RESTRICTED

International Commission for the Northwest Atlantic Fisheries

Serial No. 3482
(D.c. 2)

ICNAF Res. Doc. 75/27

ANNUAL MEETING - JUNE 1975

Size distributions of the migrant ommastrephid squid, *Illex illecebrosus* (LeSueur), in Newfoundland inshore waters

by

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Introduction

Migrant juvenile ommastrephid squid, *Illex illecebrosus*, generally arrive inshore at Newfoundland in late June or July and depart in November by which time many of the males are mature. Relationships between these stocks and those exploited by rapidly developing offshore fisheries in other parts of the Northwest Atlantic are yet to be resolved and the problem is one that must be addressed in attempting to manage the resource.

Size distributions and growth of the species at Newfoundland have previously been described by Squires (1957, 1967) and Mercer (1965, 1966, 1969a) and further data are available on size distributions in offshore areas of the Northwest Atlantic (Mercer, 1969b, 1969c, 1970, 1973a; Mercer and Paulmier, 1974). This paper analyzes in detail the heterogeneity in size compositions previously noted by the author (Mercer, 1966, 1969a) and collates data in a form amenable to application in stock discrimination particularly when viewed in combination with detailed summaries of maturity data previously reported (Mercer, 1973b).

Materials and Methods

Specimens examined

All specimens were taken by handline and jigger in inshore waters of less than 20 metres depth (Fig. 1). Conception Bay samples were taken at various localities in 1965 and all were obtained at Holyrood in succeeding years. Hermitage Bay samples were taken at various localities in 1966 and at Rencontre West only in 1965 and 1967.

Dorsal mantle lengths were measured from the antero-dorsal proturberance to the apex of the tail fin, to the nearest centimetre in 1965-67 and to the nearest half-centimetre 1971-73. Measurements of 33,041 specimens are examined in this paper.

Data analysis

Sample modes were determined by inspection where the length frequency distributions approached fairly smooth unimodal or bimodal curves. Where unimodal distributions were platykurtic (and only moderately skewed) such that the two or three adjacent size classes had nearly equal frequencies, the mode was estimated from the relationship mode = 3 median - 2 mean as outlined by Simpson et al. (1960). In some bimodal but platykurtic distributions this method could not be applied; in such cases the range within which the mode occurred was determined by visual inspection and this range applied in tables and graphs. Bulges in size distributions (corresponding to modes in temporally adjacent samples) were taken to indicate "probable modes" which were estimated from visual inspection and tabulated as such.

Arithmetic sample means calculated for unimodal distributions were found to be biased by skewness in nearly all cases. To adjust for this mean sizes were determined by plotting the cumulative length frequency distributions on probability paper, accumulating from the tail of the distribution opposite the skew. This accomplished a linear transformation and straight lines were fitted by eye to the principal data points, excluding those from the skewed end, and means were read off where the lines intersected the 50 percent co-ordinate. The standard deviation was read as the distance between the mean and the 0.8413 co-ordinate. If skewness is interpreted to be related to admixture of different size groups the above adjustment gives a better approximation of the population mean for the principal size group (see Results section). Some probability plots did not produce linear transformations and resultant plots were strongly skewed; hence the log-normal rather than the normal model was applied.

Sample means and standard deviations for bimodal distributions were calculated by the technique developed by Harding (1949) as outlined by Cassie (1950).

Results

For inshore Newfoundland three size groups can be distinguished by examination of modes of mantle length in males as follows:

I. Mode ca. 21 cm in early August increasing to 24 cm by the end of September and to 24-25 cm in October.
II. Mode ca. 17 cm in early August increasing to ca. 22 cm by the end of September and to 22-23 cm in October, November.
III. Mode ca. 16 cm in mid-August increasing to ca. 20 cm by the end of September and to ca. 20-21 cm in October.

We can analyze the composition of the samples from the various bays for each year on the basis of these groupings.

1965

Substantial homogeneity was evinced by samples taken in Conception and Trinity bays July 27 to November 13, 1965 (Fig. 2). Most samples had unimodal and fairly leptokurtic distributions comprising group I squid but two taken early in the season showed bimodality with the second mode comprising group II squid.

In 5 samples taken at Englee August 11 to September 14, 1965, length distributions were unimodal and skewed comprising predominantly group I squid; in the last sample group III was also represented.

Three samples taken at Rencontre West August 7-23, 1965, were heterogeneous comprising mostly group II squid with group III squid represented in one sample.

1966

Bimodality was apparent (Fig. 3) in samples taken from Holyrood, July 20 to November 2, 1966 (groups I and II) with a further group of small squid (group III) entering the area at the end of the season (November 2). Modes for group I squid increased from 19 to 24 cm from July 20 to October 19 for males and 20 to 26-27 cm for females. Modes for group II increased from 17 to 23 cm for males and 17 to 25 cm for females from July 20 to November 2.

Heterogeneity was also found in samples taken in Hermitage and Fortune bays, August 3-October 28, 1966 (Fig. 3). Here the situation was complex with group III predominating; group I was represented twice, forming the bulk of one sample and group II was less conspicuous. Modes for both sexes in this group increased from 15 cm in mid-August to 20 cm at the end of September; modal length remained 20 cm throughout October.

