Size-specific estimates of lobster catchability in the Baie des Chaleurs based on traps with different entrance ring sizes

M.J. Tremblay[1] , M. Lanteigne[2] and M. Mallet

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M.J. Tremblay[1], M. Lanteigne[2] and M. Mallet[2]

Invertebrate Fisheries Division
Science Branch
Maritimes Region
Fisheries and Oceans Canada

[1]Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, Nova Scotia B2Y 4A2

and

[2] Gulf Fisheries Centre
P.O. Box 5030
Moncton, New Brunswick E1C 9B6

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TABLE OF CONTENTS

ABSTRACT

Tremblay, M.J., M. Lanteigne and M. Mallet. 1998. Size-specific estimates of lobster catchability in the Baie des Chaleurs based on traps with different entrance ring sizes. Can. Tech. Rep. Fish. Aquat. Sci. 2222: iv + 16 p.

Lobster catchability was estimated near Stonehaven, in the Baie des Chaleurs, southern Gulf of St. Lawrence. Density was estimated from belt transects using SCUBA, followed by trapping with 3 different trap entrance ring diameters: 6.4 cm (2.5"), 12.7 (5"), and 16.5 cm (6.5"). Traps with small entrance rings had significantly lower total lobster weight per trap, probably because they tended to catch fewer large lobsters. There was no indication that the small ring traps were more efficient at capturing small lobsters. No difference was observed between traps with the two larger entrance rings.

Estimates of effective fished area (EFA) for lobsters off Stonehaven were 16-49 m^2 per trap (12.7 mm rings) for lobsters < 66 mm CL , and 453-860 m^2 per trap for lobsters 66-86 mm CL. Compared to previous studies off coastal Nova Scotia, the Stonehaven estimates are comparable for the smaller sizes, but are considerably higher for lobsters 66-86 mm CL. The small size of lobsters at Stonehaven relative to the coastal Nova Scotia sites may explain the difference, but underestimated densities in our study could also contribute. Population size structure appears to be an important variable affecting lobster catchability.

RÉSUMÉ

Tremblay,M.J., M. Lanteigne and M. Mallet. 1998. Size-specific estimates of lobster catchability in the Baie des Chaleurs based on traps with different entrance ring sizes. Can. Tech. Rep. Fish. Aquat. Sci. 2222: iv + 16 p.

La capturabilité du homard a été estimée près de Stonehaven dans la Baie des Chaleurs, au sud du golfe du Saint Laurent. Les densités ont été estimées en effectuant des transects à l'aide de plongeurs SCUBA suivi d'une pêche par casiers muni de 3 différents diamètres d'entrée circulaire ; 6.4 cm (2.5"), 12.7 (5"), et 16.5 cm (6.5"). Les casiers ayant des petites entrées ont présenté des poids totaux de homard par casiers significativement plus bas puisque ces casiers avaient tendance à capturer moins de homards de grande taille. Il n'y avait pas d'indication permettant d'attester que les casiers avec petites entrées étaient plus efficaces pour capturer les petits homards. Aucune différence n'a été observé entre les casiers équipés avec les deux grandes entrées circulaires.

Les estimations de surface effective de pêche (SEP) pour les homards de Stonehaven étaient de 16-49 m^2 par casier (entrée circulaire de 12.7 mm) pour les homards < 66 mm de longueur de carapace (LC) et 453-860 m2 par casier pour les homards 66-86 mm LC. En comparaison avec des études antérieures sur les côtes de la Nouvelle Écosse, les estimés de Stonehaven sont comparables pour les petites tailles mais sont considérablement plus élevés pour les homards de 66-86 mm LC. La composition plus importante en homards de petites tailles à Stonehaven comparativement aux sites de la Nouvelle Écosse pourrait expliquer la différence. Cependant, une sous-estimation de la densité dans l'étude pourrait aussi contribuer à cette différence. La structure de taille de la population semble être une importante variable qui affecterait la capturabilité du homard.

INTRODUCTION

The catch rate of fishing gear is a function of animal abundance and catchability, where catchability (q) can be defined as the probability of an animal being captured by a randomly applied unit of effort (Paloheimo 1963). In the case of lobster fisheries the unit of effort is the baited trap, and the catchability is affected by a host of factors related to lobster biology (e.g. molting), the environment (e.g. temperature), mechanical design of traps, and fishing strategy (Caddy 1979, Krouse 1989, Miller 1990). Estimates of q for lobsters are of interest because the catch rate is sometimes used as an index of stock abundance (Skud 1979, Miller 1990, Fogarty 1995). In addition size composition from trap catches is often used to estimate mortality, and any size-specific catchability should be accounted for.

Discussions of methods for estimating catchability can be found in Smith (1944), Paloheimo (1963), Chittleborough (1970), Morgan (1974), Miller (1975, 1989) and Arreguín-Sánchez (1996). Smith (1944) estimated "relative catchability" by regressing recapture rates of tagged lobsters against size. His regressions indicate an 80 mm CL lobster was about 1.3 times as catchable as a 70 mm CL lobsters. Paloheimo (1963), Chittleborough (1970) and Morgan (1974) estimated catchabilities for all sizes and sexes combined using mark-recapture estimates of abundance followed by trapping. All reported a dependence of q on temperature. Size-specific catchabilities have been generated from abundance estimates from bottom photography (Miller 1975) and dive censuses Miller (1990, 1995).

Catch (C), the number of lobsters per trap, is related to the number of lobsters on the bottom (N), catchability (q), and effort (f, number of trap hauls) as:

$$C_t = N_t\left(1 - e^{-qf_t}\right) \qquad \text{(Paloheimo 1963)}$$

If q is small and time intervals are short, catch is estimated as:

$$C_t = N_t q_t f_t \qquad \text{(Morgan 1974, Ricker 1975)}$$

If densities (D in n per unit area) are substituted for abundance then:

$$q_t = C_t/f_t(D_t)$$

In this formulation q has units of area per trap, and can be thought of as the effective fishing area (EFA) (Miller 1975). The EFA is the theoretical area from which lobsters would be removed if all had a probability of capture equal to 1. It can be used to translate catch rates into population density estimates.

