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Review of the techno-economic performance of the main global fishing fleets

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Review of the techno-economic performance of the main global fishing fleets

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by

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Preparation of this document

This review of the techno-economic performance of the main global fishing fleets was prepared in 2019–2021 by Raymon van Anrooy of the FAO Fisheries Division, Natacha Carvalho of the European Commission Joint Research Centre, Andrew Kitts of the National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA), Rajdeep Mukherjee of the BOBP-IGO, and Sjef van Eijs, Fisheries Consultant. The national report of South Africa was written by David Japp of Capricorn Marine Environmental, Cape Town, South Africa. The national report of Senegal was written by Soulèye Ndao, with assistance from Modou Mbengue and Ablaye Ndepp Sene of the Ministry of Fisheries and Maritime Economy, with support from Mamadou Ndiaye and Mamadou Faye in Dakar, Senegal.

This document provides a synthesis of technical, economic and financial information from 20 national reports describing the main marine capture fisheries fleets of Bangladesh, Brazil, Chile, China, Denmark, France, Germany, India, Indonesia, Italy, Japan, Norway, the Republic of Korea, Peru, Senegal, South Africa, Spain, Turkey, the United Kingdom of Great Britain and Northern Ireland, and the United States of America. Eighteen of these national reports were published in 2020 in regional techno-economic performance reviews of selected fishing fleets in Europe, North and South America, and Asia. The national reports of Senegal and South Africa can be found in this global review.

The information presented in this review is partly based on annual data and information collection programmes conducted by fisheries agencies in Denmark, France, Germany, Italy, Japan, Norway, the Republic of Korea, Spain, the United Kingdom of Great Britain and Northern Ireland, and the United States of America. Most of the information on the fleet segments in these countries refers to the years 2016–2017. The information presented on fishing fleet segments from Bangladesh, Brazil, Chile, China, India, Indonesia, Peru, Senegal, South Africa and Turkey refers to the years 2018–2019 and was largely collected through field surveys undertaken by the authors of the national reports.

The methodology for conducting the national review studies was discussed and agreed at the FAO/BOBP-IGO Expert Meeting on Methodologies for Conducting Fishing Fleet Techno-economic Performance Reviews, held in Chennai, India on 18–20 September 2018 (FAO, 2019). Following the preparation of the draft national review studies in 2019, an expert meeting to validate the outcomes and finalize the techno-economic performance review of the main global fishing fleets was held at FAO headquarters in Rome, Italy on 8–10 October 2019. This expert meeting considered it important to prepare not only a global review, but also to publish the national review reports within regional studies. This global review should therefore be read in conjunction with the regional review reports on the fishing fleets in Europe, North and South America, and Asia, which were published in 2020. The fishing vessel and fleet segment information on which this document is based was validated by national report authors with fishing vessel owners/operators, fisheries authorities and other stakeholders in the countries concerned. The preparatory process for the national fleet reports was coordinated and facilitated by Rajdeep Mukherjee of the BOBP-IGO.

This publication was edited by Edward Fortes, with formatting and design assistance provided by María Eugenia Escobar, Magda Morales and Marianne Guyonnet of the FAO Fisheries Division.

Abstract

This *review of the techno-economic performance of the main global fishing fleets* discusses the outcomes from 20 country-level studies of fishing fleets from Africa, Asia, Europe, North and South America. The review includes financial, socio-economic and technical information from 103 major fishing fleet segments, representing approximately 240 000 fishing vessels. Taken as a whole, these fleets are responsible for an estimated 39 percent of marine capture fisheries production worldwide. The fleets reviewed include 41 segments of bottom trawlers, 18 segments of purse seiners, 10 segments of longliners, 6 segments of pelagic trawlers, 4 segments each of gillnetters and squid jiggers, as well as fleet segments consisting of cast netters, stownetters, pole-and-line vessels, pot and trap vessels, dredgers, passive gear vessels and handliners.

The analysis of vessel characteristics reveals that there are substantial differences in fishing capacity (in terms of vessel length, tonnage and power) between fleet segments. Comparing 16 fleet segments that were also described in a previous review in 2000, an increase in the gross tonnage of individual average vessels was observed in all of these fleet segments. Moreover, substantial increases in overall average length and engine power were observed in several Asian fishing fleets. The age structure of the fishing fleets of (semi-) industrial fishing vessels in North and South America, Africa and Europe generally demonstrates an upward trend, while the age profile of most fishing fleet segments in Asia is younger, owing to the replacement and development of fishing fleets in China, Bangladesh, India and Indonesia.

An analysis of the costs and earnings data of 98 fleet segments showed that labour and running costs were the two main cost components for the majority of fleet segments reviewed. Revenue and costs appear to be related to the main fishing gears used and the target species. The highest costs and earnings were mainly found among purse seiner and trawler fleet segments targeting pelagic species.

The review shows that investments in (semi-) industrial fishing vessels and fishing operations are generally profitable, and that marine capture fishing continues to be a financially viable economic activity in all 20 fishing nations included in the review. Most fishing fleets surveyed realized sufficient income to cover depreciation costs, interest and loan repayments, and provide necessary financial resources for reinvestment. Of the 97 mostly (semi-) industrial fleet segments, 92 percent reported a positive net cash flow in the year they were surveyed, in the 2016–2019 period. Net profit margins of 10 percent or more were realized by average fishing vessels in 73 percent of the fleet segments, while 88 percent reported positive results in terms of capital productivity, as their returns on fixed tangible assets (ROFTA) were positive. Returns on investment (ROIs) of 10 percent or higher were realized by 61 percent of the fleet segments. The combined, total gross value added (GVA) contribution to the global economy by the 97 fleet segments was estimated at USD 72.5 billion, with the lion's share contributing to the Chinese economy. In more than a third of the fleet segments, the average labour productivity per full-time employed crew member was more than USD 100 000 in the survey years.

The fishing technologies used by the surveyed fleets continue to develop. Reducing fuel costs and saving energy have been key drivers for technological developments in semi-industrial fishing operations, vessels and gears. Major developments have also taken place in terms of increasing fishing efficiency, reducing the environmental impact of fishing, improving fish handling and product quality, in addition to improving safety at sea and the working conditions of fishers on-board vessels. These developments, along with a general increase in seafood prices, successful fisheries management in some areas, and improved fleet capacity management in Europe and North America, have all contributed to the ongoing, positive financial and economic performance of the main global fishing fleets in recent years.

Contents

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The authors would like to acknowledge the support received from fishing vessel owners and fishers in the 20 countries included in this global review. The vessel owners and fishers shared valuable insights, data and information on the technical aspects of their fishing operations, and provided details of the costs and earnings of their fishing operations. Without their support, the preparation of the national reports on which this global review is based would not have been possible.

The authors would also like to express their gratitude for the valuable contributions by the participants of the two expert meetings on methodologies for conducting techno-economic performance reviews of fishing fleets. The first meeting was held in Chennai, India, on 18–20 September 2018, and developed the survey methodology. The second meeting was held in Rome, Italy, on 8–10 October 2019, and reviewed the draft national reports.

The authors of this global review would like to acknowledge the contributions of the authors and coordinators of the studies carried out at the national level, which led to the 20 national reports on which this global report is based: Natacha Carvalho of the European Commission Joint Research Centre (European Union), Terje Vassdal of the Arctic University of Norway (Norway), Andrew Kitts, Greg Ardini, Christopher Liese, Minling Pan, and Erin Steiner of the National Oceanic and Atmospheric Administration (United States of America), Jesica Pino Shibata (Peru), René Pallalever Pérez (Chile), Alex Augusto Gonçalves (Brazil), Rajdeep Mukherjee and Yugraj Singh Yadava of the BOBP-IGO (Bangladesh), Hiroki Wakamatsu of Japan's Fisheries Research and Education Agency (Japan), Liming Song of the Shanghai Ocean University (China), Umi Muawanah of the Agency for Marine Affairs and Fisheries Research (Indonesia), Bong Jin Cha of the National Institute of Fisheries Science (Republic of Korea), and R. Narayana Kumar and Shinoj Parappurathu of the Indian Council of Agricultural Research-Central Marine Fisheries Research Institute (India). Technical assistance was provided by Uwe Tietze, Sjef van Eijs, Rajdeep Mukherjee and Raymon van Anrooy in the review process of the national reports. The authors are also grateful for the advice received from Simon Funge-Smith, Pingguo He and Carlos Fuentevilla (FAO), Uwe Tietze (FAO retiree) and Yugraj Yadava (BOBP-IGO) in the preparation of chapter 5 on Trends in technological innovations with an impact on fishing fleet performance. The review of FAO statistical data used in this paper by Stefania Vannuccini, Jennifer Gee, and Adrienne Egger is also acknowledged.

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Acronyms and abbreviations

AIS	automatic identification system
BOBP-IGO	Bay of Bengal ProgrammeInter-Governmental Organisation
BRD	bycatch reduction device
CPUE	catch per unit of effort
DFI	direct fuel injection
ECAs	emission control areas
ECDIS	electronic chart display information systems
EEZ	exclusive economic zone
EPS	styrofoam/expanded polystyrene
FAD	fish aggregating device
FAO	Food and Agriculture Organization of the United Nations
FOB	free on board
FRP	fibre-reinforced plastic
FTE	fulltime-equivalent (employment figures)
GDP	gross domestic product
GNSS	global navigation satellite systems
GPS	global positioning system
GT	gross tonnage
GRT	gross registered tonnage
GVA	gross value added
HP	horse power
ICEEF-3	information collection in energy efficiency for fisheries
IFO	intermediate fuel oil
IMO	International Maritime Organization
IQF	individually quick frozen
IRCS	international radio call sign
ITQ	individual transferable quotas
IUU	illegal, unreported and unregulated
JRC	European Commission Joint Research Centre
kW	kilowatt
LED	light-emitting diode
LOA	length overall
NFIFO	Fishing Technology and Operations Team (FAO)
nm	nautical mile
OECD	Organisation for Economic Co-Operation and Development
PFD	personal flotation device
RFMO	Regional Fishery Management Organization
ROI	return on investment

ROFTA	return on fixed tangible assets
RSW	refrigerated seawater
SDG	Sustainable Development Goal
TAC	total allowable catch
TED	turtle excluder device
TTEDs	turtle and trash excluder devices
UNCTAD	United Nations Conference on Trade and Development
USD	United States Dollar
UVI	unique vessel identifier
VMS	vessel monitoring systems
WGFTFB	Working Group on Fishing Technology and Fish Behaviour
WTO	World Trade Organization

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1. Introduction and background

In many countries, the marine capture fisheries sector plays an important role in the generation of employment, income, and foreign exchange earnings. The sector also contributes significantly to meeting the nutritional requirements of an increasing global population.

The United Nations 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) recognize that the fisheries sector offers many opportunities to reduce hunger, improve nutrition, alleviate poverty, generate economic growth, and to ensure better use of natural resources. In order to achieve SDG 14 (Conserve and sustainably use the oceans, seas and marine resources for sustainable development), it is imperative that fishing operations should become and remain environmentally sustainable, socially acceptable and economically viable.

Great efforts are made worldwide towards achieving sustainable fisheries in terms of its interaction with the marine environment. A considerable amount of academic research, conservation and fisheries management projects are focused on the environmental sustainability of the fisheries sector. This results in a plethora of information being available on environmental aspects of fisheries, while the economic and social aspects of the sector often receive less attention.

It is important that FAO Members, their fisheries management authorities and decision-makers are aware of the economic aspects of fishing operations. They should monitor the financial and economic feasibility of the fishing fleets, comparing both the differences between fleets and, over time, within individual fleet segments. Information on the technological and economic performance of fleets also facilitates fisheries governance processes; it constitutes an instrumental aspect of decision-making for fisheries sector stakeholders, both public and private, supporting investment decisions regarding fishing fleets, fisheries-related infrastructure and logistics.

Technical and economic information on the fishing fleets is important for FAO Members in their implementation of the Code of Conduct for Responsible Fisheries, particularly with respect to Article 7 on Fisheries Management and Article 8 on Fishing Operations (FAO, 1995). The information on the techno-economic performance of the world's fishing fleets will further assist FAO Members in the implementation of the International Plan of Action for the Management of Fishing Capacity (IPOA-Capacity). For fisheries managers and stakeholders, it is essential not only to understand the status of fisheries resources and the trends in seafood production, but also to know about the techno-economic performance of the fishing fleets. This will facilitate the development and implementation of national and regional action plans for the management of fishing capacity, in line with the IPOA-Capacity.

In addition, economic information on the fishing fleets is important to reveal the value added by the fishing industry to the economy at national, regional and global levels. Information on the contribution of the fishing industry to the economy is also essential information for fisheries policy and decision makers, when making decisions regarding fisheries sector investment and expenditure.

Therefore, FAO and particularly its Fisheries Division and Fishing Technology and Operations Team (NFIFO), regularly conduct global studies to analyze the cost structure and economic and financial performance of fishing fleets. These studies form part of the regular monitoring of the economic and financial viability of marine capture fisheries conducted by FAO in close cooperation with national fisheries research institutions, fisheries administrations and experts in selected countries in Asia, Africa, the Americas, the Caribbean and Europe.

The findings of previous studies carried out from 1995 to 1997, 1999 to 2000 and 2003 to 2005 were reported in FAO Fisheries Technical Papers 377 (FAO, 1999), 421 (Tietze *et al*., 2001) and 482 (Tietze, *et al*., 2005) respectively. The findings of these studies demonstrated that despite instances of increasing over-exploitation of fisheries resources, marine capture fisheries were an economically and financially viable undertaking in the 1990s and the first years of this millennium. However, as a result of underperforming fish stocks, decreasing catch per unit of effort (CPUE) and inadequate management leading to overcapacity (Willmann and Kelleher, 2009). marine capture fisheries were not achieving the optimum potential returns. The studies showed that marine fishing fleets largely generated enough revenue to cover the cost of depreciation as well as the opportunity cost of capital, while also generating funds for reinvestment, in addition to employment, income, and foreign exchange earnings.

The last FAO global review of the techno-economic performance of the main fishing fleets was done in 2002–2003 and published in 2005. Since then, FAO has not conducted any major comparative study on fishing fleet performance. However, many countries, including Japan, Norway, the United States of America and the European Union have continued to carry out measurements on fleet performance in order to monitor the economic and financial feasibility of their fishing sector. In view of the range of methodologies being applied by countries for techno-economic performance evaluations of their fishing fleets, FAO held an expert meeting on methodologies for conducting fishing fleet techno-economic performance reviews. The meeting was held in Chennai, India, on 18–20 September 2018 in close collaboration with BOBP-IGO. At the meeting, the advantages and disadvantages of various methodologies applied were discussed, and a general sampling/survey methodology for conducting techno-economic performance reviews – which can also be applied also in developing countries – was developed and adopted (FAO, 2019).

In 2018–2019, FAO collaborated with numerous fisheries economists worldwide to carry out national-level techno-economic performance reviews of the main fishing fleets, applying the agreed methodology. These national reviews were validated in October 2019 and published in regional review reports. This FAO review of the techno-economic performance of the main global fishing fleets should therefore be read in conjunction with the regional techno-economic performance review reports of selected fishing fleets in Europe (Carvalho *et al*., 2020), North and South America (Kitts *et al*., 2020), and Asia (Van Anrooy *et al*., 2020). The present review compiles the findings of the national and regional fleet reviews and includes a comparison with the findings of previous global reviews on the same subject.

The global review is based on the analysis of the main fishing fleet segments of 20 major marine fish-producing countries. The fleet segment selection was based on the volume and value of the landings by fleet segment in these countries. The information presented in this review is partly grounded on annual data and information collection programmes conducted by fisheries agencies in Denmark, France, Germany, Italy, Japan, Norway, the Republic of Korea, Spain, the United Kingdom of Great Britain and Northern Ireland, and the United States of America. Most of the information on the fleet segments in these countries refers to the years 2016–2017. The information presented on fishing fleet segments from Bangladesh, Brazil, Chile, China, India, Indonesia, Peru, Senegal, South Africa and Turkey refers to the years 2018–2019 and was largely collected through field surveys undertaken by the authors of the national reports. The field surveys were generally conducted on five fishing vessels per fleet segment; however in some cases averages were calculated from 12 surveyed vessels, and in some cases from only three vessels. The information collected was validated by the authors of the national reports with the fishing vessel owners/operators and fisheries authorities and was adjusted as required.

Information was collected from a total of 103 fishing fleet segments, of which data from 98 segments could be used for cost-earnings analysis, while data from 97 segments enabled economic and financial analysis.

The 20 countries covered in this review landed an estimated 50.7 million tonnes of marine capture fisheries products in 2018: this is equivalent to 60 percent of the 84.4 million tonnes of world marine capture fisheries production in the same year (FAO, 2020). Fishing fleets from eight of the ten largest marine capture fisheries countries were included in this global review study. The 97 fleet segments for which an economic analysis could be conducted landed approximately 32.8 million tonnes of fish and fisheries products in 2018, which accounted for nearly 39 percent of the worlds' marine capture fisheries production in that year.

This global review covers a wide range of fishing vessel types, including 41 fleet segments of bottom trawlers, 18 fleet segments of purse seiners, 10 segments of longliners, 6 segments of pelagic trawlers, 4 segments each of gillnetters and squid jiggers, as well as fleet segments consisting of cast netters, stow netters, pole-and-line vessels, pot and trap vessels, dredgers, passive gear vessels and handliners.

The countries included in this review also covered in the two most recent FAO global fishing fleet review studies in 2001 and 2003 were: China, France, Germany, India, Indonesia, Norway, Peru, Republic of Korea, Senegal, South Africa and Spain. A comparison of the techno-economic information between the earlier and current reviews is made wherever possible. The number of fleet segments covered in the 2003 review study was 96, which included also various artisanal fleets from Caribbean countries. Artisanal fishing fleets are not covered in the current review.


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Trends in fishing operations and fishing fleet composition

2. Trends in fishing operations and fishing fleet composition

This chapter discusses variations in the size of the global fishing fleet, as well as fishing capacity trends and vessel age in the world's (semi-) industrial fishing fleets. The data and information presented originate from two FAO publications – *The State of World Fisheries and Aquaculture 2020* (FAO, 2020), and the *FAO Yearbook of Fishery and Aquaculture Statistics* (FAO, 2020) – together with the IMO vessel database, national fisheries statistical reports from the surveyed countries, and national reports published in the above-mentioned regional techno-economic performance reviews for Europe, North and South America, and Asia.

2.1 FLEET SIZE

In 2018, the total number of fishing vessels, motorized and non-motorized, was estimated by FAO at around 4.5 million. Vessels operating in the Asian region constituted about 68 percent of the total number of fishing vessels. The number of fishing vessels in Asia declined from 3.4 million vessels in 2000 to 3.1 million in 2018, mainly as a result of a substantial reduction in China's fishing fleet. The number of fishing vessels in the Americas increased from around 380 000 vessels in 2000 to some 470 000 vessels in 2017; yet while the number of vessels and capacity increased in South America during this period, it decreased in North America (Kitts, *et al*., 2020). In European countries the trend between 2008 and 2016 revealed a gradual decrease in the number of vessels (±10 percent), accompanied by a reduction in total fleet capacity in terms of Gross Tonnage (GT) and engine capacity (kW). Some 20 percent of the global fishing fleet can be found on the African continent (FAO, 2020).

The techno-economic fishing fleet performance reviews presented in this paper focused on motorized vessels of (semi-) industrial fishing fleets. The global fleet of motorized vessels grew between 2000 and 2015 by some 17 percent, from an estimated 2.56 million vessels to 3 million vessels. However, in recent years there have been reports of a reduction in the number of fishing vessels; as a result, in 2018 FAO estimated the total number of motorized vessels at 2.86 million units (see Table 1). This figure amounts to about 63 percent of the

TABLE 1
Number of motorized fishing vessels in selected countries, 1995–2018

	1995	2000	2005	2010	2015	2018
China	432 674	487 297	513 913	675 170 F	672 416	556 150
Indonesia	352 332 F	352 332 F	352 332 F	397 920	460 658	460 658 F
India	79 724	79 724	135 676	146 159	143 020	143 020 F
Peru	4 045 F	4 045 F	3 823 F	4 557 F	4 172	4 172 F
United States of America	100 019	67 608	58 320 F	77 695 F	75 231 F	75 231 F
Norway	14 064 F	13 018	7 722	6 310	4 105	3 764
Chile	7 563	15 629	10 189	12 455	13 533	12 774 F
Republic of Korea	71 041	89 294 F	87 554	74 670	66 489	65 089
Spain	15 330	13 852	12 012	10 138	9 397	8 972
Argentina	1 501 F	1 342 F	971	1 090	938	804 F
Germany	2 124	2 172	2 010	1 642	1 443	1 382 F
World total	**2 438 334 F**	**2 564 486 F**	**2 721 644 F**	**2 944 686 F**	**3 001 280 F**	**2 863 302 F**

Note: F = FAO estimate from available sources of information, or a calculation based on specific assumptions.
Source: FAO Fishery and Aquaculture Statistical Yearbooks (2020).

total fishing fleet. Of the motorized fishing vessels, some 2.1 million are found in the Asian region, representing 75 percent of the global motorized fishing fleet. In the European region almost all commercial fishing vessels are motorized.

Three Asian countries (China, Indonesia and India) together possess more than 1.1 million vessels, which accounted for nearly 41 percent of the global fleet of motorized fishing vessels in 2018.

FAO collects fishing vessel data on an annual basis from its Members. The data collected include vessel length (LOA) split into length classes, powered/non-powered, engine power (kW or hp), tonnage (GT), decked/undecked, and vessel type information by main gears. A majority of countries provide the number of vessels by length class, but some 74 percent of the motorized fishing vessels reported in 2018 were not being reported by vessel type. Countries with the largest fishing fleets do not report by vessel type. The only region that largely reports on vessel types by gear is Europe, with 93 percent of vessels labeled by gear type. Of the vessels reported by African countries, 61 percent were labeled by gear type, while in other regions the majority of countries grouped fishing vessels together under the general category "other fishing vessels". Of the 26 percent of vessels reported to FAO by gear type, the largest categories were gillnetters (9 percent), followed by longliners (5 percent) and trawlers (2 percent). The existing gaps in reporting on active fishing vessels constrain the drawing of clear conclusions on trends in global fishing capacity.

Statistics on larger motorized vessels are generally of better quality than those on small-scale fishing vessels. Worldwide, FAO estimated that there were about 67 800 fishing vessels with an overall length (LOA) of at least 24 m in 2018 (FAO, 2020). However, this number may be very conservative in view of the 36 233 fishing vessels of ≥ 24m LOA, as reported by the Government of China in the *China Fishery Statistical Yearbook 2020* (China, 2020).

About 86 percent of the motorized fishing vessels in the world have an LOA of less than 12 m. Such vessels dominate everywhere, particularly in Africa, Latin America, the Caribbean and the Near East. Less than 2 percent of all motorized fishing craft correspond to industrialized fishing vessels of over 24 m in length, and with a gross tonnage (GT) of more than 100 GT. The proportion of small vessels of less than 100 GT in relation to the total fishing fleet is well over 90 percent in many countries (FAO, 2020). Consequently, when measures must be taken to limit fleet capacity, many governments, particularly in developing countries, will face a dilemma between reducing the industrial fleets on one side, and small-scale fishing fleets on the other. Decisions relating to reductions in small-scale fishing fleets are generally associated with major social and political issues, and not necessarily guided by biological and business considerations (FAO, 2020).

The majority of the larger motorized fishing vessels are included in established private and/or national registers. The reason for this is that larger vessels operating in areas under the management mandate of a regional fisheries management organization (RFMO), and generally also those active in the exclusive economic zone (EEZ), must be listed in a vessel registry or record and be authorized to fish. They often have an international radio call sign (IRCS) and/or IMO vessel number that serve as unique vessel identifier (UVI).

A large number of national fishing fleet registers show serious coverage deficiencies, notably with regard to small fishing boats operating in coastal and inland waters. This situation significantly constrains efforts to manage resources through adequate controls on fishing fleets, fishing effort and IUU fishing, among others (FAO, 2020). In this context, the FAO initiative to compile and disseminate certified information on fishing vessels, refrigerated transport vessels and supply vessels – known as the Global Record – can play an important role, and provides a powerful tool to deter and eliminate IUU fishing activities by enhancing transparency and traceability. Its long-term objectives are to strengthen the fisheries sector in terms of sustainability and management, to foster food security and to enhance the livelihoods of populations that depend on fisheries. The number of vessels included in the Global Record has increased rapidly in recent years and amounted to nearly 12 000 vessels at the end of 2020. Some 65 countries have reported their fishing vessels of 12 m LOA and over to the Global Record to date. Meanwhile, the IMO Global Integrated Shipping Information System (GISIS) database included just over 25 000 fishing and fishery-related vessels at the end of 2019 (IMO, 2019).

2.2 FISHING FLEET CAPACITY

Fishing capacity has been defined by FAO as: the amount of fish (or fishing effort) that can be produced over a period of time (e.g. a year or a fishing season) by a vessel or a fleet if fully utilized and for a given resource condition. (FAO, 2000).

In practice, fisheries managers generally use Gross Tonnage (GT), engine power measured in kilowatts (kW) and overall length in metres (LOA) information as the main (input control) indicators for fishing fleet capacity. Additional information collected by fisheries managers in the management of fishing capacity includes the vessel name, registration number, country of registration, port of registration, date of entry into service, date of construction, international radio call-sign, IMO number, the gear types used and its owner, as well as operator/manager information. Ward *et al*., (2004) provide an overview of the main concepts involved in the assessment and management of fishing capacity, and also address the use of other indicators such as the biological status of stocks, fishing effort data and output controls (e.g. total allowable catch and quota systems).

In this section of the review, the average vessel length, tonnage and power across eight vessel types (three categories of bottom trawlers, pelagic trawlers, purse seiners, longliners, gillnetters, and squid jiggers) are compared.

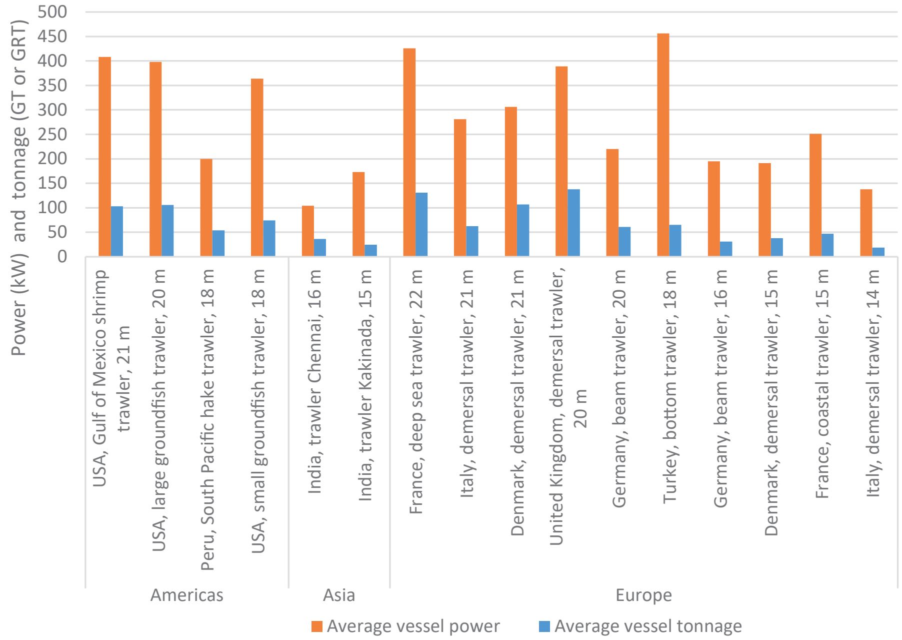
For the figures shown below, fleet segments are sorted by average vessel length within the region. As the information reveals, vessels of similar lengths can differ significantly in terms of power and tonnage. All three features (average length, power, tonnage) are rough indicators of the fleet segments' capability to catch fish. The review found that the largest fleets in terms of average vessel length, power and tonnage can be found in the pelagic trawlers and purse seine segments.[1] There are longliners and bottom trawlers with similar average lengths, but they display lower averages in terms of engine power and tonnage. The South African midwater trawlers stood out as the largest in terms of vessel size in Africa and also across all fleets surveyed.

The average length of small bottom trawlers (< 24 m) ranged from 14 m to 22 m, with engine power ranging from 104 kW to 456 kW. The tonnage of these vessels ranged from 19 tons in the Indian Kakinda trawler segment (15 m), to 138 tons in the United Kingdom of Great Britain and Northern Ireland's demersal trawler segment, which is composed of vessels with an average length of 20 m. France's deep-sea trawlers were the largest in length within this vessel type category, while Italy's demersal trawlers were the smallest. In the Americas, the largest of the small bottom trawlers are the Gulf of Mexico shrimp trawlers, closely followed by the large groundfish trawlers of the United States of America.[2]

1 The generic term, "large", is an overall assessment of the relative average length, power, and tonnage of fleet segments. There is no assessment of the number of vessels in a fleet segment.

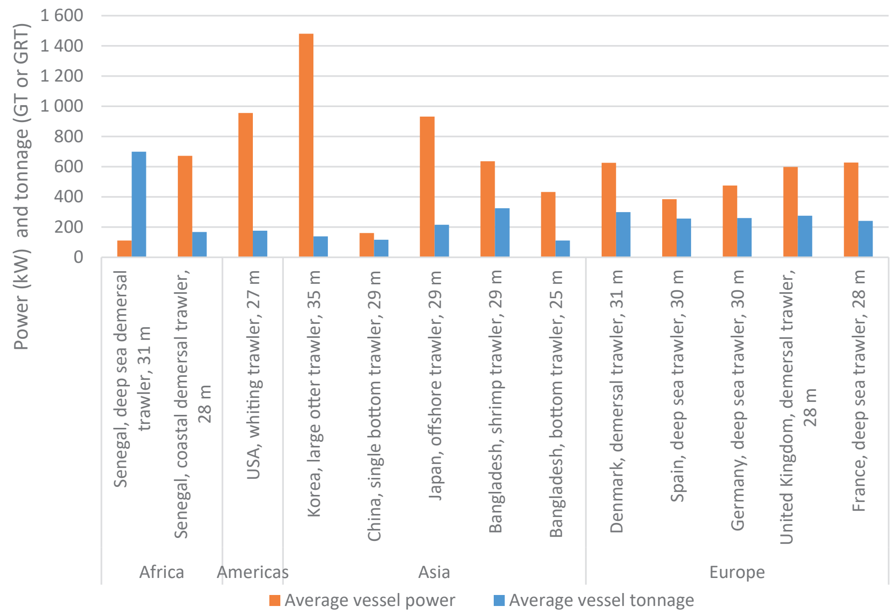
2 The term "large" is relative to the other West Coast "small" groundfish trawler fleet, even though both fleets are classified as belonging to this small groundfish trawler segment.

FIGURE 1
Average vessel power, tonnage and length of vessels in the small (< 24 m) bottom trawler fleet segments



By definition, the range of lengths evident in the medium-sized (24 m to 40 m) bottom trawler vessel category is narrower. Average vessel lengths for these fleet segments ranged from 25 m to 35 m, while average vessel power ranged from 112 kW to 1 480 kW; power was highest in the average vessels pertaining to the Republic of Korea large otter trawler fleet segment. The average vessel tonnage[3] ranged from 112 tons for

FIGURE 2
Average vessel power, tonnage and length of vessels in the medium-sized (24–40 m) bottom trawler fleet segments



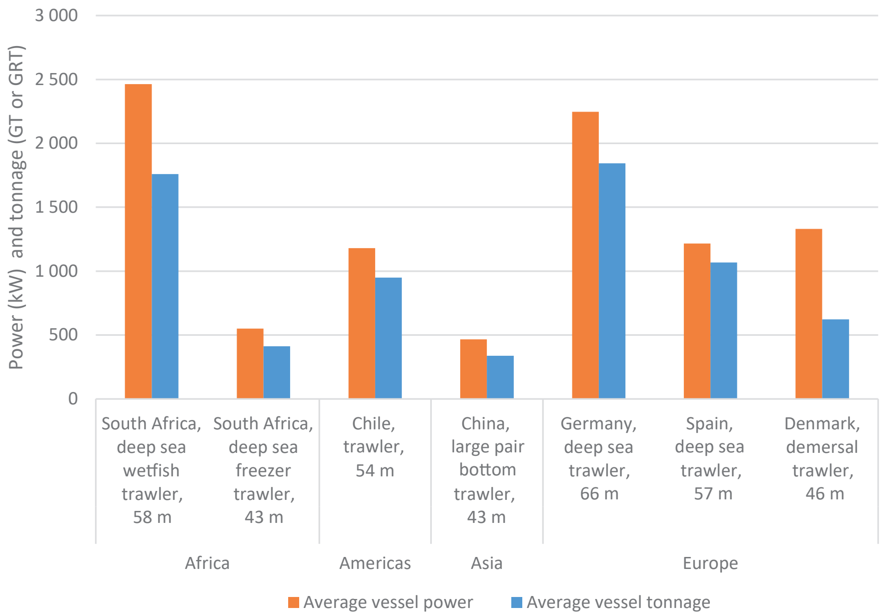
3 The generic term, “tons”, is used to indicate either gross tons or gross registered tons. Given the complexities of each of those measures, no attempt was made here to convert from one to the other.

the Bangladeshi bottom trawlers of 25 m, to 700 tons for the Senegalese deep-sea demersal trawlers of 31 m. Average vessel sizes were similar across the European fleet segments surveyed in this category. The largest vessels in this category were the large otter trawlers of the Republic of Korea.

The average length of large (> 40 m) bottom trawler fleet segments surveyed – i.e. those over 40 m in length – ranged from 43 m to 66 m.[4] Average power in this category ranged from 467 kW to 2 464 kW, while tonnage ranged from 337 tons to 1 843 tons. Germany's deep-sea trawlers were the largest of the European fleet segments in this vessel category. South Africa's deep-sea wetfish trawlers are of a similar size.

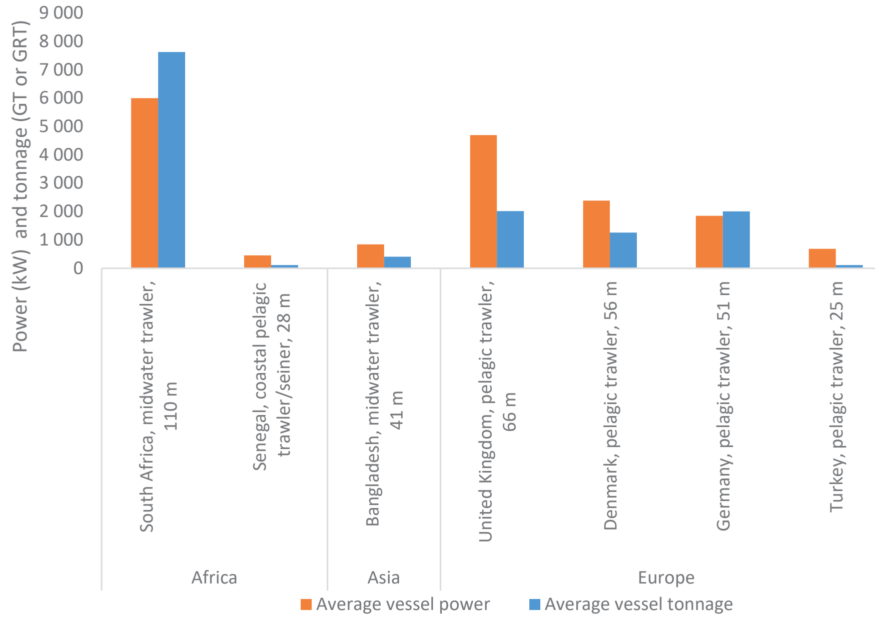
Size variation in the pelagic trawler fleet segments vessel category was substantial. For six of the seven pelagic trawler segments, lengths ranged from 25 m to 66 m. However, South Africa's midwater trawler vessels reported an average length of 110 m. Inevitably, the latter's tonnage and power are substantially greater than those of the vessels in the other six pelagic trawler fleets.

FIGURE 3
Average vessel power, tonnage and length of vessels in the large (> 40 m) bottom trawler fleet segments



4 The Norwegian fleet segments surveyed have not been included in this chapter's analysis as engine power information was not available for these vessels.

FIGURE 4
Average vessel power, tonnage and length of vessels in the pelagic trawler fleet segments



The average length of vessels in the purse seiner fleet segments ranged from 18 m to 87 m, while average power ranged from 86 kW to 3 853 kW, and average tonnage from 57 tons to 2 714 tons. On average, the largest purse seine vessels are found among the European fleet segments, most notably in France and Spain. In the Americas, Chile had the two largest purse seine fleet segments in terms of vessel size, while the two largest purse seiner fleet segments among those surveyed in Asia were found in Japan.

FIGURE 5
Average vessel power, tonnage and length of vessels in the purse seiner fleet segments

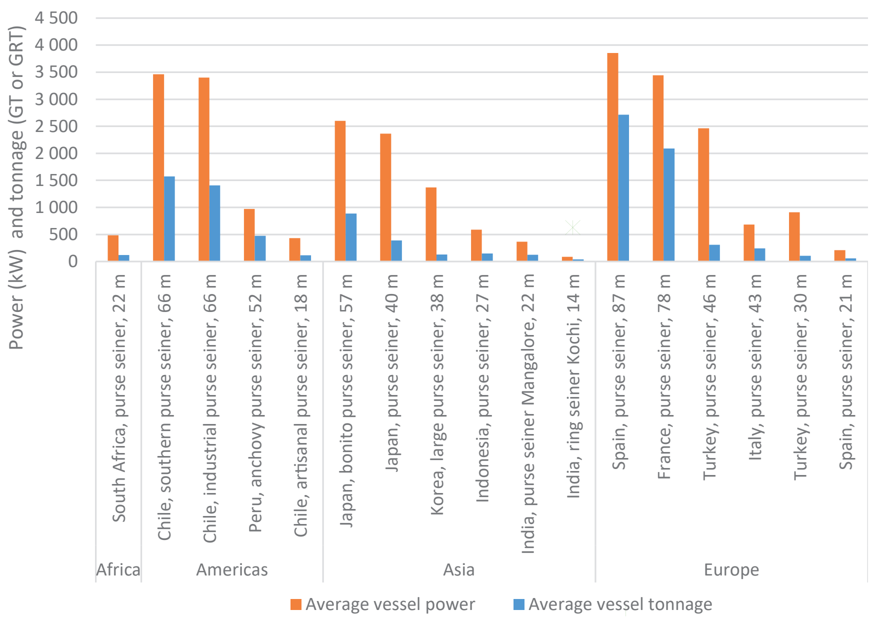
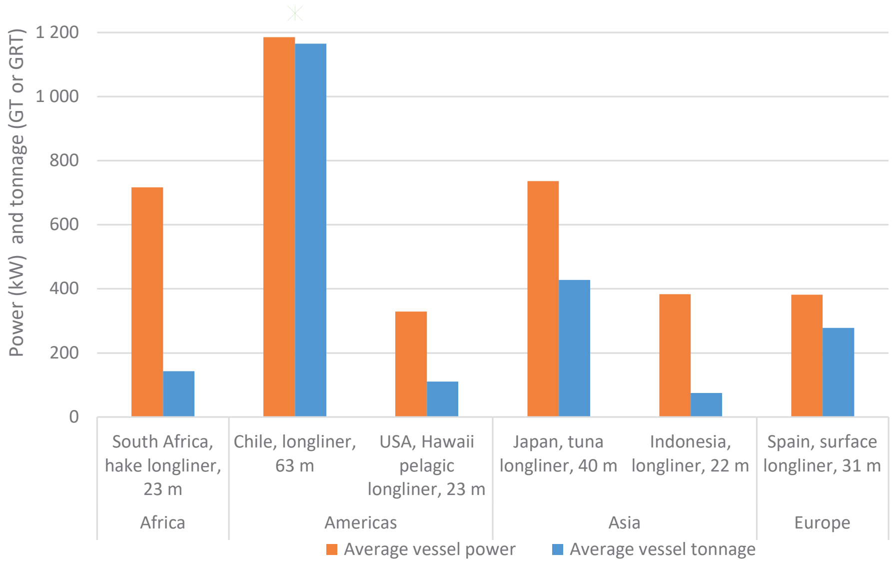


FIGURE 6
Average vessel power, tonnage and length of vessels in the longliner fleet segments



The six longliner fleet segments for which tonnage and engine power information was available showed significant variation in terms of average vessel size. The average vessel length ranged from 22 m to 63 m. Engine power ranged from 329 kW for average vessels in the Indonesian longliner fleet segment to 1 185 kW for the average Chilean longline vessels, while tonnage ranged from 75 tons to 1 165 tons. The largest longliner vessels among the fleets surveyed were found in Chile.

The review covered four gillnetter fleet segments – three in Asia and one in Europe. The largest gillnetters were found in China in terms of length, engine power and tonnage. France's gillnetters were the shortest in average length and the smallest in tonnage, but presented the second highest average engine power.

FIGURE 7
Average vessel power, tonnage and length of vessels in the gillnetter fleet segments

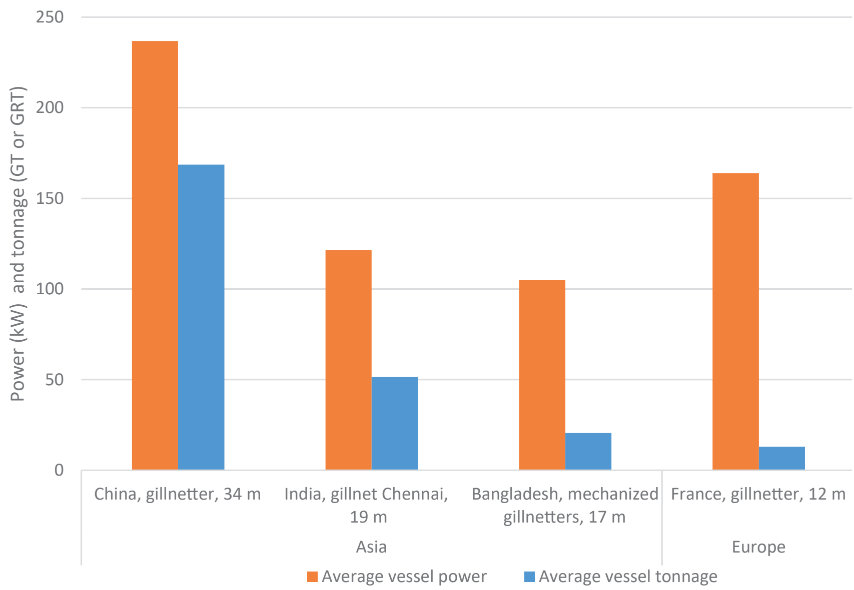
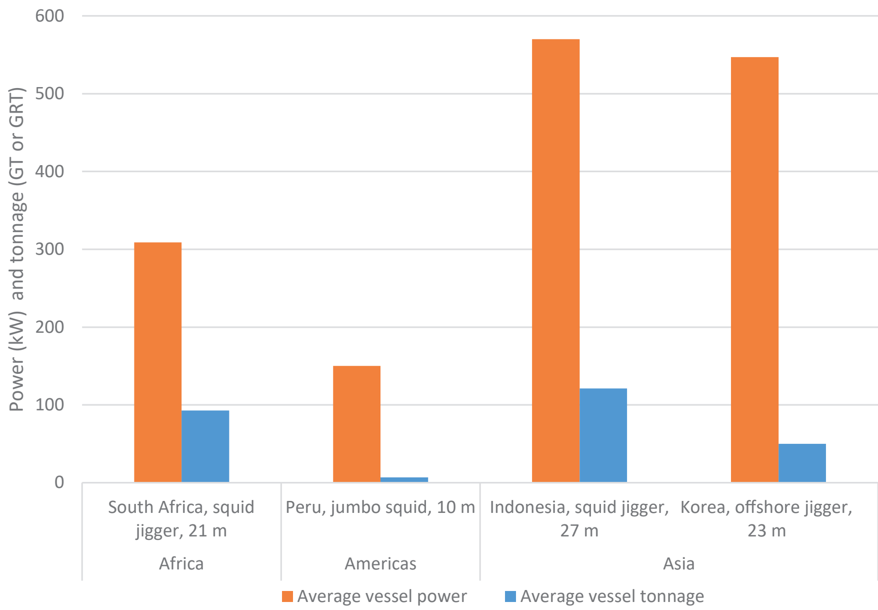


FIGURE 8
Average vessel power, tonnage and length of vessels in the squid jigger fleet segments



The review covered four squid jigger fleet segments. Indonesia and the Republic of Korea's squid jigger vessels were the largest, particularly with regard to engine power.

A substantial variation in characteristics was observed in most of the vessel type categories discussed above. While the fishing gear used within these fleet segments (e.g. purse seine nets, longlines) fall into the same general classification, the characteristics of these fisheries are highly diverse in terms of stocks targeted, fishing areas (coastal/offshore) and the value chains of their fishery products. The significant variety in fishery management regimes – which includes limits on vessel length or engine power, or creates incentives to invest in larger vessels – also leads to differences in the fleets' make-up. Furthermore, there are socio-economic differences in the countries in which the fleets operate, which may contribute to the large variation in vessel size. Table 3 presents an overview of the length, engine power and tonnage of average vessels within the selected fleet segments surveyed.

Comparing the average fishing vessel characteristics outlined above with those of similar fleet segments covered by the 1999–2000 FAO fleet performance review (Tietze *et al*., 2001) revealed an increase in average length overall for vessels in some fleet segments (Table 2). One of the most notable increases was for the Chinese pair trawlers. In 2000–2001, an average pair trawler measured 25 to 28 m (LOA), which has now increased to an average of 43 m. Average large otter trawlers and purse seiners in the Republic of Korea were also significantly longer in the present review than at the start of the millennium. For most other fleets overall lengths were similar to those reported in 2000–2001, if not slightly longer. The only fleet where the average vessel length decreased was the Indonesian tuna longline fleet, which dropped from 26 m to 22 m.

The gross tonnage of average vessels in the fleet segments that could be compared revealed an increase in individual vessel tonnage in all fleet segments. None of the 16 fleets segments in Table 2 displayed an average gross tonnage lower than that observed in 1999–2000. Increases in gross tonnage were particularly significant in the pair trawler fleet segment in China, increasing from a range of 114 tons to 158 tons, to an average of 504 tons. In the same country, the recent average tonnage for a large purse seiner was 648 tons, which is well beyond the 2000–2001 range (158 tons to 474 tons).

For the Republic of Korea large otter trawler and purse seiner fleets, recent tonnage ranges were also substantially above the 1999–2000 averages.

A similar pattern can be observed when comparing average engine power, measured in kilowatts (kW). In addition to substantial increases in engine power in the Chinese large pair trawlers and purse seiners, and the Republic of Korea's large otter trawl and purse seine fleets, there have been large engine power increases in the purse seiner and pole-and-line vessel fleet segments in Indonesia. The only fleet segments for which the engine power of average vessels has decreased were found in Europe, particularly among German deep-sea trawlers (24–40 m), and to a lesser extent among French coastal and deep-sea trawlers.

TABLE 2
Comparison of average vessel characteristics of some selected fleet segments included in both the FAO fleet performance review published in 2001 and the current review

Country	Fleet	Length overall (metres)		Gross tonnage (GT)		Engine power (kW)	
		2000	2020	2000	2020	2000	2020
China	Single boat bottom trawlers	26	29	127	174	110	161
	Pair trawlers	25–28	43	114–158	504	185	467
	Large purse seiners	28–42	46	158–474	648	280–440	889
India	Mechanized trawlers	17	10–29	n.a	n.a	87	89–410
	Purse seiners	15	10–28	n.a	n.a	79	75–261
Indonesia	Purse seiners	16–28	27	30–120	147	89–231	590
	Tuna longlines	26	22	67	75	256	383
	Pole-and-line vessels	13–25	30	10–50	80	61–258	586
Republic of Korea	Offshore jiggers	21–22	23	77	85	396	547
	Large otter trawlers	26–29	35	139	270–280	1 068	1 480
	Large purse seiner	26–28	38	126	300–365	742	1 368
France	Coastal trawlers 12–18	12–18	12–18	40–45	47	250–310	251
	Deep-sea trawlers 18–24	17–24	18–24	45–100	131	400–450	426
Germany	Deep-sea trawlers 24–40	28–32	30	200	260	550	475
Senegal	Tuna-targeting pole and liners	20–45	32	80–360	180	220–730	424
	Coastal demersal trawlers	27–49	28	120–480	168	295–1 470	671

Note: The data presented in the 2020 column are from the respective survey years (2016–2019) as specified in Chapter 1.

TABLE 3

Average length, engine power and tonnage of the vessels of selected fleet segments, organized by vessel type

	Vessel segment	Length (m)	Engine power (kW)	Gross tonnage (GT) (*=GRT)		Vessel segment	Length (m)	Engine power (kW)	Gross tonnage (GT) (*=GRT)
Bottom trawlers small	United Kingdom of Great Britain and Northern Ireland, demersal trawler, 20 m	20	389	138	Purse seiners	Chile, artisanal purse seiner, 18 m	18	430	113
	Denmark, demersal trawler, 15 m	15	191	38		Chile, industrial purse seiner, 66 m	66	3 400	1 409
	Denmark, demersal trawler, 21 m	21	306	107		Chile, southern purse seiner, 66 m	66	3 460	1 572
	France, coastal trawler, 15 m	15	251	47		France, purse seiner, 78 m	78	3 441	2 091
	France, deep-sea trawler, 22 m	22	426	131		India, purse seiner Mangalore, 22 m	22	368	126
	Germany, beam trawler, 16 m	16	195	31		India, ring seiner Kochi, 14 m	13.9	86	37.9
	Germany, beam trawler, 20 m	20	220	61		Indonesia, purse seiner, 27 m	27	590	147
	India, trawler Chennai, 16 m	16	104	36.5		Italy, purse seiner, 43 m	43	682	244
	India, trawler Kakinada, 15 m	15	173	24.4		Japan, bonito purse seiner, 57 m	56.7	2 599	886.7
	Italy, demersal trawler, 14 m	14	138	18.7		Japan, purse seiner, 40 m	40.3	2 366	390.3
	Italy, demersal trawler, 21 m	21	281	62.5		Republic of Korea, large purse seiner, 38 m	38.1	1 368	129
	Peru, South Pacific hake trawler, 18 m	18.2	200	54.1		Peru, anchovy purse seiner, 52 m	51.8	970	475
	Turkey, bottom trawler, 18 m	18	456	65		South Africa, purse seiner, 22 m	21.9	486	120*
	United States of America, Gulf of Mexico shrimp trawler, 21 m	20.7	408	103		Spain, purse seiner, 87 m	87	3 853	2 714
	United States of America, large groundfish trawler, 20 m	19.7	398	105.6		Spain, purse seiner, 21 m	21	210	57
	United States of America, small groundfish trawler, 18 m	17.6	364	74.5		Turkey, purse seiner, 30 m	30	910	107

Category	Vessel segment	Length (m)	Engine power (kW)	Gross tonnage (GT) (*=GRT)
Bottom trawlers medium	Bangladesh, bottom trawler, 25 m	25	433	111.8
Bottom trawlers medium	Bangladesh, shrimp trawler, 29 m	28.9	637	325
Bottom trawlers medium	China, single bottom trawler, 29 m	29.46	161	116.2*
Bottom trawlers medium	Denmark, demersal trawler, 31 m	31	626	300
Bottom trawlers medium	France, deep-sea trawler, 28 m	28	628	241
Bottom trawlers medium	Germany, deep-sea trawler, 30 m	30	475	260
Bottom trawlers medium	Japan, offshore trawler, 29 m	29.3	931	215
Bottom trawlers medium	Republic of Korea, large otter trawler, 35 m	34.9	1 480	139
Bottom trawlers medium	Senegal, coastal demersal trawler, 28 m	28.3	671	167.5
Bottom trawlers medium	Senegal, deep-sea demersal trawler, 31 m	30.6	112	700*
Bottom trawlers medium	Spain, deep-sea trawler, 30 m	30	385	256
Bottom trawlers medium	United Kingdom of Great Britain and Northern Ireland, demersal trawler, 28 m	28	598	276
Bottom trawlers medium	United States of America, whiting trawler, 27 m	26.5	956.3	176.9
Bottom trawlers large	Chile, trawler, 54 m	54	1 180	949
Bottom trawlers large	China, large pair bottom trawler, 43 m	43.18	466.8	337*
Bottom trawlers large	Denmark, demersal trawler, 46 m	46	1 330	623
Bottom trawlers large	Germany, deep-sea trawler, 66 m	66	2 246	1 843
Bottom trawlers large	South Africa, deep-sea freezer trawler, 43 m	42.6	550	413*
Bottom trawlers large	South Africa, deep sea wetfish trawler, 58 m	57.5	2 464	1 760*
Bottom trawlers large	Spain, deep sea trawler, 57 m	57	1 216	1 067
Pelagic trawlers	Bangladesh, midwater trawler, 41 m	41.3	847	406
Pelagic trawlers	Denmark, pelagic trawler, 56 m	56	2 388	1 261
Pelagic trawlers	Germany, pelagic trawler, 51 m	51	1 855	2 004
Pelagic trawlers	Senegal, coastal pelagic trawler/ seiner, 28 m	27.5	455	112.8*
Pelagic trawlers	South Africa, midwater trawler, 110 m	110	6 000	7 628*
Pelagic trawlers	Turkey, pelagic trawler, 25 m	25	683	114
Pelagic trawlers	United Kingdom of Great Britain and Northern Ireland, pelagic trawler, 66 m	66	4 694	2 020

Category	Vessel segment	Length (m)	Engine power (kW)	Gross tonnage (GT) (*=GRT)
	Turkey, purse seiner, 46 m	46	2 465	311
Longliners	Chile, longliner, 63 m	63	1 185	1 165
Longliners	Indonesia, longliner, 22 m	22	383	75
Longliners	Japan, tuna longliner, 40 m	40.3	736	428
Longliners	South Africa, hake longliner, 23 m	22.6	717	142.7*
Longliners	Spain, surface longliner, 31 m	31	382	278
Longliners	United States of America, Hawaii pelagic longliner, 23 m	23	329	111
Gillnetters	Bangladesh, mechanized gillnetters, 17 m	16.6	105	20.6
Gillnetters	China, gillnetter, 34 m	34.02	236.8	168.6*
Gillnetters	France, gillnetter, 12 m	12	164	13
Gillnetters	India, gillnet Chennai, 19 m	19	122	51.5
Other vessels	China, stownetter, 39 m	39.32	382.6	189.2*
Other vessels	Denmark, passive gear vessel, 7 m	7	33	3
Other vessels	France, handliner, 8 m	8	96	4
Other vessels	Germany, small-scale vessel, 6 m	6	24	2
Other vessels	Indonesia, cast netter, 23 m	23	390	61
Other vessels	Italy, passive gear vessel, 8 m	8	37	2.3
Other vessels	Senegal, deep sea crab trapper, 31 m	30.7	412	169
Other vessels	United Kingdom of Great Britain and Northern Ireland, pots and trap vessel, 7 m	7	61	4
Other vessels	United Kingdom of Great Britain and Northern Ireland, pots and trap vessel, 11 m	11	138	16
Other vessels	United States of America, Northeast limited access scallop dredger (full-time), 24 m	24	589	148
Other vessels	United States of America, Northeast limited access scallop dredger (part-time), 20 m	20	342	90
Other vessels	Indonesia, pole-and-line vessel, 30 m	30	586	80
Other vessels	Senegal, tuna pole-and-line vessel, 32 m	32	424	180*

2.3 AGE STRUCTURE OF FISHING FLEETS

The age of a fishing vessel is an important determinant of its economic performance. The age composition of fishing fleets reflects intra-sectoral dynamics such as the general profitability of fleet operations, the investment climate, the rise and fall of fish stocks targeted, operating costs, as well as technological innovations and management changes. Commissioning a new vessel usually constitutes the largest investment on the part of fishing entrepreneurs. A vessel is expected to generate a stream of benefits over its service life, which will gradually decline due to loss of efficiency. Conversely, repair and maintenance costs will increase over time, and at some point maintenance is likely to be prohibitively expensive, thus requiring either the vessel's retirement, or its second-hand sale and replacement.

References to the age of a fishing vessel usually refer to the age of its hull, as the hull is the most durable part of the vessel. The service life of the hull depends on the material used for construction, which is normally one of three main materials: wood, fibre-reinforced plastic (FRP) and steel. Other materials used for the construction of fishing vessels are plywood, aluminium alloy and reinforced concrete. While wood is historically the main material for vessel construction and is still in vogue in many developing countries, at the global level the trend has increasingly been to replace wooden vessels with FRP or steel.

In most countries, vessel age information is not readily available, making it difficult to understand the composition of fishing fleets. For this review, age data were collected from a survey of 101 fishing fleet segments and national authorities in 20 major fishing countries. These data were then supplemented with information from vessels holding an International Maritime Organization (IMO) number, which usually applies to vessels with an LOA of over 24 m.

The characteristics of the vessels in each segment are provided in the national fishing fleet reports published in Carvalho *et al.* (2020), Kitts *et al*. (2020) and Van Anrooy *et al*. (2020), as well as in Annexes A and B, which contain the South Africa and Senegal national reports. Information could be used from 82 fleet segments in the analysis of fishing fleet age structures. Vessel age information was collected in this review as either average vessel age (for the European fleet segments) or as a percentage of vessels by age group (0–10 years, 10–20 years and more than 20 years old) for most of the fleet segments of Africa, Asia, and North and South America.[5]

Age structure of European fishing fleets

Among the 11 European bottom trawler fleets covered in this review, the average age of small bottom trawlers (< 24 m) was higher than for medium-sized and large trawlers. The average age of all vessels in the small bottom trawler segments was 30 years old.[6] On average, the oldest small bottom trawler fleet segment vessels were the Danish demersal trawlers (15 m) and the German beam trawlers (16 m). The youngest fleet segment among the European bottom trawler fleets covered was found in France, where the average age of the deep-sea trawlers (22 m) was 23 years old.

Within the five European medium-sized (24–40 m) bottom trawler fleet segments, the youngest fleet segment was found in Spain. The average age of Spanish deep-sea trawlers (30 m) was 15 years old. By contrast, the average age of Danish demersal trawlers (31 m) was 26 years old. Overall, the average age of medium-sized trawlers in Europe was 20 years old.

5 The reason for applying a different approach for the European fleets is that the information of the European Union fleets was received from the EU STECF and for the other regions the data were largely collected through FAO surveys.

6 The vessel age data of the European Union, Norwegian and Turkish fleet segments used in this section are from 2016, 2017 and 2018 respectively.

The average age of vessels in the four European fleet segments of large bottom trawlers (> 40 m) was 20 years old. Among the large bottom trawler segments, the Danish demersal trawlers (46 m) were the oldest, with an average age of 34 years, while the Norwegian demersal cod trawlers (60 m) were the youngest, with an average age of 15 years.

The average age of vessels in the four European pelagic trawler segments was 21 years old. The vessels in the United Kingdom of Great Britain and Northern Ireland pelagic trawler (66 m) segment were the youngest on average, at 13 years old, while the average age of Norwegian pelagic trawlers (54 m) was 25 years.

Within the 41 European region fleet segments covered in the review, the purse seiners were the youngest overall. The average age was 16 years old for vessels in the 7 purse seiner fleet segments. The Italian purse seiners (43 m) were the oldest on average, at 25 years old, while the Turkish purse seiners (30 m) were relatively young, with an average age of just 5 years.

The vessels in the longliner fleet segments from Norway (conventional seagoing vessel, 45 m) and Spain (surface longliner, 31 m) were respectively 20 and 18 years old on average. The average age of vessels in the other segments in Europe, which are often characterized as small-scale vessels (< 12 m), was 29 years. Figure 9 provides an overview of average vessel age per vessel type.

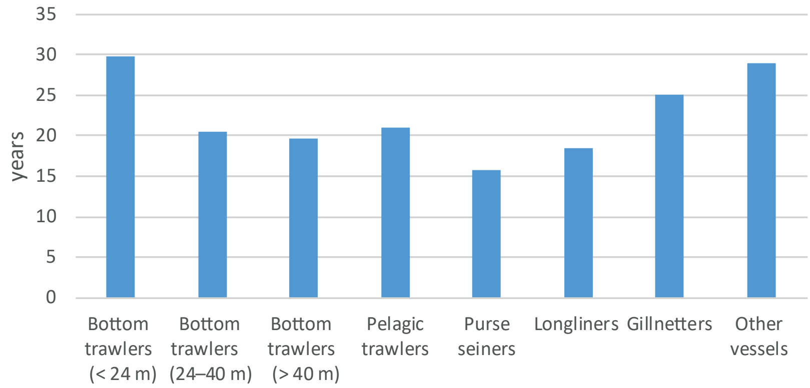
Across the 15 026 fishing vessels distributed over the 41 European fleet segments covered in this review, the average vessel age was 28 years old. Purse seiners and longliners are generally younger than other vessel types, such as bottom trawlers and small-scale vessels. Within the bottom trawler fleet segments, it seems as though there has been a tendency towards scaling up to medium- and large-sized vessels, as vessels in the small size bottom trawler segments are generally the oldest, with an average age of 30 years.

Age structure of fishing fleets in Africa, Asia and the Americas

An analysis of 42 fleet segments from the African, Asian, and North and South American regions, including more than 224 000 vessels, shows that 86 percent of vessels in these fleet segments are less than 10 years old. Some 10 percent of vessels fall into the 10–20 year age category, and only 4 percent of vessels are more than 20 years old.

These overall percentages are highly influenced by the rapid growth in the Chinese gillnetter (34 m) and bottom trawler fleet segments: the number of vessels in these two large and young fleet segments accounts for up to 54 percent of the approximately 240 000 vessels covered in this global review. As the vessels in China's industrial fishing

FIGURE 9
Average age of vessels per vessel type within the 41 European fleet segments surveyed



fleet were largely built in the last decade, they are therefore relatively young compared to the fleets of most other countries in this review. The second-largest fishing nation included in this review in terms of fleet segment size is India. The Indian fishing fleet segments included contained roughly 39 000 vessels in 2018, a figure which consists almost entirely of recently constructed wooden vessels. The lifespan of a wooden fishing vessel in India is around 12–15 years, but many are replaced at a younger age. By contrast, the steel-hulled fishing vessels that have been added to the gillnetter and trawler fleets in China in the last 10 years are expected to have a service life of around 25 years. Figure 10 shows that 87 percent of the fishing vessels in 24 of the main fishing fleet segments in Asia are less than 10 years old, and only 3 percent are more than 20 years old. However, in the case of Japan and the Republic of Korea fishing fleet development took place earlier than in most of the other Asian countries. Fishing fleets in Japan and the Republic of Korea are therefore relatively older (Table 4). Both countries are seeing a reduction in the number of new vessels entering the fleets and therefore the average age of the vessels in the fleet segments surveyed is increasing. In the case of Indonesia, relative aging was observed in the purse seiner fleet segment.

