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Exploratory Survey For Small Arctic Surfclams On The Eastern Scotian Shelf

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EXPLORATORY SURVEY FOR SMALL ARCTIC SURFCLAMS ON THE EASTERN SCOTIAN SHELF

by

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ABSTRACT

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An exploratory survey was conducted to locate concentrations of small commercial size Arctic surfclams[1] (*Mactromeris polynyma*) on the eastern Scotian Shelf. The survey took place from March 28 to April 8, 1991 on board the commercial clam vessel *Scotian Surf.* The survey did find concentrations of clams in the desired size range on the western end and southern side of Banquereau Bank. There was almost no bycatch of any other commercial species, although large numbers of northern propellerclams (*Cyrtodaria siliqua*) were caught. Data are presented on the catch rates and size distribution for *Mactromeris polynyma*, *Cyrtodaria siliqua* and *Arctica islandica* and the composition of the bycatch.

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[1]The nomenclature used in this report follows that recommended in the American Fisheries Society publication: Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks (Turgeon *et al.* 1988). In Atlantic Canada the Arctic surfclam (*Mactromeris polynyma*) is more commonly referred to as the Stimpson's surf clam. For the French common names we have used the names in use in Atlantic Canada rather than translating the AFS English names.

RÉSUMÉ

Roddick, D.L. 1992. Exploratory survey for small Arctic surfclams on the eastern Scotian Shelf. Can. Ind. Rep. Fish. Aquat. Sci. 215: 33 p.

Une campagne d'exploration a été menée pour localiser les sites où sont concentrés les individus de petite taille commerciale de la Mactre de Stimpson[1] (*Mactromeris polynyma*) à l'est du plateau néo-écossais. La campagne a eu lieu du 28 Mars au 8 Avril 1991 à bord du "Scotian Surf", un navire pêchant commercialement la mactre. L'échantillonnage permit de trouver des concentrations de mactres dans la gamme de taille recherchée à la pointe ouest et sur la face sud du Banc Banquerau. On n'a enregistré pratiquement aucune capture accidentelle d'autres espèces commerciales quoique le pitot[1] (*Cyrtodaria siliqua*) ait été capturé en grand nombre. Les données de taux de captures et la distribution de taille de *Mactromeris polynyma*, *Cyrtodaria siliqua* et *Arctica islandica* ainsi que la composition des captures accidentelles sont présentées.

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[1]La nomenclature anglaise utilisée dans ce rapport suit les recommandations de la publication de l'American Fisheries Society: Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks (Turgeon *et al.* 1988). Cependant, en l'absence d'une version francaise des appellations communes, on a préféré les dénominations généralement utilisées dans la région Atlantique canadienne, aux appellations préconisées dans Turgeon et al. (1988).

1.0 INTRODUCTION

In the 1980's, developmental clam surveys conducted by the Department of Fisheries and Oceans (DFO) showed commercial concentrations of Arctic surfclams (*Mactromeris polynyma*) on the Scotian Shelf (Rowell and Chaisson 1983). In 1987 a commercial fishery for these clams started and has steadily expanded. In 1990 the landings were 6,000 t round weight, worth $4 million. The fishery has centered on Banquereau Bank. The clams have been about 12 cm in size, which is larger than that desired by the Japanese sushi and sashimi market where most of these clams are sold. This market desires a clam around 9 cm in size. The desired size can be obtained on Grand Bank, but steaming time and weather conditions are not as attractive as on the Scotian Shelf.

This report summarizes the results of an exploratory survey to locate commercial densities of small Arctic surfclams on the eastern Scotian Shelf. This survey was proposed by the Nova Scotia Clam Company and funded by the Industry Services and Native Fisheries Branch, Scotia-Fundy Region, DFO, under the Canada - Nova Scotia Cooperative Agreement on Fisheries Development. The cruise was conducted by personnel from the Benthic Fisheries and Aquaculture Division, Biological Sciences Branch, DFO, from March 28 to April 8, 1991, using the commercial clam vessel *Scotian Surf*. During the cruise data also were collected on bycatch composition and on size and catch rate distribution of ocean quahogs (*Arctica islandica*) and northern propellerclams (*Cyrtodaria siliqua*).

2.0 METHODS

The cruise was limited to 10 days at sea and it was not possible to conduct a complete survey of the area. It was therefore decided to explore those areas that appeared to have the highest potential for commercial densities of surf clams. To identify these areas the Atlantic Geoscience Centre open file series 2244 maps were used. These maps show various aspects of the surficial geology of most of the offshore banks of the eastern Scotian Shelf. The maps used showed: point source data on the mix of fines, sand and gravel; contour maps of the grain size distribution of the sand fraction; contour maps of the bedforms; and interpretation of sidescan sonar tracks. Areas

that had characteristics similar to those with known commercial concentrations of surf clams were chosen for investigation. Since Canso Bank was not covered by this set of maps it was assigned a regular grid of stations.

One station was allocated to an area that was being fished to compare the survey catch rates in unexploited and commercial grounds. Additional tows were assigned to some areas that the Captain of the *Scotian Surf* (C. Pardy) felt were worth investigating.

Two additional studies were carried out in conjunction with the survey. In the first, a series of stations were positioned across an area on western Banquereau Bank that had been reported both by fisheries observers and the vessel captains to contain large numbers of juvenile surf clams of approximately 30 mm shell length. This transect would define the size of the recruitment patch and also give baseline data so that growth and mortality of a population in its natural habitat could be followed. This would be possible for as long as this pulse of recruitment made an identifiable mode in the length frequency data.

In the second study, tows were assigned to two areas where marked clams and quahogs had been released (Fig. 1). Although there was not time to conduct a search for the marked clams, it was decided that since the survey took the vessel into these areas, that a few tows should be made as any marked clams recovered would provide valuable growth data.

Sampling was carried out with the commercial clam vessel *Scotian Surf*, which is equipped with two hydraulic dredges. These dredges are 4.03 m wide, 0.9 m high and 6 m long. The knife blade was 3 m wide and set at a depth of 15 cm and the water pressure was 125 - 130 PSI. At each location at least two 10 minute tows were carried out using both dredges. When the dredge came up, the total volume of raw catch was recorded for both dredges. The catch of Arctic surfclams, ocean quahogs and northern propellerclams (*Cyrtodaria siliqua*) was recorded in bushels and subsampled for number and round weight. This was done for one dredge only for each tow due to the time involved in sorting the catch. In each area, length frequencies of the Arctic surfclams were recorded to the nearest mm. The mean sizes from the length frequencies were converted to raw gutted foot weights using a regression derived from commercial fishery

samples. This was done as the foot weight is the variable of interest to the industry.

One bushel samples of the raw catch were taken in each fishing area and sorted for catch composition. As weights of smaller and less abundant species could not be accurately recorded at sea, subsamples were brought back to the lab for weighing and to confirm identifications. Mean weights were then applied to the numbers per sample to get the estimated weight by species.

The speed, depth and water pressure were recorded during each tow. To determine tow path and distance, the Loran C position was automatically recorded onto a Macintosh computer at two-second intervals.

Since the catch rates of the individual tows provided a data set with a range of distances between tows, it was decided to use a semi-variogram of the data to examine the spatial autocorrelation of the survey results. This analysis provides information on the patchiness of the distribution.

3.0 RESULTS

Ice cover during the survey prevented any work on Canso Bank and the northern edge of Middle Bank. Consequently additional stations on the western end of Banquereau Bank were sampled.

The tow data is given in Table 1 and the tow locations are plotted in Figure 1. The catch rates for the different areas are shown in Figures 2 - 5 for Arctic surfclams, 6 - 9 for northern propellerclams and 10 - 13 for ocean quahogs. The regression used for the conversion from shell length to foot weight for Arctic surfclams is shown in Figure 14. The resulting distribution of mean foot weight for the survey is shown in Figure 15. The distribution of mean round weights for northern propellerclams and ocean quahogs are shown in Figures 16 and 17 respectively. No marked clams or quahogs were recovered from the release sites.

The length of hose initially on the dredge was not long enough to use the dredge properly on the deeper stations (tows 12 to 16 and 27 on Banquereau Bank, Figure 5). More hose was added on April 3 when weather permitted and the area of tows 12 to 16 was resampled.

The catch composition is shown in Table 2. There was little bycatch and almost no capture

of other commercial species.

The series of stations across the area reported to contain large numbers of juvenile Arctic surfclams did not show any sign of small surfclams. There were large numbers of the Arctic wedgeclam, *Mesodesma arctatum*, caught in this area.

The two tows in the commercially fished area on Banquereau Bank (tows 25 and 26, Figure 5) had a mean catch rate for Arctic surfclams of 40.5 g/m^2. The average for all the Banquereau Bank tows was 38.6, indicating that the majority of areas surveyed had commercial potential.

The semi-variogram of the survey results is shown in Figure 18 and indicates that there is no spatial covariance shown in the survey data.

4.0 DISCUSSION

4.1 ARCTIC SURFCLAM CATCH RATES.

The comparison of the catch rate for Arctic surfclams in the commercial area indicates that most of the areas surveyed had commercial potential. Some survey tows had considerably higher catch rates than the commercial area. However, two tows are not a very large sample on which to base such a comparison. Tow 79 was carried out for a 20-minute period instead of 10 minutes in an area that had given consistent catches between the few tows carried out there. The dredge had a volume of total catch greater than the nearby tows, but was still well below the maximum value recorded for the survey. This indicates that the dredge was not filling up and therefore should be fishing for the entire period of the tow.

A semi-variogram of a distribution with no directional trends would look like Figure 19. Pairs of tows close together have a low covariance with the covariance rising as the distance apart increases. The presence of a nugget effect shows that there is still some variation between repetitive tows at the same location. This indicates a scale of patchiness smaller than a tow length, noise due to gear/fishing effects or observational errors. The sill is the overall covariance between independent tows and the range is the distance over which spatial correlation occurs.

The semi-variogram of the survey results (Figure 18) shows that tows made close together

have as much variation as tows that are far apart. Studies in the Gulf of St. Lawrence found values for the range from 0.8 to 3.4 km for beds of Arctic surfclams fished during the summer of 1991 (Landry *et al.* 1992). This indicates that there is spatial covariance in the beds they looked at. The difference in the two studies may be partially due to weather conditions during this survey. Rough weather affects the efficiency of the dredges. It increases the variance between tows and tends to hide the spatial covariance.

Sable and Middle Bank did not show any commercial concentrations. Although neither this nor previous surveys were thorough enough to cover these areas completely, the combination of previous surveys (Rowell and Chaisson, 1983; Chaisson and Rowell 1985) and commercial exploration mean it is doubtful there are any significant commercial beds in these areas.

4.2 AREA REPORTED TO CONTAIN JUVENILE ARCTIC SURFCLAMS.

The reports of an area with large numbers of juvenile Arctic surfclams appear to be the result of an error in identification. No Arctic surfclams were found but there were large numbers of the Arctic wedgeclam, *Mesodesma arctatum*. This clam has roughly the same appearance as the Arctic surfclam but only grows to 4 cm. The discovery of the bed of *Mesodesma arctatum* instead of juvenile *Mactromeris polynyma* was disappointing. A bed with a distinct size mode lends itself to accurately follow growth and mortality of a population of clams in their natural habitat. It had been hoped that this bed could provide good estimates of these parameters. As well, there has been little sign of recruitment to the fishery and the reports of a large number of juvenile clams had been thought to be the first good indication of recruitment.

4.3 RECOVERY OF MARKED ARCTIC SURFCLAMS AND OCEAN QUAHOGS.

The failure of the tows to capture marked clams in the release sites was disappointing but expected considering the few tows done. Past studies of this type have shown that it usually takes considerable searching to find the area where the marked clams landed. Once the area has been found the recoveries are usually good.

4.4 COMPOSITION OF BYCATCH.

Catch composition shows that, except for other bivalves, there is little bycatch brought up

by the dredges. Contributions of each species would be different in a commercial fishery from that shown in this survey; only areas with commercial quantities of the target species would be fished. Species such as the sand dollar (*Echinarachnius parma*), which contributes 13% of the bycatch in this survey, are less abundant on commercial clam beds where it only contributes 0.08% of the bycatch (Roddick and Kenchington 1990).

The large catches of northern propellerclams, occasionally up to 700 kg/tow, merit some discussion. This species looks similar to a large sausage, 8-10 cm in length and only partially covered by a shell. The edges of the mantle are fused together except for small openings for the foot and siphons. The thick dark periostracum that covers the shell also covers all the exposed body of the clam. Its form indicates that it is a shallow burrower. It is found in fine sands down to 500 meters, but is most abundant between 50 and 150 meters. Its distribution coincides with that of the sand dollar *Echinarachnius parma* and is limited to the northwest Atlantic from the Strait of Bell Isle southward to a line running south west from Cape Cod (Nesis 1965).

The prospect of a commercial fishery for these clams is uncertain. They differ greatly in appearance from most commercial clam species and this probably will hinder their entrance into traditional markets. There have been limited attempts to develop a market and there has been no demand created yet.

The prospects for ocean quahogs are also uncertain. It is considered a low quality clam due to its toughness, but there is a U.S. fishery supplying it for use in chowders and minced clam dishes (DeFranssu 1990). There is a large resource on the Scotian Shelf (Rowell and Chaisson 1983, Chaisson and Rowell 1985) but no domestic market. In addition Iceland, which also is reported to have a large resource, is starting to develop a fishery directed at an export market, primarily the U.S. (DeFranssu 1990). The development of a domestic market probably will be dependent on a processing plant being set up in Atlantic Canada.

4.5 IMPORTANCE OF BIVALVES AS FOOD ITEMS FOR COMMERCIAL GROUNDFISH.

In addition to their use as a food item, clams can be an important part of the diet of commercial groundfish. Unfortunately, in most published studies looking at the stomach contents

of groundfish, mollusks are usually listed as a single group and seldom broken down to species(Kohler and Fitzgerald 1969, Powles 1958). There are a few studies that look at important bivalves. On the Grand Banks the northern propellerclam has been found in the stomachs of Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), yellowtail flounder (*Limanda ferruginea*), American plaice (*Hippoglossoides platessoides*), and other bottom feeding fish. It has been reported to make up to 20% of the food items in the stomachs of large cod (Nesis 1965). A more recent study of its importance to cod was done by Lilly and Meron (1986). They looked at cod stomachs from Southern Grand Bank and found northern propellerclams to be the only bivalve species. The largest number consumed was by an 86 cm cod who had 41 propellerclams in its stomach. All shells found were unbroken and articulated, indicating that the cod were not feeding on clams dug up by fishing activity.

