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New Estimates of Commercially Harvestable Biomass of Stimpson's Surf Clam, *Spisula polynyma*, on the Scotian Shelf Based on the January Through April 1986 Test Fishery and New Age Data

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ABSTRACT

Fishing data from the three vessels that participated in the 1986 commercial Test Fishery, and new age data, are presented in a reassessment of Stimpson's surf clam Spisula polynyma stocks on the Scotian Shelf. New boundaries enclosing a 198.6 km^2 area increased the estimated biomass for fishable concentrations on Banquereau Bank by 37,569 t, to a total of 595,111 t. Data from 345 aged animals were used to revise the estimated age (T_{max}) at which 95% of the cohort would be removed by natural mortality, to 40 yr. The new value for natural mortality of 0.08, estimated from $M=3/T_{max}$, suggested an annual removal in the order of 24,000 t. An alternate approach to exploit the stock was also presented, indicating that as the fishery progresses that data base should be enhanced so that adjustments may be made to the permissable catch levels.

RESUME

On présente les données de pêche des trois vaisseaux ayant participé à la pêche expérimentale commerciale de 1986 ainsi que de nouvelles données sur l'âge. Il s'agit d'une réévaluation des stocks mactre de Stimpson, Spisula polynyma, sur le plateau Scotian. De nouvelles frontières englobant une superficie de 198,6 km^2 ont fait augmenter de 37,569 t la biomasse estimée pour les concentrations pêchables sur le banc Banquereau; le nouveau total atteint 595,111 t. Les données sur 345 animaux dont l'âge a été déterminé ont été utilisées pour revoir l'âge estimé (T_{max}) auquel 95 % de la cohorte serait éliminée par la mortalité naturelle; cet âge révisé est de 40 ans. La nouvelle valeur pour la mortalité naturelle de 0,08, estimée à partir de $M=3/T_{max}$, indique une élimination annuelle de l'ordre de 24,000 t. On présente également une autre approche pour l'exploitation du stock, en indiquant qu'au fur et à mesure que la pêcherie progresse, la base de données devrait être enrichie de sorte qu'on puisse ajuster les niveaux des prises admissibles.

INTRODUCTION

Exploratory surveys conducted on the DELAWARE II from 1980 to 1983 indicated that commercial harvestable densities of Stimpson's surf clam, Spisula polynyma, on the Scotian Shelf were concentrated in two areas on Banquereau Bank (Rowell and Amaratunga, MS 1986). Data previously given to CAFSAC (March 1986) provided biomass estimates of virgin populations in the two areas and estimates of levels of annual removal likely to be sustainable. It was recognized that the surveys were exploratory in nature and that other areas of the Scotian Shelf might also have fishable concentrations that were not discerned.

Subsequent to the January through April commercial Test Fishery, it was suggested that sufficient new information, both from the Test Fishery and from additional ageing studies, was available to warrant a reevaluation of the biomass estimates and TAC advised by CAFSAC in March 1986. This paper considers the new data and provides an update on the previous assessment.

Test Fishery

The operational plan for development of a fishery for offshore clam resources on the Scotian Shelf, announced in December 1985, consisted of two phases. The first phase - a Test Fishery extending to April 30, 1986, was to address questions about resource abundance, compliance with human consumption standards, and factors relating to harvesting, processing, and marketing. Subject to the Test Fishery results, the next phase would be the opening of a commercial fishery. Three companies participated in the Test Fishery, each operating one licensed vessel. The vessels are labeled Vessels X, Y, and Z in order to maintain anonymity.

Observers were placed aboard each vessel to collect catch and operational data on a set-by-set basis. These data are reviewed here in the interest of determining any new areas of the Scotian Shelf that might have fishable concentrations.

Age Data

Age and growth information available to CAFSAC in March 1986 on Stimpson's surf clam S. polynyma on Banquereau Bank was limited to 102 length/age data points. Since length/age data are necessary to the estimation of natural mortality (M) and the estimation of maximum sustainable yield (MSY) in the model used at the March 1986 CAFSAC meeting, this report provides additional length/age data and revised estimates of M and MSY.

METHODS

Test Fishery

The questions being addressed in the Test Fishery had significant influence on the catch and catch rates achieved by the participating vessels. For example, each vessel was required to obtain clearance from DFO that the clams being landed from the various areas complied with human consumption standards. This represented the collection and forwarding of a small number of clams from each area to be tested for PSP and coliform contaminants. Consequently, certain station operations did not target large catches. Conversely, questions regarding resource abundance and factors relating to harvesting, processing, and marketing were addressed by the vessels operating in a commercial mode. In most instances the vessels attempted to operate in this mode; however, gear testing and mechanical difficulties, exploratory work, bad weather and icing conditions, and conflicting operational objectives severely hampered operations and resulted in many poor catches. Data available from the Test Fishery did not allow us to differentiate the operationally good tows from the bad ones. Tables 1, 2, and 3 give the locations, standardized catch rates (U.S. bushels per hour), and starting depths of operation for each vessel. The summary Table 4 gives a comparison of overall fishing activities by the three vessels.

All three vessels were primarily directed at S. polynyma on Banquereau Bank, although a small number of tows were carried out on Roseway, Western, Sable Island, and Middle Banks. The operations of Vessels X and Y were focussed on Banquereau Bank (Fig. 1 and 2 respectively) with few tows elsewhere on the Shelf, while Vessel Z had only 45% of its tows on Banquereau Bank (Fig. 3).

On Banquereau Bank, Vessels X and Y effort was concentrated on the eastern areas of Areas 1 and 2, the high-density areas described by Rowell and Amaratunga (MS 1986), and another small area north of Area 1 (see Fig. 4). Catch rates of Vessels X, Y, and Z in or near these three areas are listed in Tables 5, 6, and 7 respectively. Vessel Z devoted only 15% of its tows to Areas 1 and 2, and only one of these tows resulted in relatively significant landings.

Age Data

The earlier growth data from 102 aged animals were obtained from samples collected during the 1981 and 1983 DELAWARE II surveys. Although an attempt was made to randomly pick approximately five animals from each 5 mm size class, not all size classes were available. In order to enhance the data base, four stations from the DELAWARE II 1981 survey were arbitrarily chosen for further age sampling, three of which were from Area 1 and the other from the western region of Banquereau Bank.

In addition, one large sample of shells obtained from the Test Fishery was sectioned and aged. The text table below gives the list of samples aged.

Sample	Location	No. of Shells Aged
Research 1	Banquereau Bank (composite sample)	102
Research 2	44°27'; 59°36'	22
Research 3	44°27'; 58°19'	31
Research 4	44°27'; 57°59'	9
Research 5	44°38'; 58°02'	28
Test Fishery	44°28'; 58°00'	153
	TOTAL	345

Sections of shells were taken through the chondrophore and mounted on microscope slides as described by Ropes (1984). These thin sections (about 0.25 mm thickness) were viewed through a compound microscope to estimate age. Age determination by count of the annuli was done by two or more independent readers, and the mean count was taken as the representative age for the particular shell. Allen's (1966) method was used to estimate the von Bertalanffy growth parameters. Shell length data were collected from 6,190 animals on Banquereau Bank during the 1981 and 1982 DELAWARE II surveys. Length-frequency distributions are given in Table 8. An age-frequency distribution was constructed for these data (Table 9) using a modified APL program (Roddick and Mohn, MS 1985).

RESULTS AND DISCUSSION

Test Fishery

Assessment of the catch rates obtained in the Test Fishery is difficult in view of operational procedures followed and difficulties encountered by the vessels. For example, more than 75% of the tows experienced bad weather, ice, vessel icing conditions, and/or mechanical difficulties. Other factors, including conflicting points of view and possible objectives between a ship's captain and owner and the contracting company may also have significantly influenced catch rates. The number of hours of fishing time was limited to 88.3 h (Table 4). A more widespread distribution of stations would have made assessment more meaningful. Additionally, differences in gear among the vessels and operational differences compounded those difficulties. However, despite these limitations, the Test Fishery provided better definition of previously described areas of high density and revealed a previously undetected area of high density on Banquereau Bank.

