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MOVEMENTS OF THE LOBSTER, *HOMARUS AMERICANUS*, OFF NORTHERN CAPE BRETON ISLAND, WITH NOTES ON LOBSTER CATCHABILITY

by

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ABSTRACT

Tremblay, M.J., M. D. Eagles and G.A.P. Black. 1998. Movements of the lobster, *Homarus americanus*, off northeastern Cape Breton Island, with notes on lobster catchability. Can. Tech. Rep. Fish. Aquat. Sci. 2220: iv + 32 p.

A total of 3684 lobsters were tagged off northeastern Cape Breton between 1993 and 1995. Tagged lobsters ranged in size from 52-130 mm carapace length (CL); average size was 78 mm CL. The total first-time recapture rate was 57% over 1-2 years, ranging from 25-73% for individual areas. For those lobsters at large over one molting period, growth increments ranged from 8.7-13.1 mm CL. Greater than 80% of lobsters were recaptured less than 6 km from their release site. There was no detectable effect of size or gender on distance moved. Multiple recaptures of single lobsters indicate a variety of movement patterns.

During the May-July fishery, female lobsters measuring 80-85 mm CL were about 30% more catchable than male lobsters 70-80 mm CL and female lobsters 70-75 mm CL. This contrasts to autumn, when males are more catchable. There were no differences in spring catchability among males 70-85, 85-100 and > 100 mm CL.

RÉSUMÉ

Tremblay, M.J. and M.D. Eagles and G.A.P. Black. 1998. Movements of the lobster, *Homarus americanus,* off northeastern Cape Breton Island, with notes on lobster catchability. Can. Tech. Rep. Fish. Aquat. Sci. 2220: iv + 32 p.

On a marqué un total de 3 684 homards au nord-est du Cap-Breton entre 1993 et 1995. Il s'agissait de homards dont la longueur de carapace (CL) variait de 52 à 130 mm, la LC moyenne étant de 78 mm. Le taux total de première recapture s'établissait à 57 % sur 1-2 ans, et variait de 25 à 73 % par zone. Pour les homards en mer pendant une période de mue, les accroissements de longueur se situaient entre 8,7 et 13,1 mm de LC. Plus de 80 % des homards ont été recapturés à moins de 6 km du lieu de leur mise à l'eau. La taille ou le sexe n'avait pas d'effet perceptible sur la distance franchie. Les recaptures multiples de certains homards dénotent une variété de mouvements migratoires.

Pendant la pêche de mai à juillet, le potentiel de capture des femelles de 80 à 85 mm de LC était supérieur d'environ 30 % à celui des mâles de 70 à 80 mm de LC et des femelles de 70 à 75 mm de LC. C'est là un contraste avec la pêche d'automne, durant laquelle les mâles sont plus susceptibles d'être capturés. Il n'y avait pas de différence dans le potentiel de capture au printemps entre les mâles de 70-85, 85-100 et > 100 mm de LC.

INTRODUCTION

Seasonal movements of coastal lobsters measured from tagging studies are generally less than 10 km off Newfoundland, in the Gulf of St. Lawrence, and off the coasts of Nova Scotia and Maine (Templeman 1935, Templeman 1940, Ennis 1974, Wilder 1974, Krouse 1981, Miller et al. 1989, Campbell 1989). An exception to this rule is mature lobsters in the Bay of Fundy-Gulf of Maine system, which can move long distances (10's to 100's of km---Campbell and Stasko 1986, Campbell 1989, Robichaud and Lawton 1997). Offshore lobsters in the Gulf of Maine typically move much further than coastal lobsters (Cooper and Uzmann 1971, Pezzack and Duggan 1986).

Although the above studies indicate restricted movement for most coastal lobsters, many fishermen are interested in whether lobsters in their area follow the pattern. In areas where changes in lobster regulations are possible, descriptions of lobster movement are of particular interest. For example in areas where the minimum legal size (MLS) might be increased, fishermen want to know whether lobsters they return to the bottom in one season will be recaptured on the same grounds in future seasons. If lobsters stay in the area, lobster fishermen are more likely to be interested in regulation changes since they will have a chance to share the benefits of these changes.

On the northeastern side of Cape Breton Island (Fig. 1), (part of Lobster Fishing Area 27) the MLS was 70 mm CL from the mid 1950s until 1997. An increase in size was recommended by scientists (Miller et al. 1987) and fishermen were interested in research on the effects of such an increase (Anonymous, 1992). In 1998 fishermen voted for a larger MLS.

In response to the interest by fishermen for information on local growth and movement of lobsters, a study was initiated in the St. Anns Bay area in 1993 (Fig. 1). The growth of lobsters tagged between Wreck Cove and Englishtown (Fig. 1) is analyzed in detail in Tremblay and Eagles (1997). Here we present data on lobster movement from these areas, plus data on growth and movement from tagging studies in Aspy Bay, around the Bird Islands, in Glace Bay and off Port Morien. A byproduct of these tagging studies are data on return rate by size and gender which we use to estimate relative catchability.

METHODS AND MATERIALS

A total of 3684 lobsters from Aspy Bay to False Bay were tagged between 1993 and 1995 (Fig. 1). Most lobsters were from the area between Wreck Cove and Bird Islands (Table 1). Lobsters to be tagged were captured by research traps or commercial traps. The sizes that were tagged varied according to year and season. In 1993 all lobsters > 60 mm carapace length (CL) were tagged, as well as some as small as 53 mm CL. When the tagging was done during the fishing season (May 1994 and July 1995) only sublegal and ovigerous females were tagged since the fishermen retained all legal lobsters. In fall 1994 and 1995 only legal sizes (≥ 70 mm CL) were tagged.

Lobster tags were the polyethylene streamer type, which can yield higher tag returns than the sphyrion tag, possibly because of greater tag retention through the molt (Moriyasu et al. 1995). To insert the tags, lobsters were held with the abdomen flexed to expose the dorsal musculature, and the disposable needle was threaded through the membrane into the right abdominal muscle, up over the dorsal artery and down through the left dorsal muscle to exit on the other side. In this way the tag was visible on both sides of the lobster. Large lobsters (greater than about 90 mm CL) were tagged only in the right dorsal muscle. Lobsters were released immediately after tagging, close to where they were captured. Release position (latitude and longitude), size and sex were recorded.

Lobsters were recaptured during the commercial fishing season (May 15-July 15) with the exception of a few recaptures (< 1%) during experimental trapping in August and September. Fishermen were involved in the tagging and were informed of the need to measure the CL of the lobsters prior to removing the tag. As an incentive, fishermen received $3.00 for tag information. Return locations were given for about 95% of the tag returns. Of these locations, 46% were coordinates from electronic navigation units, while the other 54% were given as landmarks (often with depths), which were converted to latitudes and longitudes using navigational charts. We believe most of these landmark data to be accurate to within 1 km.

Carapace length measurements were made on most of the recovered lobsters. About 80% of the measurements were made to the nearest mm by trained technicians, or by the authors; about 20% were made by fishermen. In some cases fishermen indicated the lobster grade ("canner" - 70 to 80 mm CL or "market" - ≥81 mm CL) which sometimes enabled us to discern whether a lobster molted, but not the size of the growth increment. In 1994 many of the lobsters were returned to the bottom with the tag still attached after capture and measurement; some of these were captured again in later years. If location was recorded we included these lobsters as multiple recaptures. To display directional trends in lobster movement, direction frequency plots were created that show the number of lobsters traveling within 24 possible directions (15 degrees each).

Relative catchability for different size/gender groups was estimated by the return rate (number of tagged lobsters returned/number of tagged lobsters released). Only return rates based on at least 10 releases were used, and only studies where there was negligible size change due to growth between marking and recapture. Different tag groups (location/date combinations) were treated as "blocks" in a blocked analysis of variance (anova) as:

Return rate = Constant + Tagging block + Size + Sex + Size * Sex

Because different sizes were tagged in different tagging operations, sufficient numbers of the complete size range (prerecruits to large lobsters) were not available for any one set of tagging blocks. Therefore we tested the following groups independently: (i) prerecruits (60-70 mm CL) versus recruit lobsters (70-80 mm CL); (ii) 70-75, 75-80 and 80-85 mm CL; and (iii) 70-85, 85-100 and > 100 mm CL (males only). Different combinations of tagging blocks were used for each of the 3 tests. For example to test whether the catchability of prerecruit lobsters differed from recruit lobsters, 3 tagging blocks were available which had at least 10 releases for both males and females of the above sizes.

RESULTS

Of the 3684 lobsters that were tagged, there were a total of 2096 (57%) first-time recaptures from 1994-1996. The return rate ranged from 28-73% for individual tagging blocks (Tables 2-4). On average, lobsters moved from 1-5 km after one-two years at large. Many were recaptured close to their point of release. A measure of the restricted movement is the degree to which lobsters were returned by fishermen from ports that fish the grounds where the lobsters were tagged. For example 91% of the lobsters tagged off Little River in September 1993 and 1994 were recaptured by Little River fishermen (Tables 2, 3).

Lobster movement is described below by release location and date. Spring refers to the May 15-July 15 period, during the open season for lobster fishing. In the following section the number of returns or recaptures refers to those with location data; the total number of returns was sometimes higher. Maps are provided where the number recaptured was greater than 25.

Little River: July 1993

Of the 178 lobsters tagged off Little River in July 1993, 82 (46%) were recaptured the following spring (10-12 months later) (Fig. 2). Most of these lobsters (92%) molted between release and recapture, with an average molt increment of 10.6 mm CL. Many were returned to the water with tags intact after measurement. Lobsters moved an average distance of 2.5 km. The direction mode (Fig. 2) shows peaks in the northeast and southeast quadrants, indicating lobsters moved both to the north northeast and southwest, parallel to the shore. An additional 16 lobsters (9%) were recaptured the following year (spring 1995) after 22-24 months at large. For these lobsters average distance moved from the initial release point was 3.9 km.

Little River - September 1993

This group of tagged lobsters (n = 925) was the largest for any given date and location. There were 455 (49%) first-time recoveries in spring 1994; on average these lobsters moved 3.0 km (Fig. 3a). Many were returned to the water with tags intact after measurement. Growth was restricted to a few late-molters since the tagging was after the main molting season in 1993, and recaptures were in the following spring, prior to the 1994 molting season. Most lobsters moved in a northeasterly direction, although a few moved south towards Englishtown (Fig. 3a). In spring 1995, after 20-22 months at large, there were an additional 135 (15%) recaptures (Fig. 3b). Of these, 95% had molted, with an average CL increase of 12.8 mm. Average distance moved was 2.8 km, with the dominant direction again to the northeast.

Wreck Cove - September 1993

Of the 218 lobsters tagged here, 94 (43%) were recovered in spring 1994; only one had grown. Average distance moved was 1.5 km, predominantly to the south (Fig. 4a). Many were returned to the water with tags intact after measurement. In spring 1995, after 20-22 months at large a further 29 lobsters (13%) were recaptured (Fig. 4b). Of those with growth information, 96% had molted; the average increment was 11.0 mm CL. Average distance moved was 2.9 km, with the dominant direction to the northeast.

Englishtown - September 1993

Of the 222 lobsters tagged, 105 (48%) were recaptured in spring 1994. None had molted. Average distance moved was 3.4 km, mainly to the northeast (Fig. 5a). Several were recaptured close to the Bird Islands. In spring 1995 an additional 36 lobsters (16%) were recaptured after having moved an average distance of 4.9 km, again mainly to the northeast (Fig. 5b). All had molted; the average growth increment was 13.1 mm CL.

Little River - May 1994

137 sublegal lobsters were tagged at the beginning of the spring season in 1994; 49 (36%) of these were recaptured during the following 9 weeks. All were returned to the water with tags intact. Average distance moved was just 0.7 km, with most lobsters having moved shoreward of their release point. After one year at large there were another 49 recaptures. Most of these (95%) had molted with an average growth increment of 11.2 mm CL. Average distance moved was 2.6 km, with no dominant direction (Fig. 6).

Little River - September 1994

Of 198 lobsters tagged, 130 (66%) were recovered the following spring. Average distance moved was 4.1 km, mainly to the northeast (Fig. 7). An additional 13 lobsters (7%) were recaptured the following spring after 20-22 months at large; average distance moved was 3.4 km in a northeasterly direction.

Wreck Cove - September 1994

In this experiment 200 lobsters were tagged in each of two areas separated by about 3 km. Much of the area in between (centered by Wreck Cove) was sandy bottom not considered to be prime lobster habitat. The area to the north of Wreck Cove is fished by the Ingonish lobster fleet, while the southern area is fished from boats originating in Little River. Tag numbers were mixed between the two areas. There was little exchange between the two fishing grounds (Table 3). Of the 200 lobsters tagged to the north, 104 (52%) were returned, most having moved to the north (Fig. 8a). Of the 200 lobsters tagged to the south, 125 (63%) were returned with an average distance of 1.3 km from the release location (Fig. 8b). There were few records of recaptured lobsters in either area in 1996, probably because collection efforts were concentrated elsewhere in this year.

Bird Islands, Cape Dauphin and Haddock Bank releases - October 1994

A total of 544 lobster were tagged at these sites. Molting prior to recapture the following spring was rare. Of the 127 lobsters tagged off the Bird Islands, 68 (54%) were recovered, most to the west of the tagging location, with an average distance of 2.3 km (Fig. 9a). Of the 192 lobsters tagged off Cape

Dauphin, 105 (55%) were recovered (Fig. 9b). These lobsters had also moved primarily to the west, with an average distance of 2.6 km. Of the 225 tagged on Haddock Bank, 107 (48%) were recaptured at an average distance of 2.4 km from the tagging location (Fig. 9c). Few of the lobsters tagged on Haddock Bank were recaptured west of the Bird Islands. There were few records of recaptured lobsters in the 3 areas in 1996, probably because our collection efforts were concentrated elsewhere in this year.

Aspy Bay releases - July 1995

Lobster tagging in Aspy Bay was restricted to sublegal and ovigerous females, since it was done on board a fishing vessel near the end of the spring season. Of the 399 lobsters tagged, 158 (40%) lobsters were recaptured the following spring. Of those with size information 91% had molted with an average growth increment of 8.7 mm CL (Fig. 10). Lobsters moved an average distance of 2 km with no strong directional component.

Glace Bay - July 1995/Port Morien - October 1995

As for Aspy Bay, all tagged lobsters in Glace Bay were either sublegal or ovigerous because the tagging was done at the end of the fishing season. Of the 210 lobsters tagged, 58 (28%) were recaptured, but just 44 (21%) had location information. These lobsters moved an average of 2.5 km, in no particular direction (Fig. 11a). Most (95%) of the sublegal lobsters grew into legal sizes prior to recapture, with an average molt increment of 10.1 mm in CL.

