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DECLINE OF THE YELLOWTAIL FLOUNDER (*LIMANDA FERRUGINEA*) OFF NEW ENGLAND

By WILLIAM F. ROYCE, RAYMOND J. BULLER, AND ERNEST D. PREMETZ

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ABSTRACT

The yellowtail flounder fishery off New England was studied intensively from 1942 to 1949 to determine if changes in the yellowtail population were related to fishing pressure and whether regulation of the fishery was necessary to conserve the species.

Tagging and other evidence indicated the existence of five stocks, the most important of which to United States fishermen occurred off southern New England. The landings from the southern New England stock declined from 63,000,000 pounds in 1942 to 10,000,000 pounds in 1949, but the population did not exhibit the usual symptoms of heavy fishing: a declining average size, an increasing proportion of young fish, or an increasing growth rate. Estimates of mortality and recruitment indicated that the fishery was drawing gradually on a reserve which for unknown reasons was not replenished by young.

There is no clear evidence that greater total production could have been achieved by protecting fish at any size, in any area, or at any time of year.

DECLINE OF THE YELLOWTAIL FLOUNDER (*LIMANDA FERRUGINEA*) OFF NEW ENGLAND

By William F. Royce, Raymond J. Buller, and Ernest D. Premetz, *Fishery Research Biologists*

As recently as 1935, fishermen of New England found little value in the yellowtail flounder (*Limanda ferruginea*), which they caught incidentally in their trawls. This fish was considered too thin to compete with the winter, or blackback, flounder (*Pseudopleuronectes americanus*) for sale in the round, and it was not as well known as the dab, or American plaice (*Hippoglossoides platessoides*), or the gray sole or witch flounder (*Glyptocephalus cynoglossus*)—species commonly sold as fillet of sole. But two things occurred to change this. The winter flounder, mainstay of the fleet of small otter trawlers in southern New England, declined so severely in abundance in the middle thirties that fishermen and filleting concerns sought a substitute. The yellowtail, abundant, readily available, and fine-flavored, satisfied this need. Then from 1940 to 1942, the increasing demand for food that accompanied World War II was reflected in an expansion of the fisheries for almost any edible species wherever war restrictions would permit. Consequently, the catch of yellowtail rose from slightly less than 23 million pounds in 1938 to approximately 70 million pounds in 1942, at which time the fishery supported a fleet of 150 small otter trawlers.

These vessels fished from ports on Long Island, N. Y., and from Connecticut, Rhode Island, and southeastern Massachusetts ports as far north as Provincetown, Mass., and the yellowtail became the principal species of fish landed. Concurrent with the diversion of vessels to the yellowtail fishery was the development of the necessary handling and filleting facilities, chiefly at New Bedford, Mass., where about 20 filleting plants began operations.

Note.—Dr. William F. Royce is now director of the Fisheries Research Institute, University of Washington: Raymond J. Buller is central flyway representative, Bureau of Sport Fisheries and Wildlife, and Ernest D. Premetz commodity industry analyst, Bureau of Commercial Fisheries, U. S. Fish and Wildlife Service.

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The remarkable growth of the yellowtail fishery was followed by an almost equally remarkable decline. In 1944, the annual catch had been reduced by more than half and the following 9 years produced no sign of recovery. The decline and continuing scarcity of the yellowtail caused great concern, not only because this species closely paralleled the winter flounder in its decrease in the early and middle thirties (a decline from which the winter flounder had not recovered as late as 1951), but also because the fishermen who now depended on yellowtail fishing for their principal livelihood could expect to find no other abundant species of fish of similar value within the range of their small otter trawlers.

This pronounced reduction in the catch of a species of major importance to the New England fisheries was the impetus for a more concentrated study of the yellowtail. Prior to the peak of the yellowtail fishery, the question arose of how much expansion could be expected. Now, after its decline, fishermen and the general public alike want to know if they can expect a recurrence of the yellowtail's former abundance, if regulation of the fishery is needed, or if the sad history of other depleted species is to be repeated. To answer these questions we needed to know two things: First, what sizes and numbers of fish can be expected from a given fishing effort; and second, what measures would result in the greatest return from the fishery.

