Status and trends in Saba Bank fisheries

Analysis of fisheries data collected over the period 2011-2020

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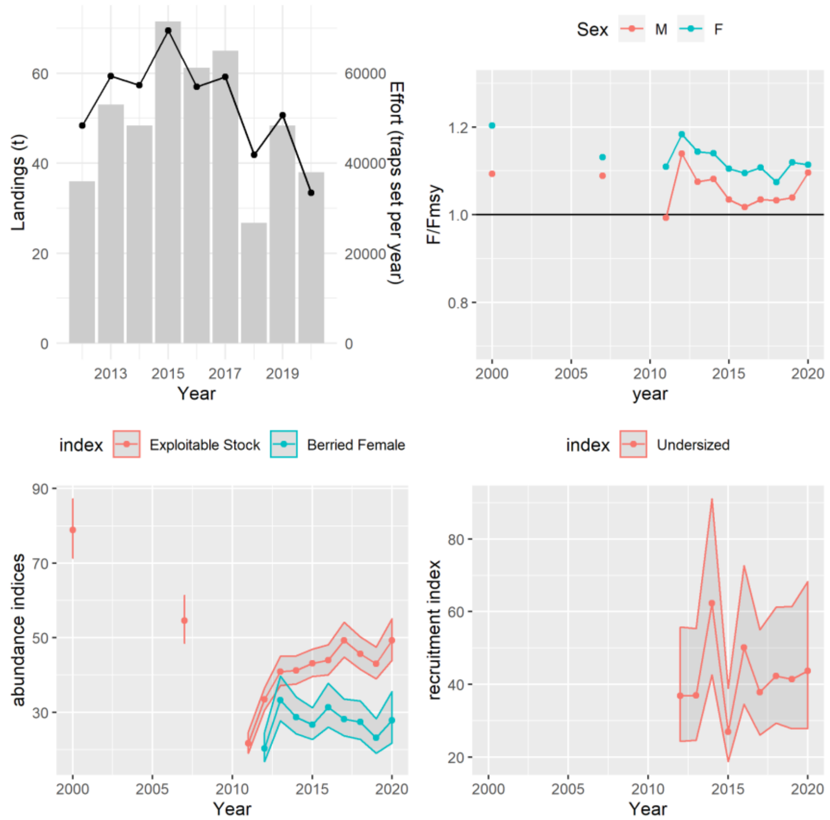
Contents

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). The new analyses presented here are based on three additional years (2018-2020) of data collected by the Saba Bank Management Unit.

Lobster fishery

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



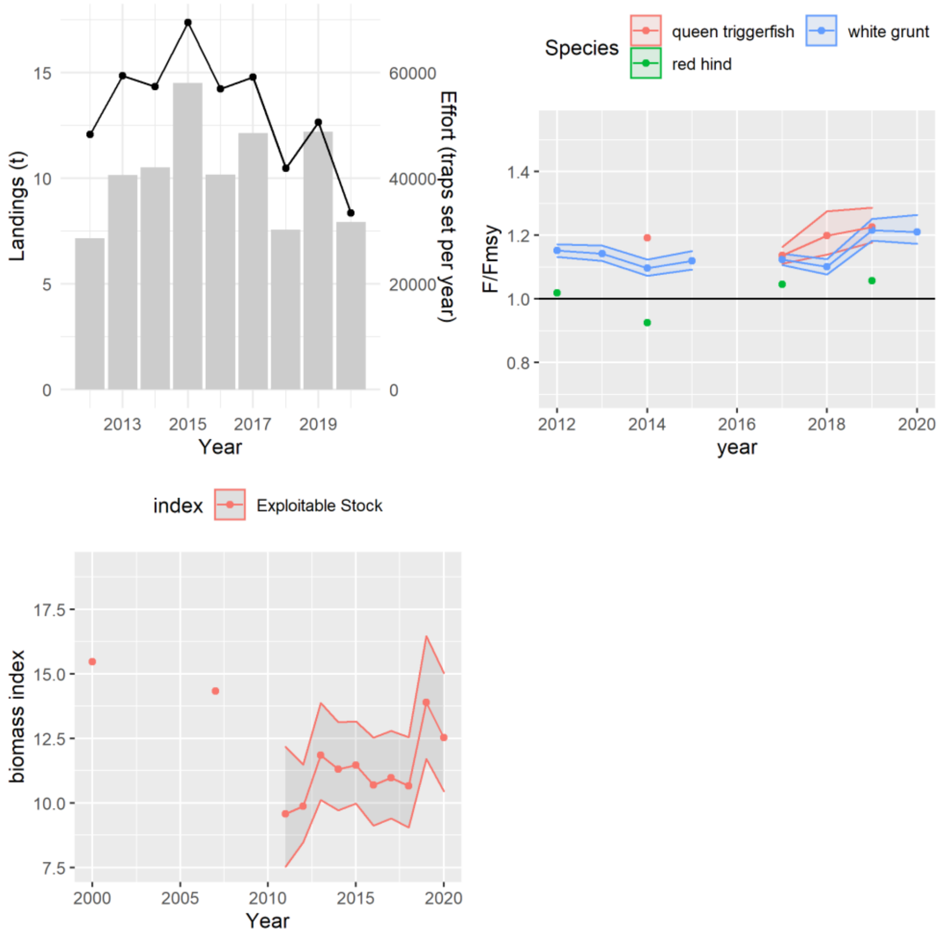
Summary plots for the lobster stock.

Top left :	landings (bars) and effort (solid line) estimates
Top right:	length-based indicator for F/F_{MSY} for male and females
Bottom left:	abundance indices for the exploitable stock and for the berried females obtained by standardising the landing-per-trip (with 90% confidence intervals)
Bottom right :	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 in subsequent years, with nearly a halving of the effort between 2015 and 2020. The resulting landings of lobster have shown a similar pattern with an increase up to 2015 when they amounted to 78t, and, after a period of relative stability in 2016-2017, showed a marked decline to 27t in 2018, before partial recovery in 2019 and 2020.
Increasing landings per unit effort (number per trip) indicate that the formerly reduced lobster abundance, which had been declining since 2000 and which reached its lowest level in 2011, has subsequently increased relatively steadily all through 2020, back to levels close to those of 2007. Length based proxies for exploitation level with respect to MSY suggest that there has been overfishing of the stock (F/F_{MSY} >1) for all the period covered by the data, and the mean size of the lobsters landed has been decreasing over the last 5 years.

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.

Top left :	landings (bars) and effort (solid line) estimates
Top right:	length-based indicator for F/F_{MSY} for three main reef fish species with bootstrap confidence intervals
Bottom left:	biomass index for the combined reef fish stocks obtained by standardising the landing-per-trip (with 90% confidence intervals)

Mixed landings of reef fish in the lobster fishery have fluctuated between 7 and 15t annually. The biomass index derived from the LPUE of these bycatch species also shows a decrease of about 35% from high levels in 2000 and 2007 to lowest levels in 2011. After a partial recovery from 2011 to 2013, the biomass declined slowly until 2018, and then rose sharply in 2019. Among the three main species landed, two - the Queen triggerfish, *Balistes vetula*, and the white grunt, *Haemulon album*,- are being overfished according to length-based indicators while the Red hind, *Epinephelus guttatus*, is being fully exploited (F/F_{MSY} close to 1).

Red fish trap fishery

The figure below gives a summary of the trends in the red fish 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 (*Lutjanidae*), the number of trips has grown from 335 to 566 (corresponding to 10 000 and 13 400 traps set respectively) during the period 2012 to 2016 but dropped considerably to 271 trips in 2017 (5 600 traps). In the last three years, the effort increased again to reach nearly 600 trips in 2020 (16 000 traps), the highest effort for the whole period considered. The landings of redfish (mainly silk snapper and in smaller proportions blackfin and vermillion snapper) broadly followed the variation of the effort, with the highest estimates (>50t) for the last two years, recovering from a low value in 2017 (25t). This drop in snapper landings and effort in 2017 is the consequence of a 6-month closed season voluntarily implemented by the fishermen that year (Graaf et al. 2017).

The biomass index derived from the LPUEs shows a decrease of 50% between 2007 and 2011, followed by a steady increase until 2019 and a sharp decrease in 2020. Length-based indicators for fishing mortality indicate that silk snapper and vermillion snapper have been heavily overfished, with a ratio F/F_{MSY} higher than 1.3. For the other two snapper species (but also for the vermilion snapper in the most recent years), the length composition data is scarce which results in a large uncertainty. Nevertheless, the F/F_{MSY} proxy also suggests that these two stocks are subject to overfishing although this is less pronounced than for the two principal species.

Summary plots for the snappers.

Top left :	landings (bars) and effort (solid line) estimates
Top right:	length-based indicator for F/F_{MSY} for four main snappers species (combined) with bootstrap confidence intervals
Bottom left:	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 bycatch landings have remained much less important and have shown no significant new developments

Overall conclusion

For both the targeted lobster and "redfish" stocks, the LPUE based indices indicate that stock size overall increased since the beginning of the current port sampling program (2011), when they were at a lower level. In this report, length-based indicators of fishing mortality levels are presented for the first time. This provides new insights on the exploitation status of the stocks. These indicators suggest that, despite the overall increase in stock size, the stocks are subject to overfishing, slightly for the lobsters, but more severely for the redfish. With the current declining trend in effort for the lobster fishery, it can be expected that the fishing mortality is declining. It is important to continue monitoring the fishery (and particularly length measurements of the landings) to see if the length-based indicator will reflect such a decline in fishing mortality in coming years.
The situation is more worrying for the redfish fishery for which the recent trend is an increase in the fishing effort. This, combined with the indication that the fishing mortality of these stocks has been well

above F_{MSY}, suggest that management action is needed to bring the fishing mortality to lower levels. Again, 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 by 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, on the long term, provide a better basis to manage the "redfish" snapper stocks.

The present study further suggests that three key finfish species, which are mainly landed as bycatch from the lobster fishery, are either being overfished (Queen triggerfish and White grunt) or are at the verge of being overfished (Red hind). The Queen triggerfish and Red hind formerly were common in the landings in the Dutch Caribbean but now still only have significant populations on the Saba Bank. Therefore, both of these species require a cautionary management approach as well.

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 formally known as Wageningen Marine Research, WMR), data collection has been conducted by the Saba Bank Management Unit 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 covering the period 2011-2015 (de Graaf et al, 2017) and the period 2011-2017 (Brunel et al, 2018). These reports indicated that the effort in both fisheries had increased (except in 2017 for the redfish trap fishery), which resulted in a similar trend in the landings for most species groups. Despite this increasing trend in the 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.

This report presents an update of these analyses, covering now the period 2011 to 2020. New analyses are also presented using length-based indicators providing proxy values for F/F_{MSY}.

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 fishery on the Saba Bank. The data collection system was set up and run by WMR until November 2017. Since then, fisheries monitoring is being 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. On average, around 40 trips per year are sampled for species composition, taken representatively from the different fishing methods (figure 2.1.1). However, for the last two years, the number of samples has been much lower.
The number of trips sampled for landings length-composition was on average 60 per year (excluding 2011), with mainly lobster and redfish trips being sampled (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)

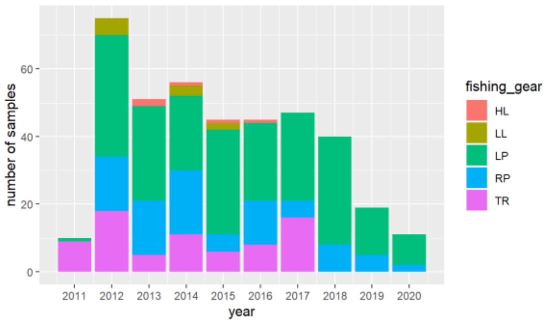


Fig 2.1.1 : number of fishing trips sampled for species composition

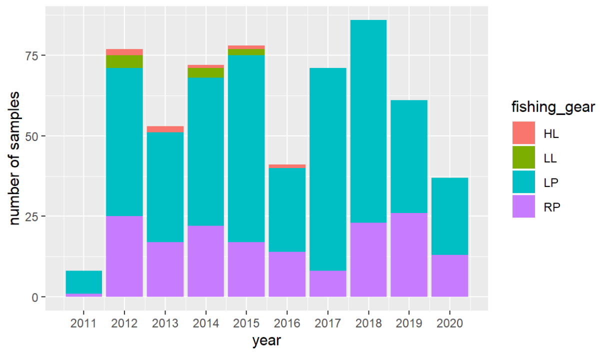


Fig 2.1.2 : number of fishing trips sampled for length composition

The 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.

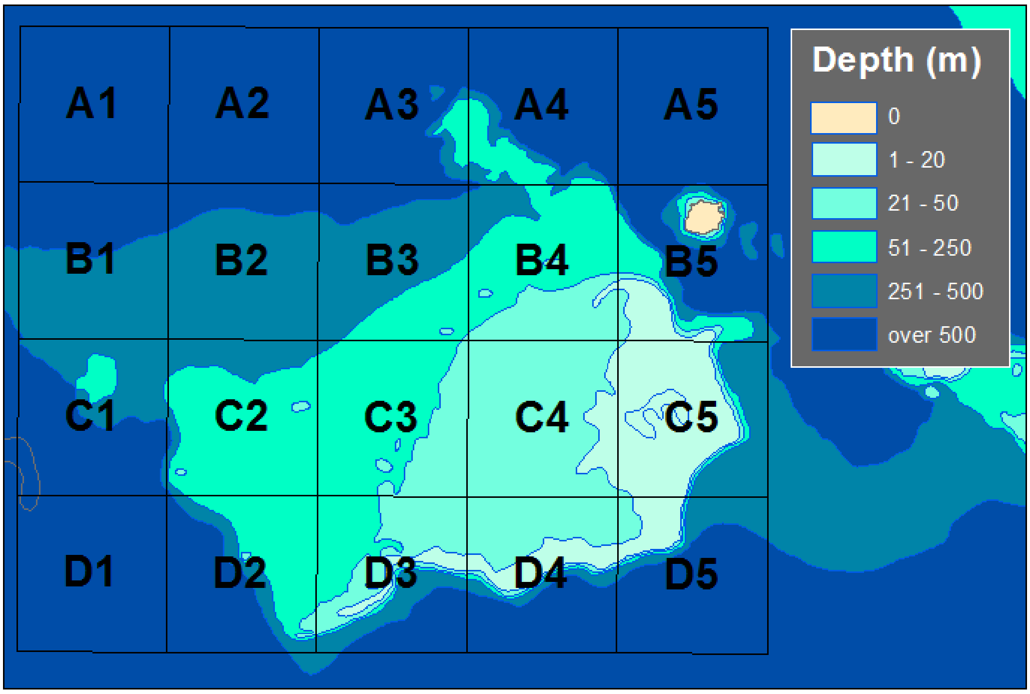


Fig. 2.1.3*: Overview of the study area with the 20 sub-areas used in the fishery monitoring scheme.*

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.

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 week days, this raising was done separately for week days 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 week days was usually good, for a majority of the month at 100%, and in most of the cases, higher that 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.
In many months, there are no observation from the survey activity during the weekend. For these months, it was assumed that no boats were fishing during the weekends.

