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## SC11 – DW12
## Cook Islands Exploratory Potting Fishery (2019-2023)

*Cook Islands*

11$^{th}$ Meeting of the Scientific Committee
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# Cook Islands exploratory lobster trap fishing in the SPRFMO - 2019-2023


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# Contents

# Executive Summary

The exploratory trap fishing provided for by Conservation Management Measure (CMM) CMM14b-2023 has successfully completed seven trips between 2019 and 2023. New biological information has been collected on lobsters (*Jasus caveorum*) and crabs (*Chaceon* sp.) The key findings are that initially the fishery caught primarily lobsters but when targeting sets below 350m the catch is dominated by crabs. For both lobsters and crabs most of the catch is made up of males (84% and 92% respectively), and that most females were not carrying eggs (in berry). This analysis provided information on population trends and the stock response to fishing and information on bycatch including bycatch of Vulnerable Marine Ecosystem (VME) indicator taxa .

The Cook Islands will continue to analyse all data collected as some material is yet to be processed. In addition, to maximise the value of future data collection for both the Cook Islands and the fishing company, we need to gain an understanding of the distribution, dynamics and status of stocks of *Jasus caveorum* and *Chaceon* sp.

The following recommendations are made:

1. Collect additional length and maturity samples from the Northern Seamounts.
2. Collect genetic samples from the Northern Seamounts and the Foundation Seamount Chain to evaluate the stock links between seamounts.
3. Provide extra training for observers in identifying crab maturity.
4. It is recommended that larger mesh sizes be tested to reduce the lobster catch overall and reduce the impact on females.
5. It is recommended that the current closed season be maintained.
6. It is recommended that the Kopernik seamount remain closed for 2023 to trap fishing (<350m) targeting lobsters.

# Purpose of paper

This paper provides SC-11 with an update on exploratory fishing for lobster and crab by the Cook Islands pursuant to CMM14b-2020. It also briefs the the 11th meeting of the Scientific Committee (SC11) on future directions of this operation and associated research and potential management arrangements.

# 1 Introduction

In 2018 the Cook Islands submitted a proposal to the South Pacific Regional Fisheries Management Organization (SPRFMO) Scientific Committee's $6^{th}$ meeting (SC-06), to carry out an exploratory research programme. The intent was to undertake trap fishing for the purpose of obtaining scientific information while targeting lobster (*Jasus caveorum* and *Projasus* sp.) and crabs (*Chaceon* sp.). The traps are set on a longline within the SPRFMO Conservation Area (Figure 1). This work aims to assess the potential for a long-term fishery in the Convention Area. The proposal was based on a precautionary ecosystems approach mandated by the SPRFMO, and has been extended to 2024. The proposal sought to comply with the application requirements of SPRFMO Conservation and Management Measure (CMM) 13-2016, 03-2018 and SPRFMO's Bottom Fishery Impact Assessment Standard (BFIAS). This exploration has resulted in a number of analyses being undertaken and should be read in conjunction with Brouwer et al. (2019); MMR (2020); Brouwer and Wichman (2020); and Brouwer et al. (2020a).

The SPRFMO Compliance and Technical Committee and Commission considered the proposal in 2023 and approved an extension to 2024 noting a hiatus in the fishery due to the COVID-19 pandemic and a change in the operator and vessel.

The fishery design work is ongoing and seven trips have been conducted by a Cook Islands vessel between March 2019 and March 2023. Preliminary results from these trips are presented in this document and its predecessors (Brouwer et al., 2019 and Brouwer et al., 2020b).

# 2 Methods

Traps were set on a longline. Originally the length of the mainline varied between 77 traps per line to a maximum of 200 per line, but was standardised after trip 2 to 100 traps per line with traps spaced at 25m intervals. A 75kg chain stabilizer and marked buoys were deployed at both ends of the line. Stackable top loading traps were used. The traps were 150cm diameter at the base, 75cm high and 50cm diameter at the top. The entrance to the trap was 35cm in diameter and the trap was covered with netting of 10.2cm mesh (knot to knot 5.1cm). The backbone (ground line) and float line for each string of traps was made of 26mm polypropylene rope. The traps were constructed with 'escape gaps' with 51mm diameter to allow for escapement of the small organisms. To prevent ghost fishing the trap was also fitted with a sewn in cotton string where parts of the traps' nylon mesh was cut and sewn back together with cotton string, so that if lost and not found, the cotton string will eventually degrade and the traps will remain opened. The traps were baited with ground up mackerel placed in bait jars that were attached to the inside of the trap with a snap.

A specially designed camera frame, fitted with an underwater camera was deployed three times during the last trip. The frame was either deployed with or without a mesh net. The footage was retrieved from the camera's memory card and will be used to identify bottom structure, the benthos and potential Vulnerable Marine Ecosystem (VME) areas. This work has yet to be undertaken but will augment the work presented in Brouwer et al. (2020a).

The vessel generally set lines straight after they were hauled. The soak time varied between 24 hours and 48 hours. Initially, the vessel experimented with long soak times of 48 hours and more, but later realised that shorter soak times yielded better lobster catch and tried to haul the lines within 24 hours. This was not always possible as the factory crew could not always process large catch within that time frame or when inclement weather prevented line hauling safely.

The Cook Islands placed two observers on each trip. The observers were instructed to record the weights of the total *J. caveorum*, *Projasus* sp., *Chaceon* sp. and bycatch per trap before retained species were channelled to the factory. The non-retained bycatch was stored in a separate bin and discarded at the end of the line by lowering it to the sea floor in the first trap of the next line set. Some species were retained for further analysis ashore. The observer collected the contents of every tenth trap which equated to approximately 10% of the traps per line being sampled. Biological information for *J. caveorum* and *Chaceon* sp. such as; length, batch weight, sex, maturity stage and shell condition were collected. Bycatch information included length, alive/dead, location on the trap (inside or outside the trap), number and weight per species. Retained biological samples were bagged, tagged and frozen for further analysis ashore.

The crew did not always retain small *Chaceon* sp. These were placed in a crate and periodically discarded overboard on the opposite side of the hauling station, while still alive. This was carried out with permission from both observers.

The data were captured directly into excel forms and a Microsoft Access database. Subsequently data were extracted from the database using the R (R Core Team, 2023) package RODBC (Ripley and Lapsley, 2022) and all analyses were performed in R.

Data were collected by the vessels and observers as part of a predetermined sampling and catch reporting strategy. For each set the vessels recorded the catch by species per set in a logsheet that included, location (start, middle and end of each set), date and time (of set and haul), setting speed, the trap type, target species, depth at start, middle and end of each set as well as recording various environmental parameters. In addition, the observer recorded the weight of catch for each trap and collected biological samples from every $10^{th}$ trap.

The observers were required to measure the first 40 target species (both lobsters and crabs) in every tenth trap (starting with number one). If there were less than 40 in the trap, then the observer simply measured all the individuals. The sample weight per species was recorded but not individual weight. During the size composition sampling, the total weight per trap was recorded by the national observer. Once a minimum of 200 lobsters were measured per line (i.e. 5 traps of 40; or 20 traps of 10 lobsters, if this was all that was caught) the observer stopped measuring lobsters on that line.

The observers sampled an average of 10% of the traps per line for biological information such as length, weight, sex, maturity stage and shell condition for the target species (*J. caveorum* and *Chaceon* sp). Bycatch was sampled for species, length, weight, condition (dead/alive/broken or whole) and location caught on the trap. The observers measured and recorded the presence of eggs (berry) on both lobsters and crabs and the berry state. The vessel recorded the number of berried females returned by set. In addition individual morphometric data were collected.

The observers noted and recorded all the birds observed during hauling and setting operations.

In order to estimate trends in biomass a relatively simple surplus production model was undertaken. The model used the Bayesian state-space Surplus Production Model (SPM) estimation framework JABBA (Just Another Bayesian Biomass Assessment) (Winker et al. (2017)). The model attempts to estimate stock status through Bayesian state-space SPMs by accounting for selectivity-induced distortion of biomass indices using prior information from spawning biomass- and yield-per-recruit models. The intent of these models is not to provide a definitive stock status to rather give an impression of the stock trends.

# 3 Results

The Cook Islands exploratory fishery has undertaken seven trips between April 2019 and March 2023 but no trips were undertaken in 2021 due to the COVID-19 pandemic (Table 1). A total of 603 line hauls have been made and over 55,000 traps have been set. Two different vessels have undertaken fishing but only one vessel per year has fished.

## 3.1 Catch

The catch per trip information shows that the initial catch was high but also shows that the overall the catch has stabilised somewhat (Figure 2). In addition, the data show that when crabs are the intended catch, as per trips 4 and 7, they dominate the catch. Overall, most of the lobster catch as well as the lobster directed effort has come from Kopernick Seamount, with smaller lobster catch coming from Jenner and Darwin A Seamounts (Figure 3). Crab catch and effort is more widely distributed with catch at 15 different seamounts (Figure 4).

## 3.2 Biology

The lobster catch is mostly made up of males which make up 84% of the catch by weight and 49% by number. Similarly, for crabs males make up 92% of the catch by weight and 99% by number (Figure 5). Female lobsters are rarely larger than 120mm carapace length (CL) and most of the catch below 110mm CL are female, while almost all individuals over 140mm CL are male. While few female crabs are caught, most females are below 110mm carapace width (CW).

Figure 6 to Figure 20 show the length distributions by seamount. The trends within the seamounts of the Foundation Seamount Chain (Figure 6 to Figure 19) are all similar with few lobster samples outside of Kopernick Seamount and the crab sex and length distributions are all similar. No lobsters were sampled in the Northern Seamounts and the crab size and sex distribution are somewhat different from those of the Foundation Seamount Chain. The catch in the Northern Seamounts had a higher proportion of females in the catch (Figure 20) and the females were larger than those in the Foundation Seamount Chain.

Female maturity was investigated for both lobsters and crabs. The lobster maturity data show that all females over 100mm CL are mature. The modelled size-at-maturity show that the estimated length-at-50% maturity was 70.5 mm CL and that the trends in the proportion mature are relatively consistent (Figure 21). Crab female maturity information was less definitive with some large crabs being staged as immature, nevertheless the estimated length-at-50% maturity for crabs was 76mm CW (Figure 22).

Lobster and crab shell state data show that, for lobsters, in the first quarter of the year almost all have a new hard shell, in the second quarter most have an old hard shell. While there are no data (due to the closed season) for the second and third quarter, in the last quarter of the year the proportion of old hard shells is declining and new hard shells are becoming more prevalent (Figure 23). Male lobsters shed their shells earlier than females and in the last quarter of the year most have new hard shells. Few lobsters with soft shells were caught. The crab shell data are variable but with a higher proportion of old hard shells towards the end of the year (Figure 24).

While very few female lobsters were sampled above 120mm CL those that were in berry ranged from 70-130mm CL, less than 10% of females sampled were in berry (Figure 25). Lobsters that were in berry were sampled in May and June with a very small number in December (Figure 26). Crabs in berry were found on individuals from 80-140mm CW (Figure 27). Berried crabs were found in increasing numbers as the year progressed and were highest in June and almost none were found in the last quarter (Figure 28).

## 3.3 Morphometric relationships

The lobster length weight relationship shows that both male and female lobsters gain weight exponentially but the medium sized females are slightly heavier at length than the males (Figure 29). The female tail weight is higher than that of the males at length, but due to their larger size males have overall heavier tails (Figure 30). Female lobsters have wider tails than the males (Figure 31).

The length weight relationships for crabs are presented in Figure 32. Crab weight gain is exponential, but there are few female data making the female length weight relationship less reliable.

## 3.4 Stock biomass trends

Catch rate data were evaluated against the trap soak time (Figure 33); depth (Figure 34); swell height (Figure 35); and trap spacing (Figure 36). The impact of these elements on both lobster and crab CPUE were tested within a Generalized Linear Model (GLM) and the data are presented in Table 2. The analyses indicated that for both lobsters and crabs the influence of trap depth, trap spacing and trip were all highly significant.

The overall lobster CPUE at Kopernick Seamount has declined over time and declines within a trip (Figure 37). The modelled CPUE shows a rapid decline at the start followed by a slower but consistent decline after the end of the first trip (Figure 38). The CPUE trends drive the modelled outputs. The JABBA model indicates that fishing mortality on lobsters is high (Figure 39); biomass has declined (Figure 40); and the stock has experienced increased levels of depletion through the time series (Figure 41). Overall the lobster population at Kopernick Seamount could considered to have declined to a point at which more stringent management intervention is required (Figure 42).

The crab population CPUE has fluctuated without trend within and between trips (Figure 43). The crab modelled CPUE is relatively low but is consistent throughout the series (Figure 44); fishing mortality is low (Figure 45) and the overall biomass (Figure 46) and levels of depletion (Figure 47) have changed little through the series. Overall the crab population within SPRFMO could be considered to be lightly fished (Figure 48).

### 3.5 Management options

Management options for trap fisheries include the manipulation of mesh size for the traps. The data presented here indicate that for both lobsters (Figure 49) and crabs (Figure 50) larger mesh size results in the capture of larger individuals.

The seven-day rolling average lobster CPUE like the raw and standardised CPUE indices for lobster show a decline, they also indicate that the CPUE has declined below the 4Kg per trap level (Figure 51) resulting in the need to trigger the requirements of paragraph 10 of CMM14b-2023 (SPRFMO, 2023) which require the closure of fishing for lobsters on Kopernick Seamount.

### 3.6 Bycatch

The bycatch in the trap fishery consists of teleosts, elasmobranchs and non-target crustaceans that are attracted to the bait and enter the trap, as well as invertebrates that are entangled in the mesh and get brought to the surface. Most of the bycatch consists of fish, mostly unidentified cusk eels (ophidiids) and tarakihi (*Nemadactylus macropterus*), as well as crustaceans mostly non-target crabs (Table 3). VME indicator taxa make up a small proportion of the bycatch (Figure 52) and most were from Kopernick and MM seamounts (Table 4). The VME interactions have declined in the most recent trips (Table 5).

## 4 Discussion

### 4.1 Catch

The catch per trip information shows that the initial catch was high but also show that the total catch is now more consistent between trips. In addition, the data show that when crabs are the intended catch they dominate the species composition. These data suggest that crabs can be targeted when that is the intent of the vessel captain.

The ability to target specific species is and important outcome of an exploratory fishery as it would allow for the deliberate capture of specific species. As a result crabs can be targeted by setting the gear deeper while lobsters can be targeted by setting the gear in shallower water. Species specific targeting of marine crustaceans is well documented and widely practised (DiNardo and Moffitt, 2007). This outcome would allow for differential targeting of crabs or lobsters on a single seamount, making the management of species specific catch limits achievable.

### 4.2 Biology

The evaluation of the biological data collected provide important information for this fishery. For both crabs and lobsters the bulk of the catch is made up of mature adult males. Like many other lobster fisheries this leaves the female part of the population relatively unmolested thereby offering some protection to the spawning biomass (Mayfielf et al.,

2005) of these populations. These trends are more pronounced for crabs than lobsters. This information suggests that the fishing impact on the spawning stock is probably lower than that of the overall population impacts. The trends among the Seamounts of the Foundation Seamount Chain are difficult to discern but the collection of more data would elucidate any trends as the fishery progresses. In addition one of the reasons we may have less maturity data for crabs is that, while easy to sex, they are slightly more difficult to examine for maturity, and that may have resulted in more individuals having no maturity state assigned to them compared to lobsters. Some additional observer training for identifying crab maturity may be required. This could have also overestimated the proportion of females in berry as mature females in a berried state are easy to identify.

Currently the lobster fishery is closed fishing during the spawning season from July through to September. Lobsters shed their shell prior to mating and females mate while the shell is in a soft state (MacDiarmid et al., 2013). The analysis of shell state and lobster berry indicate that the closed season is probably set at the right time for lobsters, noting that they are in an old hard shell state in April to June. A small proportion of new shelled lobsters and some in berry suggests that a small amount of spawning occurs prior to the closed season. However, the relativity low number of berried females in November and December suggest that spawning is completed and the eggs are released during the closed season. This suggests that the closed season is well placed and should remain in force for lobsters.

## 4.3 Stock biomass trends

Brouwer and Wichman (2020) provided the first estimates of trends in biomass for lobsters at Kopernick Seamount. That analysis showed some declines in the population which is consistent with most lobster fisheries which are characterized by high exploitation rates at the start of the fishery Fusher and Hoening (2001). The extended data series has provided an opportunity to attempt something more sophisticated than the 2020 analysis. Given the short data set and lack of biological information the model used was a relatively simplistic surplus production model and the absolute stock status should be interpreted with caution and the outcomes considered preliminary. The model for lobsters presented here are very heavily influenced by the strong trends in the CPUE index. Nevertheless, the trends indicate that the fishery has had a substantial impact on the population at Kopernick Seamount.

The very strong declines at the start also indicate that the initial catch was likely too high for a single area and the fishery would benefit from diversifying to other species as well as expanding the fished area to other seamounts thereby reducing the impact on a single area. As *Jasus* lobsters have pelagic larvae that are widely spread by ocean currents in the open ocean Groeneveld et al. (2013) it its likely that *Jasus caveorum* populations will occur on other seamounts through the Foundation Seamount Chain. Pavicic et al. (2020) have demonstrated that genetic linkages between populations can be evaluated for lobsters, and these methods could be applied to *Jasus caveorum* to evaluate the population links between seamounts.

The biomass trends for crabs have fluctuated without trend and, while the model estimates are fairly variable, none of the depletion estimates indicate that the stock is impacted by the fishery at this stage. However, fishing mortality which is variable has increased in the most recent period.

## 4.4 Management options

While this fishery is currently exploratory in nature, management is required particularly for lobsters where the biomass has declined. There are a number of management options available for this fishery.

Modifying trap mesh has showed that trap mesh can impact the size selectivity of lobsters Schoeman et al. (2002). Reducing the catch of smaller individuals will have two effects, firstly it would reduce the overall impact by leaving small individuals in the water and secondly will reduce the catch of females. This is preferential to release of small individuals as even sub-lethal injury may result in a considerable reduction to individual productivity through decreased growth Brouwer et al. (2006) or reproductive potential Schoeman et al. (2002) meaning that escape from the trap of smaller individuals is better than capture and release. It is therefore recommended that larger mesh sizes be tested in this fishery.

The current closed season appears to be correctly placed and will prevent the capture of lobsters during the spawning season. This will have the impact or reducing mating disruption and reduced damage to eggs being carried by the females. It is recommended that the current closed season be maintained.

Catch and/or effort limits are also imperative to effective fisheries management. Currently in this fishery we have a catch limit as well as effort limits, in terms of a limit in the number of traps set. In addition, there is a CPUE limit. Catch and effort limits are important measures but difficult to determine the appropriate level of catch in the early stages of a fishery. The CPUE limit included in SPRFMO (2023) could have been effective if it was implemented with more care (Figure 51). Due to MMR staff turn over and simultaneous change in observers, while the monitoring of the CPUE limit was done, but the results were not reported back to MMR until after the trip was completed as such the closure of Kopernick Seamount was implemented but later than it should have been. While Kopernik Seamount is now closed to lobster fishing, the CPUE limit should be retained when it re-opens, noting that MMR has already put protocols in place to ensure that the CPUE monitoring occurs and is reported as required back to MMR. But care will need to be taken to check the CPUE limit level, as if the gear changes and a mesh size increase is imposed on the fishery, the CPUE may decline, as a result of the non-retention of smaller individuals rather than a decline in the biomass. The objective should now switch to increasing biomass to attain for a 4kg/trap CPUE target (or equivalent if wider mesh traps are used). It should also be noted that when Kopernick Seamount is not fished for for a period of time the catch rates recover, it would be informative to assess is this recovery happens again after the current closure. Monitoring the scale and time taken to increase the CPUE, would be informative when considering a management plan should Kopernik Seamount re-open. Noting the recovery of the CPUE after the COVID closure the Stock could be expected to show some recovery by the end of 2024.

The fishery for crabs has not as yet resulted in a stock response and it is suggested that, that aspect of the fishery continue and even be expanded. The vessel should therefore be instructed to focus more on crab targeting than lobsters. It would also be useful to get more data so that aspects such as the sex ratio and maturity patterns by depth and seamount can be explored in more detail.

## 4.5 Bycatch

The bycatch rates are low as expected for a trap fishery consisting mostly of non-target fish and crustaceans. A small number of invertebrates get entangled in the mesh of the traps and some of those are VME indicator taxa. The interactions with VME indicator taxa have declined in the most recent trips, partly due to the reduction of fishing effort on Kopernick Seamount that traditionally had the highest number of interactions. However, since May 2020 the Kopernick Valley, which had high VME taxa encounter rates, was closed to trap fishing and the trips since that date have had lower VME taxa bycatch.

## 4.6 Recommendations

1. Collect additional length and maturity samples from the Northern Seamounts.
2. Collect genetic samples from the Northern Seamounts and the Foundation Seamount Chain to evaluate the stock links between seamounts.
3. Provide extra training for observers in identifying crab maturity.
4. It is recommended that larger mesh sizes be tested to reduce the lobster catch overall and reduce the impact on females.
5. It is recommended that the current closed season be maintained.
6. It is recommended that the Kopernik seamount remain closed for 2023 to trap fishing (<350m) targeting lobsters.

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# Tables

Table 1: The trip details from the Cook Islands exploratory fishery.

| Trip number | Start | End | Hauls | Traps |
|---|---|---|---:|---:|
| 1 | 2019-04-04 | 2019-05-04 | 63 | 8,423 |
| 2 | 2019-06-09 | 2019-06-26 | 60 | 5,053 |
| 3 | 2019-11-04 | 2019-12-16 | 95 | 7,209 |
| 4 | 2020-03-27 | 2020-04-27 | 70 | 6,635 |
| 5 | 2022-05-20 | 2022-06-21 | 62 | 5,630 |
| 6 | 2022-01-16 | 2022-12-28 | 109 | 9,812 |
| 7 | 2023-02-04 | 2023-03-20 | 144 | 13,009 |
| Total | - | - | 603 | 55,771 |

Table 2: The outputs fomr a general linear model showing the factors explored and the level of significance resulting from the model.

| Species | Factor | Significance |
|---|---|---|
| Lobster | Depth | p<0.001 |
| | Swell | p<0.05 |
| | Trap Spacing | p<0.001 |
| | Trip | p<0.001 |
| | Soak time | p<1 |
| Crab | Depth | p<0.001 |
| | Swell | p<0.05 |
| | Trap Spacing | p<0.001 |
| | Trip | p<0.001 |
| | Soak time | p<1 |

Table 3: List of all bycatch by seamount for all trips in the Cook Island trap fishery.

| English_name | Buffon | Darwin A | Dog leg | Galilei | GB | Humboldt | Jenner | Kopernik | Laviouer | Linne b | Mendel | Mendeleiev | Mercator | MM | Northern Seamount |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anthozoa | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ball coral | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Black coral | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Blue shark | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chaceon geryons nei | 46 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| Cnidarians nei | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 1 | 20 | 0 |
| Cusk-eels nei | 0 | 0 | 234 | 0 | 0 | 0 | 24 | 38 | 88 | 19 | 127 | 0 | 0 | 70 | 0 |
| Echinoderms | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 0 | 0 | 0 | 0 | 0 |
| Glass sponges | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gorgonians | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Hydroids, hydromedusae | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hydrozoans | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| King crabs, stone crabs nei | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 97 |
| Marine shells nei | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Moras nei | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Nylon shrimps nei | 14 | 0 | 0 | 111 | 0 | 86 | 0 | 0 | 0 | 6 | 33 | 0 | 0 | 1 | 1 |
| Porae | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 0 | 2 | 0 | 0 | 8 | 0 |
| Rhodolith | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Scorpionfishes, redfishes nei | 0 | 0 | 4 | 0 | 0 | 0 | 6 | 30 | 22 | 0 | 8 | 1 | 0 | 124 | 0 |
| Siliceous sponges | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Snipefishes nei | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tarakihi | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Trumpeters nei | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Zoanthids | 0 | 2 | 0 | 0 | 0 | 0 | 4 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 63 | 2 | 238 | 112 | 0 | 86 | 34 | 222 | 114 | 37 | 171 | 1 | 2 | 232 | 98 |

Table 4: List of VME catch by seamount for all trips in the Cook Island trap fishery.

| Name | Buffon | Kopernik | Mercator | MM | Total |
|---|---|---|---|---|---|
| Anthozoa | 0 | 9 | 0 | 0 | 9 |
| Ball coral | 0 | 50 | 0 | 0 | 50 |
| Black coral | 0 | 2 | 0 | 0 | 2 |
| Cnidarians nei | 2 | 8 | 1 | 20 | 31 |
| Glass sponges | 0 | 0 | 0 | 0 | 0 |
| Gorgonians | 0 | 1 | 0 | 1 | 2 |
| Hydroids, hydromedusae | 0 | 1 | 0 | 0 | 1 |
| Hydrozoans | 0 | 2 | 0 | 3 | 5 |
| Rhodolith | 0 | 2 | 0 | 0 | 2 |
| Siliceous sponges | 0 | 1 | 0 | 0 | 1 |
| Total | 2 | 76 | 1 | 24 | 103 |

Table 5: List of VME catch by trip for all trips in the Cook Island trap fishery.

| Name | Trip 1 | Trip 2 | Trip 3 | Trip 4 | Trip 5 | Trip 6 | Trip 7 |
|---|---|---|---|---|---|---|---|
| Anthozoa | 9 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ball coral | 0 | 50 | 0 | 0 | 0 | 0 | 0 |
| Black coral | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| Cnidarians nei | 9 | 0 | 3 | 19 | 0 | 0 | 0 |
| Glass sponges | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gorgonians | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| Hydroids, hydromedusae | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Hydrozoans | 1 | 1 | 0 | 3 | 0 | 0 | 0 |
| Rhodolith | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| Siliceous sponges | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 20 | 53 | 5 | 22 | 0 | 3 | 0 |