1967

Samples from Holyrood, July 17 to November 23, 1967, had unimodal distributions (Fig. 4). These were negatively skewed so that arithmetic mean mantle lengths were smaller than those calculated from cumulative probability plots; this I attribute to slight intermixture of group II and/or group III squid. Adjusted mean male mantle lengths increased from 19.5 cm on July 17 to an "asymptotic length" of 25.6 cm on October 18; five samples examined October 18 to November 23 had mean lengths 25.5-25.6 cm (Table 1). Females grew from 20.0 to 28.2 cm over the same period; five samples examined October 18 to November 23 had mean lengths 28.1-28.4 cm. Dispersion about the mean was less in the more leptokurtic male length frequencies where coefficients of variation were 3.54 to 8.57; in females, which grew to a larger size, these were 5.20 to 10.40 (Table 1). Average growth per month to "asymptotic length" was thus 20 mm for males and 27 mm for females; however, growth per month in successive monthly periods commencing mid-July decreased from 24-18-16 mm for males and 34-26-23 mm for females. Modes increased from 19 cm for both sexes to a maximum of 25 cm for males and 28 cm for females, both by October 18.

Most samples taken at Rencontre West August 7 to October 16, 1967, were also unimodal although a few were bimodal (Fig. 4). The unimodal distributions were positively skewed so that arithmetic means were higher than those calculated from the cumulative probability plots; this I attribute to slight admixture of group I squid. Group III predominated in 2 catches and appeared as a second modal group in a third. Adjusted mean male mantle lengths for group II increased from 16.9 cm on August 7 to 23.0 cm on October 16 at which time "asymptotic length" seemed to be approached. Females grew from 17.3 cm on August 7 to 24.3 cm on October 9 when "asymptotic length" was apparently reached; a sample taken on October 16 had a mean mantle length of 24.2 cm. As found in Holyrood samples, variability was less in males, V = 5.56 to 8.11, than in females, V = 6.01 to 8.55, for unimodal distributions (Table 1).

Average growth per month from August 14-September 13 was 42 mm for males and 52 mm for females and from September 13 to October 9 it was 30 mm for both sexes (Fig. 6). Modes for the principal size group increased from 17 to 23 and 18 to 25 cm in males and females, respectively (Fig. 4). October samples were bimodal, containing groups of smaller squid.

1971

All samples from Holyrood, July 6 to November 9-10, 1971, had unimodal leptokurtic distributions of group I squid. Modes increased from 17 and 18 cm to 24 and 27 cm for males and females, respectively. In contrast to samples obtained in 1967 the early length frequencies were positively skewed. Unadjusted mean mantle lengths increased from 17.9 cm and 18.3 cm to 24.0 cm and 26.4 cm for males and females, respectively (Table 1). No samples were obtained between September 10 and November 1 by which time "asymptotic length" had been approached. The increase in unadjusted mean mantle length between November 1 and November 10 was 1 mm for males and 3 mm for females; the latter difference can be eliminated by adjustment for skew. "Asymptotic lengths" were about 15 mm and 20 mm lower for males and females, respectively, than those observed in 1967. Growth per month was also lower than that observed in 1967; in two successive months commencing mid-July it decreased from 22 to 17 mm for males and 25 to 21 mm for females.

1973

The three samples obtained at Holyrood July 20 to August 22, 1973, had unimodal leptokurtic distributions, the first two of which were positively skewed and the last negatively. Characteristics of the distributions approximated those observed in previous years (Table 1).

Discussion

Squires (1957, 1967) reported substantial homogeneity in length distributions of *Illex illecebrosus* at Newfoundland, finding only one modal class except in November of some years. He reported the appearance inshore of a group of small squid in November, 1952 (Squires,1957, Fig. 9) and cited fishermen's reports of small squid inshore in southern Newfoundland late in the season.

Given a homogeneous age composition, between year and regional differences are still to be expected in the size composition of a short-lived rapidly growing species in response to variability in such factors as temperature and availability of food. However, results presented here indicate the presence of distinct modal classes which can be followed throughout the season in a given area, especially in 1966. This suggests presence of mixed age groups within a single year-class, possibly related to a protracted spawning season and area (Mercer, 1969a). The general pattern observed at Newfoundland is that the larger size classes of squid range farther north than do the smaller (cff 1967 data, Fig. 4). Positive skewness in Rencontre West samples contrasted with negative skewness observed at Holyrood in 1967 can be interpreted as resulting from slight admixture of the two size groups and in this case the adjustment for skew applied in analyzing length compositions produces more accurate estimates of mean sizes for the size groups.

Squires (1967) suggested a range of spawning from January to June with a major winter spawning at an age of about one year. I concur that populations fished at Newfoundland probably spawn and die in winter. An analogy can be drawn with the second southward migratory group of Todarodes pacificus at Japan as documented by Hamabe and Shimizu (1966); this group is purported to have a life span of one year, to mature at about the same size as Illex illecebrosus at Newfoundland (cff Mercer, 1973b), and to undergo an extensive southward migration in the same season. I have previously noted a decline in the proportion of male Illex illecebrosus inshore at Newfoundland late in the season (Mercer, 1973b) and suggested that this may relate to offshore migration of mature males. Such a circumstance apparently occurs in the analogous group of T. pacificus as Hamabe and Shimizu (1966) note that mature males preponderate in the southwestern Sea of Japan at the time of arrival of the group, the sex composition equalizing as more females retreat from the north.

It remains now to collate size and maturity data for offshore areas, particularly Subarea 5 Statistical Area 6 where summer fisheries for Illex illecebrosus have recently developed. A perusal of the author's limited unpublished data from this region indicates the possibility of distinguishing spawning groups analogous to those proposed for T. pacificus; however, the need for further detailed sampling is indicated.

