Movement of American lobster (*Homarus americanus*) in the southwestern Gulf of St. Lawrence

Michel Comeau
Fernand Savoie
Department of Fisheries and Oceans
343 University Ave.
Moncton, New Brunswick, Canada E1C 9B6
E-mail address (for M. Comeau): comeaum@dfo-mpo.gc.ca

Abstract—A total of 42,445 American lobsters (*Homarus americanus*) were tagged in thirty-one sites throughout the southwestern Gulf of St. Lawrence between 1980 and 1997. Results from the recapture of 8503 tagged lobsters showed small distances traveled between the release and the recapture position for animals ranging in size from 51 to 152 mm carapace length. The average distance traveled ranged from 2 km in parts of Baie des Chaleurs and western Cape Breton to 19 km in central Northumberland Strait. Lobsters moved generally along the shore (93% of the dispersion was in areas between the shore and the 20-m bathymetric contour). As a result, lobsters traveled longer distances in sites characterized by a gradually sloping bottom where the distance between the shore and the 20-m contour line was extensive in contrast to areas characterized by rapidly changing depths and by a relatively small amount of habitat shallower than 20 m. In the majority of sites (14 of 19) there was no significant difference between males and females in the average distance they traveled. In four of the five sites females moved farther than males. In general, the average distance traveled by berried females was shorter than that traveled by males or nonberried females. No relationship was observed between the distance traveled and the size of the animal. There was no strong evidence of a relationship between the average distance traveled and the number of days at liberty. In general, lobsters in the southwestern Gulf of St. Lawrence traveled short distances and dispersion was restricted to the nearshore habitat. Further, the distance traveled was not correlated to size, sex, or years at large. These findings show that there is little interaction between American lobsters from different fishing areas at the benthic level and that American lobster movements should have minimal consequences for management of the species in the southwestern Gulf of St. Lawrence.

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The American lobster (*Homarus americanus* Milne-Edwards, 1837) fishery in the southwestern Gulf of St. Lawrence (GSL) and for the entire Canadian Maritime Provinces has become the most economically important fishery of coastal communities. Consequently, there is increasing interest by fishermen and the fishing industry to better understand the biology of the species and factors that may play a role in the fluctuations of landings, including possible lobster movements between lobster fishing areas (LFAs). Fishermen are particularly concerned by lobster movements because the minimal legal size increased in different LFAs in the southwestern GSL throughout the 1980s and 1990s, and they want to know whether lobsters returned at sea in a given area could be recaptured elsewhere.

Several tagging projects have been conducted in the past to study lobster movements in the GSL (Table 1). These tagging projects, initiated in the 1930s by Templeman (1935), showed that the average distance traveled by lobsters in the GSL was generally less than 15 km and that very few animals traveled up to 70 km (for review see Stasko, 1980; Lawton and Lavalli, 1995). Other tagging studies conducted in inshore waters outside the GSL in Nova Scotia (Wilder, 1974; Campbell, 1982, 1989; Campbell and Stasko, 1985; Miller et al., 1989; Tremblay et al., 1998), Bay of Fundy (Campbell, 1986; Campbell and Stasko, 1986), Maine (Cooper, 1970; Cooper et al., 1975; Krouse, 1981), New Hampshire (Watson et al., 1999), Massachusetts (Karnofsky et al., 1989) and Rhode Island (Fogarty et al., 1980) have also shown that lobster movements were generally similar (4 to 18 km) to those from the GSL. However, long-distance movements of more than 90 km for up to 20% of the animals have also been observed for lobsters tagged inshore (Dow, 1974; Fogarty et al., 1980; Campbell and Stasko, 1985, 1986; Campbell, 1989; Robichaud and Lawton, 1997); the farthest distance traveled reported was 798 km (Campbell and Stasko, 1986). These long distances traveled are more similar to those reported for offshore lobsters tagged on the continental shelf and over the offshore deep canyons (Saila and Flowers, 1968; Cooper and Uzmann, 1971; Uzmann et al., 1977; Fogarty et al., 1980; Campbell et al., 1984; Campbell and Stasko, 1985). Movements of more than 70 km have never been reported for lobsters tagged in the southwestern GSL.

Since 1980, forty-six tagging studies have been conducted throughout the southwestern GSL, mostly in areas where information on lobster movements has been unavailable. These tagging studies have covered fishing grounds characterized by a flat bottom and having a relatively smooth transition from shore to 30 m and a narrow habitat close to shore where changes in depths occur over a relatively short distance. The purpose of our study was to investigate the benthic movement of lobsters tagged in different locations within the southwestern GSL by comparing the distance traveled, number of days at liberty, and size and sex of lobsters.

Materials and methods

The recapture position was documented for 8503 lobsters, ranging in size from 51 to 152 mm carapace length (CL), from a total of 42,445 tagged and released during forty-six tagging studies in thirty-one sites throughout the southwestern GSL (Fig. 1) between 1980 and 1997 (Table 2). The animals were captured by traps and tagged between July and November after the commercial fishing seasons (May and June in LFAs 23, 24, 26A, and 26B, and from mid-August to mid-October in LFA 25). The CL, measured to the nearest mm, sex of each animal, and presence or absence of eggs under the female abdomen were recorded. Prior to 1989, all animals were tagged with orange sphyrion anchor tags, and blue streamer tags were used after 1992. Between 1989 and 1992 inclusively, both type of tags were used. A description of the tags and the tagging technique are presented in Moriyasu et al. (1995) and Comeau et al. (1998).

The positions of recaptured lobsters came from fishermen. Because all tagging projects were undertaken after each commercial fishing season, no lobsters were recaptured during the same year of their tagging. To increase fishermen's participation in reporting tagged animals, a major awareness campaign was conducted. Prior to 1993, representatives of the Department of Fisheries and Oceans (DFO) were present at each wharf to measure and collect information on tagged lobsters that were recaptured. Beginning in 1993, letters were sent to all lobster fishermen in regions where tagging projects were conducted; in these letters the tagging project was described, in-

Table 1

Locations and authors of lobster tagging studies on movements of American lobster (*Homarus americanus)* conducted in the Gulf of St. Lawrence.

