Status and trends in Saba Bank fisheries

Analysis of fisheries data collected over the period 2011-2023

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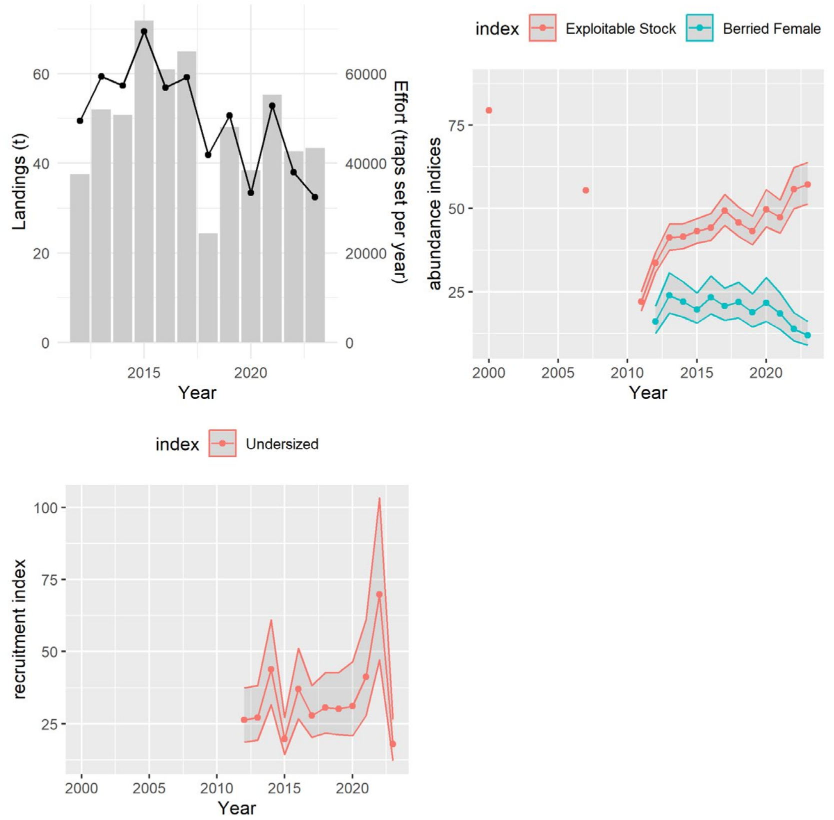
Contents

Executive Summary

This report is an update of earlier published reports on the status and trends in the of Saba Bank fisheries (Graaf et al. 2017, Brunel et al. 2018, Brunel et al. 2021). The new analyses presented here are based on three additional years of data (2021-2023) collected by the Saba Bank Management Unit.

Lobster fishery

The figure below gives a summary of the trends for the lobster fishery.



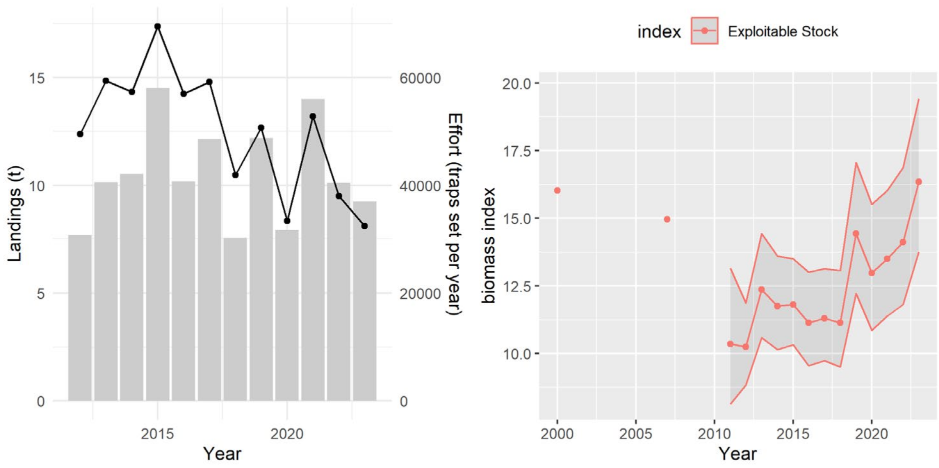
Summary plots for the lobster stock.

Top left :	landings (bars) and effort (solid line) estimates
Top right:	abundance indices for the exploitable stock and for the berried females obtained by standardising the landing-per-trip (with 90% confidence intervals)
Bottom left:	abundance index for the undersize lobster obtained by standardising the landing per-trip (with 90% confidence intervals)

After a period of increase from 2012 to 2015, fishing effort in the lobster fishery (*Panulirus argus*), has gradually declined, with nearly a halving of the effort between 2015 and 2023. The resulting landings of lobster have shown a similar pattern with first an increase up to 2015 when they amounted to 78t (tonnes). After a period of relative stability in 2016-2017, landings declined sharply to 27t in 2018. This was followed by a partial recovery until 2021, and then a slight decline again in the subsequent two years to 43t. Increasing landings per unit effort (number per trap) indicate that the lobster abundance, which had been declining since 2000 and hit its lowest level in 2011, has subsequently increased relatively steadily all through 2023, back to similar levels as in 2007.
The abundance indices show that while the exploitable stock has experienced fluctuations, it has maintained an increasing trend from 2015 onwards; however, the abundance of berried females has declined noticeably in recent years. Additionally, from 2022 to 2023, there is an accentuated decline in the recruitment index for undersized lobsters. Sharp declines in the abundance indices for berried females and undersized lobsters suggest that fishermen may be adhering more strictly to regulations, but these trends could also herald an impending recruitment failure.

Lobster fishery fish bycatch

The figure below gives a summary of the trends for the bycatch of reef fish in the lobster fishery.



Summary plots for the main reef fish stocks.

Left : landings (bars) and effort (solid line) estimates

Right: biomass index for the combined reef fish stocks obtained by standardising the landing-per-trip (with 90% confidence intervals)

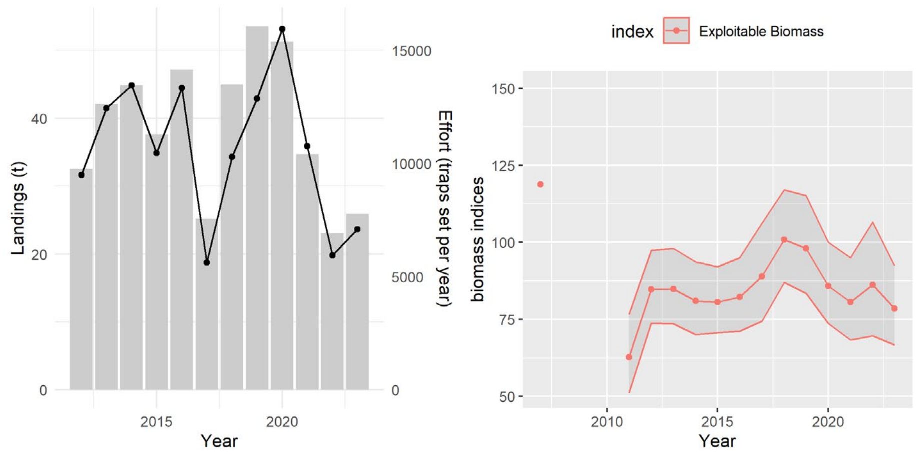
Annual mixed landings of reef fish in the lobster fishery have have been declining since peaking in 2015, reaching just under 10t by 2023. The biomass index derived from the Landings Per Unit Effort (LPUE) of these bycatch species shows a fluctuating trend over the years, with a notable decline from high levels in 2000 and 2007 to its lowest point in 2011. While there has been gradual recovery since then, particularly from 2019 onwards, the index has yet to stabilize, showing some year-to-year variability. The increasing trend in recent years suggests a growing market for bycatch species, primarily driven by demand from neighboring islands such as St. Eustatius. The recent increase in the retention of formerly discarded bycatch highlights the need for careful monitoring and management to ensure this practice remains sustainable and does not negatively impact the ecosystem or stock health.

Red fish trap fishery

The figure below gives a summary of the trends in the redfish (Lutjanidae) trap fishery, which principally targets a mix of deep water snappers such as the Silk snapper, *Lutjanus vivanus*, the Vermillion snapper, *Rhomboplites aurorubens*, the Blackfin snapper, *Lutjanus buccanella* and the Lane snapper, *Lutjanus synagris*.

In the redfish trap fishery, the number of trips has grown from 315 to 568 (corresponding to 9 500 and 13 400 traps set respectively) during the period 2012 to 2016 but dropped considerably to 270 trips in 2017 (5 600 traps). In the following three years, the effort increased again to reach nearly 600 trips in 2020 (16 000 traps), the highest effort for the whole period considered. Since then, effort has declined sharply to 283 trips (7 000 traps) in 2023. The landings of redfish (mainly silk snapper and in smaller proportions blackfin and vermillion snapper) broadly followed the variations in the effort, with the highest estimates (>50t) in 2019 and 2021 followed by a decline in the last three years reaching one of the lowest values of the entire period in 2023 (26t). This recent drop in snapper landings and effort in 2022 and 2023 can likely be attributed to a gentleman's agreement among fishermen to close the Saba Bank during these years to allow redfish stock recovery.

The biomass index derived from the LPUEs shows a decrease of 50% between 2007 and 2011, followed by a steady increase until 2018 and a decrease since then.



Summary plots for the snappers.
Left : landings (bars) and effort (solid line) estimates
Right: biomass index for the combined snapper stocks obtained by standardising the landing-per-trip (with 90% confidence intervals)

Other fishing métiers

Bottom drop longline, pelagic and shark bycatch landings have remained much less important and have shown no significant new developments.

Overall conclusion

For the targeted lobster, the LPUE based indices indicate that stock size overall increased since the beginning of the current port sampling program (2011). However, for the redfish stocks, there has been a decrease in apparent stock size over the past four years.

Continued monitoring of the fishery is essential, as well as improved biological sampling and reporting of the catches. The current ability to accurately estimate the status of individual redfish species is limited by the fact that the fisheries data is not reported per species. Being able to split the landings per species, either by encouraging the fishers to report landings per species, or by increasing the intensity of biological sampling, would, provide a better basis to manage the individual snapper species stocks. Additionally, combining fisheries-dependent data with cost-effective fisheries-independent methods, such as BRUV systems, underwater camera surveys, or targeted tagging programs, could further improve stock assessments and support sustainable fisheries management for the Saba Bank

1 Introduction

The main fisheries occurring on the Saba Bank are the trap fisheries for spiny lobster (*Panulirus argus*) and for deep water snappers ("redfish") (Meesters et al. 2010). Earlier studies have raised concerns about the impact of those fisheries on the main stocks, and also more broadly on the Saba Bank ecosystem. For instance, Meesters et al. (1996) pointed out the practically complete depletion of conch and large groupers on the bank. Dilrosun (2000) and Toller and Lundvall (2008) examined the lobster and snapper fisheries and raised concern about the small size of the Silk snappers caught. Finally, Toller et al. (2010) studied fish assemblages of the bank and confirmed Meesters et al.'s (1996) prior suggestion that large groupers were absent but, on the positive side, also drew attention to the seeming abundance of sharks in the ecosystem. This all meant that further investigation was clearly urgently needed.

In order to develop a good scientific basis to assess and manage these fisheries on Saba Bank, a fisheries monitoring program has been conducted since 2011. Initially set up by IMARES (now Wageningen Marine Research, WMR), data collection has been conducted by the Saba Bank Management Unit (SBMU, part of the Saba Conservation Foundation) since November 2017. This data collection program is primarily based on surveys of the fishing activity, describing effort and landings, complemented by biological sampling of the landings (species composition and length measurements). Analyses of this data have already been published in previous reports presenting the status and the trends in the Saba Bank fisheries since the beginning of the data collection program (de Graaf et al., 2017; Brunel et al., 2018 and Brunel et al. 2021). These reports indicated that the effort in both fisheries had increased (except in 2017 for the redfish trap fishery and in 2020 for both fisheries due to COVID-19 pandemic), which resulted in a similar trend in the landings for most species groups. Despite this increasing trend in effort and landings, no notable trends were found in the size of the landings, and abundance indices suggested either increasing or stable stock size for all species. We here provide an update of these analyses, covering now the period 2011 to 2023.

2 Materials and Methods

2.1 Data collection

A sample-based fishery survey (Stamatopoulos, 2002) was implemented in September 2011 to collect basic data on catch, effort, species composition and length frequency of the fisheries on the Saba Bank. The data collection system was set up and run by WMR until November 2017. Since then, fisheries monitoring has been conducted by Saba Bank Management Unit (SMBU).

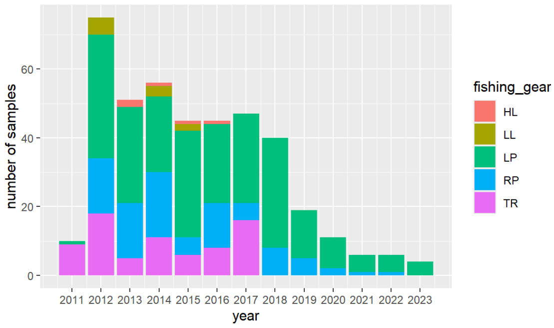
The sample-based fishery survey consists of different monitoring activities:

- *Frame Survey:* A frame survey is a census-based approach to collate a list of homeports and boat/gear categories which is used as the basis for the Active Days, Boat Activity and Landings surveys.
- *Boat Activity Survey:* Boat Activity Surveys were conducted at the only homeport on Saba (Fort Bay) to determine how many boats were active on a given day. Boat activity was recorded nearly every day.
- *Active Days Survey:* Active Day Surveys were conducted at the end of each month to determine the number of active fishing days for each strata in the survey design (e.g. home port, boat/gear category). In the current survey active days were simply defined as the number of days in a month.
- *Landings Survey:* Landings Surveys were conducted to collect data on catch, effort, species composition and length frequency. In addition to the standard landings data, information was collected on the observations of lionfish and whales and dolphins by fishermen.

In addition to this survey-based data collection for effort and landing, biological sampling is also conducted both at the landing site and onboard. For a number of fishing trips, the landings (at the harbour) or catch (onboard) species composition is determined, and length measurements are taken. Until 2018, upwards of 40 trips per year were sampled for species composition, taken representatively from the different fishing methods (figure 2.1.1). However, since then, the number of samples has been barely more than 10 trips per year, which impacts the reliability of assessments using those data. This situation is largely due to the limited capacity available for data collection by SBMU, despite efforts to double the staffing from 1 to 2 data collectors. It is important to note that effective fisheries data collection requires a minimum of two dedicated individuals, and the SBMU team also supports other essential activities which further demands their time and effort. These capacity challenges were discussed by Debrot et al. (2022), and several remedial measures were proposed to address longstanding data issues.

The number of trips sampled for landings length-composition was on average 54 per year (excluding 2011), primarily involving lobster and redfish trips, with a notable decrease in sampled trips from 2020 to 2023 (figure 2.1.2).

In addition to the data collected in the current fisheries monitoring program, data from two earlier studies are also used here: one conducted in 1999-2000 (Dilrosun, 2000) and one in 2007 (Toller and Lundvall, 2008)



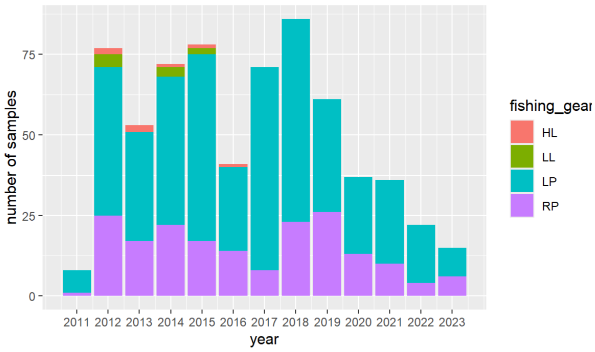


***Fig 2.1.1** : number of fishing trips sampled for species composition*

***Fig 2.1.2** : number of fishing trips sampled for length composition*

For lack of better precision, fishing activity is reported per sector of the bank (figure 2.1.3). The bank is divided into grid composed of cells of approx. 300 km2 with A-D from north to south and 1-5 from West to east. Three of the grid cells do not lie on the bank and no fishing takes place in them. Most of the grid cells cover depth ranges of several 100s of meters in depth with as a consequence that very little useful information can really be obtained from such gross spatial reporting and improvements have been recommended (Debrot et al. 2022).