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Table 1. Arithmetic mean dorsal mantle lengths with coefficients of variation and adjusted mean lengths with confidence intervals for squid sampled inshore at Newfoundland. Adjusted lengths and standard deviations were read from a cumulative probability plot summing from the right hand side of the distribution for Holyrood in 1967 and negatively skewed samples in 1971 and 1973 and summing from the left hand side for Rencontre West in 1967 and positively skewed samples from Holyrood in 1971 and 1973; these were used in the calculation of the standard errors and confidence intervals. Skewness is indicated as negative when the plot showed increasing slope from left to right, 0 when the straight line fit was good, and positive when the slope decreased from left to right when summing from the right and the converse when summing from the left.

	MALES						FEMALES					
Date	No. examined	Modal class	Arith $\overline{ML}$(cm)	V	Adj. $\overline{ML}$ +95% conf. inter.	Skew	No. examined	Modal class	Arith $\overline{ML}$(cm)	V	Adj. $\overline{ML}$ +95% conf. inter.	Skew
Rencontre West - 1967:												
Aug. 7	204	17	17.5	6.16	16.9 ± .1647	0	273	18	17.9	7.48	17.3 ± .1661	+
Aug. 14	278	16	16.5	8.11	15.9[1]± .1411	+	346	17	17.2	8.55	16.5 ± .1264	+
Aug. 23	266	18	18.3	5.82	17.8 ± .1322	0	286	19	18.8	7.17	18.3 ± .1275	+
Aug. 28	138	18	18.3	5.56	17.7 ± .1502	0	190	19	19.1	7.30	18.5 ± .1706	+
Sept. 4	229	18	18.3	6.08	17.8 ± .1295	+	337	18(21)	19.0	7.33	18.7[2]± .1495	+
Sept. 13	257	20	20.5	5.98	20.1 ± .1467	+	242	22.3[10]	22.2	6.59	21.7 ± .1764	+
Sept. 18	232	21	21.1	5.64	20.7[3]± .1415	+	252	22	22.1	6.01	21.7 ± .1482	+
Sept. 25	232	22	20.8	7.14	[5]± .1673		270	23	21.9	7.05	21.6[9]± .1789	
					21.5 ± .1802							
Oct. 2	229	22	20.7	7.81	22.0[4]± .1295		264		22.1	9.55		
		20			19.9 ± .1166							
Oct. 9	169	22	22.0	8.08	22.7[6]± .2262		247	24	23.4	9.54	24.3[7]± .2120	
		20			ca. 20.0			19			19.3 ± .0873	
Oct. 16	174	23	20.9	10.90	23.0[8]± .1486		181	25	22.1	13.24	24.2 ± .2855	
		19			19.3 ± .1634			19			19.4 ± .1777	
Holyrood - 1967:												
July 17	297	19	18.6	5.46	19.5 ± .1126	0	287	19	19.0	5.62	20.0 ± .1157	0
July 26	258	20	19.5	5.44	20.7 ± .1269	0	206	21	20.5	6.24	21.3 ± .1639	-
Aug. 1	276	21	19.5	6.25	21.2 ± .1392	-	177	22	21.0	6.47	21.8 ± .1812	-
Aug. 8	258	21	20.5	5.83	21.4 ± .1342	0	194	22	22.0	7.21	22.3 ± .2237	0
Aug. 14	216	22	21.0	5.99	22.1[11]± .1867	-	181	22	22.0	7.24	23.1 ± .2244	-
Aug. 24	271	22	21.5	7.33	22.2 ± .1441	-	238	23	22.6	8.47	23.5 ± .2058	0
Sept. 1	248	22	21.0	8.57	22.4 ± .1904	-	222	24	23.4	10.40	23.6 ± .3828	-
Sept. 15	125	23	23.5	5.82	23.9 ± .2338	0	147	25(23)	25.0	7.30	25.7 ± .2878	[12]
Sept. 19	201	24	24.0	4.48	24.4 ± .1382	-	203	26	26.1	7.49	26.2 ± .2339	[13]
Sept. 28	220	24	23.0	4.95	24.2 ± .1374	-	185	26	24.3	7.87	26.1 ± .2234	-
Oct. 3	99	24	23.5	3.97	24.7 ± .2269	0	142	26	26.5	5.56	26.9 ± .2352	0
Oct. 18	201	25	25.5	3.76	25.6 ± .1286	0	131	28	28.5	5.38	28.2 ± .2209	-
Oct. 23	186	25	24.5	4.11	25.6 ± .1308	-	182	28	27.0	5.34	28.1 ± .2049	0
Nov. 6	148	25	25.0	3.54	25.5 ± .1337	0	200	28	28.0	5.30	28.4 ± .1719	0
Nov. 15	205	25	25.5	3.67	25.6 ± .1300	-	178	28	27.5	5.20	28.4 ± .1822	-
Nov. 23	241	25	23.9	4.87	25.5 ± .1477	-	245	28	26.0	6.67	28.2 ± .1866	-

.... Cont'd

Table 1 (Cont'd):

