Baseline socio-economic study of semi-industrial longline fleet

Report prepared for the Seychelles Fishing Authority with the financial support of the French Government, “Fonds de Solidarité pour les Projets Innovants” for the regional programme “Année Bleue de l’Océan Indien”

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Abstract

The Seychelles Fishing Authority with the financial support of the FSPI French funding "Année Bleue de l'Océan Indien" implemented this study to have a baseline assessment of the economic situation of the semi-industrial longline vessels to support the management of this fishery. Fisheries management requires a range of scientific and socio-economic data to support informed decision making. This study attempts to address some information gap in the semi-industrial longline fishery in Seychelles by analyzing the socio-economic situation of the semi-industrial longline vessels and other aspect of technical performance. A sampling survey was conducted to investigate the economic attributes such as revenue, costs and investments of the vessels, as well as a set of economic performance indicators for the year 2019. The results show that in general the sampled vessels generated a **net profit of 16% of the revenue**, with 60% of the vessels achieving a positive profit in 2019. The best economic performance was associated with the highest physical productivity i.e., the more fish vessels caught the more profitable it was. The **gross margin (operating margin) was 23%** which indicates normal profitability of the operations. From the gross cash flow calculated in the survey for the 10 vessels, we impute the gross cashflow for the remaining 23 vessels in the study population. Results for the 33 vessels showed that one third of the vessels had a comfortable gross margin, 27% (9 vessels) had a negative gross cash flow and the remaining were closer to the breakeven. The study also describes the technical performance across the semi-industrial longline fleet and calculates efficiency scores for the vessels. Analysis showed that only 7 vessels reached maximum efficiency across several inputs relating to catch and effort, whilst there are **efficiency gains that can be made for 26 vessels**. Furthermore, fishing locations is also a contributing factor to performance. The implications of the findings are that **profitability can be enhanced by improving the physical productivity** of fishing vessels. The levels of profitability are determined mainly by the volume of landings and to some extent the level of effort, while high costs can degrade the profitability for vessels if they are too high.

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List of Acronyms

CPUE	Catch per unit effort
COA	Certificate of Authorization
EEZ	Exclusive Economic Zone
EU	European Union
GOP	Gainfully Occupation Permit
MT	Metric tonne (1000kg)
SCR	Seychelles Rupees
SILL	Semi-Industrial Longline
SFA	Seychelles Fishing Authority
VMS	Vessel Monitoring System

1 Introduction

1.1 Overview

The semi-industrial longline fishery started in the mid-1990s with the aim of developing local capacity to fish pelagic resources to alleviate pressure on inshore demersal stock. The fishery was initiated to target pelagic species, primarily swordfish and tuna, with the first commercial vessel starting operation in October 1995 following experimental fishing trips by SFA (SFA 1994; SFA 1995). Since the first commercial trips, SFA has implemented a monitoring program which collects mostly information on catch and effort from logbook and landing (Bargain et al. 2000; Bargain 2001). The fishery expanded over the years supported by introduction of credit facilities introduced in 2009, through a Fisheries Development Fund Scheme (FDF) funded by the EU sectoral budget support, as well as development of joint ventures with Sri Lanka (Chassot 2017). Over a period of ten years the number of active vessels grew from 9 in 2009 to 36 in 2019. However, the fishery faced several challenges over the years including reduced demand for swordfish, local workforce constraints and difficulties to service the FDF loans.

The Fisheries Sector Policy and Strategy outlines the Seychelles Government goals to increase its management effort of the semi-industrial longline fishery and to work on a development plan to support the expansion of the fishery (Government of Seychelles 2019). In line with this strategy the Seychelles Fishing Authority with the financial support of the FSPI French funding “Année Bleue de l’Océan Indien” conducted a baseline assessment of the economic situation of the semi-industrial longline vessels to support the management of this fishery. A local consultant was recruited to conduct this study in collaboration with a Lead person in SFA and Experts from the “Institut de Recherche pour le Développement” (IRD). The purpose of this study is to provide a first insight on the socio-economic situation of the Seychelles semi-industrial longline fishing fleet and analyze the main technical characteristics of the vessels. The reference year for the study is 2019.

The main objectives of the assignment as per the Terms of Reference were to:

- Understand the economic and financial situation of the semi-industrial longline fishing fleet;
- Provide Government with credible socio-economic information, including the profitability of operations and the impact of foreign crew working under GOPs, to support policy decisions related to the local semi-industrial longline sector;
- Understand both the current and potential future challenges faced by the semi-industrial longline fishing fleet;
- Make recommendations to Government for strategies to improve the operating environment of the fishing fleet.

1.2 The Semi-industrial Longline Fishery in Seychelles

The fisheries sector is one of the main pillars of the Seychelles economy, with its GDP contribution estimated at 27% (Bistoquet et al. 2018; SFA 2021). The Seychelles fishery is mostly divided in three main categories of fleet (i) the local artisanal fleet targeting demersal and pelagic species, (ii) the small-scale local (semi-industrial) longliner fleet targeting tuna and tuna like species and (iii) the large-scale (industrial) tuna fleet made up of foreign owned and foreign and Seychelles flagged purse seiners and longliners.

The semi-industrial longline fishery is reserved for Seychelles citizen ownership which also allows joint ventures with at least 51% of local ownership. Vessels operating in the sector are typically between 13 to 23.9 metres and the majority of their catches are destined for the export market.

From 1996 to 2015, the number of active vessels in the industry fluctuated between 3 to 11 (Fig. 1). The average yearly catch remained constant circa 275 MT except for the years 2003-2004 and 2013. In those years, the fishery declined sharply because of export restrictions on swordfish to the European market related to the high levels of cadmium (Lucas et al. 2006, SFA 2013). In 2016 the number of active vessels rapidly expanded to 29 from 11 in 2015, accompanied by a sharp increase in catch and a major shift in the catch composition. The rapid expansion of the fishery in the recent years is associated with an increase in the proportion of yellowfin tuna (62% in 2016) which replaced swordfish as the main targeted species as shown in Fig. 2. Prior to 2015, swordfish dominated the catch composition accounting for 62% of total yearly catch on average. These structural shifts in the fishery are mainly attributed to new fishing techniques brought in by Sri Lankan fishers, which led to increased production of tuna attracting more investment in the sector (Assan et al. 2018).

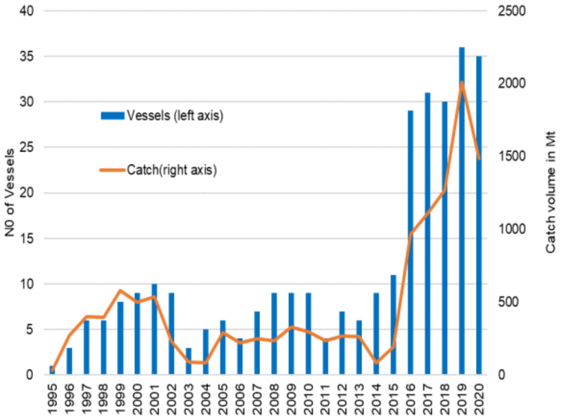


Fig. 1 Number of active semi-industrial vessels and total catch 1995-2020

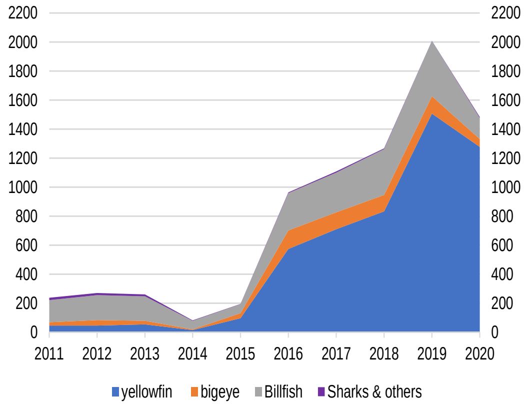


Fig. 2 Annual catch in MT by species reported by semi-industrial fleet, 2011-2020

1.3 The Semi-industrial Fishing Fleet in 2019

The semi-industrial longline fishery in 2019 was characterized by the highest recorded catch since the inception of the fishery which amounted to 2,008 MT representing an increase of 59% over the levels of 2018; along with the highest number of active vessels (36) representing an increase of 20%. This corresponded to an increase in fishing effort, with 2.55 million hooks compared to 2.07 million hooks used in 2018. The vessels conducted 397 fishing trips with the average duration of trip being 14 days. The mean catch rate (CPUE) increased to 0.79 MT/1000 hooks from 0.61MT/1000 hooks in 2018. The catch composition was dominated by yellowfin tuna (75%) followed by swordfish (15%).

There were 11 vessels having a Certificate of Authorization (COA) to fish outside the Seychelles EEZ. Analyses of the data showed 99% of the fish were caught within the Seychelles EEZ.The spatial distribution of the catch were from 50° E and 64°E in longitude, and 8°45’S to 1°50’N in latitude with 97% of the sets done inside the Seychelles EEZ. In 2019, the fishing activity was highly concentrated in the NE, NW, West and South (Ile Platte) of the Seychelles bank and in between Desroches and the Amirantes. Most of the excursions outside the EEZ were towards the Coco de Mer ridge located in the north of the EEZ (0°, 56°E). A large fraction of the sets were deployed along the slopes of the banks, at depth less than 3000m (Fig. 3).

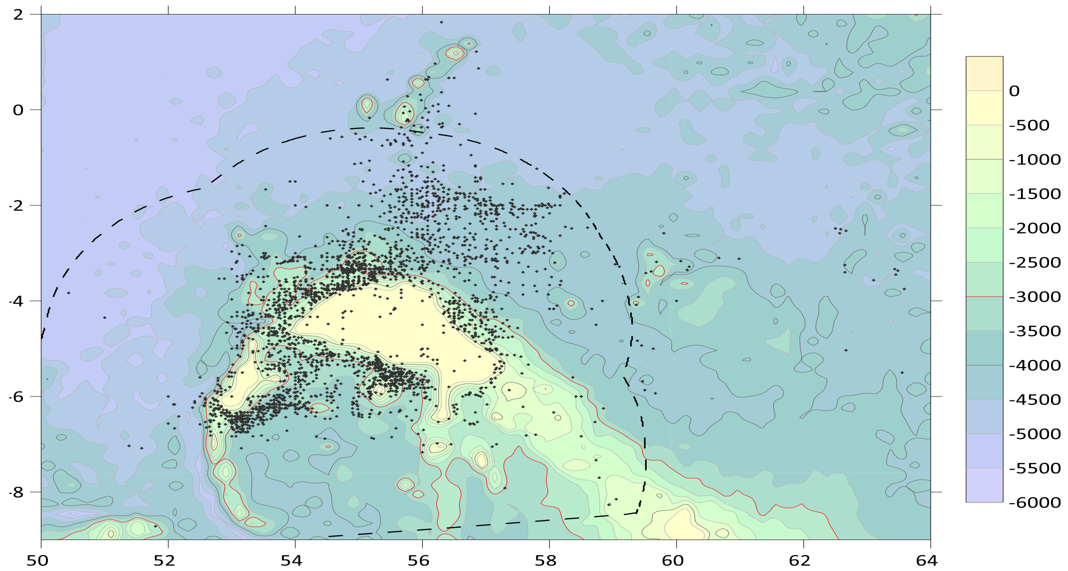


Fig. 3 Spatial distribution of semi-industrial longline sets (black dots) in 2019 plotted on the seafloor bathymetry (color shading). *The 3000 m isobath is highligted in red and the Seychelles EEZ boundary is shown in dashed line*

2 Methods

2.1 Data Collection

A survey was conducted during September to December 2021 on a sample of vessels to collect their socio-economic data with 2019 as the reference year. The targeted population was defined as the active licensed Seychelles semi-industrial longline fleet in 2019. Information was collected from vessels owners and the survey was administered through semi-structured in-person interviews. Data on owners, employment, prices and costs were obtained using a paper questionnaire (see Annex II). In most cases interviews were conducted by the local consultant, the SFA Project Lead and a representative from IRD. Interviews were held in places convenient to the vessel owners. A compilation of existing data (Table 1) from licensing registration, logbook and landing forms at the SFA was also used to supplement the interviews and conduct the analysis.

Table 1. Data collected from licensing registration, logbook and landings

List of Secondary Information		
Vessel name	Vessel length (LOA)	Sum of hooks
SZ Number	Gross Tonnage	CPUE
SFA Number	Net Tonnage	Fishing Zone authorization (COA/Coastal)
Owner Contact Number	Engine Type	Duration of fishing trips
Radio Call Signal	Horse Power	Number of trips
License validity during 2019	Certificate Type	Number of Sets
Owner names	Catch (MT)	VMS data

In order to investigate the evaluation questions the following criteria were used in the selection process of the sample: vessels with different overall length (LOA), vessels with different fishing zone authorization, vessels with different level of catches, vessels with different level of CPUE, single vessel fleet and multiple vessel fleet. The sample size had been determined by the Project Committee taking into account time and resource constraints along with the objectives of the study. Due to these constraints only a 27% coverage of the population could be achieved.

The Seychelles active licensed semi-industrial longliner fleet for 2019 consisted of 36 vessels out of which 33 vessels with sufficient data were retained as the study population for the sampling frame and the analysis. Table 2 shows the mean for some variables of the study population of the 33 selected active licensed vessels in 2019 compared to the sampled 10 vessels. There was no significant difference in the population mean and standard deviation compared to the sample for physical dimensions and the catch and effort variables.

Table 2. Comparison of variable mean for study population and sample

	Study Population		**Sample**	
Variable	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
CPUE	0.83	0.24	0.88	0.23
Catch	58.51	26.99	61.91	23.37
LOA	15.91	2.34	16.56	2.64
HP	271	102.64	306	99.47

2.2 Data analysis

2.2.1 Performance Indicators for sampled vessels

The economic analysis on the semi-industrial longline vessels operating in the Seychelles has been performed using primary data collected through the sample survey as well secondary data that were available from SFA. A set of socio-economic indicators (Table 3) were calculated for the 10 sampled vessels to evaluate their economic situation. The set of indicators selected were based on data available from the survey including data from the SFA fisheries statistical system and defined by FAO (Pinello et al 2017). The indicators described in the table have been estimated for the year 2019. To carry out standard economic analysis we calculated costs, revenue, investments for each of the sampled vessel. Traditional financial indicators such as gross cashflow, net profit and return on invested capital (ROI) were calculated to assess the economic performance of the vessels.

The depreciation, interest and invested capital were estimated based on the historical value of the purchased priced of vessels collected in the survey (IREPA et al. 2006). The capital costs (depreciation and interest) were then calculated, using depreciation schedule and interest rate.

We imputed the 23 missing values of profits of the vessels in the study population by Principal Component Analysis (PCA) method. This approach has the advantage of imputing a value close to another vessel having nearly the same characteristics of catch and effort over a large number of variables (16 variables overall). A Classification and Regression Tree (CART) approach was applied to explain the level of gross cash flow by the other set of variables.

Table 3. List of Indicators

Employment and Social	
Employment per vessel (Full time + Part time)	total number of members employed on board
Employment per vessel (Seychellois)	total number of Seychellois employed on board
Employment per vessel (non-Seychellois)	total number of non-Seychellois employed on board
Average wage of expatriate crew member	earning of expatriate crew members
Average wage of Seychellois crew member	earnings of local crew members
Cost Structure	
Personnel costs	remuneration of crews

GOP + accommodation costs	costs associated with expatriate employment
Energy costs	costs of consumed fuel and lubricants
Other operating costs	cost of purchased input linked to operational activities (fishing effort) e.g., bait, ice, food for crew
Repair and maintenance costs	costs associated with maintenance and repair of the vessel and gears
Fixed costs	expenses not dependent on the operational activities, which includes vessel insurance, fishing license, bookkeeping
Depreciation costs	annual depreciation of the vessel, engine, electronic equipment and other equipment
Opportunity costs	implicit cost incurred when an alternative investment is forgone
Economic Performance Indicators	
Revenues	value of landings measured by sale of landed products
Gross Cashflow	Revenues minus all operating costs, excluding capital cost. Represents total amount of cash that the business generates each year (operating income). An indicator of performance in the short run.
Net Profit	revenues minus all costs including capital costs
Gross Value Added	revenues minus all expenses except crew salary costs
Return on investment	percent ratio of net profit plus the opportunity cost to investment
Net Profit per vessel	average net profit per vessel
Break-even revenues	the point at which costs, and revenues are equal.