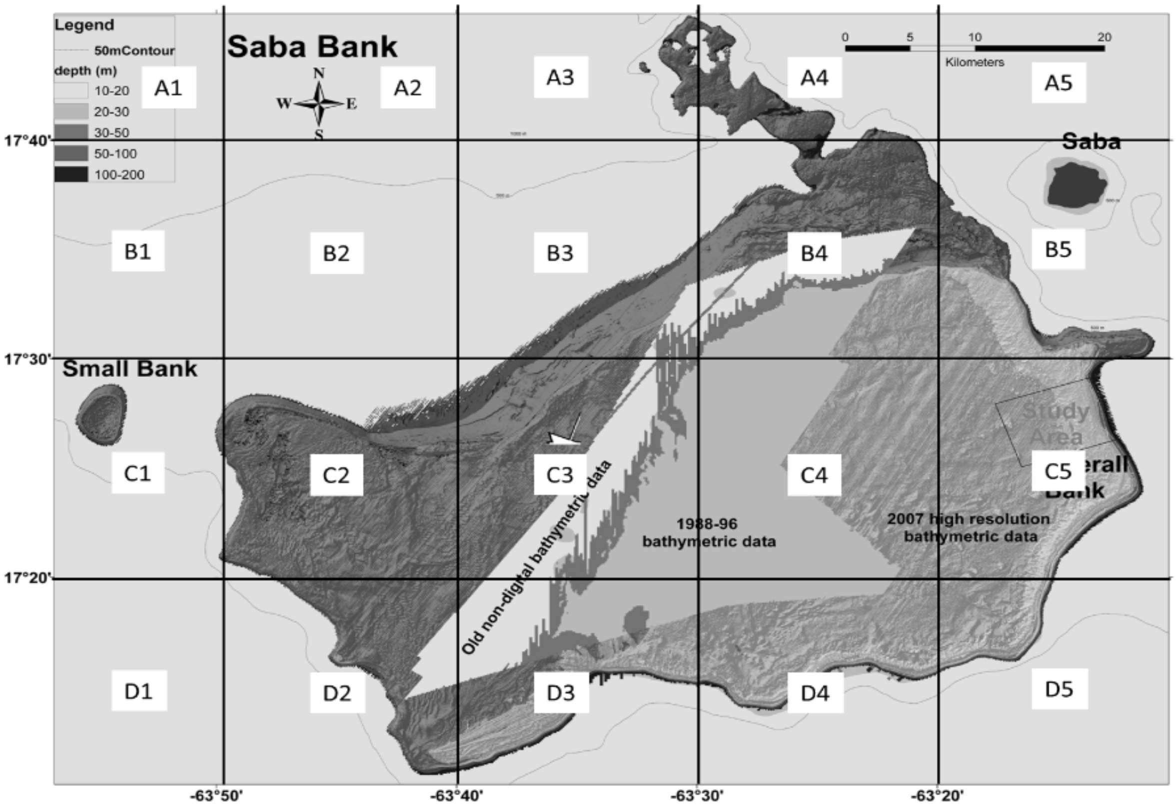


***Fig. 2.1.3**: Overview of the study area with the 20 sub-areas used in the fishery monitoring scheme.*

2.2 Effort and landings estimation

Since the fisheries survey covers all fishing boats from Saba, all calculations of effort and landings are done at the “boat level”, and then summed across boats within the different gear type fisheries.

Number of monthly trips per boat:

The number of trips carried out per month was calculated for each boat from the activity survey only. In order to take account of the fact that there was not a 100% coverage of the vessel activity (i.e. several days in the month with no observation on vessel activity), a first correction (raising) of the number of trips was conducted as follows:

raised number of trips = number of trips observed / survey coverage rate

Since fishing activity during the weekend is low compared to weekdays, this raising was done separately for weekdays and weekend days. This way, the activity for the days with no observation during the week, for a given boat and a given month, was assumed to be the same as the week days with observations, and similarly for weekend days.

Coverage for the individual weekdays was usually good, for a majority of the month at 100%, and in most of the cases, higher than 75% (figure 2.2.1). For the weekends, coverage was much lower, and therefore raised estimates of effort become more uncertain (high raising factor applied to a small number of observations). However, since the activity level is usually low in the weekend (most boats do not fish), this uncertainty about the effort during the weekend is expected to have a small impact on the overall estimate of total effort.

It is important to note that there were significant gaps in survey data coverage, particularly towards the end of 2022, and similarly in 2023. These gaps were most pronounced in November and December of each year (figure 2.2.1). As no assumptions were made to estimate the missing data for these periods, the trip estimates for these months are only representative of the days with actual data, leading to probable underestimations of the true fishing activity. This limitation must be considered when interpreting the data and its implications on overall fishing effort estimates, particularly when assessing annual trends and outcomes. Additionally, in many months, there were no observations from the survey activity during weekends, leading to the assumption that no boats were fishing during these times.

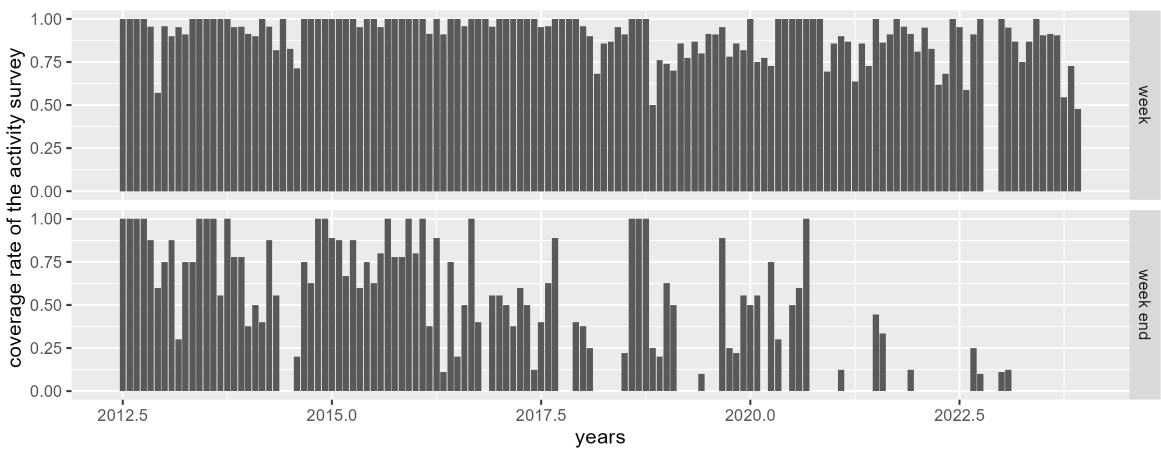


***Fig 2.2.1**. Coverage rate of the activity survey per month for week days and weekend days (numbers of days with observation in the harbor divided by the number of days in the month)*

Effort per fishing method per boat:

Based on the data collected by the landings survey, it was possible to split the effort between fishing methods (lobster and redfish trap, bottom handlining, trolling). First, at the boat and month level, the proportion of each fishing method was calculated from the landings survey and multiplied by the raised number of monthly trips (from the activity index) for the corresponding boat to get an estimate of the number of trips per fishing method per boat.

In addition, the mean number of gear type used per trip was calculated for each boat per month and multiplied by the estimated number of trips conducted for each boat and month to obtain the monthly effort in terms of total gear number. Summing over the boats gives an estimate of the effort per fishing method, both in terms of the number of fishing trips and the number of gears deployed.

Annual landings per species category

Landings per trip are reported by species categories in the landings surveys. The categories considered in this report are the lobster, reef fish (bycatch in the lobster fishery), redfish fish (snappers) and pelagic fish.

Since all the vessels are covered by the landings survey, mean landings were first estimated at the boat and month level. These mean landings were then multiplied by the estimated number of trips using the corresponding fishing method (e.g., lobster traps) for each boat and month. Finally, the results were summed across all boats and months to obtain the overall yearly total estimates. The figure 2.2.2 summarizes the successive steps and raising procedures to estimate monthly landings and effort.

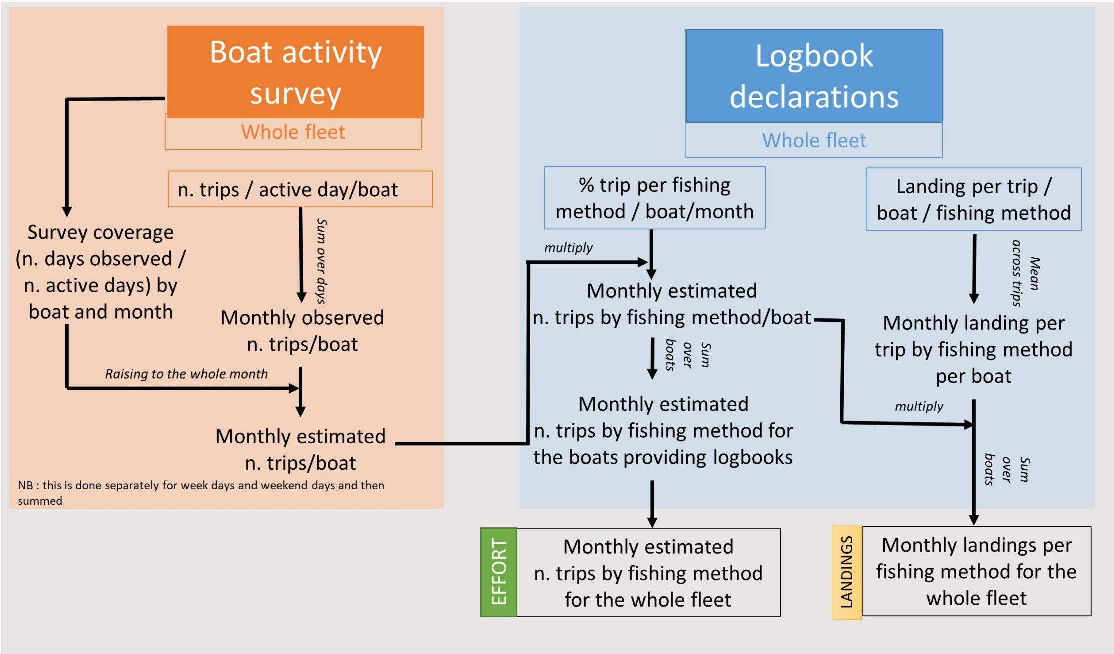


Fig 2.2.2. *Estimation method for the monthly landings per species category and "métier" (fishing method) and monthly effort by métier.*

2.3 Estimation of abundance indices

In order to get annual abundance or biomass indices for the main species groups, the landings per trip (LPUE) were analysed for each of the main species groups for each of the fishing methods. Part of the variations in the annual mean LPUE reflect other factors than changes in stock size, such as changes in overall effort, monthly or spatial repartition of the effort or even different contributions of different vessels to the annual effort. In order to standardise the LPUEs and extract an annual abundance or biomass index, the LPUE was modelled for each of the main species groups and for each of the fishing methods using a GLM with a negative binomial distribution. The formulation of the full model was as follows:

Log(landings per trip) = intercept
+ Year effect
+ Month effect
+ Boat effect
+ soaking time
+ log(fishing effort)

In this formulation of the model, one parameter is estimated for the intercept and for each of the levels of the different effects (year, month, boat and area). One parameter is also estimated for the linear regression of the log of landings (in number for the lobsters and in kg for the fish) against the log of fishing effort (in trap numbers, hours of diving). This model formulation implies a power function between the landings and the effort, which is the formulation typically used for ad hoc standardisation of LPUE in trap fisheries. The “year” effects estimated by this method corresponds to the variations in the LPUEs which are explained by the year, when all other sources of variation have been taken into account (including any changes in effort). These “year” effects can therefore be interpreted as abundance indices.

For the lobster, the GLM used a negative binomial error distribution, as the data are counts and the fit of a GLM with a Poisson distribution indicated overdispersion. As the response variable is landings in numbers, the estimated year effect is referred to as abundance index. For the GLM on fish species, the landings are reported in weight, and the model uses normally distributed errors. The index is referred to as a biomass index.

3 Results

3.1 Annual landing and effort estimates

The data show an increase in the number of fishing trips using lobster traps from roughly 600 in 2012 (for around 50 000 trap drops) to around 850 in 2015 (70 000 trap drops), followed by a steady decrease to values under 500 trips (33 000 trap drops) in 2020. In 2021 the number of fishing trips increased to around 700 trips (for around 50 000 trap drops) and since then it has decreased to around 430 trips (32 000 trap drops) in 2023 (figure 3.1.1 and table 3.1.1). The landings of lobster generally increased from 2012 to 2017, from 36 to 65 tonnes landed annually (maximum of 71 tonnes in 2015) and then dropped to 24 tonnes in 2018. From 2019 to 2021 the landings of lobster increased to 55 tonnes and dropped slightly in the following two years to 43 tonnes. In 2022 and 2023, we were unable to produce an estimate of effort and landings for the months of November and December. These estimates reflect only the available data and are not corrected for missing months due to the lack of sufficient information needed to accurately estimate landings and effort for November and December; thus, they may underestimate the true annual values, as these months typically account for approximately 8% of the annual fishing effort and 11% and 12% of the annual landings, respectively. Landings of fish from the lobster traps nearly doubled between 2012 and 2015, increasing from 8 to 15 tonnes per year, varied between 8 and 14 tonnes per year until 2020 and decreased from 14 tonnes in 2021 to 9 in 2023.

The number of trips using redfish traps increased from 2012 to 2016 (from 315 to 568 days), dropped to 270 trips in 2017, increased to 588 trips in 2020 and dropped thereafter to 283 trips in 2023. The landings of redfish followed a similar trend, increasing from 33 to 47 tonnes in 2016, dropping to 25 tonnes in 2017, increasing to 54 tonnes in 2019 and dropping again to 26 tonnes in 2023. In 2022, we were unable to produce an estimate of effort and landings for the months of March, April, May, June, November, and December, while in 2023, we could not produce estimates in November. These estimates are based solely on the observable data and do not correct for missing months due to limited data availability for these periods, which restricts the ability to produce reliable estimates. As a result, the estimates may underestimate the true annual values. The missing months typically account for approximately 7%, 8%, 9%, 8%, 13%, and 7% of the annual fishing effort and 7%, 8%, 8%, 7%, 14%, and 6% of the annual landings, respectively.

The number of trolling trips fluctuated between 29 and 77 days (in 2018 and 2014, respectively), with no specific trend. In 2019 the number of trips increased to 77 trips per year and since then have decreased to 20 trips in 2023. The landings have fluctuated between 1.6 and 3.0 tonnes, except for 2017 for which landings are estimated at around 10 tonnes. Effort and landings were not estimated for 2022 as there was no interview conducted on trolling trips that year.

The number of trips using longlines has been variable at between 2 and 14 days with two years (2015 and 2017) showing larger values (36 and 33 respectively). The effort in number of hooks is very variable, reflecting the fact that the few vessels involved, change between the years and that they each deploy different numbers of hooks per line. Trends in the landings broadly followed the trend in the number of fishing days. There was no information collected on longline trips in 2021 and 2022 and effort and landings for those years could not be estimated.

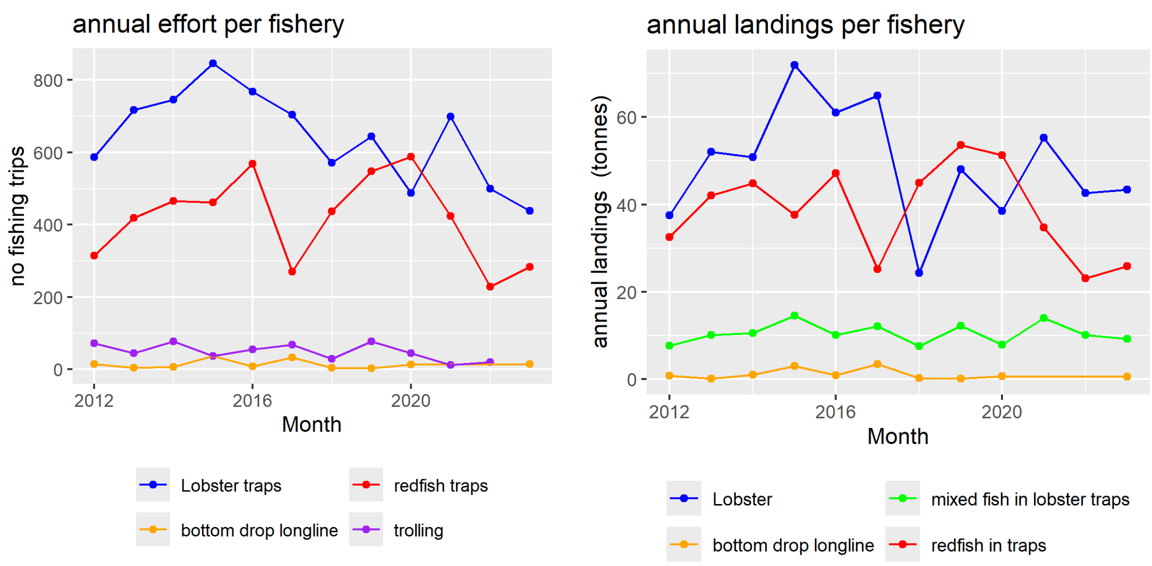


Fig. 3.1.1. *Annual landed catch per group of species (in tonnes) and fishing effort per gear type in fishing days estimated from the port sampling and activity surveys carried out from 2012 to 2023.*

Table 3.1.1. *Estimates of the annual effort (number of gear used and number of fishing trips) and annual landed catches for the year 2012 to 2023*

		landings and units		number of gears deployed		fishing days
2012	lobster	38	T	49519	lobster traps	587
	mixed reef fish	8	T	49519	lobster traps	587
	redfish in pots	33	T	9500	redfish traps	315
	longline fish	1	T	6239	hooks	15
	trolling fish	3967	number	246	lines	72
2013	lobster	52	T	59398	lobster traps	718
	mixed fish in lobster pots	10	T	59398	lobster traps	718
	redfish in pots	42	T	12442	redfish traps	419
	longline fish	0	T	228	hooks	5
	trolling fish	1220	number	178	lines	45
2014	lobster	51	T	57320	lobster traps	745
	mixed fish in lobster pots	11	T	57320	lobster traps	745
	redfish in pots	45	T	13453	redfish traps	466
	longline fish	1	T	4047	hooks	7
	trolling fish	2220	number	217	lines	77
2015	lobster	72	T	69494	lobster traps	846
	mixed fish in lobster pots	15	T	69494	lobster traps	846
	redfish in pots	38	T	10462	redfish traps	461
	longline fish	3	T	2088	hooks	36
	trolling fish	2641	number	102	lines	37
2016	lobster	61	T	56949	lobster traps	768
	mixed fish in lobster pots	10	T	56949	lobster traps	768
	redfish in pots	47	T	13344	redfish traps	568
	longline fish	1	T	552	hooks	8
	trolling fish	1489	number	383	lines	55
2017	lobster	65	T	59188	lobster traps	704
	mixed fish in lobster pots	12	T	59188	lobster traps	704
	redfish in pots	25	T	5620	redfish traps	271
	longline fish	4	T	20434	hooks	33

	trolling fish	7688	number	191	lines	68
2018	lobster	24	T	41886	lobster traps	571
	mixed fish in lobster pots	8	T	41886	lobster traps	571
	redfish in pots	45	T	10287	redfish traps	437
	longline fish	0	T	680	hooks	4
	trolling fish	486	number	69	lines	29
2019	lobster	48	T	50644	lobster traps	644
	mixed fish in lobster pots	12	T	50644	lobster traps	644
	redfish in pots	54	T	12862	redfish traps	547
	longline fish	0	T	158	hooks	3
	trolling fish	590	number	127	lines	77
2020	lobster	38	T	33416	lobster traps	488
	mixed fish in lobster pots	8	T	33416	lobster traps	488
	redfish in pots	51	T	15948	redfish traps	589
	longline fish	1	T	12523	hooks	14
	trolling fish	3366	number	132	lines	44
2021	lobster	55	T	52811	lobster traps	698
	mixed fish in lobster pots	14	T	52811	lobster traps	698
	redfish in pots	35	T	10774	redfish traps	423
	longline fish	-	T	-	hooks	-
	trolling fish	982	number	40	lines	12
2022	lobster	43	T	38039	lobster traps	500
	mixed fish in lobster pots	10	T	38039	lobster traps	500
	redfish in pots	23	T	5952	redfish traps	228
	longline fish	-	T	-	hooks	-
	trolling fish		number		lines	
2023	lobster	43	T	32430	lobster traps	438
	mixed fish in lobster pots	9	T	32430	lobster traps	438
	redfish in pots	26	T	7101	redfish traps	283
	longline fish	1	T	3653	hooks	14
	trolling fish	1381	number	397	lines	20

3.2 Lobster Trap fishery

3.2.1 Lobster

3.2.1.1 LPUE

Landings and effort data :

The mean number of traps set per fishing trip has been relatively stable at around 75 traps per trip in 2000, with occasional variations. In 2020, there was a notably lower value compared to other years (Figure 3.2.1), Considering the annual number of trips (estimated since 2012 by the boat activity survey), the fishing effort in terms of the annual number of traps set increased from approximately 49,000 traps in 2012 to 70,000 traps in 2015. After 2015, the effort progressively decreased to 32,000 traps in 2023, except in 2019 and 2021, when the number of traps set was around 50,000 per year (Table 3.1.1).

