Fisheries and Oceans Science
Pêches et Océans Sciences

C S A S
Canadian Stock Assessment Secretariat

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Research Document 2000/027 REVISED
Document de recherche 2000/027 RÉVISÉ

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Exploratory Jonah Crab, *Cancer borealis*, Fishery in Lobster Fishing Area 33 (1997 – 1999)

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This document is available on the Internet at:

Ce document est disponible sur l'Internet à:

http://www.dfo-mpo.gc.ca/csas/

ISSN 1480-4883
Ottawa, 2000

Canada

Abstract

The exploratory Jonah crab fishery in lobster fishing area (LFA) 33 has been fished from 1997-99. The fishery was assessed with sea samples, port samples and analysis of mandatory fisher logbooks.

Effort was concentrated along the western and northern edges of LaHave Basin, moving eastward each year. The landings (143 – 167 mt) and CPUE (2.6 – 3.0 kg/th) have changed only marginally from 1997 to 1999. Mean carapace width of male crab (138 – 141 mm) remained stable from 1997 to 1999. Catch composition by number was 11% sub-legal male, 22% female 12% soft-shelled male, and 54% hard-shelled male in 1997 and 1998. Due to a reduction in legal minimum size and size of trap escape gaps, 1999 female crab increased to 29% and sub-legal males decreased to 5%. Bycatch was almost non-existent (e.g., 3 lobsters in 5,675 trap hauls sampled by DFO observers).

Field experiments showed 76 x 150 mm entrance restrictions did not affect bycatch or Jonah catch, handling the catch increased crab mortality, weight of crabs in a box did not affect mortality, and shark bait was superior to pollock frames. Laboratory experiments comparing trap types showed lobster traps performed best.

This fishery operated briefly in 1983 – 84. CPUE was about double and carapace widths were similar to 1997-99.

CPUE and size frequency data suggest that current exploitation levels are not endangering the sustainability of Jonah crab stocks in LFA 33. However, fleet size should be maintained near current levels until a greater proportion of potential Jonah crab habitat has been explored.

Recommended changes in regulations are a minimum legal carapace width of 127 mm, no restriction on retention of females, escape gaps of at least 47.5 mm high, a lengthening of season, and no Jonah bycatch allowed by other fisheries.

Résumé

La pêche exploratoire du crabe nordique qui s'est déroulée dans la zone de pêche du homard (ZPH) 33 de 1997 à 1999, a été évaluée en effectuant de l'échantillonnage en mer et à quai ainsi que l'analyse des registres de pêche obligatoires.

L'effort de pêche s'est concentré le long des bordures ouest et nord du bassin LaHave, se déplaçant vers l'est chaque année. Les débarquements (de 143 à 167 tm) et les CPUE (de 2,6 à 3,0 kg/casier relevé) n'ont changé que légèrement de 1997 à 1999. Variant de 138 à 141 mm, la largeur moyenne des carapaces de crabes mâles est restée stable de 1997 à 1999. En 1997 et en 1998, la composition de la capture (en nombre) était la suivante : 11 % de mâles de taille inférieure à la taille réglementaire, 22 % de femelles, 12 % de mâles à carapace molle et 54 % de mâles à carapace dure. En raison de la réduction de la taille minimale réglementaire et de la dimension des orifices d'échappement des casiers, la part des femelles a grimpé à 29 % et celle des mâles de taille inférieure à la taille réglementaire a diminué à 5 % en 1999. Les prises accessoires ont été presque nulles : trois homards ont été capturés dans les 5 675 casiers relevés échantillonnés par des observateurs du MPO.

Dans des expériences sur le terrain, la restriction des dimensions de l'entrée des casiers à 76 x 150 mm n'a pas d'incidence sur les prises accessoires, ni sur les prises de crabes nordiques; la manipulation des prises a eu pour effet d'augmenter la mortalité des crabes; le poids des crabes dans les bacs n'a pas eu d'incidence sur la mortalité; des morceaux de requin ont été plus efficaces comme appât que des carcasses de goberge. Des expériences de laboratoire visant à comparer divers types de casiers ont montré que les casiers à homard fonctionnent le mieux.

Lorsque cette pêche s'est brièvement déroulée en 1983-1984, la CPUE était environ deux fois plus élevée que pour les années 1997-1999, tandis que les largeurs de carapaces étaient semblables.

Les données de CPUE et de fréquence des tailles laissent croire que les niveaux d'exploitation actuels ne menacent pas la durabilité des stocks de crabes nordiques dans la ZPH 33. Toutefois, la taille de la flotille devrait être maintenue près du niveau actuel jusqu'à ce qu'une plus grande partie de l'habitat potentiel du crabe nordique ait été explorée.

Voici les modifications que l'on recommande d'apporter aux règlements : fixer à 127 mm la largeur minimale de la carapace, lever les restrictions sur la rétention des femelles, fixer à au moins 47,5 mm la hauteur des orifices d'échappement, prolonger la saison et interdire la capture accessoire de crabes nordiques dans les autres pêches.

Introduction

The Jonah crab, *Cancer borealis*, is found from eastern Nova Scotia to northern Florida at depths from intertidal to 800 m (Williams, 1984). It occupies bottom types ranging from rocky (Jeffries, 1966) to sand and silt clay (Musick and McEacheran, 1972). On the Scotian Shelf it occurs from a few meters deep (personal observation) to at least 640 m (Elner and Robichaud, 1985).

Jonah crab closely resemble rock crab, *Cancer irroratus*, in appearance, but grows to a larger size and the edge of the carapace is more jagged. Jonah crab reproduction is typical of decapod crustaceans. Eggs are carried on the abdomen until they hatch, and larvae are released into the water column where they develop over a period of 40-60 days (at 20^{o} C) (Sastry and McCarthy, 1973) through five planktonic stages before settling to the bottom. Male Jonah crab mature at approximately 100 mm carapace width (CW), while females mature at approximately 85 mm (CW) (Haefner, 1977). Male and female Jonah crab rarely exceed 180 mm (CW) (0.9 kg) and 150 mm (CW) (0.5 kg) respectively (Elner, 1986).

On the Scotian Shelf, commercial landings have been taken as a bycatch of the lobster fishery since the mid-1960s (Caddy *et al*., 1974). A directed fishery took 93 t in 1983 and 150 t in 1984, but stopped because the one buyer ceased operation (Elner and Robichaud, 1985). This fishery occurred on the shelf edge south of La Have Basin (Elner and Robichaud, 1985) and on the edges of LaHave and Emerald Basins (Elner and Robichaud, 1984). The offshore lobster fleet has directed for Jonah crab on the shelf edge since 1995. They are restricted by regulation to fishing more than 50 nm from shore and have landed a maximum of 500 t per year (D. S. Pezzack, pers. comm).

In 1996 in LFA 32 (Fig. 1), fishers were issued joint rock and Jonah crab licenses; these fishers now fish rock crab only. The total Jonah landings were less than 5 t over the 4-years. The recent directed fishery in the LFA 33 portion of the Scotian Shelf began in 1997 and is restricted to 12-50 nm from shore. That fishery is the subject of this report.

Materials and Methods

Fisher Logbooks

Mandatory log books contained the weight of landed crab, number of traps set, location, date, depth, and soak time. Unclear logbook entries were confirmed with Jonah crab fishers.

The log data were used to calculate CPUE (catch per unit effort in weight per trap haul), and the geographical distribution of landings. CPUE for each trip was calculated as the ratio of total weight landed and the number of traps hauled. Seasonal mean CPUE was calculated as the mean CPUE for all trips recorded in the log data. Geographical distributions were plotted in 5' latitude x 5' longitude blocks using ACON data visualisation software (Black, 1999). Landings and effort were summed for each block, whereas CPUE was averaged. Temporal patterns in mean daily CPUE per trip were described by plotting a 7-day moving mean over the entire season for each year.

Sea Samples

Landed catch has already been sorted by fishers, such that it is not representative of the catch at sea. Sea samples avoid this problem by allowing observers to sample the legal catch (including soft-shelled males), the non-legal (females and undersized males) catch that must be discarded, and bycatch of other species. Sea samples also provide a fine scale measurement of effort and catch distributions.

Two authors, Alan Reeves in 1997 and 1998, and Blair Adams in 1999 collected sea samples. These observers randomly sampled traps from each string of 20 to 40 traps. All crabs in a selected trap were sampled, and bycatch was noted for all traps hauled. For each crab, CW, sex, presence of eggs on the abdomen of females, and shell hardness (determined by applying pressure to the underside of the chela near the first joint) were recorded. Carapace height (CH), and carapace length (CL) were also recorded for a sub-sample of crab. Fishing gear configurations (traps per string, distance between traps on a string, depth, bait type, soak time, and trap specifications) were also recorded. Over 3 years 11,365 Jonah crab were sampled from 1,454 traps on 19 sea trips. Bycatch only was recorded for an additional 4,221 traps.

Port Samples

The port samples consisted of a random sample of crab from multiple fish boxes or trays belonging to a single fisher's catch. Sub-samples of individual crab weights were recorded. Over 3 years 3,990 crabs were sampled in 18 port samples.

Simple linear regression was used to define the relationship between CW and weight for legal sized male Jonah crabs. This relationship was used whenever the number of crabs had to be converted to weight.

Temperature

Temperature data were collected using VEMCO minilog temperature recorders placed inside fishers' traps. Bottom temperatures, depth, and location were recorded from July 3, 1998 to November 27, 1998 and July 25, 1999 to November 20, 1999. Bottom temperatures were recorded hourly, and mean daily bottom temperature calculated. The mean bottom temperature for the time the traps were fishing was compared to the mean CPUE of that particular fishing trip by simple linear regression.

Experimentation

Entrance Restrictions

Rectangular entrance restrictions of 7.5 by 15 cm were placed over 13 cm diameter entrance rings with the intention of reducing bycatch. A possible secondary effect of these entrance slots was a reduction in crab catch. In each of July and September, 1998, 15 traps with and 15 without entrance restrictions were alternated on a trap string. The bycatch, number of crabs, and crab CW were compared for the two entrance types.

Handling Mortality

In September of 1998, an experiment was carried out to test the hypothesis that handling crabs increased mortality. Two-hundred pounds of crab were separated into two wooden lobster crates (100 lbs. each) and placed in a single large insulated tub, packed with ice. The crabs in one crate were sorted and the dead removed at 12-hour intervals for 72 hours. At each 12 hour interval, the number, size and shell condition (hard or soft-shell) of dead crab was recorded. Crabs in the second crate were not sorted until the end of the 72-hr period.

Packing Density

DFO personnel suspected that packing density might be an important factor in the mortality rate of landed crab. In October 1997, 450 lbs. of crabs were obtained from two fishers. Two crates each were packed with 50 lbs., 75lbs, or 100 lbs. of crab for a total of 6 crates. At intervals of 12 hours, 24 hours, 48 hours, and 72 hours, dead crabs were removed. These crab were counted, weighed, CW measured and shell condition noted. The crates were stored in a holding tank at a water temperature of 8.4°C.

Bait Bags

DFO personnel proposed that the "staying power", or life expectancy of bait in crab traps was a potentially important factor affecting crab catch rates. To test this hypothesis, fine mesh (2mm) bait bags were placed in every second trap for a total of 15 traps, in a string of 29 traps. The fine mesh bags would reduce bait consumption by sea fleas (amphipods) and crabs. The traps were set for a soak time of 5 days and crab number, sex, shell condition (hard or soft-shell), and size (CW) were recorded for each trap.

Bait Type

Jonah crab fishers have suggested that shark may out perform other bait types. To compare bait types, 40 traps on a single string were baited alternately with shark and pollock. Crab number, sex, shell condition (hard or soft-shell), and size (CW) were recorded for each trap. Bait weights were not standardised for this experiment.