In the southwest Gulf of St. Lawrence, Powles (1958) found mollusks contributed a great deal to the diet of large cod. Although whelks and *Yoldia sp.* were the most important, large numbers of northern propellerclams also were found.

On the Scotian Shelf, Kohler and Fitzgerald (1969) showed mollusks making up approximately 29% by volume of the food in 70^{+} cm cod on Banquereau Bank. They noted that although identification of species was often incomplete, the major portion was clams.

Samples of a dozen stomachs each of skate, (*Raja sp.*), haddock and cod were collected from 44° 44' N, 57° 24' W on Banquereau Bank on May 9, 1989 in 59 meters (D. Roddick, unpublished data). The skate ranged from 40 to 60 cm in length and were feeding on polychaetes. No surfclams, quahogs or propellerclams were found. The haddock ranged from 46 to 56 cm in length and were mainly feeding on brittle stars. No quahogs or propellerclams were found but there was one 4.8 mm surfclam. Eleven of the cod ranged from 39 to 56 cm and the twelfth was 87 cm in length. The cod were also feeding on brittle stars, but one had eaten quahogs, seven had eaten propellerclams, and the 87 cm specimen had fed on surfclams as well as propellerclams. This cod had the remains of 8 propellerclams and 14 surfclams in its stomach. Interestingly, no clam shell fragments were found in any of the cod stomachs except for the whole 4.8 mm Arctic

surfclam. This data indicates that clams may be an important food source for large cod, at least on Banquereau Bank.

5.0 CONCLUSION

A small survey of this type does not provide a lot of information about the population of Arctic surfclams on the Scotian Shelf. The coverage of the area was not adequate to provide reliable biomass estimates, and comparisons with known commercial areas are based on samples too small to give definite conclusions. That was known at the start and was not the purpose of this cruise. The survey was successful in its objective of looking at the size distribution of clams in areas that had a good probability of supporting commercial densities. It also provided some additional information on bycatch composition, the size distribution of ocean quahogs and northern propellerclams, and the prospects for Arctic surfclams on Sable and Middle Banks.

Results indicate that there are potentially commercial concentrations of small-sized clams on Banquereau Bank. The western end and the deeper waters of the southern side appear most promising (Figures 15 and 20).

The identification of areas of small clams on Banquereau Bank is encouraging although it will take some commercial activity to test the profitability of the catch rates. The sizes found are even smaller than that being harvested on Grand Bank, but the catch rates on Grand Bank are higher than those on Banquereau Bank.

6.0 ACKNOWLEDGEMENTS

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Table 1. Tow data from cruise SS9101, March 28 - April 8 1991, all catch data recorded on a single dredge basis.

Tow #	Speed m/sec	Dist towed	Depth m	Volume bushels	Latitude north	Longitude west	Arctic Surfclams bu	kg	mm[1]	g/clam	Northern Propellerclams bu	kg	g/clam	Ocean Quahogs bu	kg	g/clam
1	.85	463	63	-	43.5367	60.7892	0.10	1.00	-	200.0	1.20	41.50	113.70	0.00	0.00	-
2	.67	436	63	17.0	43.5353	60.7903	0.10	0.75	-	150.0	1.50	31.25	107.14	0.10	0.75	92.18
3	.66	442	38	17.0	43.8513	60.1423	0.00	0.00	-	-	0.10	4.75	-	7.00	109.75	106.77
4	.63	413	36	0.1	43.8469	60.1283	0.00	0.00	-	-	0.00	0.00	-	0.10	5.25	100.96
5	.64	385	37	0.9	43.8438	60.1364	0.00	0.00	-	-	0.00	0.00	-	1.00	19.50	104.28
6	.74	660	48	137.4	43.8177	60.0610	0.00	0.00	-	-	1.25	42.50	151.35	1.25	41.00	150.00
7	.81	666	44	34.5	43.8249	60.0545	0.00	0.00	-	-	0.16	3.00	-	3.50	94.00	-
8	.90	770	54	-	43.7560	60.0225	0.50	15.00	-	-	0.50	18.00	-	2.00	59.00	-
9	.64	437	55	-	43.7589	60.0148	0.50	19.50	-	-	0.50	11.50	191.67	4.00	63.00	-
10	.92	746	54	188.9	43.7345	59.8805	0.20	3.00	-	187.5	5.00	285.00	98.44	1.00	23.50	83.93
11	.74	484	56	17.0	43.7286	59.8812	1.00	22.50	-	180.0	10.75	313.54	90.91	5.00	124.25	103.45
12	.64	430	74	0.9	44.1529	58.7819	3.00	74.50	97.1	130.0	9.50	274.00	89.23	0.00	0.00	-
13	.65	448	75	34.5	44.1523	58.7822	3.50	77.00	95.9	117.3	5.00	95.00	81.55	0.00	0.00	-
14	.70	468	72	60.2	44.1522	58.7144	3.50	82.00	-	106.8	3.75	77.81	59.35	0.00	0.00	-
15	.75	486	72	34.5	44.1510	58.7166	1.00	23.00	-	135.3	2.50	72.00	87.96	0.00	0.00	-
16	.76	506	79	-	44.1512	58.6638	0.00	0.00	-	-	0.00	0.00	-	0.00	0.00	-
17	.69	467	59	85.9	44.3446	58.2935	0.50	8.00	80.0	63.0	14.75	464.63	108.41	0.00	0.00	-
18	.63	407	60	137.4	44.3542	58.3060	3.75	107.00	113.2	217.1	0.50	17.00	130.77	0.00	0.00	-
19	.81	529	53	85.9	44.3313	58.1805	1.25	40.00	95.6	163.3	12.00	330.00	96.49	0.00	0.00	-
20	.79	514	53	17.0	44.3273	58.1774	3.50	93.00	-	139.3	4.75	137.75	93.25	0.00	0.00	-
21	.79	523	61	188.9	44.4512	58.3184	2.50	73.50	96.2	110.4	6.25	190.63	100.32	0.00	0.00	-
22	.65	439	61	188.9	44.4494	58.3170	2.80	73.00	-	119.3	9.80	291.55	117.06	0.00	0.00	-
23	.76	505	39	17.0	44.5510	57.8987	0.10	2.75	92.4	137.5	0.50	15.75	124.02	0.10	2.50	147.06
24	.73	478	39	-	44.5500	57.9002	0.00	0.00	-	-	0.50	10.50	138.16	0.10	2.00	153.85
25	.79	525	64	188.9	44.5172	57.7625	2.75	73.00	-	205.9	15.00	472.50	94.31	0.10	3.50	-
26	.70	474	69	85.9	44.5138	57.7737	3.50	88.50	114.0	196.3	10.00	330.00	101.23	0.00	0.00	-
27	.68	452	70	-	44.4614	57.6917	0.00	0.00	-	-	0.00	0.00	-	0.00	0.00	-
28	.77	511	41	-	44.8502	57.5326	1.50	36.00	-	303.4	4.00	120.00	138.25	0.00	0.00	-
29	.65	427	41	137.4	44.8476	57.5333	3.50	96.50	126.5	276.7	1.00	34.00	128.79	0.50	15.00	-
30	.75	509	57	0.0	44.8656	57.9857	0.00	0.00	-	-	0.00	0.00	-	0.00	0.00	-
31	.81	524	52	85.9	44.6416	58.3567	2.25	54.00	99.0	131.0	2.00	52.00	121.50	0.00	0.00	-
32	.86	567	51	9.5	44.6452	58.3469	4.25	105.75	-	152.2	4.00	111.33	83.33	0.00	0.00	-
33	.82	517	51	24.2	44.5415	59.0600	1.00	29.00	-	193.3	4.00	114.00	119.25	0.00	0.00	-
34	.72	497	52	0.9	44.5428	59.0521	0.25	9.50	103.4	166.7	1.00	28.00	128.44	0.00	0.00	-
35	.76	582	53	-	44.5422	59.0614	1.00	27.00	-	162.7	4.00	96.00	118.23	0.00	0.00	-
36	.62	415	61	-	44.5007	59.2514	1.25	35.50	-	195.8	5.00	140.00	91.21	0.00	0.00	-
37	.83	562	60	-	44.5023	59.2522	2.50	67.00	111.5	-	3.00	75.00	105.04	0.00	0.00	-
38	.75	497	59	137.4	44.4982	59.2553	1.00	27.00	111.0	198.5	3.75	101.00	109.89	0.00	0.00	-

Table 1. Continued.

Tow #	Speed m/sec	Dist towed	Depth m	Volume bushels	Latitude north	Longitude west	Arctic Surfclams bu	kg	mm[1]	g/clam	Northern Propellerclams bu	kg	g/clam	Ocean Quahogs bu	kg	g/clam
39	.66	420	55	17.0	44.5096	59.3409	3.00	80.00	-	167.7	2.00	64.00	109.48	0.00	0.00	-
40	.65	429	55	188.9	44.5114	59.3388	3.25	86.00	109.0	193.2	2.25	66.50	106.78	0.00	0.00	-
41	.64	409	58	240.3	44.5113	59.3275	3.75	98.50	-	-	1.75	53.50	-	0.00	0.00	-
42	.79	530	49	137.4	44.5095	59.4711	6.50	169.50	104.2	157.1	5.00	151.25	103.56	0.00	0.00	-
43	.79	535	47	17.0	44.5119	59.4698	3.50	89.00	107.2	167.8	2.50	72.50	110.49	0.00	0.00	-
44	.71	459	49	17.0	44.5077	59.4683	3.75	93.75	-	178.8	1.75	50.00	105.45	0.00	0.00	-
45	.79	521	52	42.7	44.5000	59.5178	4.00	104.00	105.1	174.5	4.00	119.00	111.31	0.00	0.00	-
46	.74	506	53	188.9	44.5015	59.5158	0.75	18.50	-	152.9	0.75	17.00	103.03	0.00	0.00	-
47	.73	479	50	68.4	44.5029	59.5196	4.50	113.50	-	165.5	4.75	138.94	96.94	0.00	0.00	-
48	.71	468	55	188.9	44.4841	59.5673	2.00	47.00	105.2	166.7	0.75	23.50	100.86	0.25	3.50	205.88
49	.75	532	56	68.4	44.4832	59.5632	1.75	48.00	-	167.7	2.33	77.76	105.18	0.25	6.50	196.97
50	.67	446	54	240.3	44.4865	59.5666	3.50	95.00	-	173.2	6.25	193.75	99.36	0.50	11.00	224.49
51	.73	478	52	291.8	44.4872	59.5807	3.50	92.00	-	168.9	2.50	62.50	108.36	0.50	15.00	-
52	.75	519	54	240.3	44.4795	59.5887	3.00	75.00	-	166.7	2.50	70.00	118.64	0.50	8.00	400.00
53	.73	490	51	137.4	44.4846	59.5908	2.75	74.00	105.6	171.8	1.50	43.50	109.02	0.75	19.00	271.43
54	.69	454	50	188.9	44.4875	59.6000	3.00	73.00	-	167.8	1.00	28.50	112.65	0.50	5.50	229.17
55	.57	378	50	188.9	44.4845	59.6006	2.00	45.00	104.2	164.1	1.00	30.50	109.32	0.00	0.00	-
56	.62	417	51	85.9	44.4833	59.6154	1.00	26.00	-	169.9	0.50	11.00	107.84	0.00	0.00	-
57	.64	428	49	85.9	44.4825	59.6190	1.50	40.00	105.8	178.1	0.50	14.00	119.66	0.00	0.00	-
58	.60	393	50	85.9	44.4751	59.6337	1.25	47.00	-	162.8	0.75	20.00	111.11	0.25	3.50	291.67
59	.68	450	50	85.9	44.4754	59.6390	1.00	24.00	100.5	158.9	0.10	3.00	115.38	0.01	1.00	333.33
60	.65	418	50	34.5	44.4666	59.6512	0.50	14.00	104.4	168.7	4.00	96.00	81.63	0.25	5.50	203.70
61	.72	533	48	119.9	44.4671	59.6664	1.00	28.00	99.5	151.4	0.75	20.00	97.56	0.25	5.50	161.76
62	.71	479	49	9.7	44.4469	59.6891	2.25	57.50	100.8	139.2	1.00	31.50	101.29	0.00	0.00	-
63	.63	423	48	17.0	44.4529	59.6854	5.75	146.50	-	-	3.00	91.50	100.68	0.00	0.00	-
64	.68	441	47	42.7	44.4522	59.7004	5.75	152.00	99.7	147.6	2.25	66.00	98.68	0.10	1.50	250.00
65	.76	490	47	42.7	44.4461	59.7036	4.25	106.50	-	156.6	1.00	30.00	102.74	0.00	0.00	-
66	.83	579	75	119.9	44.1521	58.7782	5.00	120.50	89.2	99.2	7.00	206.50	78.38	0.00	0.00	-
67	.82	526	73	291.8	44.1527	58.7783	8.00	208.50	-	96.1	22.00	704.00	80.81	0.00	0.00	-
68	.92	722	74	260.9	44.1496	58.7153	5.00	115.00	91.0	110.6	16.00	480.00	77.72	0.00	0.00	-
69	.84	554	74	-	44.1481	58.7227	3.00	74.00	-	130.4	12.00	288.00	76.19	0.00	0.00	-
70	.82	530	79	-	44.1477	58.6660	2.50	53.00	87.5	84.7	4.00	100.00	65.79	0.00	0.00	-
71	.61	404	77	34.5	44.1507	58.6707	2.00	46.00	-	87.9	5.00	125.00	71.02	0.00	0.00	-
72	.79	522	84	0.0	44.1677	58.5010	0.00	0.00	-	-	0.00	0.00	-	0.00	0.00	-
73	.76	499	54	34.5	44.2964	58.4837	1.00	28.00	83.3	81.6	3.00	90.00	100.33	0.00	0.00	-
74	.75	510	62	188.9	44.3506	58.3011	8.00	215.50	98.4	149.2	4.00	119.00	109.67	0.25	5.00	-
75	.71	465	63	119.9	44.3484	58.3014	2.25	59.50	-	127.3	4.75	149.63	108.20	0.02	0.50	250.00
76	.74	498	73	119.9	44.1547	58.7858	10.50	301.88	88.8	-	25.25	757.50	77.41	0.05	1.00	125.00

Table 1. Continued.

