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SC8-DW02

Cook Islands Exploratory Lobster Trap Fishing in the SPRFMO - Trips 1 to 4

Cook Islands

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Cook Islands exploratory lobster trap fishing in the SPRFMO - Trips 1 to 4

Stephen Brouwer[1], **Marino Wichman**[1,2], **Chloe Wragg**[1],
Alexander Epstein[3] and **Dave Japp**[4]

[1] Ministry of Marine Resources, Cook Islands

[2] Oceanic Fisheries Programme, The Pacific Community (SPC)

[3] Oceano Seafood

[4] CapMarine

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1 Executive Summary

The three-year program of exploratory trap fishing provided for by CMM14b-2018, and subsequently superseded by CMM14b-2020, has successfully completed three trips in 2019 and one in 2020. New biological information has been collected on *Jasus caveorum* and *Chaceon* sp. The key findings are that the fishery caught primarily lobster, *J. caveorum*, most of which were male ($\sim 60\%$), and that most females were not carrying eggs (in berry). This trip provided information on populations present, target stocks and marine ecosystems. These data are being used to evaluate the effectiveness of existing mitigation measures, to ensure that the bottom trap fishery is developed through a precautionary and gradual process, in accordance with the best available scientific information. 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. At this stage, it is intended that the revised Fishery Operational Plan MMR (2020) for the future of the exploratory fishery will be presented to SC-08 in 2020 for consideration and endorsement of continuing this exploratory fishery.

2 Purpose of paper

This paper provides SC-08 with an update on exploratory fishing for lobster and crab by the Cook Islands vessel *Altar 6* pursuant to CMM14b-2020. It also briefs the Committee on future directions of this operation and associated research and potential management arrangements.

3 Introduction

The Cook Islands submitted a proposal to the Commission of the South Pacific Regional Fisheries Management Organization (SPRFMO) Scientific Committee's 6^{th} meeting in 2018, SC-06, to carry out a three-year exploratory research programme, for the purpose of obtaining scientific information through exploratory fishing for lobster (*Jasus caveorum* and *Projasus* sp.) and crabs (*Chaceon* sp.) using benthic traps set on a longline within the SPRFMO Conservation Area. 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 2022. 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. (2020). The Scientific Committee assessed the Cook Islands proposal and its conformity with CMM14b-2019 and SC7:

- Noted that catch limits are being set without a lot of strong evidence and suggested that an experiment to estimate the density of lobster and directly estimate the biomass and estimate exploitation rate could provide evidence to support the setting of the catch limits.
- Agreed that the approach outlined in the revised Fisheries Operation Plan was likely to ensure that the exploratory fishery is developed consistently with its nature as an exploratory fishery, and consistently with the objectives of Article 2 of the Convention..
- Recommended that the SPRFMO Commission extend the expiry date of CMM 14b-2019 to 2022, aligning the CMM to the start of fisheries operations.

The SPRFMO Compliance and Technical Committee and Commission considered the proposal in 2020 and approved a 2-year exploratory fishery with a combined total allowable catch limit of 300 tonnes per year.

The fishery design work is ongoing and four trips have been conducted by the Cook Islands demersal longline vessel *Altar 6* between March 2019 and July 2020. Preliminary results from these trips are presented in this document and its predecessor (Brouwer et al., 2019).

4 Methods and Results

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. (2020).

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 vessel had two observers, a Cook Islands national observer and an international observer. 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. Note that on Trip 4 experimental trap setting only was undertaken on Kopernik Seamount Brouwer and Wichman (2020), as a result biological samples were obtained but no catch and effort data are presented for Kopernik Seamount for that trip as no commercial fishing took place.

The data were captured directly into a Microsoft Access database. Subsequently data were extracted from the database using the R (R Core Team, 2018) package RODBC and all analyses were performed in R.

4.1 Catch

Between 5th April 2019 and 28th April 2020 the vessel *Altar 6* fished in four separate trips in the South Pacific Ocean (Figure 1) on 12 Seamounts (Table 1) targeting lobsters and crabs, primarily *J. caveorum* and *Chaceon* sp. The only lobsters in the catch were *Jasus caveorum* (Webber and Booth, 1995) identified through photo and physical identification by (Rick Webber (the New Zealand Museum - Te Papa) and genetically by Johan Groeneveld (Oceanographic Research Institute (ORI)). The *Chaceon* sp. is still pending identification.

Data were collected by the vessel and observers as part of a predetermined sampling and catch reporting strategy. For each set the vessel 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.

Overall 169.76t was landed from the four trips and all sets recorded *Jasus* as the target species from trips 1-3 but trip 4 was largely targeting *Chaceon* sp. which were retained and processed. An observed 168.28t of target species (99.13%) were landed, including 146.62t (86.37%) of *J. caveorum* and 21.65t (12.75%) of *Chaceon* sp. In addition, a small amount of bycatch (1.48t - 0.87%) was landed.

Most of the effort and resulting catch came from the Kopernik seamount (148t) (Table 1). The catch by set information for Kopernik, Galilei, Humboldt, Linne B and MM seamounts are shown in Figure 2, to Figure 6. While Kopernik was dominated by *J. caveorum* the remaining seamounts had high catch of *Chaceon* sp.

The catch by depth information (Figure 7 and Figure 8) shows that the *J. caveorum* and *Chaceon* sp. seem to have different depth preferences. *J. caveorum* catch and CPUE was higher in shallower water (130-300m), while *Chaceon* sp. are caught in deeper water (deeper than 300m). This suggests that separate target fisheries is possible.

When reviewing the catch data in Figure 2 there appears to be some decline in *J. caveorum* catch as the trips progressed, the catch rate data showed similar trends (Figure 9). Soak time can also influence lobster catch, as lobsters are used to living in complex habitats they can escape traps once the bait is finished. While the first 22 sets of trip 1 had high set times (Figure 10) and low lobster catch (Figure 2) the remaining sets were relatively constant at about 24h soak time. Overall shorter set times (around 24h) had higher *J. caveorum* catch per set and longer sets had slightly higher catch per set for *Chaceon* sp. (Figure 11). The high catch at the start of the trip and lower catch rates at the end of the trips (Figure 9) could indicate serial depletion and that is reviewed in more detail in Brouwer and Wichman (2020).

4.2 Biological parameters

The international observer was 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, batch weight per species, sex, maturity stage and shell condition for the target *J. caveorum* and *Chaceon* sp. Bycatch was sampled for species, length, weight, condition (dead/alive/broken or whole) and location caught on the trap.

Length data for *J. caveorum* and *Chaceon* sp. are shown in Figure 12 to Figure 17. For most seamounts there are not enough data to be informative. However, Kopernik seamount did have substantial *J. caveorum* catch and length samples (Figure 17). The *J. caveorum* samples at Kopernik seamount reveal that, like most *Jasus* species, the females are smaller than the males and the catch is male dominated. This may have some advantages for future management options (see below). Overall for *Chaceon* sp. very few females were sampled, of those that were sampled, all were small relative to the males in the sample. It appears that there was some change in the population structure between trip 1 and 2 where the smaller male lobsters in the population were less available to the fishing gear than they had been on the first trip (Figure 17).

The shell state of *J. caveorum* showed that almost all had old hard shells with a small proportion having new shells (Figure 18) during trip 1. During trip 2, the proportion of lobsters with new hard shells had increased but they were still in the minority, but by trip 3 the shell state has returned to a old hard state (Figure 18). New shells are a sign of recent moulting and mating (for females) who mate when their shells are soft. This indicates that the fishing may have taken place during or just after the spawning season on trip 2 for *J. caveorum*.

The observers measured and recorded berry on both lobsters and crabs and the berry state (Table 2 and Table 3). However, at this stage there were too few samples to make any conclusions. The vessel did record the number of berried females returned by set and this did increase over time. However, we do not have numbers of females not in berry but retained and unobserved in each set to compare to the number of berried females returned to sea. There is some indication that the number of berried females was increasing through the trip indicating that the end of the trip (May) could be approaching the spawning season. The observer data shows few berried females (Table 2) so there are not enough data to statistically assess changes in proportion berried through the trip in a meaningful way.

It is important to collect morphometric information for converting processed catch into a total weight or length into weight. Three measurements were collected for *Chaceon* sp. namely carapace width, total weight and processed weight information (Figure 19 - Figure 21). While these data are useful larger samples for *Chaceon* sp. are required to get more reliable conversion factors and additional samples of total processed to half crab weight are still required.

The carapace length (CL) of lobsters covering a wide size range (62 - 178 mm) were measured and each whole lobster weighed (WW). Nonlinear Regression Analysis using the R package *nlstools* were used to fit to the data for all lobsters combined (n = 241), females (n = 81) and males (n = 160) respectively (Figure 22 - Figure 23). The regressions were of the form WW = a x CL^b and fit the data very well with R^2 values ranging between 0.96 and 0.99.

Regressions from whole weight to tail weight and carapace length to tail weight were not done, because all lobsters were processed to whole lobster products on board the *Altar 6*. Many lobster fisheries process their catches by removing and packing lobster tails only, and discarding the carapace. Regressions and derived conversion factors between whole weight and tail weight, as well as from carapace length to tail weight are therefore still required for *J. caveorum*, so that a full set of conversion factors are available, to accommodate potential changes in processing strategy, facilitate data analyses using different metrics, or for inter-comparisons between different lobster fisheries. Therefore, additional morphometrics should be seen as a priority task for observers on future trips.

Carapace length versus whole weight regressions of females covered a smaller size range (66 - 138 mm CL) than males did (62 - 178 mm) because females did not grow as large as males (Figure 23). The regressions were very similar, and did not show a progressive increase in female weight, compared to males of the same size, with increasing size. In most other *Jasus* species, the tail becomes larger after females reach sexual maturity, hereafter females of the same length are heavier than males. Regressions of whole weight against tail weight are required to test whether tail weight of mature females increase faster than in males.

The size-at-maturity information was estimated for *J. caveorum* only (Figure 24). However, as there were very few immature females sampled, these data should be considered very preliminary at this stage. But based on these preliminary data the estimated size-at-50% maturity was estimated at 67.4 mmCL. Functional maturity was estimated from the smallest egg-bearing female (68 mmCL) and the largest female without ovigerous setae was 84 mmCL. Additional sampling with small mesh nets may provide better information in in future.

4.3 Bycatch

Overall the traps contained mostly the target *J. caveorum* and *Chaceon* sp. and there was not a lot of bycatch (Table 4) recorded in or on the traps. Most of the bycatch was *Chaceon* sp., some of which was retained but most discarded, with a number of teleosts making up the bulk of the remainder, a small amount of hard corals and other anthozoans were recorded as entangled on the trap mesh. Corals and rhodoliths are indicators of VMEs and their occurrence was noted by the vessel and the positions recorded on the chart.

With regard to VME indicator species, the observer recorded *Cnidaria stylaster* coral or hydrocoral only on four lines set on Kopernik. The fishing master, also saved the locations, as required by SPRFMO, for future reference and further analysis if needed. Rhodoliths were the most common of the benthic organisms. The underwater camera shows clips of them over a flat seabed. Where there was uncertainty on species identification, photographs were taken for further identification by Rick Webber (New Zealand Museum - Te Papa).

4.4 Species of special interest

In order to mitigate catch of seabirds, turtles and marine mammals no bait, offal, dead floating bycatch, factory offal or food waste were discarded during hauling or setting of the lines. The factory produced very little offal as *J. caveorum* were retained whole and very few *Chaceon* sp. were caught at the Kopernik seamount where the bulk of fishing activities occurred. When *Chaceon* sp. were caught and retained the offal and waste shells were ground up, retained in a holding tank and pumped out when no hauling or setting was under way.

The observers noted and recorded all the birds observed during hauling and setting operations. It was observed that sooty shearwater (*Ardenna grisea*) would sometimes land and sit on the water to feed off small bait pieces that washed off the bait jars. The area approximately 50m astern where the birds landed, was free of any fishing gear as the traps and mainline are heavy and sink fast close to the vessel. The traps landed in the water within a meter from the vessel's stern and started sinking immediately.

Sooty shearwaters and wandering albatrosses (*Diomedea exulans*) were regularly observed during setting and hauling. Apart from sooty shearwaters feeding on small bait pieces, no other bird interactions with the vessel or fishing gear was observed. One grey petrel (*Procellaria cinerea*) was observed sitting on the hauling deck. The observer moved the bird to the bow section of the vessel to prevent possible injuries from crew activities. The following morning the petrel was gone. Photos were taken of the grey petrel while on deck. The observer's camera zoom lens had a malfunction and therefore good quality bird pictures were not always possible. However, some clear pictures were recorded. Other birds observed from time to time were; black browed albatross (*Thalassarche melanophris*), grey petrel, grey headed albatross (*Thalassarche chrysostoma*) and one sighting of a pintado petrel (*Daption capense*).

4.5 Management information

One of the management measures used in lobster fisheries is using size specific gear or a size limit to reduce the catch of females. In order to assess the feasibility and impact of such a measure we compared the size of male and female lobsters in the catch (Figure 29 and Figure 30). Overall the females in the catch were smaller than the males this implies that a size limit or altered selectivity of the gear could protect the females (and thereby the spawning biomass) from exploitation.

The impact of a size limit on the fishery was explored by assessing the likely implications this could have on the operational and economics of the exploratory operations. Table 5 presents the impact on the female population and the catch of potential size limits. These data show that, for example, a size limit of 120 mmCL would exclude 99% of the females from being retained, however, this would result in only 36% of the current catch being retained, while a size limit of 100 mmCL would protect 39% of the females and allow for the retention of 79% of the current catch. While these data are preliminary (based on a single seamount) additional information from subsequent trips and more seamounts could allow for a more in depth analysis of this type of measure. Alternative measures such as altering the traps has not been considered yet.

5 Discussion

During these trips 12 seamounts were fished (Table 1). *J. caveorum* were only caught at Kopernik seamount in large volumes. *Chaceon* were landed in small volumes but at all seamounts (Table 1). Whether there are few or no *J. caveorum* at the other seamounts or whether there is in interaction between the *Chaceon* sp. and *J. caveorum* that prevents the *J. caveorum* entering the trap is as yet unknown. Alternatively, longer set times may be more conducive to higher crab catch or facilitate lobster escape thereby skewing the species composition of the traps. However, depth seems to have the strongest impact on catch (Figure 7 and Figure 8). These results indicate that species specific targeting is possible and can be undertaken on the same trip allowing for feature and species specific catch allocation as a management option.

Soak time was high initially but lower and more similar (∼24h) between sets from set 21 onward on trip 1 and maintained throughout the remaining trips, and setting on Kopernik seamount was not undertaken in a sequential manner across the seamount. This relatively random setting along with lower catch and catch rates later in the trip (Figure 2 and Figure 9) may be an indication that catch early in the trip negatively impacted the catch later on in the trip at the same location. In addition, the overall CPUE from each successive trip was lower than that of trip 1. Brouwer and Wichman (2020) show that the estimated biomass declines over the course of the fishery, this led the Cook Islands to stop lobster fishing on Kopernik Seamount at the start of Trip 4 pending further analysis.

Overall the target of 10% sampling coverage was reached for traps and *J. caveorum* sampled, but *Chaceon* were frequently over or under sampled particularly on trip 1 (Figure 25 and Figure 26). Samples tend to be over sampled from very small hauls and under sampled from very big hauls where the catch in the first five traps is large. However, the impact of this is slight and overall the sampling strategy results in the 10% sampling target being met.

As few *Chaceon* sp. were landed, there are not enough data to make meaningful interpretations on the size distribution of individuals from the catch. However, for *J. caveorum* good samples were obtained. Like many other *Jasus* species the males reach a larger size than females. This size difference may create management opportunities (see below). There also appeared to be a change in the population structure between trips 1 and 2 where the smaller male lobsters in the population were less available to the fishing gear than they had been on the first trip (Figure 17). *Jasus frontalis* is known to undertake long-shore and inshore offshore migrations (Roman et al., 2018) and it is possible that *J. caveorum* may undertake some spatial movement. However, given the topography and the apparent depth limitations of *J. caveorum* large scale movements on and off the seamount seem unlikely, continued deep water fishing in the area for crabs may provide more information in future.

Crustacean shell state can provide information on the moulting cycle. These data can be informative in deciding when to tag them for growth increment information and when the spawning season may commence. The *J. caveorum* sampled here almost all had shells that were in an old hard state from trips 1 and 3, indication that moulting had occurred some time previously. A high proportion of lobsters had new hard shells from trip 2. This along with the change in proportion of berried females through the trip as well as the few berried females samples, indicate that the fishing operation occurred outside of the main spawning period. This suggests if tagging were to occur to assessing growth, it should be undertaken in about March. Prior to moulting, lobsters commit a lot of energy to the production of a new shell, if they get tagged once the new shell is made, but prior to moulting, growth estimates are likely to reflect actual growth as the tag effect is thought to be minimised.

The size-at-maturity information was estimated for *J. caveorum* only (Figure 24). However, as there were very few immature females sampled, these data should be considered very preliminary at this stage. But based on these preliminary data the estimated size-at-50% maturity was estimated at 67.4 mmCL. Additional sampling with small mesh nets has provided better information and is recommended this be repeated for future trips. For *Chaceon* sp. very few females were landed (Table 3) so information on reproduction is limited.

Overall there was not a lot of bycatch (Table 4) recorded in or on the traps. Most of the bycatch was *Chaceon* sp. with a number of teleosts making up the bulk of the remainder. Small amounts of hard corals and other anthozoans were recorded as entangled on the trap mesh. Some of the species observed in the cameras (Rhodoliths) and entangled on the nets (corals) are indicators of VMEs. These incidents were noted and the areas where they occurred (mostly on the seamount slope will be avoided on future trips. No birds, marine mammals or sea turtles were entangled in the gear during the fishing operations. VME indicator taxa are discussed in more detail in Brouwer et al. (2020).