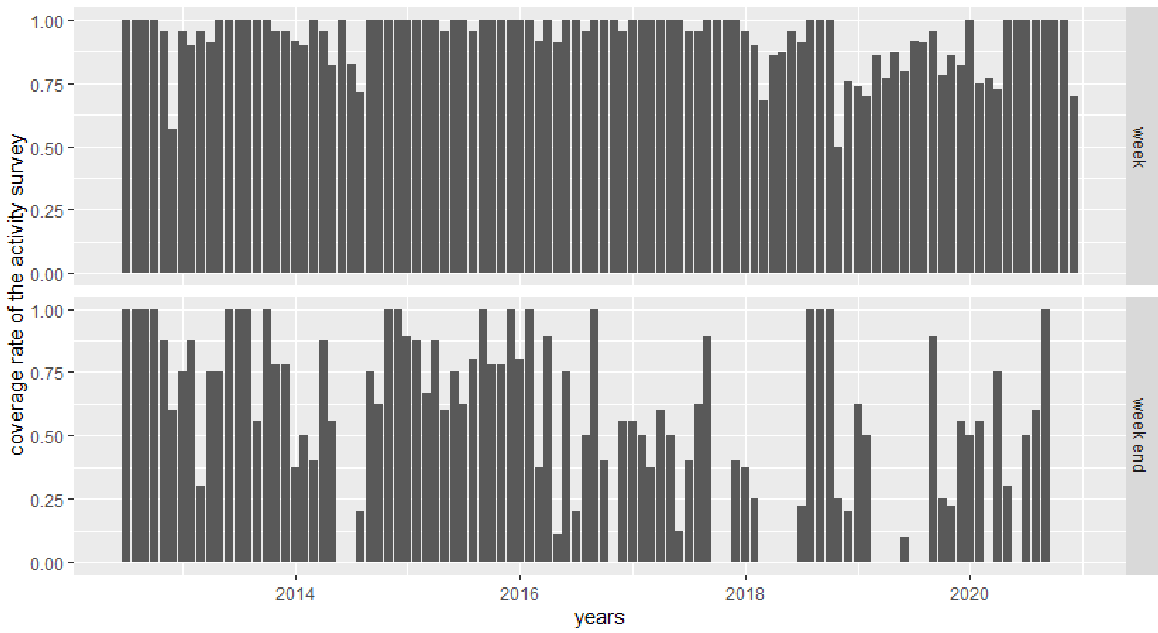


Fig 2.2.1. *Coverage rate of the activity survey per month for week days and weekend days (numbers of days with observation in the harbor divided by the number of days in the month)*

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 per 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, the landings were first estimated at the boat and month level, and then summed to obtain overall yearly total estimates.

For each boat and month, the average catch rate was calculated for each category (e.g. monthly mean number of lobster per trip) and multiplied by the estimated number of trips where the corresponding fishing method was used (i.e. lobster traps).

The figure 2.2.2 summarizes the successive steps and raising procedures to estimate monthly landings and effort.

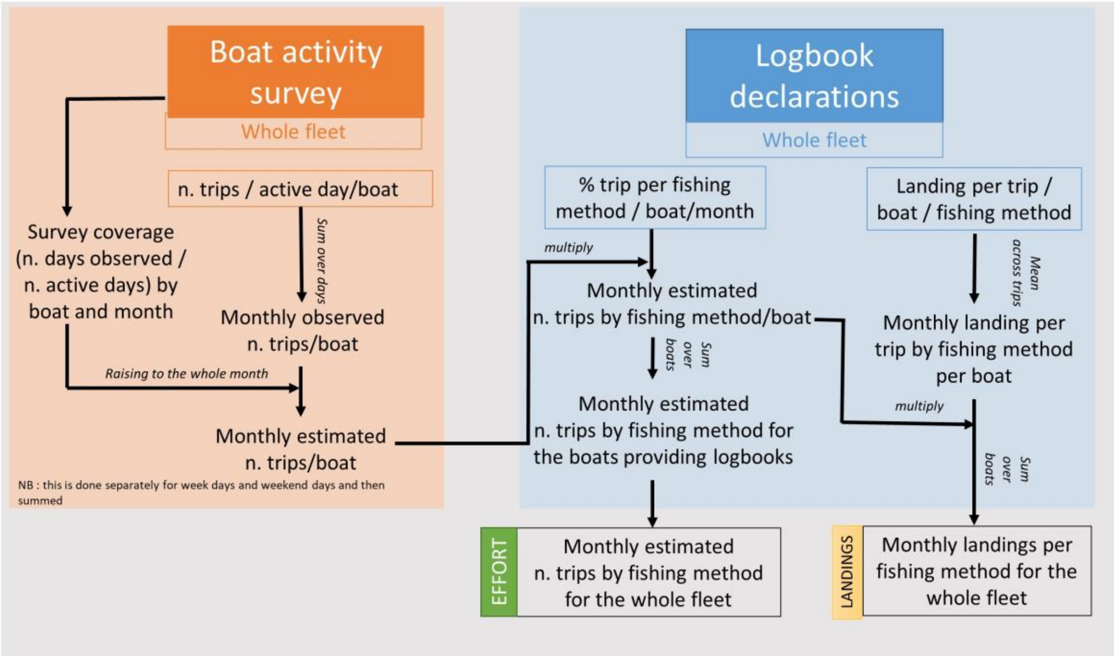


Fig 2.2.2. *Estimation method for the monthly landings per species category and "métier" (fishing method) and monthly effort by métier.*

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 where 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 are 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.

2.4 Length composition analyses and F_{MSY} proxy

The length frequency distributions were inspected for the main species and their interannual variations were quantified.
A number of length-based approaches have been developed to provide indicators of the state of the stock based on landings length-frequency data. The general underlying idea is that applying a size-selective fishing mortality to a population will result in a shrinkage of the population length-composition towards smaller sizes. Measuring the extent to which the length-composition has shrunk towards smaller sizes (compared to an unfished state) can provide an indication of the level of fishing pressure.

Here, the length-based indicator for the ratio of F/F_{MSY}, part of the ICES Data Limited Stock methods (ICES, 2018) has been applied to length frequency data for the lobster, the main reef fish species and redfish species. This approach requires the estimation of the length at recruitment in the fishery, L_c, defined as the length for which the frequency (number of fish measured for this length bin) corresponds the 50% of the frequency for the mode of the distribution (figure 2.4.1). Then, assuming that 1) the stock is at equilibrium (constant total mortality and constant recruitment) and 2) fishery selectivity follows a logistic curve, the theoretical mean length of landings larger than L_c when the stock is exploited with a fishing mortality F, equal to natural mortality M, can be approximated by:

$$L_{F=M} = 0.75\, L_c + 0.25\, L_{inf}$$

where L_{inf} is the asymptotic length from the von Bertalanffy equation.
This length $L_{F=M}$ is the expected mean length of the landings when the stock is exploited at F_{MSY} (assumed to be equal to M). Computing , L_{mean}, the observed mean length of the landings (individuals larger than L_c) and comparing L_{mean} with the $L_{F=M}$ gives an indication of the level of fishing pressure with respect to F_{MSY}. In the example of the fig 2.4.1, the value of L_{mean} is very close to the value of $L_{F=M}$, which correspond to a fishing mortality close to F_{msy}.

In practice, the ratio $L_{F=M}/L_{mean}$ can be used as a proxy for the exploitation status F/F_{msy}.
The values of the parameter L_{inf} were taken from Leocádio and Cruz (2008) for the lobster and from Ault et al. (2014) and are presented in table 2.4.1

***Table 2.4.1** : L_{inf} values used for the calculation of the length based indicators*

Species	L_{inf}
Spiny lobster male	239mm
Spiny lobster female	245mm
queen triggerfish	76cm
red hind	47cm
white grunt	51cm
Blackfin snapper	73cm
Lane snapper	62cm
Silk snapper	78cm
Vermilion snapper	65cm

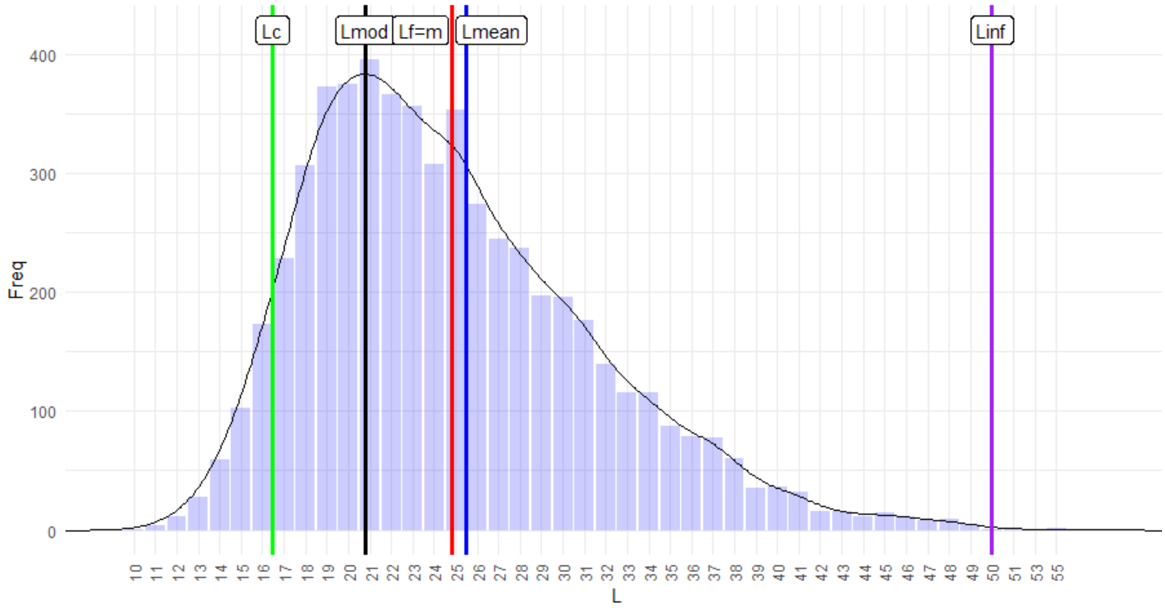


Fig 2.4.1. *Illustration of the ICES length-based indicator method (simulated length frequency distribution data).*
L_{mod}: modal length, L_c: length at recruitment to the fishery (length at 50% of modal value), L_{inf}: asymptotic length from the von Bertalanffy growth equation, $L_{f=m}$: mean length of individuals above L_c when the population is fished at F_{MSY}, L_{mean}: mean length of the landings of individuals above L_c.

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 since then to values under 500 trips (33 000 trap drops) in 2020 (figure 3.1.1 and table 3.1.1). The landings of lobster have generally increased from 2012 to 2017, from 36 to 65 tonnes landed annually (maximum of 71 tonnes in 2015) and then dropped to 27 tonnes in 2018, followed by a small increase in 2019-2020 (48 and 38 tonnes, respectively). Landings of fish in the lobster traps nearly doubled between 2012 and 2015, increasing from 7 to 14.5 tonnes per year, and varied between 8 and 12 tonnes per year in the subsequent years.
The number of trips using redfish traps also increased from 2012 to 2016 (from 335 to 566 days), dropped to 270 trips in 2017, and increased again thereafter (to 588 trips in 2020). The landings of redfish followed a similar trend, increasing from 33 to 47 tonnes in 2016, dropping to 25 tonnes in 2017 and increasing again to 54 tonnes in 2019.
The number of trolling trips have fluctuated between 28 and 77 days (in 2018 and 2014, respectively), with no specific trend. The landings have fluctuated between 1.6 and 3.0 tonnes, except for 2017 for which landings are estimated at around 10 tonnes.
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.

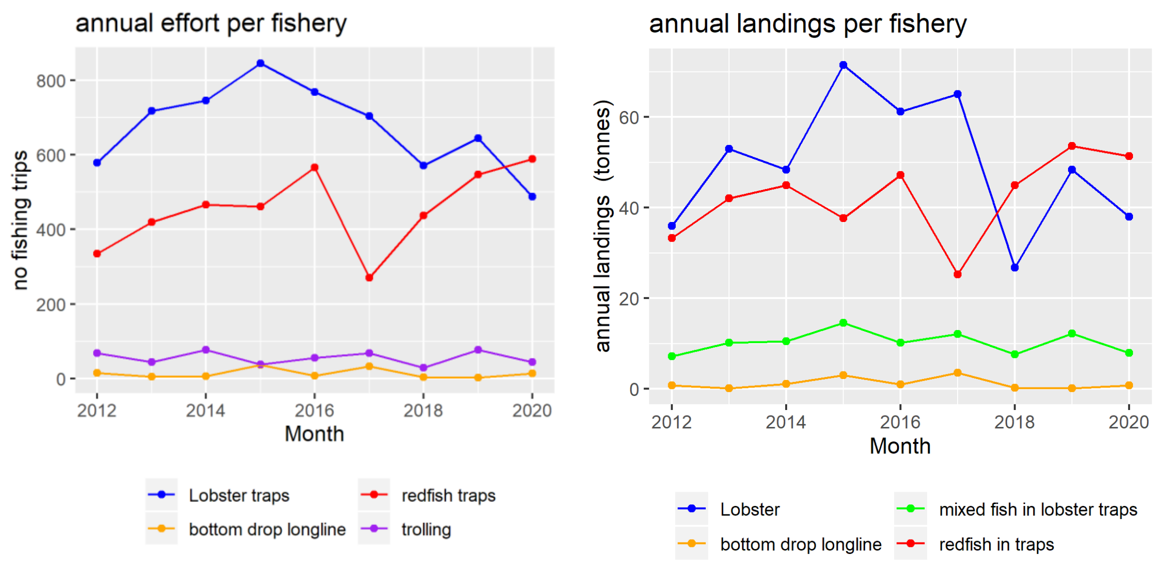


Fig. 3.1.1. *Annual landed catch per group of species (in tonnes) and fishing effort per gear type in fishing days estimated from the port sampling and activity surveys carried out from 2012 to 2020.*

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 2020*

		landings and units		number of gears deployed		fishing days
2012	lobster	36	T	48336	lobster traps	578
	mixed reef fish	7	T	48336	lobster traps	578
	redfish in pots	33	T	9942	redfish traps	335
	longline fish	1	T	6341	hooks	15
	trolling fish	3094	number	215	lines	68
2013	lobster	53	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	1219	number	178	lines	45
2014	lobster	48	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	71	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	2640	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	13338	redfish traps	566
	longline fish	1	T	552	hooks	8
	trolling fish	1515	number	388	lines	56
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	27	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

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 and since 2013, with a small increase in 2007, 2011, 2012 and 2017 at around 85 traps per trip but a markedly lower value in 2020 (figure 3.2.1). Taking in consideration the annual number of trips (estimated since 2012 by the boat activity survey), the effort in terms of annual number of traps set, has increased between 2012 and 2015 from around 48 000 traps/year to 70 000 traps/year and progressively decreased afterwards, down to 33 000 traps in 2020 (Table 3.1.1)

The spatial distribution of the effort is reported presumably accurately only since 2013 (figure 3.2.2). The data since 2013 show that the main fishing areas are areas B4, B5 and C5 (north-eastern part of the bank, closer to the Saba island) with a slight increase of the effort on the southern part of the bank (in areas D2 to D) from 2016 to 2019 (except in 2018). However, the year 2020 appears to have been an exceptional year, with most of the effort from the lobster fishery concentrated in the areas B4 and B5, corresponding to the part of the bank that is the closest to Saba island. The data also show some seasonality in the distribution of the effort on the bank, with for instance a proportional decrease of the effort on the south side of the bank (D3-5) during summer (figure 3.2.2).

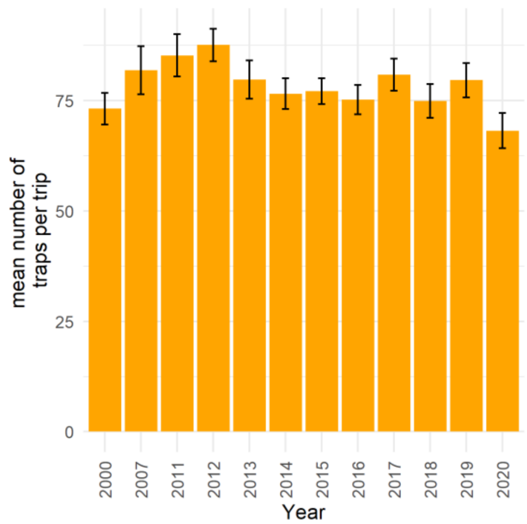


Fig. 3.2.1. *Mean number of traps lifted per trip (with 95% confidence intervals).*

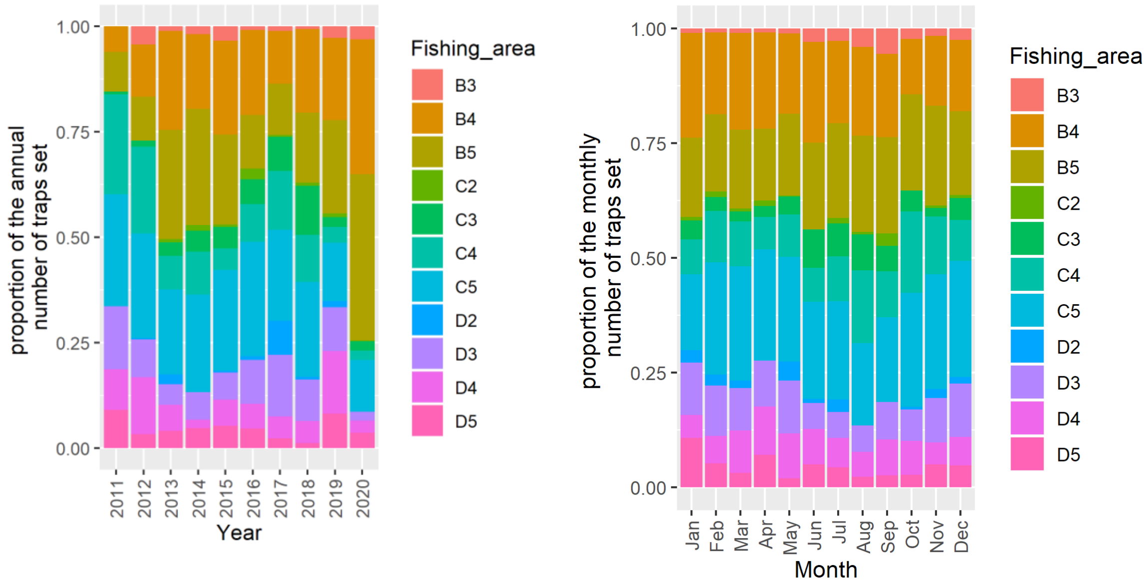


Fig. 3.2.2. *Proportion of the annual (left) and monthly (right) effort of the lobster fishery (in total number of traps set) per fishing area.*

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). 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 up to a level in 2017 similar to the 2007 level. After a small decrease in 2018 and 2019, the catch rates increased again in 2020.