2.2.2 Analysis of characteristics and technical performance of the vessels

To identify similarities between the vessels (n=33), Hierarchical Ascending Classification (HAC, or hierarchical clustering) was conducted. The vessels are clustered into homogeneous groups through PCA and a cluster analysis. The hierarchical clustering procedure aggregates step by step the closest individuals (i.e., sharing more or less the same values for all quantitative variables). These were based off the variables in Table 4.

Table 4. Variables used in PCA and cluster analysis

VARIABLES	DEFINITION
HOOKS	Sum of Hooks for 2019
CPUE	CPUE in kg/hooks
CATCH	Catch in metric tonnes
LAND	Landed weight in 2019 (metric tonnes)
SHARE	% landed weight/catch
SETS	Number of sets in 2019
CPERSET	Catch per set (Sum of kg per set)
NTRIP	Number of trips in 2019
DTRIP	Average duration of trips (in days)
FISHDAYS	Total number of days at sea
FUEL	Fuel consumption in 2019 (in Litres)
HP	Horse Power (HP)
LENGTH	Vessel length (m)
WIDTH	Vessel width (m)
GT	Gross tonnage
BILLFISH	Share of billfish species in total catch

The study uses Data Envelopment Analysis (DEA) to measure the technical efficiency of the 33 semi-industrial fishing vessels. DEA is a non-parametric method to estimate technological and economic inefficiencies of Decision Making Unit (DMU), with regard to the production possibility frontier (Charnes et al,1978). From the perspective of evaluating the efficiency of the semi-industrial longline vessels, a DMU represents the vessel owner. The study also uses the Malmquist productivity index to measure the change of productivity for a group of 16 vessels over the period 2016-2020.

Finally, we assess the spatio- temporal fishing patterns, based on 2019 VMS data of the semi-industrial longline vessels to contribute to the appraisal of vessels' performance.

3 Results

3.1 Social Characteristics

Across the surveyed vessels an average of 6 people were employed on one vessel. Out of the ten sampled units 20% (n=2) employed an all-Seychellois crew and 80% (n=8) employed Sri Lankans. The crew on one vessel were either all Seychellois or all Sri Lankans, there were no mixed compositions of nationals within one crew.

The average salary of a skipper was estimated at SCR 110, 253 per year equivalent to an average of SCR 9,188 a month. The highest remuneration was generated by the vessels employing Seychelles nationals with an estimated monthly remuneration of SCR 14, 715 whilst the basic monthly salary per non-Seychellois crew member was SCR 7,805 equivalent to USD 556. However, owners employing foreign labour bore other employee related costs, which included accommodation rent and GOP fees. These costs amounted to an average of SCR 2,795 per foreign worker a month or SCR 33,536 a year. Only vessels employing Seychelles national adopted a share system for remuneration whereas Sri Lankans were paid a fixed monthly salary in US dollars.

From the ten vessels, 6 (60%) of the vessels were under sole ownership and 3 (30%) had multiple owners and 1(10%) was leased. On average the vessel represented only around 33% of the total income for the owner. That one vessel did not represent the main income generator for the owners, as several owners were either operating other semi-industrial longline vessels or generating income from other sectors of the fishing industry such as deep demersal fishing and/or sea cucumber. In addition, some vessel owners were also operating in other economic sectors namely tourism, retail and financial industry. The most common business type under which the vessels were owned or operated were sole trader entity (60% of the vessels) followed by company (40% of vessels).

Table 5. Social Characteristics of the vessels

Ownership		
Sole ownership	60%	(n=6)
Part Owner	30%	(n=3)
Lease	10%	(n=1)
Business Type		
Company	40%	(n=4)
Sole trader	60%	(n=6)
Engagement of owner on vessel		
Owner engaged in the vessel	10%	(n=1)
Vessel income share		
SILL vessel income to total income	33%	
Employment		
Avg crew on board one vessel	6	
Seychellois employment	20%	(n=2)

Salary	per year	per month
Salary per crew member (SCR)	110,253	9,188
Salary per Seychellois (SCR)	176,575	14,715
Salary per Sri Lankans (SCR)	93,672 (USD 6,677)	7805 (USD 556)
Expatriate related cost per Sri Lankans (SCR)	33,536	2,795

3.2 Activity

Table 6 shows some main statistics on variables describing the activity of the sample fleet. The fleet operated on average, 172 days in 2019. The least active vessel spent 117 days at sea and the most active 252 days. The average catch per vessel per year was 62 MT with the average catch per trip being 5 MT. The highest catch per vessel per year was 105 MT and the lowest catch 27.8 MT whilst 75% of the observed catch data of the ten vessels were below 72.4 MT (3rd quartile). The average effort of the fleet was 74,203 hooks and average total catch per crew member was 10.2 MT. The statistics presented below shows there were differences in fishing activity and effort amongst the vessels with a few outliers in the group.

Table 6. Main statistics on activity of the vessels in the sample

Economic Variables	Min	1st Quartile	Median	Mean	3rd Quartile	Max	Standard Deviation
Volume of Catch (MT)	27.8	45.8	58.5	**61.9**	72.4	105.0	23.4
Catch per Trip (MT)	2.3	3.8	4.6	**4.7**	5.5	7.5	1.5
Number of trips	9	11	14	**13**	16	19	3
Effort - Number of hooks	25,201	54,121	73,691	**74,203**	87,561	128,876	28,435
Number of days at Sea	117	151	170	**172**	192	252	40
CPUE	0.50	0.72	0.91	**0.88**	0.99	1.29	0.23
Landings per crew (MT)	4.6	7.2	11.1	**10.2**	12.9	15.0	3.4
Fuel Consumption per day (ltrs)	117.9	180.0	200.6	**213.7**	255.8	294.2	53.5

3.3 Economic Performance

In 2019, the average turnover for one sampled vessel was estimated at SCR 3.07 million corresponding to an average net landed weight of 47.8 MT. The total cost was SCR 2.5 million resulting in an average gross cash flow (GCF) value of SCR 719 thousand. The positive GCF indicates that vessels were able to cover their operating costs. The GCF as a percentage of revenue (gross margin) was 23% indicating normal profitability of operations. Nevertheless, the moderate ratio suggests a moderate margin of security, i.e., the vessel is vulnerable to reduction in production and or increase in costs, which may result in net losses. From the survey 70% (7) of the vessels had a positive GCF and 30% (3) incurred a loss in 2019.

After accounting for capital costs, the average net profit for one vessel is estimated at SCR 483 thousand and the ratio between net profit and revenues was 16%. Only 60% (6) of the sampled vessels achieved a net profit and 40% is estimated to have made a net loss. Without the fuel subsidy the net profit is 43% lower at SCR 175 thousand pushing half of the sampled vessels into negative profits.

The gross value added represents the turnover minus the cost paid to other supplier industries, which represents an estimate of the vessel's contribution to the country's GDP (Gross Domestic Product). The average gross value added for one vessel was SCR 1.35 million.

The average capital investment for one vessel was SCR 2.76 million, with the minimum investment being SCR 850 thousand for the purchase of a second-hand vessel and the maximum investment SCR 4 million for a new vessel. The return on investment (ROI) was 20% which showed the average vessel was efficient at using its capital investment to generate a return. The 9 vessels not being leased in the sample were purchased through loan financing, 4 being Commercial Bank loans and 5 being loans from the Development Bank of Seychelles.

Table 7. List of Economic Indicators for sampled vessels, as mean values per vessel

Average per Vessel		
Variables	**SR '000**	**as a % of revenue**
Revenues		
Value of Landings	3,067	
Costs		
Energy Cost	410	13%
Bait	638	21%
Other Operating cost	300	10%
Maintenance Cost	156	5%
Fixed Cost	214	7%
Salary	630	21%
Total Operating Cost	*2,348*	*77%*
Depreciation	197	6%
Interest	75	2%
Total Cost	*2,584*	*84%*
Economic Performance		
Gross Cash Flow	719	23%
Net Profit	484	16%
Other Information		
Net Profit without fuel subsidy	*175*	*6%*
Break-even revenues	3,105	101%
Gross Value Added	1,350	44%
ROI	20%	
Invested Capital	2,761	

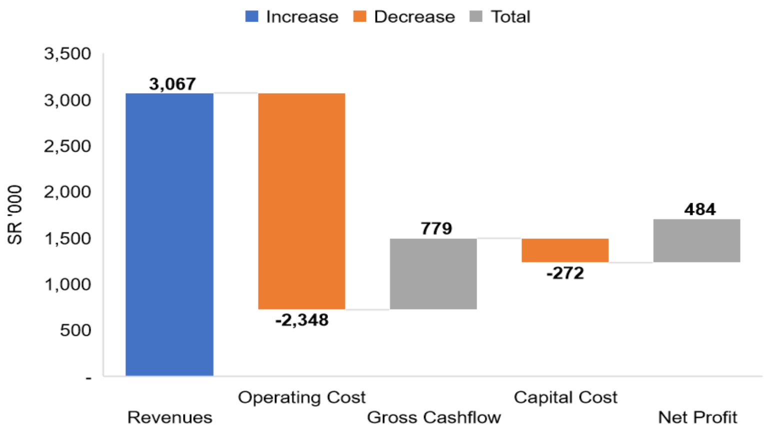


Fig. 4 Main economic performance (average per vessels)

3.4 Cost Structure

Analysis of the cost structure showed that salary, energy and bait were the most important costs for the vessels. They add up to 64% of the total cost (Fig. 5). Fuel subsidy represented 10% of the vessel's revenue but still represented an important cost for the vessel. The estimated average cost for one fishing trip was SCR 179 thousand. Fig. 6 shows the relative importance of the different type of cost per fishing trip.

Most vessel owners surveyed had contracts with processors which allowed them to procure ice and bait from the processor on credit against the guarantee of sale of their production. This input cost is offset by the processor against the sale of production after the fishing trip. This advance form of payment relieves some of the cashflow pressure and allows owners to cover the operational cost for trips.

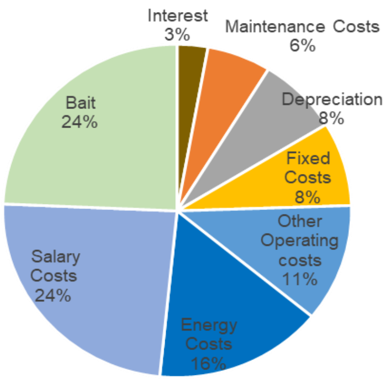


Fig. 5 Composition of total costs by semi-industrial vessel

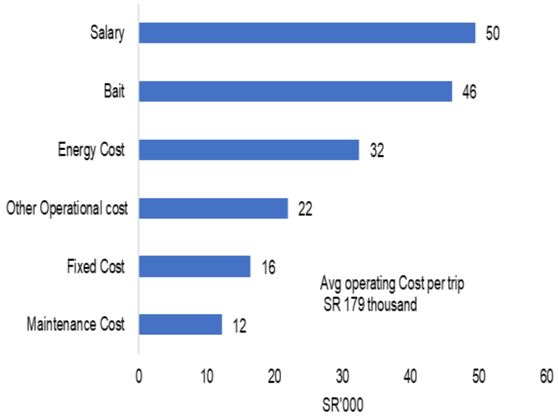


Fig. 6 Operating cost per fishing trip

3.5 Comparison of performance within the sampled semi-industrial vessels

The main statistics (

Table 8 and **Fig. 7**) shows the variability of the economic indicators within the sampled semi-industrial longline fleet, the highest variation being mostly in relation to the revenue. The highest revenue being SCR 5.3 million and the lowest 1.2 million, with 25% of the observation being below SCR 2 million and 25% above SCR 3.6 million. The difference between maximum revenue and minimum revenue being SCR 3.8 million. The variability was lower in the operating costs with the range being SCR 1.7 million. The lowest operating cost was at SCR 1.7 million and the highest at SCR 2.3 million. The highest gross cash flow was SCR 2.4 million compared to a loss of SCR 261 thousand for the lowest performing vessel.

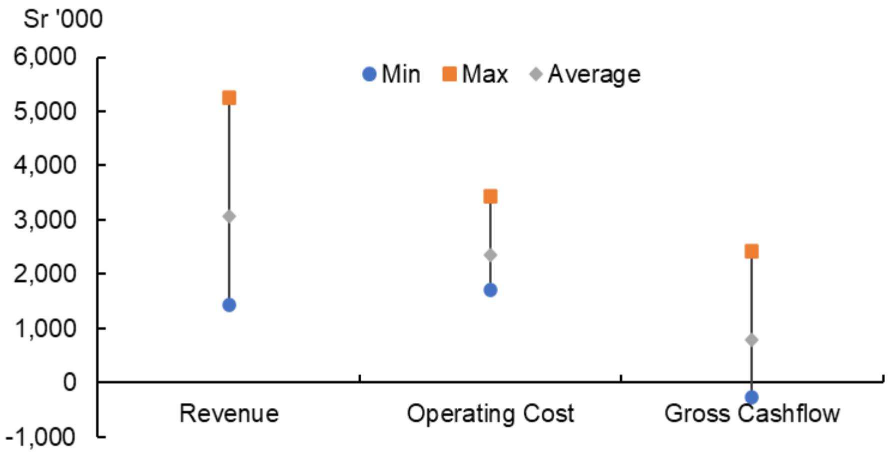


Fig. 7 Minimum, Maximum, Average value of turnover, operating cost, gross cashflow in sampled fleet

Table 8. Descriptive Statistics of the sample

Economic Variables SCR'000	**Min**	**1st Quartile**	**Median**	**3rd Quartile**	**Max**	**Standard Deviation**
Revenues	*1,441.8*	*2,099.9*	*3,064.4*	3,632.7	*5,258.2*	*1,170.4*
Costs			*80.1*			
Energy Cost	254.7	*337.7*	*375.0*	518.3	576.3	*112.2*
Bait	291.1	*411.8*	*697.6*	700.0	1,216.0	*257.9*
Other Operating cost	139.4	*227.2*	*240.5*	337.6	722.0	*156.9*
Maintenance Cost	75.0	*127.5*	*156.1*	197.5	228.6	*48.3*
Fixed Cost	56.0	*231.3*	*239.7*	260.5	284.0	*76.5*
Salary	530.2	*541.0*	*568.3*	635.7	1,109.6	*165.0*
Total Operating Cost	*1,703.1*	*2,123.7*	*2,275.2*	2,515.7	*3,443.1*	*488.2*
Depreciation	0.0	*146.3*	*205.2*	293.8	310.7	*100.9*
Interest	0.0	*56.5*	*76.3*	108.7	120.0	*38.0*
Total Cost	*1794.7*	*2,305.8*	*2,464.5*	2,832.0	*3,660.6*	*531.9*
Economic Performances						
Gross Cash Flow	*-261.4*	*- 69.1*	*714.1*	1,179.5	*2,424.6*	*829.3*
Net Profit	*-494.1*	*- 294.1*	*446.9*	931.9	*2,013.1*	*813.7*

Examination of the relationship between several factors and the gross cash flow indicates that physical productivity was more a determinant of profitability compared to other economic factors or other characteristics of the vessel. Fig. 8 shows scatterplots of the relationship of gross cashflow to some economic factors, catch and effort indicators and other vessel characteristics for the ten vessels.

The scatterplot of the relationship between gross cash flow and volume of landings showed a strong positive correlation (r= 0.942) whereas number of days at sea (r=0.588) and operational costs(r=0.539) are moderately correlated to the gross cash flow. CPUE and age of vessel had very low correlation to the economic performance of the vessels. The average price obtained by the vessels did not explain the differences in economic performance between the vessels which was most likely due to the prices being fairly fixed and there being little variations in the type of species caught between the different vessels.

