seed madagascar

sustainable environment, education & development

A Report for

PROJECT ORATSIMBA

Participatory Monitoring Programme: Analysis of 2021 and 2022 Data

May 2023

Contents

1 Introduction and Methods

1.1 Summary

Since its beginning in 2013, Project Oratsimba has been working with small-scale lobster fishing communities along the Anosy coast, southeast Madagascar, to promote community-based fisheries management. Utilising the Locally Managed Marine Area (LMMA) model, this has included supporting the establishment and training of fisheries management committees, community outreach and awareness-raising, and the establishment of two LMMAs, each with a community-designated No-Take Zone (NTZ). Amongst the monitoring measures implemented in the project was the establishment of landings effort and catch composition data collection, carried out by community members in three coastal villages: Sainte Luce and Elodrato, where Project Oratsimba focuses its efforts, and Itapera, a fishing village south of Sainte Luce that currently lacks an LMMA or NTZ.

This data collection has been ongoing for eight years in Sainte Luce (from 2015, inclusive) and five years in Elodrato and Itapera (from 2018, inclusive). The following report presents the results from the 2021 and 2022 data sets, highlighting key results that may be useful for fisheries management committees in making decisions about the fishery.

These data should also be viewed in the wider context of project data for long-term trends and insights into how the lobster fisheries have changed throughout the project's lifetime.

1.2 Methods

The methodology is described in detail in (Long, 2017b) and consists of two survey types: 'Landings/Effort Survey' and 'Catch Composition Survey.' A total of 1,479 surveys (634 Catch Composition; 845 Landings/Effort) were conducted across the two years. A breakdown of survey occasions can be found in Table 1.

The sites presented here are Sainte Luce (Main Manafiafy), Elodrato, and Itapera. Data collection did not occur at the 'Sainte Luce Lodge' site on the recommendation of Long (2018).

Notably, the 2021 season was the last year that data collection was conducted on paper, as in 2022 the data collection team transitioned to mobile data collection. While the software Open Data Kit (ODK) was previously used from March 2022 through to September 2022, in November 2022 a switch was made to Kobo Toolbox, due to greater ease of access and fewer software issues. One slight difference in data collection methods between both software, is that when using Kobo data collectors will choose to complete one survey for the day, either Landings/Effort *or* Catch Composition. Whereas on ODK, data collectors would often do both surveys on the same day, measuring lobsters from the same boats they surveyed for Landings/Effort. Nonetheless, the data have been analysed utilising the same methods and are consistent with past data collection scope and effort.

Table 1: Breakdown of survey occasions (number of days each survey was conducted) by type, landing site, and year for the participatory lobster fishing monitoring programme, southeast Madagascar.

Landing Site	Year	Catch Composition Survey Occasions	Landings/Effort Survey Occasions
Elodrato	2021	147	170
	2022	36	82
Itapera	2021	168	168
	2022	115	141
Sainte Luce	2021	133	164
	2022	35	120
All	2021	448	502
	2022	186	343

2 Results

2.1 Catch Composition

12,728 individual lobsters were measured during the 2021 season (Table 2). After removing errors (e.g., recorded measurements that were erroneous / outside of feasible biological limits for lobster size), 12,724 lobsters were included in catch-composition specific analysis, of which 2,355 lobsters were measured in Elodrato, 5,984 in Itapera, and 4,386 in Sainte Luce (Main Manafiafy).

5,302 individual lobsters were measured during the 2022 season. After removing errors, 5,237 lobsters were included in catch-composition specific analysis, of which 1,106 lobsters were measured in Elodrato, 3,231 in Itapera, and 900 in Sainte Luce (Main Manafiafy).

Table 2: Breakdown of lobsters sampled during the catch composition survey in 2021 and 2022 by landing site, year, and month for the participatory lobster fishing monitoring programme, southeast Madagascar. Note that these numbers reflect all records, before errors were removed.

Landing site	Year	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total records
Elodrato	2021	252	236	145	196	354	243	275	312	345	2,358
	2022	525	0	280	22	166	21	27	37	33	1,111
Itapera	2021	1,232	869	782	700	541	343	396	643	478	5,984
	2022	730	580	380	528	269	428	351	20	0	3,286
Sainte Luce	2021	260	236	420	765	836	698	496	387	288	4,386
	2022	414	291	5	0	32	0	25	96	42	905
All	2021	1,744	1,341	1,347	1,661	1,731	1,284	1,167	1,342	1,111	12,728
	2022	1,669	871	665	550	467	449	403	153	75	5,302

2.1.1 Species Composition

Surveys recorded lobster length (mm) and weight (kg). When plotted against each other, length and weight appeared to display an exponential rather than linear relationship in both 2021 and 2022 (Figure 1a & 1b).

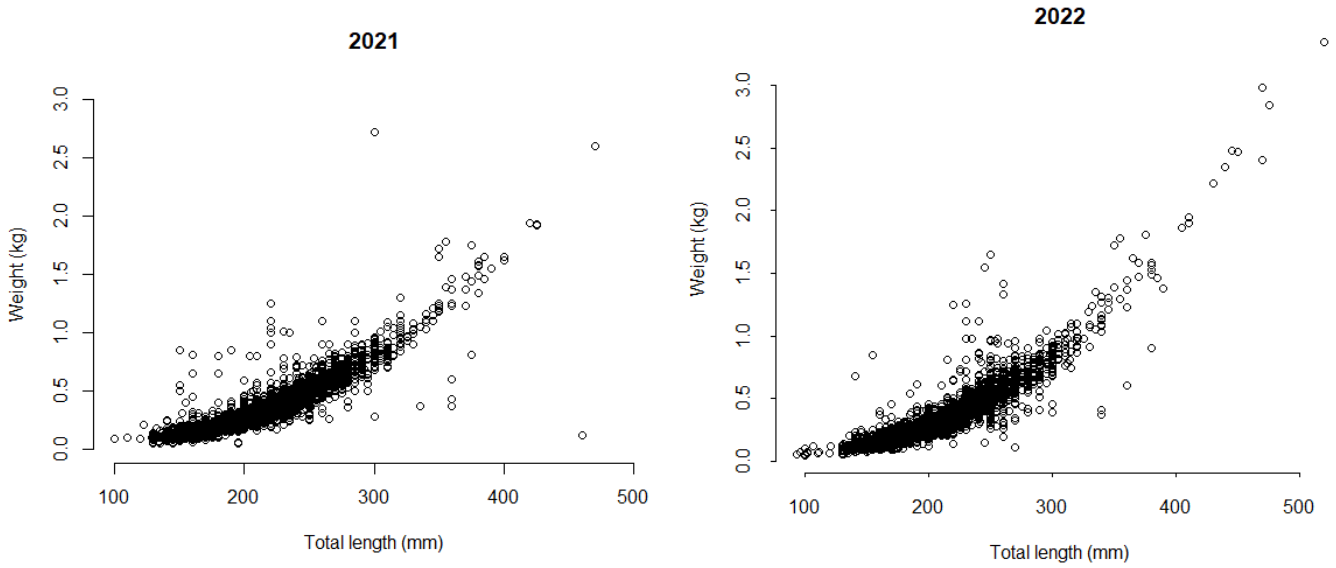

Figure 1a and 1b: Scatterplot of individual lobster length (mm) vs. individual lobster weight (kg) across all landing sites and species for a) 2021, n = 12,724, and b) 2022, n = 5,237.

The species of each lobster was also recorded, with up to eight different species identified at each landing site. The majority of lobsters were *P. longipes* and *P. homarus,* both spiny lobsters, while additional species of both spiny and slipper lobsters were also found. The species composition of catch is shown by landing site (Figure 2a & 2b).