# Figures

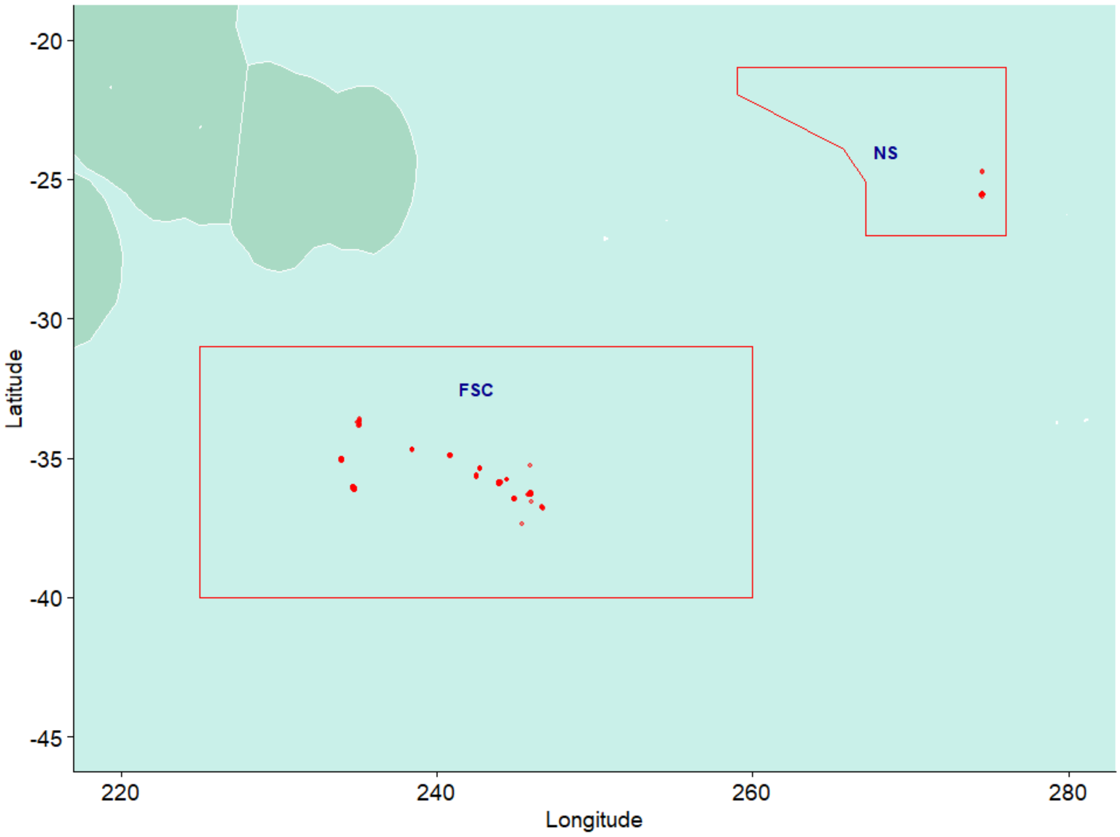


**Figure 1: Distribution of the fishing sites fished between 2019 and 2023 by the Cook Islands vessels in the SPRFMO area. Showing sites within the Foundation Seamount Chain (FSC) and the Northern Seamount (NS)**

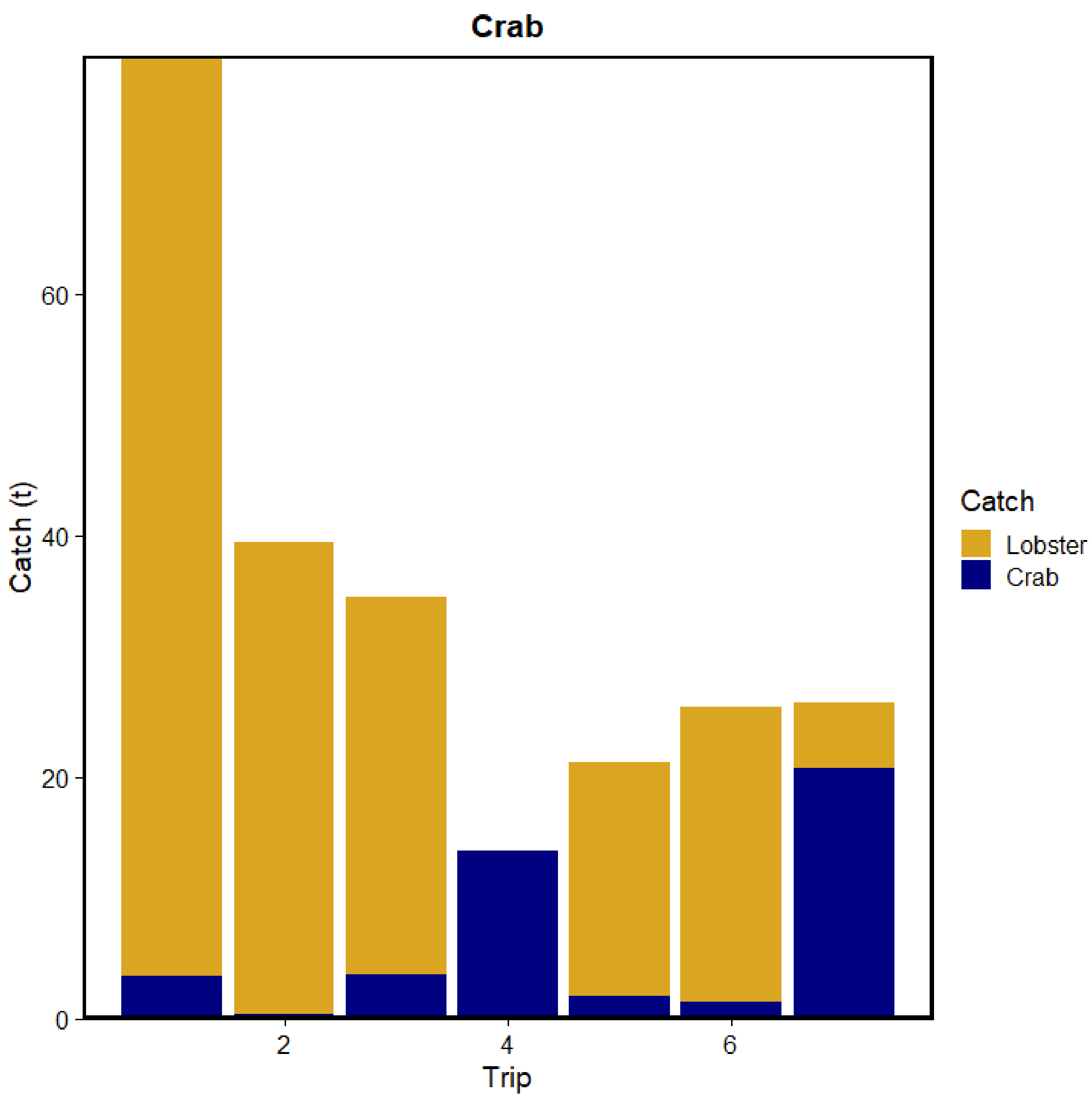


**Figure 2: Catch per trip from the Cook Islands lobster trap fishery 2019-2023.**

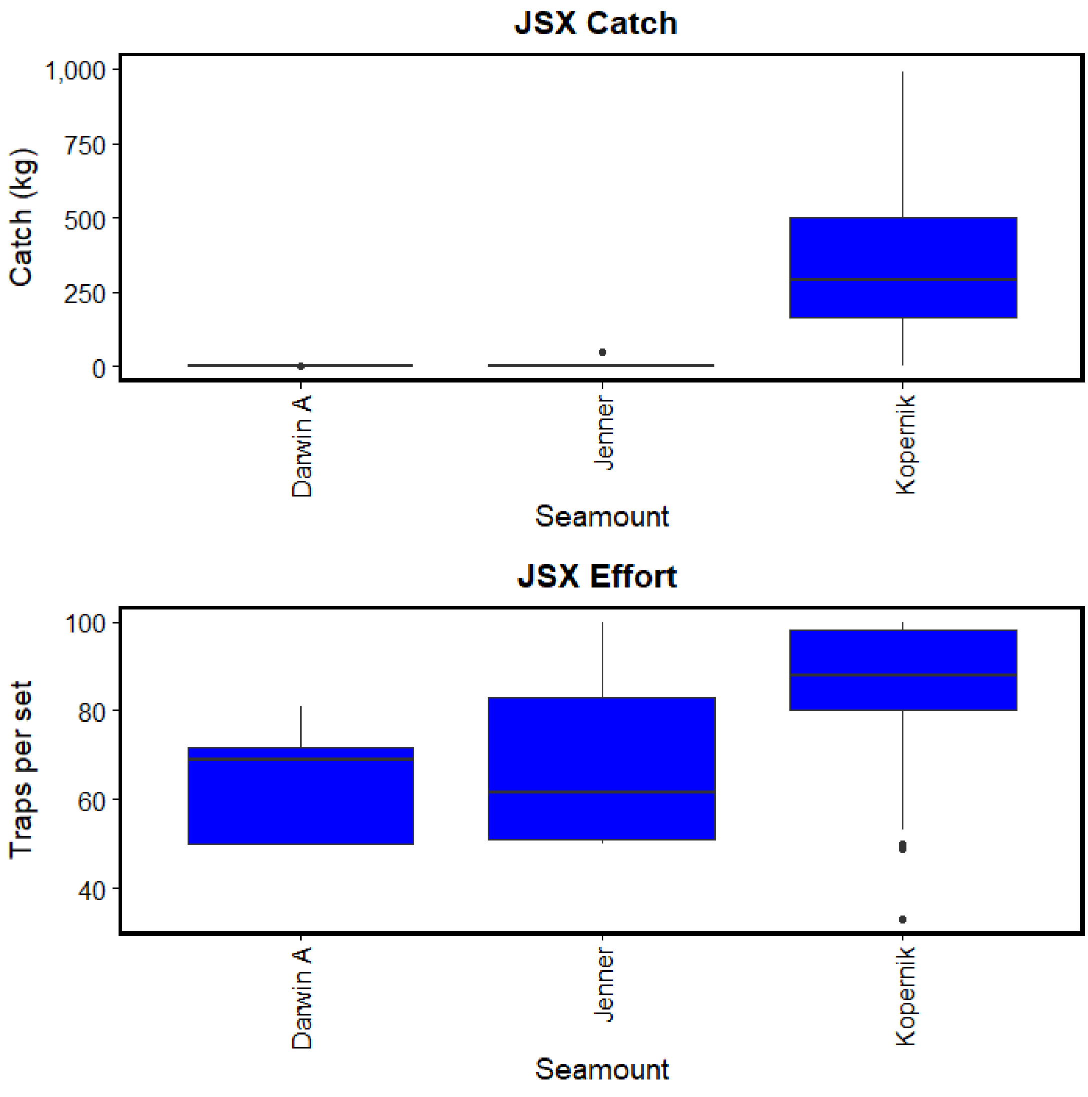


**Figure 3: Lobster directed catch and effort by seamount from the Cook Islands lobster trap fishery 2019-2023.**

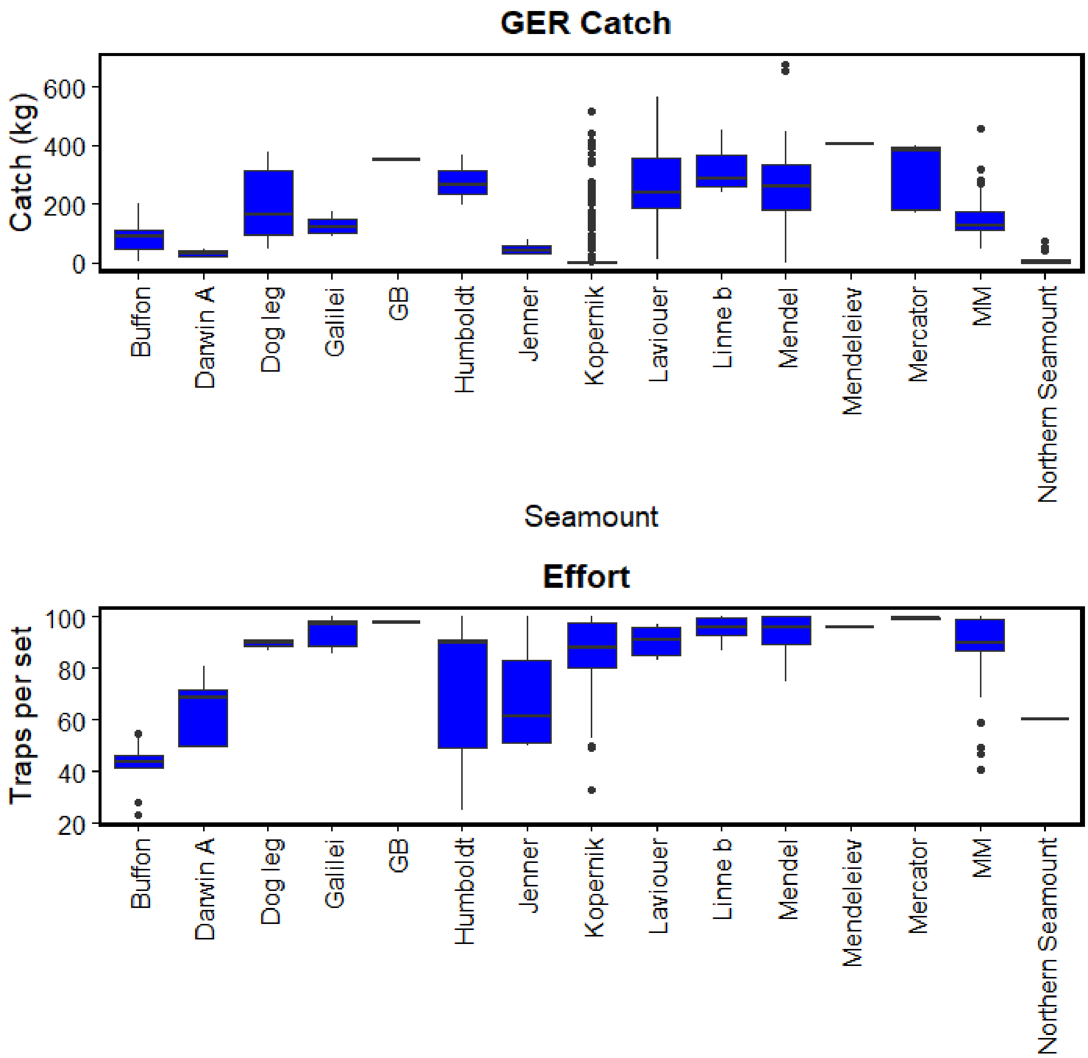


**Figure 4: Crab directed catch and effort by seamount from the Cook Islands lobster trap fishery 2019-2023.**

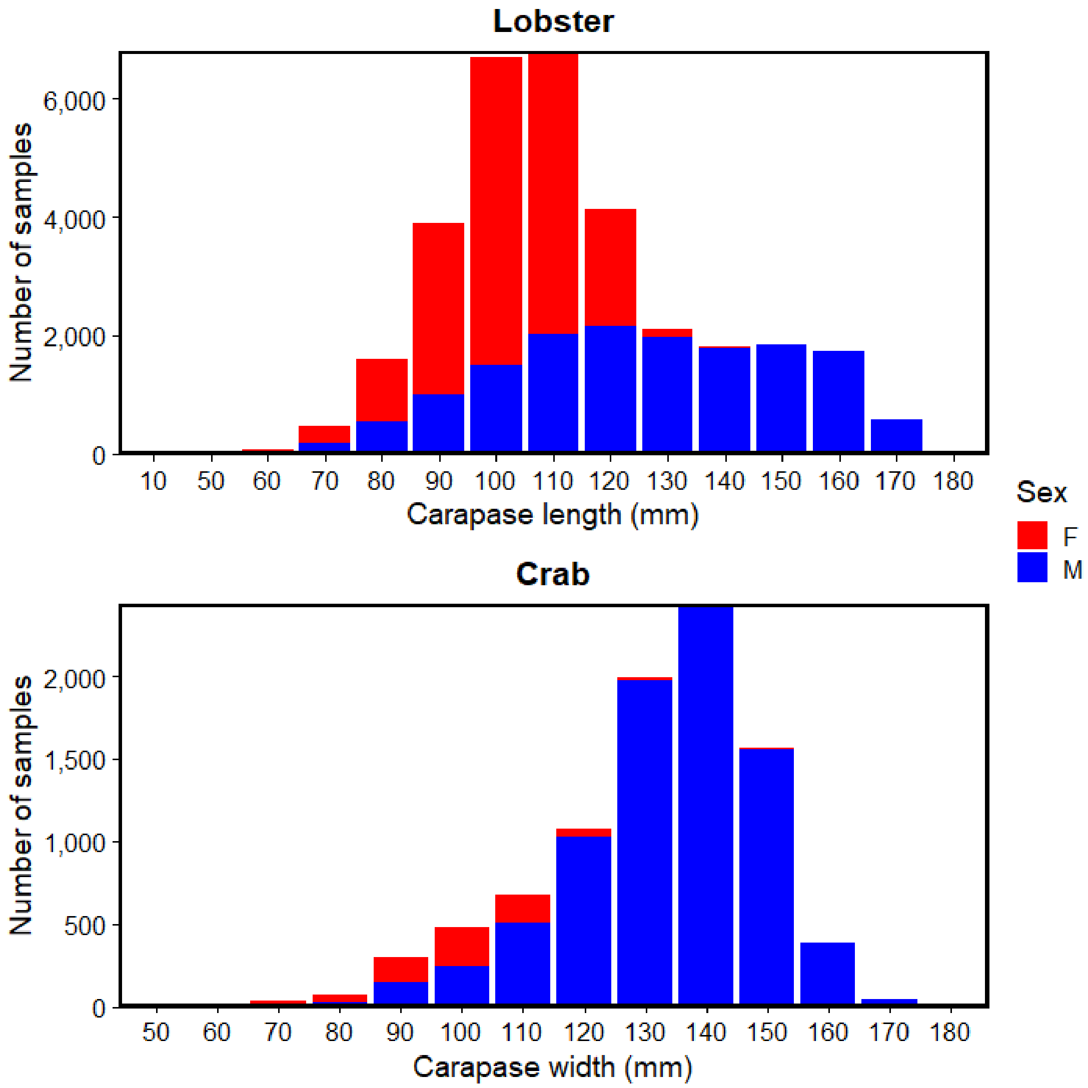


Figure 5: The length by sex from the Cook Islands SPRFMO fishery for lobsters (top) and crabs (bottom).

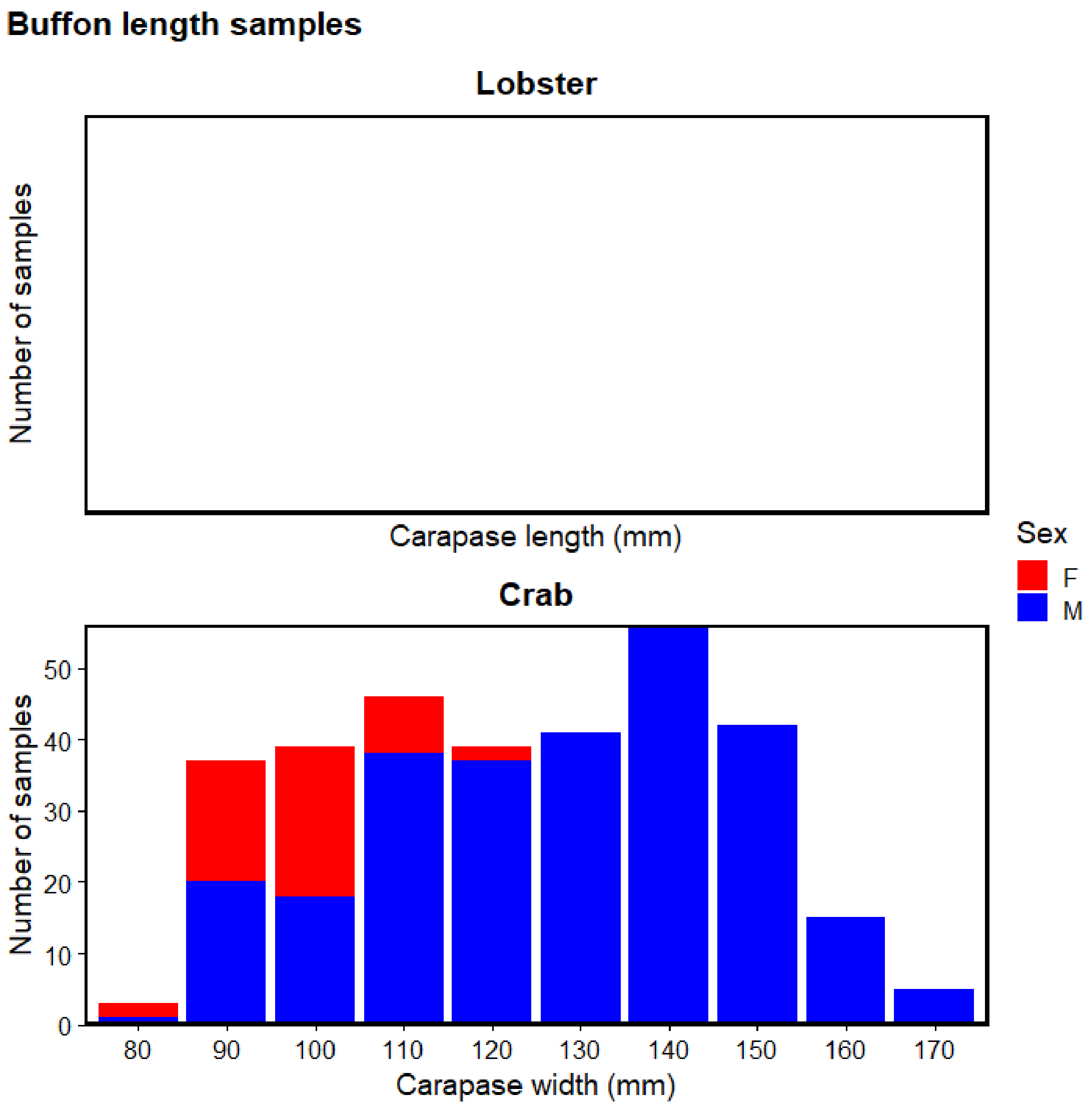


Figure 6: The length by sex from the Cook Islands fishery at Buffon Seamount for lobsters (top) and crabs (bottom).