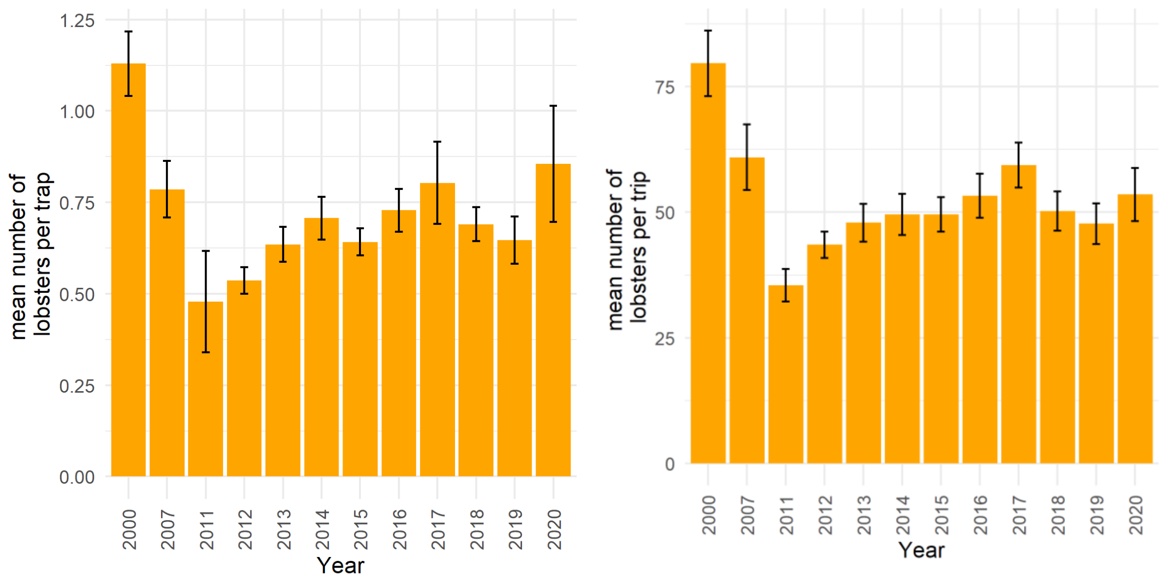


Fig. 3.2.3*. Yearly mean number of lobster per trap (left) and per trip (right) (with 95% confidence intervals).*

Standardisation of the LPUE using a GLM model

All factors, except the effect of the fishing area, 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 2020.

Table 3.2.1. *Significance of each model term tested by removing them one by one and comparing to the full model (GLM model of lobster catches per trip). 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)>		16897			
factor(Year)	9	17026	147.24	<2e-16	***
factor(Month)	11	17269	394	<2e-16	***
factor(Boat_name)	5	17149	262.36	<2e-16	***
factor(Fishing_area)	8	16913	31.84	0.995	
logTraps	1	17727	831.86	<2e-16	***

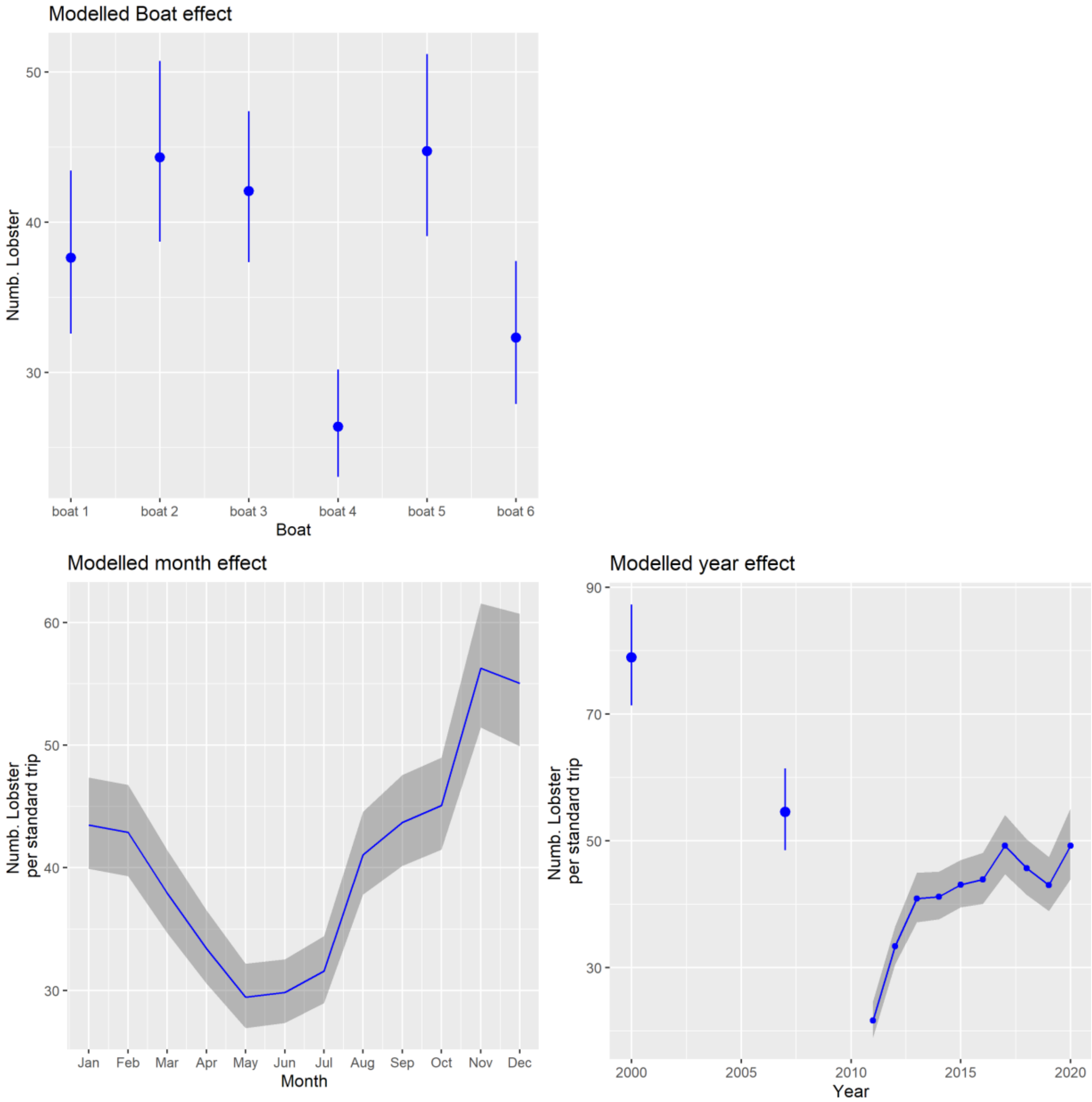


Fig. 3.2.4. *Modelled boat effect and modelled month and year effects on the landings of lobsters per trip (in numbers).*
Blue lines represent the modelled effect (and corresponding 95% prediction envelop in grey).

3.2.1.2 Fishing mortality proxy/ Length frequency

Lobster length measurements were taken on the landings during the landing surveys conducted in the harbour at the end of the fishing trips. The size of the lobsters landed, varied from 50mm (carapace length) to 200mm, but the bulk of the landings were between 70mm and 150mm (figure 3.2.7) with a mean ranging between 105 and 119mm depending on the year. These values were 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 smaller individuals landed (especially the females) in 2000 and 2012 (table 3.2.2). There was a trend towards higher mean size for both males and females between 2012 and 2016, but this trend has reversed and mean length has been decreasing since then (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 (except for 2011)
A considerable part of the lobster landings corresponds to undersized individuals (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 28% respectively (up to 43% for the females, table 3.2.2). From 2015 to 2018, the proportion of landed lobster under the 95mm was low (around 5%), but it has increased again in 2019 and 2020 to above 15% of the landings.

Table 3.2.2. *Lobster catches 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%	7%	4%	5%
2012	103	107	105	123%	43%	15%	28%
2013	109	116	114	146%	18%	7%	12%
2014	110	115	113	156%	19%	9%	13%
2015	114	120	117	154%	8%	1%	4%
2016	115	122	119	194%	8%	4%	6%
2017	113	120	117	173%	7%	3%	5%
2018	113	118	116	172%	11%	5%	7%
2019	108	116	112	135%	20%	14%	16%
2020	107	110	109	177%	25%	13%	18%

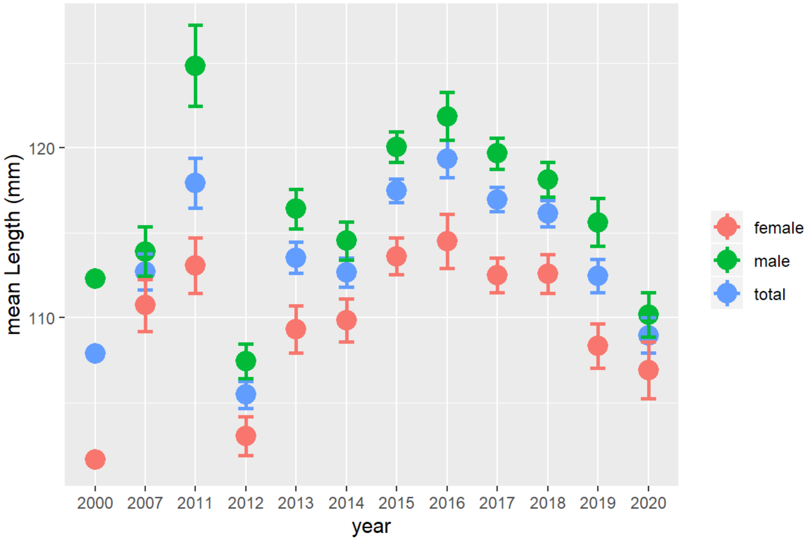


Fig. 3.2.5. *Annual mean length of lobster landings (with 95% confidence intervals).*

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

	discarded	landed
mean length	90	115
mean length (females)	93	112
mean length (males)	84	117
sex ratio (males per female)	54%	168%

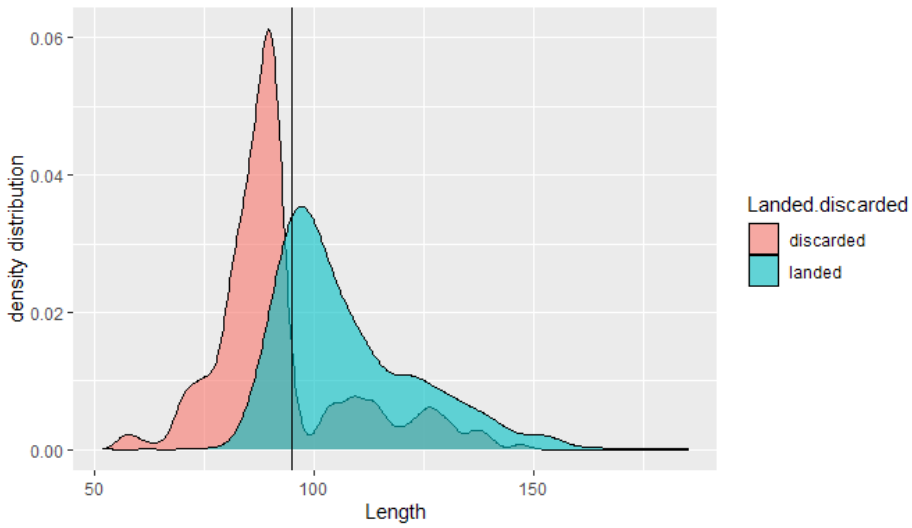


Fig. 3.2.6. *Length distribution of the landed lobsters and discards of lobster from the port sampling (long interviews). Data are from 2012 only (not enough discards measured in other years). the vertical line represents the minimum landing size of 95cm (carapace length).*

Length based indicator for F/F_{MSY}

The length at recruitment to the fishery (necessary to compute the length based indicator for F/F_{MSY}) was estimated based on the landings length-composition for all years combined and for both sexs together, at L_c= 86 mm (figure 3.2.7). Using the values for L_{inf} of 239 mm and 245 mm for males and females respectively, the corresponding value of $L_{F=M}$ is of 124.25 mm and 125.75 mm. The F/F_{MSY} proxy values suggest that the stock has been overfished over the whole period. In all year, the F/F_{MSY} proxy indicates that the females are more heavily exploited that the males (since females are of smaller size in the landings, and have a higher $L_{F=M}$ value than males due to their larger L_{inf}. For part of the period studied, the males have been exploited close to F_{MSY} (2011 and from 2015 to 2019) The variations of the length-based indicator for F/F_{MSY} are overall well correlated between the two sexes. F/F_{MSY} proxy values were high for the first to years of data (2000 and 2007), but much lower at the start of the current data collection program (2011), especially for male lobsters, for which particularly large individuals were landed in 2011. Then, for both sexes, the F/F_{MSY} proxy increased abruptly from 2011 to 2012, and generally decreased thereafter to increase again in the most recent years.