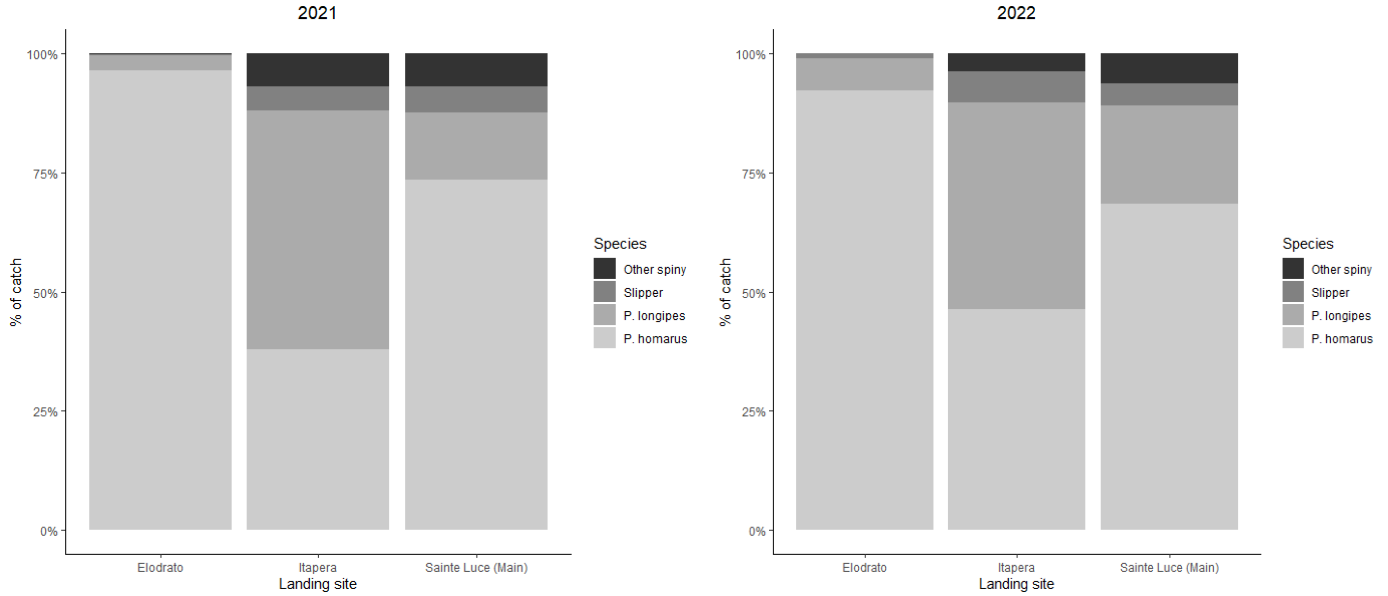

Figure 2a and 2b: a) Variation in species composition of catch (n=12,724) at three landing sites in 2021. Landing sites were Elodrato (n = 2,335), Itapera (n=5,984), and Sainte Luce (n=4,386). b) Variation in species composition of catch (n= 5,237) at three landing sites in 2022. Landing sites were Elodrato (n=1,106), Itapera (n=3,231) and Sainte Luce (n=900). Catch composition disaggregated into: slipper lobster species (S. squammosus, P. antarticus and A. regalis); other spiny lobster species (P. ornatus, P. penicillatus, and P. versicolor); P. longipes; and P. homarus. *Provisional identification.*

2.1.2 Size Classes

The size class composition of all lobsters sampled is shown (Figure 3a & 3b). During 2021, 39.7% of catch was below the nationally mandated Minimum Landing Size (MLS) of 200mm, while in 2022 that percentage was slightly lower at 38.8%. However, both values are likely to represent an underestimate, as it is known that data collectors were not able to consistently sample lobsters <160mm due to fishers often hiding or keeping lobsters under MLS.

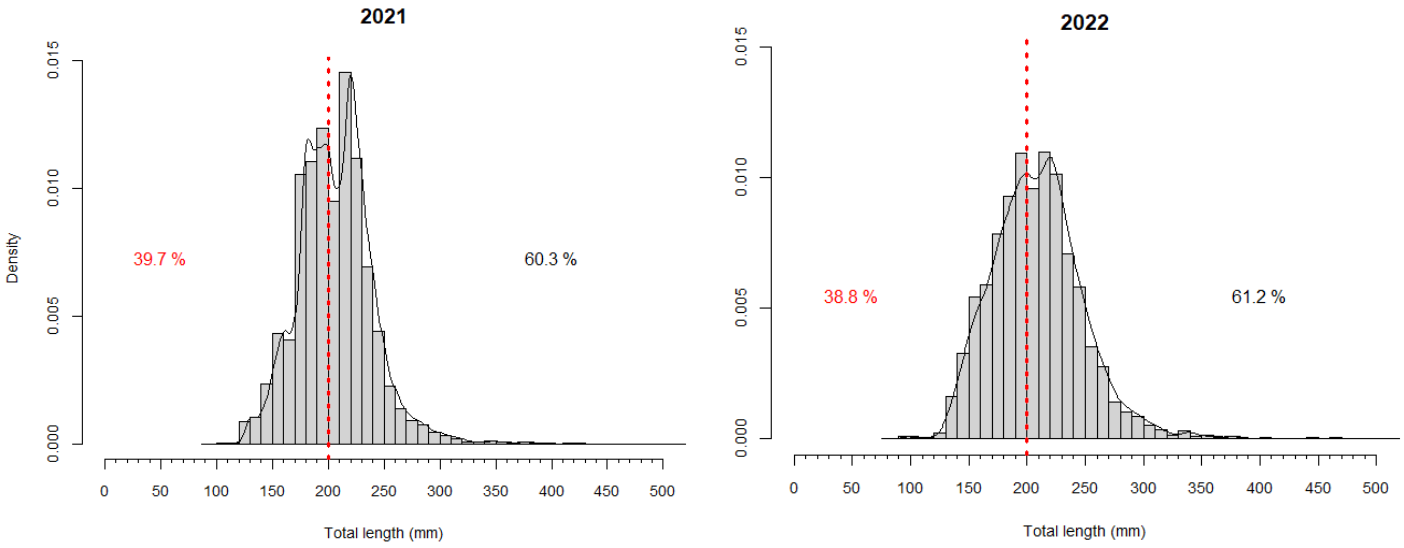

Figure 3a and 3b: a) Histogram of total length of lobsters of all species sampled from catch (n=12,724) in 2021. b) Histogram of total length of lobsters of all species sampled from catch (n=5,237) in 2022. Bin widths are 10mm, the MLS (200 mm) is shown

(thick dashed red line), kernel density estimate (bandwidth = 10) is drawn (solid black line). The percentage of undersized lobsters <200mm MLS (red text) and percentage >=200mm (black text) is shown.

When broken down by landing site (Table 3), there is a difference in the percentage of undersized lobsters present in the catch (Figure 4a & 4b). In both 2021 and 2022, most lobsters measured in Elodrato were under MLS, at 66.6% and 64.4%, respectively. Sainte Luce consistently had the lowest percentage of lobsters under MLS, at 30.6% and 38.8%, while Itapera remained below the overall percentage, with catch under MLS not breaking 35.9%.

Table 3: Percentage of undersized lobsters (<200mm MLS) from each landing site, by year and overall.

	Landing Site			
Year	Elodrato	Itapera	Sainte Luce	Overall
2021	66.6%	35.9%	30.6%	39.7%
2022	64.4%	33.2%	27.4%	38.8%

The size of lobster for the two most common species (*P. homarus* and *P. longipes*) does appear to differ slightly between communities, particularly for *P. homarus* (Figure 5a & 5b). Note these data have been truncated at 160mm because smaller lobsters were inconsistently sampled. Thus, this is approximately representative of the size distribution among the proportion of catch bought by lobster collectors, who generally do not purchase the smallest lobsters.

Taking average annual individual lobster weights and lengths across all sites, years 2021 and 2022 were within 10% of the 2018-2020 average. That said, average lobster sizes in 2021 were the lowest of any year since 2018, only 200mm and 0.28kg. In 2022 both lobster weights and lengths recovered to normal levels, averaging 210mm in length and 0.34kg in weight.

