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Mesh Selection of the Short-Finned Squid, *Illex illecebrosus*, on the Scotian Shelf using a Bottom Trawl: A Joint Canada-Japan 1978 Research Program

by

T. Amaratunga
Fisheries and Oceans Canada, Fisheries and Marine Service
Resource Branch, Halifax, N. S., Canada

and

S. Kawahara and H. Kono
Far Seas Fisheries Research Laboratory
Shimizu 424, Japan

INTRODUCTION

In recent years the short-finned squid Illex illecebrosus has become an important offshore fishery in the northwest Atlantic (Amaratunga et al., 1978). Mesh selection information on Illex has been limited to a report by Clay (1978) in experiments aimed at silver hake, and the need to determine the selective properties of the trawl gear commonly used on the Illex fishery was demonstrated by STACRES (ICNAF, 1978). A joint Canada-Japan research project was undertaken during summer, 1978, with the primary objective of carrying out mesh selection experiments for Illex on the Scotian Shelf. Japan equipped and provided a commercial stern trawler, Shirane Maru, for the project which consisted of two one-month cruises during the early and late periods of the fishing season.

Gear selectivity has been used as an important tool in fisheries management to reduce fishing mortality on certain size classes of fish. Typically, by enforcing a limitation on the minimum mesh size, small fish are permitted to escape fishing gear. With their potential capacity to grow to a larger size, there are long-term benefits to the fishery (Pope et al., 1975).

A "knife-edge" selection curve occurs if all fish at a given length have the same girth, and if all meshes in the codend had the same shape the fish that enter the net will have a chance of escape of either 0 or 1 (Jones, 1963).

Since there is a considerable range of size of fish, an increasing fraction of the total actually sustain mortality. It has been convenient to use an approximation to the knife-edge by properly choosing a mean selection length (or age) l_c that supposes that the effective fishing mortality is zero at lengths less than l_c and full fishing mortality at lengths greater than l_c (Gulland, 1963). This is usually represented by a symmetrical sigmoid selection curve. However, various factors affect this ideal selection: variations of the length/girth ratio of fish, variations in mesh size, change in mesh size during use, blockages in meshes by accumulated catch, and variation of liveliness of fish (Pope et al., 1975) are among them. In the context of squid, many important factors related to biology and behavior are recognized. Of primary concern is the morphology of the animal which is quite unlike a fish in rigidity while it is equipped with arms and tentacles capable of grasping. Another difficulty is the small size range of animals which progresses through the entire life span.

The life span of Illex, estimated at approximately one year by Squires (1967), conceivably held true for the 1977 (Amaratunga et al., 1978) and 1978 (unpublished data) stocks on the Scotian Shelf. Although a mechanism for predicting recruitment for each year is not developed yet (ICNAF, 1978), it is known that the fishery is conducted on new recruits each year. Each year is usually represented at a given time by single modes, normal distributions of narrow sise ranges (Squires, 1967; Mercer, 1973; Amaratunga et al., 1978). Growth progresses rapidly during the fishery and asymtotes usually close to the end of the fishing season. The reproductive phase is accompanied by winter emigration from the summer fishing grounds on the Shelf. Usually a new generation immigrates in the spring, with no significant overlap of generations (ICNAF, 1978) and enters the exploitation phase.

The 1978 directed fishery for Illex in SA 3 and 4 commenced on June 15, with heavy international fishing in SA 4 between July and October. The fishery, however, is influenced by problems with by-catch. In 1977 it was difficult to determine the directed species between silver hake (Merluccius bilinearis) and Illex (Amaratunga et al., 1978). Depending on when immigration takes place, Illex recruits are exploited as by-catch in the silver hake fishery even prior to the commencement of the Illex-directed fishery. Therefore, mesh size regulation for the Illex fishery must take into consideration other fisheries in the areas, especially the silver hake fishery.

STACRES (ICNAF, 1978) reported that although there was no mesh size regulation for Illex in SA 3 and 4, certain countries used 60 mm codends, the minimum mesh size for silver hake fishery, when fishing for Illex as well. Countries fishing only for Illex used codends with mesh sizes in the range of 40-48 mm. Illex fishery was conducted with both mid-water and bottom trawls. STACRES recommended mesh selection experiments to determine selection curves for Illex over the range of 40 mm to 60 mm mesh sizes. During the first cruise of this survey, mesh selectivity of 45 mm, 60 mm, and 90 mm codends were studied. The mesh sizes studied during Cruise 2 included 100 mm and 130 mm codends.

MATERIALS AND METHODS

The Shirane Maru 1978 program consisted of an "early season" study (Cruise 1) from June 3 to July 4, 1978, and a "late season" study (Cruise 2) from October 16 to November 16, 1978. Each cruise consisted of two legs of approximately two weeks' duration. Each of these segments will be referred to in the following text by the cruise number and leg number for convenience.

Specifications of Shirane Maru are given in Table 1a. Specifications of the "standard bottom trawl" (see Kono, 1978) used throughout the program are given in Table 1b. Details of the nets and rigging are shown in Figures 1, 2, and 3a and b. Diagramatic representation of the basic codend and cover is given in Figure 4. Five condend-cover combinations used were specially constructed by Japan to these basic specifications. Float attachments were altered with each codend-cover combination to ensure sufficient separation between nets. All codends and covers were made of polyethylene, except for the cover of the 45 mm codend which was nylon..

In Cruise 1, Leg 1 and 2, three codends with theoretical mesh sizes of 45 mm, 60 mm, and 90 mm were used with corresponding covers of mesh sizes 20, 35, and 40, respectively (Table 2). In Cruise 2, Leg 1, three codends with mesh sizes of 60 mm, 90 mm, and 130 mm were used with corresponding covers of 35 mm, 40 mm, and 60 mm, respectively. In Cruise 2, Leg 2, the codend meshes were 90 mm, 100 mm, and 130 mm with cover meshes of 40 mm, 60 mm, and 75 mm, respectively. Although each net was measured (as described below), the different codend-cover combinations would be referred to by their theoretical codend mesh sizes in the following text for convenience.

TABLE 1a. Vessel specifications of the Shirane Maru.

Type of ship:	Stern trawler/freezer
Overall length:	83.9 m
Beam:	13.9 m
Gross tonnage:	2528.8 MT
Net tonnage:	1344.5 MT
Power	3030 hp

TABLE 1b. Specifications of the bottom trawl used on the Shirane Maru.

Type of trawl:	Standard bottom trawl (regular type from Kono, 1978)				
Foot rope length:	72 m				
Head rope length:	54 m				
Head rope height:	7 m				
Wingspread	27 m (estimated from headrope length)				
Length of bridles:	150 m				
Type of doors:	rectangular				
Door weight:	2830 kg				
Door length:	260 cm				
Door height:	369 cm				
Distance between doors:	110 m				
Mesh size in wings:	141 m				
Mesh size in codend:					
Theoretical:	45 mm	60 mm	90 mm	130 mm	100 mm
Gear name:	type 001	type 002	type 003	type 004	type 005
Liner in codend:	Partially lined. See figure.				
Mesh size in cover:					
Theoretical:	20 mm	30 mm	45 mm	60 mm	60 mm
Gear name:	type 001	type 002	type 003	type 005	type 004
Chaffing gear fitted:	Yes. See figure.				
Rollers on footrope:	Yes. See figure.				

Sampling was randomized within a Latin square design. Four stations (Fig. 5) were occupied in each leg of Cruise 1, such that on each 24-hour period (day), depth-stratified sampling between 100 m and 300 m was carried out using a single codend mesh size within a transect (Fig. 6; the numbered boxes represent transects). An average of 9 half-hour trawls were made in a day using each codend. A total of 110 trawls were made during each leg of this cruise. Three stations (Figure 8) were occupied in each leg of Cruise 2 such that on each day, depth-stratified sampling between 100 and 1000 m was carried out using a single codend mesh size within a transect. An average of 7 one-hour trawls were made in a day. A total of 84 and 89 trawls were made during Leg 1 and 2, respectively, during this cruise.

TABLE 2. Mesh measurements of codend and cover of gear used on the selectivity study on the Shirane Maru.

Geay Type	Codend									
	001		002		003		004		005	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Theoretical mesh size (mm)	45	45	60	60	90	90	130	130	100	100
Sample size	120	120	240	240	342	340	160	160	80	80
Mean mesh size (mm)	48.27	48.87	57.76	57.87	85.95	86.01	135.47	136.16	95.71	95.52
S.D.	1.81	1.49	1.91	4.32	4.32	3.80	5.90	7.02	2.84	3.06

Gear Type	Cover											
	001		002		003		(Leg 1) 004		(Leg 2)		005	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Theoretical mesh size (mm)	20	20	35	35	40	40	60	60	75	75	60	60
Sample size	120	120	240	240	342	340	80	80	80	80	80	80
Mean mesh size (mm)	20.19	20.06	36.82	37.41	39.54	39.71	59.02	58.47	74.16	75.05	59.22	59.47
S.D.	1.73	1.48	1.30	1.36	1.36	1.58	2.60	2.34	2.51	2.38	1.86	1.96

The program had the basic design which required that fishing commenced as soon as the vessel arrived at the scheduled location on a transect. Trawls of a specified duration were carried out within the transect for a day using a single codend-cover combination. At the end of the day the vessel moved to a new transect and trawled for a day using another codend. When moving from one station to another, it was convenient not to change codends. Hence, trawling at a new station usually commenced using the last codend of the previous station. This basic design was altered on occasion when squid catches were low or when time permitted other experiments. Selectivity data was monitored during the cruises; and when it was felt that the random sampling provided insufficient numbers of squid, search and fish methods (commercial methods) were employed on a few occasions. On Cruise 2, Leg 2, one set per day employed this method.

Codend and cover mesh sizes were measured just prior to and immediately after a day's fishing, thus providing a dry and wet measurement. However, when moving from one station to another; i.e., when codends were not changed between transects, no measurements were taken. Two lines of 10 meshes each, which were pre-marked and located on the topside of the long axis (Pope, 1975), were measured using an ICES gauge (where possible) at 4 kg pressure. This gauge was not large enough for the 130 mm mesh and had to be replaced by a wedge-shaped ICNAF gauge. For measurements of the 20 mm cover, a vernier caliper was used. Table 2 gives means of S.D. of measurements of all five codends and covers in their dry and wet condition. Student t tests were applied to determine variations in the meshes due to wetness and use.

Length measurements of a random sample of approximately 250 squid from the codend and 250 squid from the cover were taken from each set (when available). Additionally, a random sample of 100 animals from each net were studied for morphometrics. Mantle lengths measured to the nearest 0.5 cm from the antero-dorsal protruberance of the mantle to the apex of the tail fin represent all squid length measurements. All weights are recorded to the nearest 0.1 kg. All fish encountered in the nets were studied by length and weight and in most cases by sex. Total catch against squid catch is tabulated in Table 3.

The selection curves obtained for each mesh size differed appreciably from one set to another. Because of this, the best method of combining squid selection data from several hauls was considered. One method was to pool all the codend catches and all the cover catches of a given mesh size and computing a mean selection curve in the usual way (Pope, 1975). Figures 7 and 8 show these ogives for Cruise 1 and 2 by mesh size. The method does not take into consideration the size of squid catch nor by-catch. In the present study, no attempt was made to determine suitable criteria to minimize effects of catch size (Clark et al., 1958; Pope, 1975) on selection. Many sets in Cruise 1 had very small squid catches (Table 3). Hence, an arbitrary criterion, which selected sets that had a minimum of 250 squid in the codend, was used to select "satisfactory" sets. These represented 33% and 39% of all sets from Cruise 1 and 2, respectively. These also included 100% and 89% (of Cruise 1 and 2, respectively) of sets in which squid constituted 50% or more of the total catch. Selection ogives for the "satisfactory" sets were drawn for each mesh size in each leg (Figure 9 and10).