The other concept related to measuring how a trap influences the target animal is the area of attraction. The area of attraction of the trap is larger than the EFA, since it circumscribes the area within which at least some lobsters can detect the bait. It embodies the fact of decreasing probability of capture with increasing distance from the trap.

Here we estimate lobster density using belt transects, and estimate size-specific EFA's for lobsters in a nearshore area in the Baie des Chaleurs, in the southern Gulf of St. Lawrence. Since mechanical trap design can affect catchability, we estimate EFA for 3 different trap entrance ring diameters: 6.4 cm (2.5"), 12.7 (5"), and 16.5 cm (6.5"). The smallest entrance was tested to assess whether it would be more efficient at capturing prerecruits for use as a research tool. The 12.7 cm ring was used because it is the most common size in the commercial fishery and the largest ring was tested because this size is present on some commercial traps.

METHODS

Description of study site

The survey site (Fig. 1) was adjacent to the Stonehaven wharf, close to an area where lobster densities have been estimated previously. Depths are less than 20 m within about 1 km of shore. Tidal amplitude in the area is about 2 m. Currents were not measured but diver observations indicate currents were usually parallel to the shore. This agrees with the current measurements off the north shore of the Baie des Chaleurs, where tidal ellipses were strongly rectilinear, directed alongshore (Bonardelli et al. 1993). Bottom temperature, measured with Vemco minilogs, ranged from 8-17 °C over the course of the present study (Fig. 2).

The bottom type encountered during three initial excursion dives was predominantly gravel to cobble (less than 20 cm diameter) with numerous horse mussel beds and some exposed ledges. Marine plants were limited to low filamentous types, with some drift kelp (*Agarum*). Rocks often had an encrusting red alga and sea anenomes were common. Sea urchins and rock crabs were sparsely distributed. Sea stars (*Asterias*) were observed in aggregations feeding on horse mussels. During the dive survey a wider range of bottom types was observed and noted on underwater slates; in addition 4 video transects were completed. Based on these sources a qualitative depiction of the bottom type is given in the Results.

The size and location of the survey area were determined by bottom depth (and SCUBA constraints), sample size (attempt to obtain about 10 per target group), and the number of belt transects required to cover approximately 10% of the survey area. Consideration of these factors resulted in a survey area of 60,000 m^2, with dimensions of 150 m × 400 m (Fig. 3). The two long sides of the survey site were demarcated with 400 m ground lines anchored at both ends. At 25 m intervals the ground lines had several concrete blocks and a line to the surface for a marker buoy.

Lobster density estimates

From Aug. 27 to Aug. 29 1996, lobsters were censused within the study area using belt transects marked by lead line. Each transect was 150 m long and 3 m wide. A total of 16 transects were completed, representing 12% of the study area. The location of the transects were randomly determined from a possible 80 positions spaced 5 m apart. If randomization resulted in 2 transects being only 5 m apart, another position was randomly chosen. Transects were laid from a 17' boat, the start position of which was estimated from the position of the surface buoys (25 m apart). Transect lines were set by dropping one end (weighted with concrete blocks) at the starting position. The lead line was then fed out under tension as the boat headed across the study area. Prior to dropping the other weighted end of the lead line, the line was pulled to remove any kinks and bends. Inspection of the line on the bottom revealed that the transect was laid reasonably straight each time. It is estimated that bends in the transect line did not reduce the total straight line distance by more than 10%.

Lobsters were counted by 2 divers swimming on either side of the transect line. A total of 6 divers were needed to complete the 16 transects. During each transect each of the 2 divers counted the lobsters within 1.5 m of the line, using a measured steel rod for distance. Divers carried gauges to measure lobsters and record them as within one of 5 carapace length (CL) groups:

≤ 55 mm CL
56-65 mm CL
66-75 mm CL
76-86 mm CL
≥ 87 mm CL

The middle three groups were the target, since they represent one molt class before legal size and the 2 succeeding molt classes. Lobsters were caught if possible, measured and sexed. If lobsters could not be captured their size group was estimated. The transect lines were marked at 25 m intervals, and the habitat type was noted by divers every 25 m. Data were recorded on underwater slates.

Densities for the target groups were calculated for each transect by dividing the count by the transect area (450 m^2). Confidence intervals for the densities of each group were then generated after the densities were transformed as Ln (density + 0.001). The transformation served to decorrelate the mean and variance, and make the distribution of the data closer to that of a normal distribution. The addition of 0.001 was to avoid undefined values when the count was 0.

Trapping Survey

From Sept 3-5 lobsters were trapped in the study area. Traps were of plastic coated wire mesh with 3.8 cm (1.5") mesh openings. Dimensions were 91 cm * 53 cm * 36 cm (36" * 21" * 14") (Fig. 4). The entrance ring size was 6.4 cm (2.5"), 12.7 cm (5") or 16.5 cm (6.5"). Unlike commercial traps, there were no gaps to allow for escape of sublegal lobsters. Wire mesh bait boxes were used to hold about one pound of mackerel per trap. Traps were set in trawls of 3, each trap with a different ring size. The distance between traps on the trawl line was 25 m, and the position of the different trap types on each trawl was randomly determined.

For trawl placement, the 400 m * 150 m study area was divided into 16 blocks of 50 m * 75 m. Blocks were randomly selected, and trawls set across the study area (Fig. 5). In this way trawls were approximately 50 m apart in the alongshore direction, and 25-30 m apart across the study area. Ten trawls were set within the study area on Sept 3 and hauled on Sept. 4. Lobsters were returned to the bottom close to their location of capture. The trawls were again randomly set on Sept. 4 and hauled on Sept. 5.