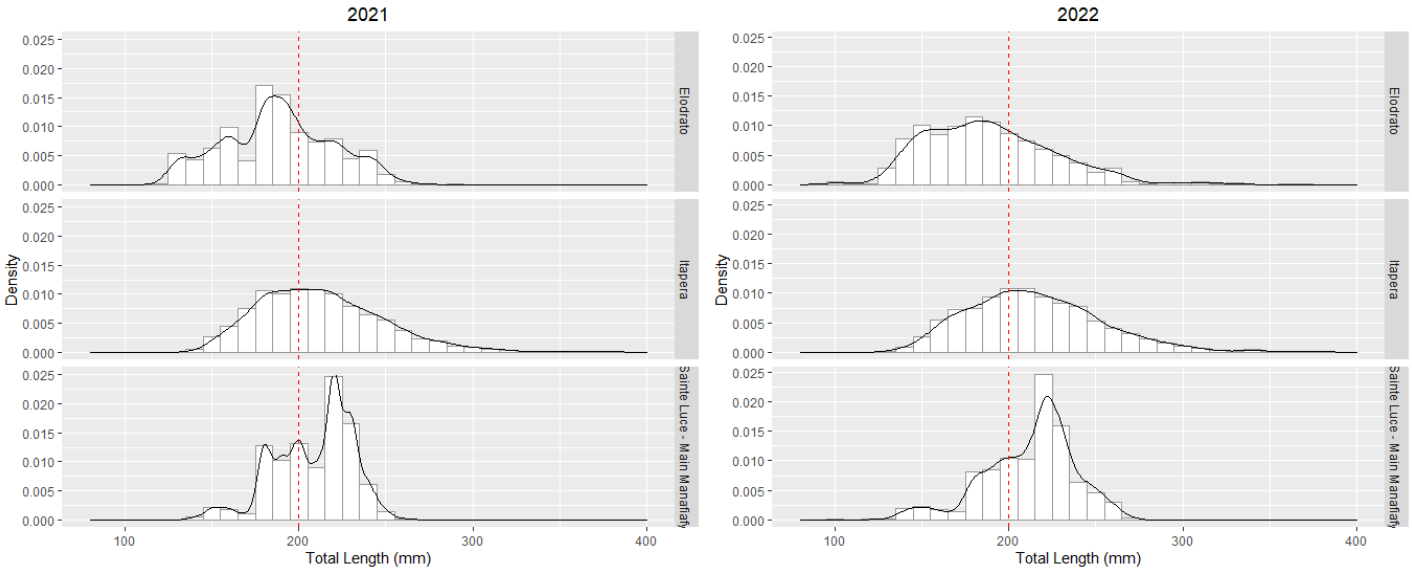

Figure 4a and 4b: a) Histogram of total length of lobsters (mm) by community in 2021 ($n_{Elodrato}$=2,355, $n_{Itapera}$=5,984, $n_{Sainte\ Luce}$=4,386). b) Histogram of total length of lobsters (mm) by community in 2022 ($n_{Elodrato}$=1,106, $n_{Itapera}$=3,231, $n_{Sainte\ Luce}$ = 900). Bin widths are 10mm, the MLS of 200 mm (red dashed line) is shown, kernel density estimate is drawn (solid black lines).

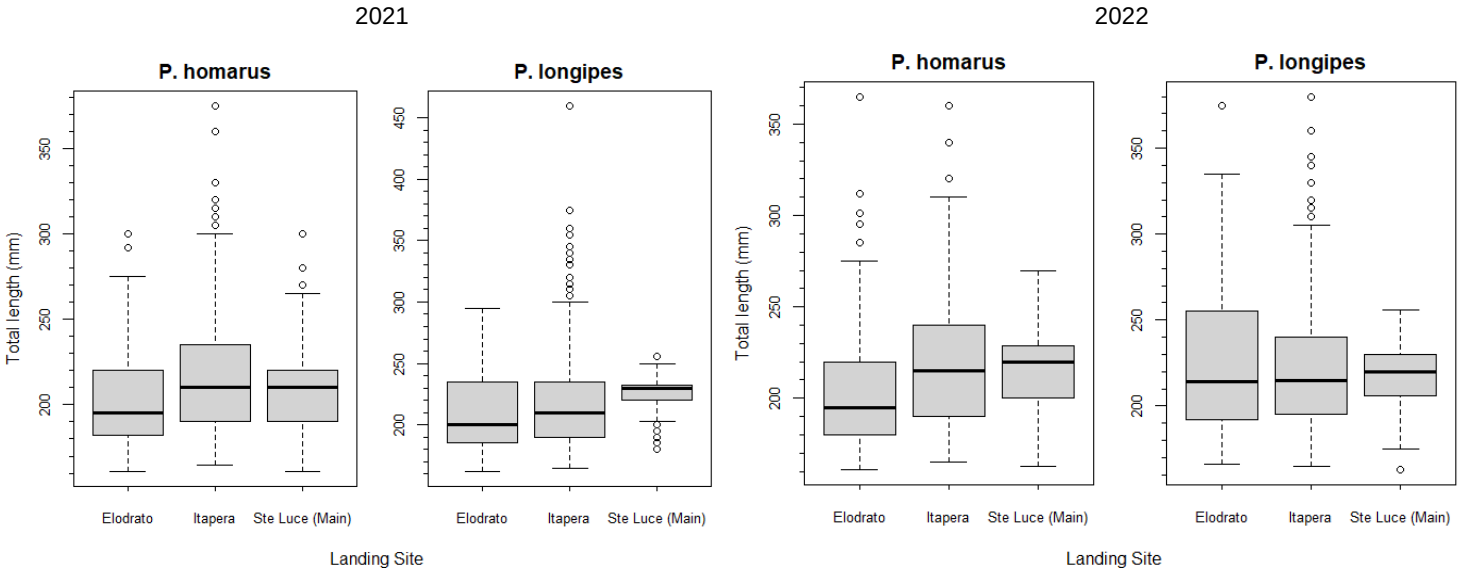

Figure 5a and 5b: a) Boxplot of total length of P. homarus (n=6,983) and P. longipes (n=3,579) in 2021, disaggregated by landing site. b) Boxplot of total length of P. homarus (n=2,675) and P. longipes (n=1,587) in 2022, disaggregated by landing site. As lobsters <160mm were inconsistently sampled, the above employs only >160mm. Outliers are drawn (open circles). Please note the different y-axis for P. longipes in 2021.

2.1.3 Seasonal Variation in Reproduction

The proportion of females in each catch carrying eggs (also known as berried) is shown for *P. homarus* and *P. longipes* (Figure 6a & 6b). These species were chosen as they account for the majority of catch in the fishery (Figure 2a & 2b). There were 5,573 female lobsters recorded in 2021 (43.8% of total lobsters), of which 5,084 were either *P. homarus* or *P. longipes*. In 2022, a similar proportion of lobsters recorded were female at 43.3% (2,270 female lobsters recorded), of which 2,072 were either *P. homarus* or *P. longipes*. A greater proportion of females of both species were berried later in the season, with *P. longipes* displaying the highest proportion of berried females in November and December. Trends were less clear in 2022, though again for *P. longipes* a greater proportion of females were berried towards the end of the calendar year.

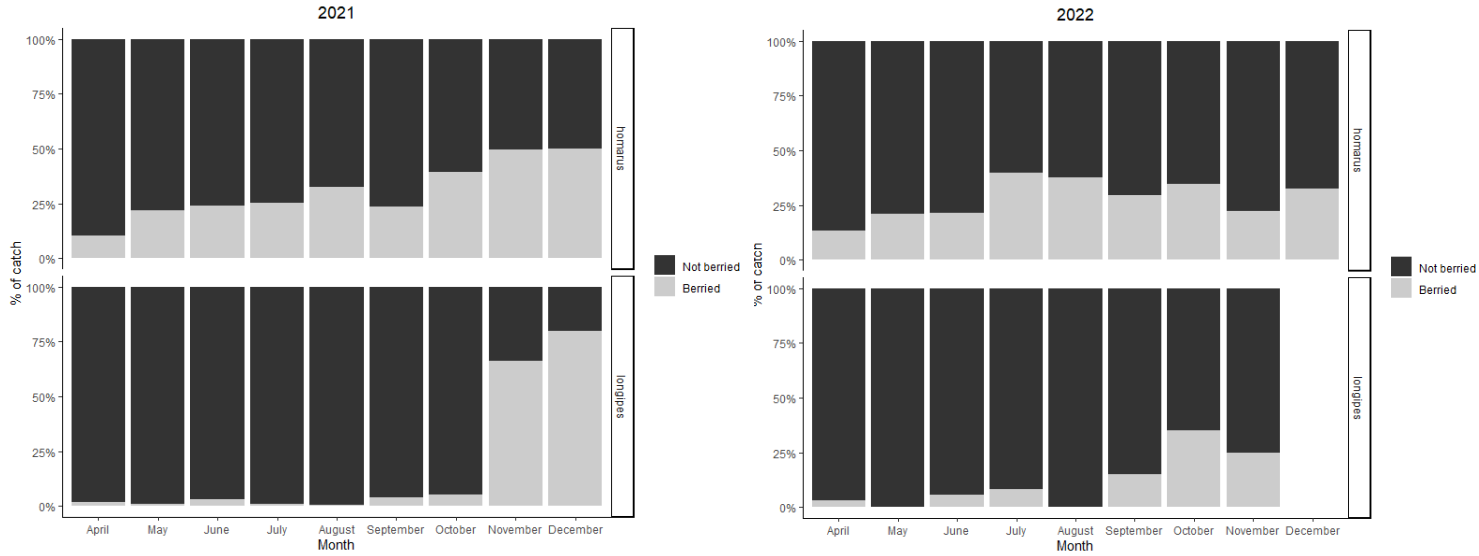

Figure 6a and 6b: Variation in the proportion of berried female lobster by month. a) Showing the proportion of female lobsters in 2021, P. homarus (n=3,493) and P. longipes (n=1,591) which were berried by month. b) Showing the proportion of female lobsters in 2022, P. homarus (n=1,373) and P. longipes (n=699) which were berried by month. Data from all landings sites.