Holden (1971) and Pope (1975) describe methods of fitting selection curves. For the present purposes, linear regressions using the least squares on lengths retained between 25% and 75%; and fitting the curves by eye, using probability paper, were the two most convenient methods. 50% retention lengths obtained by these methods are tabulated (Table 4) against the selection factors obtained for the polyethylene codends.

Illex length frequencies were taken throughout the 1978 fishing season from samples off the international commercial vessels. Growth curve plotted on a weekly basis (Figure 11) neglects selection by the commercial gear. Comparative frequencies obtained during the present survey (Table 5), depicted in Figure 12, represent samples of total squid catch, presumably without selection.

RESULTS AND DISCUSSION

Particular difficulties encountered during the program were associated with mesh measurements. The measurements were done by many individuals and the techniques could not be standardized at all times. The guages themselves also presented problems. The ICES guage (Westhoff et al., 1962), which is the recommended guage for scientific use and most often used in this experiment, presented difficulties in consistantly applying a 4 kg pressure. The measurements (Table 2) using this gauge resulted in coefficient of variance of 4-5%. The ICNAF wedge gauge used for measuring the 130 mm codend was not equipped with a pressure device and proved difficult to regulate. Although standard deviations observed were apparently large (Table 2) the coefficients of variance of 4% for dry and 5% for wet measurements compared favorably with those of the ICES gauge. Beverton and Bedford (1958) reported a study where

Table 3. Squid catch and total catch weights for each set in Cruise 1, with the calculated percentage of squid in the total catch.

1978 SQUID % CATCH FIGURES FOR CRUISE 1 LEG 1

Station 1

SET NUMBER	SQUID CATCH (KG)	TOTAL CATCH (KG)	% OF TOTAL
1	0.000	69.	0.00
2	1.000	148.	.68
3	1.300	94.	1.38
4	.200	190.	.11
5	0.000	168.	0.00
6	.100	1049.	.01
7	.800	161.	.50
8	2.000	198.	1.01
9	1.200	97.	1.24
10	.400	911.	.04
94	337.700	1050.	32.17
95	30.200	179.	16.91
96	.400	279.	.14
97	0.000	175.	0.00
98	509.000	680.	74.89
99	27.800	420.	6.62
100	1320.200	5654.	23.35
101	2.800	377.	.74
102	1.800	1833.	.10
103	0.000	656.	0.00
104	0.000	355.	0.00
105	0.000	7444.	0.00
106	0.000	502.	0.00
107	10.000	979.	1.02
108	1.600	274.	.59
109	4.500	193.	2.33
110	1.100	299.	.37

Station 2

SET NUMBER	SQUID CATCH (KG)	TOTAL CATCH (KG)	% OF TOTAL
11	50.500	109.	46.37
12	1.300	35.	3.70
13	10.700	61.	17.57
14	0.000	669.	0.00
15	35.300	275.	12.83
16	2.200	295.	.75
17	16.300	101.	16.20
18	4.400	135.	3.27
19	1.800	41.	4.43
20	5.500	370.	1.49
21	8.600	184.	4.68
22	5.300	105.	5.03
23	3.100	81.	3.83
24	46.600	62.	74.68
25	13.900	43.	32.40
26	545.800	581.	93.93
27	11.900	234.	5.09
28	1.300	311.	.42
29	16.300	195.	8.22
30	13.400	89.	15.09
31	7.000	182.	3.85
32	10.100	601.	1.68
33	8.100	75.	10.73
34	2.000	129.	1.55
35	2.800	39.	7.25
36	3.300	132.	2.51
37	302.000	338.	89.27
38	14.400	1240.	1.16

Station 3

SET NUMBER	SQUID CATCH (KG)	TOTAL CATCH (KG)	% OF TOTAL
39	10.700	433.	2.47
40	7.300	685.	1.07
41	4.700	35.	13.51
42	13.100	1886.	.69
43	3.800	287.	1.32
45	1.300	76.	1.70
46	1.200	91.	1.32
47	5.100	185.	2.75
48	1.500	719.	.21
49	124.800	379.	32.89
50	1.700	400.	.43
51	7.700	294.	2.62
52	19.100	727.	2.63
53	22.900	102.	22.50
54	3.400	261.	1.30
55	.900	725.	.12
56	2.800	386.	.73
57	5.300	536.	.99
58	43.500	1057.	4.12
59	18.500	1351.	1.37
60	61.600	400.	15.40
61	22.200	1563.	1.42
62	3.900	192.	2.04
63	0.000	630.	0.00
64	4.900	265.	1.85
65	2.500	128.	1.95
66	.300	676.	.04

Station 4

SET NUMBER	SQUID CATCH (KG)	TOTAL CATCH (KG)	% OF TOTAL
67	1.800	247.	.73
68	3.700	233.	1.59
69	21.800	215.	10.14
70	13.900	462.	3.01
71	450.000	517.	87.04
72	16.800	325.	5.18
73	10.700	92.	11.63
74	8.900	142.	6.25
75	1.600	73.	2.19
76	81.300	271.	29.99
77	12.100	346.	3.49
78	4.700	224.	2.10
79	7.100	427.	1.66
80	57.900	484.	11.96
81	11.300	355.	3.18
82	45.000	58.	77.59
83	2.900	103.	2.82
84	60.800	110.	55.29
85	12.500	90.	13.89
86	18.700	222.	8.43
87	4.100	470.	.87
88	3.300	342.	.96
89	11.600	392.	2.96
90	17.500	251.	6.97
91	23.500	255.	9.21
92	15.700	50.	31.55
93	17.800	243.	7.32

1978 SQUID % CATCH FIGURES FOR CRUISE 1 LEG 2

SET NUMBER	SQUID CATCH (KG)	TOTAL CATCH (KG)	% OF TOTAL
123	43.000	526.	8.18
124	0.000	223.	0.00
125	0.000	6271.	0.00
126	0.000	543.	0.00
127	.100	537.	.02
128	68.800	121.	56.86
129	113.100	240.	47.13
130	82.000	931.	8.81
131	12.000	2005.	.60
132	3.900	375.	1.04
133	1.800	182.	.99
134	0.000	66.	0.00
135	1.300	146.	.89
136	0.000	512.	0.00
137	96.900	3800.	2.55
138	0.000	1717.	0.00
139	5.300	379.	1.40
140	246.500	352.	70.04
141	2.100	734.	.29
142	0.000	254.	0.00
143	0.000	104.	0.00
144	0.000	238.	0.00
145	1.500	329.	.46
146	1.400	492.	.28
147	.200	4765.	.00
148	1.400	540.	.26
149	5.200	981.	.53
150	0.000	423.	0.00
151	0.000	235.	0.00

SET NUMBER	SQUID CATCH (KG)	TOTAL CATCH (KG)	% OF TOTAL
152	352.900	586.	60.19
153	42.400	127.	33.31
154	8.700	39.	22.19
155	283.300	304.	93.18
156	14.400	91.	15.82
157	3.200	136.	2.36
158	0.000	150.	0.00
159	7.100	133.	5.32
160	8.200	115.	7.14
161	79.000	202.	39.15
162	99.300	156.	63.86
163	1.700	60.	2.82
164	2.800	113.	2.49
165	15.300	59.	25.71
166	23.500	233.	10.09
167	2.700	48.	5.61
168	2.900	789.	.37
169	64.800	130.	49.92
170	46.400	73.	63.39
171	6.800	16.	42.77
172	6.700	51.	13.21
173	16.000	552.	2.90
174	152.800	215.	70.90
175	2.800	101.	2.77
176	0.000	194.	0.00
177	.700	382.	.18
178	142.400	203.	70.32

SET NUMBER	SQUID CATCH (KG)	TOTAL CATCH (KG)	% OF TOTAL
179	10.000	317.	3.16
180	4.600	53.	8.68
181	102.600	169.	60.57
182	7.200	457.	1.58
183	4.600	158.	2.91
184	7.600	863.	.88
185	1.900	639.	.30
186	1.600	7556.	.02
187	9.100	150.	6.05
188	0.000	0.	0.00
189	.700	6.	12.28
190	68.400	97.	70.39
191	66.000	136.	48.53
192	3.400	42.	8.02
193	2.400	415.	.58
194	.500	156.	.32
195	28.300	92.	30.93
196	4.700	194.	2.42
197	7.200	75.	9.60
198	154.300	193.	79.82
199	12.200	25.	48.80
200	53.800	200.	26.93
201	2.200	6610.	.03
202	.900	100.	.90
203	12.900	864.	1.49
204	61.700	194.	31.82
205	0.000	1658.	0.00

SET NUMBER	SQUID CATCH (KG)	TOTAL CATCH (KG)	% OF TOTAL
206	0.000	74.	0.00
207	2.300	480.	.48
208	315.200	400.	78.99
209	64.800	246.	26.33
210	80.900	255.	31.73
211	4.400	17.	25.87
212	10.700	137.	7.81
213	825.500	1042.	79.25
214	14.000	148.	9.48
215	2.000	151.	1.32
216	.100	260.	.04
217	25.200	99.	25.54
218	605.300	792.	76.18
219	757.900	880.	86.13
220	16.700	291.	5.74
221	91.600	187.	49.12
222	77.500	232.	33.35
223	5.500	185.	2.97
224	1.000	152.	.66
225	.300	216.	.14
226	558.400	854.	65.39
227	736.300	994.	74.07
228	1576.200	1897.	83.09
229	207.400	882.	23.55
230	95.700	665.	14.39
231	10.000	79.	12.71
232	3.500	105.	3.34

Table 3. (cont'd)

1978 SQUID % CATCH FIGURES FOR CRUISE 2 LEG 1

Station 2

SET NUMBER	SQUID CATCH (KG)	TOTAL CATCH (KG)	% OF TOTAL
274	5.700	152.	3.76
275	111.500	119.	93.46
276	393.200	402.	97.74
277	13.700	145.	9.44
278	8.100	68.	11.88
279	1.600	187.	.86
280	12.900	15.	88.36
281	28.900	47.	62.02
282	46.100	49.	95.05
283	6.400	71.	9.01
284	0.000	0.	0.00
285	0.000	0.	0.00
286	5.200	81.	6.41
287	2.400	82.	2.92
288	32.800	114.	28.87
289	6.500	24.	26.97
290	204.100	289.	70.62
291	47.500	62.	76.61
292	18.000	48.	37.82
293	17.900	124.	14.48
294	13.100	309.	4.24
295	14.000	88.	15.96
296	34.500	106.	32.64
297	5.800	455.	1.27
298	5.300	403.	1.31
299	1891.000	1691.	100.00
300	176.600	493.	35.83
301	2932.700	3065.	95.67