Trap Type

The search for an alternate trap design for fishing Jonah crab was motivated by two goals: 1) to increase crab catch, and 2) to reduce the potential for lobster bycatch. Top entry traps have been shown to be effective in achieving both goals for rock crab (Miller and Duggan, 1997). Based on these results, we hypothesize that the top entry crab trap would increase crab catch. Four trap designs were tested in 1999 in a 2 x 10 m tank with flowing seawater. The designs were a conical trap (typical conical trap used for rock crab around Nova Scotia), a dome shaped top-entrance trap, a lobster trap fitted with a top entry, and a standard lobster trap (the type of trap currently used in the Jonah Crab fishery). The tank was stocked with 30 legal size male Jonah crab. For each comparison, a baited experimental trap was placed in the tank with a baited lobster trap (control). The traps were left in the dark room for two-hours. At the end of each trial the number of crab in each trap was recorded. The bait in each trap was placed in a small wire bait box making it inaccessible to the crab, preventing the bait from being consumed during the experiment. The order in which the traps were tested was also randomized to remove any effect of time of day, or saturation of bait scent. To reduce saturation of bait scent, the tank was flushed for 3 hours between each trial. The same bait type (Atlantic salmon) and amount was used during the entire experiment.

Results

<u>Summary of the Fishery</u>

The Jonah crab fishery has operated from late spring until mid to late Autumn (May 28 to November 19, 1997, June 18 to November 3, 1998, and June 16 to October 16, 1999). The mean CPUE was 2.8 kg per trap haul (kg/th) from 1997 to 1999 (calculated as the mean of all trips)(Table 1). Annual landings ranged from 145 metric tonnes to 167 metric tonnes (Table 1). Annual total effort for the fleet ranged from 50,583 trap hauls to 57,534 trap hauls (Table 1).

Catch per Unit Effort (CPUE)

The mean CPUE was similar all three years (Table 1). The spatial distribution of CPUE for 1997 to 1999 was relatively uniform over most of the Lahave Basin (Figure 1). The spatial distribution of yearly CPUE is not presented to preserve fisher confidentiality. In the areas that have been fished in all 3 years CPUE has remained relatively stable, usually within 1 kg/th. Unusually high and low CPUEs are often the result of areas that have been fished a single time. The temporal pattern for the seven day moving mean of CPUE per trip (Figure 2) was significantly correlated between 1997 and 1998 ($r = 0.63$, $p < 0.001$), however this pattern was absent in 1999, when CPUE was stable.

The frequency distribution of CPUE per trip shows that the mode of the distribution shifted up from 1.51-2.0 kg/th in 1997-98 to 3.01-3.5 kg/th in 1999. No trips with CPUEs over 6.5 kg/th were reported (Figure 3). Even though the mean CPUE changed little, the distribution of CPUE did change. This reflects the lower temporal variability of CPUE in 1999, compared to 1997-98

The frequency distribution of catch per trap (calculated from two sea samples in 1999) showed a distinct unimodal pattern in male crab and a skewed overdispersed distribution in female crab (Figure 4). Ninety percent of the trap hauls had between 2 and 12 male crabs and 56% had no female crabs.

Effort

The geographical distribution of fishing effort has moved east each year (Figures 5, 6, and 7). The number of 5 min. x 5 min. blocks fished in one, two, or all three years were 78, 35, and 10 respectively. The relatively high numbers of blocks fished in one year may be a partial function of requests by DFO to explore specific areas. The majority of the effort has been concentrated along the northern and western edges of LaHave Basin. The mean annual effort per fisher ranged from 4,215 trap hauls in 1997 to 5,754 trap hauls in 1998 (Table 1). The cumulative effort varied slightly among the three years. Effort was expended most rapidly in 1999 and was distributed over the longest period in 1998 (Figure 8). There was no correlation between the number of trap hauls and CPUE within each 5’ x 5’ block.

Landings

The spatial distribution of landings was very similar to effort ($r = 0.98$, $p < 0.001$). The bulk of the landings also came from the northern and western edge of Lahave basin (Figure 9). Mean annual landings per fisher ranged from 11,479 kg in 1997 to 18,309 kg in 1998 (Table 1). The mode of landings per trip has moved (Figure 10) from 0-500 kg in 1997 to 1001-1500 kg in 1999.

Sea Samples

Carapace width distributions of male Jonah crab have not changed discernibly from 1997 to 1999 (Figure 11, 12, and 13); mean CW ranged from 138 mm in 1998 to 141 mm in 1997.

Female CW did change significantly in 1999 (ANOVA, $p < 0.001$) (Figure 14), when the mean CW dropped slightly to 118 mm from 122 mm in 1998.

Berried female occurrences were very few for 1997-99 seasons combined (0.05 berried females/trap hauls). The CW distribution of the berried females (Figure 15) indicates a modal size similar to non-berried females (Figure 14), although the range of sizes was much smaller.

The percentage of soft-shelled crab in the catch did not change substantially from 1997 to 1999, nor did the size distribution of soft-shelled individuals (Figures 11, 12, and 13; Table 2).

The percentage of female crab in the catch increased from 22% and 23% in 1997 and 1998, to 29% in 1999 (Table 2). The percentage of hard-shelled legal males has also been very stable from 1997 to 1999, but the percentage of sub-legal males (all shell conditions) dropped from 11% in 1997 and 1998, to 4.8% in 1999 (Table 2).

The mean catch rates from sea trips ranged from 7.7 crabs (all individuals) in 1998 to 10.5 crabs in 1999 (Table 3). Hard-shelled legal size male catch rates ranged from 3.7 crabs in 1998 to 5.6 crabs in 1997 (Table 3).

The catch rates of bycatch species were extremely low for all species (Table 4). Lobster bycatch was among the lowest with a CPUE of 1 per 1000 trap hauls in 1997 and zero in 1998 and 1999.

With increasing CW, female crabs increase in both CH and CL at a greater rate than male crabs, such that for a given CW, a female crab will be thicker and longer than her male counterpart. The relationships among CW-CH, CW-CL, and CW-weight for male and female Jonah crab are described in figures 16, 17, and 18, and table 5.

Temperature Data

No relationship could be detected between temperature and CPUE for three fishers combined or for each fisher separately (Fig. 19), although the temperature range was <1 °C.

Experiments

Entrance restrictions

The rectangular entrances had no effect on crab catch rates or bycatch. Traps with slots caught on average 9.8 crabs per trap haul, while traps without slots caught an average of 9.0 crabs per trap haul. The situation was reversed for hard-shelled legal males, traps with slots caught 2.2 crabs per trap haul and traps without slots caught 2.7 crabs per trap haul. The bycatch was 3 stone crab (*Lithodes maja*) for the traps without slots, and 2 stone crab and 1 red crab (*Geryon quinquedens*) for the traps with slots.

The maximum height and width of the opening, not the shape, restrict the admittance of crab into the traps. Bycatch is very low in this fishery, however, if the fishery expands into areas where bycatch species may be more abundant this issue should be re-examined.

Handling Mortality

The cumulative numbers of dead crab at each time interval in the handled crate were: 12 hours – 6, 24 hours – 8, 48 hours – 13, and 72 hours – 50. The total mortality for the handled crate after 72 hours was 62% dead (by weight), while the total mortality for the un-handled crate was 31% after 72 hours. Size and shell condition did not appear to affect survival. These results suggest dockside monitoring might cause increased morality in landed crab if crabs are removed from ice for weighing then re-iced.

In 1997 one buyer transferred crabs from ice at near 0^{o}C to flowing sea water tanks with temperatures as high at 14^{o}C. This resulted in high mortality and the practice stopped.

Packing Density

There was no relationship between packing density and mortality. The total number of crab dead for the entire experiment was only 16.

Packing density probably does not impact crab mortality because of the low temperature at which the crab are stored. Crab activity, and antagonistic interactions appear to increase substantially at higher temperatures (personal observations), and oxygen demands may also be greater. Although no correlation between density and mortality was detected under these experimental conditions, density may be a factor in warmer storage conditions.

Bait Bags

Bait bags did not appear to affect catch rates over the 5-day soak time of the experiment. A mean of 10 crabs per trap haul was obtained both in traps with and without bags.

Fishers have stated that the life span of bait in a trap can be very short (hours for several pounds of fish). However, the increased life span of the bait in bait bags did not appear to increase catch rate. It is possible that reduced bait scent dispersal, or the lower volume of bait (bag size restrictions) may have offset any potential benefits of increased bait life span. This experiment should be repeated on a larger scale and with standardised weight of bait.

Bait Type

Bait type had a significant affect on crab catch rates. Mean catch per trap haul for traps baited with shark was 14.9 (all crab), while the mean catch per trap haul for traps baited with pollock heads was 8.1 (all crab). The same trend is apparent in the catch rates of hard-shelled male crab, 8.1 crabs per trap with shark, compared to 4.6 crabs per trap with pollock.

We do not know why shark bait gives higher catches than pollock bait. The greater catch rates may be a function of crab preference for shark, bait volume, bait life span in the trap, or differential scent dispersal rates. Because of higher cost and lower availability, fishers rarely use shark bait.

Trap designs

Tank trials indicate that the lobster trap had the highest mean catch rate of the traps compared, 10 crab per trap haul, compared to 4.5 crab per trap haul for it's nearest competitor, the dome shaped trap (Table 6).

The trap design experiment data were drawn from a limited number of trials, but these data do suggest that top entry traps are not as effective as side entry traps in catching Jonah crab. Based on observations made during the experiment it appears that crabs have the ability to climb the top entry traps, but are more hesitant to enter a top entry trap compared to a side entry trap. The greater catch rate of the dome trap relative to the conical trap appears to be related to the lower slope and height of the trap. The conical trap provided a less direct path to the bait (compared to the dome trap). During this experiment it was noted that crabs searched for an entrance around the entire perimeter of round traps more efficiently then rectangular traps. The crabs seemed more likely to spend more time searching a round trap before leaving it. These observations indicate a round side entry trap might be most appropriate for this crab species.

Discussion

<u>**Catch per Unit Effort, Landings, and Effort**</u>

The spatial variation of effort and landings mirrored one another very closely. This relationship is expected when CPUE is relatively stable both temporally and spatially. The stability of CPUE may be the result of uniform crab distribution, movement by fishers away from areas of declining CPUE, or gear selectivity that limits catch rates to levels lower than those required to define variation in crab densities (i.e., trap saturation). Haefner (1977) indicated that Jonah crab were contagiously distributed over a depth range of 20-400 m, and that abundance was fairly even between 150 m and 400 m depth. Elner (1986) suggested that catch rates from DFO trap surveys were patchy over a depth range of 26 – 458 m. However, in agreement with Haefner (1977), Elner (1986) did report maximum relative catch rates from 43 – 393 m depth.

The distribution of male crab catches among individual traps also appears to be relatively uniform, while the distribution of female crab exhibits overdispersion (Figure 4). The difference between sexes may be the result of different catchabilities or actual spatial distributions. Trawl data from Haefner (1977) show overdispersion in the catch rates of male and female crab. However, those samples were collected over a broad range of depths (10 – 2000 m) and habitat types (shelf, canyon, slope). Haefner (1977) and Elner (1986) found an increase in male size with depth. Both Krouse (1980) and Stehlik *et al.* (1991) suggest that male and female movement patterns may differ. These conclusions were based on shifting sex ratios. Krouse (1980) points out that this may be a function of changing catchability, but Stehlik *et al.* (1991) based their conclusions on less selective trawl and dredge data indicating that the sex ratios did shift.

During mid August and late October in 1997 and 1998 CPUE fluctuated by approximately 2 kg/th. Jeffries (1966), Krouse (1980) and Stehlik *et al.* (1991) suggested the Jonah crab might exhibit seasonal movements from deeper, relatively warmer water on the continental slope in fall and winter, to the shallower continental shelf in the spring and summer. The increase in CPUE in LFA 33 towards the later part of the season in 1997 and 1998 does not seem to be in agreement with the hypothesis. However, this pattern of increased CPUE in the later part of the season was not obvious in the 1999 data.

The CPUE of the 1983-84 Jonah crab fishery around LaHave basin was substantially higher than the 1997-99 CPUE (6.5 vs. 2.8 kg/th) (Elner and Robichaud, 1985). A small portion of the higher catch rates in 1983-84 can be attributed to the inclusion of female crab in the landings. The primary difference in fishing method was trap type. The 1983-84 fishery used wooden offshore lobster traps with no escape gaps or entrance restrictions. The similar size frequencies from 1983-84 (Fig. 20) to the recent catches (Figs. 11, 12, 13) suggest catch differences may reflect abundance.

Temperature

The range of bottom temperatures recorded by the fishers (3.4 – 9.4 °C) included temperatures slightly below the range described as optimal for Jonah crab, 6 – 14 °C off New England (Jeffries, 1966), and included only a small portion of the range where maximum abundance was reported by Haefner (1977) off Virginia, 8 – 13.9 °C. Jonah crab are more common in colder waters on the Scotian Shelf than further south.