Lobsters tagged off Port Morien in October were all of legal size. Of the total of 253 tagged lobsters, 92 (36%) were recovered the following spring. None had molted prior to recovery. Mean distance moved was 2.8 km, mainly to the west (Fig. 11b).

Multiple Recaptures

Some lobsters were recaptured more than once either because they could not be legally landed (below the minimum legal size or ovigerous) or because the fishermen were interested in tracking lobster movement over time. Many fishermen off Little River decided to do this in 1994. There were 14 lobsters that were recaptured at least 6 times over one or more seasons. All of these lobsters were tagged in September 1993. Following is a description of movement for 9 of these lobsters (Fig. 12a); the other 5 showed little movement or had incomplete information.

Lobsters 1 and 2 were released in the Wreck Cove area. Lobster 1 was an 83 mm CL male. During the following spring, it stayed within an area of less than one km^2 (Fig. 12b). Lobster 2 was a 75 mm CL female. In June 1994 it was recaptured 5 times about 1 km south of the release point. Lobster 2 was recaptured 3 times again in the same area in 1995 when it was ovigerous (Fig. 12c).

Lobsters 3, 4 and 5 were all released close to Bentinck Point (Fig. 12a). Lobster 3 was a 73 mm CL male that was recaptured 5 times in spring 1994, all within 1.5 km of the release point (Fig. 12d). In 1996, almost 3 years after release, no. 3 was recaptured within 1.5 km of its starting location. This lobster had presumably molted twice (August of 1994 and 1995) since it measured 93 mm CL in 1996. Lobster 4 was a 71 mm CL ovigerous female. She was recaptured 5 times the following spring and for the last time in late June 1995 (Fig. 12e). By this time she had molted to a CL of 81 mm. All recaptures were within 2.5 km of the release point. Lobster 5, a 77 mm CL male, was recaptured 5 times in June and July 1994 within 2 km of its release point (Fig. 12f). In May 1995, after molting to 89 mm CL (probably in August 1994) it was recaptured 5 km north of its release point.

Lobsters 6, 7 and 8 were tagged about 3.5 km south of Bentinck Point. No. 6, a 68 mm CL female was recaptured in June 1995 about 10 km north of the release point (Fig. 12g). She had molted to 78 mm CL and extruded eggs in the 21 months since tagging. No. 6 was recaptured another 3 times at the northerly location (last date June 19) and then traveled south to be recaptured on July 3 and July 12. Walking speeds indicated are less than 400 m per day (2 km/15 days, 3.5 km in 9 days). Lobster 7, a 75 mm CL male, was recaptured 8 times in spring 1994, about 7 km north of the release location (Fig. 12h). In the following year it had moved south to a position less than 2 km from its release point, and had molted to 87 mm CL. Lobster 8, a 76 mm CL female, was one of the few lobsters moving more than 20 km (Fig. 12i). She was first recaptured on June 8 1994 almost 7 km north of the release point. She was recaptured 4 times 2-3 weeks later a further 4 km to the north. In the following June (21 months after release) she had traveled to Cape Smokey, a total of 28 km. She had also molted to 87 mm CL.

Lobster 9, an 80 mm CL male, was another lobster that moved much more than average (Fig. 12j). Tagged off Englishtown, it was recaptured 5 times off Wreck Point (about 23 km to the north) in June 1994. One year later, after molting to 88 mm CL, this male was recaptured a further 9 km to the north.

Distance moved versus size and gender

To examine the possibility of size and gender differences in distance moved, we restricted our statistical analysis to lobsters released at the same time of year and in the same area: tagging blocks 2 and 6 in Table 1. Of the 675 returns, 14 were ovigerous females which are not considered further because of the small number. There was no correlation between lobster size and distance moved for males or females (Fig. 13). In a complementary analysis, distances moved were placed in categories based on gender and size (50-70 mm CL and 70-90 mm CL) (Fig. 14). A chi-square test for each size category confirmed that there was no significant interaction between gender and distance moved ($p > 0.3$ for 50-70 mm CL and $p > 0.8$ for larger size class).

Effects of size and sex on recapture rate (relative catchability)

To test whether prerecruit lobsters were less catchable than recruits, we used the data from 1993 (tagging blocks 2, 3 and 4 in Table 1). Lobsters in the 60-69 mm CL size class had lower return rates than those in the 70-79 mm CL size class for each tagging block (Fig. 15). This difference was statistically significant, but there was no difference between the recapture rates of males and females.

To test for differences in recapture rate within the legal sizes (70-75, 75-80 and 80-85 mm CL), we used the data from tagging blocks 2, 6, 8-9, and 12. The other periods were excluded because only short and/or ovigerous females were tagged. Plots of the recapture rates indicate females in the largest size class (80-85 mm CL) had rates that were about 30% higher than those of the males (all size classes) and smallest females (70-75 mm CL) (Fig. 16). The blocked anova showed a significant effect of sex and size class, and a mildly significant interaction effect ($p = 0.08$). Comparisons of each size-gender combination revealed that the recapture rate of females 80-85 mm CL was significantly higher than that of males 70-75 and 75-80 mm CL, and that of females 70-75 mm CL (Table 6).

To test whether large lobsters had a different recapture rate from other sizes, we used the data from the same tagging blocks as the previous analysis, grouping sizes as follows: 70-85, 85-100 and > 100 mm CL (Fig. 17). There were too few females larger than 85 mm CL to conduct the test. The blocked anova indicates no significant difference among the recapture rates of males of different sizes (Table 7).

DISCUSSION

Movement

Greater than 80% of all lobsters tagged off the coast of northeast Cape Breton were recaptured less than 6 km from their release location. As in all mark-recapture studies inferences about movement must be made with caution. In general, tagging studies may be limited by (i) the spatial and seasonal distribution of fishing effort, and (ii) the quality of information on recaptures (related to cooperation of the harvesters).

As far as fishing effort is concerned, the spatial coverage was good but was seasonally restricted. The spatial distribution of lobster traps in the tagging areas covers the known distribution of lobsters and we expect few lobsters went beyond the bounds of the area fished by the lobster fishing fleet. Since the commercial fishery occurs only during 9 weeks in spring, we do not know where the lobsters were the other 43 weeks. We expect that seasonal movements from deeper waters in winter to shallower waters in summer does take place off eastern Cape Breton as in other areas (Ennis 1974). As such estimates of distance moved from release and recapture locations are minimum estimates. In any case where the lobsters are between seasons is not the most important question from the perspective of a lobster fisher when returning a sublegal or egg-bearing lobster to the water. Of more importance is whether that lobster will be available on his fishing grounds in subsequent years. This study indicates it likely will.

The quality of return information was generally good, and we believe we obtained information on most recaptured lobsters. For the main tagging area (Little River) exploitation rates estimated by methods other than mark-recapture are 63-75% per year (Tremblay and Eagles 1996). The first year recapture rates of legal animals (57-67%) were what we would expect if the above exploitation rates are realistic. The study was well advertised within all ports adjacent to the fishing area and there is no reason to believe that any significant numbers were recaptured outside of the main fishing grounds mentioned here.

For two areas the return rate was substantially lower than the exploitation estimate estimated using Leslie analysis (Tremblay and Eagles 1996). For Glace Bay the return rate was 28%, while Leslie analysis indicates 66-75% exploitation. For Aspy Bay, the return rate was 40%, while Leslie analysis for the northern part of LFA 27 indicates 66-80% exploitation. We believe that at least part of the low return rate was due to unreported recaptures. In Aspy Bay for example, the tagging was done with 1 week left in the season and some of the tagged lobsters could have been captured and unreported (many were close to the legal size). The size and sex composition of the tagged animals in the two areas does not appear to explain the low return rates. The Glace Bay tagging block for example was characterized by a high percentage of berried females (58%). These berried females were all carrying old eggs which should have hatched within a few weeks of tagging. Under most conditions these females would be expected to molt after egg hatching, and be available to the fishery the following year (non-ovigerous). This was the case. Females that were ovigerous when tagged were captured the following year as non-ovigerous females, 95% of which had molted. They had a higher return (31%) than either sublegal males (19%), or sublegal females (26%), probably because they were larger (see Catchability section). The Aspy Bay tagging block also had a relatively high percentage of berried females (10%). Here females that were ovigerous when tagged had a similar return rate (41%) to sublegal males (38%) and females (42%).

Greater movement has been associated with larger, mature females in some studies (Campbell 1986) but this study and others (Krouse 1981) detected no such relationship. Large females (> 90 mm CL) were rare in this study but in this area the female size of 50% maturity is about 73 mm CL (Watson 1988), and thus many of the tagged females were mature (capable of extruding eggs).

The direction moved by lobsters was not consistent among sites and is difficult to reconcile with any proposed seasonal migration. Lobsters tagged off Little River and Englishtown in September tended to move to the northeast. If there is a general movement of lobsters into the St. Anns Bay area in summer, perhaps to shallower water, it may be that when tagged in autumn the average lobster was at its most southerly point. Lobsters tagged in fall off Wreck Cove on the other hand moved both to the north and to the south depending upon the tagging and recovery periods. Lobsters tagged off the Bird Islands and Cape Dauphin in October tended to be trapped the following spring slightly to the west, in shallower waters, while lobsters tagged on Haddock Bank were trapped the following spring both to the east and west of their tagging location, also in shallower waters.

The multiple recapture data for individual lobsters are intriguing. They indicate that lobsters can molt, mate and extrude eggs within an area of a few km^2 and retain their tags throughout the process. The tracks also indicate that some lobsters can move more than 30 km, while others make return movements. What causes individuals to move to different extents is not known. In other areas (Bay of Fundy), movements can be related to season and water temperature. It is important to keep in perspective the different scale of movements however--- the lobsters moving the maximum distance in this study moved considerably less than Bay of Fundy lobsters, which can move upwards of 100 km (Robichaud and Lawton 1997).

Growth

Growth increments averaged 8.7-13.1 mm CL by tagging block, with 91-100% of lobsters molting when the period at large included the summer months. For the size of animals tagged, the average growth increments represent increases in CL of 13-17%. The growth increment data are consistent with other studies (Miller et al. 1989). Some of the variation in growth increment is due to size and sex. Analysis of a subset of these data show that molt increment increases with size in males, and is highest in males and lowest in ovigerous females (Tremblay and Eagles 1997). The timing of tagging in relation to the molt may be another factor affecting growth increment. Areas that were tagged in July, a few weeks before the molt (Little River, Aspy Bay and Glace Bay), had relatively low average increments (10.6, 8.7, 10.1 mm CL). The effect of the timing of tagging is difficult to evaluate from these data however because it is confounded with size and sex. When lobsters were tagged in July, there was a higher proportion of prerecruit and ovigerous lobsters.

Catchability

The higher relative catchability of recruit lobsters compared with prerecruit lobsters has been noted elsewhere (Smith 1944, Miller 1995) and is due both to behavioral effects and trap design. Traps now have mandatory escape gaps so that prerecruit lobsters are retained in traps to a lesser extent.

Return rate data in Smith (1944) for 2 areas of the Southern Gulf of St. Lawrence come from a different season (Aug. 10-Oct 5) and presumably different trap types. In spite of this, the difference between the return rate of prerecruits and recruits in Smith (1944) was very similar to ours:

CL (mm)	Sex	Area	Return rate	Source
60-68*	Males and females	Shediac	56%	Smith 1944
71-79	"	"	70%	"
60-68	"	Miminegash	52%	"
71-79	"	"	73%	"
60-69	Males	Little River (1993)	58%	Present study
70-79	"	"	72%	"
60-69	Females	"	58%	"
70-79	"	"	76%	"

*Smith used total lengths. These were converted using CL = 0.37 * TL -4.53 (Wilder 1953)

Data from Miller (1995) also indicate a higher catchability for recruits. At a site just north of Glace Bay (Sydney Harbour) the September catchability for male recruits was almost 5 times that of male prerecruits, while female recruits were twice as catchable as female prerecruits (Miller 1995). The greater difference in catchability between recruits and prerecruits observed in Sydney Harbour may be due to season, area or study methods. Miller (1995) estimated catchability by comparing trap catches with diver counts. Our use of recapture rates of tagged lobsters could introduce bias if tagged lobsters are more catchable than untagged lobsters.

The finding in this study that females 80-85 mm CL had a higher relative catchability than males 70-80 mm CL and females 70-75 mm CL is novel. Smith (1944) did not examine males and females separately. At the Sydney Harbour site Miller (1995) found that females were less catchable than males. For example females 80-89 mm CL were about half as catchable as males 70-79 mm CL, and less than 1/3 as catchable as males of the same size. The higher relative catchability of females that we observed is likely because our recaptures were in spring. Earlier male molting may explain some of this seasonal difference (Tremblay and Eagles 1997). Investigators modeling egg- and yield-per-recruit should examine the sensitivity of model outputs to higher catchability for females.

This study provides new data on catchability at size and adds to the weight of evidence that coastal lobsters have restricted movements over periods of months to a few years. Fishermen can be confident that few of the lobsters on their fishing grounds will walk away if left unfished for a year or so.

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Table 1. Number and size of lobsters tagged from 1993-1995 off the coast of eastern Cape Breton. MCL is mean carapace length (mm); SD is standard deviation of CL.

Tagging	Tagging	Tagging	Males			Females			Ovigerous females			Tot N
Block no.	Location	period	N	MCL	SD	N	MCL	SD	N	MCL	SD	tagged
1	Little River (LR)	July 21, '93	90	68.5	9.6	72	65.9	5.3	16	78.9	5.4	178
2	Little River	Sept. 21-23 '93	638	81.0	11.3	265	73.6	7.3	22	79.7	8.1	925
3	Wreck Cove (WC)	Sept. 24 '93	125	78.6	9.2	89	70.2	7.3	4	84.0	5.2	218
4	Englishtown (ENG)	Sept. 27-30 '93	125	77.0	9.7	89	70.6	6.6	8	76.6	5.0	222
5	Little River	May 16-17 '94	54	65.4	3.1	70	65.4	3.9	13	78.0	5.3	137
6	Little River	Sept. 19-20 '94	133	87.2	11.9	65	77.4	4.7	0			198
7	Wreck Cove	Sept. 21-22 '94	142	81.8	9.4	58	76.9	5.1	0			200
8	Ingonish (ING)	Sept. 22 '94	146	82.9	10.9	54	79.4	8.1	0			200
9	Bird I-Had. B.	Oct. 4 '94	377	87.3	14.2	167	80.8	8.5	0			544
10	Aspy Bay	July 12 '95	141	67.5	1.9	217	67.1	2.0	41	80.8	13.1	399
11	Glace Bay	July 18 '95	32	68.1	1.0	57	67.7	1.2	121	79.7	8.1	210
12	Port Morien	Oct. 11 '95	179	85.8	11.3	74	81.7	7.9	0			253
		Total	2182			1276			225			3684

Table 2. Lobsters tagged in 1993: total number returned and percentage by fishing port. N Ret = total number of first-time tag returns by all ports. ING = Ingonish, LR = Little River, ENG = Englishtown, BBD-NC = Big Bras d'Or - New Campbellton, AP = Alder Point. Wreck Cove is at the northern end of the Little River fishing grounds. Note that N Ret may be greater than number indicated in Results text because some returns did not have location information.