On Banquereau Bank the fishing activities of the vessels were spread over a number of areas of the Bank, 47% of the 309 tows being made in, or close by, the previously identified high-density Areas 1 and 2 (43 tows were clumped in or near Area 1 and 101 tows were clumped in or near Area 2) An additional 21 tows were clumped in an area immediately north of Area 1. For convenience, these areas are labeled as follows: Area 3 - the clump north of Area 1; Area 1^1 - the clump in or near Area 1; Area 2^1 - the clump in or near Area 2 (Fig. 4). The remainder of the tows were spread throughout the western end of the Bank.

Catch rates achieved by the participating vessels were probably the best indicator of resource abundance. In the absence of firm evidence to confirm which tows were good, we have used a minimum catch rate of 20 bu per hour as a criterion to indicate a good tow. These tows are likely to be of commercial significance based on the catch rates recorded in the U.S. mid-Atlantic surf clam (a different but comparable species) fishery. The U.S. fleet average was 26-48 bu/h for the years 1979-1983, and Class 3 vessels, equivalent in size to those in the Test Fishery, averaged 44 bu/h. Twenty-seven percent (27%) of the tows in the Test Fishery were >20 bu/h, and there were three tows in the Test Fishery that had catch rates >100 bu/h. The mean catch rates by the two best performing vessels - Vessels X and Y, for Areas 1, 2, and 3 in the Test Fishery (Tables 5 and 6) compare well with the U.S. fishery.

For the remaining areas of Banquereau (i.e. exclusive of Areas 1, 2, and the area now identified as Area 3), the mean catch rate was low, with only three stations resulting >20 bu/h. The one good catch (40 bu/h), near the western end of the Banquereau Bank, may again suggest the possibility of commercially fishable concentrations outside of those already described. However, further surveys are necessary to identify these.

The Test Fishery did not significantly change our information as to the boundary of Area 1 as previously described (Rowell and Amaratunga, MS 1986). Although Area 1^1 did extend slightly eastward of Area 1, the addition to the area was not considered sufficient to warrant a new calculation of additional biomass.

The data provide evidence that the boundary of Area 2 extends east of that previously described. Area 2^1 encloses 80 km^2 beyond the boundary of Area 2. The additional biomass within Area 2^1, calculated using the DELAWARE II research survey density of 0.230 kg/m^2 of Area 2, was 18,400 t.

The new Area 3 was estimated to cover 118.6 km^2. In calculating biomass within Area 3, the ratios between commercial vessel catch rates in Area 3 and those in the known high-density Areas 1 and 2 (Delaware II densities 0.248 and 0.230 respectively) were used (Table 10).

The biomass in Area 2^1 is estimated at 18,400 t and that in Area 3 at 19,569 t. The biomass for the fishable concentrations (Rowell and Amaratunga, MS 1986) on Banquereau Bank has therefore been increased by 37,969 t, to a total of 595,111 t (or rounded off to 600,000 t).

Age Data

Animals sectioned and aged ranged from 24 mm to 163 mm shell length and from 4 yr to 56+ yr in age. Shells larger than 135 mm were particularly difficult to section and age. Animals older than 35 yr were also generally difficult to age. Consequently, in the data set there are at present only 16 shells greater than 135 mm in length and 18 shells which had age readings greater than 40 yr.

Length-age scatter diagrams showed two distinct distribution patterns. These two groups were identified to originate from two sources of samples; viz: 1) the 1981 and 1982 DELAWARE II survey samples; and 2) the 1986 Test Fishery sample. Accordingly, the von Bertalanffy growth curves were fitted to: 1) All data combined (N=345); 2) DELAWARE II data (N=192); and 3) Test Fishery data (N=153). Figure 5 shows all three fitted curves.

The growth parameters from the fitted curves were as follows:

	t_o	k	L_∞
Combined data:	1.97	.114	126.5
Delaware II data:	0.69	.080	126.2
Test Fishery data:	-1.16	.092	139.2

Size of animals on Banquereau Bank observed in the DELAWARE II surveys ranged from 24 mm to 163 mm and in the Test Fishery from 65 mm to 160 mm. The age data are few in the smaller size range (<40 mm) and the largest size range (>135 mm); consequently, the fitted curves are weak in these areas. The additional age data, although poorly representative of the youngest and oldest clams, improved our ability to estimate the age (T_{max}) at which 95% of a cohort would be removed by natural mortality.

Consideration of growth curves derived from the research surveys and from the Test Fishery suggested the possibility of geographical variation in growth rate and also in natural mortality rates (M). Such variability is to be expected. Hughes and Bourne (1981) in their study of Alaskan S. polynyma found a maximum age of 25 yr and, using Ricker's (1975) model, estimated two very different values of M (0.1272 and 0.2504) in different years (1977 and 1978). These differing estimates are presumably based on samples from different areas of the surveyed grounds.

Two methods were employed to determine T_{max} from which M is determined. In the first method, the length-frequency determined from 6,190 clams measured during the research surveys on the entire Bank (Table 8) was used in conjunction with a scatter diagram (Fig. 6) plotted with the 192 aged shells from the research survey samples. From the length-frequency data it was estimated that 95% of the population reached a shell length of 123 mm. At 123 mm the age range estimated on the scatter diagram was 27 to 53 yr. The mid-point of this range, 40 yr, was taken to be the estimated T_{max}.

In the second method, the age composition of the population (Table 9) as derived from the age-length key using research survey data indicated a T_{max} of 41 yr. Natural mortality estimated by the formula $M = 3/T_{max}$, when $T_{max} = 40$ yr, is 0.075. We have rounded this value of M to 0.08 for use in calculating MSY.

It is cautioned here that the use of this method assumes equilibrium conditions within the population. The population structure evident from the research survey data indicates a non-equilibrium situation (i.e. low numbers of younger clams of a size sufficient to be fully recruited to the gear) which to some degree compromises the use of this model. The bias resulting from the analysis, however, is interpreted as being towards a low estimate of M.

Using the model $MSY = 0.5MB_0$ (B_0 = virgin biomass), a new estimate of MSY was developed for the Stimpson's surf clam on Banquereau Bank. With the biomass estimate of 600,000 t and assuming $M = 0.08$, the model suggests annual removals in the order of 24,000 t.

An alternate approach to the initial exploitation of this stock would be the establishment of an annual level of removal which would, over a defined period of time, completely remove the existing biomass. If the resource was required to last 10, 20, or 25 yr, this would equate to removals of 60,000 t, 30,000 t, and 24,000 t per year, respectively, assuming a virgin biomass of 600,000 t. This approach assumes no natural mortality, growth, or recruitment, and that all the estimated biomass is exploitable.

Neither approach is likely to jeopardize the resource in the short term. As the fishery progresses, the data base should be considerably enhanced and adjustments may be made to the permissible catch levels.

In setting the level of harvest, it should be kept in mind that levels of discarding in the new fishery may result in a significant, but currently unquantifiable, additional mortality. Discarding in the U.S. surf clam fishery (*Spisula solidissima*) is known to range from 10 to 50%, but resultant mortality levels are unknown. Additionally, it has been shown for the surf clam (*S. solidissima*) that dredge-induced mortality occurs.

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Table 1. Catch data for Vessel X giving latitude and longitude at stations, standardized catch rates (bushels per hour) and starting depth (m).