To assess whether some lobsters were captured on both days, all lobsters captured on Sept. 4 were banded. To verify that catch rates were similar near the boundary of the study area, on both days five trawls of 3 traps each were set 50-100 m beyond the perimeter of the study area.

The statistical model used to analyze the data was a randomized complete block design with traps as the experimental units, lobsters as the sampling units, days as a blocking factor, and diameter of the entrance ring as the treatment. Since entrance ring diameter was a fixed factor and day was considered a random blocking factor, the model was mixed. The F-test used was computed using Satterthwaite's method and is described for example in Montgomery (1984); the statistical package used was SAS (Statistical Analysis System).

RESULTS

Bottom habitat

After a review of habitat notes and reference to videos of the bottom obtained during 4 belt transects, bottom habitat was qualitatively assessed as being one of 4 types (Fig. 6). These were: (i) flat with mud, sandy-mud or gravel (< 20 cm), with mussels and isolated small boulders; (ii) ledge with few crevices; (iii) ledge with crevices or isolated boulders (> 20 cm) and (iv) numerous boulders (> 20 cm). Bottom types (i) and (ii) comprised about 60% of the bottom and were easy to search. Bottom types (iii) and (iv) were usually searchable with effort, but in areas where the boulders were "stacked", or where ledges had numerous deep crevices (10-20% if the bottom) searching was difficult and lobster density was probably underestimated.

Lobster counts and density estimates

A total of 340 lobsters were counted on the 16 belt transects. Total counts of all sizes by transect were quite uniform, ranging from 13-33 (mean =21.3, S.D. = 5.17) (Fig. 6). There was no clear link between lobster number and habitat---both the lowest and highest counts were from transects on bottom types of low complexity.

Of the 340 lobsters counted, the sex could not be determined for 106 (Table 1). 82 of these were identified as between 56 and 86 mm CL but the divers could not allocate them to one of the 3 size classes covering this range. Lobsters of indefinite size or sex were proportionately assigned to one of the 5 size groups (Table 1).

Most lobsters (71%) were within the two size classes below 66 mm CL. The number of lobsters < 56 mm CL was underestimated, since divers did not actively search for this size group and newly settled lobsters, if present, were missed. Only 9 lobsters greater than 86 mm were found. Within the smaller size classes, more females than males were encountered; above 75 mm males predominated.

Mean densities for the 16 transects ranged from 0.0003 m^{-2} for females in the largest size class to 0.01 m^{-2} for females in the smallest size class (Table 2). Confidence intervals for densities of the first 3 size classes overlapped for both males and females. The mean densities of lobsters in the larger sizes were significantly lower.

Trapping survey

A total of 433 lobsters were captured within the survey area in 60 trap hauls (20 for each trap type). The total number caught was similar on the 2 days (211 on day 1, 222 on day 2). The bulk of the catch in each trap type was within the 66-75 mm CL size class (Table 3). In contrast to the dive survey, less than 2% of the catch was ≤ 55 mm CL (Fig. 7). A small percentage of the lobsters captured on day 1 were recaptured on day 2. Of a total of 211 lobsters banded inside the grid, 13 (6%) were recaptured on day 2.

There are several possible approaches for analyzing these data. One approach is to sum over days and within trap type and test for an association between trap type and lobster CL using a contingency table (Table 3). This analysis indicated a significant association, with the small ring traps tending to catch fewer of the larger lobsters (Table 3). Another approach is to use analysis of variance (anova), to partition the variance by ring size, day, and trap. In an anova of lobster CL, there was no significant effect of ring size when both days were considered together (Table 4). There was a mild interaction between day and ring size however and when the analyses were done for separate days, there was a significant effect of ring size on day 2 (smaller lobsters in the 2.5" ring traps) (Table 4).

One of the difficulties with the anova on lobster CL was that it was unbalanced in the sense that there were unequal numbers of lobsters per trap. In addition the data showed some deviation from normality. For these reasons a second anova was done on lobster weight per trap. This analysis has the advantage of having equal sample sizes (one total weight per trap haul), and data that were normally distributed. Weights were estimated using a CL-weight regression (Maynard et al. 1992). In this anova there was a mildly significant effect of trap type on lobster total weight per trap (Table 5). Further tests using the Duncan's multiple comparison procedure indicated that traps of ring size 12.7 cm and 16.5 cm did not differ with respect to lobster weight but that traps of ring size 6.4 cm had a significantly lower lobster weight per trap.

The mean catch rate of 30 trap hauls outside the grid (7.67 +/- 1.22, all traps) was not significantly different from the mean of the 60 trap hauls within the survey area (7.23 +/- 0.96) .

Estimates of effective fishing area (EFA)

Point estimates of the EFA for all groups and trap types ranged from 0 to 860 m^2 per trap (Table 6). The lowest estimates were for the smallest size class; the highest for the 76-85 mm CL males. The EFA estimates for females were higher than those for males at sizes less than 66 mm CL; the reverse was the case for lobsters between 76 and 85 mm CL. Amongst the different trap types, the EFA estimates were generally lower for the 6.4 cm ring traps; the 12.7 and 16.5 cm ring traps showed no consistent difference.

DISCUSSION

The present study indicates that traps with a small entrance ring (6.4 cm) catch lower total lobster weight than traps with 12.7 cm or 16.5 cm entrance rings, but that there is no difference between the latter two trap types. Contingency table analysis indicates the lower weight per 6.4 cm ring trap results from fewer large lobsters per trap, but the anova on CL gives only mild support to this conclusion, perhaps because of the unbalanced design of the experiment.