Source Fishing Port	1993		Return by Fishing Port 1994-95				
	N tagged	N Ret	ING	LR	ENG	BBD-NC	AP
Little River, Wreck Cove (LR)	218	133 (61%)	22%	77%	1%	0%	0%
Little River (LR) (July & Sept.)	1103	711(64%)	0%	**91%**	8%	1%	0%
Englishtown (ENG)	222	148 (71%)	0%	9%	**81%**	9%	0%
Total	1543	992					

Table 3. Lobsters tagged in 1994: total number returned and percentage by fishing port. N Ret = total number of first-time tag returns by all ports. ING = Ingonish, LR = Little River, ENG = Englishtown, BBD-NC = Big Bras d'Or - New Campbellton, AP = Alder Point. Wreck Cove is at the northern end of the Little River fishing grounds. Note that N Ret may be greater than number indicated in Results text because some returns did not have location information.

Source Fishing Port	1994		Returns by Fishing Port 1995-96				
	N tagged	N Ret	ING	LR	ENG	BBD-NC	AP
Ingonish (ING)	200	111 (56%)	92%	8%	0%	0%	0%
Little River, Wreck Cove (LR)	200	128 (64%)	11%	**89%**	0%	0%	0%
Little River (LR) (May and Sept.)	336	246 (73%)	1%	**91%**	5%	3%	0%
Combined - Big Bras d'Or (BBD), Englishtown, New Campbellton, Alder Point (AP)	544	313 (58%)	0%	2%	16%	**76%**	6%
Total returns	1280	798					

Table 4. Lobsters tagged in 1995: total number returned and percentage by fishing port. N Ret = total number of first-time tag returns by all ports. AB = Aspy Bay, WP = White Point, GB = Glace Bay, FB = False Bay, PM = Port Morien, Other = Lingan, New Waterford and Main a Dieu. Note that N Ret may be greater than number indicated in Results text because some returns did not have location information.

Source Fishing Port	1995		Returns by Fishing Port 1996					
Port of release	N tagged	N Ret	AB	WP	GB	FB	PM	Other
Aspy Bay (AB)	399	160 (40%)	**96%**	4%	0%	0%	0%	0%
Glace Bay (GB)	210	58 (28%)	0%	0%	**92%**	0%	2%	6%
Port Morien (PM)	253	93 (37%)	0%	0%	9%	15%	**68%**	9%
Total returns	861	306						

Table 5. Blocked analysis of variance of size group (60-70 and 70-80 mm CL) and sex on return rate of lobsters in northeastern Cape Breton. Tagging blocks are numbers 2, 3 and 4 in Table 1.

DEP VAR: RETURN RATE N: 12 MULTIPLE R: 0.831 SQUARED MULTIPLE R: 0.691

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
TAGGING BLOCK	0.004	2	0.002	0.404	0.685
SIZE	0.062	1	0.062	11.139	**0.016**
SEX	0.007	1	0.007	1.181	0.319
SIZE*SEX	0.002	1	0.002	0.295	0.606
ERROR	0.033	6	0.006		

Table 6. Blocked analysis of variance of size group (70-75, 75-80 and 80-85 mm CL) and on return rate of lobsters in northeastern Cape Breton. Tagging blocks are numbers 2, 6, 8, 9 and 12 in Table 1.

DEP VAR:RETURN RATE N: 30 MULTIPLE R: 0.915 SQUARED MULTIPLE R: 0.837

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
TAGGING BLOCK	0.497	4	0.124	20.247	**0.000**
SIZE	0.042	2	0.021	3.415	**0.053**
SEX	0.055	1	0.055	8.905	**0.007**
SIZE *SEX	0.035	2	0.018	2.857	0.081
ERROR	0.123	20	0.006		

Bonferonni adjustment - matrix of pairwise comparison probabilities:

Size/Sex group	1	2	3	4	5	6
1. Males 70-75	1.000					
2. Females 70-75	1.000	1.000				
3. Males 75-80	1.000	1.000	1.000			
4. Females 75-80	1.000	1.000	0.927	1.000		
5. Males 80-85	1.000	1.000	1.000	1.000	1.000	
6. Females 80-85	**0.040**	**0.033**	**0.021**	1.000	**0.057**	1.000

Table 7. Blocked analysis of variance of size group (70-85, 85-100 and > 100 mm CL) on return rate of male lobsters in northeastern Cape Breton. Tagging blocks are numbers 2, 6, 8, 9 and 12 in Table 1.

DEP VAR:RETURN RATE N: 15 MULTIPLE R: 0.924 SQUARED MULTIPLE R: 0.853

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
TAGGING BLOCK	0.246	4	0.061	11.005	**0.002**
SIZE	0.014	2	0.007	1.241	0.339
ERROR	0.045	8	0.006		

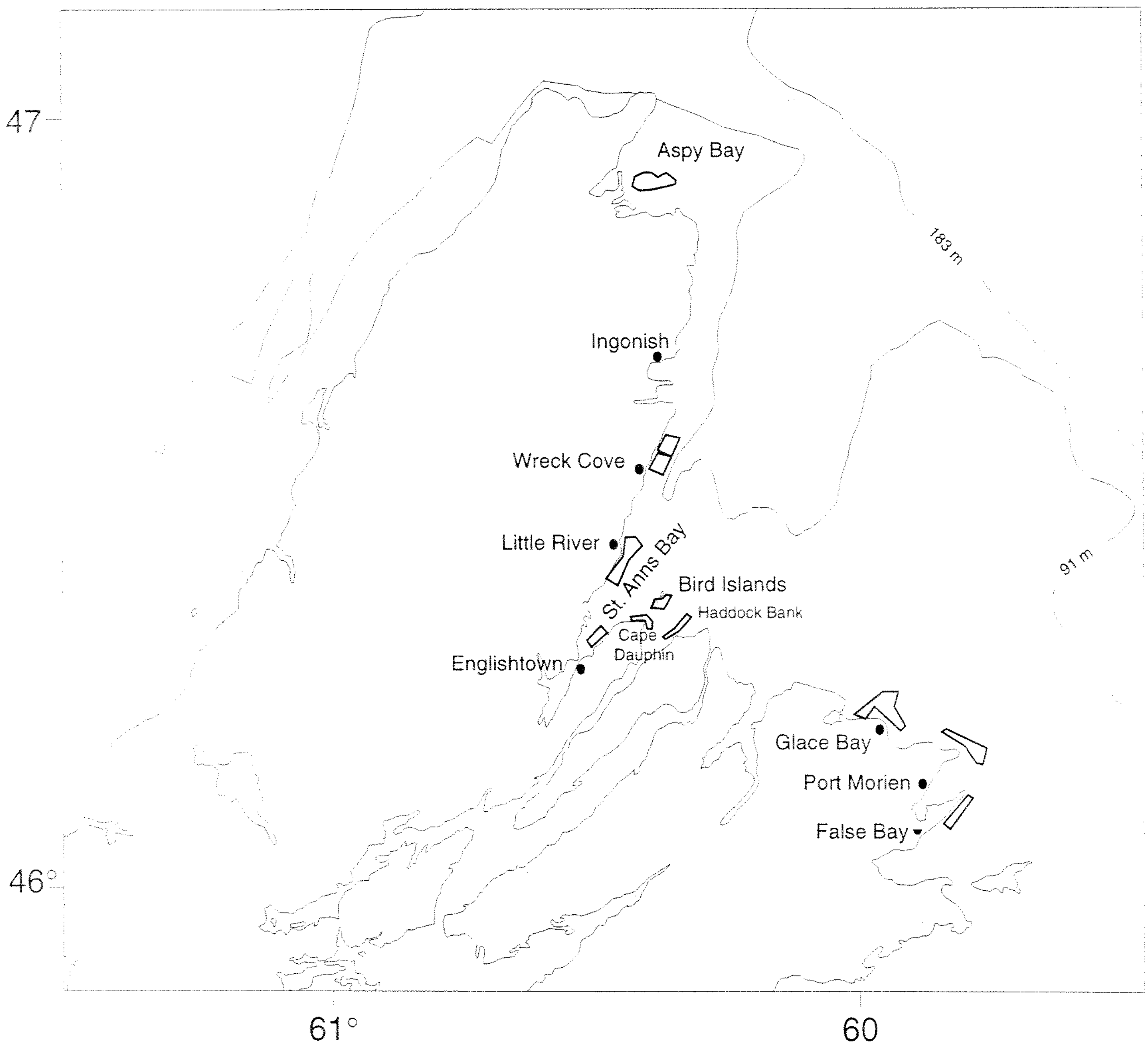


Fig. 1. Cape Breton Island showing release sites of tagged lobsters.

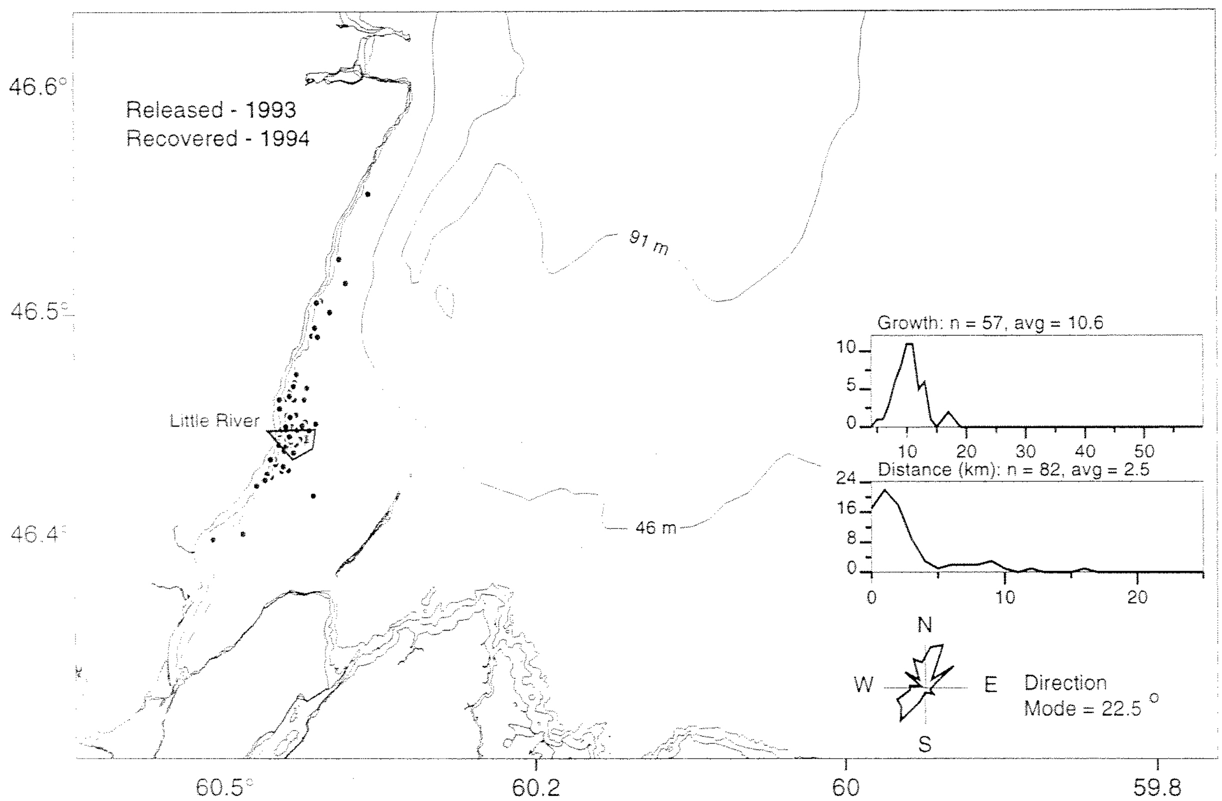


Fig. 2. July 1993 releases of tagged lobsters off Little River and 1994 initial recaptures. Release area is indicated by heavy lines; solid circles show first-time recaptures. "Plus" signs (+) show release points; these were usually overlaid by recapture symbols. Growth graph shows frequency of growth increments (mm) for lobsters that were measured upon recapture. Distance graph shows frequency of distances moved from point of release to point of recapture. Direction frequency plot is by 15 degree bins. Nearshore depth contours are 4 m and 9 m.