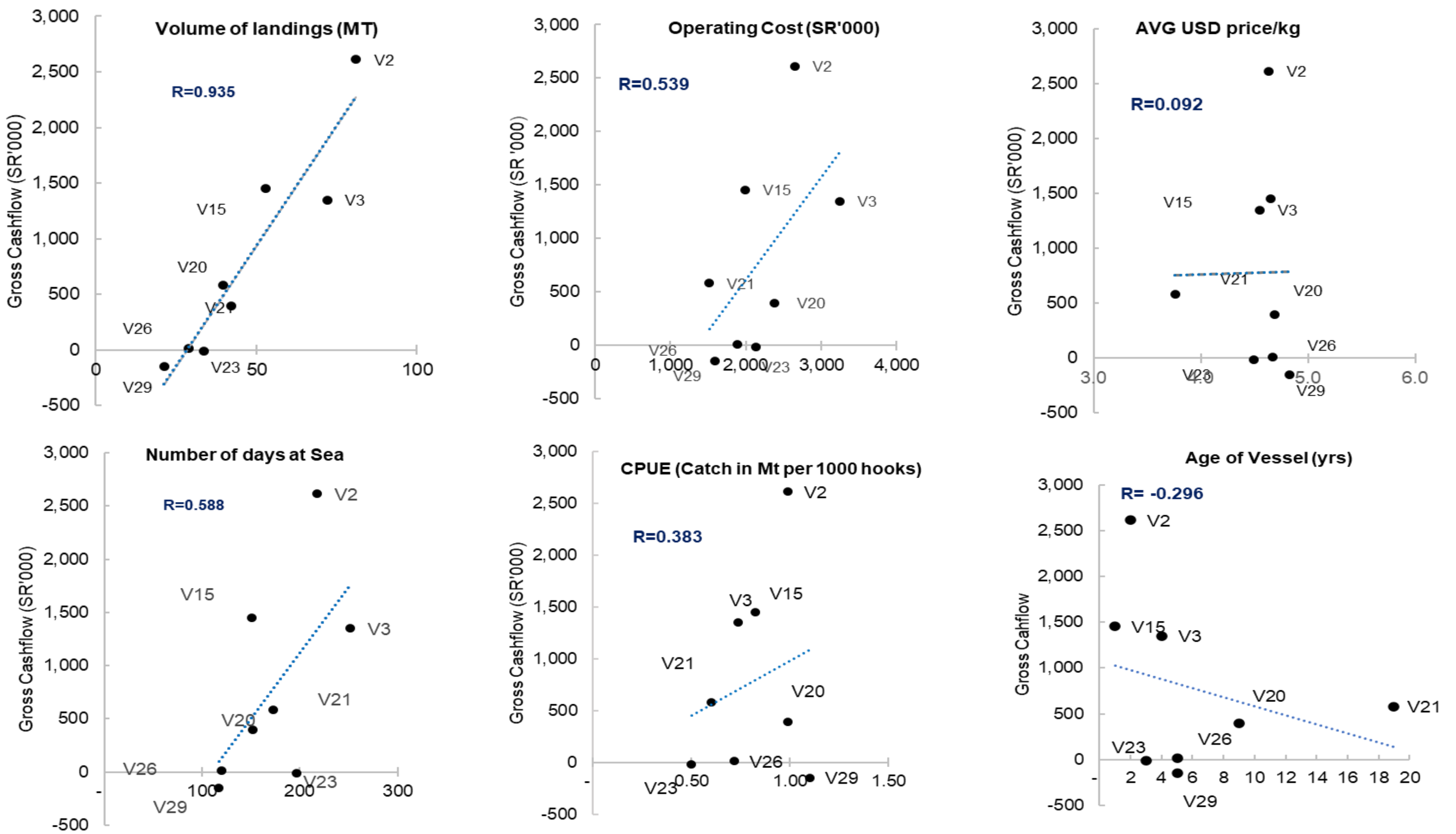


Fig. 8 Scatter Plots of Gross Cashflow /against different Productivity, economic variable and vessel characteristic

3.6 First Sale (ex-vessel)

Data was collected in the survey on the first sale point for the production, which showed that 97% of the production of the 10 sampled vessels was sold to processors. This concurred with the landings data obtained from SFA on the total active fleet in 2019: 97.2% of the first sales occurred through transaction with the processor/exporter: 1.6% is sold to wholesalers/retailers, 0.3% to restaurants (Fig. 9).

The semi-industrial longline vessels have little or no direct sales to final consumers. The production of the fishery is almost exclusively destined for the export market. The semi-industrial fisheries production local value-chains are mostly very short and involve the fishing and processing/exporting segment. There is a degree of vertical integration in the value chain with some processors owning several of the fishing vessels.

The price at which the production is sold to processors is fixed by the processors, according to species and grades in USD. Fish grading is evaluated by the processor's grader and the fishing vessels are mostly price takers. The landing data for all active semi-industrial longline vessels (36) showed that in 2019 the total fleet landing of 1,535 MT (net weight) [1] was sold to three main processors.

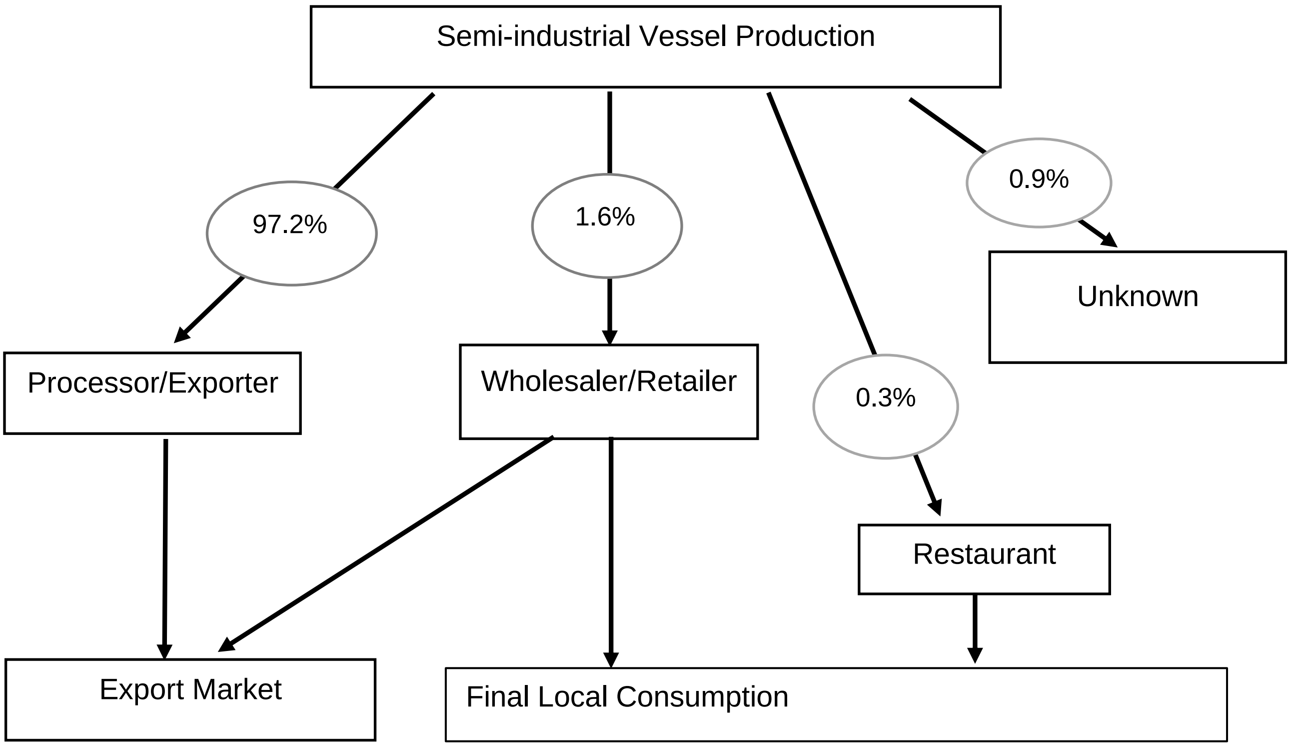


Fig. 9 First Sale of SILL Vessel Production

The export data on fresh and frozen tuna for exporters who reported to SFA in 2019 indicates that the export market of fresh and frozen tuna was made up of three big exporters matching same processors observed in the landing data, to which the production of the semi-industrial longliners were sold to, and two relatively smaller exporters. The value of fresh and frozen tuna exported in 2019 according to the SFA dataset amounted to SCR 318 million equivalent to USD 22.72 million for a net weight of 1,848 MT. The data (Fig. 10) shows very little processing is done for exported fresh and frozen tuna with only 20%

[1] The landing weight after fish has been processed onboard (e.g., headed and gutted or gilled)

exported as loins, whilst 80% is exported whole (headed & gutted) The proportion of fresh or chilled tuna was 93% and 7% was frozen (Fig. 11).

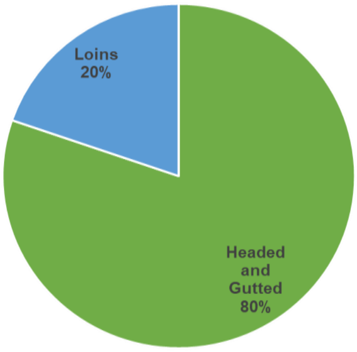


Fig. 10 Process done to exported fresh and frozen tuna (SFA data 2019)

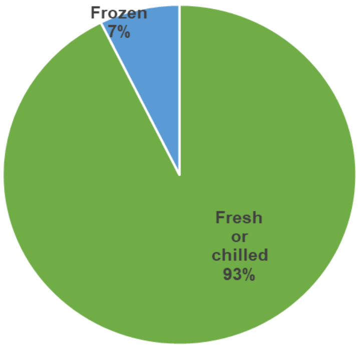


Fig. 11 Proportion of fresh and frozen tuna exports (SFA data 2019)

3.7 Sensitivity analysis

Taking the average values of the sampled vessels as the scenario of reference, a vessel would land 46 MT (net weight) at a price of SCR 64 and would face various costs to earn a gross cashflow of SCR 0.79 million. From the sample data, two extreme (pessimistic and optimistic) scenarios can be inspired by the vessel with the lowest landing (21.3 MT) and the vessel with the highest net landing weight (81MT). As far as possible, we used the accounting results of both vessels, except when the maximum value was smaller than the reference case (e.g., for Crew costs) or for prices (we selected the minimum and maximum prices of the sample). For the latter, we assume that the price of fish can vary between SCR 53 (USD 3.8) and SCR 68 (USD 4.84) per kg landings.

Looking at the gross cashflow of the extreme cases, we can observe that the fishing activity of semi-industrial longliners can be very profitable (> SCR 3.5 M), or unprofitable (SCR - 0.382 M) if the determining factors of the net profits turn wrong. The sensitivity analysis looks at the changes of gross cashflow after a percent change of each input variable when other inputs remain constant.

The tornado chart Fig. 12 indicates that the most influential factor of profits is the quantity, far ahead of any other factor. With net landings falling from 81 to 21 MT, the gross cash flow would become negative and plummet from SCR 2.9 M down to -0.9 M (see Table 9). What matters more for vessel owners is what the vessel can catch and sell. To a lesser extent, bait costs (fluctuating between 291 thousand to SCR 1.2 million) can degrade the profit if they are too high: gross cashflow would be between SCR 84 thousand and 1 million. For other operating cost (food, ice, etc.) the swing is smaller with fluctuations from SCR 164 thousand to SCR 787 thousand resulting in a gross cashflow between SCR 217 thousand to SCR 840 thousand. The price has a small influence too: oscillating between SCR 53 (3.8 USD) and SCR 68 (USD 4.8) per kg would affect the gross cashflow from SCR 86 thousand to 776 thousand.

Table 9. Results of the sensitivity analysis

	Corresponding Input Value			Output Value				Percent
Input Variable	Low Output	Base Case	High Output	Low	Base	High	Swing	Swing^2
Volume landings (t)	21.3	46.1	80.8	- 958.2	663.0	2,927.5	3,885.7	87.2%
Bait cost	1,216.0	637.5	291.1	84.5	663.0	1,009.5	924.9	4.9%
Price (Sr/kg)	52.76	64.10	67.71	86.0	663.0	775.9	690.0	2.7%
Other Operational cost	787.0	299.9	164.7	217.8	663.0	840.2	622.4	2.2%
Crew Share - Salary	1,109.6	630.4	530.2	183.8	663.0	763.3	579.4	1.9%
Energy Cost	518.5	410.4	213.7	513.1	663.0	817.9	304.8	0.5%
Fixed Cost	284.0	213.9	56.0	593.0	663.0	821.0	228.0	0.3%
Maintenance Cost	228.6	155.6	75.0	590.0	663.0	743.6	153.6	0.1%

Another way of looking at the sensitivity of the gross cashflow to the input variables is shown in the spider chart shown in Fig. 13, The swing of the output variable (gross cashflow) is given along the vertical Y-axis, and the slope of each curve indicates the degree of sensitivity. For instance, the slope of fixed costs is negative but very small, showing that the gross cashflow is poorly sensitive to this input. Conversely, the slope of the quantity input is steep, and the swing is high between SCR -0.9 and +2.9 million indicating that net profit is highly sensitive to this input.

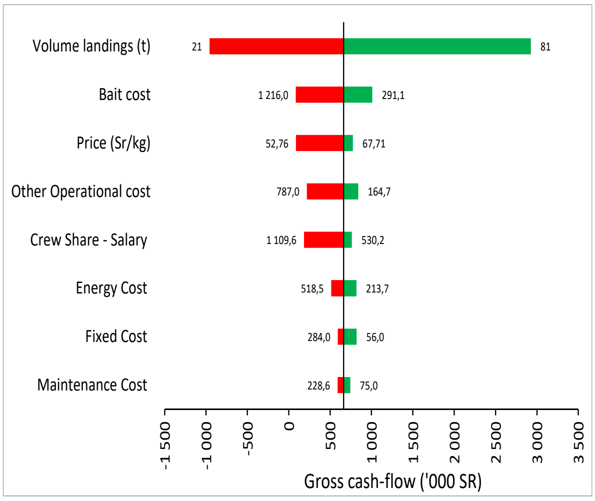


Fig. 12 Tornado Chart of sensitivity analysis of gross cashflow to several input variations

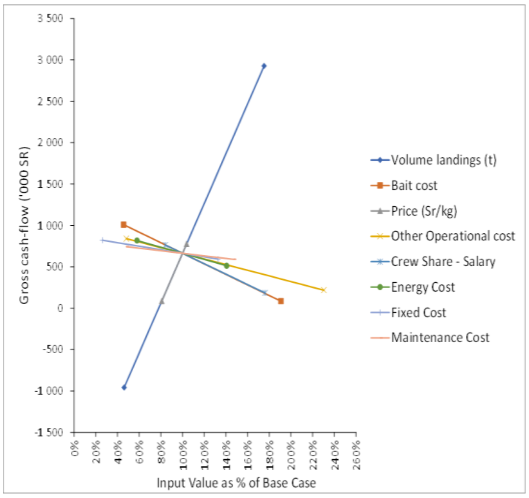


Fig. 13 Spider Chart of sensitivity analysis of gross cashflow to several input variation

We conducted the sensitivity analysis allowing a higher degree of variability in prices from SCR 50 (USD 3.5) to SCR 80 (USD 5.7) per kg landings. The results are shown in Fig. 14 . Any increase of the price per kg by SCR 5 (USD 0.37) would result in a SCR 230,700 increase of gross cashflow. In other words, an increase by SCR 15 of the price (approximately USD 1) would increase the cashflow by SCR 692,100.