5.1 Risk assessment

5.1.1 Assessment of data poor fisheries (MSC methodology)

Data on which to base fisheries management advice are generally absent or sparse in new or exploratory fisheries, and most RFMOs then require that a Precautionary Approach is followed. As part of such an approach, a formal Risk-Based Framework (RBF) can be used in data-limited fisheries. To assess the risks associated with the experimental trap fishery for *J. caveorum*, an established RBF methodology used in Marine Stewardship Council (MSC) (`www.msc.org`) assessments of data-limited fisheries, or of fisheries that lack quantitative stock status assessments, was used.

The RBF methodology is easy to implement and relies on intrinsic life history traits of fished species, and on their susceptibility to capture. The MSC has recently used RBF methodology in formal assessments or pre-assessments of several insular *Jasus* species around islands or on seamounts in the South Atlantic (*Jasus tristani* at the Tristan da Cunha archipelago), Southern Indian Ocean (*Jasus paulensis* at St Paul and Amsterdam Islands) and in the South Pacific (*Jasus frontalis* at the Juan Fernandes and Desventuradas Islands). These three species are very similar to *J. caveorum* from the Foundation Seamount chain, and we used a similar RBF framework to assess the vulnerability of *J. caveorum* to fishing pressure. This work was undertaken by Johan Greoenveld and reported in Brouwer et al. (2019) is repeated here for completeness.

A Productivity and Susceptibility Analysis (PSA) tests the vulnerability of a fished stock relative to predetermined measurable attributes and score rankings. PSA assumes that the overall vulnerability of a fished species to impacts from fishing depends on two characteristics: 1. the productivity of a species/stock based on life history traits that determine whether it could sustain or recover from fishery-related impacts; and 2. the susceptibility of the species/stock to impacts from fishery-specific activities.

5.1.2 Productivity analysis

The Productivity analysis relies on scoring six criteria for invertebrates: average age-at-maturity; average maximum age; fecundity; reproductive strategy; trophic level and density dependence (Table 6). Even though the information is not yet available for *J. caveorum* per se, the categories are relatively broad, and good approximations could be made based on information from other *Jasus* species. In *J. caveorum*, the average age-at-maturity and maximum age were estimated as 5-15 years and 10-25 years, respectively, and both attributes were therefore scored at medium risk (score=2; see MSC scoring tables in FCR 2.0). Even the smallest mature females will produce >20,000 eggs per year, thus carrying low risk (score=1). The reproductive strategy of rock lobsters is broadcast spawning, therefore also low risk (score=1). The trophic level of *J. caveorum* is somewhat ambiguous, because its diet is unknown - although it will likely feed on algae (a herbivore; trophic level 2) and scavenge for small / dead organisms in a predatory way (trophic level 3). A plausible trophic level estimate is therefore 2.75-3.25, which places it at medium risk (score=2). Strong compensatory dynamics at low population size is expected, as in other *Jasus* species (Pollock, 1991), and density dependence is therefore also scored at low risk (score=1).

5.1.3 Susceptibility analysis

The susceptibility analysis relies on scoring 4 attributes: availability, or areal overlap of fishing effort with stock concentrations; encounterability, or the position of the stock relative to the fishing gear; selectivity of the gear type; and the level of post-capture mortality (Table 6). For *J. caveorum*, availability was scored as high risk because lobsters are concentrated on seamount pinnacles which can be exhaustively covered by traps (score=3). For target species, the default score for encounterability is also 3 (high risk). Lobsters smaller than the size-at-maturity were infrequently caught in Trips 1 and 2, and if needed they can be released with high expected survivorship (low risk; score=1). For target species, the default score for post-capture mortality is also 3 (i.e. high mortality rate).

5.1.4 Comparison of PSA results with other insular trap fisheries for *Jasus*

Scores for the PSA are shown in Table 6, for *J. caveorum*, *J. paulensis* and *J. frontalis*. The scores were similar for the 3 species - which is unsurprising because they have similar life history and habitats, and are all fished with traps, using similar fishing strategies. PSA scores indicate a low intrinsic risk category. The low risk category implies that populations can sustain trap fishing pressure in well managed fisheries. This conclusion is supported by the fact that 2 of 4 trap fisheries for insular *Jasus* species are MSC certified (i.e. they have been assessed as well-managed sustainable fisheries) - with a third one (*J. paulensis*) now entering full MSC assessment (`www.msc.org`).

5.2 Management information

There are a number of management options available for lobster fisheries including the setting of Total Allowable Catch (TAC), Total Allowable Effort (TAE), size limits, trap mesh size rules and close seasons. In assessing these options, it will be necessary to take into account a range of factors, including biological (e.g. size-at-first maturity, growth rates etc.), as well as fishery-related (type, efficiency and selectivity of gear, practicality of management measures etc.). While the size considerations presented here are potentially viable other similar measures can be applied. Lobsters get injured while being handled. The most common injury is broken limbs and antennae. Research on *Jasus lalandii* has shown that leg loss decreases the time to the next moult and decreases the growth rate of lobsters (Brouwer et al., 2006). In order to reduce injuries, and air exposure, installing sorting grids and chutes that return the smaller lobsters directly to the sea would be beneficial if a size limit were to be considered as an option. Alternatively allowing these individuals to escape as the trap is lifted through changing the mesh size may be preferable due to the depth of the fishery and relatively small size of the seamounts, making it difficult to return small lobsters back to the seamount alive. These and other options could be considered as the fishery develops.

Corals and rhodoliths are indicators of VMEs their occurrence was noted by the vessel and the positions recorded on the chart. Additional work is still needed to assess the video footage of sets to assess the benthos. In the interim areas with indicator species for VMEs should be avoided in future fishing operations. This strategy was employed on all trips, in future however areas of high encounter rates of VME indicator taxa such as the Kopernik Valley are recommended to be avoided in future Brouwer et al. (2020).

6 Recommendations for future fishing trips

- Collect morphometric information from *J. caveorum* including
  - Carapace length;
  - Tail width
  - Whole weight; and
  - Tail weight;
- Continue the collection of morphometric information from *Chaceon* sp. including:
  - Carapace width
  - Whole weight;
  - Processed weight; and
  - Half crab weight.
- Tag lobsters in pre-moult condition to assess the growth rates and get estimates of fishing mortality;
- Collect fecundity information from *Chaceon* sp. and *J. caveorum*;
- Collect still camera footage of the benthos from each set to assess the benthic environment;
- Use small mesh nets on a sub-sample (4 out of 10) of the sample traps to collect biological information on smaller size classes of the lobsters and crabs (the small mesh traps must be identified separately in the database);
- Use large mesh nets on a sub-sample of the sample traps to evaluate potential size limitations on the catch;
- Collect bottom temperature data;
- Collect lobster length by depth stratum information.

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Tables

Table 1: Observed total catch from trips 1 to 4.

Seamount	*Jasus caveorum*	*Chaceon* sp.	Total catch	Traps set
MM	0.00	4.72	4.72	2742
Mendel	0.00	7.63	7.63	2489
Kopernik	146.57	1.31	147.88	18177
Linne b	0.00	2.09	2.09	682
GB	0.00	0.35	0.35	98
Mendeleiev	0.00	0.40	0.40	96
Jenner	0.05	0.10	0.15	142
Darwin A	0.01	0.16	0.16	369
Mercator	0.00	1.52	1.52	520
Buffon	0.00	1.01	1.01	467
Galilei	0.00	0.98	0.98	755
Humboldt	0.00	1.38	1.38	430

Table 2: Observed Sex and berry state of all *Jasus caveorum* sampled on trips 1 to 4.

Size Bin (mm)	Berry stage 1	Berry stage 2	Berry stage 3	Mature female	Immature female	Male
0-10	0	0	0	0	0	1
40-50	0	0	0	0	1	3
50-60	0	0	0	3	37	34
60-70	0	0	0	63	89	131
70-80	1	1	0	325	35	237
80-90	4	35	4	1601	4	348
90-100	10	78	3	3177	0	750
100-110	10	85	9	3198	0	1369
110-120	7	45	4	1338	0	1817
120-130	0	0	0	66	0	1660
130-140	0	0	0	3	0	1538
140-150	0	0	0	2	0	1581
150-160	0	0	0	4	0	1518
160-170	0	0	0	4	0	364
170-180	0	0	0	0	0	11

Table 3: Observed Sex and berry state of all *Chaceon* sp. sampled on trips 1 to 4.

Size Bin (mm)	Berry stage 1	Berry stage 2	Berry stage 3	Berry stage 4	Mature female	Immature female	Male
0-10	0	0	0	0	0	0	0
40-50	0	0	0	0	0	0	1
50-60	0	0	0	0	0	0	2
60-70	0	0	0	0	5	0	4
70-80	0	1	0	0	18	0	16
80-90	2	3	1	0	59	0	68
90-100	2	3	3	1	75	1	153
100-110	1	2	5	0	23	0	311
110-120	0	0	2	0	5	0	622
120-130	0	0	0	0	5	0	987
130-140	0	0	0	0	0	0	1046
140-150	0	0	0	0	0	0	534
150-160	0	0	0	0	0	0	101
160-170	0	0	0	0	0	0	12
170-180	0	0	0	0	0	0	1

Table 4: Observed bycatch (numbers) from trips 1 to 4.

Species	Trip 1	Trip 2	Trip 3	Trip 4
Anthozoa	9	0	0	0
Black coral	0	1	0	0
Blue shark	1	0	0	0
Chaceon geryons nei	17	0	46	0
Cnidarians nei	9	0	3	19
Cusk-eels nei	0	0	0	2
Echinoderms	0	0	0	12
Hydrozoans	1	1	0	3
King crabs, stone crabs nei	0	0	1	3
Marine shells nei	0	0	1	0
Moras nei	0	0	0	1
Nylon shrimps nei	0	0	14	237
Porae	1	0	0	1
Scorpionfishes, redfishes nei	1	0	2	4
Siliceous sponges	1	0	0	0
Tarakihi	11	0	0	0
Trumpeters nei	1	0	0	0
Rhodolith	0	0	2	0
Ball coral	0	25	0	0

Table 5: Impact of a size limit on the catch showing the percentage of females protected (below size limit) and percent of the total catch retained.

Limit (CL mm)	Females excluded from catch	Percent catch retained
50	0.00	99.98
60	0.03	99.64
70	0.65	98.32
80	3.90	95.55
90	20.21	86.32
100	52.63	67.72
110	85.39	46.10
120	99.22	31.24
130	99.87	23.25
140	99.90	16.12
150	99.92	8.80
160	99.96	1.75
170	100.00	0.05
180	100.00	0.00

Table 6: Comparative PSA scores for three insular *Jasus* species using the Marine Stewardship Council scoring methodology: 1 = low risk; 2 = medium risk; 3 = high risk

Scientific name	Productivity Scores						Susceptibility Scores				Final Score	
	Average age-at-maturity	Average max age	Fecundity	Reproductive strategy	Trophic level	Density Dependence	Availability	Encounterability	Selectivity	Post-capture mortality	Final PSA score	MSC Risk category
Jasus frontalis	2	2	1	1	2	1	2	3	3	1	94	Low
Jasus paulensis	2	2	1	1	2	1	3	3	1	3	91	Low
Jasus caveorum	2	2	1	1	2	1	3	3	1	3	91	Low

Figures

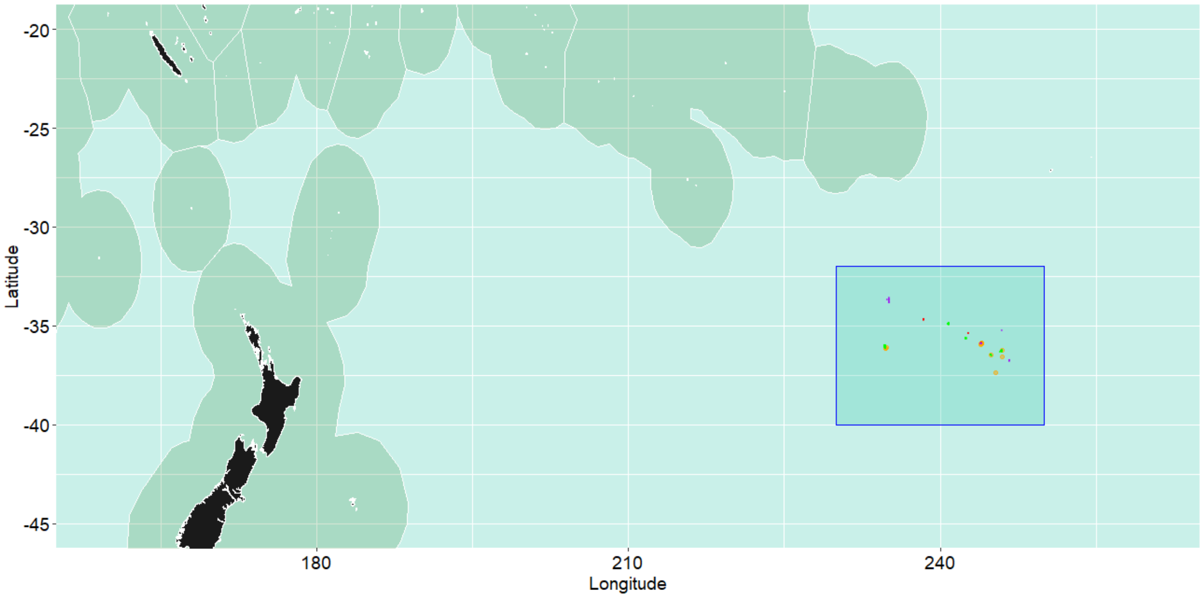


Figure 1: Map showing the South Pacific with the exploratory fishing area (blue box) and location of the fishing events.

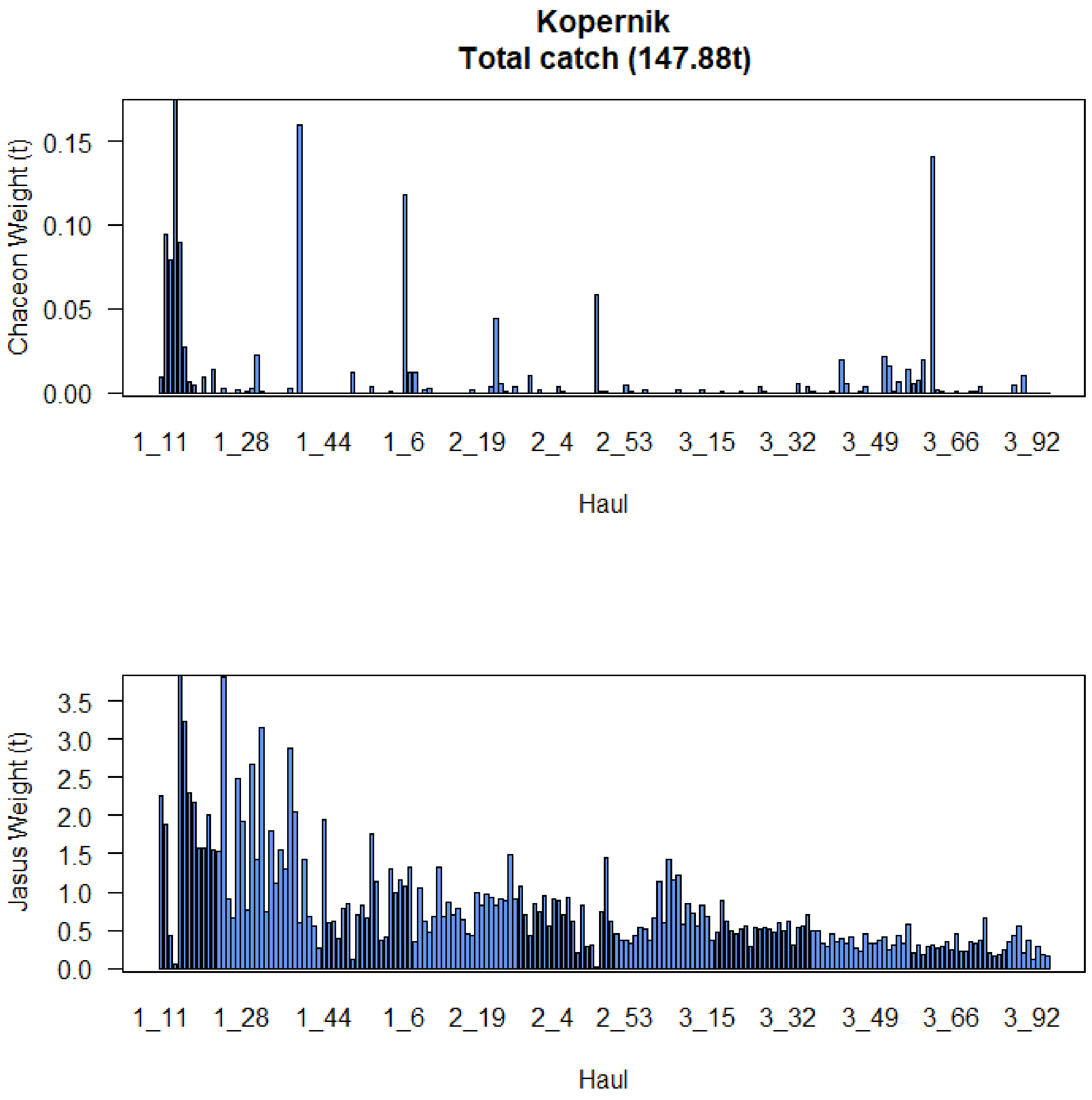


Figure 2: Total weight of crabs (upper panel) and lobsters (lower panel) from each haul from Kopernik seamount from all trips.