These percentages are in stark contrast to the age structure of fishing fleet segments in major fishing nations in Africa, such as Senegal and South Africa (Figure 11), North and South America (Figure 12) and in Europe (Figure 9). The overall age distribution of fishing vessels in the African fleet segments covered by this review – in Senegal and South Africa – appears rather evenly distributed, with 31 percent of vessels younger than 10 years old and 39 percent over 20 years old. However, more than 80 percent of the Senegalese fishing vessels are over 20 years of age and often much older than that, while the South African fleet segments are composed of vessels that are, relatively speaking, younger. For instance, an estimated 60 percent of the South African squid jiggers (21 m) surveyed entered the fleet in the last 10 years.

Aggregated data from 11 fleet segments from Brazil, Peru and the United States of America show that 34 percent of vessels are less than 10 years old, while the same percentage of vessels is more than 20 years old. At first glance this appears to be a balanced distribution, but on closer inspection most vessels in the United States of America fleet segments are more than 20 years old, while most vessels in some South American fleet segments have entered the fleets in the last 10 years. For instance, 95 percent of the Peruvian jumbo squid (10 m) vessels surveyed are less than 10 years old.

Figure 12 does not include the Chilean fleet segments. In Chile, the vessels in the longliner (63 m) fleet segment were youngest in 2018, with an average age of 18 years, while the large bottom trawlers (54 m) were generally more than 40 years old. Elsewhere, the Chilean industrial and southern purse seiners (66 m) were 23 years of age on average in 2018. Data on the Brazilian longliner fleet segments were also not available, but the estimated average age in 2018 was less than 15 years old.

FIGURE 10
Fishing vessel distribution by age group for 24 major fishing fleet segments in Asia

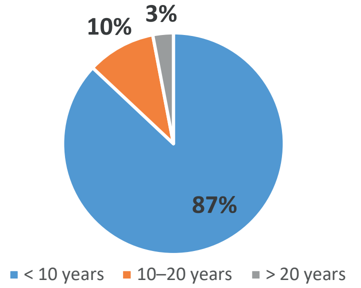


FIGURE 11
Fishing vessel distribution by age group for seven fishing fleet segments from Senegal and South Africa

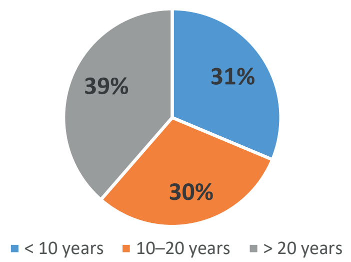


TABLE 4

Average vessel ages by age group for selected fishing fleet segments in Africa, Asia and North and South America

Vessel segment	0–10 year	10–20 years	more than 20 years	Number of vessels
Bangladesh, shrimp trawler, 29 m	10%	15%	76%	30
Bangladesh, midwater trawler, 41 m	51%	45%	4%	127
Bangladesh, bottom trawler, 25 m	20%	0%	80%	47
Bangladesh, mechanized gillnetters, 17 m	78%	13%	10%	20 359
China, gillnetter, 34 m	100%	0%	0%	96 315
China, stownetter, 39 m	60%	20%	20%	18 281
China, single bottom trawler, 29 m	80%	20%	0%	34 141
China, large purse seiner, 46 m	10%	90%	0%	7 483
India, trawler Chennai, 16 m	100%	0%	0%	30 486
India, gillnetter Chennai, 19 m	100%	0%	0%	6 502
India, purse seiner Mangalore, 22 m	100%	0%	0%	1 189
India, ring seiner Kochi, 14 m	100%	0%	0%	943
Indonesia, purse seiner, 27 m	18%	32%	50%	1 374
Indonesia, cast netter, 23 m	30%	30%	40%	442
Indonesia, longliner, 22 m	30%	30%	40%	351
Indonesia, pole-and-line vessel, 30 m	60%	20%	20%	87
Indonesia, squid jigger, 27 m	40%	30%	10%	470
Japan, purse seiner, 40 m	19%	18%	63%	60
Japan, bonito purse seiner, 57 m	25%	20%	54%	35
Japan, offshore trawler cod&pollock, 29 m	19%	18%	63%	268
Japan, tuna longliner, 40 m	14%	31%	54%	198
Republic of Korea, offshore jigger, 23 m	22%	48%	30%	588
Republic of Korea, large otter trawler, 35 m	8%	20%	73%	34
Republic of Korea, large purse seiner, 38 m	0%	3%	97%	25
United States of America, whiting trawler, 27 m	0%	0%	100%	34
United States of America, small groundfish trawler, 18 m	4%	4%	92%	20
United States of America, large groundfish trawler, 20 m	0%	4%	86%	32
United States of America, northeast limited access scallop dredger (full-time), 24 m	8%	21%	71%	313
United States of America, northeast limited access scallop dredger (part-time), 20 m	0%	34%	66%	35
United States of America, Gulf of Mexico shrimp trawler, 21 m	2%	24%	74%	1043
United States of America, Hawaii pelagic longliner, 23 m	1%	10%	89%	142
Brazil, shrimp trawler, 22 m	45%	50%	15%	1 824
Peru, anchovy purse seiner, 52 m	0%	90%	10%	126
Peru, jumbo squid vessel, 10 m	95%	5%	0%	698
Peru, South Pacific hake trawler, 18 m	0%	0%	100%	33
Senegal, tuna pole-and-line vessel, 32 m	0%	0%	100%	13
Senegal, coastal pelagic trawler/seiner, 28 m	6%	0%	94%	12
Senegal, coastal demersal trawler, 28 m	3%	1%	96%	78
Senegal, deep-sea demersal trawler, 31 m	5%	15%	80%	25
South Africa, deep-sea freezer trawler, 58 m	25%	70%	5%	51
South Africa, squid jigger, 21 m	60%	40%	0%	138
South Africa, hake longliner, 23 m	30%	30%	40%	45

Note: For purposes of this analysis the Chinese small pair bottom trawler (28 m) and large pair bottom trawler (46 m) fleet segments have been aggregated in Table 4 with the single bottom trawler (29 m) segment; this is due to separate information not being available on the number of vessels in each of these three segments. Similarly, for Brazil the demersal trawler (21 m) and bottom trawler (23 m) segments were included in the shrimp trawler (22 m) segment because only the total aggregate number of vessels in these three segments was known. Vessel age group percentages have therefore been adjusted in recognition of the fact that the average age of the demersal trawlers is higher than that of the bottom trawler and shrimp trawler segments. Similarly, the Indian bottom trawler fleet segments in Chennai (16 m) and Kakinada (15 m) have also been combined in this analysis because only aggregated data were available on the number of vessels.

FIGURE 12
Fishing vessel distribution by age group for 11 fishing fleet segments from Brazil, Peru and the United States of America

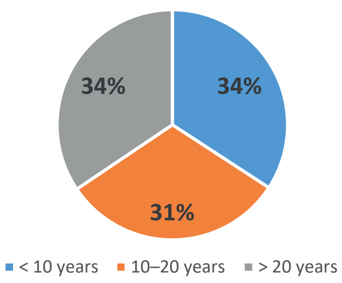


TABLE 5
Average age of capture fishing vessels registered in the IMO database, by region

Region	years
Africa	34
Asia	26
Europe	28
North America	36
South America	38
Oceania	32

Comparison of fishing fleet and merchant fleet age structures

To supplement the analysis carried out with the survey data, an analysis of the age data of fishing vessels possessing an IMO ship identification number was also carried out.[7] Most fishing vessels with IMO numbers are industrial fishing vessels with a gross tonnage of 100 tons or more. In 2019, the average age of all industrial fishing vessels (more than 23 000) in the IMO database was 32 years old. For the fishing related vessels in the database (e.g. transshipment, aquaculture supply vessels) the average age was 28 years old.

The IMO database contains fewer than 6 000 registered fishing vessels from the Asian region, including just over 2 000 Chinese fishing vessels. The average age of the IMO-registered Chinese industrial fishing vessels was 13 years old, while it was double that in the Asian region as a whole, with an average age of 26 years. By way of comparison, the average age of the Republic of Korea fishing vessels – of which there were more than 900 – was 44 years old, while the 683 registered Japanese vessels in the database had an average age of 21 years. Most Asian countries have only registered a small percentage of their (semi-) industrial fishing vessels, perhaps because these vessels are neither fishing in areas beyond national jurisdiction (ABNJ) nor are they under the mandate of an RFMO, and are therefore not required to have an IMO number. As it is more common for large fishing vessels to have an IMO number in North and South America, and Europe, the database therefore provides a better indication of average age for these regions. The average age of fishing vessels registered by various South American countries – in particular Ecuador, Uruguay and Venezuela – was more than 40 years old. Meanwhile, among African countries the average vessel age of IMO-registered vessels was 34 years or more for Côte d'Ivoire (40), Gabon (45), Guinea-Bissau (41) and Senegal (46), while the youngest fishing vessels in Africa by average age were to be found in Eritrea

[7] Data in this section originated from the IMO Global Integrated Shipping Information System (GISIS). In December 2019 the database contained a total of 23 682 fishing vessels and 1 460 fishing related vessels (e.g. for fish transport, aquaculture) from 150 countries and territories.

(15 years) and Mauritius (14). The European industrial fishing vessels registered in the IMO database were 28 years old on average, which is consistent with the findings of this review.

By comparison, the average age of the 121 000 merchant fleet vessels in the IMO database in 2019 was, at 23 years old, substantially lower than the average age of registered fishing vessels. The average age of the 61 000 cargo-carrying ships in the same database was just under 20 years old. The lifespan of merchant marine vessels of 1 000 GT and above is around 25–30 years old, depending on the vessel type (UNCTAD, 2020a). Smaller merchant vessels are being replaced by larger vessels and there is an increasing trend towards shorter lifespans in merchant marine vessels in general, particularly for container vessels and oil tankers. The steel hulls of contemporary merchant marine vessels are also getting lighter, and new vessel designs now allow for higher speeds and fuel savings through technological innovations. A number of other factors also affect shipping operations, vessel lifespan and scrapping decisions, namely: fuel (energy) costs, alternative fuel options, the reduction of GHG emissions and environmental regulations at the regional and international level (as set out by the IMO, for example), as well as global competition and the profitability of sea transport on certain routes (OECD, 2017; UNCTAD, 2020b).

REFERENCES

Carvalho, N., Van Anrooy, R., Vassdal, T. & Dağtekin, M. 2020. *Techno-economic performance review of selected fishing fleets in Europe.* FAO Fisheries and Aquaculture Technical Paper No. 653/1. Rome, FAO. https://doi.org/10.4060/ca9188en

China. 2020. *China Fishery Statistical Yearbook 2020.* China Agriculture Press. (available at www.purpleculture.net/china-fishery-statistical-yearbook-2020-p-31052/).

FAO. 1995. *Code of Conduct for Responsible Fisheries*. Rome, FAO. (also available at www.fao.org/3/v9878e/V9878E.pdf).

FAO. 1999. *Economic viability of marine capture fisheries. Findings of a global study and an interregional workshop.* Lery, J-M., Pado, J., & Tietze, U. FAO Fisheries Technical Paper No. 377. Rome, FAO. (also available at www.fao.org/3/W9926E/w9926e00.htm).

FAO. 2000. *Report of the Technical Consultation on the Measurement of Fishing Capacity, Mexico City, 29 November–3 December 1999.* FAO Fisheries Report No. 615 (FIPP/R615(En)). Rome, FAO. 51 pp. (also available at www.fao.org/3/x4874e/x4874e.pdf).

FAO. 2019. *Report of the Expert Meeting on Methodologies for Conducting Fishing Fleet Techno-Economic Performance Reviews, Chennai, India, 18-20 September 2018.* FAO Fisheries and Aquaculture Report No. 1243. (also available at www.fao.org/3/ca4427en/ca4427en.pdf).

FAO. 2020. *The State of World Fisheries and Aquaculture 2020. Sustainability in action.* Rome. https://doi.org/10.4060/ca9229en

FAO, 2021. *FAO Yearbook of Fishery and Aquaculture Statistics*. [online] Rome. [Cited 26 January 2021]. Rome. www.fao.org/fishery/static/Yearbook/YB2018_USBcard/root/fleet/fleet_&_employment.pdf

International Maritime Organization (IMO). 2021. Global Integrated Shipping Information System. In *IMO* [online]. London. [Cited 15 February 2021] https://gisis.imo.org/Public/Default.aspx

Kitts, A., Van Anrooy, R., Van Eijs, S., Pino Shibata, J., Pallalever Pérez, R., Gonçalves, A.A., Ardini, G., Liese, C., Pan, M., Steiner, E. 2020. *Techno-economic performance review of selected fishing fleets in North and South America*. FAO Fisheries and Aquaculture Technical Paper No. 653/2. Rome, FAO. https://doi.org/10.4060/ca9543en

Organisation for Economic Co-operation and Development (OECD). 2017. *Imbalances in the shipbuilding industry and assessment of policy responses*. [online]. Paris. [Cited 19 March 2021]. www.oecd.org/industry/ind/Imbalances_Shipbuilding_Industry.pdf

Tietze, U., Prado, J., Le Ry, J-M., & Lasch, R., eds. 2001. *Techno-economic performance of marine capture fisheries.* FAO Fisheries Technical Paper No. 421. Rome, FAO. (also available at www.fao.org/3/Y2786E/Y2786E00.htm)

Tietze, U., Prado, J., Le Ry, J-M., & Lasch, R., eds. 2001. *Techno-economic performance of marine capture fisheries.* FAO Fisheries Technical Paper No. 421. Rome, FAO. (also available at www.fao.org/3/Y2786E/Y2786E00.htm)

Tietze, U., Thiele, W., Lasch, R., Thomsen, B., & Rihan, D. 2005. *Economic performance and fishing efficiency of marine capture fisheries.* FAO Fisheries Technical Paper No. 482. Rome, FAO. (also available at www.fao.org/3/y6982e/y6982e00.htm).

United Nations Conference on Trade and Development (UNCTAD). 2020a. Decarbonizing maritime transport: Estimating fleet renewal trends based on ship scrapping patterns. In: *UNCTAD* [online]. Geneva, Switzerland. [Cited 20 March 2021]. unctad.org/news/decarbonizing-maritime-transport-estimating-fleet-renewal-trends-based-ship-scrapping-patterns

United Nations Conference on Trade and Development (UNCTAD). 2020b. *Review of Maritime Transport 2020*. New York. (also available at unctad.org/system/files/official-document/rmt2020_en.pdf).

Van Anrooy, R., Mukherjee, R., Wakamatsu, H., Song, L., Muawanah, U., Jin Cha, B., Narayana Kumar, R., Parappurathu, S., Yadava, Y.S. & Tietze, U. 2020. *Techno-economic performance review of selected fishing fleets in Asia*. FAO Fisheries and Aquaculture Technical Paper No. 653/3. Rome, FAO. https://doi.org/10.4060/cb1577en

Ward, J.M., Kirkley, J.E., Metzner, R. & Pascoe, S. 2004. Measuring and assessing capacity in fisheries. 1. Basic concepts and management options. FAO Fisheries Technical Paper. No. 433/1. Rome, FAO. 40 pp. (also available at www.fao.org/3/y5442e/y5442e00.htm).

Willmann, R. & Kelleher, K. 2009. *The sunken billions: the economic justification for fisheries reform*. Agriculture and rural development. Washington, D.C., World Bank Group. documents.worldbank.org/curated/en/656021468176334381/The-sunken-billions-the-economic-justification-for-fisheries-reform

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Costs structures and earnings of the marine fishing fleets worldwide

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3. Costs and earning structures of marine fishing fleets worldwide

This chapter compares the earnings and cost structures of the selected fleet segments by main fishing gear category or fishery.

The cost and earnings data were available for 98 fleet segments from 20 countries covering 5 continents, namely:

- Africa (2) - Senegal and South Africa
- North America (1) - United States of America
- South America (3)[8] - Brazil, Chile and Peru
- Asia (6) - Bangladesh, China, India, Indonesia, Japan and Republic of Korea
- Europe (8) - Denmark, France, Germany, Italy, Norway, Spain, Turkey and the United Kingdom of Great Britain and Northern Ireland.

The main fishing gear categories covered in the analysis were:

- bottom trawlers, separated into three groups, by vessel length:
  - small (< 24 m)
  - medium (24–40 m)
  - large (> 40 m)
- pelagic trawlers
- purse seiners
- longliners
- gillnetters
- squid vessels (jiggers), and
- other gear segments (including a range of gears such as stownets, pole-and-line, pots and traps, dredges).

Table 6 provides an overview of the number of fleet segments by continent, country and main fishing gear.

The revenue of most fishing fleet segments included in this review consisted solely of income earned from the sale of seafood landed, though some fleet segments did have other sources of income. For example, while fishing fleets in Bangladesh and Indonesia only generated revenue from the sale of fish, fleets in China, the European Union,[9] India, Japan and the Republic of Korea also received some income from other sources such as: government financial transfers, fuel tax rebates, fuel subsidies, subsidies for the purchase of navigational equipment, income from cooperatives, insurance payment for the damage and/or loss of gear or vessel. These other sources of income accounted for only a very minor part of total earnings.

Costs and revenue were calculated as follows; as far as possible, similar cost categories have been applied across all countries and segments.[10]

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8 North and South America are grouped together and sometimes collectively referred to as the Americas

9 Other income sources contributed between 2 and 7 percent to the total vessel earnings. This includes income invoiced during the reference period corresponding to vessel activities other than fishing supplied to third parties. Direct income subsidies and income from the lease or selling of quota and fishing rights are not included.

10 See the FAO regional reviews for more information on the methodologies used to collect cost and earnings data.

Revenue = income from the sale of seafood

Labour costs = personnel costs = labour share and wages (including social security contributions, life/accident and health insurance – N.B. unpaid labour is excluded from the data of European Union countries), food, stores and other provisions, and costs relating to crew travel.

Running costs = energy costs (including fuel, lubricants/oil/filters) and other variable costs (including harbour dues and levies, ice, bait, salt, fish-selling costs and packaging materials, and other related operational costs).

Vessel costs = gear replacements, repair and maintenance, vessel repair and maintenance, other non-variable costs (including vessel, equipment and employer's insurance; accountancy; audit and legal fees; general expenses; subscriptions), fishing licenses, permits and quota (only annual costs) and the purchase of fishing rights (quotas).

Capital costs = depreciation (of the vessel, engine, equipment, and gears lasting more than 3 years), interest and amortization of intangible assets (fishing permits, licences, etc.).

Operating costs = labour costs + running costs.

Vessel owner costs = vessel costs + capital costs.

Total costs = labour costs + running costs + vessel costs + capital costs.

TABLE 6
Number of fleet segments reviewed by continent, country and main fishing gear group

Continent	Country	Bottom trawlers small	Bottom trawlers medium	Bottom trawlers large	Pelagic trawlers	Purse seiners	Long-liners	Gill-netters	Squid vessels	Other gear segments	Total
Africa	Senegal		2		1					2	5
	South Africa			1			1		1		3
Total (Africa)			**2**	**1**	**1**		**1**		**1**	**2**	**8**
Americas	Brazil	3					3				6
	Chile			1		3	1				5
	Peru	1				1			1		3
	United States of America	3	1				1			2	7
Total (Americas)		**7**	**1**	**1**		**4**	**5**		**1**	**2**	**21**
Asia	Bangladesh		2		1			1			4
	China		2	1		1		1		1	6
	India	2				2		1			5
	Indonesia					1	1		1	2	5
	Japan		1			2	1				4
	Republic of Korea		1			1			1		3
Total (Asia)		**2**	**6**	**1**	**1**	**7**	**2**	**3**	**2**	**3**	**27**
Europe	Denmark	2	1	1	1					1	6
	France	2	1			1		1		1	6
	Germany	2	1	1						1	5
	Italy	2				1				1	4
	Norway	1		1	1	2	1			1	7
	Spain		1	1		2	1				5
	Turkey	1			1	2					4
	United Kingdom of Great Britain and Northern Ireland	1	1		1					2	5
Total (Europe)		**11**	**5**	**4**	**4**	**8**	**2**	**1**		**7**	**42**
Total		**20**	**14**	**7**	**6**	**19**	**10**	**4**	**4**	**14**	**98**

The average revenue and cost structure of the fleet segments are described below by main fishing gear or fishery. Where possible, comparisons are also made with results from previous FAO techno-economic performance reviews (e.g. Tietze *et al*., 2001 and Tietze *et al*., 2005). In most cases, these comparisons simply provide an indication of change, as both the fleet segments analysed and the methodology adopted to collect and report data may not necessarily have been the same as in the current review.

The large variation among the fleet segments within each fishing gear category, in terms of vessel size (length overall), technology, fishing region, species targeted and their stock status, makes any comparison between them very challenging and often of limited value. Income from the sale of seafood landed will largely depend on the target species, the quantities caught and ex-vessel prices, which again depend on market flows, seasonal fluctuations and bycatch, among other elements. Numerous other fishery-, country- and region-specific factors can have a major impact on revenue and the costs of fishing vessels. These may range from: management policies, which can limit the quantity of fish caught or time spent fishing (e.g. total allowable catch allocations and quotas; spatial-temporal closures, landing obligation/discarding, etc.), to market-related factors (e.g. access to local and export markets; product quality and type, value chain, etc.), labour arrangements (e.g. Pinello *et al.*, 2017) and environmental conditions. In addition, exchange and inflation rates also affect comparisons between countries and regions, and may have a significant impact on trade, for example.

3.1 SMALL (< 24 m) BOTTOM TRAWLERS

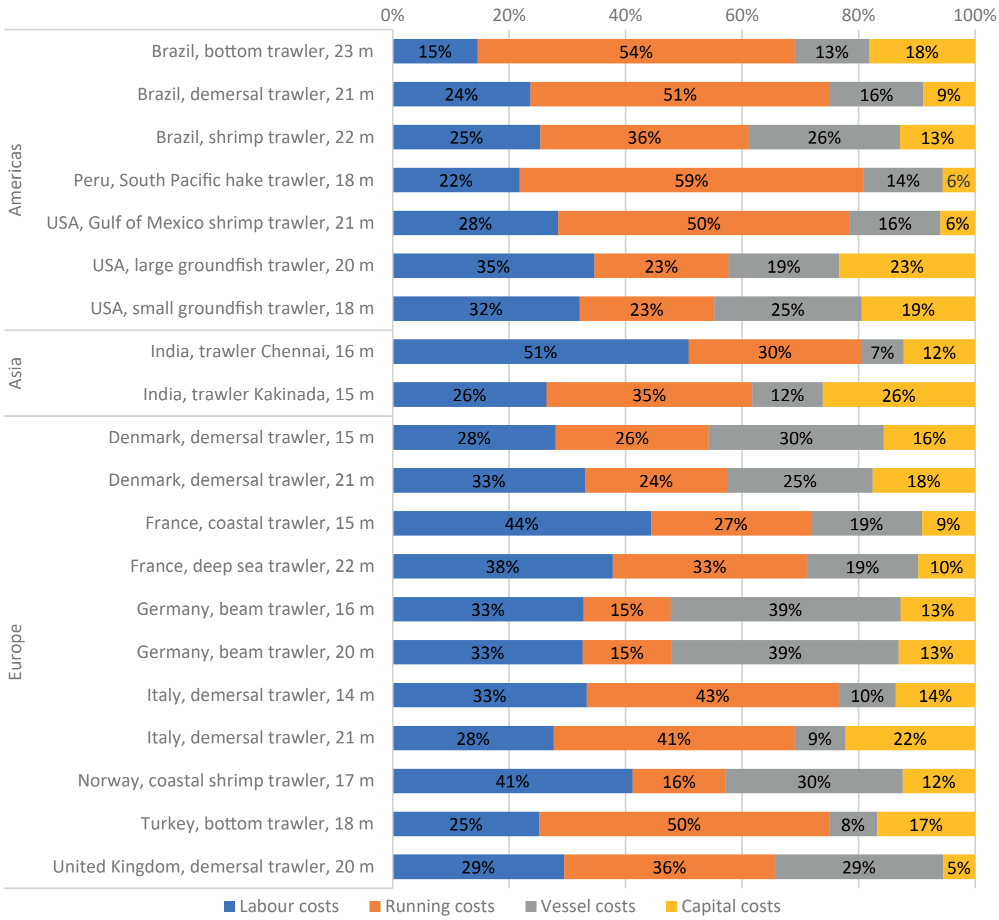
Small bottom trawler fleet segments comprised 20 percent of the segments reviewed, with 20 included in the present analysis: 2 from Asia, 11 from Europe, 4 from South America and 3 from North America (United States of America).

The total costs for these small bottom trawler segments varied widely, from USD 60 500 for the average small trawlers (15 m) of Kakinada in the Indian State of Andhra Pradesh, to USD 1.4 million for the average groundfish trawler (20 m) in the United States of America.

Running costs constituted the main cost item in half of the segments reviewed in this group. Labour costs was the largest in seven of the segments, while vessels costs was the highest in the remaining three segments. Capital costs was the smallest cost component in 65 percent of the segments (Figure 13).

The average small trawler segment (16 m) of Chennai showed the highest labour costs share within the total costs (51 percent) and the lowest vessel cost share (7 percent of total costs). Two European segments, the French coastal trawlers (15 m) and Norwegian shrimp trawlers (17 m) also showed high labour cost shares, at 44 percent and 41 percent of total costs respectively. All the other segments had labour cost shares less than 38 percent, with the lowest being for the average Brazilian bottom trawler (23 m), at 15 percent of total costs (Figure 13).

FIGURE 13
Cost structure for average vessels in the small (< 24 m) bottom trawler fleet segments (as a percentage of total costs)



Given the large differences between the specific fleet segments across regions and within countries, it is not possible to draw any major conclusions regarding cost component shares for small trawler segments. Overall, one may say that labour and running costs are the largest cost components for an average small bottom trawler vessel operating in Asia and Europe, with the average European trawler displaying significantly higher values in absolute terms (Figure 14). Conversely, running costs are the main component for homologous vessels in the Americas, particularly in the South American fleets (Figure 13).

Compared to the 2003 FAO fleet performance review (Tietze *et al*., 2005) the cost component distribution of the French demersal trawlers (12–18 m) has remained largely unchanged – albeit with lower capital cost shares fostering a slightly higher labour cost share – while total costs per year have increased by around 60 percent. In the Norwegian fleet segments, a general trend towards relatively lower labour costs is visible in the 2016 data compared to 2003 data, while capital and vessel costs have increased in relative terms. Similarly, in the German small demersal trawler segment (12–18 m), there seems to be a slight reduction in the labour cost component, while vessel costs increased. The total operational costs of an average trawler in this fleet fell from USD 175 000 in 2003 to around USD 155 000 in 2016; a reduction of USD 20 000. The German and Norwegian fleet segments present exemptions to the general rule of increasing operational and capital costs found in most fishing fleet segments in Europe.

In Asia, the size of mechanized trawlers in Chennai India, has remained largely the same over the last two decades, while the total annual costs of operating these vessels has increased from around USD 23 000 to USD 171 000 over the same period. Higher operating costs may be linked to declining CPUE figures, leading to the installation of larger engines to operate further offshore and thus higher fuel consumption. A significant part of the cost increase over time is attributed to inflation as well.

Compared to the 1999–2000 FAO fleet performance review (Tietze *et al*., 2001), running and vessels costs appear to have increased for small deep-sea trawlers in Peru: these now make up slightly larger shares, with reductions in labour and capital cost shares.

In general, vessel costs and particularly capital costs vary less than the other two cost components for these vessels across all regions. In absolute values, running costs tend to vary less than labour costs and do not appear to be linked to vessel size (length). The large dispersion observed can be attributed to the groundfish trawler (20 m) in the United States of America (Figure 14).

In relative terms, however, running costs showed the biggest dispersion, ranging from 20 percent to 67 percent of total costs. Capital costs varied the least out of all cost components for these segments across all regions, yet still ranged from 3 percent to 24 percent of total costs (Figure 14).

Figure 15 presents the average annual revenue (in USD per vessel) generated in the year of the survey for the small trawler (< 24 m) fleet segments reviewed.

FIGURE 14
Cost structure in absolute values (left) and as a share of total costs (right) for the small bottom trawler fleets (< 24 m) by region

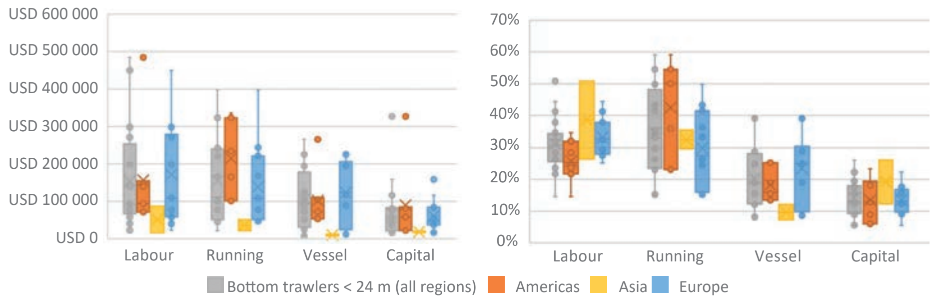
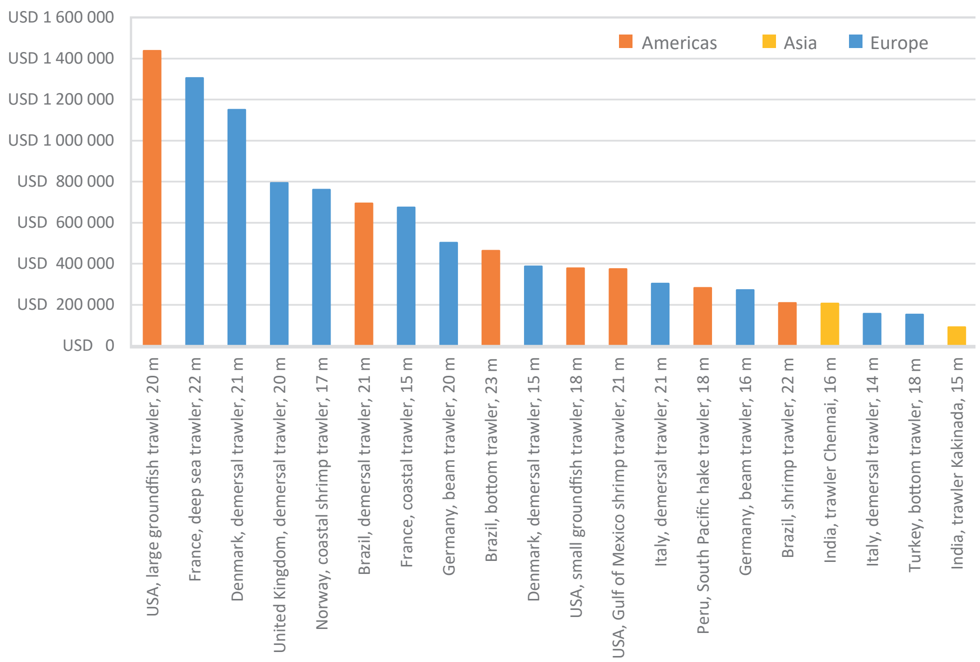


FIGURE 15
Average annual revenue (in USD) for the small bottom trawler fleets (< 24 m) by region



The average revenue obtained by these vessels ranged from almost USD 90 500 for the Kakinada trawler (15 m) segment to just over USD 1.4 million for the groundfish trawler (20 m) segment from the United States of America – the same two segments with the lowest and highest average total costs in the sample. The majority of the other small trawler segments generated an average revenue between USD 200 000 and USD 800 000. Only three segments presented ex-vessel values of over USD 1 million.

It is also not possible to draw any major conclusions regarding the revenues for small trawler segments. There is some indication that the top revenue-producing vessels have higher costs, i.e. costs tend to increase with revenue, or vice versa.

There appears to be no relationship between revenue and the size (length) of the vessel. For example, a French bottom trawler around 15 m in length obtains an average revenue of USD 674 000; this equates to seven Kakinada trawlers in India of the same length (USD 90 500). Similarly, a Danish trawler of 21 m generates an average revenue of USD 1.15 million, which is equal to the revenue obtained by three shrimp trawlers in the Gulf of Mexico (USD 373 500) and almost four Italian trawlers (USD 302 700) of the same length. Overall, the stocks in the North Sea, where the Danish fleets mainly operate, are in a better state than the stocks targeted by fleets in the Mediterranean Sea, which may partially explain the differences between the two European Union fleets.

The results also indicate that revenues vary greatly between fishing fleets targeting the same resources in different regions. For example, a Norwegian shrimp trawler (17 m) generates an average revenue of USD 761 000 – twice as much as a shrimp trawler (21 m) in the Gulf of Mexico (USD 373 500) and almost four times as much as a shrimp trawler (22 m) in Brazil (USD 208 000).

3.2 MEDIUM-SIZED (24–40 m) BOTTOM TRAWLERS

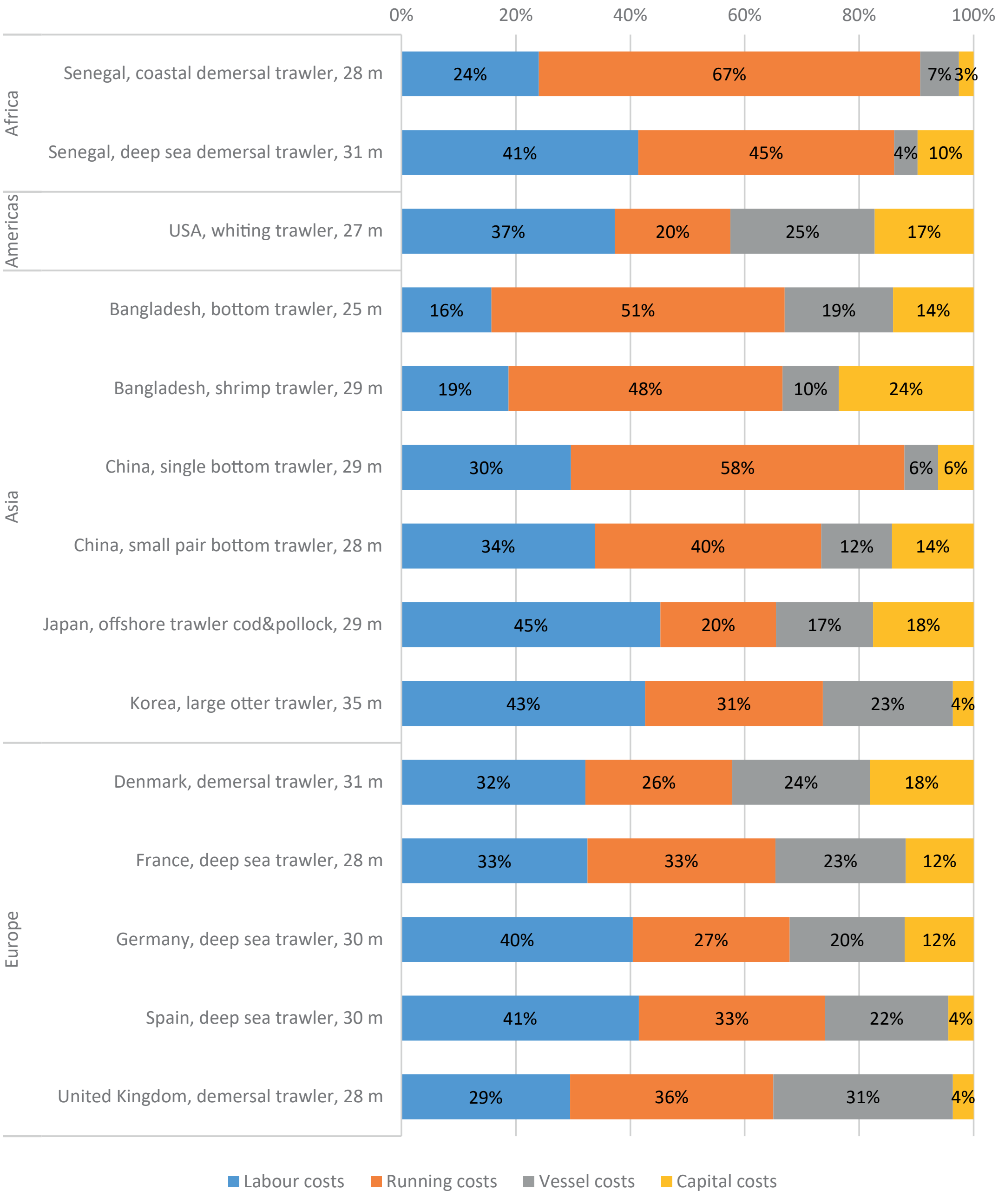
The analysis included 14 medium-sized bottom trawler segments: two from Africa, six from Asia, five from Europe and one from North America.

Annual total costs for the medium-sized bottom trawler segments varied extensively, ranging from less than USD 150 000 for the average Senegalese coastal demersal trawler (28 m) to USD 3.6 million for the average Japanese offshore trawler (29 m) targeting cod and pollock.

While there is some indication that total costs tend to increase with revenue (or vice versa), there appears to be no correlation with the size (length) of the vessel. While total costs increased with vessel length for the two Senegalese segments, there is no clear evidence of this in the fleet segments of other regions.

Running costs was the main cost item in 8 of the 14 segments reviewed in this group, and labour costs was the largest cost item in the other 6 segments. Vessels costs was the third-highest cost item in all but four segments, where capital costs were more significant.

FIGURE 16
Cost structure for average vessels in the medium-sized (24–40 m) bottom trawler fleet segments (as a percentage of total costs)



The average Japanese offshore trawler (29 m) targeting cod and pollock showed the highest proportion of labour costs to total costs (45 percent), followed by the large otter trawler from the Republic of Korea (43 percent), and the Spanish (30 m) and Senegalese (31 m) deep-sea trawler segments, both of which presented labour costs amounting to 41 percent of total costs. In the two segments from Bangladesh, labour costs accounted for less than 20 percent of the total, while all the other segments displayed an average labour cost share of 24–40 percent (Figure 16).

Running costs ranged from 20 percent to 67 percent of total costs, with the highest share observed for the average Senegalese coastal demersal trawler (28 m). The bottom trawler segments in Bangladesh (25 m) and China (29 m) also showed average running costs greater than 50 percent of total costs.

Vessel costs ranged from 4 percent of total costs in the Senegalese deep-sea demersal trawler (31 m) to 31 percent in the British demersal trawler (28 m) segment, which revealed one of the lowest capital cost shares (4 percent). Overall, capital costs ranged from 3 percent of total costs for the coastal demersal trawlers (28 m) in Senegal to 24 percent in the average Bangladeshi shrimp trawlers (Figure 16).

If the value of unpaid labour were also taken into account, the labour cost shares would be higher in several of the European Union segments. For example, labour costs would increase to 40 percent for the Danish medium-sized demersal trawler when including the value of unpaid labour.

For the French deep-sea trawlers, labour and running costs were broadly similar. While labour costs were also the most important cost component for the Spanish deep-sea trawlers, the annual depreciation costs were low compared to the value of physical capital and, as a consequence, the capital costs reported for these segments were minimal.

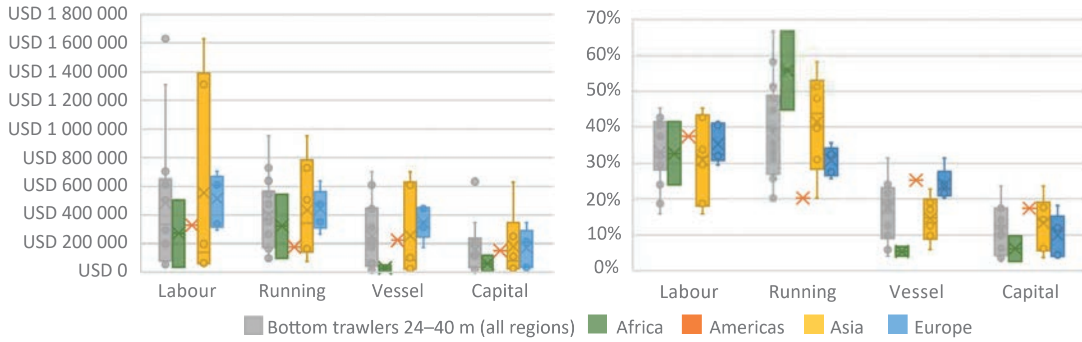
As with the other fleet segments from Japan, the medium-sized bottom trawler segment showed a rather balanced cost distribution between categories, while also revealing the highest labour cost share out of the Japanese segments included in the survey. Labour costs were the largest cost component for all the main fishing fleet segments in the Republic of Korea. In contrast with most fleet segments, labour costs were relatively low for the two trawler segments in Bangladesh. Generally, high fuel costs were the main driver for the large share of running costs for trawlers (shrimp, midwater and bottom) in Bangladesh, with expenses on ice and commissions for the sale of fish also contributing to this item. Operational costs varied greatly for the two Senegalese trawler segments, yet in both cases more than 50 percent of their operating costs was spent on fuel. The labour costs were slightly lower for smaller vessels in Senegal, largely reflecting lower crew numbers.

Given the large differences between the fleet segments across regions and within countries, it was not possible to draw any major conclusions regarding the cost component shares for medium-sized bottom trawler segments. Overall, one may conclude that labour and running costs are the two main cost components for the majority of these vessels, with running costs appearing more pronounced for fleets in Africa and Asia, whereas labour costs are more significant in Europe and the United States of America. However, vessels costs do exceed running costs for the trawlers of the United States of America, largely due to costs incurred for the purchase of fishing rights and insurance premium payments.

Compared to the 1999–2000 FAO review (Tietze *et al*., 2001), most European Union segments have seen significant reductions in the share of capital costs. This is particularly true for the German and Spanish trawlers, entailing a higher labour cost share for German trawlers and higher running and vessel cost shares for the Spanish trawlers.

As absolute values, running costs tend to vary less than labour costs and do not appear to be linked to vessel size (length). In relative terms, however, running costs have the biggest dispersion, ranging from 20 percent to 67 percent of total costs.

FIGURE 17
Cost structure in absolute values (left) and as a share of total costs (right) for the medium-sized bottom trawler fleets (24–40 m) by region

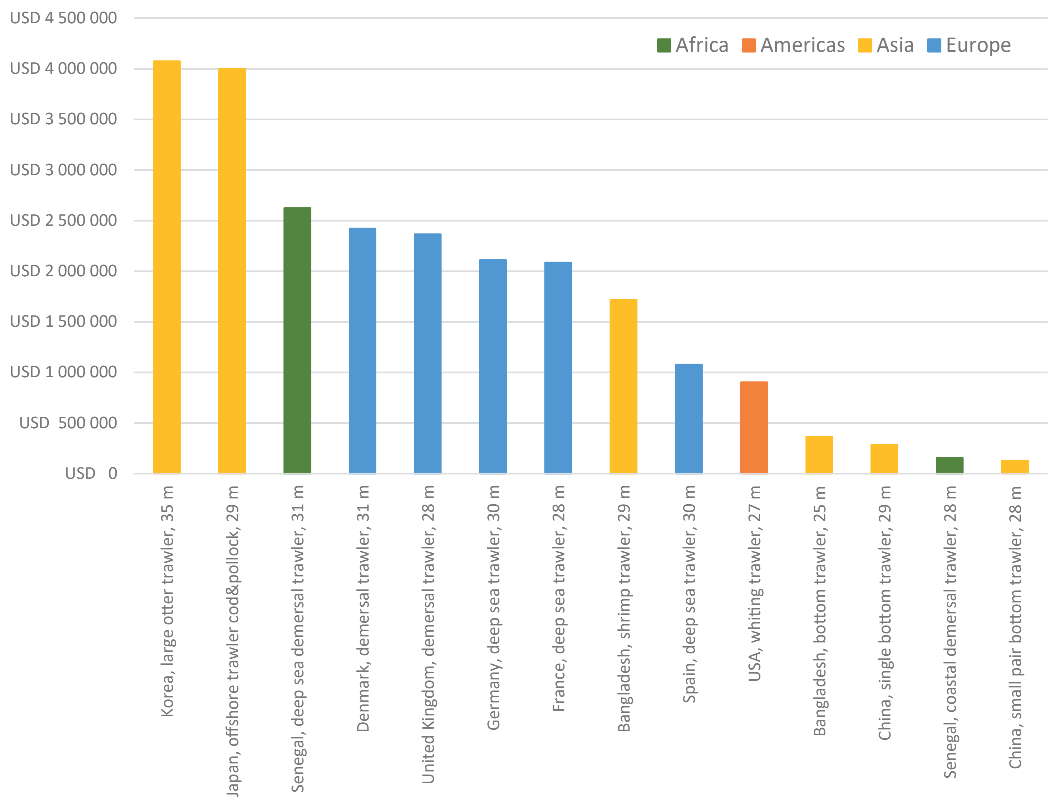


Capital costs varied the least out of all cost components for these segments across all regions, yet still ranged from 3 percent to 24 percent of total costs (Figure 17).

Figure 18 presents the annual average revenue (in USD per vessel) generated in the year of the survey for the medium-sized (24–40 m) bottom trawler segments.

The revenue obtained by vessels in this group ranged from USD 129 000 in the Chinese small pair bottom trawler (28 m) segment, to around USD 4 million in the case of the Republic of Korea large otter trawler (35 m) and Japanese offshore trawler (29 m) segments. A further five segments presented ex-vessel values of over USD 2 million and another two segments over USD 1 million. The remaining five segments generated average revenues of between USD 129 000 and USD 900 000.

FIGURE 18
Average annual revenue for medium-sized bottom trawler fleets (24–40 m) by region



As with total costs, there appears to be no relation between revenue and vessel size. For example, the Japanese offshore trawler segment targeting cod and pollock yielded an average revenue of USD 4 million; this equates to 14 single boat bottom trawlers in China of the same length (29 m) targeting hairtail and mantis shrimp. Similarly, the average 28 m British demersal trawlers generated an average revenue over USD 2 million, equal to the revenue obtained by about 15 Senegalese coastal demersal trawlers (USD 156 000) or 16 Chinese small pair bottom trawlers (USD 129 000) of the same length. Another example is that of a Senegalese deep-sea trawler (31 m) generating revenues about 17 times those of an average Senegalese coastal trawler, the average length of which will be just 3 m shorter. Other factors such as a vessel's technical features, its fishing effort, targeted species and market channels therefore have a greater impact on revenue generation.

3.3 LARGE (> 40 m) BOTTOM TRAWLERS

Seven large bottom trawler fleet segments were included in the analysis: one from South Africa (Africa), one from Chile (South America), one from China (Asia) and four from Europe.

As seen with the other bottom trawler categories, there was a substantial variation in total costs for large bottom trawlers, ranging from around USD 704 000 for the average Chinese large pair bottom trawler (46 m) to USD 14 million for the average Norwegian demersal cod trawler (60 m). Average total costs for the remaining large trawler fleet segments, with lengths of 46–66 m, ranged from USD 2.5 million to USD 6.5 million.

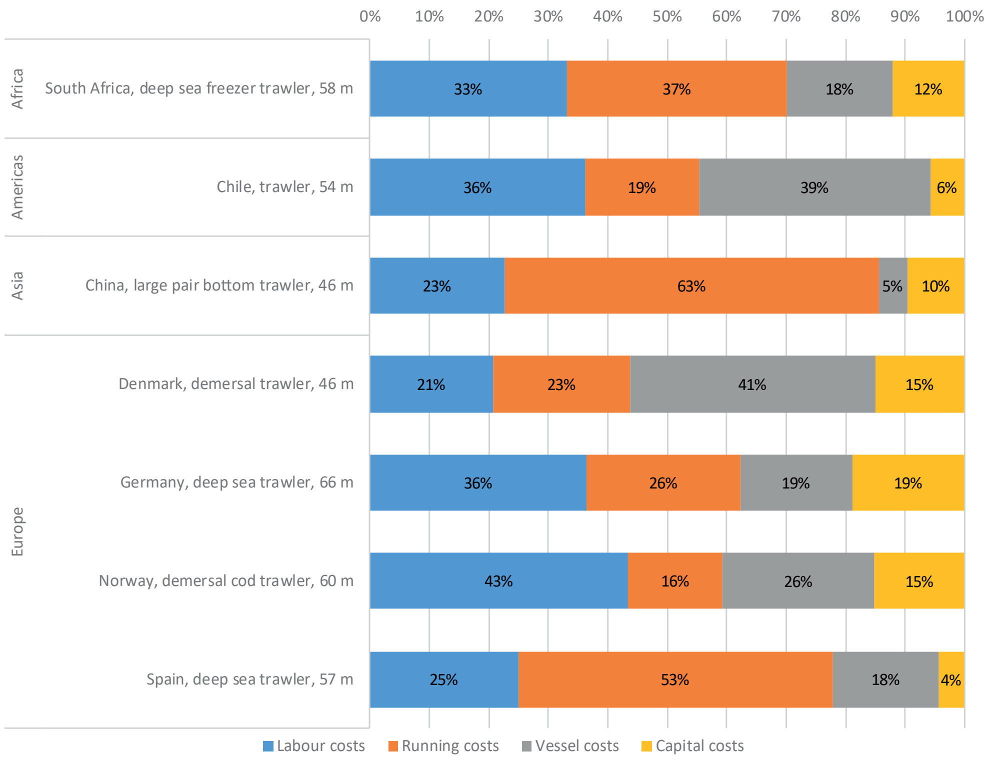
Total costs for the large trawlers tended to increase with vessel length, though without any clear pattern discernible in the cost structure. Running costs was the main cost item in three of the seven segments, while labour costs was the largest cost item in two segments, with vessel costs the largest component in the remaining two.

The average Norwegian demersal trawler (60 m) targeting cod showed the highest proportion of labour to total costs (43 percent), followed by the German deep-sea trawler (66 m) and Chilean trawler (54 m) segments, both of which revealed a labour cost share of 36 percent. The lowest labour cost share was 21 percent of total costs for fleet segments in this category (Figure 19).

Running costs ranged from 16 percent to 63 percent of total costs, with the highest share observed for the average large pair bottom trawler (46 m) segment in China. High running costs for vessels in the Chinese trawler segment were mostly due to fuel costs, which amounted to 97 percent of running costs. The Spanish deep-sea trawler (57 m) also showed a high running cost share (53 percent), while all other segments had running costs of lower than 37 percent of total costs. The relatively high running costs for the Spanish large demersal trawlers were largely due to high variable costs and less because of energy costs. For the typical South African deep-sea freezer trawlers, fuel (34 percent) and labour (47 percent) costs also made up the greatest portion of operating costs.

Vessel costs ranged from 5 percent of total costs in the Chinese pair bottom trawlers to 41 percent in the Danish demersal trawler (46 m) segment. The latter's high share is largely the result of costs related to the leasing of quota and/or fishing rights. Vessel costs were the largest cost component as a proportion of total costs in four of the five Chilean fleet segments included in the survey.

FIGURE 19
Cost structure for average vessels in the large (> 40 m) bottom trawler fleet segments (as a percentage of total costs)



Capital costs ranged from 4 percent of total costs for the Spanish deep-sea trawlers (57 m) to 19 percent for the German deep-sea trawler (66 m). Annual depreciation costs for the Spanish fleets were low compared to the value of physical capital and, as a consequence, the capital costs reported for these segments were minimal (Figure 19).

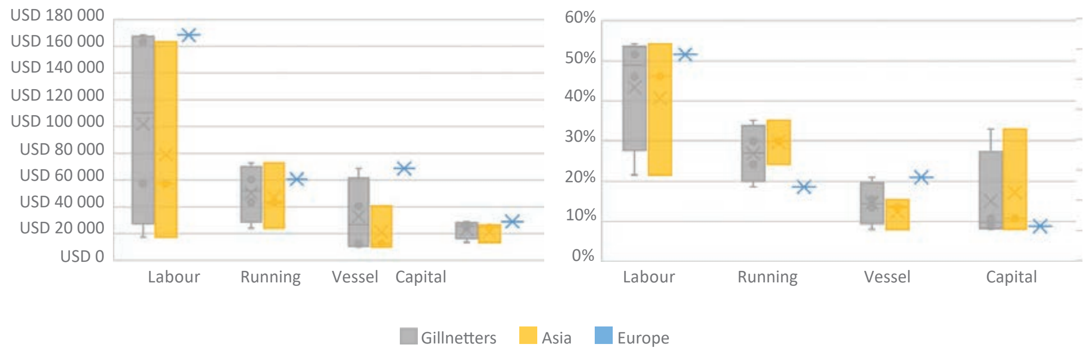
Overall, labour and running costs constitute the main cost components for the majority of the large bottom trawler fleet segments analysed; when combined, these account for around 60 percent or more of total costs. The Chilean and Danish segments provided two exceptions, as both showed above-average vessel cost shares.

When compared to the 2003 FAO fleet performance review (Tietze *et al.*, 2005), Norwegian fishing fleet segments reveal a general trend towards a relative reduction in labour costs, when comparing data from 2016 and 2003. Conversely, there has been a relative increase in vessel and capital costs. In fact, between 2007 and 2016 the average Norwegian demersal cod trawler fleet appears to have seen their total costs double (+102 percent) within a decade.

In the Chinese fleet segments, the average vessel size has grown tremendously. Bottom pair trawlers now have an average length of 43 m, when the largest vessel in this segment in 2000 was 28 m. The tonnage and engine power of typical vessels in these segments has also doubled or tripled (see Chapter 2.2.), thus increasing the annual operational costs of these vessels. The total costs of the large pair bottom trawlers increased from USD 81 000 to USD 704 000 in 2018.[11] Over the same period,

[11] A comparison between absolute annual USD costs of the fleet segments featured in the 1999–2000 and 2003 fleet performance reviews and those of the current review is of limited relevance, insofar as inflation and exchange rate fluctuations have not been taken into account. The comparison is only included here and in the following sections for illustrative purposes.

FIGURE 20
Cost structure in absolute values (left) and as a share of total costs (right) for the large bottom trawler fleets (> 40 m) by region



the relative expenditure on labour as a percentage of total costs fell from 32 percent to 23 percent, which was possible due to technological improvements and innovations. The relative reduction in labour costs enabled fishing enterprises to compensate for the increase in running and vessel costs.

As absolute values, labour costs varied by almost USD 6 million, from the lowest average costs per vessel (USD 159 390) reported for the Chinese trawler segment, and the highest average costs (USD 6.1 million) for the Norwegian cod trawlers. The dispersion of other cost components was more limited, but nonetheless remained high, at USD 2 million between the lowest and highest averages reported for running and capital costs, and USD 3.6 million for vessels costs.

As a share of total costs, average running costs for the large trawler segments varied the most (by 47 percent), followed by vessel costs (36 percent), labour costs (23 percent) and capital costs (15 percent) (Figure 20).

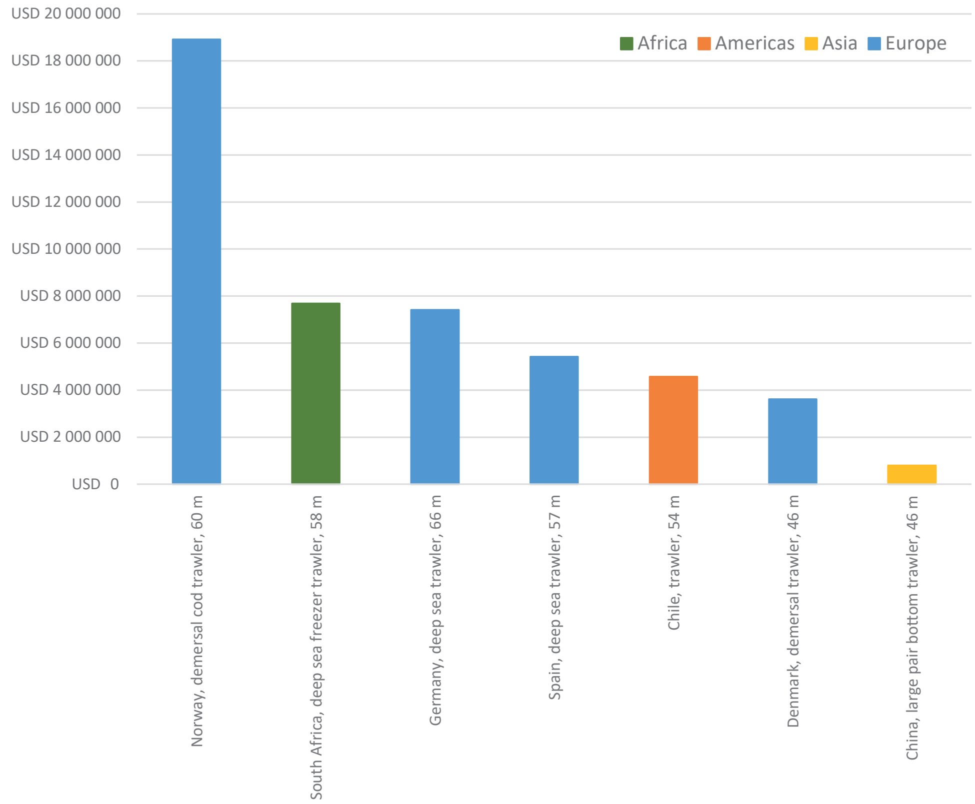
Figure 21 shows the average annual revenue (in USD per vessel) generated in the year of the survey for the large (> 40 m) bottom trawler segments.

As seen with total costs, revenues for these large bottom trawler fleet segments varied extensively, although they tended to increase with revenue. The average revenue obtained by these vessels ranged from USD 800 000 in the Chinese large pair bottom trawler (46 m) segment, to almost USD 19 million in the Norwegian demersal trawlers (60 m) targeting cod – i.e. a difference of USD 18.2 million per vessel. For the other five segments, the difference in average revenue was less at USD 4 million, ranging from USD 3.6 million for Danish demersal trawlers (46 m) to USD 7.7 million for South African deep-sea freezer trawlers (58 m).

The main source of revenue for deep-sea trawlers originates in the sale of the fish, which will vary substantially from vessel to vessel, and largely depends on the quota allocated, value addition, bycatch and other market-related factors. For example, the hake fishery in South Africa is MSC-certified, with most of the catch exported, and the price is highly dependent on exchange rates.

As with the small and medium-sized bottom trawlers, the considerable variation among large bottom trawler fleets in terms of vessel size (average length of 46–66 m), fishing regions, target species and stock status, makes a comparison between them of limited value. However, as with total costs, revenue appears to be linked to vessel size, increasing with vessel length. One exception is the Norwegian cod trawlers, which

FIGURE 21
Average annual revenue for the large bottom trawler fleets (> 40 m) by region



generate more than twice as much revenue as the average German deep-sea trawlers that are 6 m larger. Similarly, the average Danish demersal trawler presented revenues four-and-a-half times those of an average large pair trawler in China of the same length (Figure 21).

3.4 PELAGIC TRAWLERS

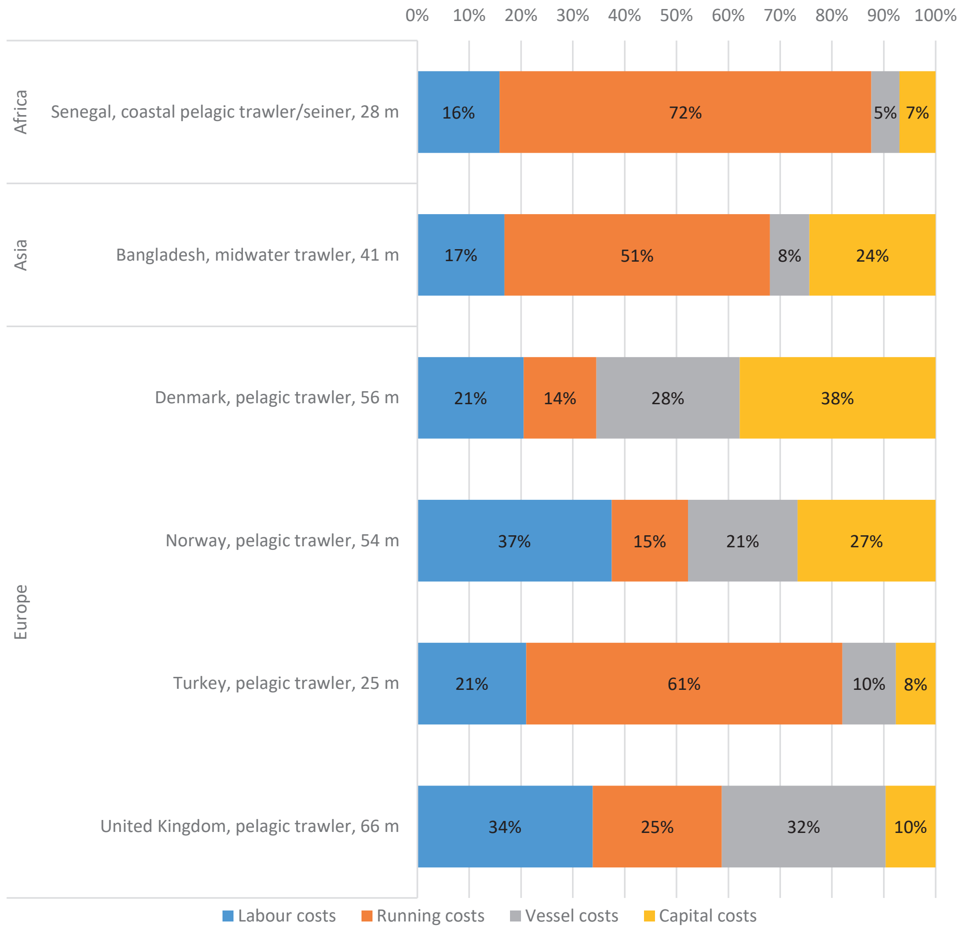
Six pelagic trawler fleet segments are included in this review: one from Senegal, one from Bangladesh and four from Europe.

Total costs for the pelagic trawlers varied substantially, from around USD 204 000 for the average Turkish trawler (25 m) to almost USD 7.7 million for the average British trawler (66 m). For the remaining pelagic trawler fleets, with average lengths of between 28 m and 56 m, total costs ranged from USD 586 300 to USD 5.9 million.

Overall, total costs for the pelagic trawlers tended to increase with vessel length and revenue. However, no clear pattern emerged with regard to cost distribution. Running costs was the main cost item in half of the fleet segments in this category; labour costs was the largest cost item in two out of the six segments, and capital costs was the largest component in the Danish pelagic trawler segment only.