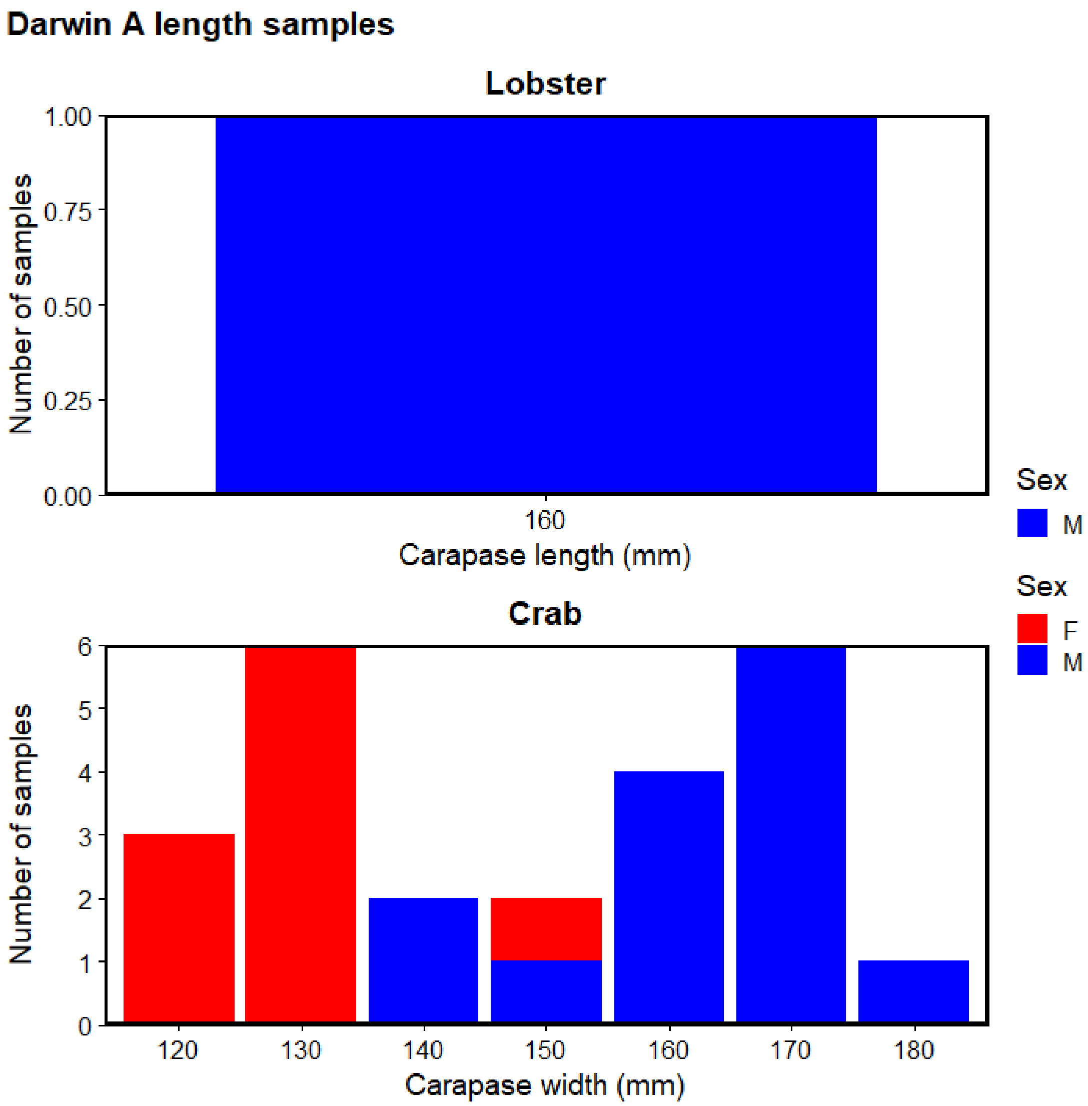


**Figure 7: The length by sex from the Cook Islands fishery at Darwin A Seamount for lobsters (top) and crabs (bottom).**

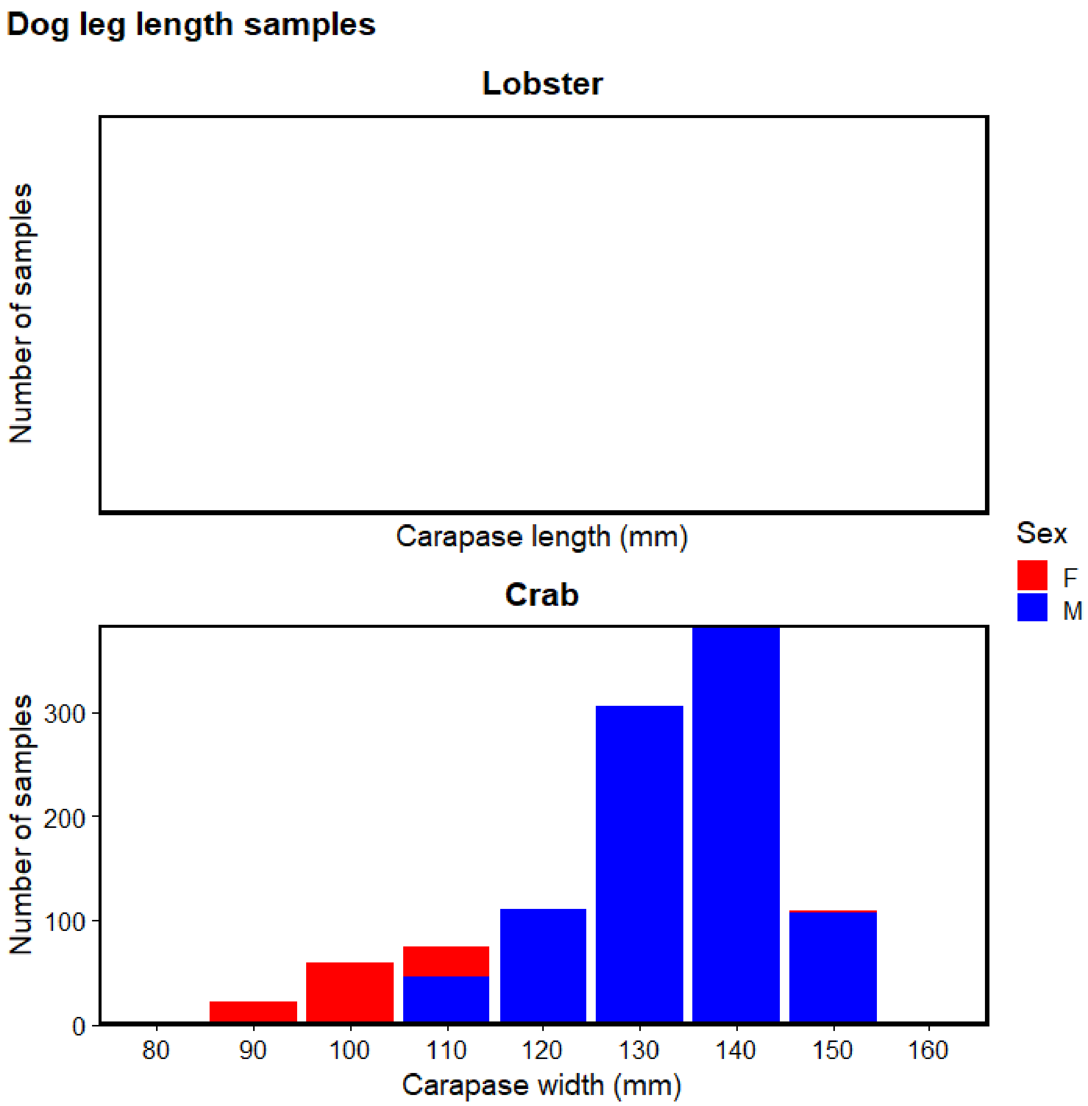


Figure 8: The length by sex from the Cook Islands fishery at Dog Leg Seamount for lobsters (top) and crabs (bottom).

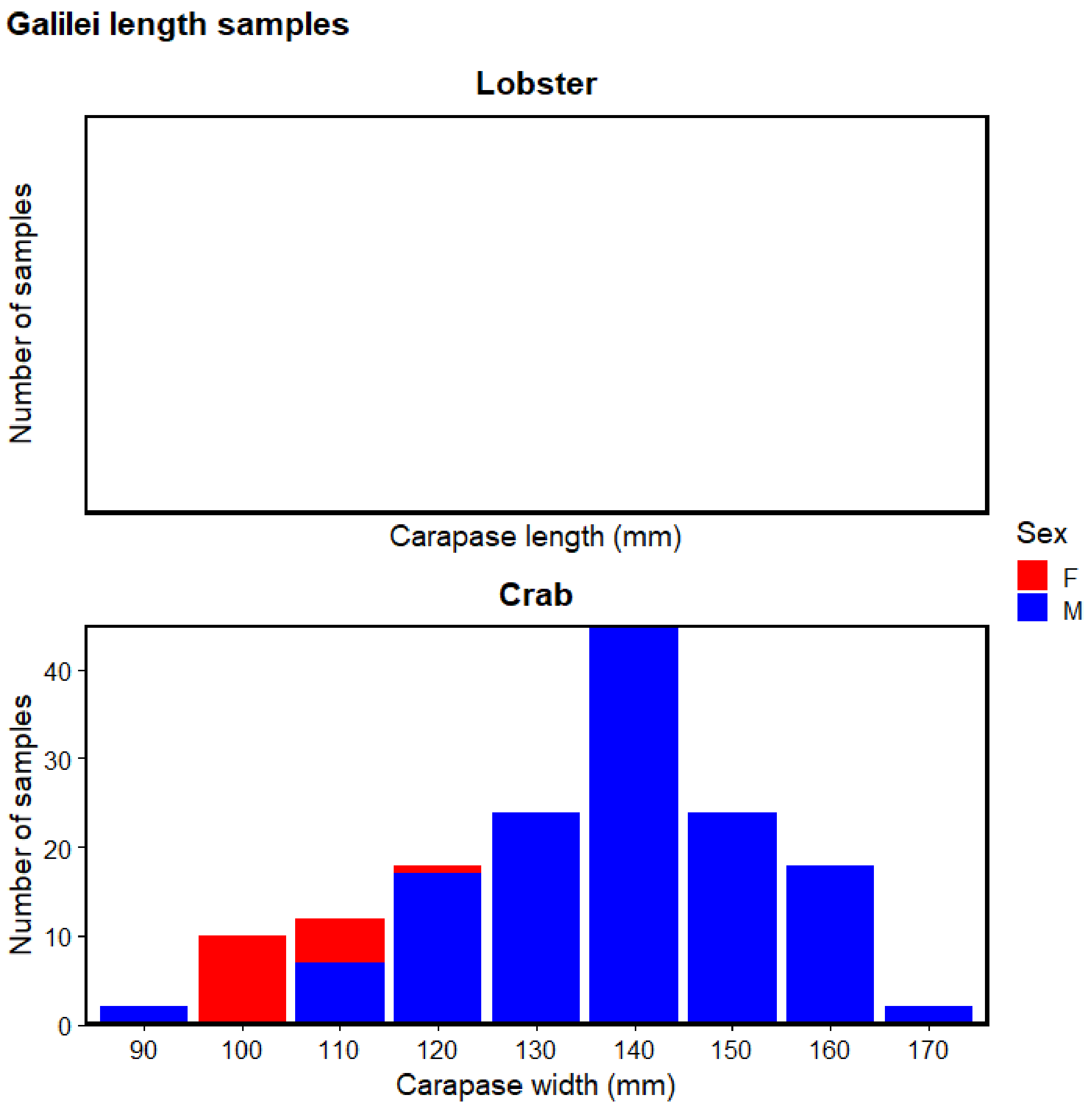


**Figure 9: The length by sex from the Cook Islands fishery at Galilei Seamount for lobsters (top) and crabs (bottom).**

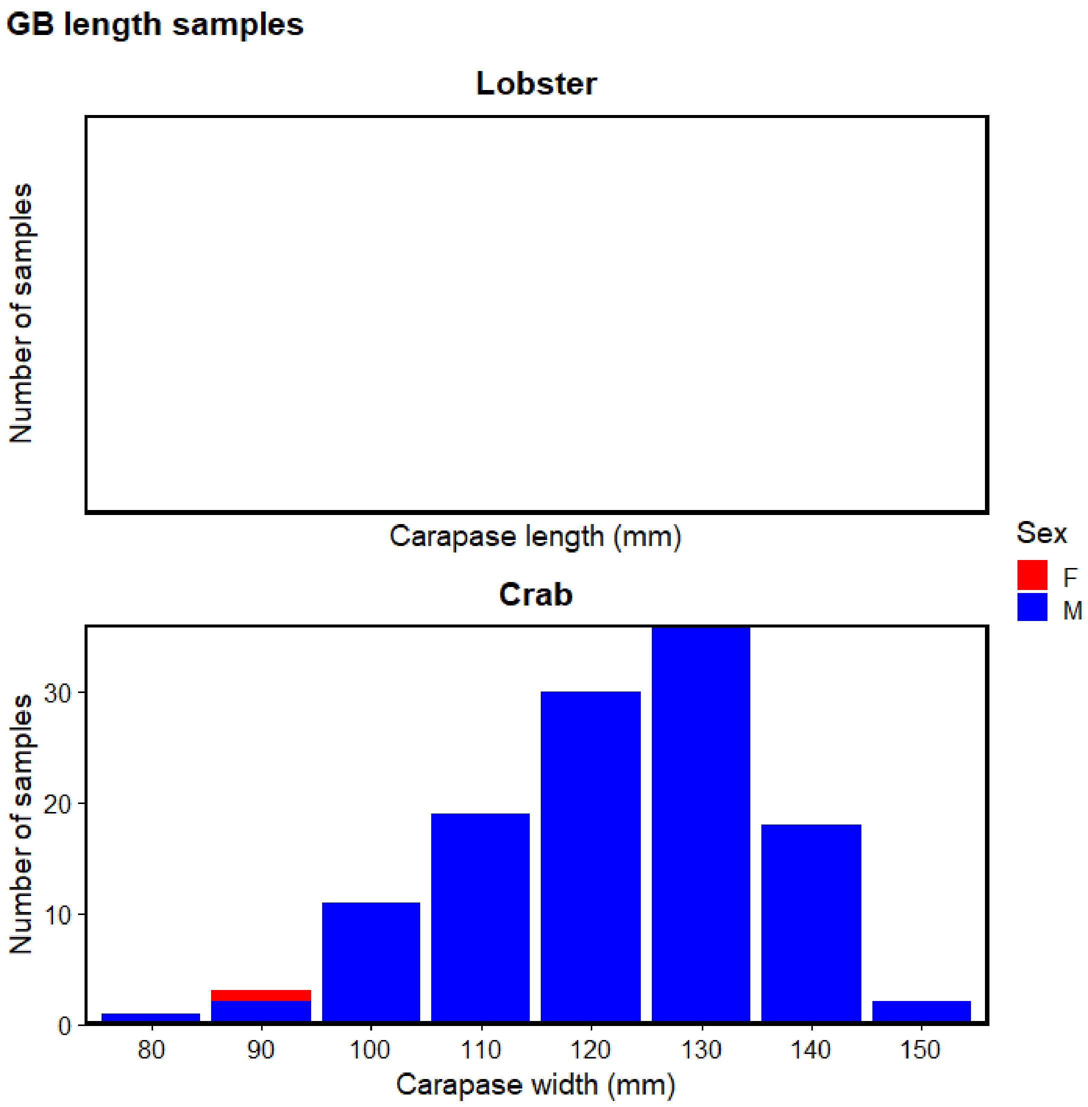


**Figure 10: The length by sex from the Cook Islands fishery at GB Seamount for lobsters (top) and crabs (bottom).**

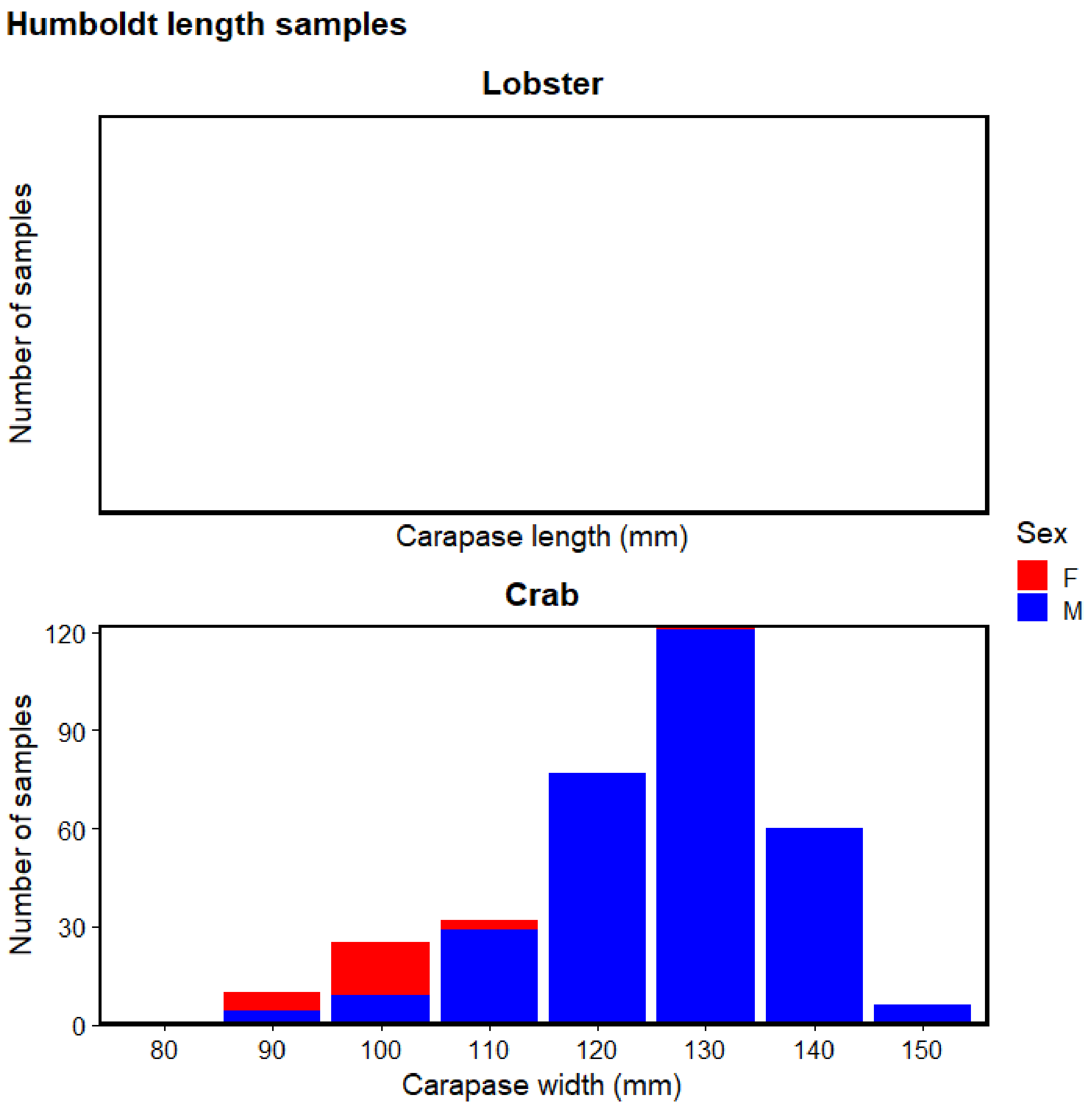


Figure 11: The length by sex from the Cook Islands fishery at Humboldt Seamount for lobsters (top) and crabs (bottom).

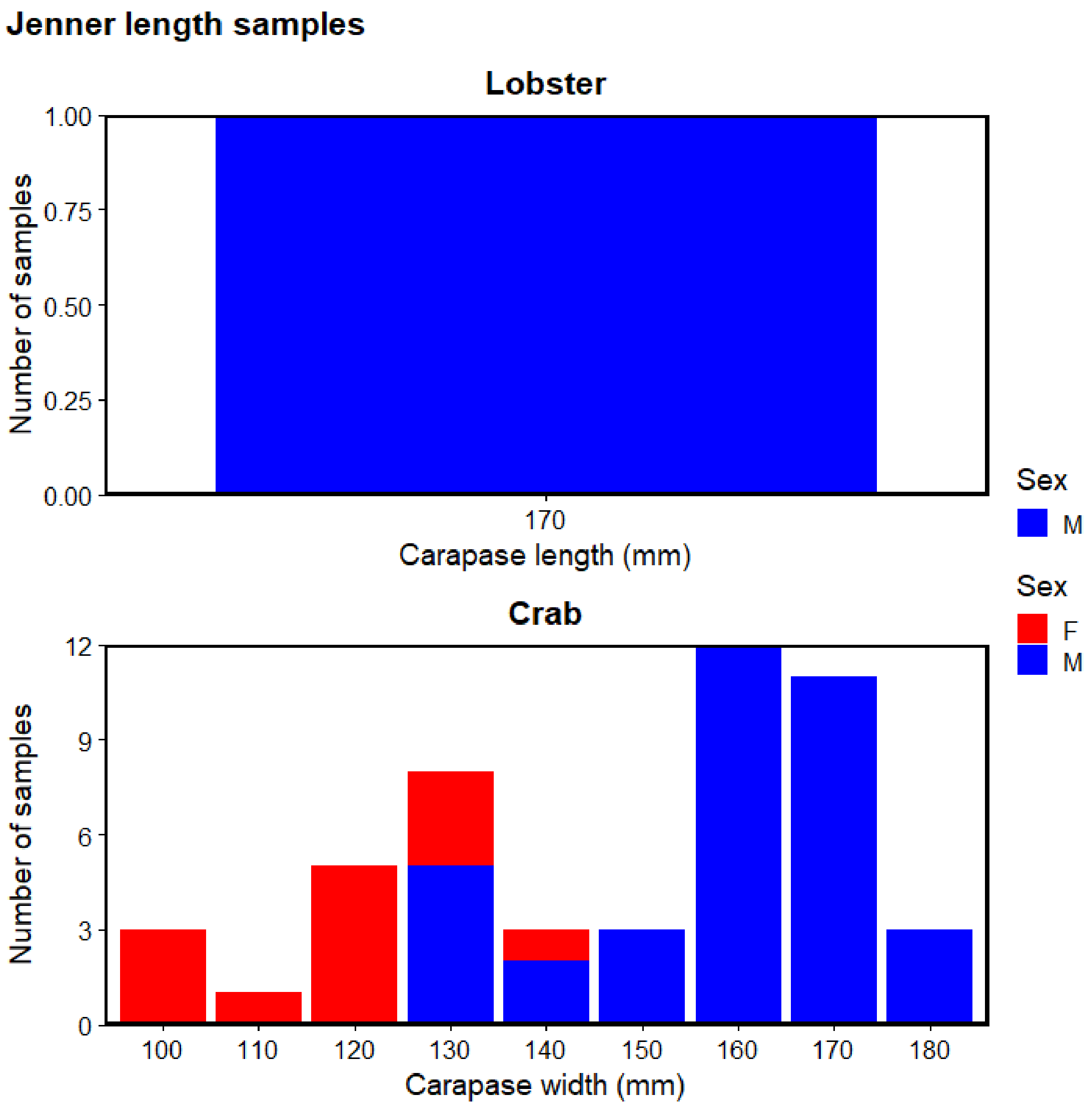


Figure 12: The length by sex from the Cook Islands fishery at Jenner Seamount for lobsters (top) and crabs (bottom).

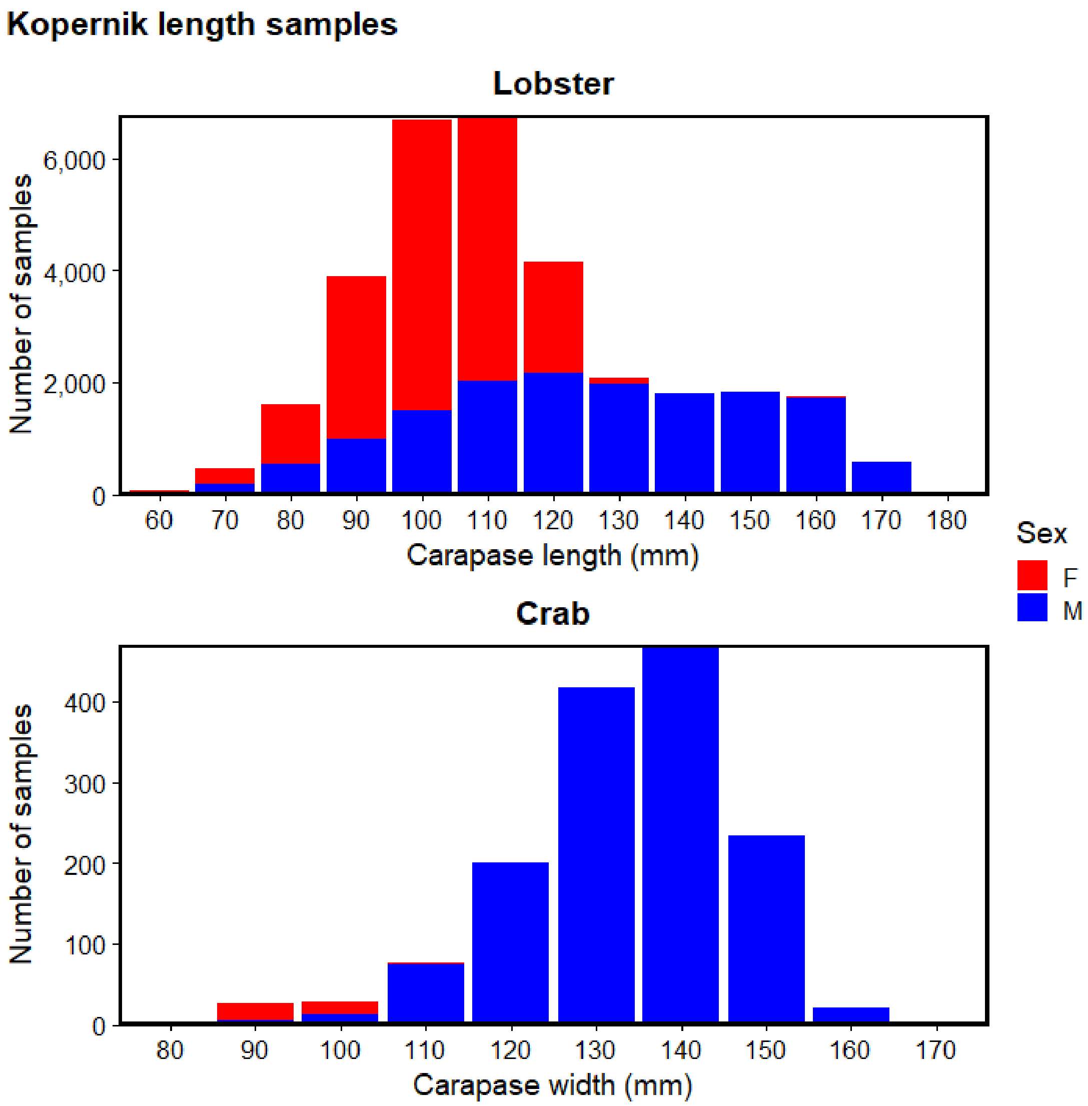


Figure 13: The length by sex from the Cook Islands fishery at Kopernik Seamount for lobsters (top) and crabs (bottom).