	MALES						FEMALES					
Date	No. examined	Modal class	Arith $\overline{ML}$(cm)	V	Adj. $\overline{ML}$ +95% conf. inter.	Skew	No. examined	Modal class	Arith $\overline{ML}$(cm)	V	Adj. $\overline{ML}$ +95% conf. inter.	Skew
Holyrood - 1971:												
July 6	422	17	17.9	7.81	17.3 ± 0.1527	+	444	18	18.3	8.49	17.7 ± 0.1274	+
July 12	344	18	18.5	7.41	18.0 ± 0.1374	+	281	19	19.1	7.71	18.7 ± 0.1742	+
July 19	327	18	18.3	7.05	17.5 ± 0.1192	+	403	18	19.2	8.14	18.4 ± 0.1142	+
July 28	83	19	19.2	6.33	18.7 ± 0.1966	+	72	20	20.3	8.59	19.6 ± 0.3190	+
Aug. 3	224	19	19.6	6.92	20.0 ± 0.1637	-	217	21	20.5	7.47		0
Aug. 10	211	21	20.8	5.26		0	200	22	21.6	5.52		0
Aug. 18	250	21	21.3	5.29		0	228	22	21.9	5.36		0
Aug. 23	261	21	21.4	4.55		0	264	22	22.4	5.79	21.9 ± 0.1544	+
Aug. 31	237	22	22.0	4.20		0	218	23	22.8	5.88	22.2 ± 0.1527[11]	+
Sept. 10	196	22	22.4	3.99		0	199	23	23.7	6.75	23.0 ± 0.2195	+
Nov. 1	60	24	23.9	4.60		0	80	27	26.1	6.93	27.1 ± 0.4339	-
Nov. 9-10	109	24	24.0	4.30		0	140	26	26.4	6.39	25.8 ± 0.2468	+
Holyrood - 1973:												
July 20	352	19	19.3	5.70	18.9 ± 0.1400	+	457	19	19.8	6.63	19.0 ± 0.1742	+
Aug. 7	90	20	20.2	6.87	19.8 ± 0.2538	+	109	21	21.1	7.85	20.6 ± 0.2722	+
Aug. 22	232	22	21.8	6.82	22.4 ± 0.1634	-	240	22	22.3	6.67	22.9 ± 0.1999	-

[1]Although positive skew in distribution, range extends farther at lower end than in previous and subsequent samples. Plot from high end gives curve.
[2]St line fit very poor - left arm of curve very steep.
[3]Higher mean from plot of cumm. freq. from upper end. Better fit to st line than other which is plotted from lower end.
[4]The smaller mean is that of a second group in a bimodal distribution, comprising 61.6% of the sample.
[5]Lower mean from plot beginning at smaller sizes where skew present. Higher from plot from higher sizes - better fit here.
[6]Plotted from higher end but skewed to higher end to include group I squid. Lower end has group III squid.
[7]Smaller mean from plot of only 3 points - comprises only 13.8% of total.
[8]The smaller means are those of a second group in a bimodal distribution comprising 57.5% of the males and 44.7 of the females.
[9]Not plotted since appears to be a mixture of two size groups.
[10]Calculated: mode = 3 median - $2\bar{x}$.
[11]Log-prob plot.
[12]See Fig. for possible second modal class.
[13]See Fig. for shape of distribution.