The average Norwegian pelagic trawler (54 m) showed the highest proportion of labour to total costs (37 percent), followed by the British pelagic trawler (34 percent). The other two European segments, the Danish (56 m) and Turkish (25 m) pelagic trawlers both revealed a 21 percent labour cost share. The Bangladeshi (41 m) and Senegalese (28 m) pelagic trawlers showed the lowest labour cost shares, at 17 percent and 16 percent respectively (Figure 22).

FIGURE 22
Cost structure for average vessels in the pelagic trawler fleet segments (as a percentage of total costs)



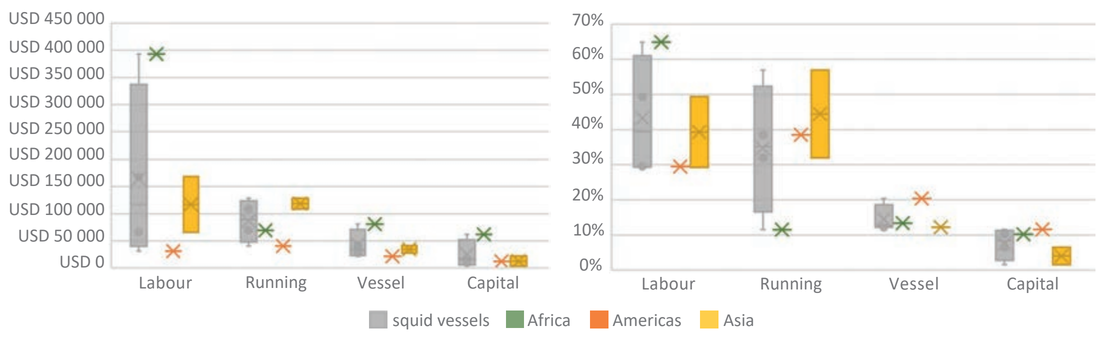
While the Senegalese pelagic trawlers had the lowest labour cost share, they showed the highest running cost share, at 72 percent. The Turkish pelagic trawlers showed the second-highest share with 61 percent, followed by the Bangladeshi segment (51 percent). The other European segments had running costs to total costs of between 14 percent (Denmark) and 25 percent (United Kingdom of Great Britain and Northern Ireland).

Vessel costs ranged from 5 percent of total costs for the Senegalese pelagic trawlers, to 32 percent for the British pelagic trawlers (66 m) segment; the latter's high vessel cost share is partly due to costs related to the leasing of quota and other fishing rights.

Capital costs ranged from 8 percent of total costs for the average Turkish pelagic trawler (25 m) to 38 percent for the Danish pelagic trawler (Figure 22). The latter fleet segment is relatively young, with an average age of 22 years.

Overall, one may conclude that running costs are the main cost component for average pelagic trawler vessels in Africa, Asia and Turkey, while labour costs constitute the main component for average pelagic trawlers in the European Union and Norway, with the exception of the Danish segment where capital costs are the dominant component (almost entirely made up of depreciation costs). For the Danish, British and Norwegian pelagic trawler fleet segments, vessel costs are higher than running costs: this is largely due to costs related to the leasing/rental of quota and fishing rights.

FIGURE 23
Cost structure in USD and share of total costs (as a percentage) for pelagic trawler fleets by region



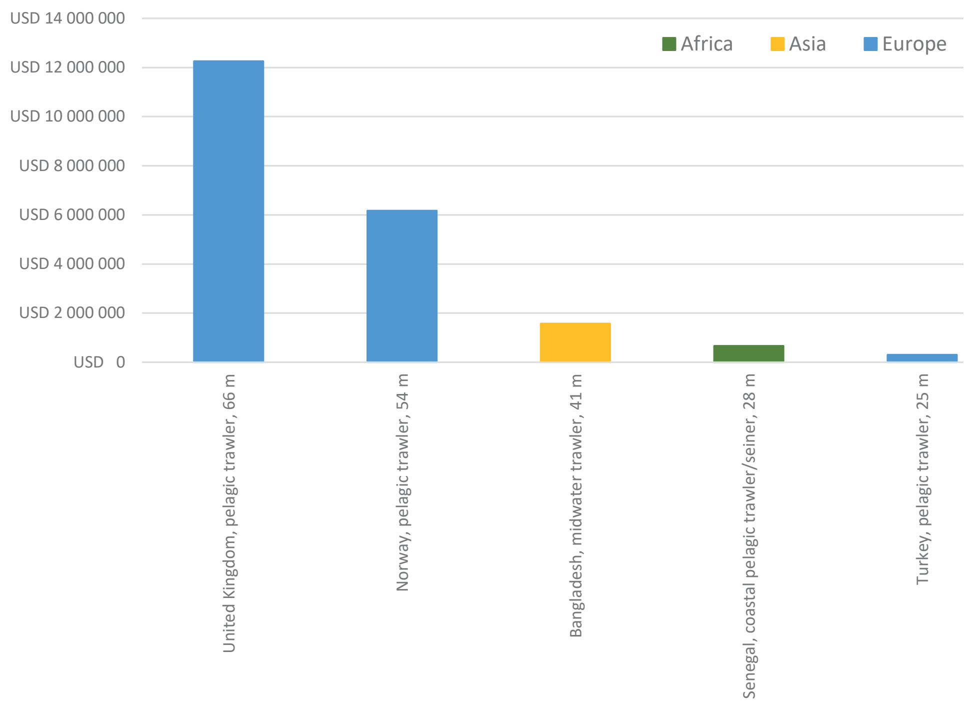
Compared to the 2003 FAO fleet performance review, a general trend towards a relative decrease in labour costs can be observed in the Norwegian fleet segments, while vessel and capital costs have seen a relative increase. In fact, between 2007 and 2016 the average Norwegian pelagic trawler saw total costs increase by 114 percent within a decade.

As absolute values, labour costs varied by over USD 2.55 million, from the lowest average costs per vessel (USD 42 900) reported for the Turkish pelagic trawlers (25 m) to the highest average costs (USD 2.6 million) for the British pelagic trawlers (66 m). The dispersion of other cost components was similar, ranging from USD 1.8 million for running costs and USD 2.4 million for vessel costs (Figure 23).

As a share of total costs, average running costs for the large trawler segments varied the most (by 58 percent), followed by capital costs (30 percent), vessel costs (26 percent) and labour costs (22 percent).

Figure 24 presents the average annual revenue in the year of the survey for the pelagic trawler segments reviewed.

FIGURE 24
Average annual revenue for pelagic trawler fleet segments by region



The average revenue obtained by the pelagic trawlers analysed ranged from USD 305 500 for the Turkish pelagic trawler (25 m) segment, to almost USD 12.2 million in the British pelagic trawlers (66 m) – i.e. a difference of over USD 11.9 million.

As with total costs, average revenue increased with vessel length for the segments analysed. However, the considerable variation among the pelagic trawler fleets covered in this report in terms of vessel size (average length ranging from 25 m to 66 m), fishing region, species targeted and their stock status, makes a comparison between them of limited value.

3.5 PURSE SEINERS

The analysis included 19 purse seiner fleet segments: 3 from Chile, 1 from Peru, 7 from Asia and 8 from Europe.

Total annual costs for the purse seiner segments included varied substantially, from around USD 80 000 for the average artisanal purse seiner (18 m) in Chile, to almost USD 13.5 million for the average Spanish purse seiner (87 m). Total costs for the remaining purse seiner segments, with average lengths of between 14 m and 78 m, ranged from USD 204 400 to USD 12.1 million.

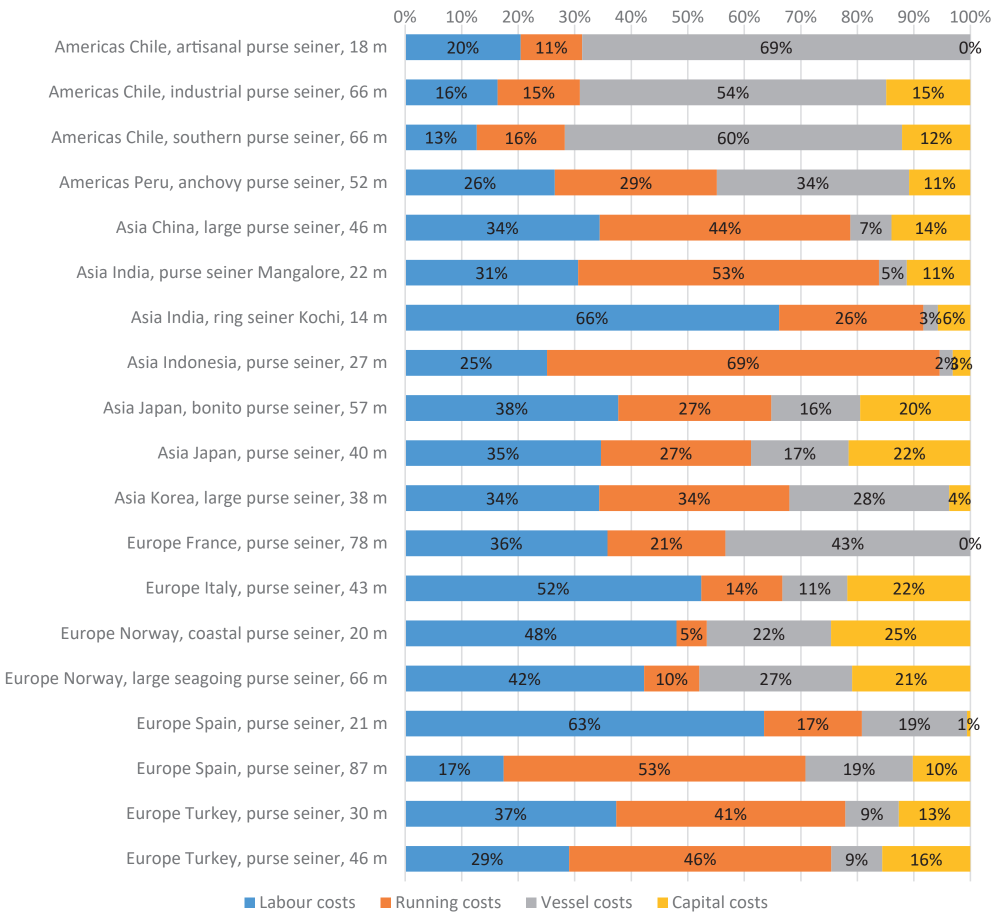
There is no apparent relation between vessel size (average length) and total costs for the purse seine segments as a whole. Considered by region, this remains largely true for the Asian fleet segments, while there is some evidence for the European and South American segments, where larger vessels tend to have higher costs. In addition, no clear pattern emerged in the cost structure for these segments. Vessel costs was the main cost item in all four of the South American purse seiner segments and the French purse seiner (78 m) segment; labour costs constituted the largest cost item in about half of the Asian and European segments, and running costs were the main cost component in three Asian and three European segments.

Labour costs ranged from 13 percent of total costs for an average 66 m purse seiner in Chile, to 66 percent of total costs for an average ring seiner (14 m) in Kochi, India. The relatively high labour costs in the ring seiner fleet of Kochi, India, is a result of a well-organized labour market where crew receive 50–60 percent of the catch share as well as the labour-intensive nature of the ring seine fishery.

Running costs ranged from 5 percent of total costs for the average Norwegian coastal purse seiner (20 m), to 69 percent of total costs for the average Indonesian seiner (27 m), which in turn showed the lowest vessel cost share (2 percent of total costs). Running costs were the largest cost component for purse seine vessels in Mangalore, India, accounting for 53 percent of the total costs in 2018 – this was due to high fuel costs that increased operating costs by up to 58 percent. Fuel expenses likewise contributed to 70–80 percent of the running costs of purse seiners in Indonesia.

For the Chilean purse seiner segments, the vessel costs share was high (from 54 percent to 69 percent), because of significant fishing rights and quota purchase expenses. The French and Peruvian segments also showed high vessels costs (43 percent and 34 percent of total costs), while vessels costs accounted for less than 28 percent of total costs for the remaining segments. Vessel costs were relatively high for the French purse seiner segment due in most part to substantial repair and maintenance costs, as the leasing of quota are not included in vessel costs and fishing rights are non-tradable in France. For the large purse seiners of the Republic of Korea, more than half of vessel costs related to vessel repair and maintenance, and another 25 percent to the repair and maintenance of fishing gears. Costs relating to the sale of fish can be quite substantial for ring seiners in India, with auction commissions ranging from one to two percent of gross revenue.

FIGURE 25
Cost structure for average vessels in the purse seiner fleet segments
(as a percentage of total costs)

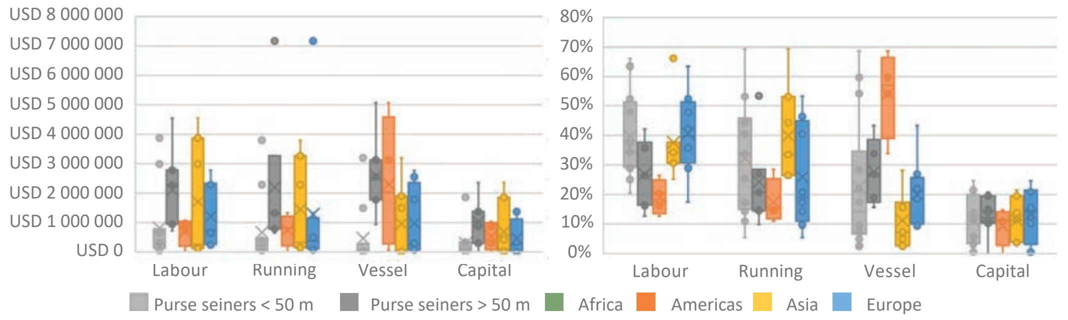


The Norwegian coastal purse seiner (20 m) showed the highest capital cost share at 25 percent of total costs. The higher capital costs (in relative terms) for the sardine- and mackerel-targeting Norwegian purse seiners were largely due to higher vessel depreciation. For the purse seiners of the Republic of Korea, interest payments were the largest contributor to the capital costs component. The opportunity cost of capital for the French fleet segment was not available, which may in turn slightly overvalue some of the other cost components. Similarly, contrary to the large purse seine fleet (> 40 m), the annual depreciation costs for the smaller Spanish purse seine fleet (21 m) remained low compared to the value of physical capital. As a consequence, the capital costs reported for these segments were minimal (Figure 25).

Given the large differences between the specific fleet segments within countries and across regions, it is not possible to draw any major conclusions regarding cost component shares for the purse seine segments. Overall, one may conclude that labour and running costs are the two main cost components for the majority of segments; when combined, these account for over 50 percent of total costs, with the exception of the Chilean segments (which all showed above average vessel cost shares).

As absolute values, labour costs varied by almost USD 4.5 million between the purse seiner fleet segments covered in this review, while running costs varied by USD 7.1 million, vessel costs by USD 5 million and capital costs by USD 2.4 million.

FIGURE 26
Cost structure in absolute values (left) and as a share of total costs (right) for the purse seiner fleets by region

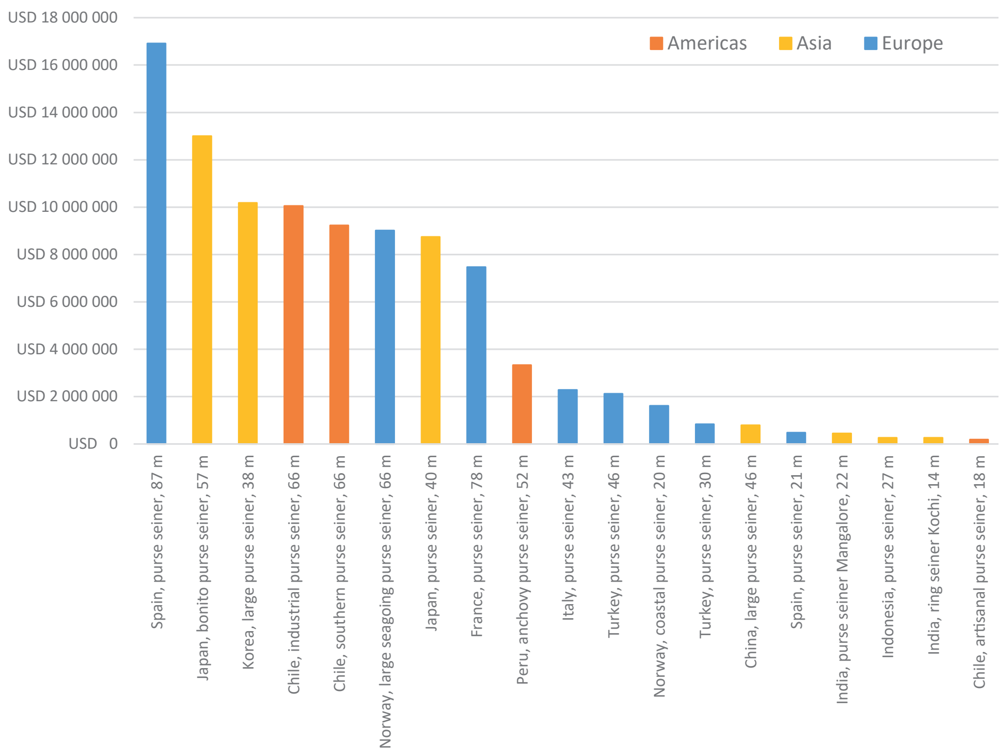


In absolute terms the large dispersion, particularly with respect to running costs, can be attributed to the Spanish purse seiner fleet, which operates predominately in distant fishing grounds in the south Atlantic and Indian oceans, thereby contributing to high energy costs. In relative terms, the large dispersions in labour and running costs can be attributed to the fleets in India and Indonesia, while this can be attributed to the Chilean purse seiners in the case of vessel costs. Similar to the other fishing gear categories, capital costs vary the least (Figure 26).

Figure 27 shows the average annual revenue in the year of the survey for the purse seiner segments.

Revenue generated by average vessels ranged from USD 182 000 in the Chilean artisanal purse seine (18 m) segment, to just over USD 16.9 million in the Spanish distant-water purse seine (87 m) segment targeting large tuna and tuna-like species. A

FIGURE 27
Average annual revenue (in USD) of purse seiner fleets by region



further four segments presented revenues of over USD 10 million, while revenues were less than USD 1 million for seven segments. The remaining eight purse seine segments revealed average revenues of between USD 1.6 million and USD 9.2 million.

As with total costs, there generally appears to be no clear relationship between vessel length and revenue for the purse seiner fleet segments reviewed. Nevertheless, for the industrial purse seiners in Chile targeting jack mackerel, sardine and anchovy, it was observed that annual revenues and operating costs tend to increase with vessel size. Revenue appears to be somewhat related to the main stocks targeted, with vessels targeting large pelagic species such as tuna generating higher revenues than vessels targeting small pelagics such as mackerel, sardine and anchovy. For example, the three purse seine segments with an average length of 66 m had similar revenues (of between USD 9 million and USD 10 million), but they were lower than the two purse seiner segments targeting tuna stocks. While one of these segments had an average vessel length of 87 m, the other segment was significantly smaller, at 57 m.

The large purse seine vessels of the Republic of Korea made around USD 9.4 million in average revenue from the sale of fish, while receiving additional income from financial investments by fishing cooperatives. Vessel owners who are members of a cooperative receive an annual dividend on their investments in the cooperative and its business. This income was over USD 800 000 in 2017, contributing about 8 percent to the total earnings of these vessels. Similarly, the sale of fish landed contributes 90 percent to the revenue generated by the Japanese bonito purse seiners: in 2017, for example, a bonito purse seiner earned an average of USD 13 million, which included USD 11.7 million from fish and USD 1.3 million from other business conducted by the fishing company. While these Japanese vessels have an advantage in terms of scale, the fish quality assurance measures are also much stricter compared to other Asian fleets, which has a tremendous impact on the ex-vessel values of the tunas caught.

Compared to the 2003 FAO fleet performance review, it can be concluded that the cost component distribution of the Peruvian large industrial purse seine vessels experienced little change. The total annual costs of an average large industrial purse seiner increased by USD 890 000 compared to 2003; a figure which is mainly down to cost increases of 50–60 percent in labour and running costs, in addition to a 100 percent increase in vessel (owner) costs. However, capital costs seem to have diminished by about 20 percent in dollar terms, which may be due to vessels being generally older now, with relatively lower depreciation costs and interest payments.

The Norwegian large seagoing purse seine fleet saw only a 28 percent increase in total costs between 2007 and 2016, as running costs in this fleet segment were actually reduced. Moreover, the Norwegian coastal purse seine vessels showed an 18 percent decrease in total costs (from nearly USD 1.2 million to USD 1 million) compared to 2007; this was primarily due to lower vessel costs and running costs, while labour costs remained largely the same.

The cost component distribution of Indian purse seiners has shifted slightly in terms of a higher share being spent on running the vessels – 53 percent in 2018 compared with 38 percent in 2002/2003. The relative expenditures for labour remained stable at 31 percent. However, total annual costs increased nearly eightfold over this period, from USD 49 000 in 2003 to USD 383 000 in 2018.

For the Indonesian purse seine vessels surveyed in 2000 and 2018, the average vessel length has remained around 27 m, with a gross registered tonnage of 120 (GRT). Meanwhile, total annual costs of a vessel of this type increased from USD 53 000 in 2000 to USD 204 000 in 2018, an increase which can be largely attributed to inflation. Labour costs made up 51 percent of total costs in 2000. The labour cost component was reduced to 25 percent in 2018, yet when taken as an absolute value, labour costs have doubled since 2000, while the costs of most other components has increased even faster than labour costs.

3.6 LONGLINERS

Ten longliner fleet segments were included in the analysis, distributed across all regions: one from Africa, two from Asia, two from Europe, four from South America and one from North America (United States of America).

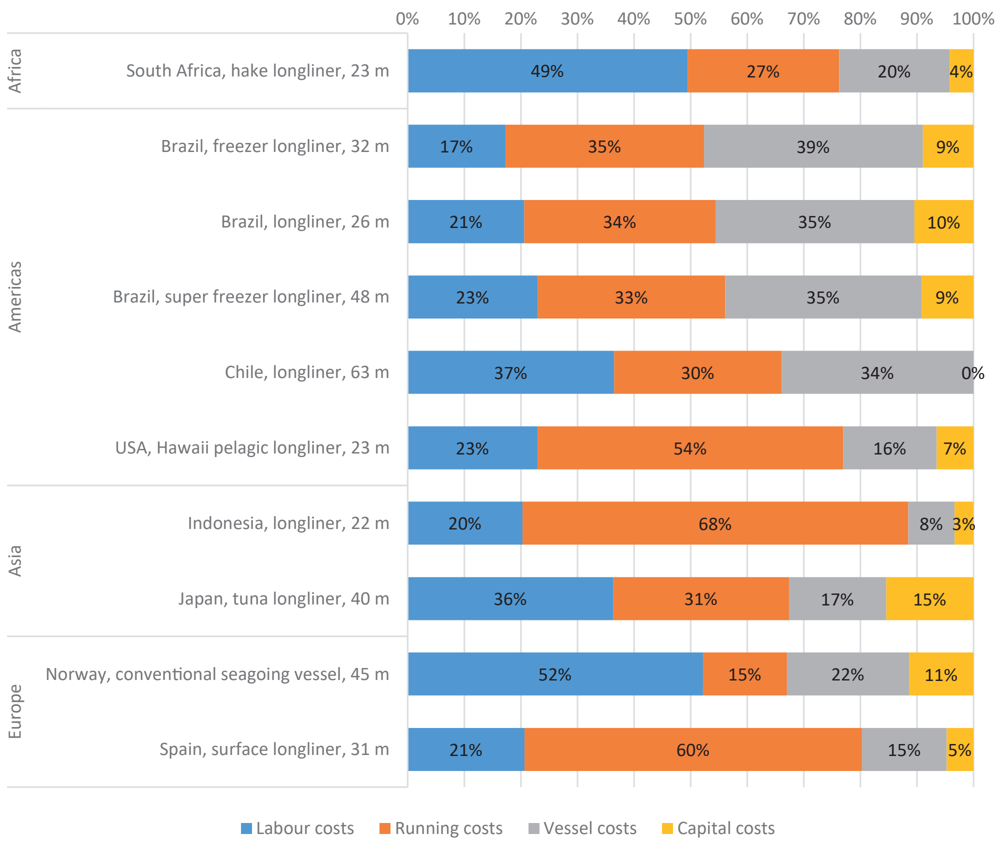
Total costs for the longliner segments in the review varied widely, ranging from less than USD 145 000 for the average Indonesian (22 m) longliner, to USD 8.5 million for the average Norwegian conventional seagoing 45 m vessel. Total costs for the remaining longliner fleets, with average lengths of between 23 m and 63 m, ranged from USD 293 000 to USD 5.5 million.

As a whole, there is no clear evidence that total costs, or any of the costs components, increase with vessel size (length). Within countries and/or regions, however, total costs tend to increase with vessel length. This was observed in the Asian, European and South American fleet segments analysed.

Furthermore, while no clear pattern emerged in the cost structure– apart from capital costs being the smallest cost component in all the longliner segments analysed – the three longliner segments in Brazil follow a very similar structure. Labour costs was the main cost component in four out of ten segments; running costs was the main cost item in three segments, and vessels costs was the highest in the remaining three segments (Figure 28).

The Norwegian conventional seagoing (45 m) vessels showed the highest labour costs compared to total costs (52 percent), followed by the South African longliners targeting hake (49 percent). As with all the Norwegian fleet segments analysed in this review, longline vessels also showed labour costs as the main cost component. The

FIGURE 28
Cost structure for average vessels in the longline fleet segments (as a percentage of total costs)



relatively low labour cost share for the Hawaii longline segment may be explained by the fact that around 39 percent of these vessels are operated by the vessel owners: while hired captains are paid a share of either the gross or net revenue in this fishery, the opportunity cost of an owner's time as captain is not included in the labour share.

The average Indonesian longliner (22 m) segment showed the highest proportion of running costs to total costs (68 percent), followed by the Spanish surface longline (31 m) segment (60 percent) and the Hawaiian pelagic longline (23 m) segment (54 percent). Running costs were particularly high for the Spanish surface longliners (31 m) due to high variable costs, and less because of energy costs.

Vessel costs ranged from 8 percent of total costs for the average Indonesian longliner (22 m) to 39 percent in the Brazilian freezer longline (32 m) fleet segment, which showed the lowest labour cost share (17 percent) (Figure 28).

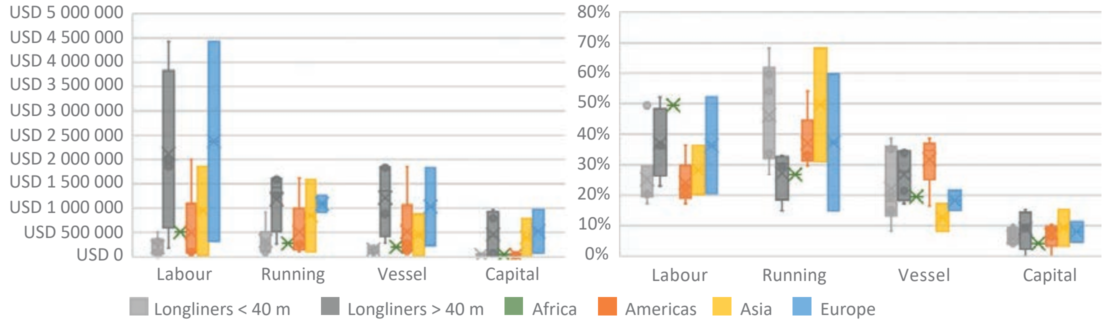
The South African demersal (hake) longliners spend large parts of their days fishing underway while hauling lines. Operational costs of these vessels are dominated by crew wages and fuel expenditure, ranging approximately from 60 to 70 percent. Commissions are paid on catch to the crew. Bait and ice are the next highest cost items within the running costs component: taken together, they are estimated at around 16 percent of the total operating costs.

Given the large differences between the specific fleet segments within countries and across regions, it is not possible to draw any major conclusions regarding cost component shares for the longline segments. Overall, one may conclude that labour and running costs are the two main cost components for the majority of the longliner segments: when combined, they make up 65 percent or more of total costs in all the segments reviewed except for the Brazilian segments, where vessel costs surpass running costs. A common factor among all the segments analysed is that capital costs make up the smallest cost component, at less than 15 percent in all cases.

Compared to the 1999–2000 FAO fleet performance review, the cost component distribution of the Indonesian longliner (26 m) has remained similar, with running costs comprising the bulk of costs, followed by labour – labour costs have increased (from 14 percent to 20 percent), while capital costs have decreased (from 15 percent to 3 percent). The Indonesian tuna longline vessels surveyed in 2018 were smaller (average length of 22 m) than those surveyed in 2000 (average length of 26 m), although the engine power had increased by approximately 100 kW, fostering an overall increase in total costs over the same period, from USD 80 000 in 2000 to USD 145 000 in 2018.

When compared to the 2003 FAO fleet performance review (Tietze *et al*., 2005), the cost component distribution of the South African hake longline segment has changed considerably, with labour costs now comprising the most important cost component (up from 16 percent in 2002). This largely comes as a result of lower running costs in 2018, which had been the main cost component in 2003, at 76 percent of total costs. The Norwegian conventional seagoing vessel fleet saw a 100 percent increase in total costs between 2007 and 2016.

FIGURE 29
Cost structure for average vessels in the longliner fleets (as a percentage of total costs)

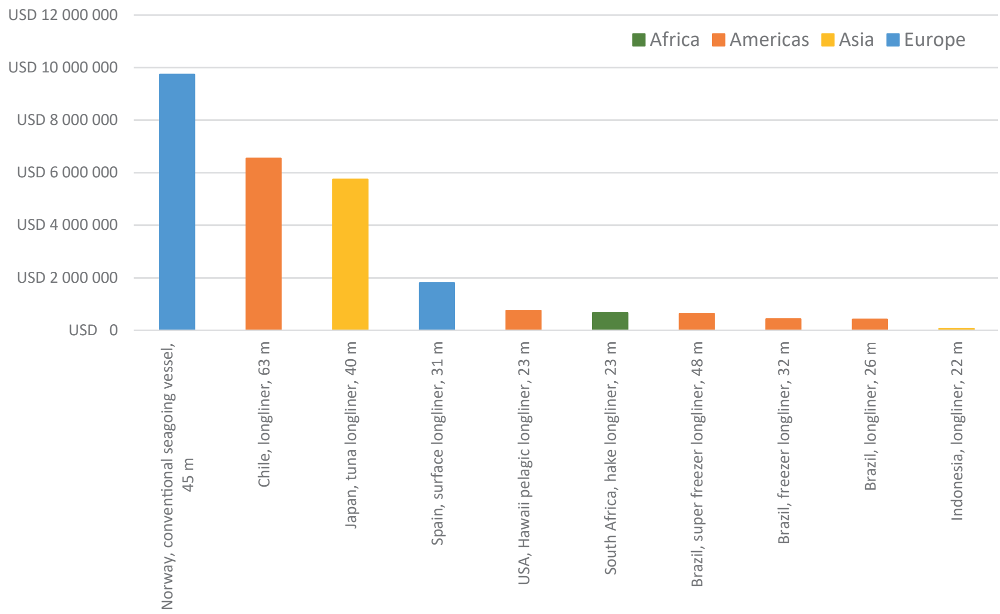


As absolute values, labour costs show the greatest variation across all regions, in particular for the European and longliner segments of > 40 m. In general, costs in USD appear to vary with average vessel size (length), though there is substantially less variation in the < 40 m segments (Figure 29).

Figure 30 presents the average annual revenue in the year of the survey for the longline segments reviewed.

The average revenue obtained by vessels in the longliner fleets segments analysed ranged from USD 72 800 in the Indonesian longline (22 m) segment, to USD 9.7 million in the Norwegian (45 m) segment. Five out of the ten segments analysed generated revenues greater than USD 1.8 million. There appears to be no link between revenue and vessel size. It is also not clear how or to what extent the main type of fishery or targeted species group (e.g. pelagic, demersal) has an impact on annual revenue. On the other hand, market factors may play an important role. For example, when the highly selective hake-directed longline fishery in South Africa first started in the 1990s, it processed fresh whole fish for direct export to Europe. Prices at that time were high and exchange rates favourable. Currently, the fishery still lands predominantly "wet fish" on ice, but now in the headed and gutted form. Given the high running costs of these vessels, small quotas and high labour costs, the average earnings from the sale of landed fish by the surveyed

FIGURE 30
Average annual revenue (in USD) of longline fleet segments by region



vessels in this fleet segment amounted to just USD 663 000 in 2017, indicating that an average vessel in this fleet was in a loss-making position in that year. Profitability was significantly higher when whole wet fish (referred to as Prime Quality or PQ hake) was exported.

3.7 GILLNETTERS

Four gillnetter fleet segments were included in the analysis: three in Asia and one in Europe.

Annual total costs for the gillnetter segments varied between USD 79 300 for an average gillnetter (19 m) in Chennai, India and USD 326 500 for an average French gillnetter (12 m), indicating that there is no evidence that total costs increase with vessel size (length). Similarly, no clear pattern emerged in the cost structure for the gillnetter segments analysed, except that all segments apart from the Chennai gillnetter showed labour costs as the largest cost component, and capital costs as the smallest. In contrast, capital costs were found to be the main cost component within the total costs reported by gillnetters in Chennai, India (Figure 19).

The gillnetters in China showed the highest proportion of labour costs to total costs (54 percent), followed by the French gillnetters (52 percent) and the Bangladeshi gillnetters (46 percent). The average gillnetter in Bangladesh showed the highest running costs as percentage of total costs (35 percent) and the French gillnetters showed the highest vessel cost share (21 percent) (Figure 19).

Labour costs were the largest cost component in the gillnetter fleet segments in Bangladesh, contrasting with the relatively low (16–19 percent) labour cost share for the other Bangladeshi fleet segments included in this review. This is mainly due to the revenue-sharing system used by gillnetters, whereas trawlers provide fixed wages with some labour incentives. There is an increasing tendency towards having salaried employees on gillnetters, especially in the Chittagong region. However, in other regions of Bangladesh the revenue sharing system is still in vogue.

Given the large differences between the specific fleet segments within countries and across regions, it is not possible to draw any major conclusions regarding the cost component shares for the gillnetter segments. Overall, one may conclude that labour and running costs are the two main cost components for the majority of gillnetter segments.

Compared to previous FAO fleet performance reviews published in 2001 and 2005, the cost component distribution of the French gillnetters (10–12 m) has remained largely unchanged: labour costs continue to be the main cost component, followed

FIGURE 31
Cost structure for average vessels in the gillnetter fleet segments (as a percentage of total costs)

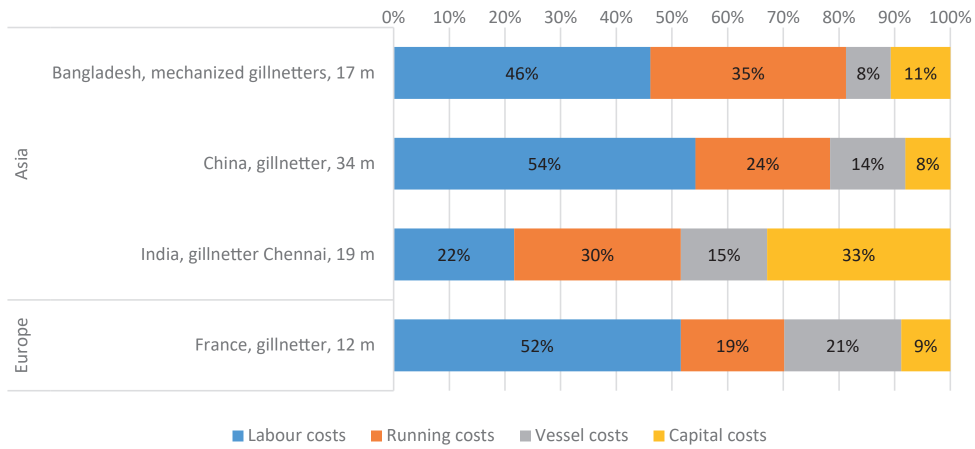
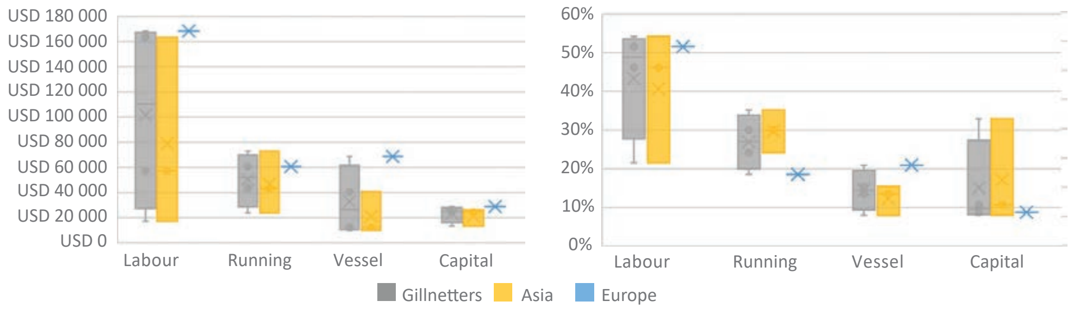


FIGURE 32
Cost structure in absolute values (left) and as a share of total costs (right) for gillnetter fleets by region



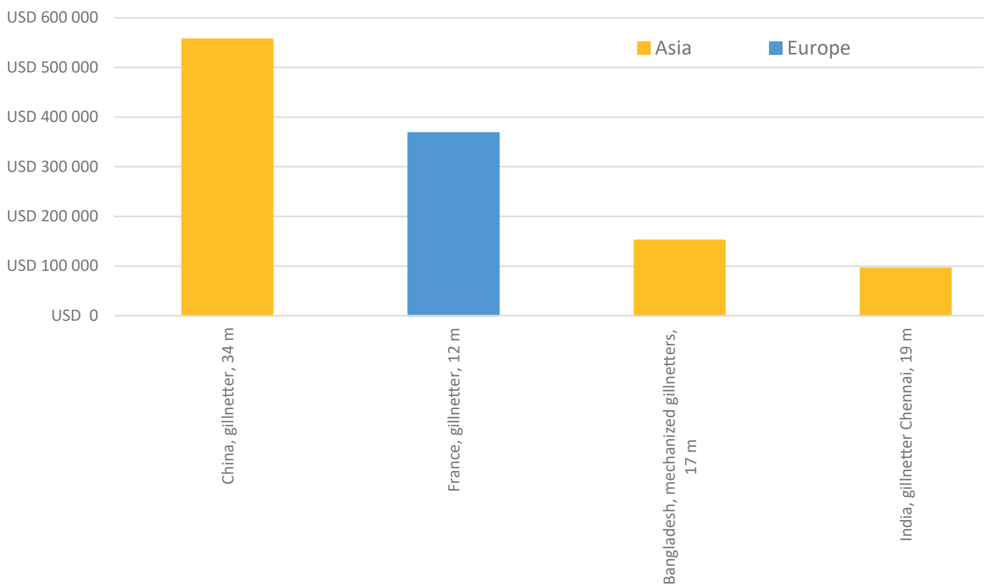
by vessel costs and, thirdly, running costs. However, in 2016 the same gillnetter spent nearly USD 100 000 more on labour costs per annum than in 2003 (an increase from USD 69 000 to USD 168 000). In 2003, the total costs of a French gillnetter amounted to around USD 141 000; by 2016 this had doubled to USD 298 000.

As absolute values, all cost components tend to vary less than labour costs, which were found to be the highest in the French fleet segment, even though the vessels in this segment were smaller on average (Figure 32).

Figure 33 presents the average annual revenue in the year of the survey for the gillnetter segments reviewed.

The average revenue obtained by these vessels ranged from USD 95 400 in the gillnetter (19 m) segment in Chennai, to USD 557 000 for a gillnetter (34 m) in China. The average 12 m gillnetter in France generated around USD 368 000 of revenue, followed by the average 17 m gillnetter in Bangladesh (USD 151 800); this indicated that revenue is not linked to vessel length. It is more likely that other vessel characteristics and fishery related factors have a greater impact on revenue, namely: fishing grounds, species targeted and their stock status, in addition to market conditions and the quality of seafood products landed.

FIGURE 33
Average annual revenue (in USD) of gillnetter fleet segments by region



3.8 SQUID JIGGERS

Four squid jigger fleet segments from Indonesia, Republic of Korea, Peru and South Africa were included in the analysis. Annual total costs for these vessels ranged from USD 105 700 for the average jumbo squid vessel (10 m) in Peru, to USD 605 700 for the average squid jigger (21 m) in South Africa. The average offshore jigger (27 m) in the Republic of Korea reported almost half the total costs of the jigger in South Africa, indicating that costs are not related to vessel size (length), at least between regions.

Similarly, no clear pattern emerged in the cost structure for the squid jigger segments analysed. For the South African and Republic of Korea segments, labour costs was the largest cost component, at 65 percent and 49 percent of total costs respectively, while segments in Indonesia revealed running costs to be the main cost component (57 percent). Running costs were also the largest cost component for the jumbo squid handline fishing vessels in Peru, with fuel and ice amounting to 35 percent and 28 percent of the running costs of these vessels respectively. The labour costs for the eight-person crew on an average jumbo squid vessel amounted to around 30 percent of their total costs. Capital costs were the smallest cost component for all segments (Figure 34).

Total costs for an average South African squid jigger surveyed amounted to USD 606 000 in 2018, including 77 percent operating costs (consisting of running and labour costs) and 23 percent vessel owner costs. Within the operating costs the main cost component was crew salaries (79 percent): this reflects the nature of the fishery, which is commission-based and does demand much fuel usage as fishing grounds are located nearshore. Compared to the 2003 FAO fleet performance review (Tietze *et al*., 2005), labour costs increased substantially, moving from the lowest cost component to the highest in 2018.

Offshore jiggers in the Republic of Korea reported relatively higher vessel depreciation costs. Compared to the 2003 review, the total annual costs of an average offshore jigging vessel in the Republic of Korea increased from USD 239 000 to USD 341 000.

Given the large differences between the specific fleet segments within countries and across regions, it is not possible to draw any major conclusions regarding cost component shares for the squid jigger vessels. Overall, one may say that labour and running costs are the two main cost components for the majority of the segments; when combined, these account for over 65 percent of total costs.

FIGURE 34
Cost structure for average vessels in the squid jigger fleet segments (as a percentage of total costs)

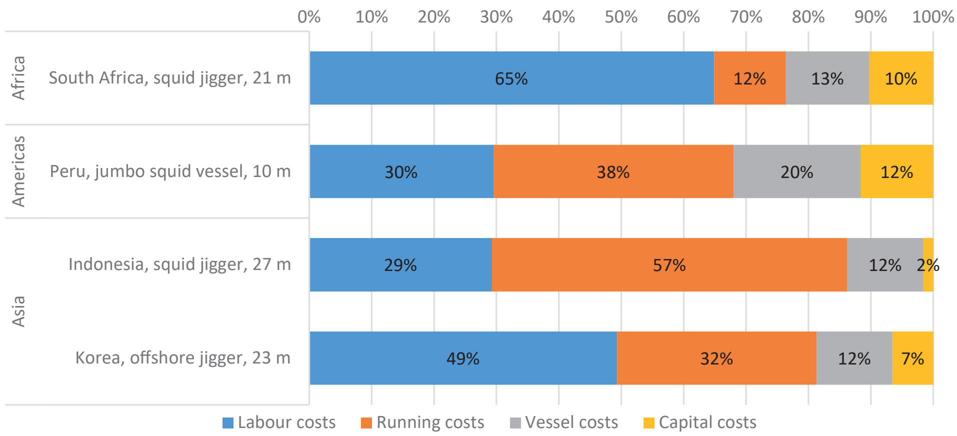
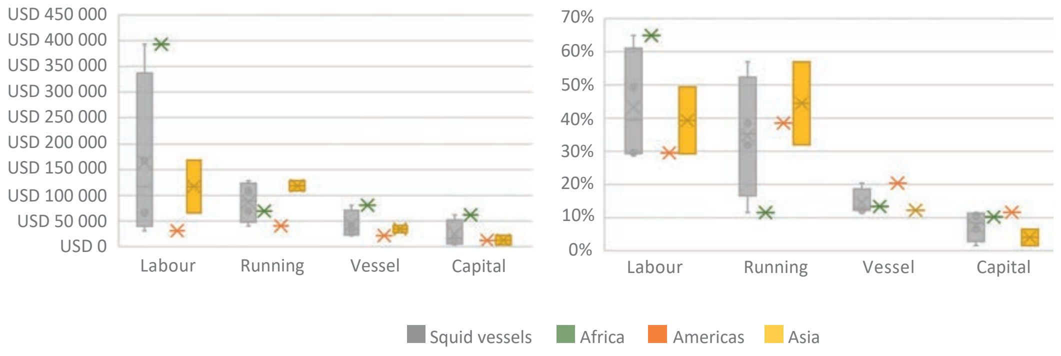


FIGURE 35
Cost structure in absolute values (left) and as a share of total costs (right) for squid jigger fleets by region

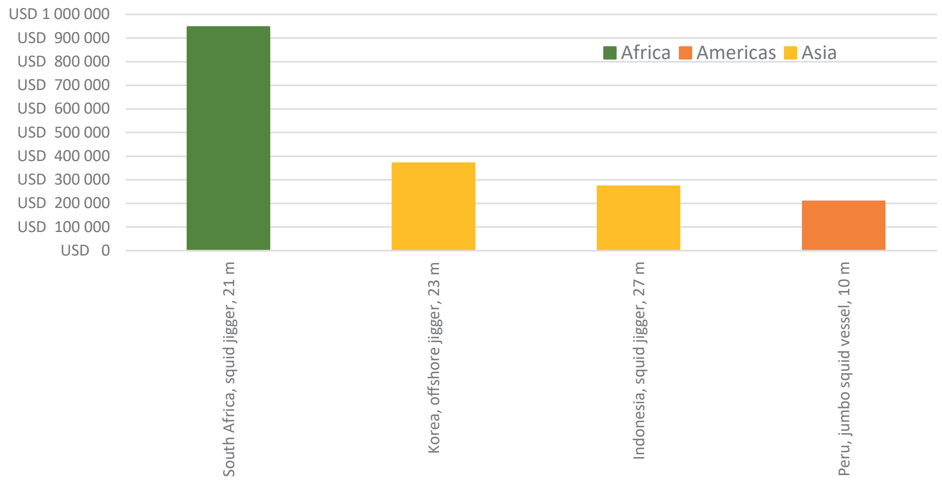


As absolute values, all cost components tend to vary less than labour costs. For example, the average squid jigger (21 m) in South Africa spends more than double on labour costs than the average Republic of Korea (23 m) offshore jigger, six times as much as the average Indonesian (27 m) jigger, and 12 times more than the average jumbo squid jigger (10 m) in Peru (Figure 35).

Figure 36 presents the average annual revenue in the year of the survey for the squid vessel segments reviewed.

The average revenue obtained by these vessels ranged from USD 209 200 for the jumbo squid segment in Peru to USD 946 500 for the South African squid jigger segment. The average 21 m squid vessel in South Africa generated a revenue 2.5 times higher than an average 23 m offshore jigger from the Republic of Korean, and 3.5 times higher than the average 27 m jigger in Indonesia – again indicating that vessel size (length) is not related to higher earnings or costs. Annual revenues are likely related to other vessel characteristics (instead of length) and fishery-specific factors, namely: fishing grounds, species targeted and their stock status, market flows and value chains. For example, in the South African jigger segment, revenues vary greatly as the resource availability is seasonal and fluctuates significantly from year to year. The fishery lands a very small volume of fresh squid, while most of the catch is frozen and packed at sea for direct export to Europe upon arrival in port.

FIGURE 36
Average annual revenue (in USD) of squid jiggers by region



3.9 OTHER FISHING VESSEL SEGMENTS

This global review also covers 14 fleet segments using a variety of other gear types, including passive gears such as pots and traps and stownets, to active gears such as dredges. The vessels ranged from 6 m to 39 m in average length.

While it makes little sense to compare these segments, it is useful to emphasize that for the majority of these segments, labour costs and running costs are the two main cost components: when combined, they make up 50 percent or more of the total costs in all but two of the segments included in this review.

Labour costs accounted for more than 50 percent of total costs in the deep-sea crab trapper segment in Senegal, the full-time United States of America scallop dredger fleet segment and the stownetters in China, as well as the Norwegian coastal vessel (13 m) and French handliner (8 m) segments. Labour costs would also be in this range for the European Union segments analysed had the value of unpaid labour been reflected in the labour cost component. The value of unpaid labour is in fact rather high in most of the small-scale fisheries of the European Union (often even higher than paid labour). For example, if the value of unpaid labour were included, labour costs for the Danish segment (7 m) would increase to 47 percent of total costs. Similarly, if unpaid labour in the Italian and German segments had been included in the calculation, total labour costs would have accounted for half the total annual costs, while the British small-scale pots and traps fishing fleet segment would have shown labour costs of about 25 percent above those presented. The value of unpaid labour was not reported for the French segment.

In Indonesia, direct labour costs were very low for pole-and-line fishing vessels, even though there are many fishers on-board. The reason for the low labour costs is that labour is remunerated by a share of the value of the catch, not a transfer of money:

FIGURE 37
Cost structure for average vessels in other fishing vessel segments (as a percentage of total costs)

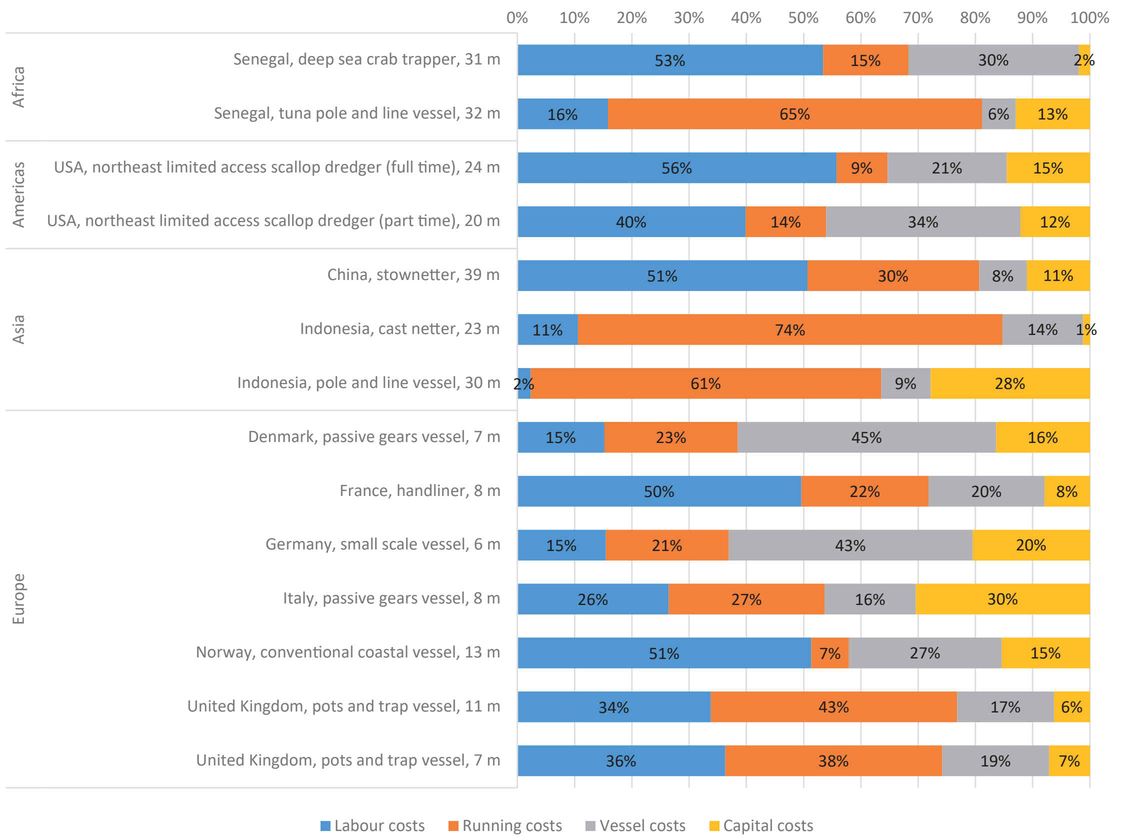
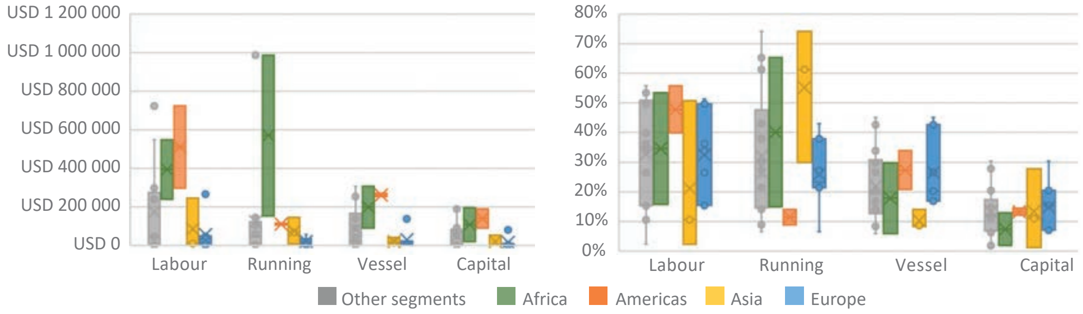


FIGURE 38
Cost structure in absolute values (left) and as a share of total costs (right) for other fishing vessel segments by region

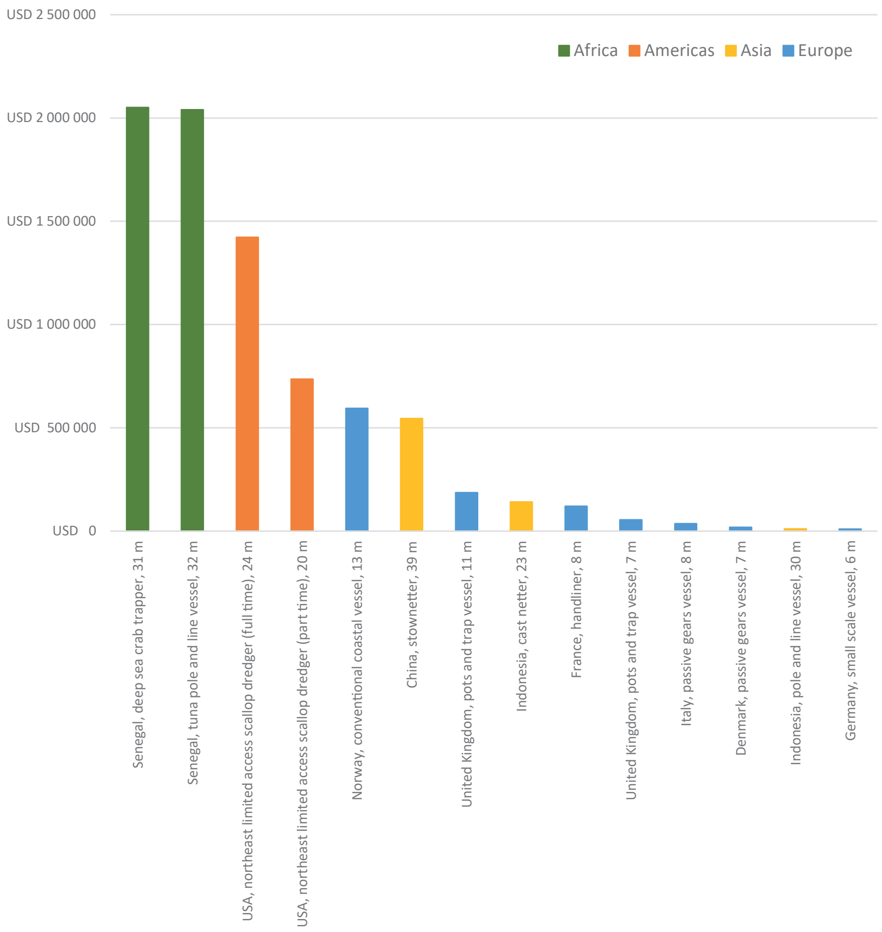


fishers get a share of the catch and do not get paid anything else (see the national report of Indonesia in Van Anrooy *et al*., 2020 for more details).

Compared to previous FAO reviews (Tietze *et al*., 2001; Tietze *et al*., 2005), labour costs continue to account for the main cost component in the Norwegian conventional coastal vessels, at over 50 percent of total costs, followed by vessel costs and then running costs. Capital costs seem to have increased over the years, taking up a slightly larger share than previously reported.

Figure 39 presents the average annual revenue in the year of the survey for the other vessel segments reviewed.

FIGURE 39
Average annual revenue (in USD) of other fishing vessel segments by region



The average revenue obtained by these vessels ranged widely, from USD 10 300 for the German small-scale (6 m) segment, to USD 2.0 million for the Senegalese deep-sea crab trapper (31 m) segment. Due to the large variety of fishing activities and vessel sizes in this group comparisons cannot be made, but it is noteworthy that the Indonesian pole-and-line segment with an average length of 30 m yielded the second-lowest annual revenue (USD 10 650), well below the average revenue of USD 2 million generated by Senegalese tuna pole-and-line segment of similar length (32 m) (Figure 39).

3.10 COSTS AND REVENUES COMPARISON ACROSS FISHING GEARS AND REGION

The costs and revenues of 98 fleet segments from 20 countries across five regions were analysed by main fishing gear category. Revenues and costs largely determine the profitability and economic performance of fishing operations. Vessel revenue chiefly depends on the target species, quantities caught and ex-vessel prices, which again depend on (local) market factors and seasonal fluctuations, among other factors.

The review shows that there is significant variation between the fishing fleet segments in terms of vessel characteristics (such as age, length, tonnage and engine power), fishing technology, areas of operation and target species. These differences in turn lead to large variations in the revenue generated from the sale of seafood products, as well as in the cost structure of the vessels. This is evident not only between continents and main fishing gears, but also within countries and fleet segments. Making a comprehensive comparison between them is therefore very challenging and, in many cases, of limited value.

Based on the findings in this chapter, one may conclude that higher earning vessels tend to have higher total costs, or vice versa. Some of the largest vessels (in length) were among the top earners and spenders, but this was not generally found to be the case. In fact, revenue and total costs do not appear to be closely linked to vessel size (length). For example, a vessel in the French purse seine fleet, with an average length of 78 m (the second-largest segment in terms of length covered in this review) generated revenues lower than those of 11 of the smaller segments (ranging from 38 m to 66 m), and incurred lower costs than 9 smaller segments, most of which were made up of purse seiners and trawlers, several within the same region.

While the majority of the fleet segments consisting of vessels under 30 m (average length) presented revenues and total costs below USD 2 million. Segments with larger vessels showed revenues and costs varying substantially by average length, even within the same fishing gear category and region. As seen previously, there are several examples of vessels of similar lengths, in the same gear category, with very different levels of revenues and total costs, as well as cost structures.

In some cases, revenues and costs appear to be linked to the main fishing gear or fishery (and target species). With the exception of the demersal trawler and conventional seagoing vessel in Norway, the top producers were predominately purse seiners and pelagic trawlers, targeting large pelagics.

Overall, the highest revenues were made by vessels in the distant-water tuna purse seine, pelagic trawler and deep-sea trawler fleet segments, from Europe, Asia and South America (Chile). Of the top ten segments, all of which generated average annual revenues greater than USD 9.0 million, six were purse seiners, two were pelagic trawlers, one was a demersal trawler and one was a longliner (or conventional seagoing vessel).

Six of the top ten segments in terms of average annual earnings generated per fishing vessel were from Europe (three from Norway, and one each from Spain, the United Kingdom of Great Britain and Northern Ireland and Denmark), two from Asia (Japan and Republic of Korea) and two from South America (Chile). Eight of the top ten segments in terms of earning were also in the top ten of segments for highest total costs. Many of these fleet segments operate in the North Sea, where the status of many commercially important stocks has improved over the last few years, or in the high seas where most stocks are managed under regional fishery management organizations (RFMOs) such as the North East Atlantic Fisheries Commission (NEAFC) and the Northwest Atlantic Fisheries Organization (NAFO) in the North Atlantic, as well as the International Commission for the Conservation of Atlantic Tunas (ICCAT) and Indian Ocean Tuna Commission (IOTC) for tuna and tuna-like species in the Atlantic and Indian oceans.

Of the 98 fleet segments reviewed, the average Norwegian demersal cod trawler (60 m) was the top earner, with revenue of USD 18.9 million, followed by the Spanish purse seiner targeting large tuna species (USD 16.9 million) and the Japanese bonito purse seiner (USD 13 million). These three segments also presented the highest total costs in the same order. Total costs to revenue for these three segments was recorded as 74 percent, 76 percent and 93 percent, respectively, indicating better performance in the two European segments. Overall, total costs to revenue ranged from 42 percent for the British demersal trawler (28 m) segment to 200 percent in the Indonesian longliner (22 m) segment.

By continent, the South African deep-sea freezer trawler was the top earner in Africa, with an average revenue of USD 7.7 million, followed by the Senegalese demersal trawler with USD 2.6 million. The Senegalese deep-sea crab trapper, and tuna pole-and-line vessels, also generated around USD 2 million in revenue annually.

In Europe, revenues of vessels of > 40 m in the large pelagic trawler fleets and large purse seine fleets were generally above USD 6 million, with the exception of fleet segments in Italy and Turkey, which presented lower revenues. Most of the large demersal trawlers recorded earnings of over USD 5 million, and over USD 2 million for medium-sized demersal trawlers. Annual revenue for coastal and small-scale vessels was generally substantially lower.

For the North and South American fleets covered in this survey, it is clear that vessels in the Chilean industrial purse seine fleet landed the highest value of seafood on average (in 2018), at USD 10 million. The ex-vessel value of landings by industrial trawlers in Chile amounted to around USD 4.5 million, and around USD 3.3 million for the Peruvian anchovy purse seiners. By comparison, the substantially smaller semi-industrial shrimp trawlers in Brazil and hook and line fishing vessels for jumbo squid in Peru presented ex-vessel values of just over USD 200 000. The United States of America fleet segments reviewed were among the smallest segments in terms of vessel length, ranging from 18 m to 27 m, with revenues of between USD 373 500 and USD 1.4 million.