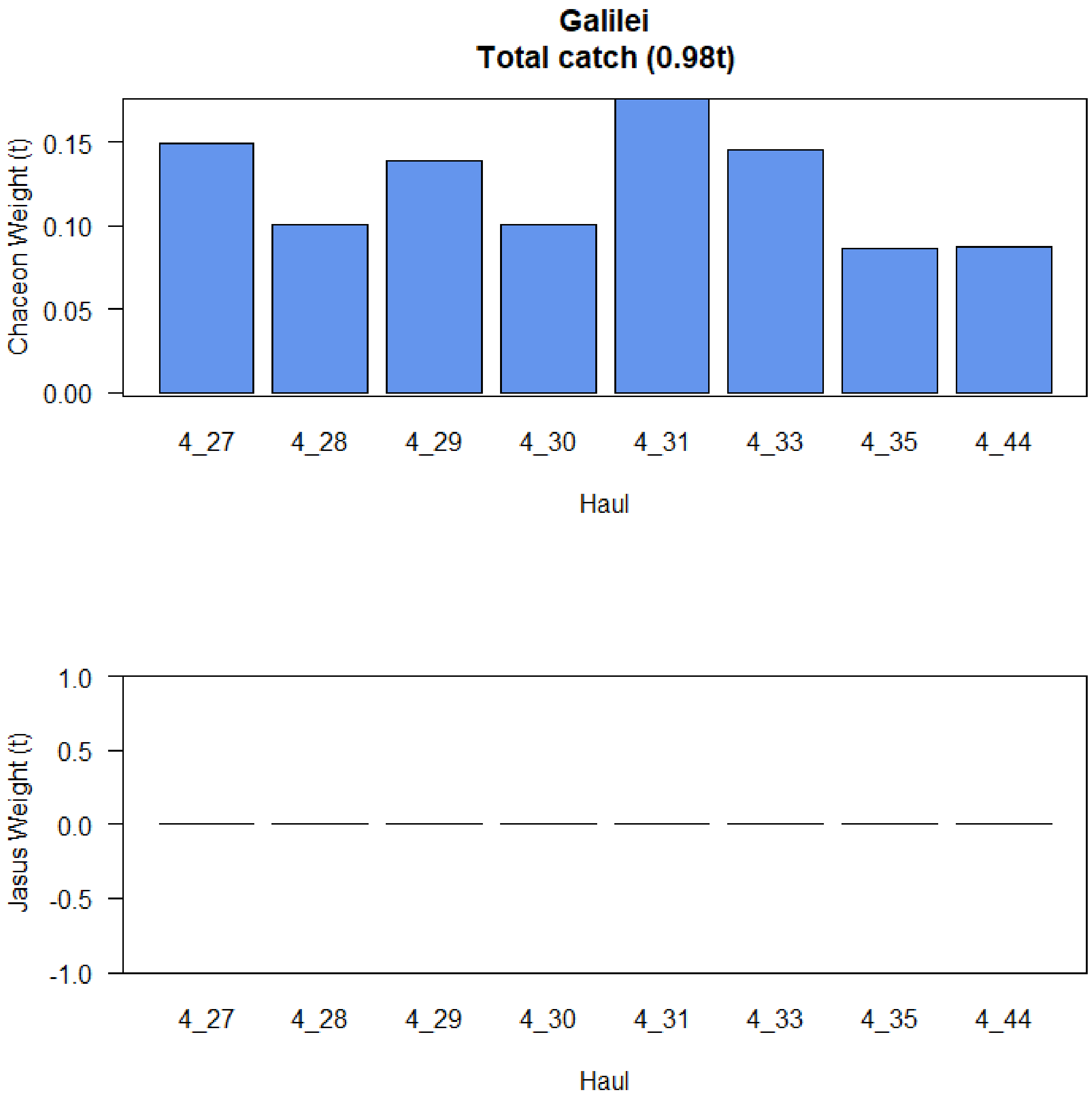


Figure 3: Total weight of crabs (upper panel) and lobsters (lower panel) from each haul from Galilei seamount from all trips.

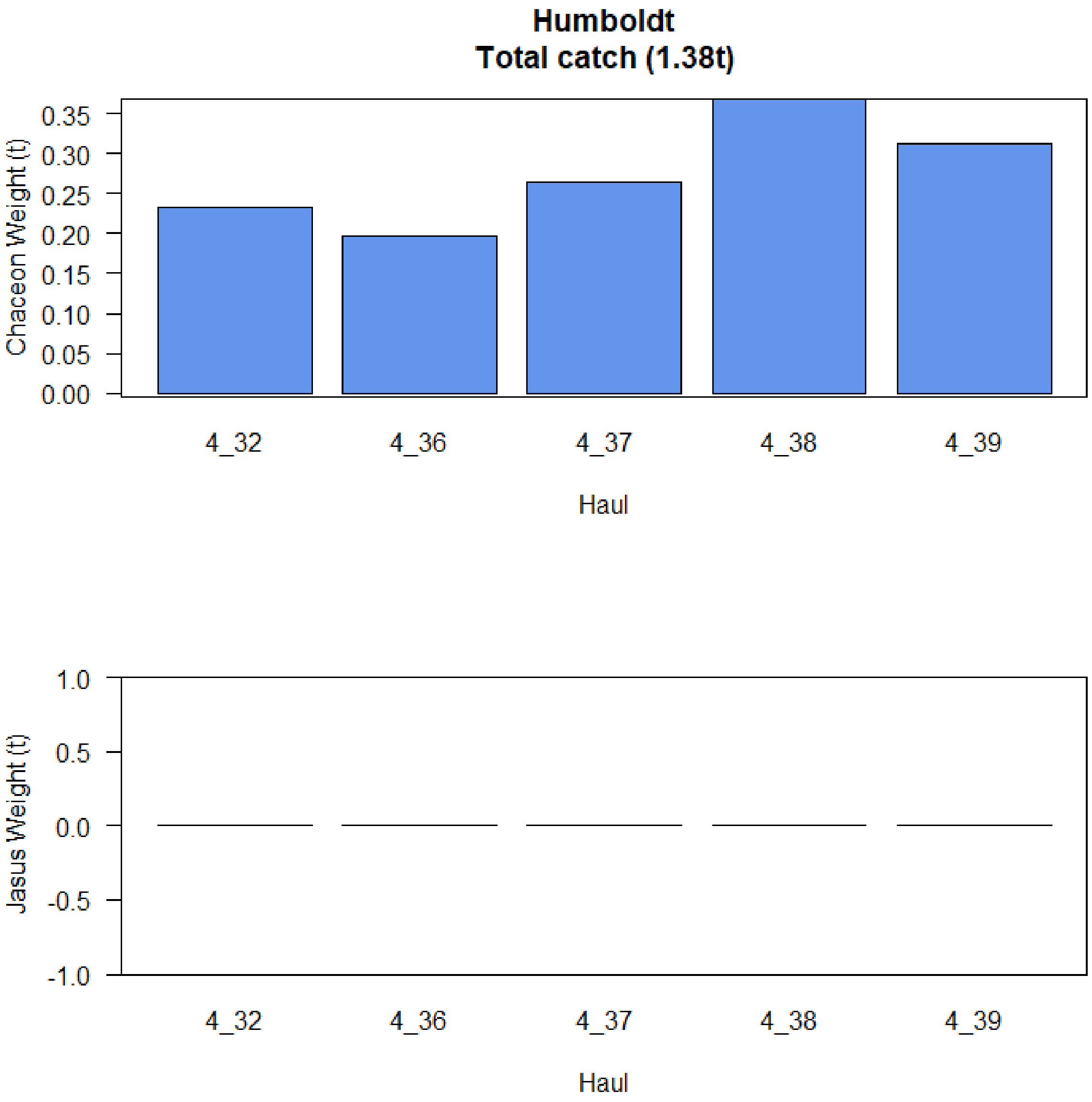


Figure 4: Total weight of crabs (upper panel) and lobsters (lower panel) from each haul from Humboldt seamount from all trips.

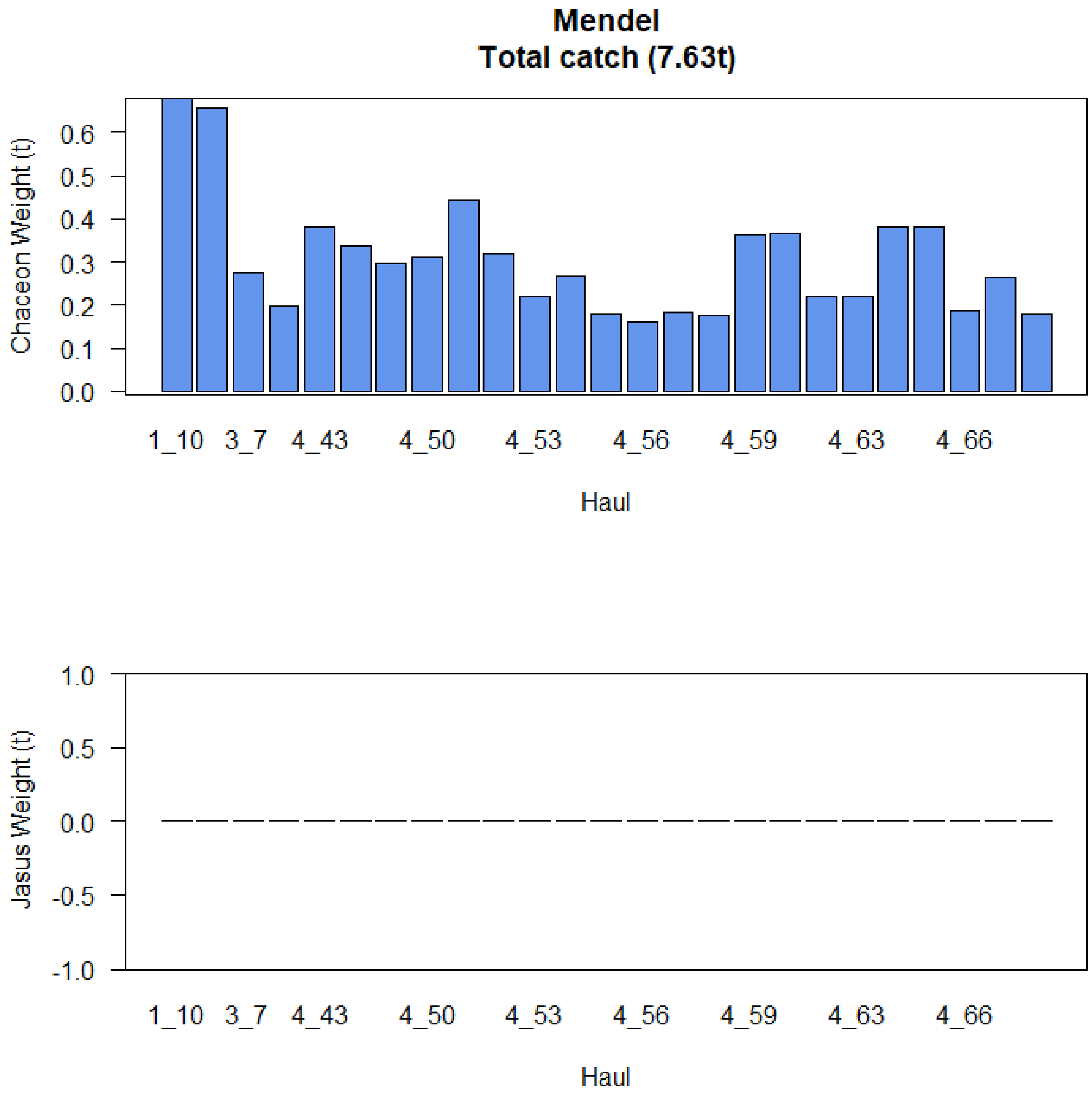


Figure 5: Total weight of crabs (upper panel) and lobsters (lower panel) from each haul from Mendel seamount from all trips.

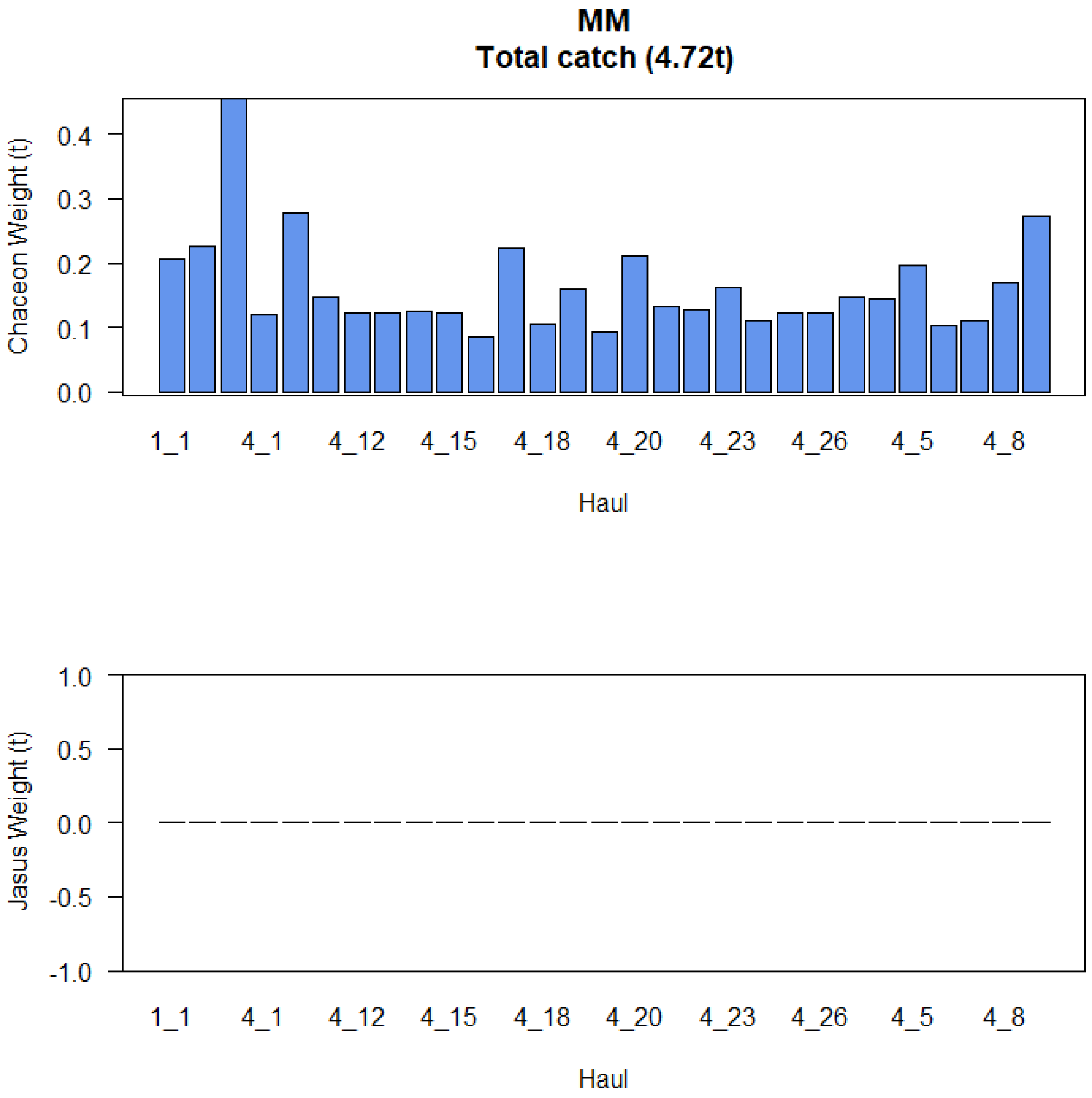


Figure 6: Total weight of crabs (upper panel) and lobsters (lower panel) from each haul from MM seamount from all trips.

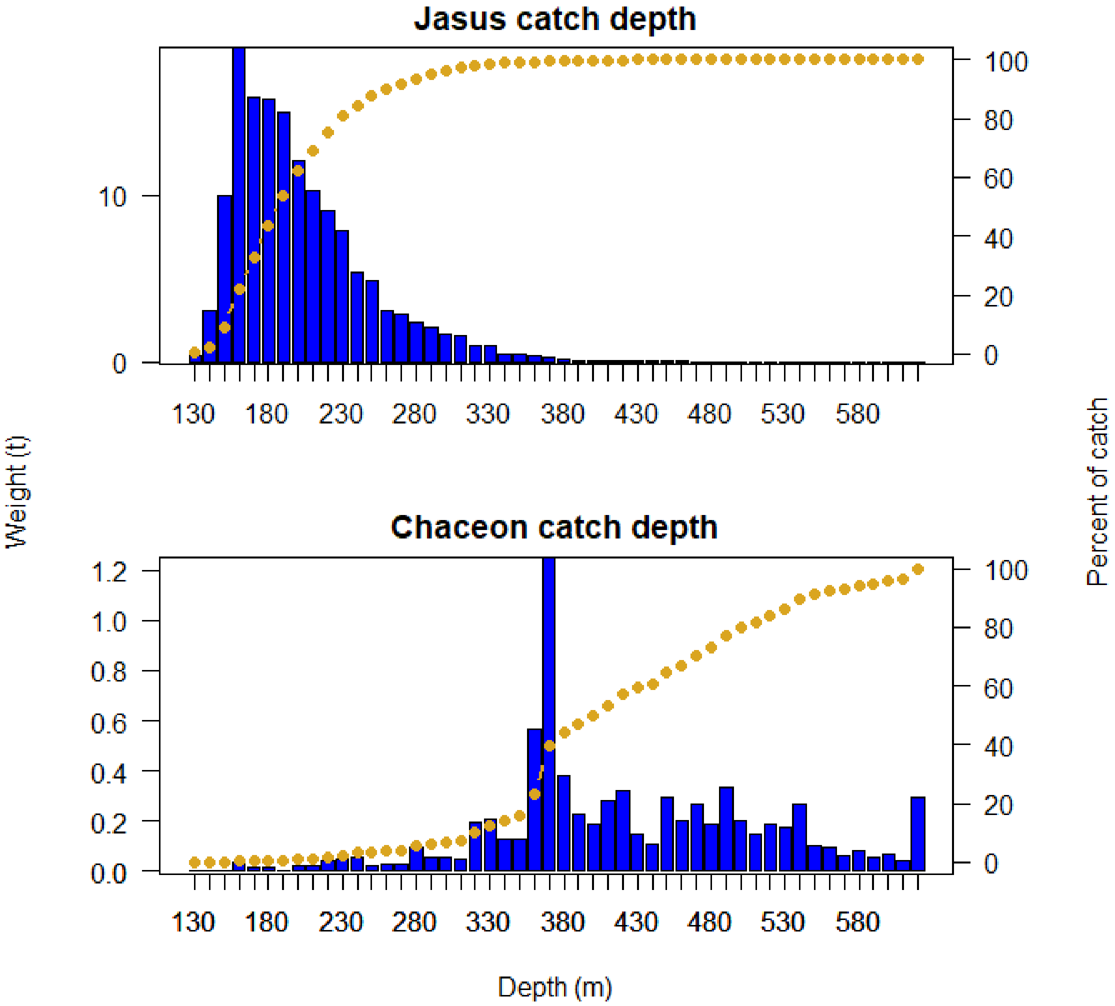


Figure 7: Total weight of lobsters (upper panel) and crabs (lower panel) by depth from all seamounts and all trips. Blue bars are the catch by depth bin and the gold dotted line is the cumulative proportion of the catch. Depth was estimated for each trap through interpolation depending on its position relative to the start, middle or end of the set where depth recordings were made.