The data suggest no relationship between temperature and CPUE in 1999 (Fig. 19). However, the temperature data included readings over only 3 months and a narrow range. Stehlik *et al.* (1991) detected a partial correlation between temperature and Jonah crab catches. The correlation was positive in the summer in the Gulf of Maine, positive in the fall on Georges Bank, and negative in the fall over the mid-Atlantic Bight. The coefficient of determination (r^2) values for the models used to estimate the partial correlation coefficients were low (0.025, 0.024, and 0.043 respectively).

Sea Samples and Port Samples

The CW distribution of male Jonah crab in the sea samples has not changed substantially since 1997. However, several small anomalies in the data must be noted. The distribution appears slightly more erratic in 1998, perhaps because of the smaller sample size relative to 1997 and 1999; 3668 (9 sea trips, 1997), 2528 (5 sea, 1998 trips), and 5628 (5 sea trips, 1999). A slight increase in the number of male crab less than 130 mm CW in 1999 and the increase in the catch of female Jonah crab under 121 mm CW in 1999 (ANOVA, $p < 0.01$; Figure 14) can be explained by a reduction in escape gap size from 47.5 to 44.5 mm. The reduction in the minimum size limit from 130 mm to 121 mm in 1999 increased the proportion of legal crab in the catch by 6% (by weight). The new minimum size appears to have added little value to the landings of legal crab and increased female discard rate substantially. Returning to or near the 130 mm size limit would reduce the female discards without a significant loss in revenue to the fishers.

There was no relationship between CW and percentage soft-shell crab. Thus, there was no evidence to indicate an interaction between size and molt frequency or molt timing (Figs. 11, 12, and 13). The timing of the sampling may also be a factor. Significant molting events may occur outside the Jonah crab fishing season.

CW-weight regressions from this study, Krouse (1980), and Briggs and Mucshacke (1982) were very similar over the broad geographic region from which the estimates were derived (coastal Maine, Northwest Atlantic shelf, and the Southeastern Scotian shelf) (Fig. 18).

The modes of the CW distributions in the 1997-99 fishery and the 1983-84 fishery were all near 143 mm (Figs. 11, 12, 13, 20). The fishing techniques differed between these fisheries, thus gear selectivity may have influenced both CW distributions, but these data indicate the size structure of the Jonah crab population(s) around LaHave and Emerald Basin have not changed substantially in the intervening years.

Management of the Fishery

Fishing area

To encourage participation in the fishery in the 1980s DFO implemented a minimum of regulations (Elner and Robichaud, 1985) (Table 7). In both the 1980s and ‘90s fisheries managers had strong reservations about the potential for illegal lobster fishing and the crab fleet was restricted to beyond 12 miles for this reason. In the ‘90s the fleet was also restricted to a maximum of 50 miles from shore, in part, because the offshore lobster fleet was permitted to take Jonah crab outside 50 miles. In 1983-84 catch rates on the shelf edge were greater than on the shelf (Elner and Robichaud, 1984).

There remains a large potential fishing area east of where the offshore fleet has traditionally fished and between the shelf edge and the 50 mile line. The existing shelf fleet could be allowed to expand into this area or a new fishery could be developed.

Additional licenses

The current fleet has not explored the limit of the potential grounds, however low profitability has discouraged extensive exploration. If the existing fleet was allowed to fish the shelf edge where catches are higher, more licenses would be justified. Under the present area limits any increases should be slight until the existing fleet has had more time to explore.

Minimum crab size

In the 1990’s, minimum sizes of 130 and 121 mm were tried. The latter increased the weight of male catch only 6% and the smaller escape gap size increased female catch by approximately 70%. As a compromise, we recommend the minimum size be increased to 127 mm (5 in.) and the escape gap size be increased.

Crab sex

Females mature well below any likely minimum legal size and the fishery captures only a small portion of the female stock. Restriction on the retention of females over the minimum legal size seems unnecessary.

Trap escape gap size

From the Jonah height-width relationship, it can be determined that an escape gap height of at least 47.5 mm would be appropriate for a crab width of 127 mm. There should be at least two of these in each parlour of a lobster trap. Maine has the same minimum lobster size as LFA 33 and they have adopted a 49 mm high escape gap. Therefore, 47.5 mm escape gap should not be too large for lobsters in cases were fishers wish to use the same traps for lobsters and crabs. A year of grace to allow fishers to convert escape gaps from the present 44.5 mm would seem reasonable.

Trap limits

Trap numbers were limited to 250 in 1997 then to 375 in 1998-99 to prevent a large investment in gear before the economic success of the fishery is demonstrated. Limits also encourage fishers to fish smarter rather than harder. However, another moderate increase in traps could be allowed to increase profitability and to make it worthwhile for fishers to explore further from their home ports. According to an analysis by J. Nelson (DFO economists, Dartmouth, N.S.) the fishery was not profitable in 1999.

Gear type

We recommend the fishery remain trap only because of the minimum habitat impact, the high quality of the catch , and the low bycatch. The bycatch of all other species is remarkably low. We are familiar with no other fishery as clean as this one. Fishers should continue to experiment with trap designs to increase catch and lower costs. The only restrictions should be the presence of escape gaps and a maximum trap volume.

Catch quota

We see no reason for a catch quota. Fishing effort, and catch if necessary, can be regulated by gear and season.

Season

The season is now set to avoid overlap with the lobster season. Because the catch has a higher value in the spring (Clearwater Fine Foods plant manager, pers. comm.) there is reason to allow it to start earlier than June 15.

Jonah bycatch in other fisheries

The existing fleet has invested considerable time and money in developing what is still a marginal fishery. It would seem unfair to let another group reap the benefits if the fishery becomes more profitable. Although the maximum fleet size that can be supported is not yet known, it will not be large. Another large fleet allowed access through bycatch could take the entire annual harvest.

Ecosystem considerations

The present low removal rate of crab suggests the fishery has little influence on predator-prey relationships involving Jonah crab. Trap fisheries cause relatively little benthic disturbance. This fishery is expected to have minimal impact on the ecosystem.

Acknowledgements

The authors would like to express their gratitude for the co-operation and input of the fishers involved in the exploratory Jonah crab fishery. A special thanks to those individuals, who installed temperature-recording devices in their gear, experimented with new trap designs and took scientific samplers to sea. These individuals made significant contributions to our knowledge of Jonah crab on the Scotian Shelf. We also thank the Jonah Crab Fishermen's Association and the Nova Scotia Dept. of Fisheries and Aquaculture for financial contributions to a HRD internship program. Greg Roach of the Nova Scotia Dept. Fisheries and Aquaculture provided administrative and financial support for the Jonah crab internship program.

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Table 1. Annual CPUE, landings, and effort for the exploratory Jonah crab fishery in LFA 33 from 1997-1999**.**

YEAR	MEAN CPUE (KG/TH)	TOTAL LANDINGS (MT)	TOTAL EFFORT (TRAP HAULS)	EFFORT PER FISHER	LANDINGS PER FISHER (KG)
1997	2.60	145	50583	4215	11479
1998	3.01	167	57534	5754	18309
1999	2.88	164	56790	5163	14403
3 - Year Mean	2.83	159	54241	5044	14730

Table 2. Sea samples catch breakdown by crab type for the exploratory Jonah crab fishery in LFA 33 from 1997-1999.

CRAB TYPE	1997	1998	1999
Sub-legal Males	11%	11%	5%
Females	22%	23%	29%
Soft-shell Legal Males	11%	14%	13%
Keepers (Hard Shell Legal Males)	56%	52%	53%

Table 3. Catch per trap haul in number of animals from sea samples taken in the exploratory Jonah crab fishery in LFA 33 from 1997-1999.

CATCH RATE	1997	1998	1999
All Sizes	10.2	7.7	10.5
Range of Mean per Trip	6.8 – 15.1	4.7 – 37.0	5.7 – 16.7
Keepers	5.6	3.7	5.5
Range of Mean per Trip	4.4 – 7.1	2.1 – 15.4	2.4 – 9.0

Table 4. Catch per 1000 trap hauls of bycatch species in number of animals for the exploratory Jonah crab fishery in LFA 33 from 1997-1999.

BYCATCH SPECIES	1997	1998	1999
Stone Crab	20	24	2
Red Crab	9	2	<1
Cusk	6	<1	0
Hake	5	1	<1
Lobster	1	0	0
Snow Crab	<1	0	0
Pout	0	0	<1

Table 5. Simple linear regression equations for carapace width (mm), carapace length (mm), carapace height (mm), and weight (g) taken from sea samples collected during the exploratory Jonah crab fishery in LFA 33 from 1997-1999.

REGRESSED VARIABLES	MALE	FEMALE
Carapace Width – Length	$CL = 0.912\ CW^{0.92}$	$CL = 0.537\ CW^{1.04}$
Carapace Width – Height	$CH = 0.525\ CW^{0.92}$	$CH = 0.275\ CW^{1.07}$
Carapace Width – Weight	$Weight = 0.00048\ CW^{2.77}$	N/A

Table 6. Catch per 2 hour set, in numbers of crab, for experimental traps and modified lobster traps (control) placed simultaneously in a flow tank.

TRIAL	CONICAL TRAP	LOBSTER TRAP (CONTROL)	DOME TRAP	LOBSTER TRAP (CONTROL)	TOP ENTRY LOBSTER TRAP	LOBSTER TRAP (CONTROL)
1	0	13	4	11	0	8
2	0	5	1	8	0	18
3	0	5	3	9	0	12
4	0	8	10	14	1	9
Mean	0	7.8	4.5	10.5	0.25	11.8

Table 7. Principal Jonah crab regulations for LFA 33 in 1983-84 and 1997-99.

	1983-84	**1997-99**
Fishing Area	12-200 Miles offshore	12-50 miles offshore; with the exception of 1997
Minimum Crab Size	130 mm CW	1997-98: 130 mm CW; 1999 121 mm CW
Crab Sex	No restriction	Male only
Catch Quotas	None	None
Seasons	None	June 15-November 15
Gear Type	Traps only	Top entry traps or lobster traps with maximum 102 mm high entrance
Trap Escape Gaps	None	Minimum of 47.5 mm high in 1997-98; 44.5 mm high in 1999
Trap Limits	None	250 maximum in 1997; 375 maximum in 1998-99
Bycatch of Jonah by lobster fishery	Unrestricted	Unrestricted in 1997-98; prohibited in 1999
Catch Records	Log records	Dock-side monitoring program
Minimum Boat Length	10.6 m	No minimum
No. of Permits	32: 10 active in 1983 3 active in 1984	16 in 1997: 14 active; 12 in 1998-99: 9 and 11 active