Location	Authors and date
Various locations in Gulf of St. Lawrence	Wilder (1974)
West coast of Newfoundland	Templeman (1940)
Magdalen Islands (Québec)	Templeman (1935)
	Bergeron (1967)
	Munro and Therriault (1983)
Gaspé Peninsula (Québec)	Corrivault (1948)
Malpeque (Prince Edward Island)	Templeman (1935)
Western Prince Edward Island	Wilder (1963)
Northumberland Strait	Templeman (1935)
	Wilder (1963)

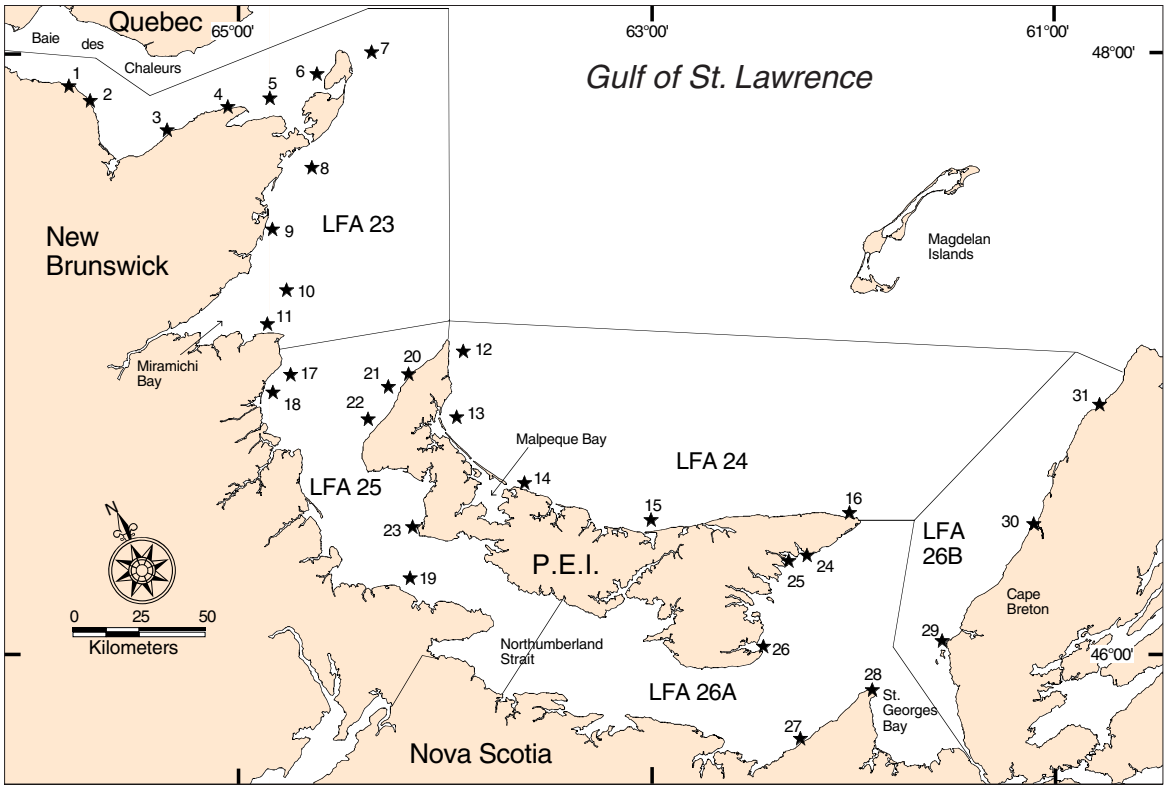

Figure 1

Locations (★) of American lobster (*Homarus americanus*) tagging studies conducted in the southwestern Gulf of St. Lawrence between 1980 and 1997. The names of each site are presented in Table 2. The lobster fishing areas (LFAs) are indicated on the map.

structions given for returning lobster tag information, and the cooperation of the fishermen was sought (Comeau et al., 1998). Similar information was posted at wharves. For each tagged lobster, fishermen were asked to record date of capture, tag number, position of capture, and depth. They were then asked to freeze the animal with the tag still attached and contact an information collection center, where they could leave their names, addresses, and telephone numbers. A DFO representative collected tagged lobsters for measurement and reimbursed fishermen according to the market value of the recovered lobsters. No reward was issued. Fishermen also had the option to bring the lobsters and the information to a fisherman-representative. If a tagged lobster under the legal size or a tagged berried female was captured, fishermen were asked to record the above information and release the lobster to the water with the tag still attached.

The distance traveled by each recaptured animal was calculated as the linear distance between release and recapture positions. The Kruskal-Wallis and Mann-Whitney (*U*-test) tests were used to compare the average distance traveled for males, females, and berried females for ani-

Table 2

Average distances traveled by American lobsters tagged in the southwestern Gulf of St. Lawrence between 1980 and 1997. The number of each site corresponds to its geographical position on the map in Figure 1. *n* = number of recaptured lobster with tags indicating release location for which distance traveled to recapture site could be calculated.

Tagging site	Year of tagging	*n*	Average carapace length ±SD (mm)	Carapace length range (mm)	Average distance traveled ±SD (km)
1 Belledune	1980	604	70.5 ±4.9	50–115	7.4 ±6.5
2 Pointe-Verte	1996	26	78.2 ±6.4	71–90	6.1 ±4.0
3 Stonehaven	1994–97	618	73.2 ±5.4	53–111	2.4 ±3.0
4 Anse-Bleue	1994	290	73.5 ±4.8	54–91	3.5 ±6.3
5 Caraquet	1993–97	1416	74.2 ±9.2	55–133	8.0 ±8.8
6 Petit-Shippagan	1994	134	76.2 ±10.4	54–116	8.7 ±8.8
7 Miscou	1995	58	69.9 ±8.2	66–117	4.5 ±6.5
8 Le Goulet	1996	101	73.8 ±6.2	59–98	5.3 ±3.5
9 Val Comeau	1985, 1996–97	519	76.3 ±9.1	57–117	7.0 ±6.5
10 Néguac	1996	74	78.0 ±8.7	65–105	14.2 ±8.2
11 Escuminac	1997	17	73.9 ±5.2	66–88	9.6 ±9.9
12 Seacow Pond	1996	62	71.1 ±6.0	61–94	5.3 ±7.8
13 Alberton	1996	62	74.0 ±6.9	65–97	5.7 ±5.9
14 Malpeque	1989	492	68.1 ±7.2	51–100	10.1 ±7.0
15 Tracadie	1984	27	68.1 ±12.4	55–111	10.4 ±10.1
16 North Lake	1996	78	72.8 ±5.0	61–89	2.5 ±3.4
17 Pointe-Sapin	1996	22	72.5 ±5.0	65–83	6.7 ±4.1
18 Kouchibouguac	1997	53	67.7 ±4.3	60–74	8.0 ±7.3
19 Cap-Pelé	1997	41	72.2 ±6.0	60–84	12.2 ±11.9
20 Skinner's Pond	1996	13	71.4 ±5.8	63–131	5.4 ±6.7
21 Miminegash	1996	37	74.1 ±8.5	64–100	8.6 ±10.8
22 Howard's Cove	1995	79	66.9 ±7.1	54–84	15.3 ±13.2
23 Egmont Bay	1982	15	66.1 ±7.0	58–77	19.4 ±16.0
24 Souris	1996	213	75.4 ±7.1	59–109	4.9 ±6.8
25 Fortune	1996	208	72.7 ±3.9	66–84	3.3 ±3.6
26 Beach Point	1982	243	88.0 ±12.9	61–120	7.4 ±8.9
27 Lismore	1997	51	78.2 ±11.4	58–103	7.8 ±12.4
28 Ballantynes Cove	1986	226	74.0 ±11.2	55–130	9.3 ±13.0
29 Port Hood	1988	339	67.4 ±11.6	51–150	4.5 ±2.9
30 Margaree	1984, 1988, 1992	1332	70.7 ±8.5	52–152	3.2 ±5.1
31 Pleasant Bay	1988, 1992	1053	69.8 ±8.1	54–130	2.3 ±2.1

mals recovered during the first recapture period following their tagging. Correlation (r) was used to determine the relationship between the distance traveled and the size of the animal. To determine the relation between the average distance traveled and days at liberty, sites with recaptures over multiple years were used. The relationship between the average distance traveled and the extent of shallow waters was also established. The extent of shallow waters was quantified as the distance from shore to the closest 30-m bathymetric contour for each tagging site.