The spatial distribution of the effort is presumably only accurately reported since 2013 (figure 3.2.2). The data show that the main fishing areas are B4, B5, and C5, which are in the northeastern part of the bank, closer to Saba Island. There is a notable concentration of effort in these areas across most years. From 2016 to 2023, there appears to be a slight increase in effort in the southern part of the bank (areas D2 to D5), although the pattern is not consistent in every year, with exceptions in 2018 and 2020. The year 2020 stands out as an exceptional year, with most of the effort concentrated in areas B4 and B5, which are closest to Saba Island.

In terms of monthly distribution (Figure 3.2.2), the data suggest variability in the effort across different areas throughout the year. However, consistent seasonality is difficult to determine definitively based on the available data, so caution should be exercised when interpreting trends related to seasonal changes in spatial distribution.

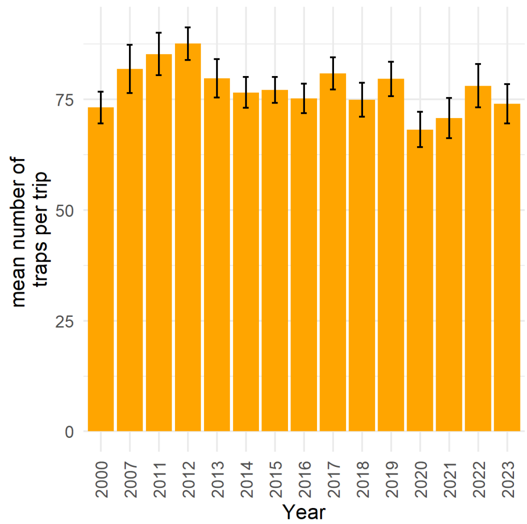


Fig. 3.2.1. *Mean number of traps lifted per trip (with 95% confidence intervals).*

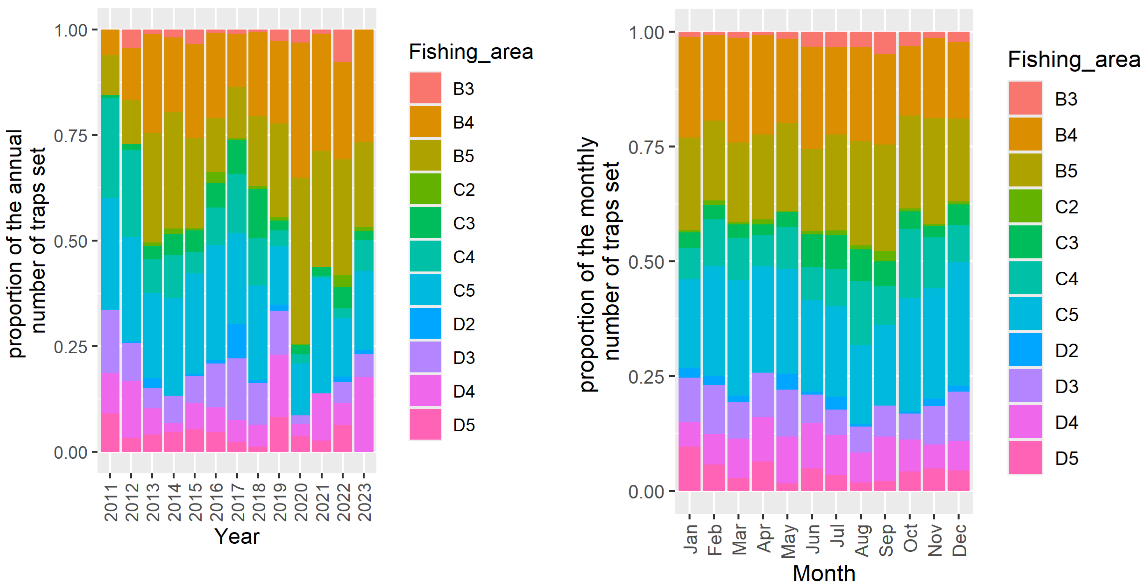


Fig. 3.2.2. *Proportion of the annual (left) and monthly (right) effort of the lobster fishery (in total number of traps set) per fishing area.*

The catch rates expressed as lobsters per trap or per trip, show broadly similar variations, with some small differences related to the variations in the number of traps used per trips (figure 3.2.3). However, it is important to note that these metrics are influenced by different factors. Specifically, the catch rate per trip depends on the number of traps used per trip, while the catch rate per trap is more directly indicative of individual trap efficiency. Despite this, both metrics reflect changes in the overall fishing efficiency and lobster abundance, leading to similar observable trends over time. Catch rates were substantially higher in the year 2000, were lower in the year 2007 and are at their lowest in the year 2011. Catch rates have then gradually increased to a level in 2017 similar to that of 2007. After a small decrease in 2018 and 2019, the catch rates increased again in 2020 and 2021. In 2022, catch rates increased to levels similar to those in 2007 and 2017, followed by a slight decrease in 2023.

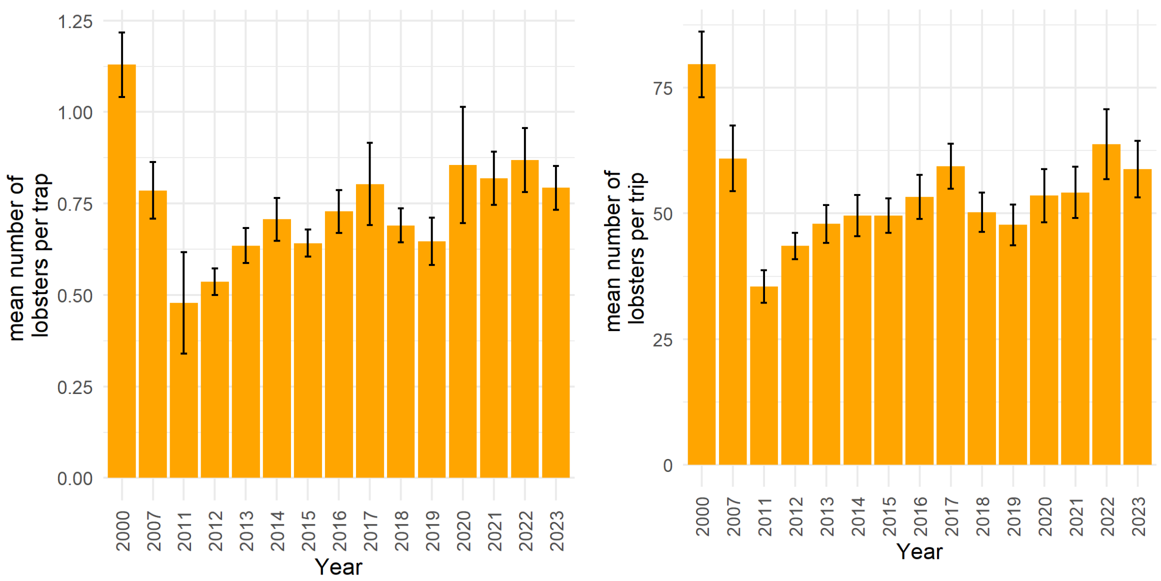


***Fig. 3.2.3**. Yearly mean number of lobster per trap (left) and per trip (right) (with 95% confidence intervals).*

Standardisation of the LPUE using a GLM model

All factors appeared to be significant for the GLM model fitted on the lobster landings per trip (table 3.2.1). The estimated effects are shown in figure 3.2.4. There were differences observed in the landings rates of the six participating vessels, with the most-efficient vessel landing 25% more per trip than the less-efficient one. The "month" effect shows the seasonality of the landings rate for a standard trip. There is a clear seasonal pattern, with highest landings rates toward the end of the year, and lowest rates during late spring/early summer. The modelled "year" effect is a standardised annual abundance index. It shows that the abundance dropped from higher levels in 2000 to lower levels in 2011, with a progressive increase towards the level of 2007 until 2017, followed by a small decrease in 2018 and 2019 and an increase in the following four years.

***Table 3.2.1.** GLM model of lobster catches per trip. Significance of each model term tested by removing them one by one and comparing to the full model. AIC stands for Akaike information criterion (the lower the value the higher the effect), a P-value lower than 0.05 (*) indicates that the effect of the corresponding factor in the model is significant. (** = P-value lower than 0.01, *** = P-value lower than 0.001)*

Model term removed	Number of parameters	AIC	Log-Likelihood ratio	p. value	Significance level
<none (full model)>		19068			
factor(Year)	12	19195	151.02	<2e-16	***
factor(Month)	11	19429	383.30	<2e-16	***
factor(Boat_name)	5	19356	298.59	<2e-16	***
factor(Fishing_area)	8	19074	22.21	0.004546	**
logTraps	1	19922	856.04	<2e-16	***

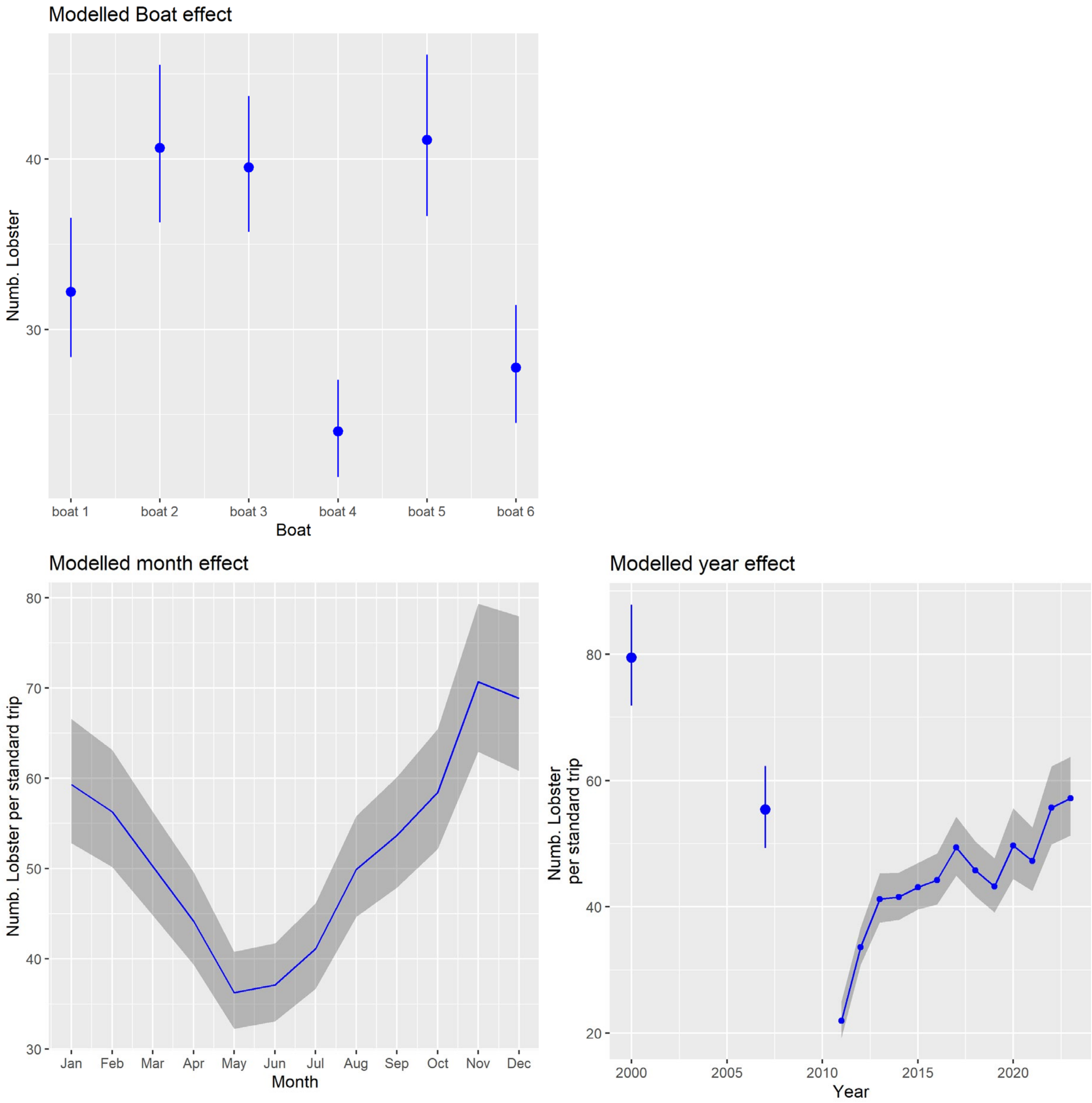


Fig. 3.2.4. *Modelled boat effect and modelled month and year effects on the landings of lobsters per trip (in numbers). Blue lines represent the modelled effect (and corresponding 95% prediction envelop in grey).*

3.2.1.2 Length frequency

Lobster length measurements were taken both during onboard sampling trips at sea (whole catch sampled) and during the surveys conducted in the harbour at the end of the fishing trips (landings only). The size of the lobsters landed varied from 52mm (carapace length) to 200mm, but the bulk of the landings were between 70mm and 150mm (figure 3.2.6) with a mean ranging between 108 and 120mm depending on the year (table 3.2.2). These values are above the minimum landing size of 95mm. There were variations in the size composition of the landing between the years, with larger individuals landed (especially the males) in 2011 and 2016 and smaller individuals landed (especially the females) in 2000, 2012 and 2022. There was a trend towards higher mean size for both males and females between 2012 and 2016. However, this trend has reversed and mean length has been decreasing, reaching its lowest point in 2022 for both sexes. In 2023 the mean length for both females and males increased slightly (figure 3.2.5). In general, the males landed were larger than the females by about 5mm, but the difference was particularly large in 2000 and 2011 (12mm). The proportion of males in the landings is also generally higher than the proportion of females but this proportion is highly variable between years.

A substantial part of the lobster landed appear to be smaller than the minimum landing size of 95mm (22%, figure 3.2.6). The length distribution of the discards (measurements taken during a small number of observer trips) show that most of the discarded individuals are just under the minimum size, but also in large proportion, much smaller individuals. There are also larger lobsters being discarded, corresponding either to the females with eggs (berried), or to lobsters damaged inside the traps by Queen triggerfishes that may feed on them.

The proportion of landed lobster below the minimum size until 2014 was high, especially in 2000 and 2012 with 27% and 20% respectively (up to 38% for the females, table 3.2.2). Since 2015, the proportion of undersized lobster in the landing is low, varying between 2% and 8%.