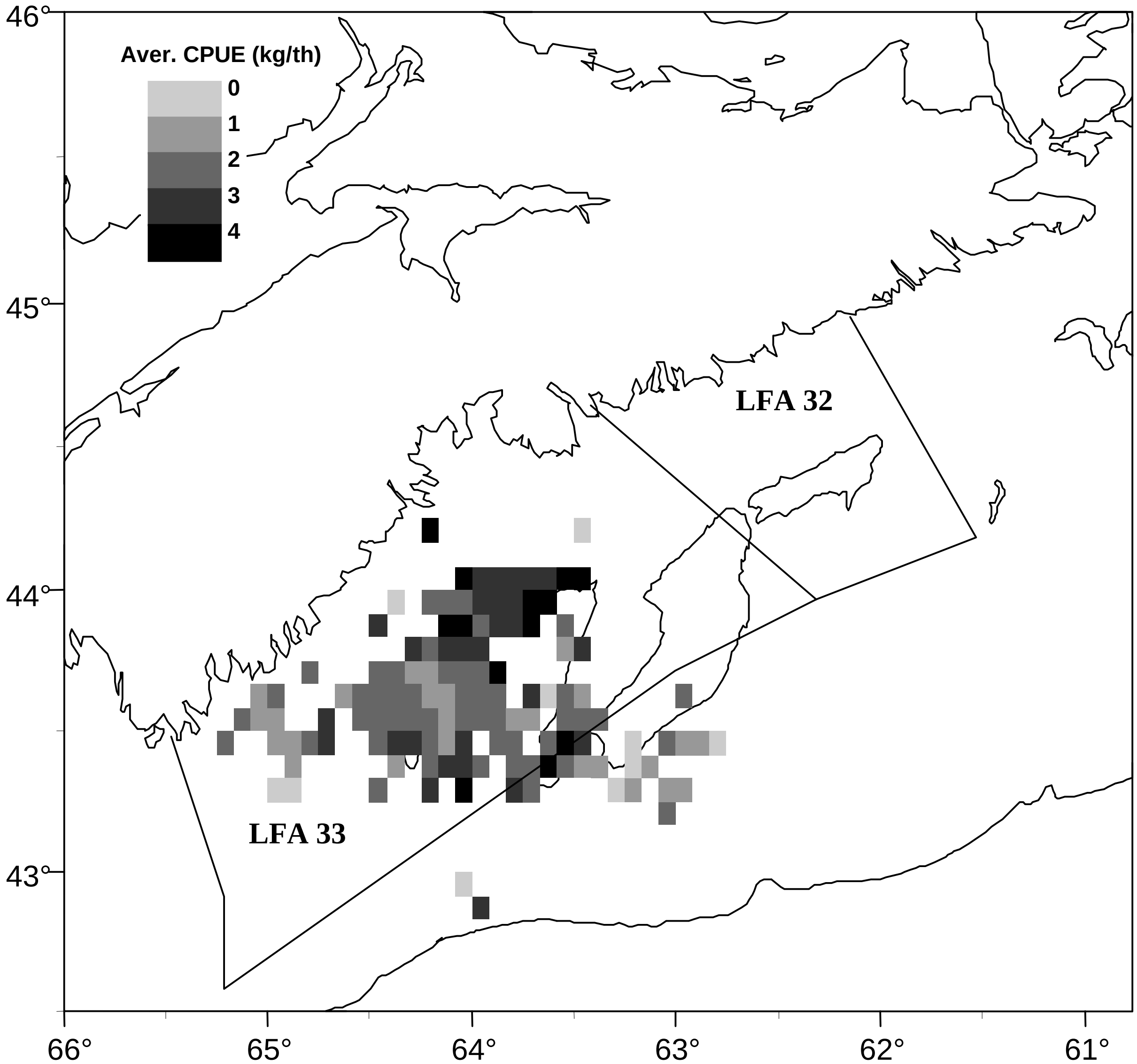

Figure 1. The geographical distribution of CPUE for the exploratory Jonah crab fishery in LFA 33 from 1997-1999.

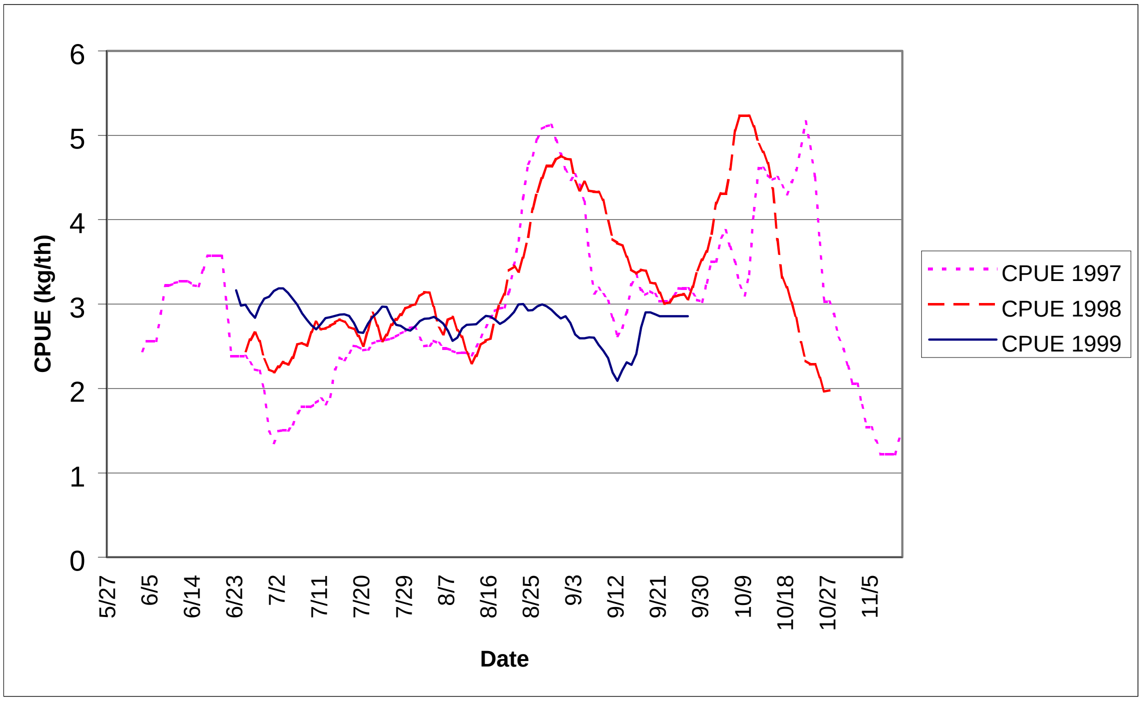

Figure. 2. A 7-day moving average of CPUE fishery for 1997, 1998 and 1999.

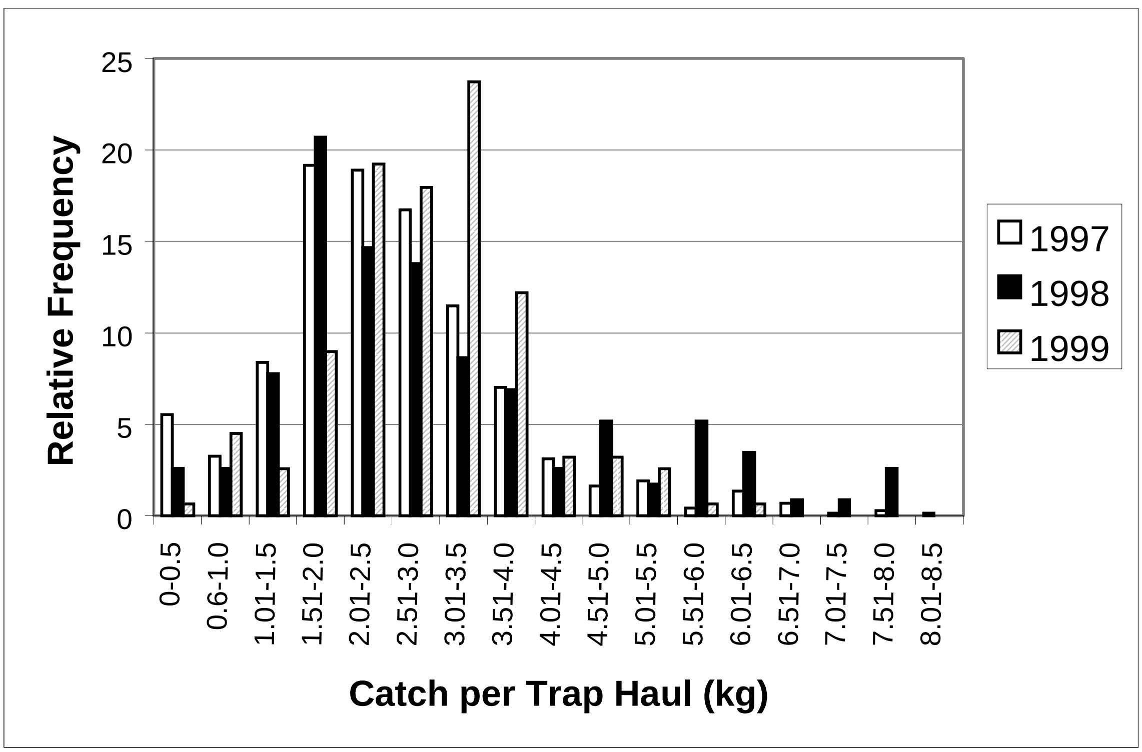

Figure 3. Relative frequency distribution of CPUE per trip for all fishers in 1997, 1998 and 1999.

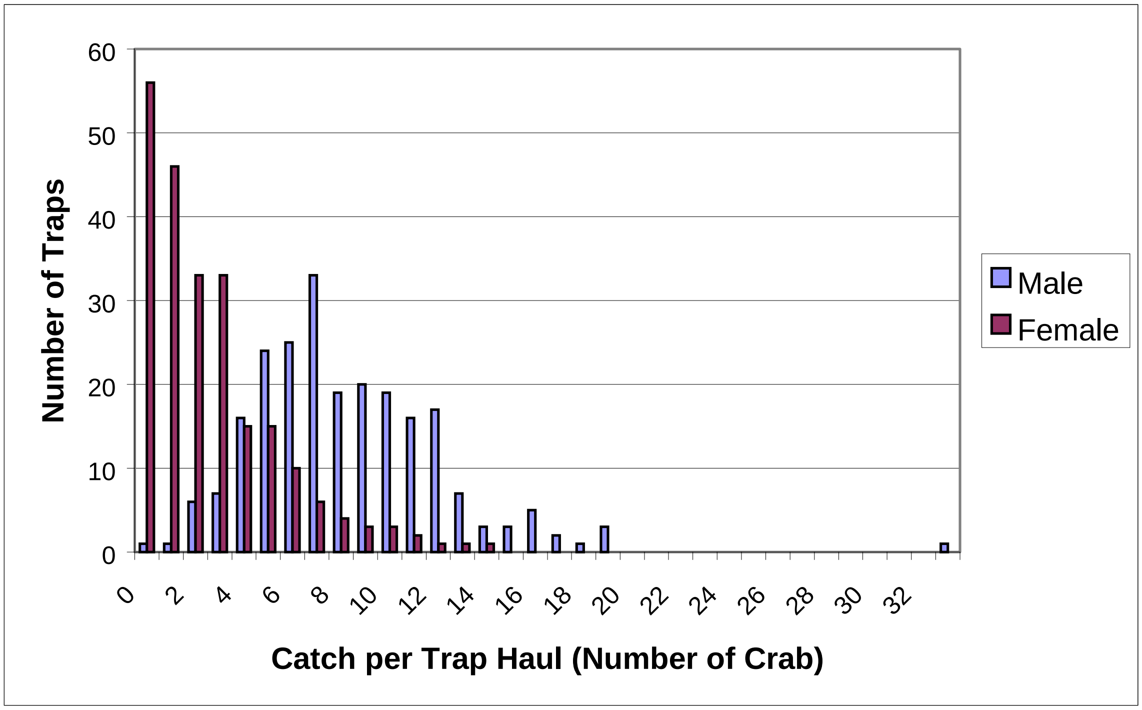

Figure 4. The distribution of catch per trap haul for male and female Jonah crab from 229 trap hauls sampled during two sea trips in 1999.