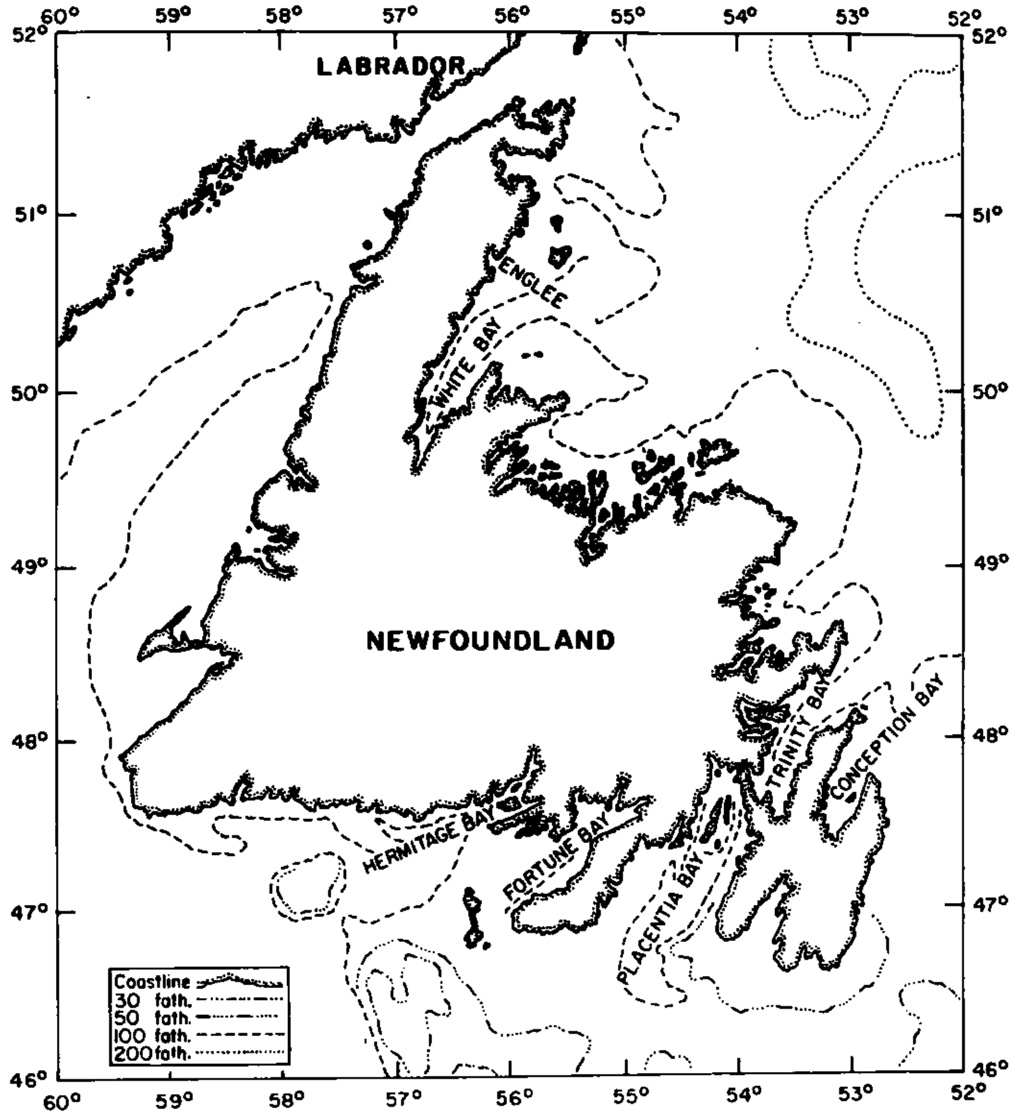

Fig. 1. Place names at Newfoundland mentioned in the text.

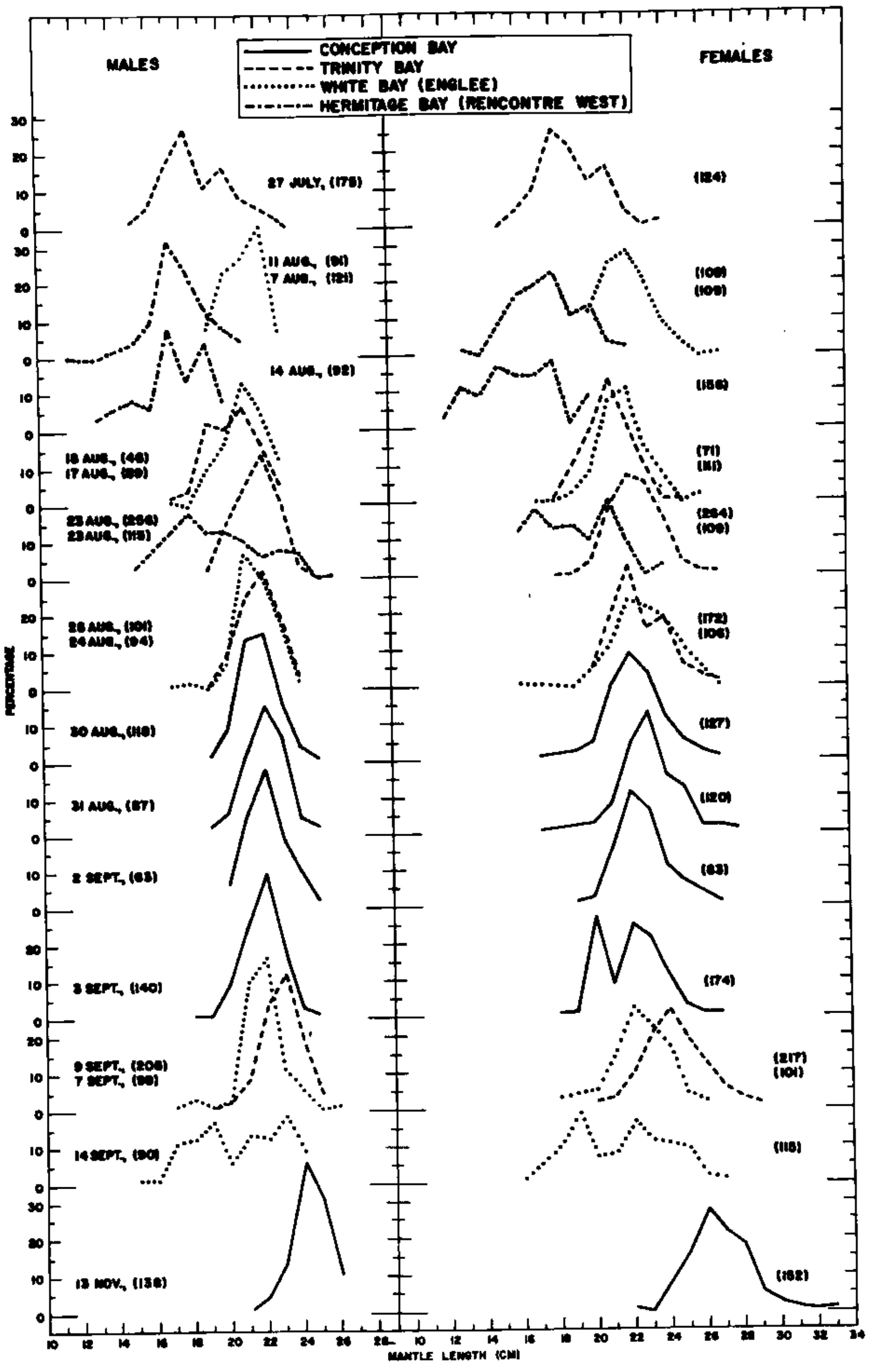

Fig. 2. Length distributions of <u>Illex</u> <u>illecebrosus</u> samples taken at Newfoundland in 1965. Numbers indicate sample sizes.