When comparing the various Asian fishing fleets covered in this review, the Japanese and Republic of Korea industrial purse seine fleets landed by far the highest value of seafood per vessel in 2018. While the Japanese bonito purse seiners landed around USD 11.3 million in revenue, the Republic of Korea large purse seiners were not far off, at USD 9.4 million per vessel. In addition, the Japanese sardine and mackerel purse seiners landed seafood with an ex-vessel value of USD 8.1 million in 2018. The review showed that only Bangladeshi, Japanese and Republic of Korea vessels in the Asian region generated income of over USD 1 million. The majority of the other fleets – mainly from China, Indonesia and India – landed significantly less seafood in value terms. In fact, more than half of the fleet segments in the Asian region generated average ex-vessel values of below USD 500 000.

The findings of this review also highlight variations in the cost structure for the different fishing gear categories. Similarly, as observed in the 2003 FAO fleet performance review, some variations are clearly related to differences in the cost of labour in specific countries. There are also differences in the cost of maintenance and repair of fishing vessels, which are generally more favourable for the fishing industry in the Asian, South American and African countries included in the study than in European countries. In other cases, reasons for the differences are not so evident, especially between vessels in the same length, gear and region categories.

TABLE 7
Main cost component by continent and fishing gear

		Bottom trawlers large	Bottom trawlers medium	Bottom trawlers small	Pelagic trawlers	Purse seiners	Long-liners	Gill-netters	Squid vessels	Other vessel segments	All	
Africa	Labour										0	8
	Running	1	2		1						4	
	Vessel						1		1		2	
	Capital									2	2	
Asia	Labour		2	1		4	1	2	1	1	12	27
	Running	1	4	1	1	3	1		1	2	14	
	Vessel										0	
	Capital							1			1	
Europe	Labour	1	4	4	2	2		1		1	15	42
	Running	2	1	4	1	5	2			3	18	
	Vessel	1		3		1				2	7	
	Capital				1					1	2	
North America	Labour		1	2						2	5	7
	Running			1			1				2	
	Vessel										0	
	Capital										0	
South America	Labour						1				1	14
	Running								1		5	
	Vessel	1				4	3				8	
	Capital										0	
		7	**14**	**20**	**6**	**19**	**10**	**4**	**4**	**14**		**98**

Overall, running costs were the highest cost component in 44 percent of the segments (43 segments), with labour costs highest in 34 percent of the segments (33 segments), vessel costs the highest in 17 percent, and capital costs the highest in 5 percent of the segments analysed (Table 7).

Distributed by continent, labour costs was the highest cost component in 71 percent of the North American (United States of America) segments, 44 percent of the Asian segments, 36 percent of the European segments and 7 percent of the South American segments. None of the African segments showed labour costs as the main cost component.

In terms of fishing gear, labour costs constituted the highest cost component in 75 percent of gillnetters, 50 percent of medium-sized bottom trawlers and 35 percent of the small bottom trawlers. Conversely, labour costs were the main cost component in only 14 percent of large bottom trawlers, 20 percent of longliners, 25 percent of squid vessels, 33 percent of pelagic trawlers and 32 percent of purse seiners.

These results indicate that labour costs tend to comprise a higher share of total costs in artisanal, small-scale or more labour-intensive fisheries in North America, Asia and Europe (e.g. purse seiners, non-mechanized gears, etc.). Labour costs also tend to be high in fleet segments with more sophisticated fishing operations, where less but more specialized (and higher paid) labour may be required.

Labour costs can vary substantially and are largely determined by the remuneration system in place. The most commonly used remuneration systems in fisheries include the fixed wage system, the shared remuneration system, or a combination of both. The shared system will vary according to the extent to which the crew participates in paying part of the costs; for example, a shared remuneration proportional to revenues minus fuel costs, or minus total operational costs. The share rate and the cost items that are deducted from the sale of seafood landed can vary substantially between countries, fleets, fisheries and vessels, as well as over time and for different crew members (Guillen *et al.*, 2017).

According to the Sunken Billions report (Willmann and Kelleher, 2009), labour costs in global fisheries was estimated at between 30 and 50 percent of total costs. In this review, labour costs ranged from 2 percent and 66 percent of total costs, with 45 percent of the segments showing labour costs between 30 and 50 percent of total costs. This figure would be higher if the value of unpaid labour was also taken into account, as this is quite significant in many European Union fleet segments.

Running costs was the highest cost component in 43 fleet segments reviewed. Distributed by continent, it was the highest cost component in 50 percent of the African segments, 52 percent of the Asian segments, 29 percent of the North American (United States of America) segments, 36 percent of the South American segments and 43 percent of the European segments.

In terms of fishing gear, running costs was the highest cost component in 57 percent of the large bottom trawlers, 50 percent in the small bottom trawlers, medium-sized bottom trawlers, purse seiners and squid vessels. Conversely, running costs was the main cost component in only 40 percent of longliners and 42 percent of purse seiners. None of the gillnetters showed running costs as the main cost component (Table 6).

These results suggest that running costs tend to be higher in larger offshore and more fuel-intensive vessels, such as deep-sea trawlers and large pelagic trawlers. Fuel costs are generally a considerable cost item within running costs, particularly for trawlers. For example, trawlers in Norway use proportionally about twice as much fuel as conventional coastal fishing vessels, while purse seiners (both coastal and seagoing) use relatively little fuel. Average prices for marine fuel were at a record low in 2016 for most European Union fishing fleets, which helped to reduce fuel costs and subsequently running costs. For example, energy costs for the European Union fishing fleet as a whole averaged around 24 percent of total costs in 2008; double what it was in 2016 (12 percent).

Vessels for which running costs is the least onerous cost component generally use more passive fishing gears such as gillnets, pots and traps, pole-and-line, handlines, longlines and to a lesser extent, purse seines. For several of the purse seine segments analysed, vessel costs tended to be higher than running costs. This may in part be the result of the number of vessels that are sometimes involved in these fishing operations, in addition to costs incurred for using FADs and for vessels operating under quota systems, or costs related to fishing rights.

Labour costs and running costs were the two main cost components in the majority (52 percent) of the segments reviewed. This combination was more pronounced in the trawler segments analysed, with the exception of the European trawler segments, where vessel costs tended to exceed running costs (Table 6). This can partly be attributed to the costs incurred for the lease of quotas and fishing rights, which may comprise a significant part of vessel costs in some fleets. Almost all major stocks and fisheries targeted by fleets in the North Atlantic are managed through total allowable catch (TACs) allocations and quotas – though not all these have a cost. In the Danish fleet, for example, quotas are mostly managed under individually transferable quotas (ITQs): in other words, they are transferable and leasable. In other European Union Member States (e.g. France, Germany, Spain), quotas are publicly owned, non-transferable and non-leasable; this means they are not included in vessel costs, which may account for some of the differences observed.

Vessel costs was the main cost component in 17 segments. Distributed by continent, the proportion of vessel costs to total costs was the highest component in 57 percent of the South American segments, 25 percent of the African segments and 17 percent of the European segments. None of the Asian and United States of America segments showed vessel costs as the main cost component. Similarly, as observed in the 2003 FAO fleet performance review, vessel costs ranked third or fourth in most of the African and Asian fleet segments, indicating that less was spent on repair and maintenance, in relative terms, by African and Asian vessel owners than by their American and European counterparts.

Compared to the 2003 FAO fleet performance review (Tietze *et al.*, 2005), the current review showed a relative reduction in the proportion of running costs to total costs for German cutters using beam trawls and Norwegian coastal shrimp trawlers. Running costs ranked third, after labour and vessel costs for these fleet segments. This can be partly explained by lower average fuel prices in recent years, which contributed to lower energy (running) costs, as well as an aging fleet with high repair and maintenance costs and changing fishing practises (e.g. several different gears), which can contribute to higher vessel costs. For example, smaller cutters (< 23 m) in Germany target cod and flatfish in the Baltic Sea and often seasonally switch to pelagic gear.

Capital costs accounted for only a minor part of total fishing costs in the majority of fleet segments analysed, and accounted for less than 20 percent of total costs in 84 segments. Nevertheless, capital costs were the main component in five segments: two in Africa (within the "other vessel segments"), one in Asia (gillnet in Chennai, India) and two in Europe (small-scale passive gears in Italy and large pelagic trawler in Denmark).

The 2003 FAO fishing fleet review noted that the share of capital costs to total fishing costs does not seem to be directly associated with a particular type of fishing vessel or fishing method but more with specific operational conditions, such as the average age of vessels in a particular category, distance to the fishing grounds and regulations in place.

REFERENCES

Carvalho, N., Van Anrooy, R., Vassdal, T. & Dağtekin, M. 2020. *Techno-economic performance review of selected fishing fleets in Europe.* FAO Fisheries and Aquaculture Technical Paper No. 653/1. Rome, FAO. 198 pp. (also available at: www.fao.org/documents/card/en/c/ca9188en).

Guillen, J., Boncoeur, J., Carvalho, N., Frangoudes, K., Guyader, O., Macher, C. & Maynou, F. 2017. Remuneration systems used in the fishing sector and their consequences on crew wages and labor rent creation. *Maritime Studies*, 16(3): DOI 10.1186/s40152-017-0056-6

Kitts, A., Van Anrooy, R., Van Eijs, S., Pino Shibata, J., Pallalever Pérez, R., Gonçalves, A.A., Ardini, G., Liese, C., Pan, M. & Steiner, E. 2020. *Techno-economic performance review of selected fishing fleets in North and South America*. FAO Fisheries and Aquaculture Technical Paper No. 653/2. Rome, FAO. 122 pp. (also available at www.fao.org/documents/card/en/c/ca9543en)

Pinello, D., Gee, J. & Dimech, M. 2017. *Handbook for fisheries socio-economic sample survey – principles and practice.* FAO Fisheries and Aquaculture Technical Paper No. 613. Rome, FAO. (also available at: www.fao.org/3/i6970e/i6970e.pdf)

Scientific, Technical and Economic Committee for Fisheries (STECF). 2020. *The 2019 Annual Economic Report on the EU Fishing Fleet (STECF 19-06). Scientific, Technical and Economic Committee for Fisheries (STECF)*. Carvalho, N., Keatinge, M. & Guillen Garcia, J., eds.. EUR 28359 EN. Luxembourg, Publications Office of the European Union. (also available at stecf.jrc.ec.europa.eu/documents/43805/2483556/STECF+19-06+-+AER+-+2019.pdf/db370547-4405-416d-b2e3-76f8276edae2

Tietze, U., Prado, J., Le Ry, J-M., & Lasch, R., eds. 2001. *Techno-economic performance of marine capture fisheries.* FAO Fisheries Technical Paper No. 421. Rome, FAO. (also available at www.fao.org/3/Y2786E/Y2786E00.htm)

Tietze, U., Thiele, W., Lasch, R., Thomsen, B., & Rihan, D. 2005. *Economic performance and fishing efficiency of marine capture fisheries.* FAO Fisheries Technical Paper No. 482. Rome, FAO. 68 pp. (also available at www.fao.org/docrep/008/y6982e/y6982e00.htm

Van Anrooy, R., Mukherjee, R., Wakamatsu, H., Song, L., Muawanah, U., Jin Cha, B., Narayana Kumar, R., Parappurathu, S., Yadava, Y.S., & Tietze, U. 2020. *Techno-economic performance review of selected fishing fleets in Asia*. FAO Fisheries and Aquaculture Technical Paper No. 653/3. Rome, FAO. 129 pp. (also available at www.fao.org/3/cb1577en/CB1577EN.pdf).

Willmann, R. & Kelleher, K. 2009. *The sunken billions: the economic justification for fisheries reform*. Agriculture and rural development. Washington, D.C., World Bank Group. documents.worldbank.org/curated/en/656021468176334381/The-sunken-billions-the-economic-justification-for-fisheries-reform

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Financial and economic performance of the main fishing fleets

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4. Financial and economic performance of the main fishing fleets

Financial and economic details were collected from 97 of the main fishing fleet segments in the world.[12] Analysis of the costs and earnings data of these fleet segments showed that 89 percent of the fishing fleets realized positive net cash flow figures, meaning that revenues from landings were larger than the total gross costs. Negative net cash flow figures were presented by large purse seiners from the Republic of Korea, pole and line vessels and tuna longline fishing fleet segments in Indonesia and small pair trawlers in China, as well as hake longliners in South Africa, freezer longliners and shrimp trawlers in Brazil, hake trawlers in Peru in 2018, and small groundfish trawlers in the United States of America in 2017. There may have been individual fishing vessels with negative cash flows in the other fleet segments covered by this global review, but on average vessels in these fleet segments were profitable.

Six indicators were used to assess the economic and financial performance of fishing vessels in the 97 surveyed fleet segments:

	Indicators
1	Net cash flow (NCF) = total revenue – total gross costs[13]
2	Net profit margin (NPM) = net profit before tax/total revenue
3	Return on fixed tangible assets (ROFTA) = net profit before tax/value of tangible assets
4	Return on investment (ROI) = net profit before tax/(value of tangible + intangible assets)
5	Gross value added (GVA) = net cash flow + labour costs
6	GVA to revenue = GVA/total revenue

Table 1 in Appendix 4.A provides more details on the various financial and economic indicators applied and how these were calculated, along with examples of some fleet segments for illustrative purposes.

The net cash flow (NCF) can be regarded as a reward for entrepreneurship. A net profit margin of more than 20 percent is often considered good, while 10 percent is regarded as average in many industries (CFI, 2021) The net profit margin is a measure of profitability after all costs have been accounted for and reflects the percentage of revenue that a vessel owner retains as profit. In this analysis it is used to measure the relative performance of a fishing vessel segment compared to other vessel segments, or other activities in the economy, as it provides an indication of the vessel segment's operating efficiency, given that it captures the amount of surplus profit generated per unit of production (STECF, 2016).

The return on fixed tangible assets (ROFTA) indicator provides a useful measure for the return on capital. A desirable result is positive as the cost of capital is considerable. The return on investment (ROI) is the most commonly used indicator

12 In total, 103 fishing fleet segments were included in this global review; however, sufficient financial information for comparative analysis was available from only 97 fleet segments.

13 The revenue from fish sales was the only revenue for 93 percent of the fleet segments included in this review. Only 7 percent of the fleet segments reported income from other sources, which contributed to the total revenue. The total gross costs here is the sum of labour costs, running costs and vessel costs.

for financial performance. For the ROI, any percentage higher than 10 percent is generally considered good (Tietze *et al*., 2005), however in some other sectors only ROI percentages of 12–15 percent and above are considered good.

Depreciation rates applied to the fishing vessels surveyed vary considerably. The variation is caused by the hull construction materials used (wooden or steel body), vessel age, the costs and quality of tangible assets (e.g. hull, engines, winches, on-board freezers), climatic conditions in the area of operations and the maintenance regime applied. Moreover, some owners prefer to apply high depreciation rates in the first years after construction to reduce taxable income. Detailed information on amortization of loans, interest payments and the value of intangible assets was not available for most of the vessels but included where possible (for details, see the country reports in Kitts *et al.*, 2020, Carvalho *et al.*, 2020). The ROI in this chapter was calculated over the initial investments and not over the sum of the prevailing values of tangible plus intangible assets. The consequence is that ROFTA and ROI figures are different, even when no information was available on the intangible assets of the vessels surveyed.

The gross value added (GVA) figure is perhaps of less importance to individual vessel owners but is an important figure for fisheries policy and decision-makers. It shows what fishing vessel operations contribute to the economy and is useful for making decisions on future fisheries sector investment and expenditure. The GVA to revenue figure is expressed as a percentage and provides for the share of revenue that contributes to the economy through the production factors (in this case mainly labour).

An overview table presenting the financial and economic performance indicators per fishing fleet segment can be found in Tables 2 and 3 of Appendix 4.A.

The regional techno-economic performance reviews of selected fishing fleets in Europe, North and South America and Asia (FAO Fisheries and Aquaculture Technical Papers 653/1, 653/2 and 653/3) present a comparative analysis of the fleet segments in these regions.

For this global review 97 fleet segments were available for the financial and economic performance analysis, grouped similarly as in chapter 3. There were 41 bottom trawler fleets, 18 purse seine fleets, 10 longliner fleets, 6 pelagic trawler fleets, 4 gillnetter fleets and 4 squid jigger vessel fleets. In addition, there were 14 fleet segments of great variety (e.g. scallop dredgers, stownetters, cast netters, pole and line vessels, handliners, pots and trap vessels, and general passive gear vessels).

The many bottom trawler fleet segments were divided by length overall (LOA) in small (< 24 m), medium (24–40 m) and large (> 40 m) trawler fleet segments.

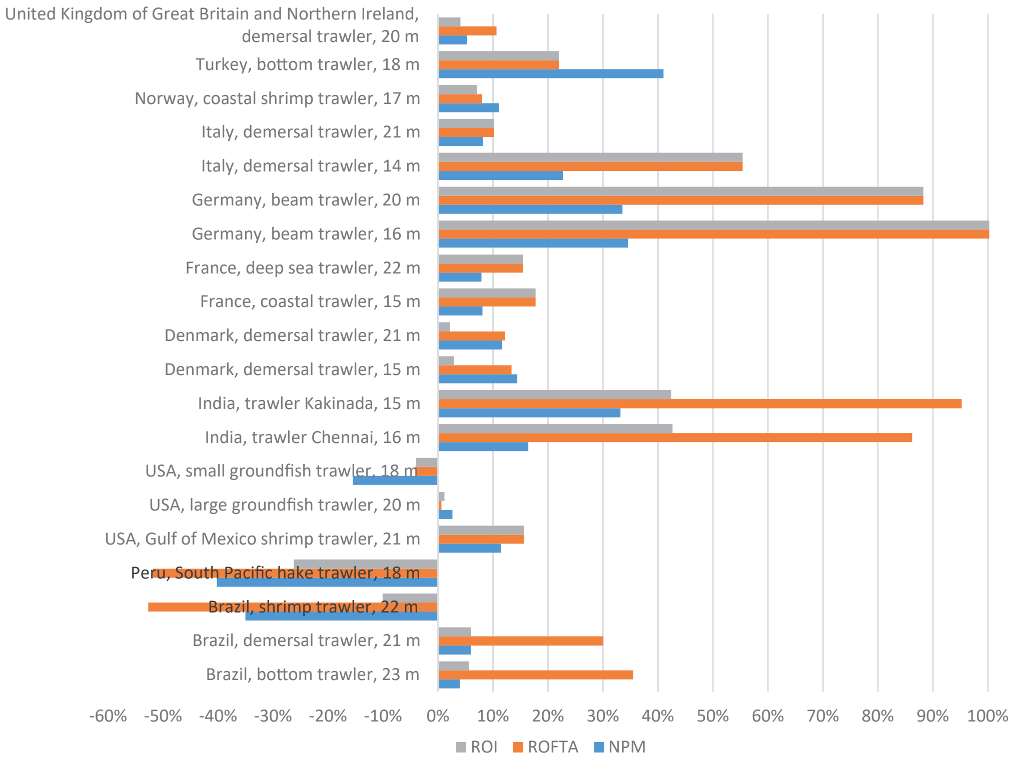
4.1 SMALL (< 24 m) BOTTOM TRAWLERS

The analysis included 20 small bottom trawler fleet segments, of which 18 (90 percent) presented a positive net cash flow. Only the Peruvian hake trawlers and Brazilian shrimp trawlers showed negative figures in 2018. The average net cash flow of all 20 small bottom trawler fleet segments included in the review was USD 116 000.[14] The highest average net profit margins were realized by bottom trawlers in Turkey, beam trawlers in Germany and trawlers of Kakinda in the Indian State of Andhra Pradesh, which all demonstrated net profit margins of over 30 percent. Demersal trawlers (14 m) in Italy also presented good NPM figures on average, of 23 percent. By contrast, the Peruvian hake trawlers, Brazilian shrimp trawlers and small groundfish trawlers in the United States of America presented negative NPM figures in the survey years. The average NPM of the 20 small bottom trawler segments surveyed was 9 percent.

The variation in return on fixed tangible assets (ROFTA) between the small bottom trawler fleet segments was large, ranging from negative 53 percent for Peruvian hake

[14] Note: the variation in survey years (see Appendix 4.A, Table 2) between fleet segments surveyed means that averages may have limited value.

FIGURE 40
Financial performance of average vessels in the small (< 24 m) bottom trawler fleets



trawlers to positive 102 percent for German beam trawlers of 16 m LOA. Of the small bottom trawler fleet segments surveyed, 75 percent showed ROFTA figures of 10 percent or higher, while the overall average ROFTA for the 20 surveyed small bottom trawler segments was 25 percent. The return on investment (ROI) variation between fleet segments was large as well: 50 percent of the surveyed small bottom trawler fleet segments demonstrated ROI percentages lower than 10 percent.

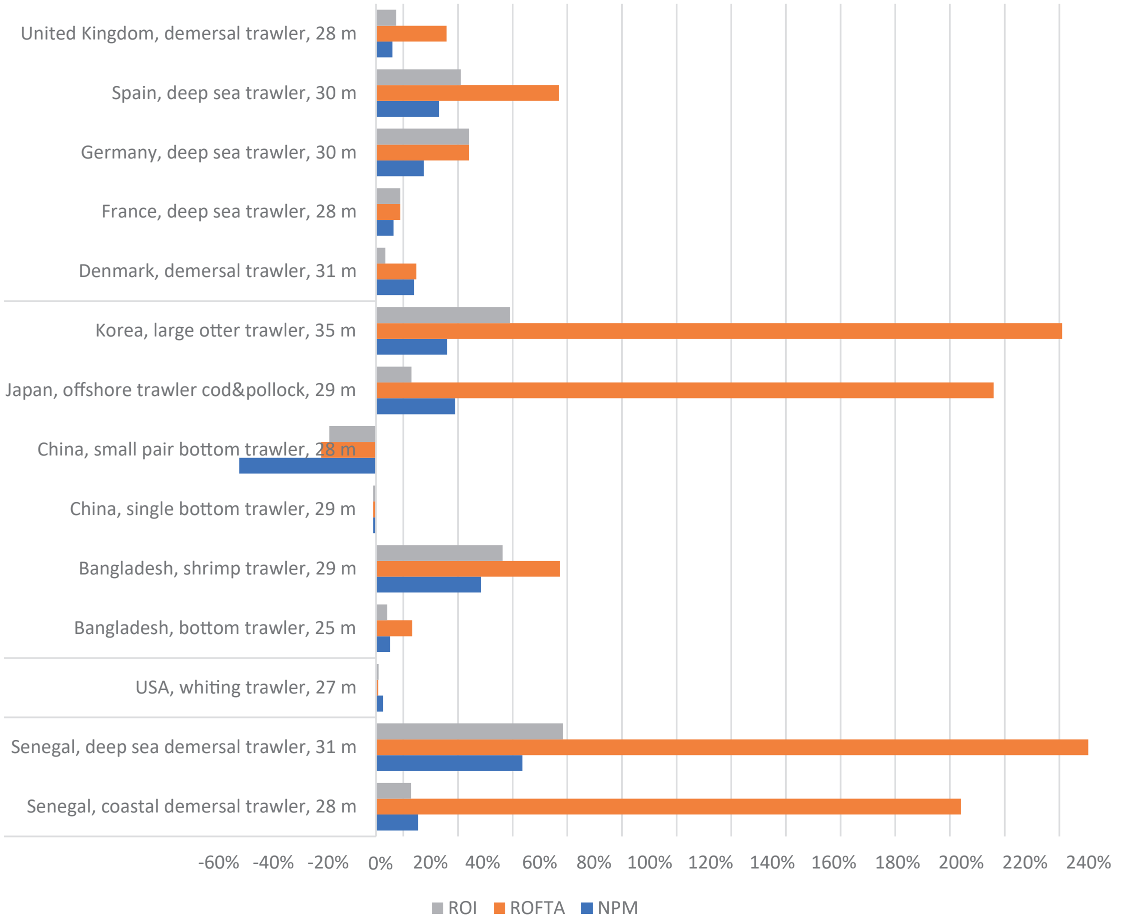
4.2 MEDIUM-SIZED (24–40 m) BOTTOM TRAWLERS

The analysis included 14 medium-sized bottom trawler fleet segments, of which 13 (93 percent) presented a positive net cash flow. The Chinese pair trawlers (average length of 28 m) were the only fleet segment in this group showing negative figures (in 2018). The average net cash flow of all 14 medium-sized bottom trawler fleet segments included in this review was USD 537 000.

The Senegalese deep-sea demersal trawlers (31 m) showed the highest average net profit margins (53 percent), followed by shrimp trawlers in Bangladesh (38 percent). Other segments that presented good NPM figures on average (above 20 percent) were the Japanese offshore cod and pollock trawlers, the Spanish deep-sea trawlers and the large otter trawlers of the Republic of Korea. The average NPM of the 14 medium–sized bottom trawler segments surveyed was 13 percent.

The return on fixed tangible assets (ROFTA) figures for the medium-sized bottom trawler fleet segments showed large variation; this is primarily caused by the variation in age of the fishing vessels and their related depreciated value. As a result, those fleet segments which included older vessels, of which the depreciated value was low, scored very high ROFTA percentages. For instance, 94 percent of the Senegalese trawlers surveyed have been in operation for more than 25 years and the investments in upgrading in recent years have been limited. Similarly, the average age of 63 percent

FIGURE 41
Financial performance of average vessels in the medium–sized (24–40 m) bottom trawler fleets

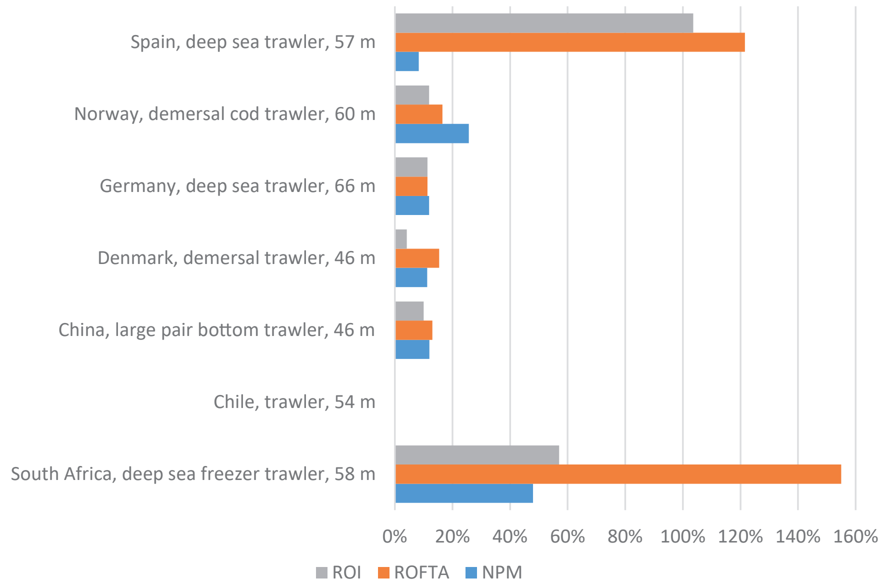


of the Japanese and 73 percent of the Republic of Korea vessels in this group of medium-sized bottom trawlers was over 20 years, resulting in relatively low values of tangible assets and positive impacts on their ROFTA figures. A total of 79 percent of the medium-sized bottom trawler fleet segments surveyed showed ROFTA figures of 10 percent or higher. The average ROFTA for the 14 surveyed medium-sized bottom trawler segments was a high 78 percent, by virtue of ROFTA percentages of over 200 percent for the aforementioned ‘older‘ fleets. The Chinese bottom trawler fleets (average length of 28 m) were the only fleet segments within the group of medium-sized bottom trawlers that presented negative ROI figures. Similarly, as for the small bottom trawlers, 50 percent of the surveyed medium-sized bottom trawler fleet segments demonstrated ROI percentages lower than 10 percent.

4.3 LARGE (> 40 m) BOTTOM TRAWLERS

Seven large bottom trawler fleet segments were included in the analysis, all of which presented a positive net cash flow. The Norwegian cod trawlers of 60 m LOA showed the highest NCF on average, adding up to nearly USD 7 million, while the Chinese large bottom trawlers of 46 m realized an average NCF of just USD 165 000 per vessel. The average net cash flow of all seven large bottom trawler fleet segments included in this review was USD 2.3 million.

FIGURE 42
Financial performance of average vessels in the large (> 40 m) bottom trawler fleets



The highest average net profit margins in this fleet segment group were achieved by the South African deep-sea freezer trawler vessels (48 percent), followed by the Norwegian cod trawlers (26 percent). The average NPM of the seven large bottom trawler segments surveyed was 17 percent.

The average return on fixed tangible assets (ROFTA) showed a variation of between 0 percent (Chilean trawlers) and 155 percent (South African deep-sea freezer trawler). Except for the Chilean trawlers (54 m LOA), all the other surveyed large bottom trawler fleet segments showed ROFTA figures of 10 percent or higher.

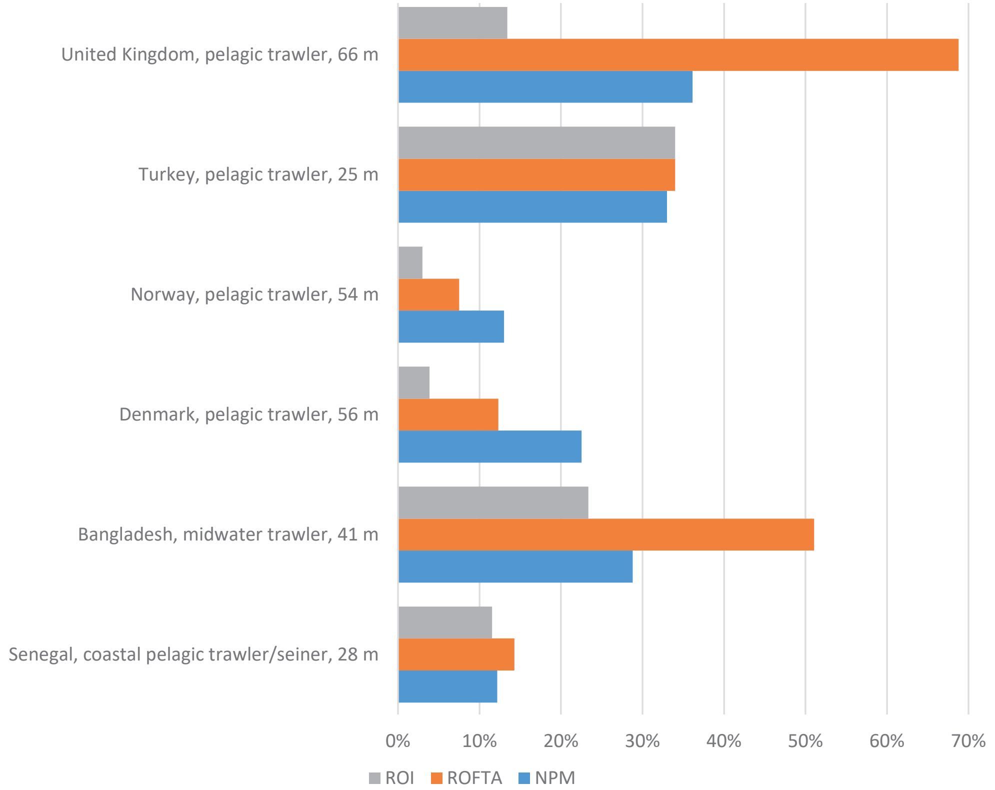
The vessels in the Spanish deep-sea trawler segment, with an average LOA of 57 m, achieved the highest ROI figures, reaching 104 percent in 2016. Five of the seven large bottom trawler fleet segments demonstrated ROI percentages higher than 10 percent.

4.4 PELAGIC TRAWLERS

The six pelagic trawler fleet segments included in the analysis all presented a positive net cash flow. The variation in vessel size within this group was substantial, with pelagic trawlers in Turkey and Senegal of 25 and 28 m LOA respectively, while the pelagic trawlers in the United Kingdom of Great Britain and Northern Ireland, Denmark and Norway were double this length. This difference is also revealed in net cash flow, which averaged around USD 120 000 for the Senegalese and Turkish vessels, while the average NCF of the larger vessels amounted to USD 2.2 million (Norwegian vessels), USD 5.3 million (British vessels) and USD 5.8 million (Danish vessels) respectively.

The NPM of the pelagic trawler segments surveyed ranged from 12 percent to 36 percent, with an average of 24 percent, which signals a good profit margin for these fleet segments. The ROFTAs were highest for the pelagic trawlers in the United Kingdom of Great Britain and Northern Ireland (66 percent on average) and the Bangladeshi midwater trawlers (51 percent). By contrast, the ROFTA of the Norwegian pelagic trawler was just 8 percent. Two-thirds of the pelagic trawler fleet segments demonstrated ROI percentages above 10 percent.

FIGURE 43
Financial performance of average vessels in the pelagic trawler fleets



4.5 PURSE SEINERS

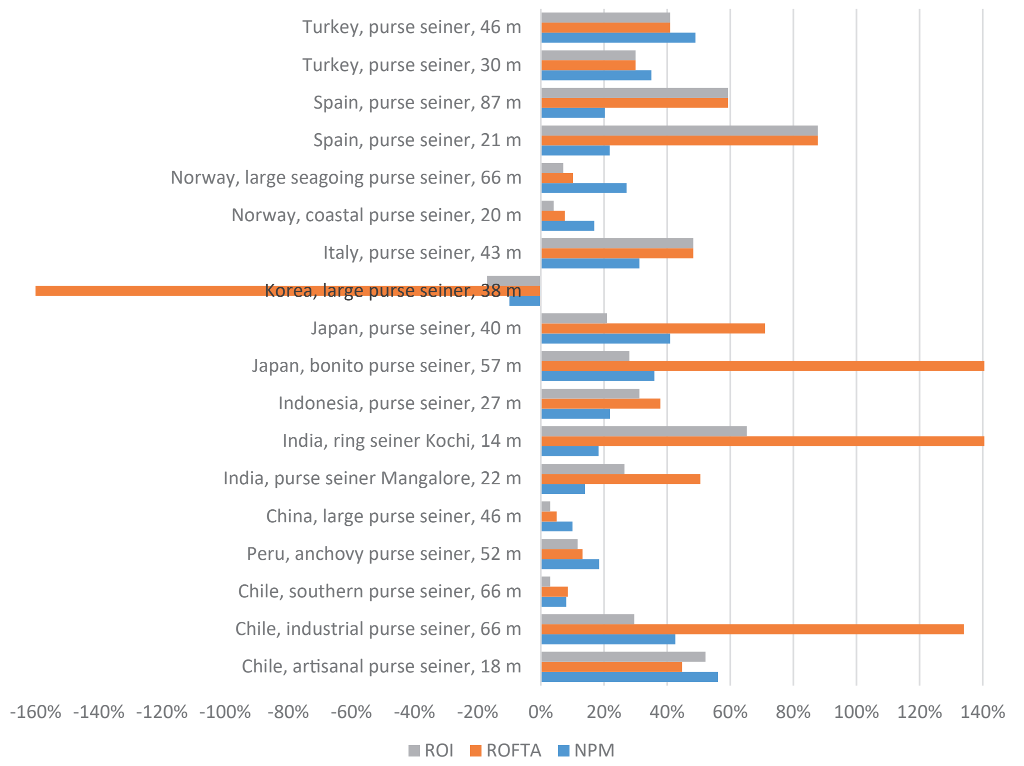
The analysis included 18 purse seiner fleet segments, of which 17 (95 percent) presented a positive net cash flow. Only the large purse seiners of the Republic of Korea (38 m) showed negative figures. The average net cash flow of all 18 fleet segments included in the review was USD 1.4 million. However, there was significant variation between segments: the smallest vessels (Indian vessels of 14 m and 22 m, Indonesian vessels of 27 m, Chilean vessels of 18 m and Spanish vessels of 21 m) presented NCF figures of just over USD 100 000 or less, while the industrial purse seiners of Chile, Japan, Norway, Spain and Turkey presented NCF figures ranging from USD 1 million to USD 5.2 million.

The purse seiners of Turkey and Japan, together with two out of the three Chilean purse seiner fleet segments, all demonstrated net profit margins of over 30 percent, which is very good. Of the fleet segments surveyed, 61 percent showed NPM figures of 20 percent or higher, which is widely considered good. In fact, the average NPM of the 18 purse seiner segments surveyed was 25 percent.

With respect to ROFTA, 78 percent of the purse seiners fleet segments presented figures of 10 percent or higher. Generally, these figures were substantially higher, given the overall average ROFTA of 42 percent across the purse seiners surveyed. The only negative exception was the large purse seiners of the Republic of Korea, which presented losses in survey year 2017. However, it was noted that the vessels operated in groups with smaller vessels that were profitable in the same year.

The ROI figures were good to very good for most purse seiner fleet segments surveyed. Overall, 72 percent of the fleet segments demonstrated ROI figures of 10 percent or higher. The only fleet segments with lower ROI figures were the Chinese and Norwegian purse seiner fleet segments and the Southern purse seiners in Chile, in addition to the loss-making purse seiners of the Republic of Korea.

FIGURE 44
Financial performance of average vessels in the purse seiner fleets

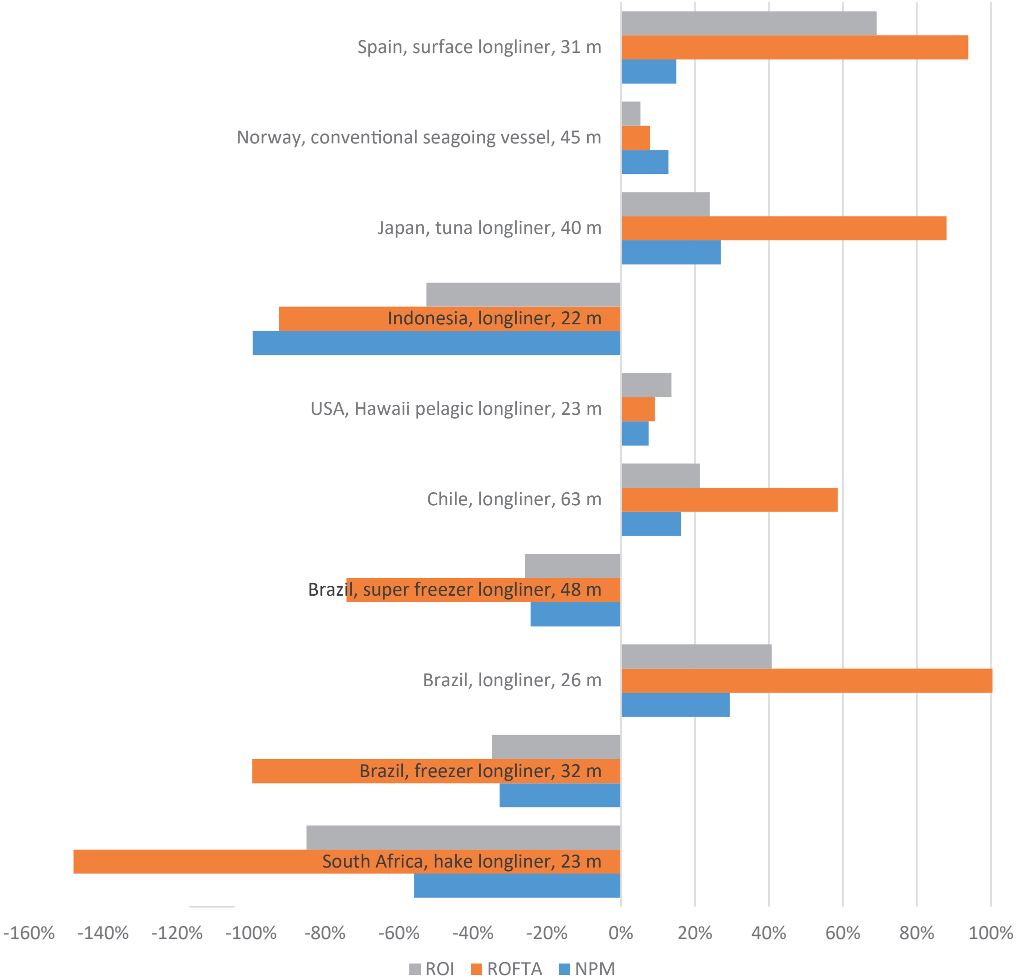


4.6 LONGLINERS

The longliner fleet segments surveyed revealed mixed results. On average, vessels in four of the ten longliner fleets presented losses in the survey years. Only 60 percent of the segments presented a positive net cash flow. The longliners of Brazil and Indonesia landed frozen product in the survey years, which impacted negatively on profitability, while the South African hake longliners suffered from low quota allocations and high running costs.

The Brazilian longliners of 26 m, landing fresh fish on ice, showed the highest NPM figure (29 percent), followed by the Japanese tuna longliners of 40 m (27 percent). These were the only two longline fleets that showed good NPM figures (of over 20 percent). The ROFTA and ROI figures showed significant variation. On average, the Spanish surface longline vessels of 31 m presented the highest ROI figures, with 69 percent. The ROFTA was highest for the Brazilian longliners of 26 m, adding up to an average of 116 percent for vessels in this fleet segment in Brazil.

FIGURE 45
Financial performance of average vessels in the longliner fleets



4.7 GILLNETTERS

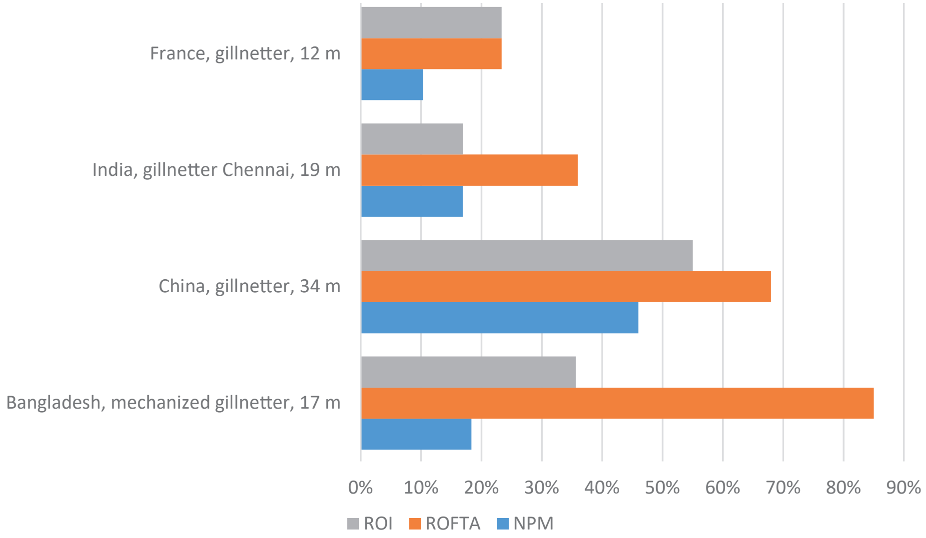
Four gillnetter fleet segments were included in the analysis. All segments presented a positive net cash flow, of between USD 41 000 (Bangladesh) and USD 280 000 (China).[15]

An average Chinese gillnetter (34 m) had a net profit margin of 46 percent in the survey year 2018, and the other gillnetter fleet segments surveyed presented NPM figures of 10–20 percent.

All four gillnetter fleet segments presented ROFTA figures of over 20 percent. The average ROFTA for the four fleet segments was 53 percent, which is very high. The ROI figures were also good to very good for most gillnetter fleet segments surveyed, indicating positive financial and economic results for these fleets. In 2018 the Indian gillnetters of 19 m showed a ROI of 17 percent, the lowest among the four fleet segments surveyed. The Chinese gillnetter fleet segment presented a ROI of 55 percent, which means that the vessel owners made a very good investment decision, as the vessels and related equipment investments will be repaid within a few years. The Chinese gillnetter fleet has therefore grown substantially in recent years: 88 percent of the vessels in the Chinese gillnetter segment entered the fleet in the last five years.

15 Among the small-scale vessels and those using passive gears, discussed further on in this chapter, some of the Danish, German, Italian and Norwegian vessels use a range of gears, which may include gillnets.

FIGURE 46
Financial performance of average vessels in the gillnetter fleets

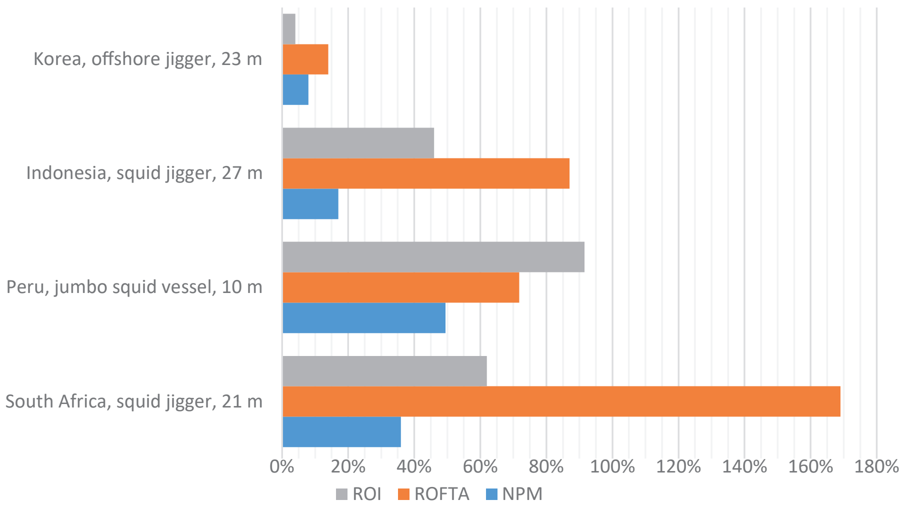


4.8 SQUID JIGGERS

Squid jigger fleet segments from Indonesia, the Republic of Korea, Peru and South Africa were included in the analysis. All four segments presented a positive net cash flow ranging from USD 51 000 (Indonesia) to USD 403 000 (South Africa).

All four fleet segments also presented positive figures in the other financial indicators (NPM, ROFTA and ROI). The Peruvian vessels (10 m) and South African vessel (21 m) presented the highest positive NPM figures, of 49 percent and 36 percent, respectively. By contrast, an offshore jigger of the Republic of Korea demonstrated a low NPM figure of 8 percent on average. Comparing the ROFTA and ROI figures of the fleet segments, it is clear that the operations of three of the four segments resulted in very high returns in the survey years. The ROFTA for the South African squid jiggers was as high as 169 percent in 2018, while the Indonesian and Peruvian vessels realized average ROFTA figures of 87 percent and 72 percent respectively. The average ROI figures for vessels in the four jigger segments ranged from a low 4 percent for the Republic of Korea vessels to a very high 92 percent for the small-scale Peruvian vessels.

FIGURE 47
Financial performance of average vessels in the squid jigger fleets



4.9 OTHER FISHING VESSEL SEGMENTS

The global review also included 14 fleet segments using other types of gears such as dredges, pots and traps, pole and line, stow nets or cast nets. While it makes little sense to compare these segments, it is useful to emphasize that the variety of fleet segments all revealed positive net cash flows in the survey years. The financial and economic performance of the Senegalese deep-sea crab trap vessels is not included in the figures below, because their average ROFTA was over 1000 percent, with a ROI of over 300 percent; this indicated an exceptional financial result in the survey year (2018), which can be attributed to the high crab catches combined with the old age of the vessels involved and limited investments made.

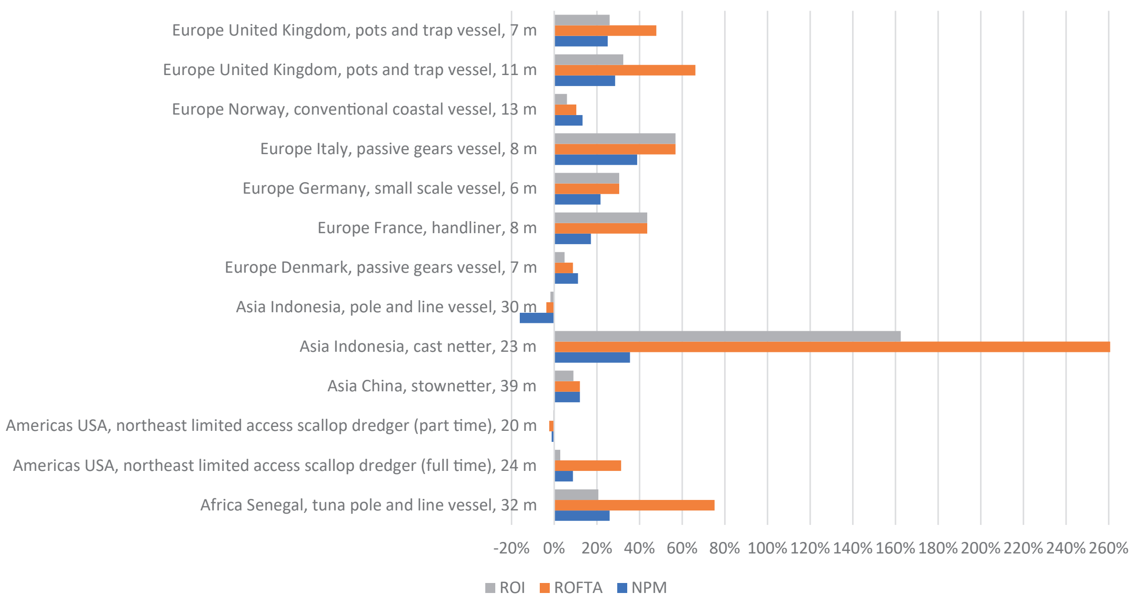
Among the other vessel segments only two showed negative results in the survey years: the part-time, limited-access scallop dredgers in the United States of America and the Indonesian pole and line vessels. As a result, 86 percent of the other vessel segments presented positive financial and economic indicators.

The Indonesian cast netters, Senegalese tuna pole and line vessels, Italian passive gear vessels, and pots and trap vessels in the United Kingdom of Great Britain and Northern Ireland all presented good NPM figures of 20 percent. Of the 14 fleet segments, 64 percent demonstrated ROFTA figures of over 20 percent, while 57 percent of the segments realized ROI percentages of over 10 percent in the survey years.

4.10 COMPARISON OF FINANCIAL AND ECONOMIC INDICATORS FOR THE FLEET SEGMENTS REVIEWED, BY FISHING GEAR

The performance of individual fishing vessels in the fleet segments analysed varied substantially in the survey years.[16] Nevertheless, the financial indicator averages by fleet segment are valuable in assisting the private sector to make investment decisions, as well as for government fisheries management purposes. The above comparison of fishing fleet segments revealed a significant diversity of financial and economic performance between fleet segments worldwide across similar fishing gears. The performance differences can have a wide range of causes including the status of the

FIGURE 48
Financial performance of average vessels in various surveyed fishing fleets



[16] For details please see the national reports within the regional review reports in Carvalho *et al.*, 2020; Kitts *et al.*, 2020; Van Anrooy *et al.*, 2020.; as well as in the annexes of this technical paper.

TABLE 8
Financial and economic performance averages of aggregated fishing fleet segments

Fleet segments	NPM (%)	ROFTA (%)	ROI (%)
Bottom trawlers small (20)	[yellow]	[blue]	[green]
Bottom trawlers medium (14)	[green]	[blue]	[green]
Bottom trawlers large (7)	[green]	[blue]	[blue]
Pelagic trawlers (6)	[blue]	[blue]	[green]
Purse seiners (18)	[blue]	[blue]	[blue]
Longliners (10)	[red]	[red]	[red]
Gillnetters (4)	[blue]	[blue]	[blue]
Squid jiggers (4)	[blue]	[blue]	[blue]

Note: The number of fleet segments included in the analysis are indicated in brackets.

Legend:

[red]	< 0% negative results = loss-making fishing operations
[orange]	> 0% to ≤ 5% slightly positive results = limited economic viability of the fishing operations; high risk of loss-making
[yellow]	> 5% to ≤ 10% moderate results = income from fishing operations is sufficient to cover depreciation costs, interest and loans repayment, but may not be enough for justifying re-investment in new vessels, equipment and quota.
[green]	> 10% to ≤ 20% good results = profitable fishing operations
[blue]	> 20% very good results = highly profitable fishing operations

stocks fished, catch landed, market prices, quota limitations, running costs, labour costs, vessel and capital costs, legislative and policy frameworks, trade barriers, subsidies and IUU fishing.

Comparing the average performance of fleet segments grouped by gear type and vessel size (in the case of bottom trawlers) may be like comparing apples and pears. The aggregated averages presented in Table 8 are compiled from averages of individual vessels of four or more fleet segments, and involve data from different years, as the survey data were not all from the same years.

Despite the high level of aggregation of the data presented in Table 8 above, and the large variety in performance of individual vessels, it can be concluded that at the global level fishing vessels in most fishing fleet segments are profitable on average. Longline vessels are the exception, as they showed negative results on various performance indicators overall (NPM, ROFTA and ROI), owing to the fact that four of the ten longliner fleet segments reported losses in the survey years.

On average, pelagic trawlers, purse seiners, gillnetters and squid jiggers presented very good NPM and ROFTA figures, of over 20 percent. The fishing operations of small (< 24 m) bottom trawlers, large (> 40 m) bottom trawlers, purse seiners, gillnetters and squid jiggers were highly profitable, with ROI percentages of 20 percent or higher in the survey years. In addition, the ROI percentages of pelagic trawlers and medium-sized trawlers (24–40 m) were 15 percent or higher, which is considered good in most industries.

The gross value added to revenue percentage indicates the share of revenue that contributes to the economy through production factors (returns to labour in this analysis) and can be seen as a measure for economic efficiency. Apart from the longliner fleet segments, all other fleet segments presented GVA to revenue percentages of 50 percent or higher. For comparison, the average GVA to revenue for European Union fleets has been around 57.9 percent in recent years (STECF, 2020).

The global averages by aggregated fishing fleet segment for these performance indicators provide insights for policymakers and fishery and blue economy investors into the profitability of the global fishing fleets, and they are useful for the analysis and evaluation of policies and plans, as well as for strategic planning purposes.

The analysis of all 97 fleet segments covered in this review showed that the net cash flow of 92 percent of the fleet segments was positive in the survey years. Average fishing vessels in 88 percent of the fleet segments presented a positive net profit margin (NPM), while 73 percent of the fleet segments realized NPM figures of 10 percent or higher; this means that every dollar of fish sold in the survey year provided approximately 10 cents of net profit. Overall, 40 percent of the fleet segments presented NPM figures of over 20 percent, which is considered high in most industries. In terms of capital productivity, 88 percent of fleet segments reported positive results, as their returns on fixed tangible assets (ROFTA) were positive. ROFTA figures of 10 percent or above were realized by 75 percent of the 97 fleet segments surveyed. Average vessels in 59 of the fleet segments surveyed (i.e. 61 percent) generated returns on investment (ROIs) of 10 percent or higher, while 51 percent of the fleet segments presented ROI figures of over 15 percent, which signals that many fleet segments are attractive for investments. As such, it can be concluded that the average profitability of a majority of the (semi-) industrial fishing fleets is on par with the top performing industries worldwide.[17]

4.11 GROSS VALUE ADDED BY FISHING FLEET SEGMENT TO THE NATIONAL ECONOMIES

The gross value added (GVA) indicator is generally applied to show the contribution of fishing vessels or fleets to the national economy. By multiplying the average GVA per vessel with the total number of vessels in the fleet segment, the contribution of the fleet segment to the national economy can be estimated. GVA averages per vessel of the surveyed fleet segments are presented in Tables 2 and 3 of Appendix 4.A.

Taken as a whole, the fleet segments included in this global review represent approximately 240 000 fishing vessels, largely consisting of semi-industrial and industrial fishing fleets. The combined total GVA contribution to the global economy of the fleet segments surveyed was estimated at USD 72.5 billion.[18] Seventy-nine percent of the estimated total GVA (USD 57.5 billion) realized by the surveyed fleet segments was attributed to the Chinese fleets. The fishing fleet segments of China contributed an estimated USD 42.7 billion (gillnetters), USD 6.6 billion (stownetters), USD 5.2 billion (trawlers) and USD 3.2 billion (purse seiners) to the country's economy respectively. By comparison, the fishing fleets of the European Union together realized an estimated GVA of EUR 4.5 billion[19] in 2017 (STECF, 2020). The estimated contributions of some other major fishing fleet segments to the national economies were as follows:

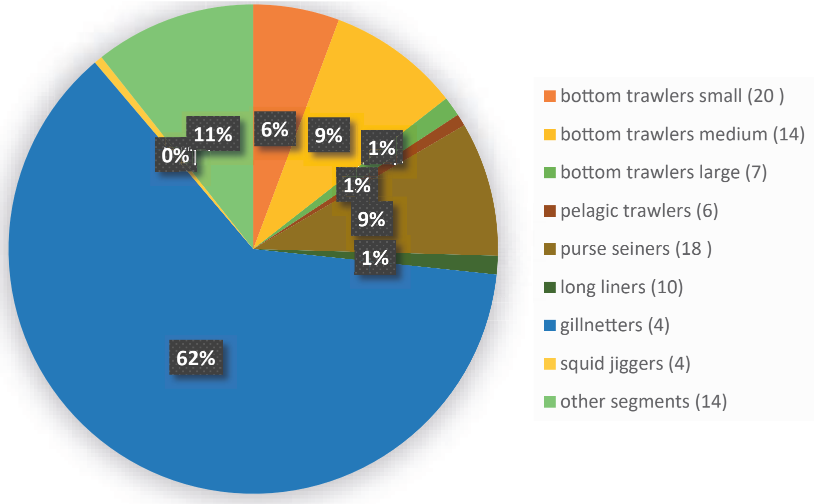
- mechanized trawlers in India (USD 3 billion)
- gillnetters in Bangladesh (USD 2 billion)
- Japanese offshore trawlers (USD 713 million)
- Japanese tuna longliners (USD 649 million)
- Turkish purse seiners (USD 577 million) and
- Norwegian conventional coastal vessels (USD 524 million).

[17] For the purposes of comparison, see for instance: csimarket.com/screening/index.php?s=roi or financialrhythm.com/profitability-margins-industry/

[18] The survey years ranged from 2012 (Hawaii longline) to 2016 for most European fleets, and 2017–2019 for most Asian fleets. The total GVA estimate provided can thus only serve as an indication for the contribution to the global economy.

[19] The average exchange rate in 2017 was 1 EUR = 1.13 USD; Therefore the EU fishing fleet GVA of EUR 4.5 billion would be approximately equivalent to USD 5.1 billion.

FIGURE 49
Percentage of total GVA contributed by vessel type, for all fleet segments surveyed



Note: In brackets the number of fleet segments surveyed by vessel type.

A list of estimated GVA by fishing vessel segment is provided in Table 4 of Appendix 4.A.

All together the gillnetter fleet segments surveyed contributed an estimated USD 45 billion to the global economy, the trawlers (small, medium and large) and purse seiners, contributed USD 11.4 billion and USD 6.4 billion respectively.

The very high number of gillnetters included in the GVA analysis, amounting to 123 000 vessels (51 percent of the total number of vessels in the analysis) provides, together with their highly positive GVA figures, the main reason for the high contribution of the gillnetter fleets to the Chinese and global economies. In this regard, it should be noted that if the target stocks of the gillnetter fleet segments were to collapse because of over-exploitation, the effects on the GVA of these fleet segments would be dramatic. Adequate management of the gillnetter fleet segments is essential in order to maintain the currently high GVA of these fleet segments for the economy.

4.12 FINANCIAL INDICATOR TRENDS FOR SELECTED FLEET SEGMENTS

It was not possible to compare the financial and economic indicator trends for all fleet segments in this analysis, due to the reasons given in chapter one. However, 35 fleet segments included in the current analysis were included also in the 2003 FAO fleet performance review (Tietze, *et al.*, 2005) and/or the 1999–2000 FAO fleet performance review (Tietze *et al.*, 2001). Table 9 presents the NCF and ROI average figures for vessels in these fleet segments. Over time the NCF figures have increased for almost all fleet segments that presented positive figures. The sometimes significantly higher NCF figures presented in 2016-2018 compared to the earlier performance reviews can be partly attributed to inflation and changes in exchange rates, but also to higher prices received for seafood landed (see Chapter 6.2), operational cost reductions (Chapter 3), technological progress (Chapter 5), higher volumes of seafood landed by some of these fleet segments, and an improvement in stock status which affected the catches of fleet segments operating in the North Atlantic.

Only 12 percent of the 35 fleet segments that could be compared showed lower (negative) NCF figures than in either of the two earlier fleet performance reviews.

Moreover, 66 percent of the 35 fleet segments presented higher ROI figures in the 2016–2018 surveys compared to the earlier reviews. The greatest improvements in NCF and ROI figures were found among European fleet segments (Germany, Norway, Spain and France) and among the Indian fleet segments.

TABLE 9
Net cash flow and return on investment figures of selected fleet segments in 2016–2018, 2003 and 1999–2000

Fleet segment	NCF (in Thousand USD) (2016–2018)	ROI (%) (2016–2018)	NCF (in Thousand USD) (2003)	ROI (%) (2003)	NCF (in Thousand USD) (1999– 2000)	ROI (%) (1999–2000)
China						
Stownetter, 39 m	116	9%	n.a	n.a	negative	negative
Single bottom trawler, 29 m	16	-1%	n.a	n.a	negative	negative
Small pair bottom trawler, 28 m	-37	-17%	n.a	n.a	negative	negative
Large purse seiner, 46 m	176	3%	n.a	n.a	150*	27%
India						
Trawler Chennai, 16 m	55	43%	5	17%	8	17%
Gillnetter Chennai, 19 m	42	17%	n.a	n.a	6	7%
Ring seiner Kochi, 14 m	59	65%	2	3%	1	n.a
Indonesia						
Purse seiner, 27 m	64	31%	n.a	n.a	9	23%
Longliner, 22 m	-67	-53%	n.a	n.a	10	11%
Pole and line vessel, 30 m	2	-2%	n.a	n.a	6	18%
Republic of Korea						
Offshore jigger, 23 m	52	4%	11	3%	3	1%
Large otter trawler, 35 m	1 109	49%	573	32%	330	23%
Large purse seiner, 38 m	-660	-17%	1 896	37%	n.a	n.a
Peru						
Anchovy purse seiner, 52 m	909	12%	362	16%	n.a	n.a
South Pacific hake trawler, 18 m	-91	-26%	9	1%	n.a	n.a
Germany						
Deep sea trawler, 66 m	2 118	11%	-109	negative	-226	negative
Deep sea trawler, 30 m	579	34%	60	3%	-34	negative
Beam trawler, 20 m	212	88%	126	14%	-11	negative
Beam trawler, 16 m	117	102%	11	1%	35	12%
France						
Deep sea trawler, 22 m	219	15%	22	3%	55*	7%
Coastal trawler, 15 m	109	18%	9	2%	1*	1%
Gillnetter, 12 m	66	23%	9	8%	10*	6%
Handliner, 8 m	28	44%	16	26%	24*	29%
Spain						
Purse seiner, 87 m	4 817	59%	n.a	n.a	618	4%
Deep sea trawler, 57 m	731	104%	n.a	n.a	39	2%
Deep sea trawler, 30 m	293	31%	n.a	n.a	37	3%
Norway						
Demersal cod trawler, 60 m	6 983	12%	121	3%	272	7%
Coastal purse seiner, 20 m	1 011	4%	120	10%	62	2%
Coastal shrimp trawler, 17 m	168	7%	-9	negative	2	2%
Conventional coastal vessel, 13 m	157	6%	15	8%	16	8%
Senegal						
Coastal pelagic trawler/seiner, 28 m	122	12%	9	31%	negative	negative
Coastal demersal trawler, 28 m	128	13%	negative	negative	negative	negative
South Africa						
Deep sea freezer trawler, 58 m	4 204	57%	1 748	31%	n.a	n.a
Squid jigger, 21 m	403	62%	184	39%	n.a	n.a
Hake longliner, 23 m	-327	-85%	170	58%	n.a	n.a

Note: * ratio of net profit/total earnings is used instead of net cash flow.