Table 3.2.2. *Lobster landings annual mean length, sex ratio and proportion of undersized individuals*

	Mean length (mm)			Sex ratio (males per female)	Proportion < 95mm		
year	female	male	combined		Females	Males	Combined
2000	102	112	108	142%	38%	19%	27%
2007	111	114	113	164%	19%	12%	15%
2011	113	125	118	71%	6%	3%	5%
2012	106	109	108	149%	35%	10%	20%
2013	109	115	113	147%	19%	8%	13%
2014	110	115	113	162%	18%	9%	13%
2015	114	120	117	154%	8%	1%	4%
2016	115	122	120	195%	7%	4%	5%
2017	113	120	118	179%	3%	2%	2%
2018	117	120	119	200%	4%	2%	2%
2019	111	119	116	149%	10%	5%	7%
2020	113	113	113	212%	7%	3%	5%
2021	114	120	118	157%	9%	3%	5%
2022	107	112	110	199%	10%	6%	8%
2023	113	121	117	118%	5%	2%	4%

Fig. 3.2.5. *Annual mean length of lobster landings (with 95% confidence intervals).*

__Table 3.2.3.__ Mean length (CL) and sex ratio of the discards vs. landed lobsters

	discarded	landed
mean length	88	115
mean length (females)	90	112
mean length (males)	83	117
sex ratio (males per female)	56%	169%

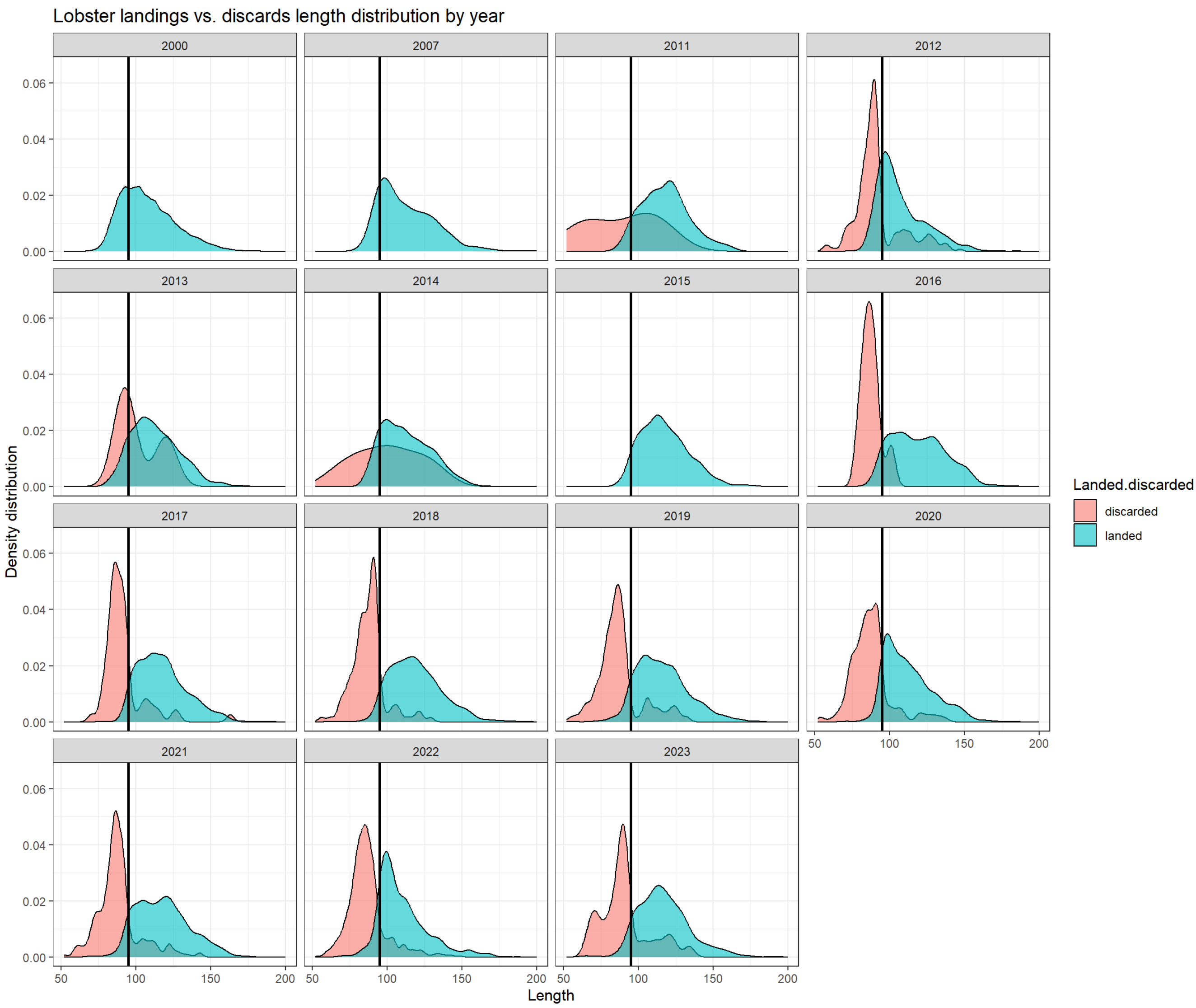


***Fig. 3.2.6.** Length distribution of the landed lobsters and discards of lobster for each year. The vertical line represents the minimum landing size of 95cm (carapace length).*

3.2.1.3 Undersized lobster

The number of undersized lobsters caught during each fishing trip was also provided during the port interviews. The catches of undersize lobster per trips were modelled using the same GLM approach as for the marketable size lobsters (section 3.2.1.1) in order to extract a yearly index for the undersized lobsters as an indicator of the strength of the incoming recruitment. For this model, all the factors tested were found to be significant, though their relative importance differed (Table 3.2.4). The model results suggest that both the fishing area and year had substantial impacts on undersized lobster catches, as evidenced by the large AIC value changes when these factors were removed. In contrast, the effects of month and boat were less pronounced, suggesting that differences in catches between months and boats were not as dramatic.

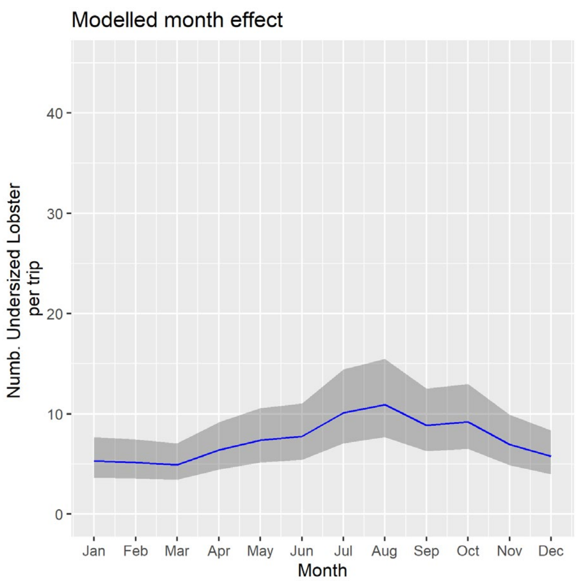
The catches of undersized lobster shows a seasonal pattern opposite to the pattern in the catches of marketable size lobsters, with higher values in late spring to early summer and lower values at the beginning and end of the year (Figure 3.2.7). The "year" effect appears rather constant, except for the years 2014 to 2016 when a high value alternated by a low one and then followed by another high one The trend continues with relative steadiness until 2020, after which there is a noticeable increase in the number of undersized lobsters per trip from 2021 onwards, peaking significantly in 2022 before dropping sharply in 2023.

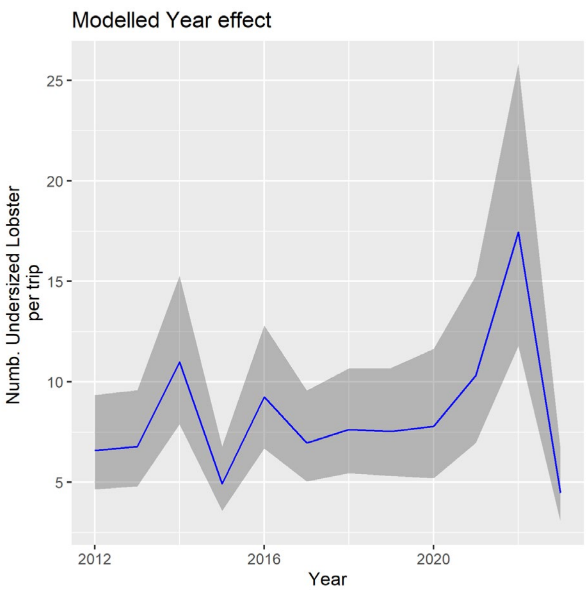
This time series of undersized lobster abundance does not seem to be a good indicator for the strength of recruiting year class, as there appears to be little relationship between the variations observed in the undersized lobster index and the exploitable stock index (i.e. high undersize index value do not seem to lead to substantial increase in the stock).

The model suggests some variation in the catches of undersized lobsters between boats, though the differences are relatively small, with overlapping confidence intervals indicating that these variations are not likely to be substantial. Finally, catches of undersized lobsters are higher in the northeastern part of the bank (areas B3,B4, B5, C3 and C4) and are lower in the southwestern part (areas C5, D3-5).

Table 3.2.4. *GLM model results of undersize lobster catches per trip. The significance of each model term was tested by removing each term from the full model, one at a time, and comparing it to the full model. AIC stands for Akaike information criterion (the lower the better), a P-value lower than 0.05 (*) indicates that the effect of the corresponding factor in the model is significant. (** = P-value lower than 0.01, *** = P-value lower than 0.001)*

Model term removed	Number of parameters	AIC	Log-Likelihood ratio	p. value	Significance level
<none (full model)>		15122			
factor(Year)	11	15248	148.497	<2.2e-16	***
factor(Month)	11	15191	91.534	8.339e-15	***
factor(Boat_name)	5	15151	38.689	2.743e-07	***
factor(Fishing_area)	8	15246	140.416	<2.2e-16	***
logTraps	1	15279	159.273	<2.2e-16	***





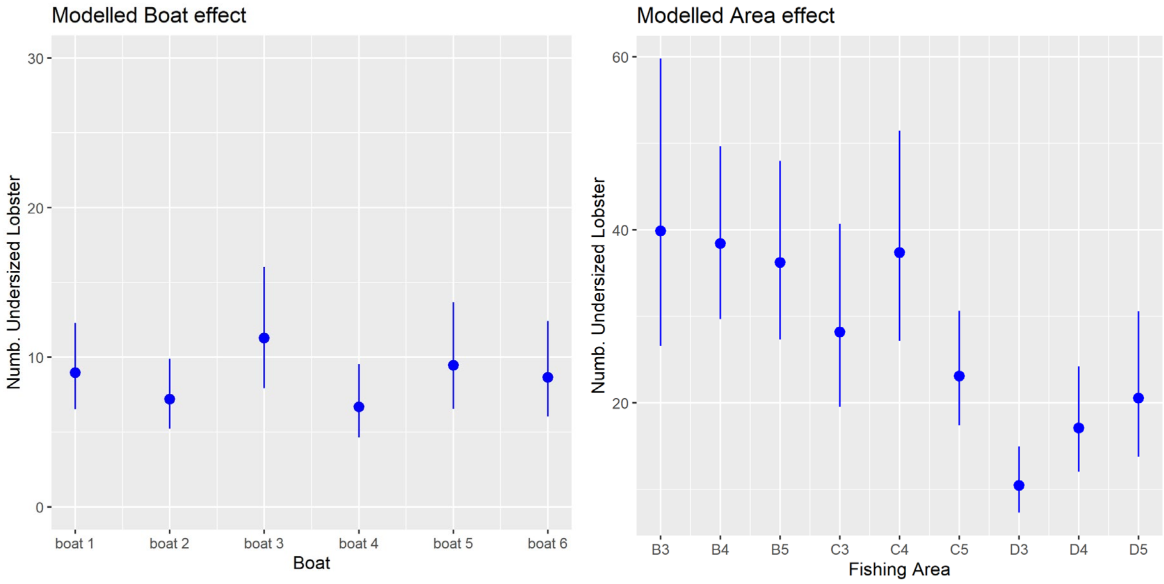


Fig. 3.2.7. *Modelled effects of the month, year, boat and fishing area on the catches of undersized lobsters per trips (in numbers). Blue lines represent the modelled effect (and corresponding 95% prediction envelop in grey).*

3.2.1.4 Spawning season

The number of berried lobsters per trip was also modelled using the GLM approach. All model factors were significant, except the fishing area (Table 3.2.5). Berried females are caught throughout the year but are more abundant between February and May (Figure 3.2.8). The spawning season in the Caribbean varies from March through August, depending on the region (e.g. Florida Keys) with peaks in March and April (Cavalcante Soares, 1990) but the lobsters are known to spawn year-round throughout the Caribbean. The model-estimated "year" effect suggests a low abundance in 2012, followed by a strong increase in 2013. The abundance fluctuated until 2020 when it decreased sharply reaching a particularly low point in 2023.

Table 3.2.5. *GLM model of berried female lobster catches per trip. Significance of each model term tested by removing them one by one and comparing to the full model. AIC stands for Akaike information criterion (the lower the better), a P-value lower than 0.05 (*) indicates that the effect of the corresponding factor in the model is significant. (** = P-value lower than 0.01, *** = P-value lower than 0.001)*

Model term removed	Number of parameters	AIC	Log-Likelihood ratio	p. value	Significance level
<none (full model)>		13624			
factor(Year)	11	13669	67.281	4.004e-10	***
factor(Month)	11	13736	134.055	<2.20E-16	***
factor(Boat_name)	5	13760	145.990	<2.20E-16	***
factor(Fishing_area)	8	13656	48.324	8.564e-08	***
logTraps	1	13932	309.853	<2.20E-16	***

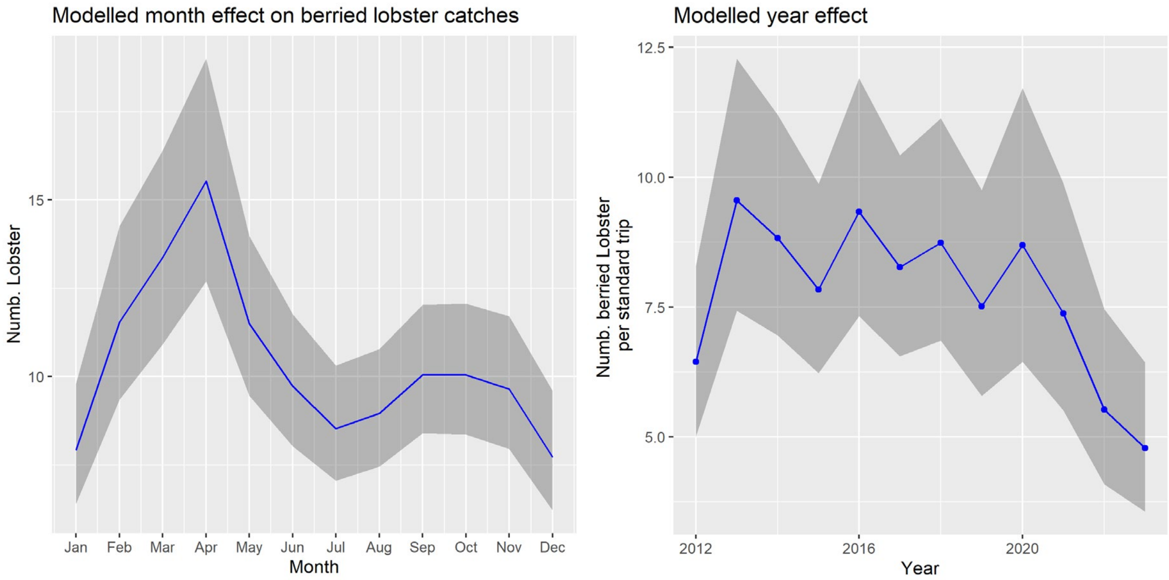


Fig. 3.2.8. *Seasonality and annual variations of the catches of berried lobsters (distribution of the monthly number of berried lobster by trip, corrected for the effect of the number of traps and the year effect from the model of lobster catches from figure 3.2.4).*

3.2.2 Mixed reef fish

3.2.2.1 LPUE

Landings and effort data :

The temporal variations of the effort and its distribution between the different fishing areas are the same as for the lobster, and show in figures 3.2.1 and 3.2.2.

The mean landings per trap show slightly higher values in the earlier years (2000 and 2007) and decrease by roughly 30% in 2011 compared to 2007. From 2012 to 2018 there are stable intermediate values, and an increase is seen towards 2023, when the highest mean landings per trap were recorded (figure 3.2.9). The mean landings per trips show similar variations, except in 2020, when the lower number of traps used per trip (figure 3.2.9) resulted in a decrease in the mean landings per trip.