STN.#	LAT	LONG	CATCH BU/HR	DEPTH
1	442700	575900	3.96	47
2	442700	575900	9.00	47
3	442700	575900	12.00	49
4	442700	575900	30.00	49
5	442700	575900	6.00	49
6	442800	580000	27.00	50
7	435400	612600	.00	48
8	435400	612400	.00	49
9	434900	612100	.00	42
10	434800	612000	.00	39
11	434900	605400	.00	47
12	434900	605200	.00	41
13	434800	605100	.00	41
14	434800	604900	.00	39
15	434100	604200	.00	38
16	434700	602900	.00	49
17	434700	602200	.00	51
18	435700	591600	.00	42
19	435800	591500	.00	42
20	442700	590000	12.00	63
21	443100	590300	5.04	53
22	443000	593100	39.96	49
23	442800	580700	8.52	51
24	442900	580000	4.44	48
25	443000	575900	2.28	50
26	443200	575900	2.04	47
27	443400	575700	2.04	48
28	443500	575600	.00	45
29	443400	575400	.00	43
30	443300	575300	.00	43
31	442500	581000	27.96	59
32	442400	580900	12.60	60
33	442400	580300	11.52	57
34	442300	580700	1.80	55
35	442300	580700	41.04	55
36	442200	580700	41.52	52
37	442300	580700	40.44	55
38	442200	580500	6.84	53
39	442200	580400	3.96	52
40	442700	580600	23.64	55
41	444800	573100	.00	36
42	444700	572900	.00	39
43	444600	572800	86.76	51
44	443400	571800	.00	67
45	443300	592500	12.96	49
46	443400	592500	9.72	52
47	443100	585700	3.72	53
48	442800	585600	.00	52
49	442700	585600	18.00	55
50	442700	585400	3.96	53
51	443200	585400	.00	55
52	443200	585400	3.96	53
53	442900	583900	8.04	68
54	444200	582200	3.96	68
55	444100	582300	48.00	64
56	443700	582200	27.96	56
57	444200	582200	41.40	65
58	444300	581800	12.00	67
59	444200	581600	3.96	61
60	444100	581700	7.92	61
61	444200	582100	.00	67
62	444200	582100	13.32	55
63	444100	582200	9.00	64
64	444400	572700	4.80	49
65	444300	572500	13.20	57
66	444300	572600	38.04	56
67	444300	572700	26.76	52
68	444300	572800	4.80	48
69	444400	572700	4.44	51
70	444300	572600	20.16	55
71	444300	572700	30.00	48
72	444400	572600	26.40	53
73	444200	572700	23.16	53
74	444100	572600	18.96	55
75	443900	573100	13.56	53
76	443900	573300	35.16	52
77	443900	573300	31.20	51
78	443900	573300	8.04	53
79	444000	573200	8.64	51
80	444300	572900	30.84	53
81	444300	573000	30.96	53
82	444200	573000	15.60	52
83	444200	573100	20.16	52
84	443900	573100	35.16	55
85	443900	573200	6.60	55
86	444000	573300	17.16	53
87	444100	573300	17.16	52
88	444200	573000	8.40	53
89	444200	573100	17.16	53
90	444600	572600	15.96	55
91	444500	572700	32.04	54
92	444500	572700	32.04	54
93	444400	572700	24.00	58
94	444300	572800	24.00	57
95	444300	572900	8.04	55
96	444300	573000	24.00	53
97	443900	573600	24.00	52
98	444000	573700	36.00	51
99	443900	573600	15.00	52
100	444000	573700	18.00	51
101	443900	573600	12.00	52
102	444000	573800	12.00	49
103	444000	573700	9.00	51
104	443900	573600	6.00	52
105	443300	573900	.00	37
106	442300	580000	17.64	50
107	441800	581100	12.00	58
108	442400	582500	20.04	63
109	442800	581900	24.00	61
110	443600	582000	15.96	60
111	444200	582100	3.96	64
112	441100	604200	3.96	60
113	440800	605600	.00	47
114	440700	605900	.00	55
115	442300	604600	2.88	64
116	442400	604600	.00	64
117	442600	603800	15.96	53
118	442600	604000	28.20	55
119	442800	603900	15.96	49
120	442800	604000	20.04	52
121	443100	604000	15.96	51
122	443100	604100	14.16	52
123	443100	602400	15.00	53
124	443200	604300	12.00	55
125	450700	602000	.00	64

Table 2. Catch data for Vessel Y giving latitude and longitude at stations, standardized catch rates (bushels per hour) and starting depth (m).

STN.#	LAT	LONG	CATCH BU/HR	DEPTH
1	432800	644000	.00	60
2	443900	603900	.00	46
3	443200	603900	12.00	48
4	442900	604300	9.00	59
5	443200	603900	26.64	48
6	442900	603900	25.68	53
7	443600	582400	12.84	57
8	443600	582300	15.00	57
9	443700	582200	20.76	57
10	443800	582100	24.00	57
11	444200	582200	2.76	65
12	444000	581900	7.56	59
13	443800	582000	7.92	60
14	443700	582100	7.92	55
15	443700	582200	6.84	59
16	444500	572700	132.00	56
17	444500	572700	16.80	57
18	444500	572600	33.00	57
19	444500	572700	9.00	56
20	444500	572800	20.52	52
21	444600	572700	14.04	57
22	444500	572800	19.44	51
23	444600	572700	15.60	56
24	444500	572800	18.48	52
25	444600	522700	15.24	57
26	444500	572800	16.20	54
27	444500	572700	17.28	56
28	444500	572800	17.04	58
29	444400	572800	12.24	56
30	444300	572900	13.56	57
31	444200	573000	28.44	56
32	444200	573100	32.28	56
33	444100	573200	32.64	55
34	444200	573200	34.32	55
35	444100	573200	23.52	55
36	444200	573100	29.76	55
37	444100	573200	34.32	55
38	444200	573100	36.48	54
39	444200	573100	33.12	56
40	444200	573100	35.04	55
41	444100	573200	39.36	56
42	444000	573000	30.00	55
43	444100	573300	20.64	55
44	444100	573200	35.40	55
45	444100	573300	20.88	56
46	444000	573300	28.80	54
47	444000	573400	26.40	55
48	444000	573300	28.80	55
49	443900	573400	27.24	55
50	443900	573500	26.88	54
51	444000	573400	45.48	54
52	444200	573100	66.72	55
53	444100	573200	52.92	56
54	443700	573500	50.04	57
55	443700	573600	60.00	56
56	443700	573600	75.00	54
57	443700	573700	133.32	52
58	443700	573700	109.08	52
59	443600	574100	6.72	42
60	443500	574000	16.32	55
61	442900	574800	21.84	59
62	442700	575900	9.00	46
63	442700	575900	9.96	49
64	442300	580400	13.80	51
65	442300	580500	32.76	51
66	441900	581000	24.96	57
67	442200	582400	42.84	62
68	442700	580400	30.00	52
69	442700	580300	50.04	51
70	442700	580300	38.16	54
71	442600	580200	16.32	53
72	442700	580200	24.96	53

Table 3. Catch data for Vessel Z giving latitude and longitude at stations, standardized catch rates (bushels per hour) and starting depth (m).