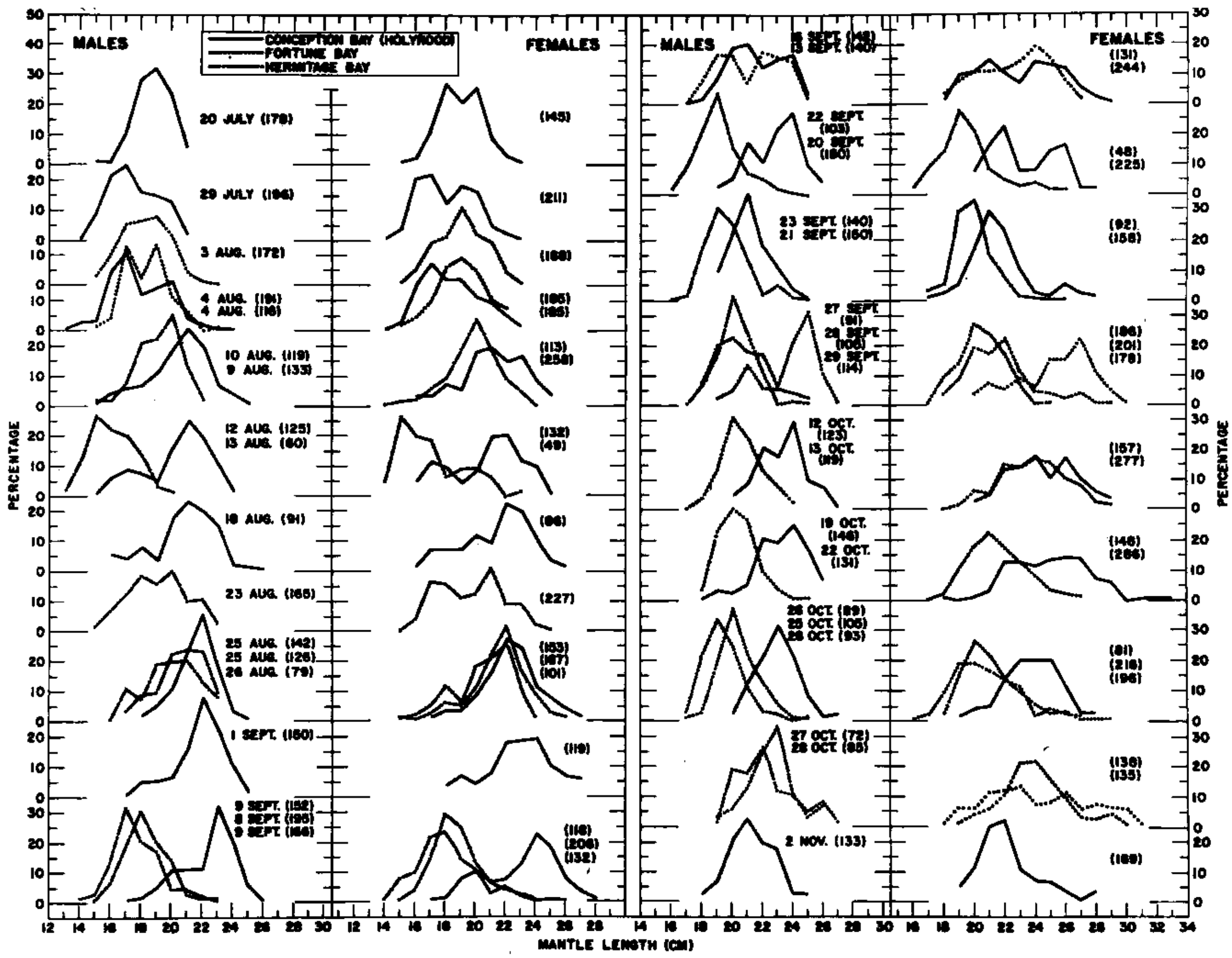

Fig. 3. Length distributions of Illex illecebrosus samples taken at Newfoundland in 1966. Numbers indicate sample sizes.

