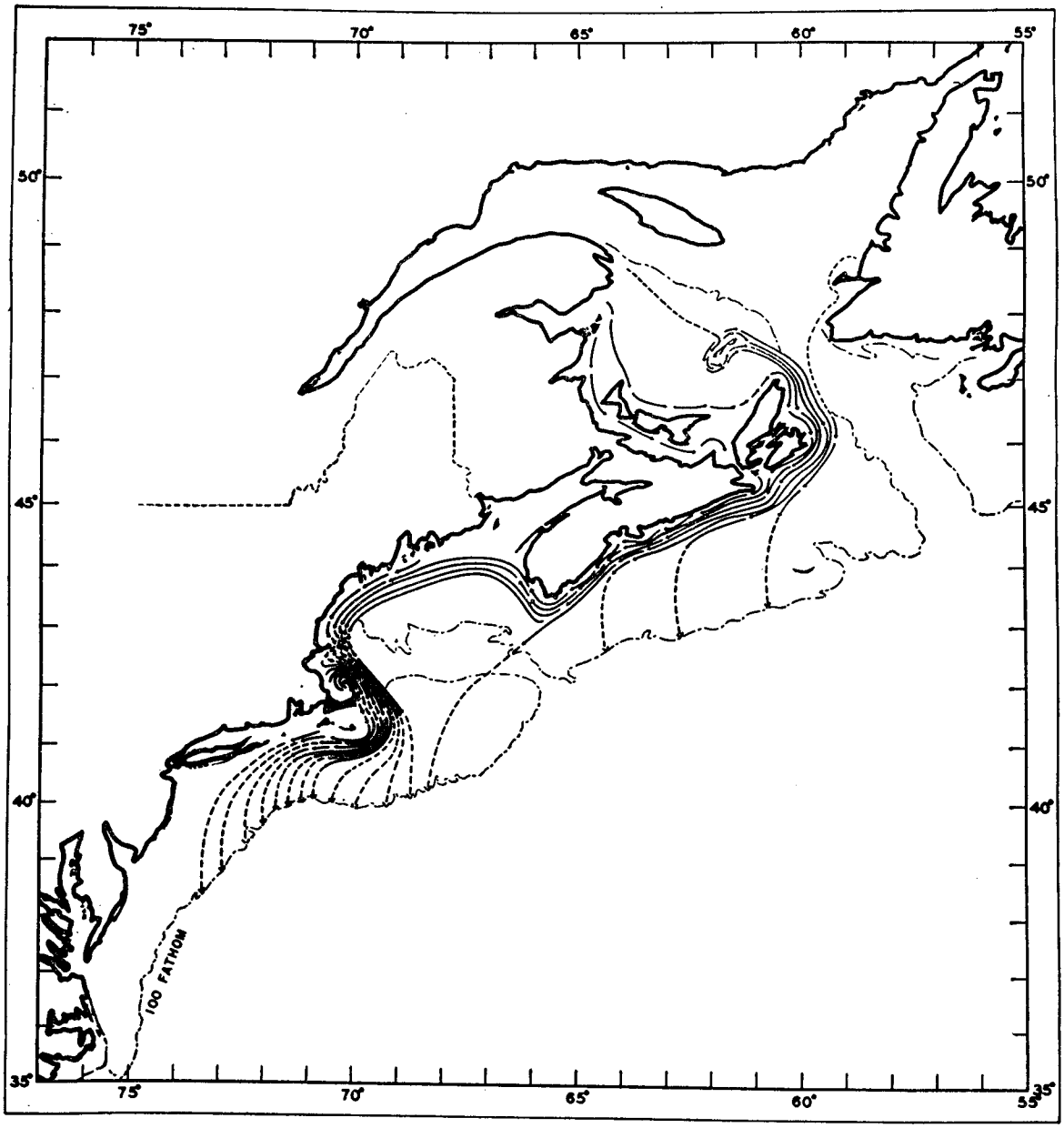


FIGURE 6.—Diagrammatic representation of the fall migration. The number of arrowshafts is roughly proportional to the relative numbers of mackerel believed to transverse the several localities. The number of arrowheads is roughly proportional to the relatve amount of commercial catch taken in the several areas. Lines of dashes indicate weak evidence as to the route or destination of migration.

The supporting evidence rests almost solely on the observed size composition of the mackerel population at various times and places, together with the time sequence of the appearance of the population—or certain portions of it—at the various points along the coast. This evidence, although indirect, has a notable advantage over the more direct method of tagging. It enables one to deal with a much larger portion of the population and to obtain a much more definite estimate of the relative numbers of individuals involved in the movements (i. e., distinguish mass-movements from stragglings) than can be

gained from the relatively small numbers usually tagged. Nevertheless, tagging experiments were done, which furnish confirmation (p. 307).[10]

DISTINCTION BETWEEN NORTHERN AND SOUTHERN CONTINGENTS

To account for the several phenomena observed in the migration study it has been necessary to recognize the existence of two subdivisions of the mackerel population which differ in their migrating habits, and which it is convenient to designate as southern and northern contingents. It is not necessarily implied that these are genetically distinct races of the species such as were believed to exist in European waters by Garstang (1898: 235–295) on the basis of differences in morphological characters. For the purpose of discussing the migrations it is preferable to regard the two contingents as subdivisions of more or less stable nature enduring through several seasons, but not necessarily from one generation to another.

The phenomena that indicated two subdivisions or contingents within the population along the North American coast are (1) the prevailing dissimilarity in size composition of the spring population along the Nova Scotian coast ("Cape Shore" in the parlance of mackerel fishermen) from the spring and summer population along the New England and Middle Atlantic coasts; and (2) the pronounced but transient alteration of sizes in the population off southern New England that takes place each year, usually in late May. The nature of these phenomena will be illustrated by the data of 1927, the relation between them will be demonstrated with the data of 1932 and finally their persistence or annual recurrence during the period of this investigation will be shown.

Because the size composition of the mackerel population was simple in 1927, the data of that year afford a favorable opportunity to illustrate both of the phenomena under consideration. In the population along New England and Middle Atlantic States, which will be termed "southern contingent," the 1923 class was so predominant that the length-frequency curves of that season were almost always characterized by a nearly symmetrical simple curve with a mode at 39 centimeters (two lowermost and three uppermost panels of fig. 7). The population along the Nova Scotian coast, which will be termed "northern contingent," on the other hand was dominated by the 1921 class as is evident from its simple mode at 41 centimeters (broken-line curve in middle panel of figure 7).[11] But the composition of the population off southern New England was altered during a brief period, so that frequency distributions of samples in the last half of May and again in the first half of June were essentially bimodal, with modes at 39 and 41 centimeters (the third and fourth panels from bottom in fig. 7). The simplest explanation of this altered size composition is that both northern and southern contingents for a time occupied the same area, were caught indiscriminately by the fishermen, and occurred in a mixture in the samples drawn from the catch. Since the alteration in size composition off southern New England (May 16–31) antedated the appearance of the larger fish along the Nova Scotian coast (June 1–15) it appears that the northern contingent in its migration first passed along the southern New England coast, mixed temporarily with the southern contingent already there, and then went on to the Nova Scotian coast, leaving the southern contingent behind.

This explanation may be tested to see whether it is fully in accord with the facts by combining the northern contingent as sampled off Nova Scotia with the southern contingent as sampled off southern New England before and after the mixing period, and comparing the resultant "synthetic" curve with the altered distribution found off southern New England, which may be termed the "mixed population." For purposes of this test the data of 1932 are more suitable than those of other years because fishing took place both off Nova Scotia and off southern New England during the periods that are critical to this experimental synthesis and hence both populations were well-sampled in that year.[12]

If the data of May and June of 1932 be summarized in reasonably short time intervals and by subareas as in figure 8, it is obvious that the southern contingent of that year was characterized by a dominant mode at 43 centimeters and a subdominant

[10] In using this order of presentation we are following the procedure actually used in arriving at the present results. Preliminary examination of tagging returns originally secured were unintelligible, and the data were laid aside for some years. It was not until the size composition study was completed that the tagging evidence was again consulted and found intelligible in the light of the hypothesis built up from the evidence gained by sampling the population.

[11] The irregularity of this curve is due to the scanty sampling afforded by the two catches from this area in 1927 and does not indicate multimodality or other complexities.

[12] In many seasons the fleet fishes either almost wholly off southern New England or almost wholly off Nova Scotia at this time so that sampling usually is deficient in either one place or the other.