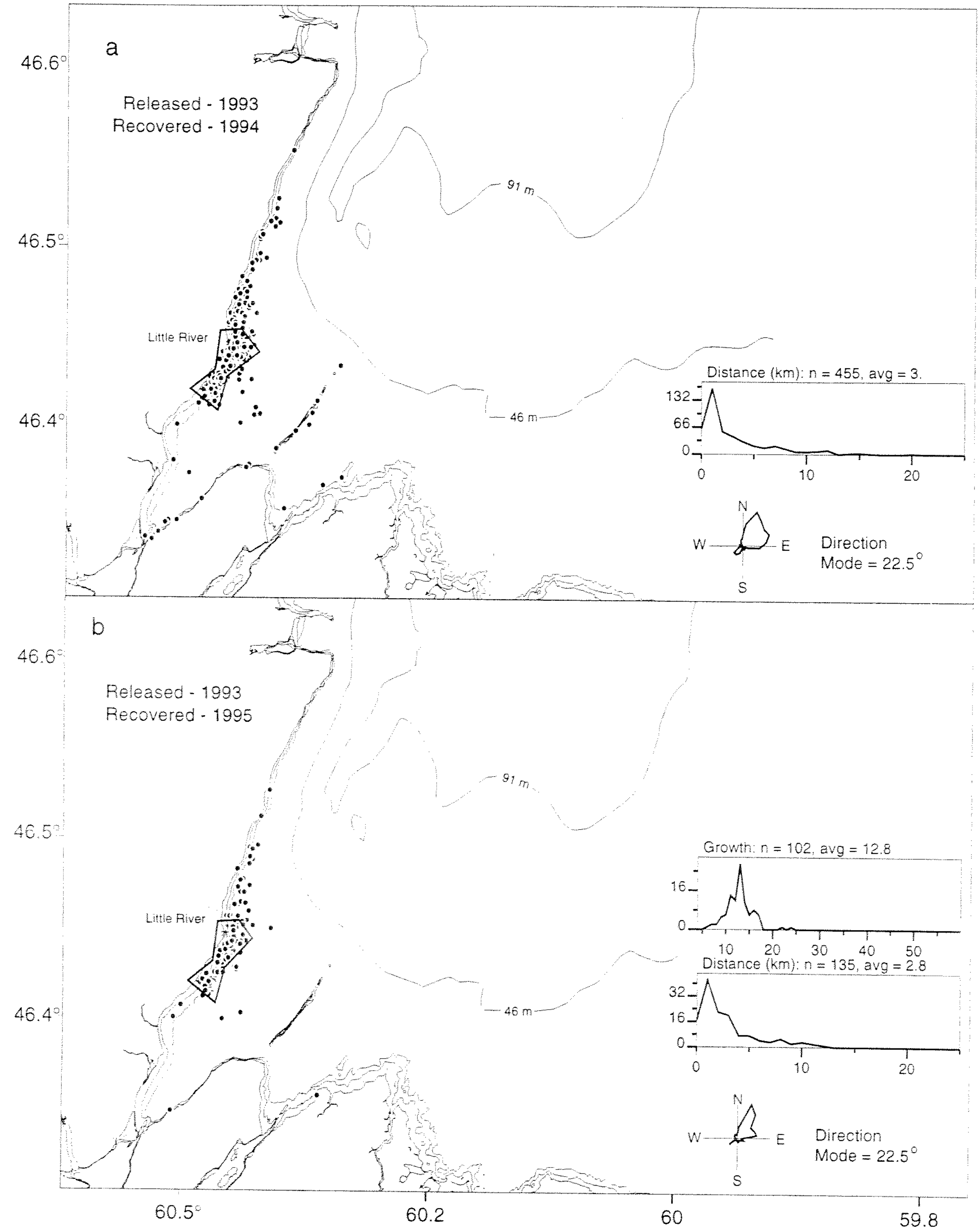


Fig. 3. September 1993 releases of tagged lobsters off Little River and initial recaptures in (a) spring 1994 and (b) spring 1995. There was little growth between Sept. 1993 and spring 1994. See Fig. 2 caption for further description of figure graphics.

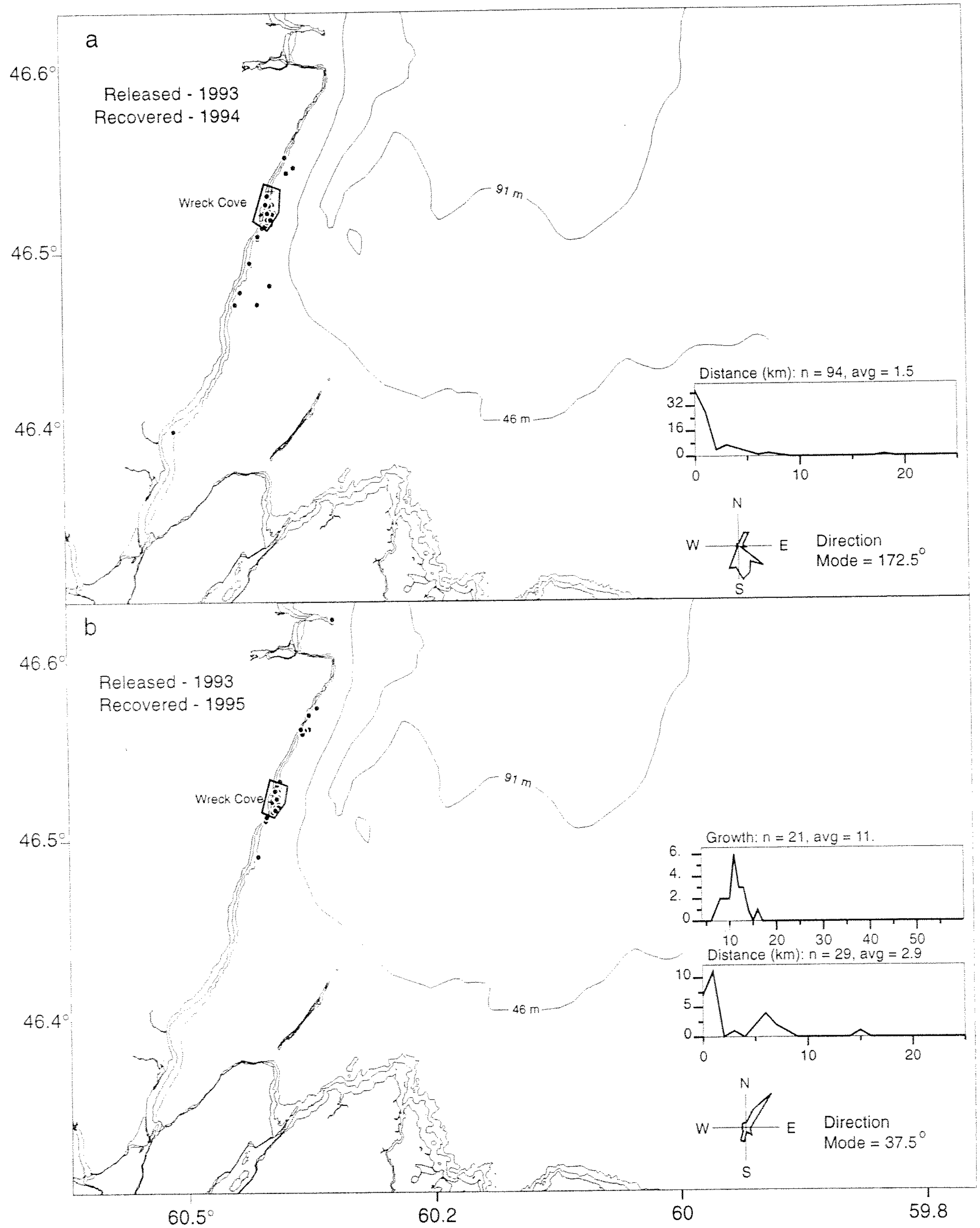


Fig. 4. September 1993 releases of tagged lobsters off Wreck Cove and initial recaptures in (a) spring 1994 and (b) spring 1995. There was little growth between Sept. 1993 and spring 1994. See Fig. 2 caption for further description of figure graphics.

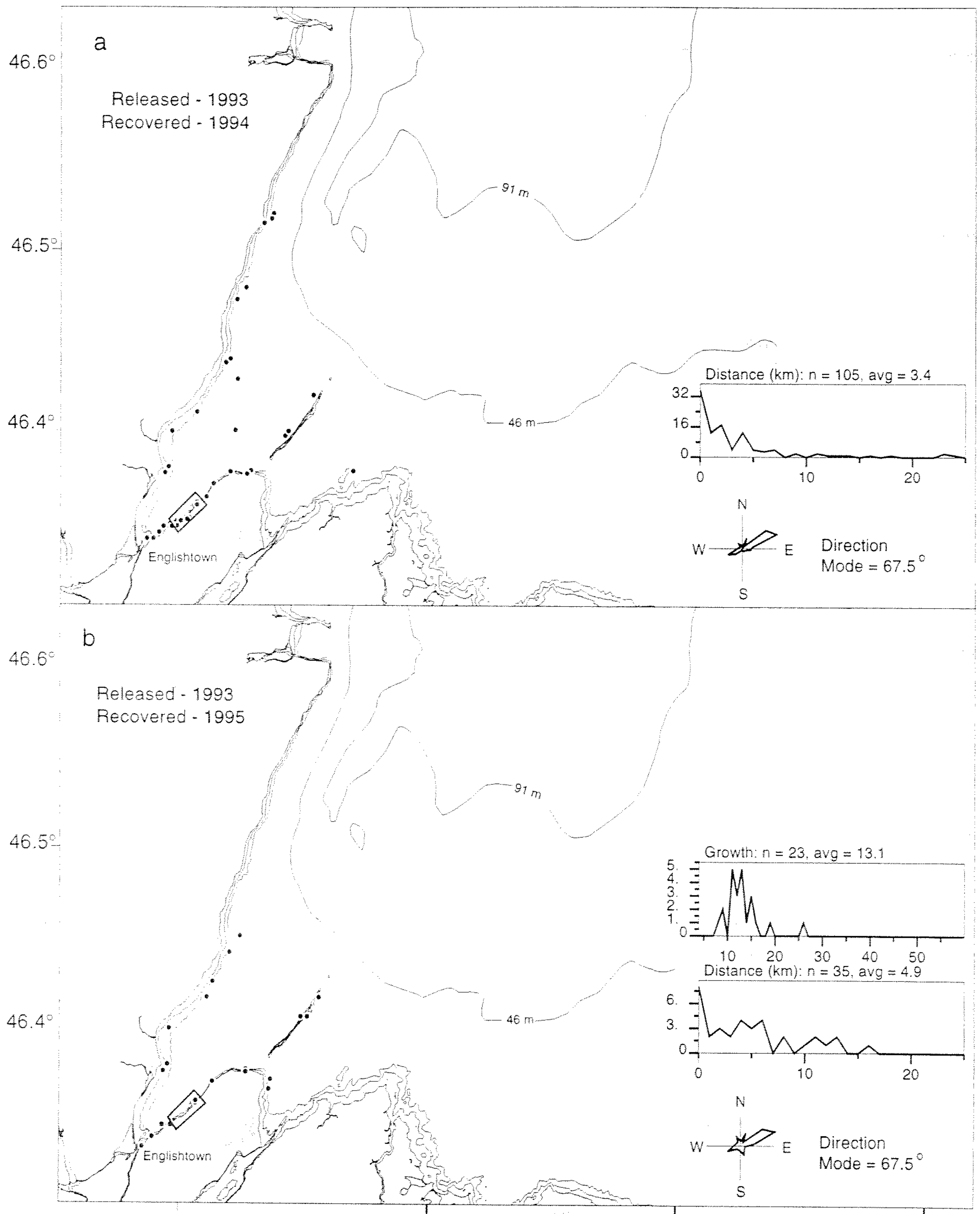


Fig. 5. September 1993 releases of tagged lobsters off Englishtown and initial recaptures in (a) spring 1994 and (b) spring 1995. There was little growth between Sept. 1993 and spring 1994. See Fig. 2 caption for further description of figure graphics.

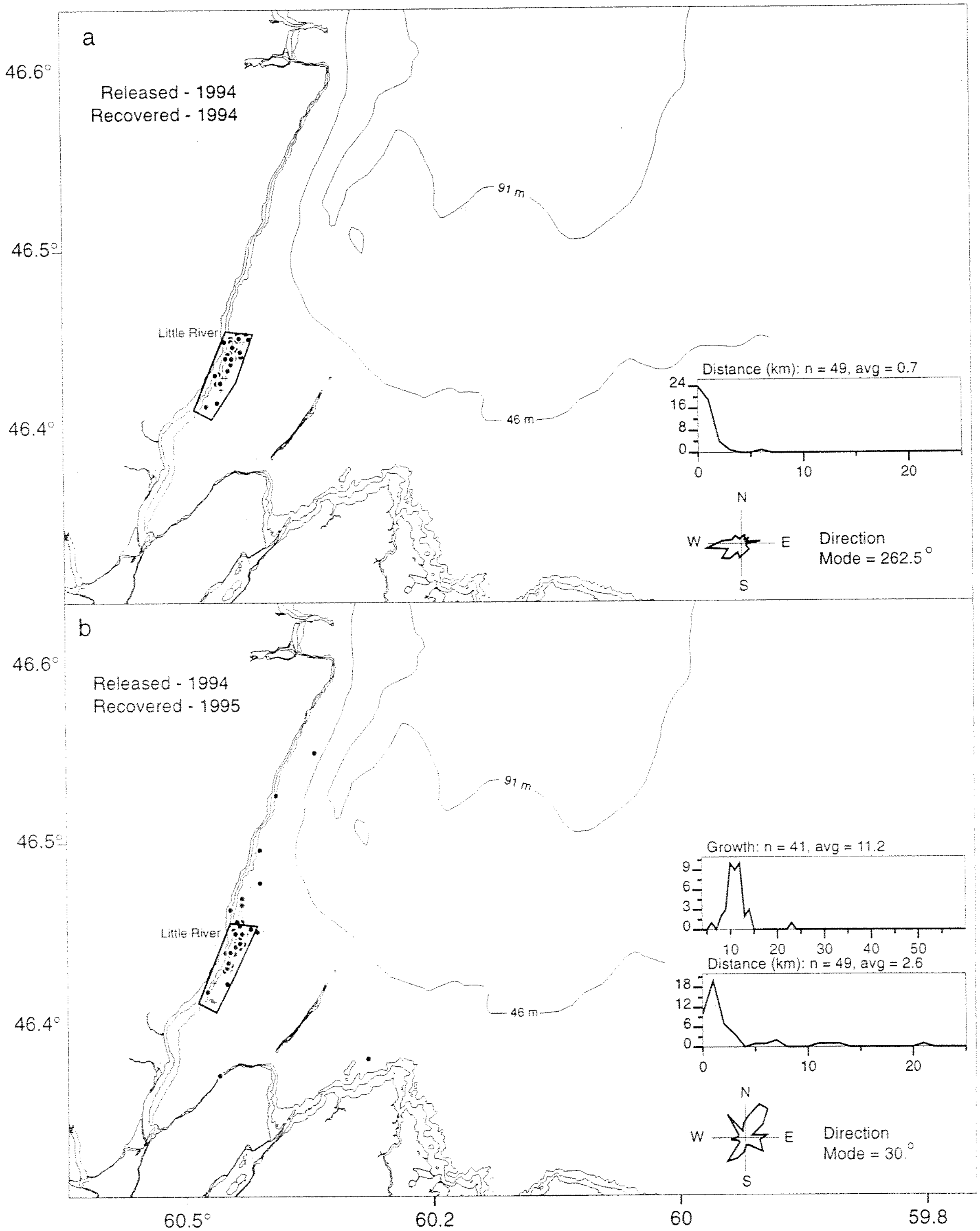


Fig. 6. May 1994 releases of tagged lobsters off Little River and initial recaptures in (a) spring 1994 and (b) spring 1995. There was no growth between release and recapture in spring of 1994. See Fig. 1 caption for further description of figure graphics.