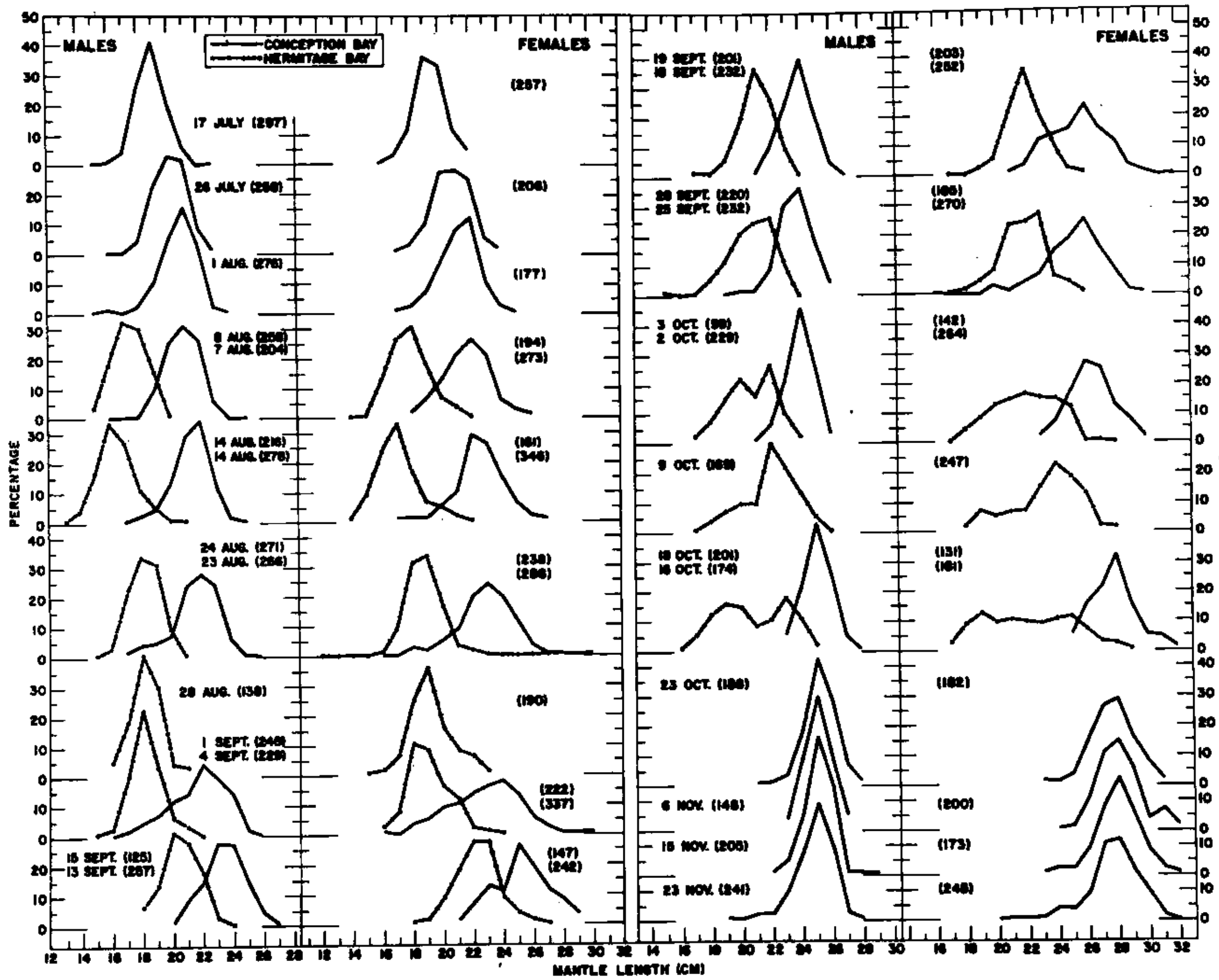

Fig. 4. Length distributions of <u>Illex illecebrosus</u> samples taken at Newfoundland in 1967. Numbers indicate sample sizes.