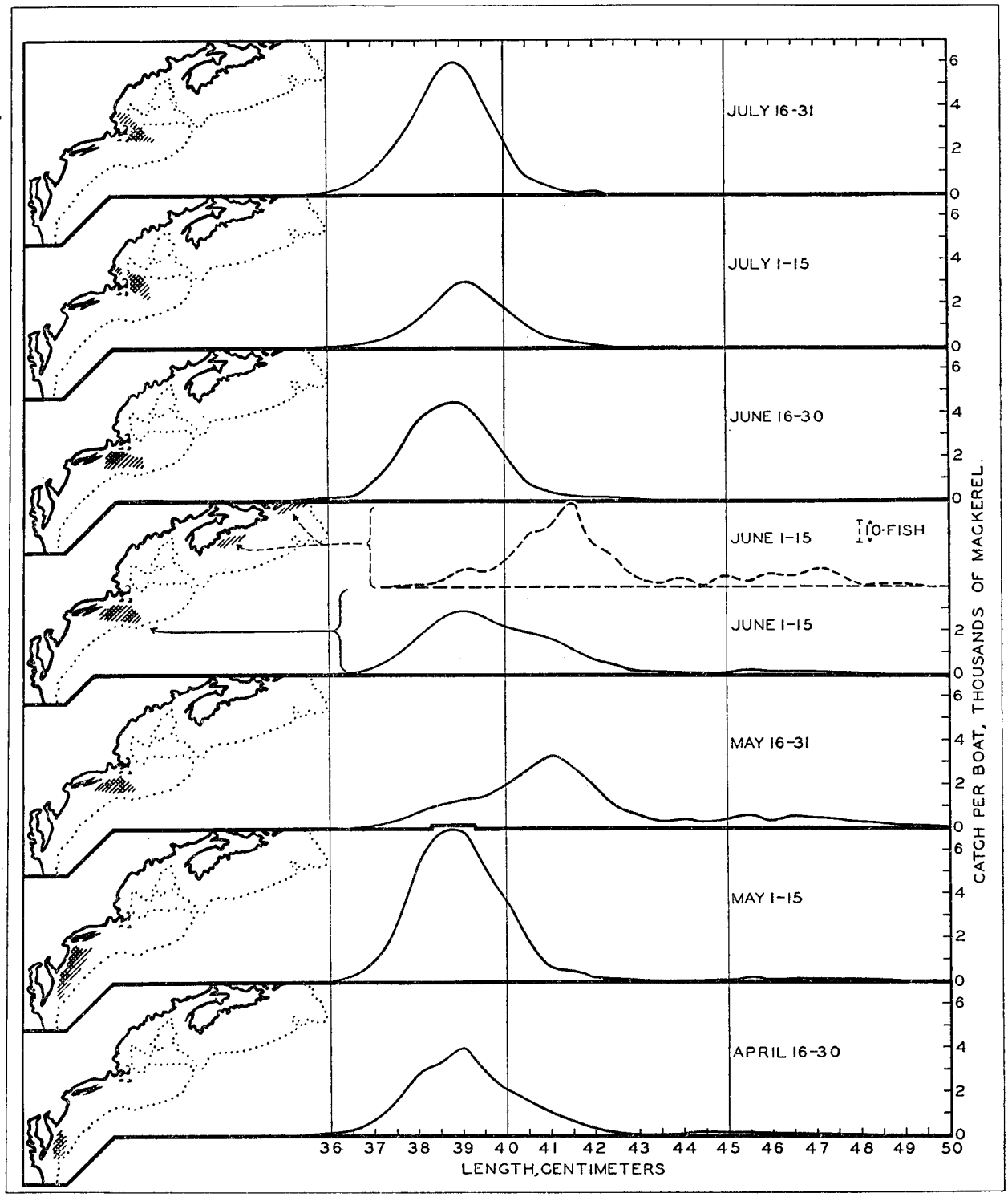
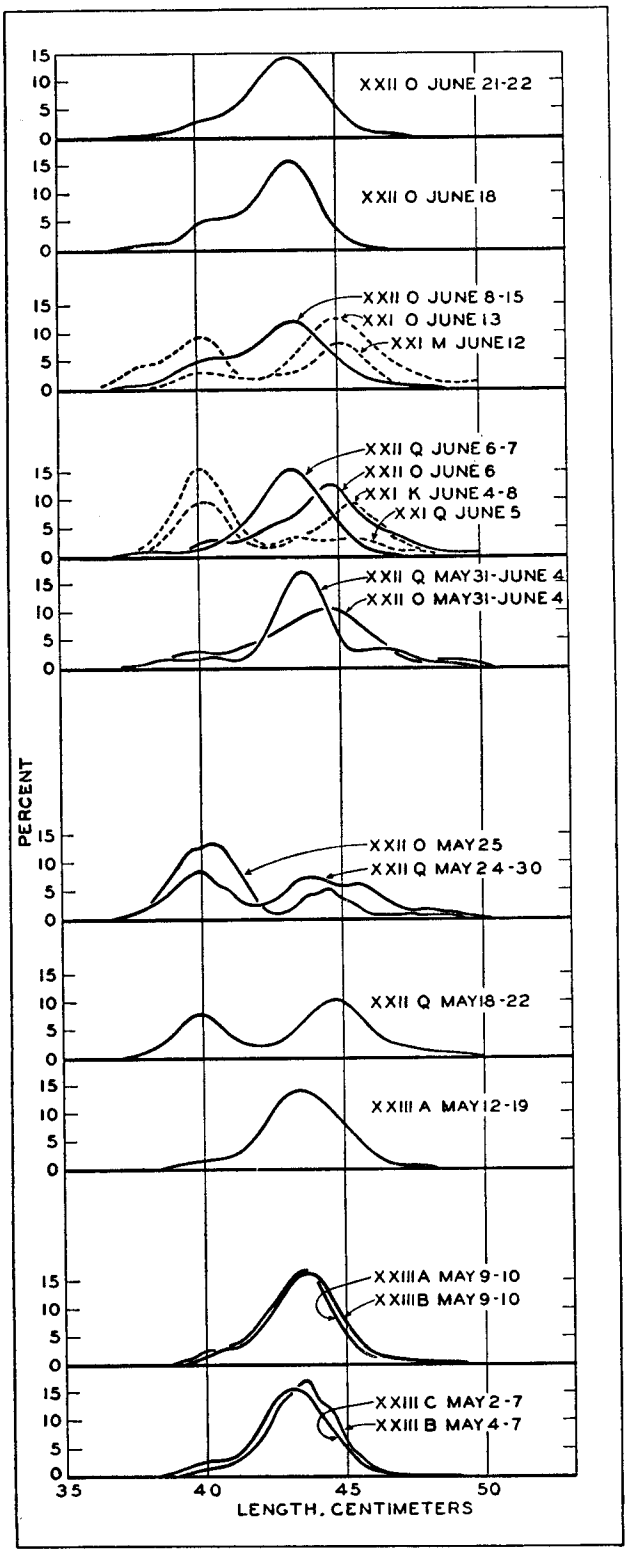


FIGURE 7.—Changes in the size composition of the mackerel in purse-seine catches in the spring of 1927. The areas under the curves are proportional to the catch per unit of effort except for the broken curve of samples from the coast of Nova Scotia, June 1–15. The shaded areas in the chart insets at the left indicate the localities of fishing during each half month.



mode at 40 centimeters and the northern contingent by nearly equal modes at 40 centimeters and at 45 or 46 centimeters. With these criteria the samples are readily classified into three groups as in tables 3, 4, and 5 representing northern, southern, and mixed population, respectively. Taking as ingredients length distributions of the northern and southern contingents smoothed as shown in figure 9, it was found by successive trials that combined in the ratio of 68 northern to 32 southern they formed a curve approximating the mixed population. Graphic indication of goodness of fit is given in the middle panel of figure 9. The chi-square test (Fisher 1932: 80) also indicates a tolerably good fit, there being as high as 1 chance in 10 that the difference might be exceeded owing to random causes alone.[13]

Hence the size composition of the so-called mixed population is consistent with the hypothesis that the ingredients of the mixture were indeed of the northern and southern contingents as here defined. The size composition also indicated that during the period of mixing the northern contingent outnumbered the southern by approximately 2 to 1.

The fact that northern contingent mackerel appeared on May 18 in southern New England waters before their appearance on June 4 in Nova Scotian waters suggests that on separating out of the mixture off southern New England, this group went to the coast of Nova Scotia. Detailed examination of the curves of frequency distribution are still more suggestive of such a movement, for in

[13] That portion of the curve above 41.5 centimeters fits much better (P=0.30) than the portion below (P=0.01). The poorness of fit below 41.5 centimeters may be attributed to sampling deficiencies rather than to significant differences in the populations concerned because a large part of the contribution to chi-square is from the excess at 39.5 and deficiency at 40.5 and 41.0 centimeters in the observed mixture and these in turn result mainly from the frequency of area XXII O, May 31 to June 4 which dominates the grouped mixture. If the five components in the mixture be recombined after giving equal weight to each (percentage frequencies) the above-mentioned excess and deficiencies are very much reduced, showing that the distribution of sampling during the period of mixing has somewhat altered the shape of this portion of the curve. Although this might be overcome by a system of weighting, this was not done because it would have interfered with the chi-square test.

FIGURE 8.—Size composition of mackerel in purse-seine catches in the spring of 1932. The spaces between base lines are approximately proportional to the time between weighted mean dates of groups of samples included in the distribution plotted on the respective base lines. Samples pertaining to each area and period were simply grouped by direct addition without weighting, smoothed by a moving average of three, and reduced to equal areas by converting to percentages.

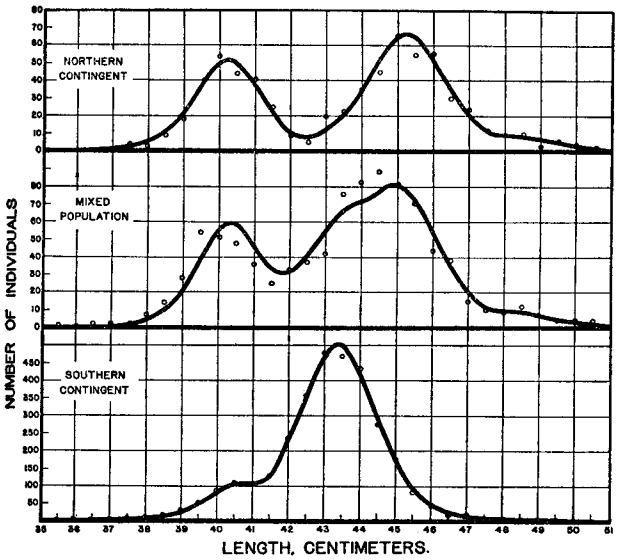


FIGURE 9.—Relationship of northern and southern contingents to the "mixed" population. In the upper and lower panels the circles represent observed numbers, the lines represent the graphically smoothed curves. In the middle panel the circles represent observed numbers, the line represents the combination of northern and southern contingents in the ratio of 68 to 32. Data were derived from tables 3 to 5.

TABLE 3.—*Size composition of the northern contingent in June 1932*

[Letters at head of columns specify subareas (fig. 1)]

Length in centimeters	Area XXI				Total
	K	Q	O	M	
	June 4–8	June 5	June 13	June 12	
	Number	*Number*	*Number*	*Number*	*Number*
37.5	1		1	2	4
38.0		1		2	3
38.5	7			2	9
39.0	11	3	2	2	18
39.5	21	7	5	4	37
40.0	38	5	7	4	54
40.5	25	8	6	5	44
41.0	30	2	4	2	38
41.5	15	3	6	1	25
42.0	5	1	3		9
42.5	1		2	2	5
43.0	8	1	10	1	20
43.5	6	3	11	1	21
44.0	12		20	2	34
44.5	16		27	2	45
45.0	28	3	30	5	66
45.5	27		25	3	55
46.0	27	2	21	3	53
46.5	16		13	1	30
47.0	12	1	11		24
47.5	4		6		10
48.0	3		6		9
48.5	6		2	1	9
49.0	3				3
49.5	2		2		4
50.0			3		3
50.5			2		2
52.0	1				1
Total	325	40	225	45	635

TABLE 4.—*Size composition of the southern contingent in May and June 1932*

[Letters at head of columns specify subareas (fig. 1)]

Length in centimeters	Area XXIII					Area XXII					Total
	C	B		A		Q		O			
	May 2–7	May 4–7	May 9–10	May 9–10	May 12–19	May 31–June 4	June 6–7	June 8–15	June 16–20	June 21–22 [1]	
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
35.5	1										1
36.0								3			3
36.5										1	1
37.0	2							1	1		4
37.5			1					3		2	6
38.0	1	1					2	2	1	2	9
38.5	2				1	1	1	7	2		14
39.0	6					2	2	17	1	2	30
39.5	10	2	1	1	4	1		24		6	49
40.0	20	3	6	2	2	1	3	31	7	10	85
40.5	17	6	8	3	4	2	3	42	9	12	106
41.0	21	4	12	1	7	2	5	34	6	11	103
41.5	30	10	9	4	6		8	34	7	20	128
42.0	62	20	26	6	18	2	18	46	12	25	235
42.5	102	26	37	9	28	8	16	71	12	48	357
43.0	131	52	46	11	38	13	36	77	25	49	478
43.5	96	39	73	15	38	15	27	91	23	52	469
44.0	87	46	54	14	35	21	28	73	19	48	425
44.5	62	26	43	7	28	10	13	54	8	25	276
45.0	27	20	26	3	22	3	12	34	6	23	176
45.5	16	6	10	2	12	2	5	21		6	80
46.0	5	4	6	1	9	3	2	11		2	43
46.5	2		2		2	3		4	1	2	16
47.0	2	1	3	1	1	3	1	5		1	18
47.5	1				2	1		3		1	8
48.0	1	2	2		1	1	1				8
48.5	1	1	1			1		1			5
49.0			1							2	3
49.5			1		1		1				3
50.0					1		1				2
50.5								1			1
Total	705	269	368	80	260	95	185	690	140	350	3,142

[1] Includes 20 from H.

TABLE 5.—*Size composition of the mixed population in May and June 1932*

[Letters at head of columns specify subareas (fig. 1)]

Length in centimeters	Area XXII					Total
	Q		O			
	May 18–22	May 24–30	May 25	May 31–June 4	June 6	
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
35.5				1		1
36.0		1				1
36.5	1		1			2
37.0				2		2
37.5		1		1		2
38.0	1	3	2	1		7
38.5	3	6	2	3		14
39.0	6	7	9	6		28
39.5	10	16	10	18		54
40.0	13	14	11	14	1	53
40.5	9	15	11	10	3	48
41.0	3	4	13	15	1	36
41.5	3	6	3	12	1	25
42.0	2	3	2	23	3	33
42.5	3	4		27	3	37
43.0	4	7	1	24	6	42
43.5	7	14	2	51	2	76
44.0	13	14	6	42	8	83
44.5	14	9	2	55	9	89
45.0	15	11	5	41	9	81
45.5	11	9	1	46	4	71
46.0	6	10		22	6	44
46.5	4	8		25	1	38
47.0	3	1	1	7	3	15
47.5	2	2		4	2	10
48.0	1	2	1	4	1	9
48.5	2	3		7		12
49.0		1		5	1	7
49.5		1	1	2		4
50.0				4		4
50.5				3	1	4
Total	136	172	84	475	65	932

area XXII–Q,[14] May 24 to 30, there is a prominence in the distribution at 45.5 centimeters which is comparable to a prominence at the same position in the Nova Scotian samples of area XXI–K, June 4 to 8. By May 31 the prominence in southern New England is more marked in the vicinity of 45.0 centimeters which may be compared to the similar prominence in the Nova Scotian material of area XXI–O and area XXI–N, June 12 and 13. In other words, there is a lag of about 10 days between the appearance of certain categories of mackerel in southern New England and the appearance of the same fish in Nova Scotian waters. This corresponds to the average lag between the first appearance of northern contingent mackerel in southern New England and first appearance in quantity of mackerel in Nova Scotia in the various years between 1926 and 1932 (p. 270).