We have approached the answers to these basic questions through a study of the effect of fishing on the yellowtail. Determining the effects of fishing required a delineation of the stocks and a breakdown of the catch data according to the geographical units in which the stocks were homogeneous or in which the fishing pressure was uniform. (In either case, we may assume that the effect of fishing on the stock or stocks will be uniform.) After determining what fishing grounds should be considered to constitute a more or less homogeneous unit, we assembled data aimed at determining the relative size of the stock, the mortality due to fishing and natural causes, the growth, and the recruitment of young fish.

A complete and accurate determination of these factors would permit a precise estimate of the effect of fishing on the species. The factors vary, however, and the best we can expect from our present knowledge is an approximation; consequently, our estimates will be subject to revision as additional data become available. Therefore, we anticipate further study of the yellowtail and are making the data fully available in this report even though some appear inconclusive or irrelevant to the major problem at this time.

Little information on the habits and life history of the yellowtail is available in the literature, although naturalists and taxonomists have known the species for many years as one of a considerable group of very similar flounders of the genus *Limanda*. Species of this genus occur off northwest Europe, in the Bering Sea, and off the west coast of Canada. In the northwest Atlantic, the yellowtail (*L. ferruginea*) occurs from the northern part of the Gulf of St. Lawrence south to the vicinity of Chesapeake Bay. Its habits have been summarized by Bigelow and Schroeder (1953, pp. 271–275) and by Hildebrand and Schroeder (1928, p. 168).

Our data are the result of many people's efforts. Milton J. Lobell was assigned in 1938 to investigate the several species of flounder. His principal task was the study of the winter flounder, but he made many observations on the yellowtail. Alfred Perlmutter, from 1939 to 1942, continued the study of the winter flounder, but, recognizing the growing commercial importance of the yellowtail, he began to tag that species and obtain samples of the commercial catch. In October 1942, a study of the yellowtail was begun by William F. Royce, who was detailed to the port of New Bedford, where most of the landings were being made. He sampled the catch and interviewed fishermen for information on place of fishing and amount of fishing effort. This work was continued by Raymond J. Buller from 1946 to 1949 and by Ernest D. Premetz from 1949 to 1951. O. E. Sette made available the data on eggs and larvae of yellowtail that he had collected in connection with his investigation of the mackerel in 1929 and 1932. We also acknowledge the interest and cooperation of many fishermen, especially Captains Albert Griek and R. E. Sutcliffe.

COMMERCIAL PRODUCTION OF YELLOWTAIL

PRICE TRENDS

Before considering any of the data that may have had a bearing on the decline of the yellowtail flounder, we considered the possibility that fluctuations in the catch may have been due to changes in demand. In table 1 we have assembled data from the statistical reports of the United States Fish and Wildlife Service on the average annual prices received for yellowtail by the fishermen. The data indicate that the greatly increased production from 1938 to 1942 was accompanied by an increase in price that may well have contributed to the increased production. However, the price rose further in 1943 when production declined markedly. In late 1943, in 1944, 1945, and part of 1946, prices were fixed under wartime price regulations, and we can note only that during this period production continued to be fairly small. After controls were removed in 1946, the average price rose to 8.1 cents a pound in 1947 and continued to rise in the following years, reaching 13 cents a pound in 1951—a price almost three times that of 1942, the peak production year. Despite this incentive the fishermen produced far less in 1951 than in 1942. Thus, the production of yellowtail has declined and remained low despite increases in price that reflect larger markets and greater demand. From this we have concluded that the decline in production was not due to a decrease in demand.

TABLE 1.—*Average price received by fishermen in New England for yellowtail, by years, 1938–51*

Year	Price per pound (cents)	Year	Price per pound (cents)
1938	[1] 2.0	1945	5.9
1939	[1] 2.0	1946	7.0
1940	[1] 2.2	1947	8.1
1941	[2] 2.4	1948	9.2
1942	4.5	1949	9.5
1943	7.0	1950	10.6
1944	6.4	1951	13.0

[1] Includes small quantities of sand dab (*Hippoglossoides platessoides*).
[2] Price at principal ports of Gloucester, Boston, and Portland only.

LANDINGS

Detailed records on the landings of most species of fish in the northeastern United States are available from the published reports of the United States Fish and Wildlife Service. Since 1938, when the several species of flounders were separated in the statistics, these records show landings of yellowtail from Maine to New Jersey (table 2). From north to south, the ports of landing have included Gloucester, Boston, Plymouth, Provincetown, Chatham, Woods Hole, New Bedford, Point Judith, Stonington, Montauk, and New York City, with a few smaller ports receiving minor quantities. Since 1941, 50 percent or more of the yellowtail catch has been landed at New Bedford, Mass., with no other port even close in total volume.