STN.#	LAT	LONG	CATCH BU/HR	DEPTH
1	444200	603400	.00	43
2	444200	603300	.24	41
3	444100	603200	.12	39
4	444100	603100	.00	36
5	444000	602900	.12	40
6	443500	603400	.24	38
7	443500	603400	.00	40
8	443500	603500	.00	43
9	443400	603500	.00	47
10	443300	603600	.00	48
11	443000	603800	6.00	49
12	442900	603900	.60	48
13	443500	603500	2.52	50
14	443500	603500	3.60	57
15	444400	572700	1.84	56
16	444600	572700	2.40	56
17	444500	573000	.00	37
18	444000	573400	21.48	53
19	444100	573600	.00	47
20	443900	573500	.00	52
21	443600	573600	4.56	53
22	443600	573700	12.90	53
23	443500	573700	7.56	55
24	443500	573700	8.52	57
25	443500	573700	3.96	61
26	442700	575800	3.60	47
27	442800	575900	.12	51
28	442900	575900	.84	50
29	443000	575900	.60	48
30	443000	575900	1.04	51
31	443000	580100	1.32	52
32	443400	590000	9.24	57
33	443400	590100	1.20	57
34	443400	590300	6.48	57
35	443400	590400	.00	60
36	443300	590400	2.04	57
37	443300	590400	1.20	57
38	443200	590600	.96	58
39	443100	590700	.24	58
40	443100	590600	8.04	59
41	443100	590700	5.04	56
42	443200	590800	1.08	59
43	443200	590900	.00	67
44	443100	592100	3.96	56
45	443100	592300	2.04	51
46	443100	592400	5.40	51
47	443100	592600	8.52	51
48	443600	592600	12.90	52
49	443300	592600	7.08	52
50	443400	592600	60.00	53
51	443400	592700	.00	51
52	443500	594400	3.17	48
53	443600	593600	5.04	56
54	443500	593700	1.56	56
55	443500	593700	3.96	59
56	442700	594600	3.96	59
57	442700	594700	.96	58
58	442700	594900	.96	58
59	442700	595000	.00	58
60	442800	595400	.36	59
61	442100	605300	.24	41
62	441200	605300	.00	37
63	441100	605200	.00	35
64	441000	605200	.00	33
65	441000	605800	.00	31
66	441000	604900	.00	28
67	440300	604000	.00	28
68	440100	603800	.00	28
69	442100	602800	.00	38
70	442200	602700	.00	37
71	442300	602600	.00	42
72	442500	602300	12.00	46
73	442600	602300	9.96	47
74	442700	602300	3.96	47
75	442800	602400	.00	41
76	442600	603100	3.96	43
77	442500	603300	6.00	46
78	442600	603500	.36	59
79	442800	603700	6.96	50
80	442900	603900	.24	53
81	443000	604000	.84	52
82	442500	603800	.00	56
83	442500	604000	.00	56
84	442500	603800	5.04	55
85	442500	604000	.60	58
86	442600	604200	.00	58
87	442700	604200	.00	58
88	442800	604200	.00	62
89	442900	604200	12.00	55
90	443000	604100	5.40	55
91	443100	604200	9.96	55
92	443200	604200	1.68	55
93	443400	604400	.00	57
94	443800	604300	8.04	56
95	443800	604400	.96	55
96	443800	604300	.00	50
97	443700	603900	.00	44
98	443600	604000	.04	46
99	443600	603800	.00	44
100	443600	603700	.00	42
101	443600	603600	.00	40
102	443900	603700	.00	41
103	432800	644200	.00	56
104	432700	644400	.00	61
105	432600	644400	.00	62
106	432500	644400	.00	61
107	432400	644600	.00	74
108	442400	644600	.00	60
109	432500	644500	.00	59
110	432800	644600	.00	60

Table 4. Summary of operations of each participating vessel.

Operational Data	Vessel X		Vessel Y		Vessel Z	
• Total # of tows	125		72		110	
• Total hrs towed	34.9		25.5		27.9	
. Total catch (bu) (*S. polynyma*)	467.8		524.1		71.8	
• No. of tows						
with zero catch	27		2		44	
with 0-9.9 bu	34		10		60	
with 10-19.9 bu	29		18		4	
with 20-29.9 bu	17		19		1	
with 30-39.9 bu	12		15		0	
with >40 bu	6		11		1	
• Ave. catch rate (bu/hr)	17.6		29.9		3.7	
• Highest catch rate achieved (bu/hr)	86.7		133.3		60	
• Catch rate by depth (bu/hr)	# of tows	bu/hr	# of tows	bu/hr	# of tows	bu/hr
35-39 m	6	0	-	-	2	0
40-44 m	7	0	1	6.7	8	0.1
45-49 m	21	9.0	5	11.5	14	0.3
50-54 m	48	18.2	19	40.1	13	3.6
55-59 m	22	19.7	43	28.1	20	8.6
60-64 m	14	11.8	3	16.9	40	4.4
65-69 m	7	11.3	1	2.8	9	0.4
70-74 m	-	-	-	-	1	0
• Ave. depth of operations (m)	52.2		54.8		50.7	
• Max. depth of operations (m)	66		65		74	
• Min. depth of operations (m)	36		42		28	

Table 5. Standardized catch rates (bu/hr) of Vessel X on locations within or near Areas 1 and 2, and in Area 3.

AREA 3

STN.#	LAT	LONG	CATCH BU/HR	DEPTH
54	444200	582200	3.96	68
55	444100	582300	48.00	64
56	443700	582200	27.96	56
57	444200	582200	41.40	65
58	444300	581800	12.00	67
59	444200	581600	3.96	61
60	444100	581700	7.92	61
61	444200	582100	.00	67
62	444200	582100	13.32	65
63	444100	582200	9.00	64
110	443600	582000	15.96	60
111	444200	582100	3.96	64

AREA 1 AND 1'

STN.#	LAT	LONG	CATCH BU/HR	DEPTH
1	442700	575900	3.96	47
2	442700	575900	9.00	47
3	442700	575900	12.00	49
4	442700	575900	30.00	49
5	442700	575900	6.00	49
6	442800	580000	27.00	50
23	442800	580700	8.52	51
24	442900	580000	4.44	48
25	443000	575900	2.28	50
26	443200	575900	2.04	47
27	443400	575700	2.04	48
28	443500	575600	.00	45
29	443400	575400	.00	43
30	443300	575300	.00	43
31	442500	581000	27.96	59
32	442400	580900	12.60	60
33	442400	580300	11.52	57
34	442300	580700	1.80	55
35	442300	580700	41.04	55
36	442200	580700	41.52	52
37	442300	580700	40.44	55
38	442200	580500	6.84	53
39	442200	580400	3.96	52
40	442700	580600	23.64	55

AREA 2 AND 2'

STN.#	LAT	LONG	CATCH BU/HR	DEPTH
41	444800	573100	.00	36
42	444700	572900	.00	39
43	444600	572800	86.76	51
44	443400	571800	.00	67
64	444400	572700	4.80	49
65	444300	572500	13.20	57
66	444300	572600	38.04	56
67	444300	572700	26.76	52
68	444300	572800	4.80	48
69	444400	572700	4.44	51
70	444300	572600	20.16	55
71	444300	572700	30.00	48
72	444400	572600	26.40	53
73	444200	572700	23.16	53
74	444100	572600	18.96	55
75	443900	573100	13.56	53
76	443900	573300	35.16	52
77	443900	573300	31.20	51
78	443900	573300	8.04	53
79	444000	573200	8.64	51
80	444300	572900	30.84	53
81	444300	573000	30.96	53
82	444200	573000	15.60	52
83	444200	573100	20.16	52
84	443900	573100	35.16	55
85	443900	573200	6.60	55
86	444000	573300	17.16	53
87	444100	573300	17.16	52
88	444200	573000	8.40	53
89	444200	573100	17.16	53
90	444600	572600	15.96	55
91	444500	572700	32.04	54
92	444500	572700	32.04	54
93	444400	572700	24.00	58
94	444300	572800	24.00	57
95	444300	572900	8.04	55
96	444300	573000	24.00	53
97	443900	573600	24.00	52
98	444000	573700	36.00	51
99	443900	573600	15.00	52
100	444000	573700	18.00	51
101	443900	573600	12.00	52
102	444000	573800	12.00	49
103	444000	573700	9.00	51
104	443900	573600	6.00	52
105	443300	573900	.00	37

Table 6. Standardized catch rates (bu/hr) of Vessel Y on locations within or near Areas 1 and 2, and in Area 3.