Results

A total of 7565 tagged lobsters were returned during their first recovery period, with size and geographical position at recapture. Only sites with fifty recaptures or more were considered. There was no evidence of a relationship between the size of the animal and distance traveled in the southwestern GSL because the correlation coefficient (r) ranged from –0.19 to 0.23 (Table 3). In this study, small lobsters (<70 mm CL) traveled as far as the large animals (>90 mm CL) (Fig. 2).

Table 3

Correlation coefficient (r) for the relationship of the distance traveled and the carapace length (CL) of American lobsters tagged in the southwestern Gulf of St. Lawrence. The number of each site corresponds to its geographical position on the map in Figure 1. n = number of recaptured lobster with tags indicating release location for which distance traveled to recapture site could be calculated.

Tagging site	n	CL range (mm)	r
1 Belledune	536	50–115	–0.12
3 Stonehaven	580	53–111	0.04
4 Anse-Bleue	232	54–91	0.02
5 Caraquet	1288	55–133	0.08
6 Petit-Shippagan	117	54–116	0.10
8 Le Goulet	90	59–98	–0.03
9 Val Comeau	500	57–117	–0.05
10 Neguac	72	65–105	0.22
12 Seacow Pond	61	61–94	0.08
13 Alberton	61	65–97	–0.08
14 Malpeque	251	51–100	0.11
16 North Lake	64	61–89	0.18
18 Kouchibouguac	51	60–74	–0.06
22 Howard's Cove	73	54–84	–0.19
24 Souris	202	59–109	0.14
25 Fortune	207	66–84	0.04
26 Beach Point	243	61–120	–0.02
27 Lismore	51	58–103	0.13
28 Ballantynes Cove	188	55–130	0.23
29 Port Hood	339	51–150	0.20
30 Margaree	1319	52–152	–0.05
31 Pleasant Bay	1040	54–130	0.04

There was no significant difference in the average distance traveled between males and females in eleven out of nineteen sites (Table 4). Females traveled significantly farther than males (Table 4) at three sites located in the upper part of Baie des Chaleurs (Fig. 1, sites 1, 3, and 4) and one site on the northeastern tip of Prince Edward Island (Fig. 1, site 25). The only site where males traveled significantly farther than females was in Val Comeau (Table 4, Fig. 1, site 9). No significant differences were observed in the average distance traveled by berried females compared with males or nonberried females in four out of nine sites where data were available for berried females (Table 4). The average distance traveled by berried females was significantly shorter than that by both males and females in three sites (Table 4, sites 9, 16, and 25) and significantly farther only in Port Hood (Table 4, site 29). In Souris (Table 4, site 24), no significant difference was observed for average distance traveled between males and berried females, but they were both significantly shorter than the average distance traveled for nonberried females.

Only seven out of thirty-one sites had a sufficient number of recaptures over multiple years to allow a comparison between distance traveled and days at liberty. A substantial decrease in the percentage of tags recaptured from the first to the second and third recovery periods was observed (Table 5), reflecting high exploitation rates by the fishery. There is no strong evidence of a positive relationship between the average distance traveled and days at liberty. No significant difference (P>0.05) was observed in the average distance traveled over time in Stonehaven (site 3), Anse-Bleue (site 4), Caraquet (site 5) and North Lake (site 16) (Table 5). The average distance traveled decreased significantly (P=0.0002) in Belledune (site 1), whereas it increased significantly in Souris (site 24) (P=0.0119) and Margaree (site 30) (P=0.004) over multiple years recovery (Table 5). Even in these areas where distances were significantly different, the differences were not large (2.4, 2.3, and 5.3 km). Also, the longest distance traveled observed for the second or third (or both) recovery periods was equal or less than the one observed for the first recovery period for all 7 sites (Table 5).

Lobster movements in the southwestern GSL seemed to be restricted to short distances along the coast near shore in areas where the lobster habitat is restricted to a few kilometers from the shore and longer distances over a broader gradually sloping bottom (Fig. 3). In general, 93% of lobster dispersions were limited to the 20-m bathymetry contour. The shorter average distances traveled (2.4–4.9 km, Table 2) were observed in part of Baie des Chaleurs (Figs 1 and 4, sites 3 and 4), the northeastern tip of Prince Edward Island (Fig. 1, sites 16, 24, and 25) and Cape Breton (Figs 1 and 5, sites 29, 30, and 31). Relatively short average distances (5.3–8.6 km, Table 2) were observed around northeastern New Brunswick (Figs 1 and 6, sites 1, 2, 5, 6, 8, and 9), the northwestern tip of Prince Edward Island (Fig. 1, sites 12, 13, 20, and 21), eastern New Brunswick (Fig. 1, sites 17 and 18) and the eastern end of

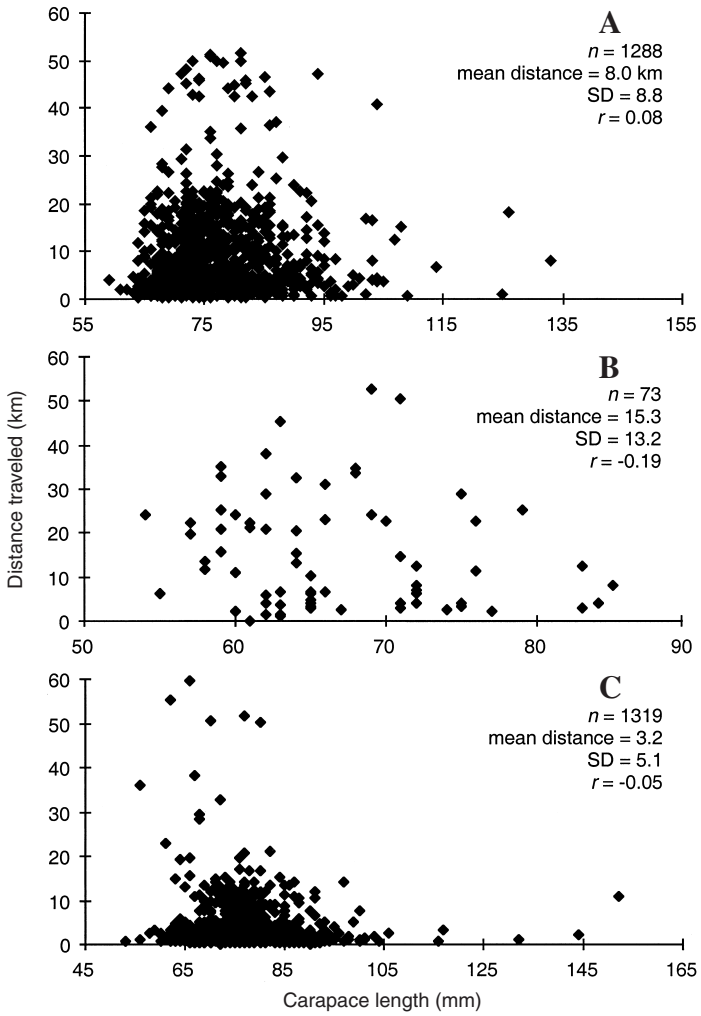

Figure 2

Relationship between the distance traveled and the size of the animal for American lobsters recaptured in (**A**) Caraquet, (**B**) Howard's Cove, and (**C**) Margaree.