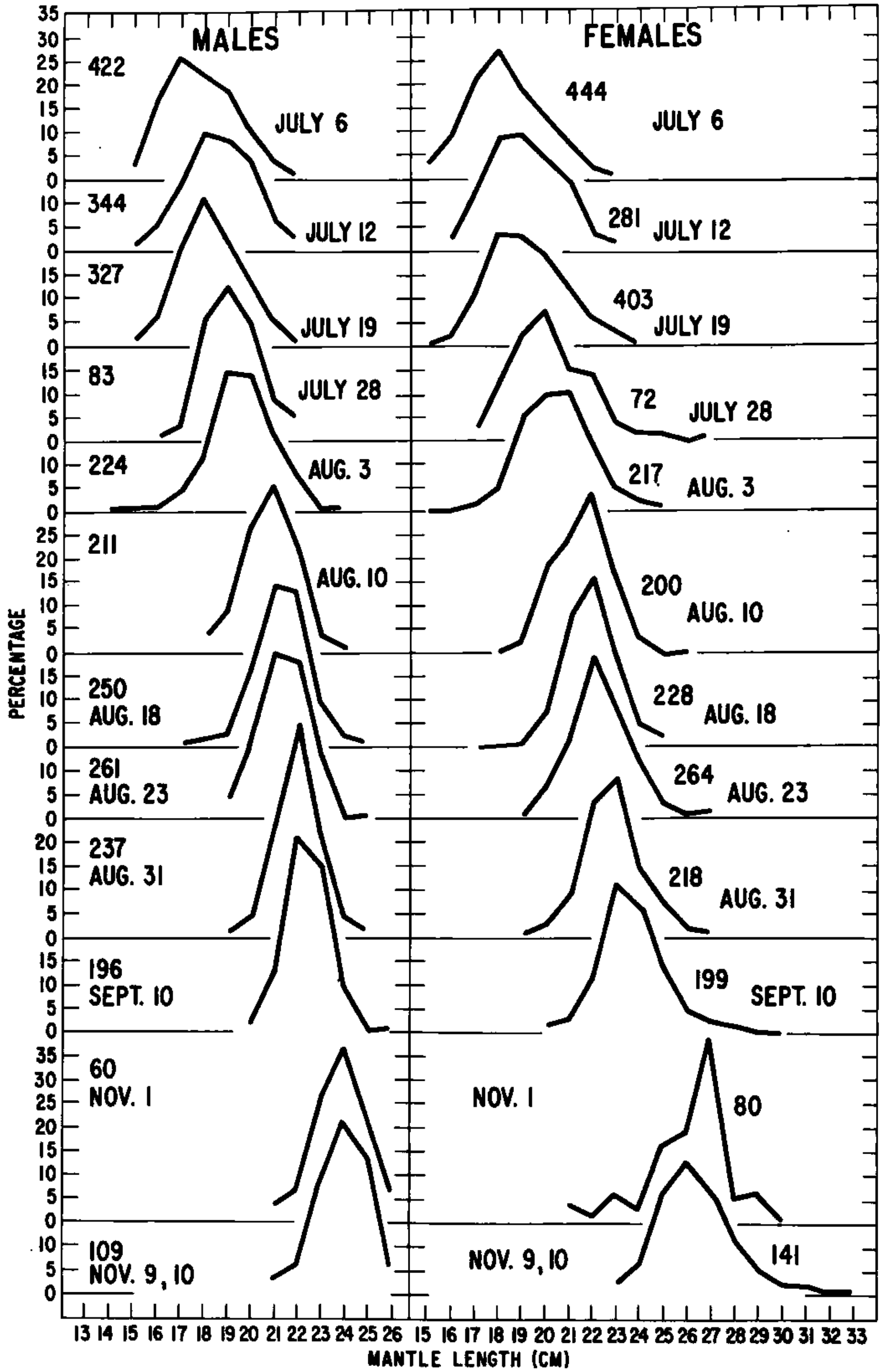

Fig. 5. Length distributions of Illex illecebrosus samples taken at Newfoundland in 1971. Numbers indicate sample sizes.

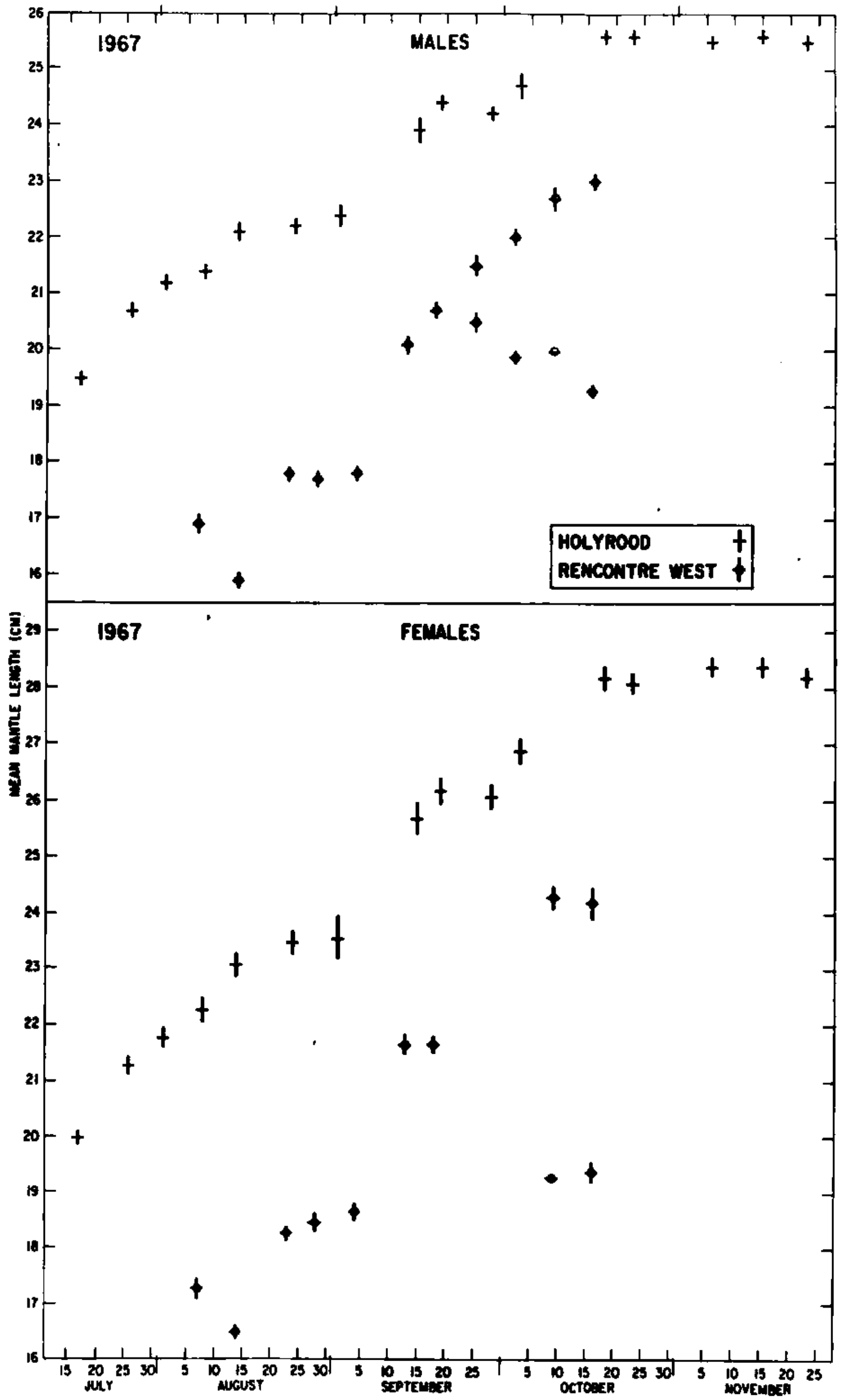

Fig. 6. Adjusted mean mantle lengths of Illex illecebrosus from samples obtained at Newfoundland in 1967. The vertical bar indicates twice the standard error of the mean on each side of the mean.