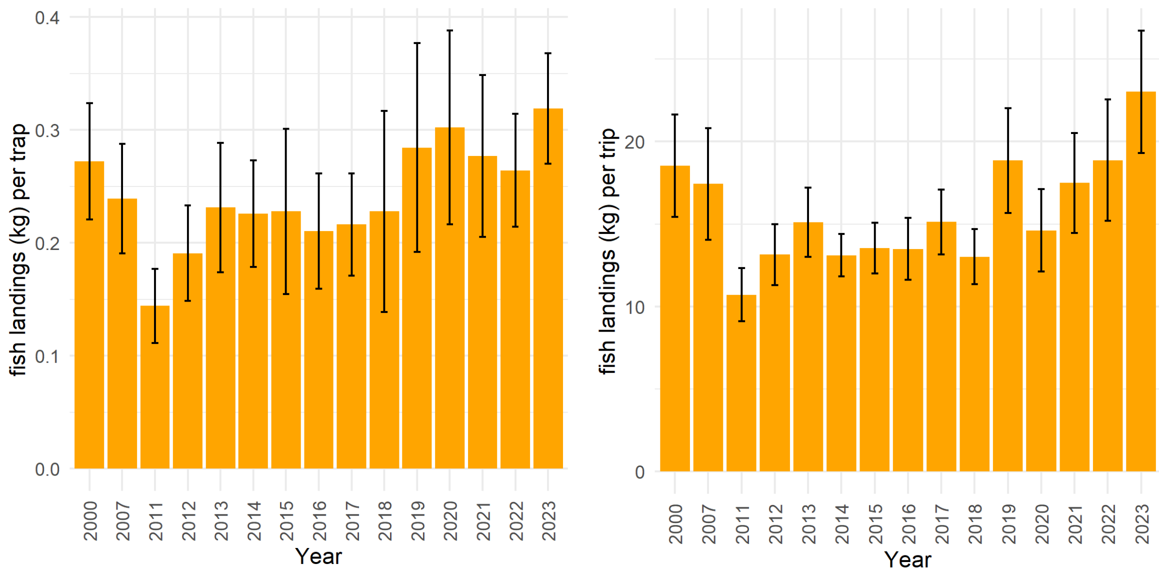


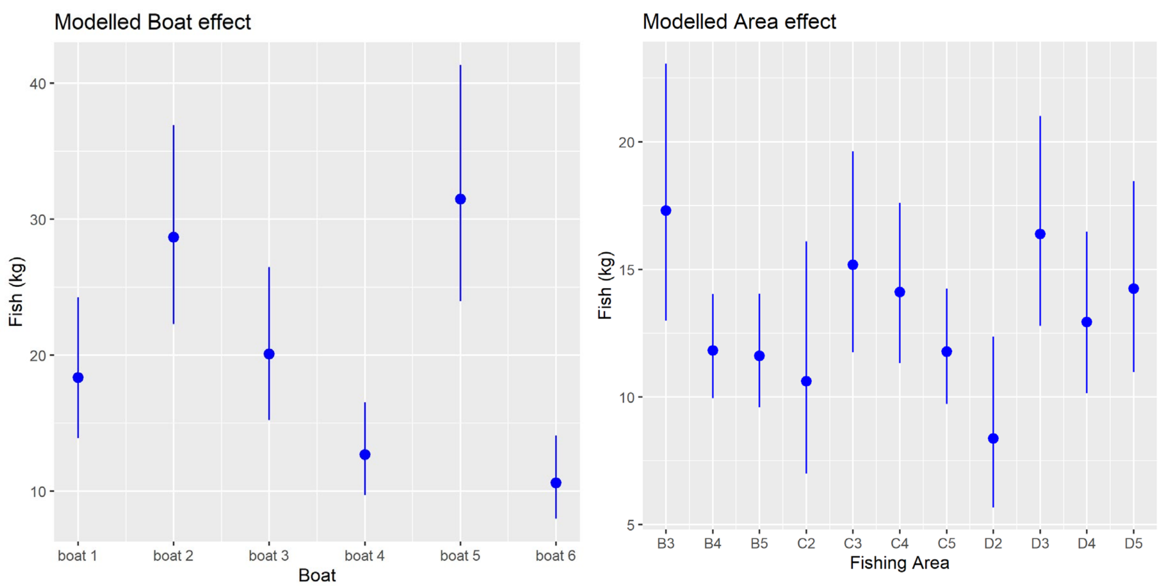
Fig. 3.2.9. *Yearly mean landings of mixed reef fish (kg) per lobster trap (left graph) and per fishing trip (right graph). Error bars are 95% confidence intervals.*

Standardisation of the LPUE using a GLM model

The GLM model results are given for all factors in table 3.2.6. Large differences were observed in the landings per trip of reef fish in lobster traps between boats (from a low of 10 to above 30 kg per standard trip, figure 3.2.10). This illustrates that some fishers tend to keep more bycatch while others prefer discarding them. The “area” effect indicates that fish catches are lower in the westernmost part of the bank (area C2 and D2), tend to be highest in the central part of the bank (B3,C3, D3 and C4), and are intermediate in the areas closest to Saba island (B4, B5, C5). The “month” effect indicated higher catches from May to October. The “year” effect indicates a similar temporal development as the raw data which show a decrease from higher levels in 2000 and 2007 to a lower level in 2011, followed by an increase until 2013 and a slight decrease thereafter and much higher values since 2019 with 2023 reaching a similar level to 2000.

Table 3.2.6. *GLM model of mixed fish landed per trip. Significance of each model term tested by removing them one by one and comparing to the full model. AIC stands for Akaike information criterion (the lower the better), a P-value lower than 0.05 indicates that the effect of the corresponding factor in the model is significant. (** = P-value lower than 0.01, *** = P-value lower than 0.001)*

Model term removed	Number of parameters	AIC	Log-Likelihood ratio	p. value	Significance level
<none (full model)>		4780.4			
factor(Year)	12	4821.2	5.3838	4.618e-09	***
factor(Month)	11	4864.2	9.6766	<2.20E-16	***
factor(Boat_name)	5	5175.1	87.6238	<2.20E-16	***
factor(Fishing_area)	10	4797.2	3.6380	7.995e-05	***
logTraps	1	4834.6	55.8663	1.144e-13	***



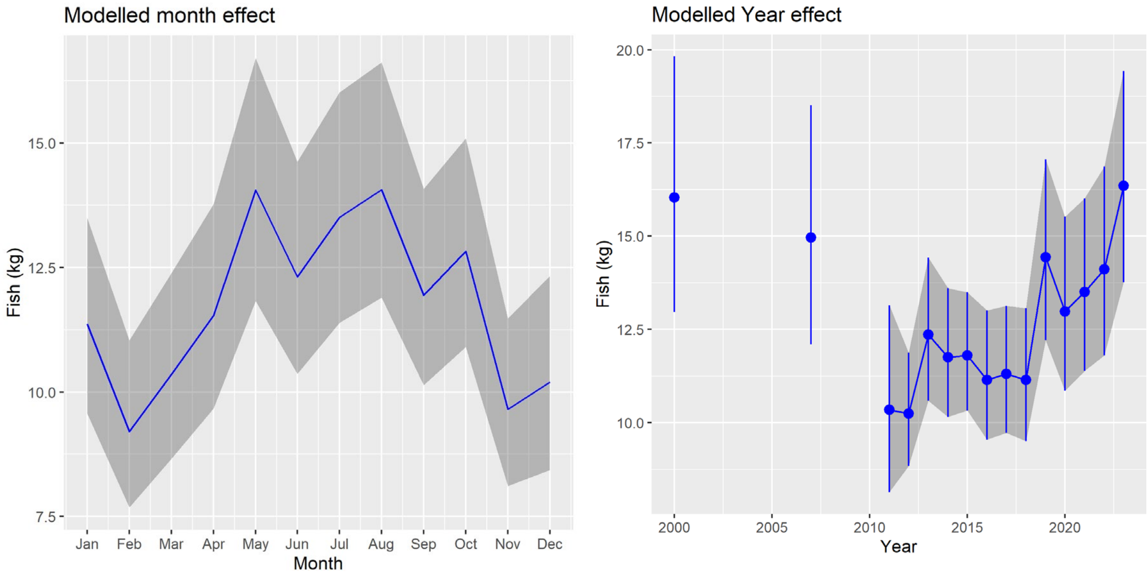


Fig. 3.2.10. *Modelled boat effect (model fitted on the data for 2011-2023) and modelled month and year effects (model fitted on the data 2000-2023) on the landings of mixed reef fish in lobster traps per trips (in numbers). Blue lines represent the modelled effect (and corresponding 95% prediction envelop in grey).*

3.2.2.2 Species composition of the landings & discards

The mixed reef fish catch in the lobster trap is composed of a variety of species. The main species landed in terms of numbers were the White grunt (*Haemulon plumierii)*, Red hind (*Epinephelus guttatus*), Cottonwick (*Haemulon melanurum)*, Doctorfish (*Acanturus chirurgus)*, Ocean surgeonfish (*Acanthurus bahianus)* and Queen triggerfish *(Balistes vetula)* (Figure 3.2.11). In terms of weight, Queen triggerfish was the main species, followed by the Red hind and the White grunt,. More than a third of the landings in numbers and in weight corresponds to a mixture of reef fish species, each representing individually less than 5% of the landings (category "other").

The average discard ratio is 35% (discards weight divided by catch weight). The most common reef fish species in the discards were the Honeycomb cowfish (*Acanthostracion polygonius)*, and the Cottonwick (Figure 3.2.12). Nurse shark also represented more than 25% of the discards in terms of weight. Again, almost 2/3 of the discards is represented by the category "other".

The proportion of some of the key species or group of species is shown on figure 3.2.13. The proportion of the Queen triggerfish is usually between 20 and 30% for the landings in weight but showed a particularly low values in 2015 and 2020-2021 (10-12%). The Red hind represents about 10% to 15% of the fish bycatch, but also showed a particularly low value in 2015, and a steep increase in 2020 (to nearly 30%) and decrease to earlier levels in 2021. The total weight of the herbivorous species landed usually represents around 12% of the landings, but peaked at more than 50% in 2015.

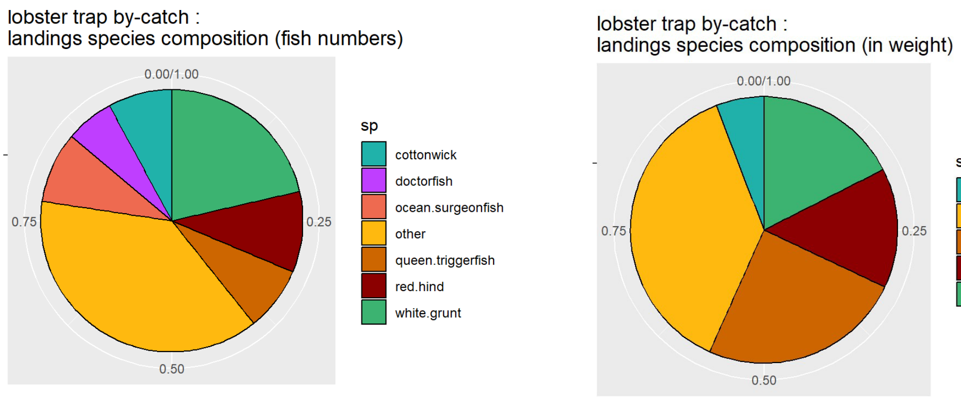


Fig. 3.2.11. *Species composition for the mixed reef fish landed in the lobster fishery (based on 226 trips sampled) in 2012-2023*

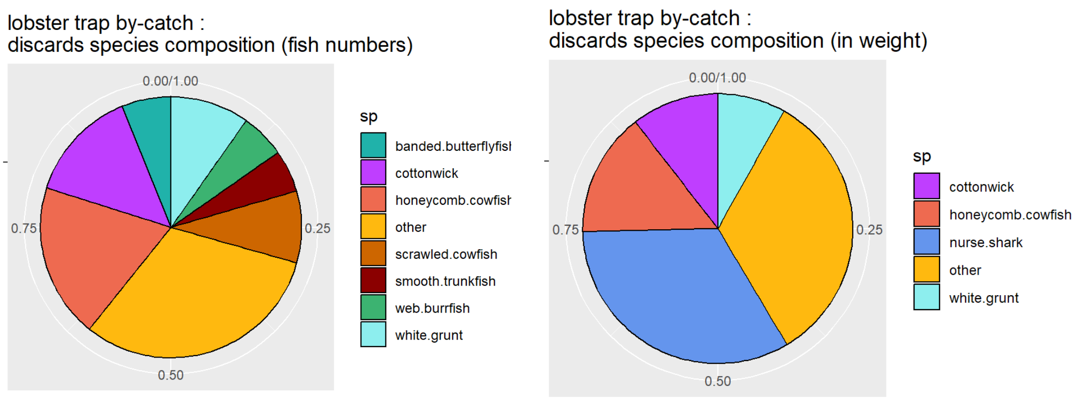


Fig. 3.2.12. *Species composition for the mixed reef fish discarded in the lobster fishery (based on 40 trips sampled) in 2012-2023.*

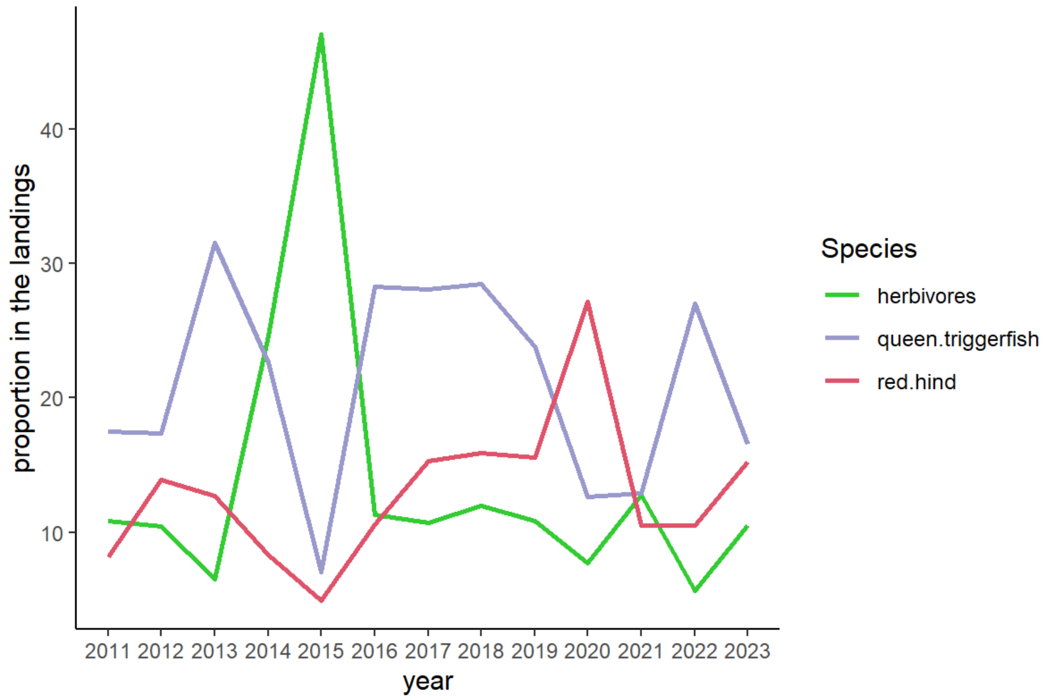


Fig. 3.2.13. *Proportion of the landings (percentage) in weights for 3 key species (or species groups) for the mixed reef fish landed in the lobster fishery.*

3.2.2.3 Length frequency of the catches

The landings length-frequency distribution was inspected for the three main reef fish species caught in the lobster fishery: the Queen triggerfish, the Red hind and the White grunt. The size ranges differed between the three species (figure 3.2.14): Queen triggerfish were the larger species, with landings mainly between 25 and 40cm. These were larger compared to the Red hind, which had landings mainly between 20 and 40 cm, and the White grunt, which were the smallest, with landings primarily between 20 and 30 cm.

The landings length-frequency distribution for each of the three species (Queen triggerfish, Red hind, and White grunt) also shows variability across different years (figure 3.2.15). Notably, some years have more consistent data with higher sample sizes, while in other years, sampling is sparse or missing entirely. This variation can be observed in the differing counts in the frequency distributions, with certain years showing distinct peaks that indicate greater catch frequencies for specific lengths. In years like 2014, 2017, 2019, and 2022, the data coverage seems more extensive, with noticeable peaks and spread for the three species, suggesting higher sampling effort during those years.

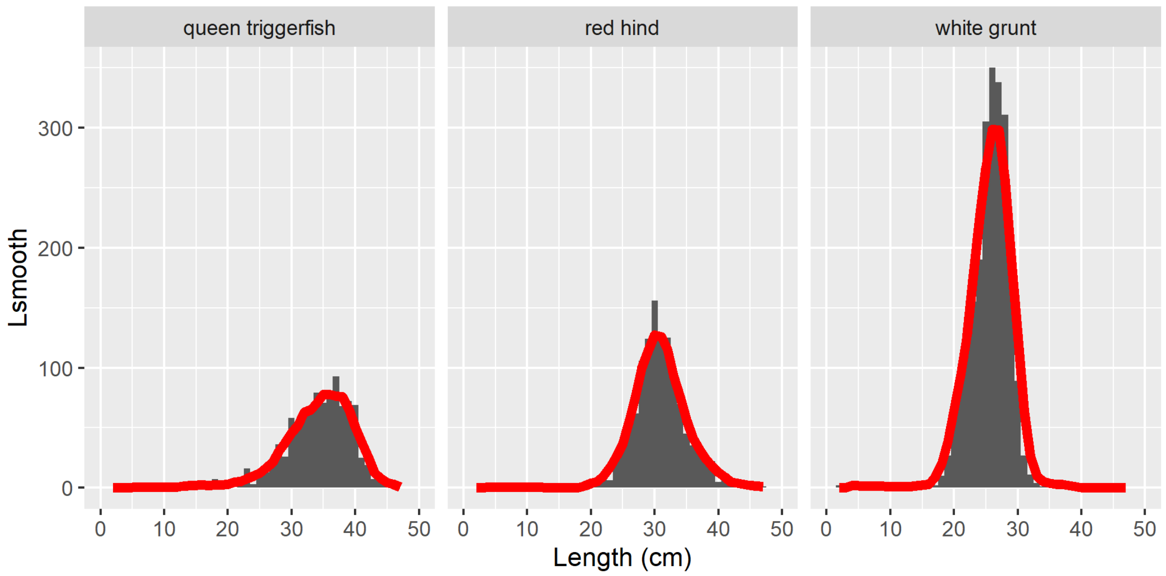


Fig. 3.2.14. *Landings length-composition for the 3 main reef fish species (all years combined). The red smooth line in the figure was created using a rolling mean (moving average) with a window size of 5. This smoothing approach helps to reduce variability and highlight general trends in the length frequency distribution.*

Fig. 3.2.15. *Annual landings length composition data for the 3 main reef fish species*

3.3 Redfish fishery

3.3.1 Trap fishery

3.3.1.1 LPUE

Landings and effort data

The average number of traps set per fishing trip increased between 2007 and 2011, and subsequently decreased from 35 to 21 between 2011 and 2017 (figure 3.3.1). After staying at about the same level in 2018 and 2019, the number of traps per trip was sharply higher in 2020 (to nearly 30). The number of traps per trip decreased slightly in 2021 and stayed at about the same level in the following two years (2022 and 2023).

The spatial distribution of fishing effort changed over the years. Most of the effort was concentrated at the centre of the bank (area C4) in 2011 (figure 3.3.2), but then increased in the north/north-western part of the bank (B3/B4). Between 2015 and 2018, the effort moved back to the centre of the bank (C4) while also increasing in the north-western part (B5) and in the southern part (areas D). In 2019 and 2020, the effort was again mainly concentrated on the northern part of the bank (areas B3 and B4). From 2021 onwards, fishing effort has increased in the central region of the bank (C4), while remaining predominantly concentrated in the northern areas (B3 and B4).