Tow #	Speed m/sec	Dist towed	Depth m	Volume bushels	Latitude north	Longitude west	Arctic Surfclams bu	kg	mm[1]	g/clam	Northern Propellerclams bu	kg	g/clam	Ocean Quahogs bu	kg	g/clam
77	.78	527	77	17.0	44.1462	58.7890	6.50	158.75	88.3	98.8	6.00	180.00	-	0.05	1.00	333.33
78	.80	530	75	119.9	44.1508	58.7893	8.00	184.00	-	104.8	24.75	792.00	74.42	0.01	0.25	104.76
79	.73	909	47	68.4	44.4506	59.7026	1.00	26.00	99.5	135.4	1.25	37.50	90.64	0.00	0.00	-
80	.74	480	55	14.0	44.4502	59.8443	4.00	89.00	-	177.3	6.50	178.75	94.83	0.00	0.00	-
81	.80	539	55	85.9	44.4515	59.8539	7.00	173.00	91.3	102.6	12.00	312.00	87.25	0.00	0.00	-
82	.73	516	48	-	44.0490	60.3014	0.00	0.00	-	-	0.00	0.00	-	0.00	0.00	-
83	.76	497	54	-	44.1180	60.6322	0.00	0.00	-	-	0.00	0.00	-	0.00	0.00	-
84	.68	446	31	3.6	44.5037	60.4321	0.05	0.25	-	-	0.10	1.25	-	0.10	2.75	-
85	.69	450	45	171.4	44.5423	60.3763	4.75	117.50	93.6	128.3	12.75	398.44	67.09	6.00	177.40	129.12
86	.73	505	63	188.9	44.6660	60.4120	0.00	0.00	-	-	0.00	0.00	-	0.00	0.00	-
87	.86	569	58	9.7	44.6212	60.3948	0.00	0.00	-	-	0.00	0.00	-	0.00	0.00	-
88	.73	485	53	137.4	44.4619	60.3278	0.00	0.00	-	-	0.00	0.00	-	0.00	0.00	-
89	.76	511	58	137.4	44.3653	60.3858	6.50	152.00	94.8	115.7	8.25	251.63	75.52	0.10	2.50	-
90	.75	499	60	42.7	44.3617	60.3973	4.50	103.25	-	177.5	10.25	298.50	67.63	0.33	7.50	92.59
91	.74	494	58	119.9	44.3627	60.3882	6.00	155.00	-	126.3	10.50	280.88	79.34	0.33	10.00	90.91
92	.65	427	55	85.9	44.4696	60.7466	4.75	103.00	-	105.5	3.00	84.00	57.49	1.00	36.00	126.76
93	.71	473	56	85.9	44.4650	60.7510	3.00	69.00	90.2	106.1	6.00	162.00	54.00	5.00	142.50	96.61
94	.73	491	71	-	44.4061	60.8229	0.00	0.00	-	-	0.00	0.00	-	0.00	0.00	-
95	.68	442	55	34.5	44.3898	60.6186	4.00	93.00	-	-	5.50	154.00	90.03	0.10	1.00	-
96	.67	447	54	34.5	44.3863	60.6257	3.50	91.00	96.4	132.3	8.50	238.00	77.78	0.15	1.25	125.00
97	.71	492	56	68.4	44.4687	60.7400	4.75	125.28	-	184.0	6.00	165.00	56.02	5.00	147.50	97.76
98	.70	454	60	94.2	44.4764	60.7368	3.50	91.00	92.9	134.7	8.33	228.03	-	4.75	133.00	106.87
99	.65	423	57	42.7	44.4737	60.7442	5.75	142.60	-	120.9	9.50	258.88	59.23	5.00	138.33	105.07
100	.70	449	80	-	44.5271	60.9010	0.00	0.00	-	-	0.00	0.00	-	0.00	0.00	-
101	.62	397	65	42.7	44.5870	60.8309	0.00	0.00	-	-	0.00	0.00	-	0.00	0.00	-
102	.61	388	53	-	44.6507	60.7508	0.00	0.00	-	-	0.00	0.00	-	0.00	0.00	-
103	.79	519	37	68.4	44.6842	60.6168	0.10	0.25	-	-	15.50	410.75	130.43	0.75	18.00	156.86
104	.76	496	55	85.9	44.4568	59.8492	3.75	93.00	-	98.1	8.00	240.00	70.59	0.00	0.00	-
105	.76	500	55	85.9	44.4572	59.8717	5.00	119.00	91.6	111.6	7.00	182.00	92.86	0.00	0.00	-
106	.78	539	55	85.9	44.4664	59.8613	5.50	140.00	-	105.3	8.00	216.00	93.75	0.00	0.00	-
107	.67	447	56	-	44.4857	59.8253	0.00	0.00	-	-	0.00	0.00	-	0.00	0.00	-
108	.79	530	56	85.9	44.4917	59.7646	3.00	71.00	94.8	116.2	10.00	260.00	79.03	0.00	0.00	-
109	.71	476	57	34.5	44.4915	59.7685	2.50	59.50	-	147.1	7.00	203.00	92.36	0.00	0.00	150.00
110	.70	464	61	-	44.5249	59.8419	0.00	0.00	-	-	0.00	0.00	-	0.00	0.00	-
111	.70	456	49	68.4	44.5619	59.6505	3.00	77.25	94.1	127.3	5.50	149.88	104.74	0.00	0.00	-
112	.71	480	59	119.9	44.6153	59.6036	6.75	171.00	100.3	142.3	19.75	498.69	91.42	0.25	1.25	138.89
113	.69	476	59	68.4	44.6162	59.5927	6.75	161.50	99.7	146.3	26.25	702.19	160.71	0.25	2.25	96.30

[1] Mean shell length from length frequency samples.

Table 2. - Composition of survey bycatch by bank.

		Sable Island Bank			Banquereau Bank			Middle Bank			Total			
Common name	Scientific name	n	wgt (kg)	% wgt	n	wgt (kg)	% wgt	n	wgt (kg)	% wgt	n	wgt (kg)	% wgt	cum. %
Northern propellerclam	*Cyrtodaria siliqua*	75	7.00	14.3	1876	204.50	33.9	1147	117.50	45.3	3098	329.00	36.1	36.1
Shell	-	-	9.75	19.9	-	195.45	32.4	-	17.25	6.6	-	222.45	24.4	60.5
Arctic surfclam	*Mactromeris polynyma*	0	0.00	0.0	692	93.25	15.5	399	36.95	14.2	1091	130.20	14.3	74.8
Sand dollar	*Echinarachnius parma*	457	19.85	40.5	1397	61.95	10.3	866	37.45	14.4	2720	119.25	13.1	87.9
Ocean quahog	*Arctica islandica*	116	11.25	23.0	22	4.26	0.7	289	23.38	9.0	427	38.89	4.3	92.2
Rock	-	-	0.20	0.4	-	19.00	3.2	-	11.75	4.5	-	30.95	3.4	95.6
Sea cucumber	*Cucumaria frondosa*	1	0.25	0.5	24	10.00	1.7	8	3.75	1.4	33	14.00	1.5	97.1
Arctic wedge clam	*Mesodesma arctatum*	0	0.00	0.0	595	5.00	0.8	0	0	0.0	595	5.00	0.5	97.7
Sea mouse	*Aphrodita hastata*	4	0.32	0.7	16	2.24	0.4	20	2.44	0.9	40	5.00	0.5	98.2
Common starfish	*Asterias* and *Leptasterias sp.*	0	0.00	0.0	8	2.83	0.5	11	1.87	0.7	19	4.70	0.5	98.7
Mud	-	-	0.00	0.0	-	0	0.0	-	4.50	1.7	-	4.50	0.5	99.2
Brittle stars	*Ophiopholis sp.*	0	0.00	0.0	131	0.69	0.1	80	0.48	0.2	211	1.17	0.1	99.4
Whelks	Various genera	0	0.00	0.0	29	0.87	0.1	7	0.21	0.1	36	1.08	0.1	99.5
Rat tailed cucumber	*Caudina arenta*	0	0.00	0.0	3	1.03	0.2	0	0	0.0	3	1.03	0.1	99.6
Jonah crab	*Cancer borealis*	0	0.00	0.0	0	0	0.0	1	1.00	0.4	1	1.00	0.1	99.7
Sea urchin	*Strongylocentrotus droebachiensis*	1	0.03	0.1	26	0.08	0.0	20	0.58	0.2	47	0.69	0.1	99.8
Atlantic jacknife	*Ensis directus*	7	0.21	0.4	0	0	0.0	7	0.21	0.1	14	0.42	0.0	99.8
Greenland cockle	*Serripes groenlandicus*	1	0.07	0.1	4	0.32	0.1	0	0	0.0	5	0.39	0.0	99.9
Iceland scallop	*Chlamys islandica*	0	0.00	0.0	4	0.32	0.1	0	0	0.0	4	0.32	0.0	99.9
Hermit crab	*Pagurus sp.*	1	0.05	0.1	1	0.05	0.0	3	0.09	0.0	5	0.19	0.0	99.9
Purple sunstar	*Solaster endeca*	0	0.00	0.0	1	0.16	0.0	0	0	0.0	1	0.16	0.0	99.9
Basket star	*Gorgonocephalus arcticus*	0	0.00	0.0	1	0.14	0.0	0	0	0.0	1	0.14	0.0	100.0
Sand lance	*Ammodytes americanus*	0	0.00	0.0	9	0.09	0.0	3	0.03	0.0	12	0.12	0.0	100.0
Spiny sunstar	*Crossaster papposus*	0	0.00	0.0	1	0.07	0.0	1	0.02	0.0	2	0.09	0.0	100.0
Sea anenomae	Various genera	0	0.00	0.0	3	0.08	0.0	0	0	0.0	3	0.08	0.0	100.0
Northern moonsnail	*Euspira heros*	1	0.03	0.1	0	0	0.0	1	0.03	0.0	2	0.06	0.0	100.0
Blue mussel	*Mytilus edulis*	0	0.00	0.0	2	0.03	0.0	0	0	0.0	2	0.03	0.0	100.0
Sand worms	Various polychaetes	0	0.00	0.0	2	0.01	0.0	6	0.02	0.0	8	0.03	0.0	100.0
Blood stars	*Henricia sp.*	0	0.00	0.0	1	0.01	0.0	0	0	0.0	1	0.01	0.0	100.0
	Sums	664	49	100	4848	602	100	2869	260	100	8370	911	100	-

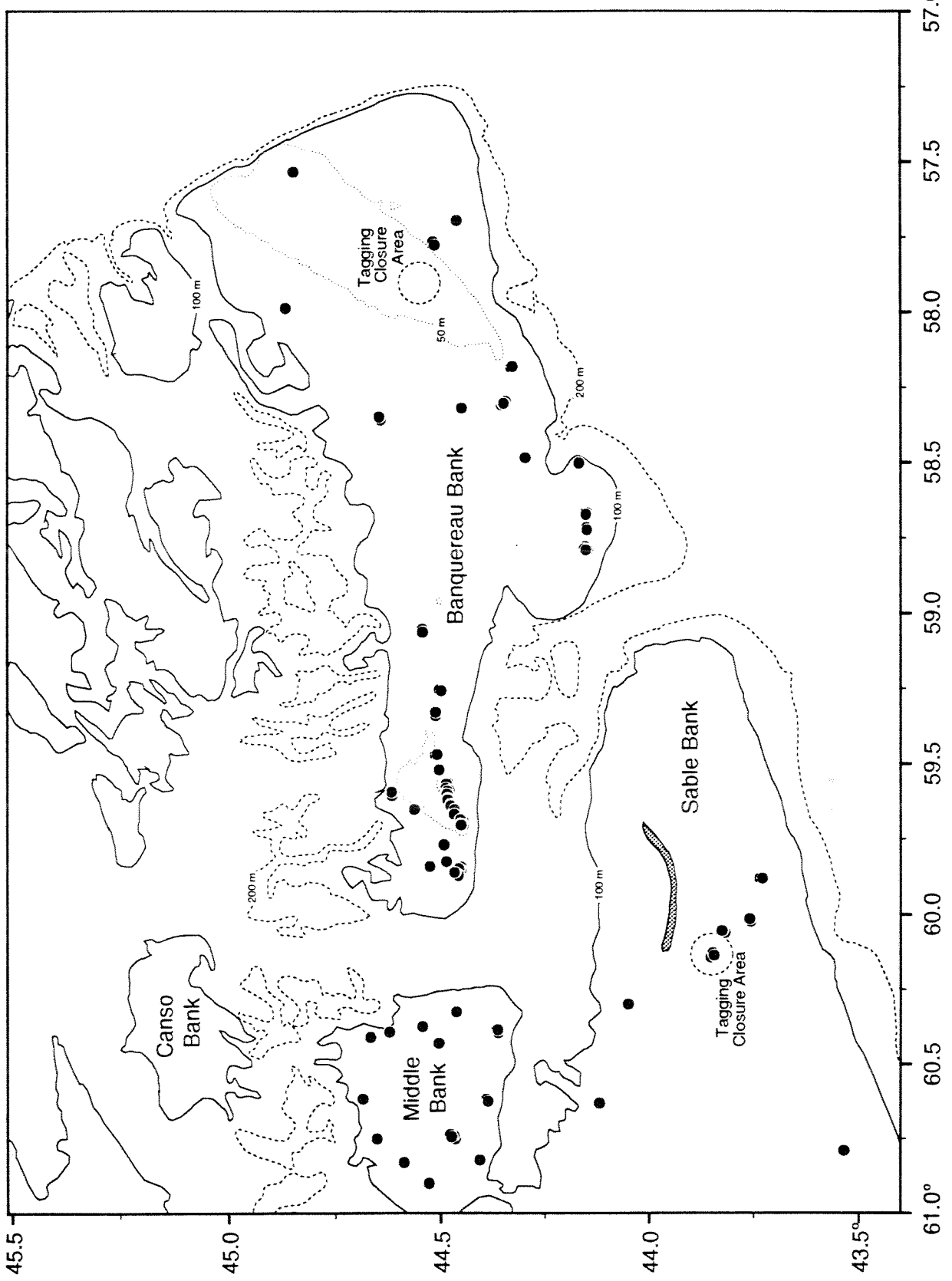

Figure 1. Tow locations for 1991 Arctic surfclam survey.

