost half (46%) of tuna catches were traded on the international market through globalised value chains (FAO 2015). In the international fishery trade, tuna is the fourth most traded product and accounts for 9% of the overall value of seafood exports, after shrimp (15%), salmon (14%), and whitefish (10%) (POTTS *et al.* 2016). Figure 4 presents an overview of how this supply chain is organised.

Figure 4: The tuna supply chain (Source: M.Lecomte, based on Macfadyen *et al.*, 2016; Macfadyen, 2016; Hamilton *et al.*, 2011



1.3 Objectives of this report

This report is a synthesis of three reports that have been elaborated on the global tuna markets, the Indian Ocean tuna value chains and the impacts of climate change on tuna fisheries.[2] Section 2 first presents the main features of the worldwide tuna markets, while Section 3 focuses on the Indian Ocean tuna fisheries and related markets and value chains. Finally, Section 4 highlights sustainability and governance challenges.

[2] Lecomte M., Rochette J., Lapeyre R., Laurans Y. (2017). Tuna: fish and fisheries, markets and sustainability; Lecomte M., Rochette J., Lapeyre R., Laurans Y. (2017). Indian Ocean tuna fisheries: between development opportunities and sustainability issues; Dueri S.,(2017). Impacts of climate change and ocean acidification on Indian Ocean tunas.

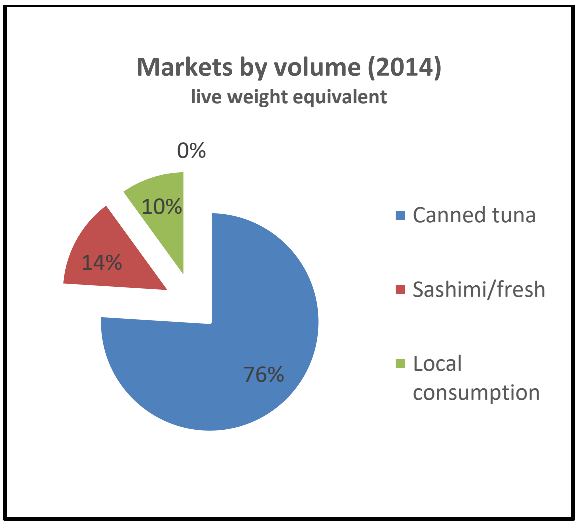
2. Worldwide tuna markets

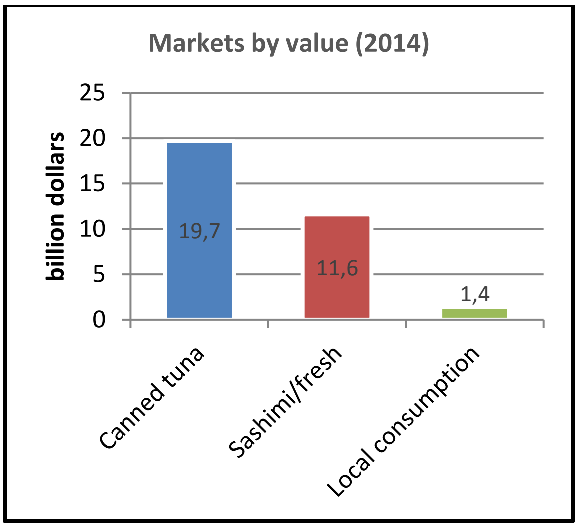
2.1 Main forms of consumption

Tuna is supplied for consumption in several different product forms (Figure 5)[3] (MACFADYEN & DEFAUX 2016):

- Canned tuna, by far the most widespread form, and tuna pouches;
- Sashimi/sushi tuna, specific to the Japanese market;
- Fresh tuna, primarily steaks, consumed in the European and American markets;
- Fresh tuna or dried/salted/smoked tuna consumed in local markets;
- Katsuobushi (a Japanese condiment made with flakes of dried bonito or skipjack tuna, which are fermented then smoked).

Figure 5: Market share of the different product forms by volume and value (Source: Macfadyen, 2016)





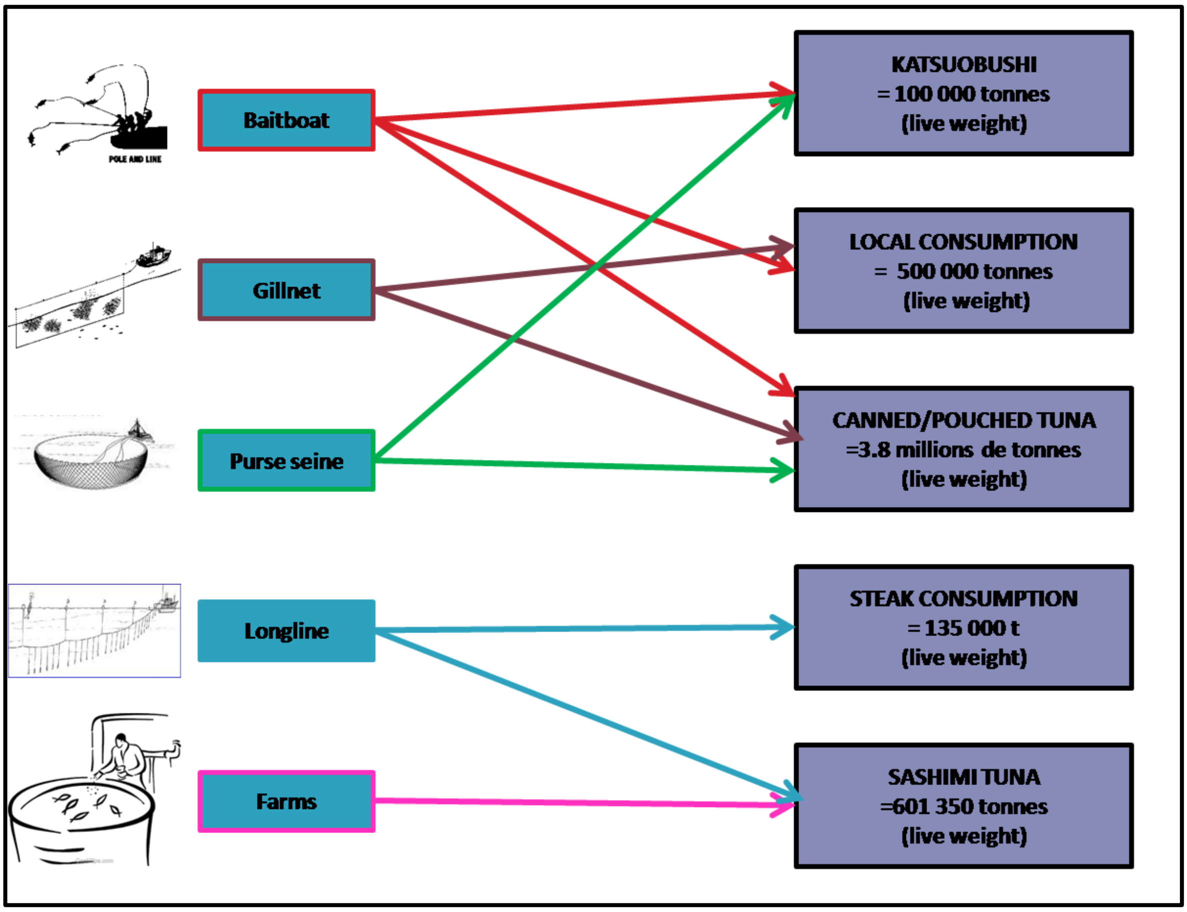
Both in terms of volume (76% live weight equivalent) and value (60%), canned tuna is the foremost form of consumption. Although sashimi-grade tuna represents only 14% of tuna catches, this market accounts for 36% of the global tuna market in terms of value. This clearly shows that sashimi tuna is a high-end market, where catches bring in elevated prices. In terms of markets, the main areas of consumption are concentrated in Japan (leader on the global tuna market, all forms of consumption combined), the United States (US) and the European Union (EU) (Kawamoto, 2016). Although local consumption accounts for a sizeable share of catches (10%), it represents only 4% of market value: the consumed value of catches is on the whole twice the ex-vessel value, as only a very low margin is made during processing (MACFADYEN *et al.* 2016).

[3] For simplicity, steak tuna has been included in the sashimi category, while katsuobushi, which is specific to the Japanese market, has been integrated into the canned category. The Japanese katsuobushi market was estimated at 36,000 tons in 2014 (Kawamoto, 2016). The market for tuna consumed as steak is estimated at 47,500 tons (ITC Trade Map, 2016, Bailly, 2016).

Each of these forms of consumption is typically associated with a specific fishing technique and/or tuna species (Figure 6):

- Almost all purse seine catches (mainly skipjack) are destined for canning;
- Line and longline catches are destined for the sashimi market (except for yellowfin, generally destined for canning);
- Gillnetter catches go to canneries and local markets as dried or smoked products;
- Pole and line catches have multiple destinations: canned tuna markets (mainly for eco-label canning), the katsuobushi market and the fresh tuna consumption market.

Figure 6: The main forms of tuna consumption (Source: M. Lecomte, based on MACFADYEN *et al.* 2016)

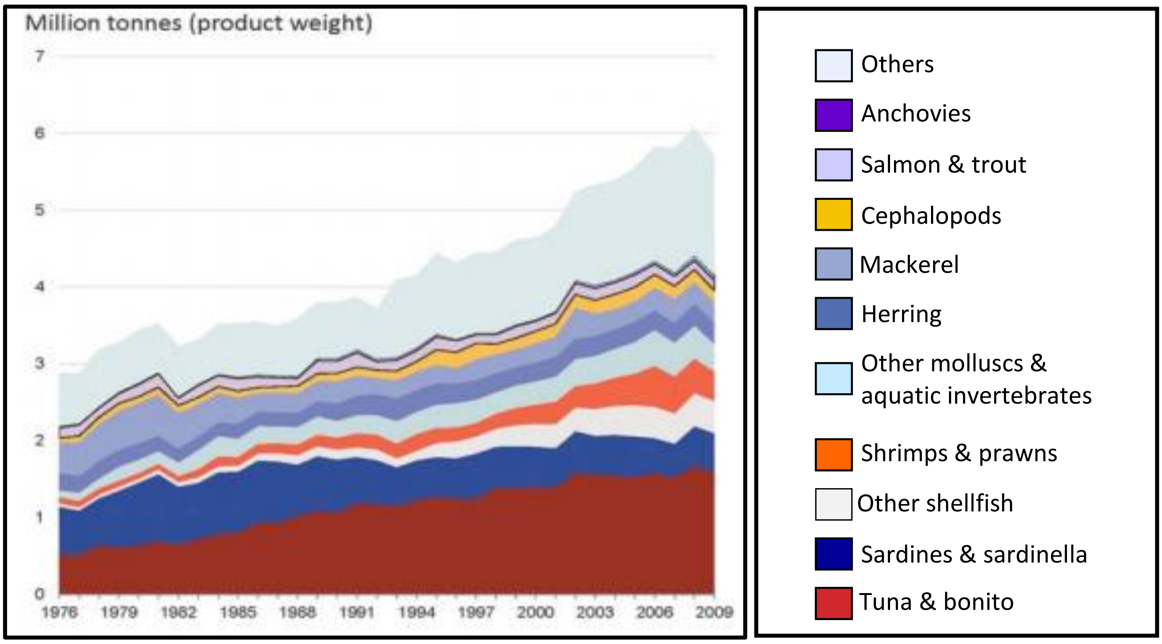


Two main value chains can be identified: the value chain for canned tuna, which supplies a global mass market, and that of sashimi-grade tuna, destined for a high-end market with catches bringing in higher prices. The sections below describe in greater detail the canned tuna and sashimi-grade tuna sectors.

2.2 Canned tuna

Tuna is a major commodity for the seafood canning industry being the world's leading canned seafood species in terms of volume (Figure 7):

Figure 7: Global production of canned fish and fishery products in 2009 (million tonnes, product weight) (Source: Vannuccini, 2012)

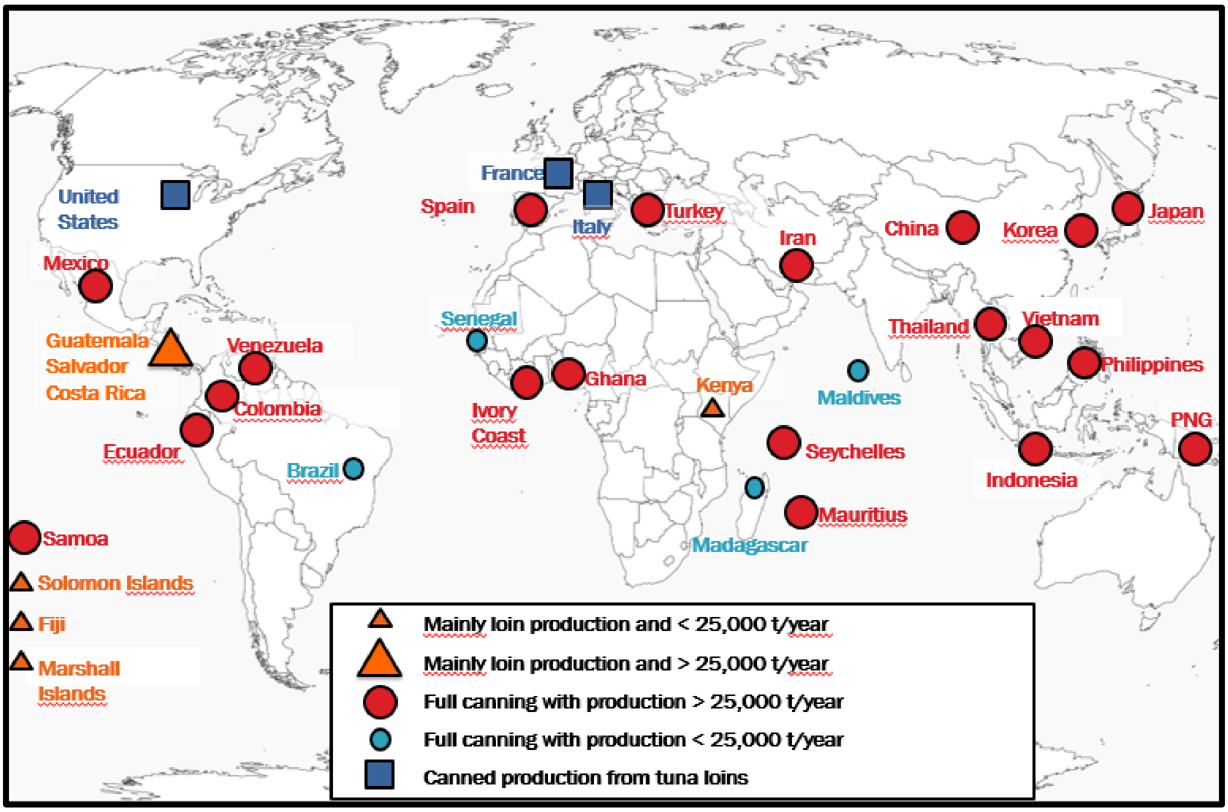


Likewise, in the tuna industry, canned tuna stands as the leading product in terms of value (60% of total value. Each year, nearly 7 % of tuna catches are destined for canning – in 2014, equivalent to 3.8 million tonnes.