TABLE 2.—*Annual United States landings of yellowtail, by ports and years, 1938–49*

[In thousands of pounds; see appendix A, p. 237, for source of the data]

Year	Maine	Massachusetts				Rhode Island	Connecticut	New York City	Long Island and New Jersey	Total [1]
		Gloucester	Boston	Cape Cod and Plymouth	New Bedford					
1938	301	108	3,012	7,794	6,071	364	1,781	2,041	1,343	22,815
1939	222	642	3,679	5,621	10,720	397	3,129	3,725	591	28,726
1940	827	2,380	4,587	3,866	17,519	1,059	4,090	4,183	2,361	40,872
1941	276	2,058	3,133	4,394	28,327	334	4,246	6,440	2,481	51,689
1942	26	3,277	2,328	5,605	36,722	2,420	6,193	8,568	3,439	68,578
1943	46	1,152	1,782	4,484	25,479	2,052	3,605	4,027	3,160	45,787
1944	127	901	964	2,999	14,354	3,027	3,187	1,428	4,090	31,077
1945	73	1,139	4,208	3,173	15,838	2,852	2,801	521	2,564	33,169
1946	37	486	3,268	2,680	17,128	2,240	3,171	394	1,917	31,321
1947	91	441	3,238	2,564	20,822	2,259	3,006	821	2,512	35,754
1948	118	635	3,258	2,320	25,214	3,293	1,352	1,201	1,577	38,968
1949	120	567	1,702	2,338	19,652	[2] 1,956	[2] 995	[2] 1,072	[2] 1,408	[2] 29,810

[1] Slight discrepancies occur due to rounding off of the figures.
[2] Includes some estimates.

PRODUCING AREAS

In order to determine the catch of yellowtail from each stock as defined on page 183, the locality fished was determined for each vessel landing at each port. Source of the catch has been obtained for all species of fish for many years at the principal ports of Boston, Gloucester, and Portland, and since 1942 at the port of New Bedford, where the collection of such information was commenced especially for the study of the yellowtail. At these ports the captain or mate of each vessel was interviewed to learn where he fished, how long he fished, and what he caught. His catch was then allocated to its statistical area (fig. 1), according to the system described by Rounsefell (1948).

At the smaller ports of Plymouth, Provincetown, Chatham, Stonington, Point Judith, and Montauk Point, the vessels were smaller and fished closer to port. Usually, after interviews with a few fishermen each year, the catch landed at these ports could be allocated satisfactorily to the one or two statistical areas concerned. At a few other ports, where the vessels were larger and interviews with the fishermen indicated that they fished with the New Bedford fleet, the landings were allocated among statistical areas in proportion to the New Bedford landings. The methods of allocation are listed in appendix B, page 238 and the resulting data are given in table 3.

Table 3 is the basis for many of the computations in this paper that concern the yellowtail populations, and it will be referred to repeatedly. At this point we note merely the following points: First, that the largest but also greatly fluctuating catches have come from the adjoining statistical subareas O, Q, S, and R, which are south of Massachusetts and Rhode Island; second, that moderate quantities of yellowtail have consistently been caught near Cape Cod in subareas E and G; and third, that the catches from Georges Bank, subareas H, J, M, and N, greatly increased from 1946 to 1949.

These statistical subareas, separated by major ecological and political boundaries, necessarily include a wide range of depth zones and bottom types, and thus give rather a poor idea of the ecological conditions preferred by the yellowtail. To provide more precise knowledge of the localities inhabited by this flounder, we have made a special study of the catch landed at New Bedford during 1943 and 1947 and allocated it to smaller

TABLE 3.—*United States landings of yellowtail, by month and fishing area, 1942–49*

[In thousands of pounds]