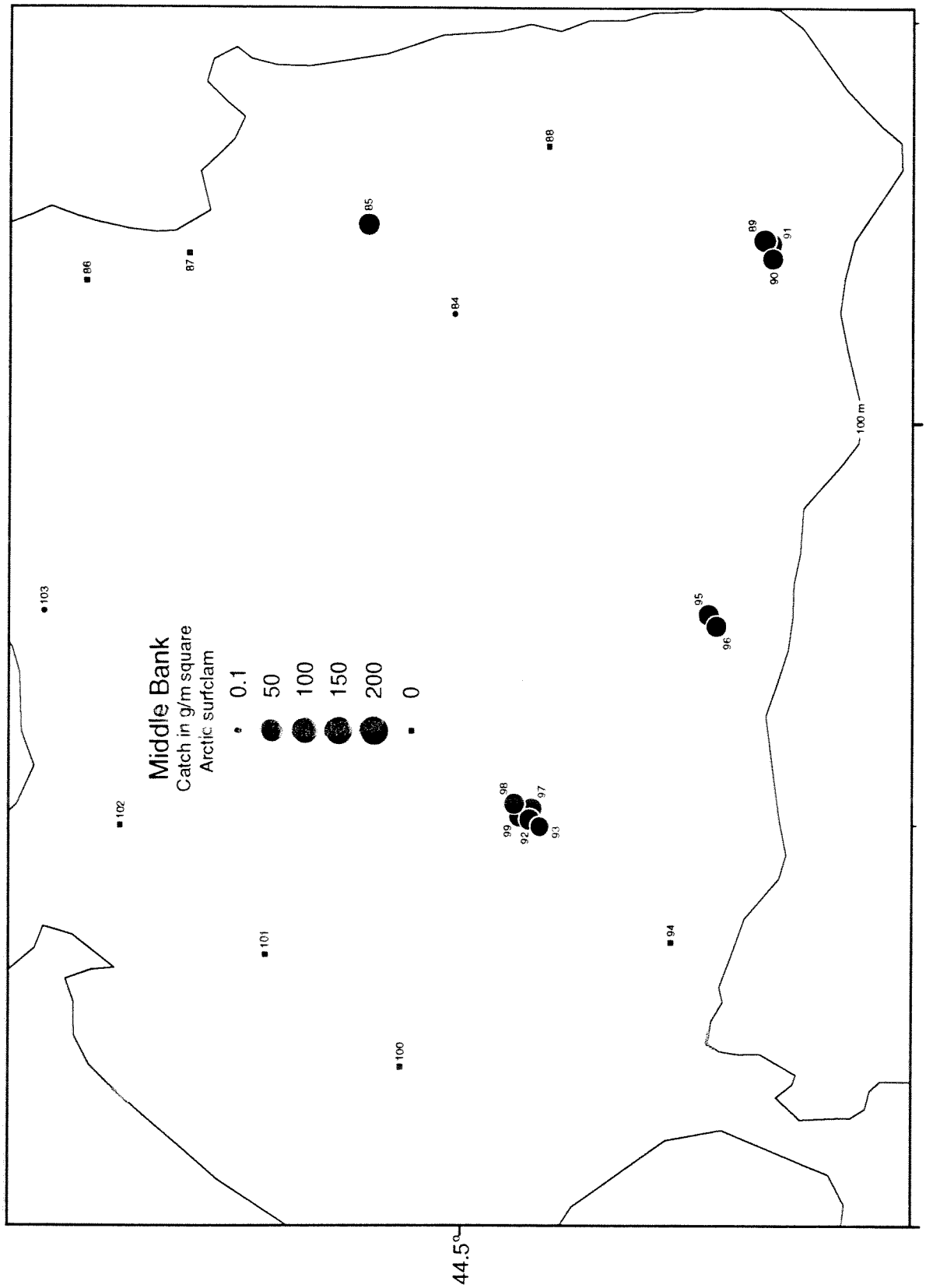

Figure 2. Catch rates for Arctic surfclams on Middle Bank stations.

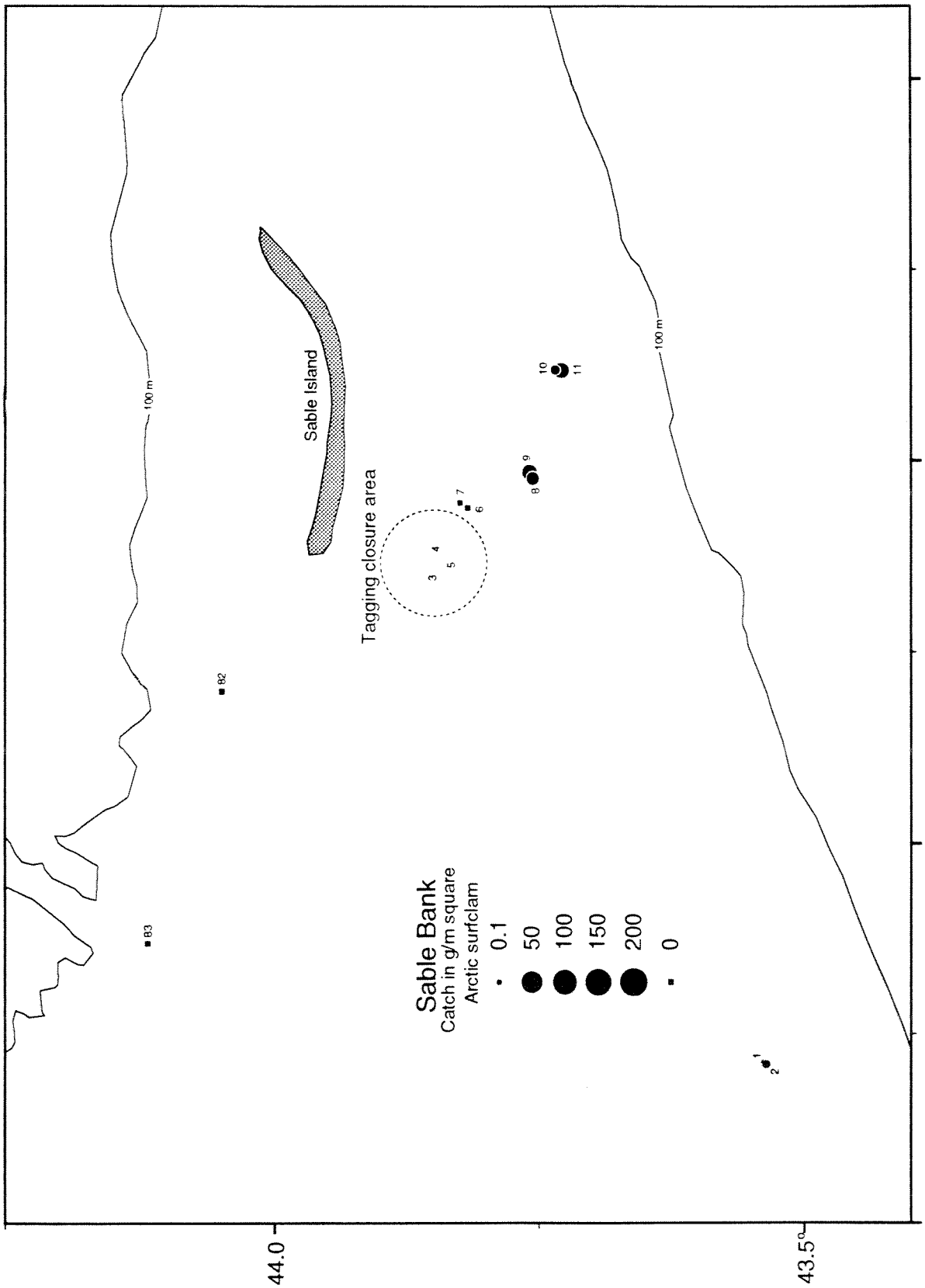

Figure 3. Catch rates for Arctic surfclams on Sable Bank stations.

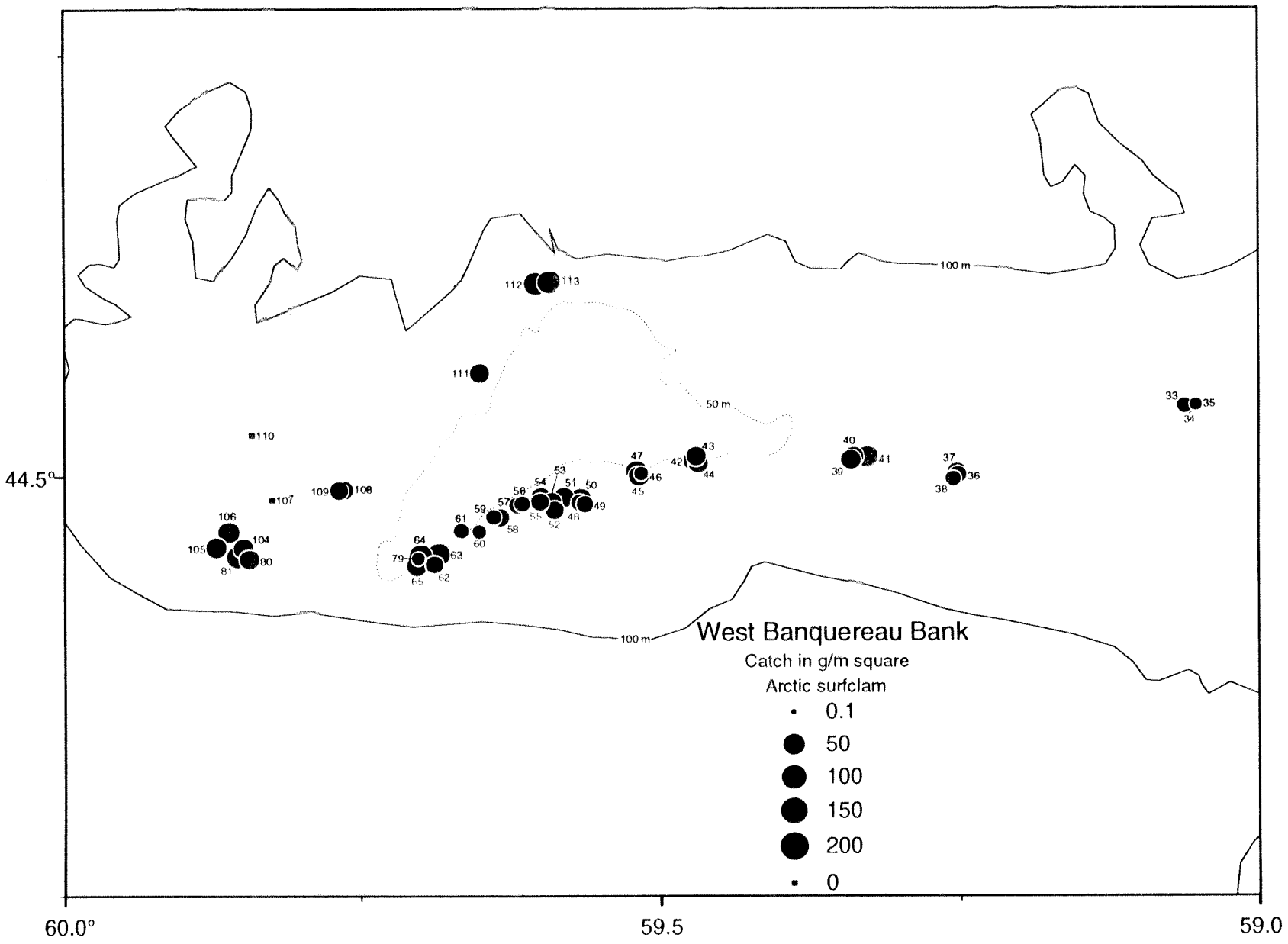

Figure 4. Catch rates for Arctic surfclams on Western Banquereau Bank stations.

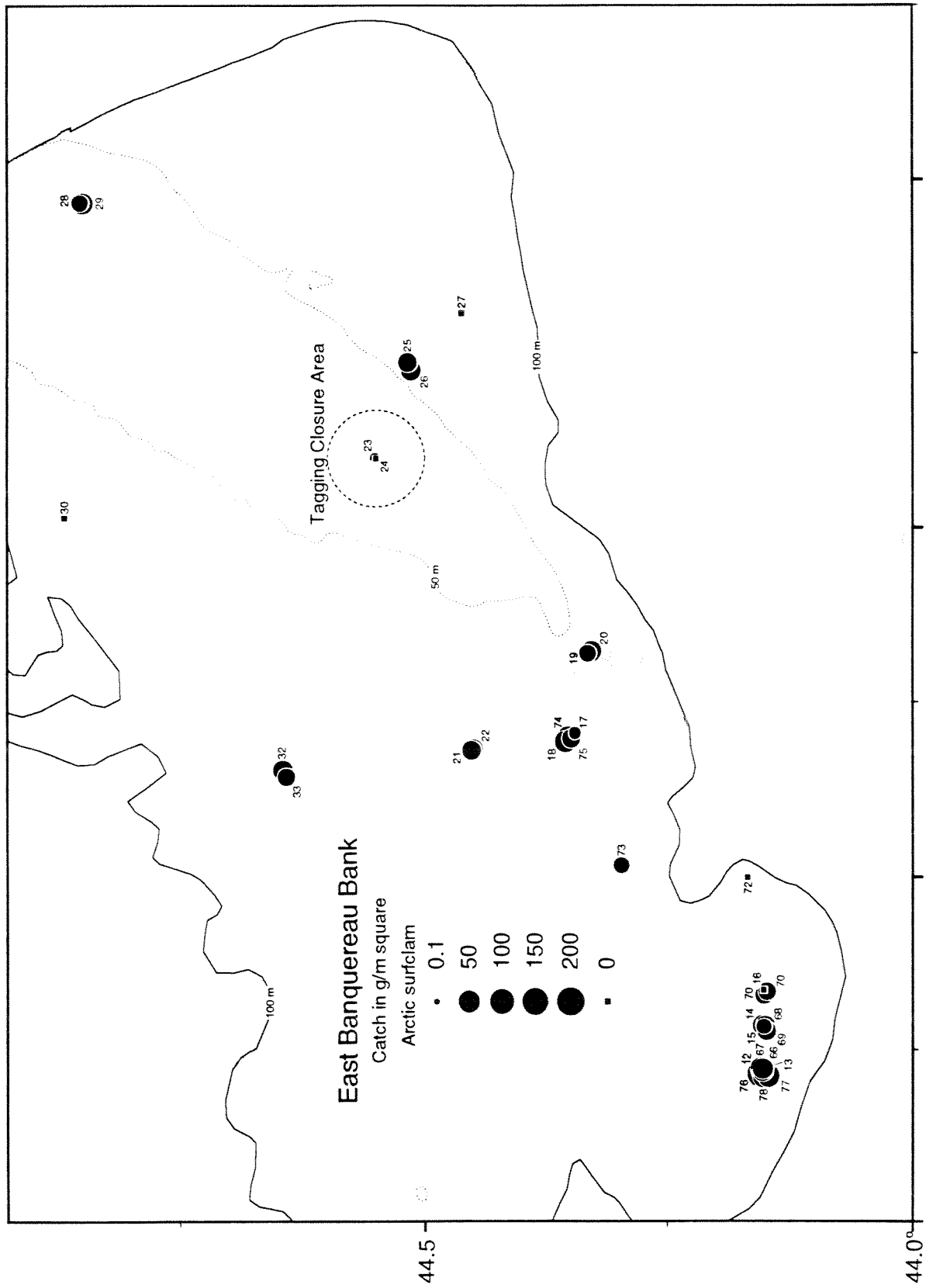

Figure 5. Catch rates for Arctic surfclams on Eastern Banquereau Bank stations.