The main species used for canning are the skipjack, yellowfin and, to a lesser extent, albacore tuna. The most-harvested species, the skipjack, is mainly destined for staple consumer products whereas the yellowfin and albacore are sold at higher prices. The largest markets for the albacore are the US, France and Spain (Oceanic Development *et al.* 2005). Most of these species are caught by purse-seiners (67% of world catches) and to a lesser extent by pole and line vessels (10% of total world catch). The purse-seiner fleet is part of a globalised international industry and most of the vessels belong to large industrial groups or investment groups. Once landed, purse-seiner catches for canneries are sold on international markets or to trading companies. When purse-seiners are owned by the large vertically integrated groups, they are required to supply the groups' own factories. On the other hand, purse-seiners belonging to fishing firms can sell their catches either directly on international markets or to trading companies. These vessels use two sales channels: either the fishing company has a commercial firm in charge of selling catches from the entire fleet or each ship's captain can sell his catches individually (CAMPLING 2012).

The tuna processing industry started up in Europe in the 1950s before gradually expanding into countries with available low-cost labour in the 1980s. Today, canned tuna is produced in nearly 40 countries (Figure 8). The three major producers are Thailand, Spain and Ecuador. The main landing ports and processing facilities are Bangkok (Thailand), Pago Pago (American Samoa) and Manta (Ecuador) (GUILLOTREAU *et al.* 2016). Most of these canneries belong to vertically integrated transnational firms that own the leading tuna brands sold on consumer markets. The canneries use two types of raw material: whole frozen tuna (known as “round tuna”) or loins. Many canneries use both forms of tuna for their production (MIYAKE *et al.* 2010).

Figure 8: Location of main tuna canneries (Source: Campling, 2015a; Campling, Havice and Ram-Bidesi, 2007; Hamilton *et al.*, 2011)



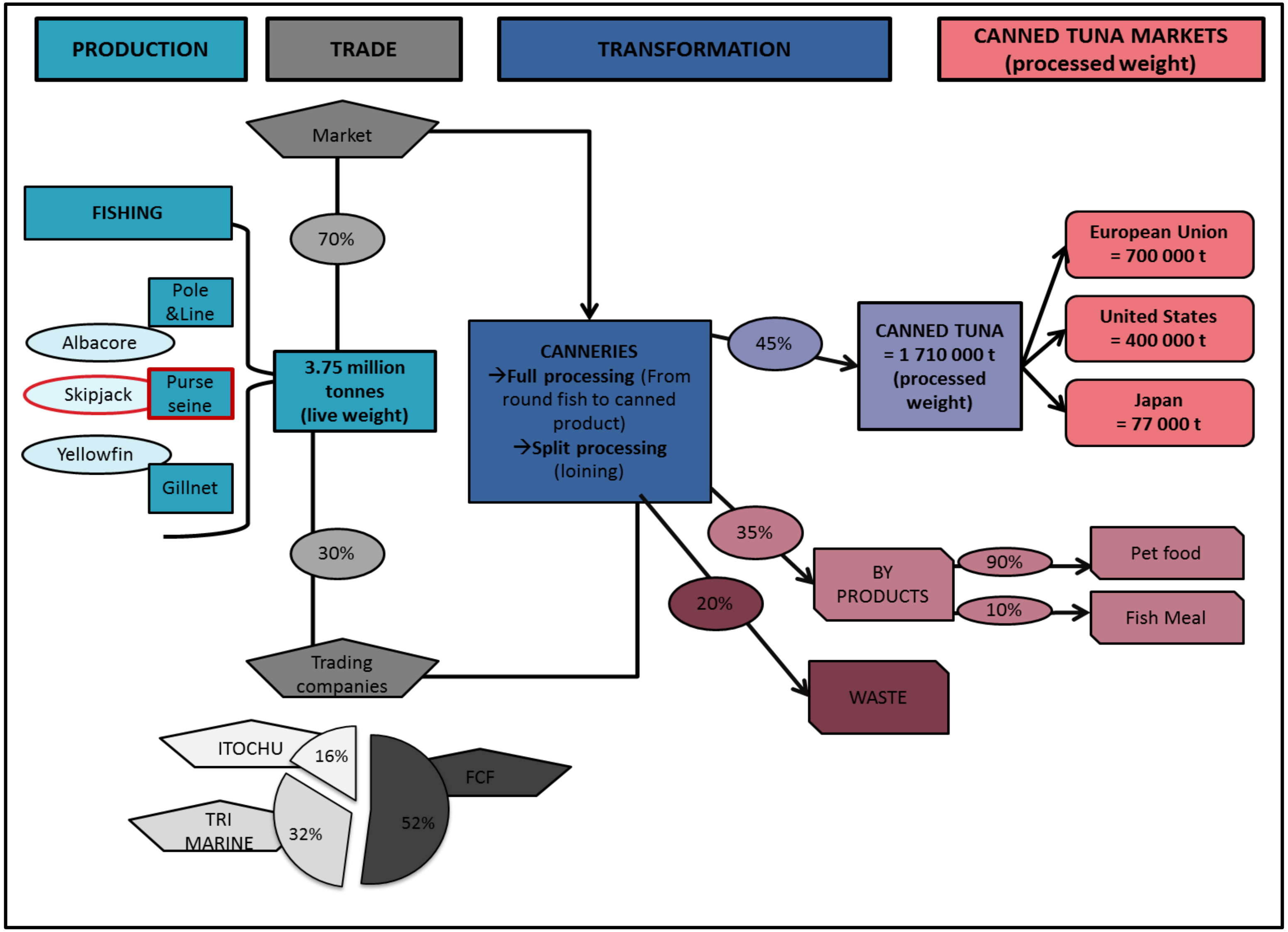
Canned tuna processing generates a sizeable quantity of by-products and waste. On average, the meat destined for canning represents 45% of the fish’s live weight[4] (MACFADYEN & DEFAUX 2016). The remaining 55 % constitute processing residues, composed of: (i) By-products that will be used by other industries and transformed in co-products (animal or fish meal, for instance); and (ii) Non-reusable waste (MACFADYEN & DEFAUX 2016). In 2014, by-products from the canning industry were valued at US$300 million (i.e. 0.9% of final value of the global tuna sector) (MACFADYEN & DEFAUX 2016).

Canned tuna is a low-cost product distributed worldwide (HAMILTON *et al.* 2011). In 2014, the global market of canned tuna was estimated at 1.7 million tonnes (processed weight) valued at US$19 billion (MACFADYEN 2016). The principal markets for canned tuna are the EU and the US. These traditional markets are currently maturing, with consumption levels stabilising in the EU and declining in the US. Growth in the sector is thus tied to demand from the Middle East, Latin America and other emerging markets such as Eastern Europe and Asia (CAMPLING 2015; GLOBEFISH 2016a).

Figure 9 depicts the sector’s overall organization.

[4] This conversion factor nonetheless varies depending on the size and species of the tuna processed.

Figure 9: The canning industry (Source: M. Lecomte based on Macfadyen *et al.*, 2016; Hamilton *et al.*, 2011)



2.3 Sashimi-grade tuna

Sushi and sashimi are internationally recognised terms, but are often misused. Sashimi denotes sliced raw fish meat traditionally served with soy sauce, wasabi and condiments. Sushi is made of vinegar-treated rice, garnished with different ingredients: fish, eggs or vegetables. Tuna sashimi is one of the main materials used for sushi. In the past, the sashimi market was limited to Japan but, in the 1990s, this form of consumption gradually expanded into Europe and North America. Japan nonetheless remains the largest (both by volume and value) and most influential market (Miyake, Guillotreau and Sun, 2010). International trade statistics tend to conflate tuna destined for sashimi and other forms of tuna for direct human consumption (i.e., loins or fillets), such that it is difficult to separate out the two markets (Miyake, Guillotreau and Sun, 2010). In this section, we consider only the sashimi market, attempting to exclude, as far as possible, other forms of tuna for direct human consumption.

The main species used for sashimi are the three bluefin species (Atlantic bluefin, Pacific bluefin and Southern bluefin), followed by bigeye and, to a lesser extent, yellowfin and albacore. Most of the tuna destined for the sashimi market is caught by the longline fleet, while fattening farms supply most of their bluefin tuna to the Japanese market.

The global sashimi market is estimated at 601,350 tonnes annually (in live weight) (KAWAMOTO 2016; HAMILTON *et al.* 2011). Japan, the world's largest market, accounts for more than 80% of consumption. As such, the market has been described by some authors as a "monopsony" (YAMASHITA 2006). The US, in second position with 47,000 tonnes, is a growing market. Secondary markets are gradually developing in East Asia given the increasing popularity of Japanese gastronomy in these countries (KAWAMOTO 2016). The sashimi markets are also globally integrated and linked to the Japanese market (PAN *et al.* 2010; GUILLOTREAU *et al.* 2016). The principal marketplace for sashimi-quality tuna is the Tsukiji wholesale fish market in Tokyo, where the tuna for the sashimi market are sold by auction.

Currently, the Japanese tuna market is stagnant due to changes in consumer purchasing preferences and declining household incomes (CAMPLING & HAVICE 2013). Over the past ten years, the amount of tuna consumed (all forms of consumption combined) has fallen by 25% (KAWAMOTO 2016). The sashimi market has not escaped this trend, with consumption dropping by 30% from 1995 to 2014 (Figure 10). This decline in the sashimi market can be explained by several factors:

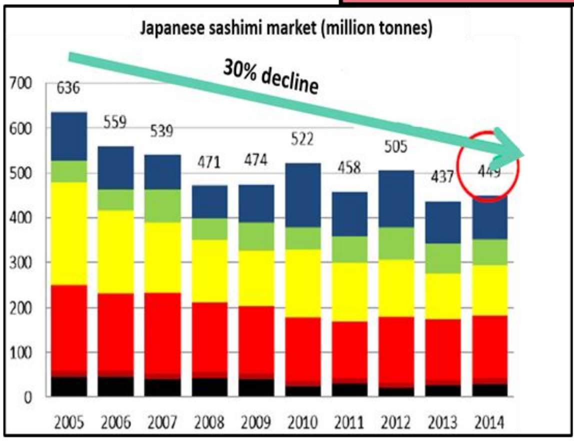
- An overall decrease in fish consumption in favour of meat, especially for young consumers (MAFF 2013);
- The westernisation of consumer preferences (TERAZONO 2016);
- The declining popularity of tuna for sashimi consumption (HAMILTON *et al.* 2011);
- A decrease in consumer income levels since the economic recession (HAMILTON *et al.* 2011);
- Saturation of the sushi-bar market (BENETTI *et al.* 2015).

Figure 11 presents the organization and trends of the sector.

Figure 10: The Japanese sashimi market (Source: M. Lecomte, based on Hamilton *et al.*, 2011; Kawamoto, 2016; Benetti, Partridge and Buentello, 2015)

JAPAN = 449 000 tonnes

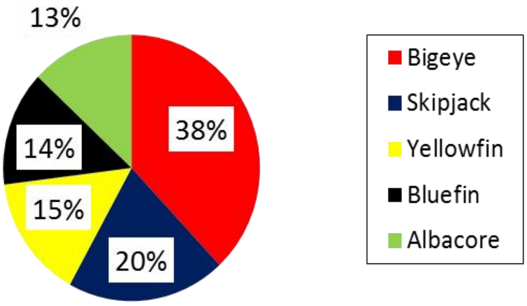
Declining consumption

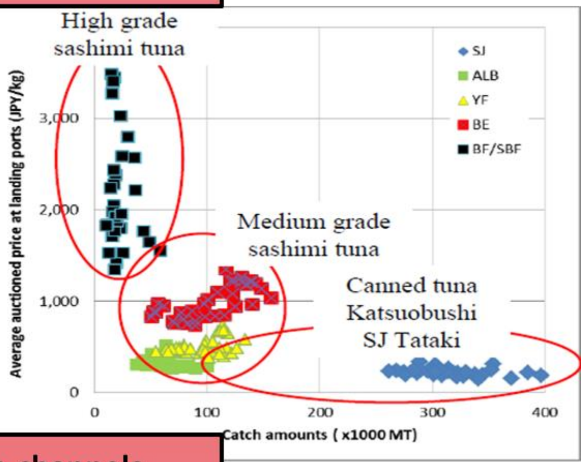


- Decline **in fish consumption**
- **Westernisation** of consumer preferences
- Drop in **popularity** of sashimi tuna
- Decrease **in household income**
- **Saturation** of sushi bar market