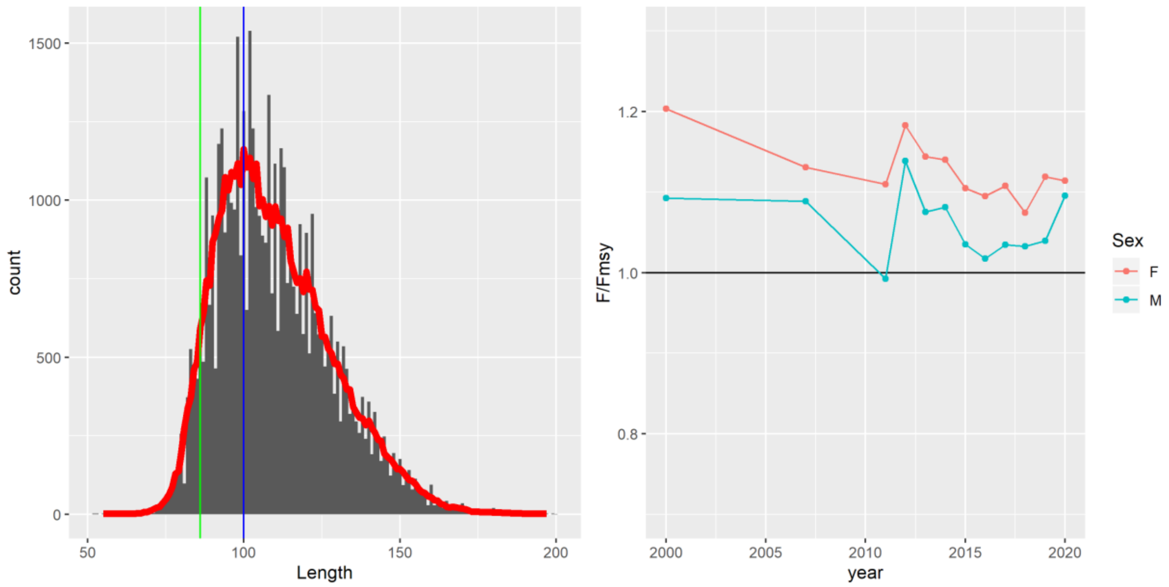


Fig. 3.2.7. *left: lobster landings length distribution (all year confounded) and values of Lmod (model length, in blue) and L_c (length at half of the value of the mode, in green) ; right : length-based indicator for F/F_{msy} calculated per sex on the annual length frequency data.*

3.2.1.3 Undersized lobster

The number of undersized lobster 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 (Table 3.2.4).
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 3.2.8). 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. 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 also shows that there are substantial differences in the catches of undersized lobsters between boats, with boat 2 and 4 catching substantially less undersized lobsters than the other boats. Finally, catches of undersized lobsters are higher in the northeaster 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. *Significance of each model term tested by removing them one by one and comparing to the full model (GLM model of undersize lobster catches per trip). 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)>		13368			
factor(Year)	8	13442	89.279	6.52E-16	***
factor(Month)	11	13438	91.983	6.81E-15	***
factor(Boat_name)	5	13420	61.685	5.45E-12	***
factor(Fishing_area)	8	13476	124.086	2.20E-16	***
logTraps	1	13504	137.88	2.20E-16	***

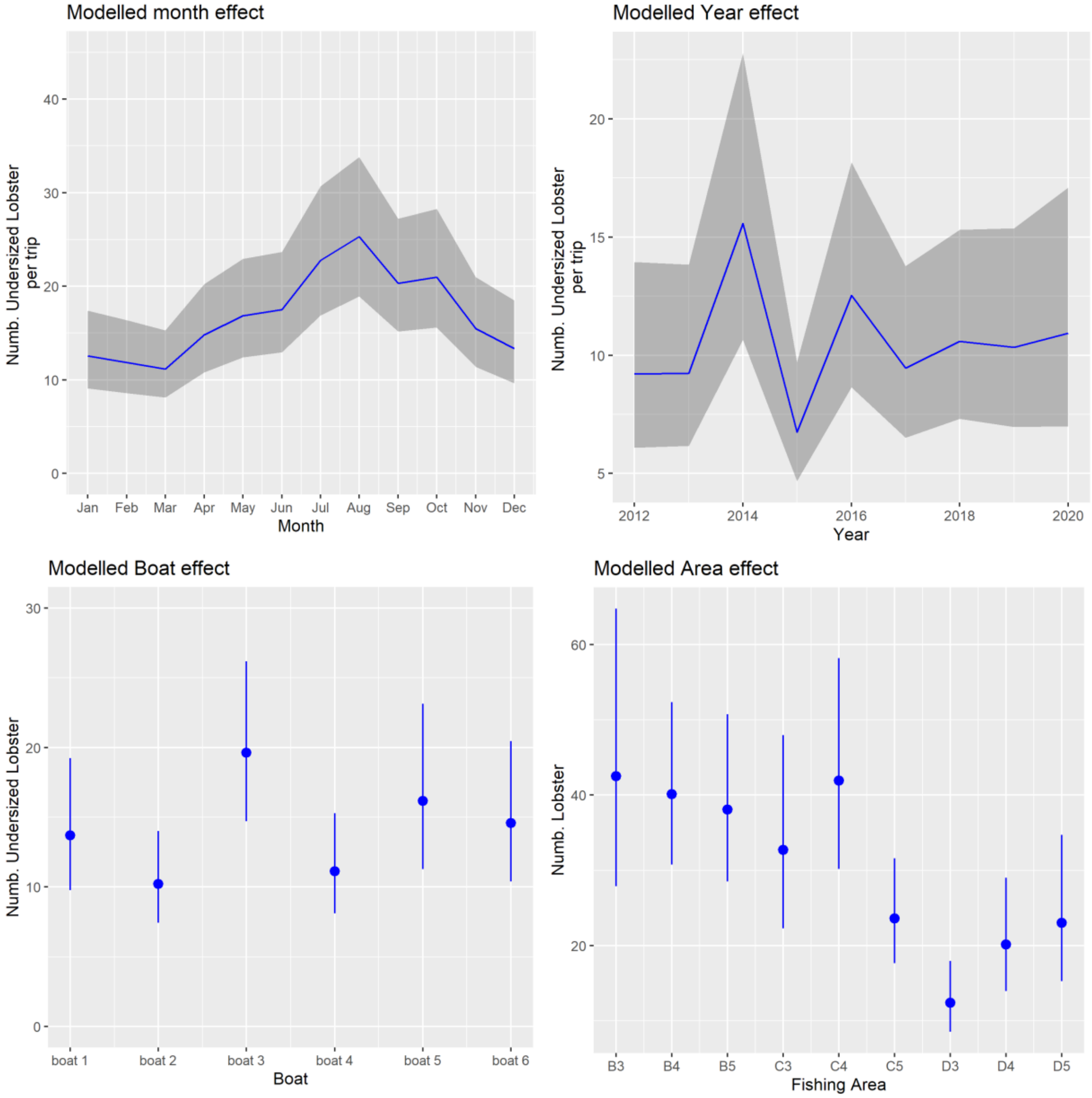


Fig. 3.2.8. *Modelled effects of the month, year, boat and fishing area on the catches of undersized lobsters per trips (in numbers). Blue lines represent the modelled effect (and corresponding 95% prediction envelop in grey).*

3.2.1.4 Spawning season

The number of berried lobster per trip was also modelled using the GLM approach. All model factors were significant, except the fishing areas (Table 3.2.5). Berried females are caught throughout the year, but are more abundant between February and May (Figure 3.2.9). The spawning season varies from March through August, depending on the region (e.g. Florida Keys) with peaks in March and April (Cavalcante Soares, 1990) but are known to spawn year-round through the Caribbean. The "year" effect suggest a low abundance in 2012, followed by a strong increase in 2013, and a steady decrease after that.

Table 3.2.5. *Significance of each model term tested by removing them one by one and comparing to the full model (GLM model of berried female lobster catches per trip). 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)>		12240			
factor(Year)	8	12253	28.789	0.000345	***
factor(Month)	11	12339	121.537	2.20E-16	***
factor(Boat_name)	5	12370	139.857	2.20E-16	***
factor(Fishing_area)	8	12268	44.429	4.72E-07	***
logTraps	1	12541	303.173	2.20E-16	***

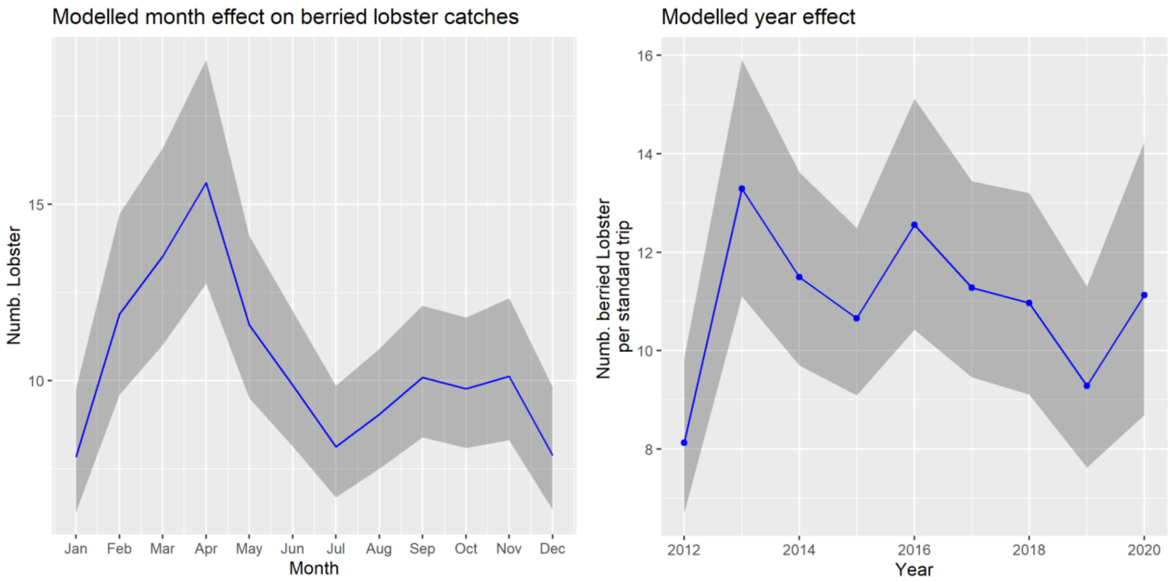


Fig. 3.2.9. *Seasonality and annual variations of the catches of berried lobsters (distribution of the monthly number of berried lobster by trip, corrected for the effect of the number of traps and the year effect from the model of lobster catches from figure 3.2.4).*

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. From 2012 to 2018 there are stable intermediate values but an increase for 2019 and 2020 (figure 3.2.1). The mean landings per trips show similar variations, except in 2020, when the lower number of traps used per trip (figure 3.2.1) resulted in a decrease in the mean landings per trip.

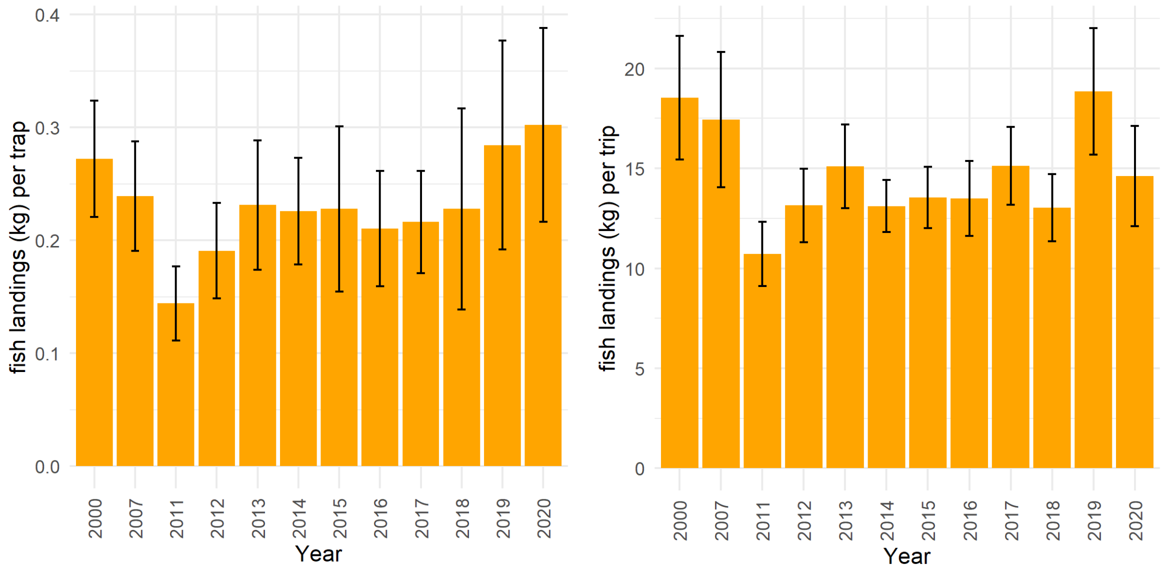


Fig. 3.2.11. *Yearly mean landings of mixed reef fish (kg) per lobster trap (left graph) and per fishing trip (right graph). Error bars are 95% confidence intervals.*

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 3.2.12). Clearly, some boats tend to keep more bycatch while others prefer discarding them. The "area" effect indicates that fish catches are lower in the western most 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 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, a slight decrease thereafter and much higher values for 2019 and 2020.

Table 3.2.6. *Significance of each model term tested by removing them one by one and comparing to the full model (GLM model of mixed fish landed per trip). 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)>		4174.1			
factor(Year)	9	4202.1	5.0727	8.56E-07	***
factor(Month)	11	4254.5	9.3803	2.20E-16	***
factor(Boat_name)	5	4527.1	78.5727	2.20E-16	***
factor(Fishing_area)	10	4193.3	3.88	3.13E-05	***
logTraps	1	4215.7	43.1581	6.57E-11	***

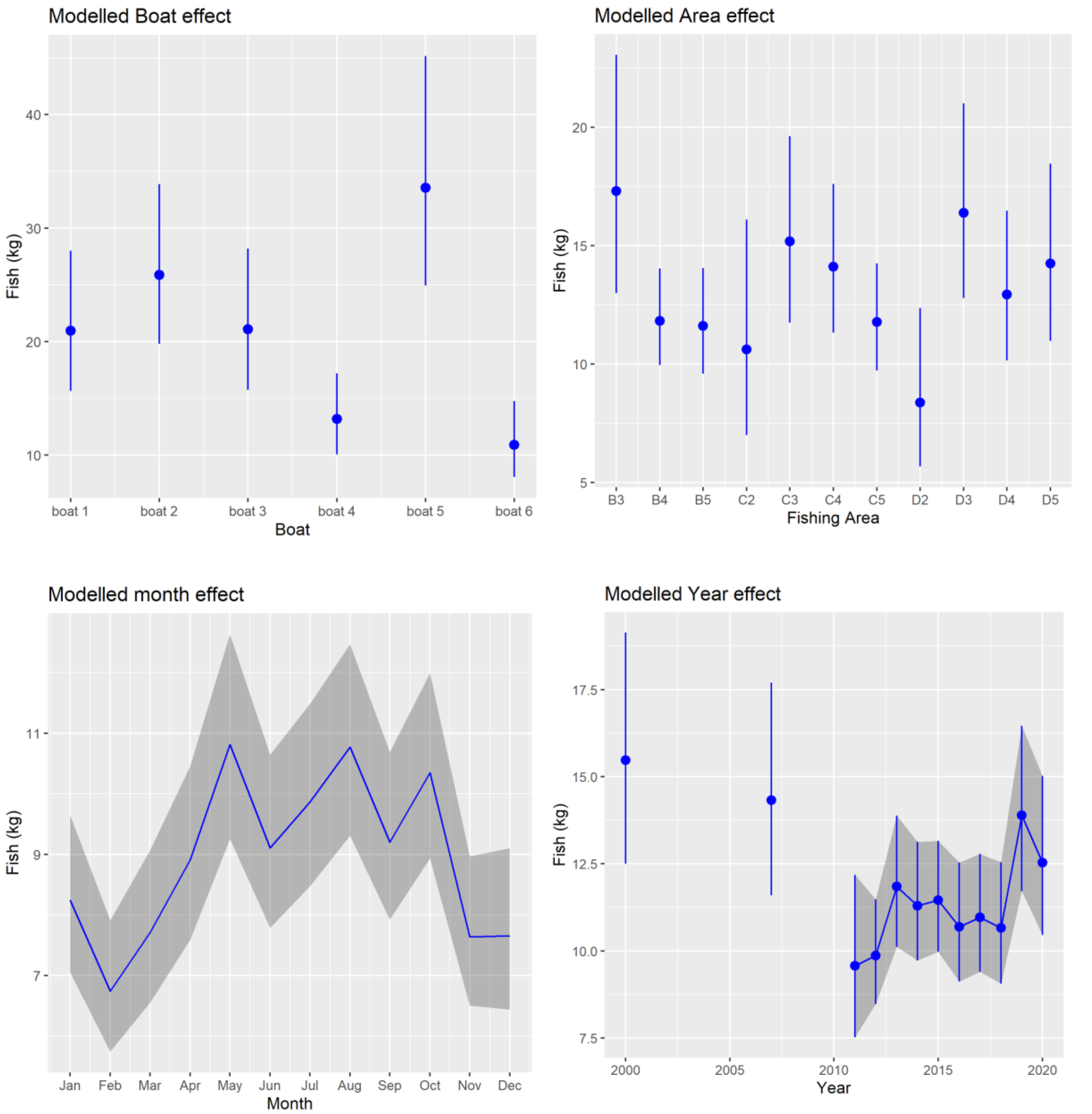


Fig. 3.2.12. *Modelled boat effect (model fitted on the data for 2011-2015) and modelled month and year effects (model fitted on the data 2000-2015) on the landings of mixed reef fish in lobster traps per trips (in numbers). Blue lines represent the modelled effect (and corresponding 95% prediction envelop 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 album)*, Red hind (*Epinephelus guttatus*), Cottonwick (*Haemulon melanurum)*, Doctorfish (*Acanturus chirurgus)*, and Ocean surgeonfish (*Acanturus pictus)* (Figure 3.2.13). 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 Cotton wick (Figure 3.2.14). 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 3.2.15. 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 (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%). The total weight of the herbivorous species landed usually represents around 12% of the landings, but peaked at more than 50% in 2015, and decreased to under 10% by 2020.