Early studies of the effect of trap design on lobster catch in the southern Gulf of St. Lawrence in traps reported no appreciable difference in the catch among traps with entrance rings ranging from 10-12.7 cm diameter (Wilder 1944). Although we detected no significant difference in the catch of traps with entrance rings of 12.7 and 16.2 diameter, this may be because of the scarcity of large lobsters in the area. Unpublished data by D. Robinson (in DFO files) suggests an effect of ring diameter at larger lobster sizes. Based on trapping in July and September of 1978 off the eastern shore of Nova Scotia, the following data were obtained on the maximum sizes (CL) of lobsters entering traps with different entrance ring sizes:

Ring diameter	N trap hauls	N lobsters trapped	Maximum CL
10 cm (4")	335	138	125
12.7 cm (5")	322	141	140
15 cm (6")	307	107	160
17.5 cm (7")	330	129	185

In traps with 17.5 cm ring entrances about 7% of the 129 lobsters caught were above 150 mm CL.

The finding in this study that catchability was lowest for the smallest lobsters has been documented elsewhere (Smith 1944, Miller 1990, 1995). Our point estimates of effective fished area (12.7 cm rings) for lobsters < 66 mm CL (16-49 m^2) are similar to estimates for lobsters < 70 mm CL by Miller (1995). Our estimates for EFA of lobsters 66-86 mm CL (453-860 m^2) on the other hand are higher than those of Miller (1995) which ranged from 169-500 m^2 for males, and 84-231 m^2 for females. This discrepancy could be due to underestimated densities in our study, or real differences in catchability.

Our estimate of density for > 55 mm CL lobsters was about 0.03 m^{-2}; Miller (1995) estimated densities of 0.06-0.09 m^{-2} for lobsters > 60 mm CL. We would expect the density of lobsters > 80 mm CL to be lower off Stonehaven because the minimum legal size for the commercial fishery (67 mm CL) is less than that of the coastal Nova Scotia sites of Miller (1995) (70 and 81 mm CL). In difficult to search areas we probably did underestimate lobster density, but for females, even if the actual density was twice as high as estimated, the estimates of EFA would still be higher than those of Miller (1995).

We believe that our higher estimates of q compared to Miller (1995) reflect real differences in catchability because of the smaller sizes off Stonehaven compared to the Nova Scotia sites investigated by Miller (1995). Off Stonehaven, the density of lobsters > 86 mm CL was estimated to be less than 0.003 per m^{-2}, and the catch rate of lobsters > 90 mm CL was < 0.5 per trap. This contrasts with the 3 coastal Nova Scotia sites, where the density of lobsters > 89 mm CL ranged from 0.005-

0.01 m^{-2}, and the catch rate ranged from 3.4-5.3 per trap. The higher proportion of large lobsters at the Nova Scotia sites may have reduced the catchability of lobsters 66-86 mm CL. Comparison of recapture rates tabulated in Smith (1944) also suggests that catchability is a function of the size distribution of the population (Miller 1995).

A potential factor affecting the absolute value of EFA estimates in this study and others (Miller 1995) is the distance between traps. There are no data here to evaluate the area of influence of the traps, nor are there data from other studies of *Homarus*. The shape of the area of influence is likely an ellipse, with the longer dimension in the direction of the currents, since the area of influence is expected to be a function of the bait odour plume. The shape probably changes over time, and is not necessarily centred on the trap (Miller 1990). In the present study traps were separated by 50 m in the along-current direction and 25 m in the cross-current direction. Thus we would expect no competition between traps if the area of trap influence was elliptical and less than about 982 m^2 (area of an ellipse with length 50 m and width 25 m). All EFAs were less than 982 m^2 but the area of trap influence was probably considerably greater. For whelks, the area of trap influence can be 10 times greater than the effective area fished (McQuinn et al. 1988). If a similar relationship exists for *Homarus*, then the traps were competing to some extent. How far might a lobster travel to a trap? Jernakoff and Phillips (1988) reported that the greatest distance traveled by a tagged rock lobster to a trap was 120 m. Whether this lobster actually sensed the bait at this distance, or was foraging and moved within the area of influence cannot be discerned. Clearly more study of the area of attraction of a lobster trap is warranted.

Although overlapping areas of trap influence may have affected the absolute value of our EFA estimates, they are still useful for several reasons. First, the trends with size (larger EFAs with increasing size) and gender (larger EFAs for large males than large females) are expected to remain with or without trap competition. If anything our EFA estimates for larger lobsters may be biased downwards to a greater extent than those for smaller lobsters. Larger lobsters are more mobile and thus we expect any effect of trap competition to be greater for these sizes. Secondly, our study is comparable to Miller (1995) because the trap distances used in the two studies were similar (25-50 m here, 20-50 m by Miller). Third, the EFA estimates are more comparable to the situation in the commercial fishery, where traps may be set at distances less than 20 m apart.

Male lobsters 76-86 mm CL were more catchable than females of the same size (Table 3). This was also observed by Miller (1995) and others have noted highly skewed sex ratios in traps in autumn (Templeman 1939, Ennis 1980). Males may be more catchable at this time because of an earlier recovery from molting (Tremblay and Eagles 1997).

Other studies indicate that season and habitat are important factors affecting catchability. This study suggests population size structure is also important. Lobsters in the size range of 67-86 mm CL may be more catchable when larger sizes are scarce. Additional studies in the southern Gulf in areas where larger lobsters are more common would be of interest.

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Table 1. Lobster counts from 16 belt transects near Stonehaven. Counts are unadjusted in "Total count" columns, and show numbers that could not be assigned a size group and/or a sex. ND = not determined. Size ND refers only to lobsters between 56 and 86 mm; the other 24 lobsters were assigned a size but not a sex.