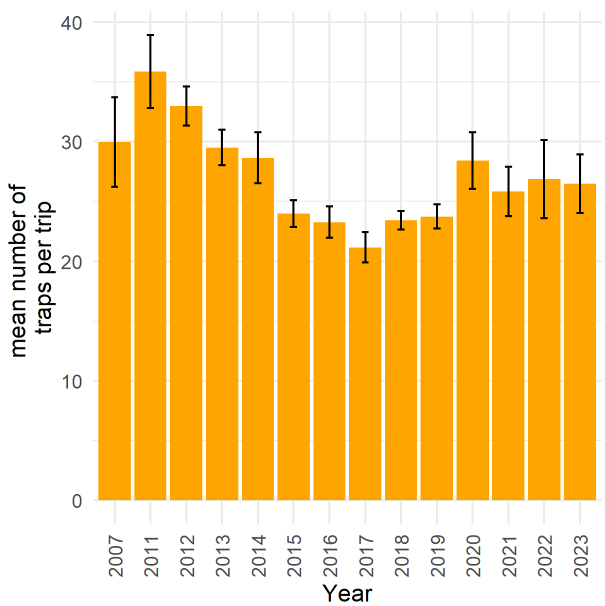


Fig. 3.3.1. *Mean annual number of traps lifted per trips (with 95% confidence intervals).*

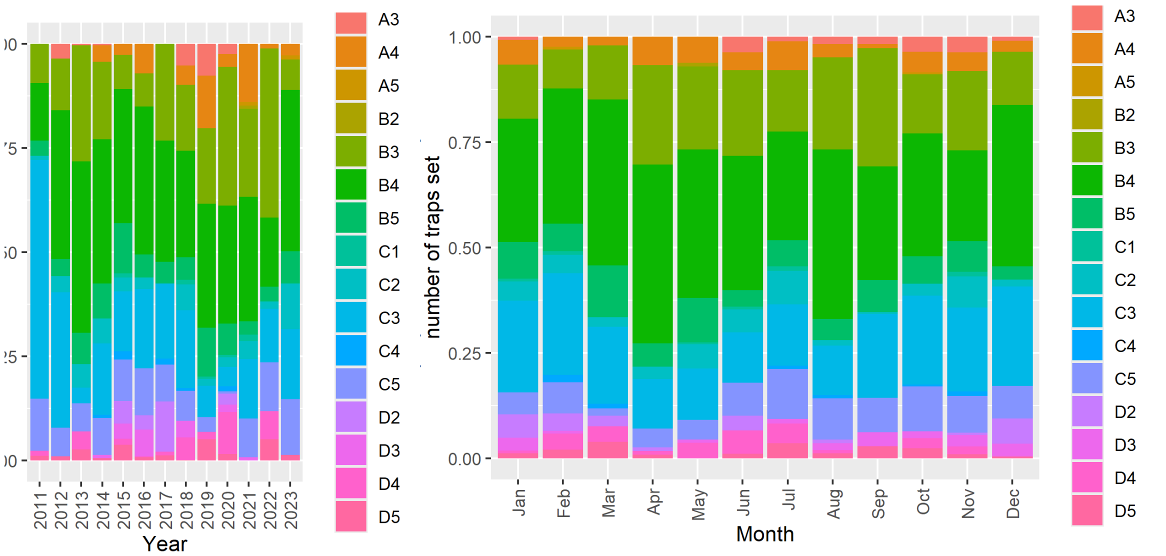


Fig. 3.3.2. *Proportion of the annual (left) and monthly (right) effort (in total number of traps set) per fishing area.*

Landing rates were at their highest in 2007 but were much lower in 2011 (figure 3.3.3). Landings rates in kg per trap gradually increased until 2017, then declined until 2020, and have remained at similar levels since then. The landing rates expressed in kg per trip have shown no particular trend since 2011, with only small variations. The difference between the two time series of landings rates, is explained by the changes observed in the number of traps used per trip (figure 3.3.1).

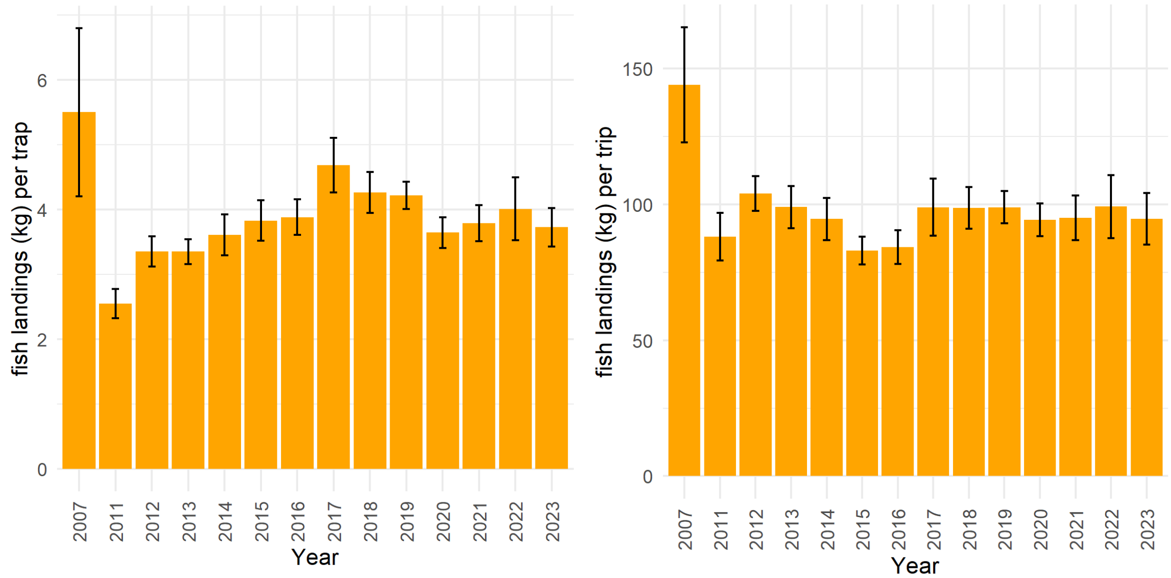


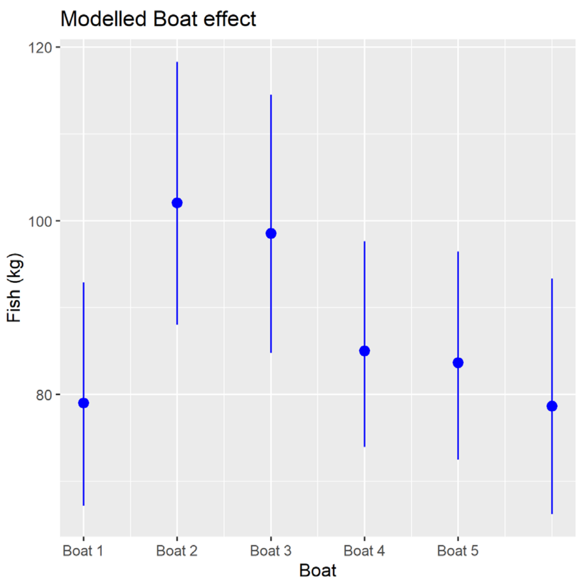
Fig. 3.3.3. *Yearly mean* Landing *of red fish (kg) per trap and per trips (with 95% confidence intervals).*

Standardisation of the LPUE using a GLM model

The redfish landings per trip were modelled using the same approach as described for the lobster in order to estimate different effects on the catch rates and ultimately extract a standardised biomass index. The model fitted, shows that all effects were significant except the “fishing area” effect (Table 3.3.1). The difference in standardised landing per trip between vessels was larger than for lobster landings. The boat with the highest landing rate landed approximately 25-30%more than the boat with the lowest landing rate (figure 3.3.4). Some seasonality was also visible in the “month” effect, with low landing rates observed between March and June, and high landing rates observed from July to October and in February. The “year” effect, which is the standardised biomass index for redfish, indicated the highestbiomass in 2007, and lowest in 2011. In 2012 a sharp increase can be found after which the index shows similar levels between 2012 and 2016. Another increasestarted in 2017 which levels off in 2019. Thereafter index levels have been decreasing to the level before the increase and currently fluctuate around those levels.,

Table 3.3.1. *GLM model of red fish caught and landed per trip. Significance of each model term tested by removing them one by one and comparing to the full model. AIC stands for Akaike information criterion (the lower the better), a P-value lower than 0.05 (*) indicates that the effect of the corresponding factor in the model is significant. (** = P-value lower than 0.01, *** = P-value lower than 0.001)*

Model term removed	Number of parameters	AIC	Log-Likelihood ratio	p. value	Significance level
<none (full model)>		2278.7			
factor(Year)	12	2294.1	3.2339	0.0001335	***
factor(Month)	11	2285.5	2.5663	0.0032184	***
factor(Boat_name)	5	2288.5	3.8761	0.0017225	**
factor(Fishing_area)	8	2276.5	1.6873	0.0970148	
logTraps	1	2393.4	118.4816	< 2.2e-16	***



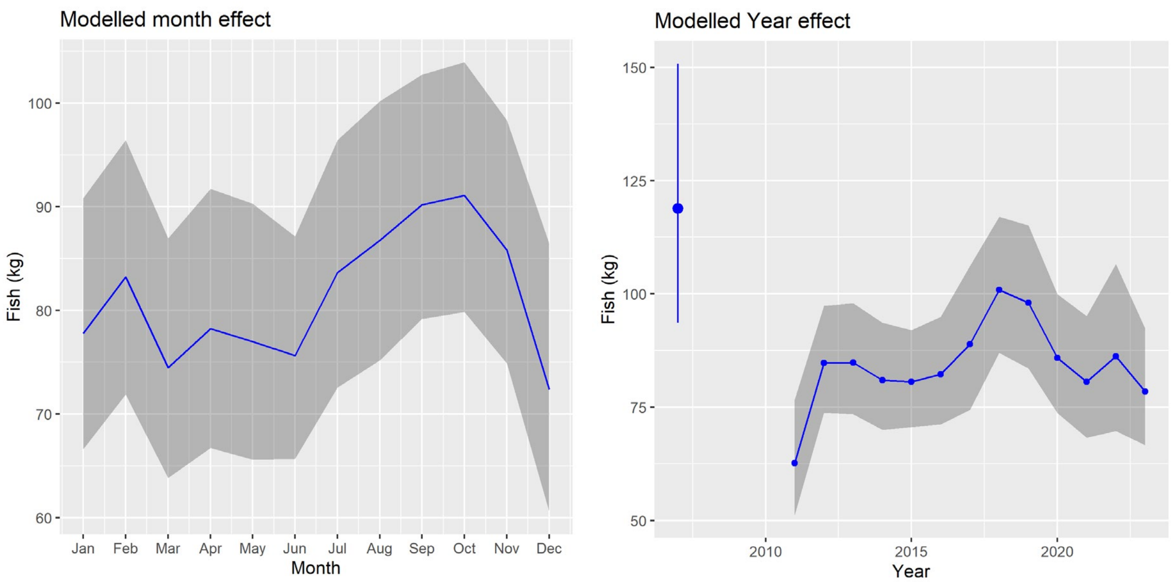


Fig. 3.3.4. *Modelled boat, month and year effects on the catches of red fish per trips (in numbers). Blue lines represent the modelled effect (and corresponding 95% prediction envelop in grey).*

3.3.1.2 Species composition

The main species landed in the redfish fishery was the Silk snapper (Fig. 3.3.5), which represents almost ¾ of the catch in both numbers and weight. The two other species well-represented in the landings are the Blackfin and Vermillion snapper. The Silk snapper is the most discarded species in numbers, representing around 50% of the discards in both numbers and weight (Fig. 3.3.6). Other important discarded species were the Lionfish, *Pterois volitans*, French angelfish, *Pomacanthus paru*, and the Nurse shark, *Ginglymostoma cirratum*. Further discussion on the potential reasons for discarding Silk Snapper and the presence of other bycatch species is provided in the discussion section.

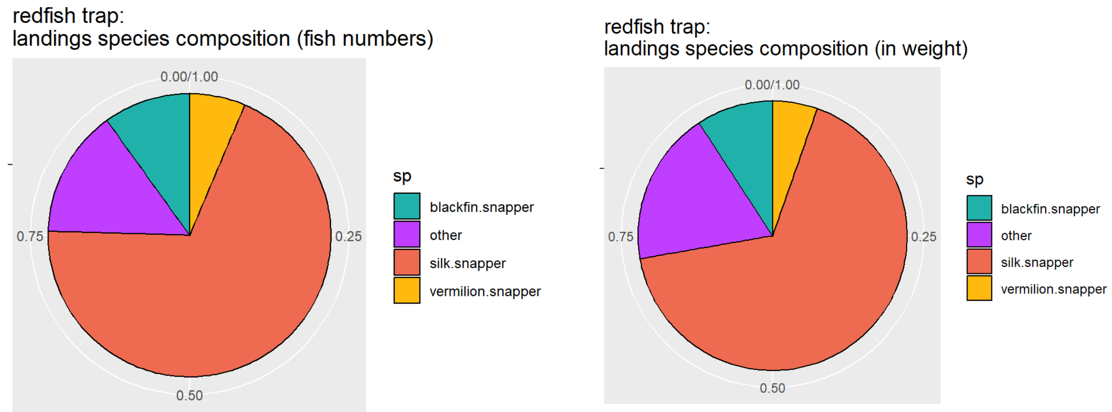


Fig. 3.3.5. *Species composition of the catches in the red fish fishery (in numbers, left ,and in weight, right) based on 87 trips sampled.*

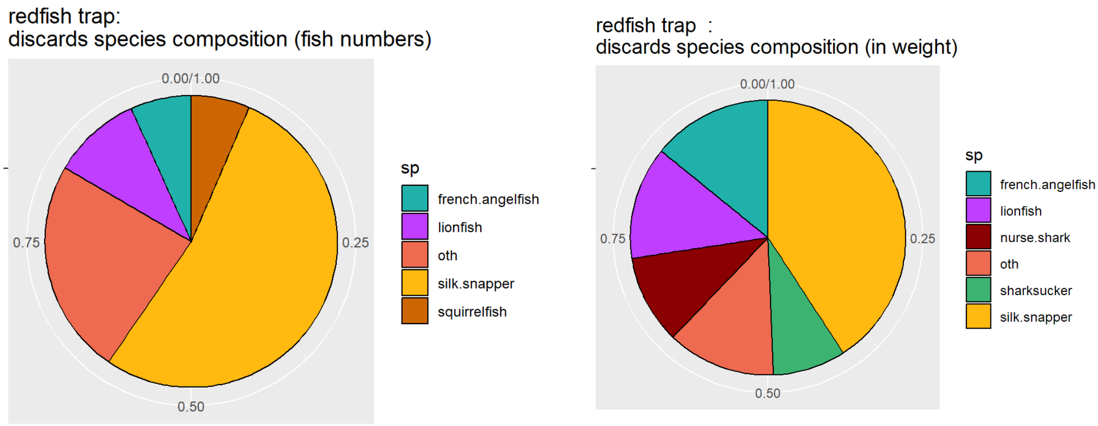


Fig. 3.3.6. *Species composition of the discards in the red fish fishery (in numbers, left and in weight, right) for the year 2011 to 2023 combined based on 9 trips sampled.*

3.3.1.3 Length frequency

The length-frequency distribution of landings was analyzed for the four primary snapper species caught in the fishery: Blackfin Snapper, Lane Snapper, Silk Snapper, and Vermilion Snapper. The size ranges differed between these species (figure 3.3.7): Blackfin Snapper primarily ranged between 20 and 30 cm. Lane Snapper exhibited a more uniform size distribution, with a slight increase around 25 cm. Silk Snapper had the clearest peak in the distribution, with most landings concentrated between 20 and 25 cm. Vermilion Snapper, similar to Blackfin Snapper, were mostly between 20 and 30 cm. The length-frequency distributions for each snapper species show variability across different years (figure 3.3.8).

For Blackfin Snapper, the data coverage is relatively sparse for certain years, but the most consistent distributions are visible in 2013, 2014, 2019, and 2022. Similarly, Lane Snapper length distributions exhibit noticeable peaks in 2015, 2019, and 2022, suggesting higher sample coverage during these years. For Silk Snapper, the data show the most consistent and well-defined distributions, especially from 2014 to 2016 and in 2019, indicating greater sampling effort.