To determine whether or not the change in size composition just noted for 1927 and 1932, and attributed to the existence of a northern contingent distinct from a southern contingent, is a regular event recurring year after year among the mackerel caught off the United States coast during the spring, each year's length-frequency distributions, grouped by statistical subareas and by relatively short periods of time, similar to the groupings used for 1932 in tables 4 and 5 and figure 8 were examined. On the basis of position and dominance of modes it was possible to distinguish distributions obviously representing a mixed population intermediate between the southern contingent (as represented in distributions displaying a stable combination of modes consistently through April, part of May and

[14] See fig. 1 for delineations of areas.

TABLE 6.—*Statistical areas and time periods characterized by mixed population in May and June in the years 1926 to 1935*

[Unless otherwise indicated only purse-seine-caught mackerel are included]

Statistical area	Time period	Number of mackerel
	1926	
XXIII B, XXII O, Q	June 14–15	100
XXII P, R	May 28–29 (caught by gill net)	120
XXII Q, R	June 1, 12 (caught by gill net)	180
XXII P	June 1, 11, 15 (caught by gill net)	160
XXII D	June 11, 14, 15 (caught by gill net)	140
XXII E	June 1–15 (caught by gill net)	1,159
Total		1,859
	1927	
XXII Q, S	May 16–20	240
XXII, P, Q, S XXIII A	May 21–25	990
XXII O, P, Q	May 26–31	670
XXII O, P, Q, S	June 1–5	1,240
Total		3,140
	1928	
XXIII A, XXII Q	May 25	160
XXII P, Q, R	May 26–31	589
XXII P, Q	June 1–2	220
Total		969
	1929	
XXII O	June 6–7	80
XXII E	June 12–17	187
XXII D	June 15	32
Total		299
	1930	
XXII S, Q	May 19	40
XXII Q, R	May 20	116
XXII Q	May 21–26	250
Total		406
	1931	
XXII Q	May 17–31	460
XXII S	May 22–23	102
XXII O	June 1	40
Total		602
	1932	
XXII Q	May 18–31	311
XXII O	May 25 to June 6	625
Total		936
	1933	
XXII Q	May 18–25	220
	1934	
XXIII A	May 14–17	740
XXII Q, R, S	May 17–19	792
XXII O, Q	May 22 to June 2	3,841
Total		4,373
	1935	
XXII Q	May 20 to June 10	3,805

June, and through July) and the northern contingent (as represented in distributions from purse-seine catches off the coast of Nova Scotia). The statistical subareas and periods of time characterized by the mixed population type of distribution are listed in table 6 together with the number of mackerel contained in the samples available from each. These samples were pooled and their length-frequency distributions summarized in table 7. The remainder of the May and June samples from areas XXII and XXIII representing the southern contingent, are similarly given in table 8 and the Nova Scotian samples (area XXI) representing the northern contingent are given in table 9. The three series, converted to percentages, are shown in figure 10. In this figure the curves have been drawn through the unsmoothed percentage-frequency values. Where they are markedly irregular it is due to the small numbers involved as can be seen by reference to tables 7, 8, and 9.

TABLE 7.—*Length frequencies, by half-centimeter classes, of mackerel in the mixed population, as represented by samples from the statistical subareas and dates listed in table 6*

Length in centimeters	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
27.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	4
27.5	-----	-----	-----	-----	-----	-----	-----	-----	-----	1
28.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	2
31.0	-----	-----	-----	-----	-----	-----	1	1	1	1
31.5	-----	-----	-----	-----	-----	-----	-----	1	3	29
32.0	-----	-----	-----	-----	-----	-----	2	4	3	50
32.5	-----	-----	-----	1	-----	-----	-----	2	5	101
33.0	-----	-----	-----	-----	-----	-----	-----	12	8	134
33.5	-----	-----	-----	-----	-----	-----	1	9	6	117
34.0	-----	1	-----	-----	1	-----	-----	11	16	115
34.5	-----	-----	-----	-----	-----	1	-----	5	43	73
35.0	-----	-----	-----	-----	-----	1	-----	14	104	36
35.5	1	-----	-----	-----	-----	-----	1	12	202	33
36.0	4	-----	-----	2	1	-----	1	2	329	68
36.5	17	2	-----	-----	-----	1	2	8	374	137
37.0	34	19	-----	1	2	3	2	2	358	275
37.5	45	55	1	-----	-----	3	2	2	220	382
38.0	71	118	4	-----	1	5	7	1	142	498
38.5	84	184	20	-----	1	29	14	3	69	448
39.0	82	219	42	1	1	25	28	-----	52	296
39.5	110	246	77	-----	1	42	54	2	31	194
40.0	127	309	89	7	1	34	53	3	49	104
40.5	166	384	129	8	5	14	48	3	80	43
41.0	166	423	122	21	4	8	36	5	89	44
41.5	139	341	121	37	10	20	25	8	128	34
42.0	108	215	81	37	14	36	33	3	103	46
42.5	67	114	62	45	21	39	37	5	125	38
43.0	41	62	48	52	28	44	42	8	156	47
43.5	29	39	31	27	47	41	76	10	202	80
44.0	39	30	16	15	47	56	83	10	262	68
44.5	47	29	13	12	54	53	89	7	263	63
45.0	75	39	14	4	42	39	81	16	260	62
45.5	76	65	10	10	32	29	71	20	240	70
46.0	76	31	8	3	16	28	44	16	148	44
46.5	85	51	17	2	12	11	38	7	131	31
47.0	62	44	16	4	11	13	15	3	68	14
47.5	25	38	13	1	18	4	10	2	39	6
48.0	38	30	7	2	13	6	9	1	29	7
48.5	14	22	10	2	8	8	12	-----	10	7
49.0	20	10	11	2	11	2	7	2	9	1
49.5	5	9	1	3	2	3	4	-----	10	2
50.0	2	5	2	-----	2	3	4	-----	3	-----
50.5	3	4	2	-----	-----	1	4	-----	2	-----
51.0	-----	1	2	-----	-----	-----	-----	-----	1	-----
51.5	1	1	-----	-----	-----	-----	-----	-----	-----	-----
Total	1, 859	3, 140	969	299	406	602	936	220	4, 373	3, 805

TABLE 8.—*Length frequencies, by half-centimeter classes, of mackerel in the southern contingent as represented by all May and June samples from areas XXII and XXIII other than those included in table 7*

Length in centimeters	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
18.0	-----	-----	-----	-----	-----	1	-----	-----	-----	-----
19.0	-----	-----	-----	-----	-----	2	-----	-----	-----	-----
19.5	-----	-----	-----	5	-----	8	-----	-----	-----	-----
20.0	-----	-----	-----	7	-----	9	-----	-----	-----	-----
20.5	-----	-----	1	9	-----	23	-----	-----	-----	-----
21.0	-----	-----	-----	3	-----	13	-----	-----	-----	-----
21.5	-----	-----	2	7	-----	25	-----	-----	-----	-----
22.0	-----	-----	6	8	-----	15	-----	-----	-----	-----
22.5	-----	-----	7	18	-----	10	1	-----	-----	-----
23.0	-----	-----	13	24	-----	5	2	-----	-----	-----
23.5	-----	-----	12	42	2	1	1	-----	-----	-----
24.0	-----	-----	15	51	5	3	2	-----	-----	-----
24.5	-----	-----	7	49	7	-----	2	-----	-----	-----
25.0	-----	-----	7	47	13	-----	12	-----	-----	1
25.5	-----	-----	4	36	27	1	18	-----	3	1
26.0	-----	-----	4	39	16	-----	49	-----	1	1
26.5	-----	-----	-----	27	20	-----	51	-----	1	1
27.0	-----	-----	3	29	5	1	99	-----	-----	2
27.5	-----	1	-----	29	11	1	117	-----	1	3
28.0	-----	-----	-----	15	7	3	179	-----	-----	2
28.5	-----	1	-----	15	3	6	230	-----	1	2
29.0	1	1	-----	22	6	2	289	1	1	1
29.5	-----	1	-----	39	2	2	258	5	3	-----
30.0	-----	-----	-----	51	3	5	300	10	10	-----
30.5	-----	-----	-----	27	2	-----	281	37	17	-----
31.0	-----	-----	-----	18	4	-----	229	71	24	4
31.5	-----	-----	-----	4	2	1	191	183	57	10
32.0	-----	-----	-----	1	5	1	113	271	102	74
32.5	-----	-----	-----	2	13	2	64	346	119	143
33.0	5	-----	-----	3	35	4	33	351	89	271
33.5	7	-----	-----	7	106	11	9	280	94	306
34.0	10	-----	-----	16	326	27	7	222	105	308
34.5	16	1	-----	19	526	46	4	174	148	220
35.0	26	8	-----	41	663	83	2	101	338	145
35.5	53	5	-----	50	631	69	2	55	617	49
36.0	170	26	1	58	370	65	3	49	781	37
36.5	379	57	1	48	202	49	1	22	802	56
37.0	727	212	9	36	73	48	4	10	584	136
37.5	1, 078	552	23	21	45	88	6	8	313	285
38.0	1, 141	1, 085	113	21	31	180	9	12	186	539
38.5	887	1, 428	340	8	21	228	15	5	66	663
39.0	562	1, 520	829	29	11	269	32	21	47	724
39.5	284	1, 216	1, 247	92	17	256	53	21	39	499
40.0	156	816	1, 410	265	30	164	89	33	69	309
40.5	124	420	1, 154	557	64	150	108	52	79	149
41.0	72	225	724	923	137	187	105	68	129	104
41.5	65	129	414	977	256	312	133	113	177	96
42.0	42	66	163	1, 001	400	538	238	147	212	154
42.5	30	34	78	682	374	673	361	230	316	168
43.0	30	23	38	429	385	770	485	301	423	295
43.5	23	15	21	183	313	638	478	298	539	353
44.0	34	20	17	98	189	483	425	234	558	451
44.5	37	14	10	44	119	294	281	198	449	417
45.0	54	27	13	30	76	165	179	135	335	351
45.5	67	40	17	20	37	96	81	59	185	270
46.0	63	33	17	27	26	49	44	34	83	161
46.5	45	30	22	15	19	25	16	14	40	72
47.0	56	21	24	27	17	21	20	11	33	32
47.5	32	14	18	19	7	21	9	6	5	10
48.0	23	11	11	15	10	16	8	8	4	5
48.5	14	13	7	11	4	22	7	7	1	2
49.0	11	2	6	9	3	10	3	3	1	2
49.5	7	1	4	8	5	3	3	3	4	2
50.0	5	3	1	6	7	7	2	-----	2	1
50.5	1	-----	1	2	2	3	1	-----	-----	-----
51.0	1	3	0	2	2	-----	-----	-----	1	-----
51.5	2	-----	1	-----	-----	1	-----	-----	-----	-----
52.0	-----	-----	2	-----	-----	-----	-----	-----	-----	-----
53.0	-----	-----	-----	2	-----	-----	-----	-----	-----	-----
Total	6, 340	8, 074	6, 817	6, 425	5, 692	6, 211	5, 744	4, 209	8, 194	7, 887