AREA 3

STN.#	LAT	LONG	CATCH BU/HR	DEPTH
7	443600	582400	12.84	57
8	443600	582300	15.00	57
9	443700	582200	20.76	57
10	443800	582100	24.00	57
11	444200	582200	2.76	65
12	444000	581900	7.56	59
13	443800	582000	7.92	60
14	443700	582100	7.92	55
15	443700	582200	6.84	59

AREA 1 AND 1'

STN.#	LAT	LONG	CATCH BU/HR	DEPTH
61	442900	574800	21.84	59
62	442700	575900	9.00	46
63	442700	575900	9.96	49
64	442300	580400	13.80	51
65	442300	580500	32.76	51
66	441900	581000	24.96	57
68	442700	580400	30.00	52
69	442700	580300	50.04	51
70	442700	580300	38.16	54
71	442600	580200	16.32	53
72	442700	580200	24.96	53

AREA 2 AND 2'

STN.#	LAT	LONG	CATCH BU/HR	DEPTH
16	444500	572700	132.00	56
17	444500	572700	16.80	57
18	444500	572600	33.00	57
19	444500	572700	9.00	56
20	444500	572800	20.52	52
21	444600	572700	14.04	57
22	444500	572800	19.44	51
23	444600	572700	15.60	56
24	444500	572800	18.48	52
25	444600	522700	15.24	57
26	444500	572800	16.20	54
27	444500	572700	17.28	56
28	444500	572800	17.04	58
29	444400	572800	12.24	56
30	444300	572900	13.56	57
31	444200	573000	28.44	56
32	444200	573100	32.28	56
33	444100	573200	32.64	55
34	444200	573200	34.32	55
35	444100	573200	23.52	55
36	444200	573100	29.76	55
37	444100	573200	34.32	55
38	444200	573100	36.48	54
39	444200	573100	33.12	56
40	444200	573100	35.04	55
41	444100	573200	39.36	56
42	444000	573000	30.00	55
43	444100	573300	20.64	55
44	444100	573200	35.40	55
45	444100	573300	20.88	56
46	444000	573300	28.80	54
47	444000	573400	26.40	55
48	444000	573300	28.80	55
49	443900	573400	27.24	55
50	443900	573500	26.88	54
51	444000	573400	45.48	54
52	444200	573100	66.72	55
53	444100	573200	52.92	56
54	443700	573500	50.04	57
55	443700	573600	60.00	56
56	443700	573600	75.00	54
57	443700	573700	133.32	52
58	443700	573700	109.08	52
59	443600	574100	6.72	42

Table 7. Standardized catch rates (bu/hr) of Vessel Z on locations within or near Areas 1 and 2. No tows were made in Area 3.

AREA 1 AND 1'

STN.#	LAT	LONG	CATCH BU/HR	DEPTH
26	442700	575800	3.60	47
27	442800	[illegible]5500	.12	51
28	442900	5[illegible]	.84	50
29	443000	575900	.60	48
30	443000	575900	10.44	51
31	443000	580100	1.32	52

AREA 2 AND 2'

STN.#	LAT	LONG	CATCH BU/HR	DEPTH
15	444400	572700	.24	56
16	444600	572700	2.40	56
17	444500	573000	.00	37
18	444000	573400	21.48	53
19	444100	573600	.00	47
20	443900	573500	.00	52
21	443600	573600	4.56	53
22	443600	573700	20.04	53
23	443500	573700	7.56	55
24	443500	573700	8.52	57
25	443500	573700	3.96	61

Table 8. Length frequency distribution of S. polynyma on Banquereau Bank observed during 1981 to 1983 DELAWARE II research surveys [N=6190].

Length (mm)	Percent frequency
0-5	0
10	0
15	0
20	0
25	0.016
30	0.048
35	0.129
40	0.194
45	0.323
50	0.582
55	0.824
60	0.565
65	1.632
70	2.116
75	3.603
80	3.667
85	6.026
90	7.189
95	10.759
100	10.921
105	12.456
110	10.065
115	11.276
120	7.351
125	5.38
130	2.359
135	1.567
140	0.598
145	0.178
150	0.081
155	0.048
160	0.032
165	0.016

Table 9. Age-frequency distribution constructed for S. polynyma from DELAWARE II data using the modified APL program of Roddick and Mohn (1985).

Age	Number at Age	Cumulative %
3	0.01	0
4	0.18	0
5	1.04	0.0002
6	3.63	0.0008
7	6.32	0.0018
8	9.45	0.0033
9	56.79	0.0125
10	90.76	0.0272
11	134.01	0.0488
12	182.95	0.0784
13	231.86	0.1158
14	274.63	0.1602
15	306.37	0.2097
16	324.36	0.2621
17	328.34	0.3151
18	320.13	0.3669
19	302.71	0.4158
20	279.37	0.4609
21	379.57	0.5222
22	339.05	0.5770
23	299.85	0.6254
24	263.44	0.6680
25	230.54	0.7052
26	201.40	0.7378
27	175.95	0.7662
28	153.94	0.7911
29	135.03	0.8129
30	118.86	0.8321
31	105.05	0.8490
32	93.27	0.8641
33	83.22	0.8776
34	74.64	0.8896
35	67.30	0.9005
36	61.01	0.9103
37	53.01	0.9189
38	49.78	0.9269
39	46.92	0.9345
40	44.39	0.9417
41	42.15	0.9485
42	26.77	0.9528
43	25.58	0.9570
44	24.52	0.9609
45	23.58	0.9647
46	22.73	0.9684
47	21.97	0.9719
48	21.28	0.9754
49	20.66	0.9787
50	20.11	0.9820
51	19.60	0.9851
52	19.15	0.9882
53	18.74	0.9913
54	18.36	0.9942
55	18.02	0.9971
56	17.71	1.0000

Table 10. Density estimates and biomass estimate for Area 3 calculated from mean catch rates (bu/hr) of Areas 1, 2 and 3 and use of catch rate ratios to determine the density of clams in Area 3 relative to known research survey densities in Areas 1 and 2.

	Vessel X	Vessel Y
Catch rate (bu/hr)		
Area 1	15.1	24.6
Area 2	21.0	35.3
Area 3	17.0	11.7
Catch rate ratios of Areas 1 and 2 to Area 3		
a) Area 3: Area 1	1.13	0.48
b) Area 3: Area 2	0.81	0.33
Estimated Density of Area 3 (kg/m^2)		
a) Ratio x 0.248* =	0.280	0.119
b) Ratio x 0.230+ =	0.186	0.076
	$\bar{x}$ = 0.165 kg/m^2	
Biomass in Area 3		
$\bar{x}$ Density x area =	0.165 x 118.6 x 10^3 = 19,569 t	

* Estimated density for Area 1 of 0.248 kg/m^2 taken from DELAWARE II research survey data.

\+ Estimated density of 0.230 kg/m^2 taken from DELAWARE II research survey data.

Figure 1. Stations occupied by Vessel X on Banquereau Bank during the January through April 1986 test fishery.