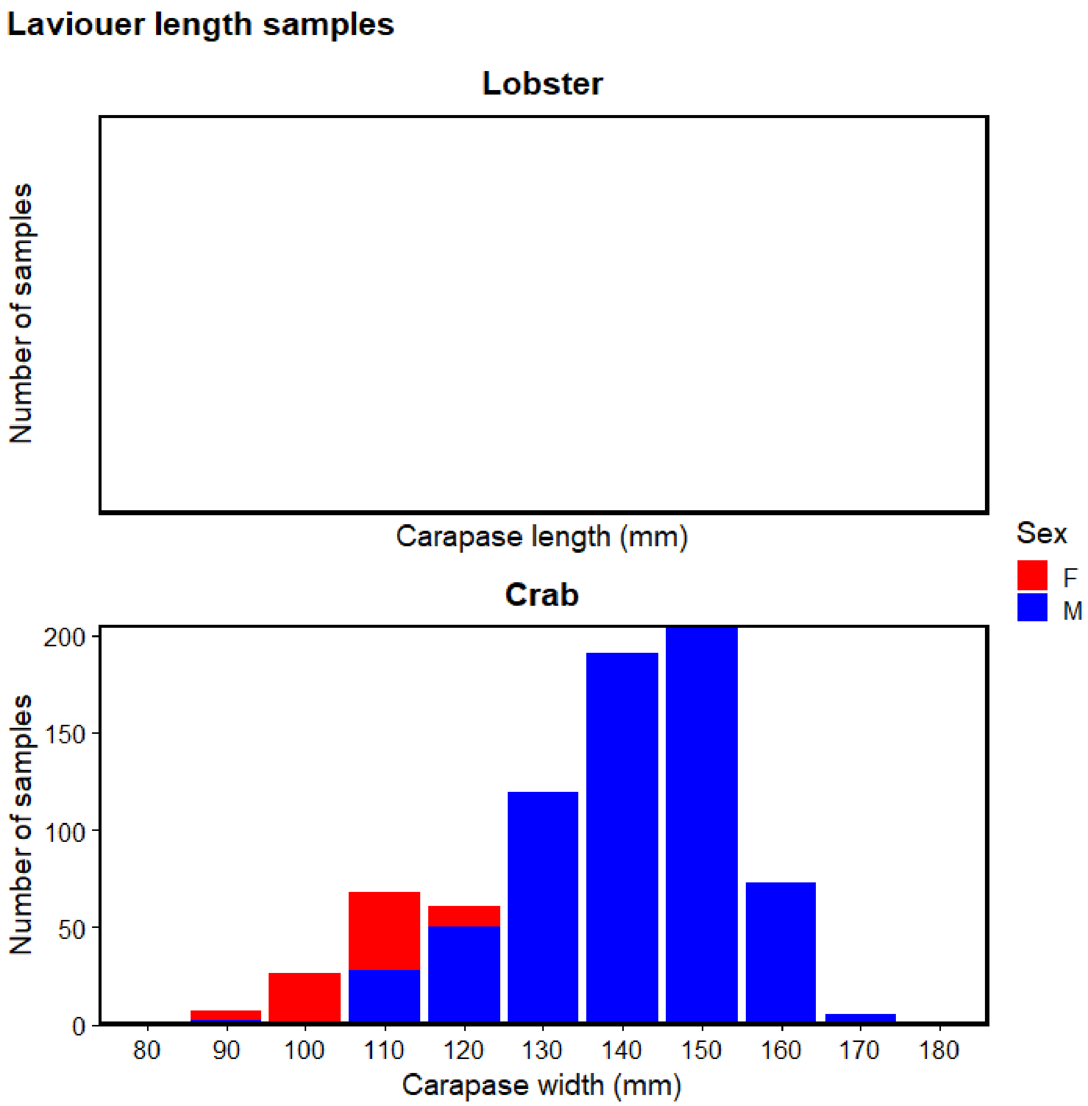


**Figure 14: The length by sex from the Cook Islands fishery at Laviouer Seamount for lobsters (top) and crabs (bottom).**

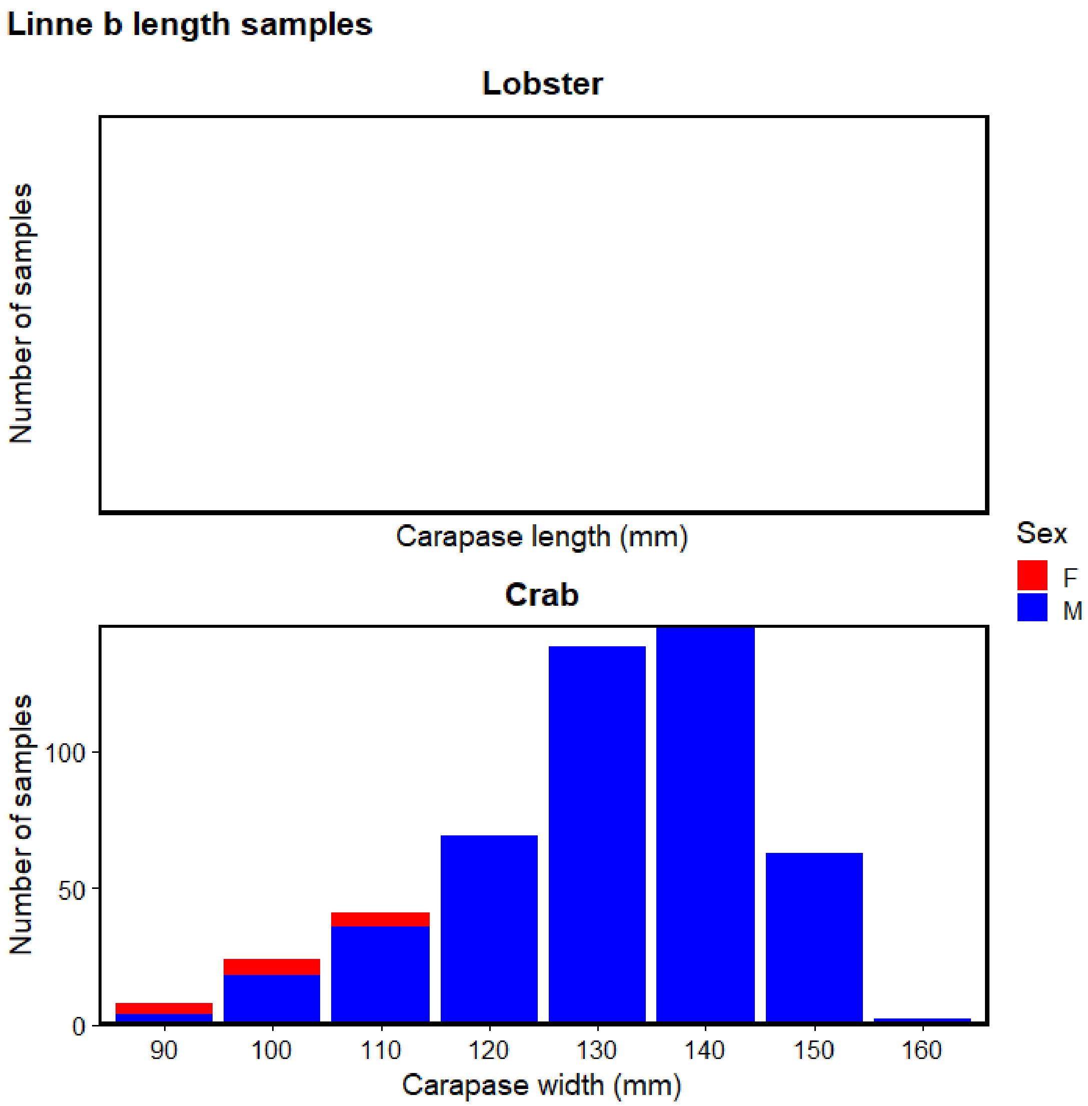


Figure 15: The length by sex from the Cook Islands fishery at Linne B Seamount for lobsters (top) and crabs (bottom).

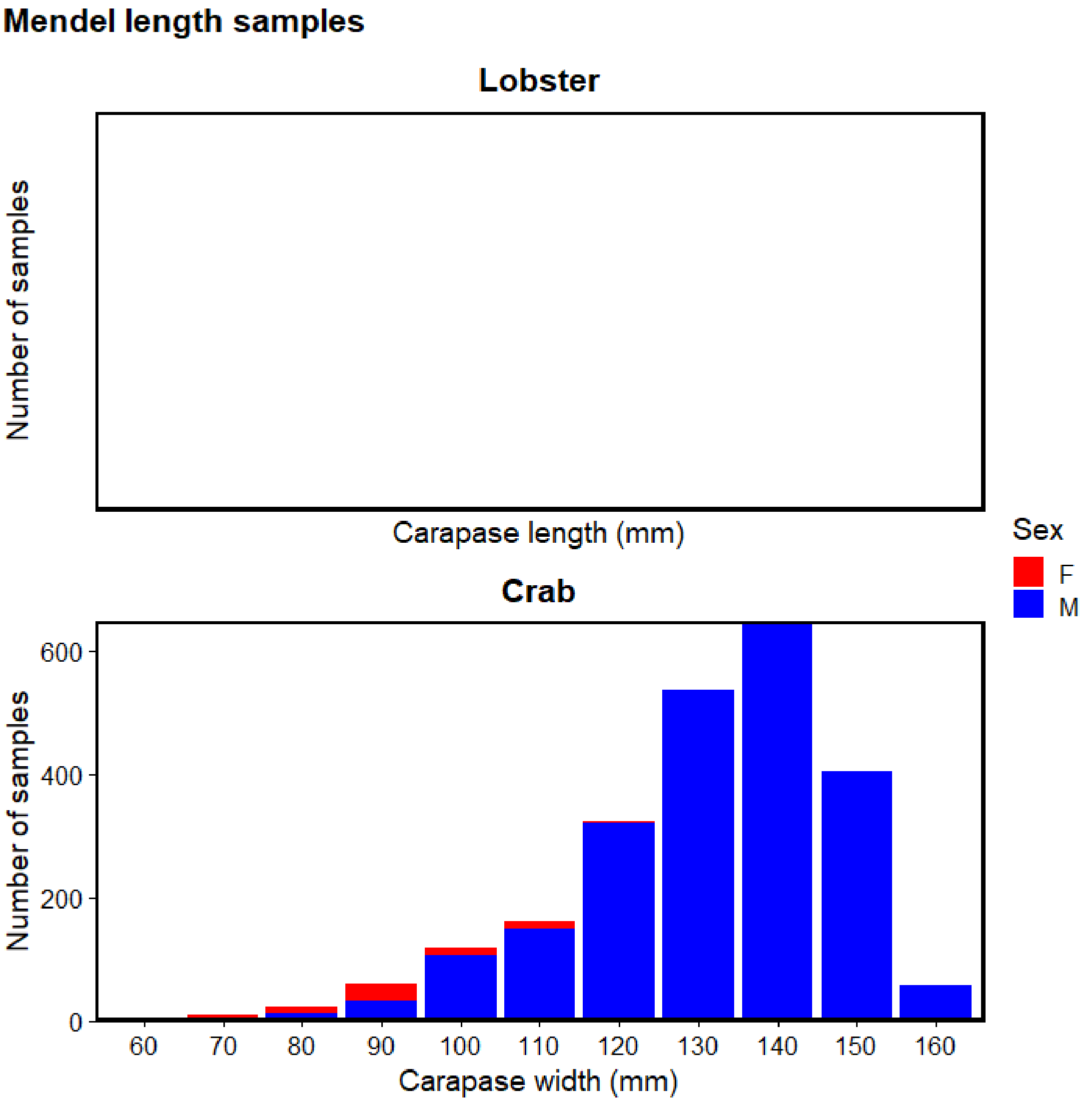


Figure 16: The length by sex from the Cook Islands fishery at Mendel Seamount for lobsters (top) and crabs (bottom).

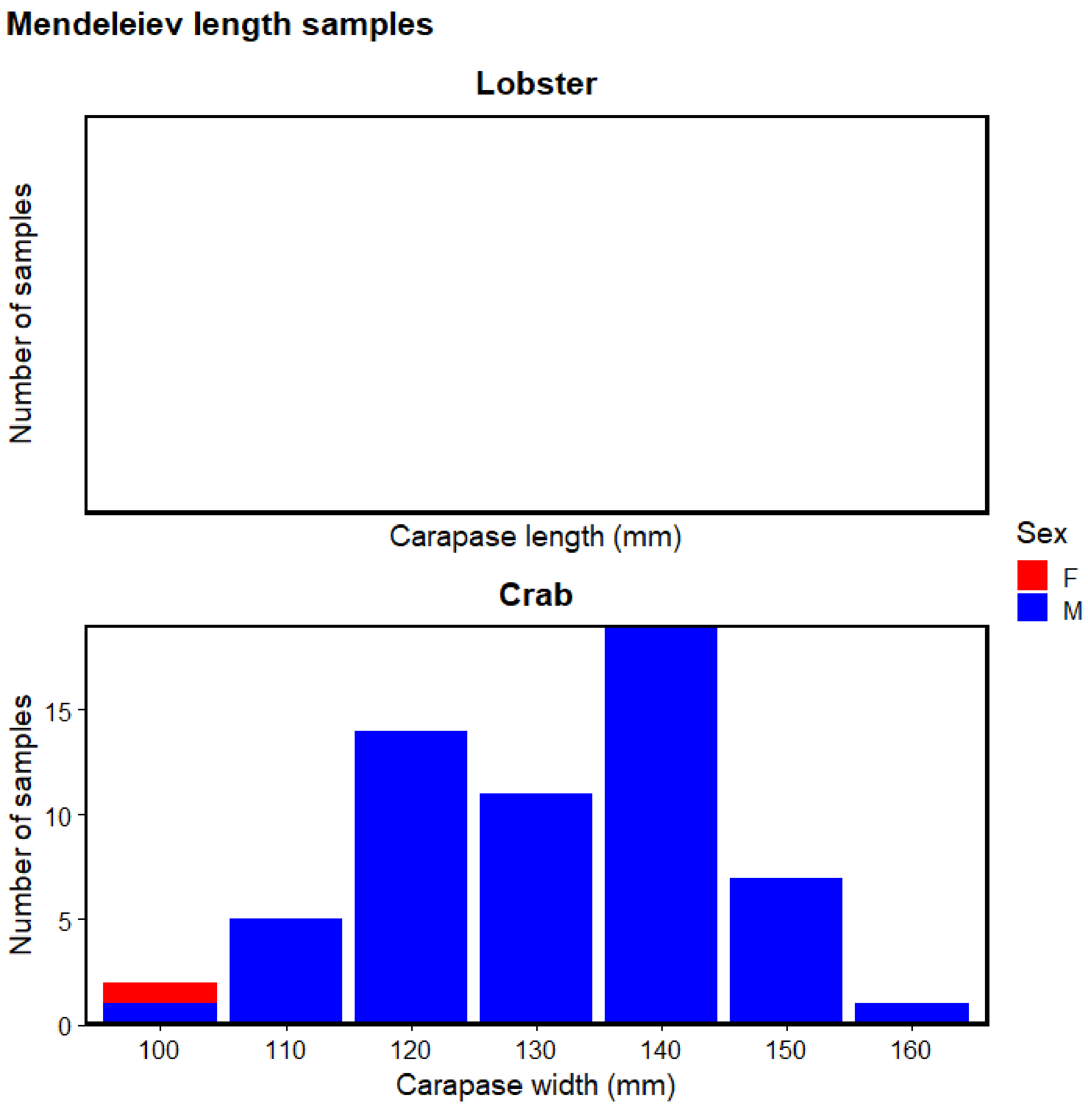


**Figure 17: The length by sex from the Cook Islands fishery at Mendeleiev Seamount for lobsters (top) and crabs (bottom).**

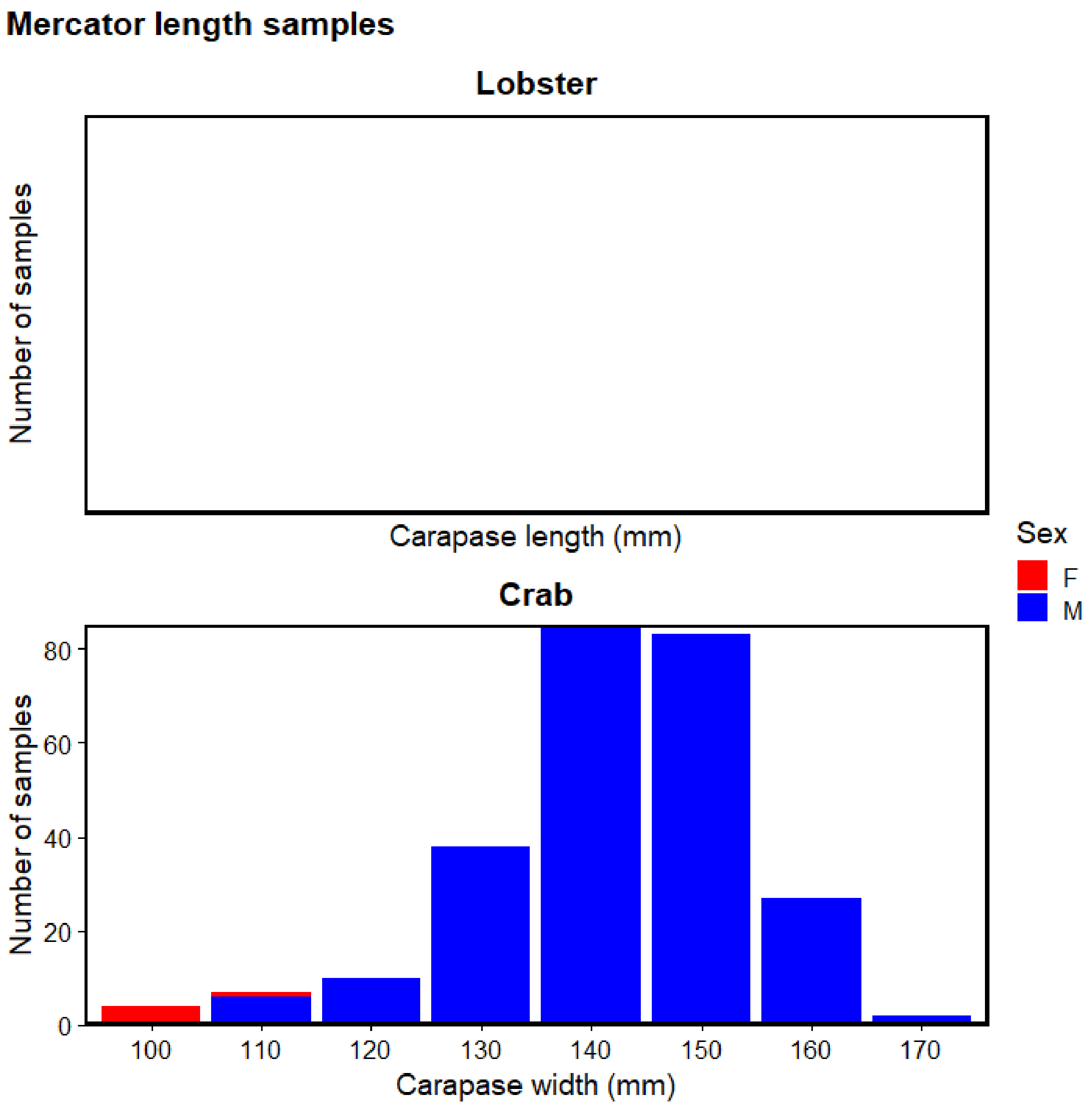


Figure 18: The length by sex from the Cook Islands fishery at Mercator Seamount for lobsters (top) and crabs (bottom).

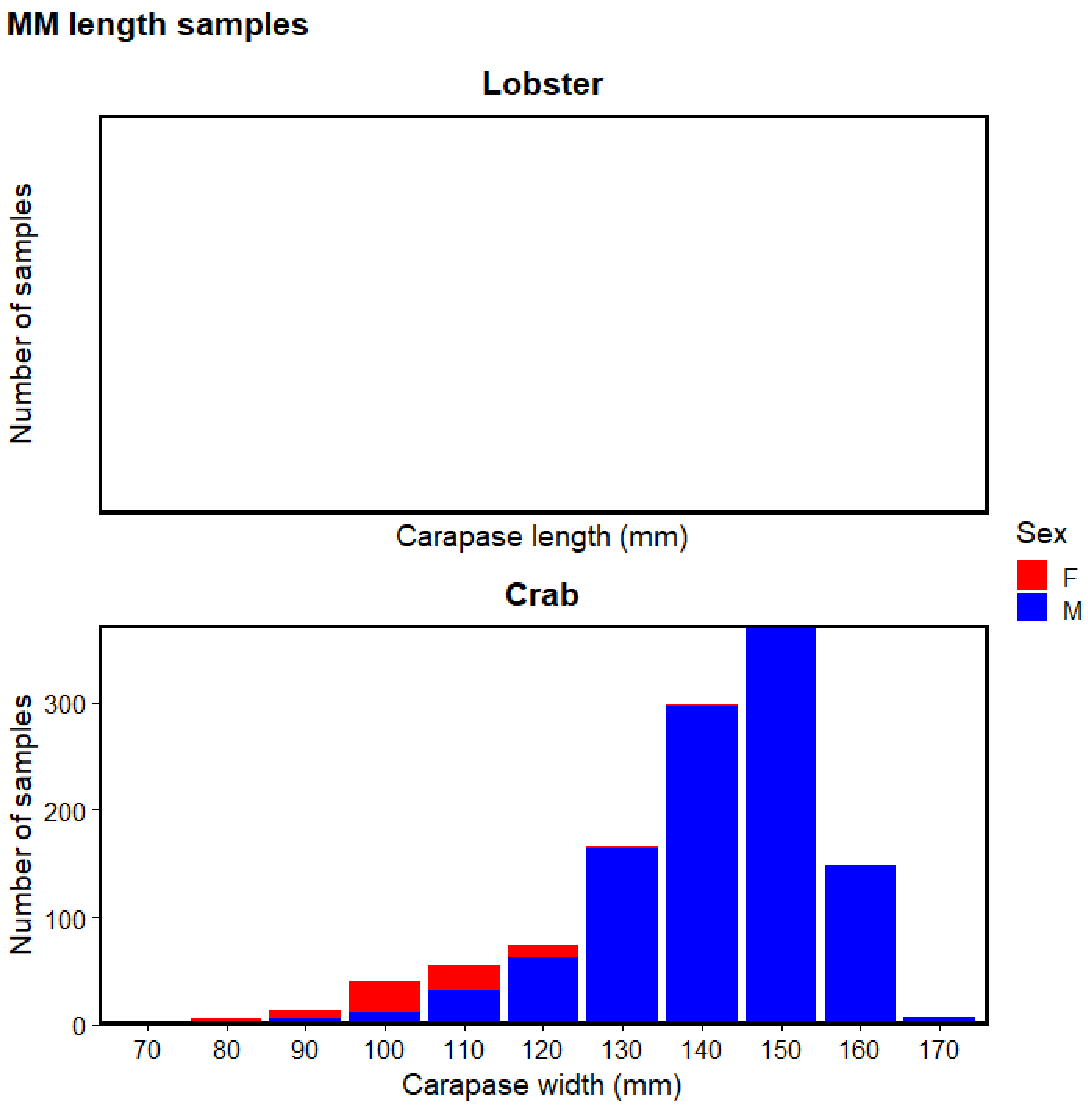


**Figure 19: The length by sex from the Cook Islands fishery at MM Seamount for lobsters (top) and crabs (bottom).**

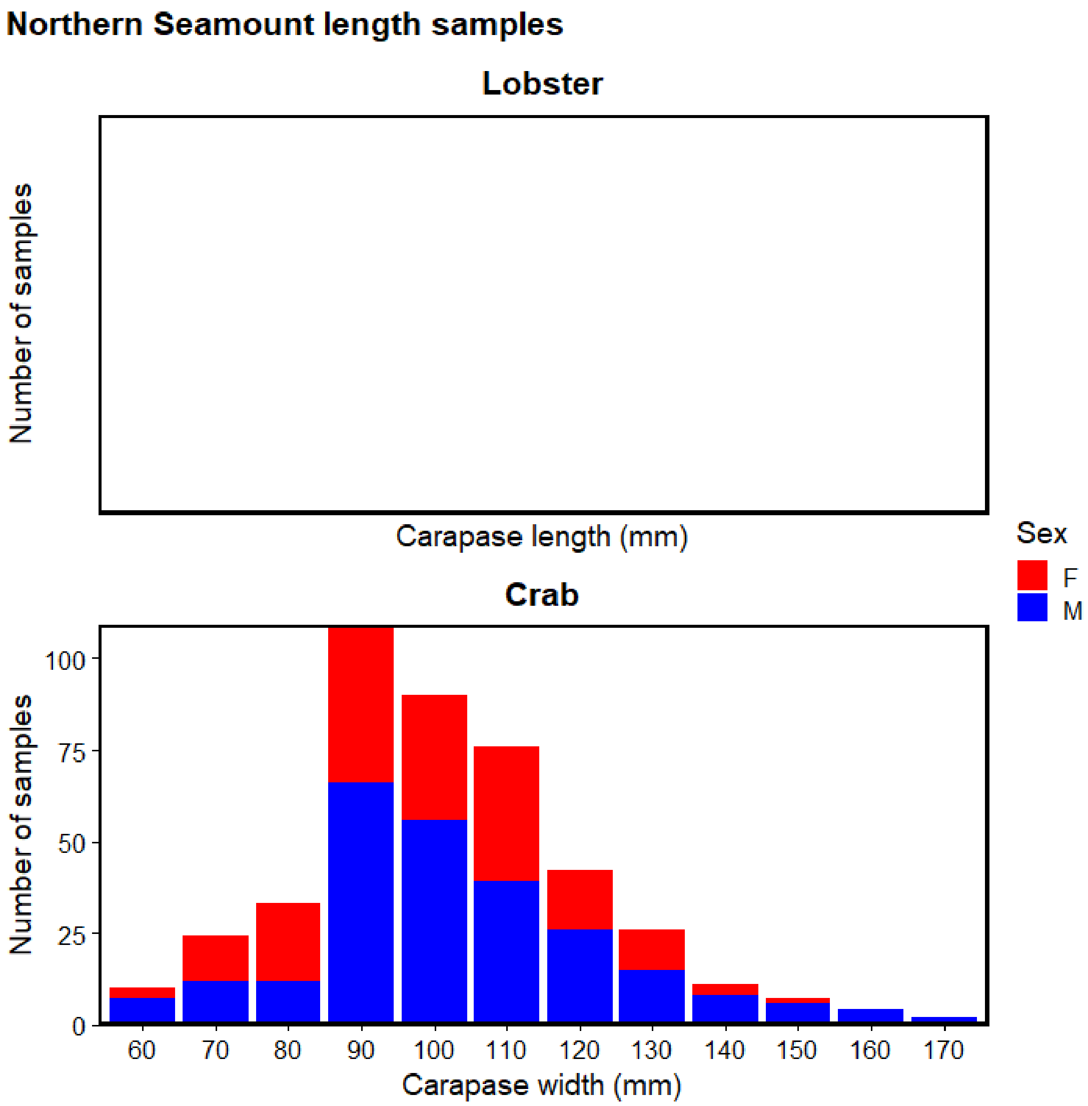


Figure 20: The length by sex from the Cook Islands fishery at Northern Seamount Seamount for lobsters (top) and crabs (bottom).