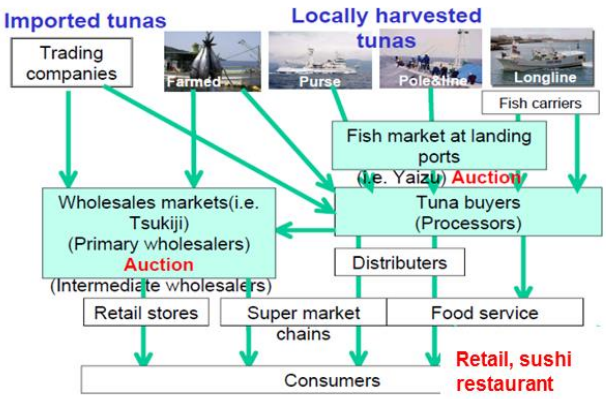
Market segmentation

Volumes per species





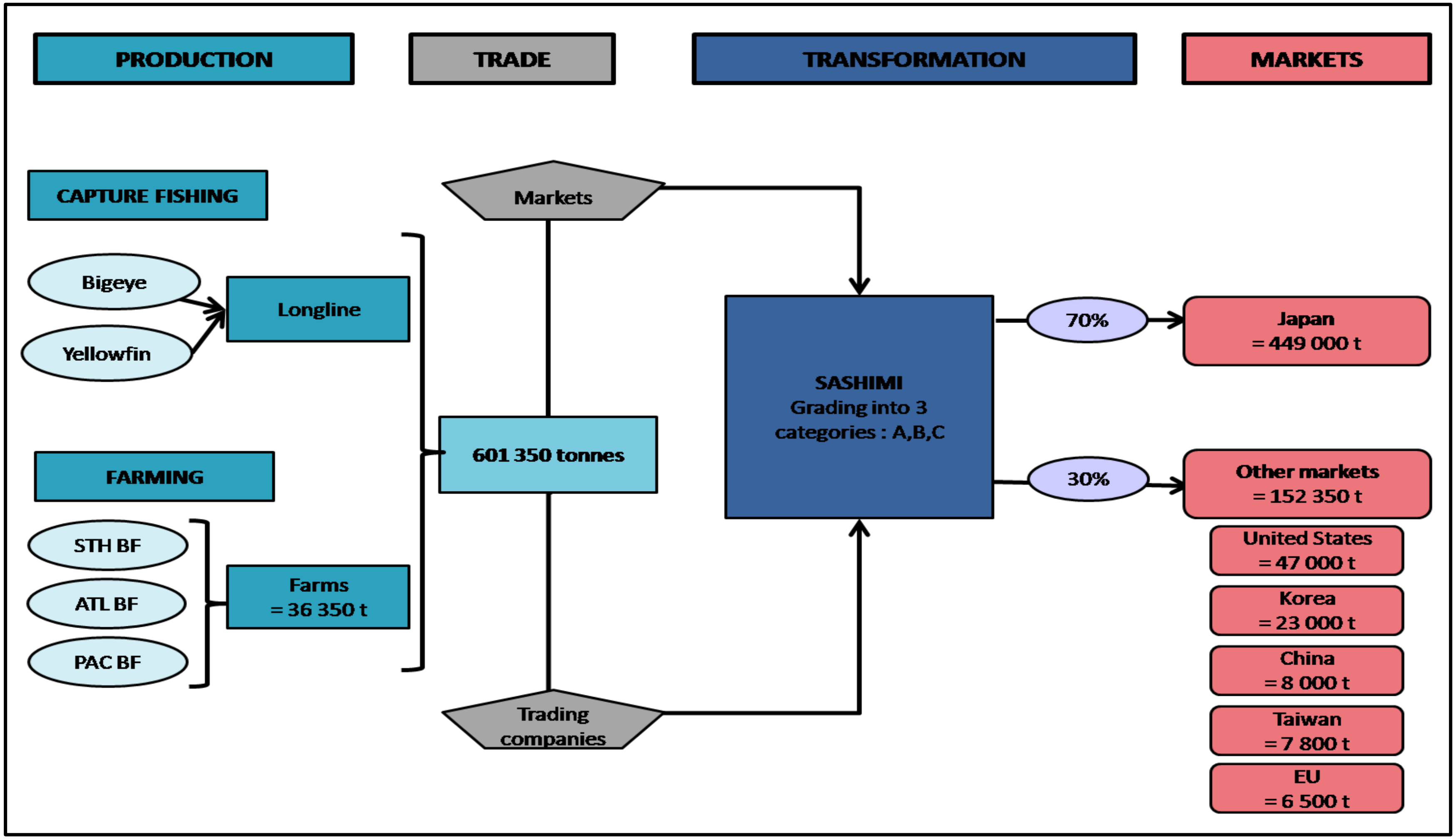
Distribution channels



Complex distribution channel dependent on :

- Origin (imported/domestic)
- Species
- Quality

Figure 11: The sashimi sector (Source: M. Lecomte, based on Hamilton *et al.*, 2011; Macfadyen *et al.*, 2016; Tveteras and Nystoyl, 2015)



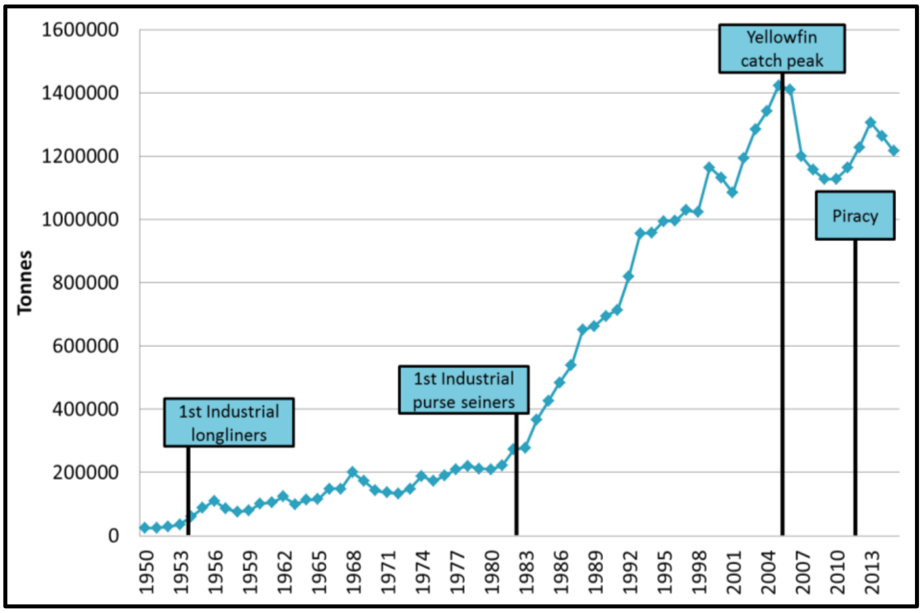
3. Indian Ocean tuna markets

3.1 The Indian Ocean, the world's second largest tuna production basin

3.1.1 General features

In the Indian Ocean, tuna is currently one of the most important fisheries: the main tuna species represent 10.4 % of total catches (FIGIS 2016). Tuna fisheries are also the largest fisheries in some coastal countries – in Sri Lanka, Maldives and Indonesia, for example. At the global level, the Indian Ocean is the second largest tuna production area, accounting for nearly 20% of world commercial tuna catches (skipjack, yellowfin, albacore, bigeye). The tuna industry in the Indian Ocean has an estimated turnover of US$6.5 billion,[5] i.e. 16% of the value of the world tuna industry (MACFADYEN 2016).

Figure 12: Development of tuna catches in the Indian Ocean between 1950 and 2015 (Source: IOTC-2016-DATASETS-NCDB 2016)



Several species of tuna are targeted in the region (CTOI 2015):

- Tropical tuna (bigeye, skipjack, yellowfin) and albacore (temperate tuna) are caught both by industrial and artisanal fisheries on the high seas and in the exclusive economic zones (EEZs) of coastal countries. These species mainly supply the export industries and some local markets in the case of skipjack tuna;
- Neritic tuna (longtail, bullet, frigate, kawakawa) are species that live closer to the continental shelf and around the islands and archipelagos, which do not undertake transoceanic migrations (FAO 1995). These species are exclusively caught by the artisanal fleets of coastal countries in the EEZs (India, Indonesia, Iran, Pakistan, Sri Lanka, and Thailand). The importance of neritic tunas, the third most caught species after skipjack and yellowfin, is specific to the Indian Ocean.

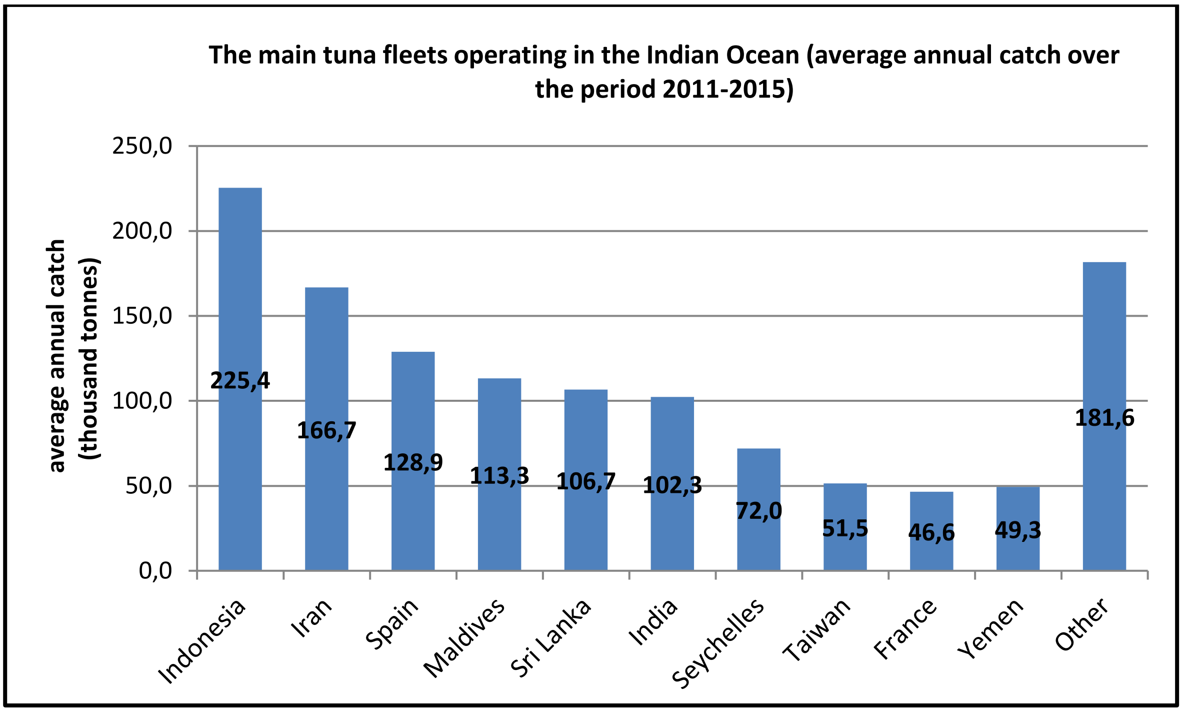
[5] Taking into account the total wholesale price of canned tuna, and not just the value of the drained weight of canned tuna (MACFADYEN *et al.* 2016).

3.1.2 Fishing fleets

Two types of fleets operate in the Indian Ocean: coastal fleets and industrial fleets.

Coastal fleets – i.e. fleets from the Indian Ocean neighbouring countries – are responsible for a significant volume of catches and constitute the main fleets operating in the Indian Ocean (Figure 13), using a wide variety of fishing gear, including gillnets, lines and small purse seines. They are mainly artisanal:[6] 81 % of their catches come from artisanal fishing units, defined by the Indian Ocean Tuna Commission (IOTC) as vessels of less than 24 metres operating only in coastal State EEZs (MORENO and HERRERA 2013). If we only consider tropical tuna catches,[7] then artisanal fisheries account for around half (52%) of the catches over the period 2011-2015 (IOTC-2016-DATASETS-NCDB 2016). There are therefore of considerable socio-economic importance, especially for coastal populations. Artisanal fisheries are thus a major employment source, with an employment/landed tonnes ratio that is much greater than that of industrial fisheries (Table 2).

Figure 13: Main tuna fleets operating in the Indian Ocean over the period 2011-2015 (Source: IOTC-2016-DATASETS-NCDB 2016)



[6] There are also some industrial coastal fleets: Seychellois and Mauritian purse seiners (European-owned), some Iranian gillnetters and many Indonesian longliners, all of which fall under the category of industrial vessels.
[7] Yellowfin, skipjack, bigeye tuna.

Table 2: The crew/landed tonnes ratio of selected fleets operating in the Indian Ocean (Source: LECOMTE.M)

Type of vessel	Ratio of crew / landed tonne per year per vessel	Ex-vessel value (US$)/crew
French industrial purse seiner	0.006 crew/tonne	272,500/crew
Japanese industrial longliner	0.09 crew/tonne	75,349/crew
Maldivian Baitboat	0.18crew/tonne	27,271/crew
Sri Lankan longliner	0.53 crew/tonne	11,003/crew
Iranian gillnetter	0.96 crew/tonne	2,592/crew

Industrial fleets are vessels over 24 metres in length and/or are vessels that operate on the high seas. Unlike artisanal fleets, industrial fleets use a single type of gear and cannot easily change fishing gear. The main fishing gears used by industrial fleets in the Indian Ocean are purse seine (60% of catches) and longline (31% of catches). The main fleets of industrial purse seiners are from Spain, the Seychelles (fleet funded by Spanish capital), France, Korea and Mauritius (funded by French capital). They include vessels between 80 and 100 metres with a capacity ranging from 1,000 to 2,500 gross tonnage (GT). These industrial tuna purse seiners target skipjack and yellowfin tuna and operate mainly using drifting Fishing aggregating devices (FADs): in 2015, 72% of their catches in the Indian Ocean involved the use of FADs (SFA 2016). The longliner fleet operating in the Indian Ocean can be divided into several groups depending on the species targeted and how the catch is preserved (POSEIDON *et al.* 2014; MORENO & HERRERA 2013; COI 2016):

- Asian freezer longliners targeting bigeye tuna (Taiwan, Seychelles (Taiwanese funded), Japan) and yellowfin tuna (Japan);
- Longliners from Indonesia and Sri Lanka that target mainly yellowfin tuna, which preserve their catches with ice;
- Longliners from Reunion Island, Seychelles and Mauritius that target swordfish and tuna, which preserve their catches with ice.