	Total count			Count corrected			M:F
CL (mm)	Males	Females	Sex ND	Males	Females	Total	sex ratio
≤55	34	56	20	41.6	68.4	110	0.61
56-65	36	46	0	57.2	73.1	130	0.78
66-75	22	19	0	35.0	30.2	65	1.16
76-86	10	6	0	15.9	9.5	25	1.67
>86	4	1	4	7.2	1.8	9	4.00
Size ND (56-86)			82				
Total	106	128	106	156.9	183.1		0.86
TOTAL			340		340		

Table 2. Mean densities (n m^{-2}) of male and female lobsters for the 16 belt transects near Stonehaven. Densities for each belt transect were estimated as: (corrected counts/450 m^{-2}). 95 % confidence intervals (CI) were for data transformed using Ln(density + 0.001). Mean' is the antilog of the mean of the logs. The lower CI (LCI) is the antilog of the lower CI for the transformed data; UCI is the upper CI, calculated in the same way.

	Males					Females				
CL	Mean	S.D.	Mean'	LCI	UCI	Mean	S.D.	Mean'	LCI	UCI
<56	0.0058	0.0040	0.0058	0.0042	0.0079	0.0095	0.0035	0.0099	0.0083	0.0118
56-65	0.0079	0.0037	0.0082	0.0065	0.0102	0.0102	0.0050	0.0100	0.0078	0.0128
66-75	0.0049	0.0030	0.0053	0.0042	0.0066	0.0042	0.0028	0.0047	0.0037	0.0059
76-86	0.0022	0.0021	0.0027	0.0020	0.0036	0.0013	0.0014	0.0020	0.0015	0.0026
>86	0.0010	0.0019	0.0015	0.0010	0.0021	0.0003	0.0006	0.0012	0.0010	0.0014
All	0.0218	0.0064	0.0218	0.0187	0.0255	0.0254	0.0087	0.0252	0.0215	0.0295

Table 3. Frequency of lobsters of different carapace lengths (CL) in 20 trap hauls of each trap type (ring diameters of 6.4, 12.7 and 16.5 cm), expected values, and chi square test. First two and last two sizes were combined so that all cell values were > 5.

Observed:

CL (mm)	6.4 cm	12.7 cm	16.5 cm	Total
<56	2	3	2	7
56-65	13	15	14	42
66-75	55	108	103	266
76-86	13	50	42	105
87-115	0	6	7	13
total	83	182	168	433

Expected:

< 65	9.39	20.60	19.01
66-75	50.99	111.81	103.21
> 76	22.62	49.60	45.78

Chi square = 9.74; p =.045

Table 4. Analyses of variance of lobster carapace length among traps with different ring diameters. Anovas are for (i) both days combined, (ii) day 1 only and (iii) day 2 only. Model was unbalanced (unequal numbers of lobsters per trap); F-tests are based on the expected mean squares (Satterthwaite's method).

(i) Both days combined:

Source	df	Numerator Type III MS	Expected mean square	F value	Pr > F
Day	1	97.741	$\sigma+4.8798\sigma_{\rho(\beta\tau)}+47.917\sigma_{\beta\tau}+143.75\sigma_{\beta}$	0.76	0.4752
Ring size	2	227.173	$\sigma+5.1552\sigma_{\rho(\beta\tau)}+50.84\sigma_{\beta\tau}+Q(\text{ring})$	1.70	0.3704
Day*ring size	2	133.667	$\sigma+5.1375\sigma_{\rho(\beta\tau)}+50.855\sigma_{\beta\tau}$	2.88	0.0606
Trap(day*ring size)	53	46.623	$\sigma+7.214\sigma_{\rho(\beta\tau)}$	1.02	0.4407
Error	374	45.693	σ		
Total (corrected)	432				

(ii) Day 1 only:

Source	df	Numerator Type III MS	Expected mean square	F value	Pr > F
Ring size	2	19.268	$\sigma+4.329\sigma_{\rho(\tau)}+Q(\text{ring})$	0.602	0.550
Trap*ring size	27	27.071	$\sigma+6.857\sigma_{\rho(\tau)}$	0.668	0.892
Error	181	40.505	σ		
Total (corrected)	210				

(iii) Day 2 only:

Source	df	Numerator Type III MS	Expected mean square	F value	Pr > F
Ring size	2	389.852	$\sigma+6.358\sigma_{\rho(\tau)}+Q(\text{ring})$	6.065	0.006
Trap*ring size	26	66.928	$\sigma+7.585\sigma_{\rho(\tau)}$	1.324	0.146
Error	193	50.558	σ		
Total (corrected)	221				

Table 5. Total lobster weight per trap type and analysis of variance. One trap had 0 lobsters.

Ring size	Total weight (kg) per trap type	
	Day 1	Day 2
6.4 cm (2.5")	13.2	10.3
12.7 cm (5")	25.9	31.9
16.5 cm (6.5")	27.8	26.6

Source	df	Numerator Type III MS	F value	Pr > F
Day	1	61804.08	0.056	0.836
Ring size	2	17856666.75	16.057	0.059
Day*ring size	2	1112067.93	1.264	0.291
Error	54	879890.84		
Total (corrected)	59			

Table 6. Lobster densities, catch rates (n $trap^{-1}$) and estimates of effective fished area (EFA) for males and females near Stonehaven. EFA is not exactly equal to catch rate/density because densities and catch rates in table are rounded.