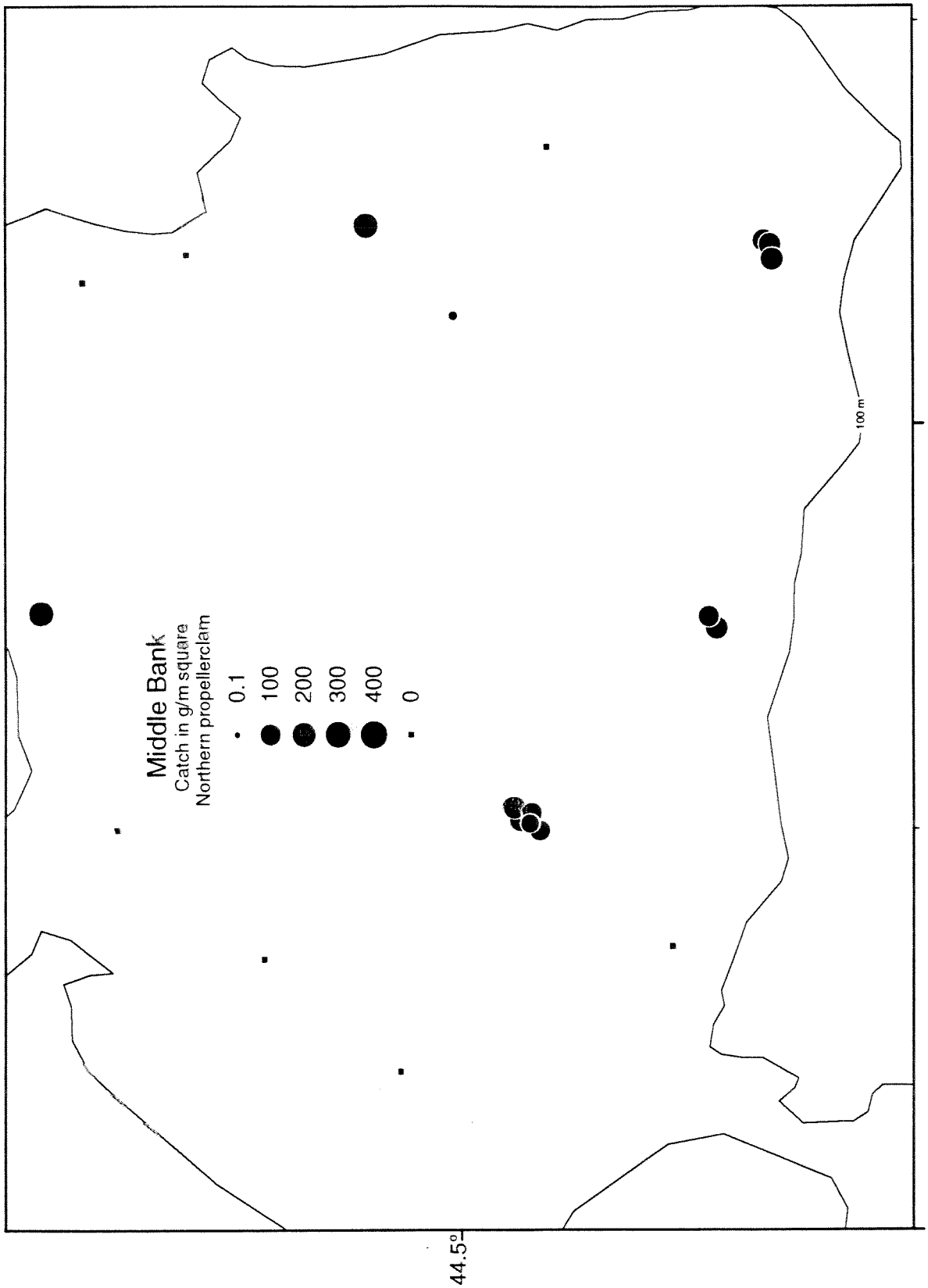

Figure 6. Catch rates for northern propellerclams on Middle Bank stations.

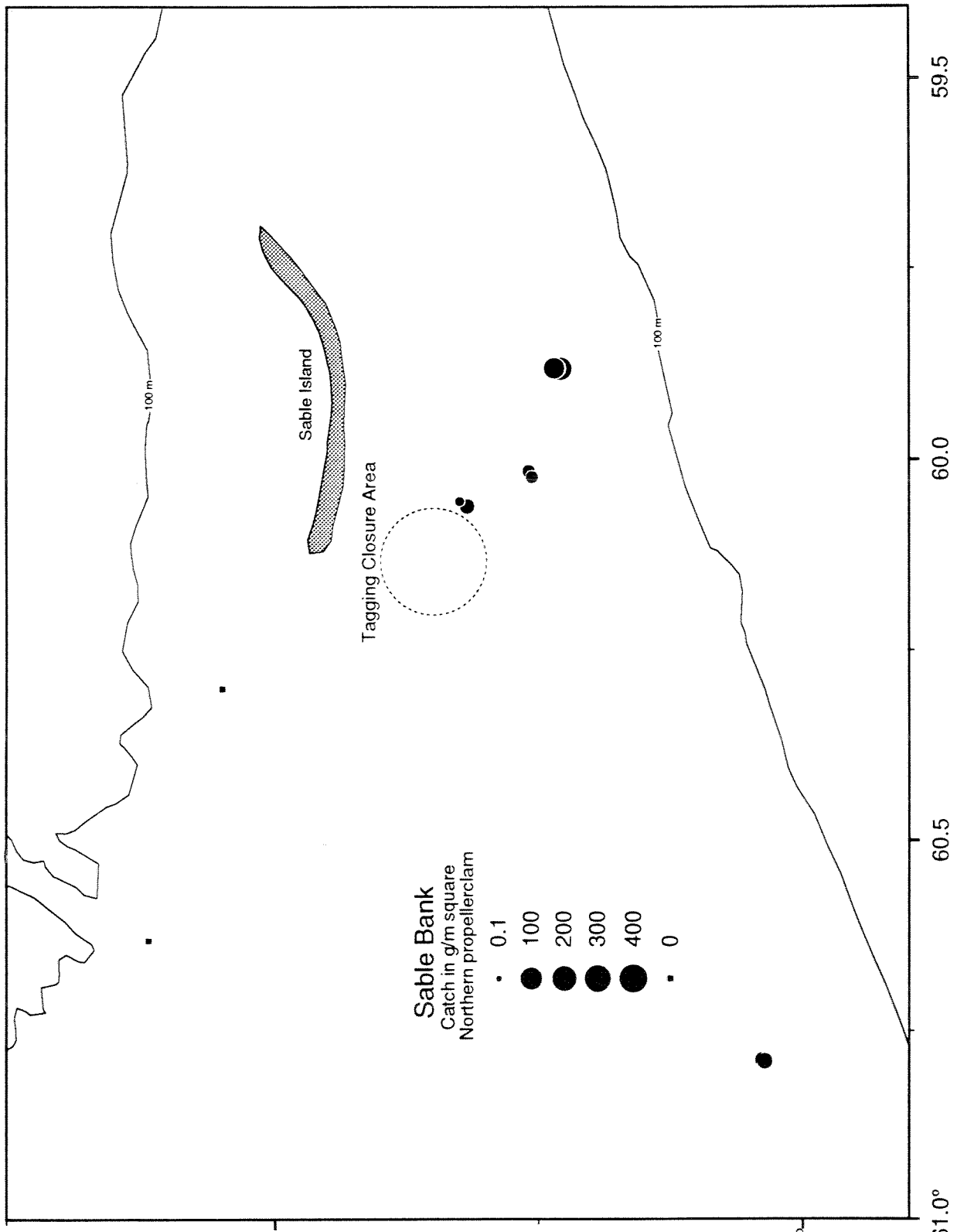

Figure 7. Catch rates for northern propellerclams on Sable Bank stations.

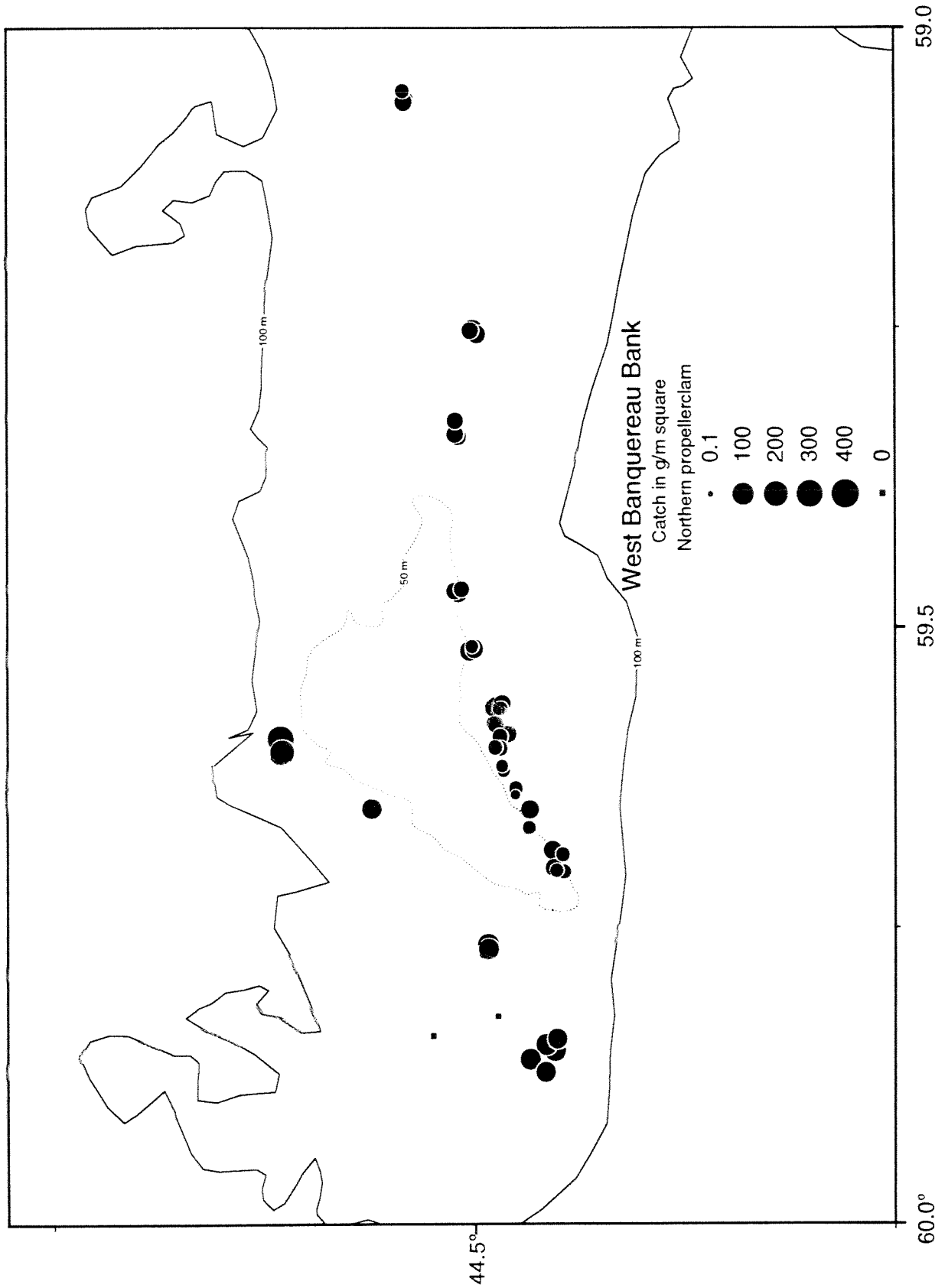

Figure 8. Catch rates for northern propellerclams on Western Banquereau Bank stations.

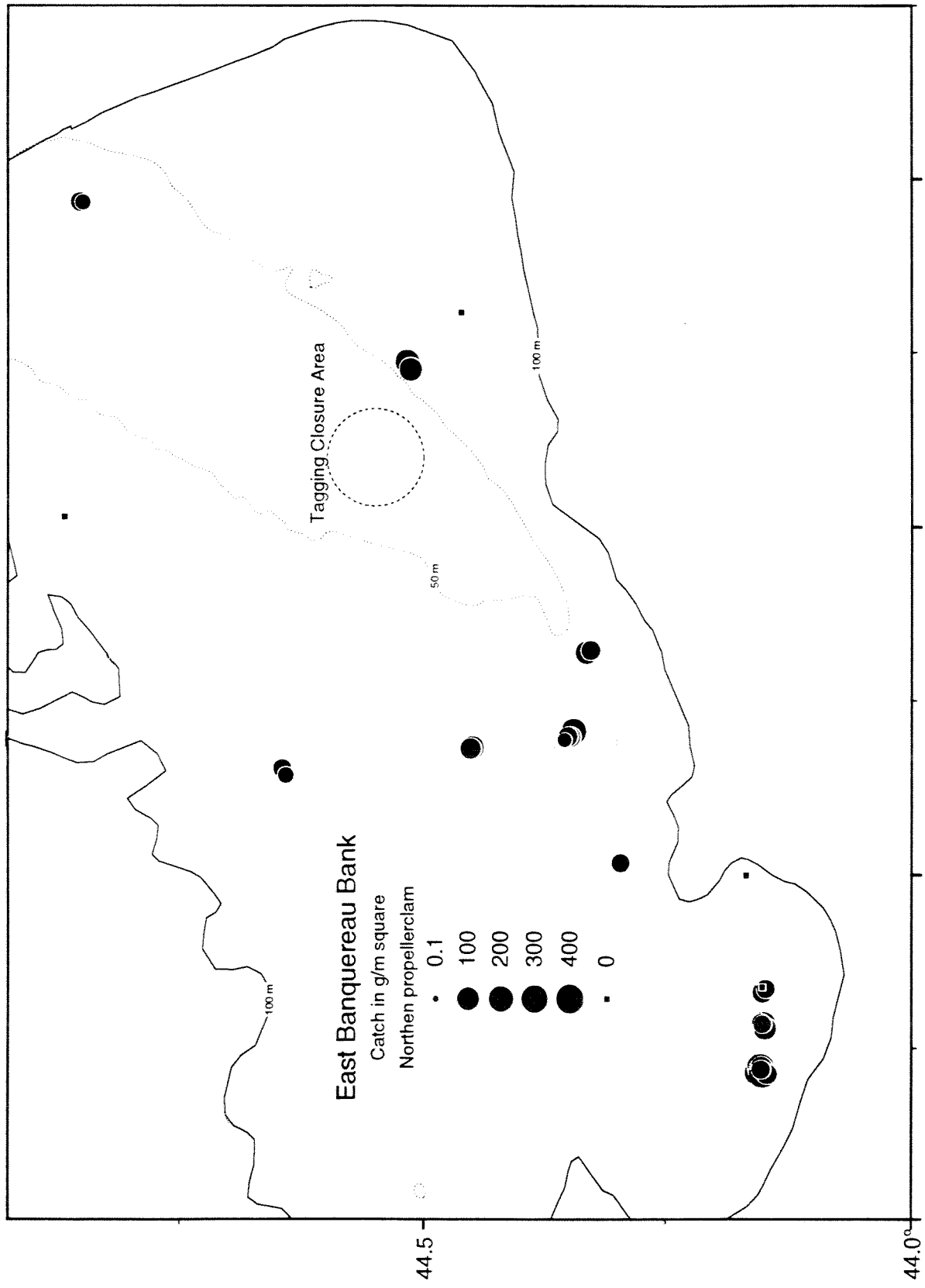

Figure 9. Catch rates for northern propellerclams on Eastern Banquereau Bank stations.