2.2 Landings/Effort

845 total Landings/Effort surveys were completed across 2021 (n=502) and 2022 (n=343), with 11,799 total records (i.e., 11,799 individual pirogues sampled from all survey occasions) (Table 4).

Table 4: Breakdown of pirogues sampled during the Landings/Effort survey in 2021 and 2022 by landing site, year, and month for the participatory lobster fishing monitoring programme, southeast Madagascar.

Landing site	Year	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total records
Elodrato	2021	189	191	110	190	263	163	184	247	233	1,770
	2022	138	0	129	67	304	159	118	85	44	1,044
Itapera	2021	192	176	196	206	216	158	141	212	172	1,669
	2022	127	131	89	130	94	138	107	138	91	1,045
Sainte Luce	2021	200	409	333	573	552	447	394	361	121	3,390
	2022	423	445	282	374	542	349	246	147	73	2,881
All	2021	581	776	639	969	1,031	768	719	820	526	6,829
	2022	688	576	500	571	940	646	471	370	208	4,970

2.2.1 Fishing Effort

The mean numbers of pirogues in each community, as determined by the Landings/Effort survey, provides a high-level indicator of fishing effort at each landing site (Table 5). Sainte Luce is the largest fishing community in terms of pirogues, followed by Itapera with just under half the number of pirogues, and then by Elodrato which has the fewest by a significant margin. In all three communities, there was an increase in mean number of pirogues from 2021 to 2022.

Table 5: Mean number of pirogues (standard deviation) operating at each landing site, based on the combined active and inactive pirogues counted on each sampling occasion in 2021 and 2022.

	Landing Site		
Year	Elodrato	Itapera	Sainte Luce
2021	21.2 (2.6)	44.0 (1.9)	105.6 (7.9)
2022	25.7 (6.6)	45.7 (1.6)	115.0 (1.6)

2.2.2 Catch per Unit Effort

Pot fishing

Catch per unit effort (CPUE) for boats deploying pots is measured in the lobsters boatday^{-1}. This is standardized to the mean number of pots used in the given landing site for the given year (Table 6). In 2021, this was standardized to 31.26 pots for Sainte Luce (sd=8.88, n=3,390) and to 18.27 (sd=3.24, n=1,770) in Elodrato. In 2022, for Sainte Luce this was standardized to 38.13 pots (sd=7.95, n=2,881) and in Elodrato to 29.07 pots (sd = 4.86, n=1,044). It is important to note that data are not available on landings for Elodrato during the month of May 2022, as the data collection device was not functional.

Due to the position that the data collector is stationed in Itapera, data are not collected from pirogues that do not catch lobsters (even if they have deployed gear). Therefore, data from Itapera are not directly comparable to the other landing sites, as data is rarely collected when catch=0.

Table 6: Mean number of pots (standard deviation) checked per boat in each landing site, by year in both Elodrato and Sainte Luce.

	Landing Site	
Year	Elodrato	Sainte Luce
2021	18.27 (3.24)	31.26 (8.88)
2022	29.07 (4.84)	38.13 (7.95)

CPUE for pot fishing differed between Elodrato and Sainte Luce, and also varied by month and year (Figure 7a & 7b; Figure 8a & 8b). In both 2021 and 2022, the median CPUE in Sainte Luce was higher than in Elodrato (Table 7). Additionally, for both communities, there was an increase in CPUE from 2021 to 2022.

Table 7: Median catch-per unit effort (CPUE) at the Elodrato and Sainte Luce landing sites in 2021 and 2022, reported in both lobsters boatday^{-1} and kg boatday $^{-1}$.

Landing Site	Year	Lobsters boatday^{-1}	kg boatday^{-1}
Elodrato	2021	1.14	0.34
	2022	5.19	1.24
Sainte Luce	2021	6.25	1.94
	2022	8.09	2.21

In 2022, for both Elodrato and Sainte Luce, there appeared to be a gradual decrease in CPUE after the lobster season opening, followed by a spike in CPUE in the first month following the NTZ opening. This was especially pronounced in Elodrato in 2022, where CPUE in August was much higher than all other months, including the opening month of April. This trend was not apparent in 2021, however, when CPUE in Elodrato stayed roughly consistent throughout the year. While in Sainte Luce, CPUE for 2021 showed a steady decline from the fishery opening until the season's end.

Sainte Luce

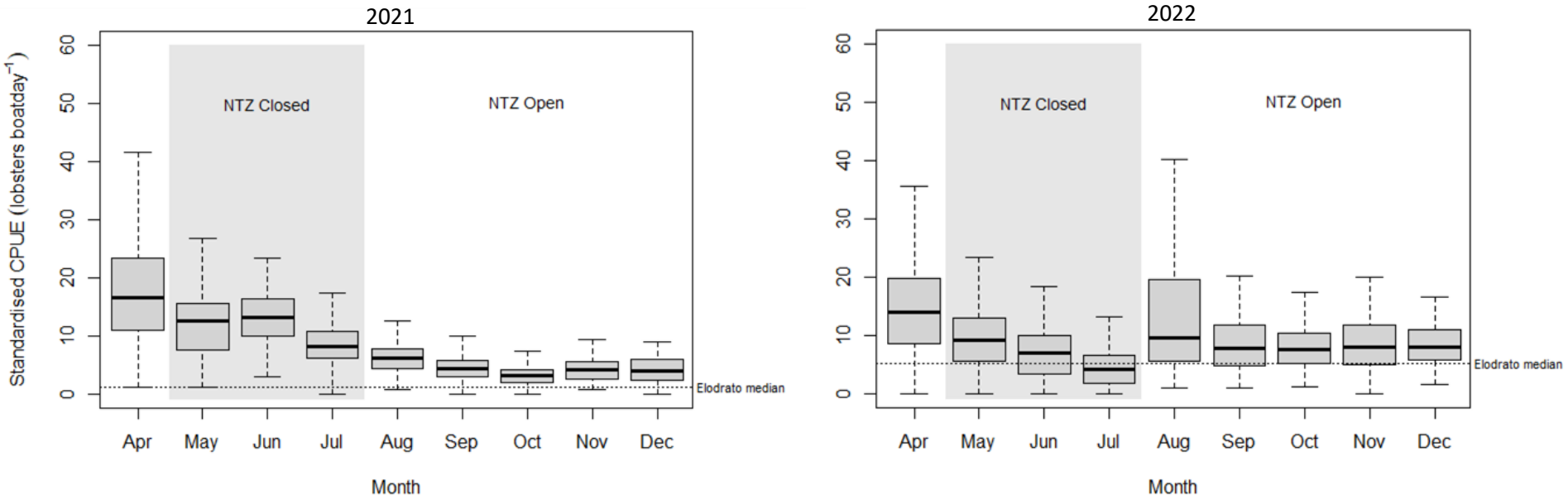

Figure 7a and 7b: Box-whisker plot showing standardised CPUE (lobsters boatday^{-1}) in Sainte Luce by month in both 2021 and 2022. Periods of NTZ closure (grey boxes) and opening (white boxes) are indicated.

a) CPUE was sampled (n=3,390) from Main Manafiafy landing site and standardized to the mean number of pots (mean=31.26 pots, sd=8.88, n=3,390) used in 2021. A reference line (dotted) shows the median CPUE in Elodrato in 2021 (1.14 lobsters boatday^{-1}). Outliers are not drawn.

b) CPUE was sampled (n = 2,881) from the Main Manafiafy landing site and standardised to the mean number of pots (mean =38.13 pots, sd=7.95, n=2,881) used in 2022. A reference line (dotted) shows the median CPUE in Elodrato in 2022 (5.19 lobsters boatday^{-1}). Outliers are not drawn.