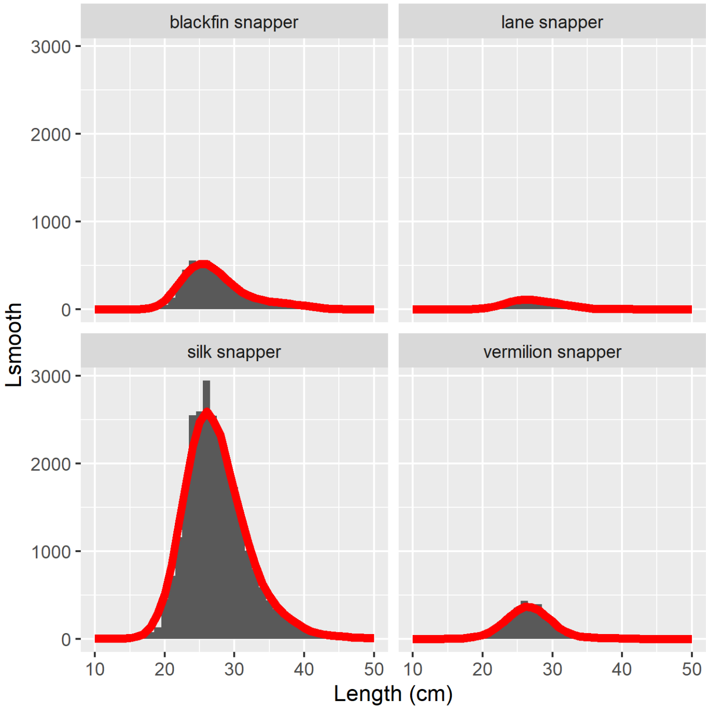


Fig 3.3.7. *Landings length-composition for the four main snapper species (all years combined). The red smooth line in the figure was created using a rolling mean (moving average) with a window size of 5.*

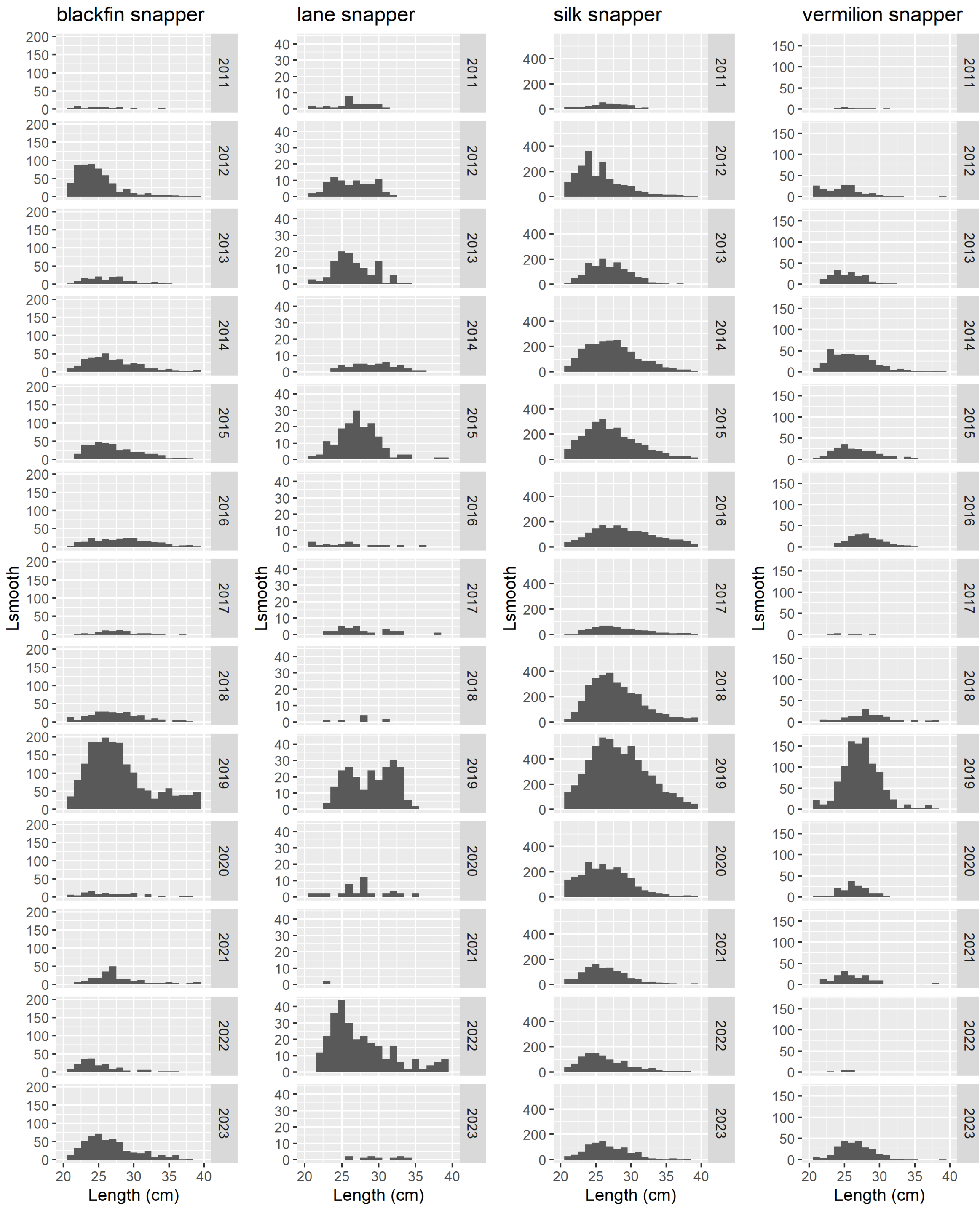


Fig 3.3.8. *annual landings length composition data for the four main snapper species caught.*

3.3.2 Bottom longline fishery

3.3.2.1 LPUE

Annual effort in the longline fishery is shown in Fig. 3.1.1 and Table 3.1.1. The estimated number of trips using longline per year has been variable with no clear trend and ranged from 3 annual trips in 2019 to 36 in 2015. However, trips using longline represent only 0.5 to 4% of the fishing trips sampled at the harbour. Since 30-50% of all fishing trips were covered by the landing surveys, and longline trips constitute such a small percentage of total trips, the likelihood of capturing one of these longline trips in the survey is relatively low. Specifically, given their scarcity, it is possible that none of the longline trips conducted in a particular month were sampled, even though 30-50% of trips overall were covered. This implies that the data on longline trips may be incomplete or lacking in some months.

Because of the scarcity of the data, it is also difficult to determine seasonal effects in the longline activity (figure 3.3.10). The estimated number of trips per month was very variable (between the years), and did not show any clear seasonality. There was also no clear indication for a seasonality in the landings per trip (figure 3.3.10, center), with large variations occurring from month to month. No clear trend could be discerned in the annual mean landings per trip, with again large uncertainty in several years.

Given the small number of sampled trips available, it was not possible to use a GLM model to standardize the landings per trip.

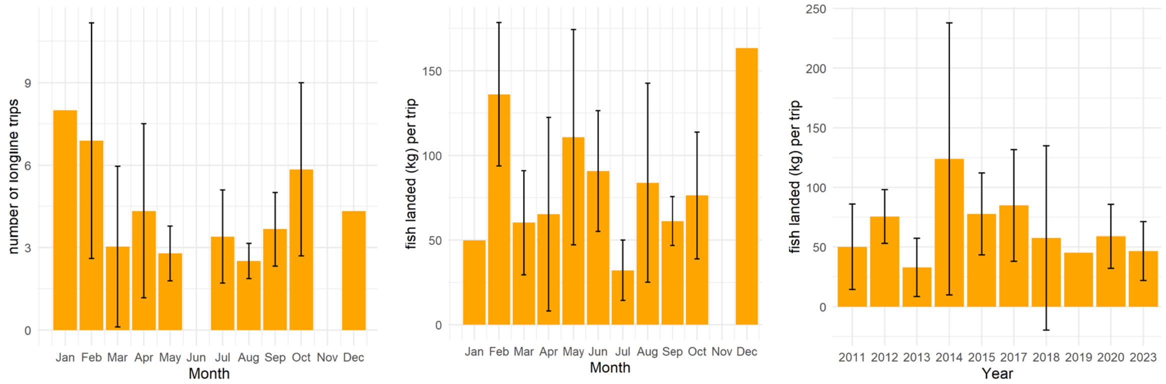


Fig. 3.3.10. *Mean number of longline trips per month (left), monthly (middle) and annual (right) mean landed catches (in kg) per trip in the long line fishery with 95% confidence interval (absence of confidence interval correspond to month with a single observation).*

3.3.2.2 Species composition

The species composition in the long line fishery is based on a very small number of sampled trips (10 over the period 2012-2023). The longline fishery targets mainly snappers, with the Wenchman snapper, *Pristipomoides aquilonaris*, being predominant in the catches both in number and weight, followed by the Queen snapper, *Etelis oculatus* (figure 3.3.11). Other important landed species included Almaco Jack, *Seriola rivoliana*, Greater Amberjack, *Seriola dumerili*, Bigeye Tuna, *Thunnus obesus*, Black Grouper, *Mycteroperca bonaci*, Black Jack, *Caranx lugubris*, Cuban Dogfish, *Squalus cubensis*, Common Dolphinfish, *Coryphaena hippurus*, Nassau Grouper, *Epinephelus striatus*, Vermilion Snapper, *Rhomboplites aurorubens*, Warsaw Grouper, *Hyporthodus nigritus*, and Yellowmouth Grouper, *Mycteroperca interstitialis*.

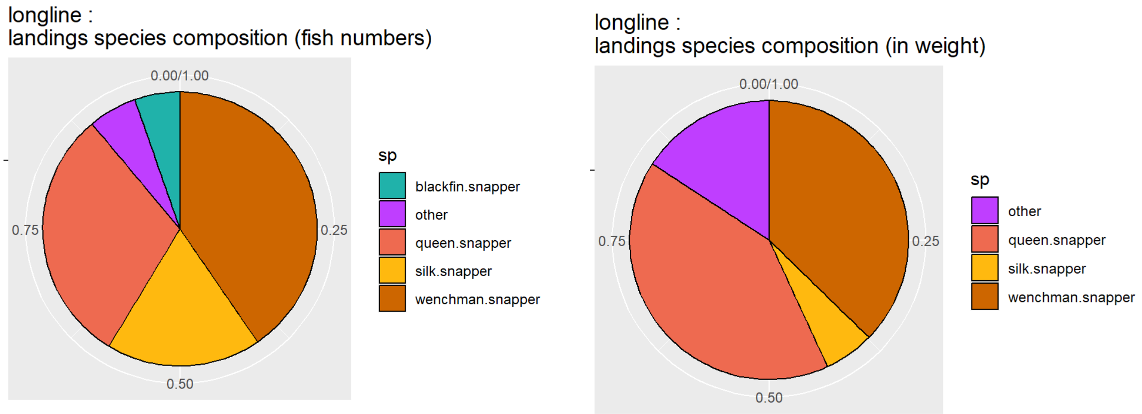


Fig. 3.3.11. *Species composition of the landed catches from the long line fishery based on the sampling realized between 2012 and 2023 based on 10 trips sampled.*

3.4 Pelagic fishery

3.4.1.1 CPUE

The annual number of trolling fishing trips is estimated to have varied between 20 and 77 in the period 2012 and 2023 respectively (Fig. 3.1.1 and table 3.1.1). Trolling trips appear to be more frequent from October to April, with markedly lower number of trips between June and August (figure 3.4.1). However, the monthly number of trips are very variable from year to year, and the monthly mean value have large confidence intervals.

Landings per trip appear to be higher for the months of March to May, but the estimates have a high uncertainty. The interannual variations in the landings per trip do not indicate any specific trend, but rather the occasional year with higher landing rates (but also more uncertain values).

As for the trolling fishery, the data is too scare to apply the GLM model for standardisation.

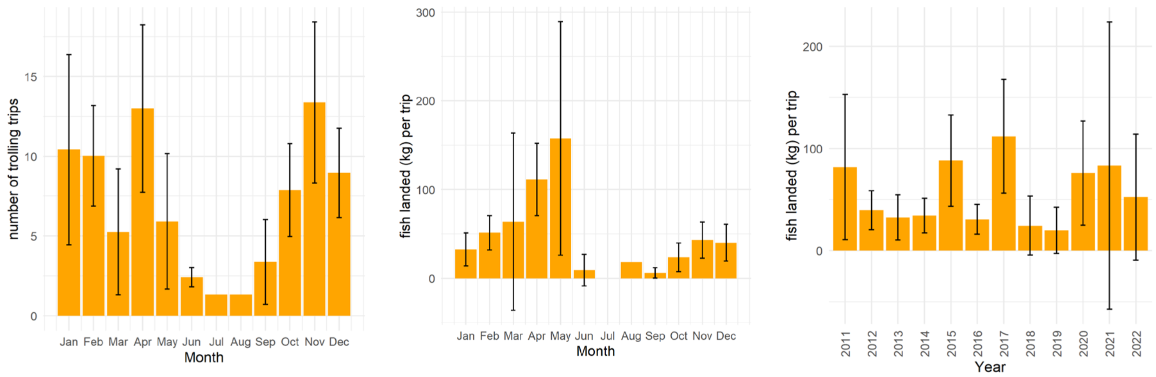


Fig. 3.4.1. *Mean number of trips per month (left), mean catch per trip (in fish number) per month (middle) and per year (right), with 95% confidence interval of the mean (absence of confidence interval correspond year or month with a single observation).*

3.4.1.2 Species composition

Catches in number of fish are mainly composed of dolphinfish, *Coryphaena hippurus*, and wahoo, *Acanthocybium solandri* (figure 3.4.2). Tuna species represent only 3% of the landings in number. There was no length measurement for the tunas, and therefore to compute a species composition in terms of weight, a mean weight of 10kg per fish was assumed. Wahoo represents 70% and dolphinfish about 20% of the catches in weight. The proportion of tunas (in weight) is about 4%.

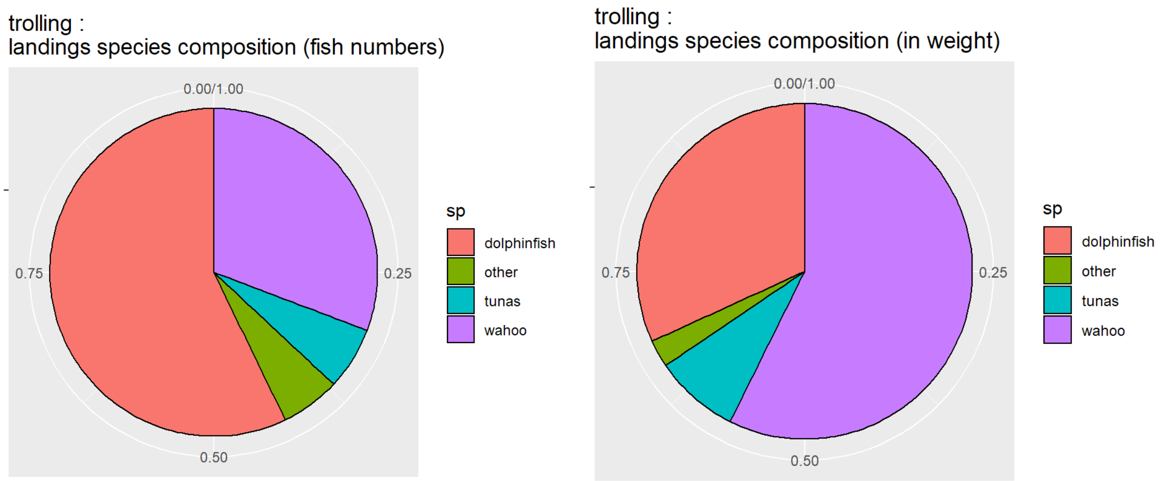


Fig. 3.4.2. *Species composition of catches in the trolling fishery (in numbers, left, and in weight, right) based on 74 trips sampled.*

3.5 Shark bycatch

Since the start of 2016, the number of sharks caught, and mainly released, during fishing trips is also recorded in the landing survey. The number of Caribbean Reef sharks caught so far are very low (6 individuals caught in total since 2016). Nurse sharks, however, are caught in around 70% of the trips targeting lobsters (figure 3.5.1). The number of individuals caught per trip is usually low (< 7 sharks per trips). However for 4% of the trips, large numbers (> 10 and occasionally up to 71 individuals) were caught. Bycatch of nurse shark was rare in redfish traps (only 5% of the trips), but one exceptional event was recorded (up to 40 sharks in the trip). No nurse sharks were caught by other gears.

Bycatch of nurse shark seems low but rather constant in the redfish fishery but has had variations in the lobster fishery (figure 3.5.2): from an average of less than 3 sharks per trip (or 0.035 per trap) until 2018, the mean catch per trip increased to 6 individuals per trip (of 0.084 per trap) in 2019 and 2020. Since then the mean catch per trip has gradually decreased to 2 sharks per trip (or 0.028 per trap) in 2023.

A crude estimate of the annual number of nurse sharks caught and released can be calculated by multiplying these annual mean catch rates by the estimates of the annual number of traps lifted (Table 3.1.1). The estimated annual number of nurse sharks caught and released thus varies between a low of 1400 for 2018 and a high of 4000 individuals per year in 2019 for the lobster fishery, and between 60 and 200 for the redfish fishery (figure 3.5.2).