In the three series all samples were drawn from purse-seine catches except those for 1926, in which samples from the drift-gill-net fishery were included to augment the very scanty data from late May and early June when most of the purse-seine fleet was off Nova Scotia, and so afforded very few samples from

TABLE 9.—*Length frequencies, in half-centimeter classes, of mackerel in the northern contingent as represented by samples from the spring purse seine fishery along the Nova Scotian coast, area XXI*

Length in centimeters	1926	1927	1928	1929	1930	1931	1932
33.0							
33.5					1		
34.0							
34.5					1		
35.0							
35.5						1	
36.0	1			1		1	
36.5	1				1		
37.0	5					1	
37.5	6					3	4
38.0	24	1				11	3
38.5	52	2				14	9
39.0	105	8	3			27	18
39.5	199	7	1		1	22	40
40.0	259	13	10	1		11	57
40.5	271	24	12	6		5	45
41.0	239	28	30	15		4	40
41.5	115	38	38	28		3	26
42.0	76	19	55	55		2	9
42.5	44	13	57	79	1	2	5
43.0	29	4	45	109	7	4	23
43.5	22	2	30	97	6	7	26
44.0	32	4	22	127	12	12	41
44.5	40	1	6	94	12	18	53
45.0	48	5	9	62	10	15	74
45.5	44	3	6	33	18	17	62
46.0	58	6	4	16	7	13	60
46.5	54	5	4	23	5	5	32
47.0	44	8	2	22	4	7	28
47.5	29	6	3	15	4	5	10
48.0	16	1	1	12	2		15
48.5	14	1	1	7			10
49.0	9	1		6		1	4
49.5	8		1	2		2	5
50.0	6			5		1	3
50.5	5			5			2
51.0	2			1			
51.5	1			1		1	
52.0	1						1
52.5	1						
53.0							
53.5							
54.0							
Total	1,860	200	340	822	92	215	705

the area in which the mixed population occurred.[15] For convenience in referring to the modes in the frequency distributions of figure 10, identifying letters have been inserted at about the modal positions. The modes are composed of either a single year class or of groups of year classes as is obvious from the fact that they progress toward larger sizes through successive years.

For the first 4 years, 1926 to 1929, mode A was consistently present and dominated the northern contingent, progressing from 40.5 centimeters to 43.5 centimeters. Mode B similarly was consistently present and dominated the southern contingent, progressing from 37.8 centimeters in 1926 to 41.5 in 1929. The mixed population appears to have elements of both modes with A definitely represented most strongly in 1926 and 1927. In the next 2 years, when evidently there was more nearly equal representation of the two groups, there is a mode intermediate between A and B.

In 1930, mode A continued dominant in the northern contingent but the shape of the curve is irregular due to chance fluctuations within the small sample of Nova-Scotian-caught fish available in that year. Mode B of the southern contingent probably should be located at 42.0 centimeters but a hump appears at 43.0 centimeters. The latter may be due in part to random sampling fluctuations and in part to the presence of a few samples that might better have been included with the mixed population. A new and strong mode at C appears in the southern contingent.

In 1931, there is a combination of modes which has already been examined in detail in the 1932 material. Mode A continues present in the northern contingent, B in the southern contingent, and C in both contingents. The latter is definitely stronger in the northern contingent where it appears to have strength about equal to that of mode A but relatively weaker in the southern contingent where it seems less than one-fourth as strong as mode B. As above remarked, this relationship continues in 1932, when also mode ED (see also p. 286) makes its appearance in the southern contingent.

Subsequent to 1933 there is less clarity, due to lack of samples from the coast of Nova Scotia, and to the less-well-marked separation of modes. Nonetheless, the before-noted relationships within the A–B–C modal complex persisted through these last 3 years about as might be expected from the previous years. The new mode at E is difficult to interpret for lack of Nova Scotia material to serve as a model by which to judge the northern contingent's length composition.

From 1926 to 1932, however, it is clear that the catches of mackerel from the late spring runs off southern New England are separable into two groups of markedly different length composition. One group, which has been named southern contingent has a size composition which is clearly distinct from that in the run that appears off the coast of Nova Scotia and which has been termed northern contingent. The other group in the catches off southern New England forms frequency distributions such as might be expected if the northern contingent mixed with the southern contingent in these areas. The data for 1933, 1934, and 1935 are

[15] In general, throughout this report, the combining of purse-seine and drift-gill-net data has been avoided inasmuch as the latter gear may be size selective and possibly be misleading. In this particular case, the gill-net samples dominate both the distribution representing the mixed population and the distribution representing the southern contingent, and it is quite obvious that net selection was not sufficient to obscure the difference between the two, although the modes may be slightly displaced in the gill-net material as compared with the purse-seine material.

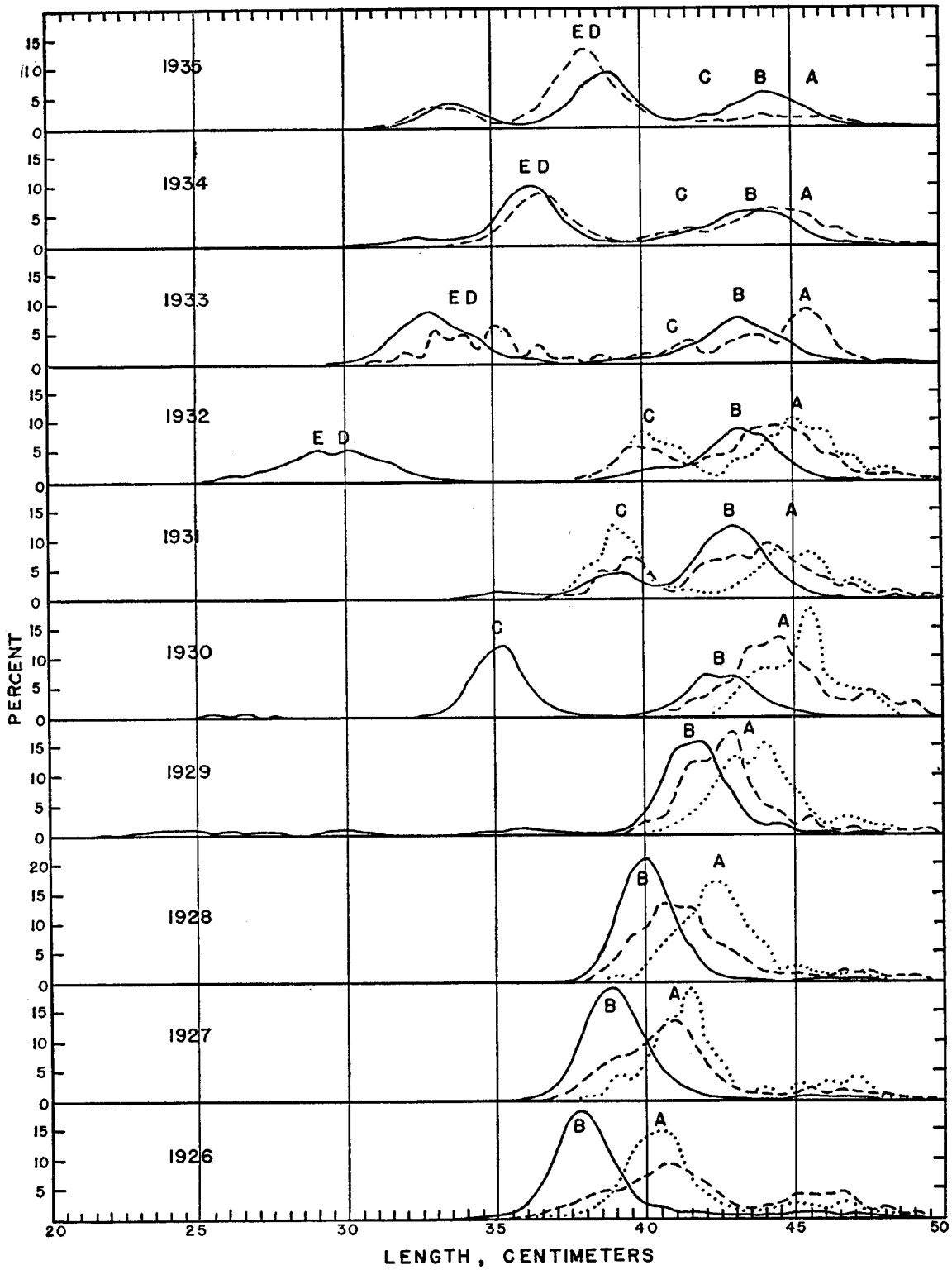


FIGURE 10.—Distribution of lengths of mackerel during May and June for the years 1926 to 1935, in three catagories—those referable to the southern contingent (solid line), northern contingent (dotted line), and to the mixed population (dashed line) comprising elements of both.

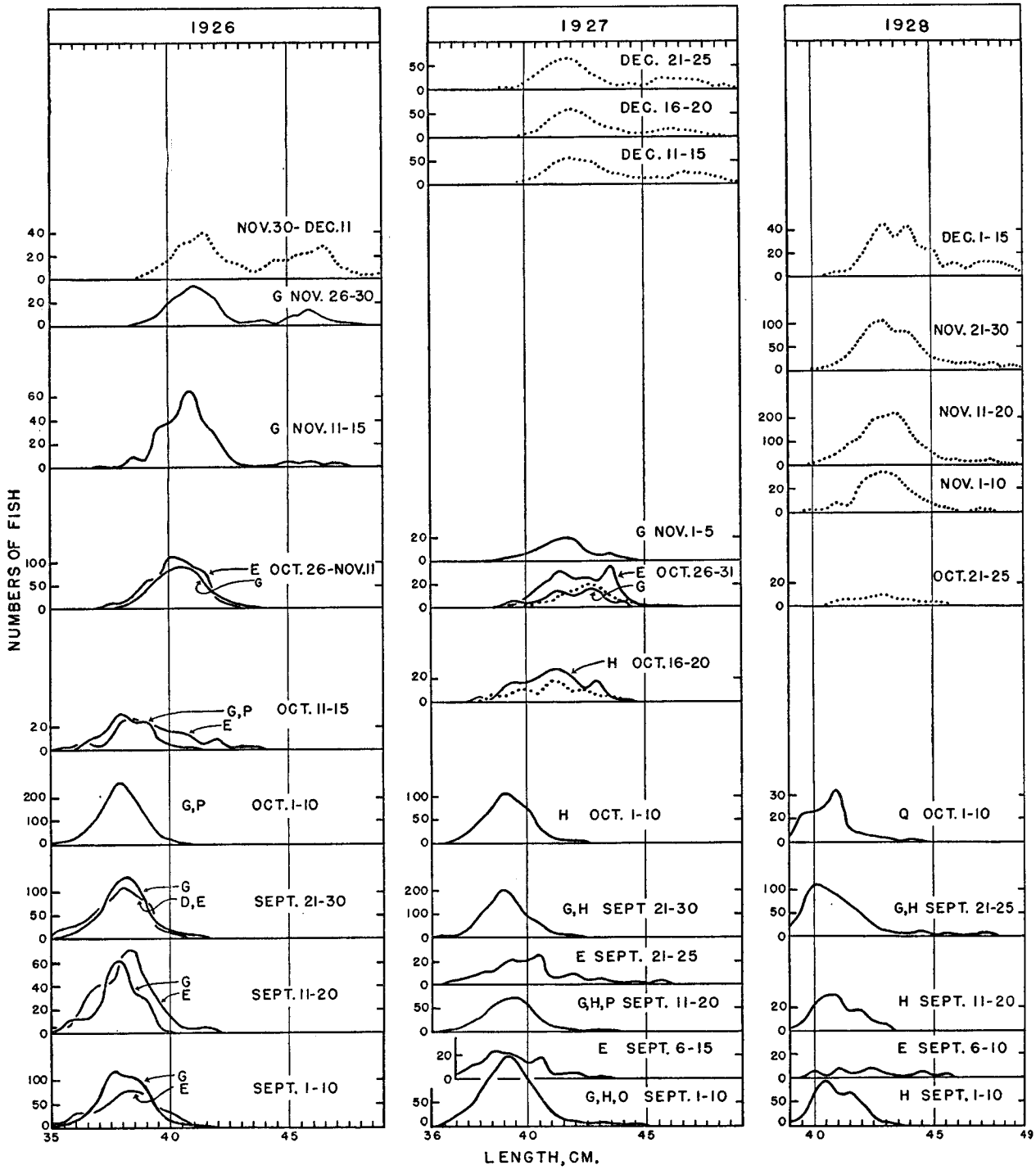


FIGURE 11.—Length composition of medium and large mackerel in catches off New England during the fall months in 1926, 1927, and 1928. Solid lines represent purse-seine catches from the subareas of statistical area XXII designated by letters. Dotted lines represent drift-gill-net catches, all of which were made in subarea E of statistical area XXII. The base lines of the curves are spaced vertically in approximate proportion to calendar date.

less decisive but they are not inconsistent with this conclusion.