4.13 LABOUR PRODUCTIVITY AND FLEET PERFORMANCE

Labour productivity is an indicator of economic performance. It is important for formulating development policies on subjects such as industry and trade, institutional innovations, government investment programmes in infrastructure, as well as human capital, technology, or any combination thereof (ILO, 2021).

Labour productivity is a particularly efficient indicator in data-deficient fisheries, as it can be derived from information on the value of output and the number of fishers (Rodgers, 2019). Moreover, it captures the accumulation of machinery and equipment, improvements in fisheries management and infrastructure, improved health and skills among workers ("human capital") and the generation and adoption of new technologies, all of which will be reflected in increased labour productivity over time.

Labour productivity in capture fisheries can be measured using the following simple formula:

$$Labour\ productivity = \frac{Total\ revenue\ from\ fishing}{Number\ of\ crew\ (Full\ Time\ Equivalents)} \quad (1)$$

Republic of labour productivity this way does not account for the costs of production in terms of inputs (such as materials, services, energy and finance). One interpretation of the indicator could therefore be the following: if higher labour productivity is the objective, maximizing these inputs could come at the expense of fishing vessel owner/operator income. Moreover, there may be inverse proportional relationship between labor productivity and remuneration and employment levels, as shown in some Mediterranean Fisheries (Gee *et al.*, 2017).

In order to overcome this, a more refined measure of labour productivity is applied in the present analysis, in line with the European Union Annual Economic Reports (as per STECF, 2020; Salz and Frost, 1992); this is achieved by dividing the gross value added (GVA) – i.e. revenues less the cost of non-labour inputs – by the number of crew:

$$Labour\ productivity = \frac{Gross\ value\ added\ (= net\ cash\ flow + labour\ costs)}{Number\ of\ crew\ (FTEs)} \quad (2)$$

Here, an increase in labour productivity depends generally on three factors: investment in physical capital, the adoption of new technology (innovation), and enhancing human capital (skills) (Investopedia, 2021). Investments in physical capital in the fishing industry typically focus on vessels, engines and on-board equipment. The combination of technologies and innovations in fishing gears, navigation, fish finding and fish aggregation, as well as fish handling and on-board storage, enable the production of higher outputs (see also Chapter 5). In addition, the fishing crew (i.e. the human capital) can, through education, knowledge and the development and specialization of practical skills, contribute to the increased production of a fishing vessel or fleet. Measuring labour productivity in fisheries therefore equally involves measuring the combined effects of fluctuations in these various factors.[20]

There was significant variation in labour productivity (GVA per FTE) between and within the 97 fishing fleet segments included in this review study. Detailed figures are provided in Table 5 and Table 6 in Appendix 4.A.

These differences in labour productivity across the 97 segments can largely be explained by the capital intensiveness of production, such as the level of investment in a fishing vessel for example, which is much higher for large trawlers and purse seiners with steel hulls than for gillnetters constructed from wood. The availability of advanced on-board technologies to handle catch, maintain food safety and quality, and process

[20] It should be noted that inflationary effects over time are not taken into account in this methodology.

products, as well as fish-catching technologies, also have a positive impact on labour productivity. On larger industrial fishing vessels, the number of crew compared to the output produced is generally lower than on smaller semi-industrial vessels; labour productivity figures are therefore generally higher for larger vessels. The crew wage bill also affects labour productivity figures, insofar as higher labour costs may encourage investment in non-labour inputs. Crew wages are higher in OECD countries compared to those in other countries included in this review.

Within the small bottom trawler category (< 24 m), the highest average labour productivity was found in large groundfish trawlers (average LOA of 20 m) in the United States of America, which realized an estimated labour productivity of USD 293 000 per FTE. The Danish, French, German and Norwegian small bottom trawlers generally presented labour productivity figures of around USD 100 000 or higher per FTE in the survey years. In the medium-sized bottom trawler category (24–40 m), trawlers from Denmark, France, Germany, Japan, Republic of Korea and the United States of America presented labour productivity figures of USD 140 000 or higher. Crew on the German deep-sea trawlers of 30 m showed the highest labour productivity of fleet segments in this category, at USD 312 000 per FTE. Among the largest trawlers (> 40 m) the average full-time crew member on a Danish, German or Norwegian vessel realized a labour productivity figure of over USD 200 000, while those working on the South African deep-sea freezer trawler produced USD 132 000 in added value in the survey year. By contrast, the labour productivity per FTE in the bottom trawler fleets of various size categories from Bangladesh, Brazil, Chile, China, India and Peru was generally well below USD 50 000.

Of the purse seiner fleet segments included in this review, 9 out of 18 presented annual labour productivity figures of over USD 100 000 per FTE. An average crew member on a Chilean industrial purse seiner (66 m) realized an estimated added value of USD 358 000 in the survey year. Other purse seiner fleet segments with labour productivity figures of over USD 200 000 per FTE included the Norwegian large seagoing purse seiners (66 m), and the Japanese bonito purse seiners (57 m) and purse seiners (40 m). By comparison, the labour productivity on Indian and Indonesian purse seiners and ring seiners was below USD 10 000 per FTE.

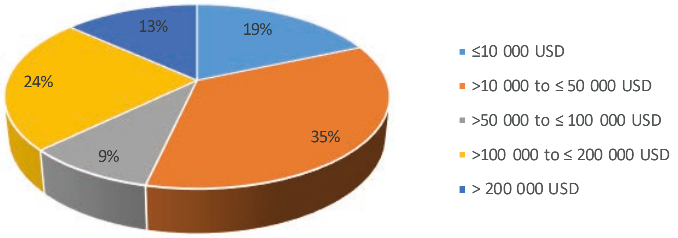
Average labour productivity figures were generally rather low in the longliners category, and lower than USD 50 000 per FTE on average. The Norwegian conventional seagoing vessels (45 m) and the Japanese tuna longliners (40 m) were two notable exceptions, which presented labour productivity figures of USD 172 000 and USD 180 000 respectively per FTE in the survey years.

While it can be concluded that the labour productivity of crew working on pelagic trawlers, large and medium-sized bottom trawlers and purse seiners was, on average, higher than the labour productivity of crew on squid jiggers, longliners and gillnetters in the survey years, the differences in labour productivity appear to be mostly associated with the national provenance of the fleet segments surveyed.

Independent of the specific fleet segment analysed, labour productivity in the (semi-) industrial fishing fleets was lowest in India and Indonesia, where the average GVA per FTE was less than USD 15 000 in each fleet segment. On the other hand, labour productivity figures per FTE were over USD 100 000 for all the French, Japanese and Norwegian fleet segments surveyed.

A comparison of the 97 fleet segments covered in this review (Figure 50) shows that in 35 percent of fleet segments one FTE employed crew member generated between USD 10 000 and USD 50 000 of gross value added. Some 37 percent of fleet segments revealed the labour productivity of an average full-time employed crew member as over USD 100 000 in the survey years. Average labour productivity of more than USD 200 000 per year was calculated for 13 of the 97 fleet segments surveyed.

FIGURE 50
Labour productivity variation in the 97 fishing fleet segments surveyed



The above differences in labour productivity between fishing fleet segments can largely be attributed to differences in the capital intensity of a fleet, the levels of technology applied in fishing operations, the size of fishing operations (vessels) and the crew wage bill. Comparing fisheries labour productivity figures from this review to those of other industries (Indexmundi, 2021) reveals that the gross value added per employee in the fishing fleet segments surveyed is generally at a similar or higher level than in manufacturing, mining, construction and public utilities in the same countries.

REFERENCES

Carvalho, N., Van Anrooy, R., Vassdal, T. & Dağtekin, M. 2020. *Techno-economic performance review of selected fishing fleets in Europe.* FAO Fisheries and Aquaculture Technical Paper No. 653/1. Rome, FAO. 198 pp. (also available at www.fao.org/documents/card/en/c/ca9188en).

CFI. 2021. What is a Profit Margin?. [Cited 5 March 2021]. https://corporatefinanceinstitute.com/resources/knowledge/accounting/profit-margin/

Gee, J., Pinello, D., & Polymeros, K. 2017. *Drivers of Labor-Related Indicators across Diverse Mediterranean Fisheries.* In: Sustainability 2017, 9, 2000. (Available at: www.mdpi.com/2071-1050/9/11/2000/pdf).

Indexmundi. 2021. Industry, value added per worker (constant 2010 US$) - Country Ranking. In: *Indexmundi.* [Cited 26 January 2021] www.indexmundi.com/facts/indicators/NV.IND.EMPL.KD/rankings

International Labour Organization (ILO). 2021. Indicator description: Labour productivity. In: *International Labour Organization – ILOSTAT* [online]. Geneva, Switzerland. [Cited 24 January 2021] ilostat.ilo.org/resources/concepts-and-definitions/description-labour-productivity/

Investopedia. 2021. Labor productivity. In: *Economy – Economics.* [Cited 24 January 2021]. www.investopedia.com/terms/l/labor-productivity.asp

Kitts, A., Van Anrooy, R., Van Eijs, S., Pino Shibata, J., Pallalever Pérez, R., Gonçalves, A.A., Ardini, G., Liese, C., Pan, M. & Steiner, E. 2020. *Techno-economic performance review of selected fishing fleets in North and South America.* FAO Fisheries and Aquaculture Technical Paper No. 653/2. Rome, FAO. 122 pp. (also available at www.fao.org/documents/card/en/c/ca9543en).

Rodgers, P.E. 2019. Methodologies for conducting fishing fleet techno-economic performance reviews. *In* FAO. *Report of the Expert Meeting on Methodologies for Conducting Fishing Fleet Techno-Economic Performance Reviews, Chennai, India, 18-20 September 2018.* FAO Fisheries and Aquaculture Report No. 1243, pp. 20–37. Rome, FAO. (also available at www.fao.org/documents/card/en/c/ca4427en/).

Salz, P. & Frost H. 1992. *Model for economic interpretation of the ACFM advice (EIAA).* Den Haag, The Netherlands, Landbouw Economisch Instituut (LEI).

Scientific, Technical and Economic Committee for Fisheries (STECF). 2016. Annual economic report (AER) report methodology. https://stecf.jrc.ec.europa.eu/documents/43805/1489224/2016_AER_6_METHODOLOGY.pdf

Scientific, Technical and Economic Committee for Fisheries (STECF). 2020. *The 2019 Annual Economic Report on the EU Fishing Fleet (STECF 19-06). Scientific, Technical and Economic Committee for Fisheries (STECF)*. Carvalho, N., Keatinge, M. & Guillen Garcia, J., eds.. EUR 28359 EN. Luxembourg, Publications Office of the European Union. (also available at stecf.jrc.ec.europa.eu/documents/43805/2483556/STECF+19-06+-+AER+-+2019.pdf/db370547-4405-416d-b2e3-76f8276edae2

Tietze, U., Thiele, W., Lasch, R., Thomsen, B., & Rihan, D. 2005. *Economic performance and fishing efficiency of marine capture fisheries.* FAO Fisheries Technical Paper No. 482. Rome, FAO. 68 pp. (also available at www.fao.org/docrep/008/y6982e/y6982e00.htm).

APPENDIX 4.A

TABLE 1

Financial and economic indicators of selected fleet segments and how these were calculated

Financial Indicators	Code	Mechanized trawler, Chennai, India	Large groundfish trawler, United States of America	Bonito purse seiner, Japan	Description
Revenue from landings	A	203 077	902 931	11 680 013	Sum of average ex-vessel prices by species × output volume by species
Total revenue	A2	205 577	902 931	13 000 385	Revenue from sales of fish + income from sale of fishing rights, subsidies, grants and other income
Labour costs	B	87 303	328 189	4 548 404	Sum of labour wages, social security, crew travel and food, and provisions
Running costs	C	51 013	177 713	3 264 669	Sum of energy costs and other variable costs (e.g. ice, bait)
Vessel Costs	D	12 477	221 890	1 895 445	Sum of gear and vessel repair and maintenance costs, fishing license costs, quota costs, and non-variable costs (e.g. insurance, accountancy)
Total gross cost (E) = B + C + D	E	150 793	727 792	9 708 518	Total gross cost = labour costs + running costs + vessel costs
Total costs (E2) = E + G + J + S	E2	171 841	833 942	12 061 801	Total costs = total gross costs + interest costs + taxes
Net Cash Flow (F) = A2 - E	F	54 785	175 139	3 291 867	Net cash flow = total revenue - total gross costs
Depreciation	G	12 632	46 059	1 576 999	Depreciation = reduction in the value of the tangible assets
Amortization	H	0	0	0	Amortization = reduction in value of intangible assets
Gross profit (I) = F - G - H	I	42 152	129 080	4 868 866	Gross profit = net cash flow - depreciation - amortization
Interest	J	8 416	106 150	169 759	Interest = cost of loans
Net profit before taxes (K) = I - J	K	33 737	22 930	4 699 106	Net profit before taxes = gross profit - interest
Net profit margin (L) = K/A2 (%)	L	16%	2.5%	36%	Net profit margin = net profit before taxes/revenue from landings
Value of tangible assets	M	39 128	2 653 750	3 294 000	Sum of the value of tangible assets (e.g. hull, engines, main equipment) or replacement value if available.
ROFTA (N) = K/M in (%)	N	86%	1%	143%	Return on Fixed Tangible Assets (ROFTA) = net profit before taxes/value of tangible assets
Value of intangible assets	O	0	0	0	Sum of the value of intangible assets (e.g. quotas, licenses).
ROI (P) = K/(T + O) (in %)	P	43%	1%%	28%	Return on Investment (ROI) = net profit before taxes/value of tangible + intangible assets
GVA (Q) = F + B	Q	140 265	503 328	7 840 271	Gross Value Added (GVA) = net cash flow + labour costs
GVA to revenue (R) = Q/A2 (in %)	R	68%	55.7%	60%	GVA to revenue = GVA divided by total revenue
Taxes	S	0	0	606 525	
Initial investment costs	T	79 083	2 653 7501	17 015 331	Sum of initial investment in the vessel hull, engines, main equipment, navigation and communication.
Year of information		2018–2019	2017	2017	

Note 1: In this global review study the ROI percentage was generally calculated over the initial investment cost, or based on available data on the vessel replacement cost for the purposes of comparison. The reason for doing so was that the value of intangible assets was not available for most vessels. Only the Norwegian fleet segments reported on the cost of amortization.
Note 2: For the US Large groundfish trawler the vessel average replacement value in 2017 was used for initial investment costs.

TABLE 2

Financial and economic performance of average vessels in the fleet segments covered in this global review (trawlers)

	Fleet segment	NCF (in thousand USD)	NPM (%)	ROFTA (%)	ROI (%)	GVA (in thousand USD)	GVA to revenue (%)	Survey year	Number of vessels
< 24 m trawler	Brazil, shrimp trawler, 22 m	-37	-35%	-53%	-10%	34	17%	2018	1 824
	Brazil, demersal trawler, 21 m	100	6%	30%	6%	254	37%	2018	a
	Brazil, bottom trawler, 23 m	99	4%	35%	6%	164	35%	2018	a
	Denmark, demersal trawler, 21 m	368	12%	12%	2%	666	60%	2016	49
	Denmark, demersal trawler, 15 m	127	14%	13%	3%	209	56%	2016	116
	France, deep-sea trawler, 22 m	219	8%	15%	15%	669	52%	2016	134
	France, coastal trawler, 15 m	109	8%	18%	18%	380	57%	2016	153
	Germany, beam trawler, 20 m	212	34%	88%	88%	321	64%	2016	63
	Germany, beam trawler, 16 m	117	35%	102%	102%	175	64%	2016	111
	India, trawler Chennai, 16 m	55	16%	86%	43%	140	68%	2019	30 486
	India, trawler Kakinada, 15 m	46	33%	95%	42%	60	67%	2019	a
	Italy, demersal trawler, 21 m	87	8%	10%	10%	163	54%	2016	633
	Italy, demersal trawler, 14 m	52	23%	55%	55%	92	59%	2016	1 232
	Norway, coastal shrimp trawler, 17 m	168	11%	8%	7%	447	59%	2016	103
	Peru, South Pacific hake trawler, 18 m	-91	-40%	-52%	-26%	-5	-2%	2018	33
	Turkey, bottom trawler, 18 m	77	41%	22%	22%	100	66%	2018	448
	United Kingdom of Great Britain and Northern Ireland, demersal trawler, 20 m	150	5%	11%	4%	348	44%	2016	167
	United States of America, Gulf of Mexico shrimp trawler, 21 m	62	11%	16%	16%	156	42%	2014	1 043
	United States of America, small groundfish trawler, 18 m	26	-16%	-4%	-4%	166	44%	2017	20
	United States of America, large groundfish trawler, 20 m	364	3%	1%	1%	849	59%	2017	32
24– 40 m trawler	Bangladesh, shrimp trawler, 29 m	908	38%	67%	46%	1 106	64%	2019	30
	Bangladesh, bottom trawler, 25 m	68	5%	13%	4%	122	33%	2019	47
	China, single bottom trawler, 29 m	16	-1%	-1%	-1%	100	35%	2019	34 141
	China, small pair bottom trawler, 28 m	-37	-50%	-20%	-17%	29	22%	2019	a
	Denmark, demersal trawler, 31 m	837	14%	15%	3%	1 450	60%	2016	34
	France, deep-sea trawler, 28 m	365	6%	9%	9%	997	48%	2016	57
	Germany, deep-sea trawler, 30 m	579	18%	34%	34%	1 282	61%	2016	9
	Japan, offshore trawler cod and pollock, 29 m	1 032	29%	226%	13%	2 660	67%	2018	268
	Republic of Korea, large otter trawler, 35 m	1 109	26%	251%	49%	2 419	59%	2017	34
	Senegal, coastal demersal trawler, 28 m	128	15%	214%	13%	276	49%	2018	78
	Senegal, deep-sea demersal trawler, 31 m	1 525	54%	263%	69%	2 029	77%	2018	25
	Spain, deep-sea trawler, 30 m	293	23%	67%	31%	629	59%	2016	107
	United Kingdom of Great Britain and Northern Ireland, demersal trawler, 28 m	515	6%	26%	7%	1 077	46%	2016	87
	United States of America, whiting trawler, 27 m	175	3%	1%	1%	503	56%	2017	34
> 40 m trawler	Chile, trawler, 54 m	260	0%	0%	0%	1 923	42%	2018	44
	China, large pair bottom trawler, 46 m	165	12%	13%	10%	325	40%	2019	a
	Denmark, demersal trawler, 46 m	1 371	11%	15%	4%	1 880	54%	2016	10
	Germany, deep-sea trawler, 66 m	2 118	12%	11%	11%	4 501	61%	2016	7
	Norway, demersal cod trawler, 60 m	6 983	26%	17%	12%	13 096	69%	2016	36
	Spain, deep-sea trawler, 57 m	731	8%	122%	104%	1 950	36%	2016	30
	South Africa, deep-sea freezer trawler, 58 m	4 204	48%	155%	57%	5 518	72%	2019	51
Pelagic trawler	Bangladesh, midwater trawler, 41 m	726	29%	51%	23%	913	58%	2019	127
	Denmark, pelagic trawler, 56 m	5 856	23%	12%	4%	7 069	74%	2016	22
	Norway, pelagic trawler, 54 m	2 248	13%	8%	3%	4 251	69%	2016	14
	Turkey, pelagic trawler, 25 m	117	33%	34%	34%	160	52%	2018	146
	Senegal, coastal pelagic trawler/seiner, 28 m	122	12%	14%	12%	215	32%	2018	12
	United Kingdom of Great Britain and Northern Ireland, pelagic trawler, 66 m	5 307	36%	69%	13%	7 905	65%	2016	28

Note: a = included in the number of vessels above.

TABLE 3

Financial and economic performance of average vessels in the fleet segments covered in this global review (gillnetters, purse seiners, longliners, squid jiggers and other fleet segments)

	Fleet segment	NCF (in thousand USD)	NPM (%)	ROFTA (%)	ROI (%)	GVA (in thousand USD)	GVA to revenue (%)	Survey year	Number of vessels
Gillnetter	Bangladesh, mechanized gillnetter, 17 m	41	18%	85%	36%	98	65%	2019	20 359
	China, gillnetter, 34 m	280	46%	68%	55%	443	80%	2019	96 315
	India, gillnetter Chennai, 19 m	42	17%	36%	17%	57	60%	2019	6 502
	France, gillnetter, 12 m	66	10%	23%	23%	235	65%	2016	173
Purse seiner	Chile, industrial purse seiner, 66 m	5 144	43%	134%	30%	6 086	61%	2018	88
	Chile, southern purse seiner, 66 m	1 769	8%	9%	3%	2 844	31%	2018	a
	Chile, artisanal purse seiner, 18 m	102	56%	45%	52%	118	65%	2018	b
	China, large purse seiner, 46 m	176	10%	5%	3%	424	53%	2019	7 483
	India, purse seiner Mangalore, 22 m	105	14%	51%	26%	215	48%	2019	1 189
	India, ring seiner Kochi, 14 m	59	18%	142%	65%	189	73%	2019	943
	Indonesia, purse seiner, 27 m	64	22%	38%	31%	115	44%	2019	1 374
	Italy, purse seiner, 43 m	1 052	31%	48%	48%	1 874	82%	2016	11
	Japan, purse seiner, 40 m	1 990	41%	71%	21%	4 970	57%	2018	60
	Japan, bonito purse seiner, 57 m	3 292	36%	143%	28%	7 840	60%	2018	35
	Republic of Korea, large purse seiner, 38 m	-660	-10%	-174%	-17%	3 208	31%	2017	25
	Norway, large seagoing purse seiner, 66 m	3 824	27%	10%	7%	6 600	73%	2016	73
	Norway, coastal purse seiner, 20 m	1 011	17%	8%	4%	1 250	77%	2016	103
	Peru, anchovy purse seiner, 52 m	909	18%	13%	12%	1 629	49%	2018	126
	Spain, purse seiner, 87 m	4 817	20%	59%	59%	7 155	42%	2016	26
	Spain, purse seiner, 21 m	106	22%	88%	88%	342	72%	2016	99
	Turkey, purse seiner, 30 m	361	35%	30%	30%	562	68%	2018	553
	Turkey, purse seiner, 46 m	1 212	49%	41%	41%	1 524	72%	2018	a
Longliner	Brazil, longliner, 26 m	153	29%	116%	41%	213	51%	2018	168
	Brazil, freezer longliner, 32 m	-89	-33%	-100%	-35%	9	2%	2018	a
	Brazil, super freezer longliner, 48 m	-83	-24%	-74%	-26%	99	16%	2018	a
	Chile, longliner, 63 m	1 062	16%	59%	21%	3 063	47%	2018	8
	Indonesia, longliner, 22 m	-67	-100%	-93%	-53%	-38	-52%	2019	351
	Japan, tuna longliner, 40 m	1 421	27%	88%	24%	3 279	57%	2018	198
	Norway, conventional seagoing vessel, 45 m	2 212	13%	8%	5%	6 643	68%	2016	19
	Spain, surface longliner, 31 m	344	15%	94%	69%	660	37%	2016	64
	South Africa, hake longliner, 23 m	-327	-56%	-148%	-85%	184	28%	2019	45
	United States of America, Hawaii pelagic longliner, 23 m	100	7%	9%	14%	259	35%	2012	142
Jigger	Indonesia, squid jigger, 27 m	51	17%	87%	46%	117	43%	2019	470
	Republic of Korea, offshore jigger, 23 m	52	8%	14%	4%	220	59%	2017	588
	Peru, jumbo squid vessel, 10 m	116	49%	72%	92%	147	70%	2018	698
	South Africa, squid jigger, 21 m	403	36%	169%	62%	796	84%	2019	138
Variety of fleet segments	China, stownetter, 39 m	116	12%	12%	9%	360	66%	2019	18 281
	Denmark, passive gears vessel, 7 m	6	11%	9%	5%	8	45%	2016	774
	France, handliner, 8 m	28	17%	44%	44%	77	65%	2016	239
	Germany, small-scale vessel, 6 m	4	22%	30%	30%	5	50%	2016	718
	Indonesia, pole and line vessel, 30 m	2	-16%	-4%	-2%	2	19%	2019	87
	Indonesia, cast netter, 23 m	51	36%	266%	163%	61	43%	2019	442
	Italy, passive gears vessel, 8 m	21	39%	57%	57%	27	74%	2016	5 144
	Norway, conventional coastal vessel, 13 m	157	13%	10%	6%	422	71%	2016	1 242
	Senegal, tuna pole and line vessel, 32 m	725	26%	75%	21%	965	47%	2018	13
	Senegal, deep-sea crab trapper, 31 m	1 045	50%	1 779%	305%	1 593	78%	2018	a
	United Kingdom of Great Britain and Northern Ireland, pots and trap vessel, 11 m	62	29%	66%	32%	107	57%	2016	178
	United Kingdom of Great Britain and Northern Ireland, pots and trap vessel, 7 m	17	25%	48%	26%	32	58%	2016	1 814
	United States of America, northeast limited access scallop dredger (full time), 24 m	314	9%	31%	3%	1 037	73%	2016	313
	United States of America, northeast limited access scallop dredger (part time), 20 m	82	-1%	-2%	0%	379	51%	2016	35

Note: a = included in the number of vessels above; b = no information available.

TABLE 4
Estimated total gross value added of the main global fishing fleets by segment (in million USD per year)

Fleet segment	GVA in million USD	Fleet segment	GVA in million USD
China, gillnetter, 34 m	42 668	Spain, deep-sea trawler, 30 m	67
China, stownetter, 39 m	6 581	Norway, pelagic trawler, 54 m	60
China, single & pair bottom trawlers, 28–46m	5 155	Spain, deep-sea trawler, 57 m	59
China, large purse seiner, 46 m	3 173	France, coastal trawler, 15 m	58
India, trawlers, 15–16 m	3 049	United Kingdom of Great Britain and Northern Ireland, demersal trawler, 20 m	58
Bangladesh, mechanized gillnetter, 17 m	2 002	United Kingdom of Great Britain and Northern Ireland, pots and trap vessel, 7 m	58
Japan, offshore trawler cod&pollock, 29 m	713	France, deep-sea trawler, 28 m	57
Japan, tuna longliner, 40 m	649	Indonesia, squid jigger, 27 m	55
Turkey, purse seiners, 30–46 m	577	Senegal, deep-sea demersal trawler, 31 m	51
Norway, conventional coastal vessel, 13 m	524	Denmark, demersal trawler, 31 m	49
Norway, large seagoing purse seiner, 66 m	482	Norway, coastal shrimp trawler, 17 m	46
Norway, demersal cod trawler, 60 m	471	Turkey, bottom trawler, 18 m	45
Chile, industrial and southern purse seiner, 66 m	393	Spain, surface longliner, 31 m	42
India, gillnetter Chennai, 19 m	371	France, gillnetter, 12 m	41
United States of America, northeast limited access scallop dredger (full time), 24 m	325	United States of America, Hawaii pelagic longliner, 23 m	37
Japan, purse seiner, 40 m	298	Spain, purse seiner, 21 m	34
South Africa, deep-sea freezer trawler, 58 m	281	Bangladesh, shrimp trawler, 29 m	33
Brazil, shrimp trawler, 22 m, demersal trawler 21 m and bottom trawler, 23 m	275	Denmark, demersal trawler, 21 m	33
Japan, bonito purse seiner, 57 m	274	Germany, deep-sea trawler, 66 m	32
India, purse seiner Mangalore, 22 m	256	United States of America, large groundfish trawler, 20 m	27
United Kingdom of Great Britain and Northern Ireland, pelagic trawler, 66 m	221	Indonesia, cast netter, 23 m	27
Peru, anchovy purse seiner, 52 m	205	Chile, longliner, 63 m	25
Spain, purse seiner, 87 m	186	Denmark, demersal trawler, 15 m	24
India, ring seiner Kochi, 14 m	178	Turkey, pelagic trawler, 25 m	23
United States of America, Gulf of Mexico shrimp trawler, 21 m	163	Senegal, coastal demersal trawler, 28 m	22
Indonesia, purse seiner, 27 m	158	Italy, purse seiner, 43 m	21
Denmark, pelagic trawler, 56 m	156	Germany, beam trawler, 20 m	20
Italy, passive gears vessel, 8 m	138	Germany, beam trawler, 16 m	19
Republic of Korea, offshore jigger, 23 m	129	United Kingdom of Great Britain and Northern Ireland, pots and trap vessel, 11 m	19
Norway, coastal purse seiner, 20 m	129	Denmark, demersal trawler, 46 m	19
Norway, conventional seagoing vessel, 45 m	126	France, handliner, 8 m	18
Bangladesh, midwater trawler, 41 m	116	Brazil, longliners, 26 m and freezer longliners, 32–48 m	18
Italy, demersal trawler, 14 m	114	United States of America, whiting trawler, 27 m	17
South Africa, squid jigger, 21 m	110	United States of America, northeast limited access scallop dredger (part-time), 20 m	13
Italy, demersal trawler, 21 m	103	Senegal, tuna pole and line vessel, 32 m	13
Peru, jumbo squid vessel, 10 m	103	Germany, deep-sea trawler, 30 m	12
United Kingdom of Great Britain and Northern Ireland, demersal trawler, 28 m	94	South Africa, hake longliner, 23 m	8
France, deep-sea trawler, 22 m	90	Denmark, passive gears vessel, 7 m	6
Chile, trawler, 54 m	85	Bangladesh, bottom trawler, 25 m	6
Republic of Korea, large otter trawler, 35 m	82	Germany, small-scale vessel, 6 m	4
Republic of Korea, large purse seiner, 38 m	80	United States of America, small groundfish trawler, 18 m	3

Notes: The following fleet segments include combinations of fleet segments, for which the average GVA was applied in Tables 2 and 3: single and pair bottom trawlers (China), trawlers of Chennai and Kakinda (India), longliners (Brazil), trawlers (Brazil), purse seiners (Chile) and purse seiners (Turkey). The reason for averaging is that only the total number of vessels of these segments was available.

TABLE 5

Gross value added per vessel and per full-time equivalent employed crew member (FTE) of average vessels in the fleet segments covered in this global review (Part 1 – Trawlers)

Type of vessels	Fleet segment	GVA per vessel (in thousand USD)	Number of full-time equivalent employed crew per vessel (FTE)	GVA per FTE (in thousand USD)
small trawlers	Brazil, shrimp trawler, 22 m	34	5.00	7
small trawlers	Brazil, demersal trawler, 21 m	254	7.00	36
small trawlers	Brazil, bottom trawler, 23 m	164	5.00	33
small trawlers	Denmark, demersal trawler, 21 m	666	4.82	138
small trawlers	Denmark, demersal trawler, 15 m	209	2.15	97
small trawlers	France, deep-sea trawler, 22 m	669	2.96	226
small trawlers	France, coastal trawler, 15 m	380	2.05	186
small trawlers	Germany, beam trawler, 20 m	321	2.10	153
small trawlers	Germany, beam trawler, 16 m	175	1.32	133
small trawlers	India, trawler Chennai, 16 m	140	10.00	14
small trawlers	India, trawler Kakinada, 15 m	60	9.00	7
small trawlers	Italy, demersal trawler, 21 m	163	3.88	42
small trawlers	Italy, demersal trawler, 14 m	92	2.63	35
small trawlers	Norway, coastal shrimp trawler, 17 m	447	3.00	149
small trawlers	Peru, South Pacific hake trawler, 18 m	-5	8.30	-1
small trawlers	Turkey, bottom trawler, 18 m	100	4.00	25
small trawlers	United Kingdom of Great Britain and Northern Ireland, demersal trawler, 20 m	348	2.36	148
small trawlers	United States of America, Gulf of Mexico shrimp trawler, 21 m	156	3.20	49
small trawlers	United States of America, small groundfish trawler, 18 m	166	2.50	67
small trawlers	United States of America, large groundfish trawler, 20 m	849	2.90	293
medium trawlers	Bangladesh, shrimp trawler, 29 m	1 106	23.50	47
medium trawlers	Bangladesh, bottom trawler, 25 m	122	22.00	6
medium trawlers	China, single bottom trawler, 29 m	100	6.00	17
medium trawlers	China, small pair bottom trawler, 28 m	29	10.00	3
medium trawlers	Denmark, demersal trawler, 31 m	1 450	8.91	163
medium trawlers	France, deep-sea trawler, 28 m	997	7.04	142
medium trawlers	Germany, deep-sea trawler, 30 m	1 282	4.11	312
medium trawlers	Japan, offshore trawler cod&pollock, 29 m	2 660	12.67	210
medium trawlers	Republic of Korea, large otter trawler, 35 m	2 419	14.00	173
medium trawlers	Senegal, coastal demersal trawler, 28 m	276	15.00	18
medium trawlers	Senegal, deep-sea demersal trawler, 31 m	2 029	21.00	97
medium trawlers	Spain, deep-sea trawler, 30 m	629	8.55	74
medium trawlers	United Kingdom of Great Britain and Northern Ireland, demersal trawler, 28 m	1 077	12.63	85
medium trawlers	United States of America, whiting trawler, 27 m	503	3.20	157
large trawlers	Chile, trawler, 54 m	1 923	49.00	39
large trawlers	China, large pair bottom trawler, 46 m	325	12.00	27
large trawlers	Denmark, demersal trawler, 46 m	1 880	6.40	294
large trawlers	Germany, deep-sea trawler, 66 m	4 501	21.00	214
large trawlers	Norway, demersal cod trawler, 60 m	13 096	51.30	255
large trawlers	Spain, deep-sea trawler, 57 m	1 950	37.87	51
large trawlers	South Africa, deep-sea freezer trawler, 58 m	5 518	39.92	138
pelagic trawlers	Bangladesh, midwater trawler, 41 m	913	38.33	24
pelagic trawlers	Denmark, pelagic trawler, 56 m	7 069	8.96	789
pelagic trawlers	Norway, pelagic trawler, 54 m	4 251	15.90	267
pelagic trawlers	Turkey, pelagic trawler, 25 m	160	5.00	32
pelagic trawlers	Senegal, coastal pelagic trawler/seiner, 28 m	215	16.33	13
pelagic trawlers	United Kingdom of Great Britain and Northern Ireland, pelagic trawler, 66 m	7 905	3.68	2 148

TABLE 6

Gross value added per vessel and per full-time equivalent employed crew member (FTE) of average vessels in the fleet segments covered in this global review (Part 2 – Gillnetters, purse seiners, longliners, squid jiggers and other fleet segments)

Type of vessels	Fleet segment	GVA per vessel (in thousand USD)	Number of full-time equivalent employed crew per vessel (FTE)	GVA per FTE (in thousand USD)
gillnetters	Bangladesh, mechanized gillnetter, 17 m	98	20.00	5
gillnetters	China, gillnetter, 34 m	443	10.00	44
gillnetters	India, gillnetter Chennai, 19 m	57	8.00	7
gillnetters	France, gillnetter, 12 m	235	2.05	115
purse seiners	Chile, industrial purse seiner, 66 m	6 086	17.00	358
purse seiners	Chile, southern purse seiner, 66 m	2 844	19.00	150
purse seiners	Chile, artisanal purse seiner, 18 m	118	10.00	12
purse seiners	China, large purse seiner, 46 m	424	11.33	37
purse seiners	India, purse seiner Mangalore, 22 m	215	32.00	7
purse seiners	India, ring seiner Kochi, 14 m	189	31.00	6
purse seiners	Indonesia, purse seiner, 27 m	115	36.00	3
purse seiners	Italy, purse seiner, 43 m	1 874	10.27	182
purse seiners	Japan, purse seiner, 40 m	4 970	18.00	276
purse seiners	Japan, bonito purse seiner, 57 m	7 840	27.00	290
purse seiners	Republic of Korea, large purse seiner, 38 m	3 208	27.00	119
purse seiners	Norway, large seagoing purse seiner, 66 m	6 600	20.00	330
purse seiners	Norway, coastal purse seiner, 20 m	1 250	6.60	189
purse seiners	Peru, anchovy purse seiner, 52 m	1 629	19.00	86
purse seiners	Spain, purse seiner, 87 m	7 155	56.39	127
purse seiners	Spain, purse seiner, 21 m	342	10.77	32
purse seiners	Turkey, purse seiner, 30 m	562	27.00	21
purse seiners	Turkey, purse seiner, 46 m	1 524	38.00	40
longliners	Brazil, longliner, 26 m	213	5.00	43
longliners	Brazil, freezer longliner, 32 m	9	6.00	1
longliners	Brazil, super freezer longliner, 48 m	99	14.00	7
longliners	Chile, longliner, 63 m	3 063	49.00	63
longliners	Indonesia, longliner, 22 m	-38	15.00	-3
longliners	Japan, tuna longliner, 40 m	3 279	18.17	180
longliners	Norway, conventional seagoing vessel, 45 m	6 643	38.60	172
longliners	Spain, surface longliner, 31 m	660	16.86	39
longliners	South Africa, hake longliner, 23 m	184	24.45	8
longliners	United States of America, Hawaii pelagic longliner, 23 m	259	6.00	43
squid jiggers	Indonesia, squid jigger, 27 m	117	31.00	4
squid jiggers	Republic of Korea, offshore jigger, 23 m	220	10.00	22
squid jiggers	Peru, jumbo squid vessel, 10 m	147	8.00	18
squid jiggers	South Africa, squid jigger, 21 m	796	17.70	45
other vessel segments	China, stownetter, 39 m	360	12.00	30
other vessel segments	Denmark, passive gears vessel, 7 m	8	0.17	48
other vessel segments	France, handliner, 8 m	77	0.57	136
other vessel segments	Germany, small-scale vessel, 6 m	5	0.74	7
other vessel segments	Indonesia, pole-and-line vessel, 30 m	2	49.00	0
other vessel segments	Indonesia, cast netter, 23 m	61	10.00	6
other vessel segments	Italy, passive gears vessel, 8 m	27	1.42	19
other vessel segments	Norway, conventional coastal vessel, 13 m	422	2.90	146
other vessel segments	Senegal, tuna pole-and-line vessel, 32 m	965	22.00	44
other vessel segments	Senegal, deep-sea crab trapper, 31 m	1 593	21.00	76
other vessel segments	United Kingdom of Great Britain and Northern Ireland, pots and trap vessel, 11 m	107	2.36	45
other vessel segments	United Kingdom of Great Britain and Northern Ireland, pots and trap vessel, 7 m	32	0.68	47
other vessel segments	United States of America, northeast limited access scallop dredger (full-time), 24 m	1 037	7.00	148
other vessel segments	United States of America, northeast limited access scallop dredger (part-time), 20 m	379	5.00	76

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Trends in technological innovations with an impact on fishing fleet performance

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5. Trends in technological innovations with an impact on fishing fleet performance

The technologies employed in fisheries continues to develop. Since the most recent FAO global review of the techno-economic performance of the main fishing fleets in 2002–3003, a wide range of additional technologies and innovations have been explored to increase fleet performance. Over the last 15 years, reducing fuel costs and saving energy have been drivers for technological developments in fishing vessels, gears and fishing operations. Fuel costs are an important component of the running costs of a fishing vessel. Fuel costs are always subject to considerable and unpredictable fluctuations, depending on crude oil prices, which can have significant negative (and positive) impacts on the profitability of fishing fleets. Other technological innovations in fishing focused on: increasing fishing efficiency, reducing the environmental impact of fishing, improving fish handling and product quality, improving safety at sea and the working conditions of fishers on board vessels, or a combination of the above.

The scientific work on fishing technologies has been tremendous, supported by research grants from the European Union, national authorities, such as in the United States of America and Norway, and large foundations. However, the uptake of innovations in energy-efficient technologies, fishing gears, vessel design and operations in commercial fisheries has often been rather limited (FAO, 2019a, 2019b). Subsidies for fishing vessel design, gears and related technologies have frequently addressed local problems and found solutions, but regional or worldwide implementation has not been achieved.

This chapter intends to provide a summary of the major technological developments that have contributed positively to fishing fleet performance in recent years. The chapter does not aim to make any judgement regarding whether it is desirable to increase the fleet performance and efficiency in capture fisheries. The authors recognize that overcapacity affects fishing fleets in many countries and regions and that, combined with certain fishing methods, this can have significant negative impacts on aquatic biodiversity, fish stocks and habitats.

This chapter considers the following five areas of technological improvements that have contributed to the economic performance of the main global fishing fleets:[21]

1. Cost reduction and energy savings in capture fisheries
2. Increasing fishing efficiency
3. Reducing the environmental/ecological impact of capture fisheries
4. Improving fish handling, product quality and food safety
5. Improving safety at sea and the working conditions of fishers.

[21] This chapter draws on information from secondary research including the regional techno-economic fleet performance reviews outlined in FAO Fisheries Technical Papers 653/1, 653/2 and 653/3, as well as discussions that took place at the Expert Meeting on Methodologies for Conducting Fishing Fleet Techno-Economic Performance Reviews, held in Chennai, India, 18–20 September 2018 (FAO, 2019c).

5.1 COST REDUCTION AND ENERGY SAVINGS IN CAPTURE FISHERIES

The reduction of fuel consumption has been important for some fleets to remain profitable. A European Commission Joint Research Centre (JRC) report on Information Collection in Energy Efficiency for Fisheries (ICEEF-3) concludes that with the latest scientific innovations a potential reduction in fuel consumption of up to 20 percent can be achieved by implementation and modernization of the propulsion systems. Fuel savings of up to 15 percent can be obtained also by modernization of the fishing gear, especially for trawl gears. Other relevant savings, from three to seven percent can come from route management, fuel consumption and gear monitoring systems (JRC, 2014).

Similarly, Barange *et al.* (2018), among others, estimate that the introduction of a bulbous bow could result in fuel savings of 5–15 percent; the installation of a propeller nozzle/duct could reduce fuel consumption by up to 15–20 percent; and vessel speed reductions could even result in fuel savings of 20–30 percent.

Cheaper fuels such as biodiesel (obtained from processing waste oil, vegetable oil, soybean oil or animal-fat-based oil) have been tested, but are not widely applied. However, a visible trend reveals that common marine diesel oil (a blend of distillates and heavy fuel oil), is gradually being substituted with intermediate fuel oils (IFO). These fuel oils are classified and named according to their viscosity and reduce fuel consumption costs. The most commonly used for inboard fishing vessel engines are IFO 180 and IFO 380.

Electric engines have been tested on fishing vessels as well, although the uptake has been limited so far. Combinations of diesel and electric power units coupled with variable-speed generators are increasingly used in trawl fleets in Europe. The efficiency of marine engines has increased further in various industrial fishing fleets through the use of hybrid engines, computer-controlled diesel engines, modern fuel injection systems, fuel spray methods, recirculation of exhaust gasses and other techniques. Currently, the implementation of Emission Control Areas (ECAs) designated under regulation 13 of MARPOL Annex VI is affecting the modernization of engines in existing fishing fleets in Europe and North America.[22] The costs associated with implementing the regulation are significant as the emission limits are being brought down, effectively forcing fishing fleets to modernize.

The use of four-stroke outboard engines on small-scale fishing vessels has increased over the last two decades, with accompanied fuel savings compared to two-stroke engines. While outboard engines are generally less efficient than inboard engines, four-stroke engines are more fuel-efficient and produce less emissions than the older two-stroke models. However, the latest two-stroke engines have advantages as well (see Appendix 5.A), as they use Direct Fuel Injection (DFI). The fact that two-stroke outboard engines are lighter than four-stroke versions of similar horsepower, are easier to maintain and repair (and possibly more widely available and less expensive), are all factors that make them more attractive for owners of small fishing boats in many regions worldwide. In inland fisheries and small-scale coastal fisheries in Asia, the availability of outboard engines has increased tremendously in the last few decades. These cheaper two-stroke engines have become more fuel-efficient as well, but generally pollute more than the four-stroke engines of major outboard engine brands.

Developments in the propulsion system – mainly to the propellers, but also to the engines driving the propellers – have led to energy savings in the last decade. Modern industrial fishing vessels have more efficient generators that support the operation of the essential winches and hydraulic cranes on-board. The generators are also the main supplier of energy for on-board freezing and cold storage, as well

[22] More information on ECAs is available at www.imo.org/en/OurWork/Environment/Pages/Special-Areas-Marpol.aspx

as for on-board processing. Some industrial fishing vessels use up to 30 percent of the energy produced on-board for on-board processing (Viðarsson *et al*., 2014). For towed fishing gears such as bottom trawls, measures to reduce fuel-related expenses and greenhouse gas emissions include multi-rig gear, efficient otter boards, off-bottom fishing, high-strength materials, large mesh sizes and smaller diameter twines (Barange *et al*., 2018). These measures have been tested and proven to be successful under many circumstances.

Fuel and engine performance monitoring systems, including energy audits, have become more widely accepted in industrial fishing fleets in Europe and Asia. These systems allow the user to compare energy performance and reduced fuel consumption. They facilitate the decision-making process of vessel owners regarding the replacement of older engines with new, state-of-the-art models that are more fuel-efficient and have lower NO_x emissions (Sala *et al*., 2013).

Developments in vessel hull design, such as the bulbous bow and hydroconic hull shapes, have been tested widely and are increasingly being used by fishing fleets in Europe, the United States of America, Canada and Japan. The new hull designs reduce wave/water resistance and contribute to a reduction in fuel use, often without compromising the space on-board. Moreover, the new designs can contribute to the fishing vessel's life, vessel stability, safety at sea and an overall reduction in operational costs.

In Asia, most of the small and medium-sized fishing vessels are made of wood, following traditional designs. These have proven to function well in practice, and there have been very limited developments in this area over the last decade. In the Americas, Europe and Oceania the use of wooden fishing vessels has further declined due to higher maintenance costs and the limited number of shipyards that are able to serve these vessels. In these regions, and to a lesser extent in parts of Asia, the number of fishing vessels made of fibre-reinforced plastic (FRP), steel or aluminum continued to increase compared to wooden vessels. Savings in operational costs were made by the fleets in these regions by virtue of the reduced energy use with lighter FRP vessels, which are relatively easier and cheaper to repair, and some have associated stability and safety improvements. The use of FRP also facilitated an increase in vessel size in some Asian countries. The availability of suitable wood for vessel construction has become a challenge in various countries, which also contributes to an ongoing fleet transition towards vessels with FRP hulls. The mechanization process in small-scale fishing fleets in the Asia-Pacific region and Africa, in particular, has continued in recent decades.

While many of the largest industrial fishing and fish processing vessels were slowly taken out of operation after the 1980s – particularly after the demise of the Soviet Union – it is clear that over the last decade a 'bigger-is-better' mindset has returned in some of the pelagic fishing fleets. Contemporary pelagic freezer trawlers are equipped with state-of-the-art fish processing lines and freezing facilities, the vessels' larger size enabling longer fishing trips with greater storage of fish, fuel and food. The modern vessel designs, accompanied by lighter gears (often midwater trawls) and the latest engine technologies, result in significantly lower energy consumption in fishing and processing.

The use of fish transport vessels and transshipment practices in high seas fisheries and pelagic fisheries has flourished so that more specialized and efficient vessels, such as those for catching high-value species (e.g. various tunas), can stay out at sea for as long as possible. Travelling to and from port to offload the catch takes up valuable time (and fuel) that could be better employed for fishing. It is therefore common practice for refrigerated transport vessels, commonly referred to as 'reefers' to do the fetching and carrying for the fishing vessels (FAO, 2018b). The positive effects of transshipment and the use of reefers on fishing fleet performance have been substantial in recent years.

However, transshipment at sea has received increasing attention in recent years as a result of some operators' involvement in IUU fishing; the non- and misreporting of catch seems particularly common and widespread (FAO, 2020a).

5.2 INCREASING FISHING EFFICIENCY

At the end of the 1990s, the Global Positioning System (GPS) became widely available to the public, including the fisheries sector. Its use has become common in all types of fisheries: small-scale, recreational and industrial, in all regions, both in marine and inland waters. The GPS allows fishers not just to plan their trips to fishing grounds, navigate and locate their positions, but also facilitates the fishing operations themselves. GPS devices are used to mark and find fishing traps, pots, nets, and fish aggregating devices (FADs). The use of GPS has certainly contributed to the fisheries profitability, as well as improvements in catch per unit of effort (CPUE) in many fisheries over the last decades. GPS can also be used for fishing zone identification/marking, as well as to provide information on the water depth and distance to shore when linked to proper maps. GPS devices have become less expensive in recent years and are therefore affordable for most small-scale fishers. They also contribute to safety at sea in fisheries, allowing safer navigation at night and in rough weather conditions.

In addition to GPS, the use of electronic chart display information systems (ECDIS) and fishfinders has become common practice in most fisheries. Fishfinders allow fishers to locate fish underwater by detecting reflected pulses of sound energy, as in sonar. The developments in fishfinders have been rapid over the last decade, as the first fish finders could only search vertically under the vessel. Nowadays, the multibeam fishfinder functions in a similar way to a sonar and allows the fisher to see what is around the vessel in all directions. The modern fishfinder uses various graphical displays, allowing fishers to interpret information to locate schools of fish, their size and species, together with underwater debris, and the bottom of body of water. The newest fishfinders used on industrial vessels are generally integrated systems of marine radar, compass, ECDIS, GPS navigation systems and fishfinders. However, small-scale fishers prefer to use these systems separately, which makes them easier to replace and reduces repair costs. The large reduction in prices of fishfinders and related technology, as well as their increasingly simple use, have made these appliances available and accessible to all fisheries sectors. Fishfinders have made both commercial and recreational fishing much more effective and have contributed tremendously to a reduction in the actual costs of fishing operations by increasing CPUE.

Fish aggregating devices (FADs) have been around in fisheries in many forms for a long time. However, the use of FADs, moored as well as drifting, has increased enormously worldwide. In the context of declining catches, many fleets, particularly tuna purse seine fleets, have modified the way they fish. More than 80 percent of the global tropical tuna catch by purse seine fleets is caught with the use of FADs (Scott & Lopez, 2014). The use of FADs is also booming in small-scale and recreational fisheries. The increasing catches of pelagic species around FADs, but also catches of vulnerable and already overexploited stocks, is not sustainable. It has been argued that the widespread adoption of FAD fisheries, with tens of thousands of FADs currently in use, is affecting recruitment of tuna resources targetted as catches consist for an disproportional part of juvenile fish and FADs appear to interfere with migration routes of many pelagic species. As a result, traditional stock assessment methods and the calculation of CPUEs may no longer be applicable anymore. The introduction of so-called 'smart' FADs, with echo sounders, have made FADs one of the most advanced technologies in fish capture. These smart FADs include sophisticated, remotely operated satellite tracking buoys, which constitutes the most significant technological development that has occurred in fisheries within the last 20–30 years (FAO, 2017). The smart FADs are getting cheaper and are therefore already widely used in tuna purse seine fisheries. They are in effect transforming the sector from a fishery to a harvesters' sector, as catches are no longer unpredictable. The smart FADs inform the vessel operator of the location of the fish, the biomass around the FAD, the depth and distribution of the school, species and size, and the direction of movement of schools of fish. The use of a network of smart FADs makes it possible for a fleet to harvest their assigned quota with relatively minor fishing effort. The positive effects on the catchability of fish and the economic performance of the fleets involved are huge, yet the question remains whether it is a desirable development in terms of stock sustainability.

The use of line-hauling systems on longline vessels fishing for tuna and automatic reels on squid jigging vessels has increased in recent years. These systems reduce fishing times and contribute to the efficiency of the fishery. The number of crew on vessels that have installed these systems is generally lower, resulting in savings in terms of labour costs in vessel operations.

Fishing with lights at night has continued to increase in the last decade. Particularly the squid jigger fleets in Asia, Southern Africa and the small-scale fishing fleets for flying fish in the Caribbean make use of lights to attract their target species. The development and increase in application of light-emitting diode (LED) lights on fishing vessels, both to reduce on-board energy consumption but also as fish attractants, has proved to be a game changer. The LED lights used display various colours (white, yellow, blue and green) to attract small prey fish and shrimps that in turn attract predator fish, as many fish species have eyes sensitive to different colours. The traditional battery or generator powered metal-halide (HM) lights are rapidly being replaced by LED lights. While the cost of LED lights is still high compared to traditional HM lights, their durability and lower energy consumption provide major savings for fishing operations at night, and the colour spectrum has a positive impact on fishing operation outcomes.

While monofilament gillnets have been used since the 1970s, their application has increased in small-scale fisheries, as a consequence of the wide availability and relatively low costs of these nets. In many fisheries the use of monofilament nets has proven to be more efficient, increasing the catch rates. The cheapness of some of the nets on the market, and the challenges to repairing monofilament nets, compared to the (traditional) multifilament gillnets, have resulted in fishers purchasing nets more frequently. In many coastal fishing communities with small-scale fishing fleets the skills to repair nets are being lost. This transition in net materials is not solely confined to the last decade, but the effects on the costs of fishing and fishing fleet operations continue to increase. In addition, the discarding or abandonment of used nets, which contribute to marine debris and ghost fishing (Macfadyen *et al*., 2009), is receiving more attention internationally. This is reflected in the endorsement of the FAO Voluntary Guidelines on the Marking of Fishing Gear in 2018, by the Thirty-third Session of the Committee on Fisheries (FAO, 2018b). The use of biodegradable nets is promoted in some countries, but these are not yet in widespread use.

Developments in trap and pot fisheries have made traps more effective, sustainable, lighter, more durable and collapsible. The use of biodegradable escape panels in lobster, crab and fish traps is increasing rapidly, following legislation on this measure (that reduces ghost fishing) by a number of countries in the Caribbean region and various states in the United States of America (Bilkovic *et al.*, 2012). The traps with these escape panels are slightly more expensive initially, but reduce potential "costs" arising from potential ongoing ghost fishing in the event they are lost or swept away during storms or hurricanes. The use of collapsible traps has also increased significantly, particularly in the United States of America, Australia and parts of Asia. As a result of this development, vessels can carry many more traps than they used to do, increasing the capacity and efficiency of fishing operations.

Seabed mapping technology is another technology which, together with GPS and plotters, is increasingly being used to pinpoint productive fishing habitats for benthic species such as scallops (He, 2007). It is used both to harvest sea scallops efficiently, and by RFMOs to determine bottom-trawling areas, resulting in shorter fishing times, lower fuel costs, less seabed impact and the improved conservation of vulnerable marine environments.

Multipurpose fishing vessels using a combination of fishing gears (e.g. gillnetting and longlining, trawling and gillnetting) are becoming more common in many countries. Regulations determine quotas and the number of days that can be fished on certain stocks, which have negative (short-term) effects on the profitability of fishing vessels. As a result, specialized fishing vessels that are not used for a large part of the year due to the above regulatory and management restrictions are transformed into multigear vessels, giving fishers longer fishing seasons and increased returns. In addition, traditional pole and line fishery methods were considered outdated in commercial fisheries at the beginning of this millennium, but there is now a return to such basic technologies (MSC, 2021). This return is the consequence of growing consumer awareness and increasing markets for eco-friendly, sustainable products and third-party certification.

5.3 REDUCING THE ENVIRONMENTAL/ECOLOGICAL IMPACT OF CAPTURE FISHERIES

Efforts by fleets to reduce the environmental impact of capture fisheries serve to maintain the long-term sustainability of the target fish stocks and their habitats. However, these are generally only successful if they are economically beneficial and embedded in a legislative framework with tight enforcement.

The developments in trawl fisheries have been significant in recent years, with the introduction of electric pulse fishing in Europe (e.g. Haasnoot *et al.*, 2017), the use of lighter and more durable trawl nets, modifications to trawl doors and the wider application of bycatch reduction devices (BRDs). This is reflected in a range of research papers and in overviews presented by the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) (ICES, 2019).

The large-scale commercial application of electric pulses in fisheries took place in China in the early 1990s, and electric beam trawling significantly increased catch rates in the shrimp fleet. However, due to a lack of management control and enforcement, the technology was banned in the early 2000s (Yu *et al.*, 2007). In the last 10 years, further development of electric pulse trawl fishing options and associated tests have primarily been carried out by the Netherlands, supported by European Union subsidies. Fleet-wide acceptance was obtained, and a large application took place until the European Parliament banned it in 2018. The advantages of the electric pulse trawl include: a much lower impact on the seabed compared to normal trawl fishing; electric pulses allow greater selectivity in terms of species and sizes; and the technology reduces bycatch and leads to a reduction in fuel costs, as gears are lighter and the engine power can therefore be reduced as well (Rijnsdorp *et al.,* 2020). The fuel consumption and CO_2 emissions of the cutter sector decreased tremendously with the application of pulse trawl systems, resulting in greater fleet profits (Turenhout *et al.*, 2016). However, the use of electricity in fishing was against the national laws of various European Union countries, and it was argued that the electric pulses could possibly cause damage to the fish and other organisms that were not retained.

The redesign of trawl doors – and particularly raising the height of the doors so the contact with the seabed is reduced – has been introduced in various fleets in northern Europe with positive effects on fleet profitability (Hansen, 2013). This is due to reducing the drag of doors (by virtue of a higher aspect ratio and better hydrodynamic design) which decreases fuel efficiency (He, 2010).

In the tropical bottom trawl fleet, the uptake of bycatch reduction innovations developed in the 1990s and early 2000s is improving. The BRDs that were developed and certified for use in the United States of America and Australia – such as the composite panel/square mesh combination, the composite panel/cone deflector, the (modified) Jones-Davis and the Popeye fisheye – are widely regarded as effective by both fishers and fisheries authorities. These BRDs are relatively recent innovations that continue to gain traction in the industry and have shown anywhere from a 30–50 percent reduction in bycatch, with a less than 5 percent reduction in shrimp catch. Fishers also find them relatively easy to install and use. The increased knowledge on BRDs (NOAA, 2021) and fish behaviour in tropical shrimp fisheries is largely driven by NOAA (United States of America), the Australian Fisheries Management Authority and FAO under various projects REBYC-I, REBYC-CTI and REBYC-II LAC (FAO, 2021a). Over the last two decades, countries have started to pass legislation demanding BRDs in bottom/shrimp trawling.

The use of Turtle excluder devices (TEDs) and more recently Turtle and trash excluder devices (TTEDs) in tropical shrimp trawling was opposed for a long time by the fishers as they were considered surplus to requirements or would reduce catches of shrimp too much.[23] Scientific studies have shown that actual shrimp catch reduction following the use of TEDs could range from 5 percent to 13 percent (Shiffman, 2011). Voluntary implementation of TEDs was therefore low for many years. However, since more and more governments have made TEDs mandatory, the application of these devices in tropical shrimp fisheries is becoming widespread.

There have been significant BRD innovations in Europe as well, particularly with the landing obligation policy instituted by the European Union (European Commission, 2021), which has been implemented gradually since 2015. The introduction of the landing obligation, which prohibits discards at sea, was supported by various projects, such as the Discardless project.[24] Similar investments in money and research have not been applied in tropical trawl fisheries. The latest BRD innovations, such as those using LED lights, a nested cylinder, or a witch's hat, have been tested and proven successful, but acceptance by the industry has been slow so far. The application of headrope multibeam net opening monitoring systems, using underwater video, is becoming more common in Europe and the United States of America, and increases fishing efficiency while contributing to bycatch reduction efforts.

In the longline tuna and swordfish fleets, the use of circle hooks instead of J-hooks has been promoted for the last decade, following research that demonstrated a reduction in bycatch of other species accompanied with similar or higher catches of target species (Watson and Kerstetter, 2006). The bycatch in tuna longline fisheries often includes protected species such as sea turtles, seabirds, marine mammals, some shark species, and some overfished billfishes. The use of circle hooks facilitates catch-and-release practices and reduces bycatch mortality for those species, given that it reduces deep hooking. By combining the circle hooks with modifications in gear deployment – such as placing the lines on a slightly different depth – the use of circle hooks contributes even more to the already high gear selectivity in longline fishing. Various regional fisheries management organizations (RFMOs), including major tuna RFMOs (e.g. ICCAT, IOTC) have issued resolutions to promote the use of circle hooks. The costs of replacing J-hooks with circle hooks are relatively minor for fishers, facilitating their uptake in longline fishing. Particularly in the last five years, the use of circle hooks has become common in longline fisheries worldwide.

[23] The TTEDs are used in French Guiana for instance and constitute an excellent innovation to the TED, essentially placing more bars in a TED to lower grid spacing and improve exclusion of medium-sized fish and objects.

[24] The project involves researchers and stakeholders working together to reduce discards in European fisheries (see www.discardless.eu)

While not a technology improvement in the strictest sense, the prohibition of use of small mesh-size nets in fisheries in various Asian and African countries in the last decade, combined with improved monitoring, control and surveillance at sea and in ports, has had positive impact on the status of various fish stocks and thus on the long-term economic sustainability of the fishing fleets concerned.

5.4 IMPROVING FISH HANDLING, PRODUCT QUALITY AND FOOD SAFETY

There is a wide variety in ways fish are handled by fishing fleets worldwide. In pelagic fisheries, pumping systems to bring the fish on board, and transport the fish to on-board processing lines and/or storage have been tested and applied in various occasions. Improvements have also been made with regard to killing caught fish effectively in a short period, using electric stunning,[25] fish bats and spikes. The same applies to the way bleeding should take place, as well as in sorting, chilling and freezing systems. Current national regulations determine the way fish are killed and slaughtered.

In the industrial fishing fleets, the application of computerized weighing marine scales and graders is now common. Many of the weighing devices installed on vessels in recent years have included motion compensation, which enables weighing processes to be very similar to those on land and nearly as accurate. The introduction of these computerized systems has assisted rapid processing, batch labelling and contributes to an overall uptake of traceability processes. Grading and batching, but also increasingly trimming and fileting technologies, which were previously available only for land-based operations, are now commonly installed on board.