Station 3

SET NUMBER	SQUID CATCH (KG)	TOTAL CATCH (KG)	% OF TOTAL
302	98.000	141.	69.36
303	543.400	672.	80.90
304	25.800	33.	77.95
305	36.800	135.	27.20
306	23.900	142.	16.84
307	67.000	91.	73.87
308	71.900	786.	9.14
309	2.100	21.	10.10
310	1982.800	1986.	99.86
311	10.900	415.	2.63
312	566.500	608.	93.16
313	0.000	717.	0.00
314	0.000	142.	0.00
315	15.500	44.	35.31
316	205.800	318.	64.80
317	24.700	36.	69.19
318	.800	45.	1.77
319	64.600	750.	8.62
320	0.000	2184.	0.00
321	2.000	840.	.24
322	1.600	309.	.52
323	0.000	99.	0.00
324	1.100	1367.	.08
325	24.800	487.	5.10
326	4.600	34.	13.57
327	22.300	3364.	.66
328	16.100	1097.	1.47
329	40.800	660.	6.18
330	1668.800	1705.	97.87
331	1164.000	1177.	98.94
332	83.000	95.	87.74
333	36.700	82.	44.98
334	15.300	515.	2.98
335	17.300	37.	46.88

Station 4

SET NUMBER	SQUID CATCH (KG)	TOTAL CATCH (KG)	% OF TOTAL
251	9.900	144.	6.89
252	171.800	199.	86.29
253	.900	2.	40.91
254	2.100	225.	.93
255	5.400	267.	2.02
256	7.900	195.	4.04
257	8.500	1227.	.69
258	165.200	196.	84.46
259	81.800	198.	41.27
260	4.300	18.	23.76
261	62.700	111.	56.33
262	34.100	103.	33.17
263	9.900	20.	50.51
264	4.900	79.	6.19
265	7.500	172.	4.36
266	31.400	34.	92.35
267	27.600	28.	97.67
268	156.600	223.	70.32
269	148.200	176.	84.35
270	54.100	239.	22.68
271	502.400	655.	76.74
272	1438.800	1451.	99.14
273	1479.000	1680.	88.05

1978 SQUID % CATCH FIGURES FOR CRUISE 2 LEG 2

SET NUMBER	SQUID CATCH (KG)	TOTAL CATCH (KG)	% OF TOTAL
364	35.500	148.	23.92
365	357.400	399.	89.57
366	2895.600	2942.	98.44
367	13.300	35.	38.33
368	28.500	49.	58.04
369	7.800	80.	9.73
370	26.800	276.	9.71
371	90.300	145.	62.40
372	3899.500	3902.	99.94
373	47.300	52.	90.44
374	1581.400	1584.	99.82
375	6.800	25.	27.64
376	168.000	196.	85.93
377	77.000	138.	55.64
378	1533.900	1555.	98.67
379	1598.500	1680.	95.14
380	345.300	381.	90.69
381	4515.700	4528.	99.79
382	987.500	1073.	92.01
383	2046.800	2060.	99.35
384	5.500	110.	5.00
385	14.900	205.	7.26
386	182.500	217.	84.18
387	60.800	120.	50.54
388	7.000	516.	1.36
389	217.900	559.	38.95
390	2.300	233.	.99
391	596.800	619.	96.48
392	1261.300	1308.	96.43
393	13.100	828.	1.58
394	15.300	48.	32.14
395	250.800	332.	75.59

SET NUMBER	SQUID CATCH (KG)	TOTAL CATCH (KG)	% OF TOTAL
396	.500	294.	.17
397	4.800	15.	33.10
398	2.800	102.	2.74
399	40.000	124.	32.15
400	28.900	84.	34.32
401	23.500	59.	39.50
402	296.200	537.	55.18
403	10.700	40.	27.02
404	7.100	189.	3.75
405	3048.000	4481.	68.02
406	560.100	1109.	50.52
407	2886.200	4350.	66.35
408	11.530	390.	2.96
409	705.300	2688.	26.24
410	4572.600	7207.	63.44
411	0.000	209.	0.00
412	6.100	81.	7.52
413	7.400	103.	7.18
414	0.000	418.	0.00
415	1817.400	2828.	64.26
416	0.000	144.	0.00
417	1654.100	4466.	37.04
418	34.100	1318.	2.59
419	3.300	181.	1.82
420	37.100	1170.	3.17
421	6.700	263.	2.54
422	10.400	833.	1.25
423	74.000	1796.	4.12
424	2.700	137.	1.98
425	814.600	841.	96.81

SET NUMBER	SQUID CATCH (KG)	TOTAL CATCH (KG)	% OF TOTAL
336	28.300	284.	9.96
337	27.900	64.	43.59
338	424.900	474.	89.57
339	3.600	95.	3.80
340	1.300	481.	.27
341	399.900	465.	85.93
342	4.800	93.	5.18
343	3471.500	3513.	98.82
344	99.800	103.	96.69
345	3887.400	3946.	98.52
346	1391.800	1495.	93.08
347	12.300	77.	16.05
348	17.800	65.	27.26
349	20.600	33.	63.00
350	18.200	20.	89.22
351	239.300	263.	90.95
352	9.000	226.	3.99
353	.800	6.	12.50
354	9.000	57.	15.87
355	5.000	23.	21.55
356	12.900	41.	31.54
357	6.700	42.	15.95
358	481.300	484.	99.50
359	31.600	557.	5.67
360	33.500	72.	46.79
361	106.900	122.	87.77
362	58.100	97.	59.73
363	3.000	343.	.87

TABLE 4. 50% retention lengths and selection factors for data sets taken from the Shirane Maru 1978 mesh selectivity study.

Cruise #	Leg #	Criterion	Codend	l_c at 50%	Selection factor
1	1 & 2	Pooled	45	109	2.4
			60	122	2.1
			90	130	1.4
1	1	Satisfactory sets	45	148	3.3
			60	123	2.1
			90	107	1.2
1	2	Satisfactory sets	45	118	2.6
			60	134	2.2
			90	136	1.5
2	1 & 2	Pooled	60	-	-
			90	183	2.0
			100	197	2.0
			130	190	1.5
2	1	Satisfactory sets	60	-	-
			90	-	-
			130	234	1.8
2	2	Satisfactory sets	90	≈185	2.1
			100	190	1.9
			130	-	-

TABLE 5. Mean mantle lengths of squid in Cruise 1 and 2 of Shirane Maru mesh selectivity study, 1978.

Week Period	Nos.	Mean length (cm)	Standard deviation
June 4-10	8,984	15.41	± 1.35
June 11-17	7,834	15.09	± 1.47
June 18-24	5,901	15.97	± 1.64
June 25-July 1	7,824	16.22	± 1.72
July 2-8	5,238	16.85	± 1.16
Oct. 15-21	5,103	23.25	± 1.46
Oct. 22-28	5,448	23.62	± 1.88
Oct. 29-Nov. 4	5,176	24.29	± 2.00
Nov. 5-11	14,239	24.12	± 1.85
Nov. 12-18	3,543	23.98	± 1.84

six observers used the wedge gauge with no pressure device had coefficients of only 3-4%. The vernier calipers which substituted the ICES gauge for the very small mesh measurements proved to be the poorest gauge (coefficient of variance of up to 9%) in the absence of a pressure device.

Selectivity of codends may be influenced by (i) "fish" (species, quantity, and behavior); (ii) gear; and (iii) operation of the gear (Holden, 1971). The present operations by and large conformed to commercial procedures although durations of tows, and time and location of tows were based on experimental design. Thus, the operational influences on the selection were considered to be of less consequence than the others.

The student t test showed dry meshes were slightly smaller than the wet measurements (Table 2), significantly so in 130 mm codend and 20 mm, 40 mm, and 75 mm cover measurements. A similar test also showed that meshes apparently changed very little with use. Mesh measurements taken during one week of use showed no significant difference to those in the next week. Pope (1975) indicated the importance of testing the meshes of the anterior region of the codend with the posterior end, where most expansion pressure is exerted on the meshes and where most fish escape from (Beverton, 1963). No significant difference in mesh size was discerned between the anterior and posterior regions of the net after use. Thus, the polyethylene codend meshes apparently did not alter significantly through the experiment. Although the ship's captain indicated concern about insufficient codend and cover separation (minimum suggested 1.5-2.0 m) due to insufficient use of floats, laboratory experiments conducted in Japan showed that the gear used on the project apparently functioned adequately. Thus, the masking effect due to improper rigging (Pope et al., 1975) was probably minimal. However, in abundance estimations from the cruise data, it was observed that mesh sizes less than 90 mm had significantly lower catches (Amaratunga and McQuinn, 1979). Indications were that gear efficiency decreased with decrease in mesh size due to alterations in flow of water.

A large number of "valid" hauls (Pope et al., 1975) were carried out during this project. The random nature of the experiment (Gaussian distribution) was thought to counter-balance the effects of the large variations in catch size and composition (Table 3). Pope et al. (1975) recommended large numbers of hauls in view of the intrinsic large between-haul variations. Thus, a group of selection ogives were obtained for all mesh sizes by pooling all valid sets (Fig. 7 and 8), without considerations to catch. The Cruise 1 data show l_c at 50% for the 45 mm, 60 mm, and 90 mm were 109 mm, 122 mm, and 130 mm, respectively. At lengths less than 130 mm, the selection ogives show considerable scatter (Fig. 7). This, in fact, relates to the small numbers of squid present in this size range. Fig. 12 shows that less than 10% of the population fall within this size range. The l_c at 50% for codends used in Cruise 2 (range of 183 mm to 198 mm) also represented a small number of observations accounting for less than 1% of the population (Fig. 8). Similarly, small numbers of squid observed in the large size ranges resulted in scatter in the upper regions of the ogives. Dotted lines represent the uncertain regions in the ogives (Fig. 7 to 10).

Clay (1979) states that in a detailed study of between-haul variations Gulland (1964) found the variation mainly due to "a real difference between sets of hauls". Jones (1958) suggested a method of combining data to take into account the variances between and within sets. However, since it is known that increases in catch size result in decreases in selection factor (Clark et al., 1958; Pope et al., 1975), the selected "satisfactory" sets (which included most sets with squid catches greater than 50%) were used in this study for comparison.

Significant differences were observed between "pooles" data and "satisfactory" data curves. Cruise 1 data in Fig. 7 and 9 show in the "satisfactory" data l_c at 50% increased in all cases except the 90 mm of Leg 1. In Cruise 2 data (Figures 8 and 10), the satisfactory data of 60 mm and 90 mm show virtually all animals encountered at 210 mm or more were retained. The ogives for 100 mm did not alter substantially. Figure 10 shows a scattered retention for the satisfactory data of 130 mm. The variations of the l_c at 50% seen for these two sets of data are in Table 4. The satisfactory data ogives obtained for Cruise 1, Leg 1, were probably the most representative for the selection of squid in the 45 mm and 60 mm codends, while satisfactory data of Cruise 1, Leg 2, were the most representative for 90 mm.

Beverton and Holt (1957) discussed avoidance of fish resulting in decrease in retention as size of fish increased. Such patterns were probably apparent in selection ogives of 130 mm (Fig. 8 and 10) and 45 mm (Fig. 9) codends. There was thus an indication that larger squid had the capacity to avoid encounters with the net. Pope (1975) discussed the possible effects of liveliness of fish that can cause variation to the selection curves. The patterns observed in the ogives of this study indicated that squid activity probably indfluenced selectivity.

Squid morphology and behavior are perhaps the most important criteria affecting the ideal "knife-edge" selection curves. While the body of the squid is not rigid, a serious incumbrance to escapement through the nets are the arms and tentacles. Laboratory and field observations on behavior have shown squid, when disturbed, actively "grab" with their arms and cling onto any accessible solid object using their suckers (virtually as a reflex action). They were often observed to bite using their beaks, in order to retain their grasps. This behavior is likely to occur in the nets and offer an explanation to the variations in selection patterns. Poor selections evident especially in Cruise 2 probably relate to behavior of squid which have at this stage reached their largest size and are capable of rapid movement.