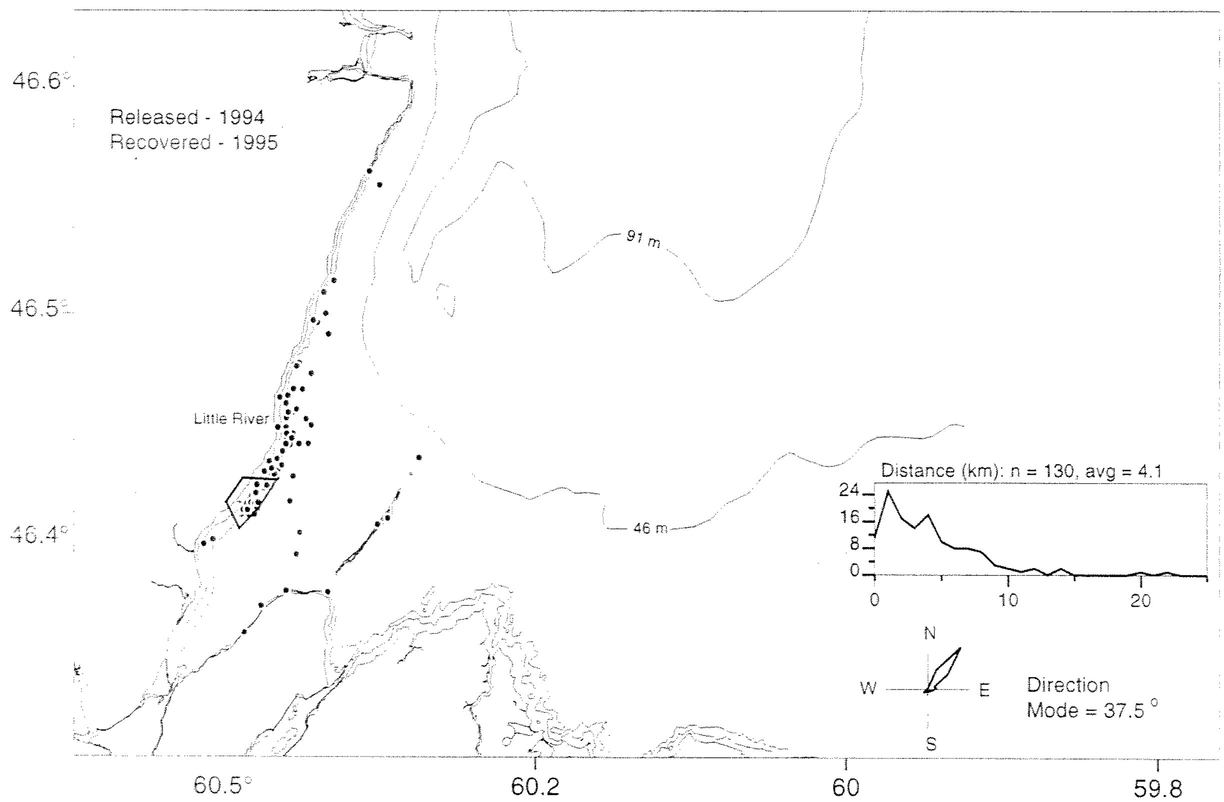


Fig. 7. September 1994 releases of tagged lobsters off Little River and initial recaptures in spring 1995. There was little growth between release and recapture. See Fig. 2 caption for further description of figure graphics.

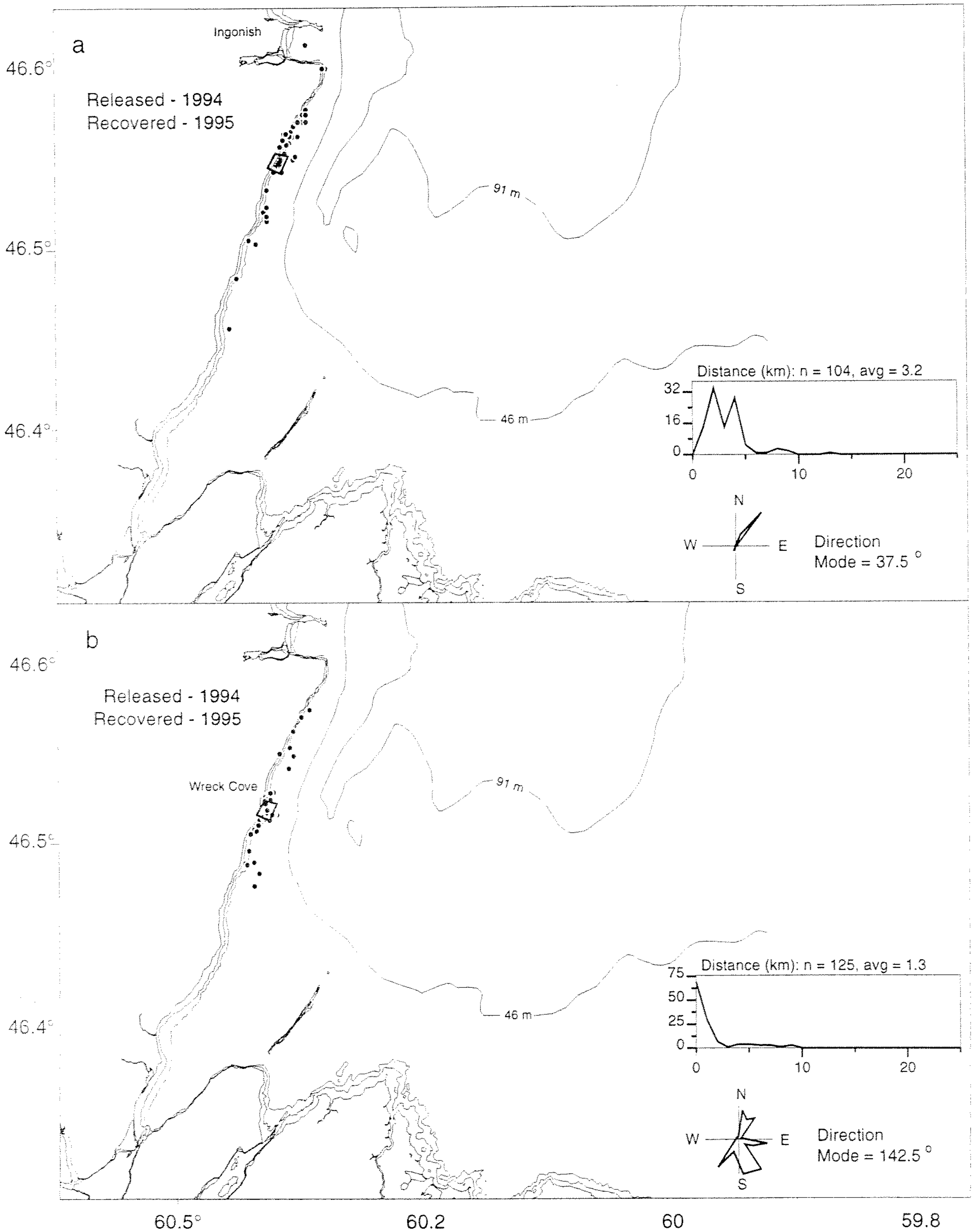


Fig. 8. September 1994 releases of tagged lobsters in the Wreck Cove area, and initial recaptures in spring 1995. (a) lobsters released on Ingonish fishing grounds, (b) lobsters released on Little River grounds about 3 km south of releases in (a). There was little growth between Sept. 1993 and spring 1994. See Fig. 2 caption for further description of figure graphics.

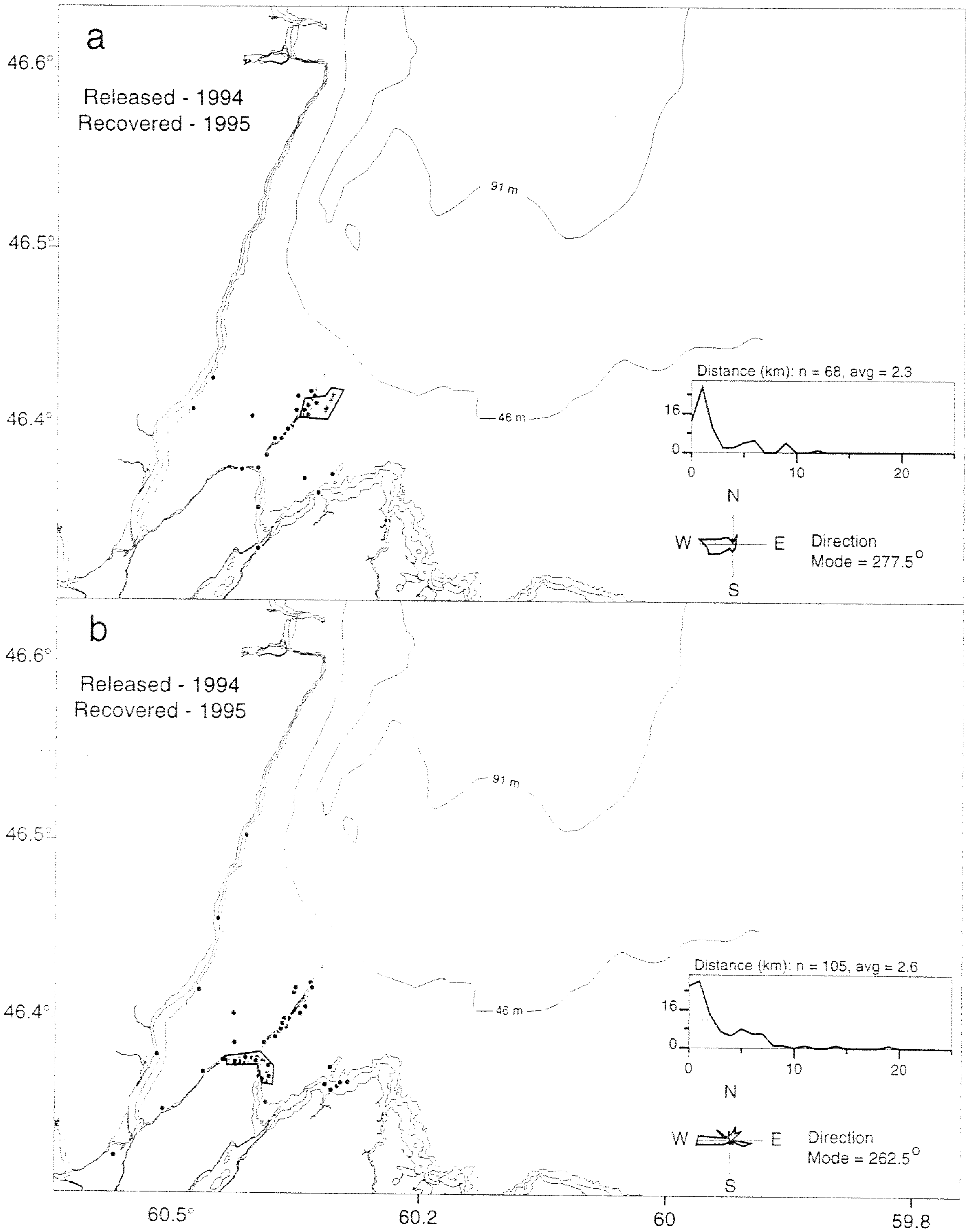


Fig. 9. October 1994 releases of tagged lobsters in the Bird Islands area, and initial recaptures in spring 1995. Panels show releases: (a) off northern most Bird Island (Ciboux); (b) off Cape Dauphin, and (c) on Haddock Bank. There was little growth between Oct. 1994 and spring 1995. See Fig. 2 caption for further description of figure graphics.

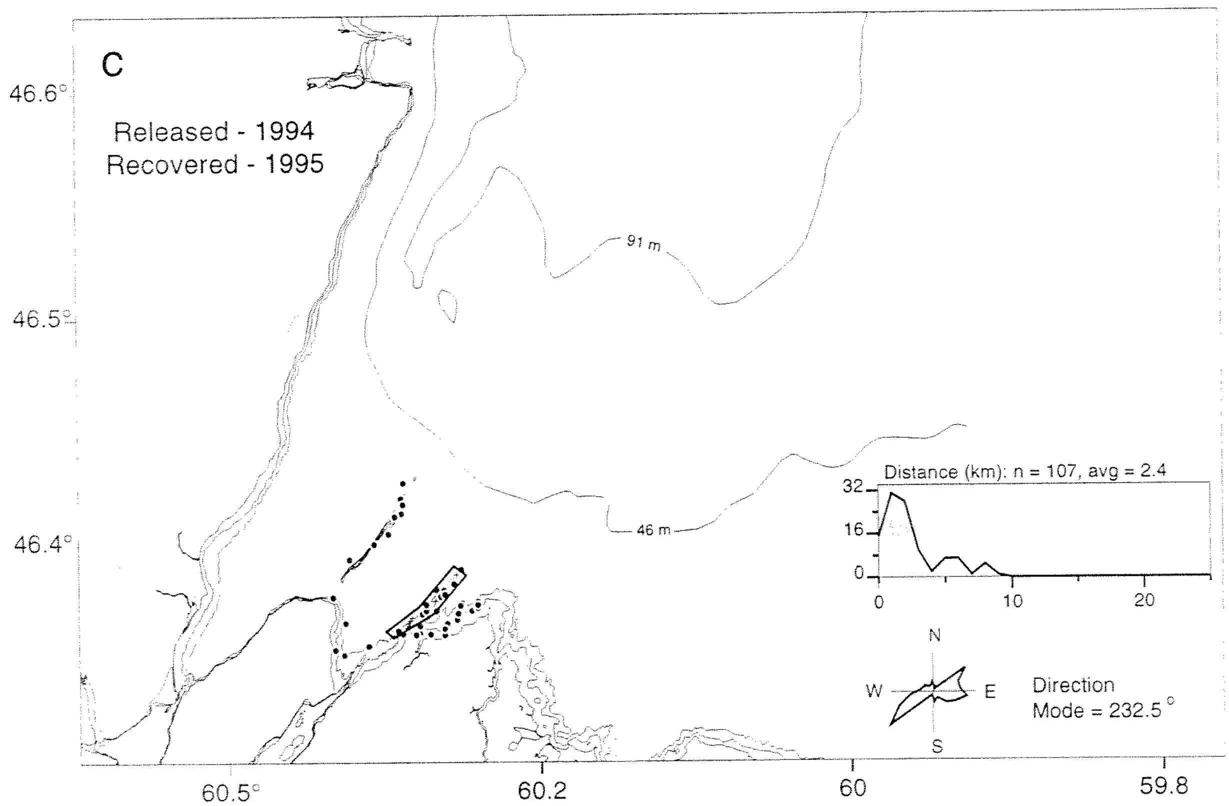

C
Released - 1994
Recovered - 1995
46.6°
46.5°
46.4°
91 m
46 m
Distance (km): n = 107, avg = 2.4
32
16
0
0
10
20
N
W
E
S
Direction
Mode = 232.5 °
60.5°
60.2
60
59.8

Fig. 9 (cont'd).