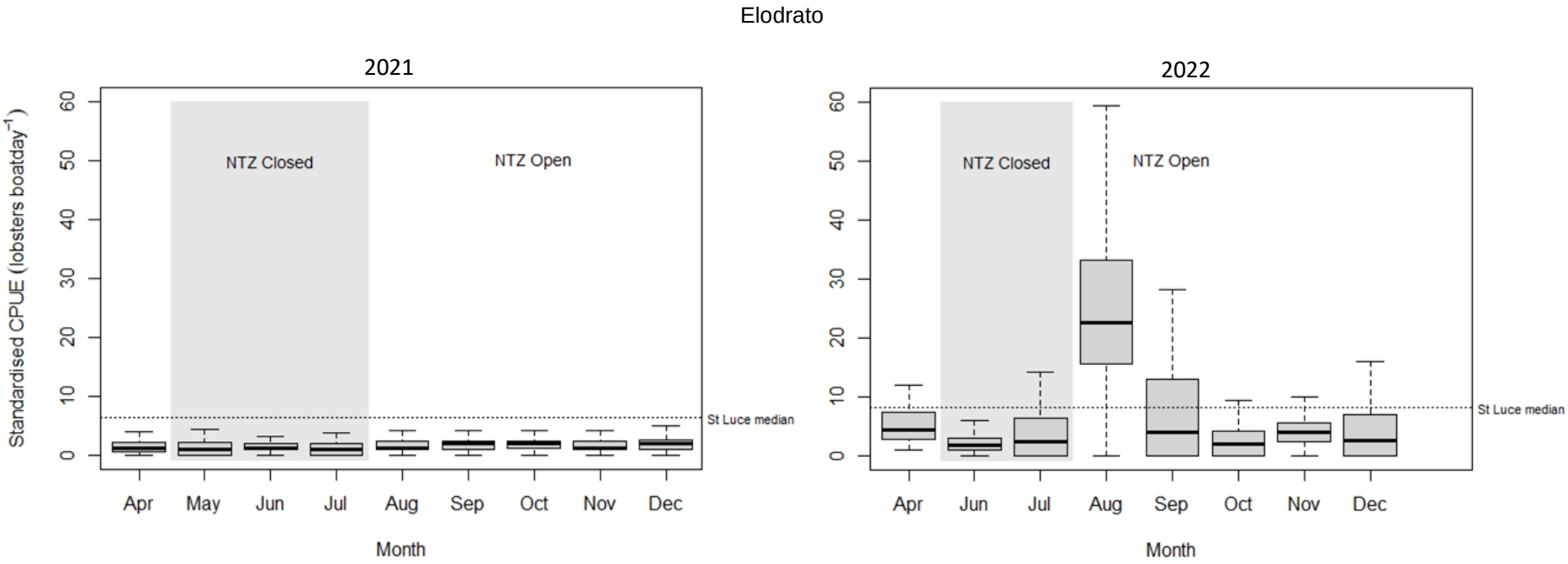

Figure 8a and 8b: Box-whisker plot showing standardised CPUE (lobsters boatday^{-1}) in Elodrato by month in both 2021 and 2022. Periods of NTZ closure (grey boxes) and opening (white boxes) are indicated.

a) CPUE was sampled (n=1,770) from the Elodrato landing site and standardized to the mean number of pots (mean=18.27 pots, sd = 3.24, n=1,770) used in 2021. A reference line (dotted) shows the median CPUE in Sainte Luce in 2021 (6.25 lobsters boatday^{-1}). Outliers are not drawn.

b) CPUE was sampled (n=1,044) from the Elodrato landing site and standardised to the mean number of pots (mean=29.07 pots, sd = 4.86, n=1,044) used in 2022. Please note that the month of May is not shown as data are not available, though May did fall within the NTZ closure. A reference line (dotted) shows the median CPUE in Sainte Luce in 2022 (8.09 lobsters boatday^{-1}). Outliers are not drawn.

Comparison of CPUE Between Communities

A general comparison of CPUE was also made between all three communities--in Itapera, multiple gear types are employed (pots, snorkels, and ground nets) and occasions where boats return with zero catch are not captured. Therefore, only a broad comparison between the three communities can be drawn. To do this, only occasions where lobsters were caught are compared (Figure 9a & 9b). Note this gives an inflated sense of CPUE as it excludes all those occasions where nothing was caught. To accommodate multiple gear types, the CPUE unit is measured as the total weight of lobsters caught per boat day.

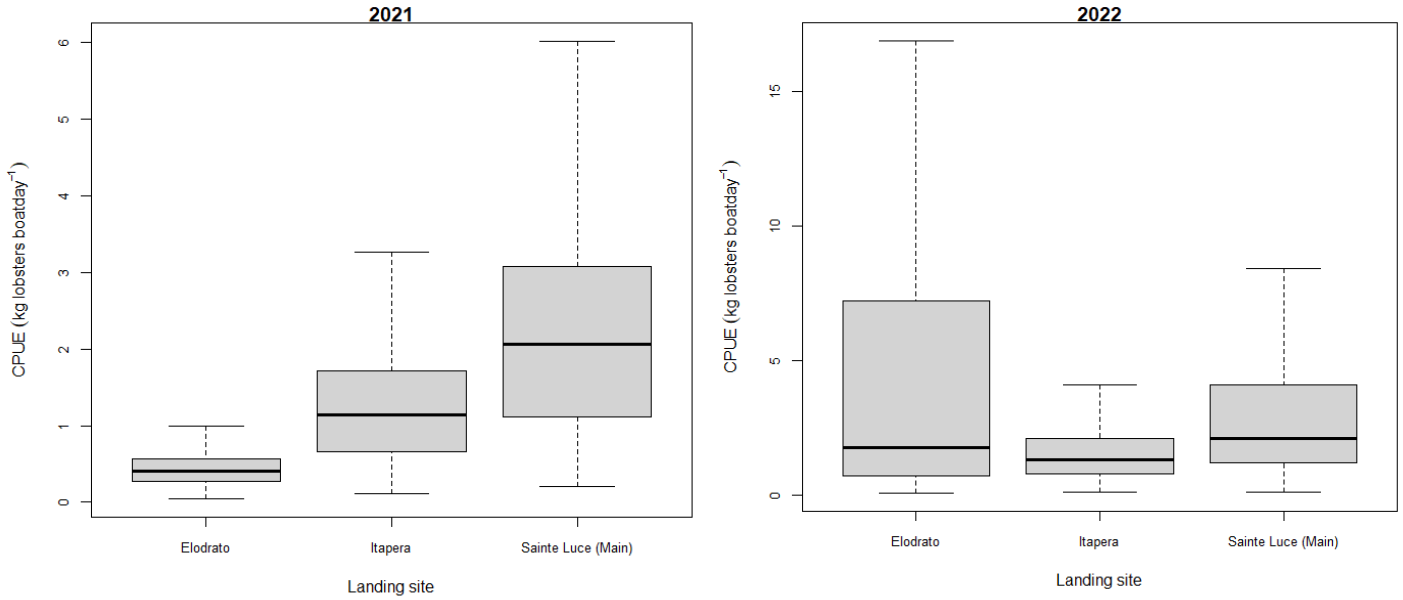

Figure 9a and 9b: Box-whisker plot showing CPUE (lobster weight(kg) boatday^{-1}) in three landing sites in a) 2021 and b) 2022, on successful fishing trips (data excludes occasions with zero catch). Outliers are not drawn. Please note the different y-axis values between the figures.

Utilising this method, the average CPUE per community varied between 0.41 and 2.10 kg boatday^{-1}, although it is important to note that these values are inflated, as they exclude days when no lobster were caught (Table 8). Consistent with prior findings, CPUE was highest in Sainte Luce, followed by Itapera and Elodrato, though again a direct comparison can't be made as zero-catch days may lower CPUE significantly if included.

Table 8: Median CPUE by year and landing site, using kg boatday^{-1}. CPUE values are inflated, as occasions where no lobster were caught are excluded in order to include Itapera.

	Landing Site		
Year	Elodrato	Itapera	Sainte Luce
2021	0.41	1.14	2.06
2022	1.78	1.32	2.10

Comparison of CPUE between NTZ Closures and Openings

CPUE was also compared between periods of NTZ closures and openings in both Sainte Luce, where the NTZ has been operational since 2015, and Elodrato, where 2021 was the first year of NTZ closure. Both number of lobsters and total weight of catch were used in calculations, with CPUE standardized to the mean number of pots used in each community in the corresponding year (Table 9). Sainte Luce consistently had higher CPUE values overall when compared to Elodrato. Within each community, different trends emerged when CPUE was disaggregated by NTZ openings and closures.