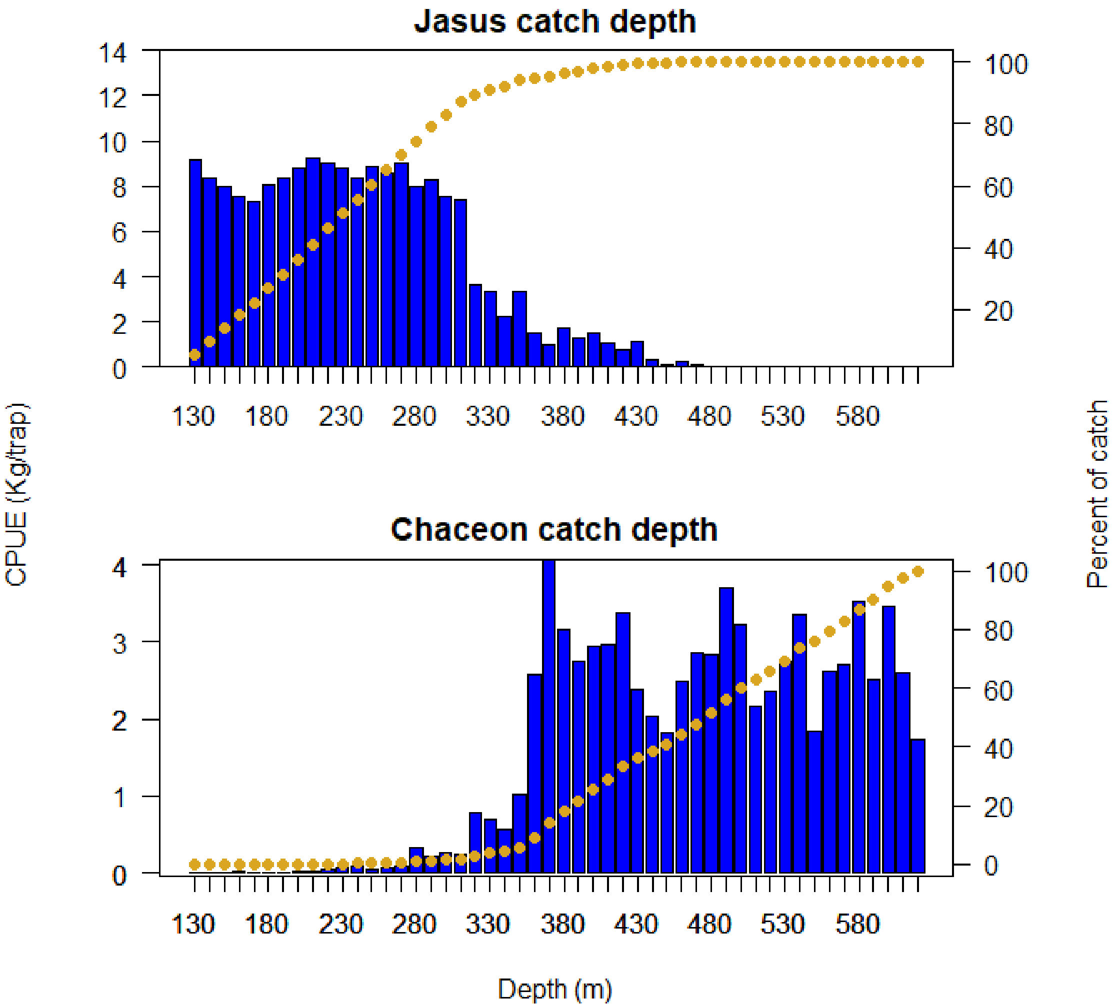


Figure 8: Catch per trap lobsters (upper panel) and crabs (lower panel) by depth from all seamounts all trips. Blue bars are the catch by depth bin and the gold dotted line is the cumulative proportion of the catch. Depth was estimated for each trap through interpolation depending on its position relative to the start, middle or end of the set where depth recordings were made.

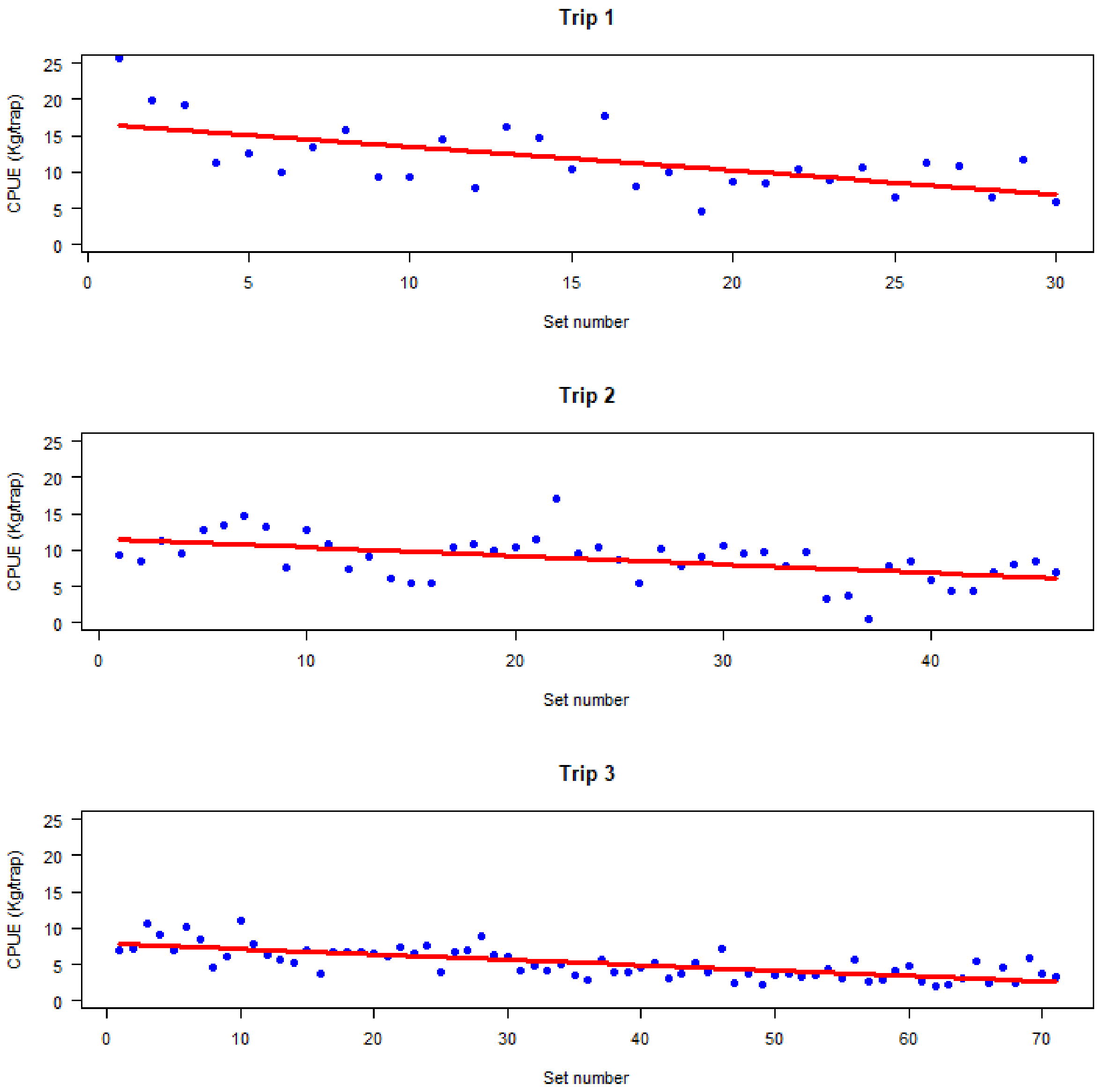


Figure 9: CPUE of lobsters by trip from each haul from Kopernik seamount. The red line indicates the trend and the slops indicates the overall change in CPUE from the start to end of each trip.

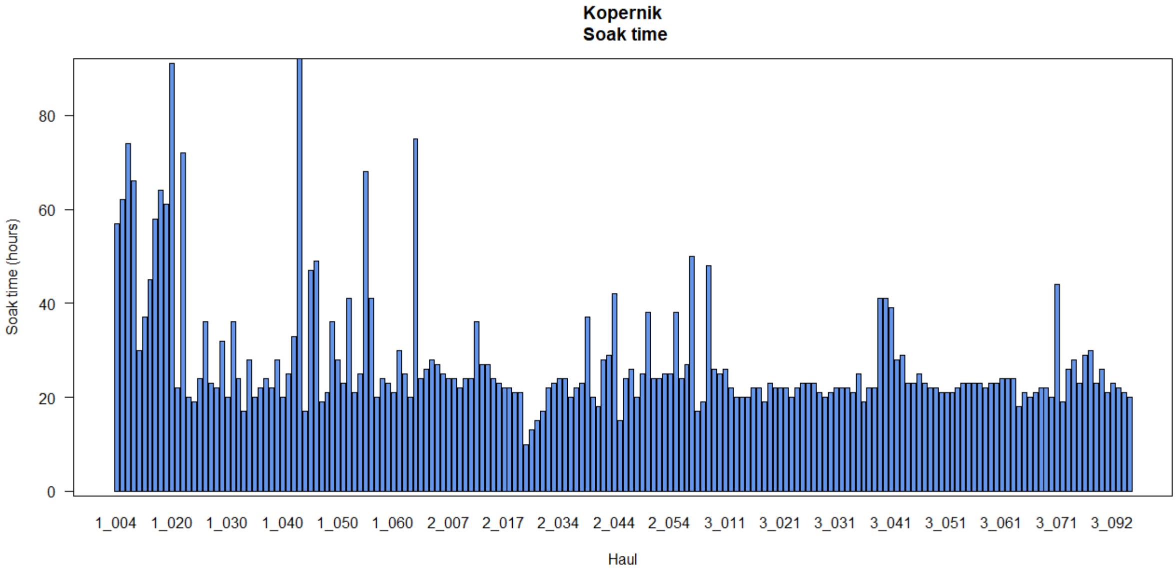


Figure 10: Trap soak time for sets on the Kopernik seamount for trip 1 to 3.

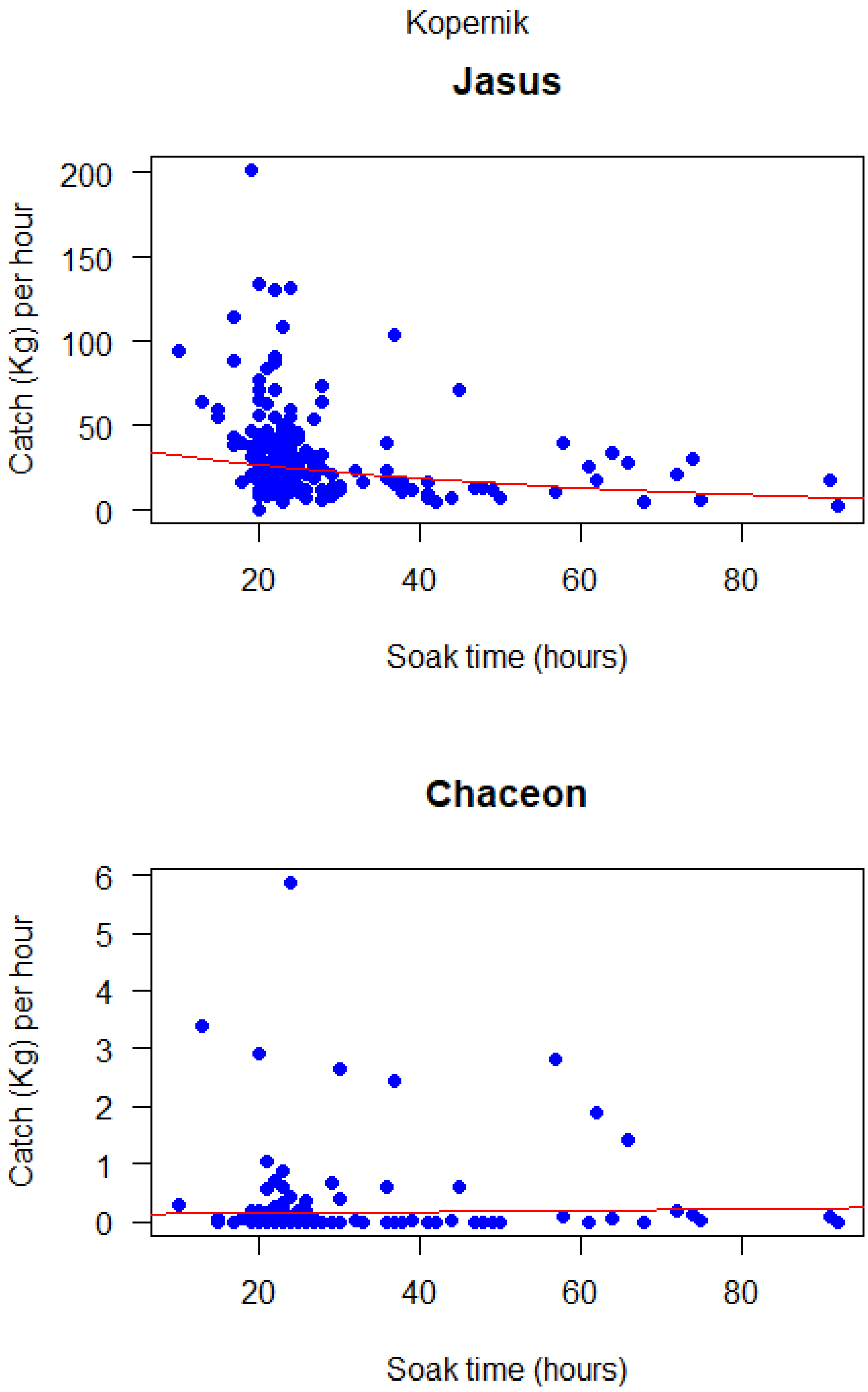


Figure 11: Catch vs. soak time for crabs and lobsters on the Kopernik seamount for sets on trip 1 to 3.

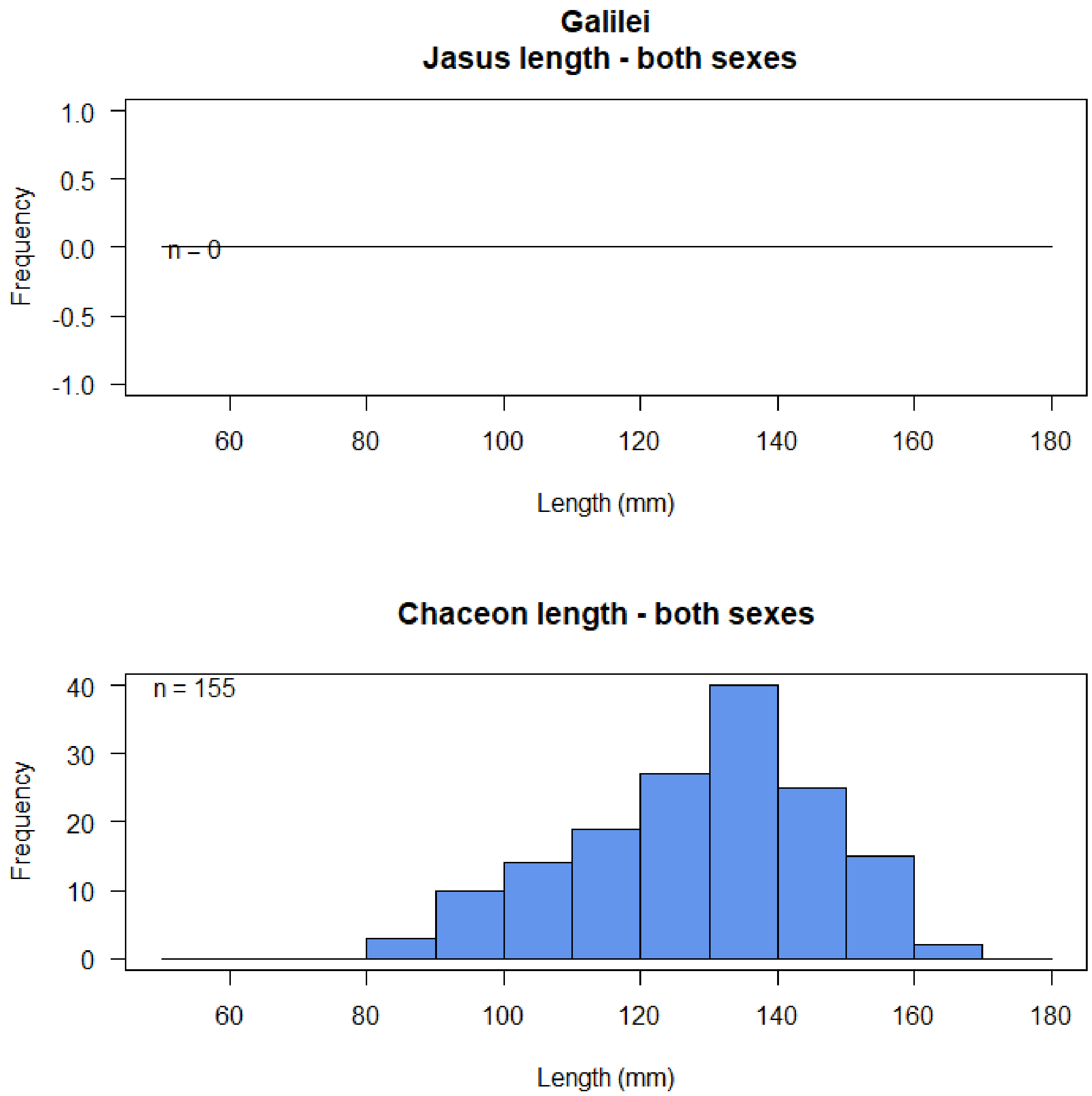


Figure 12: Length by sex of lobsters and crabs on Galilei seamount.