Distant water industrial fishing fleets operate on the high seas and in the EEZs of coastal States. Not all coastal States in the Indian Ocean allow access to their EEZs; for example, the Maldives, Indonesia and Sri Lanka have banned foreign fleets from their EEZs. In countries that permit the exploitation of fishery resources by foreign fleets, access to a country's fishing areas to catch tuna and related species may be granted through several mechanisms that are exclusive and non-cumulative (Commission Européenne 2016; CHABOUD 2013; POSEIDON *et al.* 2014):

- Public agreements between two countries in the region, or between a coastal country and a distant fishing nation;
- Fisheries Partnership Agreements (FPAs) negotiated and agreed between the EU and coastal States;

- Private trade agreements, reached by mutual agreement between countries and fishing companies, with or without the formation of a joint venture. These agreements are essential for access to EEZs in countries that have not established public agreements;
- Foreign fleets may change the flag under which they sail to use that of a coastal State[8] or there can be "joint ventures" between companies in coastal States and foreign investors.

3.1.3 Two fishing areas for two distinct development strategies

The Indian Ocean is divided into two fishing zones: the Western zone, which corresponds to FAO Area 51 and the Eastern zone, which corresponds to FAO Area 57.

Most of the catch is obtained from the Western zone. The Iranian fleets (20% of catches) and the European one (22% of catches) dominate the area (IOTC-2016-DATASETS-NCDB 2016). Catches are almost equally distributed between industrial and artisanal fleets (IOTC-2016-DATASETS-NCDB 2016). In this area, States typically seek to exploit their tuna resources by allowing foreign fleets to access their EEZs. Fisheries in these countries target mainly demersal (Seychelles, Madagascar, Mauritius, Mozambique) or freshwater species (Kenya, Tanzania). The tuna fisheries of these States are not at present particularly developed and are mainly of the artisanal or semi-industrial type (except for the Seychellois industrial longline and purse seine fleet).

The Eastern zone is dominated by artisanal coastal fleets. Indonesia and Sri Lanka are the two dominant fishing countries, accounting for 81% of catches in this area (IOTC-2016-DATASETS-NCDB 2016). In this area, States typically seek to develop their tuna fisheries by only allowing their own nationals to exploit their fishery resources (Indonesia, Maldives, Sri Lanka). The tuna fisheries of these countries are among the most important in the Indian Ocean and are almost exclusively artisanal.

3.2 Indian Ocean tuna industries

As illustrated by Figure 14, the main value chains of the Indian Ocean tuna sector include: (i) Canneries in the Western Indian Ocean; (ii) Local markets for tuna; (iii) Gillnetters supplying Iranian canneries; (iv) Processing industries for fresh yellowfin tuna; (v) Frozen tuna market for sashimi supplied by freezer longliners; and (vi) MSC-certified Maldivian pole and line tuna. They account for nearly 77% of the total catch and their trade turnover amounts to an estimated value of US$2.9 billion. Figures describing each of these value chains are available in Annex 1.

[8] This is the case for the Seychellois purse seiner fleet funded by Spanish capital, along with the Seychellois longline fleet funded by Taiwanese capital and the Mauritian purse seine fleet with French capital, however the Mauritius EEZ is not rich in tuna.

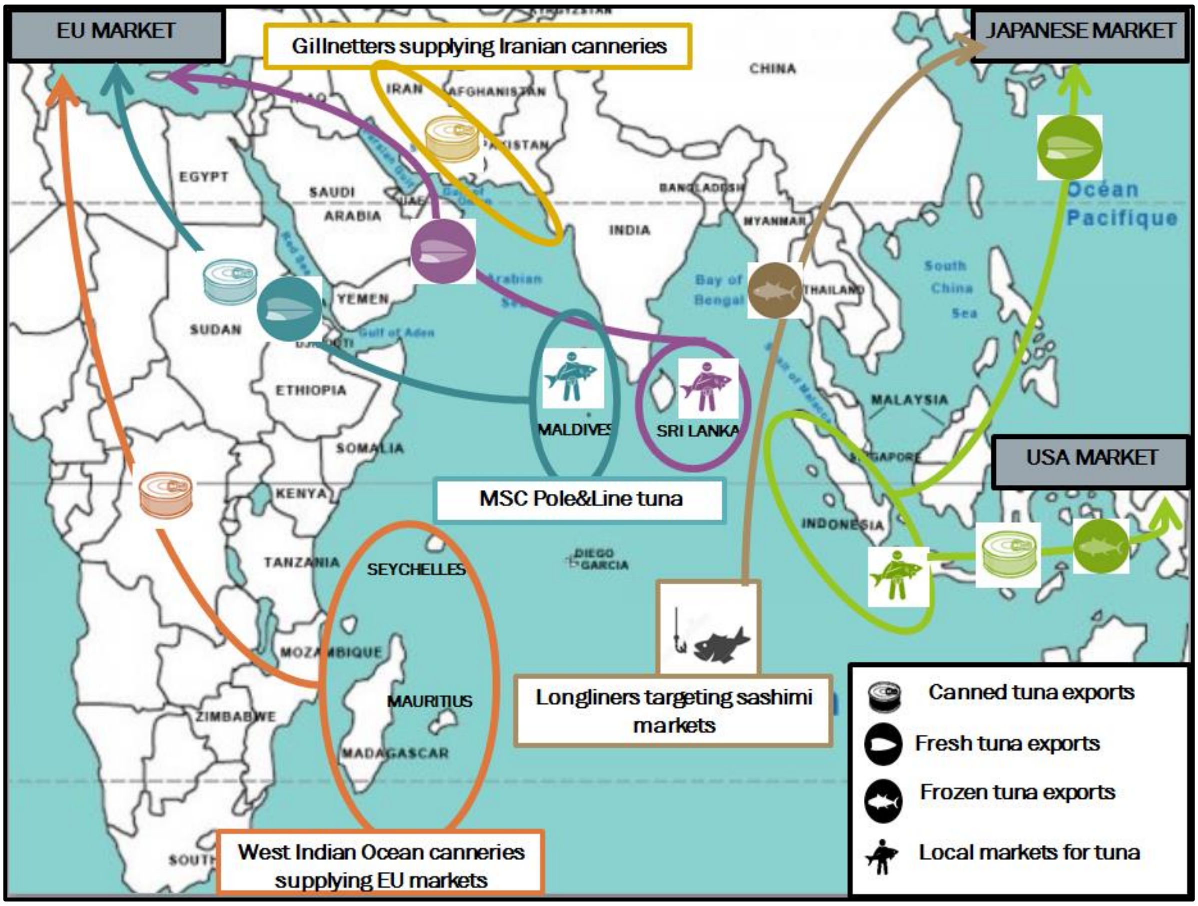


Figure 14: Indian Ocean tuna value chains (Source: LECOMTE.M)

3.2.1 Western Indian Ocean Canneries: complementarity of fishing agreements/trade agreements

Some WIO countries such as Mauritius, Madagascar and the Seychelles have large canneries that process tuna landed by industrial purse seiners operating in the region (around 300,000 tonnes per year). This processing activity represents the main contribution of the tuna sector to the economies of these three countries (YVERGNIAUX *et al.* 2016).

To access these EEZs, industrial purse seine fleets establish fishing agreements with coastal States governments. The European fleet operates under fishing agreements negotiated and concluded by the European Commission. These agreements, known as FPAs, enable European vessels to fish tuna resources in the EEZ of third countries involved, in exchange for payment for fishing rights (European Commission 2016). These fishing rights represent a significant income for the countries in the area, and make up a significant proportion of the budgets of some fishery ministries in the region.

These canneries account for 6% of the global tuna canning capacity (HSU 2012). Mauritius and Seychelles are respectively the 6th and 8th largest canned tuna exporters globally, and the combined exports of these canneries represent 7% of the world's canning market (ITC Trade Map 2017). The cumulative value of canned exports from these three countries is US$650 million.

3.2.2 Local markets: tuna as a food security issue

The Indian Ocean is also characterized by the importance of tuna consumption within coastal States. The main markets are Indonesia, Comoros, Maldives and Sri Lanka. The tuna consumed in these markets is landed by artisanal fishing units using nets (Sri Lanka), artisanal purse seine (Indonesia), pole and line (Maldives) or various types of lines (Comoros). In Indonesia, the fleet of artisanal purse seiners uses anchored FADs, mainly to supply the local market, while in Sri Lanka all catches of the tuna gillnet fleets are either processed into dried tuna or consumed fresh. In the Maldives, almost half of the catch of the pole and line vessels (or bait-boats) are consumed by the atoll populations, while the catches of the Comorian artisanal fleet are only consumed locally.

The volumes destined for these markets are substantial: it is estimated that about 282,250 tonnes of tuna (in live weight) are consumed annually within these countries, i.e. 56% of all locally consumed tuna. These local markets are valuable, estimated at almost US$814 million, with Indonesia representing the largest market. The value of tuna in these local markets is thus almost three times higher than that of tuna exports from processing units in these countries.

3.2.3 Middle East gillnetters focussing on the Iranian market

Iran and Pakistan have two large fleets in the Indian Ocean. These two fleets together accounts for 16% of the catches of the main commercial types of tunas in the region (IOTC-2016-DATASETS-NCDB 2016). However, these two countries are characterized by the small contribution of fisheries to the national economy. The contribution of the fisheries sector to GDP is minimal: around 0.23% for the Iranian fisheries and 1% for the Pakistani fisheries (FAO 2015, World Bank 2013). Exports of seafood products are very low and mainly consist of lightly processed products (PAKFEA 2011). Iran and Pakistan are also among the countries with the lowest levels of seafood consumption worldwide: 9.8 kg per capita per year for Iran and 1.9 kg for Pakistan (FAO STAT 2013, WWF Pakistan 2017, Innovasjon Norge 2016).

The catches of these two fleets almost exclusively supply the Iranian canneries. Tuna is not consumed much in these two markets and only bycatch (except marine mammals and turtles) is sold on the local market. About thirty Iranian canneries annually process around 200,000 tonnes (live weight), to which must be added nearly 30,000 tonnes of imported tuna. The Iranian market for canned tuna, estimated at almost 92,000 tonnes, constitutes an important market (equivalent to that of the French market). Canned tuna is popular on the Iranian market and is mainly sold in local bazaars at prices between US$1-1.50 a can (IFO 2017; Innovasjon Norge 2016).

3.2.4 Industrial longliners supplying the sashimi market: a sector that depends on trans-shipping

Longliners are more than 24m long and have deep-freezing capacities for ultra-low temperatures, i.e. -55°C to -60°C (MORENO and HERRERA 2013). The main freezer longliner fleets in the Indian Ocean are from Taiwan, Japan, Seychelles (funded by Taiwanese capital) and China. Fishing expeditions last from 18 months to 2 years and this fleet is characterized by the predominance of trans-shipping:[9] nearly 30% to 40% of catches are trans-shipped on the high seas. The remainder of the catch is landed in the ports of the region and exported to Japan in containers (MORENO and HERRERA 2013).

The contribution of these longline fleets to the economies of the coastal States is less than that of the purse seine fleet, due to the importance of trans-shipping, which deprives Indian Ocean countries of the incomes related to fleet expenditure in the port infrastructure. Coastal States, however, receive payments for fishing rights. The majority of Asian longliners operate under private agreements to gain

[9] Trans-shipping means the transfer of catches at sea from a fishing vessel to another ship.

access to the EEZs of Indian Ocean countries. Unlike the European agreements that are public, it is difficult to access information regarding these private agreements and the cost of licences obtained under them.

3.2.5 Fresh tuna processing units targeting sashimi and steak tuna markets

Some coastal Indian Ocean countries with a large national fleet have become specialized in processing and exporting fresh yellowfin tuna (and to a lesser extent bigeye). This processing industry is relatively new, becoming established in the 1990s in the Maldives and Sri Lanka (Sri Lankan Enterprise 2016, ADAM, JAUHAREE, and MILLER 2015). The main tuna processors in the Indian Ocean are Indonesia, Sri Lanka and the Maldives.

These processing industries are supplied by artisanal fishing units (with the exception of some Indonesian longliners which are considered as industrial by the IOTC). These fleets mainly use line or longline. Line fishing vessels do not have freezer units, so fishing trips are limited to 10-14 days so that catches retain their quality. Similarly, Sri Lankan longliners keep their catches fresh on ice. In Indonesia, however, a proportion of the longliner fleet freezes their catches on board. With the exception of the Indonesian longline sector, where some processing units are vertically integrated and have their own vessels, the majority of vessels are owned by the fishers themselves (Maldives) or by private individuals (Sri Lanka, Indonesia). These processing industries are closely linked to the presence of a tourist industry of sufficient size to allow regular flight connections to the main export markets. In the European and US markets, tuna is sold via import companies that are responsible for the redistribution of tuna to end customers.

The volumes exported by the processing units are close to 40,000 tonnes. Indonesia is the main exporter, followed by the Maldives and Sri Lanka. The total value of exports is in the region of US$231 million.

3.2.6 The Maldivian pole and line MSC certified tuna

This Maldivian fishery is also the only fishery in the Indian Ocean certified by the Marine Stewardship Council (MSC) ecolabel.[10] This fishery is the main MSC-certified pole and line tuna fishery, accounting for 74% of the catches of certified tuna pole and liners (MSC 2016). Pole and line vessels sell their catches directly to processing units or to local markets without going through middlemen. These catches are destined for several distribution channels:

- Tuna for local markets;
- Tuna for the processing units on the atolls to make dried tuna;
- Frozen tuna exported to Thailand (raw tuna);
- Tuna canned and exported to European markets.