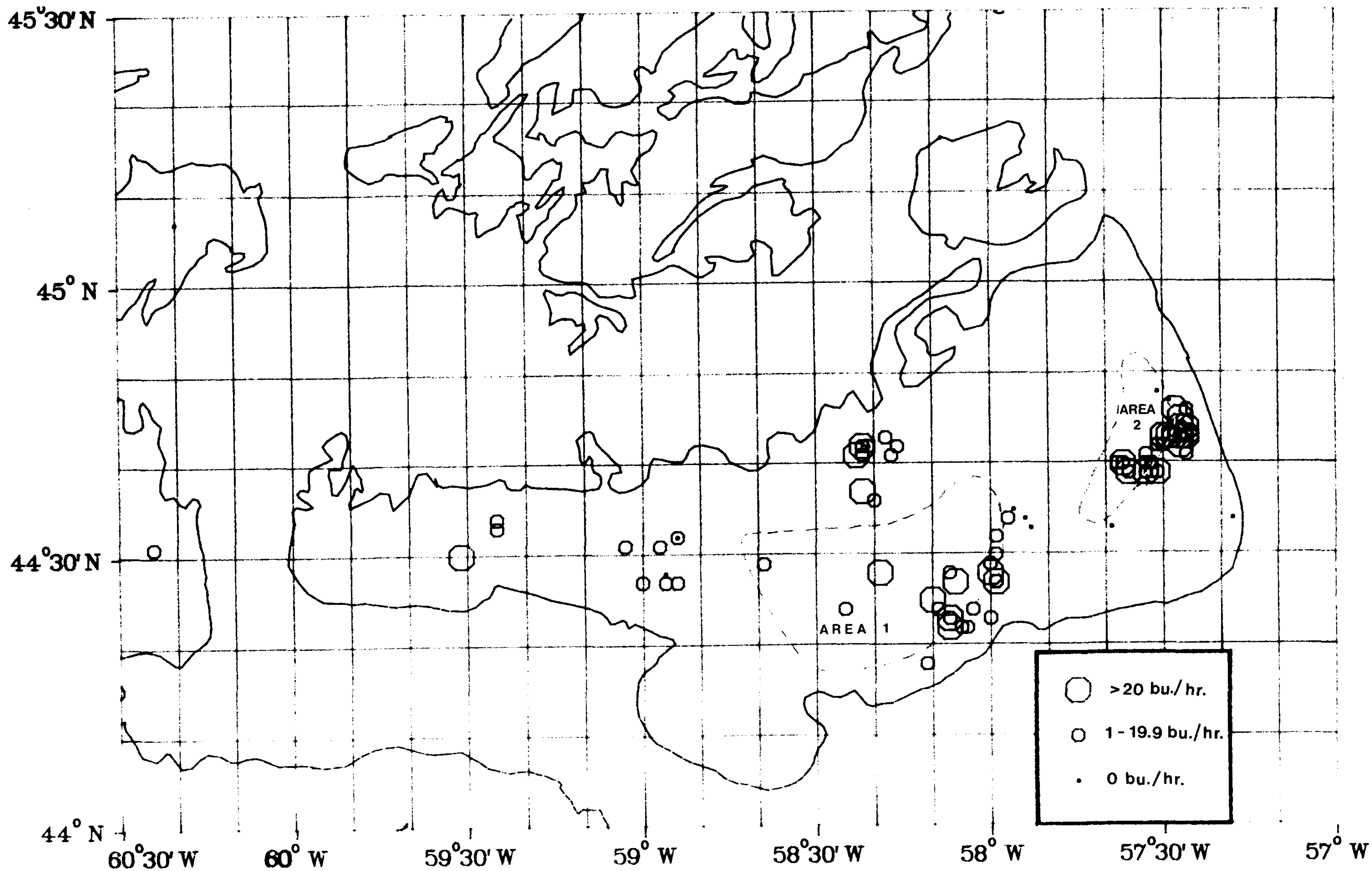


Figure 2. Stations occupied by Vessel Y on Banquereau Bank during the January through April 1986 test fishery.

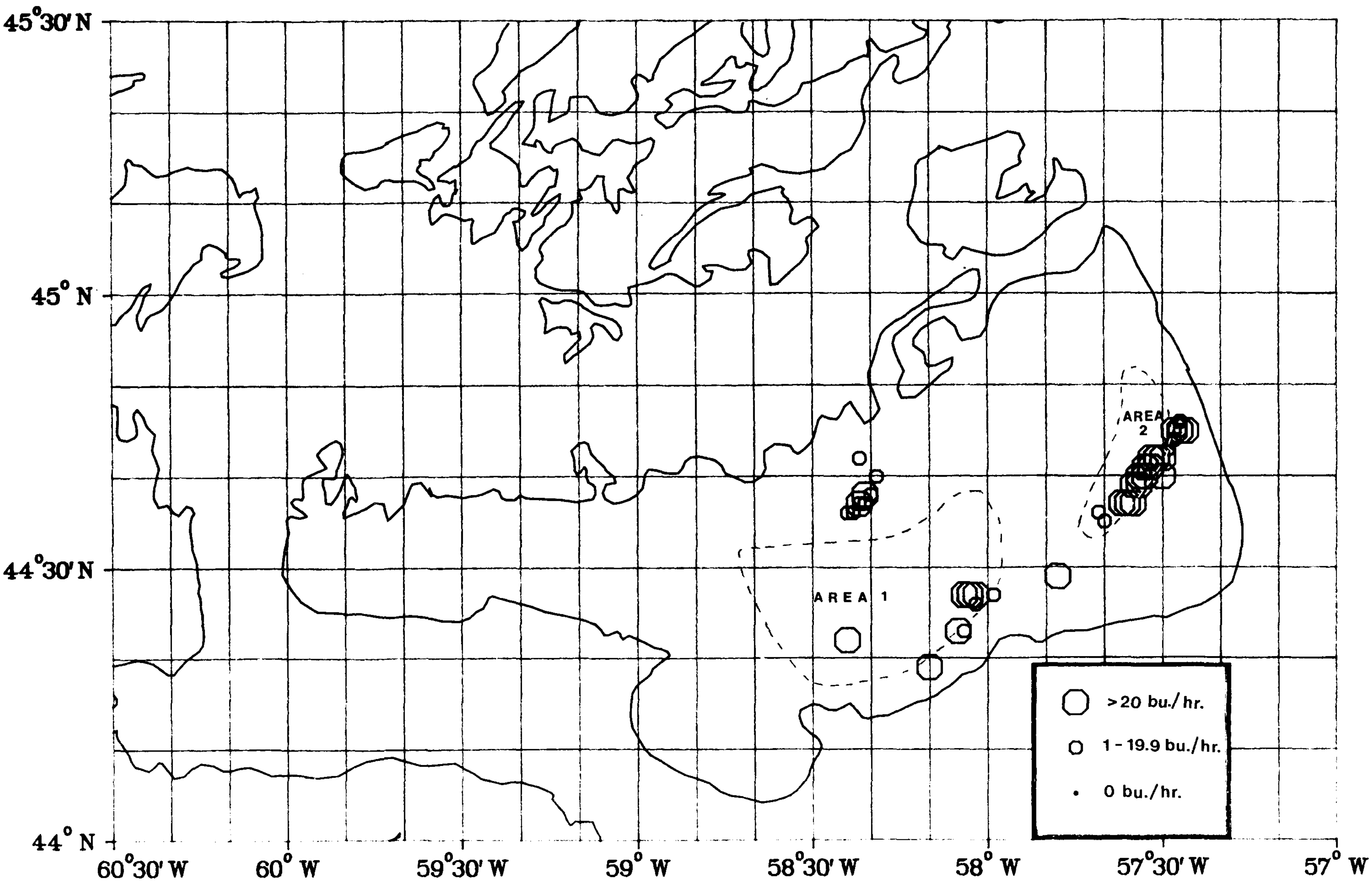
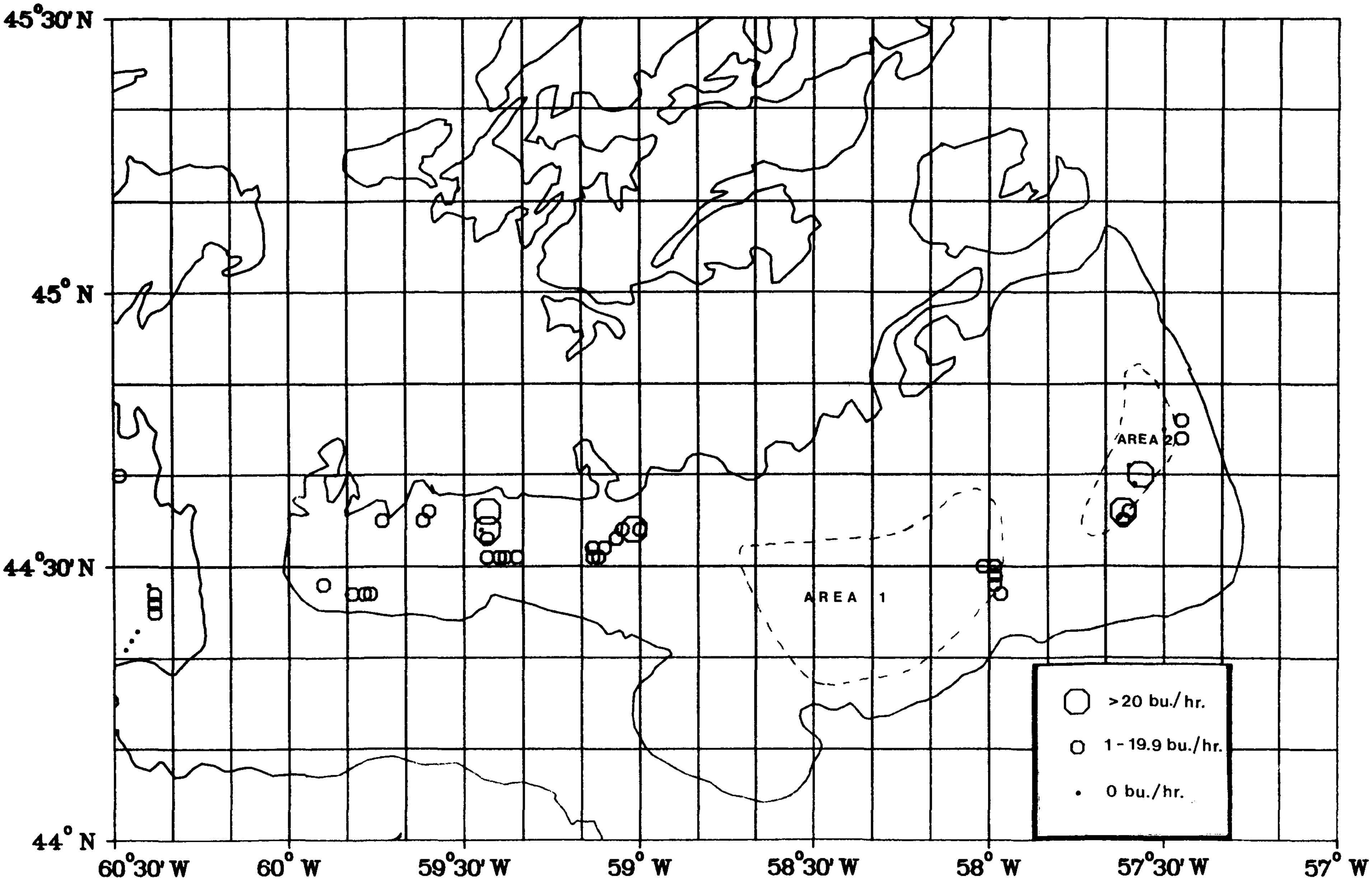