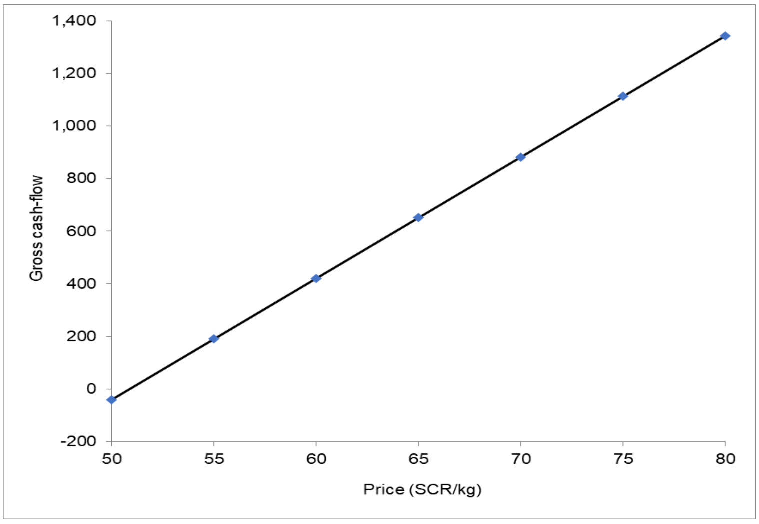


Fig. 14 Spider Chart of sensitivity analysis of gross cashflow to price variation

3.8 Profit prediction model from a regression tree and random forest model

One of the objectives in the study was to better understand the drivers of profitability. From the survey, we obtained the gross cashflow of the sample of 10 vessels, which are introduced in the full database of 33 vessels. We use the PCA method to impute the 23 missing values of gross cashflow. The final distribution of gross cashflow can be seen on the Fig. 15 below:

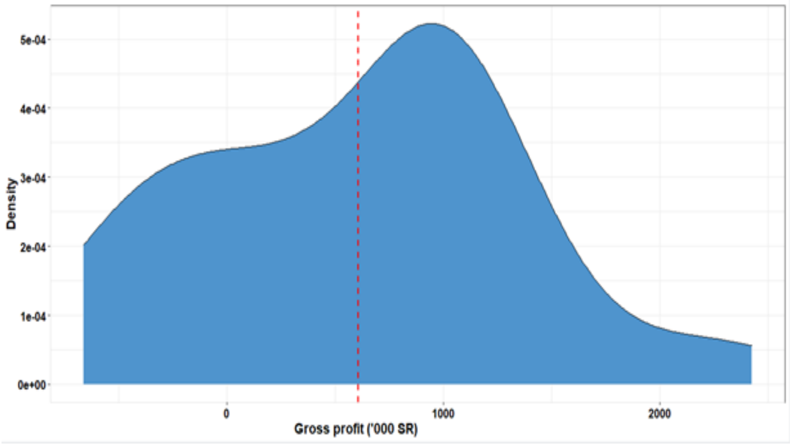


Fig. 15 Kernel density of the gross profit distribution within the fleet *(Dashed red line= median)*

The mean for the 33 vessels is SCR 607,000, and the median is SCR 734,000 the distribution being skewed to the right. About 1/3 of the fleet have comfortable positive profits, while the remaining third is closer to the breakeven threshold, some of them having even negative records. Some 9 vessels (27%) out of 33 had negative gross cashflow. The minimum gross cashflow value was SCR -660,000 and the maximum reach SCR 2.4 million.

A Classification and Regression Tree (CART) approach was applied to explain the level of gross profit by the other set of variables in the database (Breiman et al. 1994). This approach allows by statistical means to choose predictors. A condition on a variable (threshold) is given at each node of the tree to split the sample into sub-samples having the most similar profit values (i.e., minimizing the variance within the two sub-samples). With a conditional inference tree (Burger 2018), it is easy to understand that the landings is by far the most influential variable for profits: If the annual net landings is smaller than 34 MT, the profit is likely to be close to null or negative, and this is the case for 10 vessels of the fleet (average GCF of SCR -297,100). If the net landings stand between 35 MT and 53 MT, then the GCF is between SCR 500,000 and 1,000,000 (9 vessels are concerned, for an average GCF of SCR 703,778), and if the vessel can land more than 53 MT, then profits raise to SCR 1 million and more (14 vessels, for an average GCF of SCR 1.2 million).

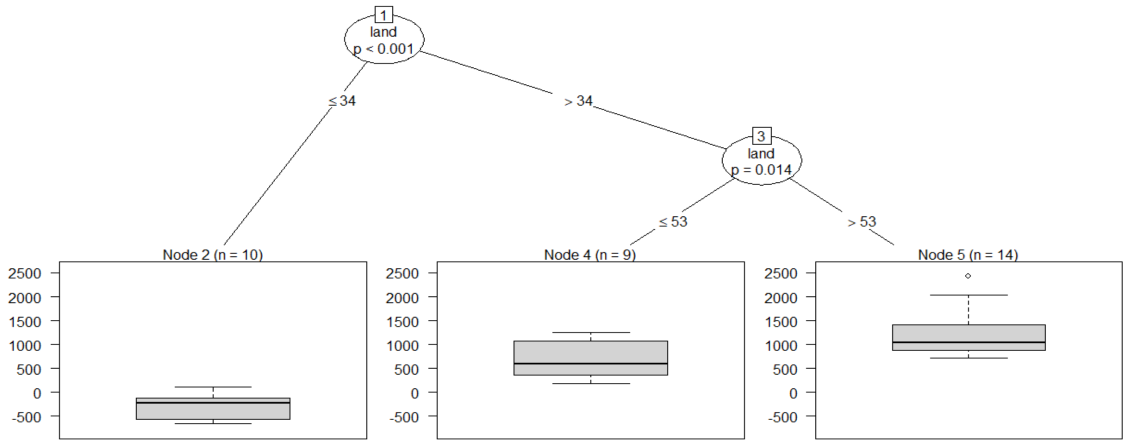


Fig. 16 Conditional Inference Tree

The optimal tree (Fig. 17) shows if the net landings are smaller than 34.5 MT, then the vessel gross cashflow is likely to be negative or very low (between SCR -576,000 and 109,000). Between 34.5 and 76.5 MT of landings, a proportion of billfish greater than 12.6% might help and a number of fishing sets exceeding 85 per year can help to increase the profits between SCR 954,000 and SCR 1.4 million. Finally, if landings exceed 76.5 MT, then the gross cashflow is likely to be greater than SCR 2 million whatever the level of other variables.

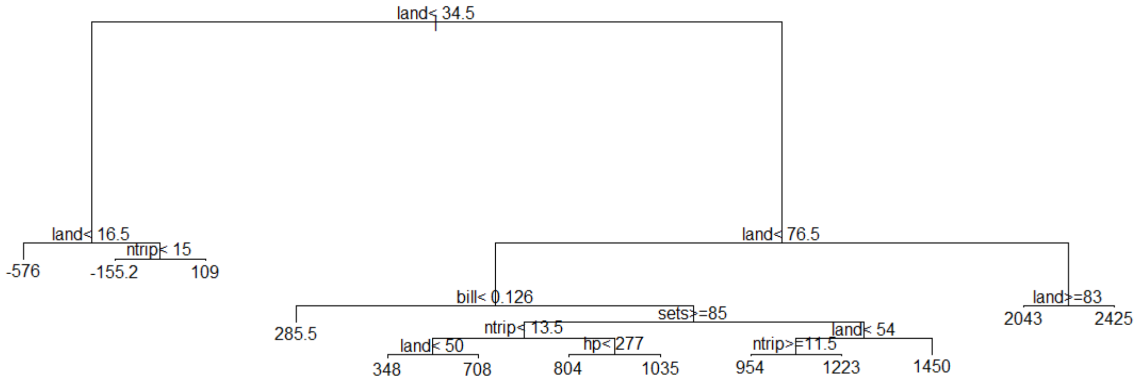


Fig. 17 Optimal tree

Because results are unstable with a single tree, we used a Random Forest (RF) approach, where a great number of trees is randomly constructed by disturbing the selection of individuals and variables (various bootstrap "Out-Of-Bag" -OOB- methods can be used, i.e., a selection of observations out of a bootstrap sample to test the prediction of the model on the other observations). The trees are then aggregated to give the final prediction, rather than choosing one of them. Using such a RF method with 200 random trees, the prediction score of the test sample now reaches 0.49, which is better than the initial R^2=0.26 with a single tree but remains below the Ridge model (0.67). However, it allows to rank the variables by their degree of importance in the model by their mean square error (MSE) when permuting the values of the j^{th} variable in a tree regression built on a bootstrap sample applied to the out-of-bag (OOB) sample (i.e., observations not included in the bootstrap sample). The variables increasing the most the of MSE are considered more influential. For instance, this is the case of the following variables in Fig. 18.

We can see that landings represent by far the best predictor of gross cashflow. Then far behind comes a group of 4 variables (number of trips, % of billfish, number of fishing days and fuel consumption). In other words, a higher level of effort will result in a higher level of catch and therefore higher gross cashflow for the vessel.

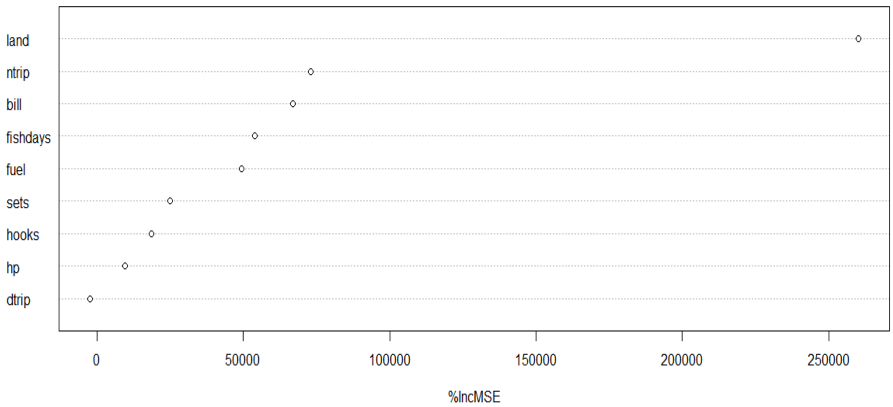


Fig. 18 The variable importance (VI) minimizing the sum of OOB errors for all trees of the RF

3.9 Principal Component Analysis (PCA) and cluster analysis

A PCA aims at synthesizing and transforming a dataset into a factorial map describing the main correlations between quantitative variables. In Fig. 19, axis 1 captures a catch-effort effect: the number of hooks, sets and trips per year, along with the level of catch and landings (catch effort dimension) is the most powerful factor of distance between vessels. The second axis captures the productivity which is independent from the level of catch: the level of CPUE and catch per set divides the sample of vessels. The third component captures the size of vessels, with the high correlation of length, and to a lesser extent width and horsepower. The fourth one is only represented by the share of landings out of the catch, and the fifth one by the gross tonnage of vessels.

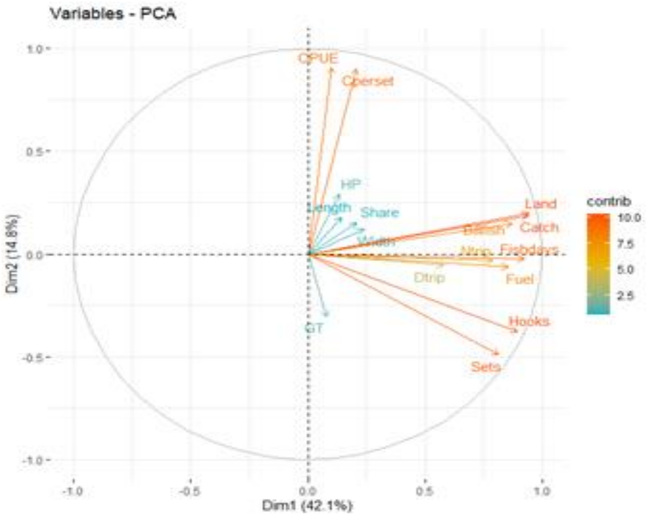


Fig. 19 PCA graph of variables and individuals along the first two dimensions

On Fig. 19, the arrowheads indicate the coordinates (or correlations) of the variables along (with) the axis (Table 2). Five variables (Hooks, Catch, Land, Sets, and Fuel) are highly correlated with the first dimension (hence between each other too) showing that vessels first differentiate between each other by the level of catch and effort (number of hooks and number of sets, catch and landing quantity, share of billfish and fuel consumption). The yield variables (catch per hook and catch per set) are rather correlated with the second factor, indicating a relative independence of CPUE with the first factor. Physical characteristics (vessel length and width) are not correlated with either first two factors, but rather correlated with the third component. In other words, catching a lot of fish does not depend on the vessel size or power, but rather on the level of fishing effort measured in terms of number of hooks, number of sets and the fuel used by the vessel.

Hierarchical clustering was used to illustrate the similarities and differences between 33 semi-industrial vessels operating in 2019. These were based on the quantitative variables described in Table 4 in Section 2.2. The results identify three main clusters (Fig. 20): a fleet with of 7 vessels with lower-than-average performance (Cluster 1), a fleet of 18 active vessels with average or slightly above average performance, and a third cluster of 8 highly performing vessels with high CPUE.

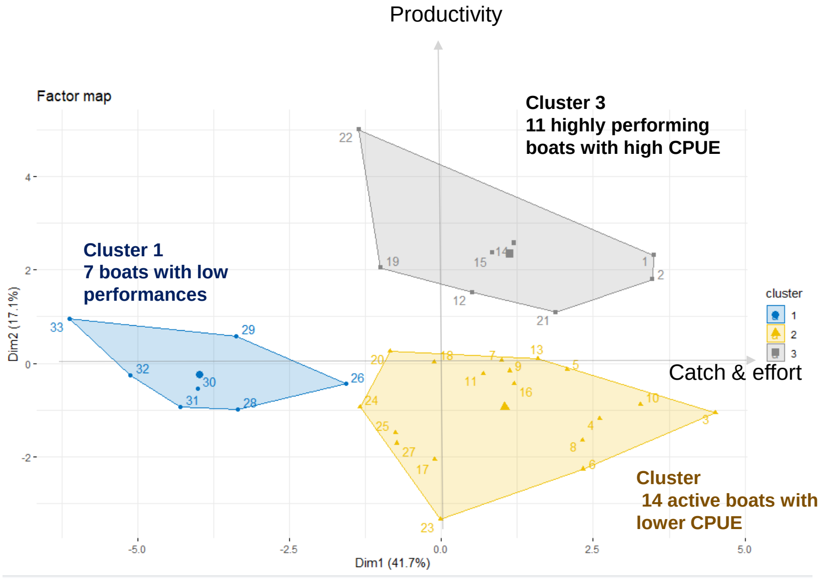


Fig. 20 Factor map with the 3 clusters

The clusters can be described by the variables of the dataset (Table 10). The first cluster gathers 7 vessels which show lower than average performances: the average catch per vessel for this cluster is 18 tonnes whereas it amounts to 59 tonnes per vessel for the whole fleet. The average number of hooks is 68% lower than the study population mean, the number of sets is 62% lower, the number of trips is 50% lower, the number of fishing days is 61% lower, the fuel consumption 55% lower, etc. Interestingly, billfish catches represent no more than 5% of the catch in this cluster (against 22% on average in the whole sample). The second cluster pools 18 active vessels which values are not significantly different from the study population mean in terms of catch (15% lower than average) and effort (-12% of sets, -% of hooks, +18% of trips). The vessels in this second cluster is only significantly different in terms of engine power being less powerful (251 HP vs 286HP) than the rest of the fleet. Finally, the third cluster encompasses the 8 most highly performing vessels with higher average catch (+34%) and higher number of sets (+31%) and higher number of hook (+33%). It is worth reporting that vessels included in this third cluster have more powerful engines (305 HP in this cluster against 286 HP on average) and longer size (18 m against 16 m) than others. In this third cluster too, billfish is over-represented (34%) in the catch compared to the whole fleet (22%), and particularly the vessels of cluster 1.

Table 10. Description of the three clusters by their most significant variables

	Mean Cluster 1	Mean Cluster 2	Mean Cluster 3	**Study pop. mean**
Avg trip duration (days)	12	14	17	**15**
Share Billfish	5%	18%	32%	**22%**
Nb of Sets	32	75	111	**85**
Fuel (L)	13,835	29727	38258	**31,012**
Nb of Hooks	23,638	65395	99079	**74,408**
Catch (t)	18	50	79	**59**
Nb of trips	6	13	13	**12**
Landings	13	38	61	**45**
Days at sea	67	165	219	**174**
Horse Power	290	251	305	**286**

Note: Values in red are not significantly different from the study pop. mean in the cluster (e.g., Vessels in Cluster 2 are only different from others because of the horsepower value).