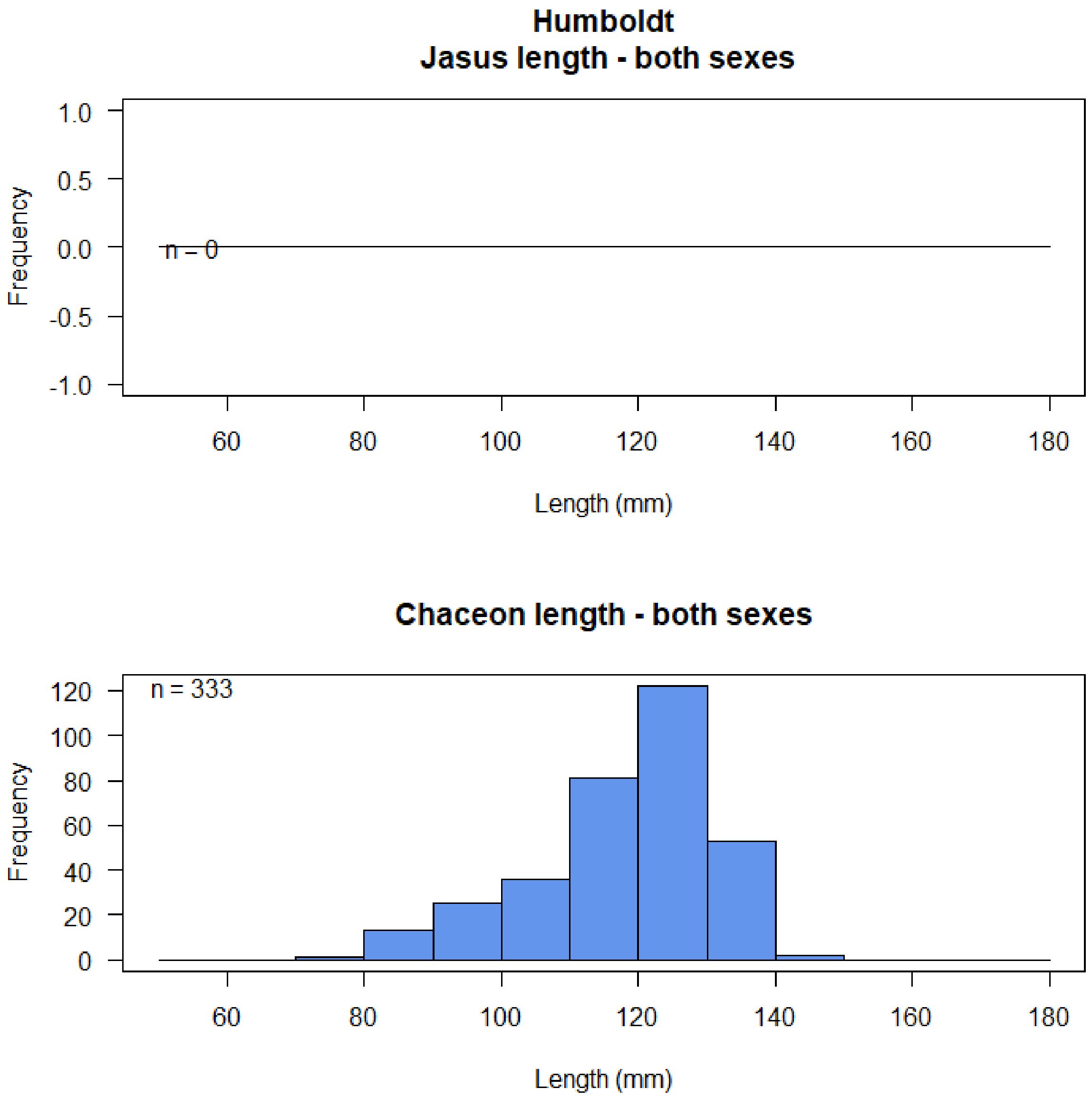


Figure 13: Length by sex of lobsters and crabs on Humboldt seamount.

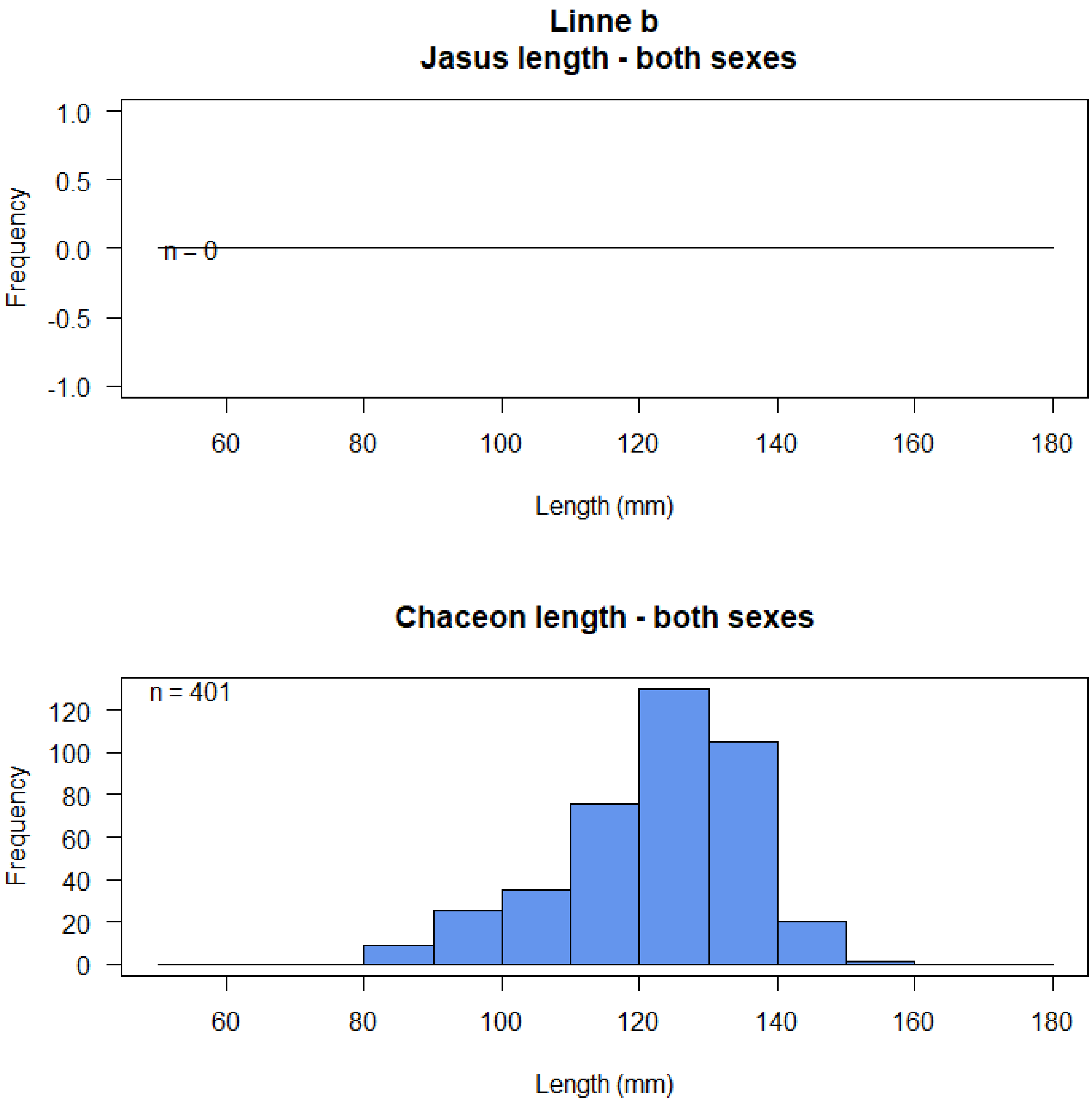


Figure 14: Length by sex of lobsters and crabs on Linne B seamount.

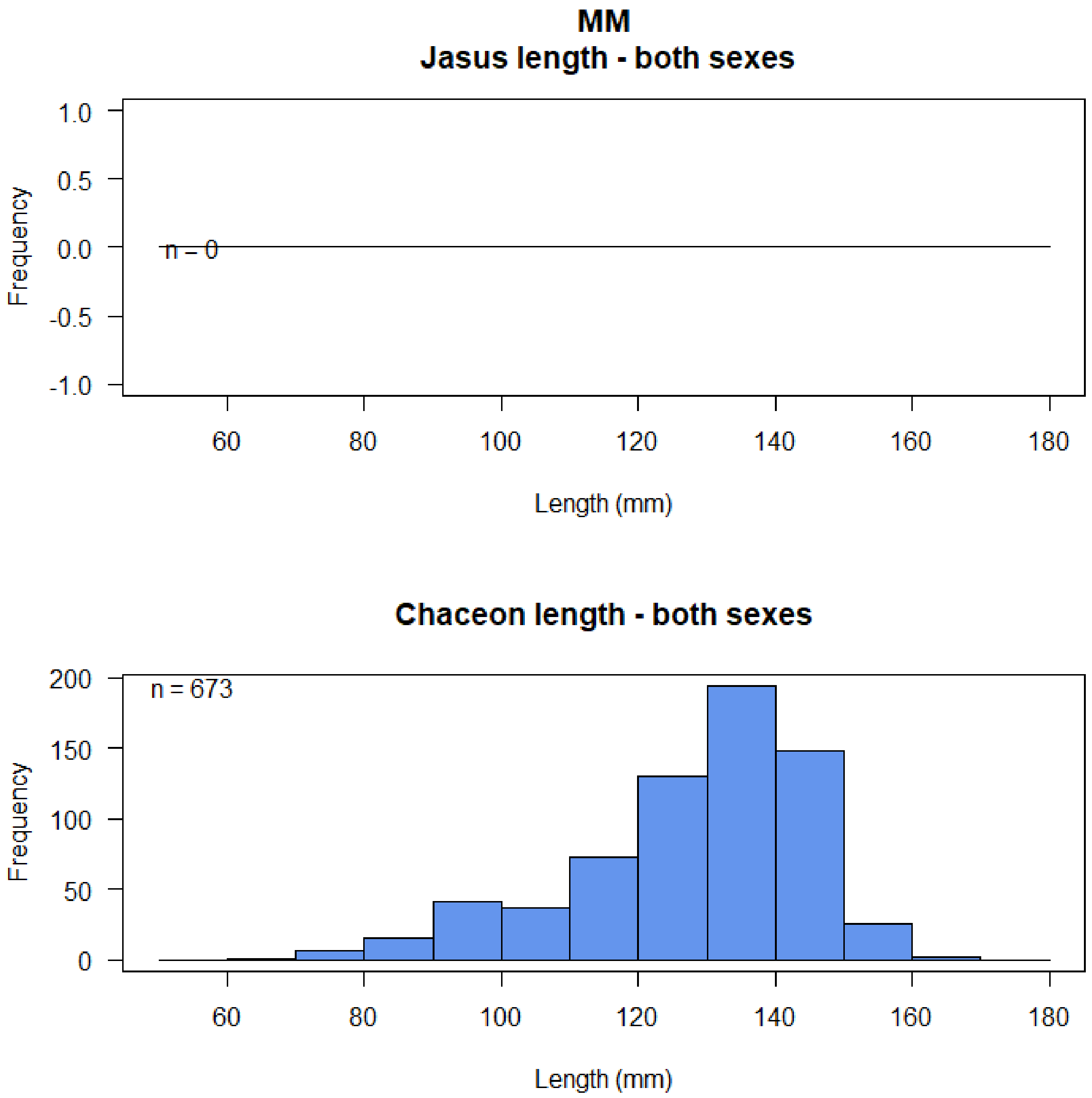


Figure 15: Length by sex of lobsters and crabs on MM seamount.

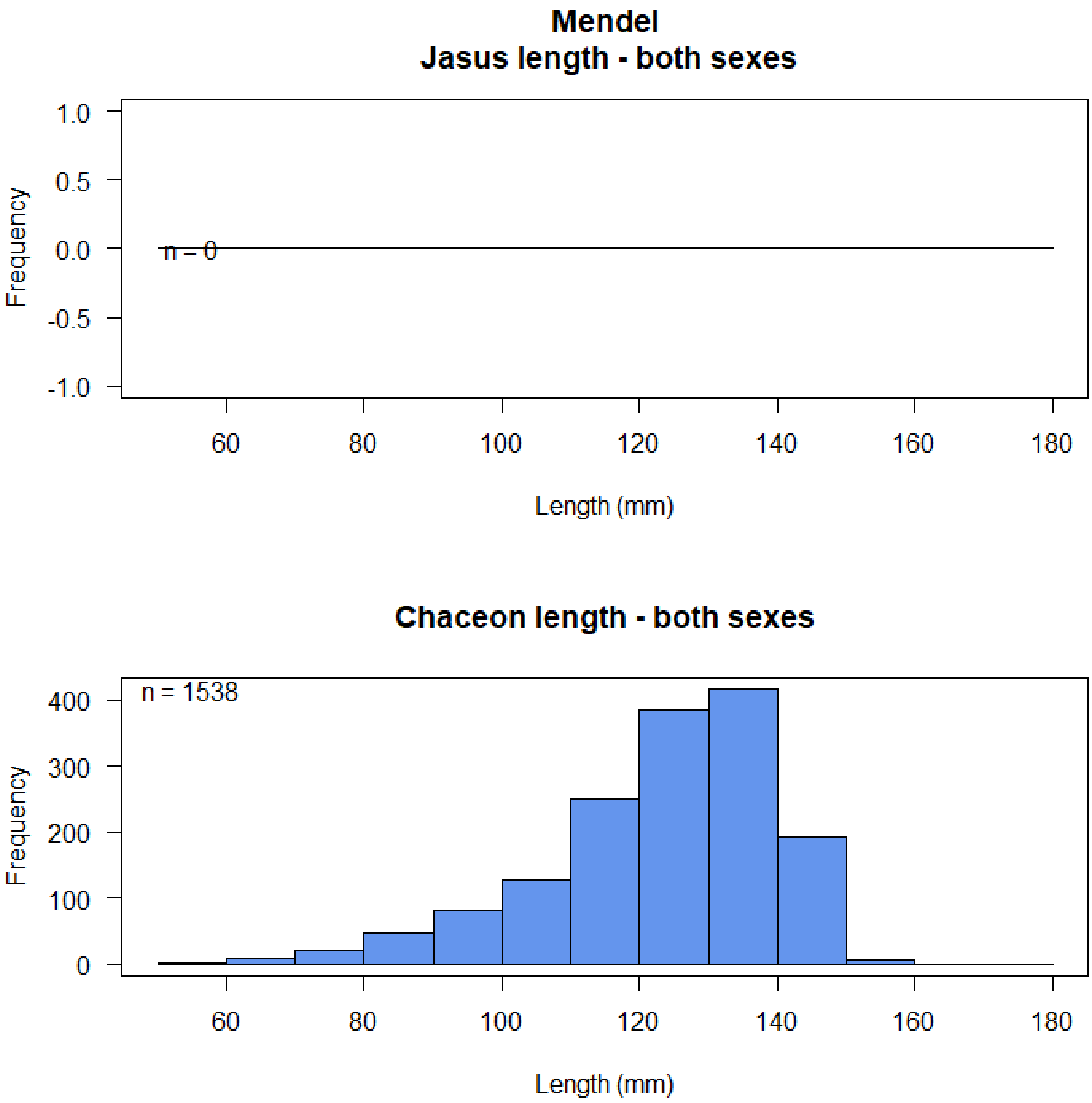


Figure 16: Length by sex of lobsters and crabs on Mendel seamount.