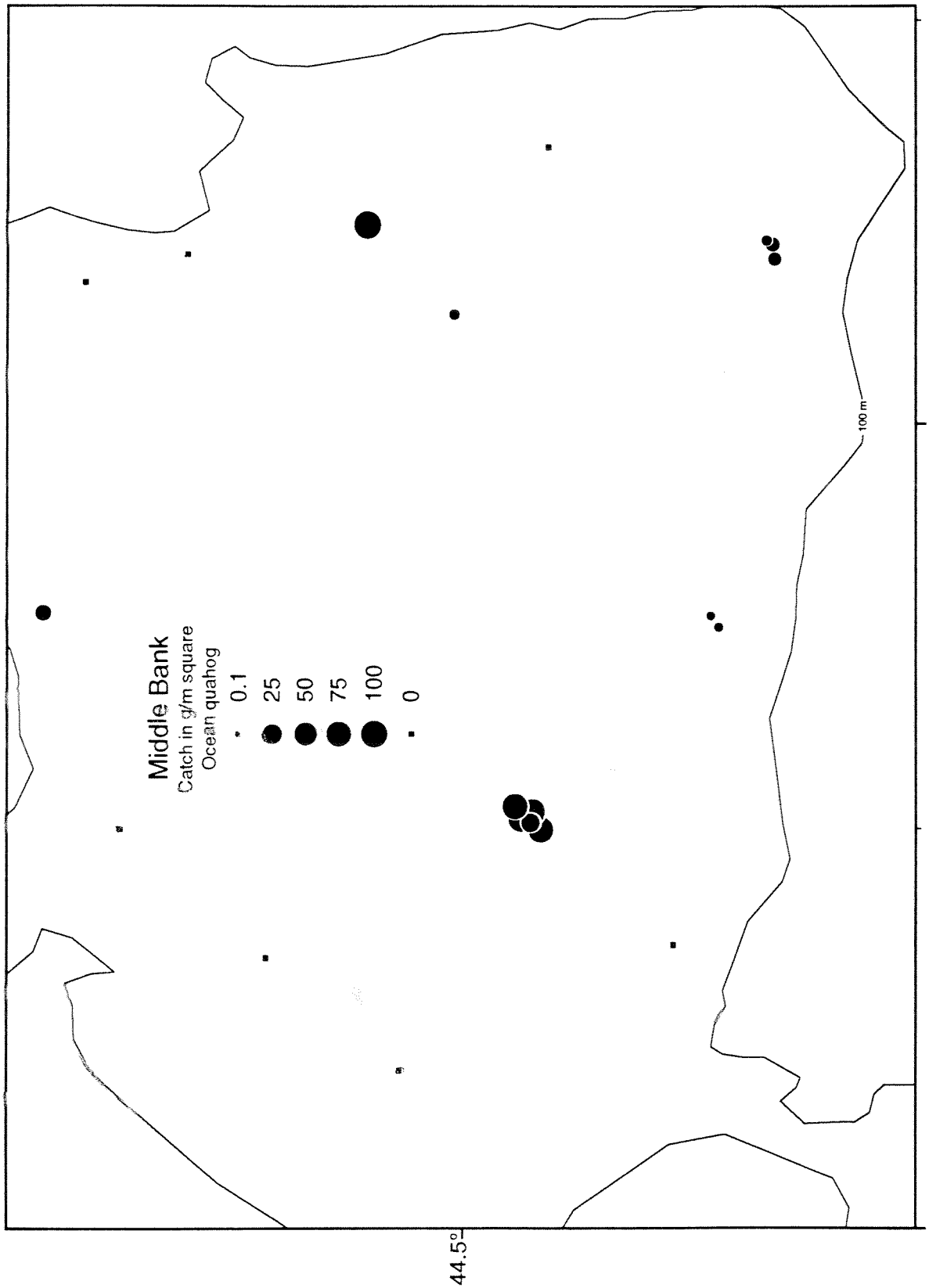

Figure 10. Catch rates for ocean quahogs on Middle Bank stations.

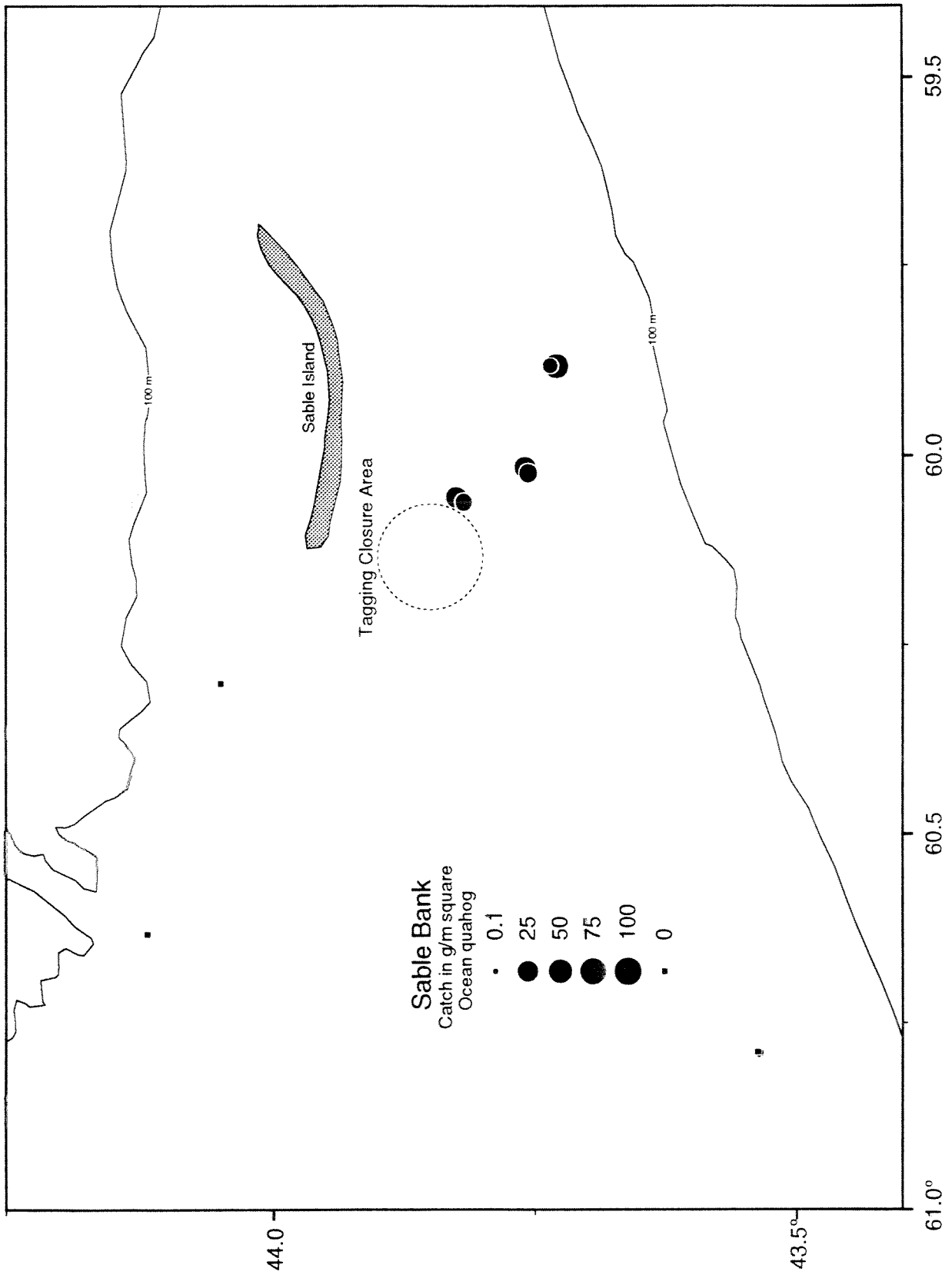

Figure 11. Catch rates for ocean quahogs on Sable Bank stations.

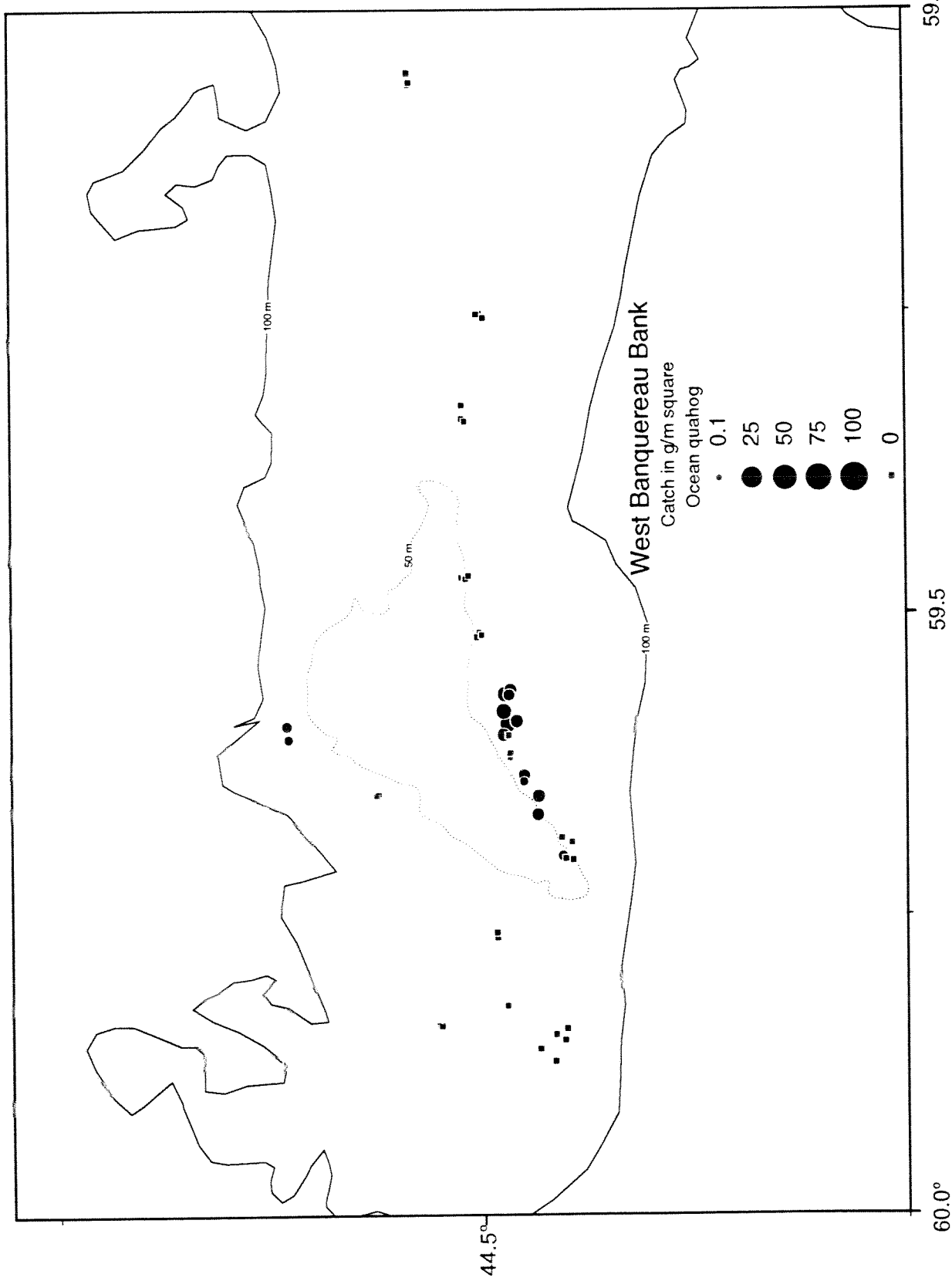

Figure 12. Catch rates for ocean quahogs on Western Banquereau Bank stations.