3.10 Technical Efficiency

A DEA approach was used to look at the technical efficiency of the semi-industrial fleet (33 vessels) in 2019. In Fig. 21 we illustrate the case of one input (the number of days at sea) and one output (the catch level). We can see that the constant return-to-scale (CRS) efficiency frontier is passing through vessel 9. Despite their very small activity, vessels 32 and 33 are close to the frontier. Other vessels look also very efficient, like vessels 2, 7, 11, 30. Under a variable return-to-scale (VRS) regime, vessels 1 and 2 would also represent the frontier because vessel 3 could improve its level of output with the same amount of inputs across the VRS vessel1-2 segment. Note that the correlation is high between the fishing effort and catches, hence a low number of vessels which are far from the efficiency frontier. We can only observe that some vessels are more active than others, but not necessarily more efficient. However, we can see that vessel 23 to 28 or 10, 13, 14 are farther than others from the frontier.

We can also see how far from the frontier are vessels by using more than one input. For instance, with 2 inputs (fishing days and number of sets), we obtain the following isoquant curve in Fig. 22: The vessels 2, 9 and 22 are all located on the efficiency frontiers, minimizing the amount of both inputs to produce a certain quantity of catch (or maximizing the output with respect to a certain level of both inputs). Vessels (9, 11, 12, 15…) also fetch very high efficiency scores with respect to these two inputs. Other scores can be easily estimated by combining more than two inputs.

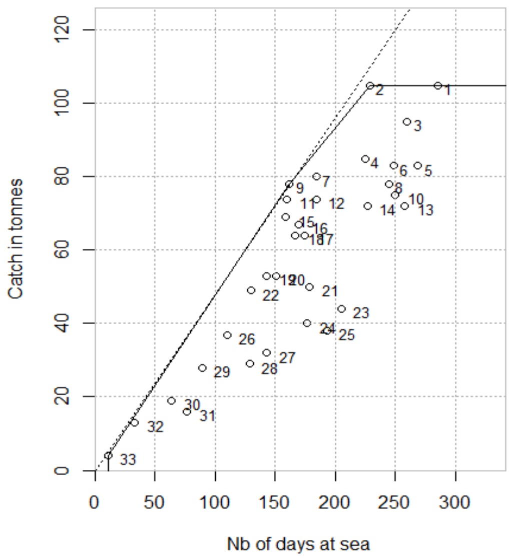


Fig. 21 The catch effort relation with CRS and VRS efficiency frontiers

(CRS frontier = dotted line, VRS frontier = solid line)

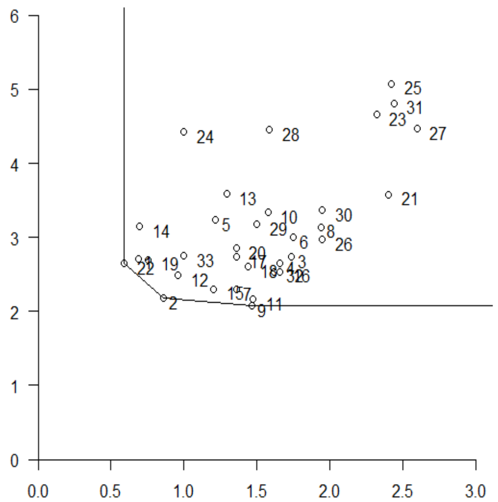


Fig. 22 Isoquant curve with 2 inputs

(number of sets per unit of catch on the X-axis, number of fishing days per unit of catch on the Y-axis).

In the following table, we estimated the efficiency scores for various inputs separately and for physical or fishing effort inputs altogether under a CRS regime. The most performing vessel of the fleet seems to be vessel 22, although not so much w.r.t. the physical inputs (this vessel has a very powerful engine, of 500 HP, and is not fishing accordingly compared to its peers). However, this vessel is on the CRS efficiency frontier or so for 2 inputs separately and for the effort inputs jointly. Vessels 1,2 and 3 are also highly efficient vessels. At least 16 vessels (i.e., half of the fleet) have a score greater than 0.90 on the 7th column ("All inputs") mixing 6 fishing effort inputs. On the other side, the bottom list from vessel 23, but also a few others (10, 21, 23, 26, etc.), are quite far from the efficiency frontier and could reduce their fishing effort substantially, by 30% to 60% (days at sea, number of hooks, number of sets…) for the same output tonnage if they were more efficient. Results are very different when considering physical inputs. Only 5 vessels make the most of these inputs, all others having huge margins of progress to reach the same efficiency. However, we saw from the PCA outcomes that the vessel size was not the most prominent factor of differentiation between vessels, and therefore the physical features should not be paid too much attention compared to the level of fishing effort.

Table 11. Efficiency scores with regard to the catch output (CRS input-oriented approach)

Id	Days at sea	Hooks	Nb of sets	Physical inputs	Fishing effort	All inputs	HAC Cluster
1	0,77	**0,95**	0,86	**1,00**	**1,00**	1,00	3
2	**0,95**	0,76	0,69	**0,99**	**1,00**	1,00	3
3	0,76	0,57	0,34	**1,00**	**1,00**	1,00	2
4	0,78	0,51	0,36	**0,97**	0,85	1,00	2
5	0,64	0,67	0,49	0,79	**0,91**	0,91	2
6	0,69	0,54	0,34	**1,00**	**0,90**	1,00	2
7	**0,90**	0,75	0,43	0,76	**1,00**	1,00	2
8	0,66	0,46	0,31	0,75	0,87	0,87	2
9	**1,00**	0,67	0,40	0,74	**1,00**	1,00	2
10	0,62	0,49	0,38	0,70	0,71	0,74	2
11	**0,96**	0,67	0,40	0,70	**0,99**	0,99	2
12	0,84	**1,00**	0,62	0,70	**1,00**	1,00	3
13	0,58	0,71	0,46	0,69	0,84	0,84	2
14	0,66	0,89	0,85	0,73	**0,96**	0,96	3
15	**0,90**	0,64	0,49	0,62	**0,93**	0,93	3
16	0,82	0,46	0,36	0,61	0,83	0,83	2
17	0,76	0,57	0,44	0,81	0,83	0,97	2
18	0,80	0,76	0,41	0,61	**0,98**	0,98	2
19	0,77	**0,93**	0,78	0,50	**0,96**	0,97	3
20	0,73	0,77	0,44	0,50	0,84	0,84	2
21	0,58	0,47	0,25	0,43	0,71	0,71	3
22	0,78	**0,99**	**1,00**	0,44	**1,00**	1,00	3
23	0,45	0,38	0,26	0,56	0,62	0,65	2
24	0,47	0,59	0,59	0,52	0,65	0,71	2
25	0,41	0,44	0,24	0,36	0,55	0,55	2
26	0,70	0,55	0,30	0,35	0,73	0,73	1
27	0,46	0,28	0,23	0,30	0,59	0,59	2
28	0,47	0,65	0,37	0,64	0,66	0,68	1
29	0,65	0,86	0,39	0,27	0,86	0,86	1
30	0,62	0,50	0,30	0,18	0,65	0,65	1
31	0,43	0,43	0,24	0,15	0,52	0,52	1
32	0,82	0,50	0,37	0,12	0,83	0,83	1
33	0,76	0,77	0,59	0,04	0,87	0,87	1

Note: Physical inputs in the column 6 are the length, width, horse power and gross tonnage. The fishing effort inputs in column 7 include the number of days at sea, number of hooks, number of sets, number of trips, trip duration, fuel consumption. Column 8 goes for all inputs. Scores > 0.90 are green, yellow between 0.75 and < 0.90, pink between 0.60 and < 0.75, and red below 0.60. Column 9 recalls the Cluster number to which the vessel belongs.

Interestingly, some vessels are experiencing better efficiency scores on some inputs relatively to others. For instance, vessel 19 has a 22%-23% margin of progress regarding the catch per hook or per set, or even more concerning its size, but is rather performing well when considering the yield per day at sea or to the overall use of fishing effort. Another illustration: vessel 7, 11, 9, 5 have good yields per hook and with fishing effort in general but could do much better with regard to the number of sets or the days at sea.

With the last column reminding the cluster of affiliation, we can check the correspondence between the DEA method and PCA/Clustering approach. Not surprisingly, the highest efficiency scores are found in clusters 2 and 3, particularly in cluster 3, i.e., where the most productive vessels are included. However, some discrepancies can be reported for specific vessels, such as vessel 21, which belongs to cluster 3 in spite of moderate efficiency scores. Similarly, vessel 25 and vessel 27 could well be associated to cluster 1 instead of cluster 2 due to their poorly efficient performances.

The inefficiencies can come from a pure inefficiency effect (i.e., for those vessels using less efficiently their inputs), or to a scale efficiency problem (operating too far from the optimal scale size). We can observe the problem of scale efficiency through the gap between CRS and VRS efficiency scores for all inputs simultaneously. The same top 8 vessels show no difference between their CRS and VRS scores. However, scores become different for other vessels, which do not operate at their optimal size, bearing scale inefficiencies which can come from oversized or undersized vessels.

We used Super-efficiency methods to rank and compare efficient units. Super-efficiency methods create scores greater than one: the effectiveness of each vessel is considered rather than the cross-comparison of the vessels (Noora et al. 2011). This approach allows for ranking between vessels. Table 12 gives a better picture of which vessel is making the most of its own resources (physical inputs, fishing effort, fuel consumption, etc.). Vessel 22 ranks lower than in previous rankings, and the vessel 6 becomes leader of the fleet with respect to its 2019 performances.

Table 12. Super-efficiency scores for al inputs (input-oriented CRS scores)

Ranking	**Vessel ID**	**Super-efficiency input-oriented CRS scores**			
1	V6	1.402	**18**	V33	0.867
2	V1	1.341	**19**	V29	0.857
3	V2	1.162	**20**	V13	0.841
4	V22	1.159	**21**	V20	0.841
5	V12	1.115	**22**	V16	0.833
6	V7	1.087	**23**	V32	0.827
7	V9	1.056	**24**	V10	0.739
8	V3	1.034	**25**	V26	0.729
9	V4	1.005	**26**	V21	0.712
10	V11	0.994	**27**	V24	0.707
11	V18	0.981	**28**	V28	0.681
12	V17	0.974	**29**	V30	0.652
13	V19	0.970	**30**	V23	0.651
14	V14	0.962	**31**	V27	0.586
15	V15	0.927	**32**	V25	0.549
16	V5	0.914	**33**	V31	0.521
17	V8	0.874			

Analysis on the potential input reductions (or further increase in output) through slack searching procedure showed that no further improvement can be achieved by further reducing the amount of the input for any vessel. However, when it comes to the physical inputs altogether, the answer to the logical test is ‘TRUE’ for 14 vessels: some physical inputs could be further reduced for these vessels to achieve the same output level. It is even more the case when it relates to effort inputs: only 7 vessels reach a maximum efficiency for all these inputs but saving gains could be reached for 26 other vessels.

3.11 Revenue Efficiency

The DEA method is used to calculate revenue efficiency to see whether the differences observed in terms of technical efficiency are also observable when looking at economic performances (i.e. allocative efficiency). We use the example of one input (number of fishing days) producing two output species (yellowfin tuna and swordfish). The method is applied to 9 vessels from the survey sample. Using the revenue information, it is possible to calculate allocative efficiencies together with technical efficiencies. The revenue efficiency (RE) is calculated by taking the gap between the observed revenue and the theoretical maximum revenue.Table 13 shows the optimal revenue is for Vessel 15 with SCR 978 thousand. Therefore, we can calculate the Revenue Efficiency (RE) as $R_{observed}/ R^*_{max}$, and then the Allocative Efficiency (AE) = RE/TE.

Table 13. Optimal revenue, RE, TE, AE scores for 9 vessels

id	R*	Robs	RE	TE	AE
V21	978.06	435.16	0.4449	1.0000	0.4449
V15	978.06	978.06	1.0000	1.0000	1.0000
V26	978.06	607.67	0.6213	0.6219	0.9991
V3	978.06	661.99	0.6768	0.8453	0.8007
V29	978.06	577.68	0.5906	0.5931	0.9958
V2	978.06	943.86	0.9650	0.9662	0.9988
V18	978.06	961.01	0.9826	0.9872	0.9953
V12	978.06	956.99	0.9785	0.9785	1.0000
V23	978.06	426.28	0.4358	0.5800	0.7514

In Fig. 23 we see the iso-revenue curve (orange line) given by V15 (combination of yellowfin per fishing day on X-axis and swordfish per fishing day on Y-axis that gives 978.96). Taking the example of vessel 21, it is on the TE frontier, so TE =1 but it has a Revenue Efficiency of 0.44, thus coming from AE = 0.44 only because RE = TE*AE. In other words, this vessel does not produce the "good" output. We can see that it harvests much more swordfish than vessel 15 and less yellowfin but the "relative prices" give in advantage to yellowfin. Consequently, the vessel should produce more yellowfin and less swordfish (like vessel 15). Vessels 12 and 18 have almost a good AE but they are not technically efficient enough and the other vessels are both far from the technical efficiency frontier and the revenue efficiency frontier.

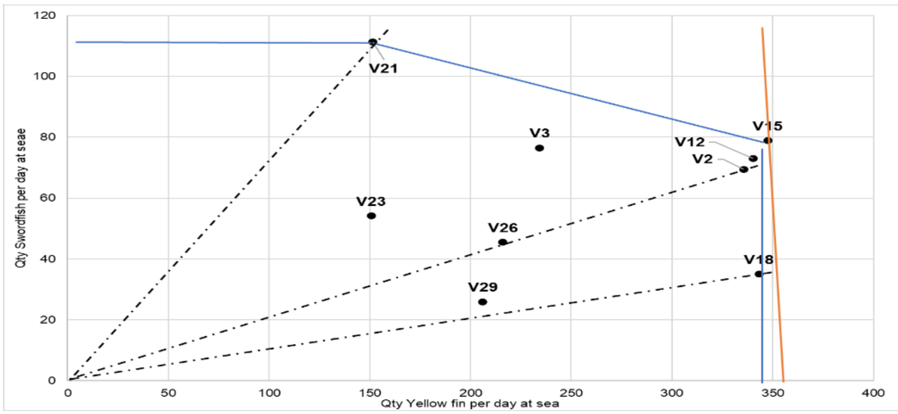


Fig. 23 Technical and allocative efficiency using one input (Number of fishing days for two outputs, SWO and YFT) *(the orange line represents the maximum revenue frontier and blue line the technical efficiency frontier)*

3.12 How has productivity changed in the course of time?

Technology may change from year to year for fishing vessels by the introduction of new electronic equipment or more productive fishing gears. Consequently, the efficiency frontier may shift, and some vessels can move faster than others, becoming more efficient or adopting more easily the technical change. The Malmquist index measures the Total Factor Productivity (TFP) change between 2 data points by calculating the ratio of distances to the frontier for every points relatively to a common technology for two time periods (Song 2019).