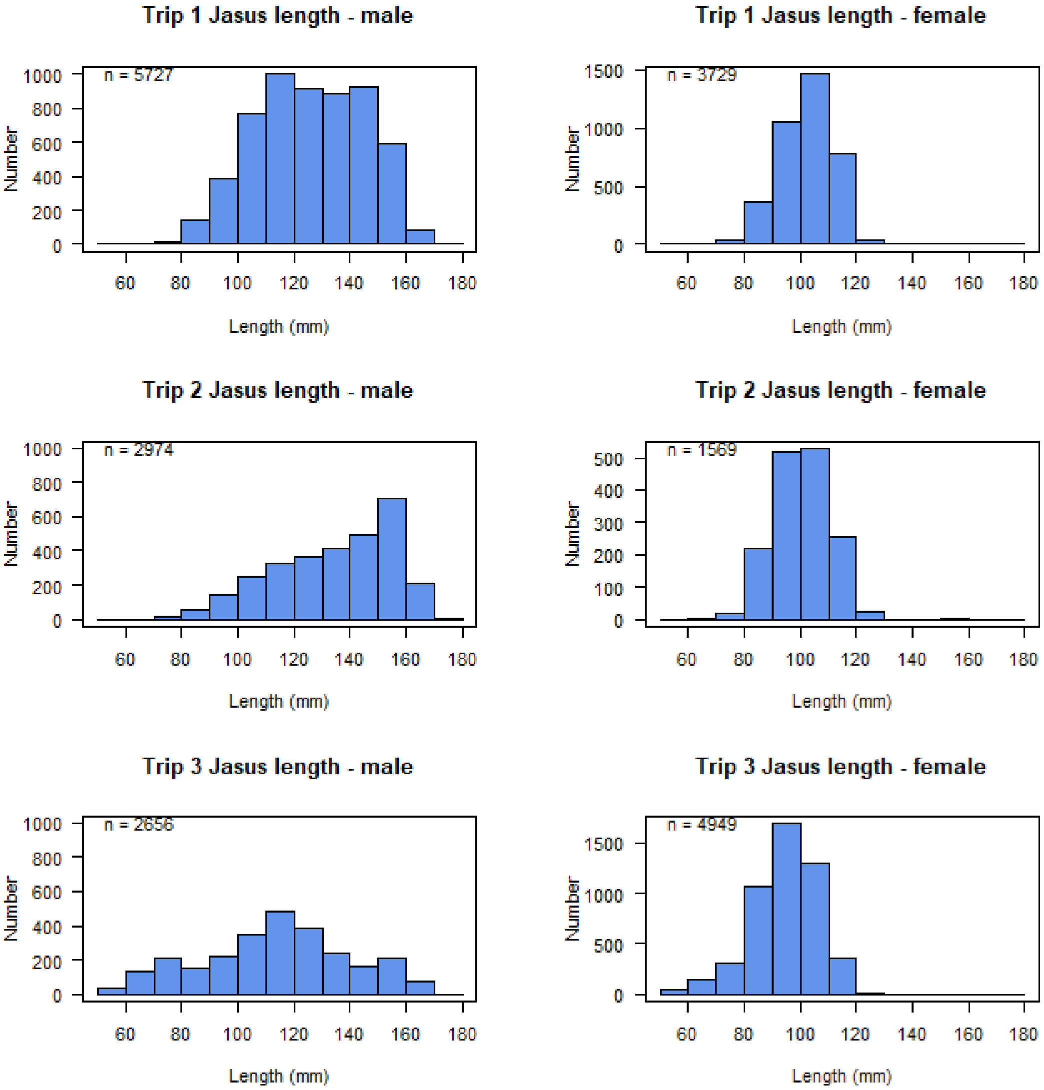


Figure 17: Length by sex of lobsters on the Kopernik seamount from trips 1 to 3.

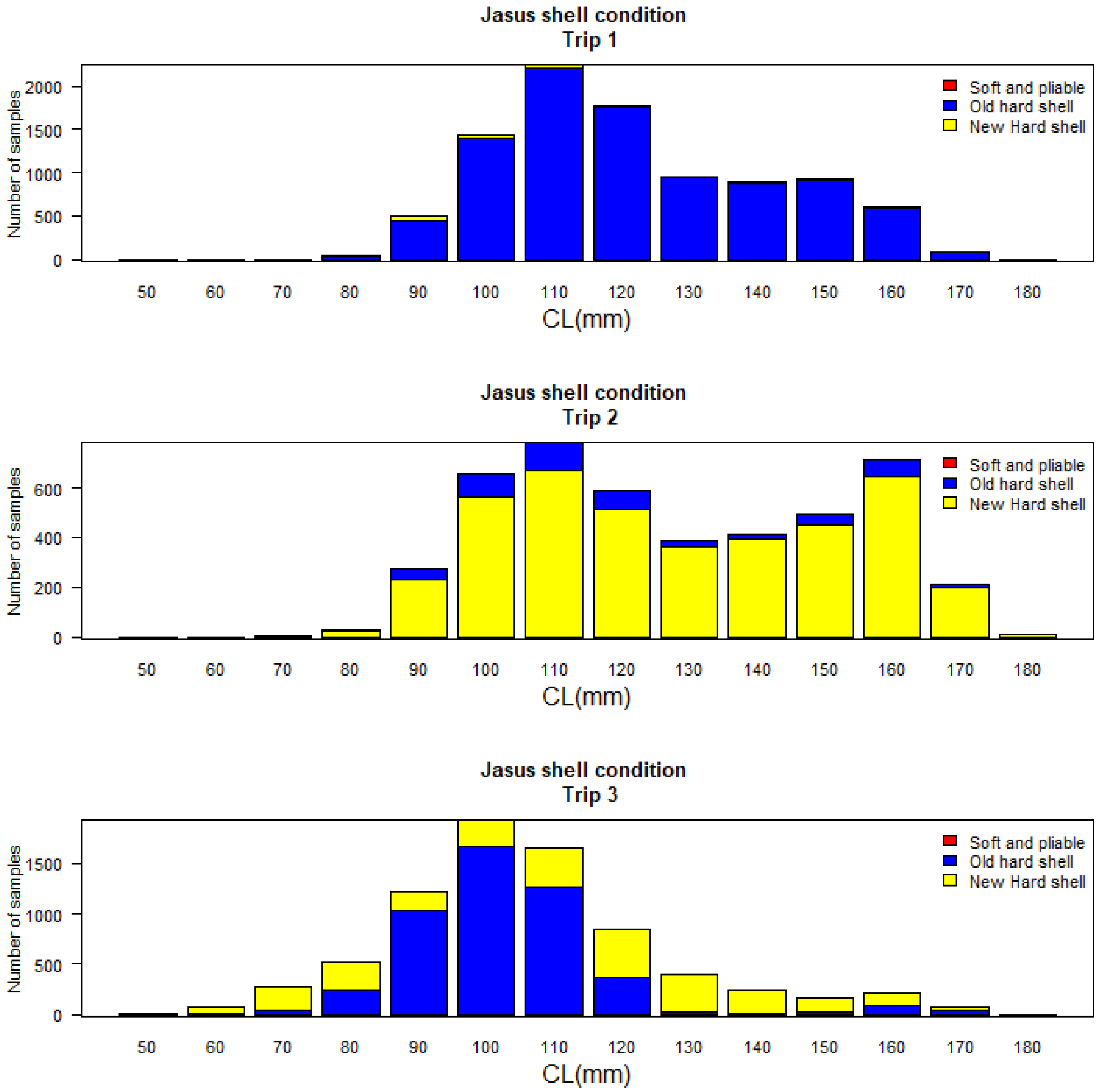


Figure 18: Shell state from *J. caveorum* sampled on trips 1 to 3.

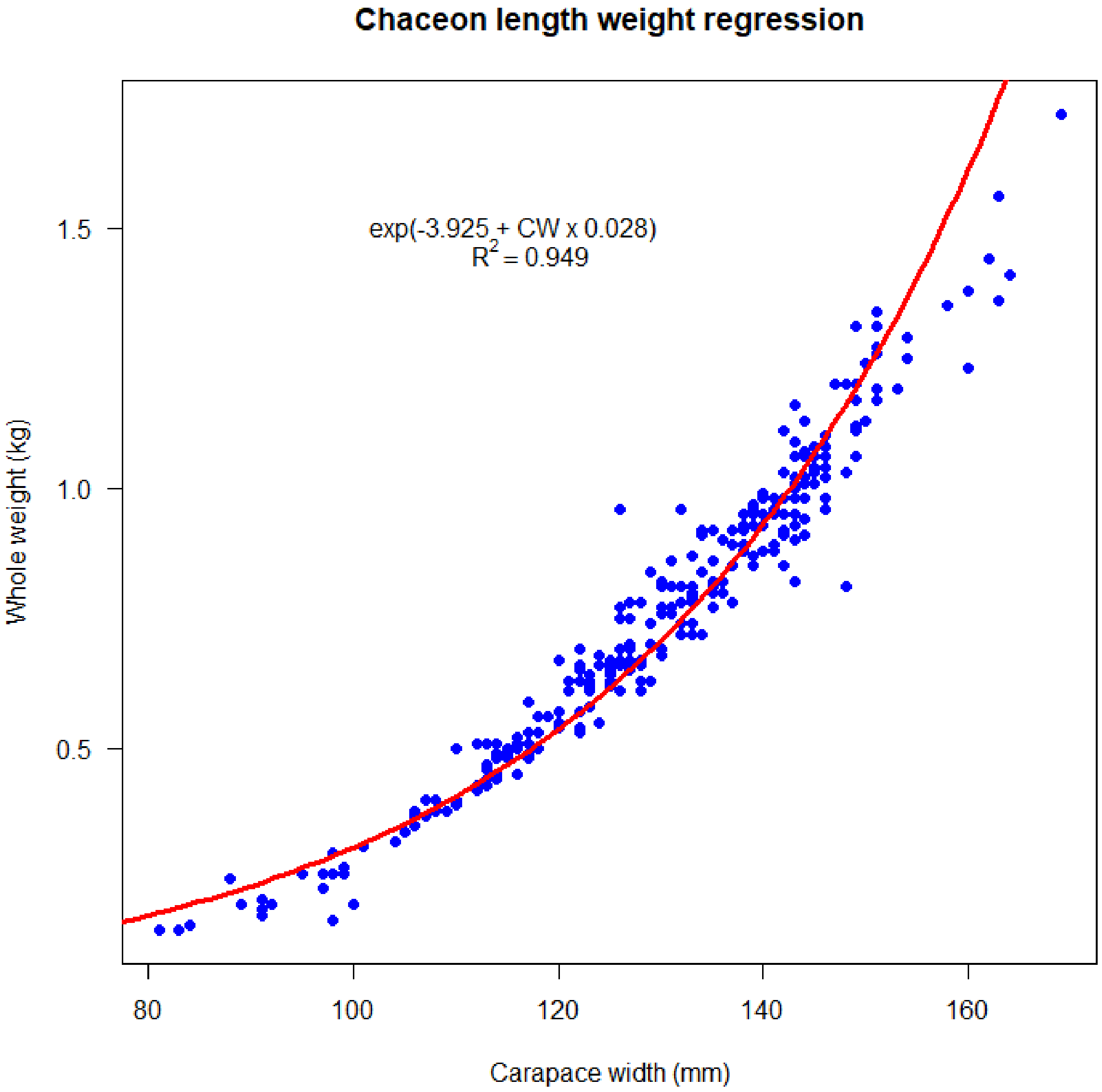


Figure 19: Length weight regression for carapace width vs. whole weight for *Chaceon* sp. sampled on trip 1 to 4.

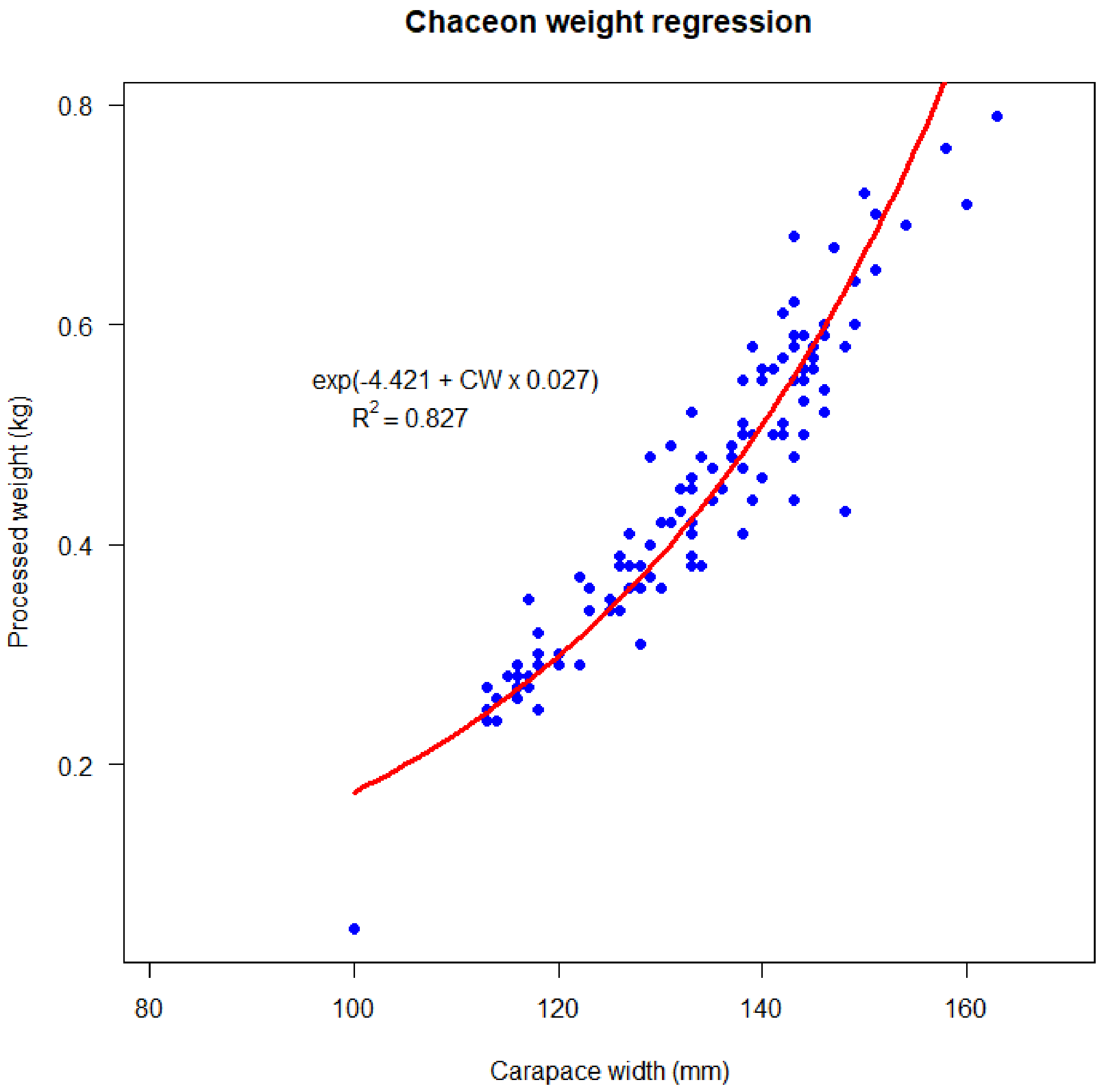


Figure 20: Length weight regression for carapace width vs. processed weight for *Chaceon* sp. sampled on trip 1 to 4.

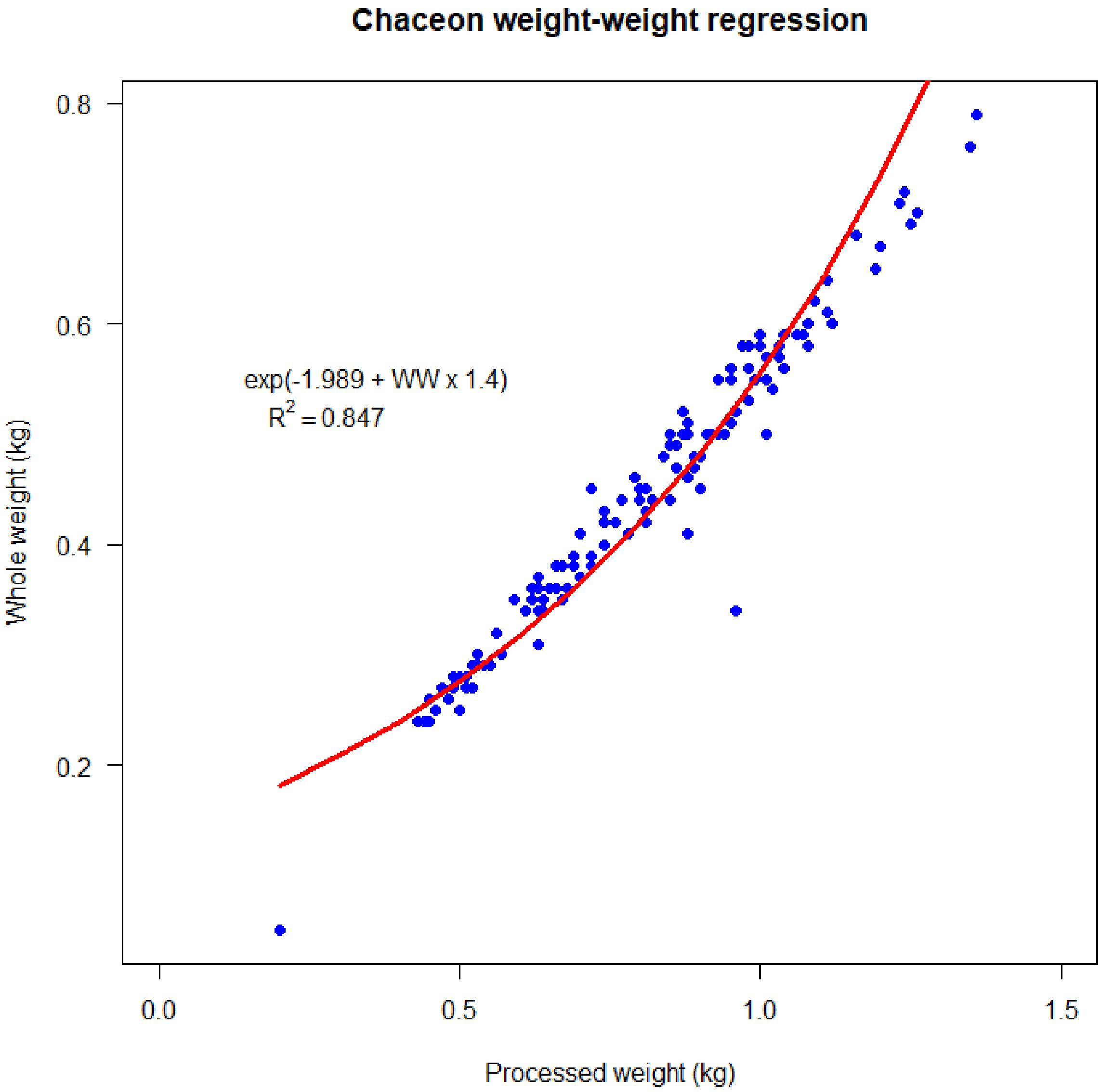


Figure 21: Length weight regression for whole weight vs. processed weight for *Chaceon* sp. sampled on trip 1 to 4.