In terms of the environment, the Maldivian pole and line fishery has a minimal impact on the ecosystem: catches and interactions with threatened or protected species or other ecologically important species are virtually non-existent (AHUSAN *et al.*, 2016). This fishery produces virtually no waste, since most of the bycatch is utilized and the rest is mostly released alive. Tuna that are too small or damaged end up in local markets or are eaten by the fishers (Marine Research Center 2016). Regarding the livebait fishery, the species used are small pelagics and recifal fish with short growth

[10] When this report was prepared in May 2017, the Maldives was the only certified fishery in the Indian Ocean and the Echebastar fleet was still under evaluation.

cycles and high spawning rates (JAUHAREE *et al.* 2015). From a social point of view, pole and line fishing is the main source of employment, particularly in remote atolls where job prospects are rare. Due to the modernity and comfort of the vessels, the working conditions are relatively good. Wages for tuna fishers are relatively high: between US$2,000-3,000 per month during the high fishing season and US$400-500 per month during the low season (Maldives Fishermen Association 2016). The average monthly income of tuna fishers is US$1,500, twice the per capita GDP of the Maldives. The income levels generated allow fishers to save enough to invest in fishing vessels and send their children to study abroad.

This model is however difficult to transpose to other fisheries. Among the main factors that have enabled the development of these fisheries, the presence of a surface thermocline[11] near the coast and the availability of live bait are essential conditions for the development of these fisheries. The traditional role played by fishing in Maldivian culture and a supportive institutional framework have also been decisive factors (HOHNE-SPARBORTH, ADAM, and ZIYAD 2013). Development assistance programmes have also played a major role in the modernization of the fishing fleet and infrastructure, but also in capacity building and the transfer of technology (LINTON and SHAREEF 2011). Finally, the dynamism of the tourism sector has also contributed to the development of the tuna sector, as some tourism investors have developed their activities in the tuna processing sector.

[11] The thermocline is a gradient of temperature in a body of water, where there is a sudden change in temperature at the boundary between a body of cold, deep water and a warmer mass of surface waters.

4. Sustainability and governance challenges

4.1 The difficult search for sustainability of tuna products

Over the past decade, the sustainability of fish and fishery products has become a major issue for many consumers, especially those in developed countries (LEADBITTER & BENGUEREL 2014). This concern for sustainability is especially visible in the canned tuna sector and focuses on three main issues (BRUS 2016): (i) Status of tuna stocks; (ii) Sustainability of fishing techniques, particularly their impact on by-catches; and (iii) Working conditions on board the vessels and in the canneries.

Table 3 illustrates the status of the tuna stocks in terms of species and oceans:

- All skipjack stocks have biomass (B) and mortality (F) levels comptatible with the maximum sustainable yield (MSY) levels (Biomass higher than Biomass than MSY and F lower than F at MSY);
- All bluefin stocks have critical biomass levels;
- The Mediterranean albacore have critical biomass and mortality levels;
- Bigeye stocks in the Atlantic and West Pacific Oceans are at critical biomass and mortality levels;
- Yellowfin are at critical levels in the Atlantic and Indian Ocean, and are in poor health in East and West Pacific;
- The Atlantic Ocean seems to be the most overexploited and overfished.

Table 3: Summary of the status of the 23 tuna stocks in 2016 (Source: ISSF 2017)

Species	Stock	Catches (10^3t)	Biomass (B)	Mortality (F)
ALBACORE	**TOTAL**	212		
	North Pacific Albacore	65	$B>B_{MSY}$	$F<F_{MSY}$
	South Pacific Albacore	68	$B>B_{MSY}$	$F<F_{MSY}$
	North Atlantic Albacore	26	$B<B_{MSY}$	$F< F_{MSY}$
	South Atlantic Albacore	15	$B<B_{MSY}$	$F\approx F_{MSY}$
	Mediterranean Albacore	3	Unknown	$F< F_{MSY}$ (uncertainty of data)
	Indian Albacore	35	$B > B_{MSY}$	$F< F_{MSY}$ (uncertainty of data)
BIGEYE	**TOTAL**	407		
	East Pacific Bigeye	105	$B > B_{MSY}$	$F<F_{MSY}$
	West Pacific Bigeye	129	$B<B_{MSY}$	$F>F_{MSY}$
	Atlantic Bigeye	80	$B<B_{MSY}$	$F>F_{MSY}$
	Indian Bigeye	93	$B>B_{MSY}$	$F<F_{MSY}$

SKIPJACK	**TOTAL**	2 782		
	West Pacific Skipjack	1828	$B > B_{MSY}$	$F \leq F_{MSY}$
	East Pacific Skipjack	331	$B>B_{MSY}$	$F<F_{MSY}$
	East Atlantic Skipjack	209	$B>B_{MSY}$	$F< F_{MSY}$
	West Atlantic Skipjack	20	$B>B_{MSY}$	$F< F_{MSY}$
	Indian Skipjack	394	$B>B_{MSY}$	$F<F_{MSY}$
YELLOWFIN	**TOTAL**	1 347		
	East Pacific Yellowfin	258	$B \leq B_{MSY}$	$F<F_{MSY}$
	West Pacific Yellowfin	573	$B>B_{MSY}$	$F<F_{MSY}$
	Atlantic Yellowfin	109	$B<B_{MSY}$	$F< F_{MSY}$ (large fishing effort)
	Indian Yellowfin	407	$B<B_{MSY}$	$F>F_{MSY}$
BLUEFIN	**TOTAL**	43		
	Pacific Bluefin	11	$B<B_{MSY}$has not beenestimated by SAC.	$F>F_{MSY}$has not beenestimated bySAC.
	East Atlantic Bluefin	16	$B>B_{MSY}$ (uncertainty of data)	$F< F_{MSY}$ (Thanks to TACs and control measures)
	West Atlantic Bluefin	2	$B<B_{MSY}$	$F< F_{MSY}$
	Southern Bluefin	14	$B<<B_{MSY}$	$F< F_{MSY}$

As far as fishing sustainability is concerned, the main consumer concern is the level of by-catches (mainly dolphins, turtles and sharks) and the use of FADs. This technique is strongly criticised as it results in a high volume of by-catch and the catch of juvenile tuna. The UK market is particularly sensitive to this issue and many retailers have committed to discontinuing sales of FAD-caught tuna. The tuna fishing method advocated by some NGOs as being the most sustainable is pole and line. Reputed to be the most selective, this technique entails almost no by-catch. However, as it accounts for only 8% of global catches, retailers have increasingly developed product ranges based on tuna harvested using free-school techniques (MSC 2016).

Finally, the question of working conditions on fishing vessels and in canneries has only recently emerged in the wake of numerous surveys and news reports on cases of slavery and forced labour in several fish and fishery industries. In the tuna industry, it is mainly Asian fishing vessels and canneries that have been singled out for their poor working conditions (Greenpeace 2015).

4.2 The weaknesses of the governance of tuna resources: an illustration in the Indian Ocean

Tuna production, both in terms of capture and farmed production, is regulated by Regional Fisheries Management Organisations (RFMOs). These are intergovernmental bodies whose members come from "coastal" countries in the zone in question and "fishing" countries with interests in the region's fisheries. Except for the Commission for the Conservation of Southern Bluefin Tuna (CCSBT), which is species-specific, the tuna RFMOs manage tuna stocks on the basis of geographical zone. The five tuna authorities are listed in **Erreur ! Source du renvoi introuvable.** below.

Table 4: List of tuna RFMOs (Source: ISSF, 2016)

Jurisdiction	RFMO	Targeted species and associated stocks	Number of stocks
Atlantic Ocean	International Commission for the Conservation of Atlantic Tunas (ICCAT)	Bigeye (1) Yellowfin (1) Skipjack (2) Atlantic bluefin (2) Albacore (3)	9
Indian Ocean	Indian Ocean Tuna Commission (IOTC)	Bigeye (1) Yellowfin (1) Albacore (1) Skipjack (1)	4
Pacific Ocean	Western and Central Pacific Fisheries Commission (WCPFC)	Bigeye (1) Yellowfin (1) Skipjack (1) Albacore (1)	4
	Inter-American Tropical Tuna Commission (IATTC)	Bigeye (1) Yellowfin (1) Skipjack (1) Pacific bluefin (1) Albacore (1)	5
Austral ocean	Commission for the Conservation of Southern Bluefin Tuna (CCSBT)	Southern bluefin (1)	1

The IOTC is the regional organization responsible for the management of tuna fisheries in the Indian Ocean. It currently has 32 members, including Indian Ocean Coastal States and distant fishing nations (IOTC 2016d). The IOTC mandate includes 16 tuna and large pelagic species. Beyond these species, the Commission Secretariat collects data on bycatch, non-target and dependent species that are affected by tuna fishing activity (CTOI 2016a). Initiatives to sustainably manage tuna resources in the region are impeded by several factors, including:

- A dichotomy of views between the distant fishing nations (including the EU, Japan, Korea and China) and the coastal States (led mainly by the Maldives, Mauritius, South Africa and, more recently, the Seychelles). While these blocs are far from homogeneous, the dichotomy can broadly be framed as a divergence of interests between distant industrial fleets motivated solely by profit, versus a mainly artisanal coastal fleet that guarantees food security and livelihoods in coastal areas.
- The difficulty in establishing a quota system. At present, the IOTC does not impose quotas (or "fishing opportunities") and for nearly 6 years the contracting parties have debated the definition of the allocation criteria for these quotas. Following the abovementioned dichotomy, foreign fleets advocate allocation criteria based on catch history, while coastal fleets argue for allocation criteria based on catch geography (based on the catch level within each EEZ).
- Weakness of the management measures in place. The management measures implemented within the IOTC are relatively weak and there are currently no quota systems or measures that constrain fleet capacity. With the exception of skipjack tuna, the IOTC has no harvest control rules in place. Moreover, although some fleets are subject to the Vessel Monitoring System (VMS), vessel position data are not centralized at the IOTC level. The data are only kept by flag States and are not analysed at the level of the IOTC Compliance Committee.
- A low level of compliance by Member States with existing conservation measures (CEO *et al.*, 2012). This lack of compliance considerably reduces the effectiveness and scope of management actions taken by the IOTC.
- Limited capacities to manage tuna stocks in some countries. Most coastal States have not defined a fishing policy and even fewer States have a specific management policy for tuna fisheries (IOC 2016). No country has set quotas or restrictions on tuna catches.

4.3 The limited responses of ecolabels and voluntary commitments

In addition to the regulations and measures introduced by States and the RFMOs, ecolabels and certification bodies have recently emerged as a means of encouraging fisheries to adopt better fishing practices. This development relies on market forces to create an incentive in terms of price or access to new markets (Gutierrez *et al.* 2016). In 2015, certified catches represented 18.6 million tonnes, or 20% of global wild catch seafood, with tuna holding third place in certified catches with a 10% share (POTTS *et al.* 2016). Among the labels certifying tuna fisheries, Friends of the Sea (FOS) and the Marine Stewardship Council (MSC) are world leaders in capture fisheries certification, while Dolphin Safe specifically covers the tuna industry. The Fair Trade label is the leading standard for capture fisheries fair trade (Fair Trade 2016).

These ecolabels have developed very different business models. MSC-certified production is mainly sourced from developed countries and feeds into these countries' distribution channels. FOS-certified production is sourced from developing countries and serves more industrial markets (POTTS *et al.* 2016). The Dolphin Safe label is found on close on 90% of the world's canned tuna. In addition to ecolabels, many of the industry's actors are taking action to promote the sustainability of their business and products (Table 5).

Table 5: Commitments of some retailers for sourcing tuna supplies (Source: Leadbitter and Benguerel, 2014; Greenpeace, 2015a; Greenpeace, 2015b)

Country	Retailer	Tuna supply policy
France	Carrefour	Carrefour has committed to source only MSC-certified tuna products
France	Système U	Système U has committed to cease selling tropical FAD-caught tuna by the end of 2016 for products sold under its private-label brands
United Kingdom	Marks & Spencer	All canned tuna sold by Marks & Spencer is pole and line-caught tuna
United Kingdom	Sainsbury's	All canned tuna sold by Sainsbury's is pole and line-caught tuna
Germany	EDEKA	EDEKA plans to source MSC-certified tuna products
US	Walmart	Walmart has committed to sourcing only MSC-certified tuna products

Despite the interest in ecolabels and voluntary commitments, they do have some important limitations (Figure 15), the first of which being their proliferation that creates some confusion for consumers, thus presenting a challenge for the credibility of the labelling schemes (Miller & Bush 2015)(RELOT & CAILLART 2009). Another limitation is linked to the reality of supply: MSC tuna catches account for only 20% of the global tuna catch (POTTS *et al.* 2016). Pole and line fishing, deemed to be the most environmentally sustainable, accounts for only 8% of the global catch (ISSF 2016). Assuming that all the catches purchased by canneries are canned, this corresponds to a volume of 244,000 tonnes, which cannot even meet US market demand. Moreover, apart from Fair Trade, ecolabels certifying catches do not cover the social dimensions of production, or do so only in a cursory fashion (POTTS *et al.* 2016; STRADOUDAKIS *et al.* 2016). Ease of access to obtaining ecolabels also poses a problem. Catch certification has been limited to fisheries already operating in a fisheries management context supported by a robust national management infrastructure (POTTS *et al.* 2016). Most certification schemes require that specific management structures and plans, as well as auditing procedures to obtain certification, to be implemented (POTTS *et al.* 2016). As a result, certified fisheries are generally those that already have management frameworks or those with the means and structures needed to rapidly improve their existing management and become eligible for certification (TLUSTY 2012). Additionally, the certification cost and related administrative constraints mean that developing world fisheries find it difficult to access certification (POTTS *et al.* 2016). The credibility of some of these labels is also questionable. Dolphin Safe, which certifies that tuna has not been caught by nets encircling dolphins, has little scientific credibility outside the context of the East Pacific Ocean as this is the only ocean basin where this fishing technique is used (Miller & Bush 2015; KORBER 1998).