Date	Statistical area—												Total[1]
	Nova Scotian Banks (XXI)	New England Banks (XXII)										Off Long Island (XXIII)	
		B-C-D	E	G	H	J	M	N	O	Q-R	S		
1942													
January	8	3	261	16	371		21	16	74	3,986	571	250	
February		2	265		16		10	2	28	2,263	1,088	340	
March		4	320	28	50	1	69	3	3,419	918	1,836	583	
April	6	7	38	197	12	93	495	2	943	886	3,316	465	
May	17		25	115	11	65	144	12	374	1,129	1,210	134	
June			45	197	8	72	23	2	50	3,221	1,113	214	
July	9	1	61	163	2	27	14		645	4,618	479	240	
August			18	355	5	10	19		3,931	3,042	287	143	
September		1	36	629		7	24		4,632	471	190	96	
October			84	42		3	21		6,303	804	519	260	
November		8	168	3	8	6	77	20	1,841	1,690	525	252	
December			224	40	625		4	15	6	2,541	539	332	
Total	40	26	1,545	1,785	1,108	284	921	72	22,246	25.569	11,673	3,309	68,578
1943													
January	1	5	235	5	784		8	25	1,338	2,542	752	273	
February		24	257	14	208		5	2	1,613	1,289	674	279	
March		5	149	276	12		46	46	2,473	1,146	923	387	
April	11	12	68	69	8	89	398	26	360	1,677	627	329	
May	32		95	165	55	86	226	23	242	722	458	207	
June	38	6	55	83	25	69	124	26	230	1,601	301	100	
July	12	3	52	78	171	20	61		135	3,016	283	104	
August	40		56	138	2	3	27	8	1,739	3,496	355	180	
September	1	2	31	56	1	6	19		3,945	726	205	103	
October	2	5	157	54		11			1,885	106	94	81	
November	159	2	561	16	11	8	83	60	119	1,578	144	79	
December	25	10	160	1	2				100	186	339	236	
Total	321	74	1,876	955	1,279	292	997	216	14,179	18.085	5,155	2,358	45,78
1944													
January		10	298	51	1,480		73	42	55	2,190	1,015	441	
February	2	8	220	78	360		15	48	567	1,677	1,133	353	
March		8	212	172	691	9	69	15	1.063	786	1,252	415	
April	11	7	164	163	19	45	91	18	284	635	1,101	498	
May	69	11	133	236	62	24	28	35	41	341	514	246	
June	12	6	37	67	13	21	8	16	49	393	359	176	
July	60		56	244	9	8	3	14	49	1,630	682	280	
August	24		70	188	3	13	26	15	727	1,514	433	240	
September	2	2	121	100	2	5	10		92	41	12	6	
October	34		153	138	2	7	4	2	14	169	309	155	
November	148	3	262	14	11	8	40	8	52	243	328	206	
December	246	13	99	59	277		13	8	16	231	272	121	
Total	608	68	1,825	1,510	2,929	140	380	221	3,009	9,850	7,410	3,137	31,087
1945													
January	93		125	16	945		13	19	113	593	422	195	
February	30		333	30	507		3	3	361	706	347	159	
March	20	3	170	283	172	3	13	5	816	1,668	626	291	
April	57	2	105	299	21	26	61	22	133	207	224	88	
May	517	5	137	165	39	9	4	58	120	161	120	53	
June	532		38	79	46	33	3	47	130	167	56	28	
July	684	1	18	54	24	23	53	24	109	813	731	174	
August	564		23	59	31	23	461	8	148	2,052	126	60	
September	191	2	39	57	3	36	58	2	588	1,900	48	24	
October	1,037		69	109	11	11	12		2,373	635	142	71	
November	575	14	196	6	27		28	34	1,457	2,031	408	177	
December	434	3	128	16	41	4	2	22	188	296	364	162	
Total	4,734	30	1,381	1,173	1,867	168	711	244	6,536	11,229	3,615	1,482	33,169
1946													
January	13	3	222	54	385		1	32	445	419	862	397	
February	1		262	19	150	2	6	4	209	444	331	160	
March	1		82	334	26	7	32	25	980	1,143	809	367	
April	26		57	277	29	13	38	49	45	76	308	154	
May	110	5	59	180	25	35	84	79	49	67	263	132	
June	266		151	65	50	14	5	10	27	355	888	268	
July	759	1	103	108	16	5	17	25	95	1,730	260	77	
August	544	5	75	107	7	16	167	69	1,102	290	78	39	
September	29	2	72	112	3	25	2		1,248	292	104	52	
October	92	4	87	70	3	17	45	17	2,220	642	279	145	
November	560	3	131	12	45	38	159	2	1,422	753	445	145	
December	336	7	114	21	64	15	52	3	10	2,469	494	278	
Total	2.737	30	1,415	1,359	803	187	608	315	7,852	8,680	5,121	2,214	31,321

[1] Slight discrepancies occur due to rounding off of the figures.