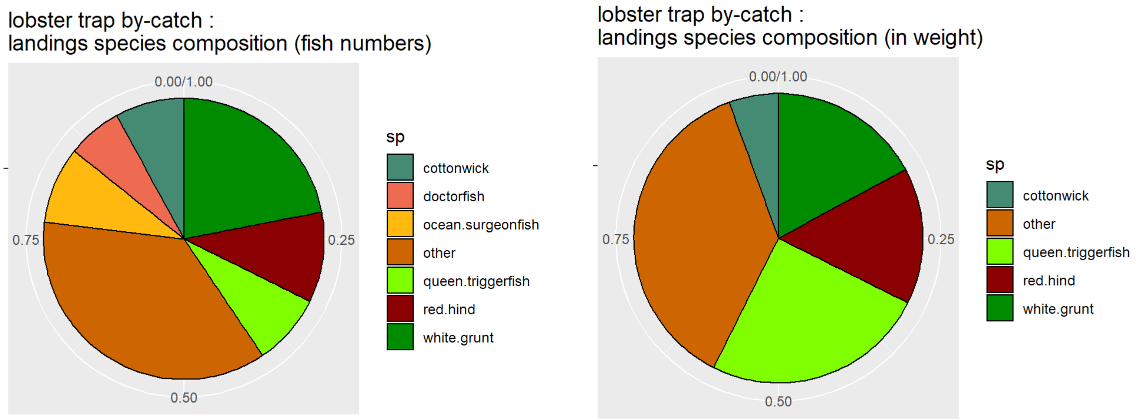


Fig. 3.2.13. *Species composition for the mixed reef fish landed in the lobster fishery (based on 210 trips sampled) in 2012-2020*

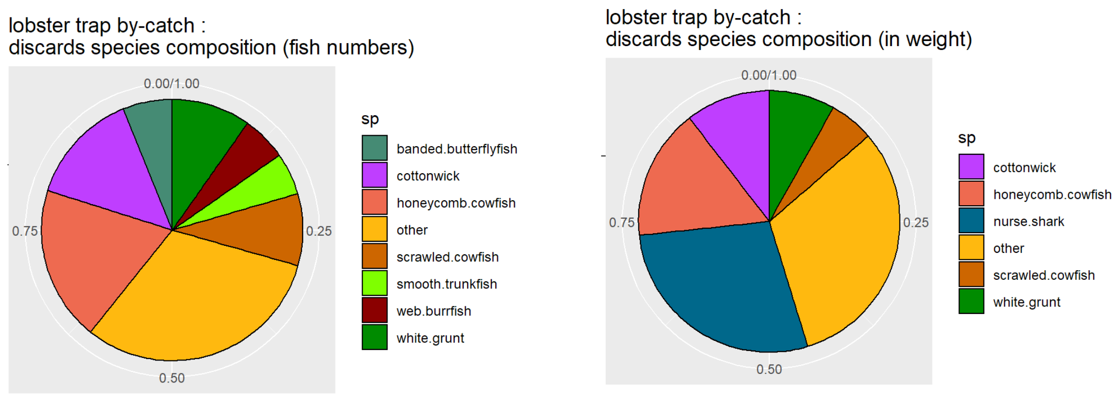


Fig. 3.2.14. *Species composition for the mixed reef fish discarded in the lobster fishery (based on 40 trips sampled) in 2012-2020.*

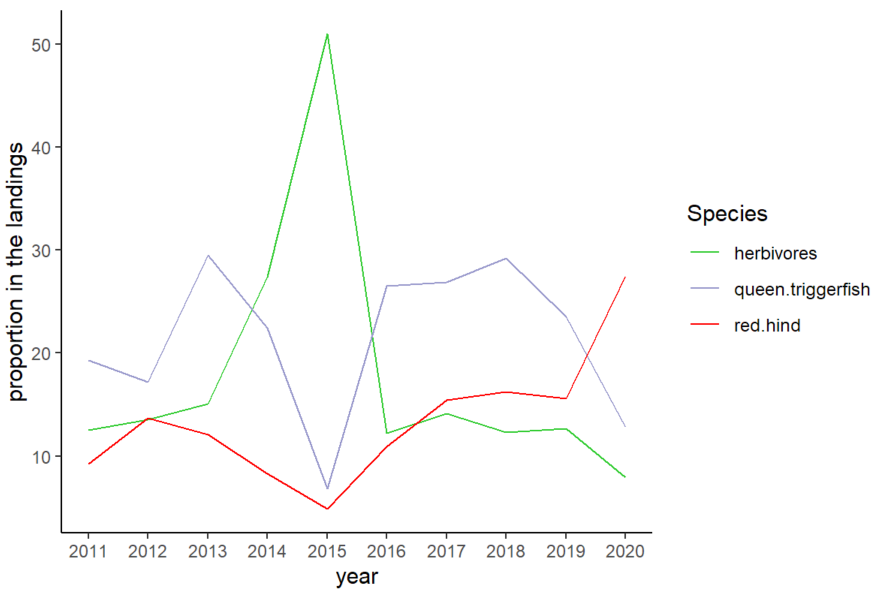


Fig. 3.2.15 *: proportion of the landings (percentage) in weights for 3 key species (or species groups) for the mixed reef fish landed in the lobster fishery*

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 3.2.16): Queen triggerfish were the larger species, with landings mainly between 25 and 40cm. These were larger than the for the Red hind (between 20 and 40cm), and the White grunt (between 20 and 30cm).

The length based indicator for F/F_{msy} was computed on a yearly basis for these species. The value of L_c was larger for Queen triggerfish (30cm), intermediate for the Red hind (26cm) and lowest for the White grunt (22cm). The mean length of the landed fish larger than L_c, L_{mean}, was calculated each year for which at least 20 fish were measured. For the Queen triggerfish and the White grunt, L_{mean} was lower that $L_{F=M}$ (figure 3.2.17) for all years, indicating that the ratio F/F_{msy} was larger than 1 (figure 3.2.18). For the Red hind, L_{mean} was close to $L_{F=M}$ and the ratio was close F/F_{msy} to 1. There were no clear changes in the landings length-compositions over the years, that would indicate any changes in the level of exploitation.

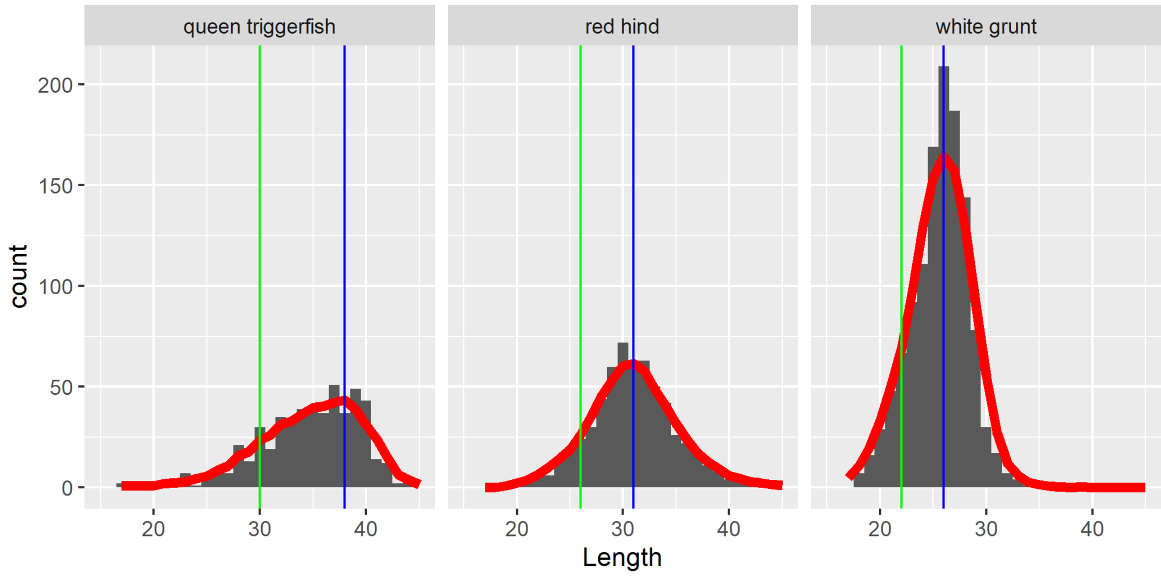


Fig. 3.2.16 *: : Landings length-composition for the 3 main reef fish species (all years combined)and values of Lmod (model length, in blue) and L_c (length at half of the value of the mode, in green)*

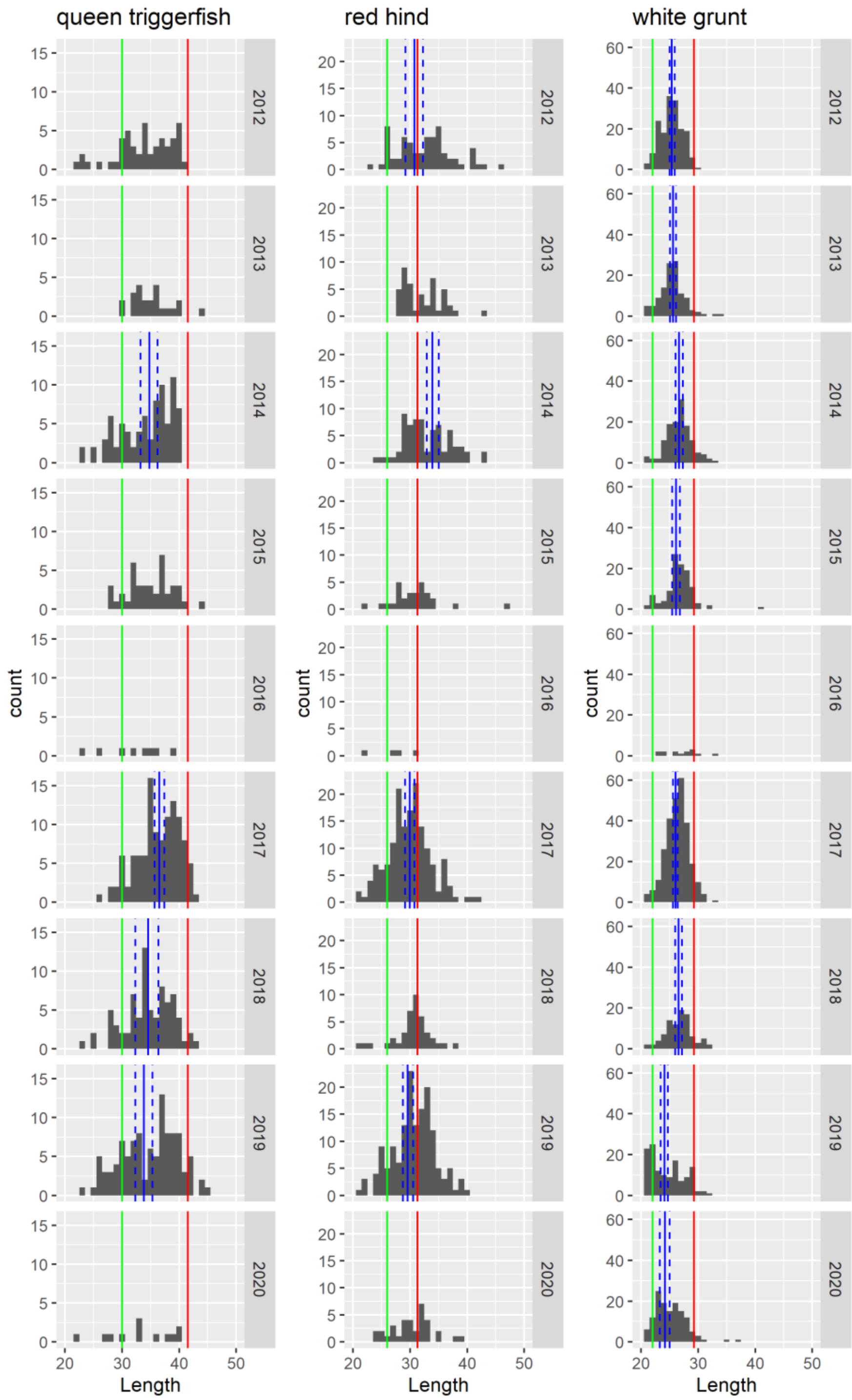


Fig. 3.2.17 *: annual landings length composition data for the 3 main reef fish species and their respective length at recruitment to the fishery, L_c (green), expected length at F=M, $L_{F=M}$=m (red) and annual value of mean length L_{mean} (blue, with confidence bounds obtained by bootstrap). Note that the calculations of L_{mean} were not done when there was less than 20 measurements for a species*

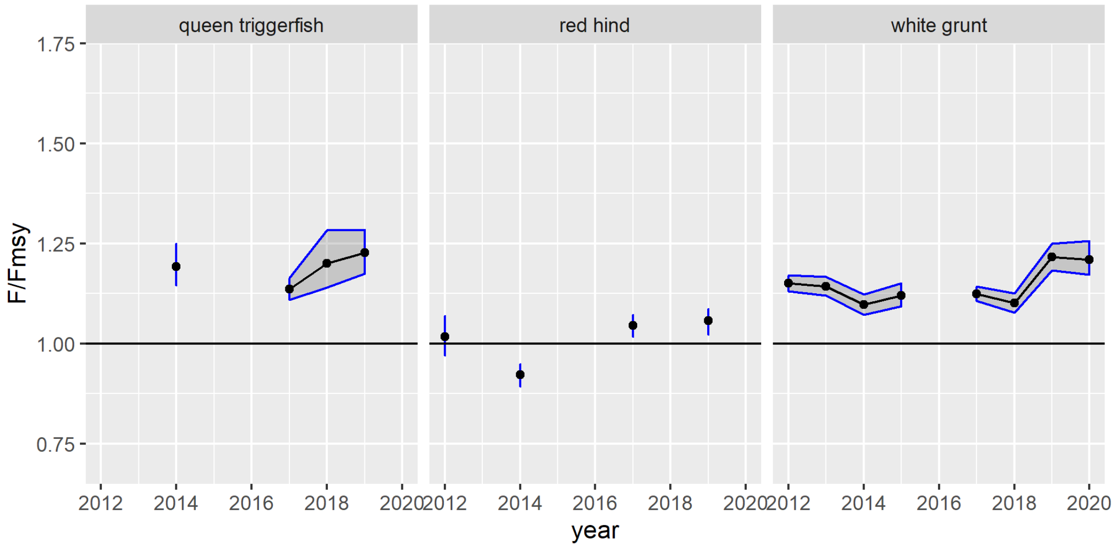


Fig. 3.2.18 *: Annual values of the length-based indicator F/F_{MSY} for the three main reef fish species (with confidence interval obtained by bootstrap). The gaps in the time series correspond to the years with low number of measurements (less than 20 fish) for which the calculations were not done.*

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 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).