the Northumberland Strait (Fig. 1, sites 26 and 27). The longest average distances traveled (9.3–19.4 km, Table 2) were observed in the immediate vicinity of Miramichi Bay (Figs 1 and 6, sites 10 and 11), Malpeque Bay and Tracadie Bay in northern Prince Edward Island (Fig 1, sites 14, and 15), St. Georges Bay (Fig. 1, site 28) and central Northumberland Strait (Figs 1 and 7, sites 19, 22, and 23).

Lobster movements in the Northumberland Strait were related to whether the site was located toward the center or at either extremity (either end) of the Strait. Lobsters at sites close to the external boundaries (Fig. 1, sites 17, 18, 20, 21, 26, and 27) traveled on average shorter distances (5.4–8.6 km) than those located in the center of the Strait (Fig. 1, 12.2–19.4 km, sites 19, 22, and 23). Although tags were recovered in the western portion of Northumberland Strait (LFA 25) at a different time (a different fishing season) compared with tag recoveries at the other LFAs, movements seemed to be related to the extent of shallow waters (<20 m) rather than the time of the recovery period.

Discussion

Lobster movements in the southwestern GSL are related to the local bottom topography and are depth-dependent, i.e. lobsters traveled on average longer distances in areas where the shallow waters (<20 m) extended farther from shore. We observed that on the narrow coastal shelf of western Cape Breton and in some areas in Baie des Chaleurs, lobsters traveled on average less than 5 km compared with distances ranging from 9.3 to 19.4 km in the gradually sloping bottom of the Northumberland Strait and some shallow bays. Similarly, Templeman (1935) reported

Table 4

Comparison of the average distance traveled between the average distance traveled by male, female, and berried female American lobsters. The number of each site corresponds to its geographical position on the map in Figure 1. *n* = number of recaptured lobster with tags indicating release location for which distance traveled to recapture site could be calculated.

Tagging site	Biological category	*n*	Average distance traveled ±SD (km)	*U*-Test or Kruskal-Wallis[1] *P*
1 Belledune	male	360	7.0 ±5.9	0.0003
	female	176	9.0 ±8.3	
3 Stonehaven	male	316	2.1 ±2.8	0.0248
	female	264	2.7 ±3.3	
4 Anse-Bleue	male	127	2.1 ±3.3	0.0056
	female	105	3.8 ±5.2	
5 Caraquet	male	746	8.1 ±9.1	0.0937
	female	487	7.7 ±8.6	
	berried female	55	5.5 ±6.6	
8 Le Goulet	male	45	5.3 ±2.7	0.4385
	female	45	5.2 ±2.7	
9 Val Comeau	male	279	7.7 ±7.1	0.0260[2]
	female	218	6.3 ±5.6	
	berried female	5	1.3 ±0.7	0.0018
12 Seacow Pond	male	20	5.0 ±7.7	0.5800
	female	41	5.5 ±7.9	
13 Alberton	male	33	6.0 ±6.7	0.8849
	female	29	5.4 ±5.0	
14 Malpeque	male	114	11.0 ±7.6	0.7310
	female	95	11.2 ±7.4	
	berried female	42	10.5 ±9.9	
16 North Lake	male	26	2.1 ±1.4	0.4700[2]
	female	33	3.5 ±4.9	
	berried female	5	0.8 ±0.6	0.0243
18 Kouchibouguac	male	25	8.9 ±7.8	0.5847
	female	26	8.0 ±7.0	
22 Howard's Cove	male	43	17.3 ±12.3	0.1333
	female	31	12.8 ±14.0	
24 Souris	male	131	3.6 ±5.3	0.5826[3]
	female	66	7.1 ±9.0	0.0140[2]
	berried female	5	1.6 ±0.7	0.0355
25 Fortune	male	133	3.2 ±3.6	0.0155[2]
	female	62	4.0 ±3.7	
	berried female	12	0.5 ±0.2	0.0001
26 Beach Point	male	178	6.4 ±6.2	0.4729
	female	65	10.1 ±13.4	
28 Ballantynes Cove	male	56	8.5 ±10.0	0.6193
	female	132	8.0 ±9.7	
29 Port Hood	male	139	4.4 ±3.1	0.7616[2]
	female	158	4.3 ±2.6	
	berried female	42	5.6 ±3.2	0.0294
30 Margaree	male	449	3.1 ±4.9	0.1478
	female	553	3.5 ±5.0	
	berried female	317	2.8 ±5.0	
31 Pleasant Bay	male	322	2.1 ±1.8	0.2638
	female	565	2.3 ±2.2	
	berried female	153	2.5 ±2.4	

[1] The *U*-test and the Kruskal-Wallis test were used to compare two and three groups, respectively.

[2] *U*-test between males and females.

[3] *U*-test between males and berried females.

Table 5

The average and the longest distances traveled by American lobsters for sites with tags returned over multiple years. The time between tagging and recapture of the animal (number of days at liberty), and the number of observations (n) are indicated. The number of each site corresponds to its geographical position on the map in Figure 1.