If in squid the maximum girth alone was to be considered in relation to escapement, one would consider the mantle (or tube) of the animal. Many constraints may be identified when using this dimension. For example, the tube has a considerable elasticity and the girth varies in dimension during each intake and outlet of water during the animal's propulsion. Similarly, the tube is capable of accommodating large quantities of food in the gut (Amaratunga et al., 1979; O'Dor et al., 1979). Fish girths are highly correlated with length (Pope, 1975), but morphology and behavior of the squid does not permit a meaningful use to such a correlation.

An alternate method of estimating selection was suggested by Clay (1969). He considered the percent of the population, during the fishing season, that would pass through each codend mesh size rather than trying to utilize l_c at 50%.

This survey began in June, essentially at the recruitment phase of the 1978 stock (Amaratunga and McQuinn, 1979). In Figure 12, Cruise 1, Leg 1 represents the recruitment curve. The mean mantle length at recruitment was 152 mm. Two weeks after the directed fishery commenced the mean mantle length was 162 mm. Mean lengths during Cruise 2, 14 weeks later, advanced from 233 mm to 240 mm. This probably represented the asymtote of the growth curve during entry to the reproductive phase (many maturing females and mature males were observed; see Amaratunga and Roberge, 1979). Growth between the periods mid June to November was extremely rapid, averaging approximately 5 mm per week. Consequently, rapid changes in percentage by weight passing through the codends were recorded and shown in Table 6 and Figure 13. The 90 mm codend released 23% early in June and only 2% in mid October. These escapees, which may be considered as yield per recruit, will tend to be smaller squid, from the tail of the distribution curve. Gulland (1963) points out appreciable differences in yield are seen when the mesh size is such that fish are caught at a size just less than the maximum attainable. The 130 mm codend (in Cruise 2, Leg 1, l_c at 50% was 234 mm; retaining squid at a large attainable size) released 43% of the catch in mid October. Earlier in the season, when squid are smaller, the 130 mm codend would require a significantly greater fishing effort. The 90 mm codend, on the other hand, retained a large enough percentage early in the season and as Clay (1979) suggested, may not affect catch rates in the fishery. The percentages released by the 45 mm and 60 mm codends were considerably lower, while gear efficiency was also questioned for these meshes (Amaratunga and McQuinn, 1979).

TABLE 6. Percentage, by weight, of squid released by five codend mesh sizes used.

Cruise No.; Leg No.	Period	Codend mesh size (mm) (gear type)	*Illex* weight in codend	*Illex* weight in cover	Percentage by weight released in codend
1;1	June 3-17	45 (001)	834.6	131.0	14
		60 (002)	542.1	83.7	13
		90 (003)	2144.8	642.2	23
1;2	June 20-July 3	45 (001)	2057.0	126.7	6
		60 (002)	2546.4	380.2	13
		90 (003)	3642.2	931.2	21
2;1	October 17-30	60 (002)	4607.6	3.2	0
		90 (003)	7546.7	144.9	2
		130 (004)	920.5	690.4	43
2;2	November 2-16	90 (003)	21241.2	287.0	1
		100 (005)	14241.3	2550.0	15
		130 (004)	9123.9	2199.2	19

CONCLUSION

Any mesh regulation if applied to the *Illex* fishery will essentially affect a single year stock. The single year class grows through the fishing season at a rapid rate and therefore can only result in short-term benefits in yield per recruit. However, laboratory and field observations indicate that any slight skin damage (when physically passing through the trawl net) usually results in death to the squid in a few days. These mortalities may counter-balance any possible increase in yield per recruit. Although the present studies were insufficient to determine possible long-term benefits such as the release of sufficient spawning stock, the indications were that behavior of squid in the late season affect selection considerably. While the benefits of a mesh regulation on the squid fishery appear to be limited, considerations must necessarily encompass its value to the other closely associated fisheries, especially silver hake. Clay (1979) states that a 90 mm mesh size appears to be suitable for the silver hake fishery on an experimental basis. The 90 mm mesh size in this experiment was apparently applicable to the squid fishery.

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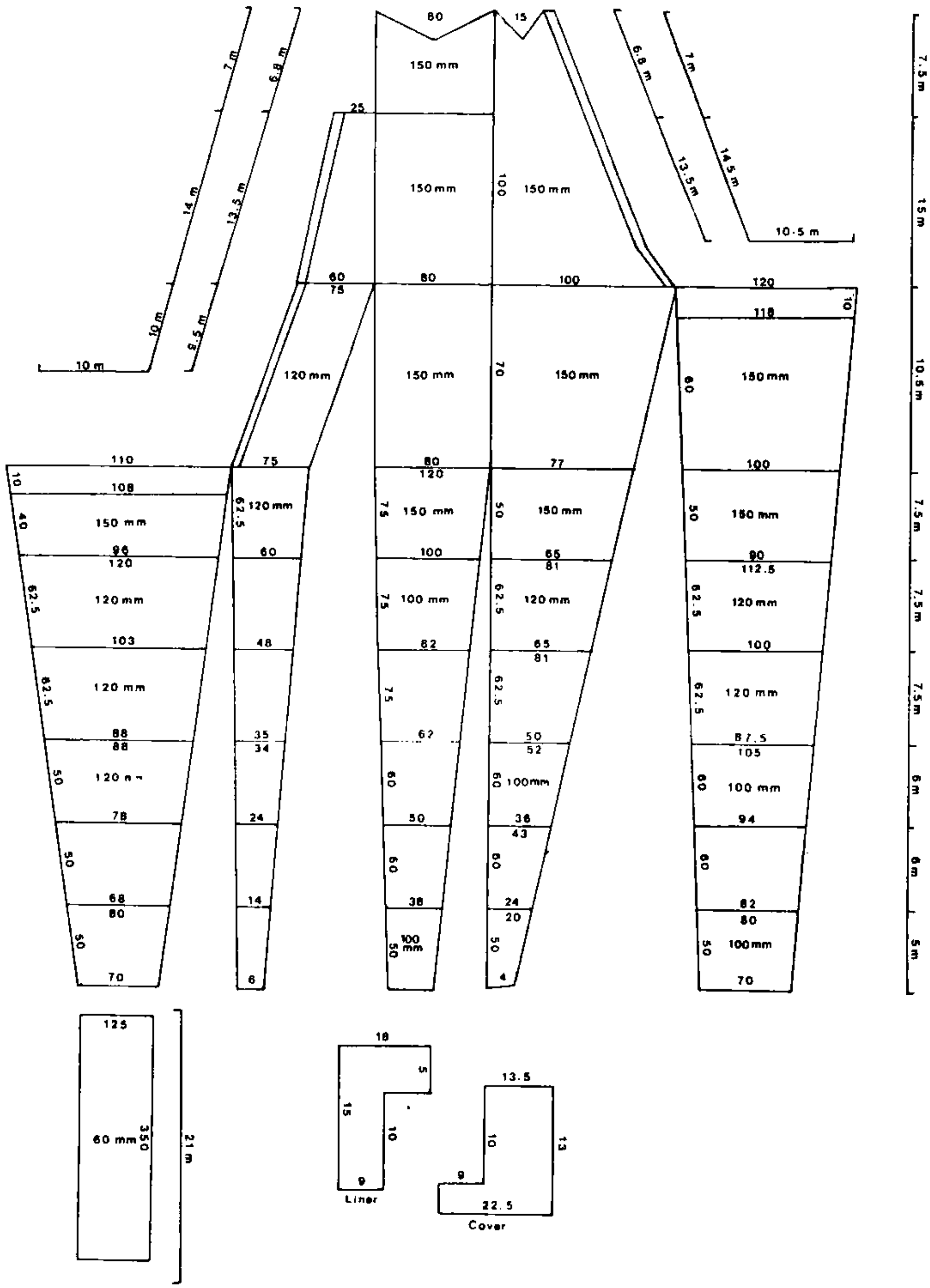


Figure 1. Net dimensions of the bottom trawl used in the 1978 Canada/Japan mesh selectivity study on squid. Measurements are in meters and number of meshes.

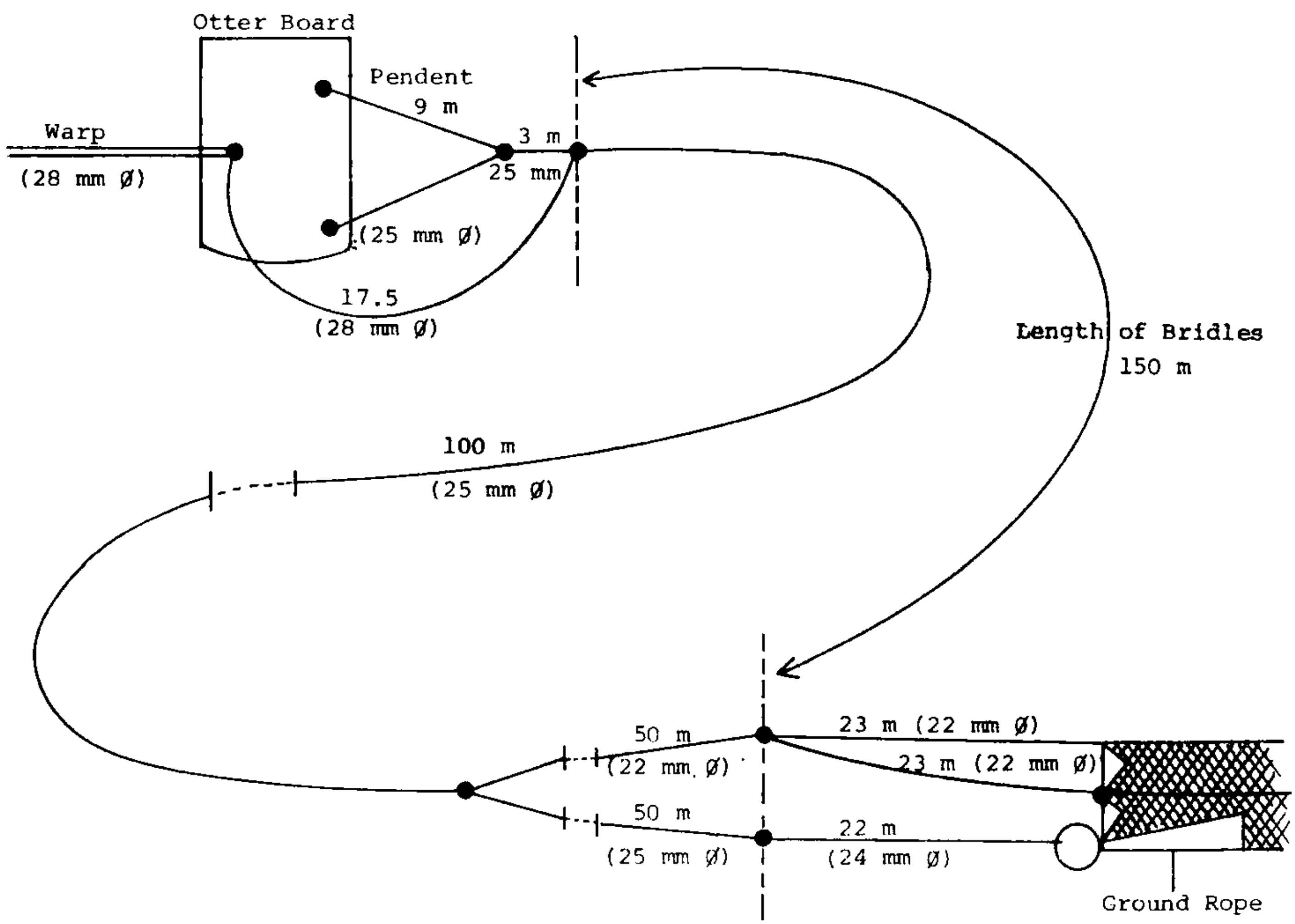


Figure 2. Diagram of the otter board and bridle attachment on the bottom trawl used during the mesh selectivity studies.