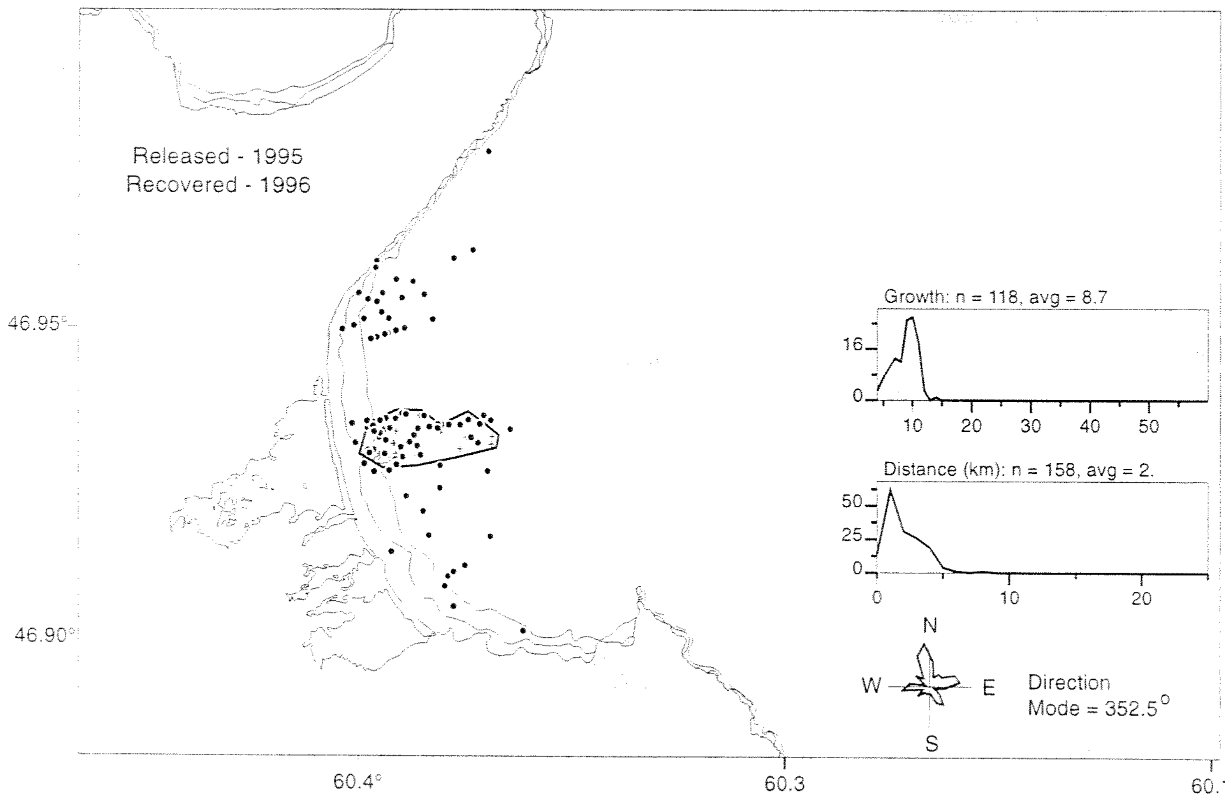


Fig. 10. July 1995 releases of tagged lobsters in Aspy Bay and initial recaptures in spring 1996. See Fig. 2 caption for further description of figure graphics.

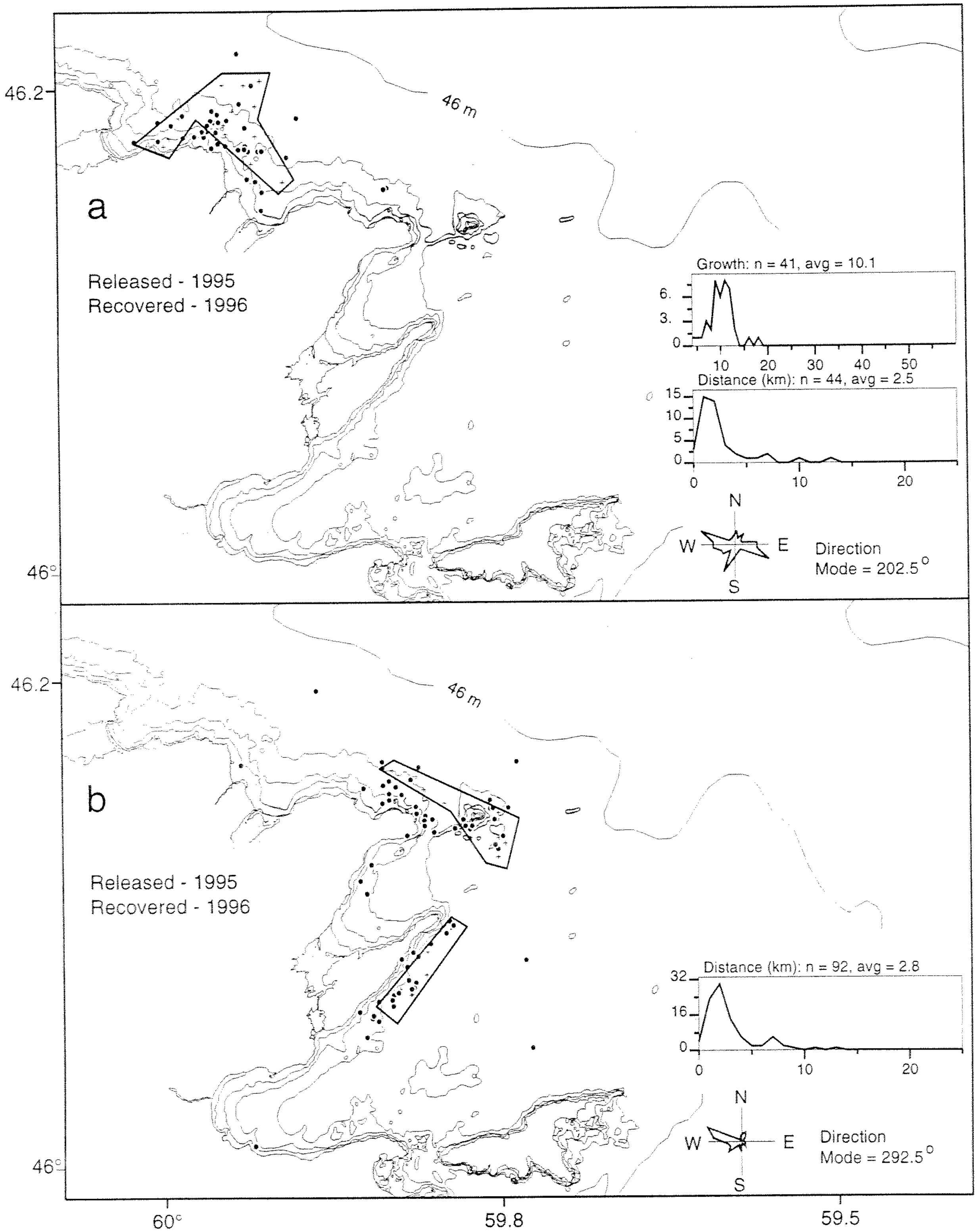


Fig. 11. Releases of tagged lobsters in the Glace Bay-Port Morien areas, and initial recaptures in spring 1996. Panels show releases: (a) in Glace Bay (July) and (b) Port Morien (October). There was no growth between Oct. 1995 and spring 1996. See Fig. 2 caption for further description of figure graphics. Nearshore depth contours are 4 m, 9 m and 18 m.

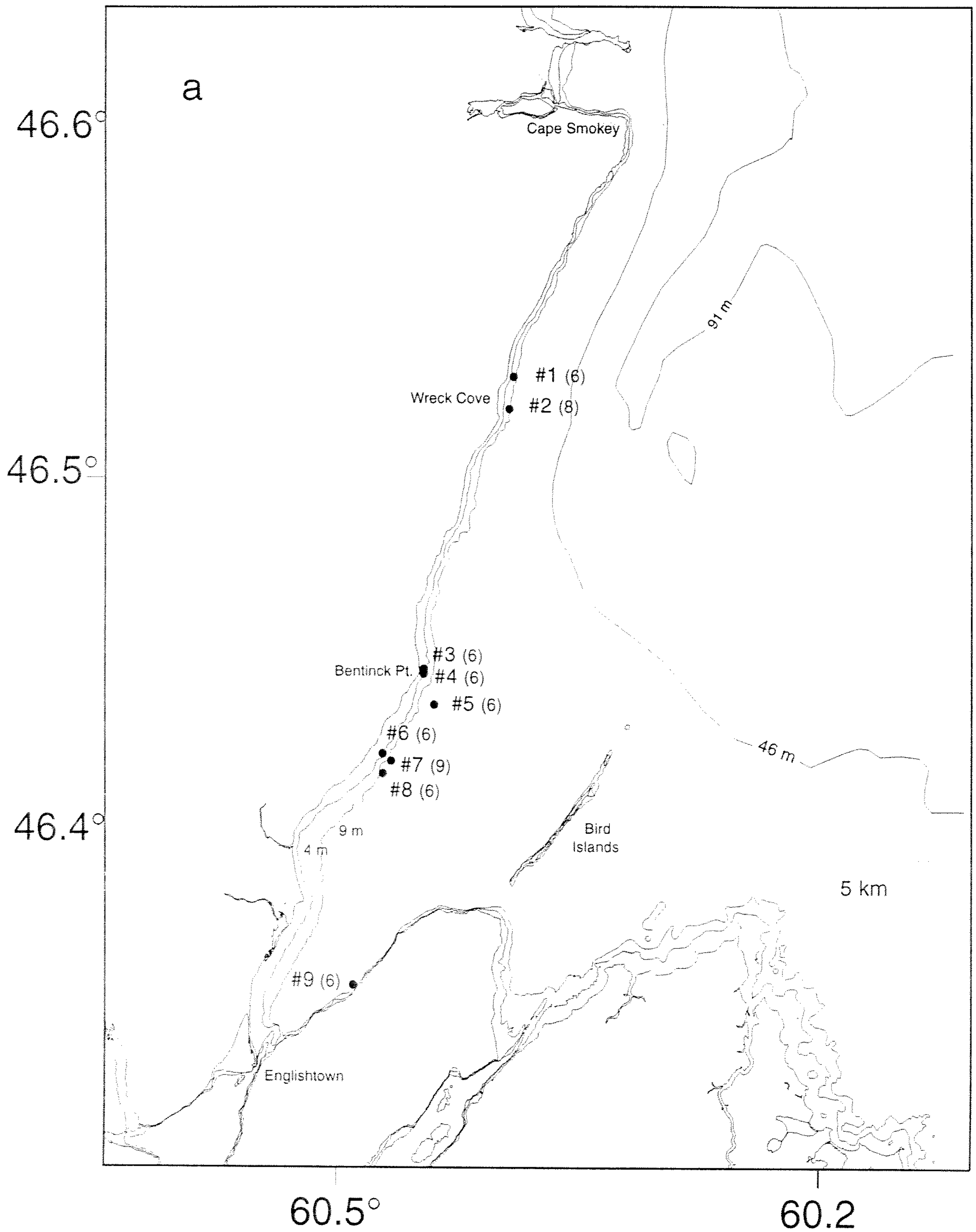


Fig. 12. Multiple recapture locations for individual lobsters. (a) release locations, with number of recaptures in brackets; (b)-(c) lobsters #1 and #2, released in the Wreck Cove area; (d)-(f) lobsters #3, #4 and #5, released off Bentinck Point (near Little River); (g)-(h) lobsters #7 and #8, released south of Bentinck Point; (i) lobster #8 released south of Bentinck Point; and (j) lobster #9 released north of Englishtown. In (b - j) large solid circle is release point; subsequent recaptures are numbered.

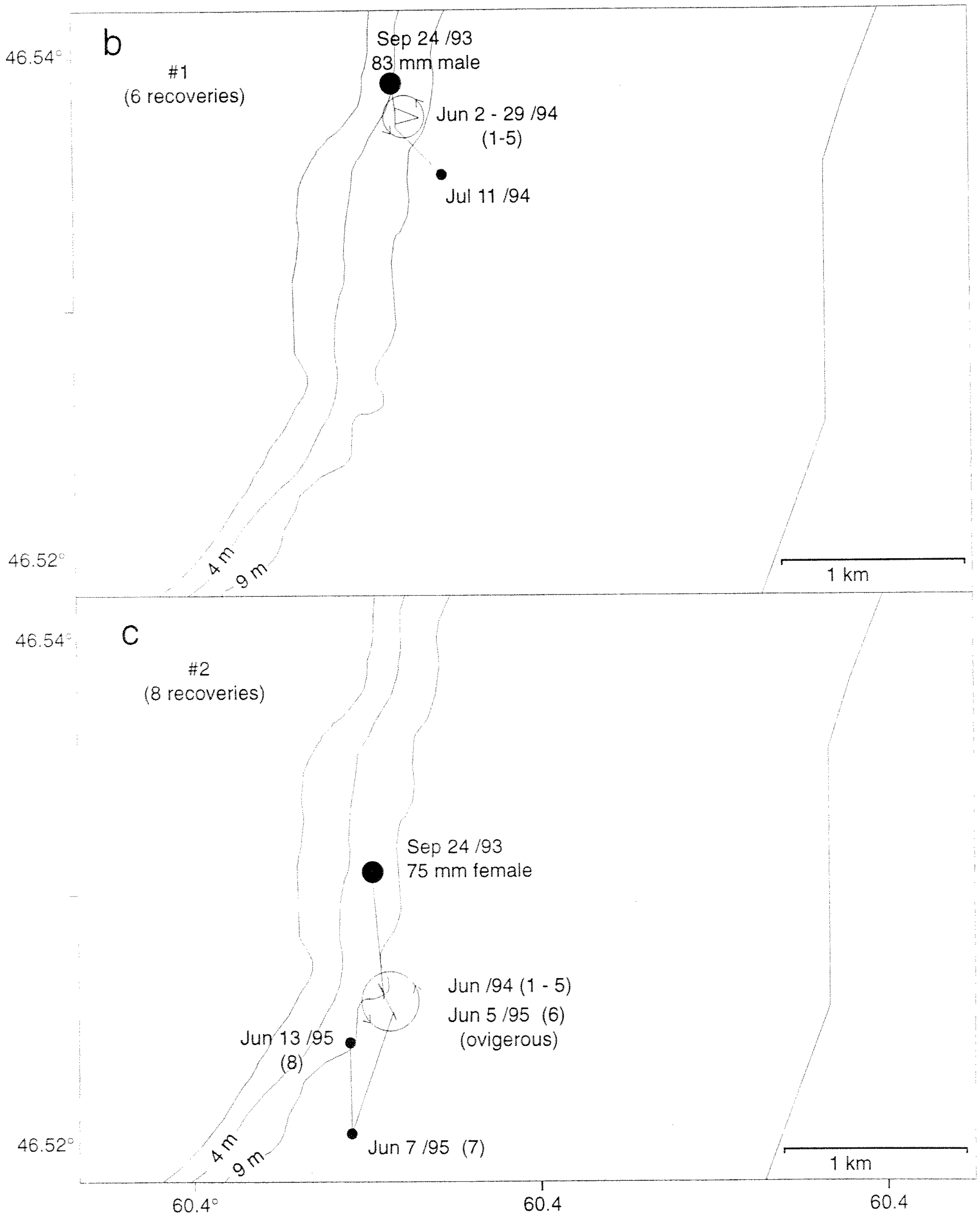

b
#1
(6 recoveries)
Sep 24 /93
83 mm male
Jun 2 - 29 /94
(1-5)
Jul 11 /94
46.54°
46.52°
4 m
9 m
1 km
c
#2
(8 recoveries)
Sep 24 /93
75 mm female
Jun /94 (1 - 5)
Jun 5 /95 (6)
(ovigerous)
Jun 13 /95
(8)
Jun 7 /95 (7)
46.54°
46.52°
4 m
9 m
1 km
60.4°
60.4
60.4

Fig 12 (cont'd).