In view of the frequent losses of Styrofoam/expanded polystyrene (EPS), plastic and waxed carton fish boxes at sea and in ports, some governments and/or fishing cooperatives in Asia and Europe have demanded that fishing vessels make use of eco-friendly fish boxes to reduce their environmental impact. These eco fish boxes are generally fibre-based, recyclable and biodegradable, and their use is therefore reducing marine pollution from fisheries.

Quality control systems are integrated in the processing lines. The glazing of fillets and Individually Quick Frozen (IQF) processes are also becoming integrated in on-board cold chain and processing systems. The computerization of the processing is a trend that has emerged in recent years, and through its integration with internet/cloud-based systems the necessary information is made available to the on-shore facilities and customers. Quality control systems monitor all stages of catching and processing on-board through sensors and video cameras, support data management and reporting, and meet the requirements of major quality systems such as HACCP, ISO, etc. Plate and blast freezer uses have become more common on board, as the sizes and energy consumption of these systems have decreased. In recent years, ice-making systems have allowed seawater to be used for the production of (flake) ice on vessels that carry out lengthy voyages. The energy consumption of most freezer, ice-making, chilling and refrigeration systems on-board is still too high for most small- and medium-sized fishing vessels (Wang and Wang, 2005), and therefore these systems are generally not used on smaller vessels of less than 100 GT.

Developments in refrigeration, ice-making and fish processing equipment have contributed to the design of vessels capable of remaining at sea for extended periods (FAO, 2021b), which have generally had a positive impact on the economic performance of these fleets. Many newly built and refurbished industrial-scale fishing vessels are now being equipped with refrigerated seawater (RSW) plants, which also contribute to the improvement of product quality and seem to be economically attractive systems. In some Asian countries such as India and Sri Lanka, the installation

[25] One example is the research conducted into the on-board stunning of trawl-caught fishes by Fishcount: fishcount.org.uk/recent-developments/research-paper-on-board-stunning

of slurry ice machines on new fishing vessels is preferred over RSW plants. Moreover, in recent years, a tendency to incorporate wastewater plants in new industrial-scale fishing vessels has emerged in order to reduce the ecological footprint of these vessels.

The rapid uptake of technologies for on-board fish processing in the industrial fleets provides a sharp contrast with the small-scale fishing sector, where limited progress has been made on this subject over the last decade. The use of ice (flake, slush and block) has increased in small-scale fisheries and more vessels carry ice boxes or have a built-in hold for ice, but a majority of vessels still do not carry ice. The food safety risks and post-harvest losses associated with this practice remain high.

5.5 IMPROVING SAFETY AT SEA AND THE WORKING CONDITIONS OF FISHERS

Satellite-based technology for navigation and communication, as well as for vessel monitoring and management purposes, have developed rapidly over the last decade. The Global Positioning System (GPS) discussed earlier, together with other Global Navigation Satellite Systems (GNSS), have significantly contributed to improving safety at sea for fishers. Moreover, these have been bolstered by a greater capacity for "big data" storage, sharing, and analysis, the increased accessibility and accuracy of satellite imagery, and an expansion in the use of Automatic Identification Systems (AIS) and Vessel Monitoring Systems (VMS) (Girard & Du Payrat, 2017).

Developments in vessel registries, the improved marking and identification of fishing vessels, together with a widespread application of AIS and VMS systems by vessels fishing in the high seas, have all facilitated the monitoring of fishing operations. In addition, the entry into force of the 2009 FAO Port State Measures Agreement (FAO, 2010), the RFMO IUU vessel listing, (TMT, 2021) and the work of the Global Record of Fishing Vessels, Refrigerated Transport Vessels and Supply Vessels (FAO, 2021d), are all slowly closing the door on fishers involved in illegal, unreported and unregulated (IUU) fishing. The increased capacity to monitor vessels, alongside the new technologies that have introduced e-logbooks and video observers on board, have contributed to the introduction of safety protocols on board industrial fishing vessels, and the installation of proper life-saving and communication equipment.

A number of instruments are expected to impact safety at sea and working conditions of fishers in the coming years, including: the entry into force on 29 September 2012 of the International Convention on Standards of Training, Certification and Watchkeeping for Fishing Vessel Personnel, 1995 (STCW-F 1995); the adoption of the Cape Town Agreement on the safety of fishing vessels in 2012; the adoption of instruments to support the implementation of the ILO Work in Fishing Convention (C188), such as guidelines for port and flag State inspectors; and the entry into force of the ILO Work in Fishing Convention itself on 16 November 2017 (FAO, 2021c; FAO, IMO & ILO, 2020). To date, the implementation of these international instruments in the global fishing fleets has been limited, but it is expected that their implementation will affect the performance of fleets in the coming years. The requirements would improve safety and labour standards in the sector, increase opportunities for legal fishers and reduce IUU fishing, and contribute to a level playing field in the fisheries sector. However, meeting the requirements of these international conventions and agreements will have costs associated with them, and vessel owners and operators will be required to invest in equipment and staff training, which can be substantial. On the other hand, the unfair disadvantage for vessels involved in IUU fishing will be slowly reduced, providing opportunities for legitimate fishers.

The working conditions of crews have improved on modern fishing vessels, where safety measures have been integrated into the design of on-deck and below-deck equipment. Hydraulic cranes, net haulers and winches have made the work of the crew lighter and seem to have had positive effects on work performance. Moreover, the introduction of emergency/safety stops on the main equipment has taken off in the last decade and is contributing to the safety of crew, together with safety training, use of safety wear and shoes, and on-board safety briefings.

Given that the largest seafood companies worldwide have built vertically integrated value chains to secure their fish supply and meet consumer demands in terms of quality, safety and traceability, it is clear that there are gains in economic performance to be made in doing so. The improved management of fleets of fishing vessels (or groups of vessels owned by the same company) – and their efficient linkages to shore-based processing and distribution channels – seems to increase their overall economic and financial efficiency as well.

In small-scale fisheries, the use of solar panels on fishing vessels has increased tremendously in recent years. Solar panels support the lighting systems used on small vessels, as well as radio communication, and contribute to safety at sea. Some fisheries authorities request fishers to install solar panels to support the VMS systems. While reductions in fuel costs are realized by the solar panels on the small vessels, their contribution to the overall profitability of the fishing operations may be rather limited.

The developments in safety at sea measures and equipment over the last decade include improvements in life jackets and life rafts. Life jackets are now much more comfortable to wear when working on board fishing vessels. Improvements in fishing vessel design, have also contributed to fishing vessel safety, with a greater emphasis on stability. Industrial fishing vessels built in recent years also generally pay greater attention to safe working practices, emergency doors, fire extinguishers and life rafts, in addition to the noise reduction of on-board machinery and better accommodation for crew.

While safety at sea training has become more common, and seaworthiness checks of vessels are institutionalized in many countries, the number of accidents and fatalities in fisheries is still too high. In many countries (even in North America and some countries in Europe) the annual rate of fatalities is frequently over 100 per 100 000 fishers. FAO estimates that there are of 32 000 fatalities per year in fisheries (FAO, 2020b). The costs of accidents and fatalities to fishing communities and the sector at large are expected to be significant, but insufficient information is available on this subject.

The working conditions on fishing vessels worldwide are still of great concern: cases of exploitation, child labour (FAO & ILO, 2013) and enslavement of crew members remain common in the sector. The dependency situation of many crew and individual fishers on the captains/owners of the fishing vessels, and the attendant exploitative relationships, affects economic performance, profitability and investments in fisheries activities. Wage structure, catch share systems and labour conditions also have a large impact on the profitability of fishing fleets, and safe working conditions.

In small-scale fisheries the use of mobile phones is now widespread and in coastal and nearshore areas mobile phones are used as device to make emergency and distress calls. Increasingly, the use of mobile phone technology includes applications featuring an emergency button that directly communicates the position of the vessel to the coastguard, so action can be taken more rapidly. The use of mobile phones has made it easier for small-scale fishers to be informed of weather conditions, to ask for assistance and advice (e.g. for engine repair at sea), and to sell their catch while at sea. As such, mobile phones are contributing positively to the safety of fishers as well as to the performance of the small-scale fishing fleets. In addition, the use of satellite phones for communication between industrial fishing vessels on the high seas, as well as with shore-based stations, has increased in recent years, which contributes to safety in the distant waters in which these vessels operate.

REFERENCES

Barange, M., Bahri, T., Beveridge, M.C.M., Cochrane, K.L., Funge-Smith, S. & Poulain, F., eds. 2018. *Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options*. FAO Fisheries and Aquaculture Technical Paper No. 627. Rome, FAO. 628 pp. (also available at www.fao.org/documents/card/en/c/I9705EN/)

Bilkovic, D.M., Havens K.J., Stanhope D.M. & Angstadt K.T. 2012. Use of fully biodegradable panels to reduce derelict pot threats to marine fauna. *Conserv Biol*., 26(6): 957–66.

DiscardLess. 2021. *DiscardLess* [online]. Copenhagen. [Cited 5 February 2021]. www.discardless.eu

Ehrhardt, N., Brown J.E., Pohlot, B.G. 2017. *Desk Review of FADs fisheries development in the WECAFC region and the impact on stock assessments*. Report for the Eighth Session of the Scientific Advisory Group (SAG) of the Western Central Atlantic Fishery Commission (WECAFC), Merida, 3–4 November 2017. (also available at www.fao.org/3/a-bs248e.pdf).

European Commission. 2021. Discarding and the landing obligation. In: *European Commission* [online]. Brussels. [Cited 5 February 2021]. https://ec.europa.eu/fisheries/cfp/fishing_rules/discards_en#Landing percent20obligation

FAO. 2010. *Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing. Accord relatif aux mesures du ressort de l'État du port visant à prévenir, contrecarrer et éliminer la pêche illicite, non déclarée et non réglementée. Acuerdo sobre medidas del Estado rector del puerto destinadas a prevenir, desalentar y eliminar la pesca ilegal, no declarada y no reglamentada*. Rome/Roma, FAO. 100 pp. (also available at www.fao.org/3/a-i1644t.pdf).

FAO. 2018a. Findings of global study on transshipment publicly presented. In: *FAO Fisheries and Aquaculture Department* [online]. Rome. [Cited 5 February 2021]. www.fao.org/iuu-fishing/news-events/detail/en/c/1145065/

FAO. 2018b. *Voluntary Guidelines on the Marking of Fishing Gear* [online]. Committee on Fisheries. Thirty-third Session, Rome, 9–13 July 2018. COFI/2018/Inf.30. [Cited 5 February 2021]. www.fao.org/3/MX136EN/mx136en.pdf

FAO. 2019a. *Report of the 2016 Symposium on Technology Development and Sustainable Fisheries. 25–29 April 2016, Merida, Mexico.* FAO Fisheries and Aquaculture Report No. 1182. Rome. 80 pp, (also available at www.fao.org/3/ca4015en/CA4015EN.pdf).

FAO. 2019b. *Report of the 2019 Symposium on Responsible Fishing Technology for Healthy Ecosystems and a Clean Environment, Shanghai, China, 8-12 April 2019*. FAO Fisheries and Aquaculture Report No. 1269. Rome. 79 pp, (also available at www.fao.org/publications/card/en/c/CA5742EN/).

FAO. 2019c. *Report of the Expert Meeting on Methodologies for Conducting Fishing Fleet Techno-Economic Performance Reviews, Chennai, India, 18-20 September 2018.* FAO Fisheries and Aquaculture Report No. 1243, Rome. 60 pp (also available at www.fao.org/documents/card/en/c/ca4427en/).

FAO. 2019d. *Voluntary Guidelines on the Marking of Fishing Gear. Directives volontaires sur le marquage des engins de pêche. Directrices voluntarias sobre el marcado de las artes de pesca*. Rome/Roma. 88 pp (also available at www.fao.org/3/ca3546t/ca3546t.pdf).

FAO. 2020a. *Transshipment: a closer look*. Rome, FAO. 8 pp. (also available at www.fao.org/3/cb0987en/CB0987EN.pdf).

FAO. 2020b. The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome. https://doi.org/10.4060/ca9229en

FAO. 2021a. Sustainable Management of Bycatch in Latin America and Caribbean Trawl fisheries (REBYC-II LAC). In: *Food and Agriculture Organization of the United Nations – In Action* [online]. Rome. [Cited 5 February 2021]. www.fao.org/in-action/rebyc-2/en/

FAO. 2021b. Fish Capture Technology. In: *FAO Fisheries Division* [online]. Rome. [Cited 5 February 2021]. www.fao.org/fishery/technology/capture/en

FAO. 2021c. Despite advances in health and safety operations, fisheries remains a dangerous sector – Blue Growth blog. In: *Food and Agriculture Organization of the United Nations – Blogs*. [online]. Rome. [Cited 5 February 2021]. www.fao.org/blogs/blue-growth-blog/despite-advances-in-health-and-safety-operations-fisheries-remains-a-dangerous-sector/en/

FAO. 2021d. Global Record of Fishing Vessels, Refrigerated Transport Vessels and Supply Vessels. In: *Food and Agriculture Organization of the United Nations*. [online]. Rome. [Cited 5 February 2021].

FAO & ILO. 2013. *Guidance on addressing child labour in fisheries and aquaculture.* Rome, FAO. (also available at www.fao.org/3/i3318e/i3318e.pdf).

FAO, IMO & ILO. 2020. *Joining forces to shape the fishery sector of tomorrow.* Rome, FAO. 22 pp. (also available at www.fao.org/documents/card/en/c/cb0627en).

Girard P. & Du Payrat T. 2017. *Issue Paper. An inventory of new technologies in fisheries*. Presented at the Green Growth and Sustainable Development Forum (GGSD), 21–22 November 2017, OECD Paris. www.oecd.org/greengrowth/GGSD_2017_Issue Paper_ New technologies in Fisheries_WEB.pdf

Haasnoot, T., Kraan, M., & Bush, S. R. 2017. Fishing gear transitions: lessons from the Dutch flatfish pulse trawl. *ICES Journal of Marine Science*, 73: 1235–1243.

Hansen U. J. 2013*. Redesign of trawls and raised doors in demersal trawling gives large reduction in environmental footprint* [online]. Hjørring, Denmark. [Cited 5 February 2021]. www.fishinggearnetwork.net/wp-content/uploads/2013/06/Redesign-of-trawls-and-raised-doors-in-demersal-trawling.pdf

He, P. 2007. Technical Measures to Reduce Seabed Impact of Mobile Fishing Gears. In: S.J. Kennelly, ed. *By-catch Reduction in the World's Fisheries*, pp. 141–179. Reviews: Methods and Technologies in Fish Biology and Fisheries, vol 7. Springer, Dordrecht.

He, P & Winger, P. 2010. Effect of Trawling on the Seabed and Mitigation Measures to Reduce Impact. In P. He, ed. *Behavior of Marine Fishes: Capture Processes and Conservation Challenges*, pp.295–314. Ames, USA, Wiley-Blackwell.

ICES. 2019. *Working Group on Fishing Technology and Fish Behaviour (WGFTFB).* ICES Scientific Reports. Copenhagen. (also available at doi.org/10.17895/ices.pub.5592)

Kennelly S. J., ed. 2007. *By-catch Reduction in the World's Fisheries. Reviews: Methods and Technologies in Fish Biology and Fisheries*, vol 7. Springer, Dordrecht.

Knapp, G. PhD. 2016. *International Commercial Fishing Management Regime Safety Study: Synthesis of Case Reports*. FAO Fisheries and Aquaculture Circular No. 1073. Rome, FAO. (also available at www.fao.org/3/a-i5552e.pdf).

Macfadyen, G., Huntington, T., Cappell, R. 2009. *Abandoned, lost or otherwise discarded fishing gear. FAO Fisheries and Aquaculture*. FAO Technical Paper, No. 523. Rome, UNEP/FAO. 115 pp. (also available at www.fao.org/3/i0620e/i0620e00.htm).

Marine Stewardship Council (MCS). 2021. Pole and line. In: *Marine Stewardship Council – Fishing methods and gear types*. [online]. London. [Cited 5 February 2021]. www.msc.org/what-we-are-doing/our-approach/fishing-methods-and-gear-types/pole-and-line

NOAA. 2021. Bycatch Reduction Devices – Gulf of Mexico and South Atlantic. In: *NOAA Fisheries – Bycatch*. [online]. Silver Spring, USA. [Cited 5 February 2021]. www.fisheries.noaa.gov/southeast/bycatch/bycatch-reduction-devices-gulf-mexico-and-south-atlantic

Rijnsdorp A.D., Boute P., Tiano J., Lankheet M., Soetaert K., Beier U., de Borger E., Hintzen, N., Molenaar P., Polet H., Poos J. J., Schram E., Soetaert M., van Overzee H., van de Wolfshaar K. & van Kooten T. 2020. *The implications of a transition from tickler chain beam trawl to electric pulse trawl on the sustainability and ecosystem effects of the fishery for North Sea sole: an impact assessment*. Wageningen University & Research report C037/20. (also available at https://edepot.wur.nl/519729).

Sala A., Notti E., Martinsohn J. & Damalas D. 2013. *Information Collection in Energy Efficiency for Fisheries (ICEEF2012). Final Report.* Ancona, Italy, CNR-ISMAR. (also available at www.ismar.cnr.it/file/file-generali/iceef-2011/ICEEF2012 percent20-percent20RF_final.pdf)

Sala A., Notti E., Martinsohn J. & Damalas D. 2014. *Information Collection in Energy Efficiency for Fisheries (ICEEF-3). Final Report*. European Commission – Joint Research Centre – Institute for the Protection and Security of the Citizen (IPSC). Luxembourg. (also available at https://op.europa.eu/en/publication-detail/-/publication/b5e69c02-4f82-4a23-964e-def82f8cee21/language-en/format-PDF/source-120419866)

Scott, P. G. & Lopez, J. 2014. *The use of FADs in tuna fisheries*. European Parliament. Directorate General for Internal Policies. www.europarl.europa.eu/RegData/etudes/note/join/2014/514002/IPOL-PECH_NT(2014)514002_EN.pdf

Shiffman, D. 2011. Turtle excluder devices: analysis of resistance to a successful conservation policy. In: *Southern Fried Science* [online]. [Cited 5 February 2021]. www.southernfriedscience.com/turtle-excluder-devices-analysis-of-resistance-to-a-successful-conservation-policy/

Trygg Mat Tracking (TMT). 2021. *Combined IUU Fishing Vessel List* [online]. Oslo. [Cited 5 February 2021]. https://iuu-vessels.org/.

Turenhout, M.N.J., Zaalmink, B.W. Strietman W.J. & Hamon, K.G. 2016. *Pulse fisheries in the Netherlands; Economic and spatial impact study*. Wageningen, Wageningen Economic Research, Report 2016-104. (also available at www.wur.nl/upload_mm/3/0/2/19133a58-eea3-4cd9-8a87-13935e3b706a_2016-104 Zaalmink_final.pdf).

Viðarsson, J.R., Grong Aursand, I., Digre, H., Hansen, U.J. & Smith, L. 2014. *New technology for the Nordic fishing fleet. Proceedings from a workshop on fishing gear and effective catch handling held in Reykjavik, 1-2 October 2013*. Skýrsla Matís 01-14. (also available at www.matis.is/media/matis/utgafa/01-14-New-technology-for-the-Nordic-fishing.pdf).

Wang, S.G. & Wang, R.Z. 2005. Recent developments of refrigeration technology in fishing vessels. *Renewable Energy*, 30(4): 589–600.

Watson, J.W. & Kerstetter, D.W. 2006. Pelagic Longline Fishing Gear: A Brief History and Review of Research Efforts to Improve Selectivity. *Marine Technology Society Journal*, 40(3): 5–10.

Yu, C., Chen, Z., Chen, L., & He, P. 2007. The rise and fall of electrical shrimp beam trawling in the East China Sea: technology, fishery, and conservation implications. *ICES*

Journal of Marine Science, 64: 1592–1597

APPENDIX 5.A

Four-stroke engines generally consume less gasoline than two-stroke engines and have lower emissions. This is entirely correct when comparing four-stroke engines with older two-stroke engines, but probably does not hold when comparing them with newer two-stroke engines.

In a two-stroke engine, the fuel–air mixture enters the combustion chamber via an opening in the side of the cylinder. The exhaust exits through another port in the cylinder. Initially, two-stroke engines used carburetors to control the fuel–air mixture. Carbureted outboards are not particularly efficient and use a lot of fuel. However, today's top-of-the-line two-stroke engines use a computerized Direct Fuel Injection (DFI) system to regulate the fuel–air mix precisely, in order to suit the operating conditions. This results in substantial performance gains, as well as better fuel economy and lower emissions. Typically, a two-stroke outboard is lighter than a similar-sized four-stroke engine, because the two-stroke's method of operation doesn't require a valve train — camshafts, valves, belts or chains. Since a two-stroke engine is not encumbered with a valve train, the engine has fewer moving parts and less rotating mass. A two-stroke outboard can often accelerate faster than a four-stroke engine of the same horsepower. The engine's internal components receive lubrication from oil mixed into the fuel. While traditional carbureted two-strokes are being replaced due to their inability to comply with increasingly stringent emissions legislation, the DFI two-stroke outboards continue to remain popular.

Four-stroke outboards use an engine very similar to an automobile engine. The air–fuel mixture flows into the combustion chamber through intake valves, and the exhaust leaves the engine via exhaust valves. Because of these intake and exhaust valves (the valve train), a four-stroke outboard is usually heavier than a two-stroke outboard of the same horsepower. That is changing, however, as four-stroke manufacturers continue to pursue new ways to lighten the engines and extract more horsepower. A four-stroke outboard's lubrication system is like a car's, complete with oil pan and filter — and the engine needs periodic oil changes to keep things running smoothly. The majority of four-stroke outboards feature sophisticated computer engine management systems and fuel injection for good performance across the power band, low emissions, and improved fuel efficiency.


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Effects of fisheries resources status and seafood prices on fleet profitability


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6. Effects of fisheries resources status and seafood prices on fleet profitability

6.1 MARINE FISHERIES RESOURCES AND FISHING FLEET CAPACITY MANAGEMENT

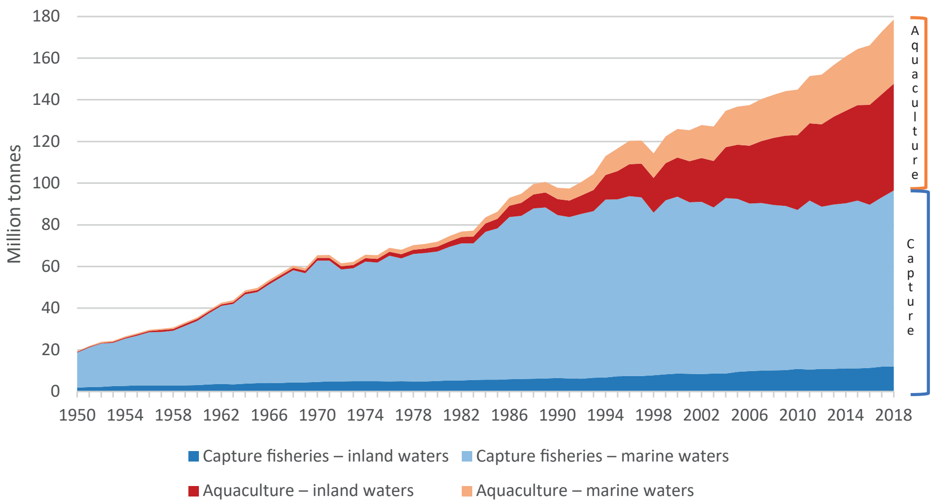
Spurred on by the globalization of seafood markets, fish has become one of the most internationally traded food and agricultural commodities. Around 38 percent of global fish production was traded on the international market in 2019, up from 35 percent in 2014. From 1990 to 2018, total food fish consumption increased by 122 percent, including aquaculture produce (FAO, 2020a).

Global per capita seafood consumption continued to grow by about 1.5 percent per year in the period 1961–2017, as a result of steady demand and an increase in the combined supply of growing aquaculture production and relatively stable capture fisheries output. Per capita consumption rose from 9.0 kg in 1961 to 20.3 kg in 2017, with developing countries showing the largest increase. Fish plays an important role in global food provision, accounting for about 20 percent of animal protein and 6.7 percent of all protein consumed by humans (FAO, 2016; FAO, 2020a). In addition to protein, food from the sea provides essential vitamins, minerals, long chain omega-3 fatty acids and other nutrients not found in plant-source foods or other animal proteins (Allison *et al*., 2013; Golden *et al*., 2016).

Worldwide, marine fish stocks that form the backbone of many commercial fisheries are near or past their most productive levels. Until the end of the twentieth century, fishing pressure on traditional stocks was generally close to or beyond optimal levels. However, for reasons relating to resource management and economics, overall fishing pressure has gradually declined to levels that could guarantee an acceptable level of sustainability for most resources (Melnychuk *et al*., 2020).

FIGURE 51

World capture fisheries and aquaculture production in million tonnes by environment



Source: FAO, 2020a.

Total global capture fisheries production reached 96.4 million tonnes in 2018. Although this volume of landings showed an increase of 5.4 percent over the 2015–2017 period, it should be noted that overall yearly landings have remained relatively stable since the late 1980s. The contribution of marine capture fisheries to the 2018 total capture landings consisted of 84.4 million tonnes. Yearly fluctuations in marine capture landings can mainly be attributed to landings of small pelagics, which appear more sensitive to short-term oceanographic phenomena. For example, finfish represented 85 percent of the total marine capture volume in 2018, with small pelagics constituting by far the major group, followed by gadiformes and tuna and tuna-like species (FAO, 2020b).

A projection by FAO (FAO, 2020a) suggests that yearly capture fisheries production will remain stable over the next decade and reach around 96 million tonnes in 2030. The most important factors likely to exercise downward pressure on landings during this period are the aforementioned fluctuations in small pelagic stocks as a result of oceanographic occurrences, and the decrease in capture fisheries by China, which plans to continue its policies of reducing the number of fishing vessels and fishers, as well as imposing stricter controls on licensing and landings. However, the shortfall is likely to be compensated for by developments including an increase in catches of new and/or recovered resources, the elimination of IUU fishing, and an improved utilization of harvest by optimizing the use of discards and by-catch. In addition, inland capture fisheries are expected to continue their modest annual growth curve.

A number of historical developments can be identified that have contributed to the growing fishing effort and the consequential state of the majority of commercial seafood resources. Many of these processes are still ongoing, and governments have tried to control them depending on both the financial and institutional resources available and the socio-economic situation of their respective countries. As per Costello, *et al*. (2020) the most important of these processes include:

- Open access to fisheries: Open access generally leads to vessels racing to fish resulting in overexploitation of fish resources. Industrial fishing fleet operations are generally more regulated than the artisanal fleets, but there are significant shortcomings. Particularly in developing countries, the impact on restricting production and the number of vessels and fishers has serious socio-economic consequences.
- The provision of subsidies: It has been argued that subsidies lead to economic inefficiency and unfair competition between the various fleets as well as between countries. Capacity enhancement subsidies constitute the largest share of these and are still growing. Asia is the region where most subsidies are being disbursed (Cochrane, 2020; Sumaila *et al*., 2019).
- Ineffective governance of resources: Despite globally accepted concepts and multilateral conventions relating to fishery resource management, most countries struggle to have effective fishery management and enforcement systems in place with adequate stakeholder participation.
- Illegal, unreported and unregulated (IUU) fishing: These three issues have a major impact on a state's knowledge of the status of global fishery resources. Highly migratory fish and stocks in international waters are particularly vulnerable to IUU fishing. In this context, regional fisheries management organizations (RFMOs) have so far been unable to apply due diligence to this issue, primarily because of a limited mandate and/or lack of political commitment by their Member States.

The four processes mentioned above must be considered in the context of significant growth in seafood demand and prices, the severe socio-economic consequences of fishing effort reductions and the technological developments in the fishing technology, which boost productivity and profitability.

All of the countries that have participated in techno-economic performance reviews over the years have collaborated with the United Nations, and with FAO in particular, to develop and implement policies directed at responsible and sustainable fishery resource management. Much of this work was initiated in the 1970s, when coastal nations began to extend the jurisdictional boundaries of their traditional fisheries and declared EEZs in order to protect what they considered to be their resources and fishing industry. This process found its formal acceptance in the 1982 United Nations Convention on the Law of the Sea.

Article 7 and Article 8 on Fisheries Management and Fishing Operations of the *FAO Code of Conduct for Responsible Fisheries* both stress the need for technical and economic information on the fishing fleets' performance to achieve efficient, equitable and transparent management of the fishing capacity (FAO, 1995; Kitts *et al*., 2020)

Other important agreements promoted and/or supported by FAO that have impacted the operations, capacity and size of fishing fleets since 2000 include:

- the the 2001 WTO Ministerial Conference, held in Doha, launching the negotiations on fisheries subsidies (paragraph 28 of the Doha Ministerial Declaration);
- the 2001 International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (IPOA-IUU), reinforced by the 2009 Agreement on Port State Measures; and
- the 2001 Reykjavik Conference on Responsible Fisheries, which promoted the incorporation of ecosystem considerations into capture fisheries management.

In addition, Sustainable Development Goal (SDG) 14 of the United Nations 2030 Agenda for Sustainable Development deals with the conservation and sustainable use of the oceans, seas and marine resources. The Goal also stresses the need for fishing operations to become environmentally sustainable, socially acceptable and economically viable. A number of other, species-specific agreements (notably on sharks, turtles and dolphins, among others) have an impact on fishing fleet operations, as well as non-fisheries agreements such as CITES and the UNFCCC-Climate Change Framework Convention.

There are various underlying reasons for the continuous strive to increase fisheries production. For many countries, capture fisheries are an important if not vital source of employment and foreign exchange, while they also contribute substantially to nutritional and food security. Consequently, there is widespread interest in drafting and executing effective fishery resource management and enforcement programmes in order to perpetuate the harvesting of these benefits. Multiple studies have shown that implementing strong, consistent, and science-based fishery resource management could lead to sustainable resource abundance; it would substantially elevate not only the landings, which now appear to have stagnated, but also encourage widespread economic, social and ecological progress, particularly for those directly involved in the sector (Melnychuk *et al*., 2020). However, the development and implementation of such management systems can be costly, requiring scientific data and specific expertise, and take time. Some of these requirements are generally in short supply in developing countries.

Long-term monitoring of marine fish stocks conducted by FAO has revealed that the percentage of stocks fished at biologically unsustainable levels increased from 10 percent in 1974 to 34 percent in 2017 (FAO, 2020a). Over the last 30 years, the percentage of biologically sustainable fished stocks has improved, mainly as the result of improved management and enforcement measures. About 78 percent of marine capture landings currently originate from biologically sustainable stocks. Initially, only those areas with traditionally large numbers of fishers and fishing craft, coupled with a ferocious demand for seafood, experienced stock reductions and falling productivity. However, with the advent of industrial fishing this spread to other areas. Unsurprisingly, in 2017, the Mediterranean and Black Sea (#37) had the highest percentage (62.5 percent) of stocks fished at unsustainable levels among FAO Major Fishing Areas, followed by the Southeast Pacific (#87 – 54.5 percent) and the Southwest Atlantic (#41 – 53.3 percent).

The status of fishery stocks is a complex issue. There are in excess of 1 300 individual stocks and not all of these are monitored, while only about 62 percent are the subject of some form of biological investigation; these cover about 34 percent of worldwide landings as reported by FAO (Melnychuk *et al.*, 2020).

The substantial number of unassessed resources form a serious constraint to understanding the prevailing stock status and therefore complicate the implementation of effective management and enforcement systems (Cochrane, 2020).

The 2020 regional techno-economic performance reviews of selected fishing fleets cover semi-industrial fleets that fish in all FAO Major Fishing Areas, but for some of the resources targeted the data are lacking. This is particularly the case with Asian countries whose fleets operate in FAO Major Fishing Area 61 (Pacific, Northwest) and which represents the largest total landings among all FAO Major Fishing Areas (Table 10). Less than a quarter of landings in Area 61 are covered by stocks assessments. It should also be noted that fishing resources are not only affected by fishing effort, but also by issues such as climate change, the productivity of the ecosystems, management, pollution, the introduction of alien species and the degradation of coastal ecosystems. The effects of these drivers are typically cumulative, multiplying the severity of the individual issue (FAO, 2020a).

Some desk studies by economists of renowned global institutions indicate that a reduction of some 45 percent in fishing effort would be required in order for traditional stocks to recover to optimal levels of production (see for more information: World Bank, 2017). This may be a suitable scenario for developed countries, where most traditional fishery resources have already experienced a phase of over-exploitation, and fishers and shipowners can be compensated and/or make use of the existing social security safety nets. However, for most developing countries it is a challenge to reduce fishing effort in terms of the number of fishers and fishing vessels, as it will have direct, negative consequences for unemployment, food security, poverty levels and social and geographical mobility, among other aspects.

TABLE 10
World Capture Fishery Production, by selected FAO Major Fishing Areas, 2000–2018 (in tonnes)

FAO Area	Zone	2000	2005	2010	2015	2018
21	Atlantic, Northwest	2 068 154	2 160 396	2 047 932	1 854 417	1 682 461
27	Atlantic, Northeast	11 018 147	9 622 208	8 772 901	9 139 940	9 316 499
37	Mediterranean and Black Sea	1 510 249	1 438 301	1 433 391	2 438 678	1 788 633
41	Atlantic, Southwest	2 295 118	1 836 778	1 761 508	2 438 678	1 788 633
51	Indian Ocean, Western	3 971 280	4 387 476	4 247 367	4 715 322	5 513 759
57	Indian Ocean, Eastern	5 064 312	5 085 935	6 850 716	6 350 221	6 769 644
61	Pacific, Northwest	23 202 716	21 617 741	20 937 688	21 087 762	20 058 661
67	Pacific, Northeast	2 477 803	3 207 723	2 436 831	3 173 267	3 090 706
71	Pacific, Western Central	9 700 245	10 794 108	11 769 750	12 735 161	13 540 458
87	Pacific, Southeast	15 803 790	14 564 926	7 787 563	7 703 689	10 269 885
Total Marine Capture Fisheries		**95 509 607**	**93 253 346**	**89 086 276**	**91 656 658**	**96 433 736**

Source: FAO Fishery and Aquaculture Statistical Yearbooks (FAO, 2020b).

Despite the decreasing resource availability and increasing vessel age in most regions except Asia (see chapter 2.3), only a small percentage of vessels have been scrapped worldwide under fleet capacity management programmes. Fleet reduction efforts have been more successful where monetary incentives have been provided, whether for direct scrapping or for a change of register. It may also be worth noting that mobility within the sector has increased, as many vessels are refitted and technologically upgraded to start a new life in another fishery, often as a result of local and/or international management regulations, the collapse of a stock or the emergence of new fishery. For instance, many shrimp and finfish trawlers have been converted into longliners to catch higher value species, particularly tuna and tuna-like species.

The fishing vessel owners/operators who participated in the techno-economic performance fleet reviews were generally conscious of the fact that many commercial fishery resources are under pressure and that improvements in economic performance have to be obtained through proper fisheries management, adequate exploitation practices, and the appropriate technological improvements and innovation. These encompass areas such as the use of cheaper and more efficient energy sources, up-to-date electronic equipment, and a focus on quality and safety in the on-board handling of catch, in order to enhance value addition and marketing options (see also Chapter 5). Although the techno-economic fishing fleet performance reviews demonstrate that most fleets generate sufficient financial returns to cover costs and leave room for (re-) investment, it is likely that in a majority of countries few new fishing vessels will be built, as vessel owners/operators will opt to upgrade/convert existing vessels on the basis of cost and administrative considerations. However, these conversions, which involve major technological updates – including modern, energy-efficient engines and propulsion systems with increased power – may also entail a silent increase in fleet capacity, which may in turn have a negative impact on resource management efforts.

National fisheries policy and legislation, based on a harmonization of minimum standards established by the international instruments and frameworks relating to fishery resource management and IUU fishing, are central to getting a handle on the size and operations of the world's fishing fleets.[26]

A specific voluntary instrument to support the management of fishing capacity was adopted by the international community at the FAO Committee on Fisheries in 1999, in the form of an International Plan of Action (IPOA). The International Plan of Action for the Management of Fishing Capacity (IPOA-Capacity) was elaborated within the framework of the 1995 FAO Code of Conduct for Responsible Fisheries (CCRF), with the aim of achieving an efficient, equitable and transparent management of fishing capacity worldwide by 2005. This objective has not yet been realized, but many countries have indicated to FAO over the years that the subject has their attention.

In the most recent (2020) review of CCRF implementation, which benefited from the collaboration of 119 FAO Members including the European Union (Member Organization), 52 percent of Members identified fishing overcapacity as a problem. Of these, 55 Members have taken steps to prevent further build-up of overcapacity. The most prominent steps reported were: limited entry regimes (70 percent) and a freeze on the number of vessels/licenses (53 percent). Moreover, 83 percent reported taking steps to reduce overcapacity, with the most prominent being NPOA-Capacity development and implementation (28 percent), public buy-back and decommissioning schemes, as well as monitoring and research into fishing overcapacity (26 percent) (FAO, 2021a).

[26] Among others, these instruments include: the 2009 Agreement on Port State Measures (FAO, 2010), the 1995 UN Fish Stocks Agreement (UN, 1995), the 1993 Compliance Agreement (FAO, 1993), the FAO Global Record (FAO, 2021b) and the 2012 IMO Cape Town Agreement (IMO, 2018).

As part of the same CCRF survey, 58 Members reported having launched a preliminary fishing capacity assessment, with 22 Members planning to do so in the future, which is significantly fewer than in earlier surveys. Of the 119 Members of FAO that responded to the 2020 CCRF survey, 38 had developed a national plan of action for the management of their fishing fleet capacity (NPOA-Capacity).

Of the 20 countries covered in this fishing fleet review study, 11 have national or regional level plans in place to manage fishing fleet capacity. The European Union Member States referred to in this fishing fleet review, as all 27 European Union Member States, have to adhere to the Common Fisheries Policy (CPF) (EC Regulation 1380/2013), Article 22 of which stipulates that Member States must ensure that their fishing fleet does not at any point exceed the fishing capacity limits specified in Annex II of the regulation (European Union, 2019). Norway and Turkey also indicated having fishery management plans in place that reduced their fishing fleet capacity.

In the North and South American regional review (Kitts *et al*., 2020). The national report of the United States of America details the various ways in which the United States National Marine Fisheries Service (NMFS) influences fleet capacity. It does so through the Fishing Capacity Reduction Program, under the Magnuson-Stevens Fishery Conservation and Management Act, as well as through catch share fisheries management and by limiting the number of fishing permits in a fishery. The authors of the national fishing fleet reports of Brazil, Chile and Peru did not find any specific fishing fleet capacity management plans in place in these countries in 2018; however, general fisheries legislation is in force, which contains regulations that influence the development of the fishing industry in the three countries.

In the Asian region, there are various countries that implement specific regulations to limit the number of certain types of fishing vessels. For instance, Bangladesh has a policy in place to convert bottom trawlers to midwater trawlers. Similarly, India has regulations in place that allocate fishing zones to specific vessel types and operations, while a nationwide ban on trawling was issued in Indonesia in 2015. However, national plans for the management of fishing fleet capacity were not in place in these two countries in 2018–2019.

The National Fisheries Development Plan of the Thirteenth Five-Year Period of China contains clear targets to reduce fishing effort and capacity. Meanwhile, Japan and the Republic of Korea both have national plans and programmes in place that aim to reduce fishing fleet capacity. Buyback programmes and subsidies to remove vessels are in place, particularly for those fleet segments that fish for highly migratory species such as sharks and tunas, as well as vessels targeting depleted stocks.

Within the Asian region, members of the Indian Ocean Tuna Commission (IOTC) are requested to submit their tuna fishing fleet capacity management plans to comply with IOTC resolution 15/11 "On the implementation of a limitation of fishing capacity of Contracting Parties and Cooperating Non-Contracting Parties" (IOTC, 2015).

Of the countries from the African region that participated in the 2020 review, South Africa does not have any plans to reduce fleet capacity, while the NPOA-Capacity that was prepared in Senegal in the early 2000s was never implemented.

Most management plans are based primarily on marine sciences, which highlight the important and constructive biological concept of maximum sustainable yield (MSY). However, implementation of fishery management plans is highly dependent on the collaboration of fishers in the preparation, implementation and evaluation phases. If vessel owners/operators are guaranteed a fair and consistent share of the value of the resources they exploit, such collaboration is more likely. Therefore, it is imperative that components of the economic–analytical approach to fisheries are included as management indicators, as these contribute significantly to the comprehensiveness of management plans. The various techno-economic fishing fleet performance reviews provide compelling information on the performance and operations of fishing vessels: in doing so, they prove how this type of economic analysis can provide crucial information when drafting and executing fishery management and enforcement plans that will lead to viable and constructive fishing operations (FAO, 2019).

6.2 SEAFOOD PRICE TRENDS AND FLEET PROFITABILITY

In recent decades the volume, value and variety of seafood species and products on the world's markets has expanded dramatically. The increase in seafood trade has been driven by a number of factors, including significant advances in production, processing and preservation technologies. Seafood has become a popular, internationally traded commodity – one which is in short supply overall. This results in mainly price-based competition on the world market. Factors that have affected consumer demand for high-priced seafood products include an overall increase in income, the diversity of produce on offer and its perceived health benefits, among others.

The evolution of both ex-vessel and market prices for capture fishery products has followed a trend of consistent increase over the last two decades. Prior to 2018 there were few experts who discerned signs that overall prices might weaken. The only relative threat was expected to come from the growing output of aquaculture. However, there is a general consensus that the massive increase in the output of farmed fish has actually helped to keep the overall price increase in wild-caught fish for direct human consumption in check, while at the same time enhancing the availability and popularity of seafood globally, throughout the food sector.

Live, fresh or chilled seafood products for human consumption constitute about 44 percent of traded seafood: in part because these are the product's basic, traditional forms, and partly because of the catering industry's more recent, renewed interest in fresh produce. The share of frozen products in the international seafood trade has increased at a very steady rate since the 1960s and reached 35 percent in 2018 (FAO, 2020c).

The 2000–2007 period was one of stable seafood market conditions, although from the perspective of species groups and geographical regions it did include some fluctuations. In 2008 a severe worldwide economic crisis occurred, which had a detrimental effect on the overall consumption of foodstuffs over the next two years. Major seafood markets also felt the impact of the crisis and experienced a considerable weakening in value and volume as sales decreased and prices had to be adjusted. During the 2010–2017 period consumer confidence recovered and so did overall price levels. For instance, consumer fish prices increased by an average of 3 percent per year in the European Union (currently the largest seafood market) in the same period. Furthermore, since 2014 the percentage increase in seafood prices has been particularly significant, and outpaced those of meats and other basic foodstuffs (EUMOFA, 2018).

From 2017 the global economic situation started to deteriorate again. Globalization was being questioned, which led to trade tensions in the business world. This uncertainty deepened as Brexit and internal governance issues within the European Union fostered political unrest, which had a progressive impact on markets and consumer confidence. These issues were subsequently compounded by the outbreak and global spread of the Covid-19 pandemic in 2020. The progressive and cumulative impact on economic growth indicators, and the evident limitations of governments when dealing with the socio-economic implications of these developments, will likely have a sustained negative effect on markets (FAO, 2020d).

Prior to the full impact of the various events that would shape the global economy from 2017 onwards, the seafood market looked set for a period of relatively steady growth. The nominal prices for seafood from both capture fishing and aquaculture were expected to continue to increase, based on the assumption that demand would remain strong, driven by the continued popularity of seafood and an improving balance between supply and demand. It was even anticipated that over the period from 2018 to 2030 an increase of some 23 percent in the average nominal price of fish for human consumption would be feasible, in spite of the fact that overall average prices in terms of real value (i.e. adjusted for inflation) were expected to decline slightly, even while remaining high (FAO, 2020a).

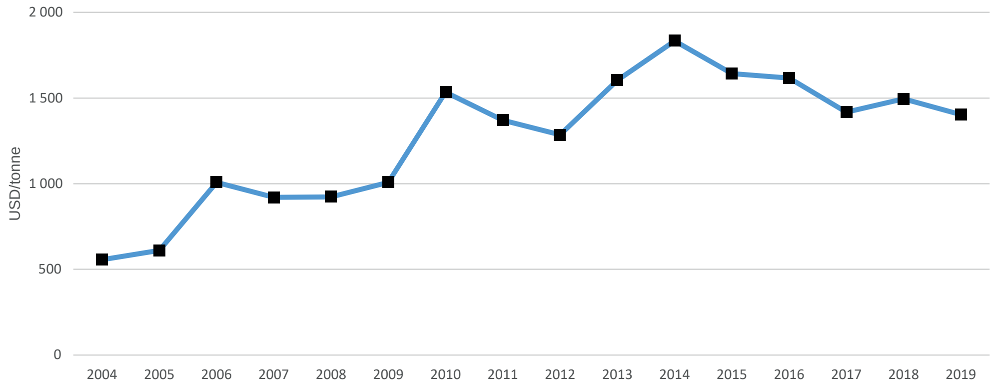
Statistics from major seafood markets, though incomplete, show that real market prices of all fishery products increased in the 2003–2005 and 2018–2020 periods, albeit with large variations between the various product groups and markets, reflecting distinct regional preferences and economic conditions (FAO, 2020d; FAO, 2007). In general, market prices for capture fishery products have benefitted from a growing demand from both traditional and emerging markets, as well as tight supplies. By virtue of its year-round production, aquaculture has had a stabilizing effect on the traditionally volatile market price trends of seafood, as it enables supply fluctuations to be mitigated more effectively (FAO, 2020a).

Luxury seafood items and product forms (e.g. live, fresh and chilled) show a relative elasticity in terms of price and demand when economic growth indicators undergo a temporary downward trend. In times of oversupply, wholesalers have mostly been successful in moving inventories by lowering prices. The market behaviour of more regular seafood products is closer to unit elasticity, particularly in those markets where seafood is a staple. With prices increasing for less readily available, regular seafood products, the latter have also experienced positive cross-elasticity to other animal protein sources, particularly chicken (Babović *et al.*, 2012). On the production side, ex-vessel prices can be assumed to be rather inelastic as production factors for capture fisheries are slower to react to market fluctuations.

Aquaculture has been a major force in popularizing certain seafood products, with the surge in cultured shrimp output regularly leading to saturated markets. Groundfish, cephalopods and tuna showed steady price trends in the 2000–2018 period. Meanwhile, raw materials for canned seafood products experienced market price increases, the latter mainly as a result of increasing demand from markets in developing countries. Growing aquaculture production stimulated the price of small pelagics used for reduction, as demand for fishmeal and oil sharply increased, both of which are vital ingredients in formulated compound feeds.

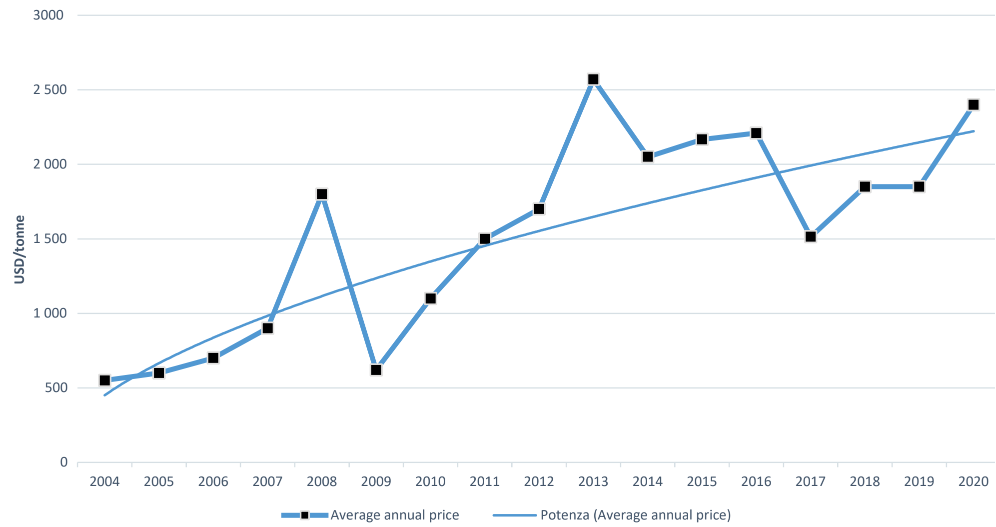
However, over the past years the production of fishmeal and oil from specific targeted small pelagic resources has undergone structural decline. The aquaculture industry has been on the lookout for alternative (and cheaper) compound feed ingredients, while the demand for small pelagics for direct human consumption has increased, insofar as it is viewed as an abundant and relatively cheap source of polyunsaturated fatty acids, which are of major benefit to human health (FAO, 2020a). Nevertheless, the total volume of fishmeal and fish oil to be produced in years to come can be expected to increase slightly, thanks to supplies of fish waste and offal from the fish processing

FIGURE 52
Average annual prices for 65 percent steam-dried fishmeal, 2004–2019, FOB Callao, Peru (USD/tonne)



Source: Graph produced using data from CMC Report Asesores y Consultores S.A.C., Peru (CMC, 2020).

FIGURE 53
Fish oil prices, FOB Callao, Peru, 2004–2020 (USD/tonne)



Source: Graph produced using data from CMC Report Asesores y Consultores S.A.C., Peru (CMC, 2020).

industry (FAO, 2020a). These developments are evident in the price trends (Figure 52 and Figure 53). In 2004, prices for both fishmeal and fish oil were around USD 500 free on board (FOB - Peru) per tonne. By comparison, export prices for fishmeal ranged from USD 1 400 to USD 1 500 in 2018–2019, while fish oil reached USD 2 000/tonne.

The revenue resulting from the sale of landed catch at prevailing ex-vessel prices is a major driver of fishing fleet operations. Other variables, such as the fisheries management regimes in place, the fish species targeted, fish stock status, fishing methods and technologies, as well as operating costs (labour, running, vessel and capital costs – see Chapter 3) also influence the financial and economic performance of fishing fleets. According to the 2020 FAO regional techno-economic fishing fleet performance reviews, an average of 93 percent of the revenue of the fleet segments surveyed originated from the sale of landed fish. Unfortunately, ex-vessel prices were not the subject of major research in past techno-economic fishing fleet performance reviews; a comparison of the ex-vessel prices obtained by specific fleet segments in the 2001, 2005 and current review was therefore not possible.

The use of seafood market prices in the analysis of fleet performance would be less accurate, as market prices do not necessarily relate to the way raw materials are produced, their origin, or ex-vessel prices: they mainly refer to the functioning and peculiarities of different levels of the value chain. Nevertheless, time-series of market prices can be relevant for resource and fleet management plans and strategies, as they can indicate a species' popularity in the short, medium and long term – and consequently influence the fishing effort and revenues through the ex-vessel prices offered.

Comparisons of the prevailing ex-vessel and market price trends of seafood produce in the 2003–2005 and 2018–2020 periods are generally complicated by virtue of a lack of consistent and comparable data. Few countries worldwide have ex-vessel price data available, but even these are often marred by inconsistencies and limitations because of issues such as variations in the units of landed product, the price references relative to product forms, as well as species groupings and identification. Moreover, vessel owners and operators are generally hesitant to provide data on ex-vessel prices and revenues for tax, administrative or operational reasons. This is particularly evident in developing countries. In many developed countries compliance with regulations that require vessel owners/operators to submit data is much better, as non-compliance can have serious consequences with respect to future commercial fishing licenses, quota applications and possibly fines.

The National Oceanic and Atmospheric Administration (NOAA) of the United States of America has maintained ex-vessel price records since the 1950s. Such data facilitate the analysis of historic price trends and economic performance by fishing vessel segment, comparing annual revenue growth to increases in operational costs.

The data presented in Table 11 represent the price trends for finfish and shellfish landed and paid at the dock in three states. The species analysed correspond to those targeted, by fleet segment, as presented in the national report of the United States of America, in Kitts *et al.* (2020). Although all ex-vessel prices have improved over the 2000–2019 period, the increase for swordfish, big-eye tuna and sablefish is minimal for a period of almost 20 years. On the other hand, ex-vessel prices for Dungeness crab and shrimp more than doubled. It should be noted that prices for all species – with the exception of shrimp – have dropped from the much higher levels seen during the years 2015 and 2016, and that the ex-vessel price of Dungeness crab appears particularly sensitive to supplies. The data in Table 11 make it seem as though pelagic longline vessels in Hawaii would find it hard to cover operational cost increases with higher income from the sale of catch. However, the national report of the United States of America indicated that these longliners achieved an average net profit margin of 7.4 percent and an average return on investment of 9.1 percent in 2012 (Kitts *et al.*, 2020).

TABLE 11
Volumes landed and ex-vessel value for selected species and states, United States of America, 2000–2019 (USD/lbs)

	Hawaii				Oregon				Florida	
	Swordfish		Big eye tuna		Sablefish		Dungeness crab		Shrimp Penaeoid	
Year	Q	USD	Q	USD	Q	USD	Q	USD	Q	USD
2000	6 521	1.96	6 171	3.48	6 256	1.48	11 180	1.34	134	1.82
2005	3 446	2.25	10 935	3.30	5 834	1.48	17 730	1.50	247	3.80
2010	3 153	2.31	13 060	3.89	6 301	2.39	15 869	2.06	149	3.56
2015	2 044	2.26	18 701	3.78	5 001	2.55	2 293	5.28	505	2.72
2016	1 640	2.93	17 642	4.10	5 544	2.74	15 715	3.55	252	3.63
2017	2 561	2.27	16 976	3.82	5 556	2.80	19 017	3.09	133	3.61
2018	1 744	2.12	15 978	4.16	5 678	2.10	23 135	3.22	288	3.69
2019	2 981	2.55	32 957	3.86	5 837	1.61	19 035	3.57	340	3.86

Q = in 1000 pounds (lbs) landed at dock
Source: National Oceanic and Atmospheric Administration / United States of America Department of Commerce (NOAA), 2020.

The European Union collects fleet performance data through its Scientific, Technical and Economic Committee for Fisheries (STECF), which also includes extensive data on live weight volume and the value of landings, by species and Member State. Tables 12 and 13 provide data on the ex-vessel value (in Euros per tonne of landed product) of selected species from a number of European Union Member States in 2008-2019. The selection was based on the volume and value of those species that are mainstays of specific fleet segments, as reported by the vessel owners/operators who participated in the FAO techno-economic performance review.

TABLE 12

Annual average ex-vessel values for selected species and countries in the European Union, 2008–2019 (EUR/tonne)

Species: Atlantic mackerel												
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Germany	852	900	900	900	928	920	900	900	900	897	899	896
Denmark	1 272	869	1 095	1 590	978	1 077	991	833	989	956	1 228	n.a.
France	815	876	1 004	1 250	658	1 332	1 386	921	1 052	1 068	1 106	n.a.
Italy	2 969	3 620	3 163	3 452	3 285	3 258	3 762	3 082	3 534	4 227	4 358	n.a.
Spain	1 123	1 149	1 149	1 157	1 153	916	790	658	968	968	1 064	1 667
United Kingdom of Great Britain and Northern Ireland	1 006	997	1 006	1 298	1 156	1 052	979	888	1 032	1 023	1 197	1 365
Species:Atlantic cod												
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Germany	1 870	1 311	1 441	1 530	1 560	1 503	1 603	1 798	1 880	2 148	2 148	2 368
Denmark	2 211	1 614	1 743	1 867	1 735	1 900	1 874	1 874	2 130	2 368	2 614	n.a.
France	2 941	2 567	1 361	2 864	2 615	2 703	2 638	2 689	3 124	3 642	2 900	n.a.
Spain	2 192	2 193	2 226	2 276	2 290	2 505	3 005	2 889	2 749	2 598	1 377	n.a.
United Kingdom of Great Britain and Northern Ireland	2 172	1 586	2 050	2 302	2 041	1 846	2 026	2 335	1 947	2 334	2 444	2 582
Species: Haddock												
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Germany	1 604	1 128	1 296	1 265	1 287	1 284	1 617	1 722	1 847	1 844	1 694	1 824
Denmark	1 173	1 128	1 090	1 263	1 227	1 318	1 465	1 641	1 740	1 759	1 753	n.a.
France	1 464	1 239	1 228	1 080	1 083	1 466	1 562	1 807	1 981	1 994	2 113	n.a.
Spain	1 340	1 239	1 278	1 230	1 420	1 143	1 318	1 908	1 537	2 204	1 278	2 651
United Kingdom of Great Britain and Northern Ireland	1 384	1 100	1 320	1 412	1 301	1 321	1 725	1 866	1 606	1 718	1 639	1 717
Species: Common sole												
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Germany	9 363	9 860	11 313	11 367	9 522	7 922	9 294	10 197	10 418	10 490	11 243	11 440
Denmark	10 385	9 518	11 237	11 577	10 499	8 641	8 985	10 162	10 751	10 402	11 558	n.a.
France	10 696	10 339	11 755	11 674	11 693	10 602	10 647	11 301	12 951	12 684	13 011	n.a.
Italy	14 839	15 716	15 875	18 701	15 219	13 318	10 130	12 049	11 835	10 721	11 424	n.a.
Spain	17 235	15 729	14 891	17 303	16 316	14 964	15 596	10 440	14 156	14 741	16 298	n.a.
United Kingdom of Great Britain and Northern Ireland	9 262	8 566	10 457	10 496	10 124	8 595	8 949	10 792	11 376	10 645	11 517	12 978
Species: European hake												
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Germany	1 919	1 842	1 789	1 978	2 009	1 963	1 913	1 990	2 098	2 412	2 615	3 320
Denmark	2 041	1 546	1 613	1 686	1 884	1 903	1 881	1 998	2 091	2 449	2 445	n.a.
France	2 994	2 649	2 464	2 507	2 422	2 419	2 364	3 057	2 783	2 929	2 997	n.a.
Italy	7 375	7 522	7 813	8 231	7 916	6 885	7 298	7 665	8 072	8 209	7 367	n.a.
Spain	3 158	3 214	3 130	3 321	3 279	3 343	3 659	3 612	4 011	4 226	3 837	4 847
United Kingdom of Great Britain and Northern Ireland	2 213	2 182	2 114	2 108	2 611	2 999	2 850	3 255	2 886	2 470	2 480	2 814
Species: Monkfish												
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
France	4 442	4 398	4 383	4 472	4 134	4 157	4 186	4 306	4 153	4 218	4 585	n.a.
Spain	5 805	5 822	5 912	5 810	5 395	5 366	4 865	3 542	3 478	3 773	4 581	5 536
Species: Angler fish												
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Germany	4 039	2 998	4 408	5 760	3 064	3 965	4 034	3 515	4 164	4 285	3 712	3 394
Spain	6 422	5 967	5 802	5 499	5 021	5 228	4 869	5 212	5 409	5 439	5 106	7 225
United Kingdom of Great Britain and Northern Ireland	3 456	3 520	3 846	3 859	4 044	3 575	3 590	3 548	3 581	3 350	3 679	3 831

n.a.: not available All prices adjusted for inflation; 2008 constant prices; in Euros nominal

Source: European Union Scientific, Technical and Economic Committee for Fisheries (STECF, 2020).

TABLE 13
Indexed annual average ex-vessel values for selected species and countries in the European Union, 2008–2019 (2008=100)

Species: Atlantic mackerel												
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Germany	100	106	106	106	109	108	106	106	106	105	106	105
Denmark	100	68	86	125	77	85	78	66	78	75	97	n.a.
France	100	107	123	153	81	163	170	113	129	131	136	n.a.
Italy	100	122	107	116	111	110	127	104	119	142	147	n.a.
Spain	100	102	102	103	103	82	70	59	86	86	95	148
United Kingdom of Great Britain and Northern Ireland	100	99	100	129	115	105	97	88	103	102	119	136
Species: Atlantic cod												
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Germany	100	70	77	82	83	80	86	96	101	115	115	127
Denmark	100	73	79	84	78	86	85	85	96	107	118	n.a.
France	100	87	46	97	89	92	90	91	106	124	99	n.a.
Spain	100	100	102	104	104	114	137	132	125	119	63	n.a.
United Kingdom of Great Britain and Northern Ireland	100	73	94	106	94	85	93	107	90	107	113	119
Species: Haddock												
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Germany	100	70	81	79	80	80	101	107	115	115	106	114
Denmark	100	96	93	108	105	112	125	140	148	150	149	n.a.
France	100	85	84	74	74	100	107	123	135	136	144	n.a.
Spain	100	92	95	92	106	85	98	142	115	165	95	198
United Kingdom of Great Britain and Northern Ireland	100	79	95	102	94	95	125	135	116	124	118	124
Species: Commonsole												
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Germany	100	105	121	121	102	85	99	109	111	112	120	122
Denmark	100	92	108	111	101	83	87	98	104	100	111	n.a.
France	100	97	110	109	109	99	100	106	121	119	122	n.a.
Italy	100	106	107	126	103	90	68	81	80	72	77	n.a.
Spain	100	91	86	100	95	87	90	61	82	86	95	n.a.
United Kingdom of Great Britain and Northern Ireland	100	92	113	113	109	93	97	117	123	115	124	140
Species: European hake												
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Germany	100	96	93	103	105	102	100	104	109	126	136	173
Denmark	100	76	79	83	92	93	92	98	102	120	120	n.a.
France	100	88	82	84	81	81	79	102	93	98	100	n.a.
Italy	100	102	106	112	107	93	99	104	109	111	100	n.a.
Spain	100	102	99	105	104	106	116	114	127	134	121	153
United Kingdom of Great Britain and Northern Ireland	100	99	96	95	118	136	129	147	130	112	112	127
Species: Monkfish												
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
France	100	99	99	101	93	94	94	97	94	95	103	
Spain	100	100	102	100	93	92	84	61	60	65	79	95
Species: Anglerfish												
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Germany	100	74	109	143	76	98	100	87	103	106	92	84
Spain	100	93	90	86	78	81	76	81	84	85	80	113
United Kingdom of Great Britain and Northern Ireland	100	102	111	112	117	103	104	103	104	97	106	111

n.a.: not available 2008=100
Source: European Union Scientific, Technical and Economic Committee for Fisheries (STECF, 2020).

As the tables reveal, the variation in ex-vessel values for specific species between countries is quite substantial. Factors that influence the value of landed products include the variation in how seafood quality is preserved on-board, the product forms landed and the final market destination, as well as seasonal supply variation and quota allocations. Over the 2008–2019 period a moderate increase in overall ex-vessel values can be observed, although those of traditionally popular species (e.g. Atlantic cod) appear to have hit a ceiling.