A sub-sample of 16 vessels was selected because of their presence throughout the full period 2016-2020. This period corresponds to a massive introduction of new vessels built in Sri-Lanka and hiring mostly Sri-Lankan crew. This shift introduced many changes in the fishery, such as the extension of the trip duration from 6-8 days to 14-18 days, and a greater productivity. Ten variables from year 2016 to year 2020 were applied to 16 observations (vessels). The main statistics are presented in Table 14:

Table 14. Main statistics of the 2016-2020 sample of 16 LL vessels

	Min.	*1st Qu.*	*Median*	*Mean*	*s.d.*	*3rd Qu.*	*Max.*
Catch	4	32	51	48	23	65	95
Hooks	6,966	38,233	70,907	73,199	39,354	108,144	151,287
Sets	3	47	89	86	47	120	180
Ntrip	1	9	12	11	4	14	20
Dtrip	9	13	14	14	2	16	19
Fishdays	18	116	170	163	69	219	273
HP	160	284	284	295	73	320	500
Length	13	16	16	16	1	16	18
Width	2.00	4.5	4.70	4.53	0.72	4.80	5.40
GT	15	28	28	30	8	30	51

The Malmquist productivity index (MPI) was calculated on the basis of two inputs (number of hooks and number of fishing days) and one output (catch). The first results are displayed in Table 15:

Table 15. Farrell efficiency scores by year

Id	*E(16,16)*	*E(17,17)*	*E(18,18)*	*E(19,19)*	*E(20,20)*
V3	0.32	0.39	0.61	0.81	0.44
V4	0.45	0.51	0.65	0.82	0.44
V5	0.45	0.65	**1.00**	0.77	0.61
V7	0.49	0.46	0.72	**1.00**	0.59
V8	0.37	0.69	0.47	0.69	0.36
V10	0.73	0.53	0.45	0.67	0.56
V11	0.56	0.53	0.65	**1.00**	**1.00**
V13	0.38	0.66	**1.00**	0.73	0.49
V16	0.34	0.49	0.68	0.85	0.54
V20	0.43	0.52	0.86	0.88	0.91
V22	**1.00**	**1.00**	**1.00**	**1.00**	0.76
V23	0.77	0.54	0.49	0.50	0.57
V24	0.51	0.51	0.45	0.60	0.43
V25	0.87	0.60	0.34	0.49	0.39
V26	0.43	0.50	0.51	0.76	0.55
V28	0.27	0.39	0.43	0.66	0.94

If some vessels show a remarkably constant level of performance, like V22 standing on the technical efficiency frontier for all years but 2020, some others depict a variable level of performance from year to year. Some vessels have improved their efficiency, such as V11, V28 or V20, but others have become less efficient in the course of time (e.g., V23 and V25). Finally, some longliners alternate good and bad scores (e.g., V5, V8, V7).

The results of Table 16 below, measuring the super-efficiency through an input-oriented approach with constant return-to-scale for 4 inputs (number of hooks, number of sets, number of trips, number of fishing days) and one output (the catch). The results are similar but allows for ranking between vessels. Interestingly, V22 is clearly the leader of the fleet, but its leadership decreases in the course of time, either because other vessels become more efficient or because this vessel has reduced its level of productivity. An opposite trend is reported for V11, which has constantly upgraded its performance to the extent of becoming the new leader of the fleet in 2020. Conversely, V10, V25 and V23 fleet is clearly inefficient and, more worryingly, shows decreasing performances throughout the period.

Table 16. Super efficiency scores (CRS, input-oriented) with one output (catch) and four inputs (number of hooks, number of sets, number of trips, number of fishing days)

Id	*2016*	*2017*	*2018*	*2019*	*2020*
V3	0,522	0,583	0,740	0,810	0,636
V4	0,527	0,811	0,911	0,903	0,709
V5	0,454	0,653	**1,019**	0,938	0,775
V7	0,668	0,692	0,865	**1,006**	0,670
V8	0,553	0,893	0,733	0,773	0,562
V10	0,955	0,870	0,686	0,773	0,635
V11	0,714	0,852	0,836	**1,140**	**1,555**
V13	0,501	0,656	**1,016**	0,832	0,486
V16	0,501	0,769	0,951	0,905	0,742
V20	0,452	0,519	0,874	0,879	0,908
V22	**3,155**	**2,058**	**1,896**	**1,694**	**1,325**
V23	0,771	0,633	0,559	0,520	0,660
V24	0,599	0,611	0,449	0,622	0,689
V25	0,865	0,600	0,340	0,495	0,436
V26	0,586	0,679	0,555	0,758	0,704
V28	0,269	0,394	0,427	0,707	0,941

Table 17 shows the Malmquist productivity index (MPI) based on DEA efficiency scores by year. It allows to see which vessels have increased or decreased their productivity and also this approach allows to disentangle the technical change and efficiency change effects in this productivity index.

When looking in Table 17 at input-oriented efficiency scores of 2020 based on the technology frontier of 2016, V28 is the vessel which has most improved its productivity (multiplied by more than 3 times). Most of its progress was made since 2018 mainly by increasing its own efficiency rather than surfing on a technical change effect. Symmetrically, we saw in Table 15 and Table 16 that V22 was always located on the efficiency frontier for all years but the last one. Consequently, this vessel has the lowest TFP change index between 2016 and 2020. Its efficiency is constant for the first 4 years, but declines by 24% during the last period, partially compensated in the TFP by the technical change effect. Noticeably, this technical change effect is strong for all 16 vessels between 2019 and 2020 (1.5 on average) whereas the average efficiency was falling by 20% on average (only V11, V20, V23 and V28 have improved their efficiency for the last year, V11 being the efficient benchmark).

Table 17. Malmquist productivity index between 2016 and 2020

	2016-20			2016-17			2017-18			2018-19			2019-20		
Id	*MPI*	*TC*	*EC*	*MPI*	*TC*	*EC*	*MPI*	*TC*	*EC*	*MPI*	*TC*	*EC*	*MPI*	*TC*	*EC*
V3	1,098	0,805	1,364	0,878	0,730	1,202	1,536	0,983	1,562	1,182	0,887	1,333	0,865	1,588	0,545
V4	0,787	0,804	0,979	0,835	0,737	1,133	1,247	0,983	1,268	1,149	0,915	1,256	0,835	1,540	0,543
V5	1,243	0,930	1,337	1,118	0,777	1,439	1,518	0,991	1,531	0,817	1,060	0,770	1,053	1,337	0,787
V7	0,977	0,806	1,212	0,638	0,686	0,929	1,615	1,016	1,590	1,238	0,897	1,379	0,947	1,592	0,595
V8	0,766	0,796	0,962	1,272	0,686	1,853	0,692	1,016	0,681	1,333	0,915	1,457	0,805	1,538	0,523
V10	0,669	0,875	0,765	0,534	0,730	0,731	0,852	1,016	0,839	1,355	0,898	1,509	1,296	1,569	0,826
V11	1,467	0,819	1,791	0,647	0,686	0,942	1,262	1,016	1,243	1,400	0,915	1,530	1,578	1,578	1,000
V13	1,174	0,930	1,263	1,325	0,777	1,705	1,513	0,992	1,524	0,812	1,108	0,733	0,805	1,214	0,663
V16	1,406	0,885	1,589	1,053	0,730	1,441	1,414	1,016	1,392	1,140	0,915	1,246	0,978	1,538	0,636
V20	1,718	0,819	2,097	0,876	0,730	1,199	1,628	0,980	1,662	1,083	1,064	1,018	1,368	1,324	1,034
V22	0,623	0,819	0,761	0,730	0,730	1,000	0,983	0,983	1,000	0,996	0,996	1,000	1,005	1,321	0,761
V23	0,691	0,930	0,744	0,541	0,777	0,697	0,867	0,957	0,906	0,939	0,916	1,025	1,641	1,428	1,149
V24	0,749	0,888	0,844	0,778	0,777	1,001	0,848	0,957	0,886	1,376	1,036	1,328	0,975	1,361	0,717
V25	0,417	0,919	0,453	0,539	0,777	0,694	0,548	0,974	0,563	1,537	1,049	1,465	1,167	1,473	0,793
V26	1,050	0,819	1,282	0,808	0,686	1,177	1,010	0,987	1,024	1,312	0,891	1,473	1,147	1,587	0,723
V28	3,259	0,930	3,505	1,140	0,777	1,467	1,049	0,967	1,085	1,700	1,107	1,535	1,764	1,229	1,435

Note: MPI = Malmquist productivity index, TC = technical change, EC = efficiency change.

3.13 Spatial Analysis

We used the georeferenced catch and effort data, identified by vessel and trip. Catch were not disaggregated by species in the file used, so the catch data include tuna and billfish. We computed the catch per unit effort (CPUE), which is expressed in kg per 100 hooks. The limitation here is that we are using nominal CPUEs which do not reflect all the processes leading to success or failure of a set. The 2019 dataset includes information for 36 vessels.

3.13.1 Annual distribution of fishing effort and CPUE for 2019

The CPUE values recorded for the fleet in 2019 ranged from 0 to 773 kg/100 hooks. In order to represent the annual spatial pattern in production, we interpolated the CPUE values on a 0.5 x 0.5 degree grid, as shown in Fig. 2. On an annual basis, the highest CPUE are achieved along the northeastern eadge of the Seychelles bank, with two cores of CPUE > 160 kg/100 hooks. Another area of relatively high CPUE is located in the West of the Seychelles bank. The two “bulleye areas” shown west of Amirantes and outside the EEZ, in the east, should not be considered because of the very low number of sets in those areas. It is quite surprising to see high CPUEs on the Seychelles bank, as the depth is generally limited to 60-70 m on that shelf. These data are either misreported or correspond to very shallow sets. The data used do not indicate the species caught, so it is still uncertain why such sets were made on the shelf.

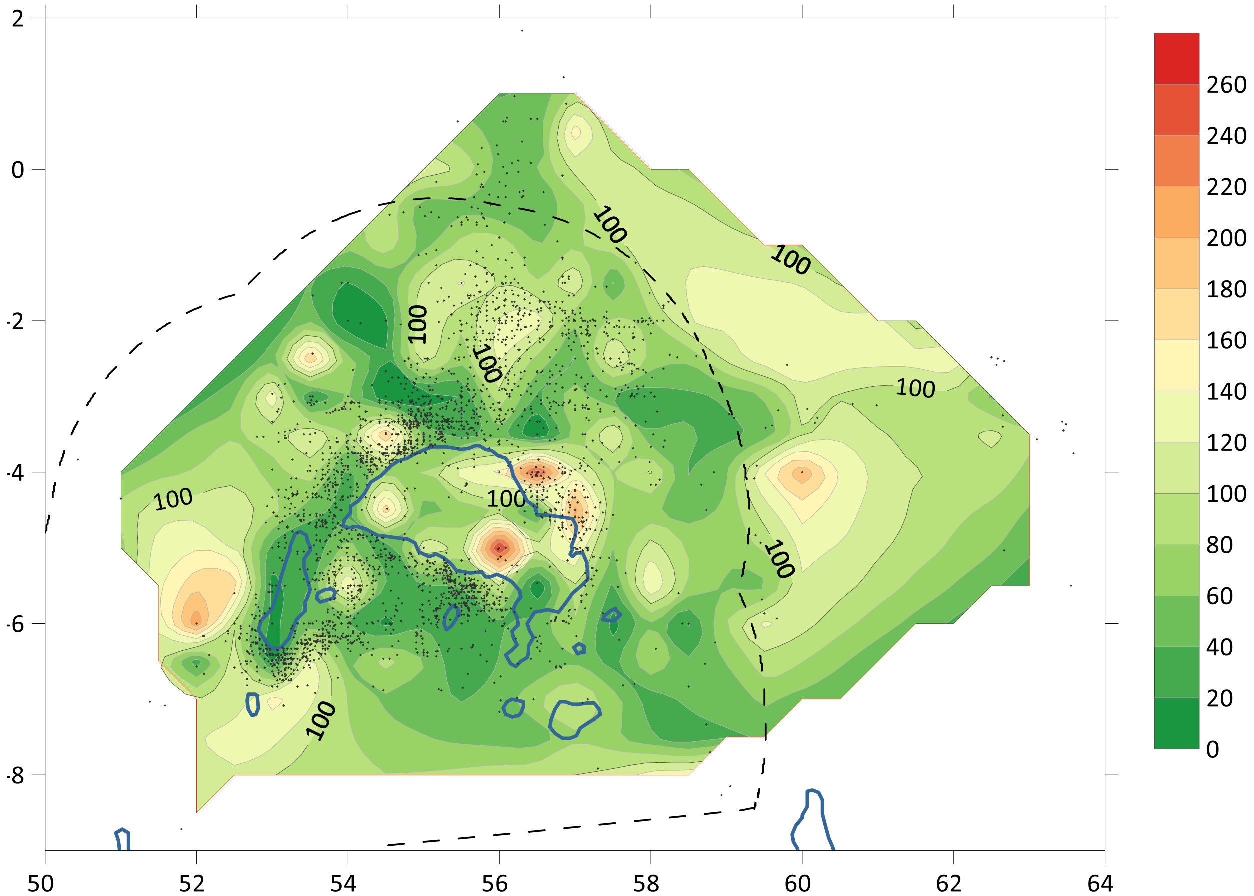


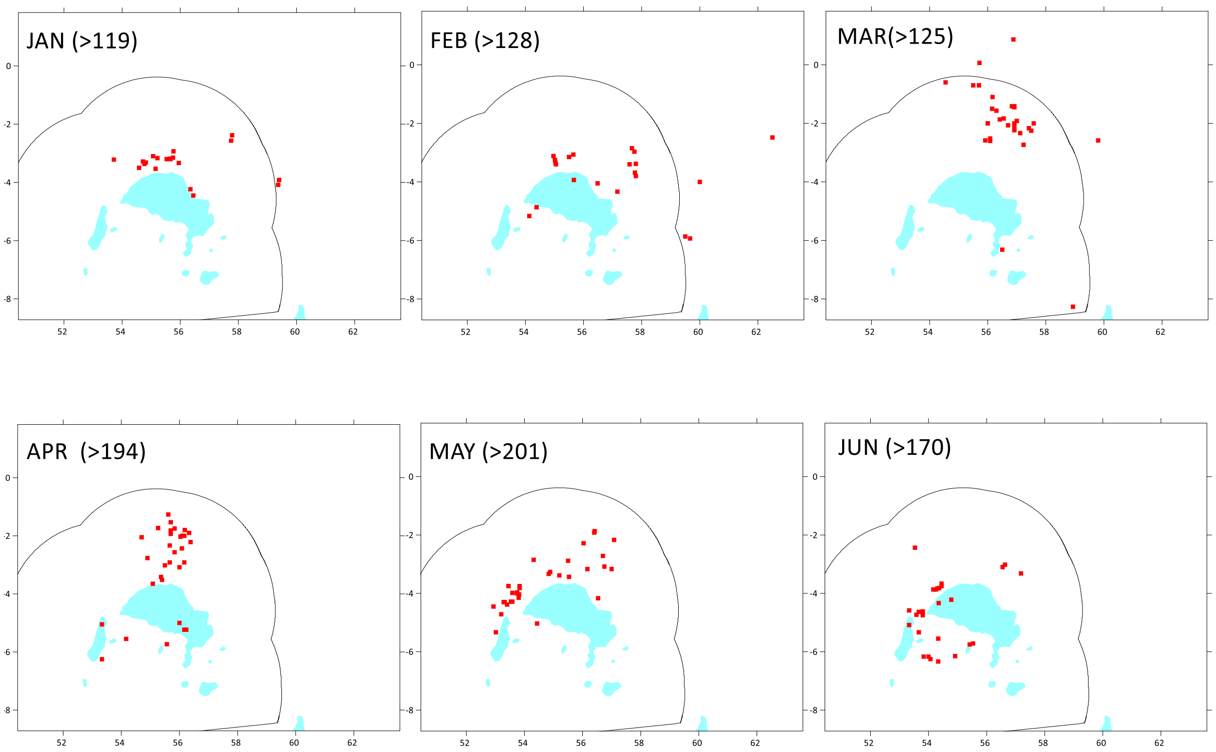
Fig. 24 Spatial distribution of SI longline sets (black dots) in 2019, and gridded CPUE values (color shading). (*The 200 isobath is represented in blue to delineate the banks. The Seychelles EEZ boundary is shown in dashed line.)*

The areas with the highest number of sets do not show particulary high CPUEs, likely an artifact due to the concentration of fishing effort. Longline catch rates are characterized by a non-linear relationship along fishing effort, denoting a process called hyperstability (Maunder et al. 2004). Here, even high catches can lead to moderate or low CPUEs when divided by a large number of hooks. On the other hand, the northern part of the EEZ, halfway between the Seychelles bank and the EEZ boundary, shows significantly high CPUEs, above 100 kg/100 hooks.