Figure 3. Stations occupied by Vessel Z on Banquereau Bank during the January through April 1986 test fishery.



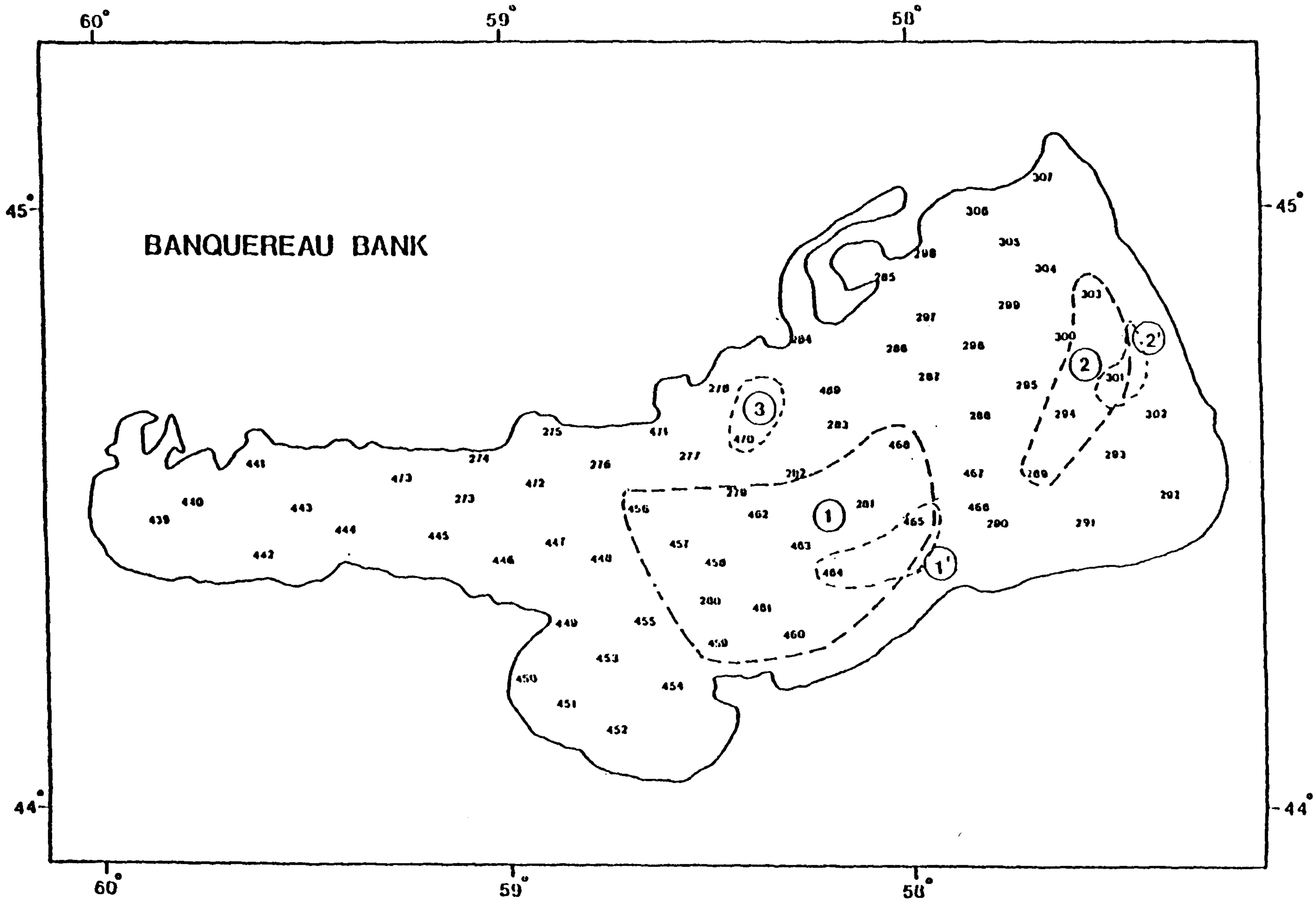


Figure 4. Banquereau Bank showing boundaries of areas of most significant concentrations *Spisula polynyma*. Area 1 and Area 2 are those identified in the 1981-1982 research surveys. Area 1[1], Area 2[1] and Area 3 are those identified from the 1986 Test Fishery [N.B. Areas 1[1], 2[1], and 3 are not accurate representations of the true areas given in accompanying text].