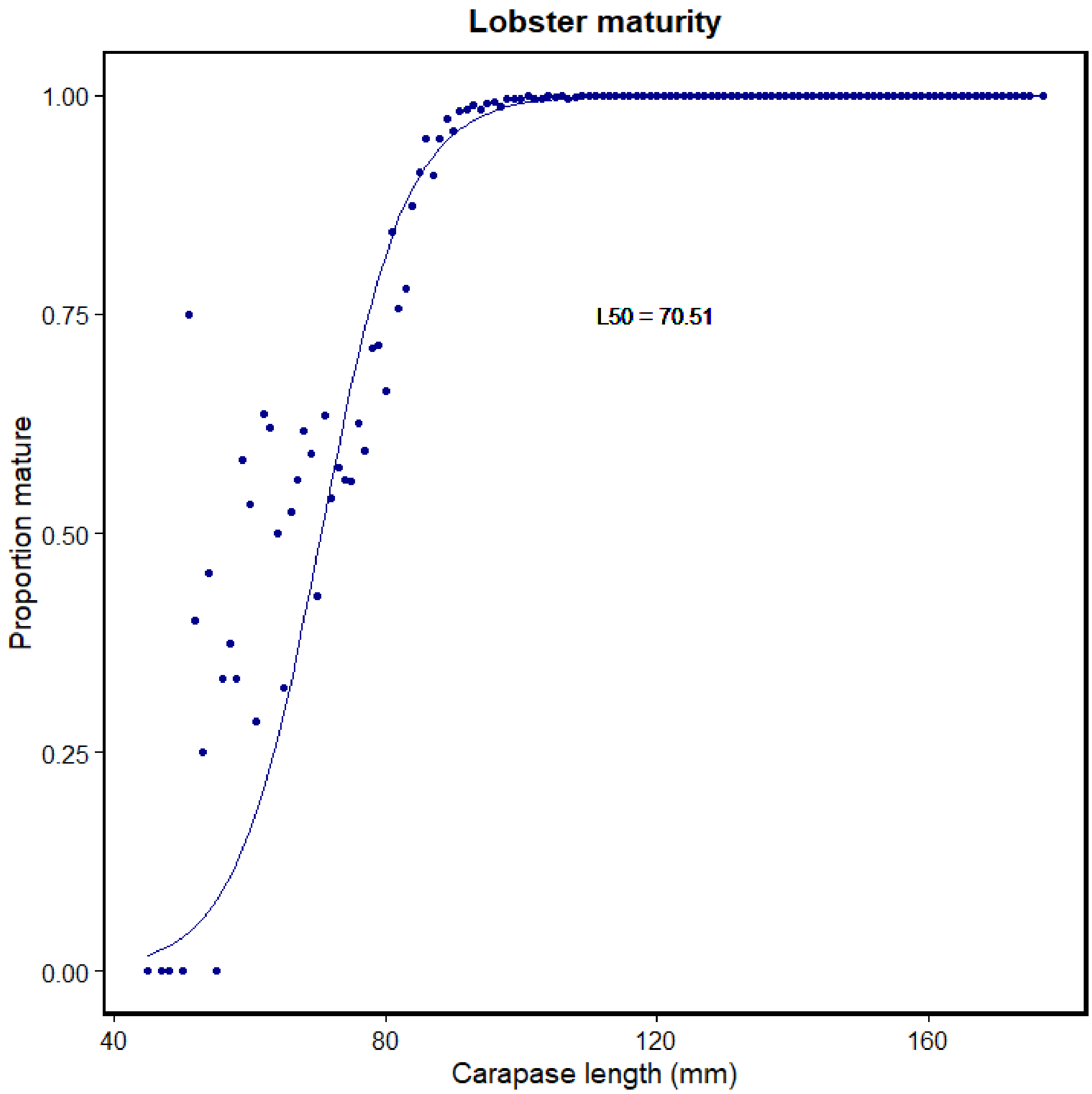


Figure 21: The lobster maturity estimates sampled in the Cook Islands SPRFMO fishery and the estimated maturity curve L50 = Length-at-50% maturity.

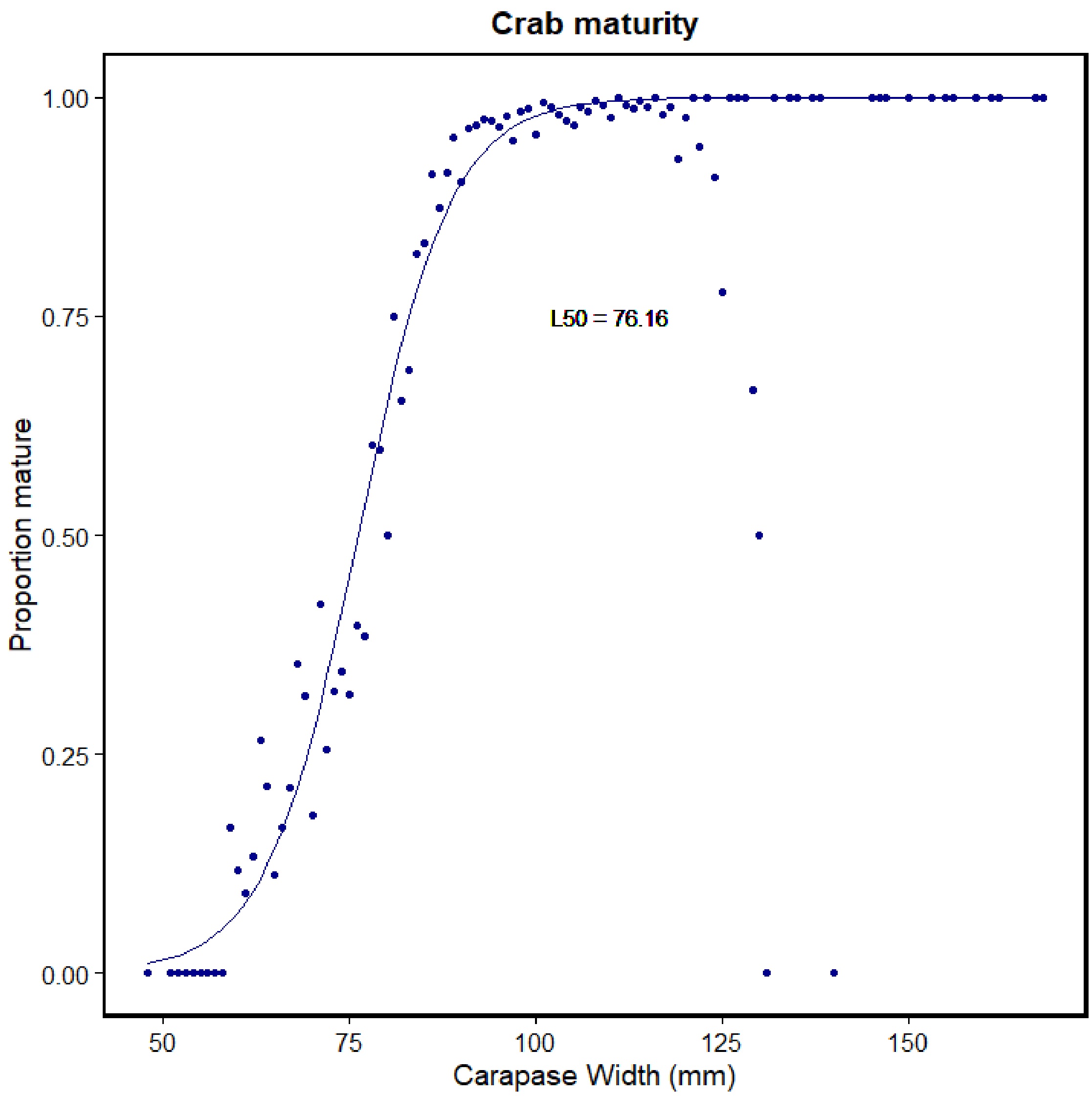


**Figure 22: The crab maturity estimates sampled in the Cook Islands SPRFMO fishery and the estimated maturity curve L50 = Length-at-50% maturity.**

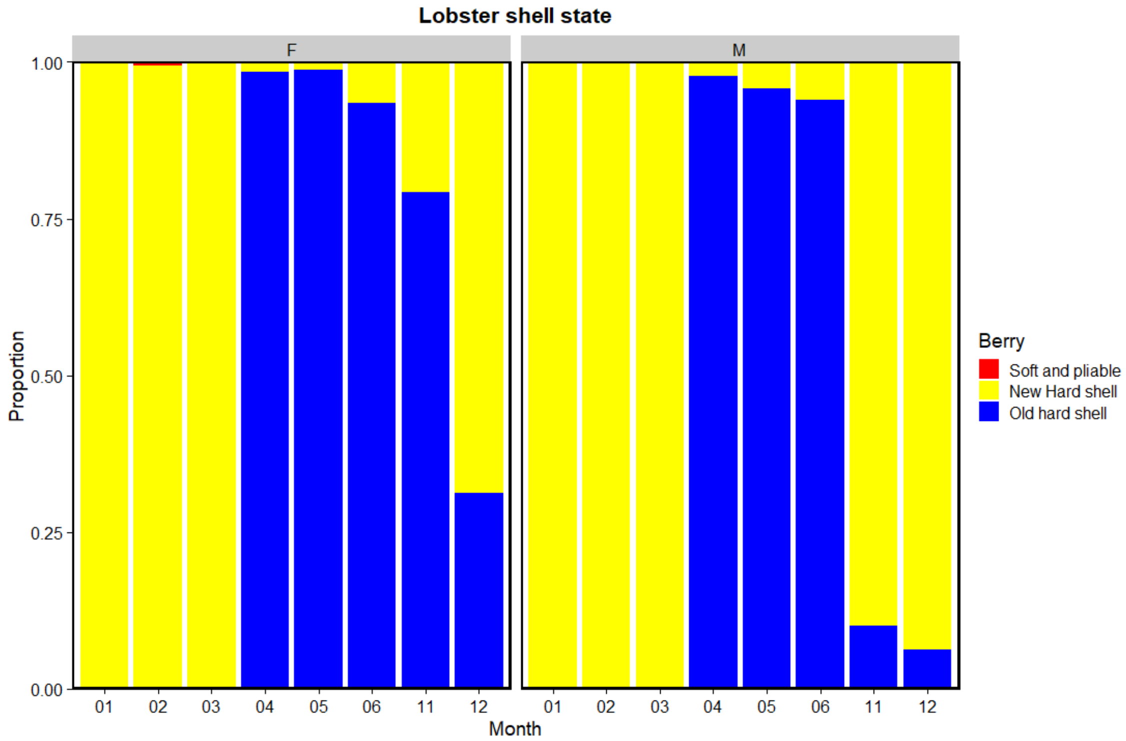


Figure 23: The monthly proportions of lobster shell state. Note only months with data are included.

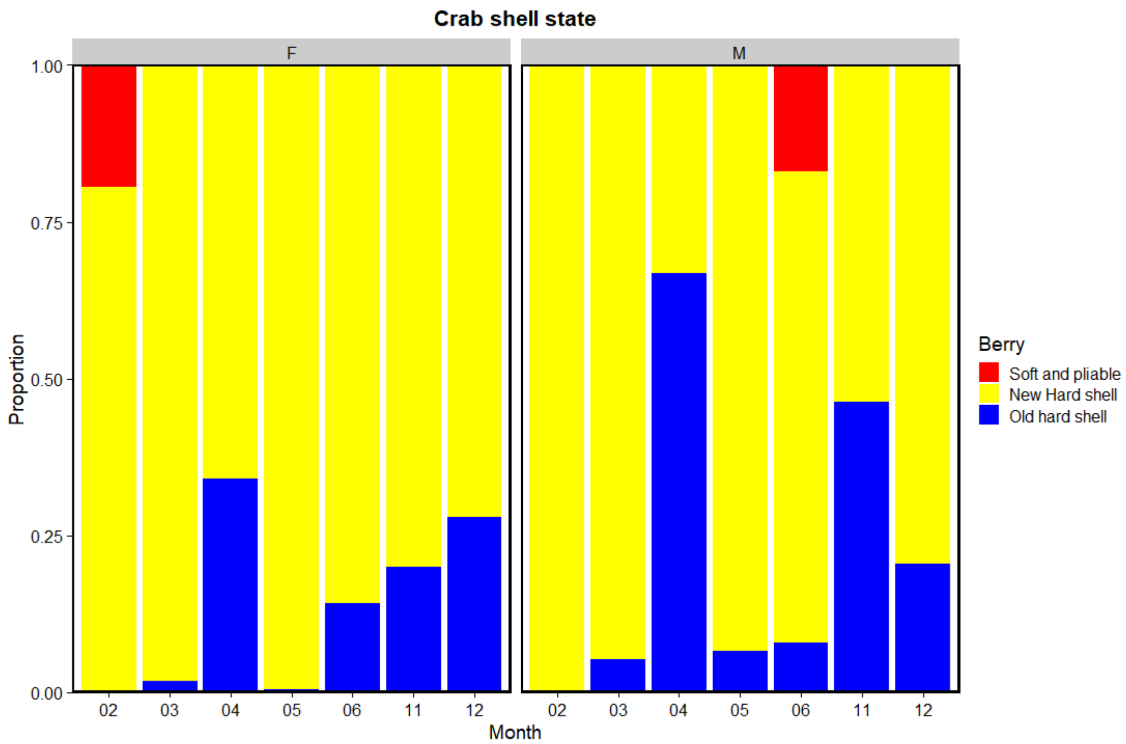


Figure 24: The monthly proportions of crab shell state. Note only months with data are included.

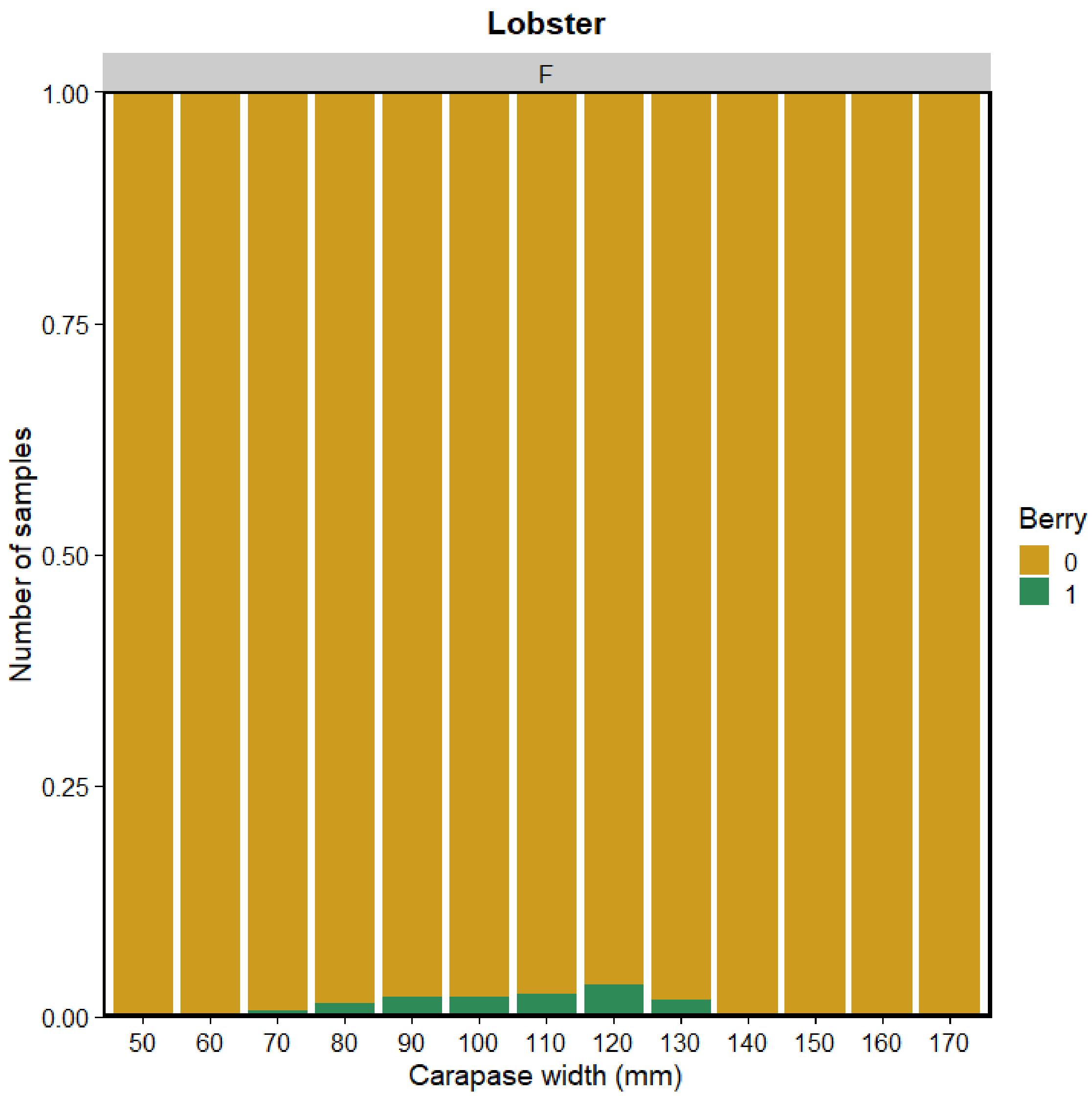


**Figure 25: The proportion of the catch of lobsters in berry by size class in the Cook Islands lobster fishery.**

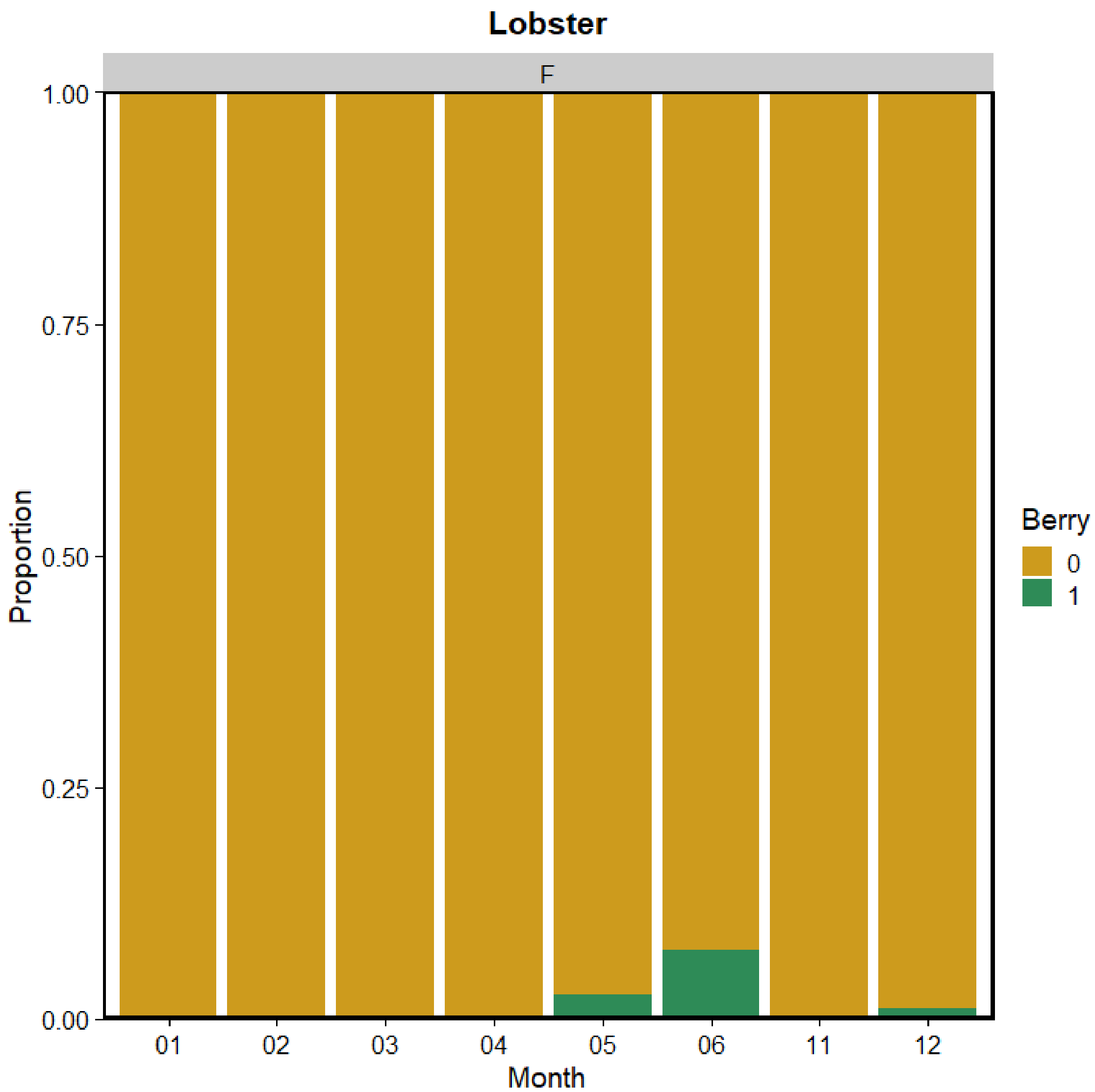


**Figure 26: The proportion of the catch of lobsters in berry by month class in the Cook Islands lobster fishery. Note only months with data are included.**

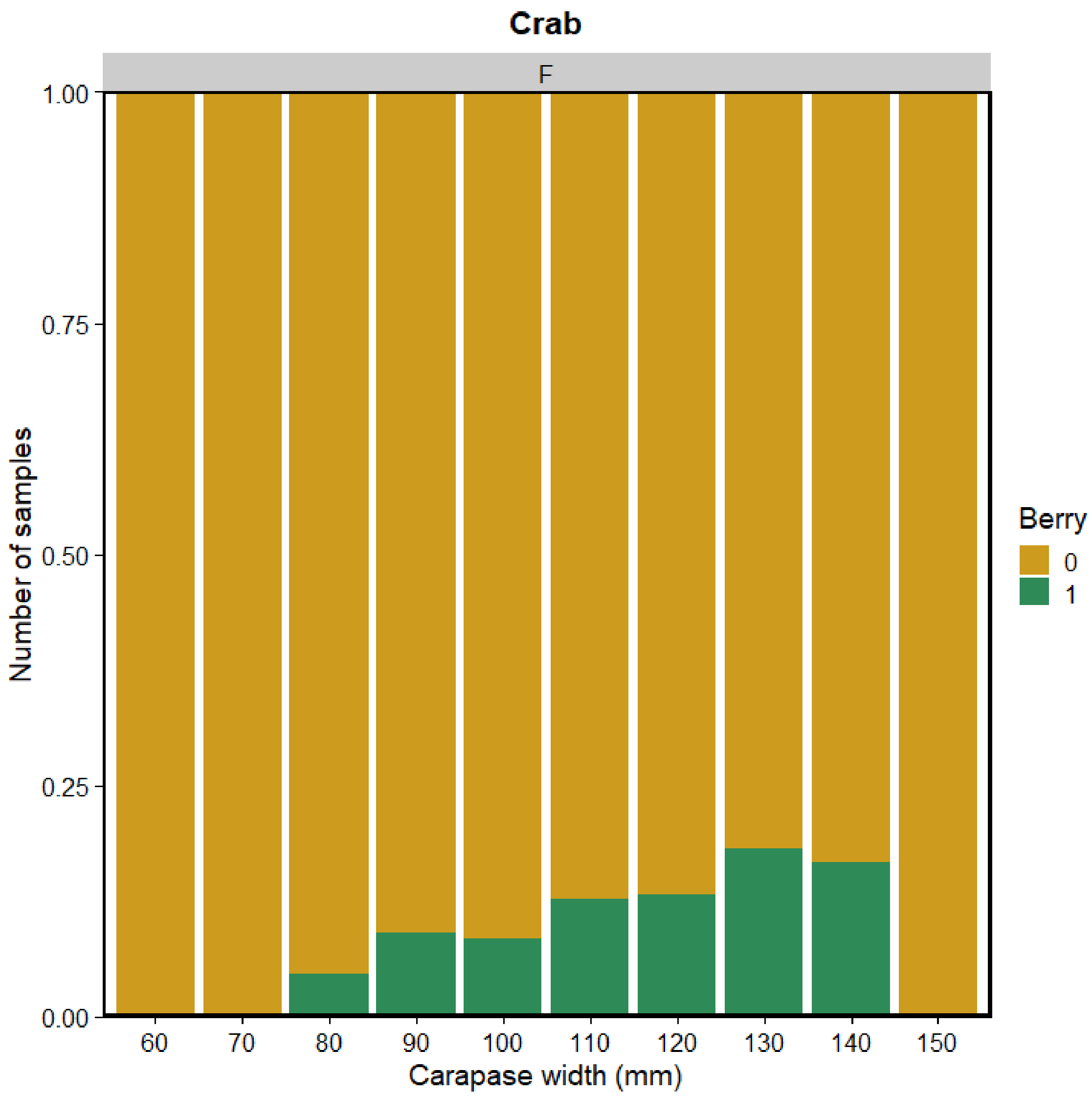


**Figure 27: The proportion of the catch of crabs in berry by size class in the Cook Islands lobster fishery.**

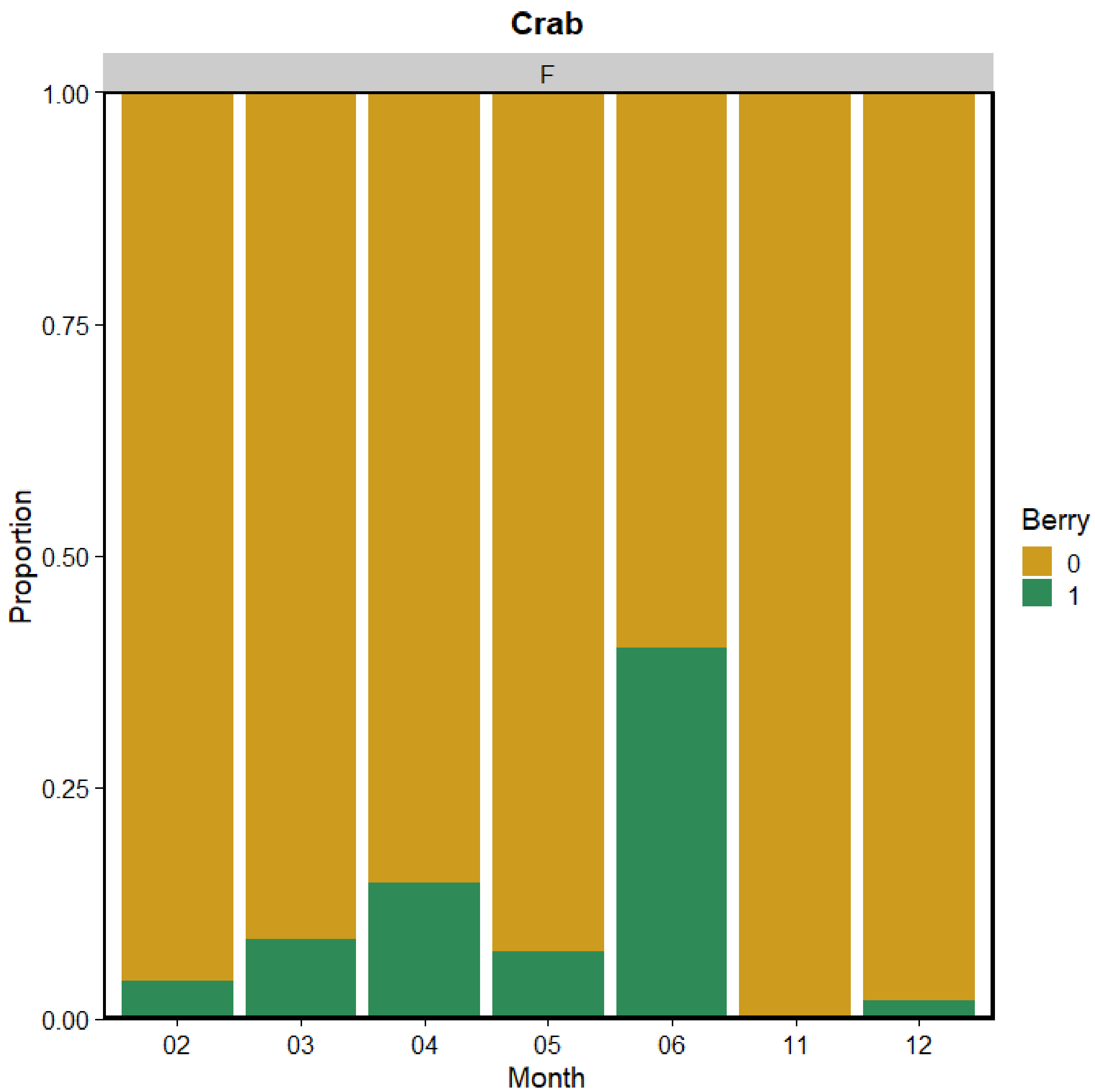


**Figure 28: The proportion of the catch of crabs in berry by month class in the Cook Islands lobster fishery. Note only months with data are included.**