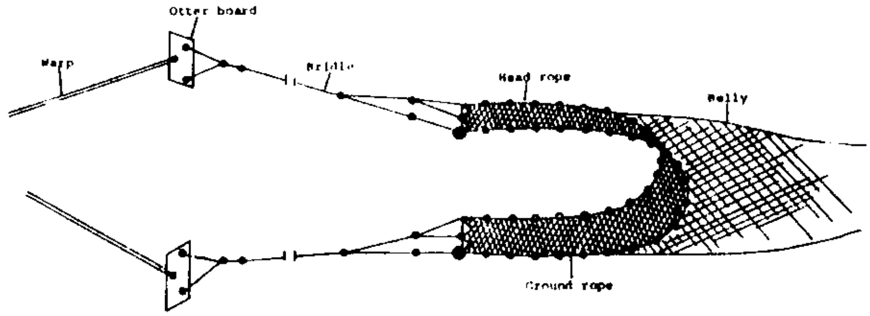


Fig. 3a. Diagrammatic representation of the mouth of the bottom trawl used in the selectivity study.

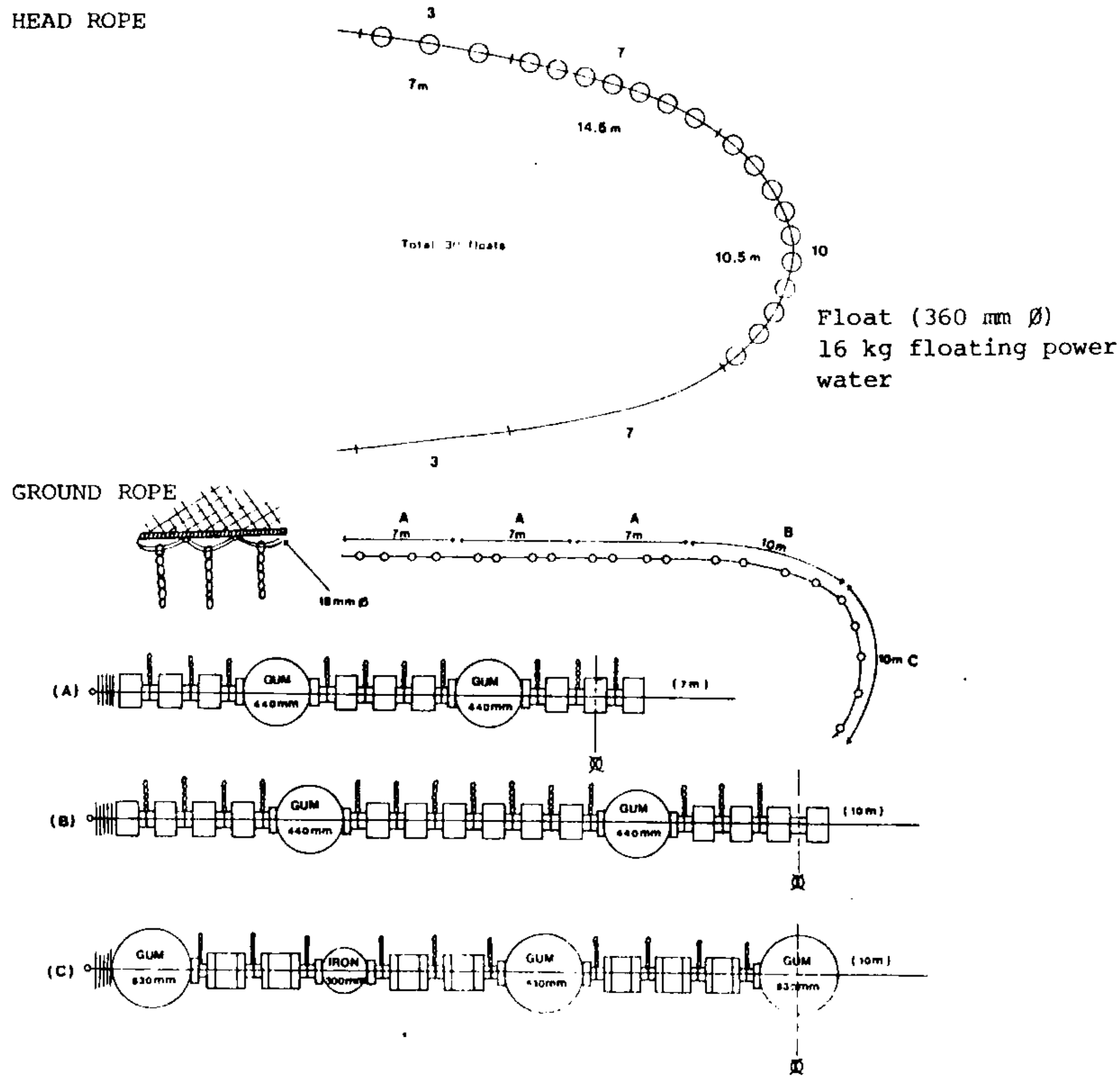


Fig. 3b. Head rope and ground rope of the bottom trawl used in the selectivity study.

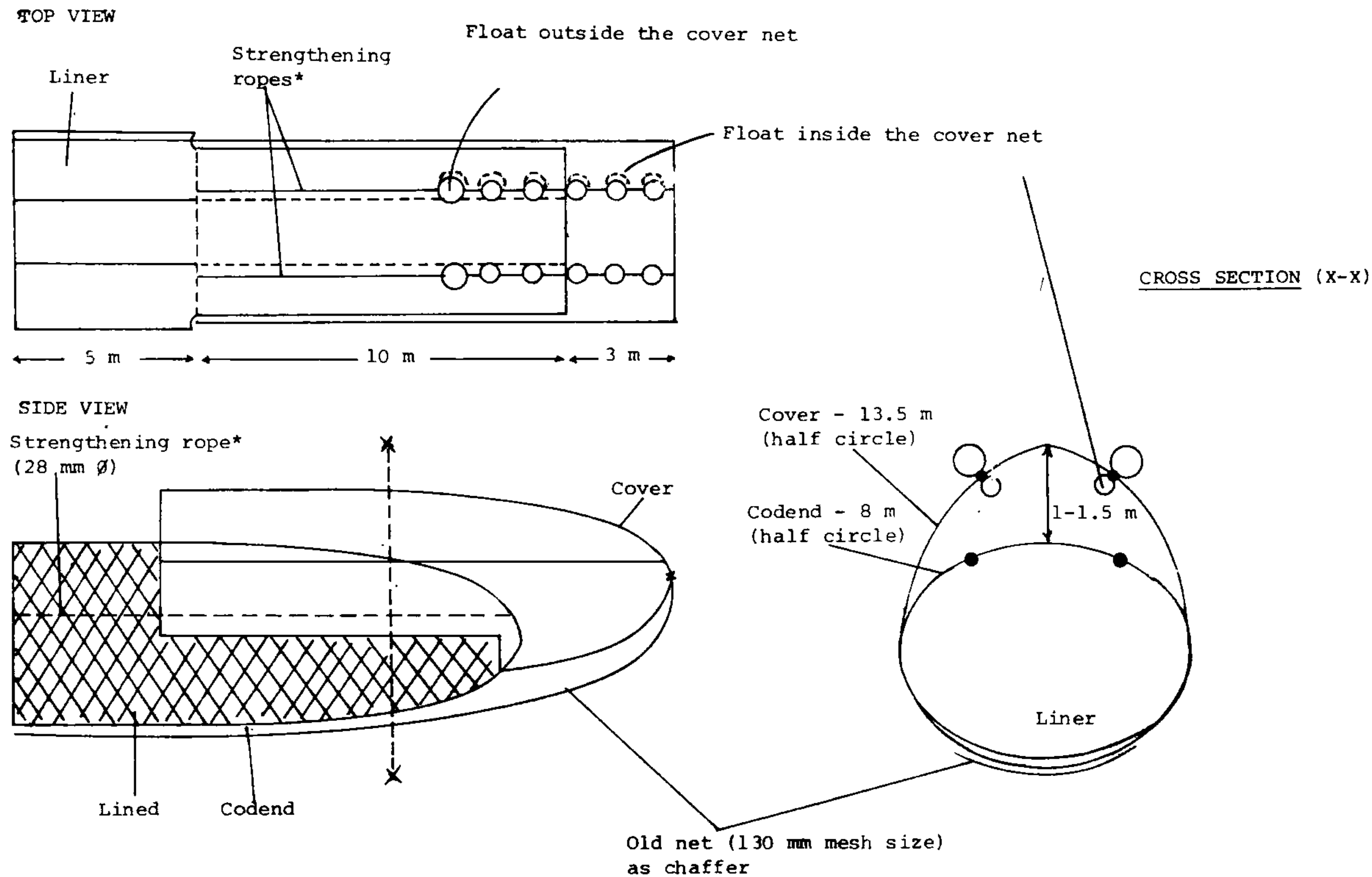
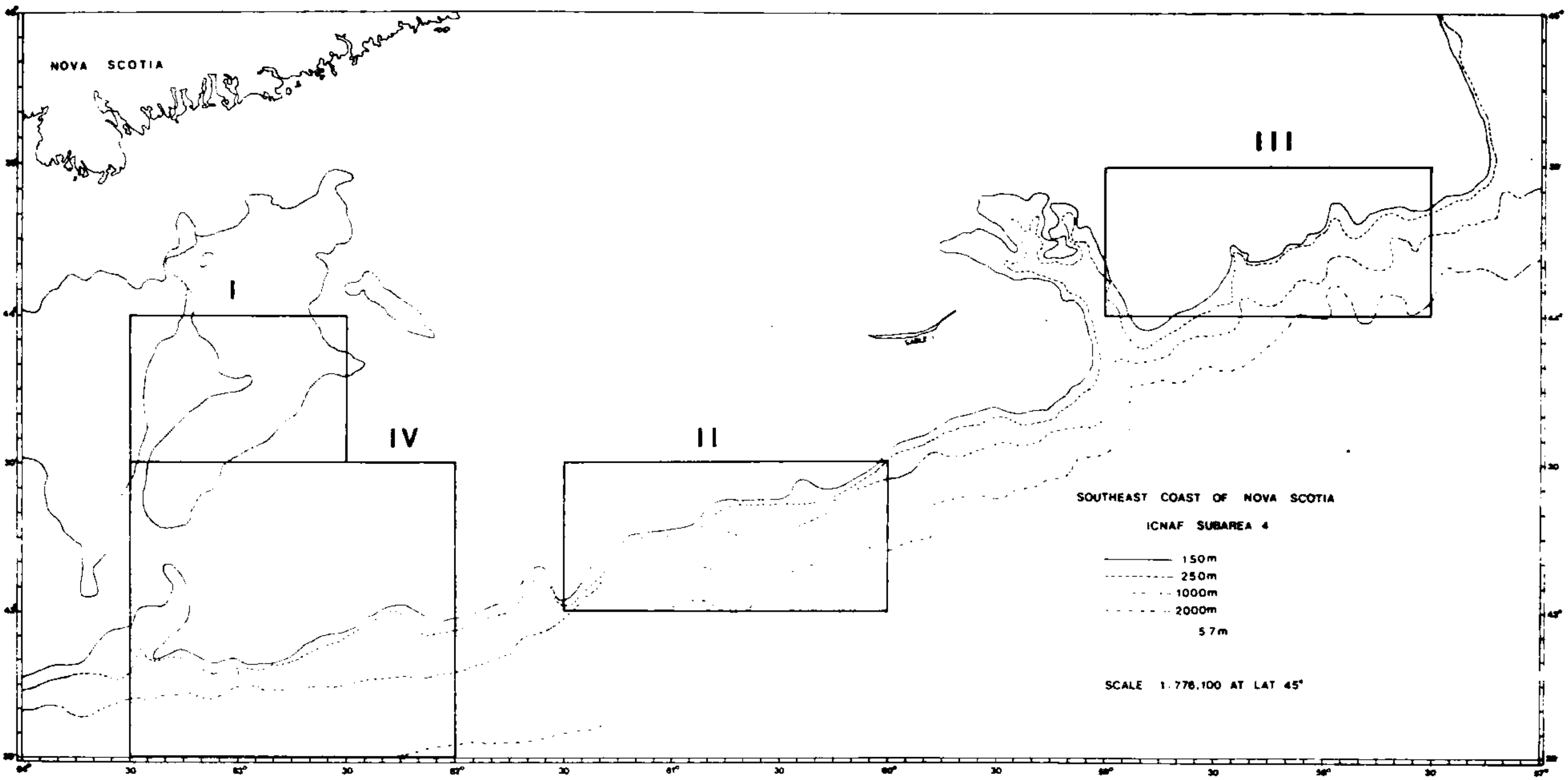