Table 9: CPUE by NTZ status for both Sainte Luce and Elodrato, reported in both lobsters boatday^{-1} and kg boatday^{-1}, by year.

Landing Site	Year	CPUE while NTZ closed		CPUE while NTZ open		Overall CPUE	
		Lobsters boatday^{-1}	Kg boatday^{-1}	Lobsters boatday^{-1}	Kg boatday^{-1}	Lobsters boatday^{-1}	Kg boatday^{-1}
Elodrato	2021	1.07	0.30 kg	1.22	0.36 kg	1.14	0.34 kg
	2022	1.85	0.57 kg	7.26	1.92 kg	5.19	1.24 kg
Sainte Luce	2021	10.42	3.05 kg	4.69	1.40 kg	6.25	1.94 kg
	2022	6.51	2.09 kg	9.24	2.29 kg	8.09	2.21 kg

In Elodrato in 2022, there was a marked difference between closures and openings. The median during NTZ closures (0.57 kg lobsters boatday^{-1}) was nearly three times lower than the CPUE by weight during NTZ openings at 1.92 kg lobsters boatday^{-1}, and a much larger spread existed between the first and third quartiles. This result held when looking at 2022 CPUE in Elodrato in terms of number of lobsters boatday^{-1}, with 7.26 median lobsters boatday^{-1} during NTZ openings and 1.85 median lobsters boatday^{-1} during NTZ closures (Figure 11a & 11b), in line with results seen in Figure 8b (prior section). In 2021, there did not appear to be a notable difference in CPUE between NTZ openings and closures, with only a very slight increase seen during NTZ openings.

In Sainte Luce in 2022, the median CPUE (by weight) did not differ hugely between NTZ openings and closures, with a median of 2.09 kg lobsters boatday^{-1} during NTZ closures, and a median of 2.29 kg lobsters boatday^{-1} during NTZ openings. There was a larger difference when viewing CPUE in terms of lobsters boatday^{-1}, with a higher CPUE of 9.24 lobsters boatday^{-1} recorded during NTZ openings (Figure 12a & 12b).

In 2021, this trend was the opposite, with median CPUE (lobsters boatday^{-1}) being higher during the NTZ closures in Sainte Luce, at 10.42 lobsters boatday^{-1} versus 4.69 lobsters boatday^{-1}.

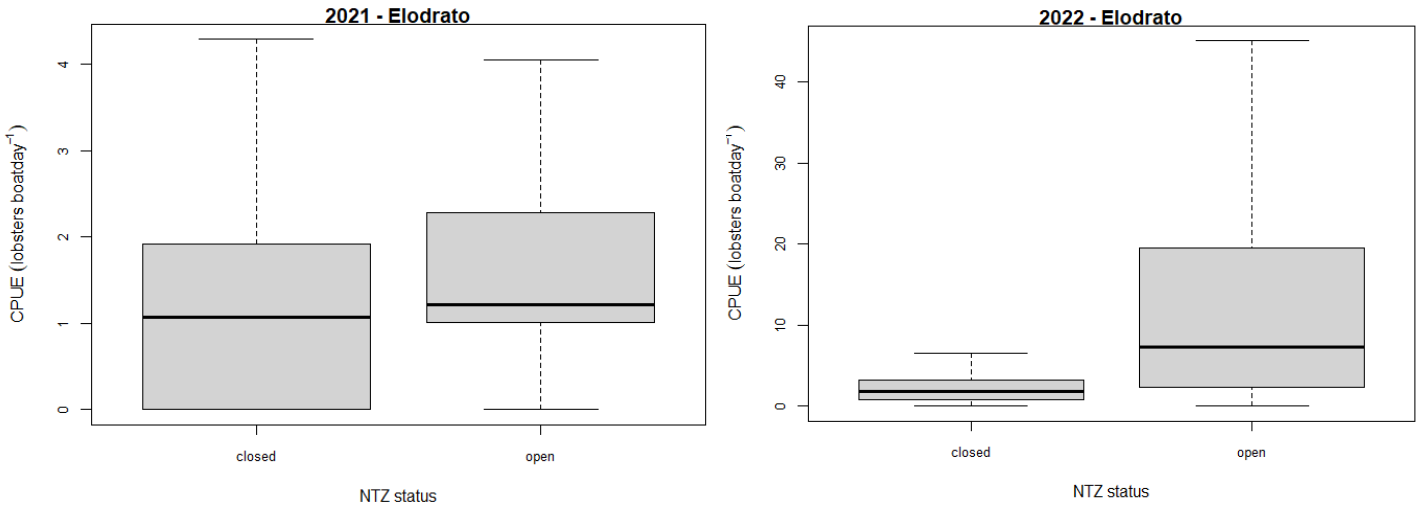

Figure 11a and 11b: Box-whisker plots showing Elodrato CPUE (number of lobsters boatday^{-1}) in 2021 and 2022 based on the status of the NTZ (closed or open). For both 2021 and 2022, the Elodrato NTZ was closed from May 1 to July 31, inclusive, and open for all other months of the lobster fishing season. Please note the different y axis scales for each figure.

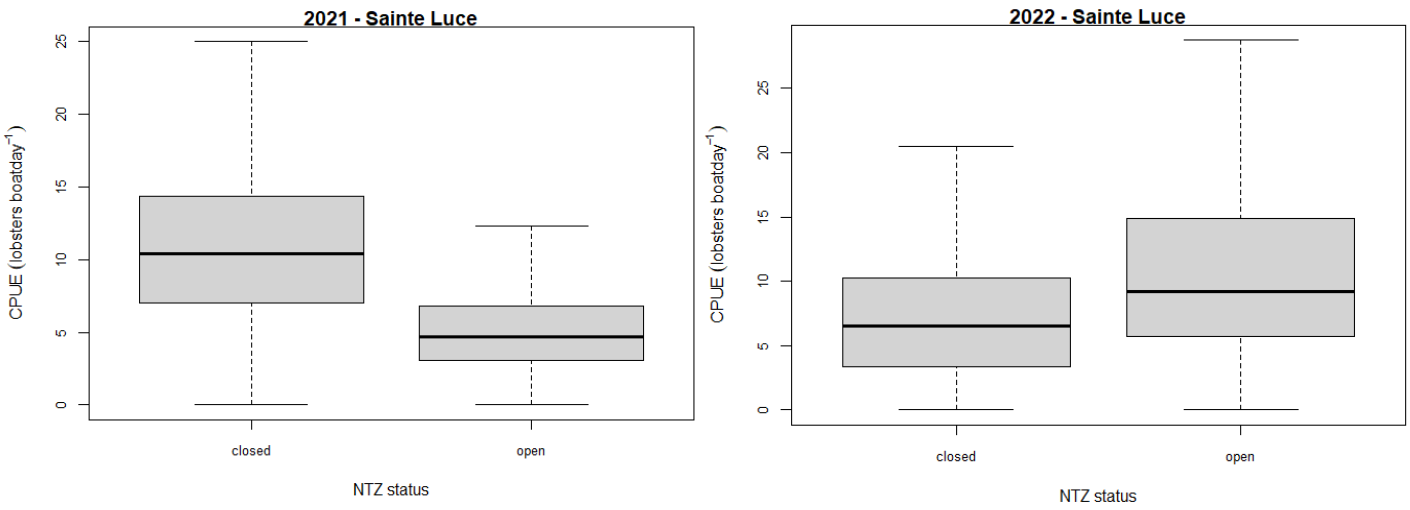

Figure 12a and 12b: Box-whisker plots showing Sainte Luce CPUE (number of lobsters boatday^{-1}) in 2021 and 2022 based on the status of the NTZ (closed or open). For both 2021 and 2022, the Sainte Luce NTZ was closed from May 1 to July 31, inclusive, and open for all other months of the fishing season.

2.2.3 Price at First Point of Sale

Comparisons of point-of-sale prices for lobster show relatively stable market prices for the majority of the year around the median 20,000 MGA kg^{-1} at each landing site, though greater variability was seen in 2022 (Figure 13a & 13b). Prices by month remained consistent April to November, with increases to around 22,000-23,000 MGA kg^{-1} towards the end of the year.