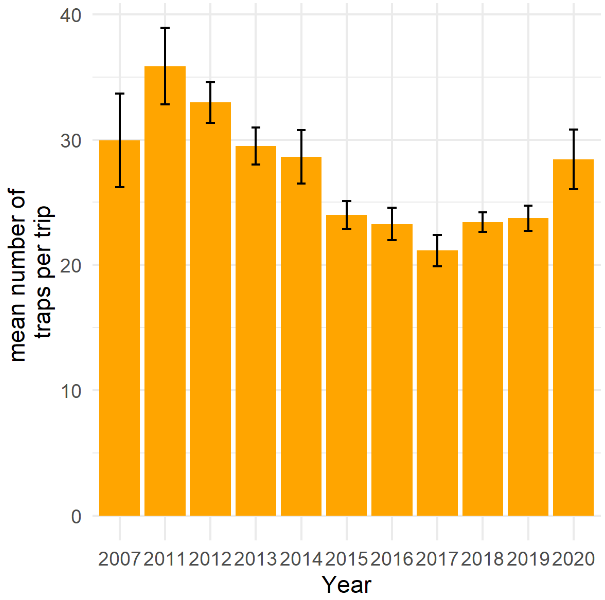


Fig. 3.3.1. *Mean annual number of traps lifted per trips (with 95% confidence intervals).*

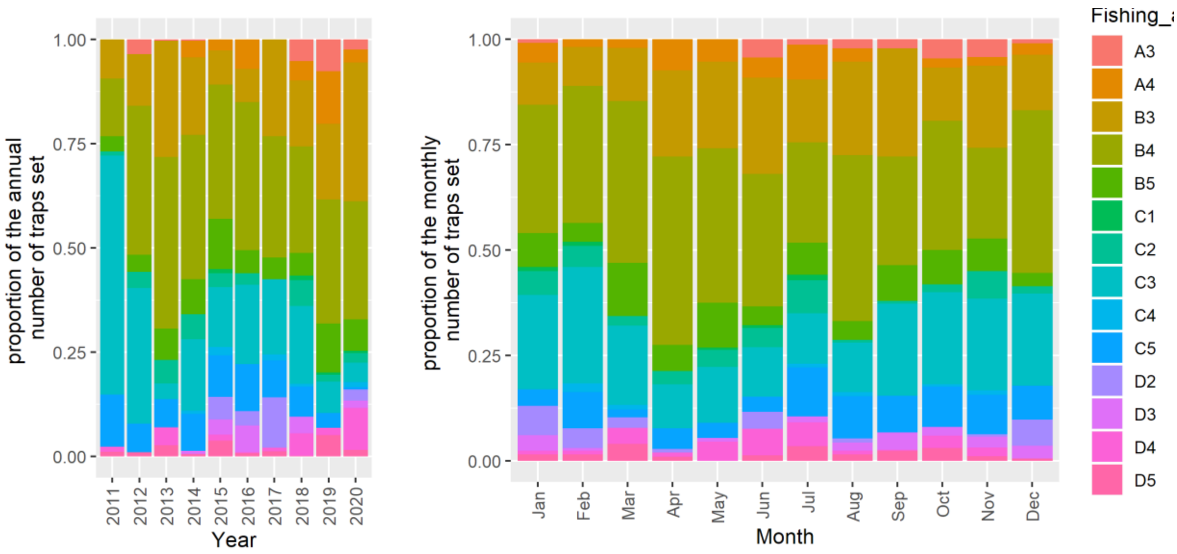


Fig. 3.3.2. *Proportion of the annual (left) and monthly (right) effort (in total number of traps set) per fishing area.*

Landing rates were at their highest in 2007 but were much lower in 2011 (figure 3.3.3). Landings rates in kg per trap then slowly increased until 2017 but decreased after that. 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).

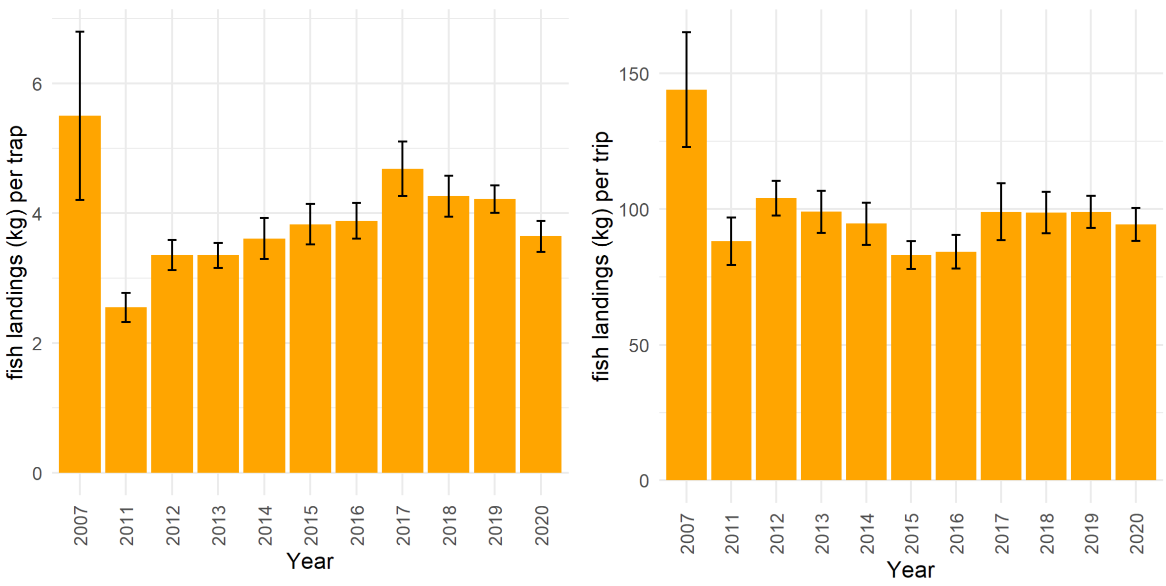


Fig. 3.3.3. *Yearly mean* Landing *of red fish (kg) per trap and per trips (with 95% confidence intervals).*

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 60% 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 in September-October and in February. The "year" effect, which is standardised biomass index for the redfish, indicated a higher biomass in 2007 than for the rest of the time series. The biomass index was low for 2011, slightly higher and constant between 2012 and 2016, and increased markedly in 2017 and 2018, followed by a decrease in 2019 and 2020.

Table 3.3.1. *Significance of each model term tested by removing them one by one and comparing to the full model (GLM model of red fish caught and landed per trip). 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)>		1756.7			
factor(Year)	9	1785.5	5.1441	7.52E-07	***
factor(Month)	11	1767.4	2.9262	0.000806	***
factor(Boat_name)	5	1790.1	8.5702	5.67E-08	***
factor(Fishing_area)	8	1751.6	1.3286	0.225017	
logTraps	1	1839.7	85.5854	< 2.2e-16	***

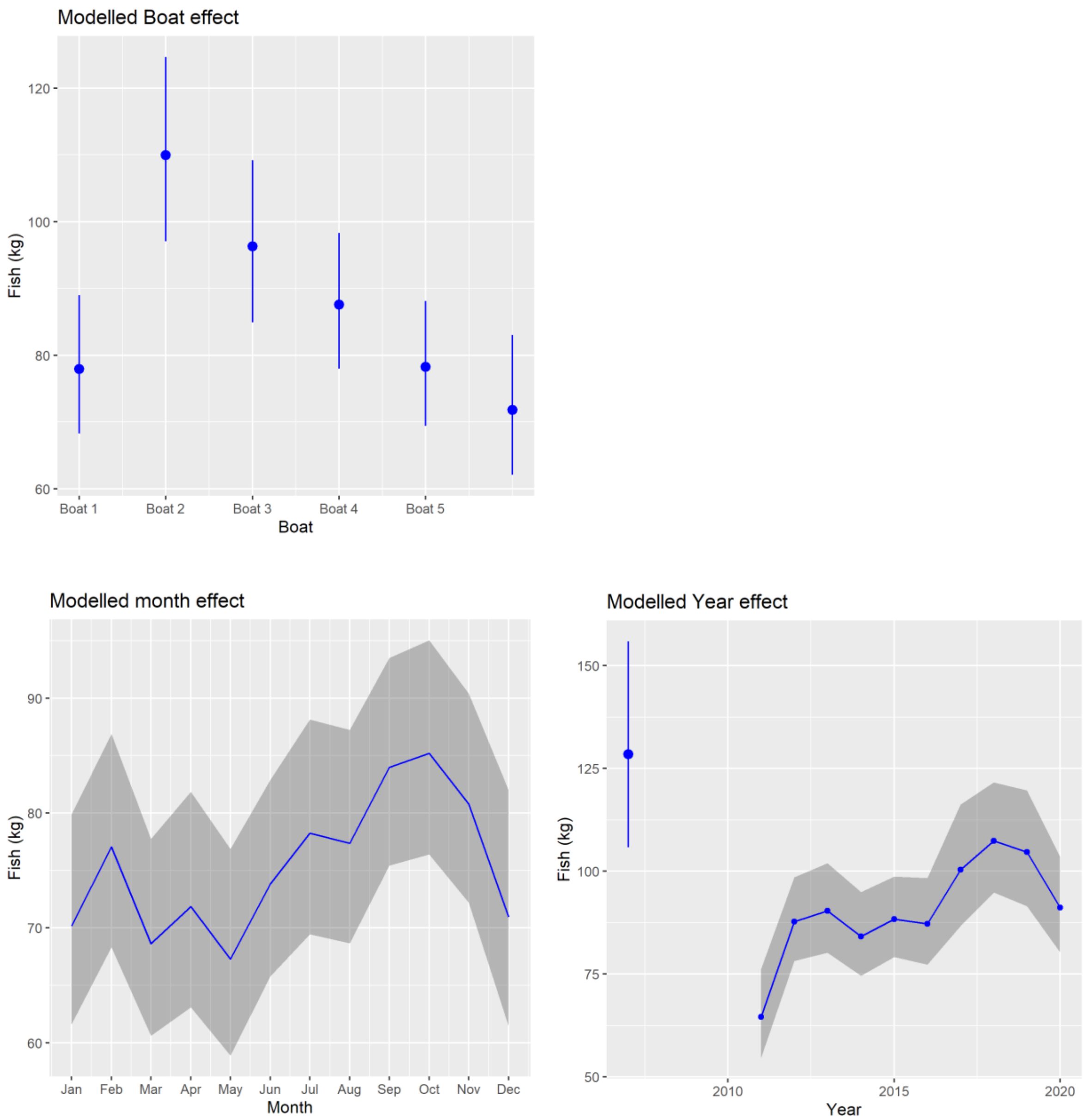


Fig. 3.3.4. *Modelled boat, month and year effects on the catches of red fish per trips (in numbers). Blue lines represent the modelled effect (and corresponding 95% prediction envelop in grey).*

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 snappers. The Silk snapper is also the most discarded species, representing around 50% of the discards in both numbers and weight (Fig. 3.3.6). Other important discarded species were the Lionfish, *Pterois vomes*, French angelfish, *Pomacanthus paru*, and the Nurse shark, *Ginglymostoma cirratum*.

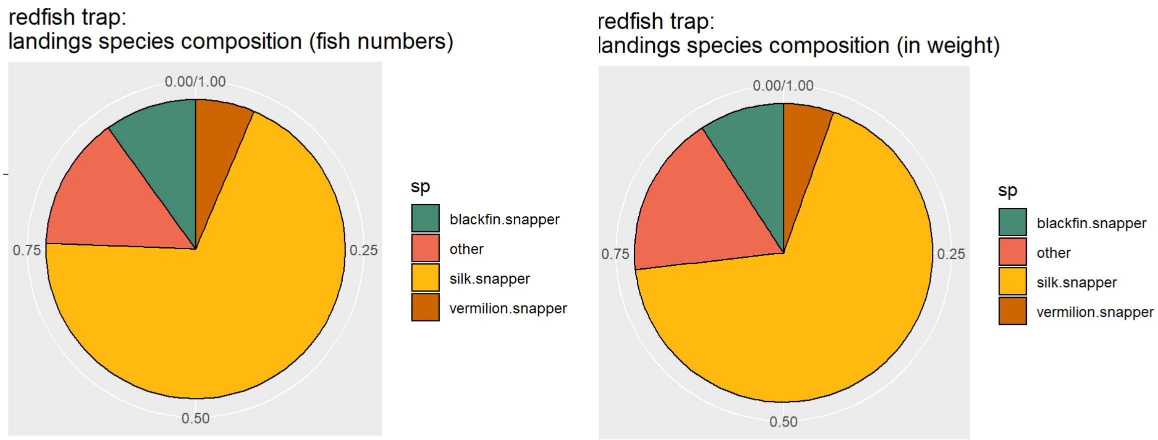


Fig. 3.3.5. *Species composition of the catches in the red fish fishery (in numbers, left ,and in weight, right) based on 84 trips sampled.*

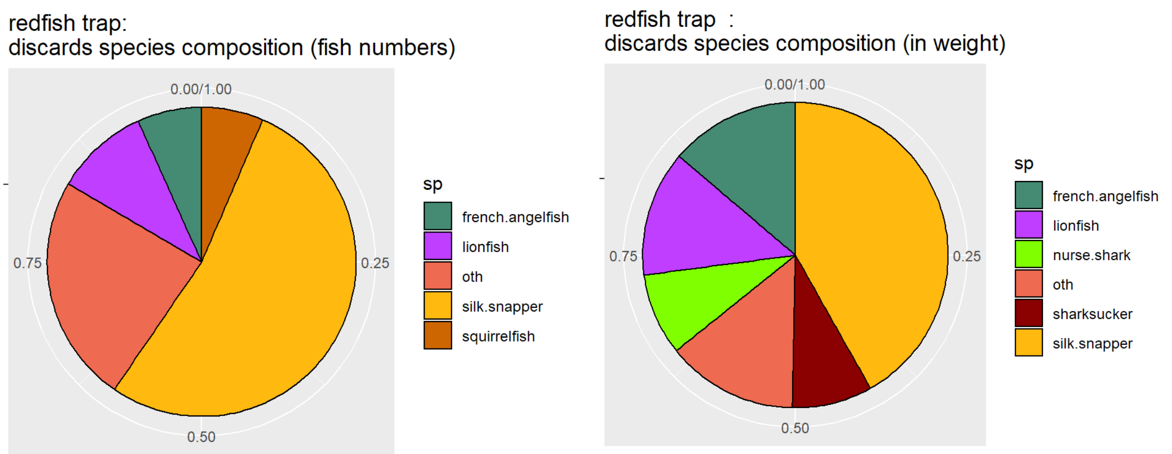


Fig. 3.3.6. *Species composition of the discards in the red fish fishery (in numbers, left ,and in weight, right) for the year 2011 to 2020 combined based on 9 trips sampled.*

3.3.1.3 Length frequency and fishing mortality proxy

The length based indicator for F/F_{MSY} was also computed on a yearly basis for the four main snapper species caught in the redfish traps. The length at recruitment to the fishery, L_c, defined as the length corresponding to half of the value of the mode of the distribution, was first computed based on the landings length composition for all years combined. The four species had a similar L_c value, ranging from 21cm for the Blackfin snapper to 23cm for Vermillion and Lane snapper (fig. 3.3.7). From these values and the values of L_{inf} of each species, the theoretical mean landing length (for landings over L_c) was computed. Values of $L_{F=M}$ ranged from 32.75cm for the Lane snapper to 36cm for the Silk snapper (fig 3.3.8).
The mean length of the landings (only fish above L_c) was then computed on an annual basis, and the confidence intervals were obtained by bootstrap. For the Lane snapper and the Vermillion snapper (and to some extent the Blackfin snapper in some years), the number of fish measured was generally low, which resulted in large confidence intervals around L_{mean} (fig 3.3.8). For the four species, although quite variable between years, the L_{mean} values were always lower than the corresponding $L_{F=M}$ values. This suggests that all four species considered are subject to overfishing. The length based indicator for F/F_{MSY} (equal to the ration $L_{F=M}$ / L_{mean}) is therefore above 1 for all species (fig 3.3.9). The exploitation level appears to be higher for the Silk snapper and lower for the Lane snapper. Although it is difficult to interpret variations in the yearly values of F/F_{MSY} (see discussion), there is no clear temporal trend for any of the species that would suggest any changes in the level of exploitation.