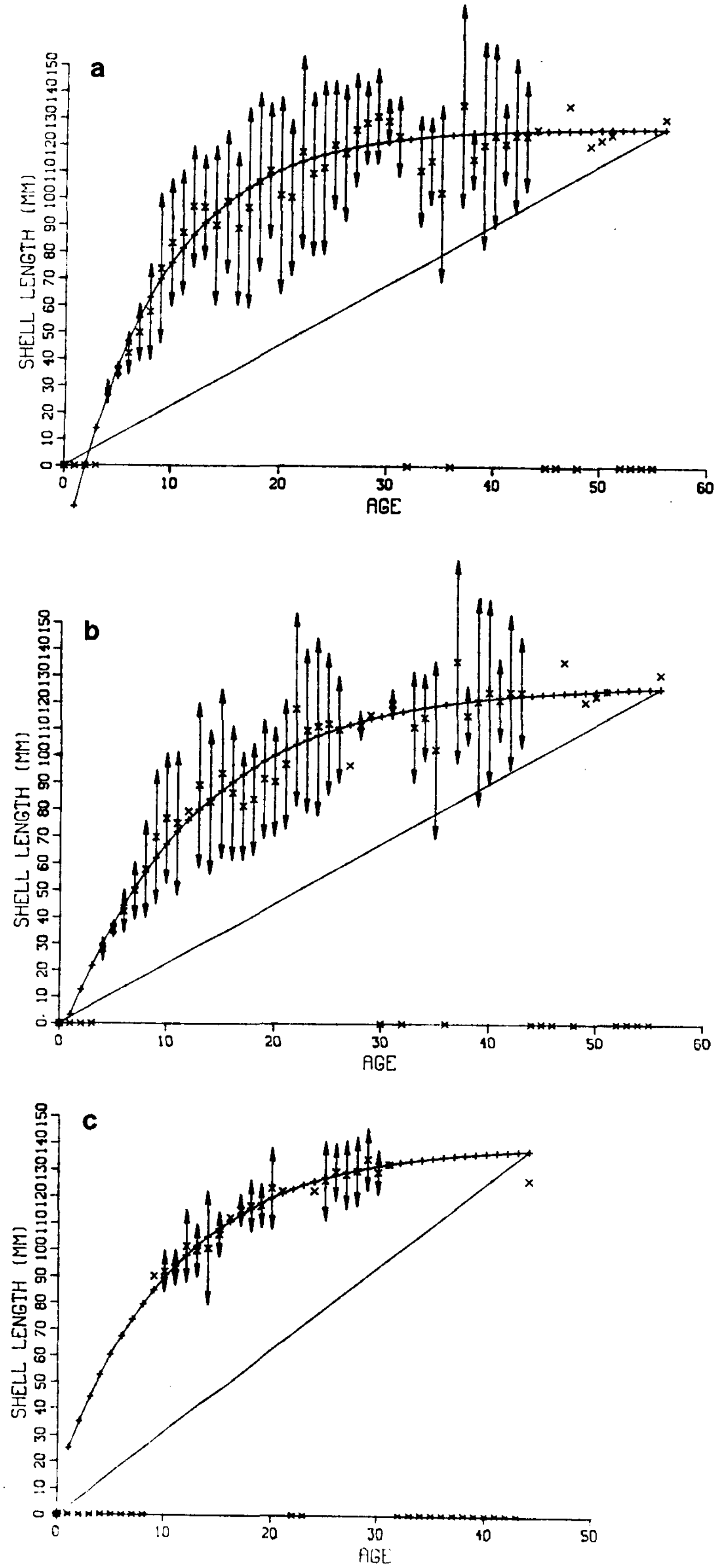


Figure 5. von Bertalanffy growth curves fitted to (a) all length-age data (N = 345), (b) DELAWARE II research survey length-age data (N = 192) and (c) Test Fishery length-age data (153) using Allen's (1966) method.

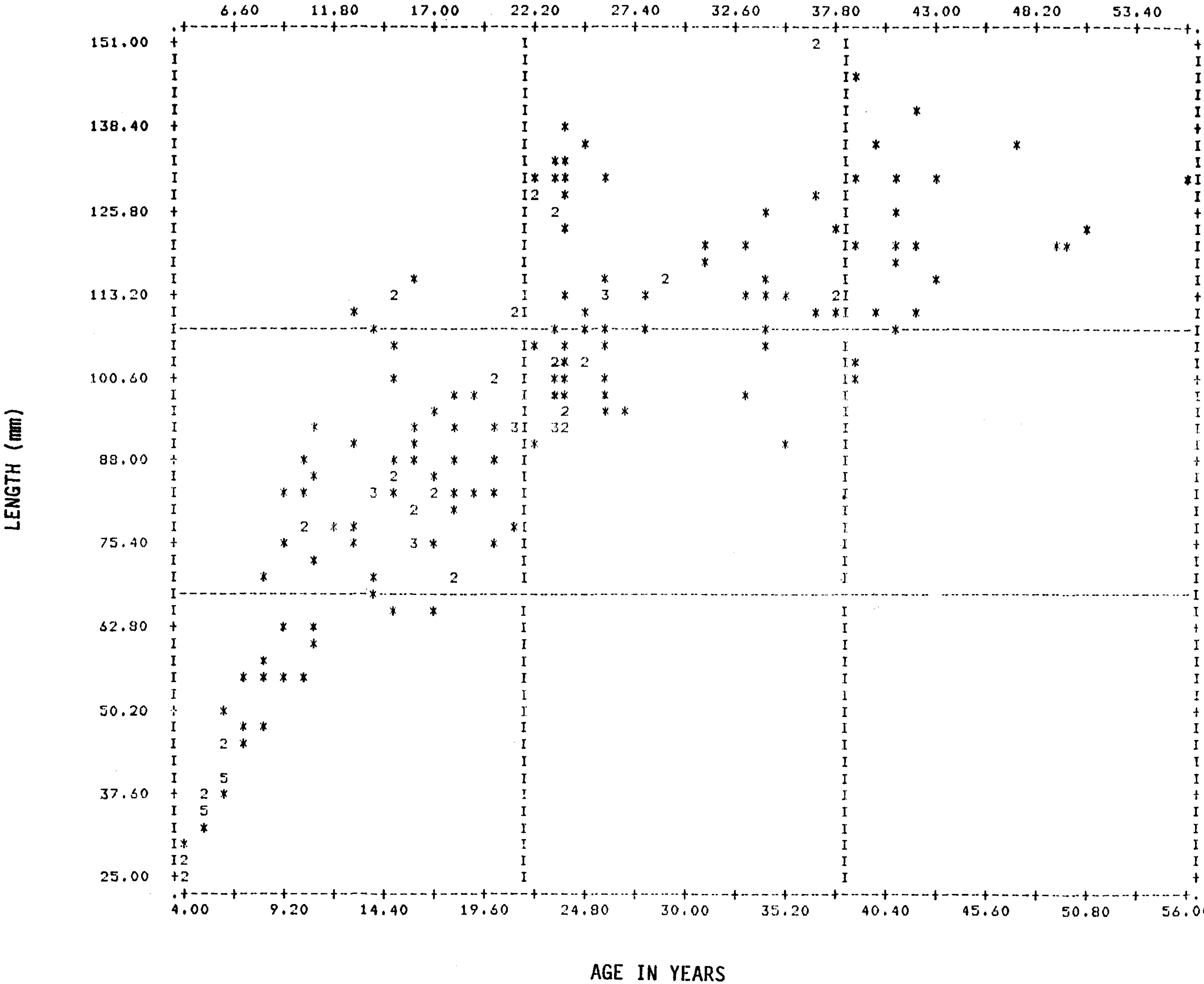


Figure 6. **Length (mm) - Age (yrs) scatter diagram for animals aged from samples collected during the 1981 and 1982 Delaware II research surveys in Banquereau Bank.**