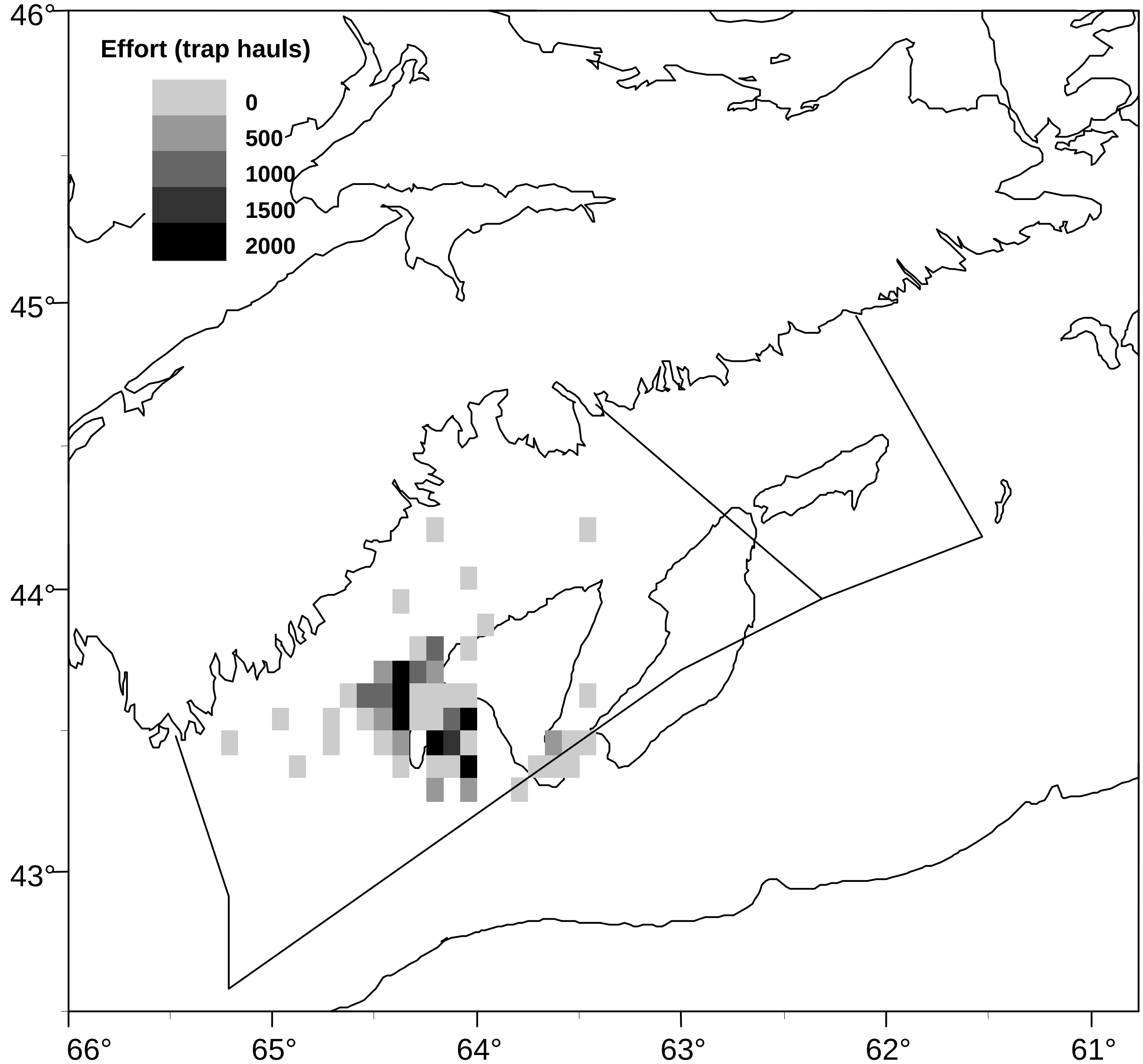

Figure 5. The geographical distribution of effort for the exploratory Jonah crab fishery in LFA 33 for 1997.

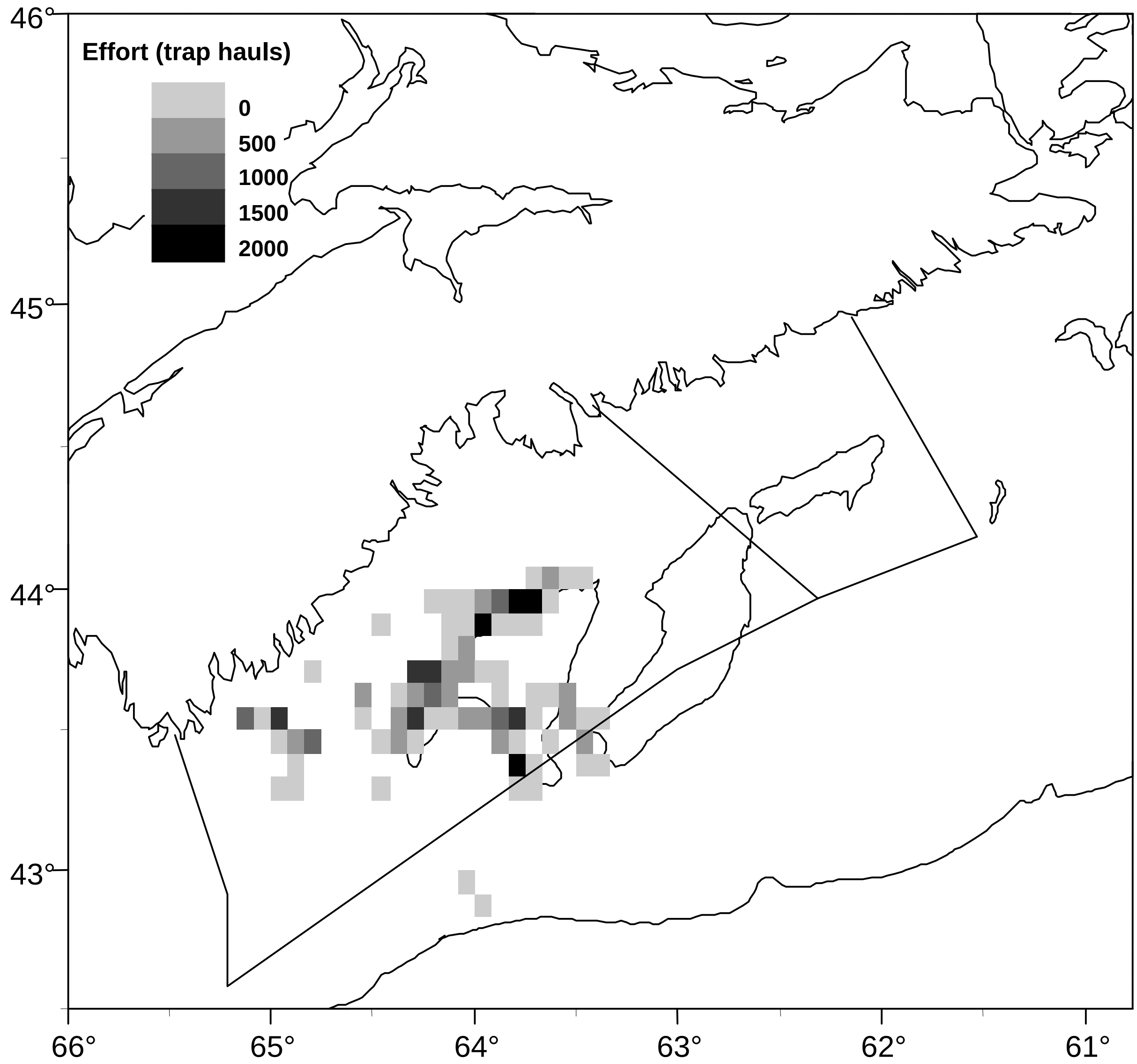

Figure 6. The geographical distribution of effort for the exploratory Jonah crab fishery in LFA 33 for 1998.

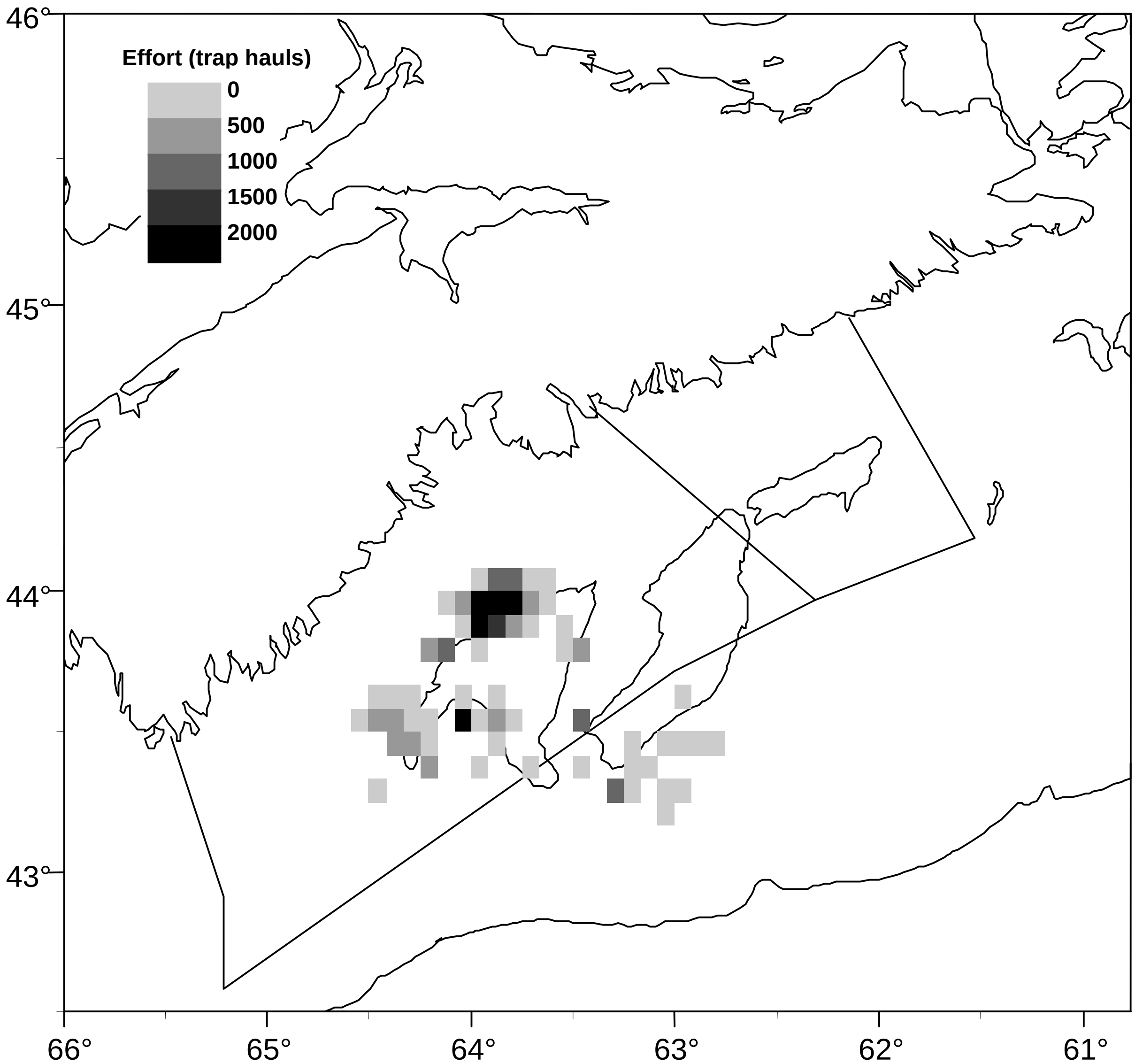

Figure 7. The geographical distribution of effort for the exploratory Jonah crab fishery in LFA 33 for 1999.

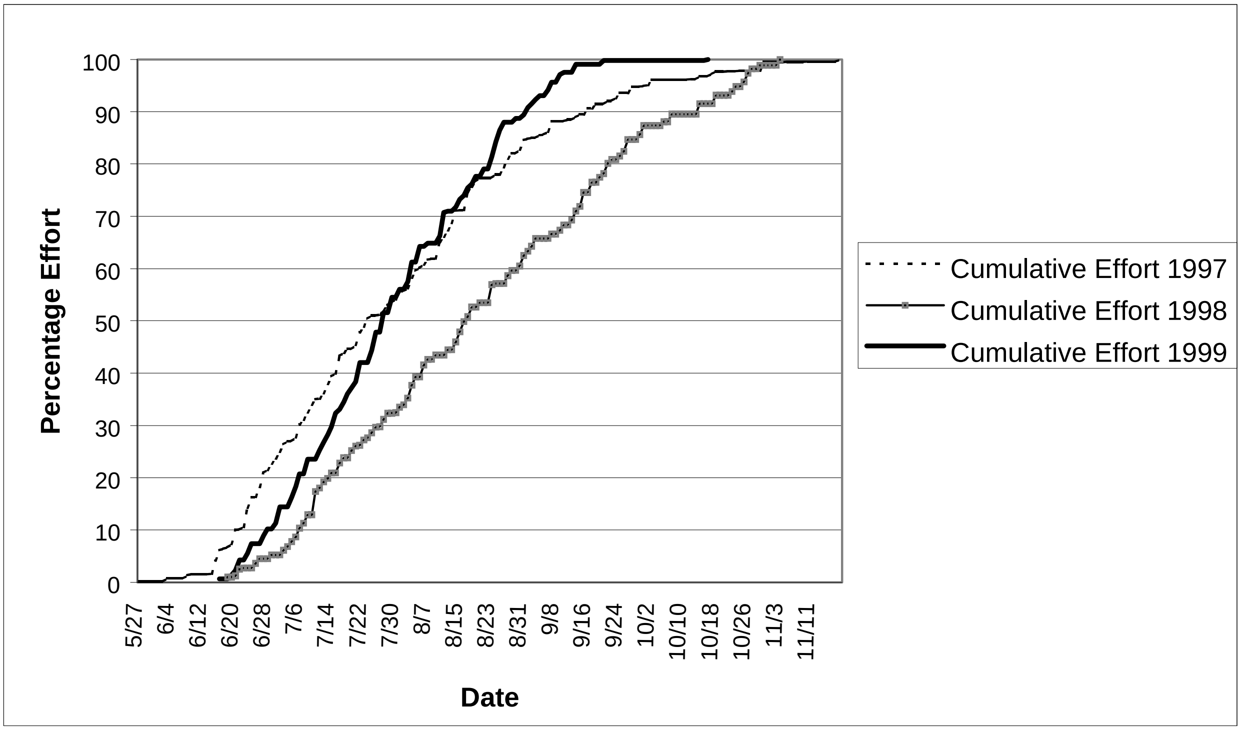

Figure 8. Cumulative effort for 1997, 1998 and 1999.