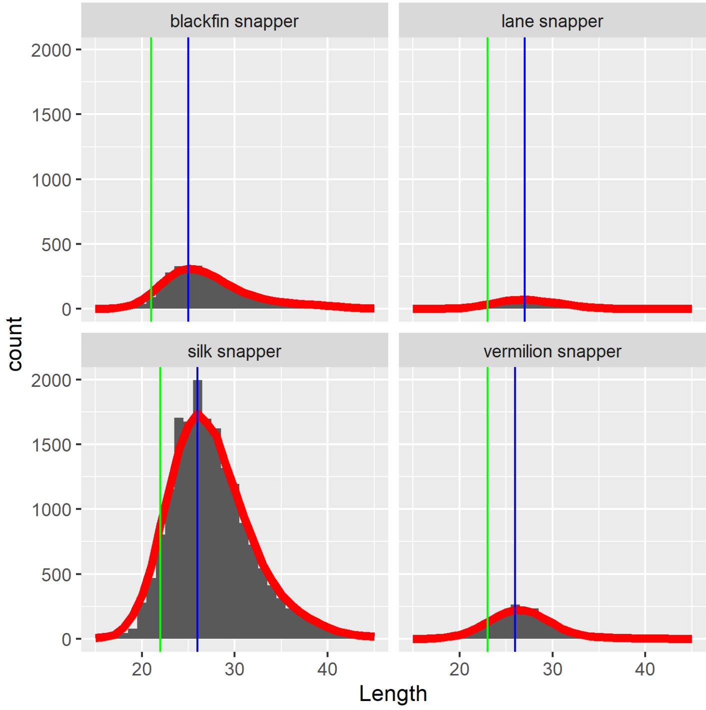


Fig 3.3.7. *Landings length-composition for the 4 main snapper species (all years combined) and values of L_{mod} (model length, in blue) and L_c (length at half of the value of the mode, in green)*

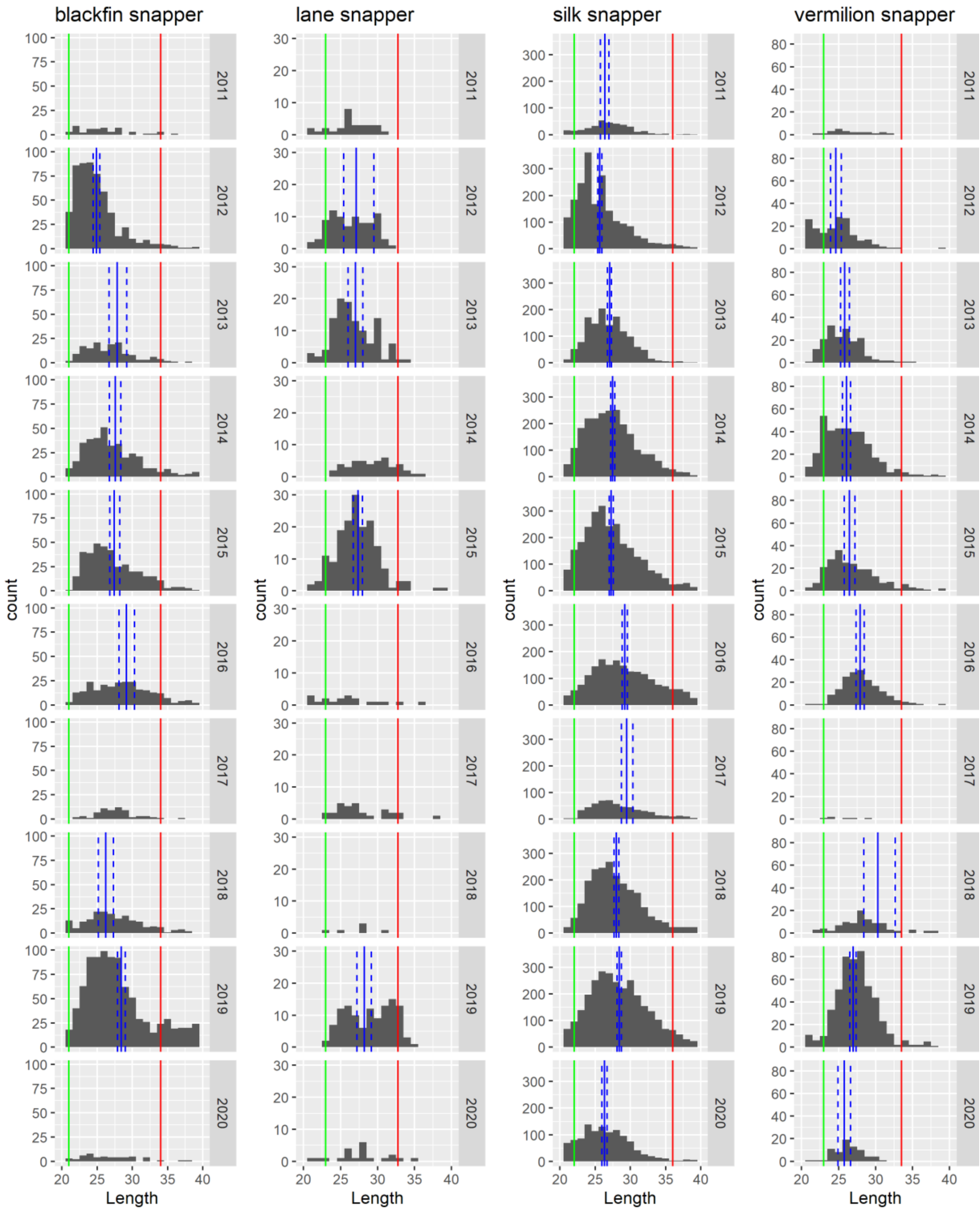


Fig 3.3.8. *annual landings length composition data for the 4 snapper species and their respective length at recruitment to the fishery, L_c (green), expected length at F=M, $L_{F=M}$ (red) and annual value of mean length L_{mean} (blue, with confidence bounds obtained by bootstrap). Note that the calculations of L_{mean} were not done when there was less than 20 measurements for a species*

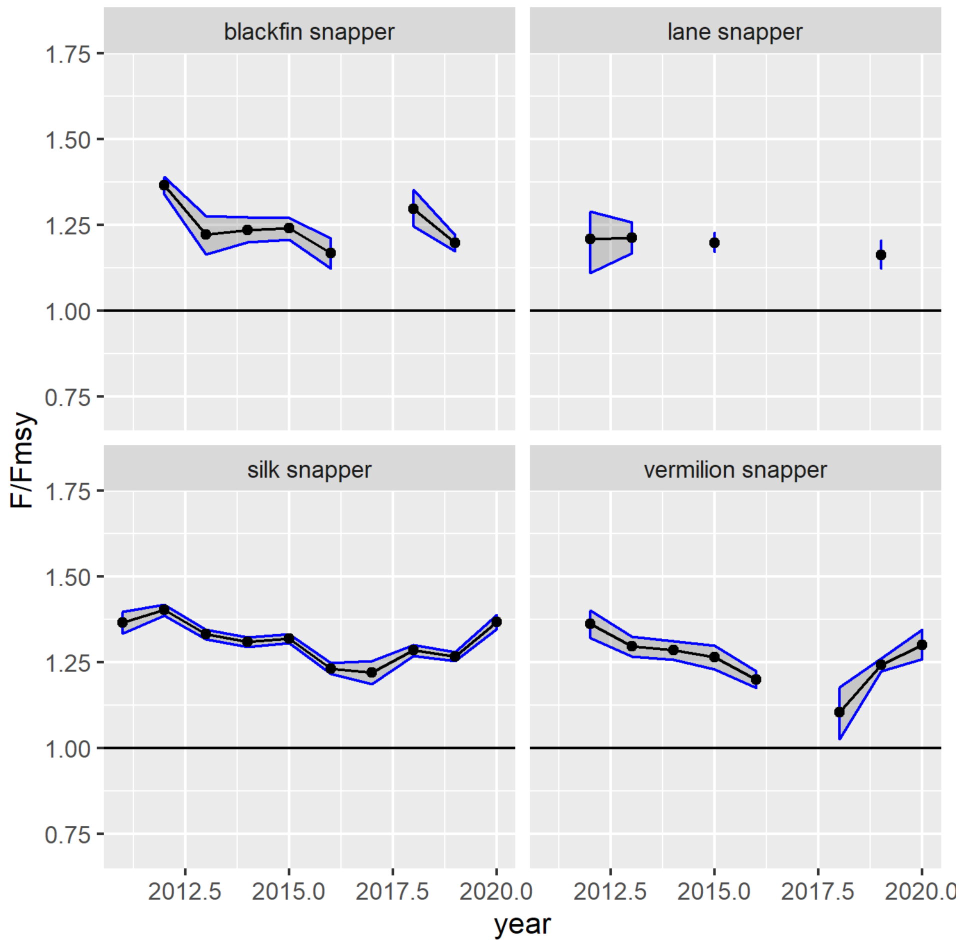


Fig 3.3.9. *Annual values of the length based indicator F/F_{MSY} for the 4 main snapper species (with confidence interval obtained by bootstrap). The gaps in the time series correspond to the years with low number of measurements (less than 20 fish) for which the calculations were not done*

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 trips sampled at the harbour. Considering that between 30 and 50% of the trips were covered by a landing survey, there is a fair chance that none of the few trips using longline carried out in a given month was actually covered by the landing surveys.
Because of the scarcity of the data, it is also difficult to examine for seasonality 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.

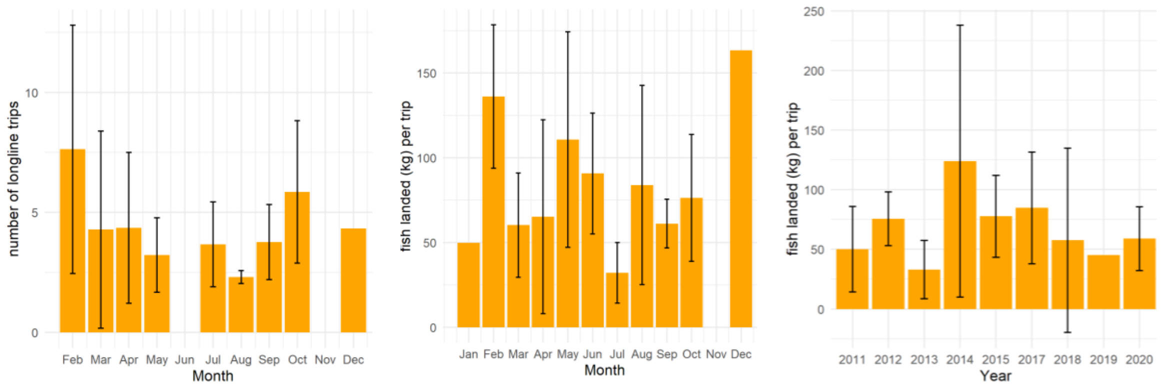


Fig. 3.3.10. *Mean number of longline trips per month (left), monthly (middle) and annual (right) mean*
landed catches (in kg) per trip in the long line fishery with 95% confidence interval (absence of confidence interval correspond to month with a single observation).

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 2012-2020). The longline fishery targets mainly snappers, with the Wenchman snapper, *Pristipomoides aquilonaris*, being predominant in the catches in number and the Queen snapper, *Etelis oculatus*, being dominant in the catches in terms of weight (figure 3.3.11). Species composition of the discards is based on a single trip. The main discarded species was the Cuban dogfish, *Squalus cubensis*. (figure 3.3.12).

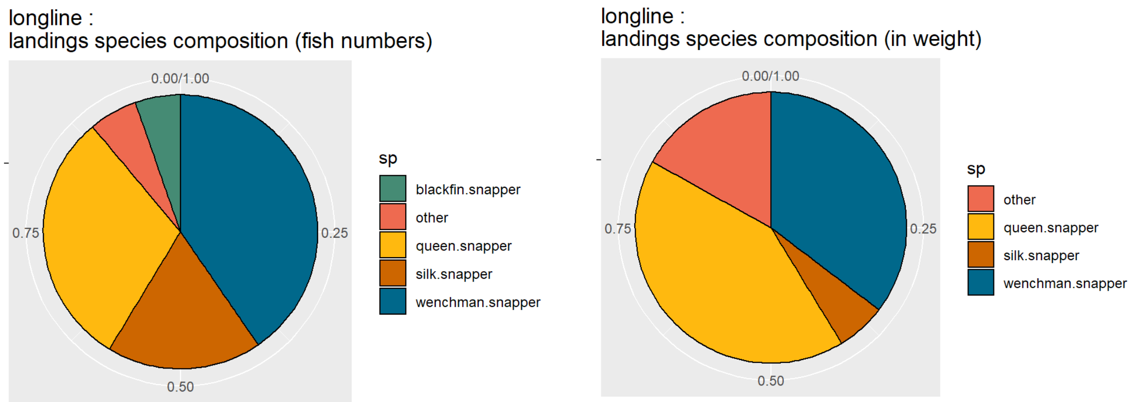


Fig. 3.3.11. *Species composition of the landed catches from the long line fishery based on the sampling realised between 2012 and 2020 based on 10 trips sampled.*

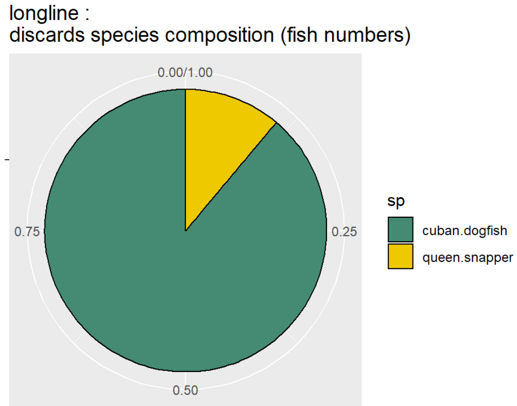


Fig. 3.3.12. *Species composition of the discards from one bottom long line fishing trip based on 1 trip sampled for a total of 9 discarded fish.*

3.4 Pelagic fishery

3.4.1.1 CPUE

The annual number of trolling fishing trips is estimated to have varied between 29 and 77 in the period 2012 and 2019 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 longline fishery, the data is too scare to apply the GLM model for standardisation.

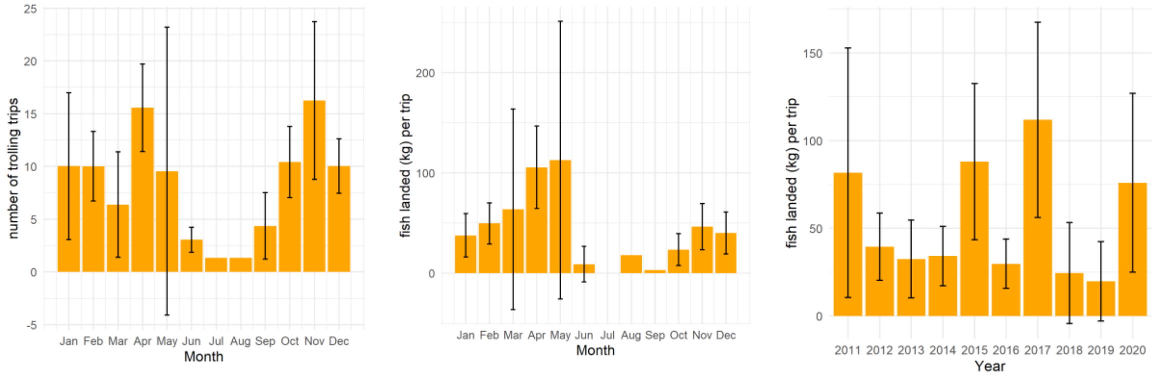


Fig. 3.4.1. *Mean number of trips per month (left), mean catch per trip (in fish number) per month (middle) and per year (right), with 95% confidence interval of the mean (absence of confidence interval correspond year or month with a single observation).*

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 represent 70% and dolphinfish about 20% of the catches in weight. The proportion of tunas (in weight) is about 4%.

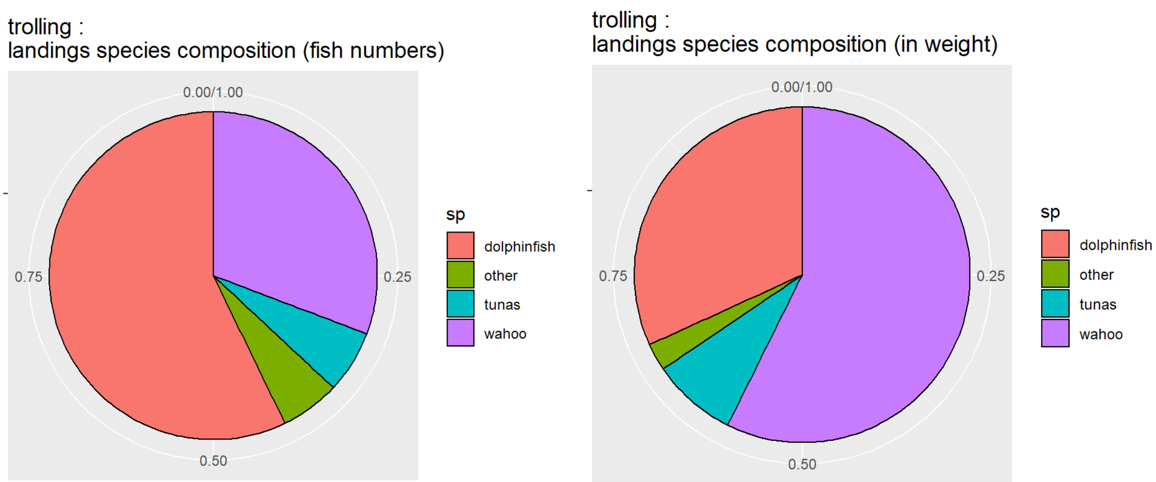


Fig. 3.4.2. *Species composition of catches in the trolling fishery (in numbers, left, and in weight, right) based on 425 fish from 73 trips sampled.*

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 (3 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 6% of the trips, large numbers (> 10 and occasionally up to 71 individuals) were caught. Bycatch of nurse shark were rare in redfish traps (only 9% 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 rather constant in the redfish fishery, but has increased 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.
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).