In the fall of the year there is a characteristic change in size composition similar to the one that takes place in the spring. This is demonstrated in detail in figure 11 for three autumns—1926, 1927, and 1928. In preparing this figure, working graphs were drawn for the samples from each subarea of statistical area XXII (the only area fished by the American fleet at this season of the year) for each short time interval of 5 days and often less. Space does not admit of reproduction in such detail of these many curves. For this reason the data were grouped in longer time intervals, usually 10 days for figure 11, wherever this could be done without obscuring essential details. However, the source of samples and the aggregate numbers of individual measurements available daily from each area are given in tables 20 and 22 and the frequency data either by weekly or by 10-day periods in tables 21 and 23. The curves of figure 11 were drawn through the unsmoothed frequency values and are irregular where the numbers are few.

When the irregularities associated with small numbers are disregarded, it is evident that in each of the 3 years from the 1st of September to the 10th of October the catches from the various areas through the successive time periods were of essentially uniform size composition.[16] Following October 10 the few samples available from mid-October indicate that the size composition had become unstable. The mode which had been pronounced and relatively constant throughout September and the first 10 days of October at about 38 centimeters in 1926, 39 centimeters in 1927, and 40.5 centimeters in 1928 tended to disappear; and there was a marked accretion of fish several centimeters longer. These tended to form a mode at a point where formerly there was a mere "tail" in the distribution. By the last days of October there were practically no fish left at lengths which had been modal during September and early October. Instead a strong mode appeared at about 41 centimeters in 1926, 42 centimeters in 1927, and 43 centimeters in 1928. In addition to the dominant mode there is a secondary one at 41 to 42 centimeters in most of the curves.

[16] There is a relatively small but consistent difference between the mackerel caught north of Cape Cod (subareas D and E) and those southeast and south of Cape Cod (subareas G, H, O, P, and Q). The significance of this small difference will be discussed in later sections on the summer sojourn and the fall return. For the time being it is sufficient to note that the difference within this segment of time and space is far less than the change that took place after October 10 in all 3 years.

For purposes of discussion the period of stability through September and early October may be called "early fall," the mid-October period of instability may be called the "midfall transition" and the period of stability through November and into December may be called "late fall."

Using these designations it is obvious that the population of early fall has a size composition entirely different from that in the late fall. The difference is too extreme to be attributed to anything other than a change in the population between early and late fall—in other words—the existence of two populations; one succeeding the other in the same region. It is apparent, too, from figure 11, that the midfall transition is a period when elements of both populations are evident in the samples. These appear in the panel for October 11–15 in 1926 and for October 16–20 in 1927.

It is further evident by comparison of the curves of figure 11 with those in the three lower panels of figure 10, that the early fall population had a length composition identifying it with the spring southern contingent while the late fall population may similarly be identified with the northern contingent as it was sampled by the spring catch off Nova Scotia. The midfall transition has its mixed population comparable to the spring mixed population which was studied in some detail, but the sampling was too sparse during the midfall transition to repay intensive examination of the material.

Length-frequency distribution curves for short time intervals during autumn for the remaining 7 years of the investigation prove that the change from one population in early fall to another in late fall occurred consistently, year after year. Space does not permit reproduction of these hundreds of frequency curves, but the length compositions characteristic of the two populations are shown for all 10 years in the "fall" panels of figure 12.

The data for the curves in these fall panels were assembled as follows: Curves were plotted for each date-locality group of samples listed in table 23. September 1 was initially selected as the arbitrary starting point for each fall series but paucity of medium and large mackerel in the September catch and consequently in the samples during September in some years led to the inclusion of a portion of August in such years in order to get a representation of these sizes. From inspection of each season's series it was obvious that termination of the purse-seine fishery and initiation of the drift-gill-net

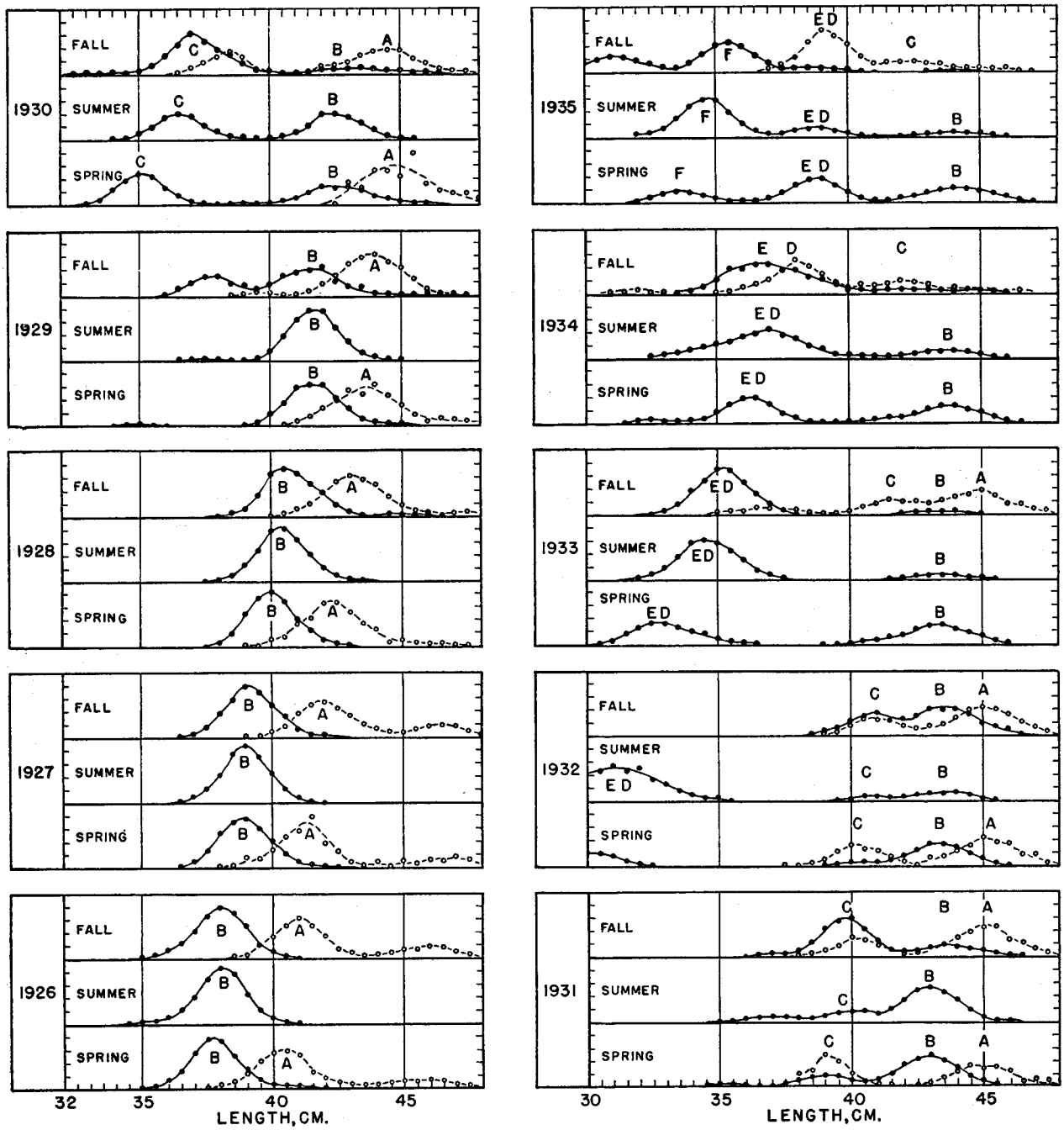


FIGURE 12.—Length-frequency distributions illustrating the size composition of the two types of mackerel population: southern contingent (solid dots and solid lines) and northern contingent (open circles and broken lines), during 10 seasons. The curves are on a percentage basis and the graduation marks on the vertical axis represent 5 percent intervals.

fishery nearly coincided with the "mid-fall transition" in all years except 1926. To avoid heterogeneity with respect to catching method, it was decided to include as early fall category all purse-seine samples up to date-group first showing, by a change in size composition such as registered October 11–15 in 1926 and October 16–20 in 1927 (fig. 11), evidence of a change in population, and to include as late fall category all drift-gill-net samples after the size composition showed stability by essential uniformity

of the curves through successive 5-day (or weekly in some instances) periods. The resulting groups are listed in table 10 and the summed frequencies for early fall in table 11 and for late fall in table 12. These summed frequencies, converted to equal areas by computing the percentage of fish in each size class were plotted in the "fall" panels of figure 12 and smooth curves drawn either through the points or in such relation to the points that the deviations above and below were in balance and the square of each deviation (in actual, not percentage, numbers of fish) of the curve from the point is less than the number of fish in the class. This is intended to fulfill, roughly, the requirement that the smoothed curve "fits" the empirical data, with a confidence above the P=0.05 level as judged by the chi-square test. Actually no rigorous test is possible for want of definitive knowledge as to the number of degrees of freedom absorbed in such "free-hand" curve fitting.

TABLE 10.—*Organization of data in tables 11 and 12*

Item	Included as "early fall" in table 11		Excluded from tables 11 and 12		Included as "late fall" in table 12	
	Period	Number of fish	Period	Number of fish	Period	Number of fish
1926:						
Purse seine	Sept. 1–Oct. 10	4,060	Oct. 11–Nov. 10	1,420		
Drift gill net					Nov. 11–Dec. 11	873
1927:						
Purse seine	Sept. 1–Oct. 10	3,030	Oct. 11–Nov. 10	580		
Drift gill net			Oct. 11–31	200	Dec. 11–25	1,260
1928:						
Purse seine	Sept. 1–Oct. 10	1,415				
Drift gill net					Oct. 21–Dec. 5	2,540
1929:						
Purse seine	Aug. 21–Sept. 20	1,044	Sept. 21–Oct. 10	55		
Drift gill net			Sept. 21–25	60	Oct. 21–Nov. 15	1,430
1930:						
Purse seine	Aug. 11–Oct. 25	3,015				
Drift gill net			Sept. 21–Oct. 20	70	Oct. 21–Dec. 5	2,453
1931:						
Purse seine	Aug. 11–Oct. 31	3,912				
Drift gill net			Oct. 21–Nov. 10	270	Nov. 11–Dec. 7	1,865
1932:						
Purse seine	Aug. 11–Oct. 5	1,751				
Drift gill net					Sept. 26–Dec. 15	2,535
1933:						
Purse seine	Aug. 27–Sept. 30	3,701	Oct. 1–Nov. 4	3,077		
Drift gill net					Oct. 29–Dec. 14	3,197
1934:						
Purse seine	Sept. 21–Oct. 20	2,338				
Drift gill net					Nov. 13–Dec. 5	1,209
1935:						
Purse seine	Sept. 1–Nov. 11	115				
Drift gill net					Nov. 1–Dec. 20	3,602