Tagging site	Number of days at liberty	n	Average distance traveled (km)	U-test or Kruskal-Wallis[1] P	Longest distance traveled (km)
1 Belledune	295–378	497	7.6 ±6.1	0.0002	44
	678–747	72	6.7 ±7.5		37
	1048–1102	35	5.2 ±3.9		17
3 Stonehaven	231–291	580	2.4 ±3.0	0.5827	28
	598–648	38	2.4 ±4.1		17
4 Anse-Bleue	217–270	235	2.9 ±4.3	0.2753	32
	577–628	48	6.2 ±11.9		56
	942–972	7	5.0 ±7.3		17
5 Caraquet	213–360	1302	7.9 ±8.4	0.6416	51
	584–725	97	7.7 ±11.8		49
	965–1057	17	11.8 ±14.5		50
16 North Lake	232–280	65	2.7 ±3.7	0.2075	24
	605–641	13	1.7 ±1.5		6
24 Souris	230–285	202	4.7 ±6.9	0.0119	31
	584–625	11	7.0 ±4.2		13
30 Margaree	250–308	147	3.3 ±3.7	0.004	23
	622–671	13	8.6 ±7.6		21

[1] The U-test and the Kruskal-Wallis test were used to compare two and three groups, respectively.

that the average distance traveled by lobsters from sites located on the north side of Prince Edward Island and the western part of the Northumberland Strait ranged from 7 to 10 km. As with our results, longer movements were reported in the Egmont Bay area (central Northumberland Strait); lobsters traveled an average distance of approximately 14 km (Wilder, 1963) on lobster habitat in shallow (<20 m) waters. In other sites within the GSL, lobsters also traveled on average small distances. Lobsters in the Magdelan Islands (Templeman, 1935; Bergeron, 1967) and on the northern shore of Baie des Chaleurs (Corrivault, 1948) traveled average distances ranging from 3 to 16 km and 12 km or less, respectively. On the west coast of Newfoundland, Templeman (1940) reported that lobsters traveled an average of 3.2 km in St. George's Bay and 8.2 km in Port-au-Port Bay; hence, lobsters disperse within the GSL, in general, over small distances in inshore waters.

Most of the lobster movements observed in the southwestern GSL were oriented along the coast in inshore waters. Although the shallow (<20 m) gradually sloping bottom of the central Northumberland Strait, the Malpeque Bay, and Miramichi Bay areas allows for longer and more broader dispersions, lobsters remain close to either the New Brunswick, Nova Scotia, or Prince.Edward Island coastline, or confined to a bay environment. However, dispersions along the coast might not be the only types of lobster movements in southwestern GSL. Movements perpendicular to the coast have been documented in the Magdalen Islands (Templeman, 1936; Bergeron, 1967; Munro and Therriault, 1983), Bonavista Bay in Newfoundland (Ennis, 1984), and on the north shore of Baie des Chaleurs (Corrivault, 1948) because a migration of lobsters moving inshore in the spring and offshore in the fall was observed.

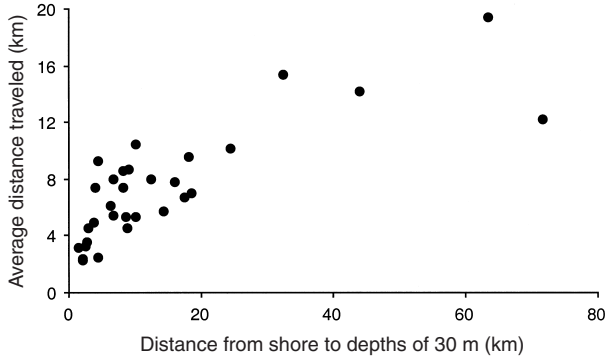

Figure 3

Relationship between the average distance traveled and the extent of shallow waters measured by the distance from shore to the closest 30-m bathymetric contour.

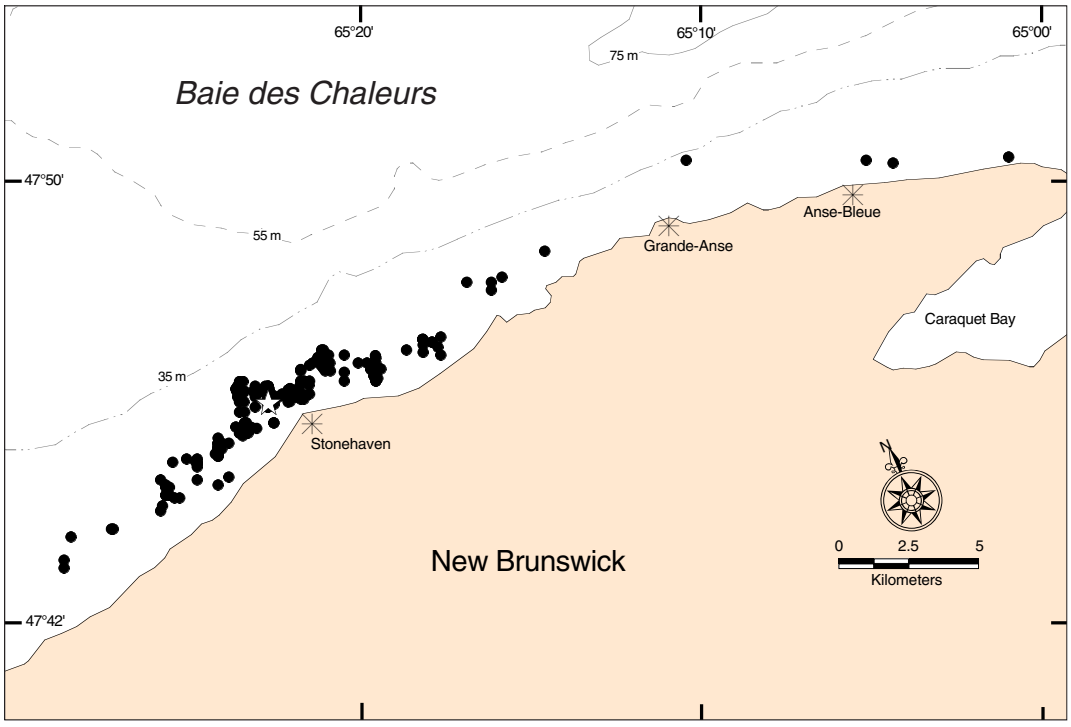

Figure 4

Locations (•) of tagged American lobsters recaptured in 1995 and 1996 (n=296) from the 1994 tagging project conducted in Stonehaven, New Brunswick. The release sites are indicated by a star symbol.

Recently, a trawl survey conducted at a depth of 40 m in the Caraquet area (Baie des Chaleurs) over a 7-month period produced lobsters in mid-May, late-October, and November, but not between June and early-October (Comeau, personal obs.). Further, the recapture positions during the fishing season showed that lobsters tagged during these trawl surveys were recaptured along the coast at depths less than 20 m from Stonehaven to Miscou (Comeau, personal obs.). This finding suggests that there is an inshore–offshore movement on the south shore of Baie des Chaleurs similar to the one observed by Corrivault (1948) on the north shore of that bay. Unfortunately, our tagging projects were not designed to study this type of movement and did not allow us to speculate more on inshore–offshore movements.