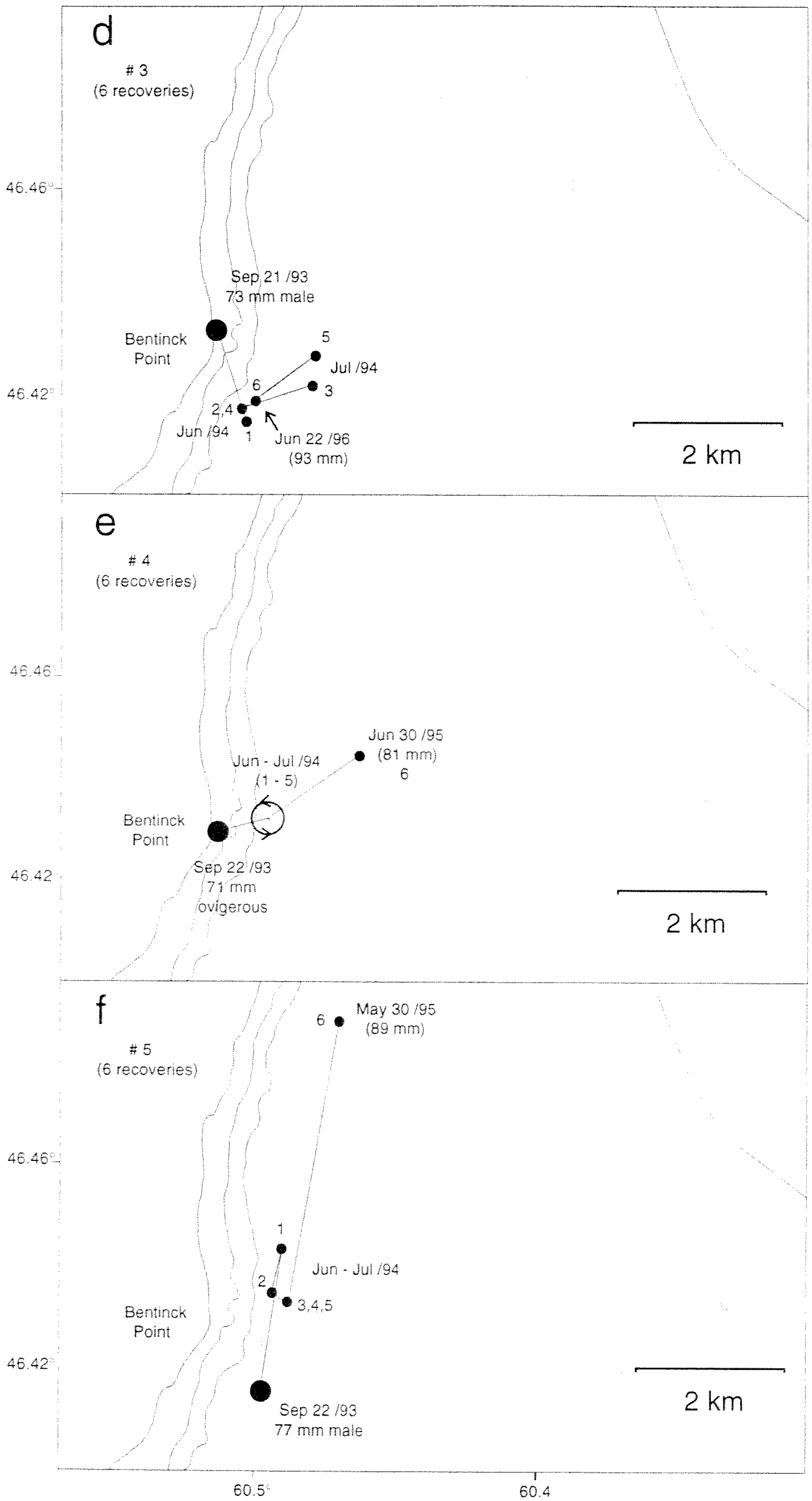

d
3
(6 recoveries)
46.46°
Sep 21 /93
73 mm male
Bentinck
Point
5
Jul /94
6
3
46.42°
2,4
Jun /94
1
Jun 22 /96
(93 mm)
2 km
e
4
(6 recoveries)
46.46°
Jun 30 /95
(81 mm)
6
Jun - Jul /94
(1 - 5)
Bentinck
Point
46.42°
Sep 22 /93
71 mm
ovigerous
2 km
f
6
May 30 /95
(89 mm)
5
(6 recoveries)
46.46°
1
Jun - Jul /94
2
3,4,5
Bentinck
Point
46.42°
Sep 22 /93
77 mm male
2 km
60.5°
60.4

Fig 12 (cont'd).

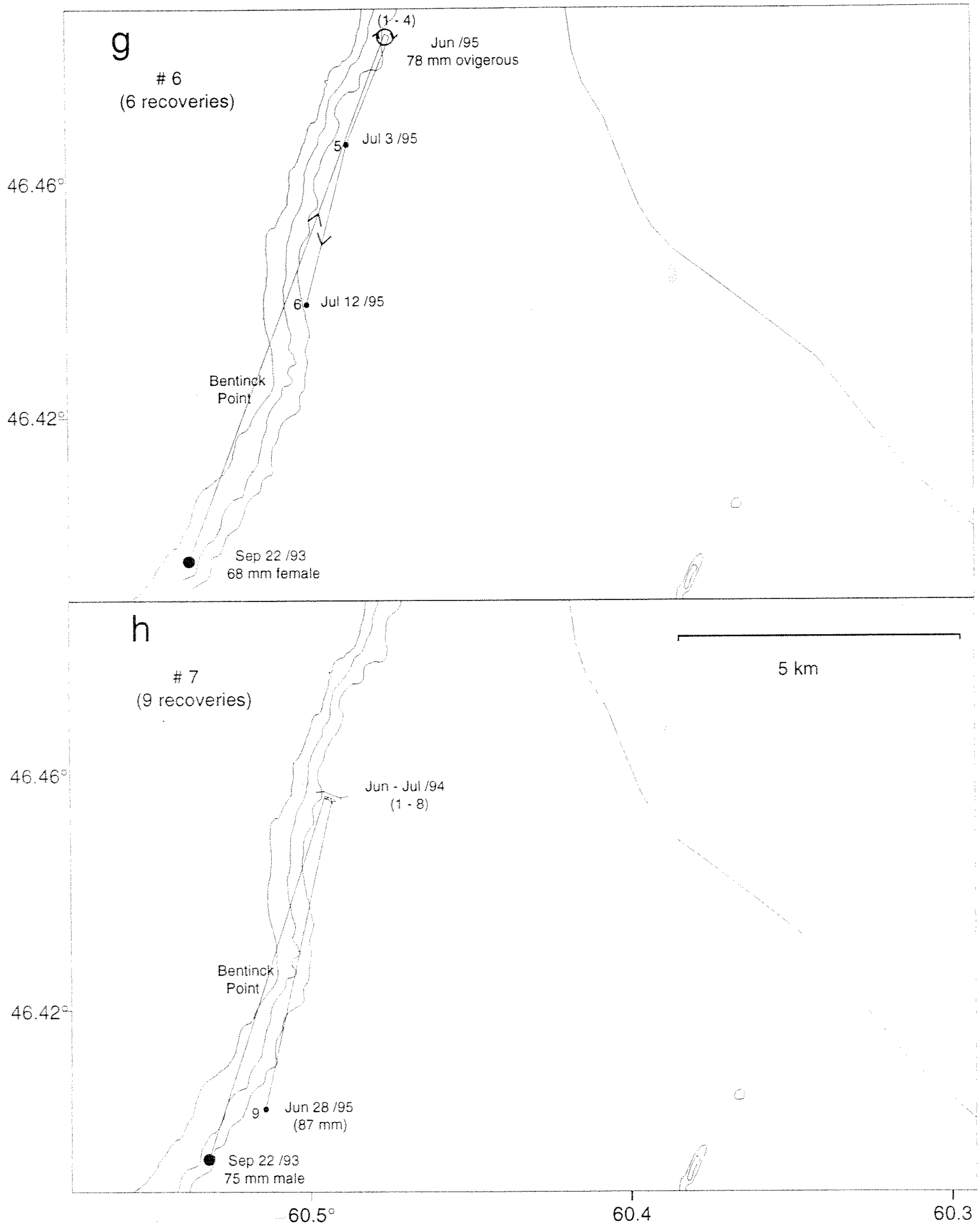
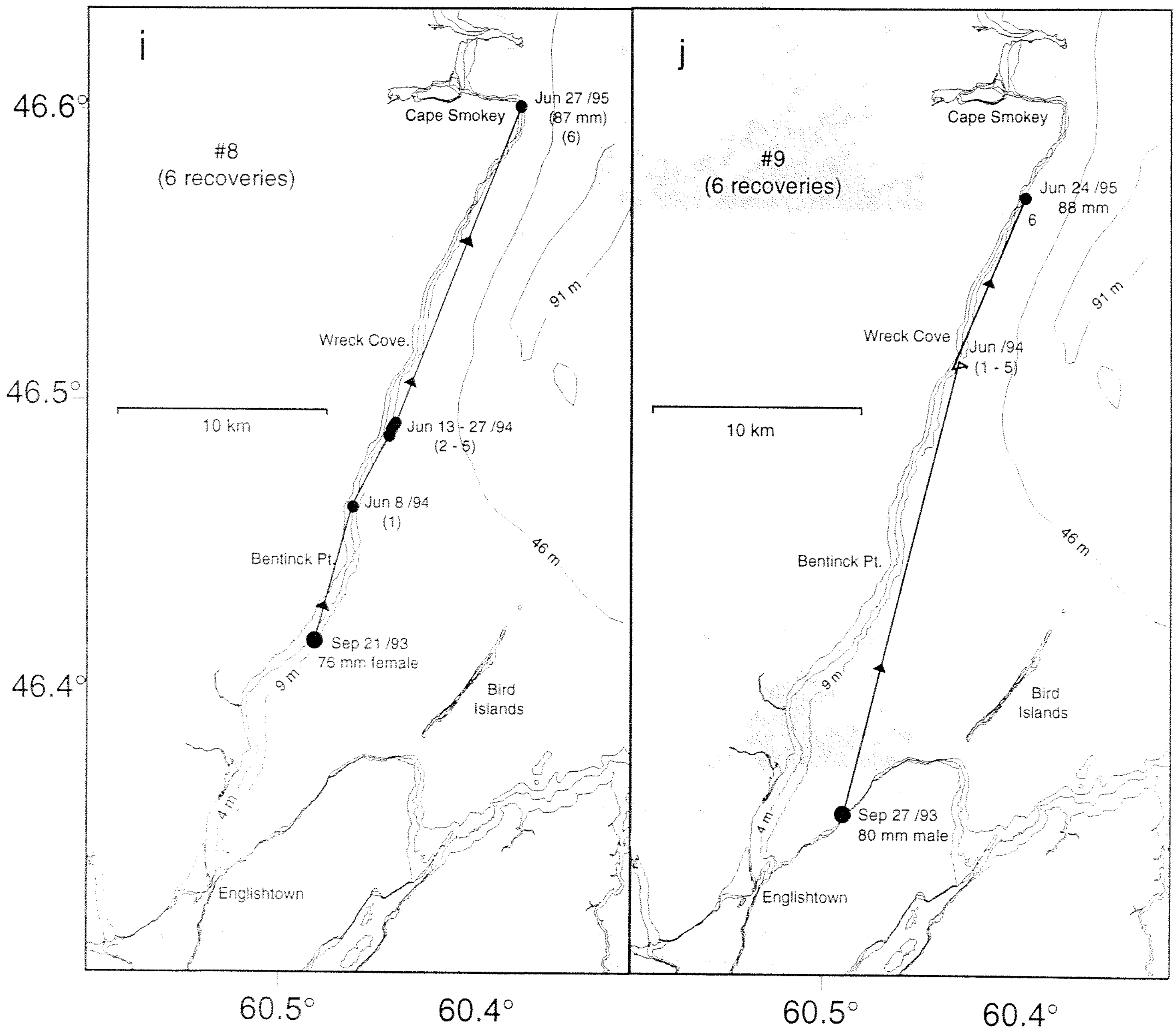

g
6
(6 recoveries)
(1 - 4)
Jun /95
78 mm ovigerous
5
Jul 3 /95
6
Jul 12 /95
Bentinck
Point
Sep 22 /93
68 mm female
46.46°
46.42°
h
7
(9 recoveries)
5 km
Jun - Jul /94
(1 - 8)
Bentinck
Point
9
Jun 28 /95
(87 mm)
Sep 22 /93
75 mm male
46.46°
46.42°
60.5°
60.4
60.3

Fig 12 (cont'd).



i
#8
(6 recoveries)
Cape Smokey
Jun 27 /95
(87 mm)
(6)
91 m
Wreck Cove.
10 km
Jun 13 - 27 /94
(2 - 5)
Jun 8 /94
(1)
Bentinck Pt.
46 m
Sep 21 /93
76 mm female
9 m
Bird
Islands
4 m
Englishtown
j
#9
(6 recoveries)
Cape Smokey
Jun 24 /95
88 mm
6
91 m
Wreck Cove
Jun /94
(1 - 5)
10 km
Bentinck Pt.
46 m
9 m
Bird
Islands
Sep 27 /93
80 mm male
4 m
Englishtown
46.6°
46.5°
46.4°
60.5°
60.4°
60.5°
60.4°

Fig 12 (cont'd).