TABLE 11.—*Length composition of mackerel in the "early fall" period, 1926 to 1935*

Length in centimeters	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	Total
23.0											
25.0										1	1
26.0										1	1
27.0										1	1
27.5										1	1
28.0										6	6
28.5										16	16
29.0										55	55
29.5									1	115	116
30.0										225	225
30.5					1					397	398
31.0	1				6					549	555
31.5	1				2				2	673	678
32.0	4	2			5					632	638
32.5	7	2			8			2	4	518	538
33.0	13	8		1	15	1		8	7	344	385
33.5	11	1		5	20	2	1	36	9	243	337
34.0	10	2		2	18	1		103	12	197	345
34.5	11	1		6	30	2		229	22	378	679
35.0	28	2		4	25	3		389	64	719	1,216
35.5	66	3		6	43	6	3	597	119	1,121	1,925
36.0	130	4		1	107	10	2	615	231	1,262	2,297
36.5	243	20		10	221	13	1	447	217	1,099	2,142
37.0	416	53	2	30	345	37	3	350	257	748	2,032
37.5	672	130		50	468	55	2	175	261	397	1,877
38.0	799	295	6	74	388	51	2	68	206	175	1,762
38.5	700	437	15	75	274	110	5	26	216	175	1,977
				50	215	208	14	21	145	169	1,962

TABLE 11.—*Length composition of mackerel in the "early fall" period, 1926 to 1935*—Continued

Length in centimeters	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	Total
39.0	502	599	41	43	124	419	36	7	129	217	2,093
39.5	203	536	115	30	49	518	55	8	74	141	1,691
40.0	144	389	236	45	35	558	94	11	39	95	1,581
40.5	44	257	254	81	18	400	134	11	33	57	1,266
41.0	15	96	235	92	29	226	152	34	19	33	916
41.5	17	55	174	103	39	119	107	40	37	22	704
42.0	9	39	130	113	53	111	110	65	29	23	675
42.5	4	13	66	58	57	123	129	75	30	33	576
43.0	2	20	37	39	58	148	177	85	32	44	633
43.5	2	12	11	36	77	174	170	75	33	44	625
44.0	2	11	9	12	63	166	185	81	22	53	591
44.5	3	8	17	12	50	124	141	60	30	41	478
45.0	4	8	11	6	46	115	87	45	26	31	372
45.5	4	5	10	8	21	74	63	17	17	32	247
46.0	4	5	8	8	31	61	41	11	9	15	185
46.5	2	3	5	9	17	29	14	2	2	13	94
47.0	1	5	9	8	16	17	10	2	2	2	70
47.5	3	3	7	6	11	12	7	4			52
48.0	4	3	4	4	13	8	3				39
48.5	5	1	4	8	7	2	2	2	2		33
49.0	1	1	4	5	4	6				1	21
49.5	2	1	2	2	1		1				9
50.0	1		2		2						5
50.5					1	1					2
51.0				1	1	1					3
51.5					1						1
52.0				1		1				1	3
54.0			1								1
Total	4,060	3,030	1,415	1,044	3,015	3,912	1,751	3,701	2,338	11,115	35,131

TABLE 12.—*Length composition of mackerel in the "late fall" period, 1926 to 1936*

Length in centimeters	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	Total
28.5										1	1
29.5									1		1
30.0				1							1
30.5						1			4		5
31.0									8		8
31.5									12		12
32.0									22		22
32.5									6		6
33.0									9		9
33.5								1	3		4
34.0					1		1	14	5		21
34.5					1		1	11	4		17
35.0					2		5	37	10		54
35.5					1		3	54	14	2	74
36.0				1	4		1	54	32	3	95
36.5				1	14		2	82	46	9	154
37.0	1				59	2	3	86	67	52	270
37.5	1	1		1	107	5	1	76	104	108	404
38.0	2			5	167	12	4	63	152	199	604
38.5	10			6	208	26	4	40	125	414	833
39.0	14	7		10	165	49	16	33	90	569	953
39.5	51	5	3	20	71	77	41	31	52	506	857
40.0	72	27	11	15	42	141	101	62	32	395	898
40.5	109	58	34	10	26	117	167	105	40	222	888
41.0	132	116	76	13	25	86	152	140	36	123	899
41.5	109	161	133	28	25	46	136	184	47	141	1,010
42.0	78	174	226	67	80	27	102	166	57	130	1,107
42.5	34	145	350	110	86	30	75	159	50	146	1,185
43.0	21	106	394	174	111	55	94	143	39	118	1,255
43.5	12	64	364	213	173	84	110	181	24	113	1,338
44.0	15	47	315	224	212	135	177	220	27	72	1,444
44.5	20	34	198	185	225	178	255	250	18	61	1,424
45.0	28	26	123	154	228	215	265	291	24	63	1,417
45.5	32	43	60	91	145	216	253	227	17	45	1,129
46.0	40	52	50	37	101	129	202	145	12	54	822
46.5	38	59	38	26	56	103	143	136	10	23	632
47.0	22	57	39	14	41	54	80	84	3	17	411
47.5	13	30	51	14	28	36	47	50	4	12	285
48.0	6	16	25	7	17	17	34	21	1	2	146
48.5	5	12	23		9	9	21	17		1	97
49.0	4	5	14	2	7	7	16	15	1	1	72
49.5	1	5	6		3	2	13	13	1		44
50.0	2	2	2		4	5	4	3			22
50.5		5			2	1	3	2			13
51.0	1	2	4		2		1	1			11
51.5			1		3		2				6
52.0		1		1	1						3
52.5					1						1
Total	873	1,260	2,540	1,430	2,453	1,865	2,535	3,197	1,209	3,602	20,964

The resulting sets of curves shown in the panels labeled "Fall," in which the curves of the early fall category have been drawn with solid lines and those of the late fall with broken lines, demonstrate that there was a marked difference between the early and the late fall populations every year. The difference was comparable in degree and in character to the differences previously noted in spring. That is, the fall fishery gives evidence of regularly drawing on two different contingents of mackerel, just as was found true of the spring fishery.

NATURE OF THE TWO CONTINGENTS

In applying a name to the two recognizably different parts of the mackerel population the term "contingent" was selected in order to avoid terms such as "race," "subspecies," or "variety," which have acquired particular technical connotation through their use in fisheries and in micro-systematics. The search for a technically noncommittal term has resulted in the choice of a word that is appropriate only in the sense of one of its less common meanings, that is, "any of the local groups of an assemblage" (Webster's New International Dictionary of the English Language, second edition, unabridged, G. & C. Merriam Co., 1944). As used here, the adjective "local" should be omitted from the definition, since it is not desired for the time being, at least, to imply any specific local geographical affinity.

Having adopted a noncommittal term, it is possible, without prejudice, to discuss the nature of the two groups within the mackerel population which are here designated as southern contingent and northern contingent.

For purposes of this discussion the principal reference will be to figure 12. The composition of the frequency distributions described by the curves in the panels labeled "fall" has already been given. The curves in the panels labeled "spring" are the same ones as given in figure 10 omitting the so-called mixed population and smoothing as described for the curves of the fall panels. The curves of the panels labeled "summer" simply are summed frequencies of all mackerel catches sampled between the end of the spring period and the beginning of the fall period (i. e., June 30 of each year, to the particular date listed in table 10 for the beginning of the "early fall" period) converted to percentage and smoothed as described for the curves in the fall panels. Although this assemblage of curves involves omission of some blocks of data [17] it contains all of the characteristic length-frequency groupings found in the catches of the United States vessel fishery for mackerel during the 10-year period except the "mixed" populations of spring and fall as these were defined in the preceding section. The curves on the intermediate size compositions during these periods of mixing are essential to this discussion but could not be included in figure 12 without either making a confusing tangle of lines or multiplying the panels beyond graphic utility.

Reviewing, now, the times and localities represented by the various blocks of data: the catch off the United States coast south of Cape Cod in the springtime was composed purely of the southern contingent except for a brief period in late May and early June (figs. 7 and 8) when members of the northern contingent mixed with them (broken-line curves in fig. 10). In late May and early June also, in years when American mackerel vessels fished along the coast of Nova Scotia they caught only the northern contingent there (broken-line curves in the spring panels of fig. 12). After the brief period of mixing along the United States coast in late May and early June, the catch reverted to southern contingent mackerel and continued to be comprised of such mackerel through summer and early fall. At the latter time or shortly thereafter the southern contingent disappeared and with its disappearance the purse-seine fishery usually terminated. However, at this time northern contingent mackerel appeared in the Gulf of Maine and continued to furnish catches to the drift-gill-netters through late fall and sometimes well into December, before they disappeared and the mackerel fishing season ended.

From this succession of events, practically the only possible conclusion is that the southern contingent is a body of mackerel that appears in early spring well south of Cape Cod, proceeds northerly along the coast and into the Gulf of Maine to spend the summer, and then disappears again in midfall; whereas, the northern contingent appears in late spring briefly off southern New England, moves quickly to the coast of Nova Scotia, and passes out of the range of the modern American fishery, returning again in late fall through the Gulf of Maine as it moves to its winter grounds. Thus, the two contingents are bodies of mackerel of different size

[17] Omitted are (1) all small or yearling mackerel (because not here under consideration), (2) samples prior to May 1 and all drift-gill-net fishery samples of the spring period (these do not differ from the solid line curves in the spring panels of fig. 12 in any way that is material to the present discussion).

composition and different migrating habits. The southern contingent appears earlier in the spring, spends the summer in more southerly waters, and disappears earlier in the fall than the northern contingent. But a large part of the routes of both contingents is through the same waters, and at particular times of the year they are in the same waters together.

Recalling that the two principal spawning grounds of the American mackerel are widely separated, a southern one being in the great oceanic bight between Cape Cod and Cape Hatteras and a northern one in the Gulf of St. Lawrence (Sette 1943), and noting that the southern contingent is on the southern spawning ground in spawning season and the northern contingent, when last evident to our fishery, is well beyond this on a route leading to the Gulf of St. Lawrence prior to the time spawning takes place there, it would appear that the two contingents are well separated from each other when spawning. This separation during reproduction would favor an hypothesis that the two contingents were generically distinct races. Eventually this may prove to be true. For the present, however, it does not appear to be consistent with other evidence, some of which is contained in figure 12.

The most striking features of figure 12 are the prominent modes and their progression to successively greater fish lengths through successive years. Both of these features are so prominent and so consistent that there is no difficulty in identifying homologous modes. Several series of them have been marked with the letters A, B, C, etc. It is obvious that each mode is comprised of a single year class or a group of year classes and the progression of homologous modes is due to growth of the members of the particular year classes. Anticipating the results of a partially completed study of age, it is provisionally determined that mode A is comprised mainly of the 1921 class, mode B of the 1923 class, mode C of the 1928 class and mode D of the 1930 class. The latter apparently was a class of atypically slow growth during early life and was soon overtaken by the 1931 class, so that both the 1930 and 1931 classes contribute to the mode labeled ED from 1932 to the end of the series. Mode F is the 1932 class.

According to this interpretation, a number of year classes were missing or present in very small numbers. It is to the absence of year classes that the wide separation of the modes may be attributed. More important, it is the absence of different year classes in the two contingents, particularly during the first 7 years of the series, that underlies the characteristic difference of the contingents in size composition and permits them to be distinguished one from the other. The consistent absence of mode A in the southern contingent and of mode B in the northern contingent is a prime example of this.

On the other hand, some modes are not as consistently absent from one contingent or the other. Mode C, for instance, was present in both contingents. In 1930 when it first appeared this mode was most strongly represented in the southern contingent. In later years it tended to decline in the southern contingent and increase in the northern contingent. By 1933 and 1934 it had declined in the southern contingent so severely that it was barely perceptible while it still was prominent in the northern contingent. This suggests that members of a year class may transfer from one contingent to another. If this does happen, the genetic strains of the two contingents could not remain distinct.