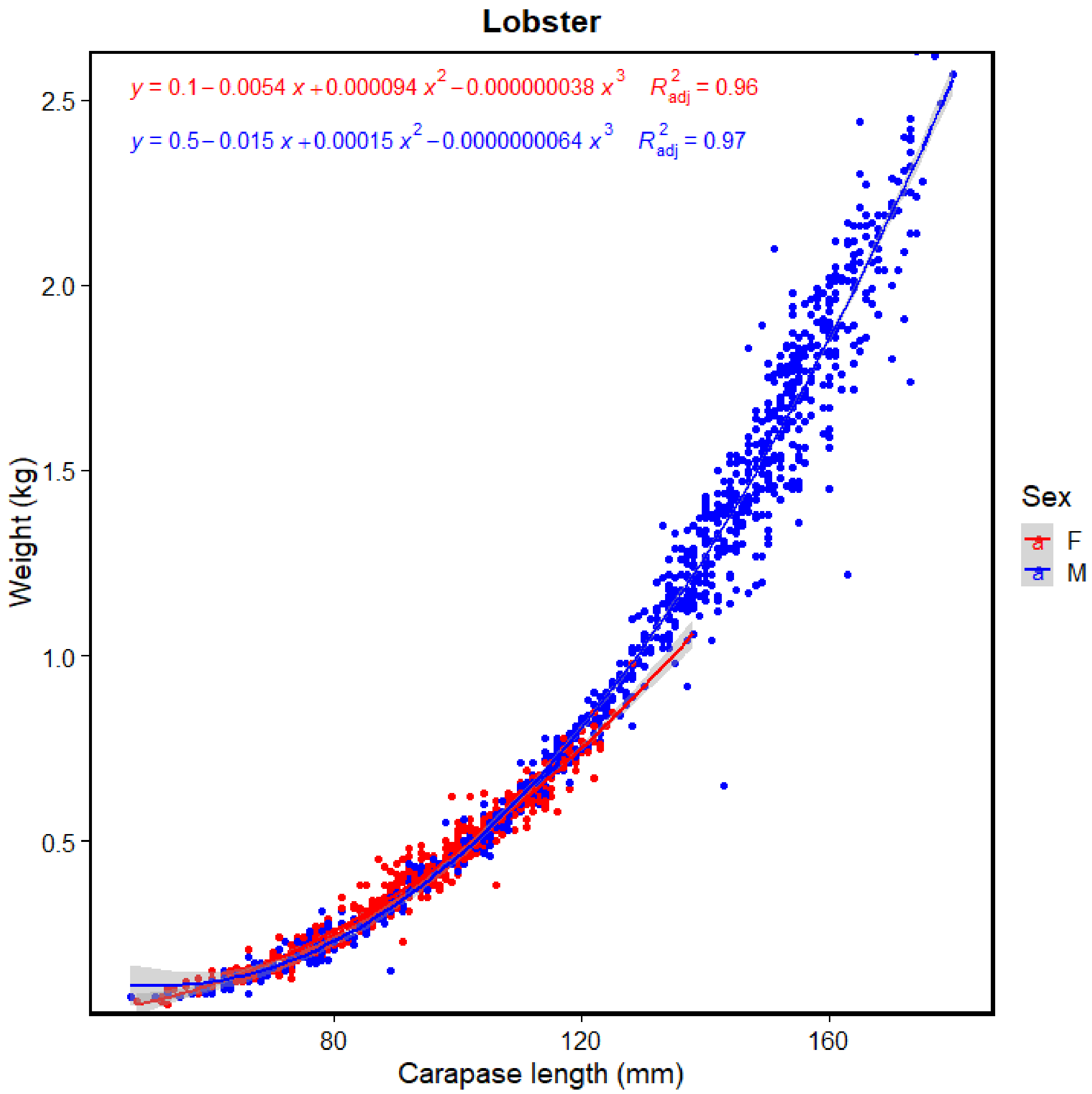


Figure 29: The length-weight relationship for lobsters in the Cook Islands SPRFMO trap fishery.

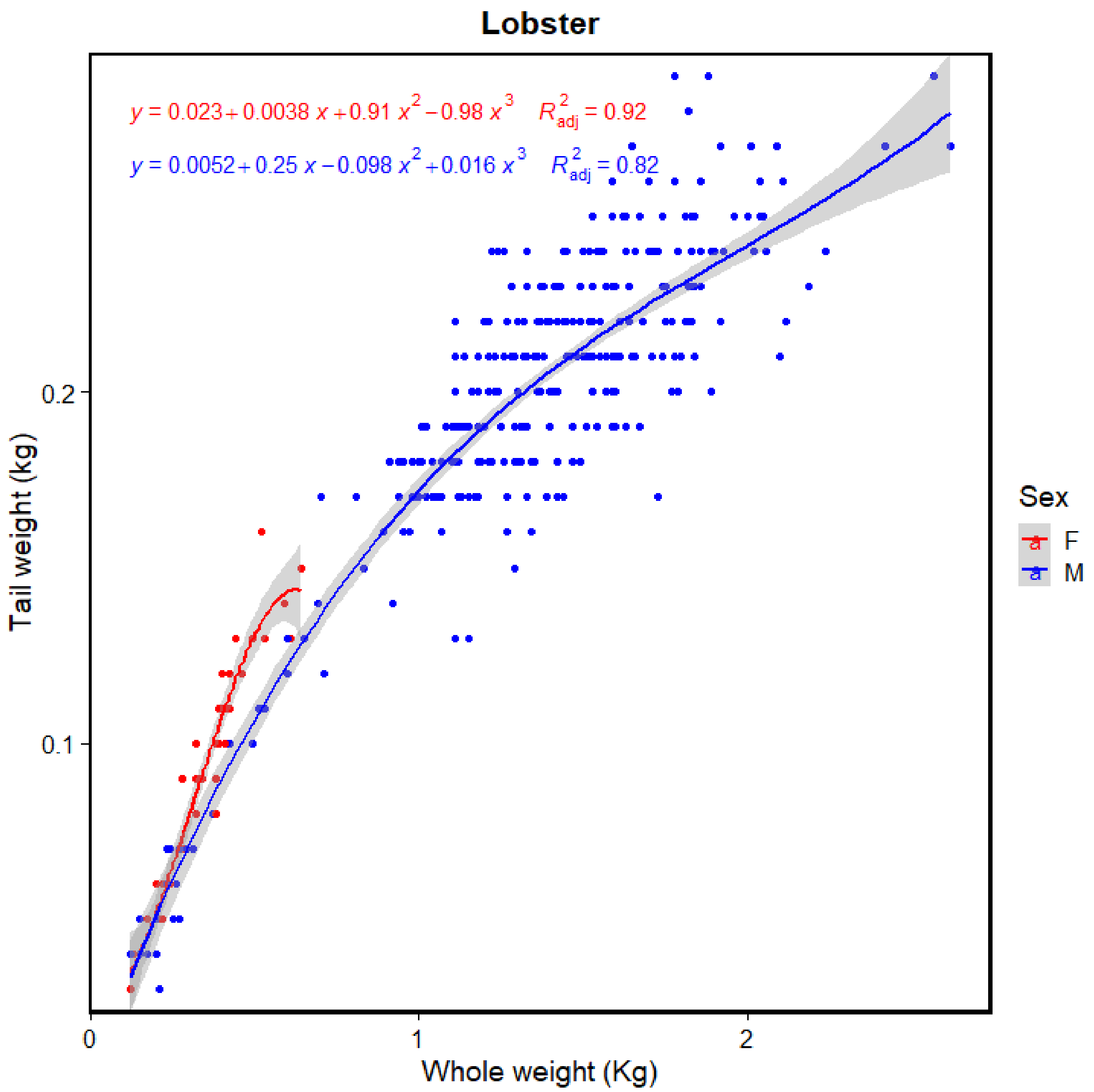


Figure 30: The whole weight-tail weight relationship for lobsters in the Cook Islands SPRFMO trap fishery.

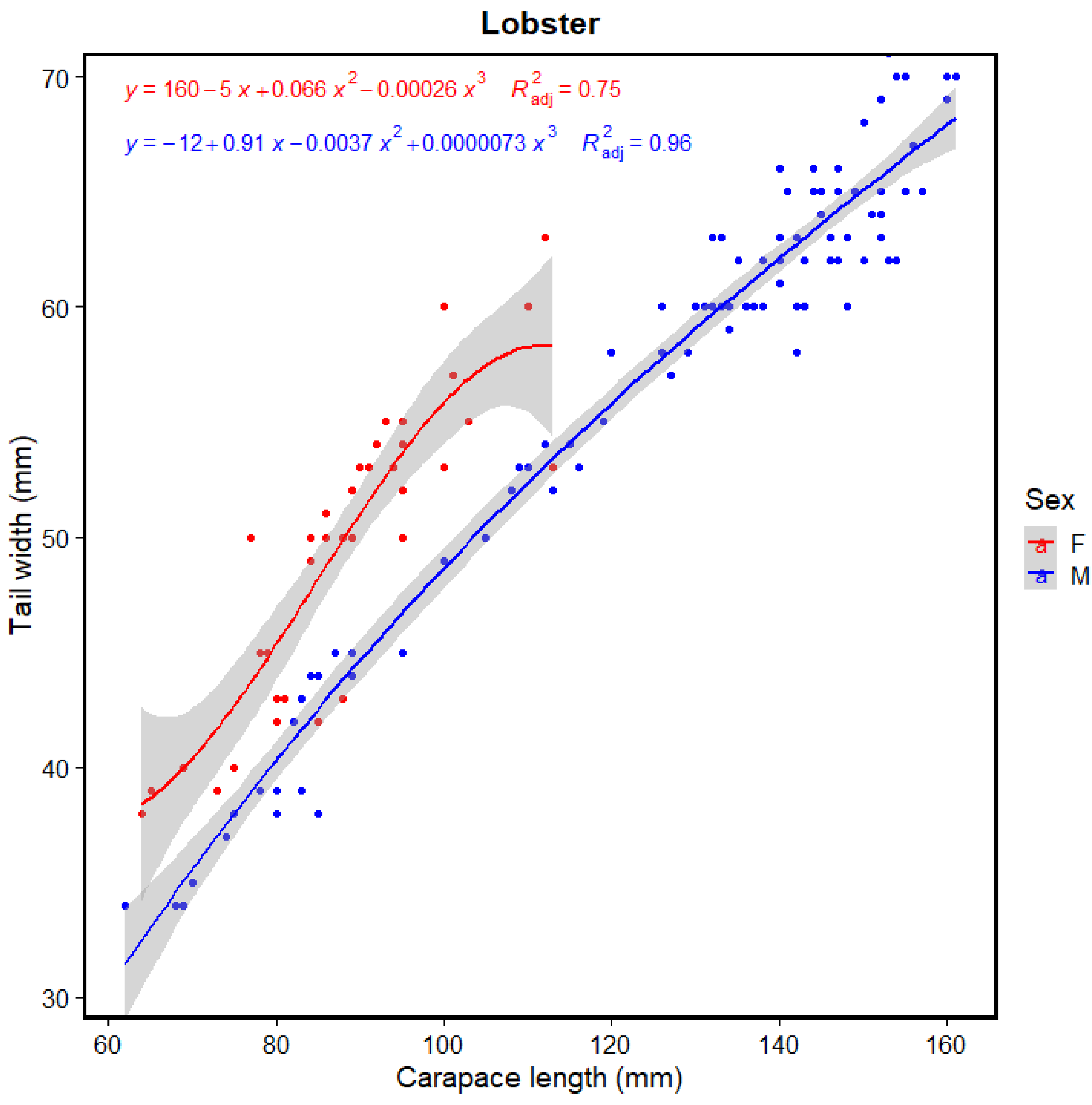


**Figure 31: The carapace length tail width relationship for lobsters in the Cook Islands SPRFMO trap fishery.**

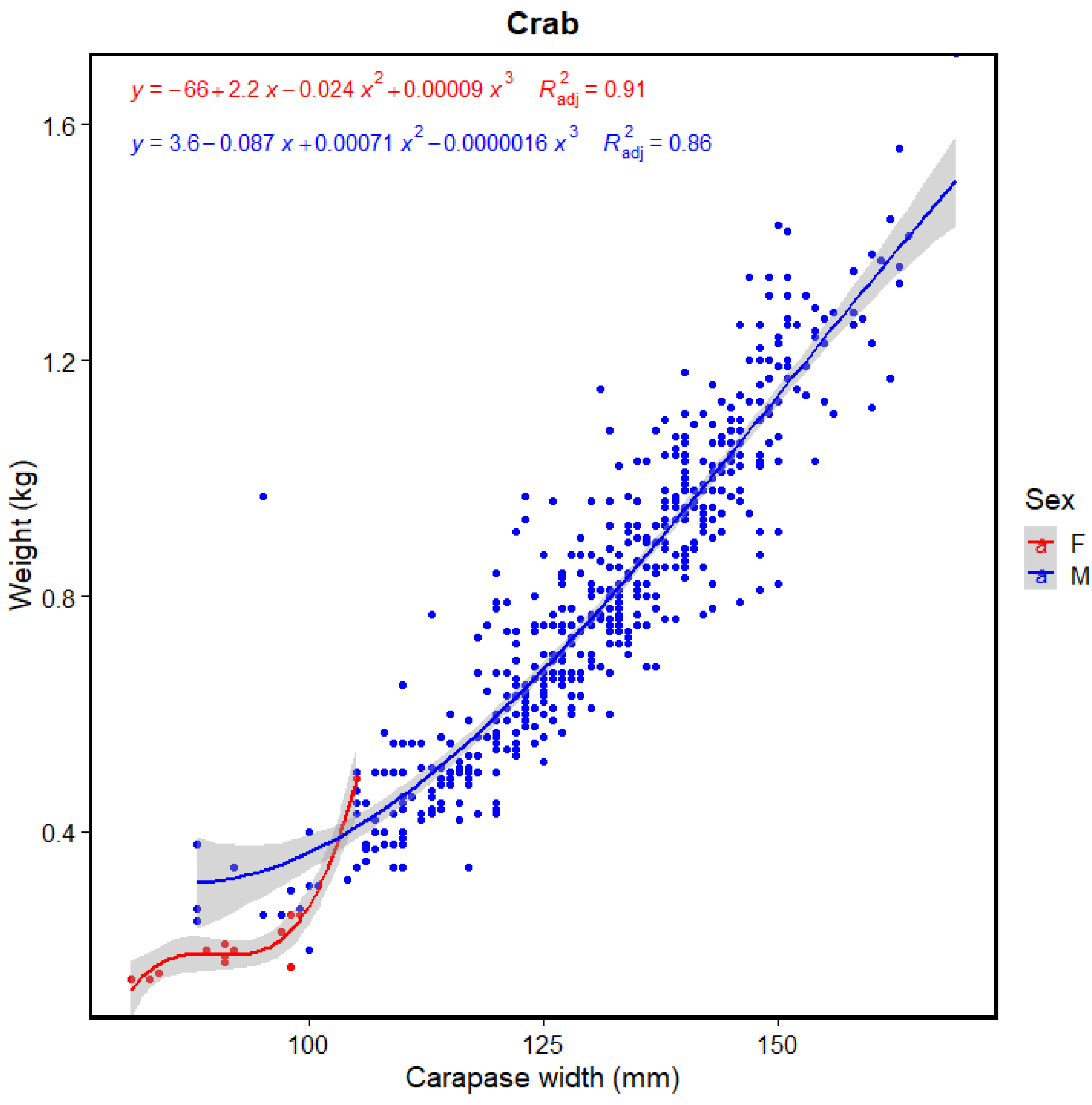


**Figure 32: The length weight relationship for crabs in the Cook Islands SPRFMO trap fishery.**

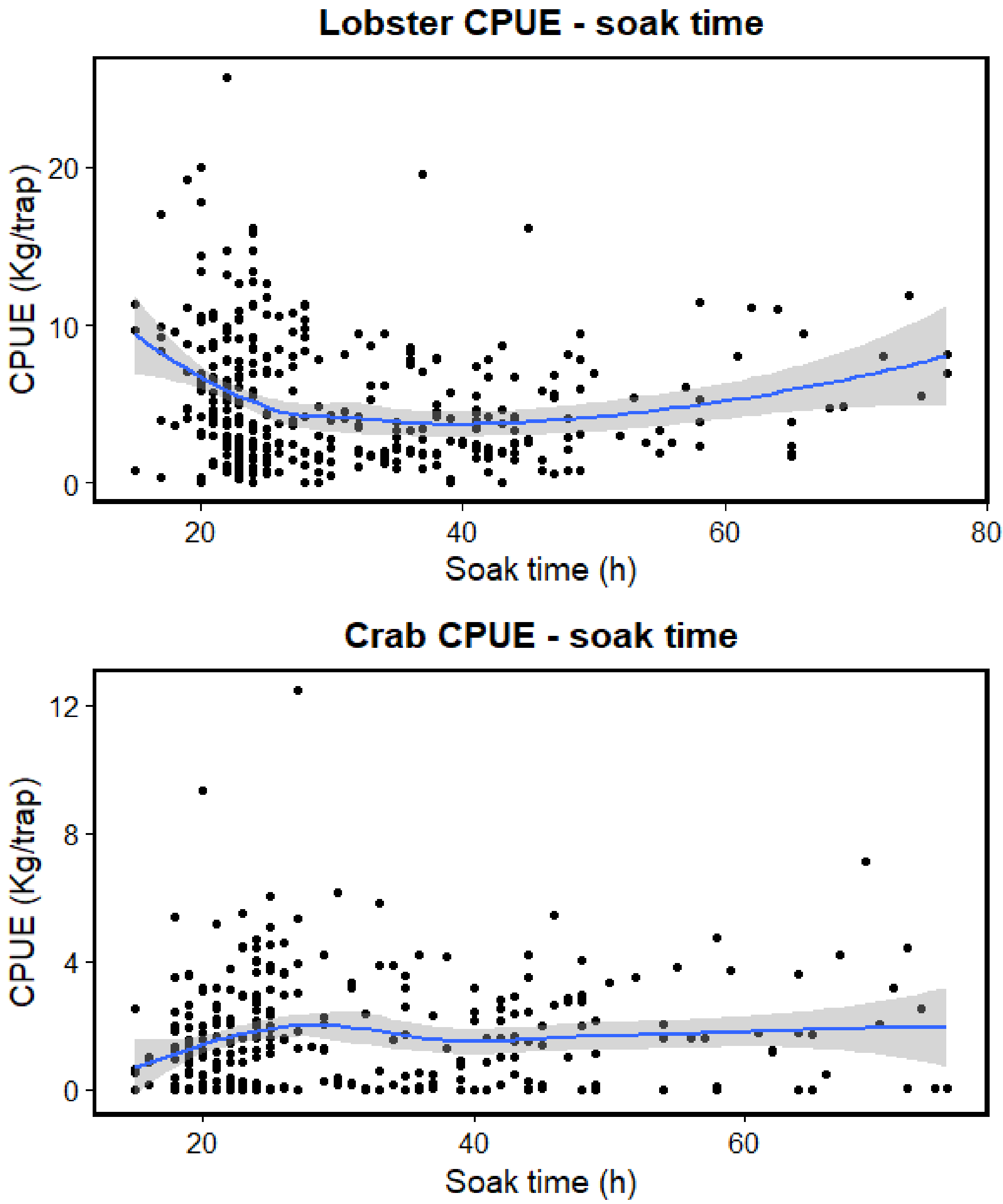


**Figure 33:** Catch tare relative to the trap soak time for lobsters (top) and crabs (bottom).

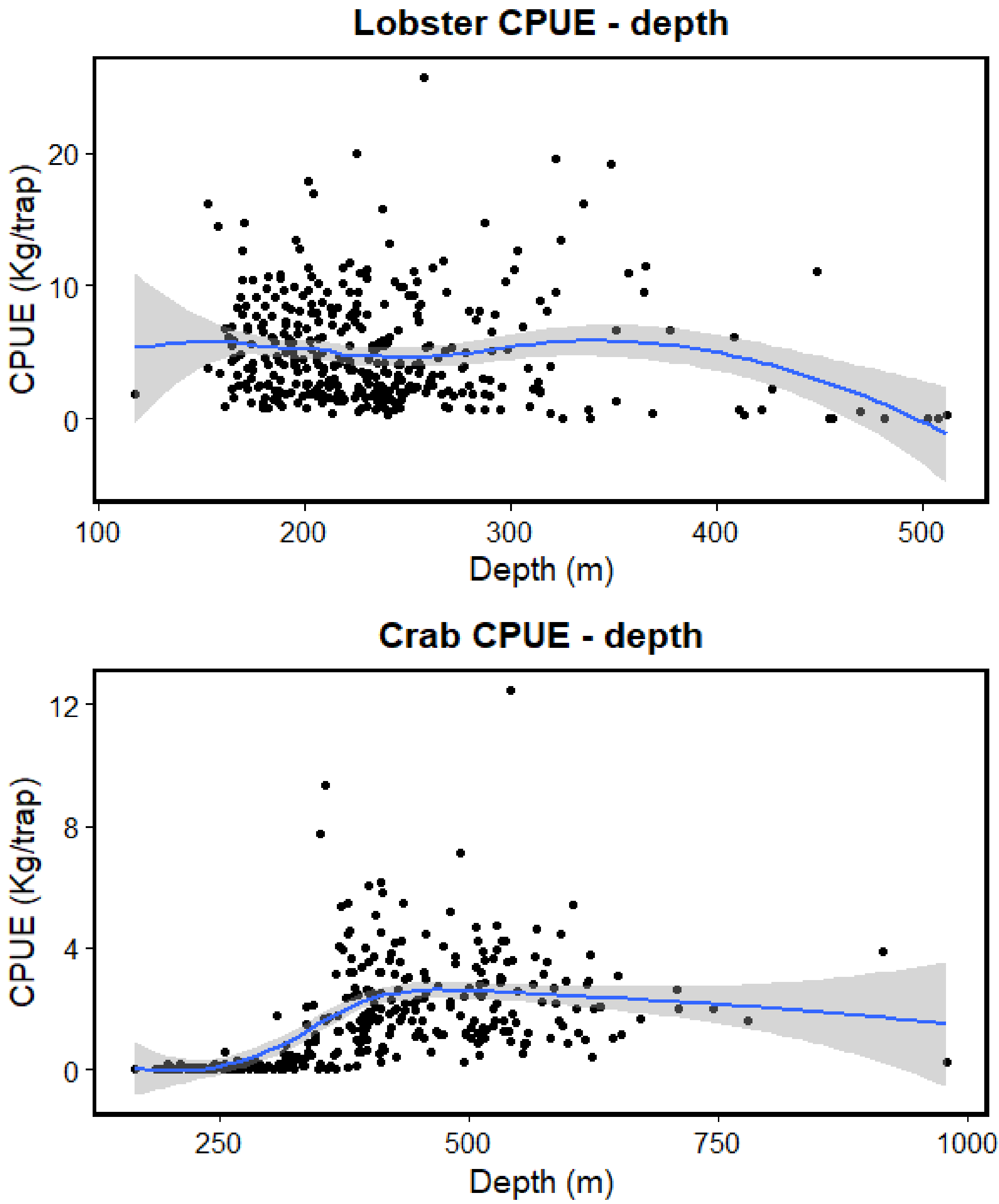


**Figure 34: Catch rate relative to the trap depth for lobsters (top) and crabs (bottom).**

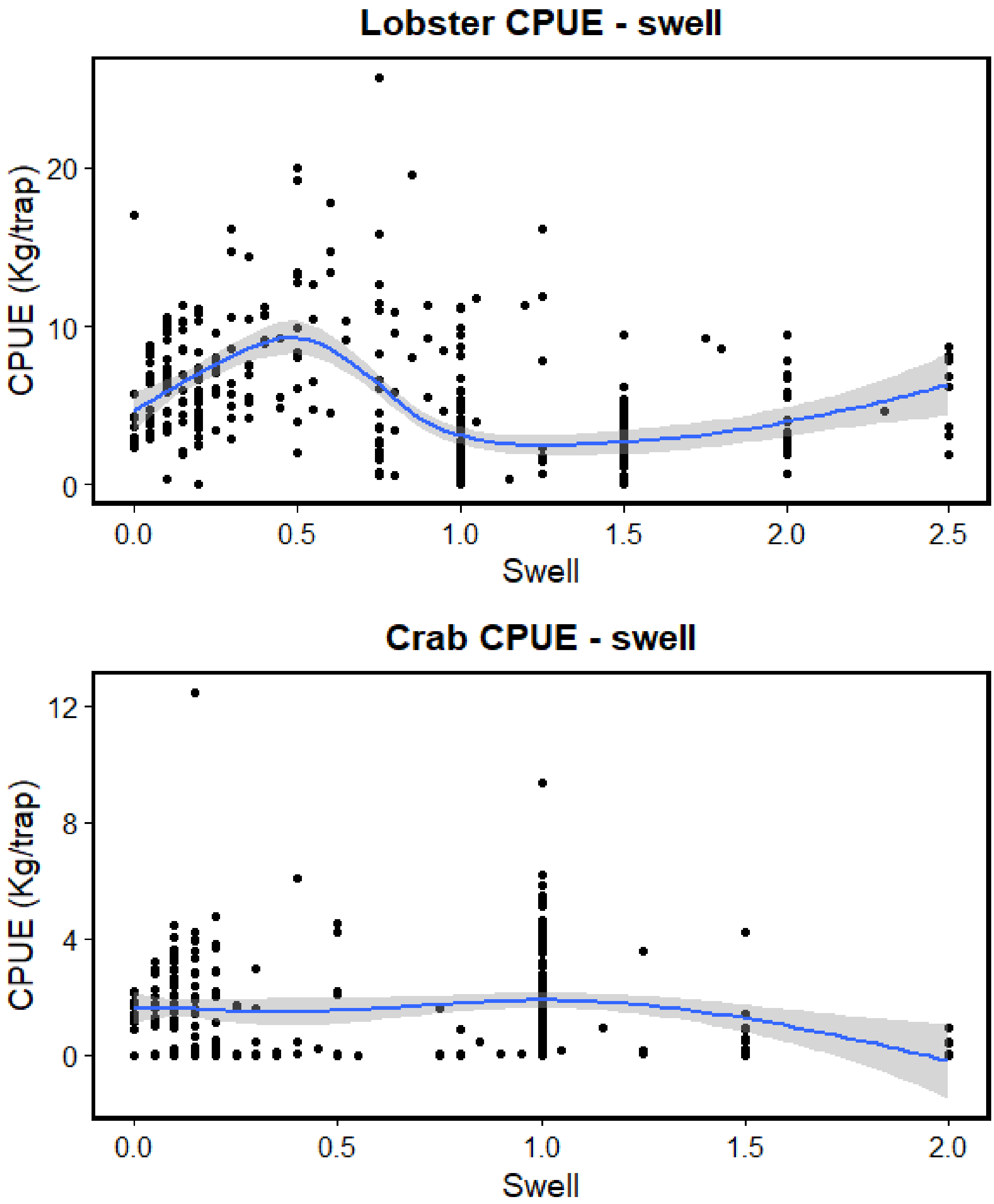


**Figure 35: Catch rate relative to the mean swell measured at setting and hauling for lobsters (top) and crabs (bottom).**