Fishers in Sainte Luce experienced the greatest range of sale prices, in 2021, selling at between a minimum 15,000 MGA kg^{-1} and maximum 25,000 MGA kg^{-1}. Average prices were more consistent in 2022 between 20,000 MGA kg^{-1} to 22,300 MGA kg^{-1}. In contrast Elodrato exhibited little variation from the 20,000 MGA kg^{-1} sale price in either year. Sainte Luce and Itapera had highest relative increase in average prices in 2022 compared to 2021. Itapera in particular saw a large comparative increase over this period, receiving the highest prices of any site in 2022.

Importantly prices showed low elasticity in response to the NTZ and national opening periods. There was little to no price suppression in August or April months in response to increases in lobster supply. Price data for months April to June were missing in 2021 for several landing sites, however data availability is much more comprehensive in 2022.

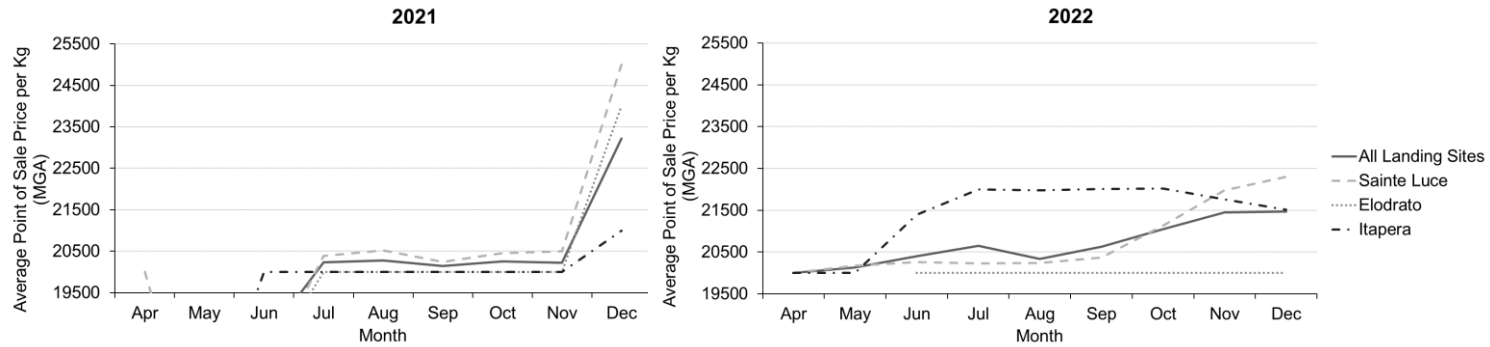

Figure 13a and 13b: Line plots showing monthly average lobster prices at point of sale (MGA kg^{-1}) in 2021 (a) and 2022 (b) at Sainte Luce, Elodrato, Itapera, and the average across All Landing Sites.

2.2.4 Fisher Income

Average daily fisher income was calculated by month assuming four fishers per pirogue (Figure 14a & 14b). Income is highly seasonal and closely linked to the local NTZ opening and national opening periods. In line with CPUE results, the NTZ had a greater influence on fisher incomes in 2022 rather than 2021, with much higher incomes across all sites in 2022. In 2021 incomes were very low at all sites and fluctuated around an annual average of 7,824 MGA. In 2021, fishers received their highest average incomes in April of 15,373 MGA and July of 9,103 MGA. In contrast, in 2022, fishers received an average daily income of 13,069 MGA and experienced two peak income months in April and August. These followed the opening of the national lobster fishing season in April when fishers received 22,188 MGA, and the opening of the local NTZ in August when they received their highest average daily income of 32,445 MGA.

Between sites, in 2021 average incomes were highest in Sainte Luce, reaching a maximum of 19,121 MGA in April, whereas in 2022 incomes were highest in Elodrato, reaching a maximum of 51,739 MGA in August. After these peak months, income then declines in all sites towards the end of the year. Upticks in daily income in November and December align with short-term increases in point-of-sale prices in these months which may mitigate the gradual decreases in income.

It is important to note that a high level of unpredictability in the quantity of daily catches between pirogues means that incomes vary a large amount on a day-to-day basis even in the same landing sites. In some cases, fishers may receive over 250,000 MGA in a single day during the peak season, while on others they will return with no catch at all.

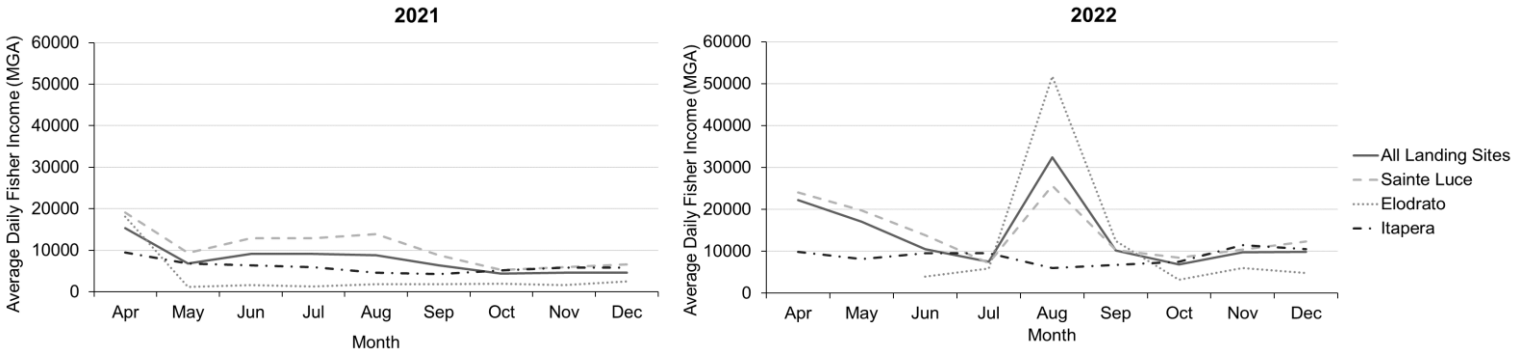

Figure 14a and 14b: Line plots showing daily average fisher income per month (MGA) in 2021 (a) and 2022 (b) at Sainte Luce, Elodrato, Itapera, and the average across All Landing Sites.

3 Discussion

Both Catch Composition and Landings/Effort data revealed important insights about the regional lobster fishery, with implications for conservation and livelihood goals. This report can be viewed alongside the 2018-2020 report in order to draw comparisons across years.

3.1 Catch Composition

Widely, many of the catch composition results were consistent between both 2021 and 2022, and with past years. **Species composition** for each community was generally similar to that shown in data from 2018-2020, with Elodrato, Itapera, and Sainte Luce all remaining consistent in their species compositions over the five-year period.

Findings regarding **MLS** were also important in that they indicated that a high number of undersized lobsters are regularly landed in each community. This is particularly true for Elodrato, where the majority of lobsters are below MLS, exhibiting a low level of compliance with this regulation. This is also consistent with past years, in that Elodrato has exhibited rates between 59.5% (2020) and 66.6% (2021) for all of 2018-2022. While the proportion of undersized lobsters, and therefore the rate of noncompliance, was significantly lower in Itapera and Sainte Luce, landing undersized lobsters still appears to be a regular practice. Promisingly, the proportion of undersized lobsters in Sainte Luce in particular seems to be declining, reducing from 51.1% in 2018 to 30.6% in 2021 and 27.4% in 2022. According to these findings, 2022 had the lowest rates ever of noncompliance with MLS in Sainte Luce. It is worth discussing with data collectors and fishers why this might be, and if fishers are changing their practices, or if other factors could be at play. Nonetheless, it is important to note that because lobsters <160mm are not regularly sampled, the proportions of lobsters below MLS in each community are likely higher in reality.

Importantly, and consistent with past findings, it appeared that **lobster length and weight** did not have a linear relationship, but instead weight grows disproportionately with increases in length. This is important information for the fishery in that lobsters are worth significantly more when they are bigger, as collectors pay based on weight. In this regard, it would be advantageous to put small lobsters back in the sea, with the knowledge that returns will be much greater if lobsters are caught and sold when they are larger, and therefore weigh much more.

Additionally, though the **total lengths** of the two most common species, *P. homarus* and *P. longipes* did not appear to vary significantly between 2021 and 2022 or between landing sites, it could be worth comparing these lengths to historical data to uncover whether lobster sizes remain consistent, or whether certain size classes are becoming rarer due to overfishing. For example, in a previous report focused on 2018 records, the average sizes of lobsters landed of these two species appears to be over 200mm in most cases. While in recent years the averages are closer to, and sometimes under, 200mm.