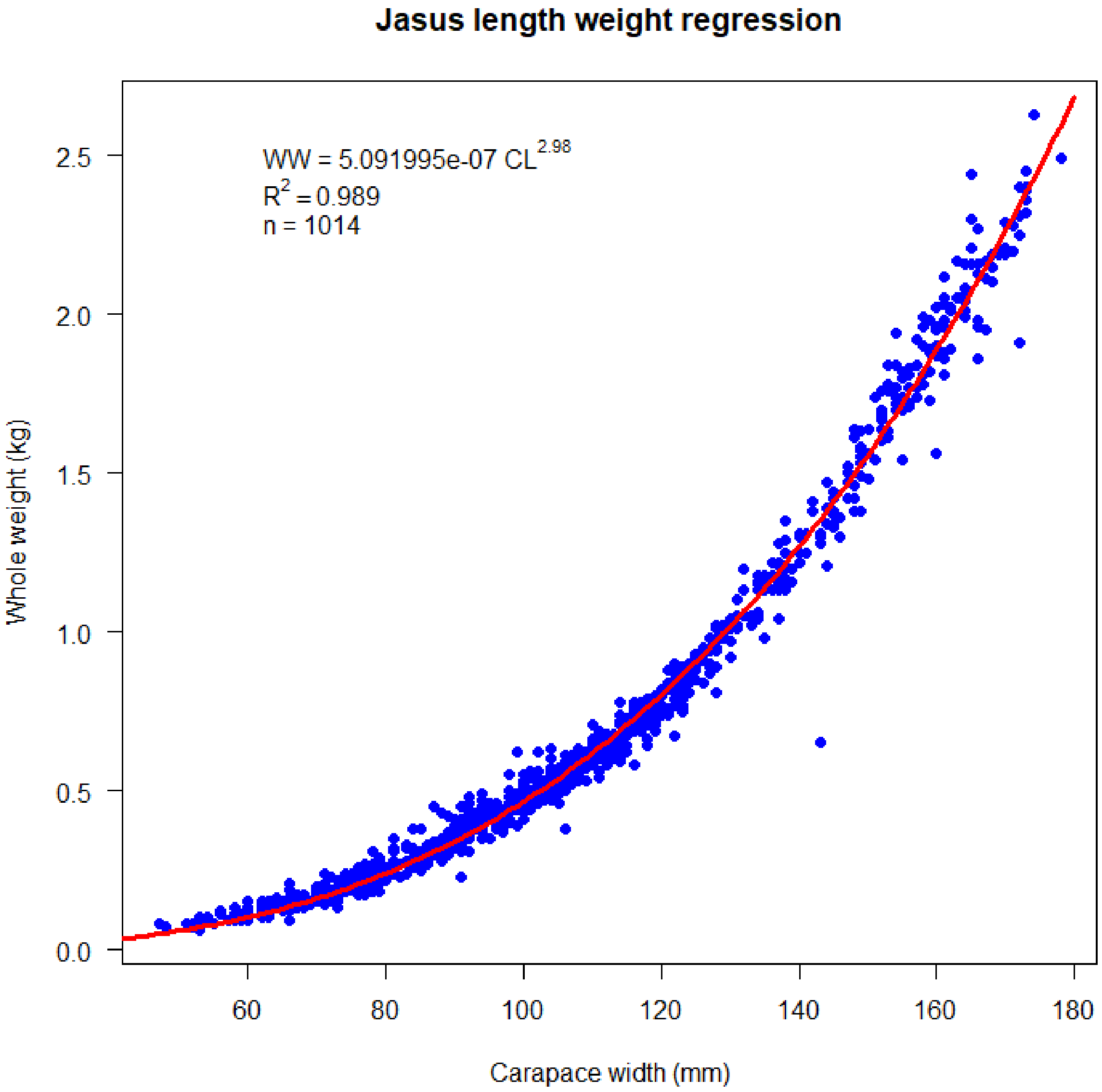


Figure 22: Length weight regression for carapace length vs. whole weight for all *J. caveorum* sampled on trip 1 to 4.

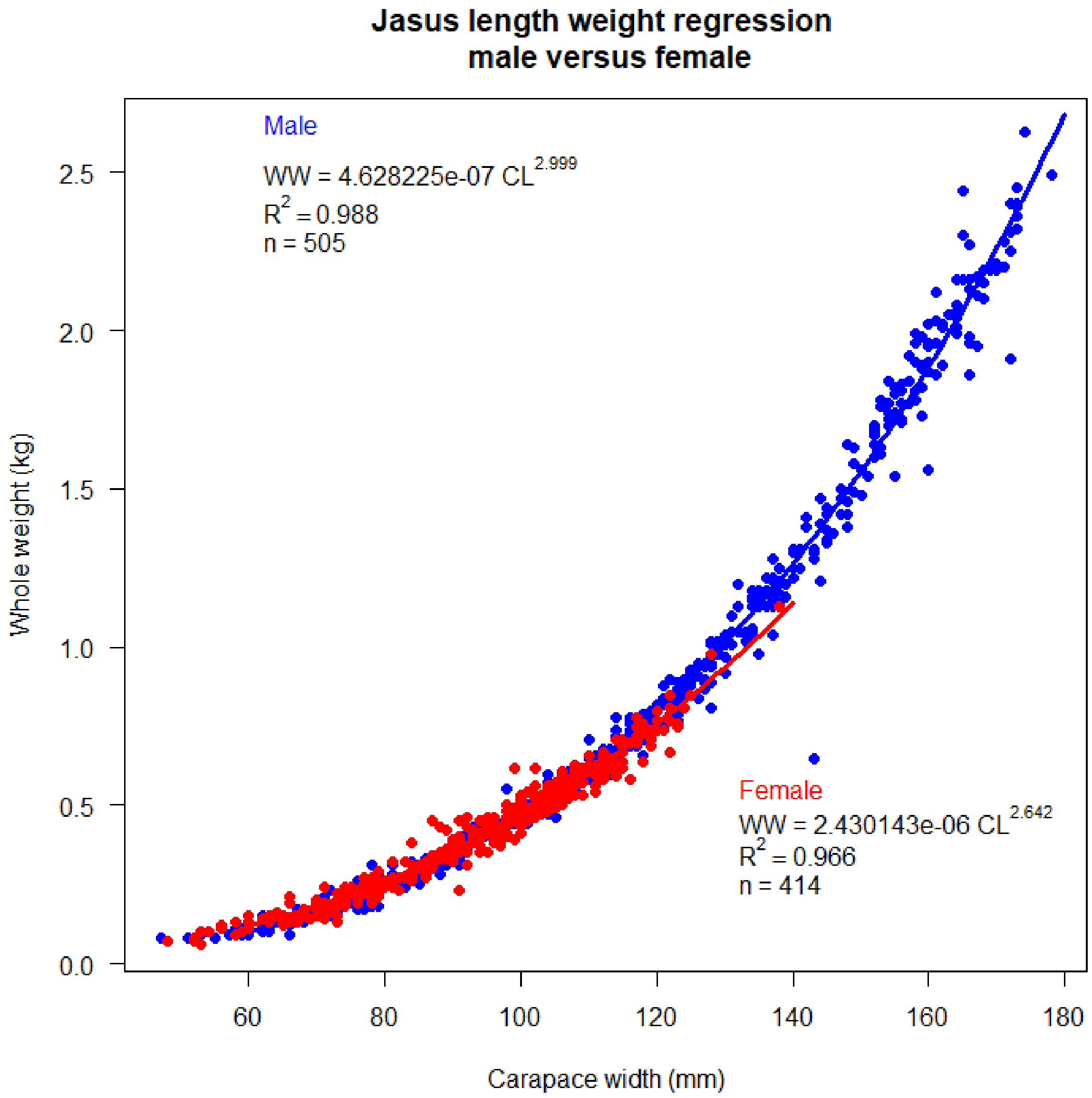


Figure 23: Length weight regression for carapace length vs. whole weight for male and female *J. caveorum* sampled on trip 1 to 4.

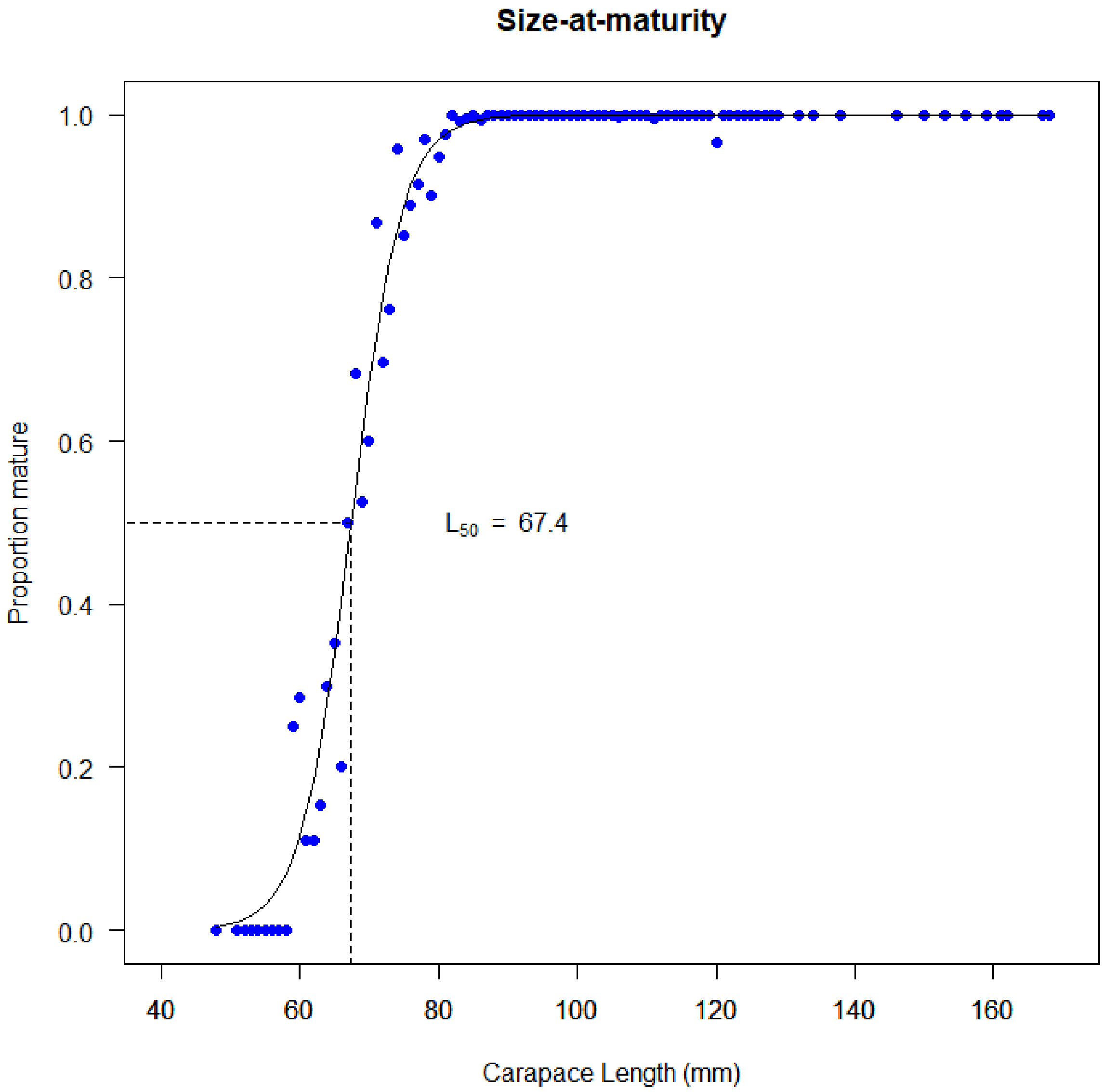


Figure 24: Size-at-maturity of *J. caveorum* from trip 1 to 4 sampled at all seamounts.

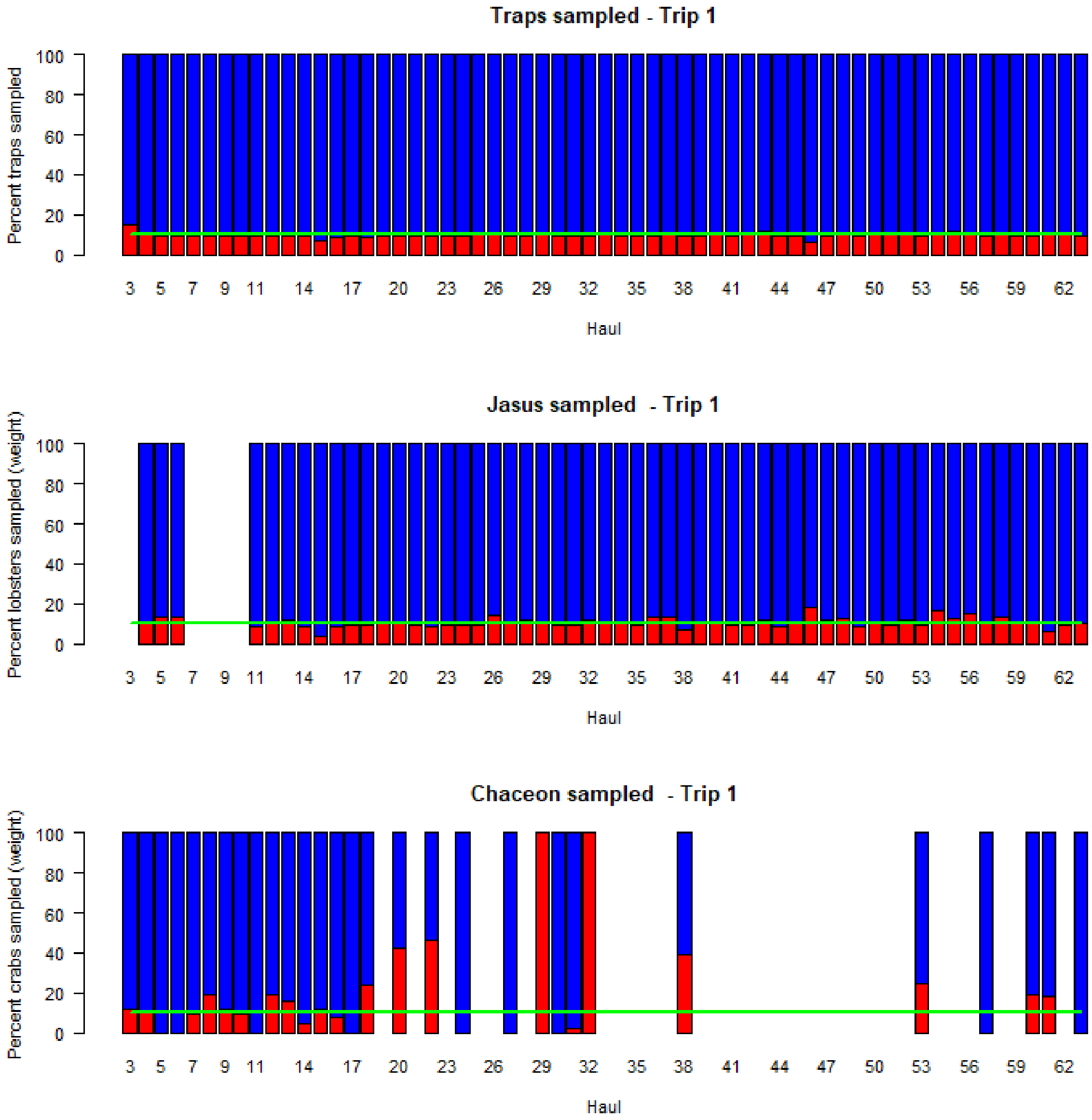


Figure 25: The proportion of traps, *J. caveorum* and *Chaceon* sp. sampled relative to the number of traps set and catch weight for trip 1. The red bars indicate the sampling effort or catch, blue bars indicate effort or catch not sampled and the green line represents the 10% target sample.