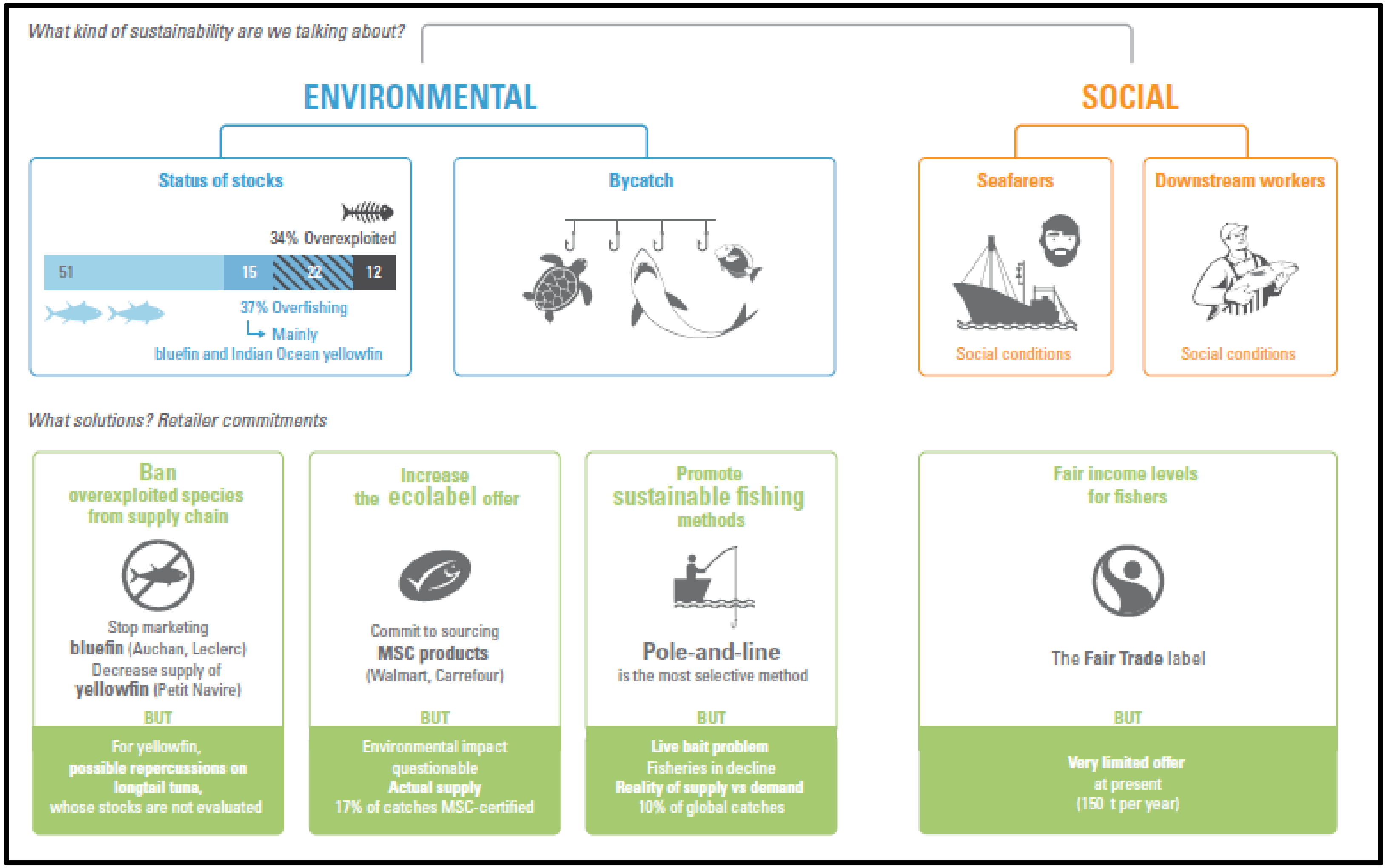
The proven impact of these ecolabels sometimes comes under debate. A 2012 study by Froese and Proelss found, for instance, that some stocks certified by FOS and MSC were actually overfished.[12] According to these authors, there is insufficient information to establish stock status or the level of exploitation for 11% of MSC-certified stocks and 53% of FOS-certified stocks (Froese & Proelss 2012). For stocks where information was available, 19% of FOS-certified stocks and 31% of MSC-certified stocks were overfished[13] (Froese & Proelss 2012).

Furthermore, certification does not necessarily lead to an improvement in the situation of certified fishery stocks. In the case of MSC certification, some stocks with biomass levels below MSY biomass levels did not see their biomass levels increase following certification. In fact, half of the stocks that were overfished in 2011 did not experience an increase in their biomass after certification (Froese & Proelss 2012). Finally, there is regular criticism of the lack of transparency in the governance of some ecolabels (Miller & Bush 2015). The certification process or objection procedures are not always clear or explicit, and objection procedures may be very expensive. For example, the MSC charges US$8,000 to launch an objection to a certification (POTTS *et al.* 2016).

[12] Here, we present the results without taking into account the debate that followed this publication and which mainly focused on how the concept of overfishing was to be defined (see Agnew *et al.* 2013; FROESE & PROELSS 2013).

[13] For the purposes of this paper, we consider that there is overfishing when $B<B_{MSY}$.

Figure 15: Limits of sustainability approaches (M. Lecomte, based on various sources)



4.4 The expected impacts of climate change on tuna fisheries

Oceans play a crucial role in climate regulation. Since 1971 they absorbed more than 93% of the heat generated by anthropogenic global warming (Reid, 2016; Rhein *et al.*, 2013) and captured 28% of anthropogenic CO_2 emission (Gattuso *et al.*, 2015). This regulating function comes at the cost of important changes in physical and chemical properties, such as temperature, salinity, sea level, pH, dissolved carbon and dissolved oxygen concentrations (Rhein *et al.*, 2013). Future projections from Earth system models forecast increasing seawater temperatures, growing ocean acidification, increasing oxygen depletion and changes in oceanic currents (Ciais *et al.*, 2013, Collins *et al.* 2013). They also project an increase in surface ocean stratification, a reduction of nutrients supply to surface waters and a decrease of primary production, the basis for marine food webs (Bopp *et al.*, 2013).

Changes in the ocean's physical and chemical properties affect the structure and the productivity of marine ecosystems. Marine species respond to climate change by shifting their distribution to higher latitudes and deeper water, modifying phenology and decreasing calcification (Poloczanska *et al.*, 2016). Increasing temperature affects the spatial distribution of mobile species, which move following their species-specific thermal tolerance. Temperature impacts also the physiological rates, with consequences on growth, body size, immune defence and reproductive success (Gattuso *et al.*, 2015). Changes in ocean currents, ocean productivity and temperature are likely to affect the dispersal and survival of larvae, with important consequences on fish recruitment.

Climate change is expected to affect fisheries, including tuna fisheries, by modifying the spatial distribution and abundance of exploited fish species. This may impact national economies of coastal countries, since quantity and quality of marine fish catch will be redistributed between nations' EEZs (Sumaila *et al.*, 2011). Substantial catch declines are projected for tropical fisheries even under the most optimistic Representative Concentration Pathway (RCP) 2.6 scenario by mid–21st century (Gattuso *et al.*, 2015) and global catches for the next 50 years are projected to shift from tropical waters to higher latitudes (Cheung *et al.*, 2010). This may deeply affect communities in tropical developing countries that depend heavily on coastal fisheries for food and economic security (Barange *et al.*, 2014). Moreover, the price and value of catches may vary, changing fishers' incomes and earnings to fishing companies (Sumaila *et al.*, 2011).

Table 6 summarizes the main impacts of climate change on Indian Ocean tuna species.

Table 6: Summary of habitat and biomass changes for skipjack, yellowfin, bigeye, albacore and longtail tuna (Source (DUERI 2017))

Species	Habitat change	Biomass change	Source
Skipjack tuna	**2010-2050** - Degradation of habitat conditions in equatorial waters - Improvement of habitat conditions along the Somali coast and in latitudes above 10°N and 10°S **2050-2095** - Strong decrease in equatorial waters - Decrease along the Somali coast and in the North Indian Ocean	**2010-2050** - Increase in biomass -Displacement to higher latitudes **2050-2095** - Strong decrease in biomass	Projections according to RCP 8.5 scenario (DUERI *et al.* 2014)
Yellowfin tuna	- Temperature range favourable to spawning is exceeded - Decreased availability of prey - Degradation of habitat quality	- Long-term decline in biomass after 21st century	Projections using RCP 8.5 scenario (SENINA *et al.* 2015)
Bigeye tuna	- Habitat could move towards deeper waters and/or higher latitudes - Decreased availability of prey	Unknown	Evaluations by S. DUERI (DUERI 2017)
Albacore tuna	- Decreased dissolved oxygen concentration in areas and depths where catches of albacore are currently reported - Possible habitat limitation due to oxygen availability	Unknown	Estimations by S. DUERI (DUERI 2017)
Longtail tuna	Unknown	Unknown	

4.5 Increasing global demand: what consequences for the tuna fisheries?

At the present time, the growth in both world population and income point to probable changes in future global demand for tuna (whether consumed fresh or canned) (MIYAKE *et al.* 2010; MULLON *et al.* 2016; CAMPLING 2015). Based on various assumptions about world population growth and the increase in GDP per capita in some emerging economies, some authors project that world demand for tuna may well reach 7.8 million tonnes by 2025 (VALSECCHI 2016).

Yet, the global demand for tuna differs according to the type of product. While canned tuna demand is inelastic and insensitive to price variations, the demand for fresh and frozen tuna is a function of inverse demand, which links quantities and prices (MIYAKE *et al.* 2010; HOLT & BISHOP 2002). These two markets thus show different consumption trends.

The canned tuna market is volume-based, with a low-price product. Between 1976 and 2011, based on global canned tuna imports, demand grew by around 3% annually (MULLON *et al.* 2016). In 2015, the low prices for round tuna had little impact on canned tuna demand on the EU and US markets, which signals the saturation of consumer demand on the traditional markets (GLOBEFISH 2016a). The leading exporters (Thailand, Ecuador, Spain) have seen their export revenues fall and have directed their production towards emerging markets in some developing countries (GLOBEFISH 2016a). Canned tuna imports to Middle Eastern markets, especially Egypt, Saudi Arabia and the United Arab Emirates, have increased significantly. On the contrary, Southeast Asian demand remains relatively flat despite the fact that the countries in the region have local canning factories (ANTHONYSAMY 2016).

On the other hand, the market for sashimi-grade tuna and fresh tuna constitutes a higher-value market and is developing in European and North American countries. In 2015, the US imports of fresh and frozen tuna rose by 24%, driven by the high demand from the retail and food service industry (GLOBEFISH 2016a). Consumption of sushi and sashimi is increasingly popular on the European and US markets, notably in the food service sector(CHERRY 2016), where there are some 16,000 sushi restaurants (CHERRY 2016).

This increase in the demand for tuna is driven by some emerging country markets (especially for canned tuna) and is not without effect on the tuna fleets' fishing efforts. A 2016 study established a clear relationship between global demand for tuna and the catch level (MULLON *et al.* 2016). The increase in global demand seems to lead to a rise in prices and profits, which in turn fuels increased investment in fishing capacity, then greater pressure on fishing, resulting in the rapid decline of stocks and their possible collapse (MULLON *et al.* 2016).

According to this model, a 6% increase in tuna demand (canned or fresh) over a period of more than ten years would lead to steady investment in fishing capacity and cause the collapse of the tuna industry were there to be no regulatory measures to limit catches, investment and the technical efficiency of vessels (MULLON *et al.* 2016).

Moreover, the increase in global demand has repercussions on the tuna fleet's fishing effort. Today, however, commercial tuna catches seem to have reached a threshold and the overall status of stocks leaves little room for any increase in future catches, as current catches are already close to MSY levels. Some authors estimate that the maximum potential in catches lies somewhere between 6.3 and 6.8 million tonnes (VALSECCHI 2016).

Thus, given the current status of tuna stocks, it would be difficult for the fishing fleet to meet global demand.

To maintain a satisfactory level of stocks, the fishing effort needs to be regulated. This is mainly the responsibility of the five tuna RFMOs, who are each in charge of managing tuna fisheries in their assigned ocean basin. Currently, the main management tools envisaged involve setting up fishing closures or marine protected areas, and restricting the use of FADs (KAPLAN *et al.* 2014; MULLON *et al.* 2016). However, implementing this last measure is complicated, as highlighted by recent IOTC meetings. Moreover, the increased capacity of some vessels compels them to adopt a volume-based strategy, where by greater quantities are harvested to make the investments profitable. As a result, it is becoming difficult to limit the tonnage fished by this type of vessel as this would mean jeopardising the ship owners' profitability.

In view of the growing demand and the sometimes difficult and thus slow implementation of tuna regulations, there is a danger than the fishing effort could increase up to levels that are no longer sustainable for tuna stocks.

Thus, the movement towards sustainability, even though its effects are still limited in some cases, could lead actors to adopt more sustainable fishing strategies to meet the high current demand (nonetheless limited to canned tuna markets). What remains needs to be defined is the extent to which these measures based on market incentives will prove effective in driving the shift towards more sustainable fishing practices.

References

Agnew, D.J. *et al.* (2013). Rebuttal to Froese and Proelss "Evaluation and legal assessment of certified seafood." *Marine Policy*, 38, pp.551–553.

ANTHONYSAMY, S. (2016). Asian Tuna Trade and Markets.

BENETTI, D., PARTRIDGE, G. & BUENTELLO, A. (2015). *Advances in Tuna Aquaculture: From Hatchery to Market*, Elsevier Science.

BRUS, H. (2016). How the EU Consumer Landscape Is Changing.

CAMPLING, L. (2015). Assessing Alternative Markets : Pacific Islands Canned Tuna & Tuna Loins.

CAMPLING, L. (2012). The tuna "commodity frontier": business strategies and environment in the industrial tuna fisheries of the Western Indian Ocean. *Journal of Agrarian Change*, 12(2–3), pp.252–278.

CAMPLING, L. & HAVICE, E. (2013). FFA Trade and Industry News-September-October 2013. *FFA Trade and Industry News*, 6(5), p.20.

CHABOUD, C. (2013). Les accords de pêche avec les pays du sud-Problématique et enjeux.