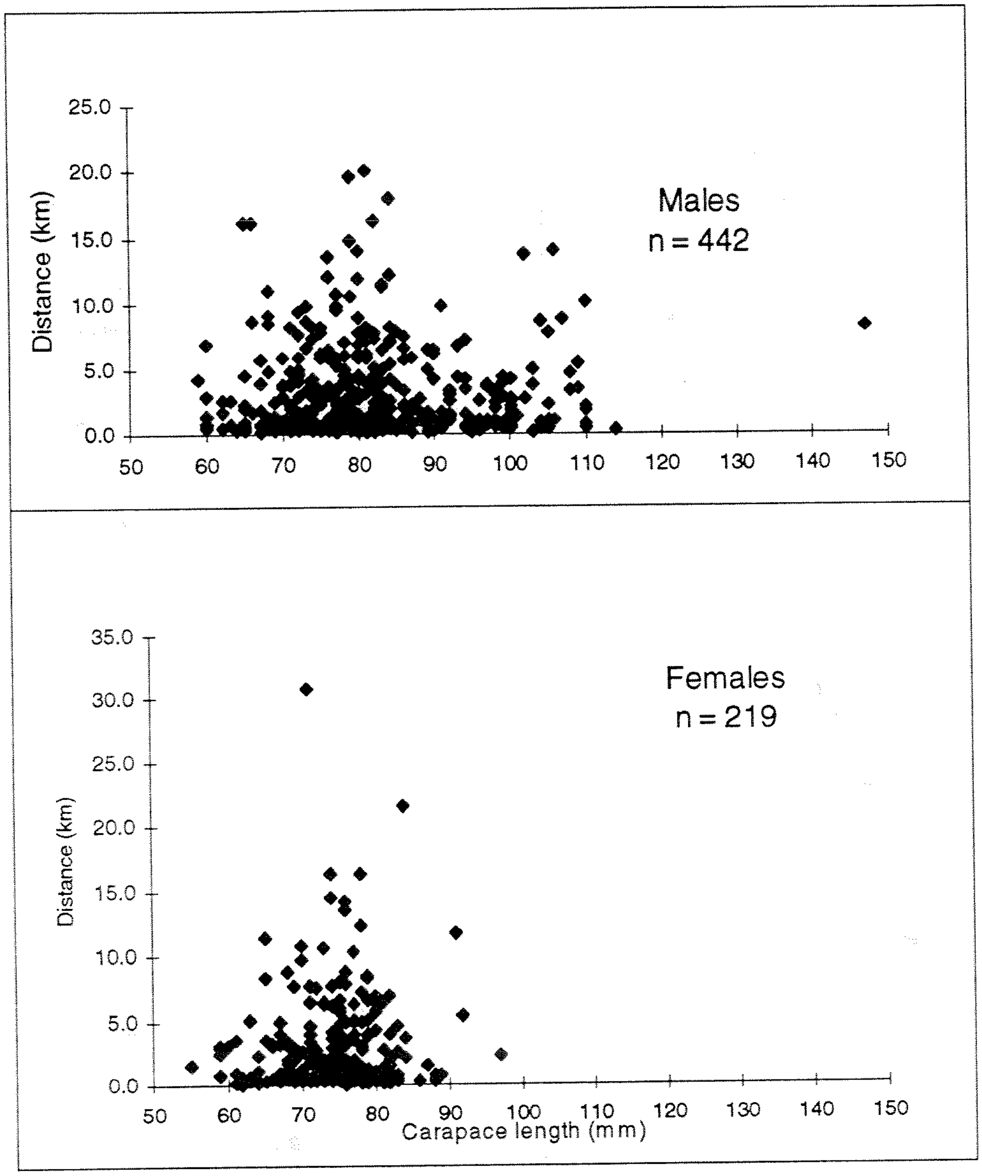


Figure 13. Distance moved versus lobster size. Data are from lobsters tagged off Little River in Sept. 1993 and 1994 and recaptured the following spring.

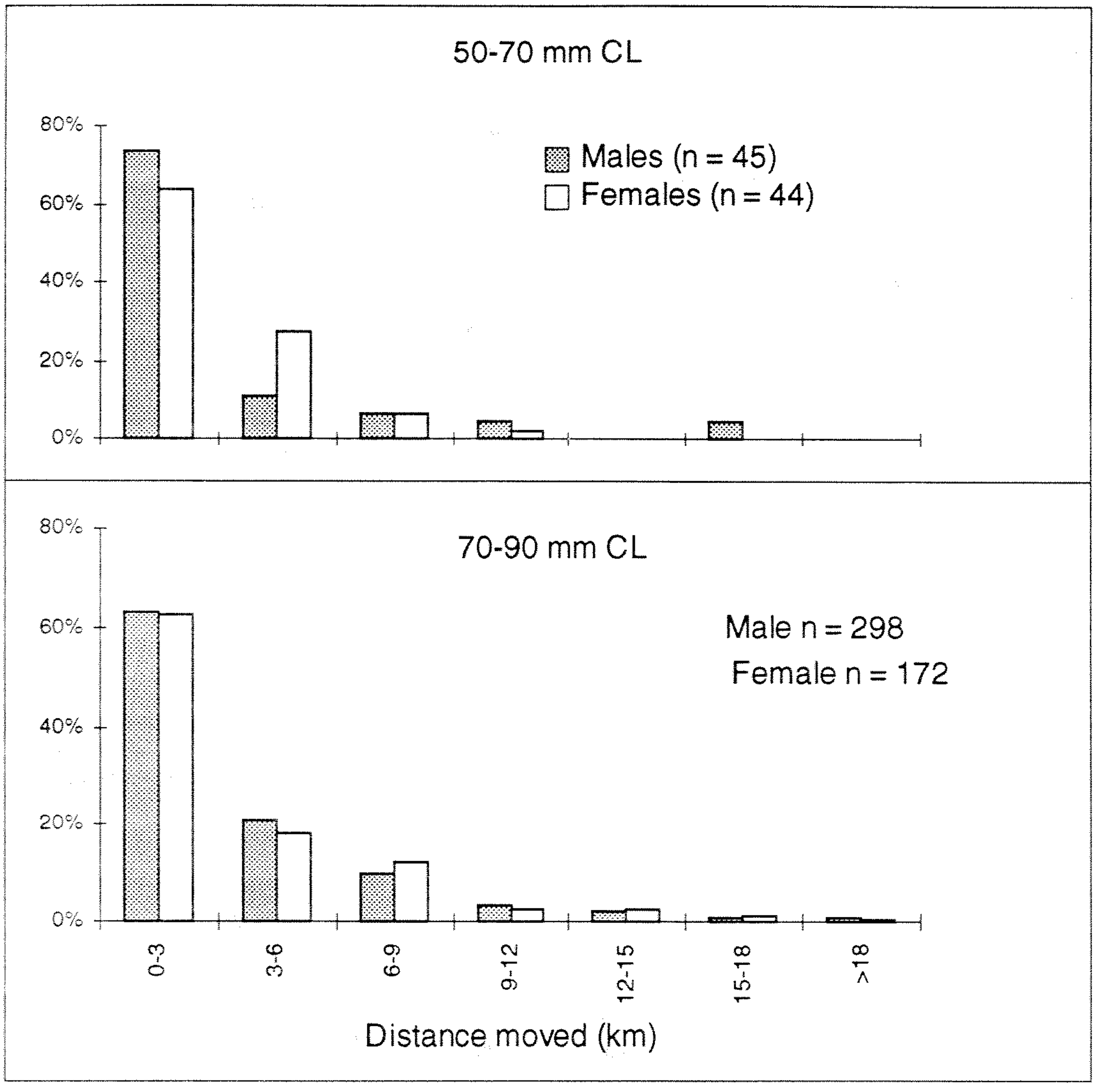


Figure 14. Percentage of male and female lobsters within distance moved categories. Data are from lobsters tagged off Little River in Sept. 1993 and 1994 and recaptured the following spring.

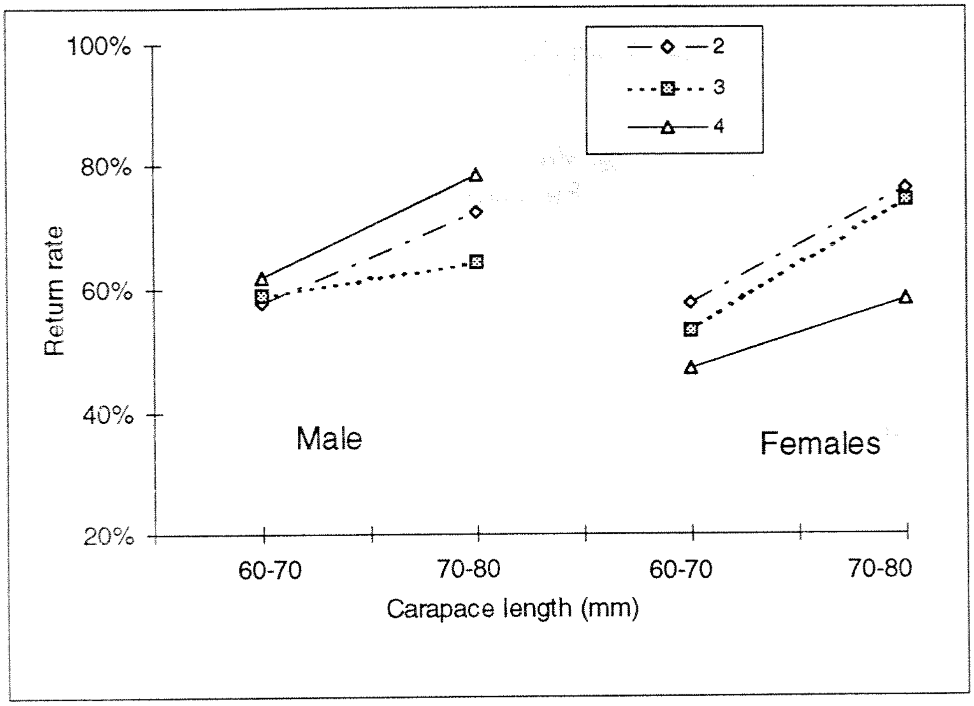


Figure 15. Return rate (relative catchability) for prerecruits versus recruits. Each point represents the return rate from one of the 3 tagging blocks (2, 3, 4), and is based on a minimum of 17 releases (mean = 65).

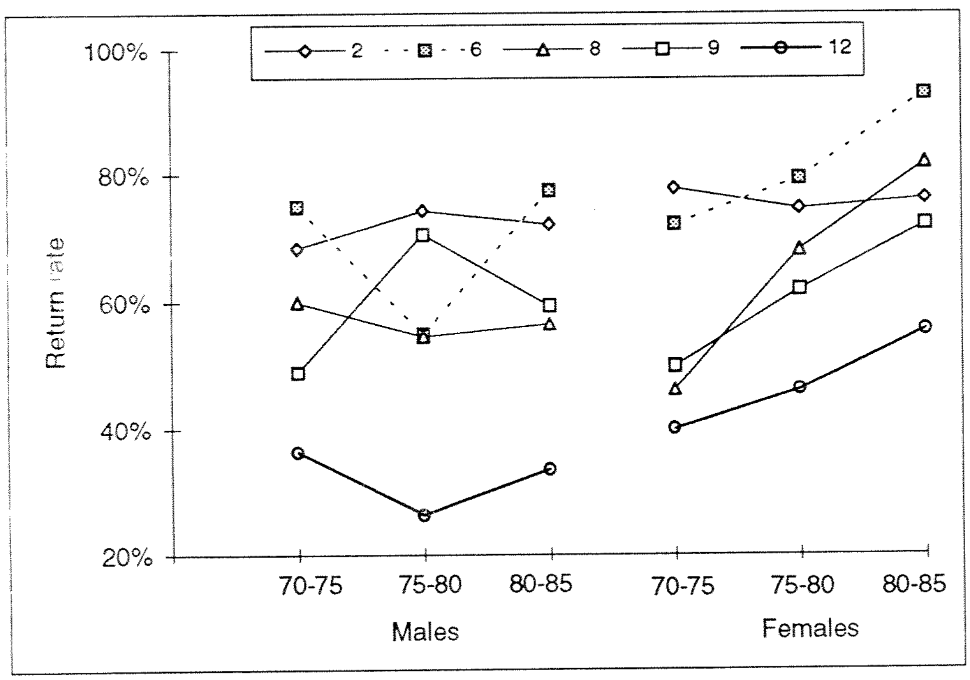


Figure 16. Return rate (relative catchability) for different sizes of recruit lobsters. Each point represents the return rate from one of the 5 tagging blocks (2, 6, 8, 9, 12), and is based on a minimum of 10 releases (mean = 45).

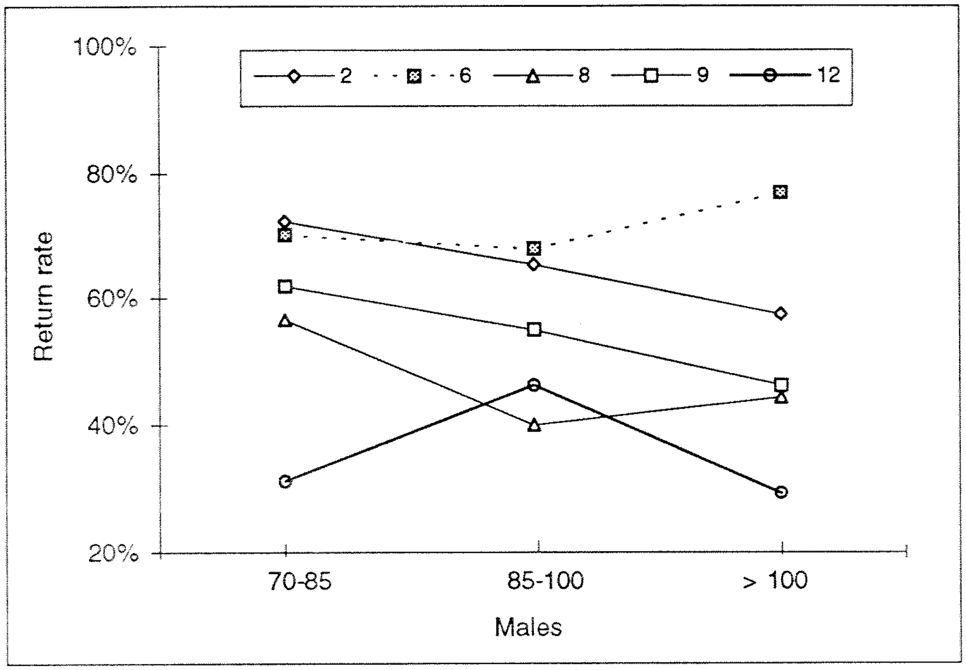


Figure 17. Return rate (relative catchability) versus size for males. Each point represents the return rate from one of the 5 tagging blocks (2, 6, 8, 9, 12), and is based on a minimum of 13 releases (mean = 92).