Although the ex-vessel values are presented in real terms (i.e. adjusted for inflation), the increase in the 2008–2019 period does not appear sufficient to explain the reported profitability levels for most of the European fishing vessel segments covered in this review. Data reveal that the improved profitability levels in selected European fleet segments (compared to 2003–2004) are in large measure the result of a higher volume of landings per vessel, and reductions in operational costs, particularly lower fuel costs.

The FAO Fishery and Aquaculture Statistical Yearbook (FAO, 2020c) also provides information on average annual ex-vessel seafood values per tonne, but by species groups (Table 14). As with other attempts to provide ex-vessel value time series, it can be argued that these may not be adequate for use in the techno-economic performance analysis of fishing vessels, but they may prove very useful for decision makers, fishery resource managers and investors.

Various projects to build models that provide comprehensive time series of ex-vessel prices have demonstrated that adequate time series can be obtained on the basis of first-hand, albeit partial ex-vessel quotes, and by extrapolating market prices (Sumaila *et al*., 2007; Swartz *et al*., 2012). The resulting time series mostly concern aggregated groups of species or products.

TABLE 14
Global average ex-vessel prices per species group, 2000–2018 (in USD/tonne)

Year	2000	2003	2006	2009	2012	2015	2018	% Change 2000–2018
Cods, hakes, haddocks	900	885	1 000	1 100	1 650	1 550	1 700	189%
Demersal fishes misc.	1 335	1 345	1 500	1 700	2 400	2 200	2 930	219%
Herring, sardines, anchovies	240	264	300	310	695	615	660	275%
Tunas, bonito, billfishes	1 450	1 400	1 600	1 650	1 700	1 600	1 950	134%
Pelagic fish, misc.	505	492	530	505	690	630	850	168%
Shrimp, prawns	3 620	3 280	3 400	3 450	3 700	3 850	4 500	124%
Clams, cockles, arkshell	950	910	910	980	1 150	1 210	1 400	147%
Squid, cuttlefish, octopus	1 520	1 710	1 700	1 820	2 000	2 050	2 600	171%
Fish for reduction	107	132	165	177	300	295	310	290%

Source: FAO Fishery and Aquaculture Statistical Yearbooks (FAO, 2020c).

FAO Fish Price Index (2014–2016 = 100)

Source of the raw data for the FAO Fish Price Index: EUMOFA, INFOFISH, INFOPESCA, INFOYU, Statistics Norway.

One of these time series is provided by the FAO Fish Price Index (FPI),[27] which is a good price indicator to study trends as it combines price and volume. The FPI relies on seafood import and export trade statistics, while taking into consideration that seafood is a heavily traded internationally commodity and exposed to a high degree of price competition (Tveterås *et al*., 2012). The FPI is therefore a useful global indicator as it tracks the extent to which seafood as a whole is becoming more or less expensive, by considering trade movements in volume and value terms. However, what must also be considered is that regional and seasonal price volatility can be substantial, in spite of the fact that seafood is generally considered as highly tradeable.

A comparison of the FAO Fish Price Index (FPI) levels during the FAO techno-economic fishing fleet performance review periods of 2003–2005 and 2016–2020 reveals a substantial increase of 28 points. In May 2018, the FPI hit the second highest level at 113, marking the culmination of a trend driven by tight supplies for many heavily traded species, coupled with strong demand worldwide (FAO, 2020e). Despite supply improvement for several species from the end of 2018 onwards, which slowed the rate of price increases, overall price levels for seafood products remained high. In 2020, the sector was hit by the Covid-19 pandemic with the FPI averaging 95 points, 7 percent down on 2019. This decline was mainly the result of lower aquaculture prices, particularly for salmon prices. Due to a longer production cycle, salmon producers were not able to adapt as quickly to the poor market conditions, leading to price declines. Prices for popular wild-caught species also declined over 2020, but less than farmed species prices, reflecting a reduced fishing vessel effort.

It can be concluded that the general increase in ex-vessel prices over the last two decades has contributed positively to the improved financial and economic performance of the fishing fleets covered in this review. However, the relative importance of ex-vessel seafood prices in contributing to the overall fleet profitability compared to other factors – such as the higher volume of landings per vessel and reductions in operational costs – is not clear.

The impact of the global Covid-19 pandemic on production and the seafood market remains uncertain. Before the Covid-19 pandemic it was anticipated that higher prices at the production level, coupled with a continuous, steady demand for fish for human consumption, would stimulate an estimated 22 percent increase in the average price of internationally traded fish by 2029 relative to 2017-2019 (OECD/FAO, 2020). In view of the various uncertainties affecting the global economy, the expectation is for seafood prices to grow again from 2021, but at a slower rate than previously expected.

REFERENCES

Allison, E.H., Delaporte, A. & Hellebrandt de Silva. D. 2013. Integrating Fisheries Management and Aquaculture Development with Food Security and Livelihoods for the Poor. Report submitted to the Rockefeller Foundation. Norwich, UK: School of International Development, University of East Anglia.

Babović, J., Ignjatijević, S. & Đorđević, D. 2011. Supply, Demand and Elasticity of Fish. *Economics of Agriculture [S.l.]*, 58 (4): 595–608.

CMC. 2020. *CMC Report Asesores y Consultores S.A.C*., by Cesar Casahuaman Malaver. Peru.

Cochrane, K.L. Reconciling sustainability, economic efficiency and equity in marine fisheries: Has there been progress in the last 20 years? *Fish Fish*. 00: 1–26. https://doi.org/10.1111/faf.12521

Costello, C., Cao, L., Gelcich, S. et al. 2020. The future of food from the sea. Nature 588, 95–100 (2020). https://doi.org/10.1038/s41586-020-2616-y

[27] For more information visit: www.fao.org/in-action/globefish/fishery-information/world-fish-market/en/

European Market Observatory for Fisheries and Aquaculture Products (EUMOFA). 2018. *The EU Fish Market, 2018 Edition* [online]. Brussels. [Cited 10 March 2021]. www.eumofa.eu/documents/20178/132648/EN_The+EU+fish+market+2018.pdf

European Union (EU). 2019. Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy, amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and repealing Council Regulations (EC) No 2371/2002 and (EC) No 639/2004 and Council Decision 2004/585/ EC. https://eur-lex.europa.eu/eli/reg/2013/1380/oj [version of 14/08/2019].

FAO. 1993. *Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas* [online]. FAO Conference. Twenty-seventh Session, November 1993 through Resolution 15/93. [Cited 18 February 2021]. www.fao.org/fileadmin/user_upload/legal/docs/012s-e.pdf

FAO. 1995. *Code of Conduct for Responsible Fisheries*. Rome, FAO. 41 pp. (also available at www.fao.org/3/v9878e/V9878E.pdf).

FAO. 2007. *GLOBEFISH Highlights, July 2007. A quarterly update world seafood market report*. Globefish Highlights No. 3–2017. Rome, FAO.

FAO. 2016. *The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all*. Rome, FAO. (also available at www.fao.org/3/a-i5555e.pdf).

FAO. 2019. *Report of the Expert Meeting on Methodologies for Conducting Fishing Fleet Techno-Economic Performance Reviews, Chennai, India, 18-20 September 2018.* FAO Fisheries and Aquaculture Report No. 1243, Rome. 60 pp (also available at www.fao.org/documents/card/en/c/ca4427en/).

FAO. 2020a. *The State of World Fisheries and Aquaculture 2020*. Sustainability in action. Rome, FAO. 244 pp. (also available at https://doi.org/10.4060/ca9229en).

FAO. 2020b. *How is COVID-19 affecting the fisheries and aquaculture food systems*. Rome, FAO. 5 pp. (also available at https://doi.org/10.4060/ca8637en).

FAO. 2020c. *FAO yearbook. Fishery and Aquaculture Statistics 2018/FAO annuaire. Statistiques des pêches et de l'aquaculture 2018/ FAO anuario. Estadísticas de pesca y acuicultura 2018*. Rome/Roma, FAO. 110 pp. (also available at https://doi.org/10.4060/cb1213t).

FAO. 2020d. *GLOBEFISH Highlights April 2020 issue, with Annual 2019 Statistics – A quarterly update on world seafood markets*. Globefish Highlights No. 2–2020. Rome, FAO. (available at https://doi.org/10.4060/ca9528en).

FAO. 2020e. *FAO Fish Price Index - March 2018 update, includes September 2017.* [Cited 20 March 2021] www.fao.org/in-action/globefish/market-reports/resource-detail/en/c/338601/

FAO. 2021a. *Progress in the implementation of the Code of Conduct for Responsible Fisheries and related instruments.* [online] Committee on Fisheries. Thirty-fourth Session, 1–5 February 2021. COFI/2020/Inf.7. [Cited 18 February 2021] www.fao.org/3/ne627en/ne627en.pdf

FAO. 2021b. Global Record of Fishing Vessels, Refrigerated Transport Vessels and Supply Vessels. In: *Food and Agriculture Organization of the United Nations*. [online]. Rome. [Cited 18 February 2021]. www.fao.org/global-record/en/

Golden, C.D., Allison, E.H., Cheung, W.W.L., Dey, M.M., Halpern, B.S., McCauley, D.J., Smith M. et al. 2016. Nutrition: Fall in Fish Catch Threatens Human Health. *Nature*, 534 (7607): 317–20. (also available at https://doi.org/10.1038/534317a).

International Maritime Organization (IMO). 2018. *Cape Town Agreement of 2012 (2018 Edition).* London, IMO Publishing.

Indian Ocean Tuna Commission (IOTC). 2015. Resolution 15-11 On the implementation of a limitation of fishing capacity of Contracting Parties and Cooperating Non-Contracting Parties. In *Indian Ocean Tuna Commission – Conservation and management measures* [online]. [Cited 2 February 2021]. www.iotc.org/cmm/resolution-1511-implementation-limitation-fishing-capacity-contracting-parties-and-cooperating

Kitts, A., Van Anrooy, R., Van Eijs, S., Pino Shibata, J., Pallalever Pérez, R., Gonçalves, A.A., Ardini, G., Liese, C., Pan, M., Steiner, E. 2020. *Techno-economic performance review of selected fishing fleets in North and South America*. FAO Fisheries and Aquaculture Technical Paper No. 653/2. Rome, FAO. 122 pp. (also available at www.fao.org/documents/card/en/c/ca9543en).

Melnychuk M. C., Baker N., Hively D., Mistry K., Pons M., Ashbrook C. E., Minto C., Hilborn R. & Ye Y. 2020. Global trends in status and management of assessed stocks: achieving sustainable fisheries through effective management. FAO Fisheries and Aquaculture Technical Paper No. 665. Rome, FAO. 152 pp (also available at https://doi.org/10.4060/cb1800en).

OECD/FAO (2020), OECD-FAO Agricultural Outlook 2020-2029, OECD Publishing, Paris/FAO, Rome, https://doi.org/10.1787/1112c23b-en.

STECF. 2020. *Economic Analysis (fleet, processing, aquaculture): Final reports*. Scientific, Technical and Economic Committee for Fisheries (STECF). [Cited 22 March 2021] https://stecf.jrc.ec.europa.eu/reports/economic

Sumaila R., Marsden A., Watson R. & Pauly D. 2007. A global ex-vessel fish price database: construction and applications. *Journal of Bioeconomics*, 9(1): 39–51.

Sumaila, U, R., Ebrahim, N., Schuhbauer, A., Skerritt, D., Li, Y., Kim, H.S., , Mallory, T.G., Lam, V.W.L., Pauly, D. 2019 Updated estimates and analysis of global fisheries subsidies. *Marine Policy,* 109: 103695: https://doi.org/10.1016/j.marpol.2019.103695

Swartz W., Sumaila R. & Watson R. 2012. Global Ex-vessel Fish Price Database Revisited: A New Approach for Estimating 'Missing' Prices. *Environmental and Resource Economics*, 56(4): 1–14.

Tveterås, S., Asche, F., Bellemare, M.F., Smith, M.D., Guttormsen, A.G., Lem, A., Lien, K., & Vannuccini, S. 2012. Fish Is Food - The FAO's Fish Price Index. *PLoS ONE,* 7(5): e36731 [online]. [Cited 10 March 2021]. https://doi.org/10.1371/journal.pone.0036731

United Nations (UN). 1995. *Agreement for the Implementation of the Provisions of 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*. New York. (available at https://documents-dds-ny.un.org/doc/UNDOC/GEN/N95/274/67/PDF/N9527467.pdf).

World Bank. 2017. *The Sunken Billions Revisited: Progress and Challenges in Global Marine Fisheries*. Washington, DC: World Bank. Environment and Sustainable Development series. (also available at openknowledge.worldbank.org/bitstream/handle/10986/24056/9781464809194.pdf?sequence=8&isAllowed=y

7. Conclusions

- The information presented in this paper was collated from 103 major fishing fleet segments originating from 20 countries (Bangladesh, Brazil, China, Chile, Denmark, France, Germany, India, Indonesia, Italy, Japan, Norway, Peru, the Republic of Korea, Senegal, South Africa, Spain, Turkey, the United Kingdom of Great Britain and Northern Ireland, and the United States of America). These are among the largest marine fishing nations in their respective regions.
- The inclusion of countries and specific fleet segments in this review was made based on the volume of seafood landed and the contribution of specific fishing fleet segments to the landed volume in a country. The 97 fleet segments for which an economic analysis could be conducted landed approximately 32.8 million tonnes of fish and fisheries products in 2018, which accounted for nearly 39 percent of the world's marine capture fisheries production in that year.
- This global review covered a wide range of fishing vessel types, including 41 fleet segments of bottom trawlers, 18 fleet segments of purse seiners, 10 segments of longliners, 6 segments of pelagic trawlers, 4 segments each of gillnetters and squid jiggers, in addition to fleet segments consisting of cast netters, stownetters, pole-and-line vessels, pot and trap vessels, dredgers, passive gear vessels and handliners.

7.1 FISHING FLEET CHARACTERISTICS

- A comparison of average vessel characteristics indicating the degree of fishing capacity (length, tonnage and power) demonstrated substantial differences between fleet segments. While the fishing gear used within these fleet segments (e.g. purse seine nets, longlines) fall into the same general classification, the characteristics of these fisheries are highly diverse in terms of stocks targeted, fishing areas (coastal/offshore) and the value chains of their fishery products. Moreover, the significant variety in fishery management regimes, and the socio-economic conditions of the countries from which the fleets operate, also leads to differences in vessel characteristics and capacity.
- Comparing the average fishing vessel characteristics with those of similar fleet segments covered by the 1999–2000 FAO fleet performance review (Tietze *et al*., 2001) revealed an increase in the gross tonnage of average individual vessels in all fleet segments that could be compared. Moreover, substantial increases in the average length overall (in metres) and engine power (in kW) of vessels were observed in several fleet segments (e.g. Chinese pair trawlers, and the large otter trawlers and purse seiners of the Republic of Korea) since the start of this millennium. In Europe, a few fleet segments have seen a reduction in the engine power of average vessels since 2000.
- The age structure of the fishing fleets of (semi-) industrial fishing vessels in North and South America, Africa and Europe generally follows an upward trend. In most fishing fleet segments in these regions the vessels (hulls) have a longer economic lifespan than in the past, which is often supported by proper maintenance regimes, engine replacement and the retrofitting of on-board equipment and electronics. The average age of fishing vessels in Europe is 28 years old. The small bottom trawler(< 24 m) segments contained, in relative

terms, the oldest vessels of the fleets of European countries, with an average age of 30 years. In North and South America and Africa, the average fishing vessel age registered in the IMO database for large vessels (with a gross tonnage of over 100 tons) was 36, 38 and 34 years old respectively. The review found that most of the fishing fleet segments in the United States of America and Senegal are aging. On the other hand, investments in squid-targeting vessels in Peru and South Africa, and bottom (shrimp) trawlers in Brazil, have led to the emergence of some relatively young fleets in these countries in the last ten years.

- On average, the age profile of fishing fleet segments in Asia is younger, relatively speaking, than those of the other regions. This is primarily the result of the development of fishing fleets in Bangladesh, China, India and Indonesia. China, in particular, has continued to develop its offshore fishing capacity over the last decades, resulting in a younger fishing fleet mainly consisting of gillnetters and bottom trawlers with steel hulls. The various Indian fleet segments (trawlers, gillnetters, purse seiners and ring seiners), together with the Bangladeshi mechanized gillnetter (17 m) fleet segment, have been almost entirely renewed in the last 10 years, as the lifespan of the wooden-hulled vessels in these segments is generally 12–15 years. The sheer number of new vessels entering these fleet segments over the last decade means that 87 percent of fishing vessels in the 24 major Asian fishing fleet segments reviewed are less than 10 years old. By contrast, the average vessels in the Japanese and Republic of Korea fishing fleets are more than 20 years old. These two Asian countries both have well-established fishing fleets with a more balanced vessel age structure.

7.2 REVENUES AND COSTS

- The extensive variations in vessel characteristics, degree of technology, fishing areas, target species and value chains in the fleet segments analysed translate into large differences in the revenue and cost structures of the vessels. This is evident not only between regions and main fishing gears, but also within countries and fleet segments, and makes comparisons very challenging.
- As observed in the 2003 FAO fleet performance review (Tietze *et al*., 2005), some of the aforementioned variations are clearly related to differences in the labour, maintenance and repair costs of fishing vessels in different countries, which are generally more favourable for fishing fleets in Asia, South America and Africa than their counterparts in North America and Europe. In other cases, factors such as management policies (e.g. TACs and quotas) may explain some of the differences between vessels of the same length, gear and regional categories.
- Overall, vessels with higher earnings tend to have higher total costs. Some of the largest vessels (in terms of LOA) were found to be among the top earners and spenders. When considered by main fishing gear this was more evident within specific country or regional segments, while little evidence was found across regions. This can be partially explained by the differences between countries in terms of purchasing power, inflation and exchange rates.
- Revenues and costs appear to be related to target species and the main fishing gears used. With the exception of the demersal trawler and conventional seagoing vessels of Norway, the top producers globally were predominately vessels from Europe, Asia and South America (Chile) targeting large pelagics, in the purse seiner and trawler fleet segments.

- Labour and running costs were the two main cost components in the majority of fleet segments reviewed. This combination was more pronounced in the trawler segments, with the exception of the European trawlers, where vessel costs tended to surpass running costs. This can be partly explained by the costs incurred by these vessels for access and fishing rights.
- Labour costs tend to account for the largest share of total costs in artisanal, small-scale or more labour-intensive fisheries (e.g. purse seiners, non-mechanized gears) in North America, Asia and Europe. Labour costs also tend to be high in fleet segments with more sophisticated fishing operations, where less but more specialized (and higher paid) labour is required. None of the African segments showed labour costs as the main cost component.
- Running costs tend to be higher for larger and more fuel-intensive vessels operating in offshore fishing regions, such as deep-sea and pelagic trawlers. Vessels where running costs comprise the least significant cost component generally use more passive gears, such as gillnets, pots and traps, pole-and-lines and handlines.
- Similarly, as observed in the 2003 FAO fleet performance review (Tietze *et al*., 2005), unlike in the American and European segments, vessel costs ranked third or last in most of the segments in Africa and Asia, indicating that less was spent on repair and maintenance by owners of African and Asian vessels than their American and European counterparts.
- Capital costs accounted for only a minor part (generally less than 10 percent) of total costs in the majority of the fleet segments analysed; these have generally decreased over the last decade or more, which is largely in line with the aging of many fleets.

7.3 FINANCIAL AND ECONOMIC PERFORMANCE

- The review shows that investments in (semi-) industrial fishing vessels and fishing operations are generally profitable. Marine capture fishing continues to be a financially viable economic activity in all 20 fishing nations included in the review. Most fishing fleets surveyed realized enough income to cover depreciation costs, interest and loan repayments, and provided sufficient financial resources for reinvestment.
- The analysis of 97 (semi-) industrial fishing fleet segments showed that 92 percent of these reported a net positive cash flow in the survey years. This means that average vessels in these fleet segments fully recouped their operating costs (not including depreciation and interest costs). Comparison with the 2003 FAO fleet performance review (Tietze *et al*., 2005), reveals that globally the percentage of fleet segments with positive net cash flow figures decreased slightly from 94 percent to 92 percent.
- Average fishing vessels in 73 percent of fleet segments realized net profit margins of 10 percent or more, while 40 percent presented NPM figures of over 20 percent, which is considered high in most industries.
- The profitability of a majority of the (semi-) industrial fishing fleets is on a par with the top performing industries worldwide: 75 percent of fleet segments reported positive results in terms of their capital productivity, with returns on fixed tangible assets (ROFTA) of more than 10 percent. Average vessels in 59 of the fleet segments surveyed (i.e. 61 percent) generated returns on investment (ROIs) of 10 percent or more, while 51 percent of the fleet segments presented ROI figures of over 15 percent, which suggests that many fleet segments are attractive for investment.

- In terms of gear types the fleet segments of pelagic trawlers, purse seiners, gillnetters and squid jiggers presented very good NPM and ROFTA figures of more than 20 percent. The fishing operations of small bottom trawlers (< 24 m), large bottom trawlers (> 40 m), purse seiners, gillnetters and squid jiggers were highly profitable, with ROI percentages of 20 percent or more in the survey years. In addition, the ROI percentages of pelagic trawlers and medium-sized trawlers (24–40 m) were 15 percent or more. Longline vessels appear to be an exception, as four of the ten longliner fleet segments reviewed reported losses in the survey years; as a consequence, the overall performance indicators (NPM, ROFTA and ROI) for the longliners were negative.
- The combined total gross value added (GVA) contribution to the global economy by the fleet segments covered in this review (totaling approximately 240 000 fishing vessels), was estimated at USD 72.5 billion. By comparison, the total GVA of all European Union fleet segments in 2017 was estimated at USD 5.1 billion, while the mechanized trawlers of India contributed an estimated GVA of USD 3 billion to the Indian national economy in 2019. In order to maintain these high GVA contributions from fishing fleets it is crucial that fishing operations are well managed, the status of fisheries resources remains healthy, and the fishing industry at large is economically vibrant.
- Significant variation in the labour productivity per full-time employed (FTE) crew member was observed across the 97 fleet segments covered in the review. For some 37 percent of the fleet segments the labour productivity was over USD 100 000 per FTE in the survey years, while average labour productivity for 13 of the 97 fleet segments was over USD 200 000 per year. The variation in labour productivity between fishing fleet segments can largely be attributed to the differences in the fleets' capital intensity, technology levels applied in fishing operations, the size of fishing operations (vessels) and the crew wage bill. Comparing fisheries labour productivity figures from this review with those in other industries (such as manufacturing, mining, construction and public utilities) in the same countries revealed that the value added per employee in the fishing fleet segments is generally at a similar or higher level than those in other industries.

7.4 FISHING TECHNOLOGIES

- The fishing technology applied in the industry has continued to develop in the last two decades. Reducing fuel costs and saving energy have been drivers for technological developments in (semi-) industrial fishing operations, vessels and gears. Fuel costs are generally an important component in the running costs of a fishing vessel and can therefore have a substantial impact on the profitability of fishing operations. Moreover, the introduction of intermediate fuel oils, improvements in vessel hull designs and propulsion systems, hybrid- and fuel-efficient engines, as well as a transition from wooden to lighter fibre-reinforced plastic (FRP) hulls, have all contributed to energy savings and fuel cost reductions in many fleet segments.
- Other technological innovations that have been important to maintaining and improving the economic performance of (semi-) industrial fishing operations include:
    1. increasing fishing efficiency (e.g. GPS, ECDIS, fish finders, FADs, LED lights and multipurpose vessels),
    2. reducing the environmental impact of fishing (e.g. BRDs, TEDs, electric pulse trawls and circle hooks),
    3. improving fish handling and product quality (e.g. pumping systems, tuna bleeding techniques, more efficient on-board refrigeration, IQF,

ice-making and fish processing equipment, eco fish boxes, electronic weighing); and

4. improving safety at sea and the working conditions of fishers on-board vessels (e.g. AIS, VMS, hydraulic cranes, net and line haulers and winches, as well as improvements to safety gear and equipment).

7.5 FISHERIES RESOURCES, FLEET CAPACITY MANAGEMENT AND SEAFOOD PRICES

- This techno-economic fleet performance review covers (semi-) industrial fishing fleets that operate in all FAO Major Fishing Areas, but there is a lack of fish stock status data for some fisheries resources. This is particularly the case with Asian countries whose fleets generally operate in FAO Major Fishing Area 61 (Pacific, Northwest), which accounts for the largest total landings of all FAO Major Fishing Areas. Less than a quarter of landings in Area 61 are covered by stocks assessments.
- Fishing vessel owners/operators who participated in the techno-economic performance fleet reviews were generally conscious of the fact that many commercial fishery resources are under pressure. They recognize that improvements in economic performance depend on the status of the fish stocks they target, and that adequate fisheries management – including fleet capacity management plans and the appropriate technological improvements and innovations – are essential to transforming the sector towards sustainability.
- The global fleet of motorized fishing vessels grew from an estimated 2.56 million vessels in 2000 to 2.86 million vessels in 2018. Meanwhile, 34 percent of the targeted fish stocks (by number of fish stocks) have been assessed as being overfished (FAO, 2020). It is therefore obvious that national fisheries policy and legislation are needed to get a grip on the size and operations of the world's fishing fleets – based on the minimum standards established by international fisheries instruments, as these relate to fisheries management and IUU fishing. However, only 11 of the 20 countries covered in this global review have national- or regional-level plans in place to manage fishing fleet capacity. The European Union Member States participating in this fishing fleet review referred to the Common Fisheries Policy (CPF) (EC Regulation 1380/2013), which manages the European Union fishing fleet capacity in line with the 1999 FAO International Plan of Action for the Management of Fishing Capacity (IPOA-Capacity).
- The general increase in seafood prices, as shown by the FAO Fish Price Index (FPI), and particularly the increase in ex-vessel prices over the last two decades, has contributed positively to the improved financial and economic performance of most of the fishing fleets covered in this review. However, the relative importance of ex-vessel seafood prices in contributing to overall fleet profitability – as compared to other factors such as the higher volume of landings per vessel and reductions in operational costs – is not clear.
- The use of ex-vessel seafood prices appears more representative than market prices as a means to evaluate the economic performance of fishing fleet segments, given that the former determine the bulk of revenue obtained. Market prices, on the other hand, can be useful as an indicator of demand trends, which may have an indirect impact on ex-vessel seafood prices. In order to incorporate price information in future techno-economic performance analyses, it is worth obtaining ex-vessel prices and building ex-vessel seafood price timelines.

7.6 FUTURE REVIEWS

- The number of countries that carry out techno-economic fishing fleet performance reviews has increased in recent decades, as these reviews provide important information for fisheries authorities, vessel owners, fisheries investors, financial institutions and other fisheries stakeholders.
- The methodology developed by the Expert meeting on methodologies for conducting fishing fleet techno-economic performance reviews, held in Chennai, India in 2018 (FAO, 2019) has proven easy to implement, widely applicable and comprehensible. Harmonization of the methodology applied, including the indicators and terminology used in this review, offers comparative benefits.
- Future techno-economic fleet performance reviews could benefit from collecting more detailed information on ex-vessel fish prices, investments in safety-at-sea equipment and training of crew, fuel efficiency, in addition to information on taxes and subsidies, and their impact on vessel profitability.
- The significant gap in time between the 2003 FAO fleet performance review and the current review did not allow for detailed comparative analysis of revenues, costs and profitability; this situation could be avoided through a more frequent organization of FAO global technic-economic performance reviews, such as every five years.

REFERENCES

FAO. 2019. *Report of the Expert Meeting on Methodologies for Conducting Fishing Fleet Techno-Economic Performance Reviews*, Chennai, India, 18-20 September 2018. FAO Fisheries and Aquaculture Report No. 1243. (also available at www.fao.org/3/ca4427en/%20ca4427en.pdf).

FAO. 2020. *The State of World Fisheries and Aquaculture 2020. Sustainability in action.* Rome. https://doi.org/10.4060/ca9229en

Tietze, U., Prado, J., Le Ry, J-M., & Lasch, R., eds. 2001. *Techno-economic performance of marine capture fisheries.* FAO Fisheries Technical Paper No. 421. Rome, FAO. (also available at www.fao.org/3/Y2786E/Y2786E00.htm).

Tietze, U., Thiele, W., Lasch, R., Thomsen, B., & Rihan, D. 2005. *Economic performance and fishing efficiency of marine capture fisheries.* FAO Fisheries Technical Paper No. 482. Rome, FAO. (also available at www.fao.org/3/y6982e/y6982e00.htm).

Annex 1 – National Report of the Republic of South Africa

Annex 1 – National Report of the Republic of South Africa

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1. SOCIO-ECONOMIC AND GEOGRAPHIC INFORMATION

The Republic of South Africa has a total area of 1 220 813 km^2 (Stats SA, 2019) and an exclusive economic zone (EEZ) of 1 071 883 km^2 (SANBI, 2004). The country's coastline extends over 3 500 km and it has 5 244 km of land boundaries. South Africa is rich in natural resources, including gold, chromium, antimony, coal, iron ore, manganese, nickel, phosphates, tin, rare earth elements, uranium, gem diamonds, platinum, copper, vanadium, salt and natural gas.

In 2018, the country's Gross Domestic Product (GDP) was worth USD 366.3 billion, which represents 0.59 percent of the world economy. The current (2019) population of South Africa is 58.6 million (World Bank, 2021). The population is concentrated along the eastern, southern and southwestern coasts, as well as inland around Johannesburg. The eastern half of the country is more densely populated than the west. The extreme west, towards the Namibian border, is arid and sparsely populated, while the east Kwazulu Natal province is the most heavily populated part of the coast.

2. GENERAL INFORMATION ABOUT MARINE CAPTURE FISHERIES IN SOUTH AFRICA

The economic performance of fishing fleets globally was last assessed in 2003 by FAO (Tietze *et al*., 2005). At that time, South Africa was one of the countries selected for the assessment. Since 2003, South African fisheries have undergone significant changes. These changes relate more to changes in the socio-economic and political landscape than fisheries *per se*. In 1996, political transformation in the country resulted in a process of reallocation of fishing rights. This process, which began in 1997, led to the issuing of medium-term rights (four years initially) and then long-term rights from 2005 onwards. All fishing fleet segments have been affected by this process, as evidenced by the revisions to the "General Policy" in 2013, in addition to changes to several other fishery-specific policies (DAFF, 2013).

The South African government targets to transform the fishery sector are broad. In essence, they aim to achieve greater equity for all South Africans, in particular those who had previously been politically disadvantaged. One of the effects of this has been that some fishing fleet segments have seen significant increases in the number of fishers and boats. Many new fishing vessels entered some segments, while at the same time, the Department of Environment, Forestry and Fisheries (DEFF)[1] tried to manage fishing effort within sustainable limits.

Two instruments underpin fisheries management in South Africa, namely: the Marine Living Resources Act, No 18 of 1998 as amended by Act No. 5 of 2014,[2] and the "Policy for the small scale fisheries sector in South Africa" (DAFF, 2012). This

[1] Formerly the Department of Agriculture Forestry and Fisheries or DAFF. The organization changed its name to "DEFF" in July 2020.

[2] The Act is available via the FAOLEX Database at www.fao.org/faolex/results/details/en/c/LEX-FAOC171051

techno-economic assessment has therefore been undertaken at a time of uncertainty in the fishery sector, which certainly influenced the responses to this survey.[3]

While South Africa has a coastline of some 3 500 km spanning two ecosystems (the Benguela and Agulhas ecosystems), its main commercial fishery is focused on the west coast in the Benguela upwelling system, and to a lesser extent on the south coast in the Agulhas system. There is an established, low-volume commercial fishery for shrimp only on the east coast in the Indian Ocean. There is also a bottom longline directed offshore fishery in the waters of the Southern Ocean for Patagonian toothfish around South Africa's Prince Edward Islands.

The Department of Agriculture Forestry and Fisheries (DAFF) reported that South Africa produced approximately 612 655 tonnes of wild-caught fish in 2016, which accounts for less than one percent of the estimated global fishery production. Statistics submitted to FAO show that from 2002 to 2016, the average annual fish catch was 673 916 tonnes (standard error = 126 206 tonnes) (FAO, 2020). This variability, as with many other global fisheries, is primarily the result of inter-annual fluctuations in small pelagic catches, mainly sardine and anchovy.

South Africa has important fisheries that contribute to global markets, in particular for hakes (*Merluccius* spp.), anchovy and sardine, squid and horse mackerel. The most recent available economic data issued by DAFF show that the total wholesale value of all South African commercial fisheries was ZAR 4 059 million[4] – or USD 281 million, in 2016.[5] Augustyn *et al*. (2019) report that there are 22 recognized fishery fleet segments in South Africa, excluding aquaculture. Primary fisheries in terms of economic value and overall tonnage of landings are the demersal (bottom) trawl and longline fisheries targeting the Cape hakes (*Merluccius paradoxus* and *M. capensis*), the pelagic-directed purse seine fishery, targeting sardine (*Sardinops sagax*), anchovy (*Engraulis encrasicolus*) and red-eye round herring (*Etrumeus whitheadii*), as well as the West Coast rock lobster trap fishery (*Jasus lalandii*).

Comparatively, in terms of value, Augustyn *et al*. (2019) report that hake is the most valuable fishery (43 percent, USD 335 million), followed by the small pelagic (26.4 percent, USD 203 million) and then West Coast rock lobster (8 percent, USD 61 million). These three fisheries operate primarily in the Benguela Large Marine Ecosystem (BCLME). The hake fisheries overlap with the Agulhas system. Other smaller fishery segments have a wider exploitation range, extending from the west coast and onto the southern and eastern coasts of South Africa. The other commercial fishing fleet segments (Table A1.1) target the highly migratory tuna and tuna-like species. These are caught seasonally, predominantly beyond territorial limits and on the high seas by the large pelagic longline and pole fisheries, in addition to two other crustacean fisheries, namely: the deepwater South Coast lobster (*Palinurus gilchristi*) line trap fishery and a small trawl-directed prawn fishery on the east coast.

There is also a midwater trawl fishery targeting horse mackerel (*Trachurus capensis*) predominantly on the Agulhas Bank, and a hand-jig fishery targeting chokka squid (*Loligo vulgaris reynaudii*) exclusively on the south coast. The traditional line fishery targets a large assemblage of species close to shore including snoek (*Thyrsites atun*), Cape bream (*Pachymetopon blochii*), geelbek (*Atractoscion aequidens*), kob (*Argyrosomus japonicus*), yellowtail (*Seriola lalandi*) and reef fishes. This fishery is

3 Some operators were reluctant to reveal social and economic details of their operations as the information requested might be used in assessing the allocation of rights.

4 de Swardt, personnel communication.

5 The exchange rate applied in this report is the average exchange rate of the South African Rand (ZAR) to the USD in 2019 was 14.45 ZAR = 1 USD, as per www.exchangerates.org.uk/USD-ZAR-spot-exchange-rates-history-2019.html.

important for fishing communities, particularly those in the Western Cape. Table A1.1 below shows the main offshore commercial fishing fleets, fishing ports, landed catches, fishing rights holders and target species.

Commercial fisheries are regulated and monitored by DEFF. Information presented in this analysis was collected in 2018/2019 and enhanced by a series of economic studies undertaken in 2019 in support of the Fishing Rights Allocation Process (FRAP).

TABLE A1.1
South African offshore commercial fishing fleet segments, ports, landings, number of rights holders, wholesale catch value and target species (DEFF)

Fleet segment	Areas of operation (Coastal zones)	Main ports in order of priority	No. of rights holders (vessels)	Landed catch (tonnes)	Wholesale value in thousand ZAR (USD million)	Target species
Small pelagic purse seine	West, South coast	St Helena Bay, Saldanha, Hout Bay, Gansbaai, Mossel Bay	111 (101)	399 612	3 210 924 (222)	Anchovy (*Engraulis encrasicolus*), sardine (*Sardinops sagax*), Redeye (*Etrumeus whiteheadi*)
Demersal trawl (offshore)	West, South coast	Cape Town, Saldanha, Mossel Bay, Port Elizabeth	50 (51)	151 456	3 927 000 (272)	Deepwater hake (*Merluccius paradoxus*), shallow-water hake (*Merluccius capensis*)
Demersal trawl (inshore)	South coast	Cape Town, Saldanha, Mossel Bay	18 (31)	6 956	131 793 (9)	East coast sole (*Austroglossus pectoralis*), shallow-water hake (*Merluccius capensis*), juvenile horse mackerel (*Trachurus capensis*)
Midwater trawl	West, South coast	Cape Town, Port Elizabeth	34 (6)	30 000	Not given	Adult horse mackerel (*Trachurus capensis*)
Demersal longline	West, South coast	Cape Town, Saldanha, Mossel Bay, Port Elizabeth, Gansbaai	146 (64)	9 027	338 600 (23)	Shallow-water hake (*Merluccius capensis*)
Large pelagic longline	West, South, East coast	Cape Town, Durban, Richards Bay, Port Elizabeth	30 (31)	7 492	123 367 (9)	Yellowfin tuna (*T. albacares*), big eye tuna (*T. obesus*), Swordfish (*Xiphius gladius*), southern bluefin tuna (*T. maccoyii*)
Tuna pole	West, South coast	Cape Town, Saldanha	170 (128)	2 809	124 009 (9)	Albacore tuna (*T. alalunga*)
Traditional line fish	West, South, East coast	All ports, harbours and beaches around the coast	422 (450)	6 445	109 763 (8)	Snoek (*Thyrsites atun*), Cape bream (*Pachymetopon blochii*), geelbek (*Atractoscion aequidens*), kob (*Argyrosomus japonicus*), yellowtail (*Seriola lalandi*), Sparidae, Serranidae, Carangidae, Scombridae, Sciaenidae
South Coast rock lobster	South coast	Cape Town, Port Elizabeth	13 (12)	735	351 196 (23.699)	*Palinurus gilchristi*
West Coast rock lobster	West coast	Hout Bay, Kalk Bay, St Helena	240 (105)	1 033	537 516 (36.272)	*Jasus lalandii*
Kwazulu-Natal prawn trawl	East coast	Durban, Richards Bay	6 (5)	181	17 859 (1.205)	Tiger prawn (*Panaeus monodon*), white prawn (*Fenneropenaeus indicus*), brown prawn (*Metapenaeus monoceros*), pink prawn (*Haliporoides triarthrus*)
Squid jig	South coast	Port Elizabeth, Port St Francis	92 (138)	8 500	781 908 (52.763)	Squid/chokka (*Loligo vulgaris reynaudii*)
Gillnet	West coast	False Bay to Port Nolloth	162 (N/a)	634	10 433 (.704)	Mullet / harders (*Liza richardsonii*)
Beach seine	West, South, East coast	N/a	28 (N/a)	1 600		Mullet / harders (*Liza richardsonii*)
Oysters	South, East coast	N/a	146 pickers	42	3 300	Cape rock oyster (*Striostrea margaritaceae*)
Seaweeds	West, South, East	N/a	14 (N/a)	6 172	23 566	Beach-cast seaweeds (kelp, *Gelidium* spp and *Gracilaria* spp)
Abalone	West coast	N/a	N/a (N/a)	86	59 500	*Haliotis midae*

This techno-economic fleet performance assessment aimed to include the fishing fleet segments that:

a. were of significant economic value,
b. had socio-economic significance, and
c. reflected the ongoing changes in the commercial fisheries of South Africa.

3. CHARACTERISTICS OF FISHING FLEETS OPERATING IN SOUTH AFRICA

The total number of fishing vessels and the changes that have taken place in the last decade are difficult to quantify exactly. An overview is provided in Table A1.2, showing the main commercial fishing fleet segments, the number of fishing vessels, scale, fishing area and main fishing ports in 2018. The main fishing fleet segments consist of industrial and semi-industrial fishing vessels and all fish in the Southeast Atlantic Ocean (FAO Major Fishing Area 47).

The change in rights allocations have affected all fishing fleet segments, from the late 1990s up to the present day, and caused significant fluctuations. In 2017–18 there were some 1 116 registered commercial fishing boats. The main changes occurred in the small-scale handline fishing fleet segment, which has fallen from around 2 000 to 450 commercial and semi-commercial boats since the 1990s.

Other fleet segments saw an increase, however. This includes the tuna pole-and-line fisheries, where effort was purposely increased to raise South Africa's performance in the albacore (longfin) tuna fleet within the ICCAT fishing area. In the other tuna fishing fleet segment, pelagic longline fisheries, effort significantly decreased with the removal of the foreign joint venture fleets in the late 1990s, and the development of a national tuna fleet comprising of some 31 vessels. The five economically most important semi-industrial and industrial fishing fleets, by fishing gear, in terms of volume of seafood landed are:

1. deep-sea bottom trawlers for hake;[6]
2. purse seiners for small pelagic species;
3. squid jiggers;
4. midwater trawlers for horse mackerel; and
5. demersal longliners for hake.

The midwater trawler fleet segment is split and partly subsumed by the bottom trawl sector, as the total allowable catch (TAC) – which approximates 48 000 tonnes – includes a directed midwater component of about 30 000 tonnes, caught mainly by a single vessel and

TABLE A1.2
Overview of main fishing fleet segments

Fleets segments by fishing gear names	Number of vessels	Scale*	FAO Major Fishing Area	Main fishing ports
Deep-sea hake trawlers	51	Industrial	47	Saldanha Bay, Cape Town, Mossel Bay, Port Elizabeth
Purse seiners	100 (75 active)	Semi Industrial	47	St Helena Bay, Saldanha Bay, Hout Bay, Mossel Bay, Port Elizabeth
Squid jiggers	138 (reported but not all active)	Semi Industrial	47	Port Elizabeth, Port St Francis
Midwater trawlers	6 (1 directed, 5 dual purpose)	Industrial	47	Cape Town, Port Elizabeth
Hake longliners	45 active	Semi Industrial	47	Cape Town, Saldanha Bay, Hout Bay, Mossel Bay, Port Elizabeth

Note: * The scale categories are industrial, semi-industrial, or artisanal/small-scale.

[6] South Africa differentiates between deep-sea and inshore trawl fleets (see Table A1.1). The deep-sea fleet segment only targets hake and is restricted to waters of > 110 m depth. The inshore trawl sector has a boat length limitation of 30 m and targets hake and sole.

five to six multipurpose bottom/midwater trawlers.[7] Most of the main fishing fleets fish in both territorial waters and within the EEZ. The main fishing harbours where the seafood is landed are shown in Table A1.2. In the previous FAO review (2003), the nearshore rock lobster fishery was also included, but this was not considered appropriate as the fishery is currently overexploited.[8]

Hake deep-sea trawl fishery

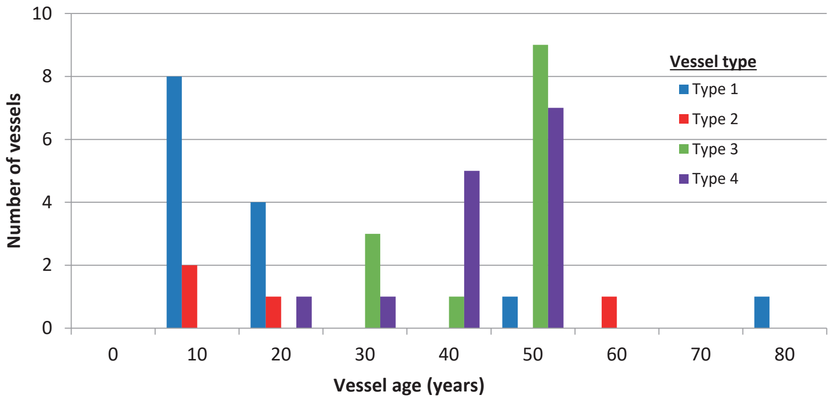
There were 51 stern trawl vessels of various sizes engaged in the hake deep-sea bottom trawl fishery in 2019. These vessels are either freezer trawlers or wet fish trawlers. Freezer trawlers, of which there were 21, are further split between those that process headed and gutted (H&G) frozen hake products (11) and the balance (10), which can be classified as on-board processors. The vessels in the wet fish fleet comprised smaller stern trawlers, which carry ice to maintain the quality of the catch. This wet fish vessel fleet segment consisted of 30 vessels in 2019, which predominantly focus on harvesting hake for further processing in land-based processing facilities (Fiandeiro *et al.*, 2019). Rights holders in the deep-sea hake trawl fishery have continued to invest in the industry by buying new vessels since long-term rights were allocated in 2005. The size and sophistication of the vessels used in deep-sea trawling require substantial capital investments, and the fleet is reported to have a total insured asset value of approximately USD 280 million (SADSTIA, 2019).

Purse seine fishery

The purse seiner fleet targets small pelagics, such as anchovy and pilchard, with occasional catches of red-eye round herring. Based on volume, the fishery is the largest in South Africa, and most of the catch is processed into fishmeal. In 2019, the fleet comprised largely of relatively small vessels of 15–30 m LOA, with a 50–400 gross tonnage (GT) wooden or steel-hulled purse seine vessels. In a recent study (Anchor Environmental, 2014), this fleet was classified into four types (Figure A1.1), namely:

- Type 1: relatively small-sized vessels (13.5–21 m), with wooden or Fiberglass Reinforced Plastic (FRP) hulls, which land almost exclusively sardines on ice/chilled seawater.
- Type 2: medium-sized (17–22 m) wooden or FRP vessels, which carry ice/chilled seawater and catch sardines and anchovies in similar quantities, with a smaller average annual catch of round herring.

FIGURE A1.1
Age composition of purse seiners (small pelagic) by vessel type in 2014 (after Anchor Environmental, 2014)



[7] Five fleet segments were selected for this review, while only one midwater trawler was considered for the reasons given above.

[8] The West Coast rock lobster is currently (2019) estimated to be below 3 percent of pristine stock size. The reasons for this are due in part to historical exploitation as well as to the current high levels of systematic poaching.

- Type 3: larger, on average, than Type 2 vessels (19.6–25.3 m), though still constructed with wooden or FRP hulls. Type 3 vessels have fish pumps and focus almost exclusively on fish for industrial fishmeal production.
- Type 4: large (27–39 m), steel-hulled vessels that land large quantities of all three species. These larger vessels have the ability to carry ice or refrigerated seawater. All vessels in this category have fish pumps and deliver sardines and round herring for canning, or anchovy and round herring for fishmeal production.

Squid jig fishery

Chokka squid (*Loligo* sp.) were first targeted commercially in 1984, and originally caught by handlines from ski boats (3–5 m) (SASMIA, 2019). The fishery transformed into a large commercial operation using only large freezer vessels, with the capacity to stay at sea for up to three weeks, processing high-quality frozen squid for export. These vessels are equipped with strong lights to attract the squid.

Total allowable effort (TAE) is the main management measure in place for this fishery, although recently a closed season and effort day controls have also been applied. The fleet is divided into vessel categories and a maximum crew complement is specified for each vessel category. In 2019 the fleet consisted of decked vessels ranging in length from 10 to 20 m, with a crew capacity of 16–26. The fishery relies on hand-caught jigging and operates nearshore within territorial water limits, mostly in shallow (< 50 m water depth) waters, fishing on spawning aggregations. The fleet comprises both older factory freezer vessels, as well as some new locally constructed FRP vessels.

Midwater trawl fishery

A single large midwater trawl vessel operates in South African waters and is restricted to the southeast coast (Agulhas Bank). This vessel is a large factory trawler with a gross registered tonnage of 7 627 tons. The vessel is similar to vessels used in other fisheries targeting horse mackerel in Namibia as well as for pollock in the Northern Pacific. Daily production is up to 150 tonnes of unprocessed whole frozen horse mackerel.

Hake longline fishery

The South African hake longliner fleet segment can be described by grouping vessels into GRT categories. This categorization system has identified five distinct vessel categories, namely: vessels of 40–60 tons, 60–80 tons, 80–100 tons, 100–120 tons and over 120 tons. From the available information, it appears that vessels of 80–120 tons are the most numerous. Generally, vessels smaller than 20 m are traditional, wooden-hulled trawler-type fishing boats, while larger 20–30 m vessels are made of fibreglass or steel, and all are equipped with line haulers. A small number of vessels are factory freezers, but the majority are wet fish vessels, carrying ice with a capability of doing trips of 4 to 7-days long (SAHLLA, 2019). While there are 146 fishing rights, individual allocations are small; the hake longline fishery has therefore consolidated into approximately 45–50 vessels.

The main species targeted by each fleet segment are listed in Table A1.3. The deep-sea trawlers and hake longliners depend on two species of hake and the fishery is managed by TAC. Upper precautionary catch limits (UPCL) for monkfish (*Lophius*

TABLE A1.3
Main species targeted by fishing fleet

Fleets/species targeted	1	2	3	4	5
Deep-sea hake trawlers	Hake	Monkfish	Kingklip	horse mackerel	snoek
Purse seiners	Anchovy	Sardine	Red-eye round herring		
Squid jiggers	Lolligo squid				
Midwater trawlers	Horse mackerel				
Hake longliners	Hake	Kingklip			

Note: The species targeted are ranked in the table from 1 (most important) to 5 (least important).

TABLE A1.4
Main species commonly caught by fleet

Fleets/species commonly caught	1	2	3	4	5
Deep-sea hake trawlers	Hake	Monk fish	Kingklip	Snoek	Horse mackerel
Purse seiners	Anchovy	Sardine	Red-eye round herring		
Squid jiggers	Lolligo squid				
Midwater trawlers	Horse mackerel	Mackerel (*Scomber japonicus*)			
Hake longliners	Hake	Kingklip			

Note: The species caught are ranked from 1 (most important) to 5 (least important).

vomerinus) and kingklip (*Genypterus capensis*) have been set for the fleets fishing for hake; snoek (*Thyrsites atun)* is a bycatch species for deep-sea hake trawlers. The species is sometimes targeted seasonally and has a catch limit as a percentage of total catch. The purse seine fleet segment has a TAC for anchovy and sardine. There are also UPCLs for red-eye round herring (*Etrumeus whitheadii*) and juvenile horse mackerel for the purse seiners fleet. The midwater trawler fleet segment has a TAC for adult horse mackerel.

The main species commonly caught by each fleet and their commercial value are listed in Table A1.4. Monkfish and kingklip are the most valuable species in terms of ex-vessel price per kilogram. The hake fishery is Marine Stewardship Council (MSC) certified and has a premium export value. The purse seiner fishery for anchovy is a reduction fishery (mostly fishmeal), while sardines caught are generally canned. Horse mackerel is a low-value product, which is mostly sold whole to West Africa. The kingklip catch by the hake longliner fleet is subject to an 8 percent bycatch allowance.

Table A1.5 shows the main species discarded at sea, by fleet. Discarding is not permitted in South African fisheries although it is known to occur. The first estimates of discarding by South African fleets were reported by Japp (1997). Discarding in the deep-sea hake trawler fleet segment consists mostly of small or juvenile hake and other species, including grenadiers (various species of the family *Macrouridae*). The purse seine fishery is considered to be 'clean'. All unwanted bycatch, if it occurs, goes into fishmeal production. For the midwater trawl, occasional large catches of ribbon fish (*Lepidopus caudatus*) are converted into fishmeal and some may be discarded. Discarding of a few other species during midwater trawler operations occurs, including some shark species, but generally the fishery is 'clean', with the main bycatch being ribbon fish. The hake longline has a very low bycatch, occasionally discarding juvenile jacopever (*Helicolenus dactylopterus*) and various shark species.

Fisheries legislation and its effects on fishing fleet operation

With respect to legislation, there are three levels governing fishery operations in South African fisheries. Broadly, South Africa subscribes to an ecosystem approach (EA) and this is incorporated into legislation that underpins fisheries, such as the Marine Living Resources Act No. 18 of 1998 as amended by Act No. 5 of 2014. Under this Act,

TABLE A1.5
Main species discarded at sea by fleet

Fleets/main species discarded	1	2
Deep-sea hake trawlers	Rat-tail (Grenadiers)	Juveniles and other unprocessed species
Purse seiners	No discarding	
Squid jiggers	No discarding	
Midwater trawlers	Ribbon fish and snoek	Waste and unwanted fish goes into fishmeal
Hake longliners	Occasional juvenile jacopever and sharks	

regulations prescribe conditions for fisheries as a whole, as well as for specific fisheries operations. Furthermore, specific permit conditions apply for each fishery, which are enforced by the fisheries inspectorate of the Department of Environment, Forestry and Fisheries (DEFF).

There are spatial and temporal measures, as well as some technical limits, for all fishing fleet segments. All fisheries are subject to licensing by the South African Marine Safety Authority (SAMSA), before fishing licenses are approved. Examples of measures that affect operations in each fleet segment include:

1. Deep-sea hake trawlers: minimum mesh sizes are hake-specific (110 mm). Vessels are not permitted to fish in shallower waters than 110 m water depth. The trawl areas have also been ring-fenced. There are no limits on vessel size or power, but all applications for the construction of new vessels and/or the entry of new vessels into the fleet must be approved by DEFF.
2. Purse seiners: mesh size limits as well as spatial and temporal constraints are in place. The net size and vessel capacity is generally constrained by pumping and hold capacity. The purse seiners are restricted to day-to-day operations, as most vessels use refrigerated seawater (RSW) for sardine.
3. Squid jiggers: the main operational constraint for vessels in this fleet segment relates to the number of crew permitted on a vessel, which requires a specific number of rights (numbers of persons). Initially, this fishery was constrained by vessel size. In recent years, vessel size limits have been removed and restrictions on the number of crew on specific vessels are being applied.
4. Midwater trawlers: the only limitations for these trawlers relate to mesh sizes (75 mm) and spatial limits. In practice, vessel power is the principal constraint in a fishery, with only vessels capable of operating with midwater trawl nets and related gear (doors and warps) permitted.
5. Hake longliners: historically, the number of hooks permitted to be set in any one day was restricted in some areas. However, this limit seems to have fallen away.

In addition to the above-described act and regulations, the “Policy for the small- scale fisheries sector in South Africa” (DAFF, 2012) is expected to impact some fleet segments through the allocation of rights. For example, it is anticipated that 25 percent of the current commercial rights for squid will be allocated to small-scale fisheries cooperatives. This is likely to lead to realignment within the squid jigger fleet segment, increasing the number of small-scale vessels.

Age of vessels in each sector

There are no specific, government-driven initiatives to modernize the fishing fleets: any changes are entirely driven by the industry itself. South Africa does have a healthy boatbuilding industry, with most new FRP fishing vessels constructed in shipyards in the Saldanha Bay area.

However, the ongoing reallocation of fishing rights is leading to uncertainty among existing rights holders, with negative consequences for the shipyards. Fishing rights allocations for the fleet segments considered in this review were originally granted for a 15-year period in 2005. At the time of writing (2020) they are being reallocated. In the deep-sea trawler segment, for example, investing in a trawl vessel carries a considerable risk, as the current rights allocation process is uncertain.

Many new vessels entered the fleets during the current 15-year allocation period, with the average age of the fleet reported as 11 years old in 2014 (SADSTIA, 2014). In the purse seine sector the fleet is somewhat old, with about 50 percent of the Type 3 and Type 4 vessels in the over-50-years category, with the rest of the fleet in the 10–40-year categories (Anchor Environmental, 2014).

TABLE A1.6
Average age of fishing vessels by fleet in years (in percentages)

Fleets/average age of vessels as a percentage of total fleet size (%)	0–5 years	5–10 years	10–20 years	more than 20 years
Deep-sea hake trawlers	5	20	70	5
Purse seiners	0	10	40	50
Squid jiggers	10	50	40	0
Midwater trawlers	0	40	50	10
Hake longliners	10	20	30	40

The hake longliner fleet segment is dominated by old multipurpose wooden vessels. These vessels, generally owned and managed by Portuguese owner operators, are also used for pole-and-line fishing and are more than 30 years old. With the allocation of 15-year fishing rights in 2005, new vessels with FRP hulls entered this fleet segment; these vessels are now mostly in the 10–20-year age class. The fleet nevertheless remains somewhat old.

The squid jigger fleet segment has gone through a commercial change in the last decade. The fishery developed a strong export market for sea-based freezer products. With the 15-year rights allocation, the construction of factory freezers got a boost; vessels are mostly of FRP construction. Broadly, this fleet segment is between 5 and 20 years old, with some new vessels under construction.

Table A1.6 provides an overview of the age structure of the vessels in the main fishing fleet segments. The numbers are approximations and provide only a broad overview of the age distribution of the vessels in the five fleet segments.

4. TECHNOLOGICAL AND OPERATIONAL CHARACTERISTICS OF FISHING VESSELS

Deep-sea hake trawlers

The deep-sea trawl fleet can be characterized by an average length (LOA) of 45 m (ranging from 30 to 70 m) and a gross registered tonnage of 750–2 500 GRT (see Table A1.7). The South African Deep-Sea Trawling Industry Association (SADSTIA) voluntarily introduced an effort management system for their fleet in 2006. This was based on the assumption that the best measure of a bottom trawler's ability to perform work is its shaft horsepower.

The introduction of this effort management system suggested that on average, freezer trawlers would require one horsepower (hp) for every 4.07 kg of hake caught per day at sea in 2006. Wet fish (ice) vessels would require one hp to achieve 3.94 kg of hake catch per day at sea. This enabled the generation of a comprehensive control system, using a fairly straightforward calculation, based on the assumption that a standard trawler is at sea about 265 days per year.

TABLE A1.7
Technological and operational characteristics of deep-sea trawlers surveyed

	Wet fish trawler	Freezer trawler 1	Freezer trawler 2
Length overall (LOA) (in metres)	42.6	57	58
Gross registered tonnage (GRT)	413	1 923	1 597
Total power of main engines in kilowatts (KW)	**550**	**2 500**	**2 427**
On-board storage facilities (tonnes)	100	1 200	1 000
Fishing gear		Bottom trawl	
Crew size (persons)	15	69	60
Ownership (state, shared, chartered, company)		Company	
Total days fishing at sea	240	295	310
Number of fishing trips	20–30	6–10	8
Fishing season (months)			12 months

TABLE A1.8
Technological and operational characteristics of purse seiners surveyed

	Type 1 vessel	Type 2 vessel	Type 3 vessel	Type 4 vessel
Length overall (LOA) (m)	16.5	18.7	21.5	30.6
Gross registered tonnage (GRT)	31	96	100	253
Total power of main engines in kilowatts (kW)	253	370	459	861
On-board storage facilities (metric tons)	49	121	155	306
Fishing gear	Purse seine			
Crew size (persons)	9	9	9	11
Ownership	Company			
Total days fishing at sea	120–240 days at sea per year			
Number of fishing trips	60	74	90	78
Fishing season (months)	12 months			

A mix of freezer and wet fish vessels operate under this effort control regime. The smallest has an engine power of 750 hp, while the largest is around 3 000 hp.[9] On-board storage capacity also varies, with smaller vessels undertaking 4–10-day trips, with a hold capacity of 100–500 tonnes (about 100–500 m^3). The largest freezer trawlers, meanwhile, can undertake 30–50-day trips and have an average hold capacity for 2 000 tonnes of product.

The main fishing gears are typical bottom trawls, featuring a 24–32 mm warp, deck winches, bottom-trawl doors and nets with footropes. They occasionally use rock-hopper gear. The fleet is generally sophisticated, carrying the most recent echo sounders, vessel monitoring systems (IMARSAT) fish-finding and communication technologies. The average crew size is 30, although the larger freezer vessels may have up to 85 crew and the smaller vessels only 20.

The number of days at sea per vessel ranged in 2016/2017 from 240 days for wet fish vessels to up to 310 days for freezer vessels. Table A1.7 provides the characteristics of three vessels that are typical of the deep-sea trawler fleet for hake.

Purse seiners

The purse seine fleet can be characterized by an average length (LOA) of 20 m and a gross registered tonnage of 100 GRT (see Table A1.8). The power of the main engines ranges from 250 to 900 kW and on-board storage capacity for fish ranges from 40 to over 300 tonnes. The main fishing gears carried are purse seine nets (size-dependent, based on the species targeted) and the principal deck equipment of small pelagic vessels consists of a triplex hauler and pumps.

Most vessels carry refrigerated seawater (RSW) to preserve fish quality. These vessels are primarily targeting anchovy (for reduction) or sardine for canning and or bait. The average crew size is 9–11 and the number of days at sea is highly variable, depending on the season and availability of small pelagic species.

On-board electronics include electronic navigation systems, vessel monitoring systems (VMS) and Sonar searching equipment. The small vessels engage in fishing trips of 1 to 2 days in the proximity of their home port to facilitate a quick turnaround. The small vessels are often constrained by weather conditions, while the large steel vessels are less so. Days at sea per vessel range from 120 to 240 days per year. The number of fishing trips undertaken depends on the available quota allocated to each vessel, but there can be up to 80 trips a year.

[9] 1 horsepower = 0.746 kilowatts.

TABLE A1.9
Technological and operational characteristics of squid jiggers surveyed

	Vessel 1	Vessel 2	Vessel 3	Vessel 4
Length overall (LOA)	21.35	20.80	21.32	13.70
Gross registered tonnage (GRT)	107.7	84	87	<25
Total power of main engines in kilowatts (KW)	330	298	298	123
On-board storage facilities (metric tons)	83	40	40	15
Fishing gear	Squid jigging by handline			
Crew size (persons)	26	26	26	16
Ownership company	Company			
Total days fishing at sea	180	155	183	157
Number of fishing trips	9	9	11	9
Fishing season (months)	7	8	8	8

Squid jiggers

The squid jigger fleet segment can be characterized by an average length (LOA) of 20 m and a gross registered tonnage of 80 GRT (see Table A1.9). The power of the main engines ranges from 123 to 330 kW. On-board storage capacity for fish is typically between 15 and 83 tonnes.

There are few wet fish vessels in this fleet segment. The fleet mostly consists of factory freezers and processors for direct export. Vessels are open-deck type vessels used by fishermen, who stand and jig with two to three jig lines each; automatic jiggers are not used. Electronic GPS navigation systems are used with state-of-the-art echo sounders to detect squid aggregations. Vessels use two or three large anchors to enable them to stay on squid aggregations in rough weather conditions. The average crew size depends on the license, as it is an effort-controlled fishery.

Most operators maximize the number of crew, which means up to 30 members for the largest boats. The fishery has a closed season for one month (October), which has been increased voluntarily by the operators for an additional three months between April and June. The number of days at sea per vessel varies but may be over 180 days per year. The average number of fishing trips in 2016/2017 stood at eight trips per vessel, with some vessels capable of staying at sea for up to a month at a time.

Midwater trawlers

The midwater trawler fleet segment is comprised of two types of vessels. The first vessel type in this fishery exclusively deploys midwater trawl gear (doors and nets) and fishes the bulk of the horse mackerel allocation for a group of rights holders. The second type is a multipurpose vessel, of which there are six in the South African fleet. The data from these vessels is difficult to extract, as the vessels are primarily hake-directed bottom trawlers that switch to midwater trawling operations when horse mackerel is available.