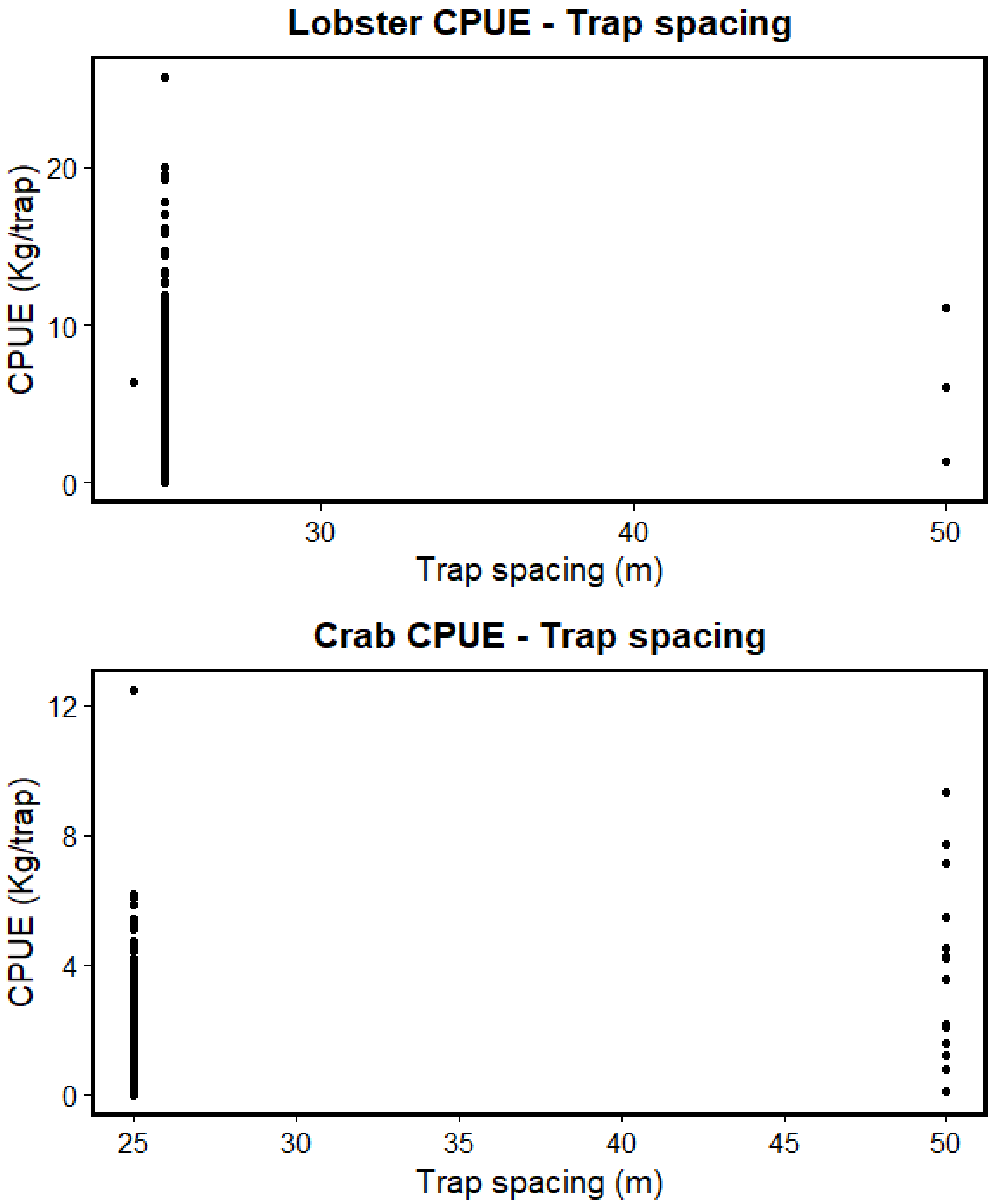


**Figure 36: Catch rate relative to the trap spacing setting and hauling for lobsters (top) and crabs (bottom).**

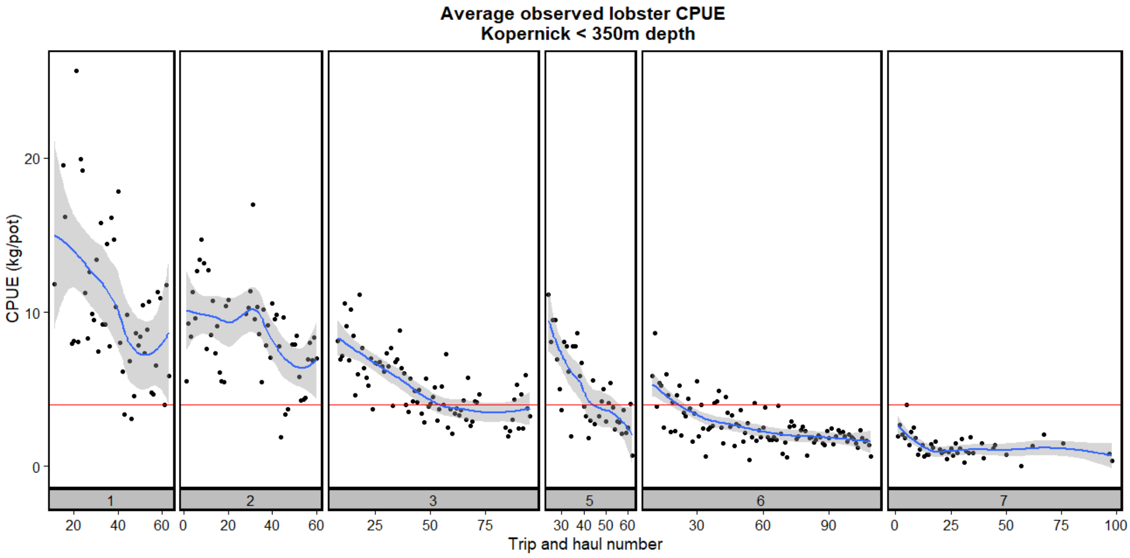


**Figure 37: The raw daily catch per unit effort (Kg/trap) of lobsters at Kopernick seamount from the Cook Islands trap fishery. Red line represents 4kg/trap.**

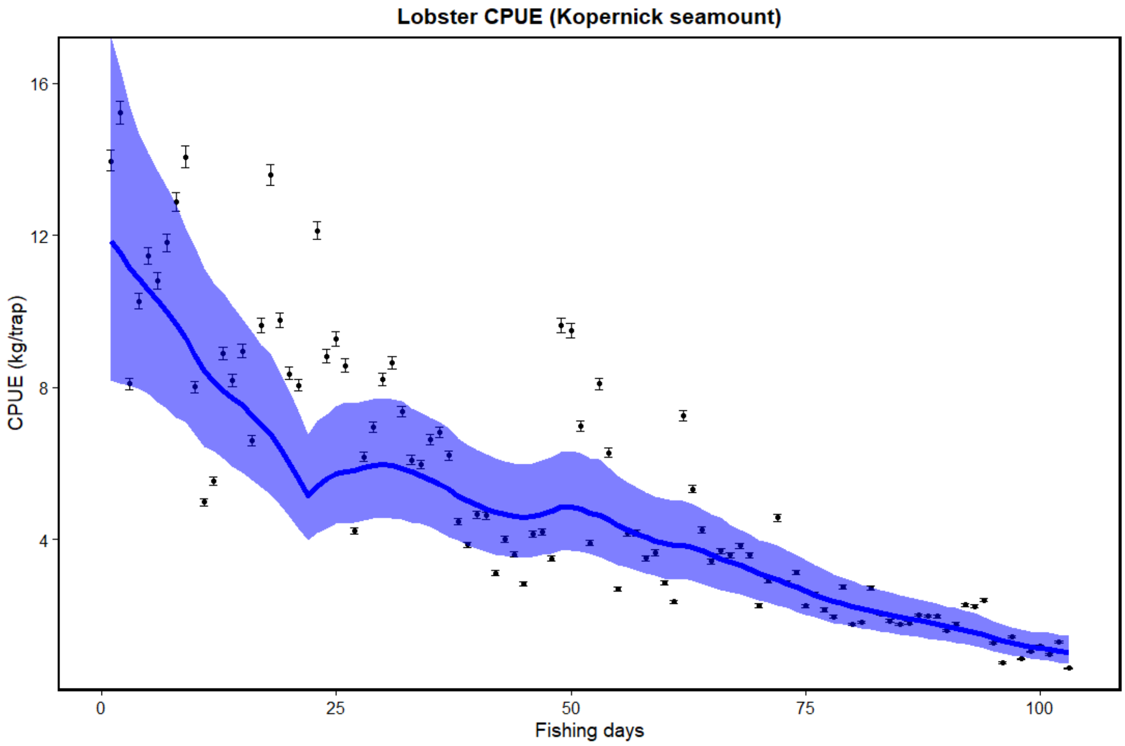


**Figure 38: The standardised daily catch per unit effort (Kg/trap) of lobsters at Kopernick seamount from the Cook Islands trap fishery. Showing the weekly mean and standard deviation (points and error bars), the modelled trend (blue line) and the 95$^{th}$ percentile (blue shaded area).**

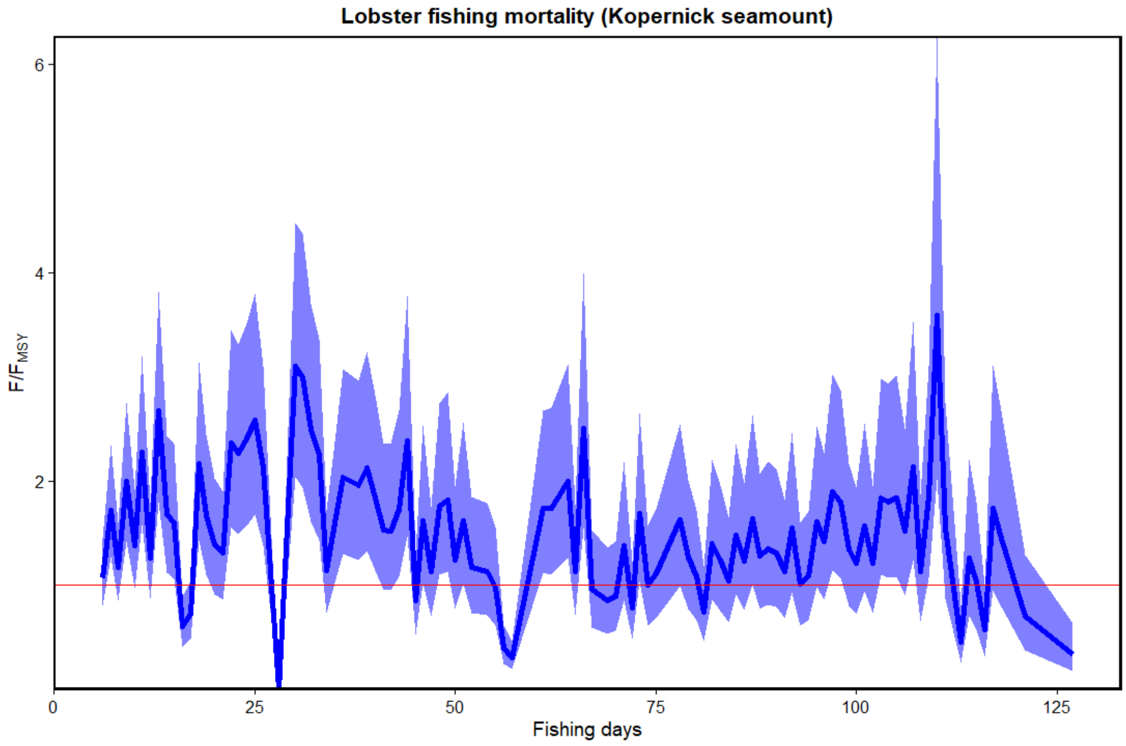


Figure 39: The estimated trends in fishing mortality relative to the fishing mortality that will achieve maximum sustainable yield (blue line) and the $95^{th}$ percentile (blue shaded area).

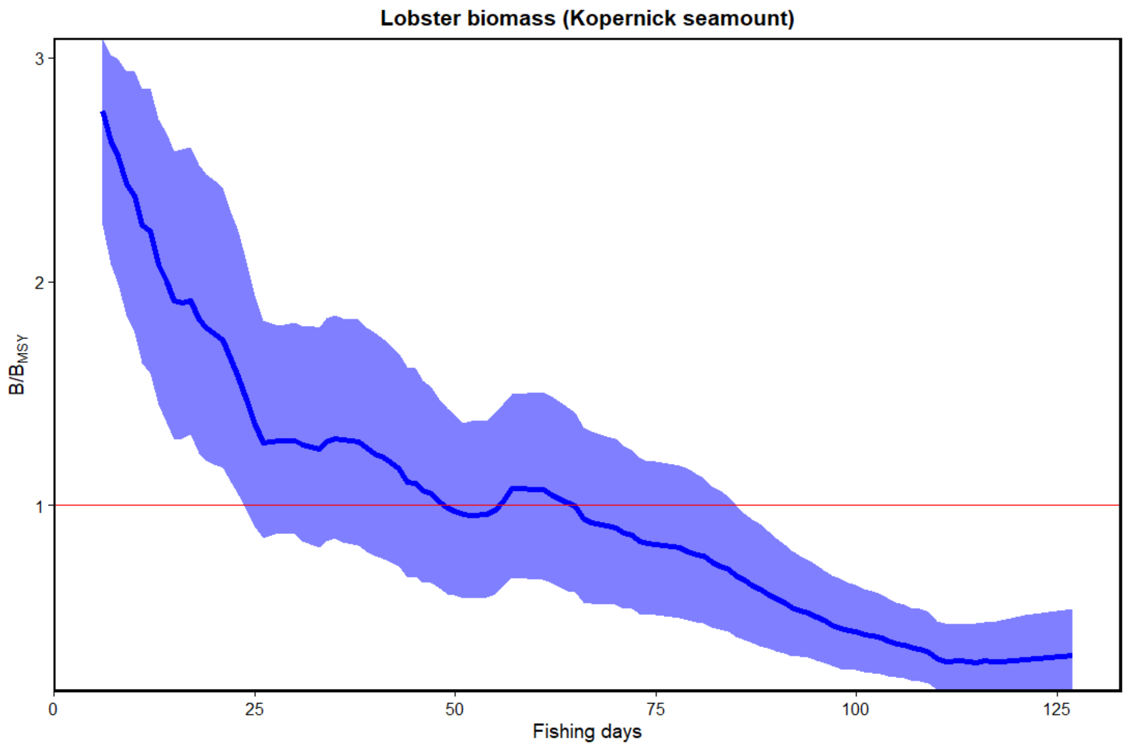


Figure 40: The estimated trends in adult biomass relative to the biomass at maximum sustainable yield (blue line) and the $95^{th}$ percentile (blue shaded area).

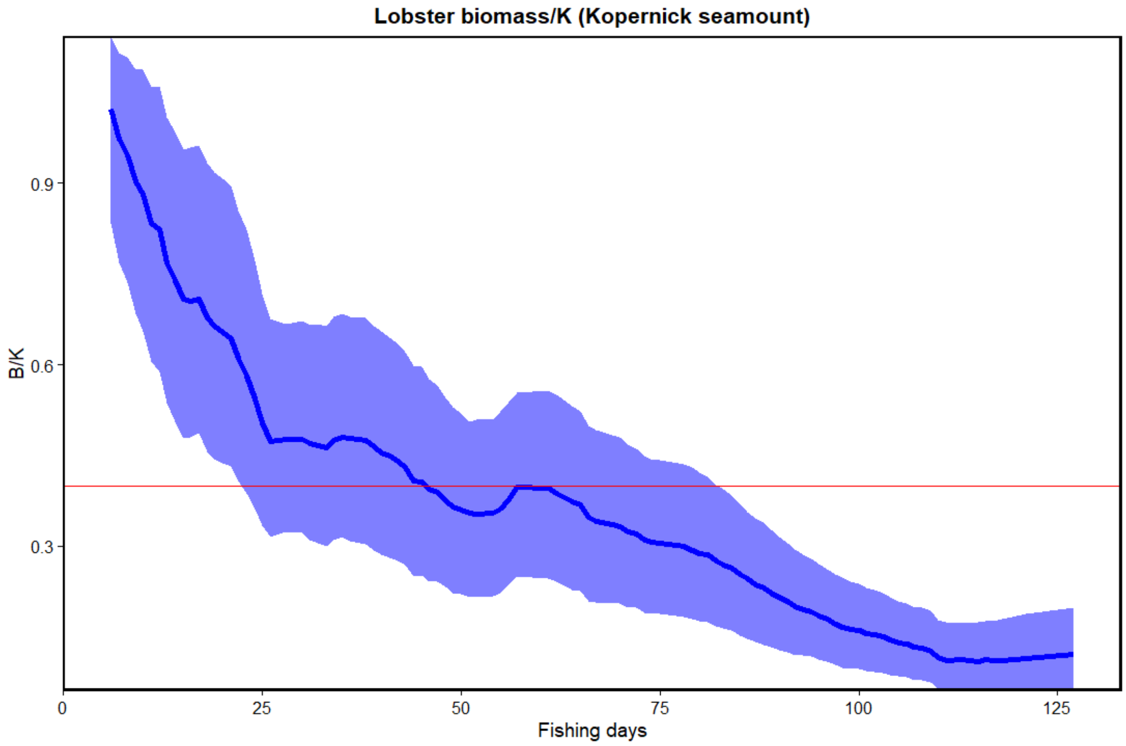


Figure 41: The estimated trends in adult biomass relative to the carrying capacity yield (blue line) and the 95$^{th}$ percentile (blue shaded area).

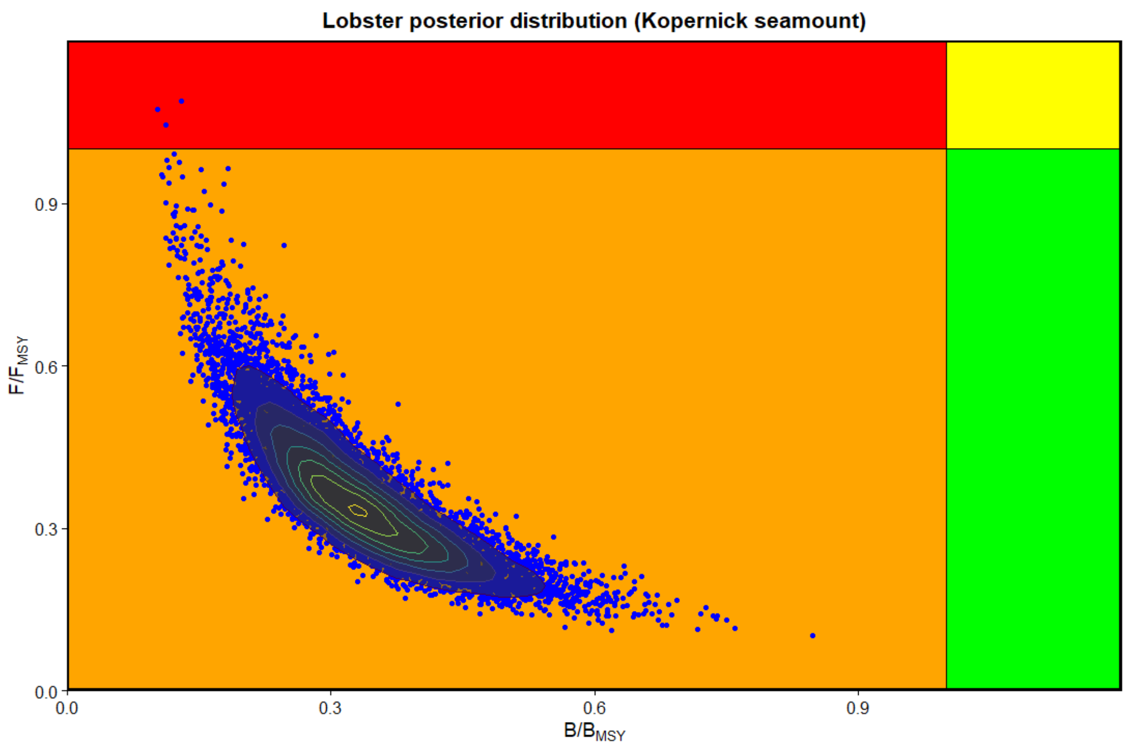


Figure 42: The modelled posterior distributions for 1,000 model runs from a JABBA surplus production model showing the fishing mortality and biomass relative to MSY at the end of the series.

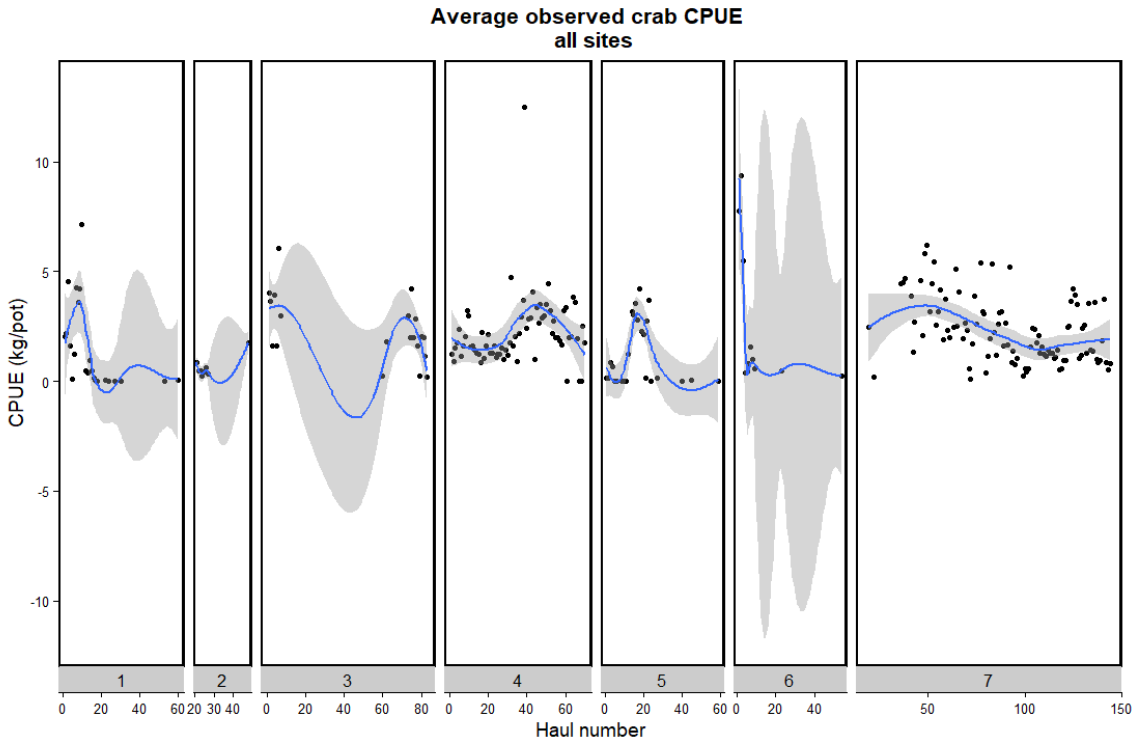


Figure 43: The raw daily catch per unit effort (Kg/trap) of crabs in the SPRFMO area from the Cook Islands trap fishery.