However, the evidence that members of a year class transfer from one contingent to the other is far from conclusive. The curves of figure 12 are on a percentage basis and a given mode may be prominent or not, depending on the numbers of fish in the remaining portions of the distribution. Thus C declines in the southern contingent when ED joins the stock and fails to decline correspondingly in the northern contingent because new recruits such as ED did not join that contingent in proportionately as large numbers. However, the changes in C relative to B in the southern contingent and C relative to A in the northern contingent are not subject to this effect and could be changed only by a differential mortality, by an emigration out of or by immigration into the stock. The questions then become: (1) In the southern contingent did C decline relative to B due to a higher mortality than B or due to emigration from the stock? (2) In the northern contingent did C increase relative to A in the northern contingent due to a higher rate of mortality in A than in C or due to immigration of C into the stock of the northern contingent?

The first alternative in each instance would not be contradictory to the hypothesis of genetic separation of the two contingents while the second alternative would be. At present, knowledge is not sufficient to definitely select one alternative or the other.

There is the further question: Was the sampling

of the two stocks sufficiently representative to warrant the drawing of conclusions from the proportionate heights of the several modes? While I have considerable confidence that the sampling of the catch was not seriously biased in favor of one group of sizes as opposed to another, a similar confidence cannot be placed in the nonselective nature of the fishermen's catch from the existing stock. Indeed, there is abundant indication, especially marked in some seasons, that the several size groups are selectively "available" to the fishery. One particularly marked phase of this will be discussed in a later section.

It is possible that some light may be thrown on this and the two preceding questions by further analyses involving abundance indices. Preliminary work of this nature has suggested that some year classes, as sampled by the commercial fishery, have disappeared from the stock drawn upon by the United States fleet at a moderate rate of about 20 percent per annum and others at a much higher rate in the neighborhood of 80 percent per annum during successive years in the fishery (Sette 1933, 1934). The ones disappearing at a slow rate were termed "persistent" year classes; the ones disappearing at a high rate "transitory" year classes. The rate of disappearance may be due either to mortality or to departure of members of the year class from the stock fished by the United States fleet, or a combination of the two. Since the southern contingent is the principal stock fished by the United States fleet, the departure of members from year classes in this contingent to join the northern contingent would produce the effect noted for the transitory year classes. Those year classes not departing from the southern contingent would diminish only from mortality and so would have some lesser rate of disappearance. Among the year classes classified as persistent or transitory (classes 1923 to 1929, inclusive), and also abundant enough to create prominent modes (classes 1923 and 1928), the 1923 class formed mode B which was consistently present in the southern contingent and consistently absent in the northern contingent, and the 1928 class formed mode C which was relatively more prominent in the southern contingent early in mature life and later became relatively more prominent in the northern contingent. Thus, provisionally at least, the weight of evidence, if not definitely in favor of the shift of individuals from one contingent to the other, at least is sufficiently suggestive of this to prevent adoption of the view that the two contingents maintain their integrity throughout life and from one generation to another, as would be necessary for postulation of genetically separate stocks.

An even simpler view as to the phenomenon underlying the existence of the two contingents, is that mackerel have a southerly distribution when young and comprise the southern contingent and that the mackerel extend their migration farther north as they enter the later years of life and comprise the northern contingent. This would be consistent with the evidence afforded by the 1928 class of mode C but would be utterly contrary to the behavior of the 1923 class of mode B which continued prominent in the southern contingent for more than 9 years and never was represented strongly enough in the northern contingent to be detectable.

Thus it does not seem possible, at present, to define the biological nature of the contingents more explicitly than to say that they are aggregates of mackerel migrating as units that are recognizable by the configurations of their length-frequency curves, and the configurations are sufficiently stable from spring to fall and from one season to another to suggest that the majority of the individuals retain their memberships in the same contingent through a number of years though not necessarily throughout life, nor from one generation to another.

In conclusion, it appears that the adult stock of mackerel contains two populations which migrate along the coast in the springtime, each composed of a different complex of year classes which causes the distinctive size composition by which they are recognized. The one most southerly in the place of its first appearance (off the Virginia Capes) and its final destination (the Gulf of Maine) is termed the southern contingent, while the one more northerly in the place of its first appearance (off southern New England) and in its final destination (Nova Scotia and the Gulf of St. Lawrence) is termed the northern contingent. During a portion of the migration (past southern New England) these contingents are mixed in demonstrable proportions. The southern contingent spends the summer and early fall in waters off New England and disappears in late fall. At about this time the northern contingent populates these waters, presumably on its way from Canadian waters to its winter quarters. Various aspects of the migrations of each contingent remain to be considered in detail. As yet, there is

no positive evidence as to whether the two contingents inhabit the same waters in the wintertime and are then mixed, separating when their respective spring migrations are performed, or whether the southern contingent winters mainly in the southerly portion of the warm zone at the edge of the continental shelf, say abreast of Long Island and southward, and the northern contingent winters along the edge from abreast of Long Island and eastward. The respective localities of their first appearance render the latter supposition the more likely.

SPRING MIGRATION OF THE SOUTHERN CONTINGENT

First Appearance

The opening of the mackerel season has from early times held such interest that records of first catches were often published. Many of these were assembled by Sette and Needler (1934: 38–39), four by Goode, Collins, Earle, and Clark (1884: 9) and 10 more during the present investigations. From the date of earliest catch in each of the 56 seasons for which this datum is available (fig. 13) it may be calculated statistically that the average date for the opening of the season is April 11, that usually (two out of three times) it opens between April 3 and 19. Since mackerel often may be present some days before the first catch, the date of appearance of the mackerel (as distinguished from the date of catching) must be somewhat earlier and probably is somewhat less variable.

From the 29 available records on the locations of first catches listed in table 13 and plotted in figure 14, it is obvious that the first mackerel of the season are most frequently taken along the outer third of the continental shelf between the thirty-seventh and thirty-eighth parallels of latitude, though they occasionally are found as far south as latitude 35°20′ (near Cape Hatteras) or as far north as latitude 39°0′ (80 miles off Atlantic City) a spread of 200 miles parallel and 60 miles vertical to the coast line. When taken north of latitude 37° (mouth of Chesapeake Bay), they are inclined to be at the outer edge of the shelf, and when south of latitude 37° they may be either inshore or offshore.[18]

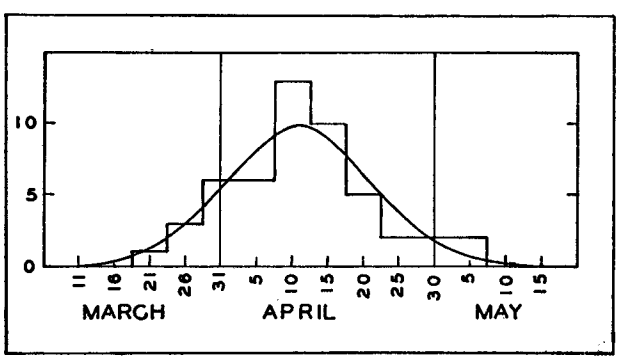


Figure 13.—Date of first catch of the season in various years during the period 1878 to 1935. The histogram represents the number of times the first catch fell in each 5-day period, and the smooth curve describes the corresponding normal probability.

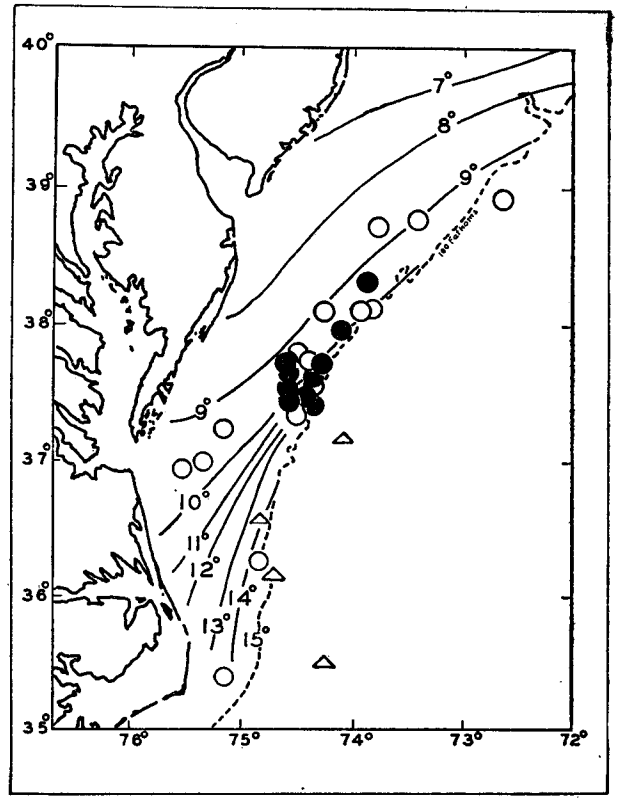


Figure 14.—Position of first catches in each of 29 seasons. Triangles represent seasons 1878 to 1881; open circles, various seasons, 1887 to 1925; solid-black circles, seasons 1926 to 1935. The isotherms relate to the period April 3 to 11, 1930, and illustrate the distribution of surface temperatures at this season.

[18] Although 3 of the 29 positions are well outside the continental shelf area, we are not inclined to place much emphasis on these offshore records because mackerel fishermen for the most part determine their position by "dead-reckoning" and on the long course runs in this southern fishery, a slight lack of precision in designating a bearing or estimating the speed of sailing might easily put the supposed position a number of miles from its true one; and as none of these catch records were particularly noted as being beyond soundings it may be doubted that they were as far offshore as indicated.

TABLE 13.—*Date and locality of "first catch of the season" of mackerel* [1]

Year	Date	Locality
1878	Apr. 16	Lat. 36°10′ N., long. 74°45′ W.
1879	Apr. 12	Lat. 36°35′ N., long. 74°50′ W.
1880	Apr. 1	Lat. 35°30′ N., long. 74°15′ W.
1881	Mar. 20	Lat. 37°10′ N., long. 74°05′ W.
1887	Apr. 21	Lat. 37°20′ N., long. 70°30′ W.
1895	Apr. 17	Lat. 36°20′ N., long. 74°50′ W.
1902	Apr. 9	100 miles south of Barnegat Light.
1903	Apr. 13	85 miles southeast of Barnegat Light.
1904	Apr. 7	30 miles east of Cape Henry.
1905	Apr. 10	40 miles off Cape Henry.
1911	May 1	70 miles southeast of Cape Henlopen.
1914	Apr. 22	50 miles east by north of Cape Charles.
1915	Apr. 9	100 miles east by south of Cape Henlopen.
1916	Apr. 5	80 miles east by south of Cape Henlopen.
1920	Apr. 14	35 miles southeast of Winterquarter Light.
1921	Apr. 7	Lat. 37°50′ N. in 32 fathoms.
1923	Apr. 9	Lat. 37°50′ N. in 30 to 40 fathoms.
1925	Apr. 13	35 miles southeast of Fenwick Island.
1926	Apr. 10	Lat. 37°35′ N., long. 74°35′ W.
1927	Apr. 18	70 miles south ½ east of Cape May.
1928	Apr. 9	25 miles southeast of Winterquarter Lightship.
1929	Apr. 8	75 miles south by east of Cape May.
1930	Apr. 5	80 miles south of Five Fathom Bank Lightship.
1931	Apr. 9	43 miles south of Fenwick Lightship.
1932	Apr. 15	49 miles south of Fenwick Lightship.
1933	Apr. 10	70 miles south-southeast of Cape May.
1934	Apr. 14	90 miles south of Cape May.
1935	Apr. 5	60 miles southeast of Cape May.

[1] Records of 1878 to 1881 from Goode, Collins, Earle, and Clark 1883, p. 9; records of 1887 to 1925 from Sette and Needler, pp. 38–39; records of 1926 to 1935 from present investigations.