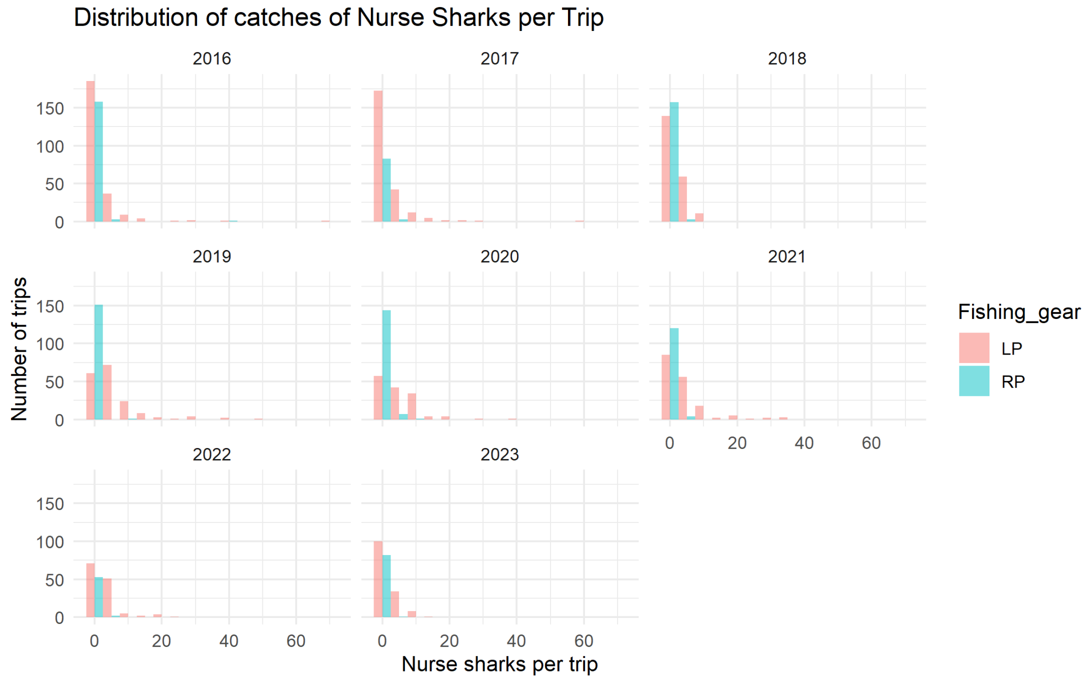
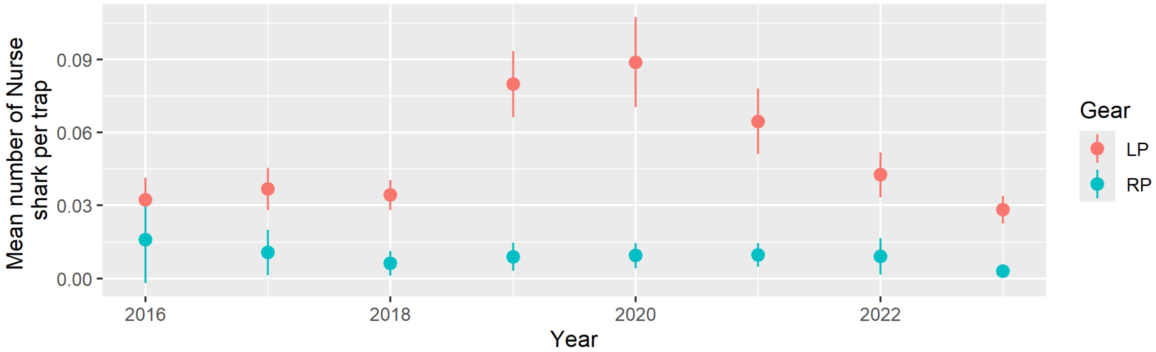


Fig. 3.5.1. *Distribution of the number of nurse shark caught per trip (right) in relation with the type of trap (LP : lobster pots, RP : redfish traps) used per year from the landing survey.*



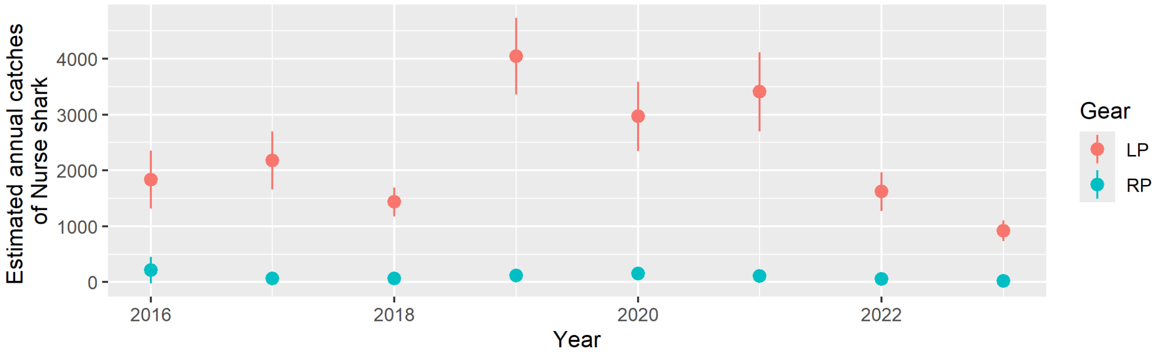


Fig. 3.5.2. Estimates of the mean nurse shark number per trap and total catches per year *(LP : lobster pots, RP : redfish traps)*

3.6 Lionfish

Overall, lionfish were significantly more abundant (ca. 10 x higher) in the deep-water redfish traps on the slopes of the Saba Bank than in the shallow-water lobster traps on the flat top of the bank (figure 3.6.1). This may reflect a particular depth preference for the lionfish but may also reflect a difference in catchability between the two types of traps used. Whereas redfish traps are designed to trap fish, lobster traps are not. The abundance of Lionfish in shallow-water lobster traps appear to have peaked between 2012 and 2015 but to have declined since then (Debrot, Brunel & Izioka, 2023). Similarly, in the deep-water redfish traps, lionfish initially increased between 2012 and 2014 and then continuously declined to reach its lowest value in 2021.

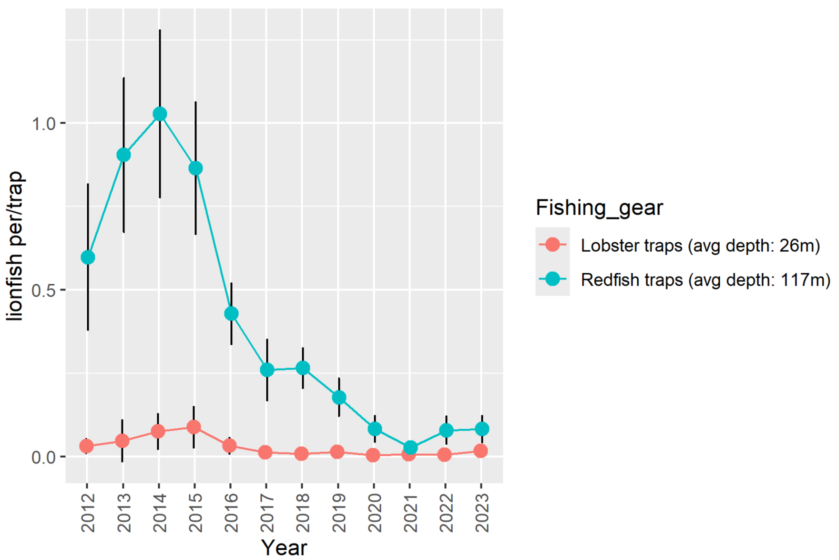


Fig. 3.6.1. *Trend in the abundance (average catch rate) of lionfish in the deep-water redfish traps and shallow-water lobster traps on the Saba Bank. Error bars indicate 95% CI of the yearly average.*

4 Discussion of Current Fisheries Trends and Historical Context

4.1 Historical overview of fisheries on the Saba Bank

In this report we assessed the current status of the fisheries on the Saba Bank and reported on the port-based fisheries monitoring results for the first 13 years of data collection (2011-2023). During the nineteen seventies, eighties and early nineties there was extensive overfishing of the bank by foreign vessels with a (recognized) major depletion of its stocks of large groupers and conch (Meesters et al. 1996). After the Exclusive Fishing Zone of the Netherlands in the Caribbean was declared in 1993 and enforcement by the newly established Coast Guard began in 1995, foreign fishing was quickly brought to an end. This allowed renewed local interest in fishing on the bank and has given the bank new perspectives for ecological recovery.

In 2010, the bank was designated as "National Park" by the Netherlands, following in 2012 as "Particularly Sensitive Sea Area (PSSA)" by the International Maritime Organization, "Specially Protected Areas and Wildlife (SPAW) Protected Area", within the SPAW Protocol and as "Ecologically or Biologically Significant Marine Area (EBSA)" within the Convention on Biological Diversity (CBD). Finally, in 2015, it was designated as part of the "Yarari Marine Mammal and Shark Sanctuary" by the Netherlands. Also, numerous biodiversity assessments have taken place and continue to take place on the Bank (e.g. Saba Bank Expedition 2018 by WMR).

4.2 Current fisheries and recent developments

Today the Saba Bank has two main commercial fisheries, both of which target demersal species principally using traps. One fishery targets the West-Indian spiny lobster and the other targets several deep water snappers. We discuss the trends and developments in these two main fisheries and conclude with a few key recommendations for management and research.

The directed lobster fishery started in the 1980s associated with the rise of the tourism industry of St. Maarten. During this period, it has been the most valuable fishery of the Saba Bank with annual landings fluctuating between a recorded low of 24 tons (in 2018) and high of 71 tons (in 2015). The snapper fishery is the second most valuable fishery with annual landings ranging between a recorded low of 25 tons (in 2017) and high of 54 tons (in 2019). Effort in the lobster fishery increased from 2012 to 2015, but has been decreasing since then. The annual amount of traps set in 2023 is almost half of the amount of traps set in 2025). The landings have also decrease over this period, but not in the same proportion as the effort. In the redfish fishery, the effort has been variable, without any pronounced trend. Both fisheries were impacted by the hurricane Irma which struck in September 2017, just before the main year-end snapper season. This can be seen in terms of significant reductions in effort for snapper in 2017 and for lobster in 2018, and corresponding lowest landings during the 13 year study period (figure 3.1.1). Both fisheries were also impacted by the outbreak of the COVID-19 which greatly reduced the market demand for lobster in St. Maarten, and led to lower effort in 2020. The fishers have also implemented a partial closure of the Bank on the basis of a Gentlemen's agreement in 2022 and 2023, which explain the drop in effort (for the redfish fishery) in these two years. However, it is important to note that missing trip data for the last two months of 2022 and 2023 prevents us from accurately estimating the effort for these months, resulting in incomplete estimates for these years. While this does not affect the monthly seasonal effects, it does impact the overall annual effort estimates.

4.2.1 Lobster

Based on our abundance index for lobsters, the stock size dropped from higher levels in 2000 to lower levels in 2011. Since then, there has been a progressive increase of the stock size followed by a gradual levelling off from 2017 to 2020 and a gradual increase again until 2023, reaching levels similar to those in 2007. Hence, contrary to our earlier cautiously positive assessment of the recovery trend for lobsters (de Graaf et al. 2017, Brunel et al. 2018, Debrot and de Graaf 2018, these new analyses suggest that even though recovery of the stock under the current management regime has shown substantial progress the stock has not yet reached the levels observed in 2000,. This trend indicates an ongoing recovery, with the stock levels in 2023 reaching those seen in the mid-2000s. Continued monitoring and management efforts will be essential to sustain this positive trajectory and aim for further recovery towards historical stock levels.

In one of our previous reports (de Graaf et al. 2017) we addressed that over the longer term, the temporal trend observed in the lobster catches from Saba Bank seems broadly in line with the trend at the scale of the whole Caribbean, showing a long term increase The lobster stock should be seen as a regional stock that should be managed based on a regionally coherent management approach (FAO 2015). This is needed for most other species as well. Joining regional fisheries management initiatives can be recommended as a priority for policy goals (e.g. CARICOM 2002).

With respect to the berried lobsters, current permits stipulate that both berried lobsters and sublegal-sized lobsters should legally be released back into the water. However, data suggests that some sublegal and berried lobsters are still being brought to land, particularly on St. Eustatius compared to Saba. In some cases, the eggs may be removed, intentionally or unintentionally, and the berried females are then landed. This highlights potential gaps in awareness or enforcement of these regulations. Addressing these issues through better awareness programs and enhanced enforcement could help mitigate this problem and improve compliance with the regulations.

4.2.2 Mixed fish

The biomass index for the mixed reef fish species increased continuously since 2011, reaching levels comparable to 2000. This suggest that the gradual decrease of the effort in the lobster trap fishery has also benefited the reef fish populations. However, our recent assessment of measures to protect the Red hind have shown no indication of the seasonal closure measures as currently applied being sufficient within their first five years (Debrot et al. 2020). It is possible that the closure area is too small to be effective, for too short a period to be effective or insufficiently enforced. It could also be that overall fishing pressure on the red hind as being caught in the lobster trap fishery outside the closed season already exceeds sustainable harvest levels. Consequently, additional research is currently underway to evaluate the proper placement and timing of the seasonal closure measure.

4.2.3 Redfish

The biomass index for redfish presented here suggests that after increasing fairly consistently from 2011 up to a peak abundance in 2018, the size of the combined four redfish stocks has been declining since then. This new assessment, therefore, with the levelling off and recently declining stock biomass gives a more pessimistic perception of stock status as in our most recent advice (Brunel et al. 2018, Debrot and de Graaf 2018). These results suggest that in order to allow stock recovery to levels of 2007 and earlier, additional protective measures will be required. The lower effort in the redfish fishery over the last 2 years does not seem to have led yet to any increase in stock biomass.

The high discard rate of Silk Snapper, one of the key species in the redfish fishery, could be due to several factors, including the presence of undersized individuals that do not meet market preferences or possible legal size restrictions (if they exist). It is also possible that these discards represent individuals that were not in good condition or exceeded market demand. This indicates that the redfish fishery may have bycatch issues involving Silk Snapper that do not meet specific criteria (e.g., size or quality). Addressing this bycatch and improving selectivity in fishing practices should be key considerations in future management measures to ensure stock recovery.

For the reef fish and for the redfish, landings are not reported at the species level, and the biomass indices presented here are representative for a group of species. The trends described in these indices may correspond to contrasting trends at the species level, and there no inference can be made regarding the changes at the species level. Collecting information at the species level is one of the priorities for the future development of the fisheries monitoring program on Saba.

4.2.4 Shark and lionfish catches

This report furthermore presented trends in abundance for two additional species of interest. First, the average CPUE of nurse sharks in lobster pots showed a significant increase in 2019, suggesting an initial rise in abundance for this protected species. This trend continued into 2021, which would be good news considering that the Saba Bank also forms a key part of the Yarari Marine Mammal and Shark Sanctuary. However, the data from 2022 and 2023 show a considerable decrease in the average of CPUE of nurse sharks in lobster pots. Tagging recapture programs (REF) indicate that tagged sharks are frequently recaptured, and a formal analysis of the tagging/recapture data would be necessary to understand if changes in recapture rates could potentially be an alternative explanation for the changes observed in the CPUE. Secondly, the CPUE for the invasive Lionfish have shown a consistent declining trend since 2014. This suggests that the abundance of this invasive species may have peaked and that densities are now starting to decline as the ecosystem, and particularly predators, adjust to the presence of this species (Debrot et al. 2023).

4.3 Recommendation

Finally, while significant progress has been made over the past 12 years of monitoring, gaps remain in our understanding of the Saba Bank fisheries and their interactions with the broader ecosystem. A major limitation is the lack of life history parameter estimates specific to Saba Bank species, which restricts our ability to precisely model the fisheries. To address this, WMR's expanded fisheries research program, initiated in 2022, aims to collect critical biological information and develop parameter estimates for the various Saba Bank stocks.

There were significant gaps in survey data coverage, particularly towards the end of 2022, and similarly in 2023. This was caused by personnel attrition at SBMU which was difficult to tackle within the small organisation. In an evaluation of the Saba Bank Management Structure EY (2022) concluded that the SBMU would benefit from improved governance and focus on monitoring. In fulfilment of these recommendations mid 2024 a pilot started in which SBMU members work more closely together with WMR. A project member of WMR has since been involved in weekly meetings, planning and quality assurance. Having dedicated well-trained fisheries data collection officers on Saba is key to ensure frequent and reliable data collection of fish landings and composition from the Saba Bank. We recommend to seek a long-term solution beyond the pilot period, for instance by bringing the Saba fisheries monitoring in the Dutch WOT fisheries (statutory tasks). The ministry of LVVN is currently preparing this.

Continued fisheries and ecological research remain essential to address key questions and develop a robust time series of monitoring data to identify opportunities and challenges early. To ensure sustainability, the development of precautionary and adaptive management approaches is highly recommended (de Graaf et al. 2017). A best-practice harvest strategy framework to manage for MSY should be developed collaboratively with stakeholders to ensure its feasibility and successful implementation.

In particular, we recommend addressing the issue of berried lobsters through targeted awareness programs and better enforcement mechanisms. SBMU could engage with fishermen to raise awareness about the importance of releasing berried lobsters, as stipulated by current regulations, and emphasize the ecological benefits of compliance. Establishing clear communication and focusing enforcement efforts on the most critical violations could strike a balance between ecological needs and maintaining good relationships with stakeholders.

Additionally, efforts could include exploring the possibility of involving enforcement authorities to support compliance. Awareness campaigns should also highlight the ecological role of berried lobsters in stock replenishment, creating a shared understanding of long-term benefits for both the ecosystem and the fishery.

Acknowledgments

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The roles fulfilled in producing this report were as follows: M. Domingues: analysis and writing of key results; A. K. Izioka, T. Brokke and J. Odinga: data collection, field coordination and review; A. O. Debrot and T. Brunel: project leadership, writing and review.

5 Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. This certificate is valid until 15 December 2021. The organisation has been certified since 27 February 2001. The certification was issued by DNV GL.

Furthermore, the chemical laboratory at IJmuiden has EN-ISO/IEC 17025:2017 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2021 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation. The chemical laboratory at IJmuiden has thus demonstrated its ability to provide valid results according a technically competent manner and to work according to the ISO 17025 standard. The scope (L097) of de accredited analytical methods can be found at the website of the Council for Accreditation (www.rva.nl).

On the basis of this accreditation, the quality characteristic Q is awarded to the results of those components which are incorporated in the scope, provided they comply with all quality requirements. The quality characteristic Q is stated in the tables with the results. If, the quality characteristic Q is not mentioned, the reason why is explained.

The quality of the test methods is ensured in various ways. The accuracy of the analysis is regularly assessed by participation in inter-laboratory performance studies including those organized by QUASIMEME. If no inter-laboratory study is available, a second-level control is performed. In addition, a first-level control is performed for each series of measurements.
In addition to the line controls the following general quality controls are carried out:

- Blank research.
- Recovery.
- Internal standard
- Injection standard.
- Sensitivity.

The above controls are described in Wageningen Marine Research working instruction ISW 2.10.2.105. If desired, information regarding the performance characteristics of the analytical methods is available at the chemical laboratory at IJmuiden.

If the quality cannot be guaranteed, appropriate measures are taken.

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Justification

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The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

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