The lack of long-range movements across the southwestern GSL could be explained by the presence of an extensive cold (<1.5°C) intermediate layer (CIL). In the southwestern GSL, the CIL is a large volume of water sandwiched between the coastal water and the deep water located in the Laurentian channel. The top of the layer ranges from 20 to 40 m depth from June to October and rises to the surface from January to April (Gilbert and Pettigrew, 1997). As it was hypothesized by Stasko (1980), there seems to be no advantage in long-distance movement to deeper water (>40 m) for lobsters in the GSL because it is cold (<1.5°C) in both summer and winter (CIL). Although lobsters can tolerate temperatures ranging from –1.5° to 30°C, at temperatures below 0°C they are in a state of hibernation, and below 5°C molt induction is blocked (Waddy et al., 1995). It is clear that lobsters can "tolerate" cold temperature but to be active they need warmer waters. Lobster movements of more than 40 km were rare in the southwestern GSL and movements exceeding 70 km through deep, colder waters (>40 m) were not observed. In contrast, lobsters from the Bay of Fundy, from coastal waters of southwestern Nova Scotia, and from coastal waters off New England can take advantage of warmer temperatures in deep waters in the Gulf of Maine and on the continental shelf during the winter (Campbell and Stasko, 1986). Campbell and Stasko (1985) and Campbell (1989) showed that lobsters tagged in the inshore waters of southwestern Nova Scotia traveled up to 240 km to the edge of the continental shelf off Georges Bank to depths below 200 m, seemingly without crossing a wide area of cold water. Similarly, lobsters tagged in the Bay of Fundy were also recaptured in deep waters at the edge of the continental shelf across the Gulf of Maine and along the coastal waters of the United States (Campbell and Stasko, 1986), at a distance of more than 780 km. These types of movements were not observed in the southwestern GSL. Lobster movements between mainland New Brunswick, Prince Edward Island, or Cape Breton, and the Magdalen Islands, for example, have not been reported. The Magdalen Islands are an archipelago with a substantial lobster fishery located in the middle of the southwestern GSL, surrounded by >60 m depths at about 80 to 90 km from Prince Edward Island, and Cape Breton. Lob-

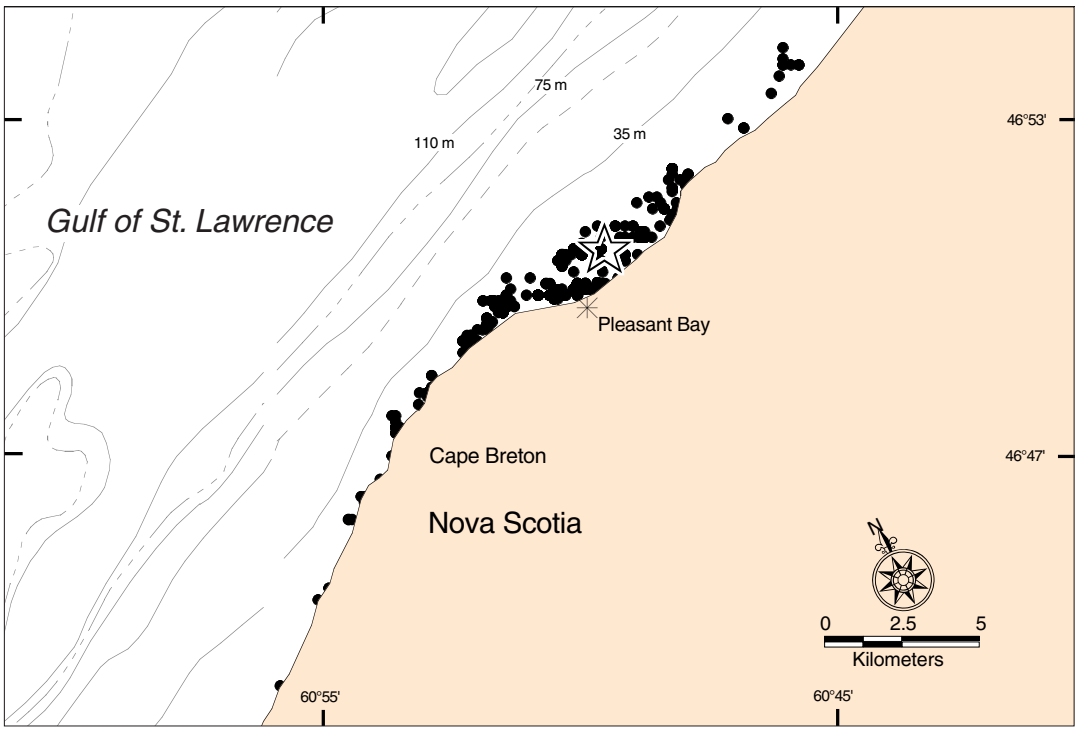

Figure 5

Locations (•) of tagged American lobsters recaptured in 1993 (n=777) from the 1992 tagging project conducted in Pleasant Bay, Nova Scotia. The release sites are indicated by a star symbol.

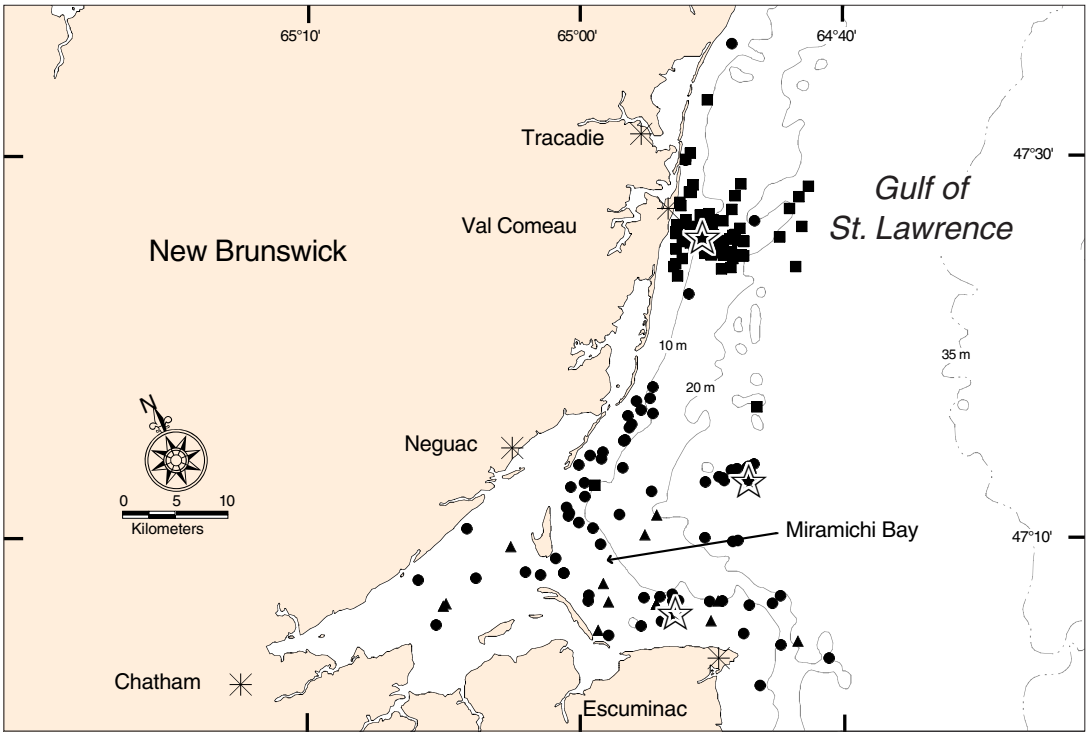

Figure 6

Location of tagged American lobsters recaptured in the Val Comeau and the Miramichi Bay area. Squares represent lobsters recaptured from the 1996 Val Comeau (n=127) tagging project, circles represent lobsters recaptured from the 1996 Neguac (n=74) tagging project, and triangles represent lobsters recaptured from the 1997 Escuminac (n=17) tagging project. The release sites are indicated by a star symbol.