VERNAL ADVANCE

After mackerel of the southern contingent first appear in coastal waters they are caught progressively farther north as indicated by figure 7. As earlier mentioned, this has been considered by some as a migration *en masse* of the whole population, by others as separate bodies of mackerel successively approaching coastal waters from directly offshore. My own observations lead to the belief that it is a mass migration but that the main body, as it moves northeasterly parallel to the coast is joined by lesser bodies of fish from farther offshore.

That it is a mass migration is supported by the almost complete disappearance of the mackerel from the region south of Long Island after the brief but productive fishing period in April and May, and by the relatively constant size composition of the population each spring as the fishery advances from the offing of Virginia to southern New England.

That additional schools join the main body as it advances along the coast is indicated (1) by occasional slight changes in size composition of the population, and (2) by the more frequent instances in which bodies of mackerel of slightly different size composition are taken well in advance of the main fishing area, as if the new school had come inshore at a point ahead of the main body.[19]

The passage up the coast is fairly rapid, the center of fishing shifting from the Virginia coast to the Massachusetts coast, a distance of 300 miles, in about 6 weeks. Reaching the neighborhood of southern New England in the midle of May, the southern contingent tarries for nearly 6 weeks; and it is not until nearly the first of July that it usually deserts this ground. In doing so the main body appears to go by way of the southern edge of Nantucket Shoals and through South Channel, judging from the daily shift of the fleets' catches. This does not preclude the possibility of considerable numbers going through Vineyard and Nantucket Sounds or passing right over the Shoals. That some take the route through the Sounds is indicated by catches in pound nets along their shores; that the main body does not do so is evident from the small quantities so caught.

Having passed Nantucket Shoals and arrived in the Gulf of Maine, the southern contingent has reached the grounds of its summer sojourn.

SPRING MIGRATION OF THE NORTHERN CONTINGENT

FIRST APPEARANCE

As previously noted, the mackerel that cause the abrupt alteration in the size composition of the population in southern New England each May are members of the northern contingent; and the alteration is evidence of their first appearance each spring. In Nova Scotia their first appearance is evident simply from the date of the first catch of mackerel. These dates appear in table 14. They refer mostly to the vicinity of Yarmouth. For the 6 years included in the table, the first appearance has been between May 12 and 28 in southern New England

[19] A further argument, based on spawning maturity, is that a "run" of mackerel reaching a given locality often consists of individuals about ready to spawn. Hence the new runs come from offshore rather than from along shore over grounds where mackerel had already spawned. This argument probably is baseless. Moore (1899: 5) found several size classes of eggs in the ovaries of spring-caught mackerel. The existence of such size groups in mackerel ovaries was verified by F. E. Firth (unpublished notes) in the present study. Although Moore's interpretation was that each size group was a season's batch of eggs, it now seems more likely that the groups are due to be spawned at intervals during the season, as was found for the pilchard, *Sardinops caerulea*, (Clark 1934), for the jack smelt *Atherinopsis californiensis*, (Clark 1929), and for the grunion, *Leuresthes tenuis*, (Clark 1925). If this holds true also for the mackerel, appearance of near-ripe individuals in the catch is neither proof that they did not spawn previously nor indication that they came directly from offshore.

and between May 21 and June 4 in Nova Scotia. But the dates of appearance in southern New England of necessity refer not to the very first arrivals of members of the northern contingent, for a few such mackerel would not be detected among the larger numbers of individuals of the southern contingent already there. They refer rather to the arrival in southern New England waters of large numbers of the northern contingent, and for comparability the earliest date of catching large quantities in Nova Scotia must be used. These dates lie between May 24 and June 7 and the lag behind the southern New England appearance is from 0 to 22 days, averaging 12 days over the period in question.

TABLE 14.—*Dates of arrival and departure of the "northern contingent" off southern New England,*[1] *and dates of arrival off Nova Scotia*[2]

Year	Off southern New England		Off Nova Scotia		Number of days between arrival off Southern New England and first catches of large quantities off Nova Scotia
	Arrival	Departure	First catch	First catches of large quantities	
1926	May 28	June 15	May 25	May 28	0
1927	May 16	June 9	do	June 5	20
1928	do	June 6	June 4	June 7	22
1929	May 24	June 7	May 28	June 3	11
1930	May 12	June 2	May 24	May 24	12
1931	May 17	June 6	May 21	May 26	9

[1] As indicated by alteration of the size composition in purse seine catches.
[2] As reported by the Gloucester, Mass., *Times* and the Boston Fish Bureau.

The locality where the northern contingent appears has varied from year to year. During the period in question in southern New England, it has usually been along a rather broad front from as far west as the offing of the eastern end of Long Island (long. 72° W.) to as far east as the vicinity of the Nantucket Shoals Lightship (long. 69°40′ W.), a range alongshore of over 100 miles. Sometimes the first catches of mackerel have been made far inshore. In 1927, for instance, they were first taken close to Block Island. Whether or not this indicates the mackerel of this contingent usually keep to deep levels until close in to land before rising to the surface is not evident from our available information, because fishermen, as a rule, have not explored the offshore waters in this sector, their attention usually being occupied by the southern contingent up to the time the northern contingent appears.

The locality where the northern contingent first appears in Canadian waters in recent years has usually been at the southwesterly end of Nova Scotia.[20] During the 7 years 1926 to 1932, United States purse-seiners fishing off Nova Scotia have located their first mackerel at various points along the coast from off Yarmouth to Scatari Island, but on no occasion were these catches made on dates earlier than mackerel reported (by the press or by trade bulletins) at Yarmouth. Until additional data are available on this subject it would seem that mackerel strike in along a considerable extent of the Nova Scotia coast almost simultaneously but with a general tendency to arrive earliest at the southwesterly end.

VERNAL ADVANCE

Since the northern contingent appears in two widely separated regions, southern New England and Nova Scotia, the advance from each place will be considered in turn.

Off southern New England the northern contingent, having appeared along the coast from Long Island to Nantucket Shoals, rapidly moves eastward, usually reaching the southern border of Nantucket Shoals in about 2 weeks. From here the major portion goes to the coast of Nova Scotia and a minor portion enters the Gulf of Maine. The course taken is somewhat in doubt, but it is probable that the mass movement is directly across the outer portion of the Gulf of Maine (Georges Bank), with a small fraction rounding Cape Cod into Massachusetts Bay, and still others circling back from the southwestern tip of Nova Scotia, thence, along the coast of Maine and even down to Massachusetts Bay. Pound nets, traps, and weirs, located along the shores of that Bay, according to daily catch records during four recent years, usually take their first mackerel earliest at Gloucester, next at Provincetown, and last at Sandwich and Barnstable, strongly suggesting a north to south movement such as would result from the fish circling back. On the other hand, the usual absence of catches along the coast of Maine this early in the season casts doubt upon it.

Whatever course may be taken by those of the northern contingent that enter the inner parts of the Gulf of Maine, it is evident from the small catches here,[21] that only a small fraction of the northern

[20] Huntsman (1922), on the contrary, reported earlier appearance at Cape Breton (May 5) than at Yarmouth (May 16) in 1894.

[21] Later, when the southern contingent enters the Bay, the catches become large. That these larger catches are of the southern rather than the northern contingent is obvious from the sizes of the individuals caught.

contingent is involved and that the major portion goes to the coast of Nova Scotia where it supports an important Canadian shore fishery and where, in many seasons, American purse seiners make large catches offshore.

Information on the advance of the major portion of the northern contingent along the Canadian coast is somewhat meager. During the 10 years of this investigation, only in 1926 did the purse-seine fleet fish along the Nova Scotian coast over a long enough period to cast some light on this question. From table 15 it is evident that the fishery took place off the central portion in the first few days of June, off the eastern portion between the 5th and 10th and in the Canso region between the 11th and 15th of June. Although the fishery progressed along the coast, it cannot be assumed that the fish did.

TABLE 15.—*Progress of mackerel along the Nova Scotian coast in 1926 as indicated by the number of catches made by United States mackerel purse-seiners in each area each day*

Date	Area XXII O (southern Nova Scotia)	Area XXII M (central Nova Scotia)	Area XXII K (eastern Nova Scotia)	Area XXII D (Canso)
May 30		1		
May 31		1		
June 1		4		
June 2		3		
June 3				
June 4		2		
June 5		2	3	
June 6	1	1	1	
June 7		1	2	
June 8			2	
June 9			4	
June 10			2	1
June 11		3	7	5
June 12		1		8
June 13				5
June 14			1	
June 15				4

Samples of the catches taken during this period (table 16 and fig. 15) indicate considerable differences in size composition of the schools. Throughout the period there are two modes located at about 40 and 46 centimeters, respectively, but the relative numbers of fish in those modes shift from nearly equal representation in the early days to a marked preponderance in the 40-centimeter mode in the late days of the period. Moreover there are changes within these modes, the modal length in the 40-centimeter group shifting downward and in the 46-centimeter group shifting upward.

This, I believe, indicates (1) that in 1926 there was a mass movement of mackerel northeasterly alongshore causing the fishery to shift in that direction, and (2) that schools from offshore (or from places not previously fished by the fleet from which our samples were taken) joined those already alongshore in sufficient numbers to change the size composition of the alongshore population. Inasmuch as the change in size composition took place in central Nova Scotia as well as eastern Nova Scotia and in the Canso region, the new schools joining those already there must have done so along a broad front extending from Halifax to Cape Canso.

TABLE 16.—*Sizes of mackerel taken by purse seines along the Nova Scotian coast in the spring of 1926*

[Periods May 30 to June 2, June 4, to 9, and June 10 to 15 are represented by samples of 6, 13, and 29 catches, respectively]

Length in centimeters	May 30–June 2		June 4–9		June 10–15	
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*
36.0					1	0.1
36.5					1	.1
37.0			1	0.2	4	.4
37.5			2	.4	4	.4
38.0	1	0.2	5	.9	18	2.0
38.5	2	.5	12	2.2	38	4.2
39.0	8	1.9	24	4.4	73	8.1
39.5	11	2.6	52	9.6	136	15.1
40.0	24	5.7	71	13.1	164	18.2
40.5	36	8.6	81	15.0	154	17.1
41.0	35	8.3	89	16.5	115	12.8
41.5	26	6.2	38	7.0	51	5.7
42.0	18	4.3	25	4.6	33	3.7
42.5	15	3.6	17	3.1	12	1.3
43.0	12	2.9	11	2.0	6	.7
43.5	13	3.1	8	1.5	1	.1
44.0	22	5.2	5	.9	5	.6
44.5	25	6.0	7	1.3	8	.9
45.0	28	6.7	14	2.6	6	.7
45.5	24	5.7	16	3.0	4	.4
46.0	26	6.2	14	2.6	18	2.0
46.5	27	6.4	14	2.6	13	1.4
47.0	22	5.2	12	2.2	10	1.1
47.5	14	3.3	6	1.1	9	1.0
48.0	9	2.1	5	.9	2	.2
48.5	7	1.7	3	.6	4	.4
49.0	4	1.0	3	.6	2	.2
49.5	2	.5	2	.4	4	.4
50.0	4	1.0	1	.2	1	.1
50.5	3	.7	1	.2	1	.1
51.0	1	.2			1	.1
51.5	1	.2				
52.0					1	.1
52.5			1	.2		
Total	420	100.0	540	99.9	900	99.7

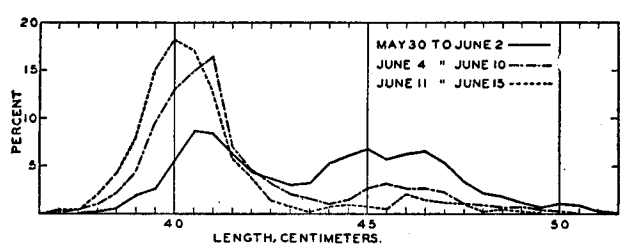


FIGURE 15.—Changes in mackerel population along the coast of Nova Scotia in the spring of 1926, as indicated by length-frequency distributions.