3.13.2 Characterization of CPUE hotspots

We selected the sets with CPUE > 90th centiles of the CPUE distribution to point out possible CPUE hotspots (in other words, the 10% best CPUE of the fleet). The analysis is conducted on a monthly basis, i.e. the 90th centile value est calculated for each month separately and only CPUEs with value above this threshold are plotted on a map (Fig. 25). These maps disaggregate the information presented in Fig. 24 and underline the higher values.

The location of hotspots varies substantially between months. From December to May, the hotspots are distributed north of the Seychelles Bank. The most distant hotspots from Mahe during that period are observed in March-April. Hotspots located outside of the EEZ are seldom (January to March). From June to November the hotspots are more densely distributed near the banks. In August 2019 only, the fleet expanded to the east, with high CPUE reported outside the EEZ.



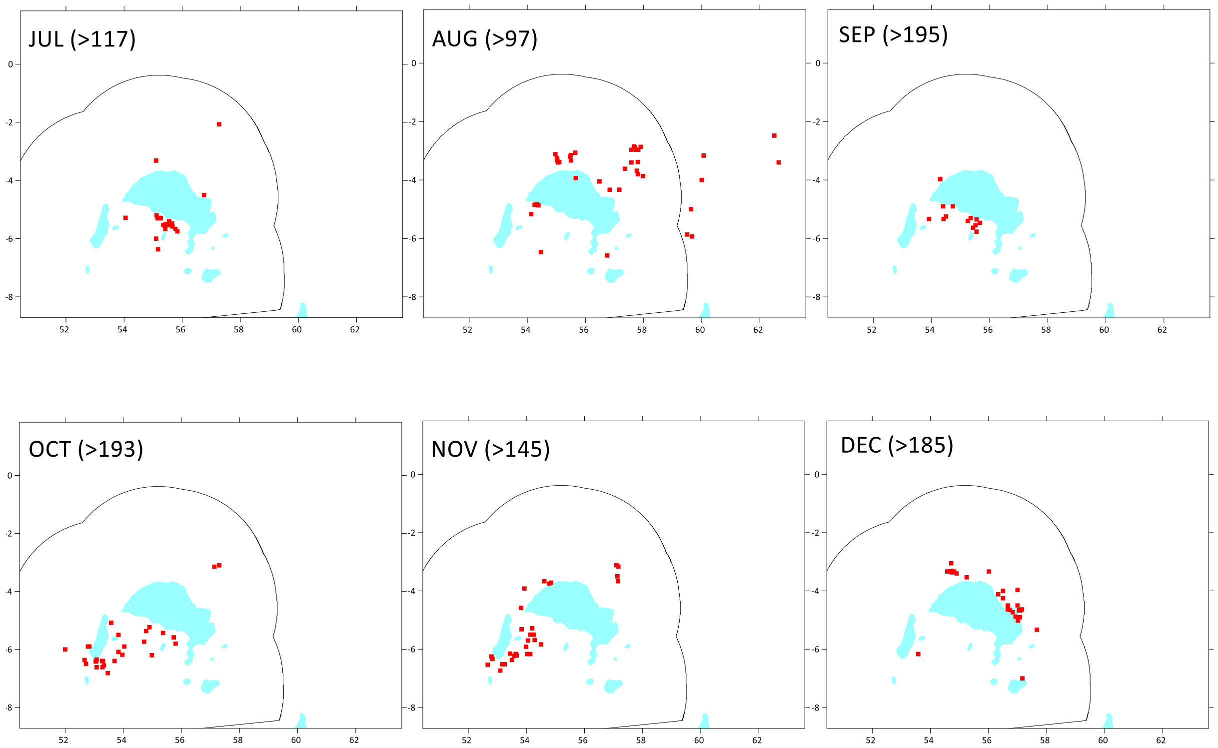


Fig. 25 Distribution of the >90th centile CPUE by month in 2019, all fleet and species combined. (*The value in bracket is the 90th centile threshold (kg/100 hooks)*)

3.13.3 Relations between the vessels "super efficiency scores" and monthly CPUE hotspots

The super-efficiency scores considered in this analysis were produced by the DEA analysis (see section 3.10) conducted on 33 of the 36 vessels available in the dataset. These scores are vessel specific. Here, we investigate if a link exists between this ranking and the performance of the vessels relative to the hotspots. In other words, do the more efficient vessels operate more frequently inside CPUE hotspots compared to less efficient vessels?

To estimate this relationship, we calculated the number of times each vessel has achieved sets inside hotspots (Table 18). Firstly, we indicate the months when the vessels were fishing (light blue shaded cells). The occurrences were summed and averaged for the year, and a ratio of occurrence/month is calculated, along with the coefficient of variation (CV, in %). The lower CV values indicate that a vessel is generally performing well throughout the year relative to hotspots, whereas higher CVs indicate much more varying monthly performances.

The general statistics show that a substantial fraction of the fleet operate in the hotspots throughout the year, ranging between 64% and 88% from October to July. The ratio is much lower in August –September, during the Southeast monsoon when the sea conditions are rough.

Graphics associated to this table provide a clear representation of how spatio-temporal indicators are related to the overall performance of the vessels. The occurrence of sets in hotspots fluctuates (Fig. 26) with a tendency of more frequent occurrence of sets achieved by the most efficient vessels. Yet, the highest occurrence is not achieved by the first ranked vessel, rather by the 3rd ranked vessel (V2). There is also other high occurrence of sets for vessels ranked in the middle of the list (e.g., V1) or among the least efficient vessels (V28). A scatterplot of all 33 vessels (Fig. 27) confirms a significant positive relationship between occurrence in hot spot and efficiency of the vessels ($r = 0.54$, $\alpha < 0.05$).

Table 18 . Statistics on the occurrence of each vessel's operation in CPUE hotspots.

Rank	Vessel	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL	Mean	No months	Occ/month	CV %
1	V6		0	0	0	1	0	1	1	0	3	1	0	7	0.6	11	0.6	145.27
2	V1	5	2	2	2	2	2	2	2	0	2	0	3	24	2	12	2.0	63.96
3	V2	4	1	4	4	3	2	6			1	0	0	25	2.5	10	2.5	80.55
4	V22	0		1	2	2					2	1	0	8	1.1	7	1.1	78.73
5	V12																	
6	V7	0	2	1	0	2	2	0	0	0	0	4	2	13	1.1	12	1.1	121.05
7	V9		0	0	0	3	1	0	0	2	2	1	3	12	1.1	11	1.1	111.93
8	V3	0	2	1	0	0	2	0	1	2	1	1	2	12	1.0	12	1.0	85.28
9	V4	1	0	1	1	0	0	0		1	0	0	0	4	0.4	11	0.4	138.74
10	V11	2	1	0	3	1	0	0			1	3	4	15	1.5	10	1.5	95.58
11	V18																	
12	V17	1	0	0	0	0	0				2	0	3	6	0.7	9	0.7	167.71
13	V19	0		1	2	0	3	1				3	0	10	1.3	8	1.3	102.54
14	V14				2	3	2	2	1	2	2	2	0	16	1.8	9	1.8	46.88
15	V15			2	2	0	0	0		0	1	1	1	7	0.8	9	0.8	107.14
16	V5	2	6	3	0	1	1	0	1	0	0	0	1	15	1.3	12	1.3	141.16
17	V8	1	1	0	0	0	0	0		1	1	0	0	4	0.4	11	0.4	138.74
18	V33												0	0	0.0	1	0.0	
19	V29			2	1	2		0		2	0	2	0	9	1.1	8	1.1	88.09
20	V13	1	1	3	1	1	1	1	1	0	0	1	0	11	0.9	12	0.9	86.50
21	V20	0	1		1	1	2	1	1	1	2	0	3	13	1.2	11	1.2	73.94
22	V16		1	0	0	0	0	0		0	0	0	0	1	0.1	10	0.1	316.23
23	V32											0	0	0	0.0	2	0.0	
24	V10	0	0	0	1	1	2	1			0	1	0	6	0.6	11	0.5	116.53
25	V26	0	0	0	0	2	0	4				0	0	6	0.7	9	0.7	212.13
26	V21	0		1	0	1	0	0		0	4	3	0	9	0.9	10	0.9	161.02
27	V24	2	0	1	0	0	1				0	0	0	4	0.4	9	0.4	163.46
28	V28	0	1	3	3								0	7	1.4	5	1.4	108.33
29	V30				2	1	0	0	0					3	0.6	5	0.6	149.07
30	V23	0	0	0	0	1	0	0				4	0	5	0.6	9	0.6	240.00
31	V27	0	0	1	0	0	0	0				0		1	0.1	8	0.1	282.84
32	V25	1	0	0	0	1	1	0			0	0	0	3	0.3	10	0.3	161.02
33	V31					0	0	1			0	0	0	1	0.2	6	0.2	244.95
	Sum of occurrences	20	19	27	27	29	22	20	8	11	24	28	22					
	No of vessels	21	21	25	28	28	26	25	10	15	23	28	29	31				
	% of fleet	64	64	76	85	85	79	76	30	45	70	85	88					
		Indicates the months when vessels are operational																

(The rank of the vessels (first column) is the result of the super-efficiency scoring produced by the PCA)

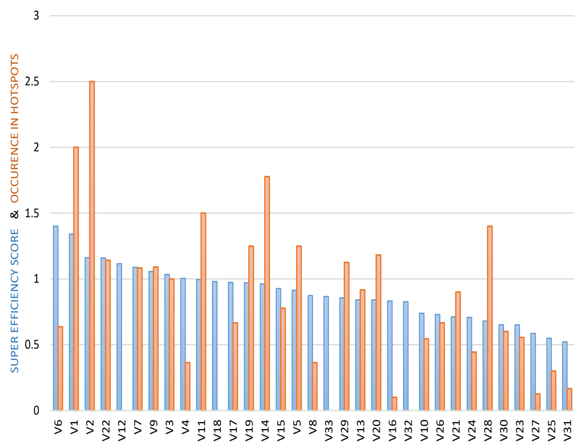


Fig. 26 Distribution of the average monthly occurrence of sets in hotspots (orange bars) along a decreasing gradient of vessel performance (blue bars)

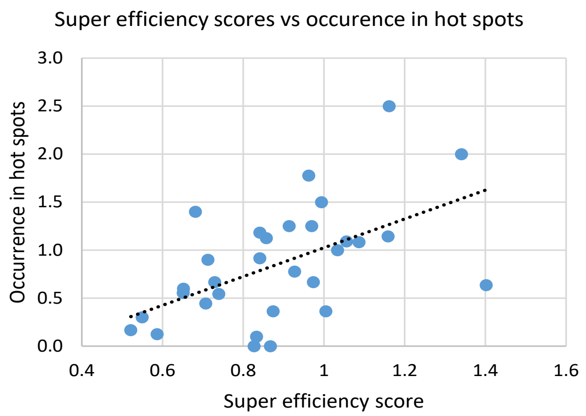


Fig. 27 Scatterplot of the relationship between occurrence (Y axis) and super efficiency score (X axis)

Likewise, the comparison is conducted between the efficiency score and the coefficient of variation (%) of occurrences of sets in hot spots. There is a clear cut-off point between the 21 more efficient vessels and the rest of the fleet that indicates lesser CV for efficient vessels compared to least performing vessels (Fig. 28). This is confirmed by the scatterplot (Fig. 29) with a significantly declining CV along the super efficiency score ($r = 0.54$, $\alpha < 0.05$).

This analysis concludes that spatio-temporal indicators, such as the location of monthly CPUE hotspots in the fishery, contribute to explain the variable performance of the fleet. It appears that the most efficient vessels operate more often in the hotspots, and that their activity is much more stable overtime in these hotspots, compared to the least efficient vessels. Several factors can drive such differences in the fleet. There could be operational factors, like the quality of the maintenance on the vessels (to keep them in good condition); an efficient management of the vessel's activity by the fishing company to minimize the time in port; and the skipper's experience and knowledge of the fishery allowing to achieve better catch throughout the year.

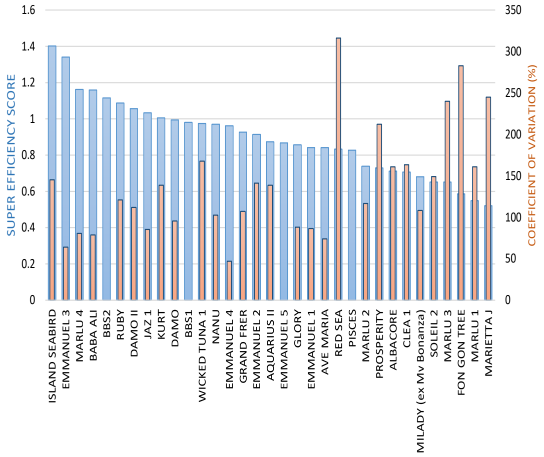


Fig. 28 Distribution of the coefficient of variation (in %) of the monthly occurrence of sets in hot spots (orange bars) along a decreasing gradient of vessel performance (blue bars)

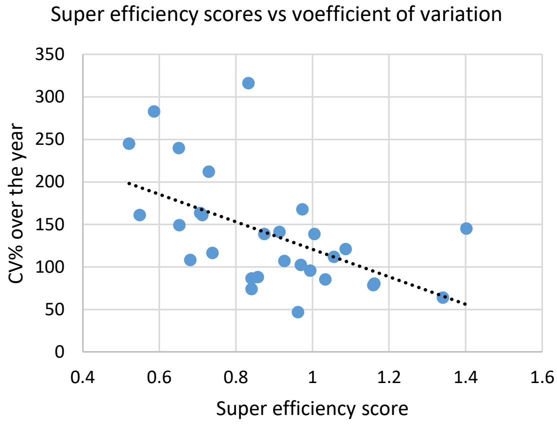


Fig. 29 Scatterplot of the relationship between coefficient of variation (Y axis) and super efficiency score (X axis)

4 Discussion and Conclusion

4.1 Economic performance and sustainability concerns

The results shows that the semi-industrial longline fishery is a profitable business though there are varying economic performance within the Seychelles semi-industrial longline fleet. The levels of profitability are determined mainly by the volume of landings and to some extent the level of effort, while high costs may erode profitability for vessels with low gross margins subsequently pushing more vessels into net loss.

Reduction in physical productivity and increasing costs, mainly fuel and bait, which negatively impacts profits, is of particular concern for the Seychelles fleet because of the vulnerability to international market shocks. The study showed that bait cost was a significant component for the vessels and vessel owners expressed concerns over the rising bait prices over the years, which has not been accompanied by increase in fish prices.

The data collected on prices in this study represents only one-year, further study is required covering more years to analyse whether there has been any decline in the average landing price in real terms over the years (i.e. below inflation) affecting economic performance in the fishery. Expanding the size of the surveyed population of vessels would also be useful to consolidate the outcomes of the study.

Another sustainability concern is the over dependency of the sector on foreign labour. Foreign labour can present both opportunities and challenges. It can potentially reduce wages in the short run and displace local workers from the sector and on the other hand tends to positively increase output (Koczan 2021). In terms of general socio-economic gain to the Seychelles economy, there is certainly an argument to finding mechanism to increase local workforce participation in the sector to reduce money leaked externally in the form of remittances.

4.2 Ex-vessel market dynamics

The main channel for the ex-vessel sale of fish is the processor. Prices are set by the buyer and has remained mostly unchanged over the years (as informed by the vessel owners), the fishing vessels being mostly a price-taker. The vessels may enter contractual arrangements with the processor for advance payments on ice and bait. This system helps vessels with their cashflow but may also have an indirect effect on prices by hindering the ability of the seller to bargain a better price.

The study shows that improvements in prices and valuation of grade of fish would improve the profitability of the vessels; with USD 1 dollar/ kg landing increase resulting in an increase of SCR 0.6 million in the average gross cashflow. Unfortunately, the scope of this study did not cover an analysis of how benefit/value is distributed along the value chain, from the vessel to processor to understand whether there are any large discrepancies in prices/benefits.

The high perishability of the production requires quick sale of catch and quick transportation to the export market. In view of this, constraints in availability of air transport and fluctuating transport prices may be a challenge for the fishery. Vessel owners proposed assistance from Government for access to chartered air freighter, as well as exploring the viability of frozen market.