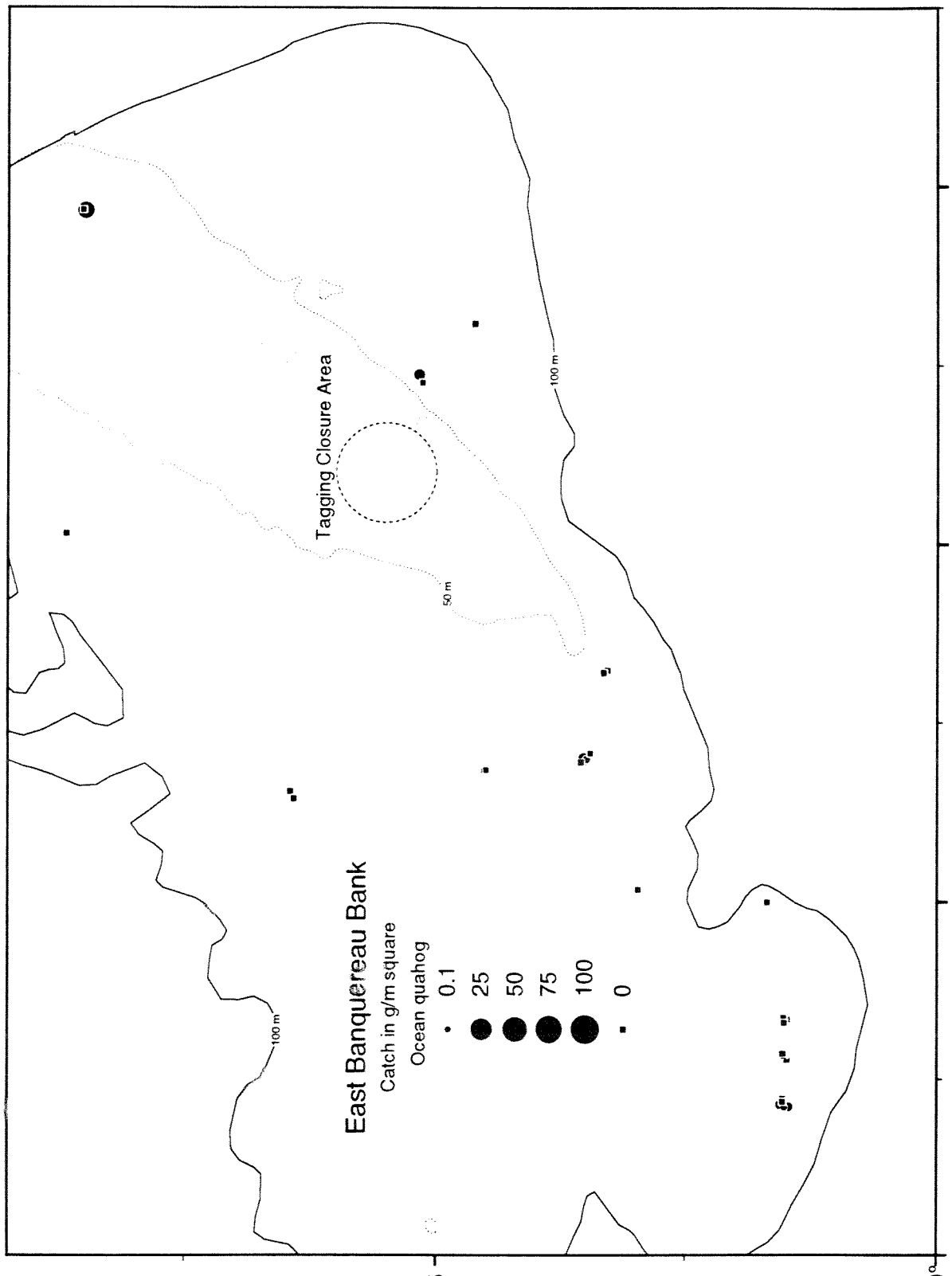

Figure 13. Catch rates for ocean quahogs on Eastern Banquereau Bank stations.

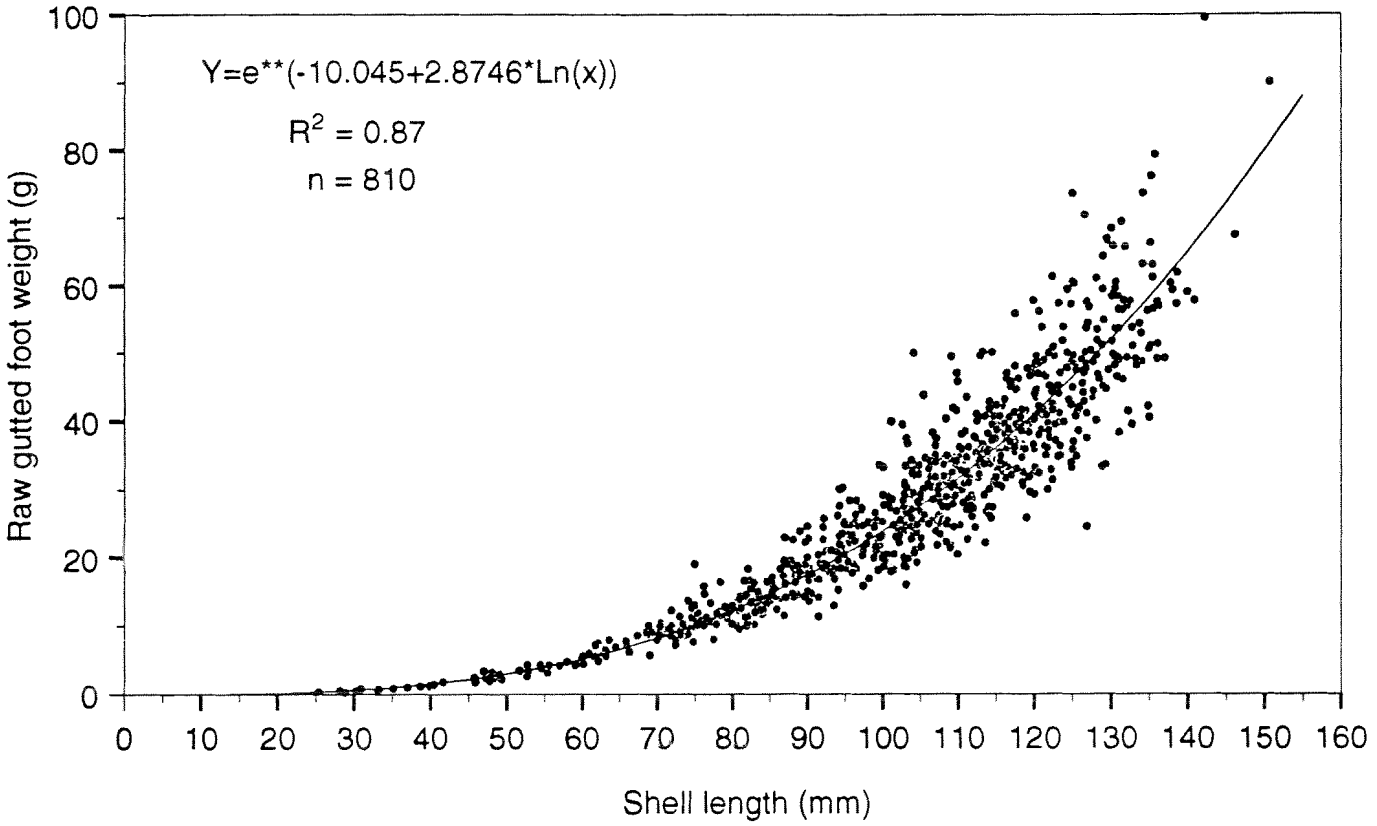

Figure 14. Regression of raw gutted foot weight against shell length for *Mactromeris polynyma*. Commercial fishery samples from the Scotian Shelf.

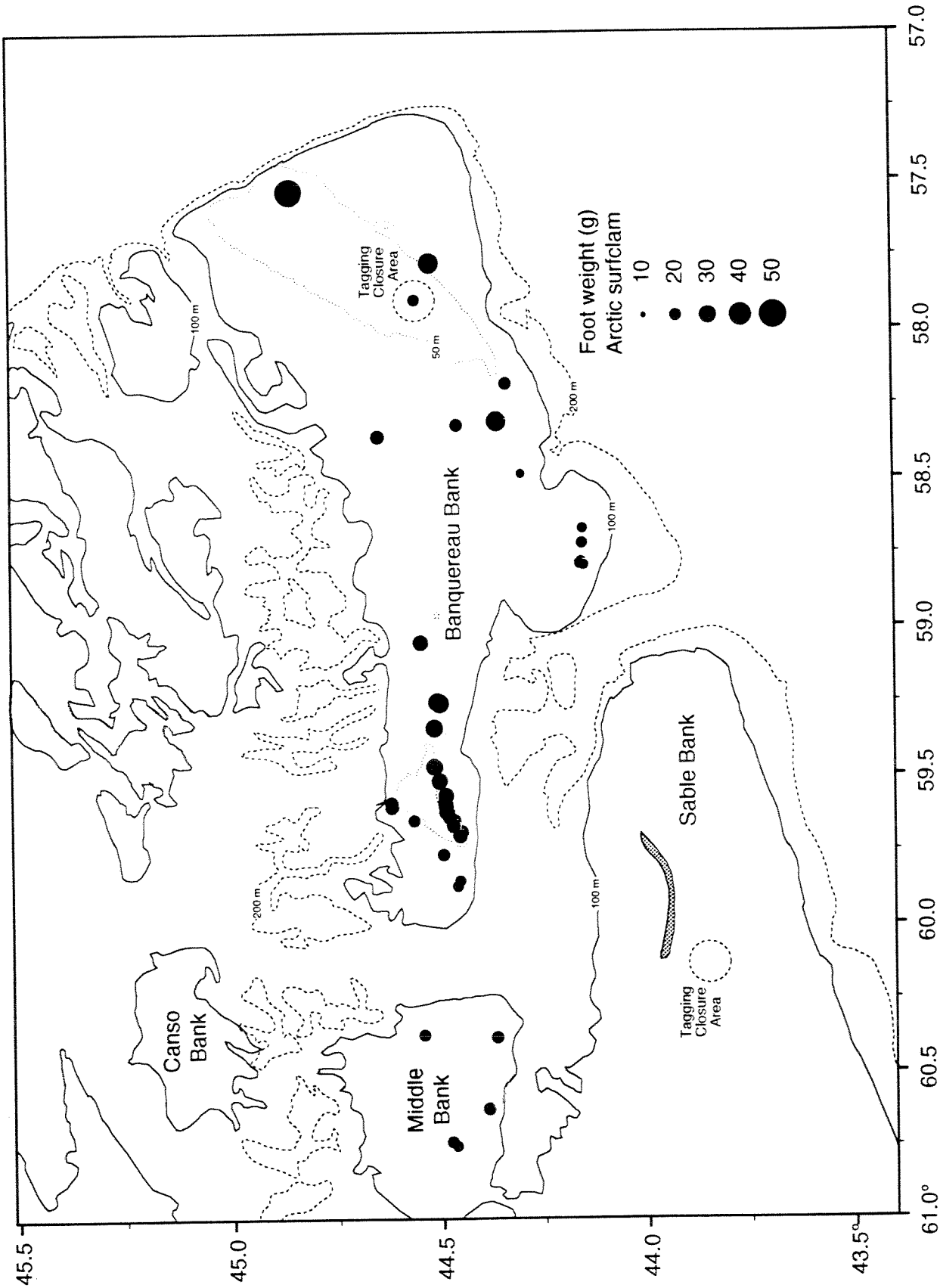

Figure 15. Estimated mean foot weight (g) of Arctic surfclams, converted from shell sizes.

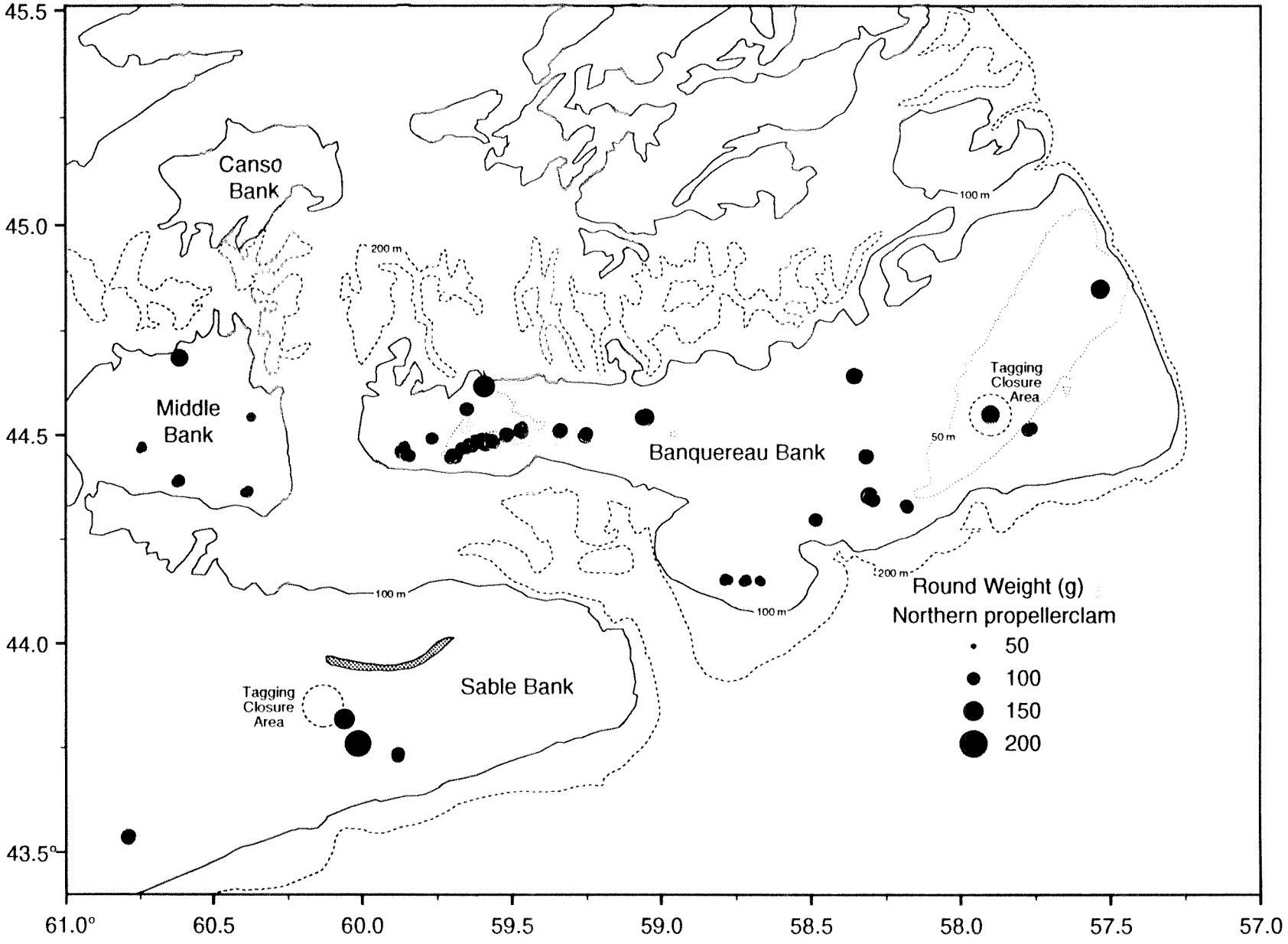

Figure 16. Mean round weight (g) of northern propellerclams in samples.