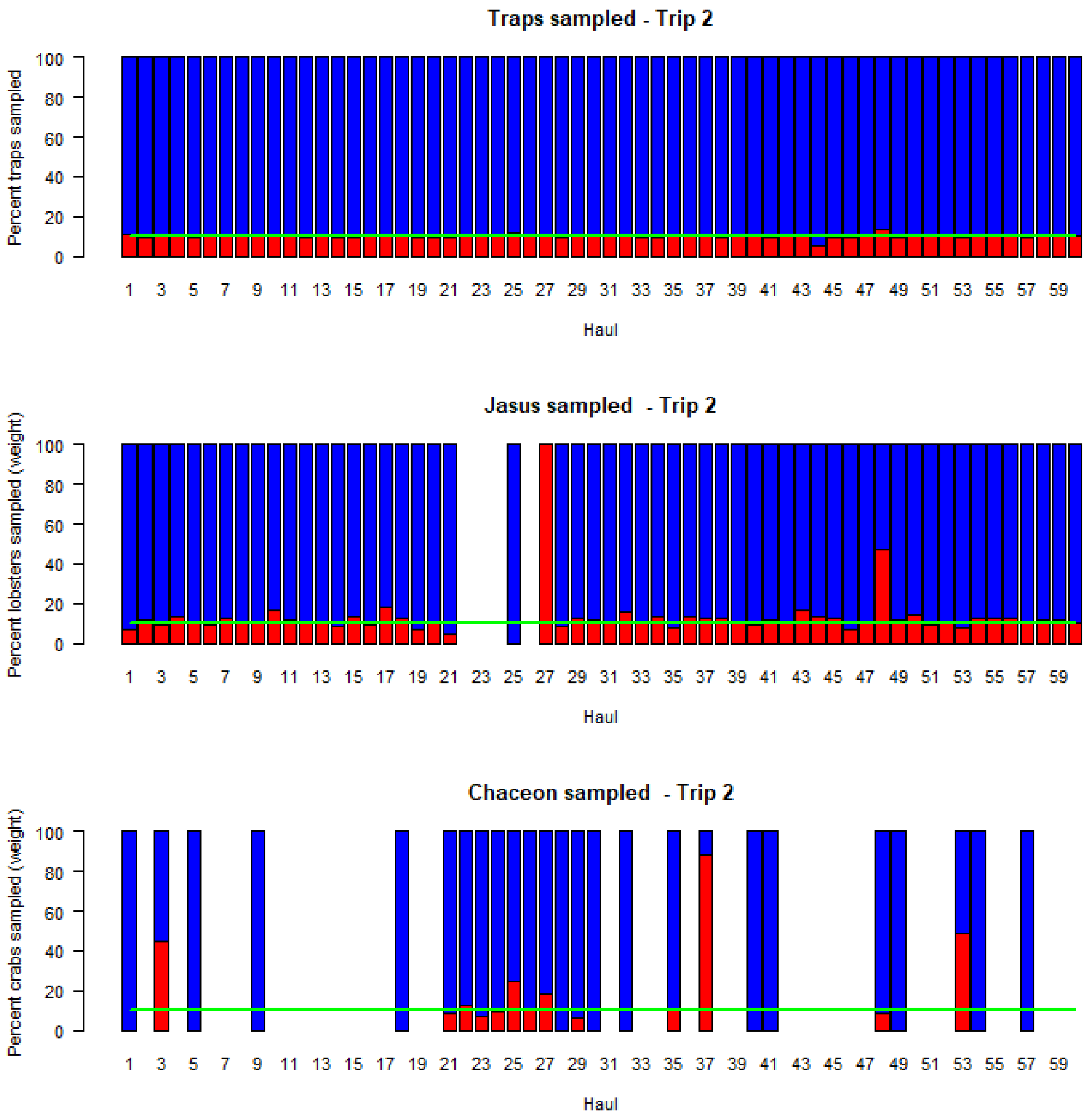


Figure 26: The proportion of traps, *J. caveorum* and *Chaceon* sp. sampled relative to the number of traps set and catch weight for trip 2. The red bars indicate the sampling effort or catch, blue bars indicate effort or catch not sampled and the green line represents the 10% target sample.

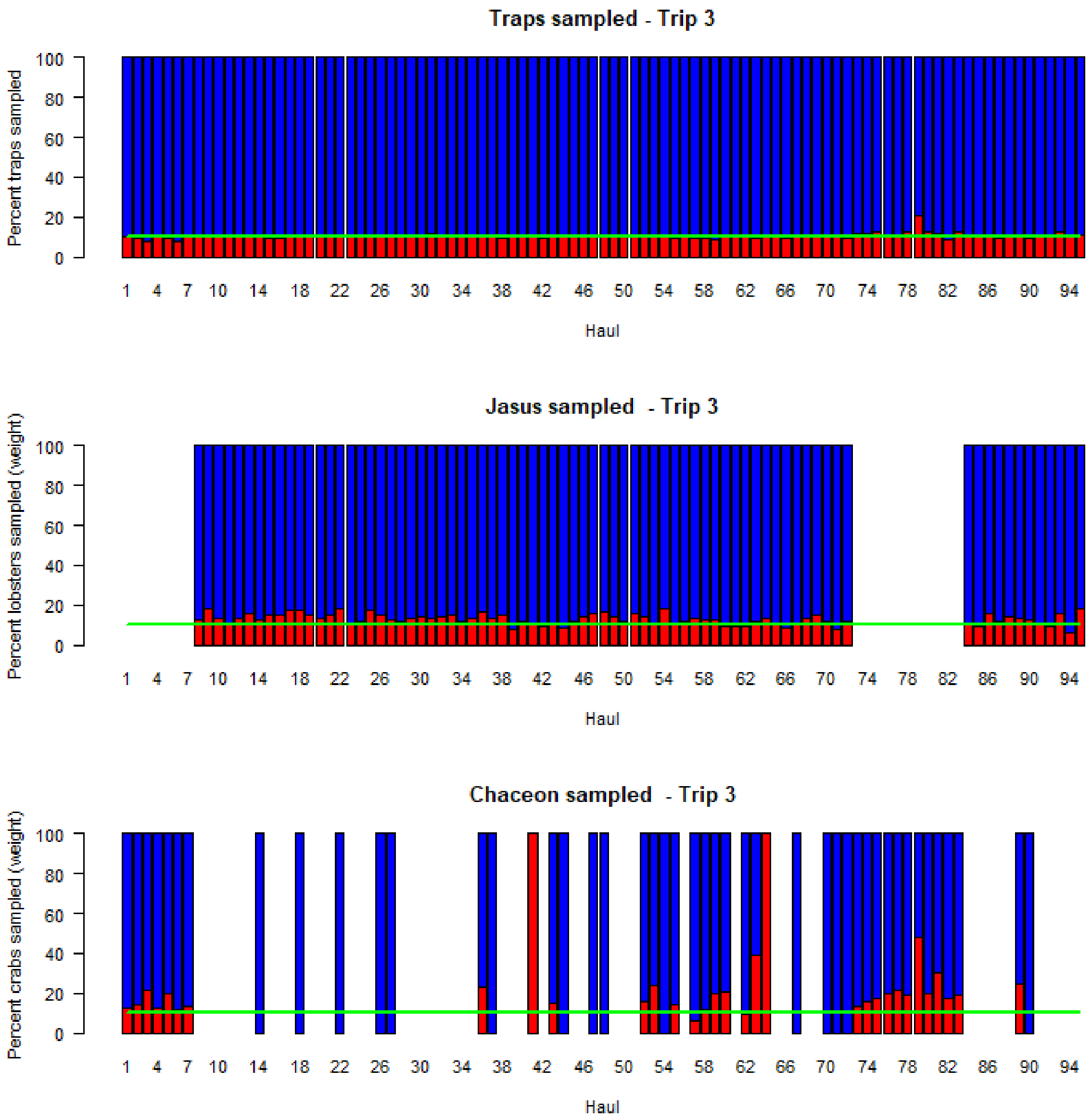
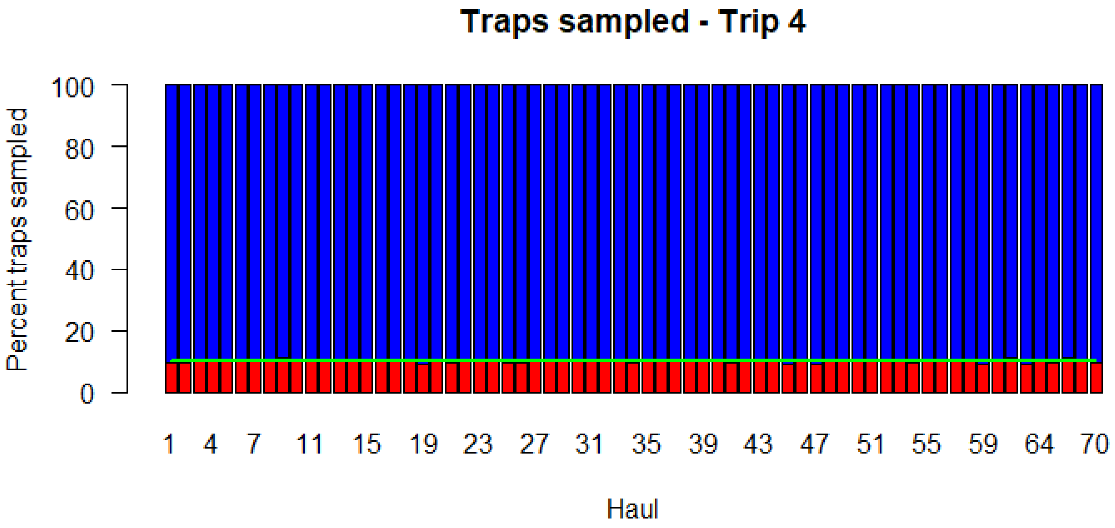


Figure 27: The proportion of traps, *J. caveorum* and *Chaceon* sp. sampled relative to the number of traps set and catch weight for trip 3. The red bars indicate the sampling effort or catch, blue bars indicate effort or catch not sampled and the green line represents the 10% target sample.



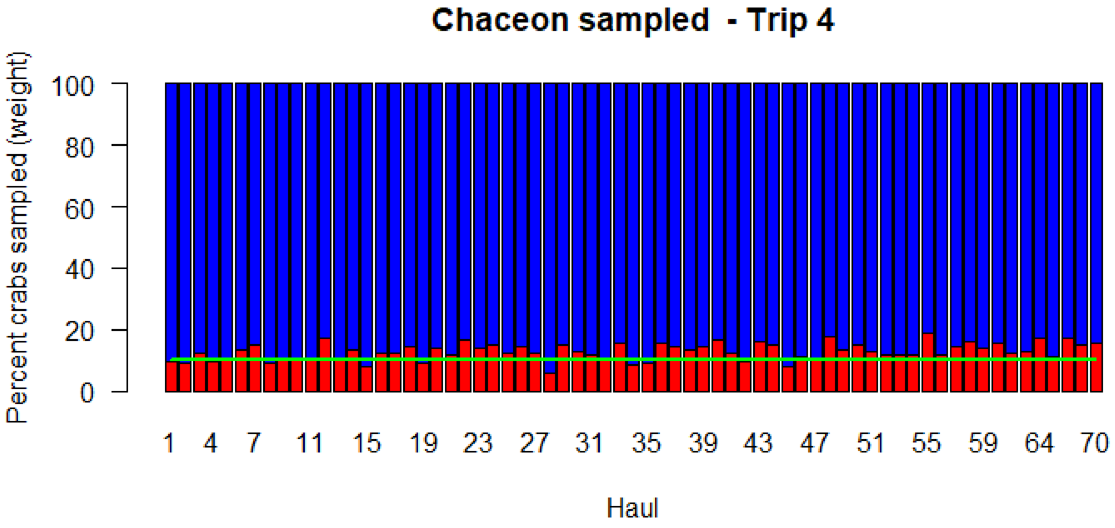


Figure 28: The proportion of traps, *J. caveorum* and *Chaceon* sp. sampled relative to the number of traps set and catch weight for trip 4. The red bars indicate the sampling effort or catch, blue bars indicate effort or catch not sampled and the green line represents the 10% target sample.

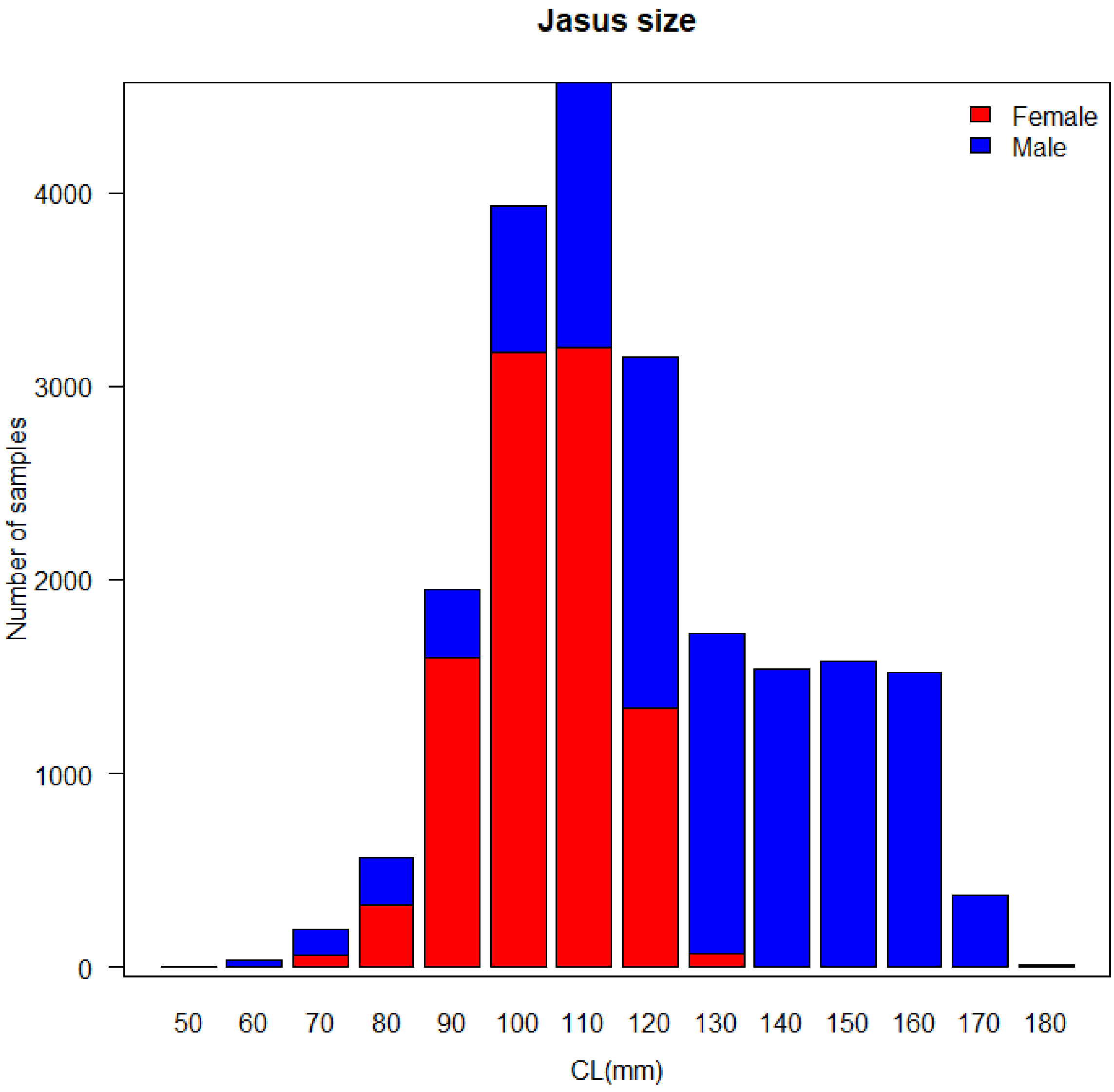


Figure 29: Size vs. sex for *J. caveorum* sampled on trip 1 to 3.

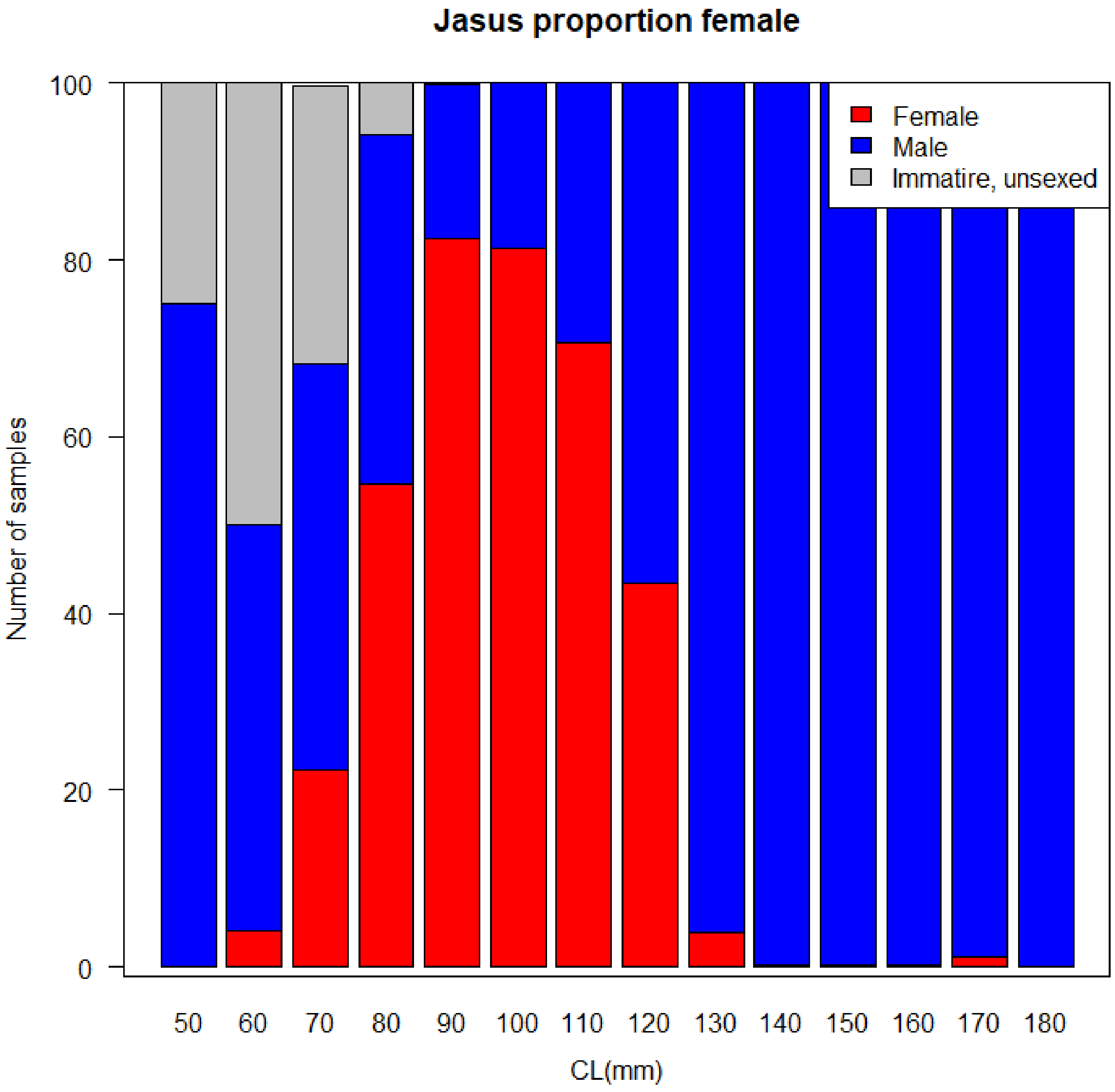


Figure 30: Size vs. sex for *J. caveorum* sampled on trip 1 to 3.