	Carapace length (mm)	Mean density	Mean catch rate (n per trap type) 2.5"	5"	6.5"	Effective fishing area (m^2 per trap) 2.5"	5"	6.5"
Males	<56	0.0058	0.00	0.00	0.10	0	0	17
	56-65	0.0079	0.35	0.25	0.30	44	31	38
	66-75	0.0049	1.85	2.80	2.70	381	576	556
	76-86	0.0022	0.50	1.90	1.65	226	860	747
	>86	0.0010	0.00	0.45	0.40	-	450	400
	All	0.0218	2.70	5.40	5.15			
Females	<56	0.0095	0.10	0.15	0.00	11	16	0
	56-65	0.0102	0.30	0.50	0.37	30	49	36
	66-75	0.0042	0.85	2.45	2.21	203	584	527
	76-86	0.0013	0.10	0.60	0.47	75	453	355
	>86	0.0003	0.00	0.00	0.00	-	-	-
	All	0.0254	1.35	3.70	3.05			

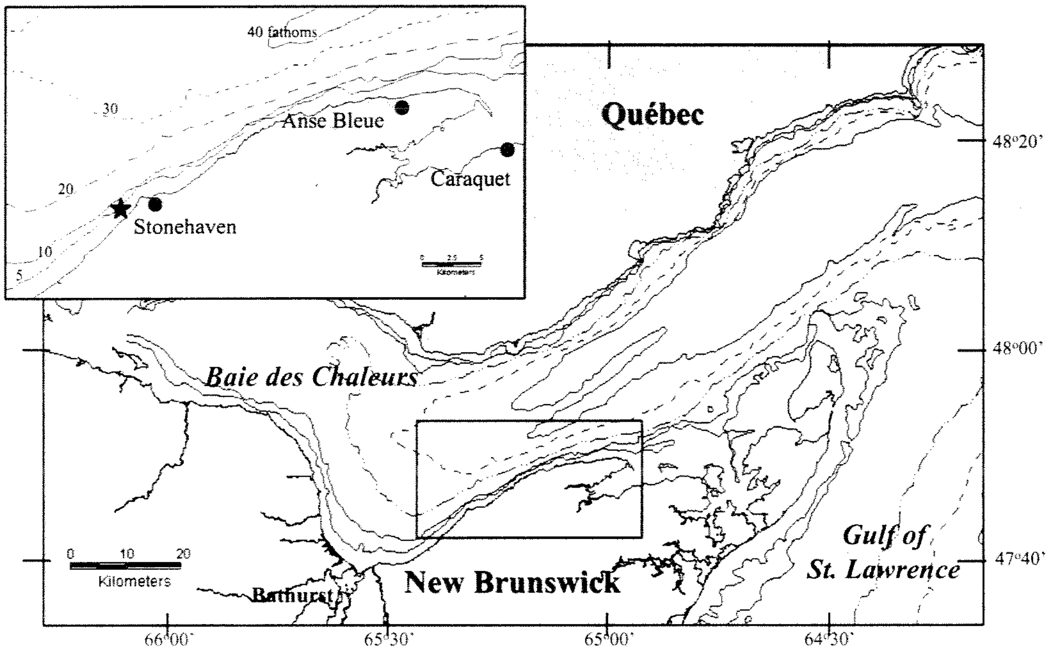

Figure 1. Location of the study area near Stonehaven. All depth contours in fathoms.

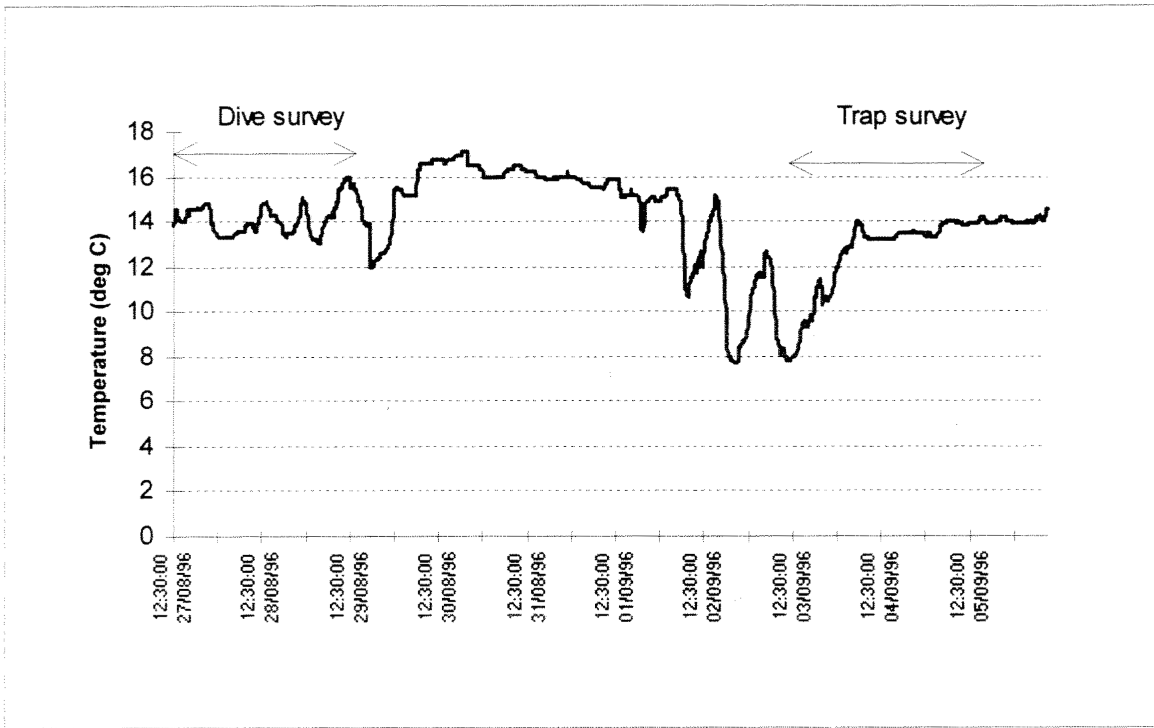

Figure 2. Bottom temperature at 10 m off Stonehaven from Aug. 27-Sept. 5 1996.