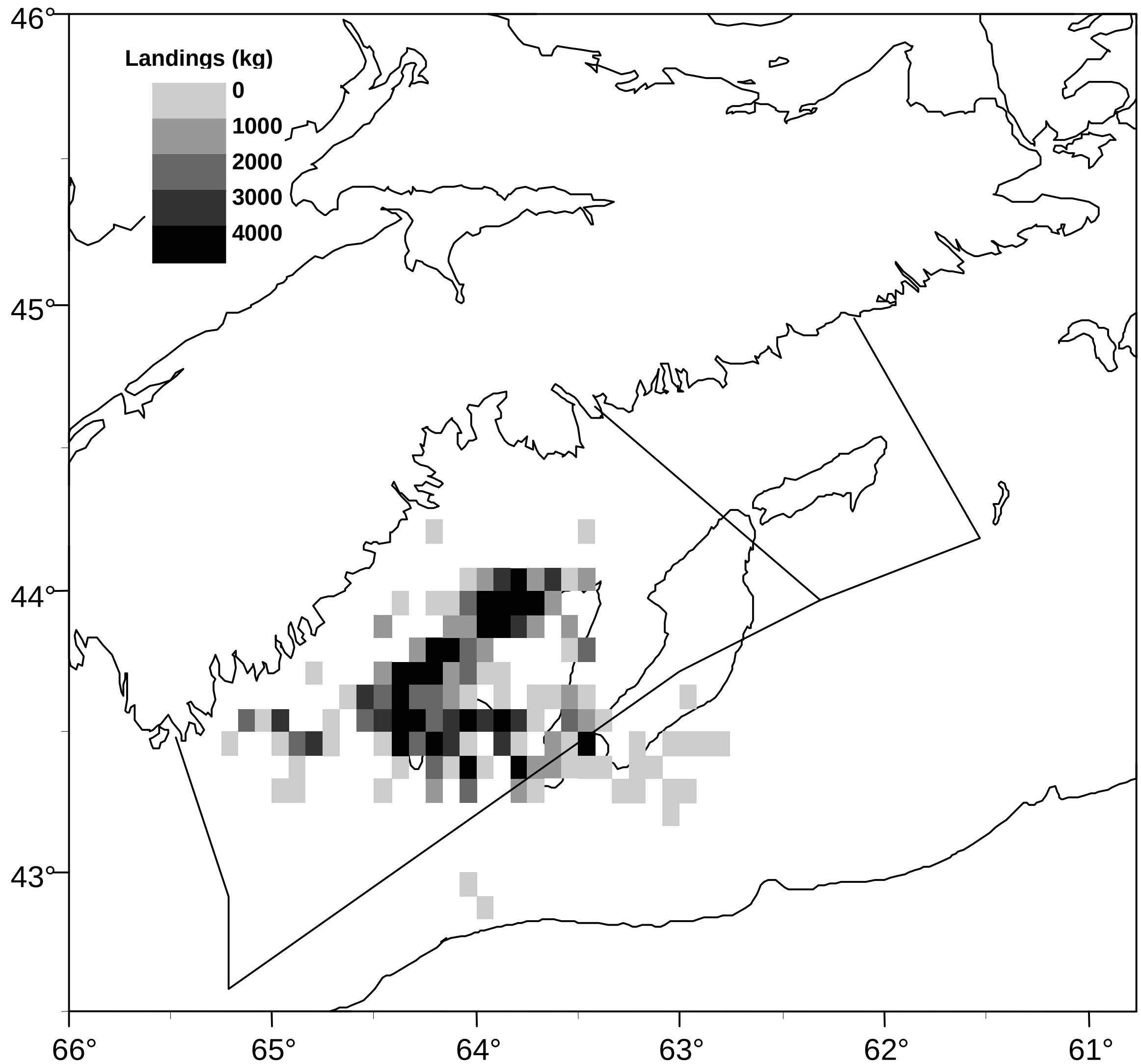

Figure 9. The geographical distribution of landings for the exploratory Jonah crab fishery in LFA 33 from 1997-1999.

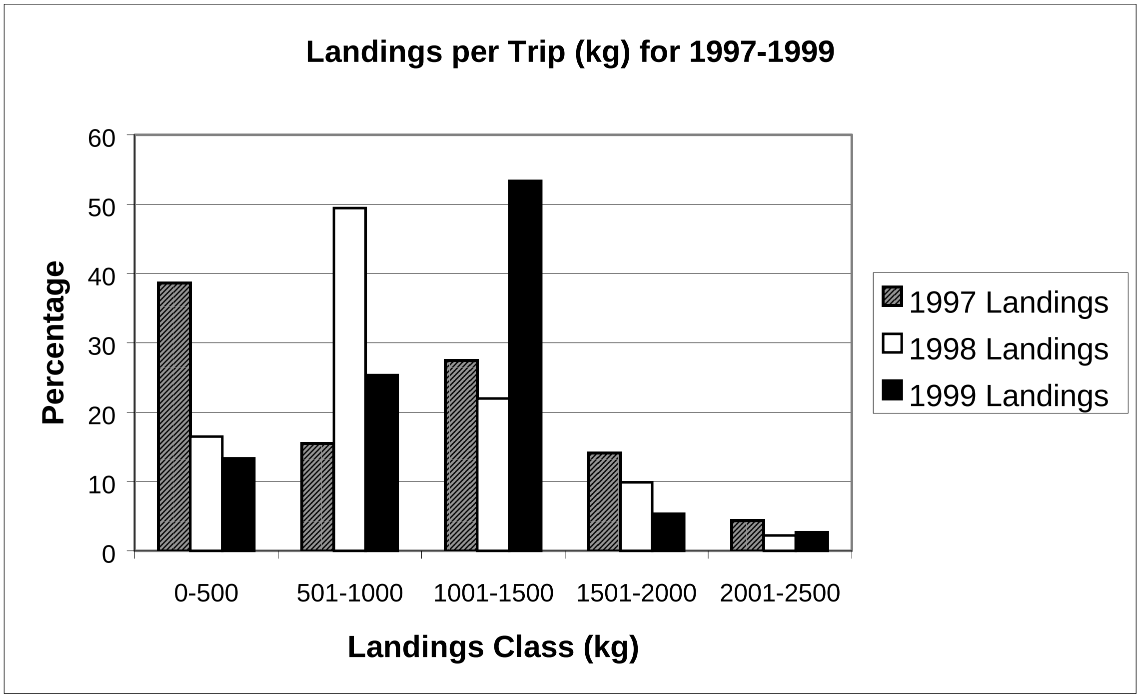

Figure 10. Landing per trip for the exploratory Jonah crab fishery in LFA 33 for 1997, 1998 and 1999.

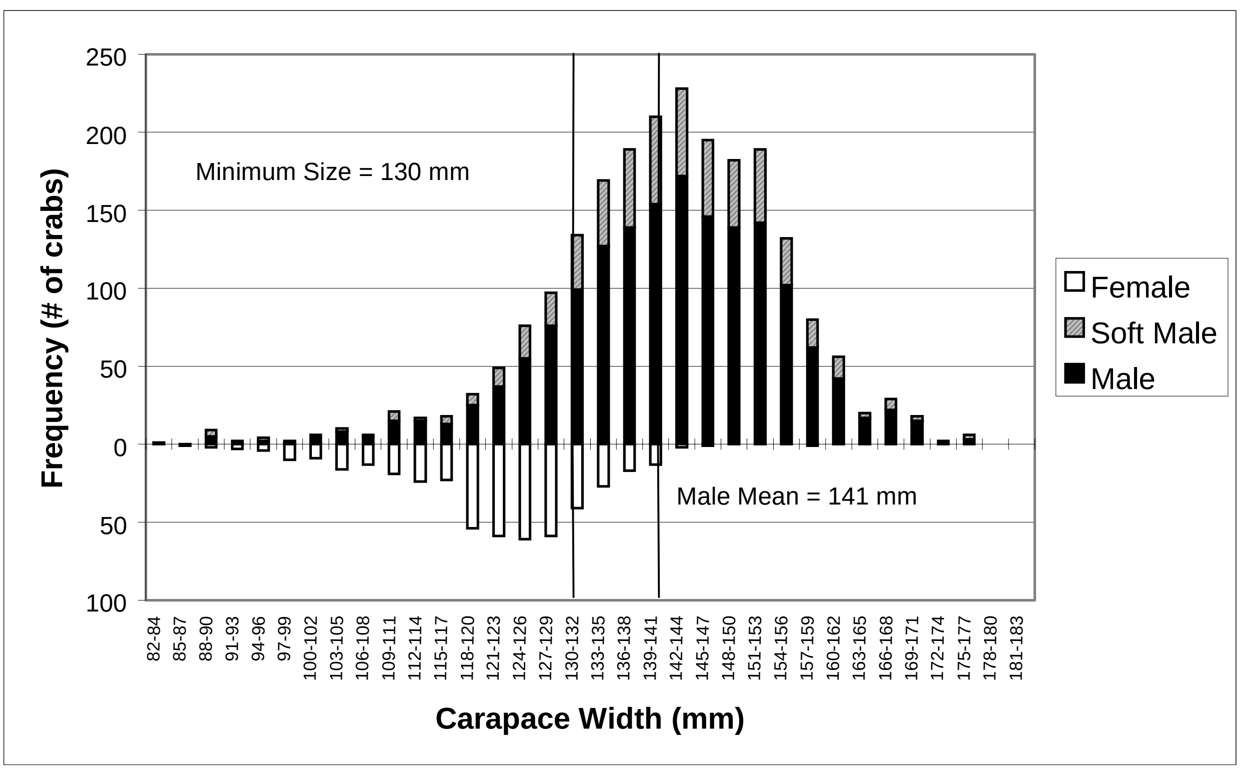

Figure 11. Carapace width distribution of the catch of hard and soft shelled male and female Jonah crab from 1997 sea samples.