Seasonal variation in reproduction revealed that for both *P. homarus* and *P. longipes*, the later months of the calendar year (~September onwards) seem to contain a larger proportion of **berried females**. Particularly in 2021, over 50% of females landed of both species were berried in November and December, signalling that these months may have heightened importance for lobster reproduction. This is consistent with past reports and anecdotal data, in that November through February / March are peak reproductive months, the latter of which are protected by the national closed season for lobster fishing. Additionally, these findings reveal a high level of non-compliance with returning berried females to the sea.

Overall, catch composition data reveal consistent challenges with compliance with both **MLS** and **returning berried females**. Within the wider socioeconomic context, this is unsurprising as fishers cannot often afford to return marketable catch and must earn enough money to support their basic household needs. Nonetheless, some of the findings herein can help fishers create management measures that both support their livelihoods and ensure future

income and prosperity. This includes planning NTZ closures for key periods in the lobster reproductive cycle, and working jointly to ensure that smaller lobsters are returned to the sea for greater benefits in successive years.

3.2 Landings/Effort

Landings/Effort surveys provided key insight into the lobster fishery as a whole and may indicate positive results for management measures across Elodrato and Sainte Luce.

Importantly, **effort** was shown to have increased from 2021 to 2022. When compared to data from 2018-2020, this increase becomes even greater. For example, whereas the **mean number of pirogues** in Itapera ranged between 30.9 and 36.4 from 2018-2020, this number raised to 44.0 in 2021 and 45.7 in 2022. Similarly, the mean number of pirogues in Sainte Luce raised from 100.0 in 2018 to 115.0 in 2022. Interestingly, the mean number of pirogues in Elodrato decreased, with the highest value being at 35.7 in 2018, as compared to 21.2 and 25.7 in 2021 and 2022, respectively.

The **mean number of pots** deployed also increased dramatically in Sainte Luce, going from 23.0 in 2018 to 31.3 in 2021 and 38.1 in 2022. This was also the case in Elodrato, specifically for 2022, when the mean number of pots deployed was 29.1 as compared to the 2018-2020 high of 25.0.

These increases in effort could have important consequences for the fishery, depending on how sustainable fishing is, and how many boats and pots the lobster population is able to support. It will be important to uncover the driving forces behind this increased effort and ensure that if new fishers are entering the fishery, they have access both to the knowledge of fisheries management committees, and an awareness of the local *dinas*. As no legal barriers currently exist to entering the fishery, management committees may wish to continually monitor this increase in pirogues and pots, as uninhibited increases could lead to overexploitation and stock decline.

Interestingly, findings surrounding **CPUE** support the notion that fishing *is* sustainable within Sainte Luce and Elodrato (data are not available to the same extent in Itapera). CPUE, both in terms of number of lobsters boatday^{-1} and the total weight (kg) of lobsters boatday^{-1} went up in both communities from 2021 to 2022. The increase in Elodrato was dramatic at nearly five times the CPUE (1.14 lobsters boatday^{-1} as compared to 5.19 lobsters boatday^{-1}), while Sainte Luce had the highest CPUE overall at 8.09 lobsters boatday^{-1} in 2022. This difference is even more remarkable when looking at data from 2018-2020, where the overall medians for both Sainte Luce and Elodrato were between 2.0-3.3 lobsters boatday^{-1}.

This increase was also true when looking at catch weight across all three landing sites, with CPUE (kg boatday^{-1}) from Elodrato, Itapera, and Sainte Luce all increasing from 2021 to 2022. The **community comparison** also revealed that CPUE is typically highest in Sainte Luce, followed by Itapera and then Elodrato. This would also track with findings that a higher proportion of lobsters tend to be undersized in Elodrato in particular.

It will be important to examine whether the average lobster size is changing when interpreting these results. For example, if CPUE in terms of *number of lobsters* increases, but CPUE in terms of *total weight of catch* does not increase proportionally, it could be that fishers are catching many *small* lobsters. This is not necessarily beneficial in terms of income or the ultimate longevity of the fishery, as it will prevent lobsters from reaching reproductive size or mean more lobster are completing fewer reproductive cycles before being caught.

When viewing CPUE contextualized within **NTZ openings and closures**, more important findings emerge. In August 2022, the first month following the NTZ opening, both Sainte Luce and Elodrato experienced spikes in CPUE. This was especially prominent in Elodrato, where CPUE exceeded CPUE at the opening of the fishing season. Consistent with past reports, this can likely be attributed to fishers regaining access to highly productive areas of the fishing grounds and concentrating their efforts within the NTZ for a period of time. These findings should be discussed and contextualized with fishers in order to understand the specifics of how the NTZ benefits CPUE and income, and

whether there is room for even greater improvement. It will also be important to uncover how beneficial the NTZ closures are for lobster growth and recovery, and what duration of closure can be most beneficial for lobster stocks, and therefore fishers. In line with this, it will also be interesting to discuss with fishers the relative lack of benefits from the NTZ in 2021, when CPUE did not appear to change much with the NTZ opening and was in fact lower in Sainte Luce than during closures. With the NTZ being a flagship management measure of many LMMAs in Madagascar, it will be important to uncover how to maximise this tool's benefits to both marine environments and fisher livelihoods.

Assessments of **average daily fisher incomes** show high monthly variability and a lack of sustainable income streams at certain times of the year, primarily during the lean season. During the national closed period (Jan – Mar) and towards the end of the year is when livelihood support is most needed. Greater engagement with fishers and communities on financial management has scope to enable fishers to sustain the benefits of the NTZ opening and national openings over the longer term. Incomes peak in April and August and then experience rapid declines over the following months as the catch is exploited. Fortunately, low price elasticity in response to seasonal fluctuations in lobster supply suggests that the livelihood benefits of the NTZ are being directly captured by the fishers, especially in 2022, rather than further up the value chain. However, this only works when the NTZ is well enforced and understood by the local community. In 2021 the impact of the NTZ on both CPUE and daily fisher income was far less significant.

Lobster prices remain stable over most of the year with minor increases in November and December. This aligns with more dangerous fishing conditions and reducing supply as the lobster population declines. Inequality of pirogue ownership in different communities remains a significant barrier to competitive market access among fishers. In the overwhelming majority of cases, fishers borrow pirogues from the same operators that they are then obligated to sell their catch to. This results in suppressed market prices and a lack of competition among buyers. Elodrato in 2022 provided a strong example of collective bargaining where all fishers in the community agreed, prior to the opening of the lobster season, to sell at a set 20,000 MGA kg^{-1} minimum. This meant that sale prices were stable during the most productive fishing periods and subsequently resulted in the highest average fisher incomes in 2022 compared to Sainte Luce and Itapera. Value chain details also vary between landing sites with international buyers only purchasing lobster in Sainte Luce. For fishers in Elodrato this means that all landed catch for export must be transported by foot to Sainte Luce over several hours.

Overall, while effort has been increasing across all three landing sites so too has CPUE. These findings potentially indicate positive results for fisheries management in Sainte Luce and Elodrato and a sign of sustainability, though contextualized within general increases also seen in Itapera.

4 Conclusion

Findings from the catch composition survey revealed that species composition, lobster sizes, and reproductive status have remained consistent across 2021-2022, and with prior data collection years. These results can also provide insights into lobster demographics, useful to fisheries management committees, ministries, and fisheries scientists interested in the Anosy region lobster fishery. Importantly, Landings/Effort surveys revealed both increases in effort *and* in CPUE; a positive result for fishers and the sustainability of the fishery. However, these results need to be contextualized in conversation with fishers themselves, including the Fisheries Management Committees of Elodrato and Sainte Luce, to fully understand the observed changes and what factors may have led to them. While correlation cannot be directly drawn between management measures and increases in CPUE, these initial results can be used as positive motivation to promote locally-led management. Similarly, the stronger effect of the NTZ opening on catch, CPUE, and much higher increases in average fisher incomes in 2022, suggest positive livelihood outcomes from these interventions. Importantly, though compliance with national regulations was low, it is necessary to consider the socioeconomic context of the fishery and the ability of fishers to comply with top-down management measures. Overall, these results can be used, in combination with local fisher knowledge, to inform community-implemented management measures and identify both challenges and context-specific solutions to continually improve the sustainability of the lobster fishery.

5 Acknowledgements

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