It is unlikely that economic efficiency is achieved at the current level of output on the frozen market. The illustration on economic efficiency on the proportions of swordfish to tuna illustrated how vessels targeting higher proportion of lower valued species can be very far from the maximum potential revenue. At the current output, the lower yield that vessels would get from frozen fish exports would push more vessels into net loss. Economic performance of vessels will be better enhanced by targeting and increasing production higher valued fish, which is fresh whole tuna.

4.3 Technical efficiencies

From the analyses on technical efficiency, it can be seen that there were still room for efficiency gains for some vessels by using more efficiently their inputs. Out of 33 vessels 7 vessels achieve optimal efficiency for their efforts inputs whilst saving gains could be reached for 26 other vessels. Likewise, many vessels are operating far from their optimal size, bearing scale inefficiencies that can come from oversized or undersized vessels.

The spatio-temporal indicators also contribute to explain the variable performance of the fleet. It appears that the most efficient vessels operate more often in the hotspots locations, and that their activity is much more stable overtime in these hotspots, compared to the least efficient vessels. The difference in the fleet can be attributed to several factors including age of the vessels, quality of the maintenance of the vessels and the skipper’s experience and knowledge of the fishery allowing to achieve better catch throughout the year.

Further evaluation should be undertaken on how vessels can improve their productivity, which seems a major determinant of economic performance.

4.4 Employment

Fisher productivity and skipper experience appears to be one of the determining factors to increasing productivity of vessels, which in turn has a direct impact on revenue. With the current situation of labor constraint in the local market, foreign labor seems inevitable. However, employment of foreign labor is not without problems for the vessel owners partly due to language barriers and difficulties encountered to verify qualifications of Sri Lankan fishers. SFA and MoFBE can work with Ministry responsible for Employment to find mechanism to verify expatriate employment in the sector.

5 Innovative Perspective

5.1 Tracking temporal changes

This study provides a base for continuous collection of socio-economic data of the semi-industrial longline fishery in Seychelles. Given the ‘generalization’ aspect of the survey method and statistical techniques applied, the study has the benefit of extending and adapting to other fisheries with target elements (DMUs) being fishing vessels. Following the transfer of knowledge from the consultant and IRD experts to the SFA team on the principles and practice of socio-economic sample surveys, data grouping, performance measurement technique, regression and classification, spatio-analysis, SFA should perform follow-on projects that will firstly establish a continuous monitoring program for the fishery (data management system and standard operating procedures for data capture). Secondly, replicate over a longer stretch of time the statistical techniques used to achieve more stable and robust results. This will allow Seychelles to constantly track temporal changes and milestones in the fishery as well as identify key levels.

5.2 Evidence-based policymaking

Robust, relevant, and timely data and appropriate statistical techniques are two ingredients necessary to produce quality policy research and sound decision-making. This combination is fundamentally important as it will achieve better governance through the incorporation of evidence-based policymaking. The statistics acquired from this study should be used as complementary inputs to formulate future development policies for the subsector and to address sectoral challenges such as processing capacity constraints, access to credit facilities, non-performing loans, etc. According to our findings, we have seen that it is economically inefficient (allocatively) to target lower valued species given the current level of output capacity. Even though a vessel may be operating at the frontier of their technical capability it falls short of its maximum revenue potential due to the relative prices of fresh swordfish and yellowfin. Now with frozen prices much lower than fresh this worsens the vessel’s revenue efficiency and may perhaps negatively impact gross cash flow. As a starting point this study provides a preliminary assessment of the viability in diversifying into the frozen market, but supplementary market studies should be undertaken to firmly provide a technical conclusion.

5.3 Private sector collaboration

Communication with stakeholders is critical as it helps to have common understanding of ‘success’. As we have seen from the Data Envelopment Analysis, which is a performance measurement technique, a number of vessels have been identified with various degrees of inefficiencies on the basis of their input/output or species targeted. With such functional deliverables, SFA should continue to inform stakeholders, in our case vessel owners, of its ability to provide advice on production decisions that will enhance business performance and reduce or minimise waste. In a data-driven world it is critical for businesses to evaluate success and gather insights needed for a sustainable business. Through a consultative approach SFA should extend its technical expertise to collaborate and support the industry by performing targeted one-to-one sessions with the vessel owners. These sessions will allow boat owners to understand the purpose of setting up operational performance measures and acquire knowledge on where to improve to add value to their operations.

5.4 Regional comparison

Economic impacts based on common species provide the most appropriate basis for comparing relative contributions. Comparison helps to identify similarities and differences and is viewed as a means of improvement. From a regional standpoint and in line with the regional program “Année Bleue de l’Océan

Indien" the findings of this study ought to be used for cross-country comparison of the performance of similar fisheries. This will provide an understanding of the level of competition, challenges encountered, and lessons learned from our country counterparts of the shared resource. Additionally, with a participatory approach Seychelles should provide capacity building with the member states of the program to share the knowledge acquired. The intent is to deliver benefit sharing of the "Fonds de Solidarité pour les Projets Innovants" to elevate the positive impact of such funds.

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6 Annexes

6.1 Annex I List of data

Table 1. Economic Variables and Indicators -Average per Vessel (USD)

Average per Vessel	USD '000
Revenues	
Value of landings	*218.6*
Costs	
Energy Cost	29.3
Bait	45.4
Other Operating cost	21.4
Maintenance Cost	11.1
Fixed Cost	15.2
Salary	44.9
Total Operating Cost	*167.3*
Depreciation	14.1
Interest	5.3
Total Cost	*184.1*
Economic Performances	
Gross Cash Flow	*51.3*
Net Profit	*34.5*
Net Profit without fuel subsidy	*12.5*
Break-even revenues	*221.3*
Gross Value Added	*96.2*
Invested Capital	*196.8*

Table 2. Economic performance per vessel per trip (SCR'000)

Average Per trip	SCR '000
Revenues	
Value of Landings	228.4
Costs	
Energy Cost	32.4
Bait	46.1
Other Operational cost	22.0
Maintenance Cost	12.2
Fixed Cost	16.5
Salary	49.5
Total Operating Cost	178.7
Depreciation	16.2
Interest	6.1
Total Costs	210.9
Economic Performances	
Gross Cash Flow	42.7
Net Profit	19.5
Other Information	-
Fuel subsidy	26.6
Net Profit without fuel subsidy	-7.07
Break-even revenues	233.4
Gross Value Added	96.1

Table 3. Descriptive Statistics of Economic Variables of the Survey Sample

SCR'000	Mean	Standard Deviation	Standard Error	Coefficient of Variation
Revenues	3,067	1,170	370	*38%*
Energy Cost	410	112	35	*27%*
Bait	638	258	82	*40%*
Other Operational cost	300	157	50	*52%*
Maintenance Cost	156	48	15	*31%*
Fixed Cost	214	76	24	*36%*
Salary	630	165	52	*26%*
Volume of landings (MT)	48	18	6	*37%*
Effort-Number of Hooks	65,314	35,454	11,212	*54%*
Number of days at sea	172	40	13	*23%*

Table 4. Descriptive statistics of quantitative variables used in PCA and HCA for 33 Vessels

	Min.	*1st Qu.*	*Median*	*Mean*	*s.d.*	*3rd Qu.*	*Max.*
Hooks	4015	52113	82016	73305	34061	89724	129673
CPUE	0.37	0.65	0.83	0.83	0	0.99	1.3
Catch	4	38	64	58	27	78	105
Landings	3	30	50	45	21	60	85
Share	0.58	0.75	0.77	0.76	0.05	0.78	0.88
Sets	4	46	87	83	40	109	165
Cperset	387	571	674	764	327	825	1693
Ntrip	1	9	13	12	4	14	19
Dtrip	10	12	14	15	3	16	21
Fishdays	11	143	175	173	68	227	285
Fuel	4500	26671	30500	31042	11536	35000	53480
HP	160	284	284	292.2	72	320	500
Length	13.1	15.9	15.9	16.06	2	16	23
Width	2	4.7	4.7	4.642	1	4.7	5.5
GT	15	28	28	28.7	7	28	51
Billfish	0	0.13	0.23	0.22	0.13	0.30	0.54

Table 5. CRS, VRS and scale efficiencies

Vessels	crs_all inputs	vrs_all inputs	Scale Efficiency (e_crs/e_vrs)	Test e_crs = e_vrs
1	1.00	1.00	1.00	TRUE
2	1.00	1.00	1.00	TRUE
3	1.00	1.00	1.00	TRUE
4	1.00	1.00	1.00	TRUE
5	0.91	0.97	0.94	FALSE
6	1.00	1.00	1.00	TRUE
7	1.00	1.00	1.00	TRUE
8	0.87	0.94	0.93	FALSE
9	1.00	1.00	1.00	TRUE
10	0.74	0.88	0.84	FALSE
11	0.99	1.00	0.99	FALSE
12	1.00	1.00	1.00	TRUE
13	0.84	0.96	0.87	FALSE
14	0.96	1.00	0.96	FALSE
15	0.93	1.00	0.93	FALSE
16	0.83	0.94	0.89	FALSE
17	0.97	1.00	0.97	FALSE
18	0.98	1.00	0.98	FALSE
19	0.97	1.00	0.97	FALSE
20	0.84	0.98	0.86	FALSE
21	0.71	0.86	0.83	FALSE
22	1.00	1.00	1.00	TRUE
23	0.65	1.00	0.65	FALSE
24	0.71	1.00	0.71	FALSE
25	0.55	0.96	0.58	FALSE
26	0.73	0.92	0.79	FALSE
27	0.59	0.94	0.62	FALSE
28	0.68	1.00	0.68	FALSE

29	0.86	1.00	0.86	FALSE
30	0.65	0.99	0.66	FALSE
31	0.52	0.96	0.54	FALSE
32	0.83	1.00	0.83	FALSE
33	0.87	1.00	0.87	FALSE

Note: Scores > 0.90 are green, yellow between 0.75 and < 0.90, pink between 0.60 and < 0.75, and red below 0.60.

6.2 Appendix II Survey Questionnaire

FOR SURVEYOR USE ONLY

Name of Enumerator:

Location: E.g. Providence

Date of Interview:

Start time:

End time:

CONSENT *(to be read out to respondent before signature required)*

You are being invited to participate in a survey that aims to understand the socio-economic characteristics of semi-industrial long-line fishery in Seychelles. This study is being commissioned by the Ministry of Fisheries and the Blue Economy, in partnership with the Seychelles Fishing Authority. The survey will take no more than 45 minutes to complete. Your participation in this study is entirely voluntary and you can refuse to answer any particular question or withdraw at any time.

The purpose of this study is to assess the viability of the sector, examine the potential social and economic benefits of the sector and provide recommendations to improve the performance of the sector. The information gathered in this survey is solely for the use of the Department of Fisheries and the Seychelles Fishing Authority and will not be shared to third parties.

There are no perceived risks associated to your participation in this study. The answers you provide in this study will be aggregated and treated confidentially.

The reference period for the questionnaire is: 01.01.2019 – 31.12.2019

Do you have any questions?

Would you like to proceed with the survey?

Ensure that the consent form is signed.

Name of respondent:

Sign:

Source of Information

1. Name of vessel:
2. Vessel number:
3. Sole ownership:
4. Partnership:

	Share	Nationality
Owner 1		
Owner 2		
Owner 3		
Owner 4		

Owner 5		

Ownership/business structure

5. What is the structure of your business?

☐ Sole trader ☐ Partnership ☐ Company

6. How many years has the vessel been operating in this fishery?

7. Is the owner engaged on the vessel?

☐ Yes ☐ No

8. Is the revenue from semi-industrial fishing activity your main source of income?

☐ Yes ☐ No

9. If no, what proportion of your total income is made up by revenue from semi-industrial fishing activity?

10. Do you use this vessel for other fishing activities?

☐ Yes ☐ No

11. If yes, specify what activity? How many months in a year are you engaged in this activity?

12. How many boats do you own?

Type of license	License 1	License 2	License 3
Boat 1			
Boat 2			
Boat 3			
Boat 4			
Boat 5			
Boat 6			

Crew

13. Engaged crew per trip	Part time	Full time	Trainees from SMA
Total number of crew per trip			

	Skipper	Fisher 1	Fisher 2	Fisher 3	Fisher 4	Fisher 5
14. Age						
15. Nationality						
16. Education level						
17. Other duties (e.g. cook/mechanic etc...)						
18. Years of experience						

19. If foreign labour is employed, what is the cost of Gainful Occupational Permit (GOP) per year?

20. If foreign labour is employed, where do they live?

16. What is the monthly cost associated with housing foreign labour?

21. How are the crew paid?

☐ Fixed monthly salary

What is the monthly salary? Specify currency.

☐ Share system per trip (complete table below)

	Owner	Skipper	Each fisher	Other specify
Share (as a fraction of %)				

Indicate whether the share is of the gross or net revenue:

☐ Gross ☐ Net

22. Do you pay the following for crew members? If yes, state how much per month.

☐ Pension (SCR ______ per crew member monthly)

☐ Income tax (SCR _____ per crew member monthly)

23. Do you have any additional workers involved in onshore activities related to the vessel activity?

☐ Yes ☐ No

24. If yes, what type of activity and how many hours engaged per day?

Type of activities	Number of hours engaged per day	Salary (SCR)

FISHING ACTIVITY & EFFORT

25. What is your average number of fishing trips per month?

26. Is this regular throughout the year?

27. If no, why?

28. Average duration of days per trip?

29. What is the main type of gear used?

30. What is the speed of the vessel?

COMMERCIAL (FIRST POINT OF SALE)

31. Where is the catch stored onshore?

32. Is any processing done to the catch before it is sold?

☐ Yes ☐ No

33. If yes, describe how the catch is processed?

34. What % of the catch is reserved for the owner or the crew (self-consumption)?

35. Where do you usually sell your catch? (If more than one option, indicate the one most frequently used)

__ General public (households and individuals)
__ Restaurants
__ Fish monger (middleman)
__ Processor/Exporter
__ Other

36. How is the selling price for catch secured?

☐ Fixed price set by purchaser

☐ Price negotiated between boat owner and purchaser

☐ Contractual agreement with purchaser

37. Fill out the following table (information should be per trip).

Species landed	Processing done	Grade	Selling price (SCR)

Investment

38. What investments have been made in the business?

Type of investment	Year	Cost (SCR)
Engine		
Gear		
Safety equipment		

Refurbishment		

Vessel purchase & Financing

39. When was your vessel purchased (month and year is possible)?

40. How was your vessel purchased?

☐ Self-financed
☐ Loan (specify DBS or commercial): ____________________
☐ Other (specify): ____________________

41. Was your vessel imported?

☐ Yes ☐ No

42. If yes, where from?

43. Was the vessel purchased new or second-hand?

☐ New ☐ Second-hand

44. If second-hand, how old was the vessel when purchased?

45. What was the purchase price of the vessel (SCR)?

46. Do you have any loans relating to any other aspect of your fishing activity? If yes, specify.

Repair & Maintenance

47. What is the average yearly cost of repairs and maintenance?

	Average cost per year (SCR)
Vessel (body)	
Engine	
Gear	

Operational and commercial cost

48. Approximately how much do the following cost on average per trip?

Operational cost	**Cost (SCR)**	**Additional information**
Bait		Type of bait Purchased or caught? Stored where?
Ice		
Food		
Onshore transportation		
Lubricant		

Fixed costs

49. What are the monthly costs of the following? (Only fill out what applies)

Fixed cost	**Cost (SCR)**	**Additional information**
Fishing License		
Loan repayment		
Insurance		
Accountant/book-keeping		
Legal expert		

Income

50. Do you pay any of the following taxes? If yes, state how much per month or year.

Tax	**SCR**	**Notes**
Business tax		
Income tax		
Presumptive tax		
CSR tax		
Other		
Other		

51. Other than those caused by the pandemic, if any, what challenges are you facing in your business?

- Fishing technique
- Fish stocks
- Bycatch
- Depredation
- Economics

52. Do you have any other sources of income? If yes, what sector are you involved in?

53. Why do you continue to operate if you are not profitable?