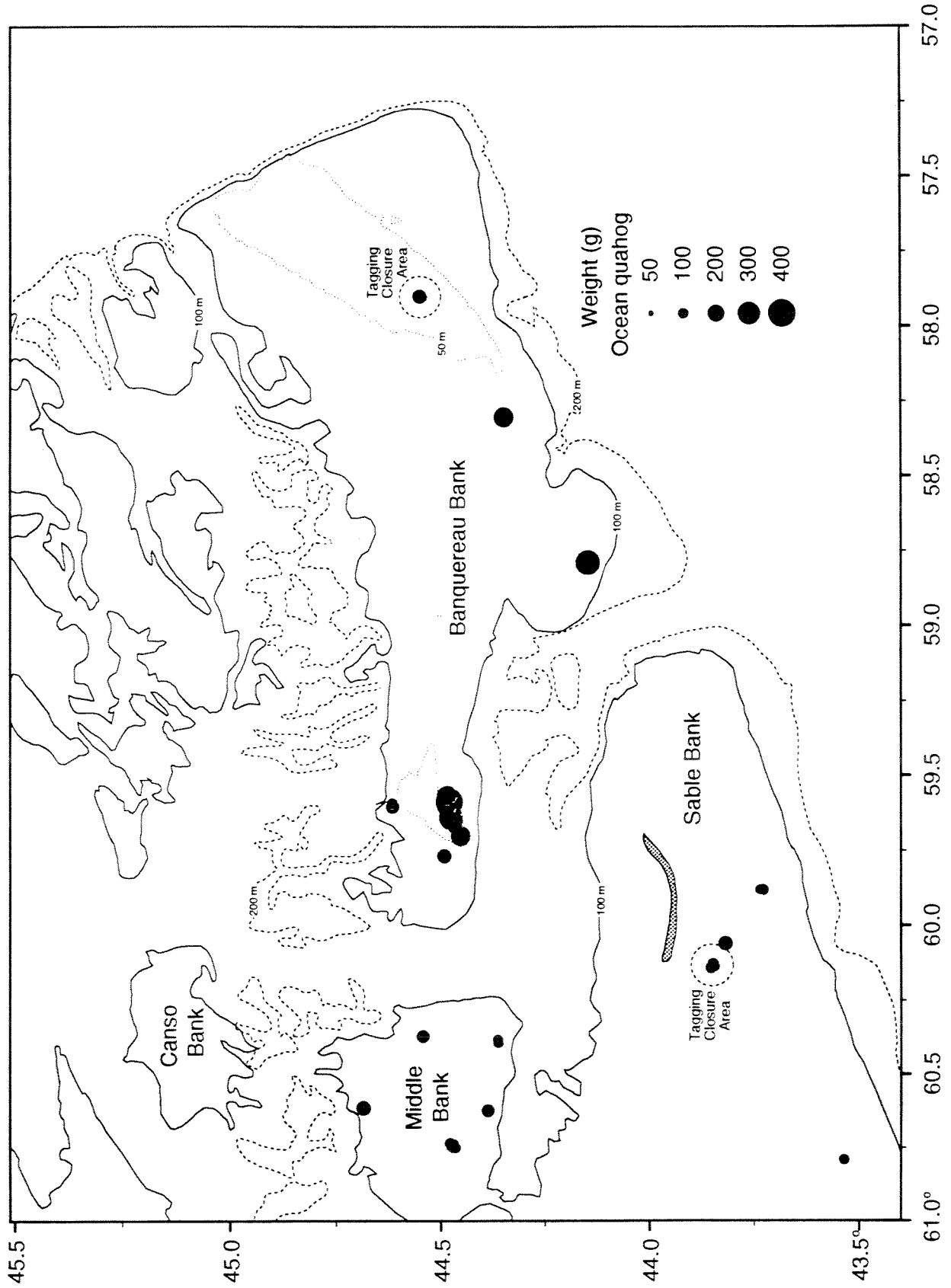

Figure 17. Mean round weight (g) of ocean quahogs in samples.

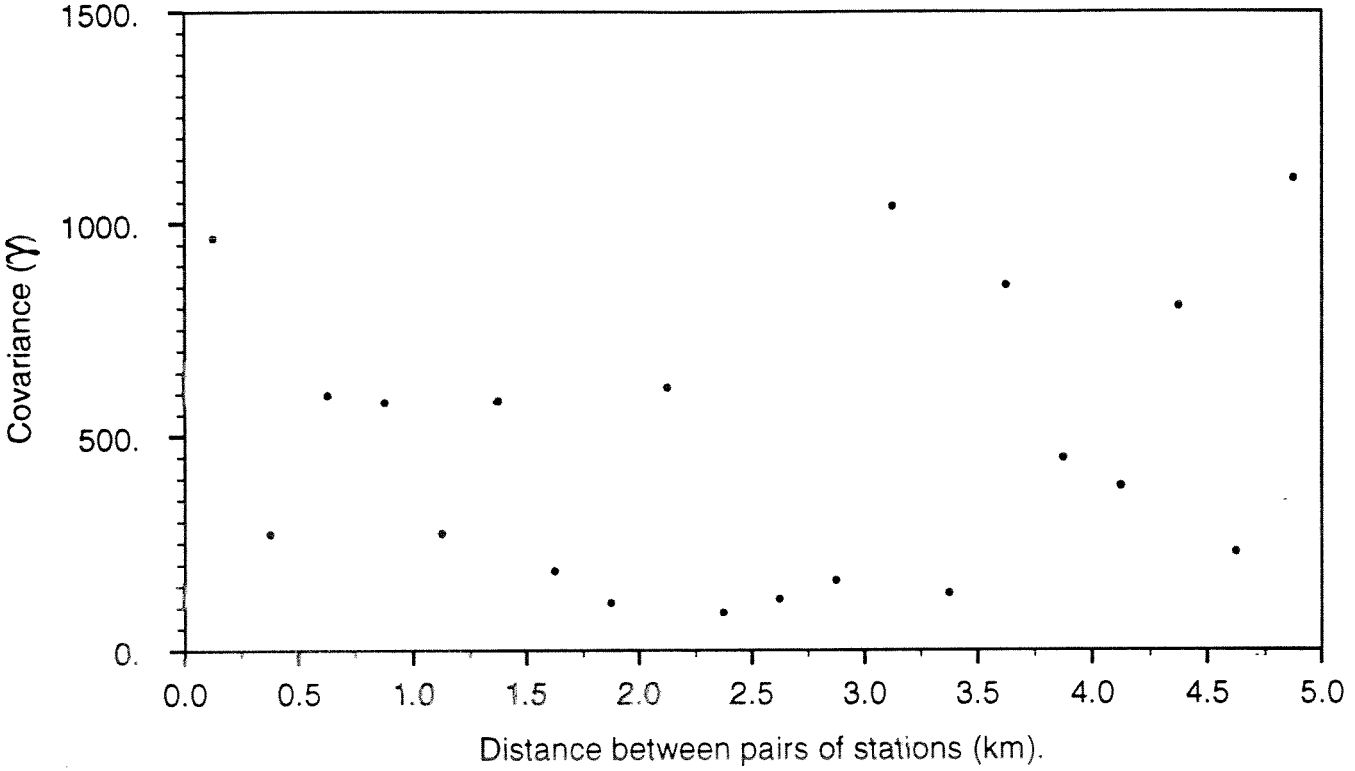

Figure 18. Semi-variogram of SS9101 survey data except stations 12-16, 27.

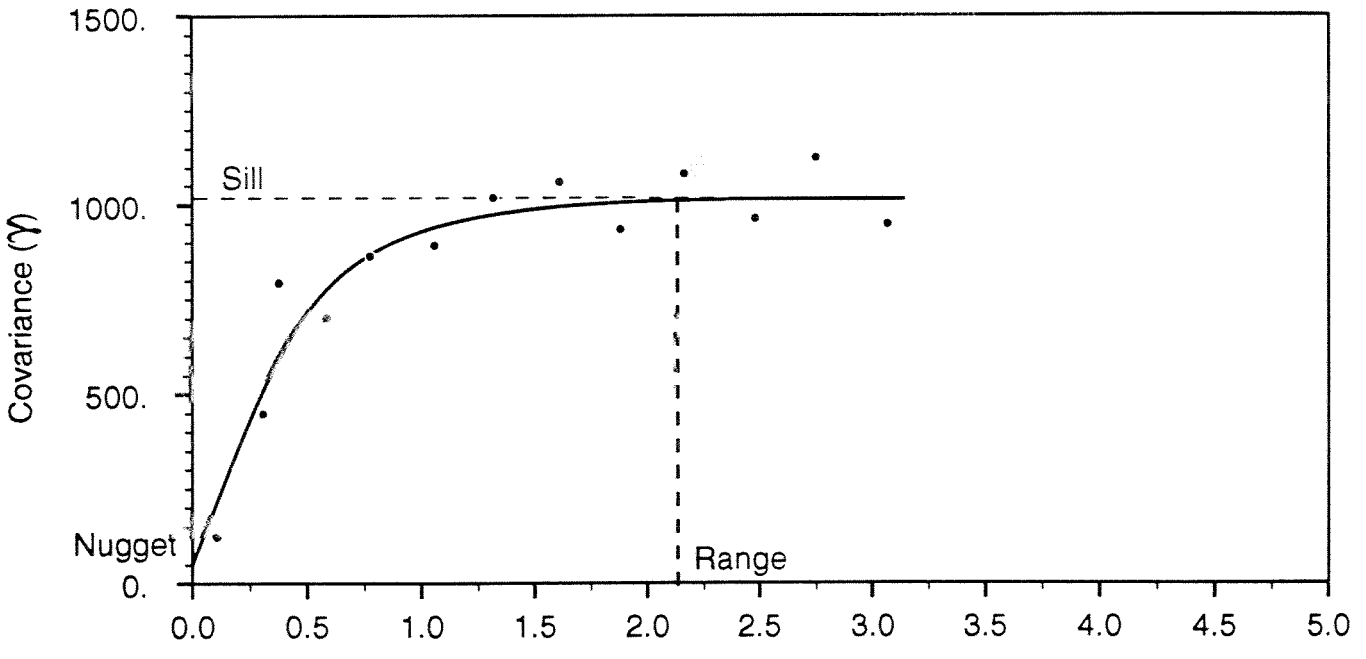

Figure 19. Theoretical semi-variogram showing sill, range and nugget.

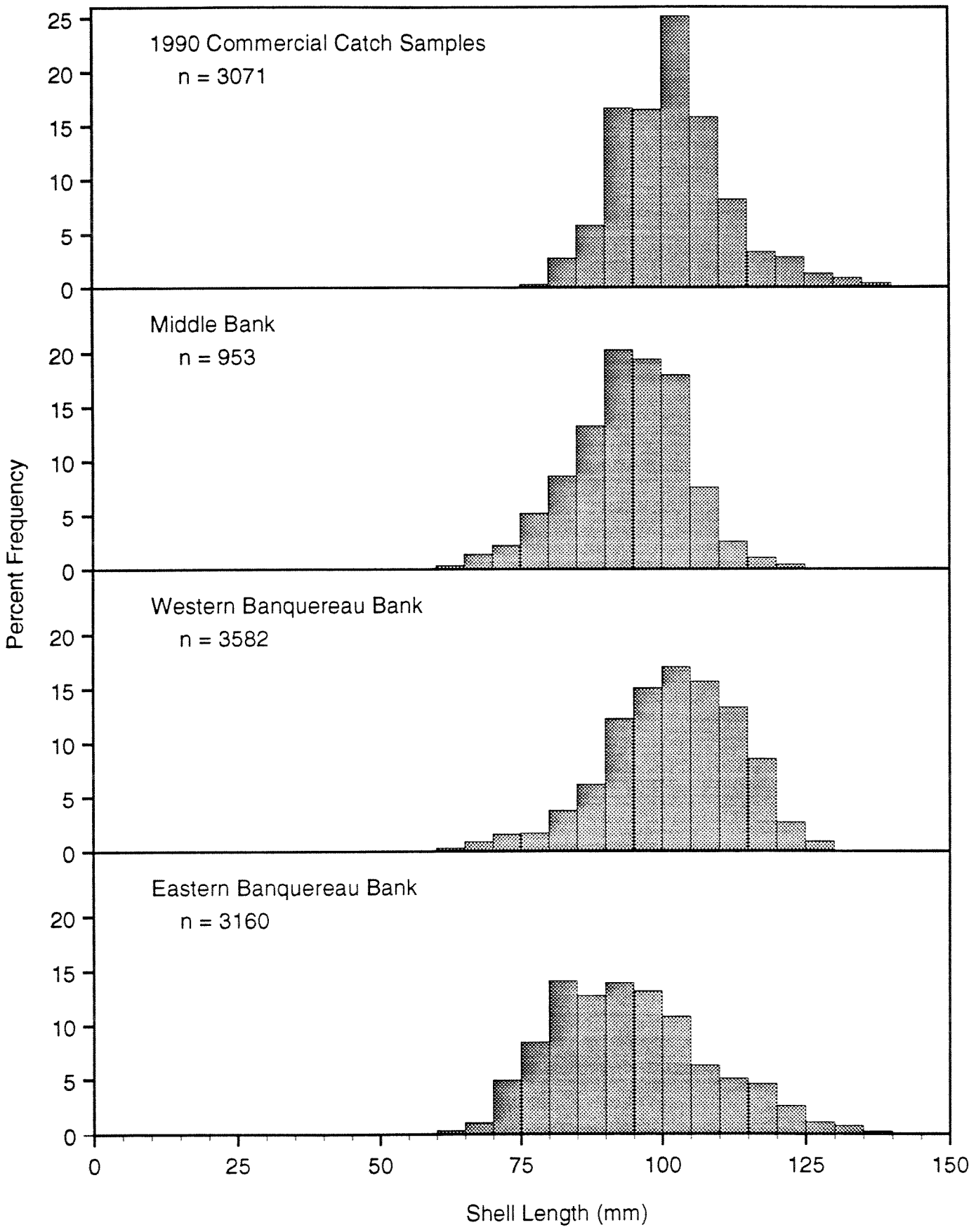

Figure 20. - Length frequencies of Arctic surfclams from 1990 commercial samples and 1991 survey samples.