Fig. 4. Diagramatic representation of codend and cover of the bottom trawl used in the selectivity study. (N.B. The numbers and sizes of floats used were altered to suit the different mesh sizes.)

Materials: Net, all codends, and covers: Polyethylene, except cover net of 45 mm codend: Nylon.

*Four ropes were used circumfirentially on the cover as further support on all covers. The positions were not determined by us, but they were in the aft end of the net.



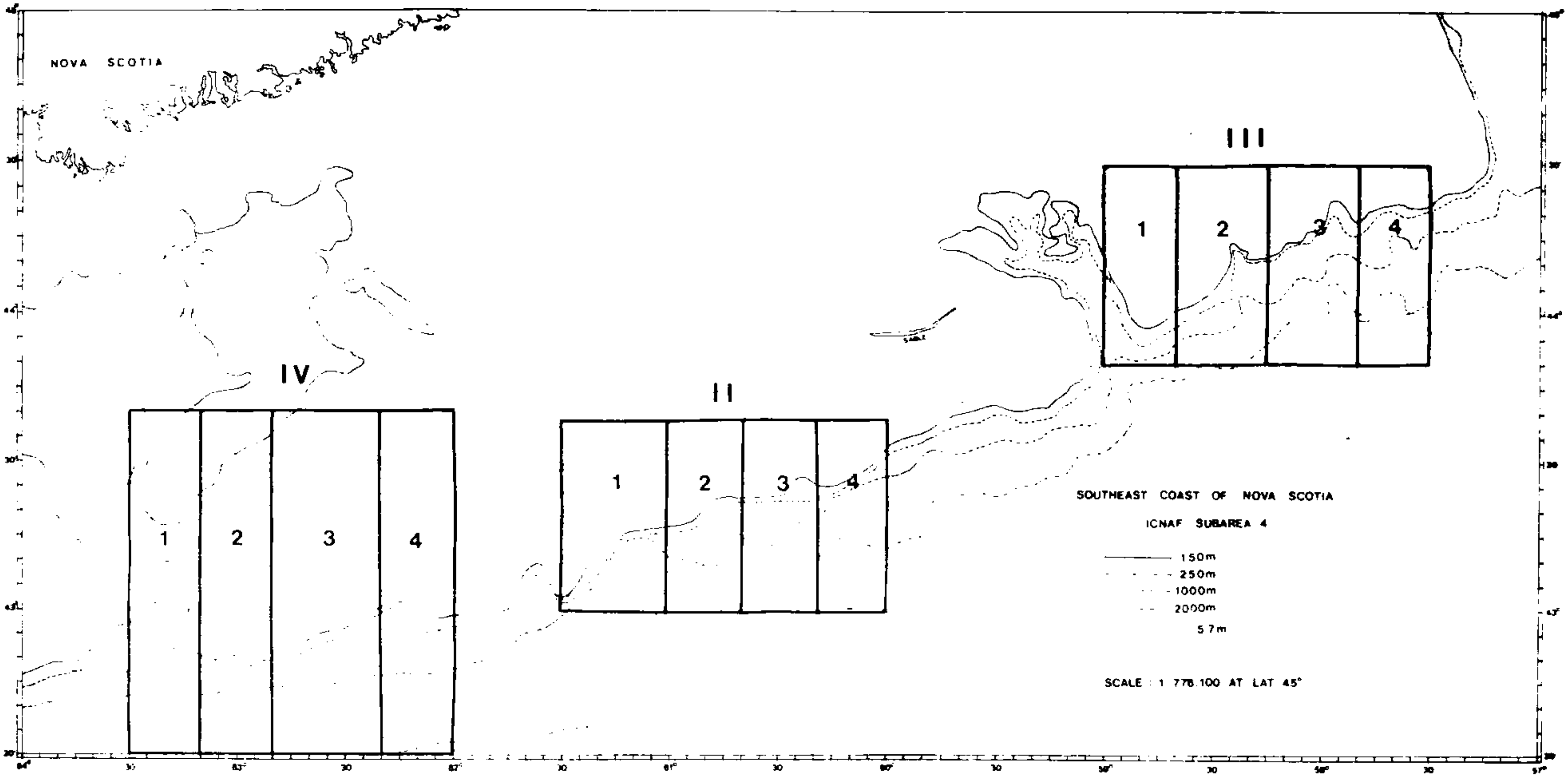
I - Emerald Basin

II - Sable Island Bank

III - Banquereau Bank

IV - Emerald Bank

Fig. 5. Map showing the four stations occupied during Cruise 1 of the selectivity study on the Shirane Maru, 1978.



II - Sable Island Bank
III - Banquereau Bank
IV - Emerald Bank

The numbered boxes represent transect within stations.

Fig. 6. Map showing the three stations occupied during Cruise 2 of the selectivity study on the Shirane Maru, 1978.

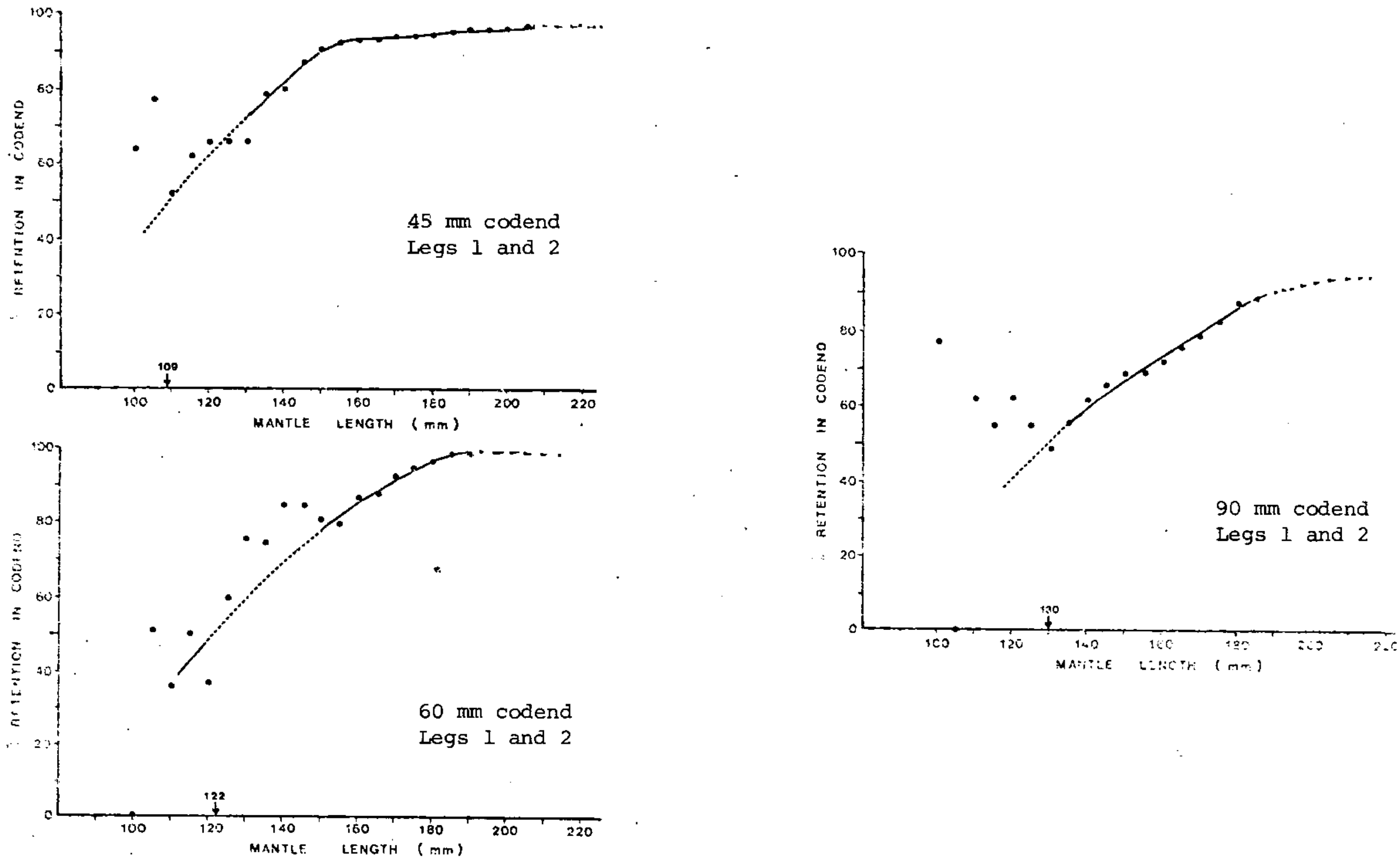


Fig. 7. Selection ogives for "pooled" data of Cruise 1, Legs 1 and 2 combined, for the three codends used.