CHEMERINSKI, D. (2013). Emerging Tuna Markets of the Upcoming decade: a look at the surprising "3G" countries. *InfoFish International*, 4, p.6.

CHERRY, D. (2016). Is sushi still the future of seafood ? *Intrafish*.

COI (2016). *Promouvoir le développement de filières thonières domestiques dans les pays de la Commission de l'Océan Indien : Cadre stratégique régional pour la promotion d'une pêche fraiche durable*, Commission de l'Océan Indien.

Commission Européenne (2016). Accords de pêche bilatéraux avec les pays non membres de l'UE. *Commission Européenne-Pêche*.

CTOI (2015). *Tableau des résumés de l'état des stocks issu du dernier rapport du comité scientifique*, CTOI.

DUERI, S. (2017). *Impacts of climate change and ocean acidification on Indian Ocean tunas (in press)*,

DUERI, S., BOPP, L. & MAURY, O. (2014). Projecting the impacts of climate change on skipjack tuna abundance and spatial distribution. *Global Change Biology*, 20(3), pp.742–753.

Fair Trade (2016). Product Certification-SEAFOOD PROGRAM.

FAO (2016). *La situation mondiale des pêches et de l'aquaculture 2016- Contribuer à la sécurité alimentaire et à la nutrition de tous.*, Rome: FAO.

FAO (2014). *Situation mondiale des pêches et de l'aquaculture*, Rome: FAO.

FAO (2015). Tuna as a Global Food Source: FAO Perspective.

Froese, R. & Proelss, A. (2012). Evaluation and legal assessment of certified seafood. *Marine Policy*, 36(6), pp.1284–1289.

FROESE, R. & PROELSS, A. (2013). Is a stock overfished if it is depleted by overfishing? A response to the rebuttal of Agnew *et al.* to Froese and Proelss "Evaluation and legal assessment of certified seafood." *Marine Policy*, 38, pp.548–550.

GLITNIR (2007). *Tuna Seafood Industry Report*, Glitnir.

GLOBEFISH (2016a). Canned Tuna Market Remained Dormant in 2015. *GLOBEFISH*.

GLOBEFISH (2016b). World Fish Market at a Glance. *GLOBEFISH*.

GOUJON, M. (2013). *Généralités sur les thons*,

Greenpeace (2015). *Supply Chained : human rights abuses in the global tuna industry*,

GUILLOTREAU, P. *et al.* (2016). Local, regional and global markets: what drives the tuna fisheries? *Reviews in Fish Biology and Fisheries*.

Gutierrez, N.L. *et al.* (2016). The current situation and prospects of fisheries certification and ecolabelling. *Fisheries Research*, 182, pp.1–6.

HAMILTON *et al.* (2011). *Market and Industry Dynamics in the Global Tuna Supply Chain*, Honiara : Pacific Islands: Forum Fisheries Agency.

HOLT, M.T. & BISHOP, R.C. (2002). A semiflexible normalized quadratic inverse demand system: An application to the price formation of fish. *Empirical Economics*, 27(1), pp.23–47.

IFO (2017). *Entretien avec IFO*,

Innovasjon Norge (2016). Aquaculture in Iran.

IOTC-2016-DATASETS-NCDB (2016). NOMINAL CATCH BY SPECIES AND GEAR, BY VESSEL FLAG REPORTING COUNTRY.

ISSF (2016). *ISSF TUNA STOCK STATUS UPDATE - 2016-Status of the World Fisheries for Tuna*, Washington D.C, USA: International Sustainable Seafood Foundation.

JAUHAREE, R., NEAL, K. & MILLER, K.I. (2015). *Maldives Pole-and-line Tuna Fishery : Livebait Fishery Review*, MRC, IPLNF, MSPEA.

KAPLAN, D. *et al.* (2014). Spatial management of Indian Ocean tropical tuna fisheries: potential and perspectives. *ICES Journal of Marine Science, 71*, pp.1728–1749.

KAWAMOTO, T. (2016). Tuna Market in Japan, Current Status, Challenges and Prospects.

KORBER, A. (1998). Why everybody loves Flipper: the political-economy of the US dolphin-safe laws. *European Journal of Political Economy*, 14(3), pp.475–509.

LEADBITTER, D. & BENGUEREL, R. (2014). Sustainable Tuna – Can the Marketplace Improve Fishery Management? *Business Strategie and the Environment*, 23(6), pp.417–432.

MACFADYEN, G. *et al.* (2016). *Estimate of Global Sales Values From Tuna Fisheries-Phase 1 Report*, United Kingdom: Poseidon Aquatic Resource Management Ltd.

MACFADYEN, G. (2016). *Estimate of Global Sales Values From Tuna Fisheries-Phase 3 Report*, United Kingdom: Poseidon Aquatic Resource Management Ltd.

MACFADYEN, G. & DEFAUX, V. (2016). *Estimate of Global Sales Values From Tuna Fisheries-Phase 2 Report*, United Kingdom: Poseidon Aquatic Resource Management Ltd.

MAFF (2013). *White Paper on Fisheries: Summary*, Japan Fisheries Agency.

Miller, A.M.M. & Bush, S.R. (2015). Authority without credibility? Competition and conflict between ecolabels in tuna fisheries. *Journal of Cleaner Production*, 107, pp.137–145.

MITZMAN, D. (2014). Nutella: How the world went nuts for a hazelnut spread. *BBC News*.

MIYAKE, M.P., GUILLOTREAU, P. & SUN, C.-H.J. (2010). *Recent developments in the tuna industry-Stocks, fisheries, management, processing,trade and markets*, Rome: FAO.

MORENO, G. & HERRERA, M. (2013). *ESTIMATION OF FISHING CAPACITY BY TUNA FISHING FLEETS IN THE INDIAN OCEAN*, Busan, Korea: IOTC.

MSC (2016). Small islands, big opportunities. *MSC*.

MULLON, C. *et al.* (2016). Exploring future scenarios for the global supply chain of tuna. *Deep Sea Research Part II: Topical Studies in Oceanography*.

Oceanic Development, Poseidon Aquatic Resource Management Ltd & MegaPesca Lda (2005). *The European tuna sector : economic situation, prospects and analysis of the impact of the liberalisation of the trade*,

PAN, M., SUN, C. & SQUIRES, D. (2010). Tuna price in response to changes of market structure and ecosystem conditions— Price linkage between Hawaii and Japanese Tuna sashimi Markets. In Montpellier, France, p. 8.

POSEIDON *et al.* (2014). *Review of tuna fisheries in the western Indian Ocean*, Brussels.

POTTS, J. *et al.* (2016). *State of Sustainability Initiatives Review : STANDARDS AND THE BLUE ECONOMY*, Manitoba, Canada: Roma Ilnyckyj and Eve Rickert.

RELOT, A. & CAILLART, B. (2009). L'écolabellisation dans le domaine de la pêche. *Ethique et économique*, 6(2).

SENINA, I. *et al.* (2015). *SEAPODYM application for yellow tuna in the Pacific Ocean*, WCPFC.

STRADOUDAKIS, Y. *et al.* (2016). Fisheries certification in the developing world: Locks and keys or square pegs in round holes? *Fisheries Research*, 182, pp.39–49.

TERAZONO, E. (2016). Japan's tuna imports fall as young prefer steak to sushi. *The Financial Times*.

TLUSTY, M.F. (2012). Environmental improvement of seafood through certification and ecolabelling: theory and analysis: Modelling seafood improvement. *Fish and Fisheries*, 13(1), pp.1–13.

VALSECCHI, A. (2016). Social Responsibility towards global sustainability.

YAMASHITA, H. (2006). Food-System of tuna industry : market distortions in canning and sashimi markets. In Portsmouth, p. 12.

YVERGNIAUX, Y., GREBOVAL, D. & BREUIL, C. (2016). *Le secteur des pêches et de l'aquaculture dans l'espace COI: retombées socio-economiques versus dépenses publiques engagées pour sa gestion*, Ebène, Mauritius: SmartFish.

Annex 1

Figure 16: The Western Indian Ocean cannery value chain (Source: LECOMTE.M from SFA 2016; ITC Trade Map 2017)

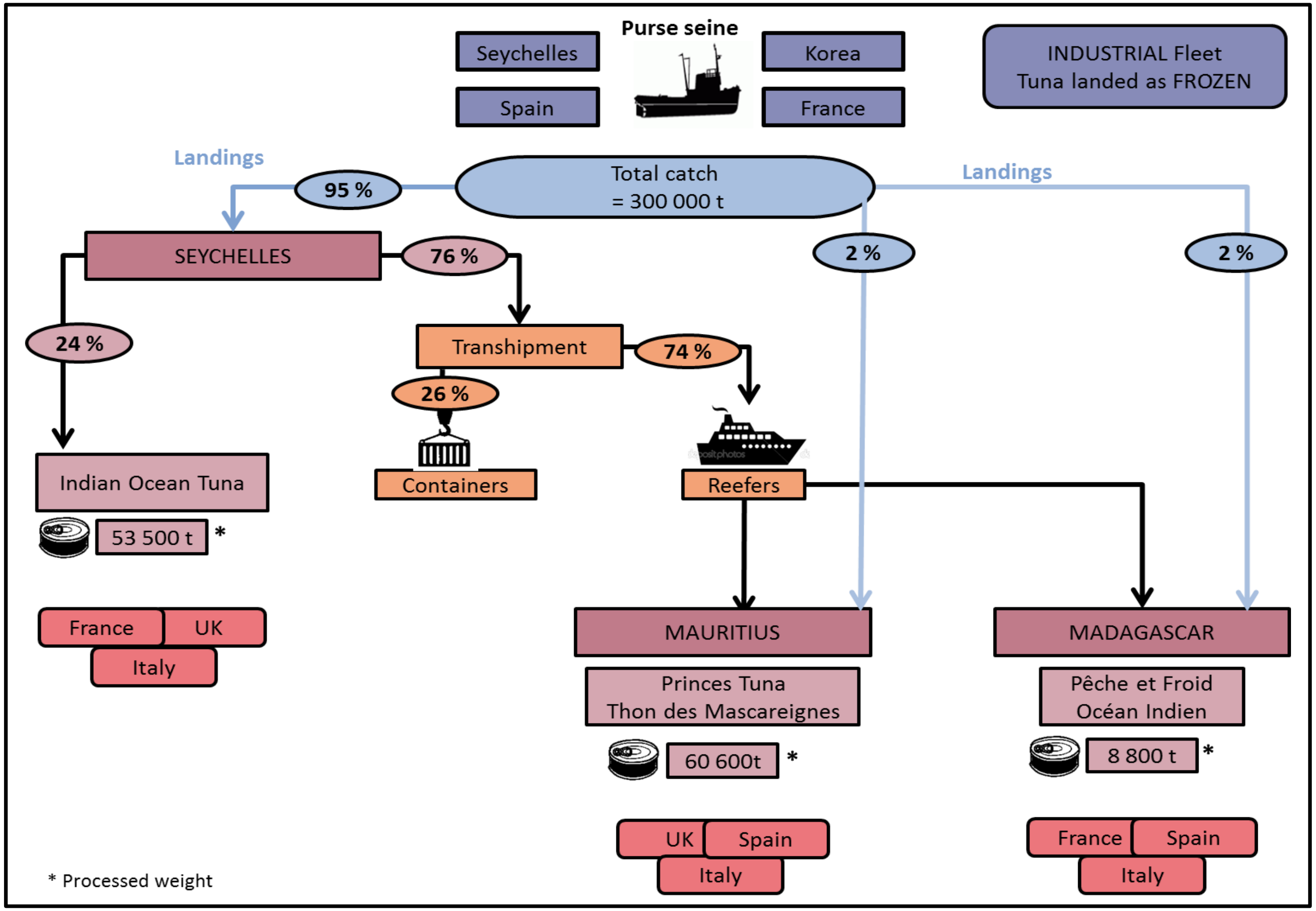


Figure 17: The value chain of local markets for Indian Ocean tuna (Source: LECOMTE.M from MFARD 2016; MAHAMOUD 2013; POSEIDON *et al.* 2014)