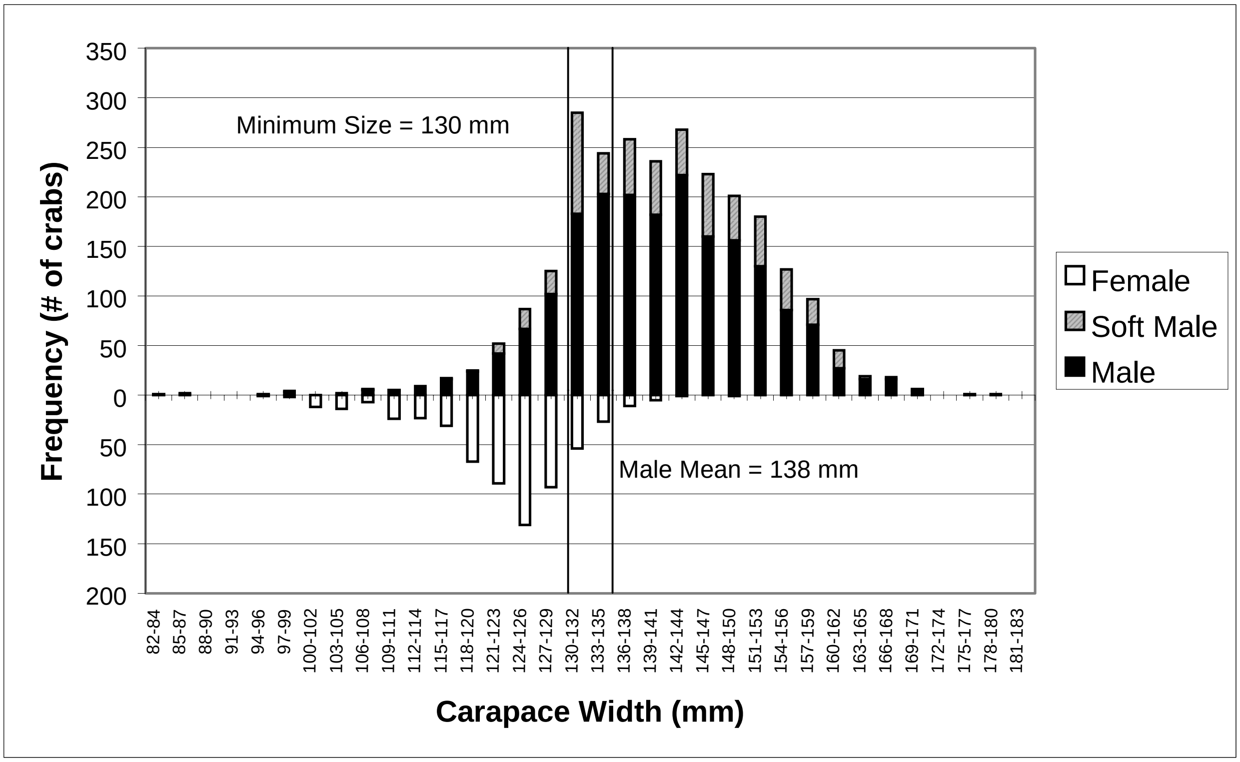

Figure 12. Carapace width distribution of the catch of hard and soft shelled male and female Jonah crab from 1998 sea samples.

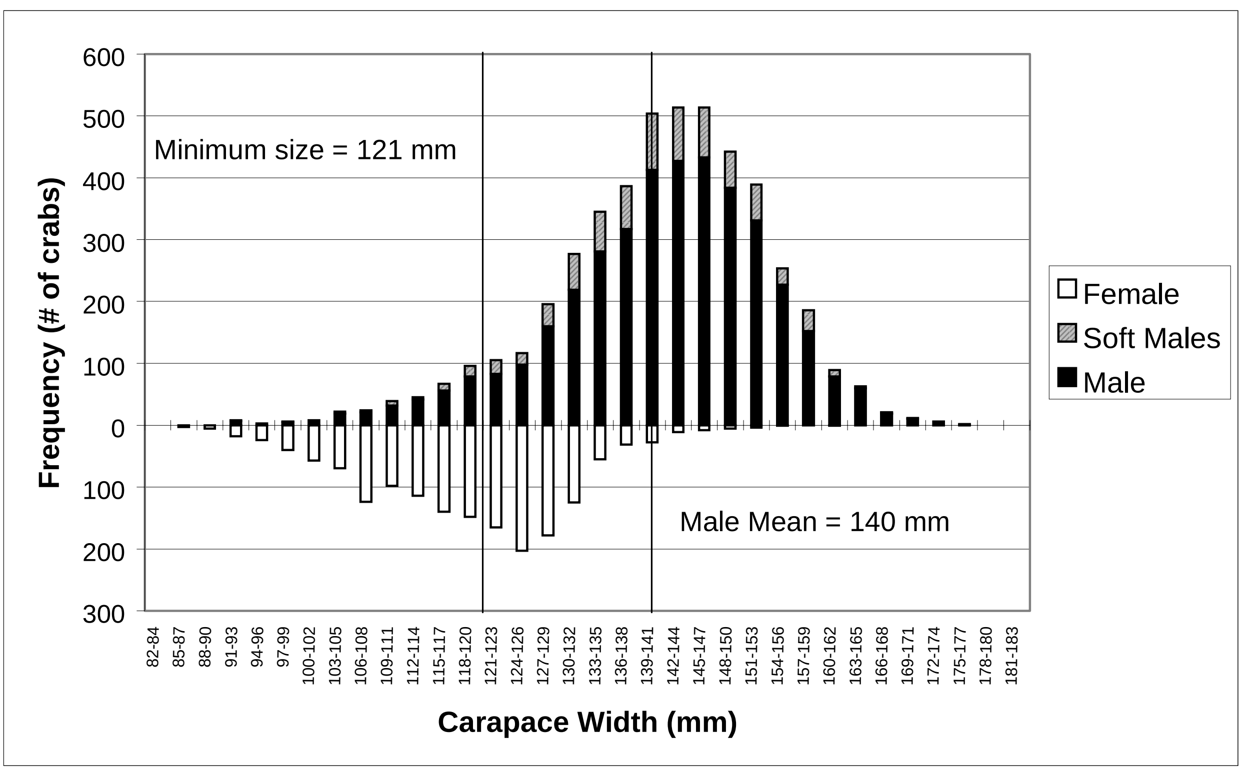

Figure 13. Carapace width distribution of the catch of hard and soft shelled male and female Jonah crab from 1999 sea samples.

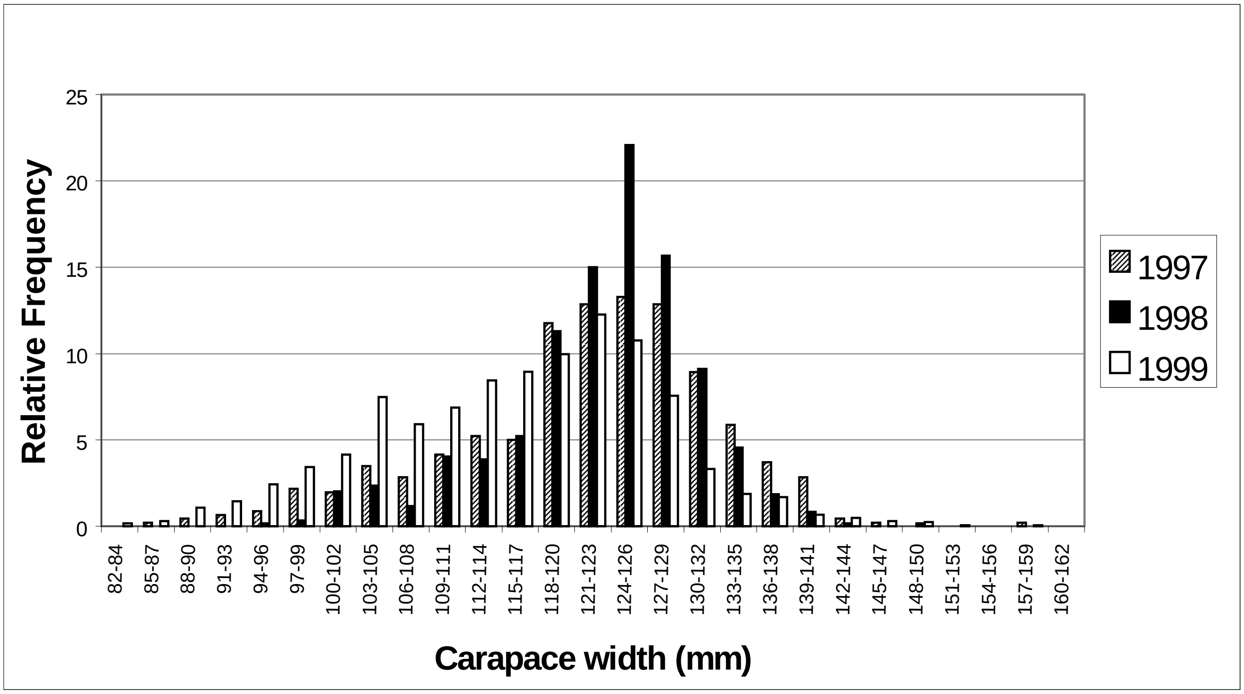

Figure 14. Carapace width distribution for female Jonah crab based on the catch sampled during sea trips in 1997, 1998 and 1999.

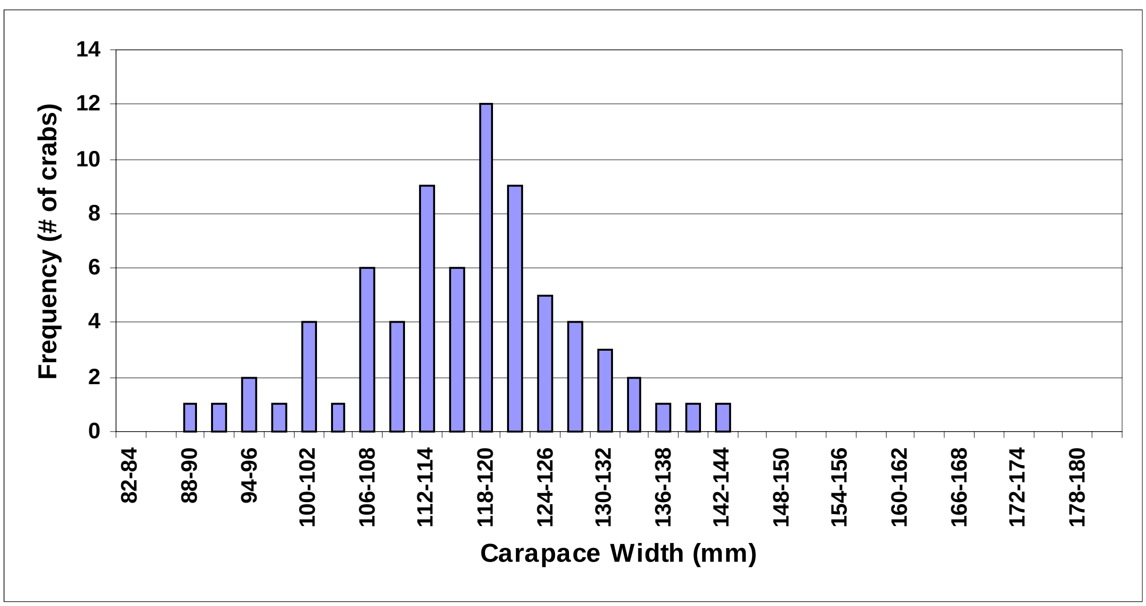

Figure 15. Carapace width distribution for berried female Jonah crab based on the catch sampled during sea trips in 1997, 1998 and 1999 (all years combined).

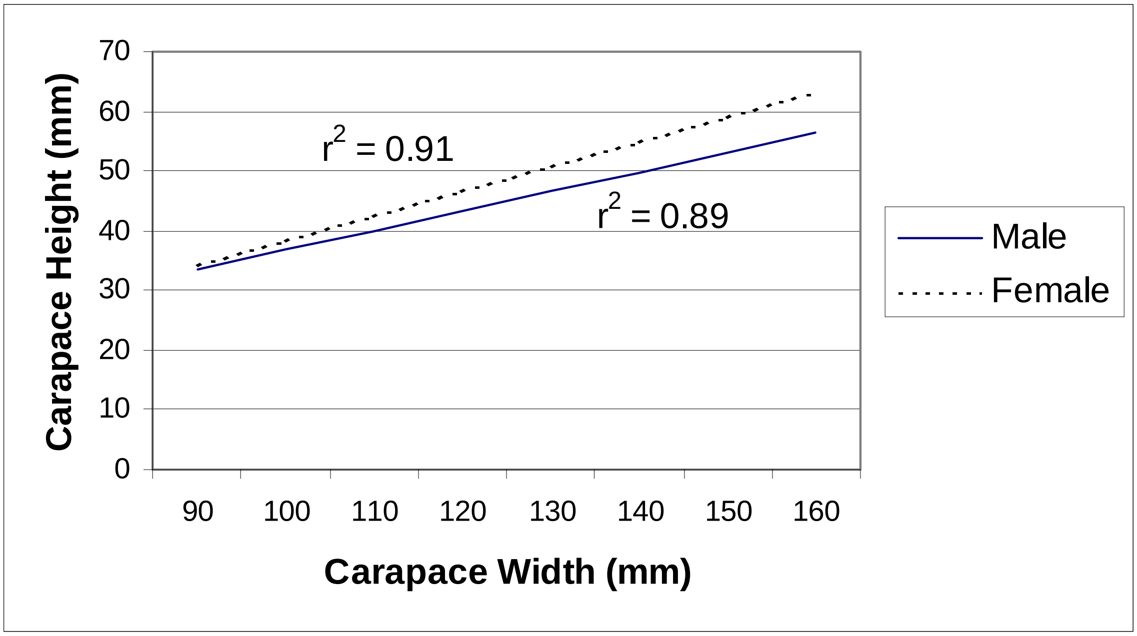

Figure 16. Linear regression of carapace height-carapace width for male and female Jonah crab based on sea sample data from 1997-1999.