TABLE A1.10
Technological and operational characteristics of mid water trawlers surveyed

	Type 1 vessel	Type 2 vessel
Length overall (LOA) (m)	110	43
Gross registered tonnage (GRT)	7 628	698
Total power of main engines in kilowatts (kW)	6 000	1 500
On-board storage facilities (tonnes)	2 500	500
Fishing gear	Midwater trawl	Multipurpose bottom / midwater trawl
Crew size (persons)	110	31
Ownership company	Company	
Total days fishing at sea	300	290
Number of fishing trips	7	6–10
Fishing season (months)	12 months	

Both vessels types are described in Table A1.10. The directed midwater trawler (Type 1) has an LOA of 110 m and a gross registered tonnage of 7 628 tons (see Table A1.10). The power of the main engines is 6 000 kW with on-board processing and storage capacity of 2 500 tonnes. This vessel is typical of other international midwater trawlers, for example those fishing pollock in Alaskan waters. Type 2 vessels are typical of hake-directed bottom trawlers, as previously presented in Table A1.7; they can have an LOA of up to 60 m, with a storage capacity of about 1 200 tonnes of frozen product.

The main fishing gears carried include specialized midwater trawl doors and lighter warps than used for bottom trawl operations, as the gear is “flown” in midwater. Deck equipment available on-board generally includes sonar for detecting midwater shoals, as well as net sounders, GPS and VMS. The Type 1 vessel can process up to 150 tonnes a day and has a 110-person crew, while the smaller multipurpose vessels carry a crew of 30–40 persons. In 2016/17, the number of days at sea per vessel in this fleet segment ranged from 240 to 315 days. The type 1 directed midwater vessel took seven fishing trips in 2016/2017.

Hake longliners

There are up to 50 hake longliners using a total of 150 quota allocations for hake. Allocations per vessel are generally small and do not exceed 100 tonnes of hake annually. Some vessels use consolidated allocations to increase their economic viability.

The hake (demersal) longline fleet can be characterized by an average length (LOA) of 25 m and an average gross registered tonnage of 200 tons (see Table A1.11). The power of the main engines generally does not exceed 500 kW and the fleet is predominantly composed of wet fish vessels, although in recent years, some owners have also invested in freezer vessels.

TABLE A1.11
Technological and operational characteristics of hake longliners surveyed

	Vessel 1	Vessel 2	Vessel 3
Length overall (LOA) (m)	27.1	21	19.8
Gross registered tonnage (GRT)	241	117	70
Total power of main engines in kilowatts (kW)	1 300	500	350
On-board storage facilities (tonnes)	200	40	30
Fishing gear			Demersal longline
Crew size (persons)	29	23	20
Ownership (state, shared, chartered, company)			Company
Total days fishing at sea	203	231	90
Number of fishing trips	29	33	9
Fishing season (months)	Year-round; constrained by the hake quota allocation		

TABLE A1.12
Labour employed in the selected fishing fleet segments and related land-based fish processing (2018)

	Vessel crew (full-time)	Workers in related land-based processing	Other contract workers	Total
Deep-sea trawlers	2 036	2 533	1 559	6 128
Purse seiners	700	3 490	-	4 190
Squid jiggers	2 443	557	-	3 000
Midwater trawlers	110 (directed fishery only)	20	10	140
Hake longliners	1100 (est.)	150	20	1 270
Total	5 289	6 650	1 589	14 728

Note: The data presented in table 12 includes some estimates. Socio-economic data on gender and age of crew per fleet segment were either not available or of insufficient quality to provide accurate breakdowns.

The on-board storage capacity for fish varies widely, but general does not exceed 50 tonnes. However, on large freezer vessels with consolidated fishing rights the storage capacity can be up to 200 tonnes.

The fleet comprises many wooden vessels that are over 20 years old, as well as some vessels that entered the fleet more recently. Deck equipment comprises two winches – i.e. a hydraulic line hauler for the fishing line and a smaller warp drum for hauling the top line and anchors. All vessels are equipped with state-of-the-art navigation equipment, VMS, echo sounders, etc.

Most vessels in this fleet segment are multipurpose and will fish for tuna in the summer using either pole and line, bait boats and/or handlines. Sea trips are generally short and do not exceed seven days. Annual sea days are constrained by the allocated hake quota and reveal a large variation of 20–260 days. A vessel with a large allocation will operate longer.

Table A1.12 presents the estimated number of full-time and part-time workers in each of the main fleet segments. Most workers on these vessels are employed full-time. There are very few female fishers. There is no information available on the age structure of the labour force of these fleet segments.

5. CAPITAL INVESTMENTS, COSTS AND REVENUES

The financial and economic characteristics of capture fisheries in South Africa are generally poorly understood, although the ongoing Fishery Resource Allocation Process (FRAP) has resulted in some industry associations undertaking economic analyses to support their rights allocation process. Vessel owners were generally reluctant to provide operating cost information. The summary of information by fleet segment below is in some cases generic (i.e. it applies to the whole sector), and in other cases vessel-specific.

Deep-sea trawlers

Capital investments

The total investment in vessels and processing facilities for the deep-sea trawlers fleet segment was estimated at USD 4.4 billion. This includes some 51 trawlers and land-based processing plants (Fiandeiro *et al.*, 2019).

Typically, newly built demersal trawlers (< 2 000 tons) would require an initial investment of approximately USD 6.5 million, while smaller, FRP-constructed vessels would be significantly less costly. With respect to vessel age, there are few new vessels in the deep-sea hake trawl fleet, with only the large quota holders either building or purchasing new, or relatively new, trawlers. The age of the fleet ranges from as old as 50 years to some recently constructed vessels of 3 years old. On average, the fleet was 10–20 years old in 2019. The average insurance value of vessels similar to those surveyed was around USD 2.4 million in 2018 (see Hodge *et al.*, 2018).

Operating and vessel owner's costs

Data provided for industrial hake trawlers suggest that annual operating costs for typical deep-sea trawlers range from USD 2 to 7 million. Fuel (34 percent) and labour (47 percent) make up the greatest portion of operating costs. Other important operational expenditure includes harbour dues and levies. In 2018, the main owner costs categories were, in order of importance: depreciation (40 percent), vessel repairs (36 percent), fishing gear replacement and maintenance (19 percent) and insurance (6 percent).

Revenue

The main revenue of the deep-sea trawler fleet segment originates from the sale of fish, which will vary from vessel to vessel and depends on its allocated quota, value addition, bycatch and other market-related factors. Deep-sea trawl fisheries in South Africa are MSC-certified (for hake fisheries). Most hake caught is exported and the price is highly dependent on exchange rates. On average, a year's operation realized USD 7.6 million of revenue per vessel in 2018, based on the vessels surveyed. The total earnings for the whole deep-sea trawling fleet from all fish sales were estimated at around USD 303 million in 2018.

Purse seiners

No vessel-specific economic data were provided for this assessment. The purse seiners, which fish for small pelagics, constitute the largest fleet segment by volume of fish landed. They generate revenue mostly from fish reduction – in the case of anchovy – and from canning and bait in the case of sardines. The information provided in the Anchor Environmental (2014) report remains largely the same, with inter-annual fluctuations between the two primary target species. It is worth noting that in 2019 and 2020 the sardine TAC was at its lowest level on record, and the fleet was largely dependent on anchovy for its earnings.

Capital investments

Investment in the sector has not been explicitly calculated because of the large diversity between vessels in terms of size and species targeted.

Operating costs

In 2014, the average operating cost of a purse seiner was USD 808 000 and it generated around USD 875 000 of revenue. Anchor Environmental estimated the net rate of return (NRR)[10] for an average small pelagic fishing boat in South Africa at 9 percent. Labour costs and fuel costs respectively accounted for 40 percent and 30–35 percent of operating costs. Purse seine net replacement and repairs were an important component in the owner costs.

Revenue

In 2014, the total revenue estimated from the sardine-directed fishery in that year approximated USD 54 million. In 2016, DEFF estimated the revenue generated from the whole fleet at USD 216 million, based on a landed catch of some 400 000 tonnes. In 2019, the combined total catch of anchovy and sardines was similar and consisted largely of anchovy. Preliminary revenue estimates for the total purse seiner fleet segment ranged from USD 216 to 269 million.

[10] Net internal rate of return (net IRR) is a performance measurement equal to the internal rate of return after fees and carried interest are factored in.

Squid jiggers

Capital investments

There were 123 vessels operating in the squid jigging fleet segment in South Africa in 2019 with a variety of vessel lengths, up to about 22 m (LOA). The total estimated replacement cost for this fleet segment was estimated at USD 67 million. The average replacement cost of a squid jigger freezer vessel in 2019 was about USD 547 000, which would include gear and accessories. The average book value of the vessels surveyed was USD 202 000, while some survey respondents indicated that "new builds" would cost about USD 471 000, which probably reflects the vessel investment costs without the associated gears and accessories.

Operating and owner costs

The average total annual operational costs of the squid jiggers surveyed was USD 606 000 in 2018; these included 76 percent operating costs (consisting of running and labour costs) and 24 percent vessel owner's costs. Within the operating costs, crew salaries accounted for the main cost component (79 percent). This reflects the nature of the fishery, which is commission-based and does not entail much fuel usage as fishing grounds are located near the shore. Fuel costs are nevertheless the next biggest operating cost component at 9 percent, followed by provisions (5 percent). As far as owner's costs are concerned, repairs and maintenance account for the largest proportion (28 percent), followed by depreciation (24 percent) and administrative and logistical costs (23 percent).

Revenue

In 2016, the fishery landed 8 499 tonnes of squid with an estimated value of nearly USD 53 million. Revenues vary greatly, however, as resource availability is seasonal and fluctuates from year to year. For the vessels surveyed, average earnings from landed squid sales amounted to approximately USD 946 000 in 2018. The fishery lands a very small volume of fresh squid; most of the catch is frozen and packed at sea for direct export to Europe upon its arrival in port.

Midwater trawlers

Neither costs nor earnings information was provided for the large, directed midwater trawler. Running costs for this vessel are high. On a per-trip basis, the vessel lands around 2 500 tonnes of whole frozen horse mackerel after 30–40 days at sea. Midwater trawling is a volume-driven fishery, targeting aggregations. The frozen product is sold mainly to Central and West African countries.

The annual fishery economics assessments conducted by DEFF do not include an assessment for this fleet segment, though some multigear trawlers in this fleet are included in the demersal trawler assessments carried out by DEFF. Revenue on a per-trip basis for the large, directed midwater trawler can be estimated at USD 1.6–2.7 million. With estimated daily running costs of an operation that includes 110 crew members and consumes 20–40 tonnes of diesel per day, fuel and labour costs are expected to be higher than for deep-sea trawling operations. Conservatively estimated fuel costs per trip would account for roughly 40 percent of operating costs, while labour costs would account for roughly 30 percent. The NRR is estimated at around 10 percent.

Hake longliners

Capital investments

The average initial capital investments in the hake longliner vessels surveyed are unknown, as the vessel hulls were over 45 years old. However, the engines, propulsion systems, top haulers and bottom line haulers, freezers and heading machinery below deck, together with the navigation and communication equipment, were replaced more recently. The average combined investment in these items added up to USD 433 000 per vessel.

The engines were the largest recent investment, together accounting for 50–65 percent of the investment cost. The book values or replacement values of the vessels were not available.

Operating and owner costs

Demersal (hake) longliners spend large parts of their fishing trips on the move while hauling lines. The operating costs of hake longliners are dominated by crew wages and fuel expenditure, which account for approximately 60–70 percent. Demersal longline fishery fuel and wage structures are similar to the bottom trawl fisheries, with commissions paid on catch to the crew. Bait and ice are the next highest running costs, estimated together at around 16 percent of total operating costs. The average operating costs of the hake longliners surveyed, which varied in length between 21 and 27 m (LOA), were around USD 787 000 in 2017.

The total owner costs for a typical hake longliner in 2017 amounted to roughly USD 245 000, although this figure fluctuated considerably. The main owner expenses related to depreciation, repairs and maintenance, insurance and port fees. The total annual operational costs (operating and owner's costs) of an average vessel in this fleet segment was over USD 1 million in 2017.

Revenue

Reports by DEFF show that in 2016 the hake longliner fleet segment landed 9 000 tonnes of hake and a small amount of bycatch, with an estimated total landed value of USD 22 million. Hake-directed longlining is highly selective. When the fishery first started in the 1990s, the fishery processed fresh whole fish for direct export to Europe. Prices at that time were high and exchange rates favourable.

Currently the fishery still predominantly lands "wet fish" on ice, but now in the headed and gutted form (H&G). Given the high running costs of these vessels, small quotas and high labour costs, the average earnings of landed fish by the vessels surveyed in this fleet segment were just USD 663 000 in 2017. This indicates that an average vessel in this fleet segment made a financial loss in that year. The respondents mentioned that the profitability was significantly higher when whole wet fish was exported, and referred to as "Prime Quality" or PQ hake.

The depreciation applied in the table for hake longliners is an estimate based on investments in engines, propulsion and equipment with a life cycle of 10 years. Given their ages, the hulls of the surveyed vessels were considered fully depreciated.

TABLE A1.13
Average revenue and costs of surveyed vessels in selected fleet segments

		Squid jiggers	Deep-sea trawlers	Hake longliners
Category	**Item**	**USD**	**USD**	**USD**
Earnings (=Revenue)	Total fishing revenue	945 527	7 687 097	662 666
	Subsidies and grants	939		
Total earnings		946 467	7 687 097	662 666
Running costs	Fuel	41 056	946 588	104 665
Running costs	Lubricants/oil/filters	1 174	49 915	
Running costs	Harbour dues and levies	6 604	76 323	2 538
Running costs	Ice	-		38 311
Running costs	Bait	-		90 845
Labour costs	Food, stores and other provisions	20 062	80 479	29 348
Running costs	Materials (packaging, boxes)	3 977	122 883	1 255
Labour costs	Crew travel	5 321	17 169	8 932
Running costs	Other operating costs	16 861	271 144	39 027
Labour costs	Labour share and wages (including social security contributions, life/ accident and health insurance)	367 603	1 216 491	472 382
Total operating costs		462 659	2 780 993	787 304
Vessel owner costs	Fishing license fees, permits and quota	-	436	
Vessel owner costs	Insurance fees (vessel, employers, equipment)	7 120	66 821	8 157
Vessel owner costs	Gear replacements, repairs and maintenance of gears with a lifespan of less than 3 years	-	226 461	
Vessel owner costs	Vessel repairs and maintenance	40 434	408 363	
Vessel owner costs	Other fixed costs (accountancy, audit and legal fees, general expenses, subscriptions, etc.)	33 392	-	
Vessel owner costs	Depreciation (vessel, engine, equipment, and gears that last more than 3 years)	34 611	480 886	43 300
Vessel owner costs	Interest	27 472		
Total vessel owner costs		**143 030**	**1 182 967**	**245 041**
Total annual operational costs		**605 689**	**3 963 960**	**1 032 345**

Notes: the table shows the average costs and earnings of surveyed vessels, including four squid jiggers and three deep-sea (hake) trawlers in 2018, and three hake longliners in 2017. The average exchange rates in 2018 and 2017 were USD 1 = ZAR 13.2 and USD 1 = ZAR 13.3.

Most of the surveyed vessels included in Table A1.13 did not report any other fishing income. The fish sales costs of the vessels surveyed were included in other operating costs. Except for insurance costs, the information on owner costs of hake longliners was only available as an aggregated total of owner costs. No costs were reported for the purchase of fishing rights (quotas), taxes on profits and investments.

TABLE A1.14
Financial and economic indicators for fleet segment in USD

	Code	Squid jiggers	Deep-sea trawlers	Hake longliners
Revenue from landings	A	945 527	7 687 097	662 666
Total revenue	A2	946 467	7 687 097	662 666
Labour costs	B	392 986	1 314 140	510 662
Running costs	C	69 673	1 466 853	276 642
Vessel costs	D	80 946	702 082	201 741
Total gross cost (E) = B + C + D	E	543 605	3 483 074	989 045
Total costs (E2) = E + G + J + S	E2	605 689	3 963 960	1 032 345
Net cash flow (F) = A2 - E	F	402 861	4 204 023	-326 379
Depreciation	G	34 611	480 886	43 300
Amortization	H	0	0	0
Gross profit (I) = F - G - H	I	368 250	3 723 137	-369 679
Interest	J	27 472	0	0
Net profit before taxes (K) = I - J	K	340 778	3 723 137	-369 679
Net profit margin (L) = K/A2	L	36%	48%	-56%
Value of tangible assets (2017/2018)	M	202 000	2 400 000	250 000
ROFTA (N) = K/M	N	169%	155%	-148%
Value of intangible assets	O	0	0	0
ROI (P) = K/(T + O)	P	62%	57%	-85%
GVA (Q) = F + B	Q	795 847	5 518 162	184 284
GVA to revenue (R) = Q/A2	R	84%	72%	28%
Taxes & extraordinary losses	S	0	0	0
Initial investment costs	T	547 000	6 500 000	433 000

Note: Information presented in Table A1.14 for squid jiggers and deep-sea trawlers related to the year 2018; for hake longliners it was 2017.

6. ECONOMIC AND FINANCIAL PERFORMANCE OF FISHING VESSELS

Some information and estimates on the financial performance of fishing vessels in South Africa, such as the net rate of return (NRR), was included above based on earlier studies. Midwater trawlers were assessed to have a net rate of return on investment of about 10 percent, while purse seiners were assessed to have an NRR of below 10 percent. Based on the vessel surveys conducted, indicators have been calculated for deep-sea trawlers, squid jiggers and hake longliners and presented in Table A1.14.

Squid jiggers

The average gross profit of a squid jigger in 2018 was USD 368 000. The net profit was nearly USD 341 000, after deduction of interest payments. The ratio of net profit to total revenue (i.e. net profit margin) was high, at 36 percent. This means that for every dollar earned by vessel operations some 36 cents were kept as profit. The return on fixed tangible assets (ROFTA) was very high, at 169 percent; this was largely due to the depreciated value of the fishing vessels. The return on investment (ROI), calculated here over the initial investment in the vessels was also high, at 62 percent. The gross value added (GVA) of an average vessel in this fleet segment was substantial, amounting to nearly USD 796 000 in 2018.

Deep-sea trawlers

An average deep-sea trawler realized a gross profit of USD 3.7 million in 2018. The net profit margin of an average vessel in this fleet segment was high, at 48 percent. The ROFTA was estimated at 155 percent, using the average insured value of vessels in this fleet segment as the value of tangible assets. The ROI – calculated against an average initial investment estimated at USD 6.5 million – was high for vessels in this fleet, at an estimated 57 percent. The GVA of a vessel in this fleet segment was USD 5.5 million in 2018.

HAKE LONGLINERS

Many South African hake longliners were in a loss-making position in 2017, with the average loss per vessel amounting to USD 326 000. These losses are associated only with the hake-directed operations, however, though vessel operators may also target other species. Some vessels in this fleet segment also operate seasonally as pole-and-line vessels and fish for albacore tuna. Economic and financial data provided for this fleet segment are therefore negatively biased by virtue of the occasionally small hake allocations. The GVA for a vessel in this fleet was estimated at USD 184 000 in 2017, but this does not take into account the revenues from other fishing activities.

7. FINANCIAL SERVICES AVAILABLE TO THE FISHERIES SECTOR, INCLUDING INSTITUTIONAL CREDIT PROGRAMMES

The Government of South Africa has not established any direct mechanism to provide finance for the sustainable development of the commercial fishing sector. However, the Industrial Development Corporation (IDC) and a Small Business Development Cooperation (SBDC), both provide competitive financial services for fishery development, including for (small-scale) fishing vessels and fish processing, with the aim of promoting economic development and generating jobs. Commercial banks also provide finance to the fisheries sector, but generally the industry is considered a high-risk venture.

8. SUBSIDIES AND SUPPORT FOR THE SECTOR

The Government of South Africa does not provide subsidies to commercial fisheries. There is a partial fuel tax exemption for diesel, which applies equally to the agricultural and fisheries sectors, but the government does not provide financial compensation for a reduction in fishing effort – such as the scrapping of fishing vessels, for example.

9. TECHNOLOGICAL INNOVATIONS IN GEARS, EQUIPMENT AND VESSELS THAT IMPACT THE ECONOMIC PERFORMANCE OF FISHING VESSELS

The main technological innovations that have had an impact on the economic performance of the fishing fleet in South Africa since 2000 are presented in Table A1.15.

10. SUMMARY DESCRIPTION OF NATIONAL PLANS AND POLICIES FOR THE ADJUSTMENT OF FLEET CAPACITIES

South Africa has no plans in place that limit or reduce the capacities of its fishing fleet.

TABLE A1.15

Technical innovations impacting fishing fleet performance

Category	Specific innovations
Cost reductions and energy savings	No specific innovations reported, although operators are moving towards greater fuel efficiency. Reduced trawling times, combined with a reduced travel speed, are leading to some fuel savings.
Increasing fishing efficiency	Shorter trawling times.
Reducing the environmental/ ecological impact	There is a general increase in awareness in the sector about the environmental impact of fishing, with the retention of waste (no dumping), and the ecosystem approach are now entrenched.
Improving fish handling, product quality and food safety	Improved fish handling, shorter trips and a better use of ice. Some fisheries have moved towards MSC certification, which has contributed to on-board fish quality maintenance practices.
Improving safety at sea and the working conditions of fishers	Health, safety, and environment (HSE) standards are improving in South African fisheries. The South African Maritime Safety Authority (SAMSA) is enforcing IMO and ILO conventions and guidelines.

REFERENCES

Anchor Environmental. 2014. Assessment of the socio-economic implications of a reduced minimum sardine TAC for the small pelagics purse seine fishery in South Africa. Report prepared for the South African Pelagic Fishing Industry Association (SAPFIA) (unpublished).

Augustyn, J., Cockcroft, A., Kerwath, S., Lamberth, S., Githaiga-Mwicigi, J., Pitcher, G., Roberts, M., van der Lingen, C. & Auerswald, L. 2019. In B. F. Phillips & M. Pérez-Ramírez, eds. *Climate Change Impacts on Fisheries and Aquaculture: A Global Analysis, Volume II*, pp. 479–522. Chichester, UK, Wiley Blackwell.

Department of Agriculture, Forestry and Fisheries (DAFF). 2012. *Policy for the small-scale fisheries sector in South Africa.* Staatskoerant 20 junie 2012. No. 3545. [Cited 05 February 2021]. www.gov.za/sites/default/files/gcis_document/201409/35455gon474.pdf

Department of Agriculture, Forestry and Fisheries (DAFF). 2013. *General Policy on Allocation and Management of Fishing Rights: 2013* [online]. Department of Agriculture, Forestry and Fisheries. General Notices. Staatskoerant 17 julie 2013, No. 36675. [Cited DD Month Year]. www.gov.za/documents/general-policy-allocation-and-management-fishing-rights-2013-and-fishery-specific-policies

FAO. 2020. Fishery and Aquaculture Statistics. Global capture production 1950–2018 (FishstatJ). In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 2020. www.fao.org/fishery/statistics/software/fishstatj/en

Fiandeiro, F., Ntanzi, A., van der Hoven, Z., Moses, P.J. & Msimango, N. 2019. *Economic Study of the Hake Deep-Sea Trawl Fishery and the Implications for Future Fishing Rights Allocation Policy*. Johannesburg, South Africa, Genesis Analytics (Pty) Ltd. (available at www.sadstia.co.za/assets/uploads/GenesisHDSTReport_FINAL.pdf).

Hodge, J., Ntanzi, A., van der Hoven, Z., Moses, P.J. & Msimango, N. 2018. *Economic Study of the Hake Deep-Sea Trawl Fishery and the Implications for Future Fishing Rights Allocation Policy*. Johannesburg, South Africa, Genesis Analytics (Pty) Ltd.

Japp, D.W. 1997. Discarding practices and bycatches for fisheries in the Southeast Atlantic Region (Area 47). In I.J. Clucas & D.G. James, eds. *Report of the Technical Consultation on Reduction of Wastage in Fisheries. Tokyo, Japan, 28 October–1 November 1996*,. Rome, FAO.

SANBI. 2004. *South African National Spatial Biodiversity Assessment 2004: Technical Report. Volume 4: Marine Component*. Pretoria, South Africa, South African National Biodiversity Institute. (available at sanpcc.org.za/pssa-old/articles/includes/NSBA Vol 4 Marine Component Draft Oct 04.pdf).

South African Deep-Sea Trawling Industry Association (SADSTIA). 2014. Facts and figures. In: *South African Deep-Sea Trawling Industry Association* [online]. Cape Town, South Africa. [Cited 05 February 2021]. www.sadstia.co.za/fishery/facts-and-figures/

South African Deep-Sea Trawling Industry Association (SADSTIA). 2019. *Investment in the Hake Deep-Sea Trawl Fishery. Factsheet 5* [online]. Cape Town, South Africa. [Cited 05 February 2021]. www.sadstia.co.za/assets/uploads/Factsheet-5-Investment.pdf

South African Hake Longline Association (SAHLLA). forthcoming. *Economic assessment of the hake long-line fishery*. South African Hake Longline Association. Cape Town, South Africa.

South African Squid Management Industrial Association (SASMIA). forthcoming. *Socio-economic study of the squid jig fishery in South Africa*. Port Elizabeth, South Africa.

Stats SA. 2019. *Stats in Brief: 2019* [online]. Pretoria, Department of Statistics of South Africa. [Cited 05 February 2021] www.statssa.gov.za/publications/StatsInBrief/StatsInBrief2019.pdf

Tietze, U., Thiele, W., Lasch, R. Thomsen, B., & Rihan, D. 2005. *Economic performance and fishing efficiency of marine capture fisheries*. FAO Fisheries Technical Paper No. 482. Rome, FAO. 68 pp. (also available at www.fao.org/3/y6982e/y6982e00.htm).

World Bank. 2021. Data bank: South Africa [online]. [Cited 05 February 2021] https://data.worldbank.org/country/ZA

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Annex 2 – National Report of Senegal

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I. OBJECTIVES AND CONTEXT

Background and justification

The economic performance of the fishing fleets of the Republic of Senegal has been presented in previous FAO global reviews – in 1999, 2001 and most recently in 2005. The main fishing fleets covered in the previous analyses included: purse seiners, surrounding gillnetters, handliners, longliners, coastal (demersal) trawlers, industrial deep-sea trawlers and small-scale multipurpose canoes.

The current fleet assessment is part of the fourth global assessment of the techno-economic performance of the main fishing fleets in the world conducted by FAO and aims to compare the financial and economic performance between fleets, and over time within fleets.

Senegal also participated in the FAO global studies on the techno-economic performance of the main fishing fleets with data and information from 2018. In that year, the country's marine fishing fleets produced an estimated 452 747 tonnes (FAO, 2020a), which accounted for approximately 0.54 percent of the global capture fisheries production of 84.4 million tonnes; as a result, it was included in the present global fishing fleet performance assessment conducted by FAO.

1.2 Sectoral context and survey methods used

As a country with a coastline of 718 km, the fisheries sector is important to the economy of Senegal. In 2015, the sector contributed 1.8 percent to GDP in 2015 and provided direct employment to more than 53 100 people, together with an estimated 540 000 indirect jobs, mainly in artisanal fishing and processing. The number of decked fishing vessels reported in 2015 was 147, most of which ranged from 30 to 45 m length overall (LOA). A significant number of artisanal, undecked fishing vessels were reported in the same year, including 8 053 powered vessels and 1 430 unpowered vessels (FAO, 2017). By 2018, the number of decked vessels had decreased to 94 vessels > 24 m LOA and 29 vessels from 12 to 24 m (FAO, 2020b).

In the early 2000s, Senegal took into account the FAO International Plan of Action for the Management of Fishing Capacity (IPOA-CAPACITY) and formulated a maritime fishing capacity adjustment project for financing by the African Development Bank (AfDB), which remained unfunded. Aware of the importance and challenges involved in managing fishing capacity, the Government of Senegal has included this subject under Programme 1 of the Fisheries and Aquaculture Sector Policy (2016–2023): "Sustainable Fisheries Resource Management and Habitat Restoration".

In addition to this policy, Senegal has put in place various fisheries management plans that take into account fisheries capacity management, such as the management plan for deep-sea shrimp, and the establishment of a vessel buyback programme for industrial coastal vessels fishing on demersal stocks. This programme aims to adjust fishing effort and capacity to sustainable levels, through reduction in fishing vessels, to address the over-exploitation of targeted stocks (MPEM, 2013). In 2014 Senegal adopted a national plan of action to eradicate illegal, unreported and unregulated (IUU) fishing in its exclusive economic zone (EEZ) and strengthened its fisheries monitoring, control and surveillance systems (MCS) to coordinate actions at the national and international levels more effectively. The various plans and programmes enable the Ministry of Fisheries and Maritime Economy (MPEM) to guide the management of the fishing fleet.

The Marine Fisheries Code (Law No. 2015-13 of 18 July 2015), with particular reference to the related Decree No. 2016-1804 of 22 November 2016, states in Article 55 that

> "commanders of industrial fishing vessels and those responsible for small-scale fishing vessels authorized to operate in waters under Senegalese jurisdiction are required to provide information on catches under the conditions set by the Minister in charge of marine fisheries. This includes information on the weight and/or number of fish caught, species caught, transshipped or transported, catch and/or transfer dates and catch areas, fishing vessel characteristics, fishing gears and methods used, or any other information that may enable good management of fisheries resources and effective monitoring of fishing operations".

The same Code requires that all industrial fishing vessels be included in a national register for industrial fishing vessels. This survey of the techno-economic performance of the main fishing fleets received collaboration from the fishing vessel owners and operators under the above-mentioned Code.

2. CHARACTERISTICS OF THE FISHING FLEETS OPERATING IN SENEGAL

The marine capture fisheries production of Senegal fluctuates significantly, primarily due to variation in the availability of pelagic species. In the 2000–2018 period the lowest production was recorded in 2006, with 334 000 tonnes, while the highest production (501 000 tonnes) was achieved in 2017. This report discusses the performance of the fishing fleet operating in Senegal in 2018, when marine capture fisheries production was estimated at nearly 453 000 tonnes. The production consisted of roughly 68 percent of pelagic species, 17 percent of demersal fish species, 8 percent marine fish not elsewhere identified (NEI), 4 percent cephalopods, 2 percent moluscs and 1 percent crustaceans (FAO, 2020a).

TABLE A2.1
Overview of the main fishing fleets

Fishing fleet Listed by gear name	Number of vessels	Scale	FAO fishing area	Main fishing port
Purse seiners and Pole-and-line vessels (tuna)	13	Industrial	34	Dakar
Seiners/trawlers (coastal pelagics)	12	Industrial	34	Dakar
Coastal demersal trawlers	78	Industrial	34	Dakar
Deep-sea demersal trawlers	25	Industrial	34	Dakar

TABLE A2.2
Main species targeted by fishing fleet

Targeted species by fleet	1	2	3	4	5
Purse seiners and pole-and-line vessels (tuna)	Skipjack (*Katsuwonus pelamis*)	Yellowfin (*Thunnus albacares*)	Bigeye tuna (*Thunnus obesus*)	Albacore (*Thunnus alalunga*)	Thonine (*Euthynnus alletteratus*)
Seiners/trawlers (coastal pelagics)	Chinchard (*Selar crumenophthalmus*)	Mackerel (*Scomber scombrus*)	Plate sardines (*Sardinella maderensis*)	Round sardines (*Sardinella aurita*)	Ethmalose (*Ethmalosa fimbriata*)
Coastal demersal trawlers	Pageot (*Pagellus bellottii*)	Pagre (*Pagrus caeruleostictus*)	Plexiglas (*Galeoides decadactylus*)	Octopus (*Octopus spp*)	Otoliths (*Pseudotolithus senegallus*)
Deep-sea demersal trawlers	Gambas (*Penaeus notialis*)	Alistado – crevette rouge (*Aristeus antennatus*)	Senegalese hake (*Merluccius senegalensis*)	Saint pierre (*Zeus faber*)	

Note: main target species are ranked from 1 to 5, with 1 being considered the most important.

The main industrial fishing fleets in terms of volume and value of seafood landed were the following: purse seine for tuna, seiners for coastal pelagics, coastal trawlers for demersal fish species and deep-sea trawlers for demersal species. The coastal demersal trawler fleet is the largest industrial fishing fleet segment in terms of number of vessels, and the pelagic trawler/seiner fleet is the largest in terms of volume caught. In 2018 the combined plate and round sardinella production was estimated at around 170 000 tonnes, which accounted for more than a third of the annual marine capture fisheries production of Senegal.

The main species targeted and commonly caught by each fishing fleet segment are listed in Table A2.2 and Table A2.3. In terms of commercial value generation, the tuna species are key to the purse seiner fleet, while various mackerels and sardines are important for the fleet segments fishing on coastal pelagics.

Both the fishing vessels targeting coastal pelagic species and the deep-sea demersal trawlers do not generally discard at sea and land all fish caught. Purse seiners discard or release dolphins and turtles caught in their nets. The coastal demersal trawlers generally discard mojarra (*Geres melanopterus*) and chinchard at sea.

TABLE A2.3
Main species landed by fleet segment

Species landed by fleet segment	1	2	3	4	5
Purse seiners and pole-and-line vessels (tuna)	Skipjack	Yellowfin	Bigeye tuna	Albacore	Thonine
Seiners/trawlers (coastal pelagics)	Chinchard	Mackerel	Plate sardines	Round sardines	Ethmalose
Coastal demersal trawlers	Pageot	Pagre	Plexiglas	Octopus	Red mullet (*Mullus spp*)
Deep-sea demersal trawlers	Gambas	Crevette rouge	Senegalese hake	Saint Pierre	Sole (*Solea senegalensis*)

TABLE A2.4
Average age of fishing vessels by main fleet segment in 2019 (in percentages)

Fleets / Average age of ships as a percentage of total fleet size (%)	0–5 years	5–10 years	10–20 years	20–25 years	More than 25 years
Purse seiners and pole-and-line vessels (tuna)	-	-	-	18%	82%
Seiners/trawlers (coastal pelagics)	6%	-	-	-	94%
Coastal demersal trawlers	-	3%	1%	2%	94%
Deep-sea demersal trawlers	3%	2%	15%	12%	68%

Most of the industrial fishing vessels in Senegal have been in use for more than 25 years. Of the vessels in the main industrial fishing fleet segments, 87 percent were older than 25 years in 2019 (Table A2.4). In recent years, only a few new seiners and deep-sea demersal trawlers have been constructed. Most industrial fishing vessels that have entered the fleet in recent years were second-hand vessels originating from Europe and Asia.

3. TECHNICAL AND OPERATIONAL CHARACTERISTICS OF THE FISHING VESSELS SURVEYED

The techno-economic fleet performance survey in Senegal included 12 industrial fishing vessels, which were categorized by target species and main gears used. The vessels included were representative of the type and size of vessels fishing for the specific resources.

The fleet segment targeting tuna species consists of pole-and-line vessels and large purse seiners. The pole-and-line vessels are generally around 30–35 m (LOA) and have engines of between 200 hp and 600 hp. They only use pole-and-line and do not fish with other gears. The average crew size is around 20 persons and the fishing trips range from 2 to 4 weeks in length (Table A2.5). Vessel 1 was constructed in 1986/1987. Its hull was 31 years in 2018 and the most recent replacement of the engines took place in 2005.

The fleet segment targeting coastal pelagics consists of seiners and pelagic trawlers, generally with an LOA of 20–35 m (Table A2.6). The vessels are “ice-boats”, in the sense

TABLE A2.5
Technical and operational characteristics of two surveyed pole-and-line vessels targeting tuna and one purse seiner

Characteristics of fishing vessels targeting tuna	Vessel 1 Pole-and-line vessel	Vessel 2 Pole-and-line vessel	Vessel 3 Purse seiner
Length overall (m)	30	35	60
Gross tonnage (GT) or gross registered tonnage (GRT)	160 GRT	200 GRT	1 349 GT
Total horsepower (hp) of main engines	600	248	3 600
On-board storage facilities (in metric tonnes)	90	200	600
Fishing gear	Pole-and-line	Pole-and-line	Purse seine
Crew size (persons)	19	25	30
Ownership	National company	National company	National company
Length of one fishing trip (days)	15–30	15–30	40
Number of fishing trips	1–2 trips per month	1–2 trips per month	monthly
Fishing season (months)	12	12	12

TABLE A2.6
Technical and operational characteristics of coastal pelagic seiner/trawler vessels surveyed

Characteristics of vessels fishing for coastal pelagics	Vessel 1	Vessel 2	Vessel 3
Length overall (m)	21.4	34	27.15
Gross tonnage (GT) or gross registered tonnage (GRT)	47.5 GRT	222 GT	69 GT
Total horsepower (hp) of main engines	350	800	680
On-board storage facilities (in metric tonnes)	50	60	25
Fishing gear	Seine	Pelagic trawl	Seine
Crew size (persons)	18	16	15
Ownership	National company	National company	National company
Length of one fishing trip (days)	0.5 day	3 days	3 days
Number of fishing trips	4 per month	4 per month	6 per month
Fishing season (months)	12	12	12

that they carry ice to keep the catch fresh, and they return to port when the ice has been used. They do not have on-board freezers. The engine power of vessels in this fleet segment ranges from 300 to 1000 hp. Their crew contingent is generally 15–20 persons. Vessel 3 is a new vessel, which recently entered the fleet (2017). Vessel 2 was constructed in 1982 and its hull was some 36 years in 2019. The engines and other major equipment on-board were replaced in 2014/2015.

The coastal demersal trawler fleet segment largely consists of vessels of 25–30 m (LOA) and with engine power of 750–1000 hp. Their gross registered tonnage is often above 150 GRT and they have the freezer capacity to store the fish caught. Some of the vessels are equipped with beam trawls, while others have stern trawling equipment. The average crew size is 15 persons and fishing trips for this vessel type commonly last 3–4 weeks. Vessel 2 was constructed 34 years ago and got a new engine in 2017. The hull of vessel 3 was 55 years in 2018 and the main engine was replaced in 2007/2008.

The fleet segment fishing for deep-sea demersal species (e.g. shrimp, hake and crab) mainly consists of demersal trawlers. However, some trawlers have been modified and use traps or pots, mainly to catch crab. The vessels are generally 25–35 m (LOA), though there is enormous variation in their engine power. The crew size is 15–25 persons on most vessels in this fleet segment and the trips carried last 2–8 weeks. As with the other fleet segments, these vessels operate all year round.

TABLE A2.7
Technical and operational characteristics of the coastal demersal trawlers surveyed

Characteristics of coastal demersal trawlers	Vessel 1	Vessel 2	Vessel 3
Length overall (m)	29.66	18	27
Gross tonnage (GT) or gross registered tonnage (GRT)	179 GT	46 GRT	156 GRT
Total horsepower (hp) of main engines	800	250	1000
On-board storage facilities (in metric tonnes)	58	15	45
Fishing gear	Demersal trawl	Beam trawl	Beam trawl
Crew size (persons)	15	9	15
Ownership	National company	National company	National company
Length of one fishing trip (days)	25–30	4	21
Number of fishing trips	1 per month	1 per week	1 per month
Fishing season (months)	12	11	12

TABLE A2.8
Technical and operational characteristics of deep-sea demersal trawlers surveyed

Characteristics of deep-sea demersal trawlers	Vessel 1	Vessel 2	Vessel 3
Length overall (m)	34.24	27.1	30.70
Gross tonnage (GT) or gross registered tonnage (GRT)	373 GRT	98 GRT	169 GT
Total horsepower (hp) of main engines	1000	400	552
Onboard storage facilities (in metric tonnes)	200	100	50
Fishing gear	Demersal trawl	Demersal trawl	Crab traps
Crew size (persons)	21	20	15
Ownership	National company	National company	National company
Length of one fishing trip (days)	15	60	60
Number of fishing trips	2 per month	5 or 6 per year	5 or 6 per year
Fishing season (months)	12	12	12

TABLE A2.9
Number of fishing crew on-board of vessels with Dakar as their homeport (2018)

Type of crew	Number of crew	Percentage
Apprentices	372	13
Crew with fixed-term contracts	513	19
Crew with long-term (indefinite) contracts	1 869	68
Total	**2 754**	**100**

Source: Seafarers and Maritime Labour Directorate (DGMTM, 2018).

All the crew on the fishing vessels surveyed in 2019 were male; there were no women working on any of the vessels. Most fishing crew are employed full-time and 68 percent have a long-term labour contract (Table A2.9).

4. FINANCIAL AND ECONOMIC CHARACTERISTICS OF INDIVIDUAL FISHING UNITS

Capital investments

A total of ten fishing vessels were surveyed in 2019, each of which provided a fair reflection of the average vessels in the selected fleet segment. The initial investment in the hull, engines and major on-board equipment of the vessels surveyed was not easy to obtain. Most of the vessels were old and have had several owners since their construction, which meant reliable investment data for only seven of the ten vessels surveyed could be collected. While it is common to apply an annual depreciation rate of 4 percent for the hull – considering the average lifetime of a fishing vessel is 25 years – it appeared that most vessels surveyed in Senegal were much older; the value of the hull would therefore be set at close to nil. In line with previous practices (FAO, 2019) a 2 percent depreciation rate over the initial investment in the hull was applied per year for vessels older than 25 years. The depreciation rate applied for the main engines, on-deck equipment and main electronic devices was 10 percent per year, 5 percent for below-deck equipment and 20 percent for major gears. Most vessels surveyed did report replacements of one or more engines and main equipment in recent years, and these data were incorporated into the analysis provided in this report.

The average initial investments of indicative vessels for the selected vessel segments (tuna-targeting pole-and-line, coastal pelagics, coastal demersal trawlers, and deep-sea demersal trawlers) are shown in Table A2.10.

The highest capital investments were made in pole-and-line vessels and deep-sea demersal trawlers, with USD 2.6 million and USD 2.1 million investments respectively.

TABLE A2.10
Investment costs and depreciated value of the surveyed vessels (in thousand USD)

Investment costs per vessel (in Thousand USD)	Pole-and-line vessel	Coastal pelagic seiner	Coastal pelagic trawler	Demersal trawler	Deep-sea demersal trawler	Deep-sea demersal trap vessel
Vessel (hull)	1 615	646	239	431	1 292	212
Main engine(s)	462	185	68	123	369	61
Equipment on deck (e.g. cranes, beams)	128	51	19	34	103	17
Equipment below deck (e.g. cold storage, ice-making, freezers)	256	103	38	68	205	34
Fishing gears (> 3 years)	51	21	8	14	41	7
Electronic devices (navigation, fish finding and communication)	51	21	8	14	41	7
Total investment	2 564	1 026	379	684	2 051	336
Age of the hull (years)	31	1	36	55	78	40
Depreciated value (2018)	705	967	169	41	534	58

Note: The original investment cost data were provided by the vessel owners/operators in West African CFA franc. The exchange rate applied here is the official average CFA: USD exchange rate in 2019 (1 USD = 585 CFA)

For all vessels surveyed the investments in the vessel hulls were 53–63 percent of the total initial capital investment. The engines and propulsion system expenses generally ranged from 15 to 20 percent of the total initial expenses.

Earnings

The vessels surveyed only reported income from the sale of landed fish and fishery products. No other source of earnings (such as income from sale of fishing rights, quota rights and subsidies) was reported by the owners/operators. The pole-and-line vessel and the vessels targeting deep-sea demersals generated earnings of over USD 2 million in 2018, while the other vessels surveyed reported earnings between USD 156 000 and USD 769 000 in the same year. The ex-vessel prices in 2018 in the port of Dakar were good, which contributed to the profitability of the vessels surveyed.

Operating and owner costs

None of the vessels surveyed reported any costs associated with the sale of fish, crew travel, purchase of fishing rights or quotas, amortization of intangible assets (fishing permits, licenses, etc.), repayment of loans or interest on loans. The costs listed in Table A2.11 have been validated with other fishing vessel operators for correctness.

TABLE A2.11
Operational costs and earnings of the individual vessels representing the pole-and-line vessel and coastal pelagics fleet segments, 2018 (in USD)

Category	Item	Pole-and-line vessel	Coastal pelagic seiner	Coastal pelagic trawler
Earnings	Fishing revenue (gross value of landings)	2 040 531	769 231	565 812
	Total revenue	**2 040 531**	**769 231**	**565 812**
Running costs	Fuel	394 444	406 154	338 462
Running costs	Lubricants/oil/filters	70 619	8 123	2 708
Running costs	Harbour dues and levies	3 419	427	2 051
Running costs	Ice	0	55 385	27 692
Running costs	Bait	5 128	0	0
Labour costs	Food, stores and other provisions	59 829	14 769	7 385
Running costs	Materials (packaging, boxes)	0	0	0
Running costs	Other operating costs	512 821	0	0
Labour costs	Labour share and wages (including social security contributions, life/accident and health insurance)	179 487	61 538	102 564
	Total operating costs	**1 225 748**	**546 397**	**480 862**
Vessel costs	Fishing licenses, permits and quota (only annual costs)	2 297	1 115	10 376
Vessel costs	Insurance (vessel, employers, equipment)	17 094	20 513	17 094
Vessel costs	Gear replacements, repairs & maintenance	8 547	0	0
Vessel costs	Vessel repairs & maintenance	51 282	4 274	10 256
Vessel costs	Other fixed costs (accountancy, audit and legal fees, general expenses, subscriptions, etc.)	10 256	0	0
Capital costs	Depreciation (vessel, engine, equipment, and gears that last more than 3 years)	195 385	59 692	22 086
	Taxes on profit	295 900	56 208	5 492
	Total vessel owner costs	**580 761**	**141 801**	**65 305**
	Total annual operational costs	**1 806 509**	**688 198**	**546 166**

Note: The original investment cost data were provided by the vessel owners/operators in West African CFA. The exchange rate applied here is the official average CFA: USD exchange rate in 2019 (1 USD = 585 CFA).

Pole-and-line vessel

The total operational costs of a pole-and-line vessel in 2018 was about USD 1.8 million, of which 68 percent was spent on operating costs and 32 percent on vessel owner costs. Fuel was a major running cost, accounting for 32 percent of the operating costs. Vessel depreciation was estimated at 11 percent of total operational costs in 2018, while in the same year taxes on profits amounted to a substantial 16 percent of total operational costs.

Coastal pelagic seiner and trawler

Typical operational costs for a coastal pelagic seiner vessel were around USD 688 000, while the costs for a trawler vessel fishing for coastal pelagics amounted to some USD 546 000. Both vessels fishing for coastal pelagics reported significant fuel expenses in 2018; these accounted for 74 percent (seiner) and 70 percent (trawler) of operating (running + labour) costs respectively. Labour costs (i.e. wages and food stores) were relatively low, at just 14 percent (seiner) and 23 percent (trawler) of the operating costs of these respective vessels. Within the vessel owner costs for the trawler vessel, some 16 percent was spent on vessel repairs and maintenance. For the seiner, depreciation and taxes on profits were both around 8 percent of the total operational costs in 2018. Vessel insurance costs were some 3 percent of total operational costs for both vessels.

Demersal trawlers

Typical operational costs for the demersal trawler varied significantly. The smaller vessel of 18 m (LOA) with a crew of 9 people presented total operational costs of USD 151 000, while the larger vessel of 27 m and a crew of 15 spent around USD 510 000 in 2018 (Table A2.12). The smaller vessel spent 89 percent on operating

TABLE A2.12

Operational costs and earnings of individual vessels representing the demersal trawlers and deep-sea demersal fleet segments, 2018 (in USD)

Category	Item	Demersal trawler (large)	Demersal trawler (small)	Deep-sea demersal trawler	Deep-sea demersal trap vessel
Earnings	Fishing revenue (gross value of landings)	570 000	156 120	2 623 385	2 051 282
	Total revenue	**570 000**	**156 120**	**2 623 385**	**2 051 282**
Running costs	Fuel	203 077	81 231	406 154	141 026
Running costs	Lubricants/oil/filters	16 000	0	21 333	8 889
Running costs	Harbour dues and levies	2 632	855	4 274	855
Running costs	Ice	0	17 231	0	0
Running costs	Bait	0	0	0	0
Labour costs	Food, stores and other provisions	46 154	4 923	16 410	85 470
Running costs	Materials (packaging, boxes)	30 769	0	112 821	2 137
Running costs	Other operating costs	0	0	0	0
Labour costs	Labor share and wages (including social security contributions, life/accident and health insurance)	102 564	30 769	487 795	462 393
	Total operating costs	**401 197**	**135 009**	**1 048 786**	**700 769**
Vessel costs	Fishing licenses, permits and quota (only annual costs)	6 838	643	15 636	15 167
Vessel costs	Insurance (vessel, employers, equipment)	10 256	2 564	25 641	85 470
Vessel costs	Gear replacements, repairs & maintenance	0	1709	0	0
Vessel costs	Vessel repairs & maintenance	23 932	5 128	8 547	205 128
Vessel costs	Other fixed costs (accountancy, audit and legal fees, general expenses, subscriptions, etc.)	0	0	0	0
Capital costs	Depreciation (vessel, engine, equipment, and gears that last more than 3 years)	39 795	3 829	119 385	19 578
	Taxes on profit	28 077	2 171	421 617	307 551
	Total vessel owner costs	**108 897**	**16 045**	**590 826**	**632 894**
	Total annual operational costs	**510 094**	**151 054**	**1 639 612**	**1 333 663**

costs (consisting of running and labour costs), while this was 78 percent for the larger vessel. Both vessels spent more than 50 percent of their operating costs on fuel. Labour costs accounted for 29 percent and 24 percent of total operational costs for the larger and smaller trawler respectively.

Deep-sea demersal trawler

The operational costs of the surveyed deep-sea demersal trawler added up in 2018 to USD 1.6 million, of which 63 percent was spent on operating cost items. Labour costs (wages and food) as well as fuel were major items of expenditure and added up to 31 percent and 25 percent of the total operational costs respectively. Reported taxes on profit were substantial at 26 percent of total operational costs.

Deep-sea demersal trap vessel

The crab trap vessel of 30.7 m (LOA) with a crew of 15 people presented total operational costs of USD 1.3 million in 2018, of which nearly half (48 percent) were vessel owner costs. The owner spent over USD 200 000 on vessel repair and maintenance in 2018 and the taxes on profit were over USD 300 000. The labour costs in the same year accounted for 41 percent of the total operational costs and were thus the largest item of expenditure. Insurance costs were higher for this trap vessel, at 6 percent of the total operational costs, than for the other vessels surveyed.

5. ECONOMIC AND FINANCIAL PERFORMANCE OF FISHING VESSELS

The economic and financial indicators presented in Table A2.13 encapsulate the performance of the main fishing fleet segments in Senegal. While the information presented is from individual vessels in these segments, the data validation efforts by the survey team demonstrated that other vessels in the same segments presented comparable figures in 2018. All the fishing vessels surveyed showed positive net cash

TABLE A2.13
Financial and economic indicators of selected fishing vessels, 2018 (in USD)

	Code	Pole-and-line vessel	Coastal pelagic seiner	Coastal pelagic trawler	Demersal trawler (large)	Demersal trawler (small)	Deep-sea demersal trawler	Deep-sea demersal trap vessel
Revenue from landings	A	2 040 531	769 231	565 812	570 000	156 120	2 623 385	2 051 282
Total revenue	A2	2 040 531	769 231	565 812	570 000	156 120	2 623 385	2 051 282
Labour costs	B	239 316	76 308	109 949	148 718	35 692	504 205	547 863
Running costs	C	986 431	470 089	370 913	252 479	99 316	544 581	152 906
Vessel Costs	D	89 477	25 901	37 727	41 026	10 045	49 824	305 765
Total gross cost (E) = B + C + D	**E**	**1 315 225**	**572 298**	**518 588**	**442 222**	**145 054**	**1 098 610**	**1 006 534**
Total costs (E2) = E + G + J + S	**E2**	**1 806 509**	**688 198**	**546 166**	**510 094**	**151 054**	**1 639 612**	**1 333 663**
Net Cash Flow (F) = A2 - E	F	725 306	196 933	47 224	127 778	11 067	1 524 774	1 044 748
Depreciation	G	195 385	59 692	22 086	39 795	3 829	119 385	19 578
Amortization	H	0	0	0	0	0	0	0
Gross profit (I) = F - G - H	I	529 922	137 241	25 138	87 983	7 238	1 405 390	1 025 170
Interest	J	0	0	0	0	0	0	0
Net profit before taxes (K) = I - J	K	529 922	137 241	25 138	87 983	7 238	1 405 390	1 025 170
Net profit margin (L) = K/A2	L	26%	18%	4%	15%	5%	54%	50%
Value of tangible assets (2018)	M	704 915	966 741	168 962	41 103	21 922	534 338	57 631
ROFTA (N) = K/M	N	75%	14%	15%	214%	33%	263%	1779%
Value of intangible assets	O	0	0	0	0	0	0	0
ROI (P) = K/(T + O)	P	21%	13%	7%	13%	11%	69%	305%
GVA (Q) = F + B	Q	964 622	273 241	157 172	276 496	46 759	2 028 979	1 592 611
GVA to revenue (R) = Q/A2	R	47%	36%	28%	49%	30%	77%	78%
Taxes & extraordinary losses	S	295 900	56 208	5 492	28 077	2 171	421 617	307 551
Initial investment costs	T	2 564 103	1 025 641	379 487	683 761	68 400	2 051 282	336 388

flows (total earnings minus total gross costs) in 2018 and are therefore generating surpluses that can be invested. The fishing vessels targeting deep-sea demersal species were most profitable, which is clear from their profit margins of 50 percent and higher. By contrast, the coastal pelagic trawler and small demersal trawler surveyed showed net profit margins of 4 percent and 5 percent respectively.

Pole-and-line vessel

The pole-and-line vessel surveyed presented a gross profit of USD 530 000 in 2018. Given that no interest on loans was paid, the net profit was the same. The ratio of net profit to total revenue (the net profit margin) was good, at 26 percent. The return on fixed tangible assets (ROFTA) was high, at 75 percent. This is largely caused by the estimated depreciated vessel value of USD 704 000, which is just 27.5 percent of the initial investment cost of this vessel (USD 2.6 million). The return on investment (ROI)[1] was good with 21 percent. The gross value added (i.e. sum of the net cash flow and labour costs) of the pole-and-line vessel was estimated at USD 965 000 in 2018.

Coastal pelagic (seiner and trawler)

The vessels targeting coastal pelagics presented gross profits of USD 25 000 (trawler) and USD 137 000 (seiner) in 2018. Neither of the two vessels had any outstanding loans nor did they pay interest in 2018. The net profit margin of the seiner (18 percent) was much better than for the trawler (4 percent). This difference lies in the relatively similar gross costs reported, but when the two vessels' earnings were compared, the seiner's were roughly one-third higher. The ROFTA indicators of both vessels fishing for coastal small pelagic species were similar, at 14 percent (seiner) and 15 percent (trawler) respectively. The ROI was average, at 13 percent for the relatively new seiner and rather low (7 percent) for the older trawler. The gross value added (GVA) was positive, at 21 percent. The gross value added to the economy in 2018 amounted to USD 157 000 in the case of the trawler, and USD 273 000 in the case of the seiner.

Demersal trawlers

The two demersal trawlers surveyed varied largely in size (18 vs 27 m length overall) and initial investment (USD 68 000 vs USD 684 000). The gross costs of the larger vessel were three times higher than for the smaller vessel, while the earnings were 3.6 times as high for the larger trawler. The net profit margin of the larger vessel was 15 percent, while it was only 5 percent for the smaller trawler. The old age of the larger trawler (55 years), and the vessel's limited remaining value, impacted the ROFTA significantly. This indicator was estimated at 214 percent, while if the return were to have been calculated over the initial investment (the ROI) then the vessel would have reported an ROI of just 13 percent in 2018. The smaller trawler – the hull of which was 34 years old – reported a ROFTA and ROI of 33 percent and 11 percent respectively. In 2018 the GVA estimates amounted to USD 276 000 for the larger trawler and USD 47 000 for the smaller trawler.

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[1] The ROI in Table A2.13 is calculated based on the initial investment made in the fishing vessel and its main equipment. The reason for doing so was that no intangible assets were reported by the vessel owners/operators, and ROFTA and ROI would result in similar figures as a consequence.

Deep-sea demersal vessels

The two deep-sea demersal vessels were old, with hulls constructed 78 and 40 years ago respectively. The older vessel is used as demersal trawler and the younger fishes for crab with traps. In 2018, the demersal trawler realized earnings of USD 2.6 million at a gross costs of USD 1.1 million. The demersal trawler's operations were highly profitable in 2018. Its net profit margin was high at 54 percent, as were the ROFTA and ROI figures for this vessel, at 263 percent and 69 percent respectively. The gross value added of this deep-sea demersal trawler was, at over USD 2 million, the highest of all vessels surveyed in Senegal. The deep-sea trap vessel also demonstrated a high net profit margin in 2018, with 50 percent. This vessel had a high net profit of over USD 1 million in 2018, while the depreciated value of the vessel was less than USD 60 000. The ROFTA was therefore very high, at 1 779 percent. The ROI (calculated over the initial investment) was over 300 percent. It appears that this vessel made considerable profits for its owner in 2018, and these high figures are likely to attract other vessels and new entrants into trap fishing for crab. The GVA of the demersal trap vessel was substantial in 2018, at USD 1.6 million.

6. FINANCIAL SERVICES AVAILABLE TO THE FISHERIES SECTOR IN SENEGAL

In 2018–2019 there were no dedicated governmental credit programmes to support the sustainable development of the fisheries sector in Senegal. Credit was available from commercial banks but at high interest rates, making the loans unattractive to the fishing vessels owners/operators.

7. SUBSIDIES AND SUPPORT FOR THE FISHERIES SECTOR

The Senegalese commercial fisheries sector does not have access to grants, but the import and export of vessels, engines, major equipment and gears is exempt from taxation (Table A2.14). Senegal has established preferential regimes to facilitate investment, of which the commercial fisheries sector is also a beneficiary. A fishing company can apply for status as a free export company (for companies that export 80 percent or more of their products), while tax exemptions are provided to fisheries sector companies that sell 60 percent or more at the local level, under the investment code. These programmes provide eligible companies with tax advantages such as the exemption from customs duties for the import of gears and the suspension of VAT.

TABLE A2.14
Availability of subsidies and tax exemptions for the commercial fisheries sector

	Capital grants	Import tax exemption (%)	Local tax-free purchase (%)	Business tax exemption (%)
Vessels (hull)	none	100%	100%	100%
Engines	none	100%	100%	100%
Gears	none	100%	100%	100%
On-board equipment	none	100%	100%	100%
Fuel and lubricants	none	none	100%	100%
Ice	none	none	100%	100%

8. TECHNOLOGICAL INNOVATIONS IN FISHERIES THAT IMPACT THE ECONOMIC PERFORMANCE OF FISHING VESSELS

The main technological innovations that have had an impact on the economic performance of the fishing fleet in Senegal since 2000 are outlined in Table A2.15.

REFERENCES

FAO. 2017. FAO Fishery country profile for Senegal (updated in April 2017) (online) [Cited 11 January 2021]. www.fao.org/fishery/facp/SEN/en

FAO. 2019. *Report of the Expert Meeting on Methodologies for Conducting Fishing Fleet Techno-Economic Performance Reviews, Chennai, India, 18–20 September 2018*. FAO Fisheries and Aquaculture Report No. 1243. Rome, FAO. 60 pp. (also available at www.fao.org/3/ca4427en/CA4427EN.pdf).

FAO. 2020a. FishStatJ Global capture fisheries production database [accessed 8 November 2020].

FAO. 2020b. The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome. https://doi.org/10.4060/ca9229en

Ministry of Fisheries and Maritime Economy (MPEM). 2013. *Revue et synthèse des documents disponibles sur la gestion de capacité de pêche au Sénégal*. Dakar, Directorate for Maritime Fisheries, Ministry of Fisheries and Maritime Economy.

TABLE A2.15

Technical innovations with an impact on fishing fleet performance

Category	Specific innovations	How these have affected the economic performance of the fleet
Increasing fishing efficiency	Fish aggregating devices (FADs)	The use of FADs reduced the fishing effort (catch per unit of effort) by reducing fishing time
	Introduction of the Normord grid	This grid increased the selectivity in trawl fisheries and reduced bycatch of undesired species
Reducing the environmental / ecological impact	The use of refrigerants such as R410a, R407c, R134a (non-ozone depleting, ternary mixtures of hydrofluorocarbons, HFCs) that are more environmentally sustainable, to replace other harmful products such as R22	These (new) refrigerants have the advantage of not being harmful to the ozone layer and offer superior energy efficiency
Improving fish handling, product quality and food safety	Hazard Analysis and Critical Control Points (HACCP) systems and better hygiene practices have been introduced on board and in port	The quality of Senegalese fishery food products has improved, resulting in higher market prices and increased market acceptance
Improving safety at sea and the working conditions of fishers	GPS systems are now widely used	The introduction of GPS has facilitated navigation and the electronic localization of fishing vessels
	Emergency Position Indicating Radio Beacons (EPIRBs) have been introduced in the event of emergencies at sea.	The EPIRBs enable the emission of a rapid warning to the coastguard and facilitate the detection of vessels and crew, as well as their rescue, in emergency situations.

This review of the techno-economic performance of the main global fishing fleets discusses the outcomes from 20 country-level studies of fishing fleets from Africa, Asia, Europe, North and South America. It includes financial, socio-economic and technical information from 103 major (semi-) industrial fishing fleet segments, which are responsible for an estimated 39 percent of marine capture fisheries production worldwide.

The analysis of vessel characteristics reveals substantial differences in fishing capacity (in terms of vessel length, tonnage and power) between fleet segments. An increase in the gross tonnage of average vessels was observed in fleet segments also covered in previous reviews. Substantial increases in average length overall and engine power were observed in several Asian fishing fleets. The age structure of the fishing fleets in most regions, except Asia, shows an upward trend.

An analysis of the costs and earnings data showed that labour and running costs were the two main cost components for the majority of fleet segments. Ninety-two percent of 97 fleet segments reported a positive net cash flow in the year they were surveyed, in the 2016–2019 period. Net profit margins of 10 percent or more were realized by average fishing vessels in 73 percent of the fleet segments. Returns on investment (ROIs) of 10 percent or higher were realized by 61 percent of the fleet segments. The review also discusses developments in fishing technologies. These developments, along with a general increase in seafood prices, successful fisheries management in some areas, and improved fleet capacity management in Europe and North America, have all contributed to the ongoing, positive financial and economic performance of the main global fishing fleets in recent years.

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