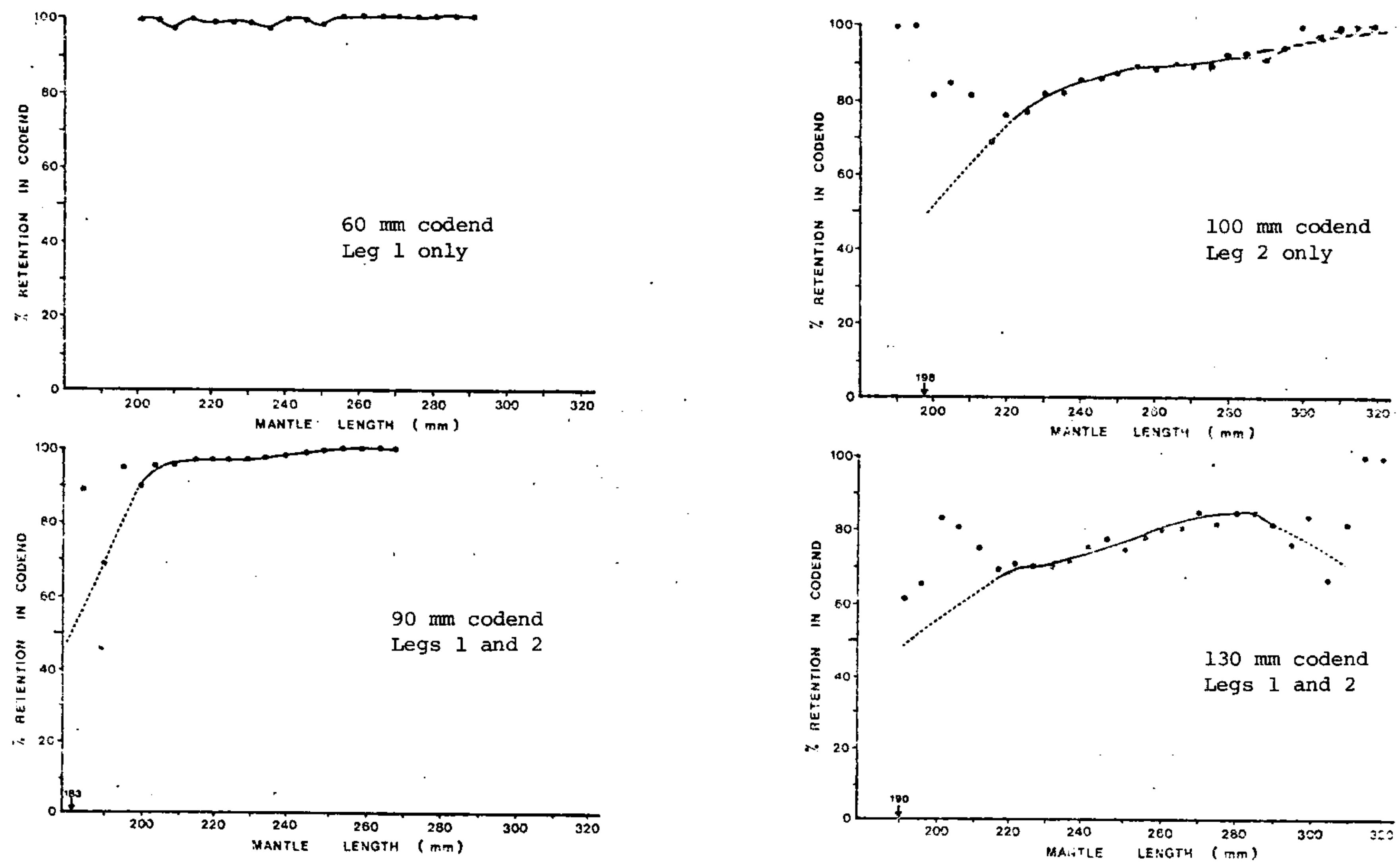


Fig. 8. Selection ogives for "pooled" data from Cruise 2, Legs 1 and 2 combined, for the four codends used.

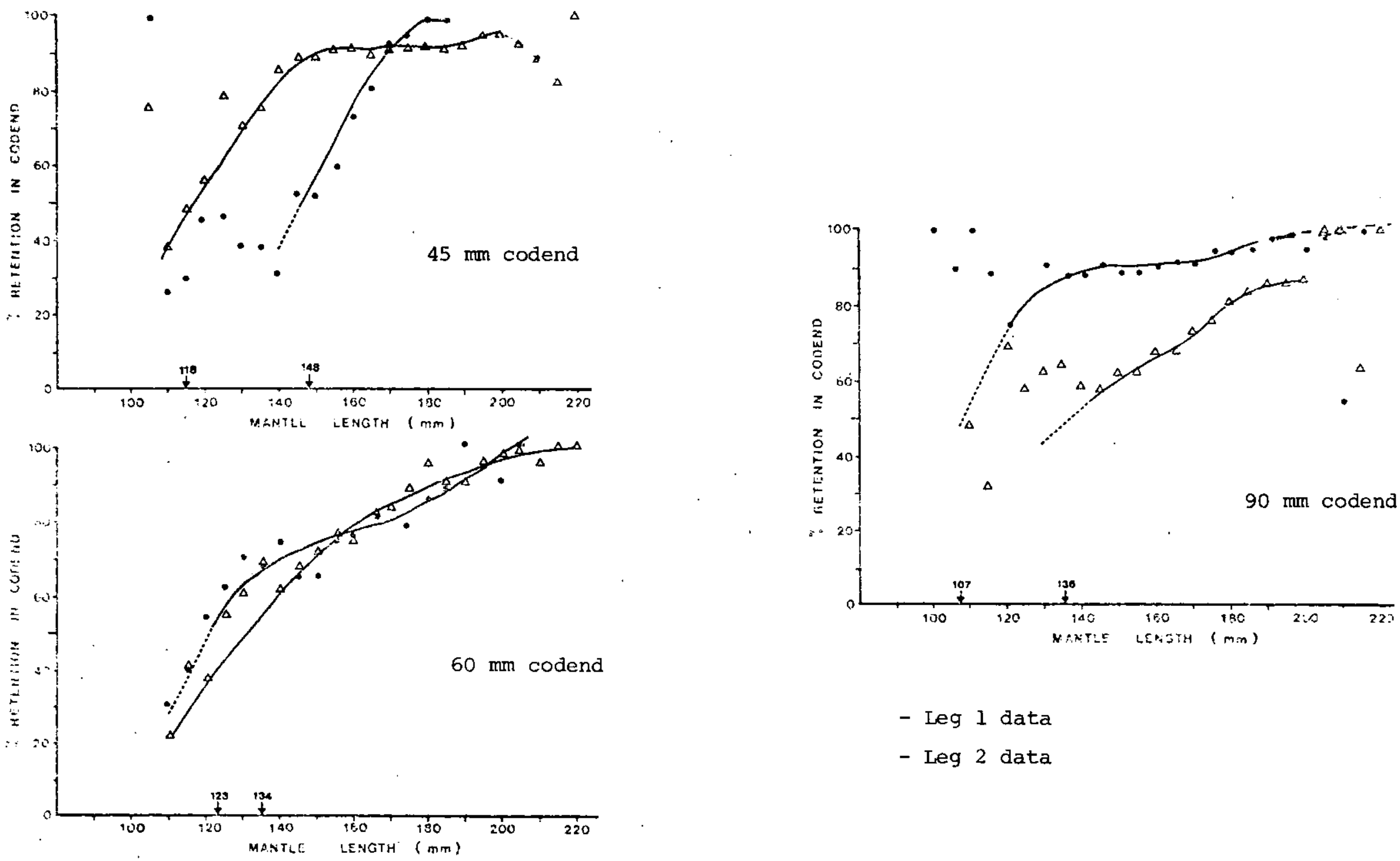


Fig. 9. Selection ogives for "satisfactory" data of Cruise 1, Legs 1 and 2 separate, for the three codends used.

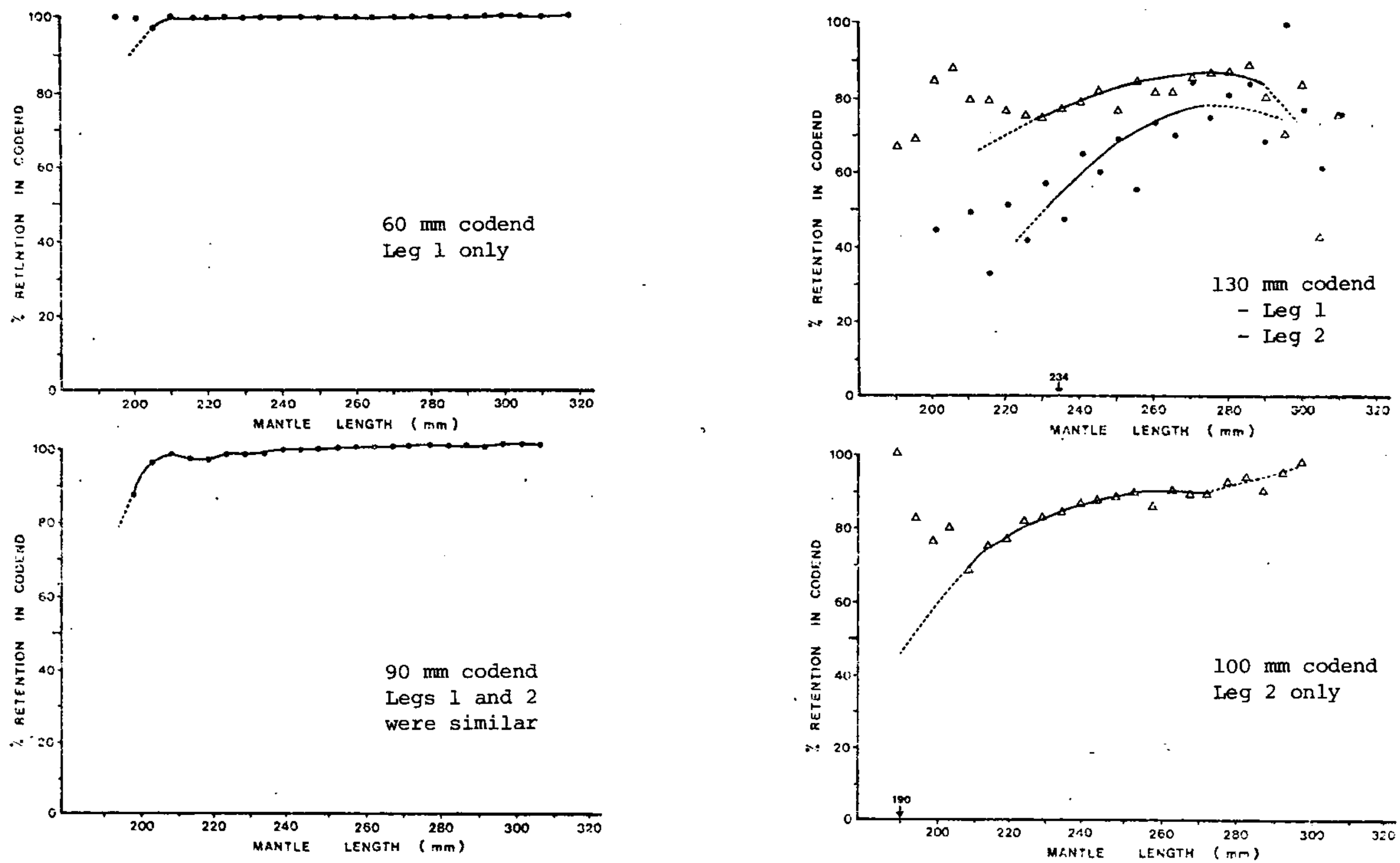


Fig. 10. Selection ogives for "satisfactory" data of Cruise 2, Legs 1 and 2 separate, for the four codends used.