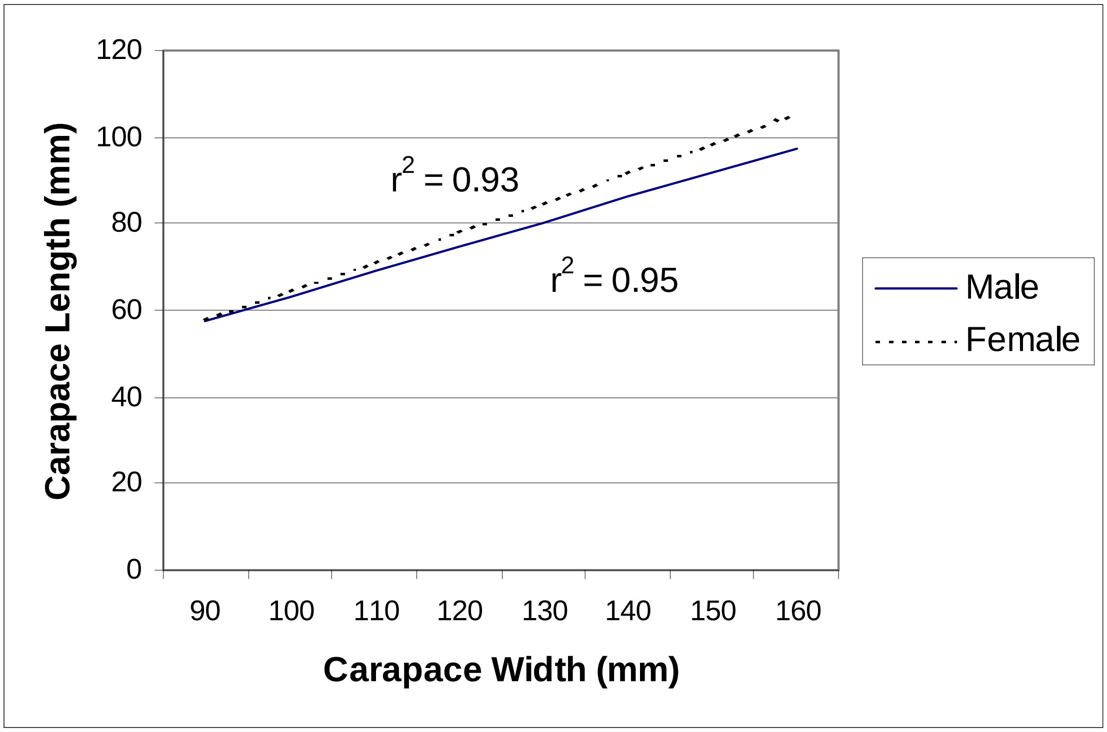

Figure 17. Linear regression of carapace length-carapace width for male and female Jonah crab based on sea sample data from 1997-1999.

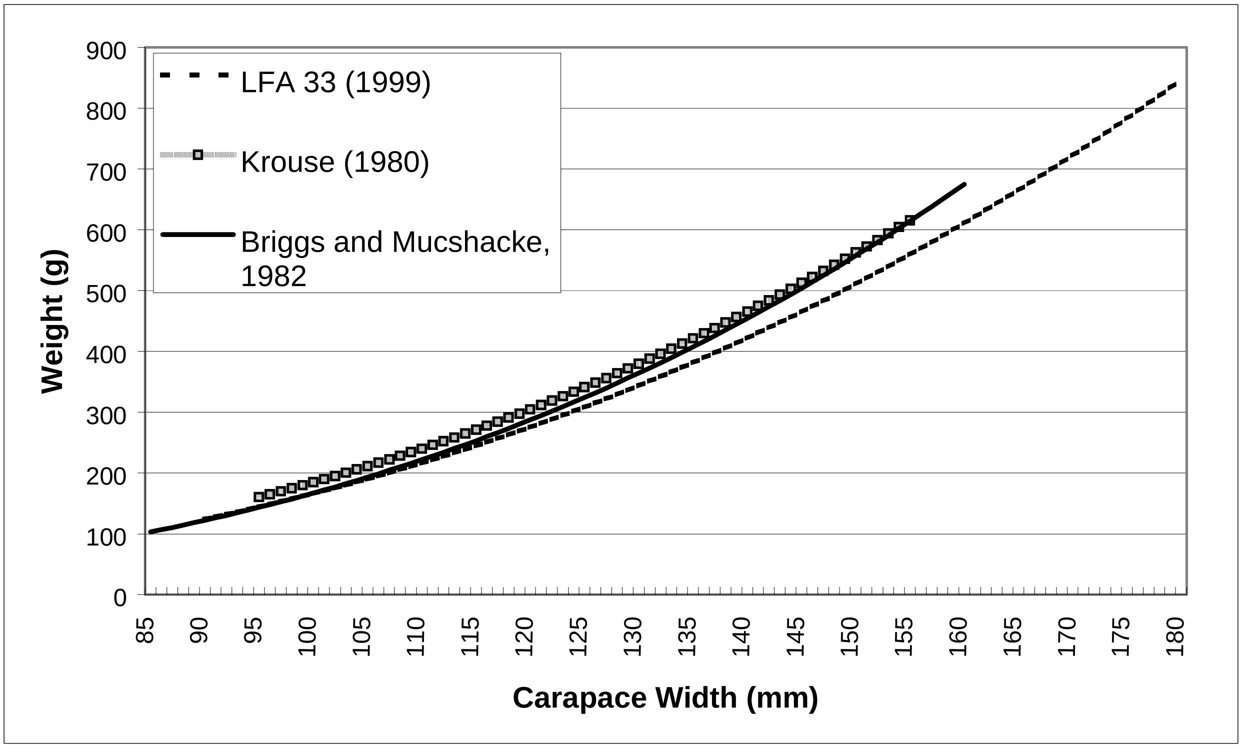

Figure 18. Carapace width -weight regressions for male Jonah crab based on port samples of crab from lobster fishing area 33 and carapace width – weight plots for male Jonah crab from coastal Maine (Krouse, 1980) and the Northwest Atlantic Shelf (Briggs and Mucshacke, 1982).

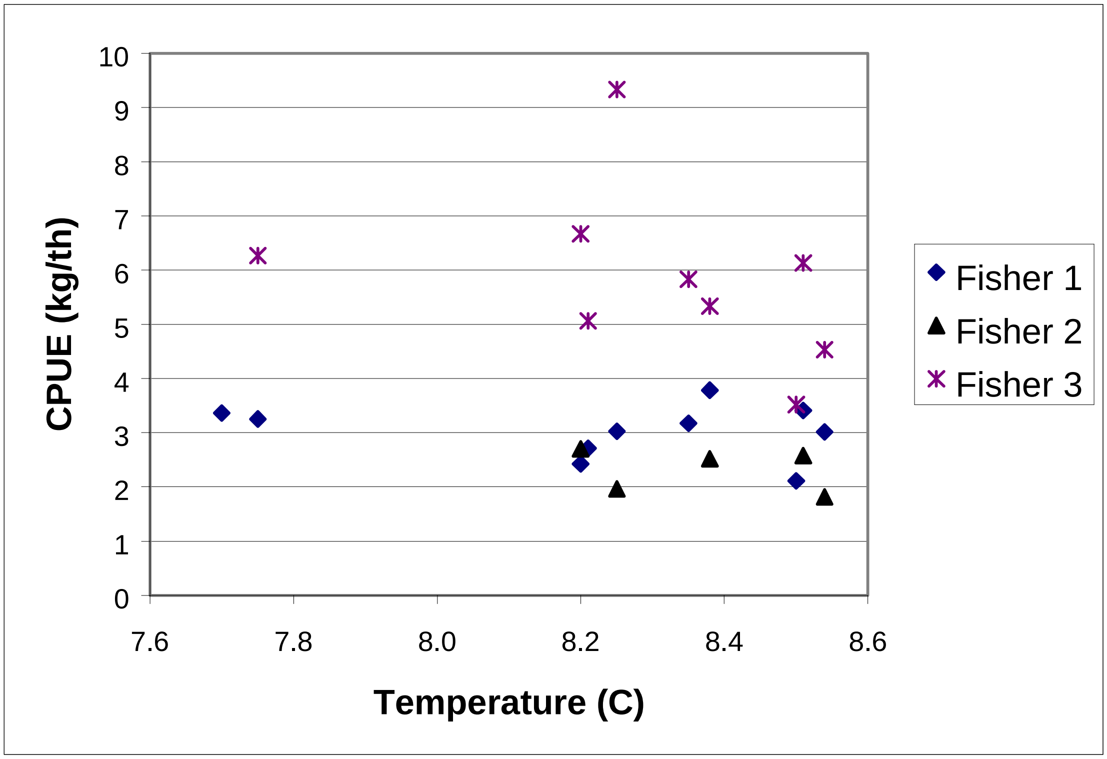

Figure 19. Mean bottom temperature for the duration of the soak between trips taken from VEMCO minilogs vs. trip CPUE for all fishers from the 1999 exploratory Jonah crab fishery in LFA 33.

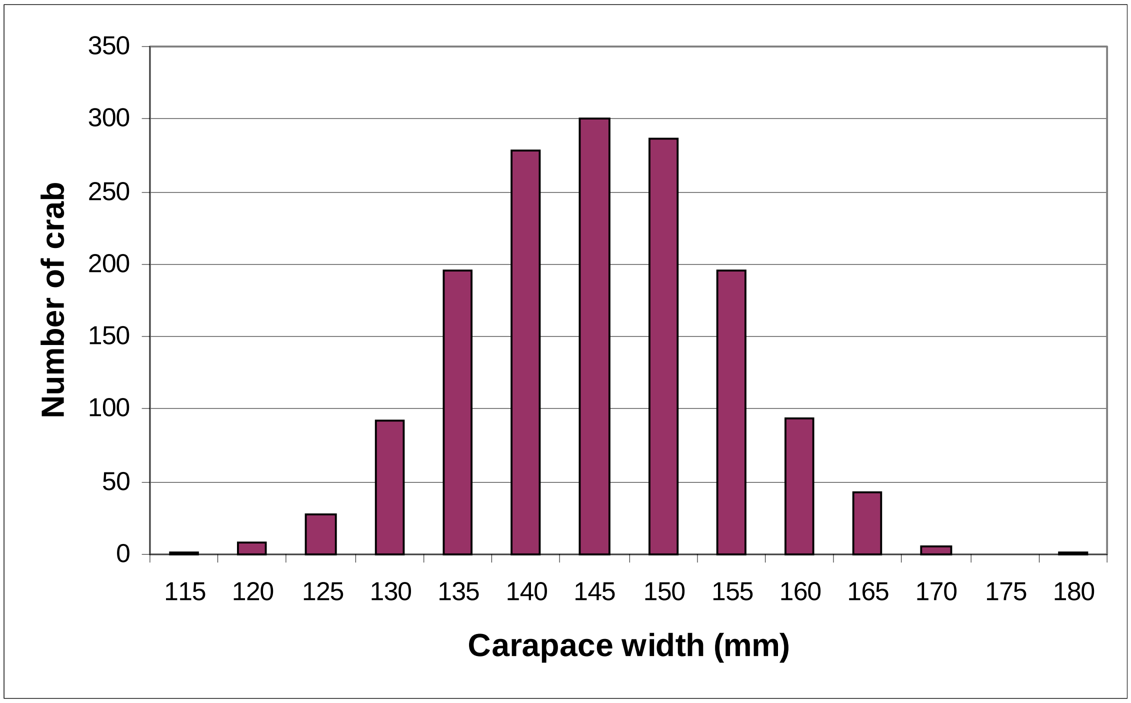

Figure 20. Carapace width distribution for male Jonah crab on taken from port samples during the 1983-84 directed fishery (catches from Emerald and LaHave Basin). Modified from Elner and Robichaud (1985)