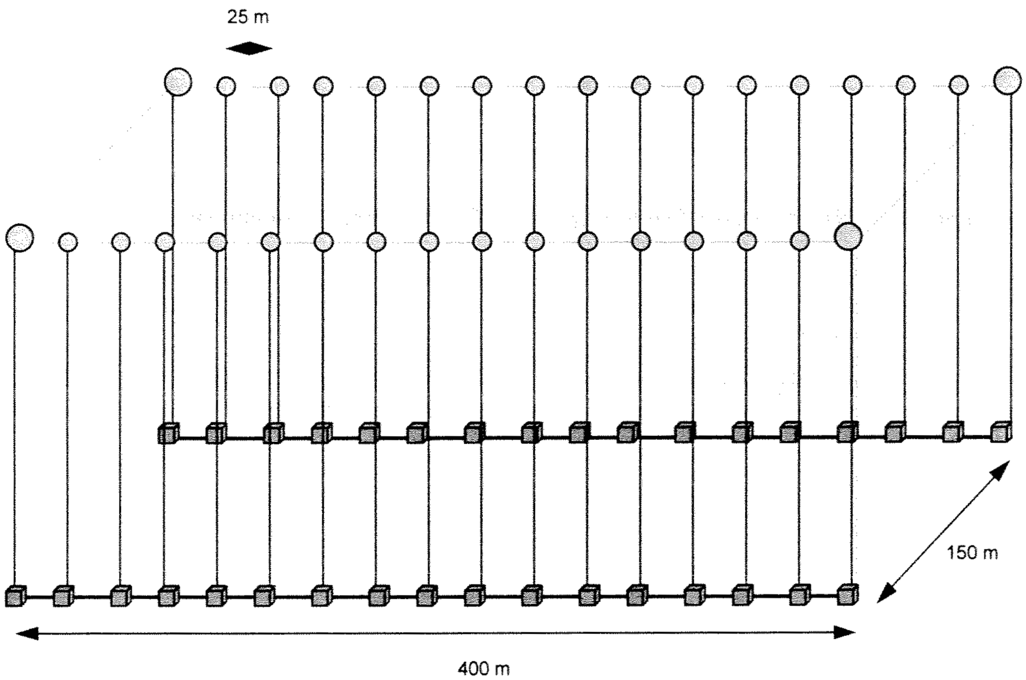

Figure 3. Dimensions of survey area off Stonehaven and location of marker buoys. Buoys were anchored by concrete blocks which were joined by a groundline.

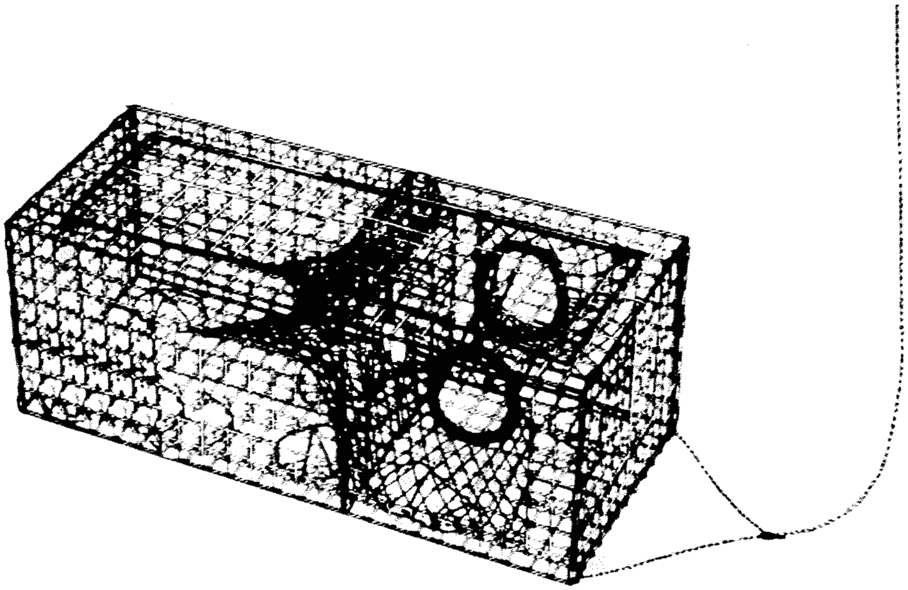

Figure 4. Lobster traps used to estimate catchability. Trap dimensions were 91 cm long by 53 cm wide by 36 cm high. Wire mesh was 3.8 cm square. Entrance rings were 6.4 cm (2.5"), 12.7 cm (5") or 16.5 cm (6.5").