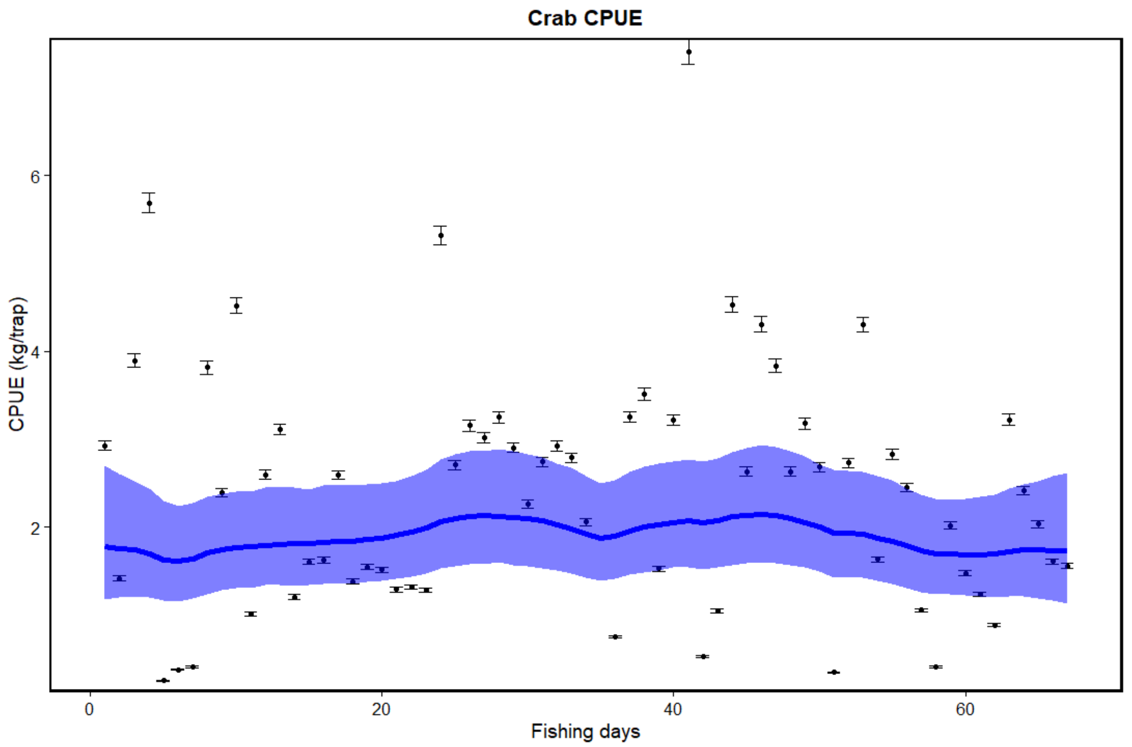


Figure 44: The standardised daily catch per unit effort (Kg/trap) of crabs in the SPRFMO area from the Cook Islands trap fishery. Showing the weekly mean and standard deviation (points and error bars), the modelled trend (blue line) and the $95^{th}$ percentile (blue shaded area).

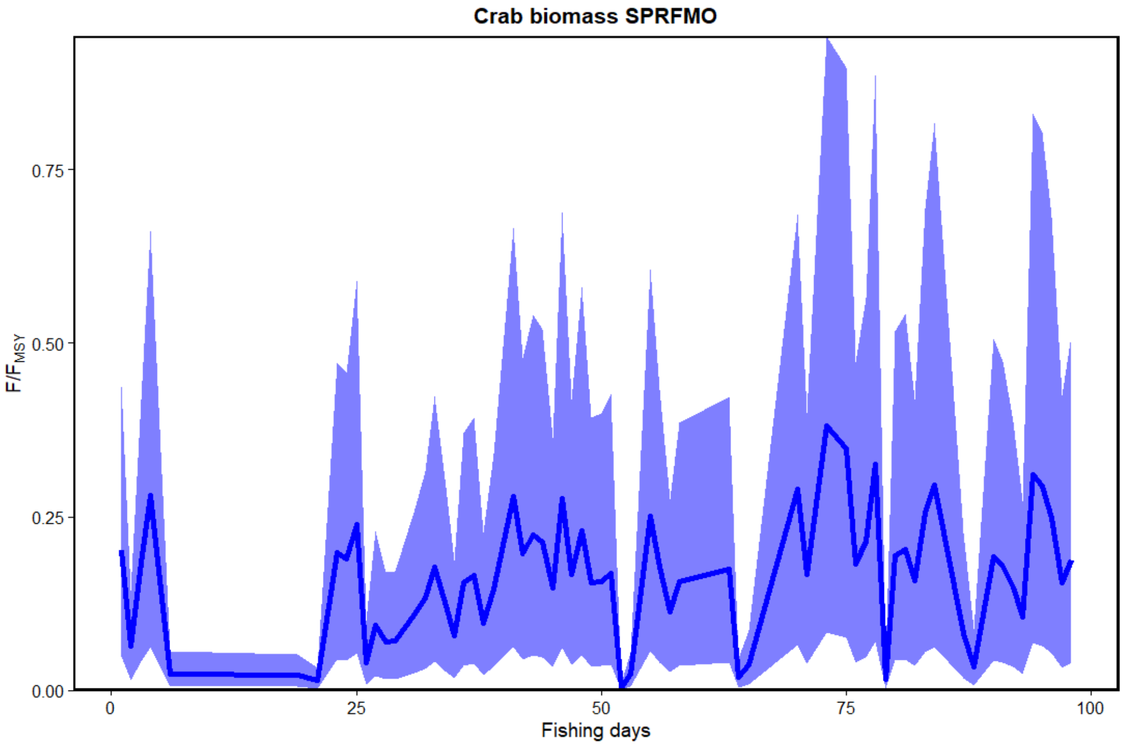


Figure 45: The estimated trends in fishing mortality relative to the fishing mortality that will achieve maximum sustainable yield (blue line) and the 95$^{th}$ percentile (blue shaded area).

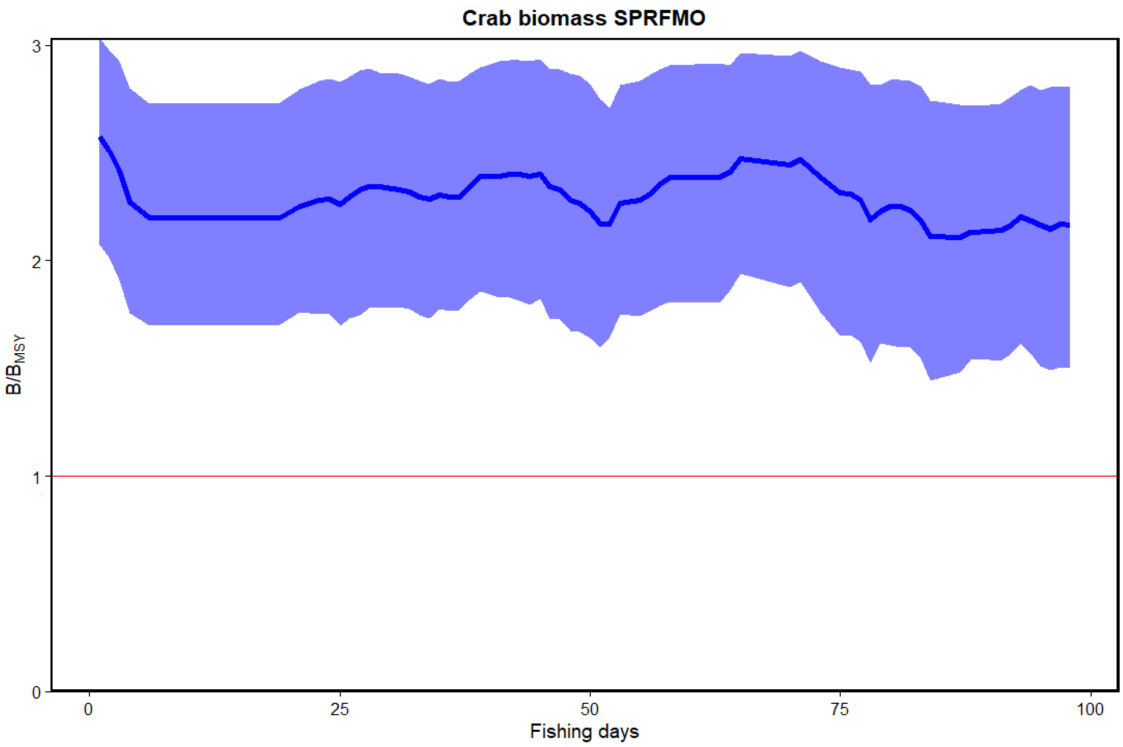


Figure 46: The estimated trends in adult biomass relative to the biomass at maximum sustainable yield (blue line) and the 95$^{th}$ percentile (blue shaded area).

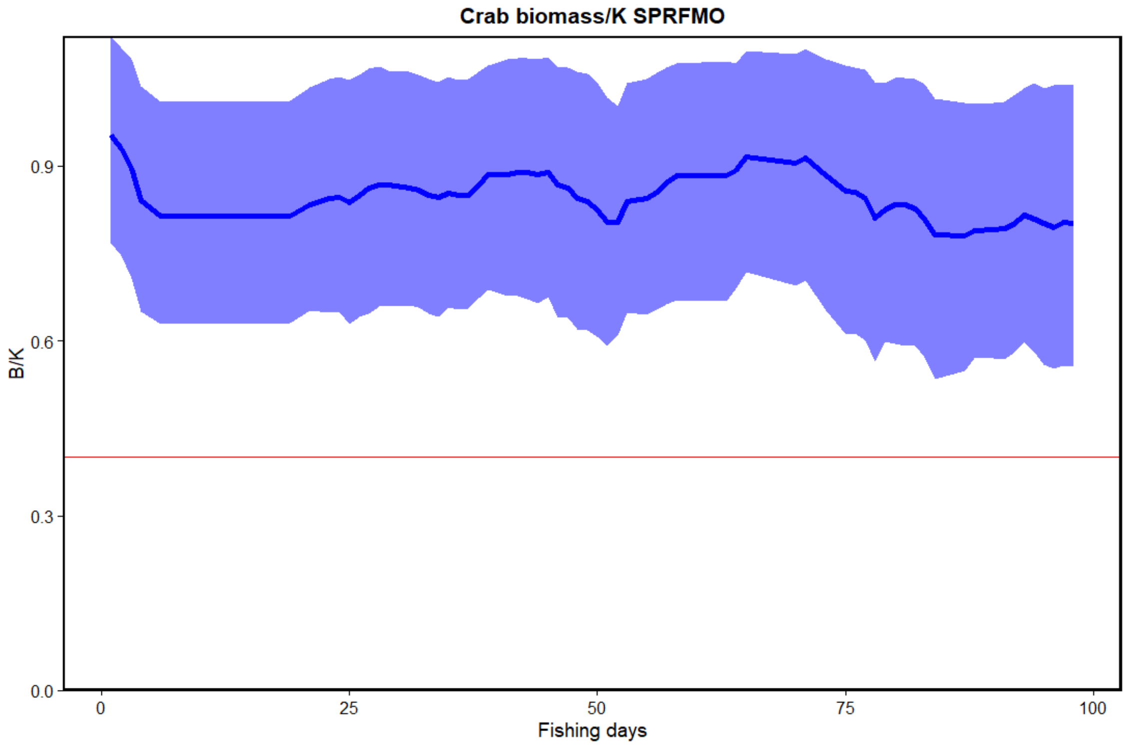


**Figure 47: The estimated trends in adult biomass relative to the carrying capacity yield (blue line) and the 95$^{th}$ percentile (blue shaded area).**

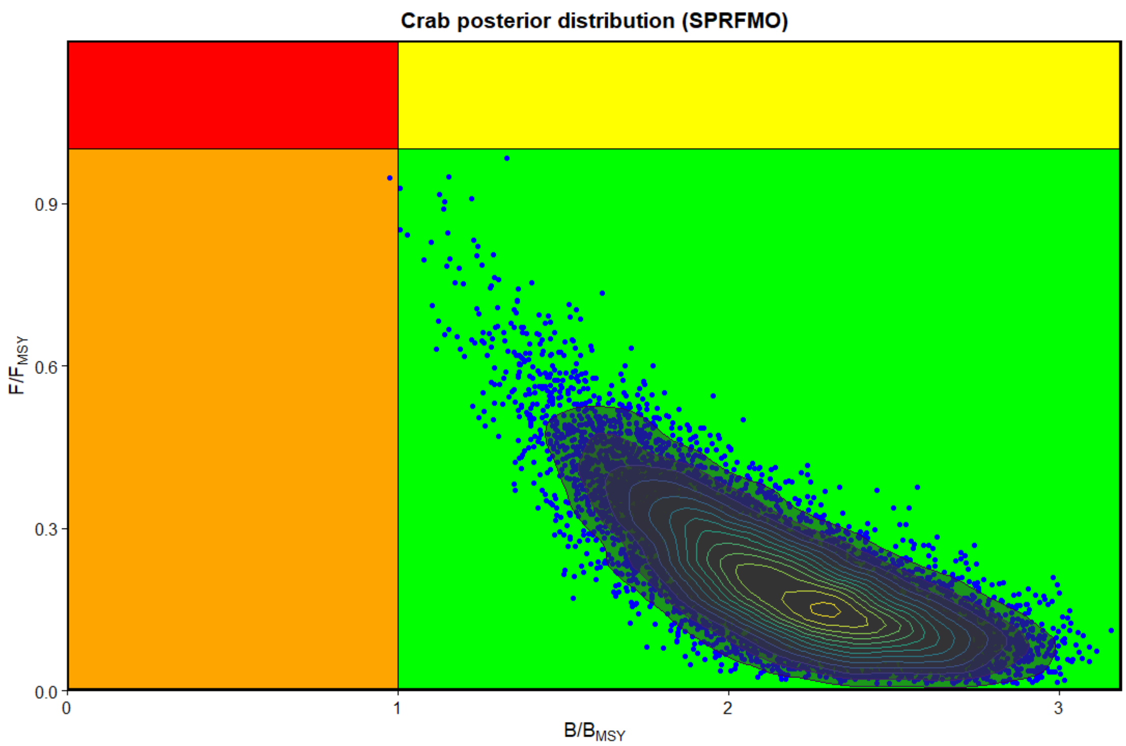


**Figure 48: The modelled posterior distributions for 1,000 model runs from a JABBA surplus production model showing the fishing mortality and biomass relative to MSY at the end of the series.**

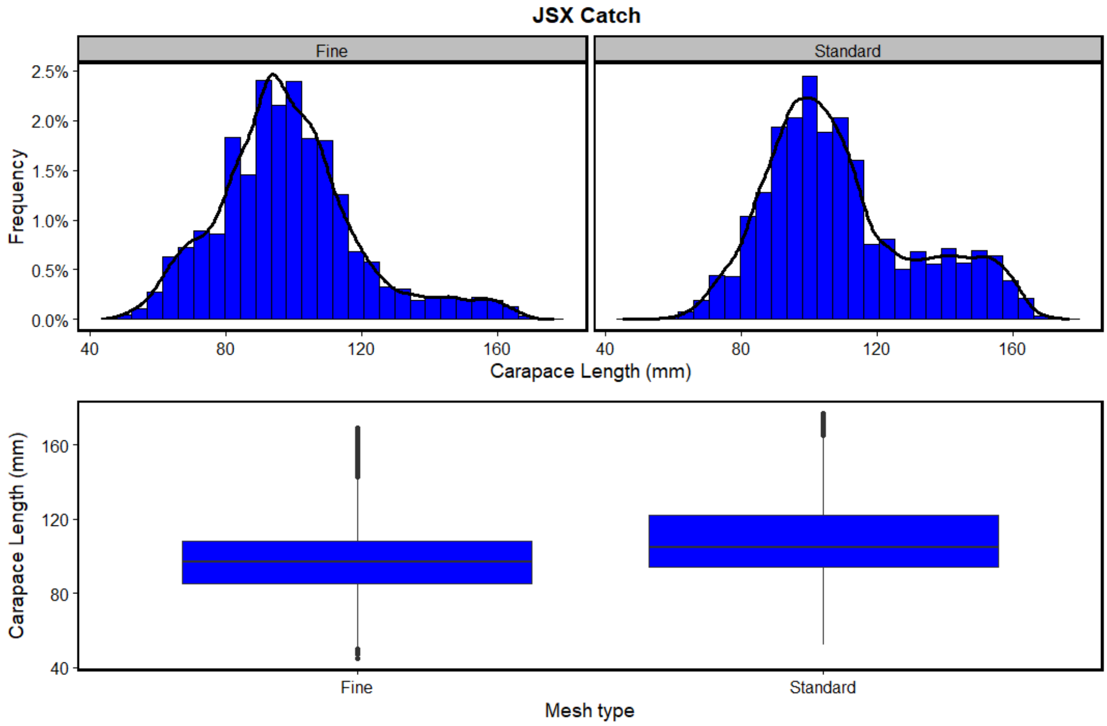


Figure 49: Lobster catch-at-size for separated into traps with fins mesh and standard mesh.

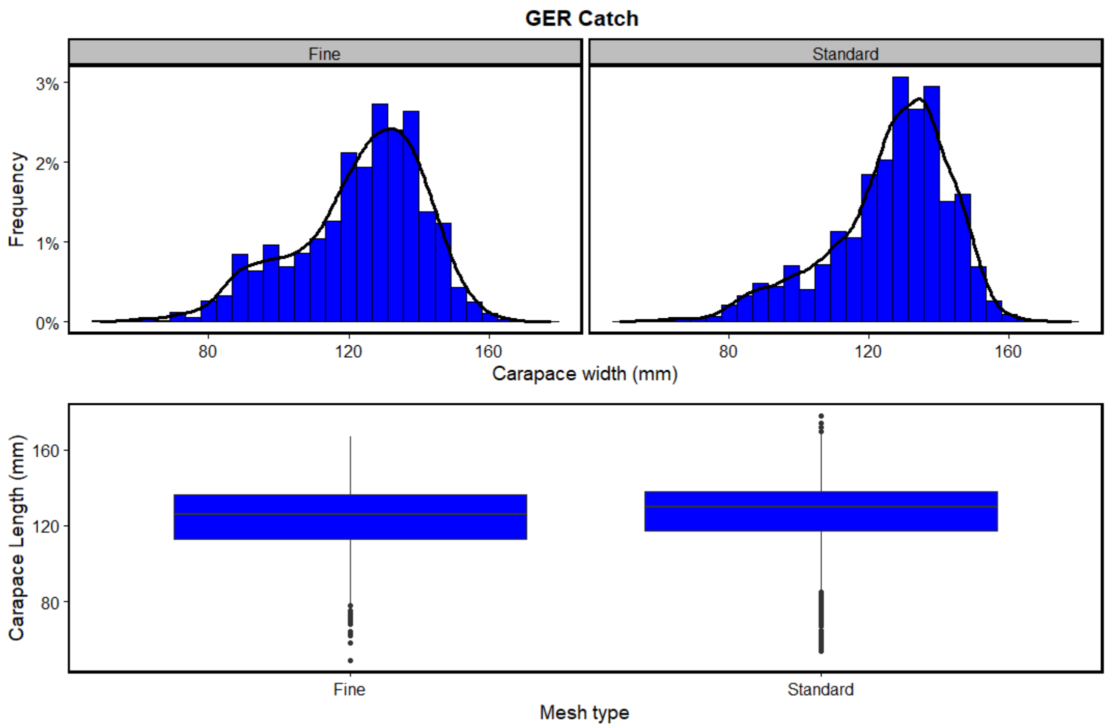


Figure 50: Crab catch-at-size for separated into traps with fins mesh and standard mesh.

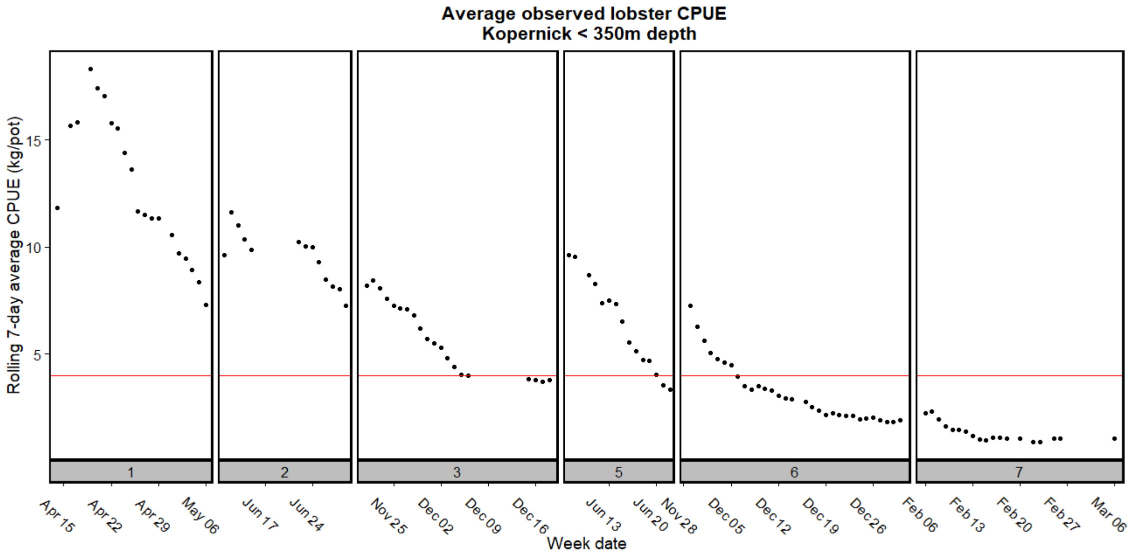


**Figure 51: Kopernick seamount rolling 7-day average CPUE from the Cook Islands trap fishery.**

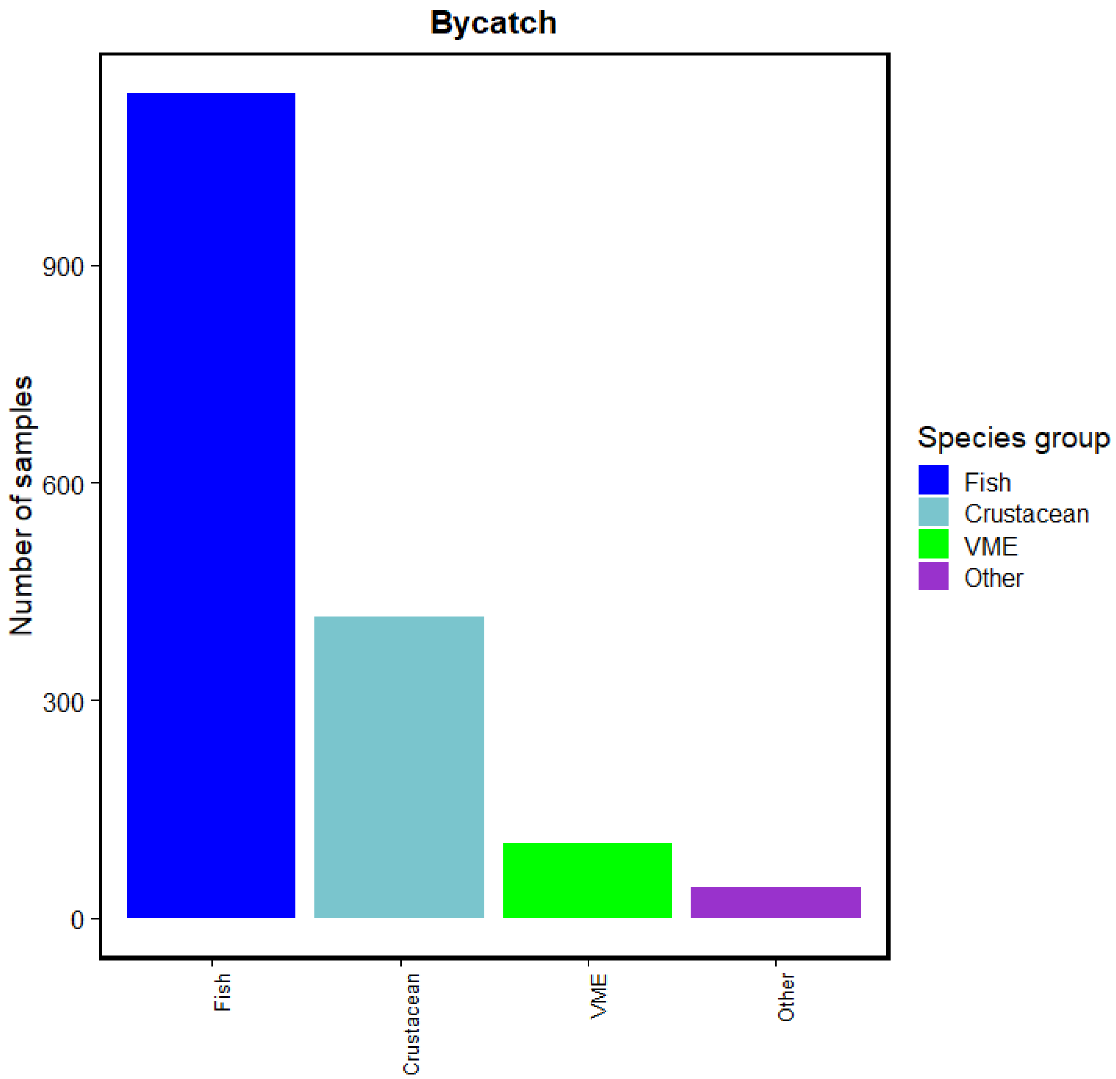


**Figure 52: Bycatch by species group from the Cook Islands trap fishery.**