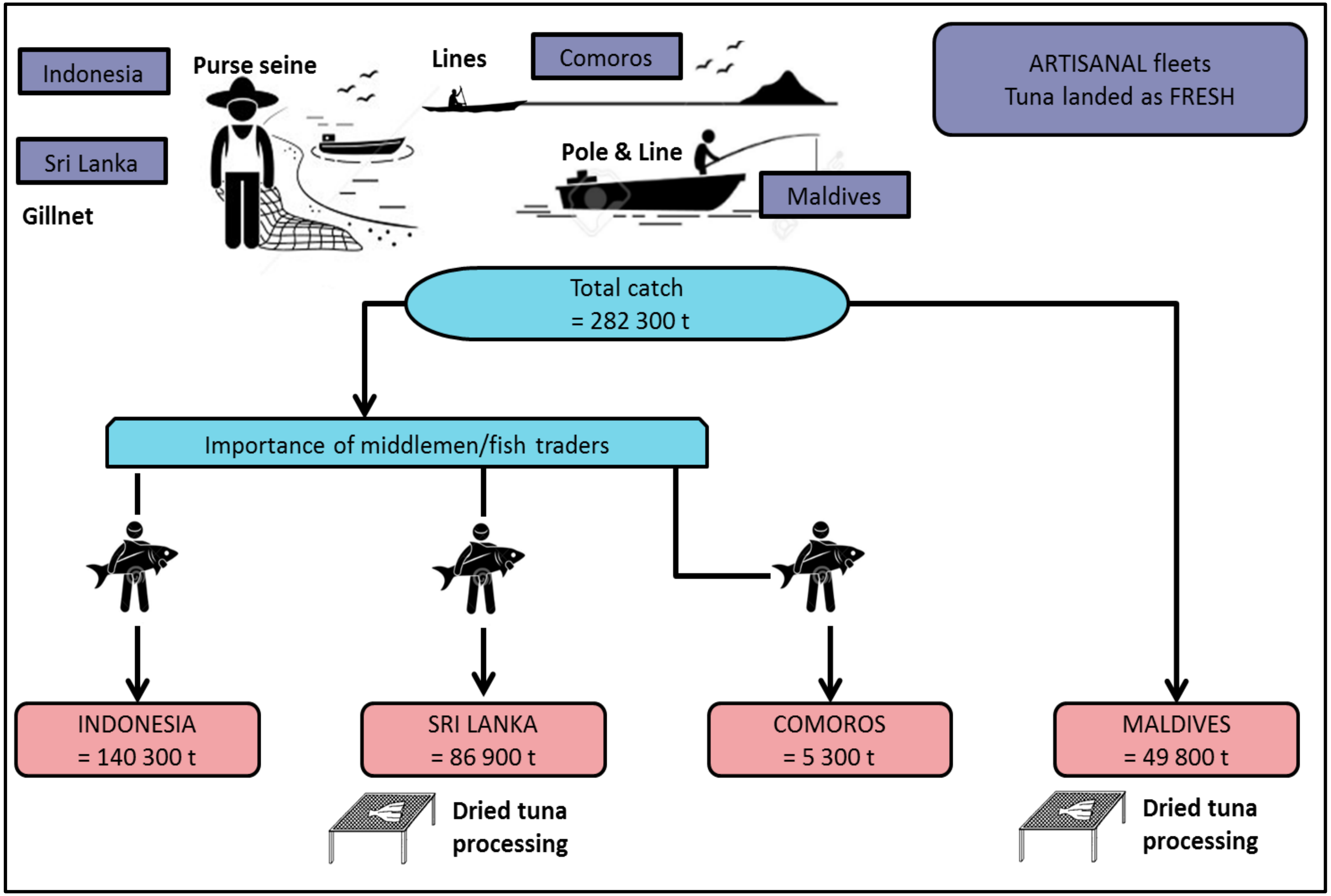


Figure 18: The Middle East gillnet value chain (Source: LECOMTE.M from IFO 2017; WWF Pakistan 2017)

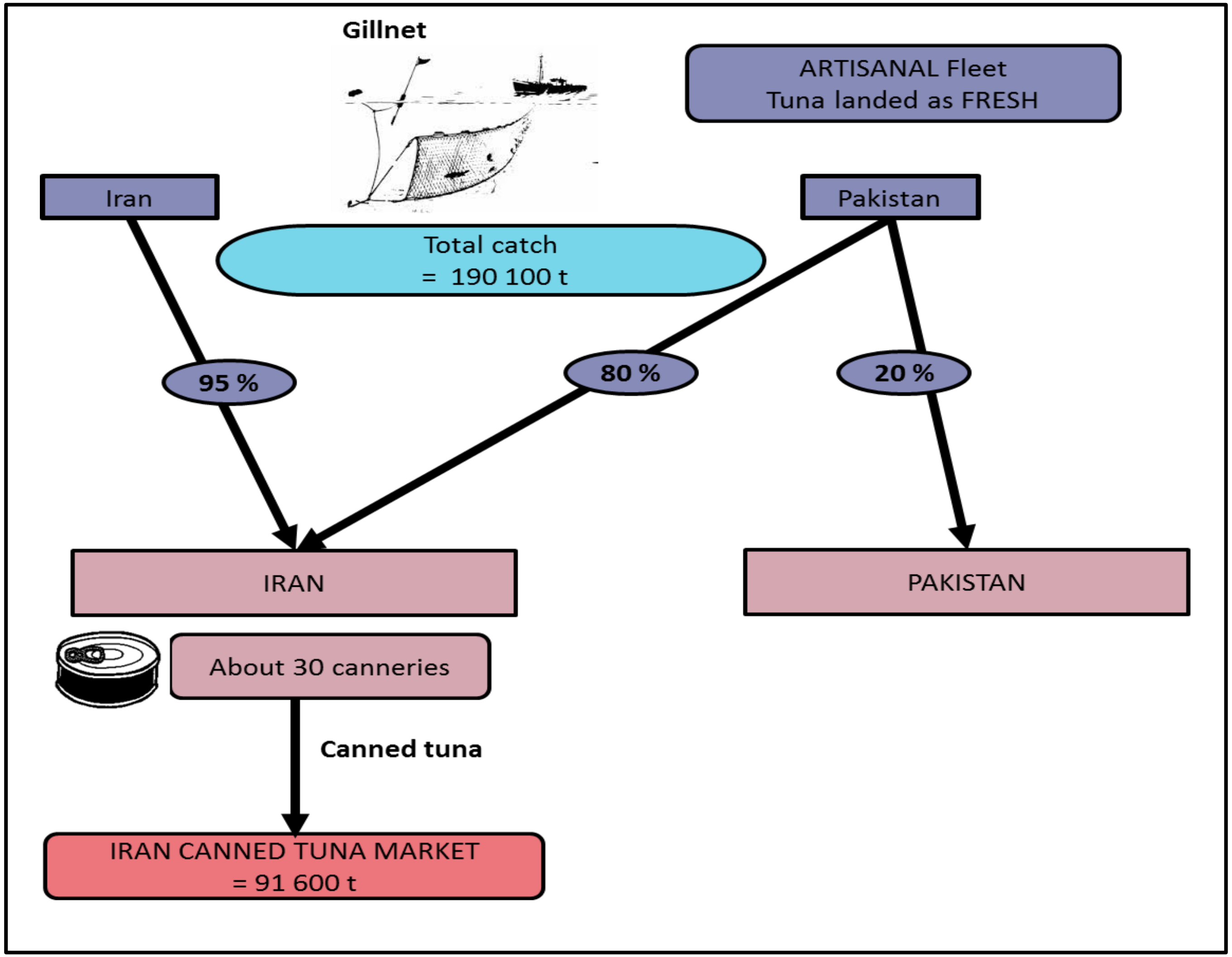


Figure 19: The industrial longline value chain (Source: LECOMTE.M from (ITC Trade Map 2017; IBL 2016; MOOTOOSAMY *et al.* 2016))

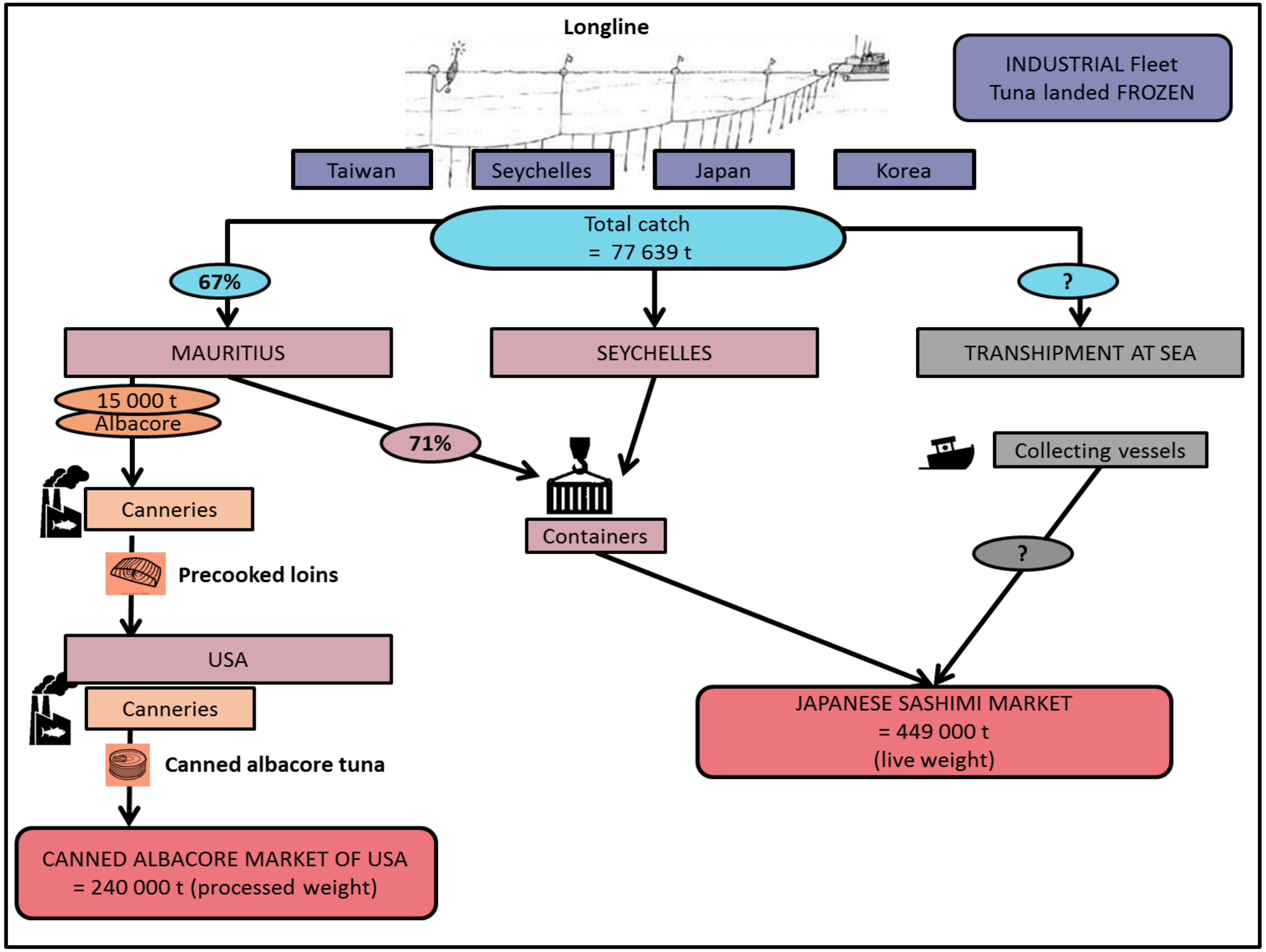


Figure 20: The value chain of fresh tuna processing units (Source: LECOMTE.M from ITC Trade Map 2017; MACFADYEN *et al.* 2016; BAILLY 2017)

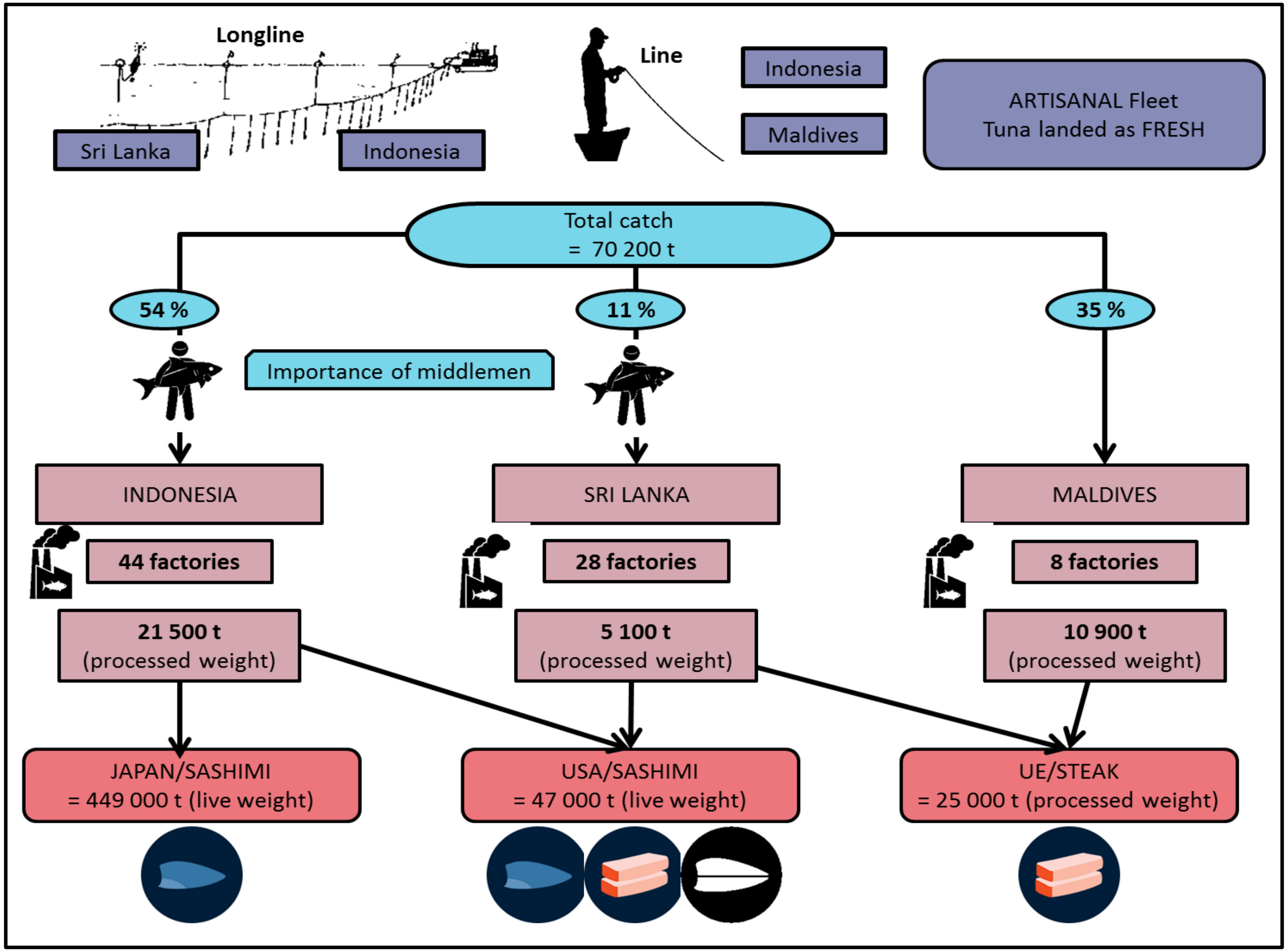


Figure 21: The Maldivian pole and line tuna value chain (Source: LECOMTE.M from IOTC-2016-DATASETS-NCDB 2016; ITC Trade Map 2017; POSEIDON *et al.* 2014)