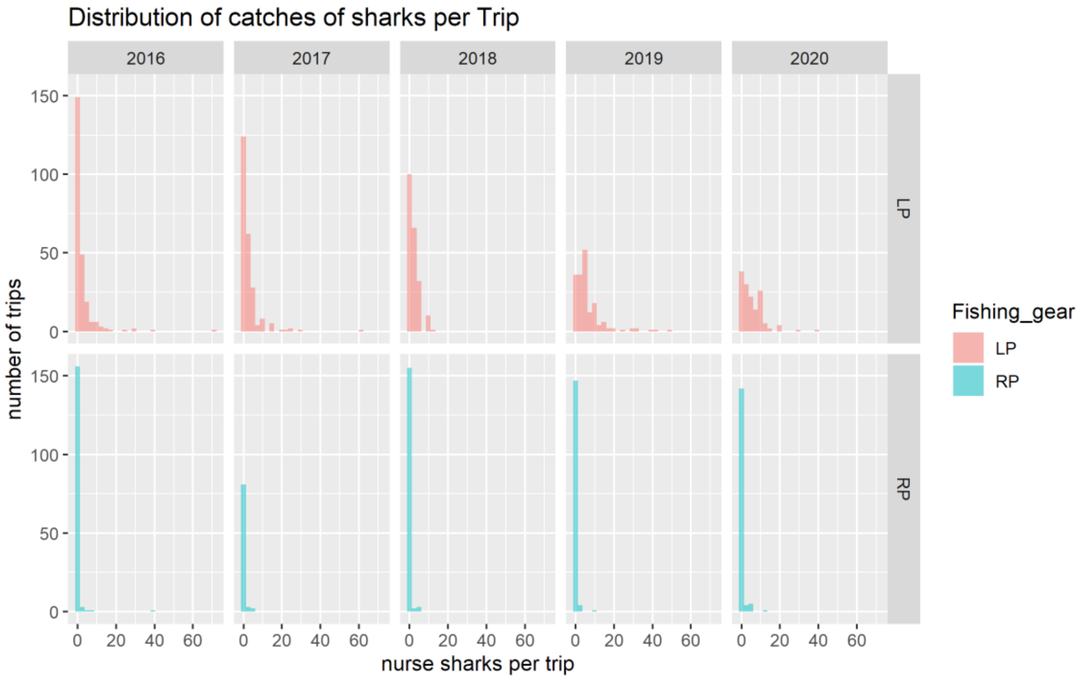


Fig. 3.5.1. *Distribution of the number of nurse shark caught per trip (right) in relation with the type of trap (LP : lobster pots, RP : redfish traps) used per year from the landing survey.*

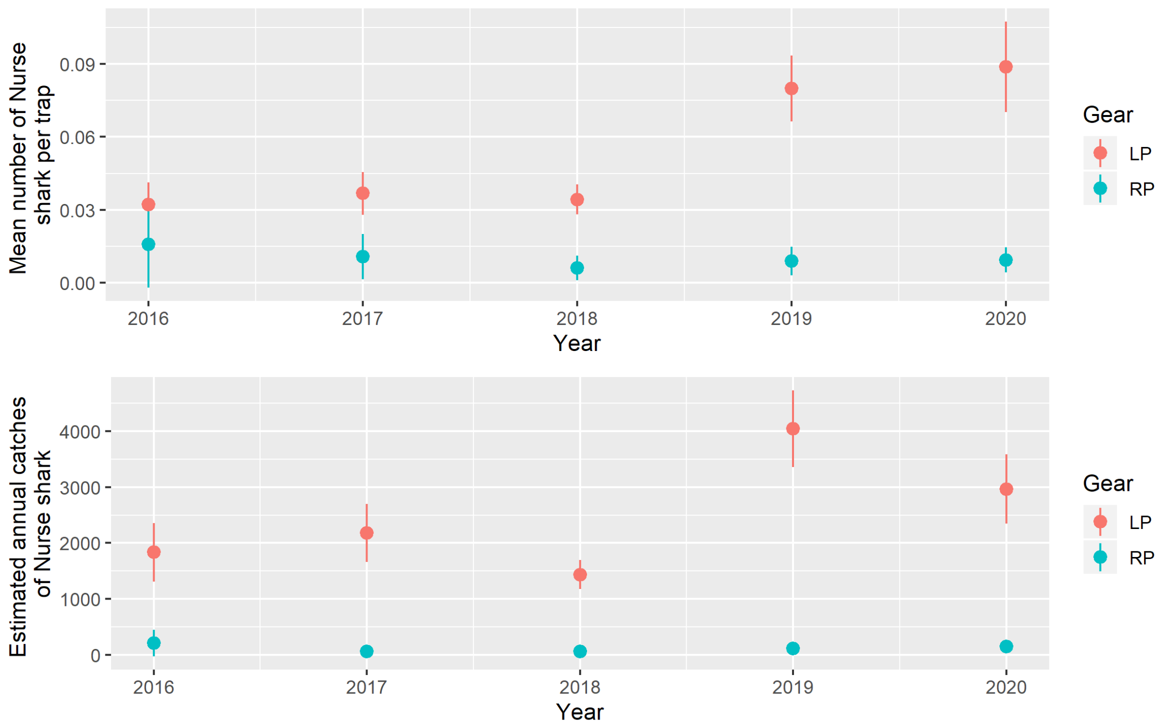


Fig. 3.5.2. Estimates of the mean nurse shark number per trap and total catches per year *(LP : lobster pots, RP : redfish traps)*

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 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. Similarly, in the deep-water redfish traps, lionfish initially increased between 2012 and 2014 and then continuously declined to reach its lowest value in 2020.

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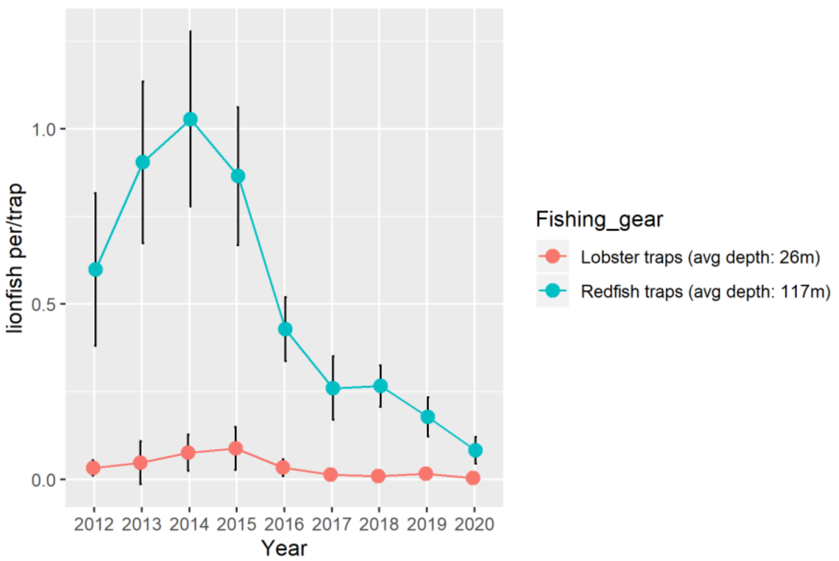

Fig. 3.6.1. *Trend in the abundance (average catch rate) of lionfish in the deep-water redfish traps and shallow-water lobster traps on the Saba Bank. Error bars indicate 95% CI of the yearly average.*

4 Conclusions and recommendations

In this report we assess the current status of the fisheries on the Saba Bank and report on the port-based fisheries monitoring results for the first 10 years of data collection (2011-2020). 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). 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 27 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). After a period of about 5 years there was a gradual recovery in both stocks, recovery now seems stalled and additional measures will be required in order to restore yields of these stocks to MSY levels.

From 2012, effort and yields increased rapidly in both fisheries peaking in 2015 for the lobster fishery and in 2016 for the snapper fishery. This period was followed by a decline largely due to 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 10 year study period (figure 3.1.1). Since then, both fisheries have shown partial recovery in effort but also some tapering off in 2020 due to the impacts of COVID-19 which greatly reduced the market demand for lobster in St. Maarten. Hence, both the recent impacts of a hurricane and the Covid epidemic can be seen to have affected these fisheries.

Based on our abundance index for lobsters, it appears that after dropping from higher levels in 2000 to lower levels in 2011, there has been a progressive increase of the stock size but most recently also a gradual levelling off by 2020. 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 initial recovery of the stock under the current management regime seems to be insufficient to allow recovery to stock levels of 2000 and earlier. This levelling off of recovery is now being accompanied by growing landings of sublegal sized lobsters and also by what our new length-based analyses suggest to be a fishing pressure structurally exceeding the levels corresponding to maximum sustainable yields (especially for the females). Hence, addressing these two issues will be necessary before further stock recovery will be possible. Options for addressing these issues are more fully presented in de Graaf et al. (2017).

In our previous report (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 and a highest level reached around 2000. The lobsters stock should be seen as a regional stock that should be managed based on a regionally coherent management approach (FAO 2015). This is actually 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).

Length-based assessments for the three main reef fish species bycaught in the lobster fishery, namely the Red hind, the Queen triggerfish, and the White grunt, also suggest a fishing pressure at or above the F_{MSY} level. Our recent assessment of measures to protect the Red hind have shown no indication of success within their first five years (Debrot et al. 2020).

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. For all four species the length based indicator of F_{MSY} suggest that for all these species fishing mortality has been consistently subject to overfishing. This new assessment therefore, with the levelling off and recently declining stock biomass and characterised state of overexploitation 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.

This report furthermore presented trends in abundance for two additional species of interest. First, the average CPUE of nurse sharks in lobster pots shows a large increase in the last two years, suggesting an increasing in abundance for this protected species. which essentially would be good news considering that the Saba Bank also forms a key part of the Yarari Marine Mammal and Shark Sanctuary. However, 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 in 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.

Finally, as should be clear from this report, we are only at the beginning of the process of developing the knowledge base needed to understand the various fisheries of the Saba Bank and how they interact with each other and the ecosystem of the Bank. Continued fisheries and ecological research will be essential to address several applied fisheries questions and to develop a time series of fishery monitoring data which are needed to signal opportunities and problems ahead of time. As these, just like other fisheries are affected by many uncontrolled and even unknown factors, to ensure their sustainability, the development of precautionary and adaptive management approaches are highly recommended (de Graaf et al. 2017). A best-practice harvest strategy framework to manage for MSY can best be developed together with stakeholders to form an integrated and implementable management package.

Acknowledgments

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

References

Ault, J.S, S.G. Smith, J.A. Browder, W. Nuttle, E.C. Franklin, J. Luo, G.T. DiNardo, J.A. Bohnsack, 2014. Indicators for assessing the ecological dynamics and sustainability of southern Florida's coral reef and coastal fisheries, Ecological Indicators, 44, 164-172,

Brunel, T., A. Kuramae, J. Odinga and A. O. Debrot. 2018. Update on the 2016-2017 catch trends in the Saba bank fisheries. Wageningen University & Research Wageningen, The Netherlands. Report C083/18. 22 pp.

CARICOM. 2002. Strategic plan for: Caribbean Regional Fisheries Mechanism. Caricom Fisheries Unit. Georgetown, Guyana. 141 pp.

Cavalcante Soares, C.N., 1990. "Reproductive season of the Caribbean spiny lobster Panulirus argus in the coastal waters of northern Brazil," Fishbyte, The WorldFish Center, vol. 8(3), pages 27-28.

Debrot, A. O., Brunel, T., Schop, J., Kuramae, A., & Bakkers, Y. (2020). Assessing effectiveness of the seasonal closure of the Moonfish Bank of the Saba Bank for two species of concern, the Red Hind and the Queen Triggerfish: the first five years. Wageningen Marine Research, Wageningen, The Netherlands. Report C040/20..

Debrot, A. O. and M. de Graaf. 2018. Saba bank fisheries: reasons for cautious optimism. Wageningen Marine Research Policy Brief, Wageningen, The Netherlands. 26 February, 2018. 5 pp.

Debrot, A.O., R.J.G.H. Henkens, P.J.F.M. Verweij. 2018 (eds.). Staat van de natuur van Caribisch Nederland 2017. Wageningen Marine Research Wageningen, The Netherlands. Report C086/17: 214 pp.

Debrot, D. (A.O.), and S. van der Burg. 2019. Food from the Oceans. Factsheet 3. Nexus interventions for small tropical islands: case study Bonaire. 9 pp. In: Slijkerman, D. and M. van der Geest. 2019. (eds.). Nexus interventions for small tropical islands: case study Bonaire. Wageningen, The Netherlands. WUR letter report 1900369.JA-ih. 85 pp.

Dilrosun, F. 2000. Monitoring the Saba Bank Fishery. Environmental Section Department of Public Health and Environmental Hygiene, Curacao, Netherlands Antilles.

FAO. 2015. Report of the first meeting of the OSPESCA/WECAFC/CRFM/CFMC Working Group on Caribbean Spiny Lobster, Panama City, Panama, 21–23 October 2014. FAO Fisheries and Aquaculture Report. No. 1095, Bridgetown, Barbados. 112 pp.

Graaf, M. de, Brunel, T. Nagelkerke, L. and A.O. Debrot. 2017. Status and trends Saba Bank fisheries: 2015. Wageningen Marine Research, Wageningen, The Netherlands, Report C077/17. 127 pp.

ICES. 2018. ICES reference points for stocks in categories 3 and 4. ICES Technical Guidelines. 13 February 2018. http://www.ices.dk/sites/pub/Publication%20Reports/Guidelines %20and%20 Policies/16.04.03.02_Category_3-4_Reference_Points.pdf

Leocádio AM & R Cruz. 2008. Growth parameters of the spiny lobster (Panulirus argus) in the great Caribbean: a review. Revista de Investigaciones Marinas 29(3): 239-248.

Lotz, L.A.P., A.O. Debrot, F. Neijenhuis, C. Stanghellini en R.E.E. Jongschaap. 2020. Ontwikkelingsmogelijkheden voor de agrarische sector in Caribisch Nederland. Wageningen Plant Research, Wageningen, The Netherlands, Repport WPR-1026. 44 pp.

Meesters, E. H., H. Nijkamp, L. Bijvoet 1996. Towards sustainable management of the Saba Bank. A report for the Department of Public Health and Environment (VOMIL), Curacao, Netherlands Antilles. AIDEnvironment, Amsterdam, The Netherlands. 58 pp.

Meesters, H.W.G. D.M.E. Slijkerman, M. de Graaf, A.O. Debrot, 2010. Management plan for the natural resources of the EEZ of the Dutch Caribbean. 81 pp.

Stamatopoulos C (2002) Sample-based fishery surveys: a technical handbook. FAO Fisheries Technical Paper. No. 425. Rome, FAO. Pp. 132.

Toller W., Debrot, A.O., Vermeij, M.J.A., Hoetjes, P.C. 2010. Reef Fishes of Saba Bank, Netherlands Antilles: Assemblage Structure across a Gradient of Habitat Types. PLoS ONE 5(5): e9207. doi:10.1371/journal.pone.0009207

Toller, W., Lundvall, S. 2008. Assessment of the commercial fishery of Saba Bank. Saba Conservation Foundation, 47pp.

Justification

Report C062/21
Project Number: 4318100256

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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With knowledge, independent scientific research and advice, **Wageningen Marine Research** substantially contributes to more sustainable and more careful management, use and protection of natural riches in marine, coastal and freshwater areas.

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