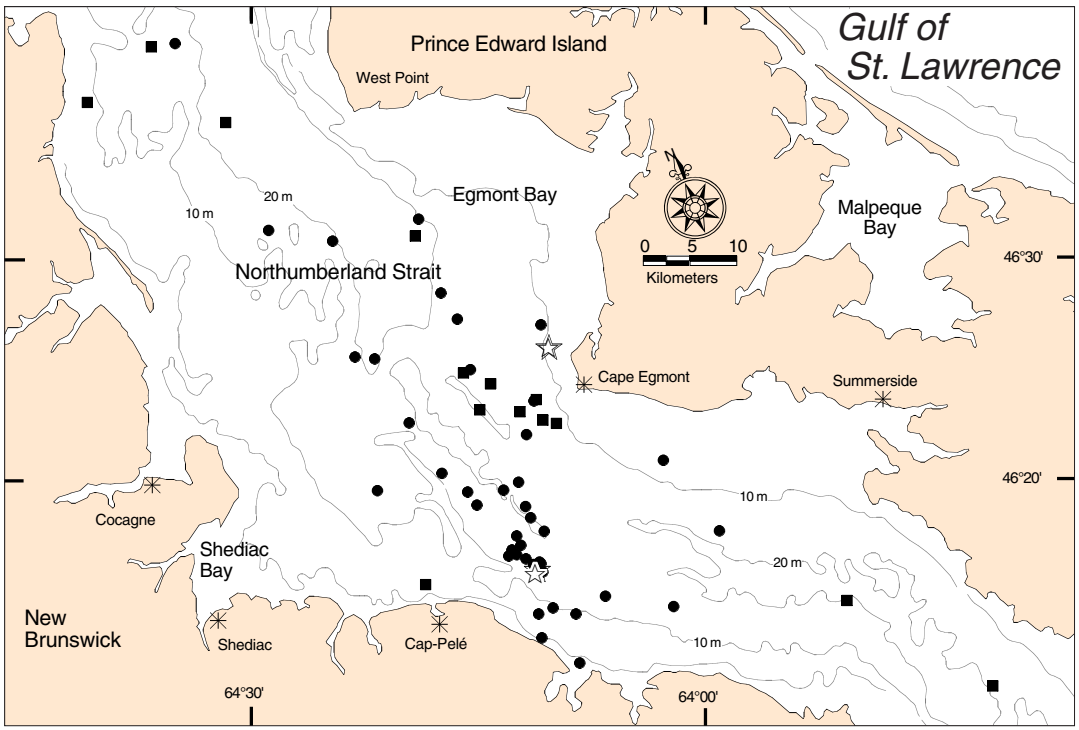

Figure 7

Location of tagged American lobsters recaptured in central Northumberland Strait. Squares represent lobsters recaptured from the Egmont Bay (n=15) tagging project and circles represent lobsters recaptured from the Cap-Pelé (n=41) tagging project, conducted in 1982 and 1997, respectively. The release sites are indicated by a star symbol.

ster movements in the southwestern GSL seem to be temperature-dependent because the cold waters of the CIL appeared to be an effective barrier to movements between the shallow waters of the Magdelan Islands and the shallow coastal waters of the rest of the southwestern GSL.

The distances traveled by lobsters (>60 mm CL) in the southwestern GSL were not sex- or size-dependent, except for berried females. Similar to our findings, the results of most recent studies do not indicate significant differences between the distance traveled in relation to size or sex for lobsters tagged in coastal waters (Fogarty et al., 1980; Krouse, 1981; Campbell, 1982; Tremblay et al., 1998). In contrast, Templeman (1935) and Bergeron (1967) suggested that lobster movements were sex-dependent, but neither author reported whether the differences were supported in a statistical or biological sense. Campbell and Stasko (1985, 1986) and Campbell (1989) indicated that lobster movements were size-dependent because they observed that large mature animals (≥95 mm CL) on average traveled significantly farther than small immature ones. They explained that mature animals would move more extensively to reach the warmest seasonal temperature to maximize their degree-days (the accumulative sum of daily mean temperatures recorded above 0°C) needed for somatic and gonadic development. This was not the case in our study. We observed, however, that on average berried females in the southwestern GSL traveled shorter distances than males and nonberried females. Saila and Flowers (1968) indicated that the distance traveled by berried females was related to their physiological state. In a tagging experiment, they captured berried females on the continental shelf, tagged, and released them in the inshore waters off the coast of Rhode Island at about 220 km from their captured position. When females were carrying eggs, they traveled only short distances within the inshore waters. Once they shed their eggs, however, these females returned to the continental shelf where they were originally captured. Berried females tagged in inshore waters in the Magdalen Islands (Munro and Therriault, 1983), Jeddore Harbour and Clam Bay, Nova Scotia (Jarvis, 1989), and New Hampshire (Watson et al., 1999) also traveled short distances. In the Cape Cod area, berried females tagged in the inshore waters were reported to have traveled an average distance of 30 km, mostly parallel to the coast (Morrissey, 1971; Estrella and Morrissey, 1997). Off Grand Manan Island, Campbell (1986, 1990) reported relatively small inshore–offshore migration, less than 15 km, for 75% of the berried females and attributed this migration to an effort to maximize egg development by exposure to warmer water. In general, it seems that the condition of carrying eggs could influence the extent of movements in the southwestern GSL, not the size or sex of the animal.

In terms of fishery management, there is relatively little interaction between lobsters at different LFAs at the benthic level because lobster traveled on average small

distances. The main concern of fishermen in the southwestern GSL was the minimal legal size (MLS) disparity between LFA 24 (MLS of 63.5 mm CL) located on the north side of Prince Edward Island and the other LFAs (MLSs from 65.1 to 70.0 mm CL). More precisely, they were interested in lobster movements in relation to time, i.e. if lobsters released in a given area in one season would be recaptured in the same area in future seasons. From our findings, lobsters do not move farther if they are at large for a longer period. Distances traveled by lobsters were not time-dependent for lobsters at large between 200 (with at least one winter season) and 1102 days. Results of our tagging studies were consistent with results from earlier studies carried out in the southwestern GSL and demonstrated that lobsters in their benthic stages have little long distance interaction. Hence, lobster movements in the southwestern GSL should have minimal consequences in terms of lobster management.

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Literature cited

Bergeron, T.
1967. Contribution à la biologie du homard (*Homarus americanus* M. Edw.) des Îles-de-la-Madeleine. Naturaliste Can. 94:169–207.