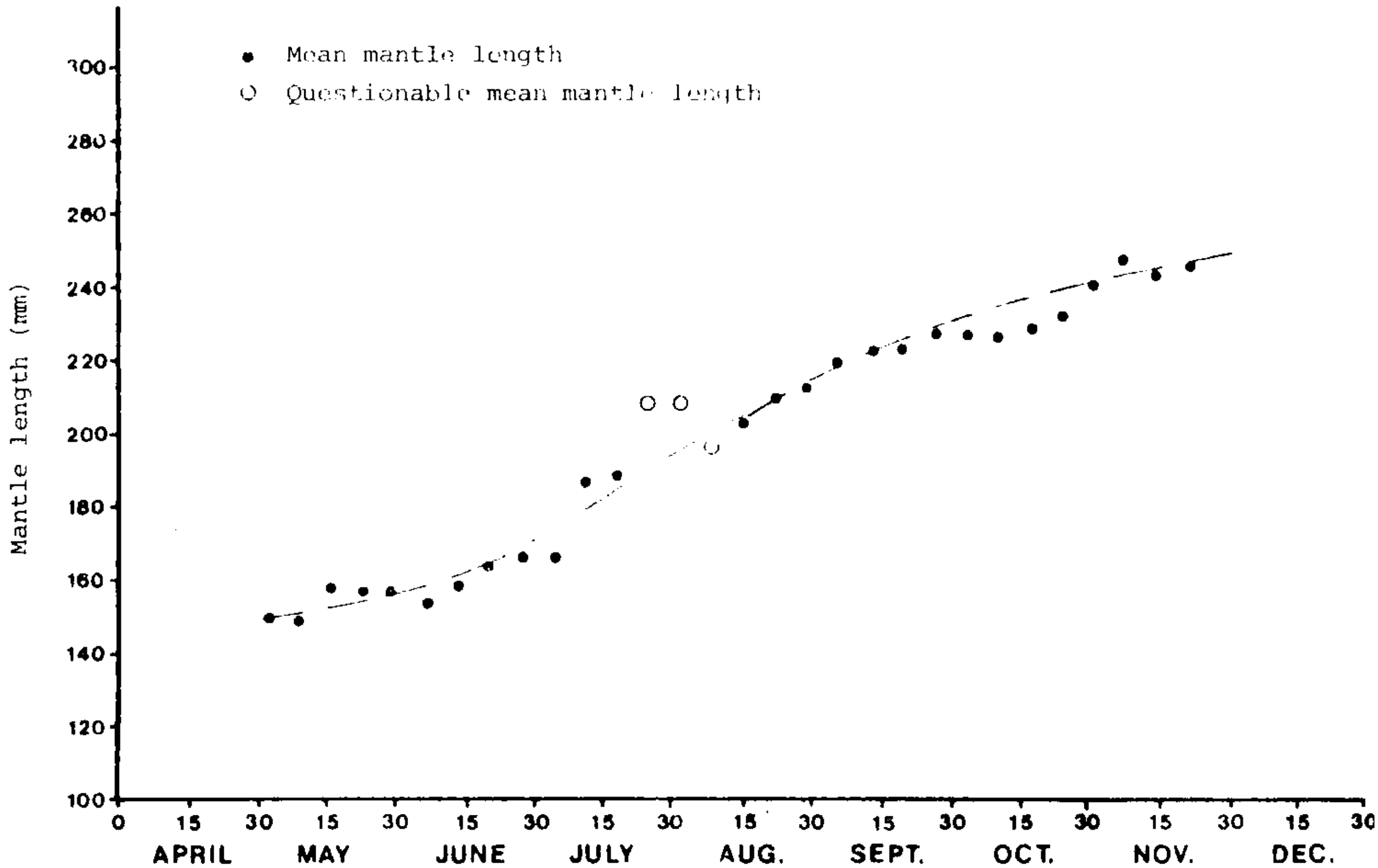


Fig. 11. Growth of Illex illecebrosus from the Scotian Shelf in 1978. Circles represent mean mantle length for unsexed squid.

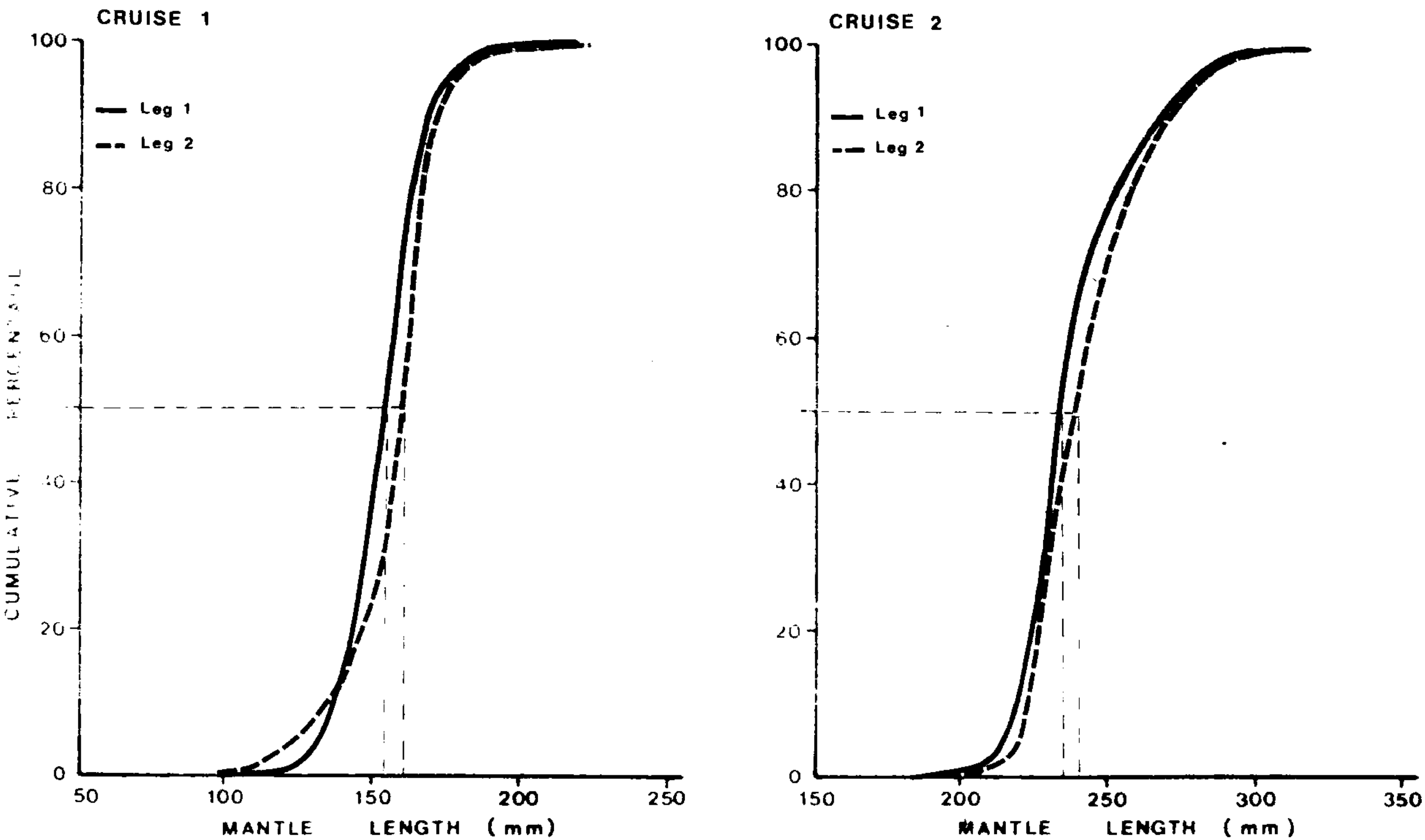


Fig. 12. Cumulative percent distribution of <u>Illex</u> observed during the selectivity study on the <u>Shirane Maru</u>, 1978.

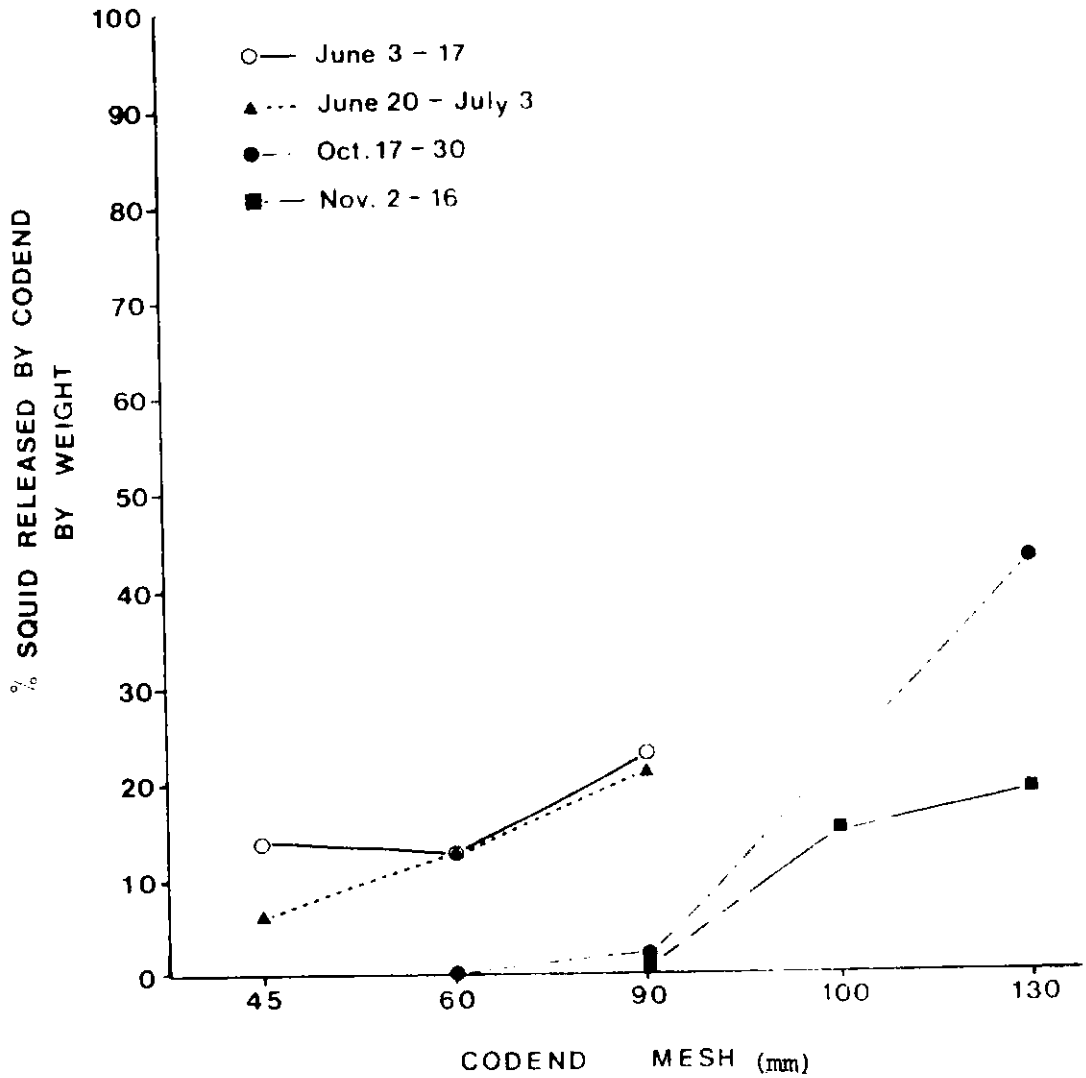


Figure 13, Percentage of squid, by weight, released by each codend mesh size for each leg of the cruises.