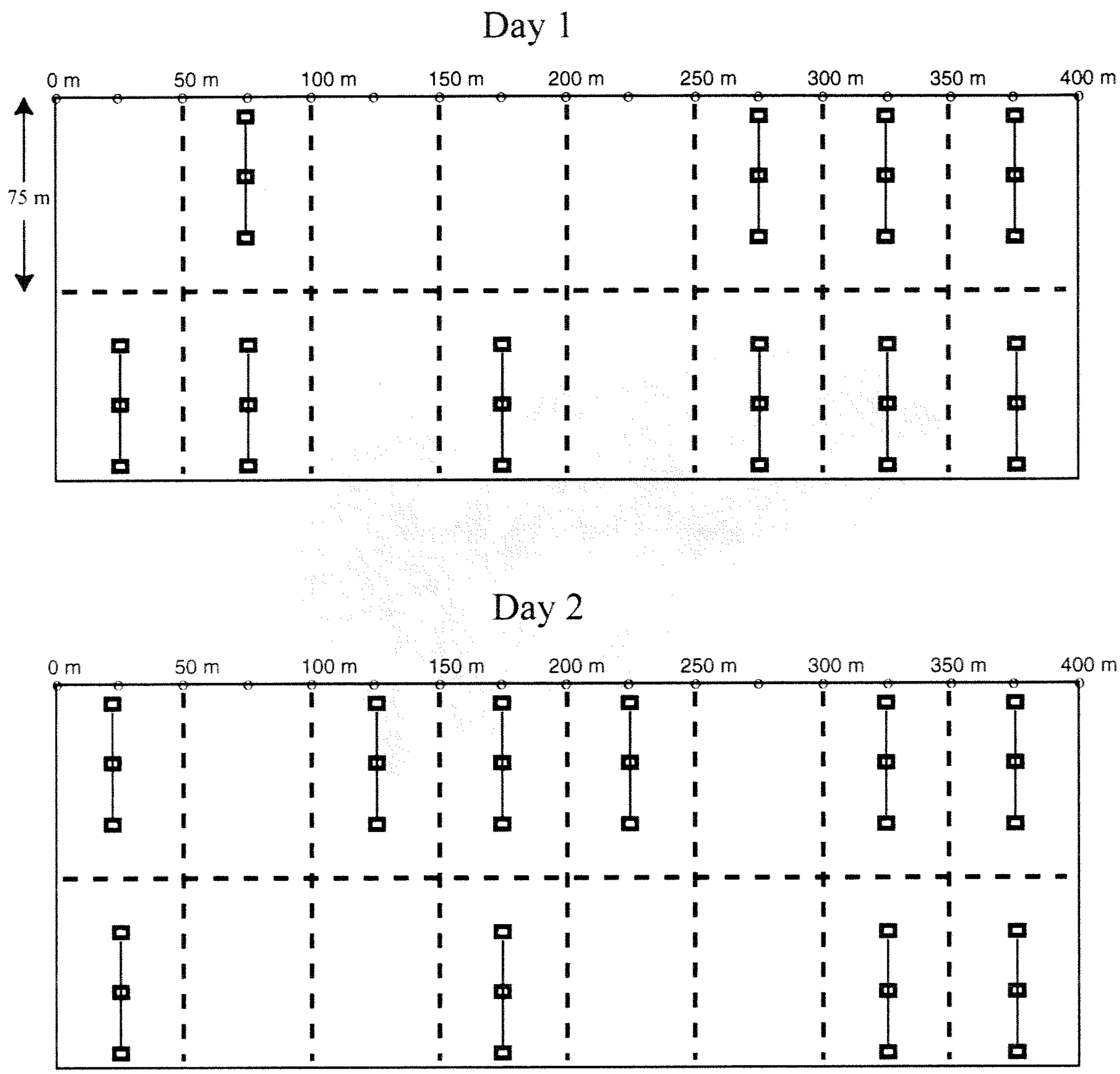

Figure 5. Survey area showing grid for trap survey and positions of the trawls within each grid rectangle on each day. Each trawl had one trap of each ring size (2.5", 5" and 6.5").

0 m | 50 m | 100 m | 150 m | 200 m | 250 m | 300 m | 350 m | 400 m

	1	4	4	1	2	4	1	1	3	3	1	4	3	1/3	4	1
	1	1	4	1	2	1	1	1	3	3	1	1	3	2	3	4
	1	1	1	1	1	1	1	1	3	1	1	4	2	2	3	4
	1	1	1	1	1	4	1	2	3	1	4	4	2	2	2	1
	1	1	1	2	1	4	2	2	3	1	1	2	2	2	1	1
	4	4	2	4	4	2	4	4	3	4	4	2	2/4	2	1	1/4
Tot count:	**33**	**18**	**30**	**18**	**22**	**22**	**22**	**22**	**22**	**18**	**15**	**20**	**17**	**13**	**21**	**27**

Habitat codes: 1 - flat, sandy-mud or gravel (< 20 cm), mussels, isolated small boulders
2 - pavement with few crevices
3 - pavement with crevices or isolated boulders
4 - boulders (> 20 cm)

Figure 6. Qualitative depiction of bottom habitat at Stonehaven site, and lobster total count per transect (at bottom). Based on visual assessment by divers while doing lobster counts on belt transects (records at 25 m intervals).

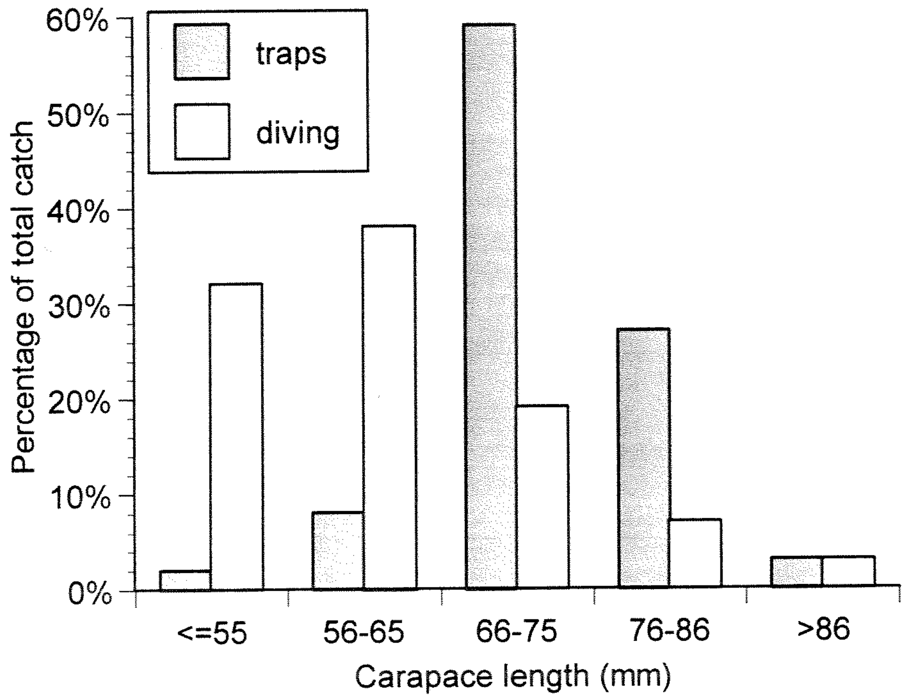

Figure 7. Size composition of lobster catch by traps (5" ring) versus catch by divers.