Campbell, A.
1982. Movements of tagged lobsters released off Port Maitland, Nova Scotia, 1944–80. Can. Tech. Rep. Fish. Aquat. Sci. 1136, 41 p.
1986. Migratory movements of ovigerous lobsters, *Homarus americanus*, tagged off grand Manan, eastern Canada. Can. J. Fish. Aquat. Sci. 43:2197–2205.
1989. Dispersal of American lobsters, *Homarus americanus*, tagged off southern Nova Scotia. Can. J. Fish. Aquat. Sci. 46:1842–1844.
1990. Aggregations of berried lobsters (*Homarus americanus*) in shallow waters off Grand Manan, eastern Canada. Can. J. Fish. Aquat. Sci. 47:520–523.

Campbell. A., D. E. Graham, H. J. MacNichol, and A. M. Williamson.
1984. Movements of tagged lobsters released on the continental shelf from Georges bank and Baccaro bank, 1971–73. Can. Tech. Rep. Fish. Aquat. Sci. 1288, 16 p.

Campbell, A., and A. B. Stasko.
1985. Movements of tagged American lobsters, *Homarus americanus*, off southwestern Nova Scotia. Can. J. Fish. Aquat. Sci. 42:229–238.
1986. Movements of lobsters (*Homarus americanus*) tagged in the Bay of Fundy, Canada. Mar. Biol.. 92:393–404.

Comeau, M., W. Landsburg, M. Lanteigne, M. Mallet, P. Mallet, G. Robichaud, and F. Savoie.
1998. Lobster (*Homarus americanus*) tagging project in Caraquet (1993)—tag return from 1994 to 1997. Can. Tech. Rep. Fish. Aquat. Sci. 2216, 35 p.

Cooper, R. A.
1970. Retention of marks and their effects on growth, behavior and migrations of the American lobster, *Homarus americanus*. Trans. Am. Fish. Soc. 99:109–417.

Cooper, R. A., and J. R. Uzmann.
1971. Migrations and growth of deep-sea lobster, *Homarus americanus*. Science 171:288–290.

Cooper, R. A., R. A. Clifford, and C. D. Newell.
1975. Seasonal abundance of the American lobster, *Homarus americanus*, in the Boothbay region of Maine. Trans. Am. Fish. Soc. 104:669–674.

Corrivault, G. W.
1948. Contribution à l'étude de la biologie du homard (*Homarus americanus*) des eaux de la province de Québec. Ph.D. diss., Université Laval, Québec, 283 p.

Dow, R. L.
1974. American lobsters tagged by Maine commercial fishermen, 1957–59. Fish. Bull. 72:622–623.

Ennis, G. P.
1984. Small-scale seasonal movements of the American lobster, *Homarus americanus*. Trans. Am. Fish. Soc. 113:336–338.

Estrella, B. T., and T. D. Morrissey.
1997. Seasonal movement of offshore American lobster, *Homarus americanus*, tagged along the eastern shore of Cape Cad, Massachusetts. Fish. Bull. 95:466–476.

Fogarty, M. J., D. V. D. Borden, and H. J. Russell.
1980. Movements of tagged American lobster, *Homarus americanus*, off Rhode Island. Fish. Bull. 78:771–780.

Gilbert, D., and B. Pettigrew.
1997. Interannual variability (1948–1994) of the CIL core temperature in the Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 54 (suppl. 1):57–67.

Jarvis, C.
1989. Movement patterns of late-stage ovigerous female lobsters (*Homarus americanus* Milne-Edwards) at Jeddore, Nova Scotia. M.S. thesis, Dalhousie Univ., Halifax, Nova Scotia, Canada, 148 p.

Karnofsky, E. B., J. Atema, and R. H. Elgin.
1989. Natural dynamics of population structure and habitat use of the lobster, *Homarus americanus*, in a shallow cove. Biol. Bull. 176:247–256.

Krouse, J. S.
1981. Movement, growth, and mortality of American lobsters, *Homarus americanus*, tagged along the coast of Maine. U.S. Dep. Commer, NOAA, Tech. Rep. NMFS SSRF-747, 12 p.

Lawton, P., and K. L. Lavalli.
1995. Postlarval, juvenile, adolescent, and adult ecology. *In* Biology of lobster, *Homarus americanus* (J. R. Factor, ed.), p. 47–81. Academic Press, New York, NY, 528 p.

Miller, R. J., R. E. Duggan, D. G. Robinson, and Z. Zeng.
1989. Growth and movement of *Homarus americanus* on the outer coast of Nova Scotia. Can Tech. Rep. Fish. Aquat. Sci. 1716, 17 p.

Moriyasu M., W. Landsburg, and G. Y. Conan.
1995. Sphyrion tag shedding and tag induced mortality of the American lobster, *Homarus americanus* H. Milne Edwards, 1837 (Decapoda, Nephropidae). Crustaceana 68:184–192.

Morrissey, T. D.
1971. Movements of tagged American lobsters, *Homarus americanus*, liberated off Cape Cod, Massachusetts. Trans Am. Fish. Soc. 100:117–120.
Munro, J., and J.-C. Therriault.
1983. Migrations saisonnières du homard (*Homarus americanus*) entre la côte et les lagunes des Îles-de-la-Madeleine. Can. J. Fish. Aquat. Sci. 40:905–918.
Robichaud, D. A., and P. Lawton.
1997. Seasonal movement and dispersal of American lobsters, *Homarus americanus*, released in the upper Bay of Fundy. Can Tech. Rep. Fish. Aquat. Sci. 2153, 21 p.
Saila, S. B., and J. M. Flowers.
1968. Movements and behaviour of berried female lobsters displaced from offshore areas to Narragansett Bay, Rhode Island. J. Cons. Int. Explor. Mer 31:342–351.
Stasko, A. B.
1980. Tagging and lobster movements. Can. Tech. Rep. Fish. Aquat. Sci. 932:141–150.
Templeman, W.
1935. Lobster tagging in the Gulf of St. Lawrence. J. Biol. Board Can. 1:269–278.
1936. Local differences in the life history of lobster on the coast of the maritime provinces of Canada. J. Biol. Board Can. 2:41–88.
1940. Lobster tagging on the west coast of Newfoundland 1938. Nfld. Dep. Nat. Resource Fish. Res. Bull. 8, 16 p.
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, 32 p.
Uzmann, J. R., R. A. Cooper, and K. J. Pecci.
1977. Migration and dispersion of tagged American lobsters, *Homarus americanus*, on the southern New England continental shelf. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-705, 92 p.
Waddy, S. L., D. E. Aiken, and D. P. V. De Kleijn.
1995. Control of growth and reproduction. *In* Biology of lobster, *Homarus americanus* (J. R. Factor, ed.), p. 217–266. Academic Press, New York, NY, 528 p.
Watson III, W. H., A. Vetrovs, and W. H. Howell.
1999. Lobster movements in an estuary. Mar. Biol. 134:65–75.
Wilder, D. G.
1963. Movement, growth and survival of marked and tagged lobsters liberated in Egmont Bay, Prince Edward Island. J. Fish. Res. Board Can. 20: 305–318.
1974. Inshore and offshore lobster stocks. Fish. Res. Board Can. MS Rep. 1293, 14 p.