TABLE 3.—*United States landings of yellowtail, by month and fishing area, 1942–49*—Continued

[In thousands of pounds]

Date	Statistical area—												Total [1]
	Nova Scotian Banks (XXI)	New England Banks (XXII)										Off Long Island (XXIII)	
		B-C-D	E	G	H	J	M	N	O	Q-R	S		
1947													
January	62	3	154	31	126	5	35	94	231	2,172	221	17	
February	22	2	13	29	42	22	132	71	199	453	69	16	
March	36	20	131	40	45	12	107	72	300	1,494	215	28	
April	82	15	165	70	55	80	270	94	286	846	240	29	
May	305	3	50	72	100	31	63	96	273	588	183	14	
June	428	....	50	86	59	39	37	103	263	964	453	26	
July	323	2	110	444	40	18	26	124	189	1,792	541	381	
August	94	....	47	178	40	14	29	47	1,278	401	53	18	
September	24	1	142	72	40	12	22	910	2,098	473	71	20	
October	39	1	134	50	57	14	79	745	2,446	1,391	101	23	
November	85	1	99	43	112	7	46	73	292	2,198	138	17	
December	136	1	122	55	616	7	39	69	241	2,395	524	45	
Total	1,636	49	1,217	1,170	1,332	261	885	2,498	8,096	15,167	2,809	634	35,754
1948													
January	40	2	108	40	285	9	48	190	190	1,102	595	122	
February	96	2	95	12	149	4	60	267	263	685	167	145	
March	34	2	84	8	19	2	58	191	276	650	400	378	
April	27	3	204	21	20	68	81	172	378	399	430	67	
May	754	....	77	29	46	7	229	180	473	379	113	61	
June	1,133	2	86	30	95	10	61	165	258	555	336	600	
July	377	11	115	42	36	21	152	188	1,120	914	471	757	
August	102	....	56	37	25	8	235	2,817	962	207	34	55	
September	59	....	71	49	40	9	709	2,195	1,244	285	68	80	
October	76	....	49	48	29	5	140	2,724	1,369	288	70	81	
November	192	1	64	26	49	20	118	220	2,376	550	40	59	
December	247	....	83	30	52	13	65	186	264	1,431	59	66	
Total	3,137	23	1,092	372	845	176	1,956	9,495	9,173	7,445	2,783	2,471	38,968
1949													
January	14	4	176	85	265	11	209	107	225	887	48	2	
February	8	1	160	82	111	3	236	97	570	794	36	2	
March	9	5	108	145	162	6	417	104	585	280	17	2	
April	131	5	140	140	33	47	300	109	142	132	130	2	
May	49	2	61	136	146	17	164	113	111	64	40	1	
June	56	3	74	102	165	16	236	343	269	94	31	30	
July	44	1	67	115	59	12	272	928	156	131	179	11	
August	21	....	34	103	37	6	2,523	1,021	392	117	16	2	
September	8	....	49	153	45	46	2,304	95	848	93	13	2	
October	36	9	165	123	33	3	2,414	624	377	125	15	2	
November	228	13	144	124	42	5	1,043	338	964	343	16	2	
December	47	3	127	98	66	4	234	526	965	996	20	26	
Total	651	46	1,305	1,406	1,164	176	10,352	4,405	5,604	4,056	561	84	29,810

[1] Slight discrepancies occur due to rounding off of the figures.

areas, or unit areas, which are rectangles of 10 minutes of latitude or longitude to a side and enclose an area of about 70 square miles. Thus, for about 60 percent of the catch we have determined the actual unit areas fished. By assuming that this distribution of the catch was representative of the fishing from all ports during 1943 and 1947, the total catch for each subarea was allotted among the unit areas. Figure 2 shows the localities fished and the catches made during 1947. The fishing grounds of 1943 were almost identical with those of 1947 and therefore have not been shown.

Most of the catch came from near the 20-fathom contour from south of Montauk Point to south of Nantucket Shoals, with smaller quantities taken on Georges Bank, in the vicinity of Cape Cod, and farther north in the Gulf of Maine. Most of the catch was taken between 15 and 35 fathoms, although moderate quantities were taken out to a depth of 45 fathoms. This is the preferred depth range of the species if we assume that these fishing grounds represent the areas inhabited by most of the yellowtail. This assumption is reasonable, because there are very few localities too rough to trawl and most of the Continental Shelf is heavily fished for other species. The chance of yellowtail concentrations remaining undiscovered is extremely small.

The ocean bottom in the areas of yellowtail

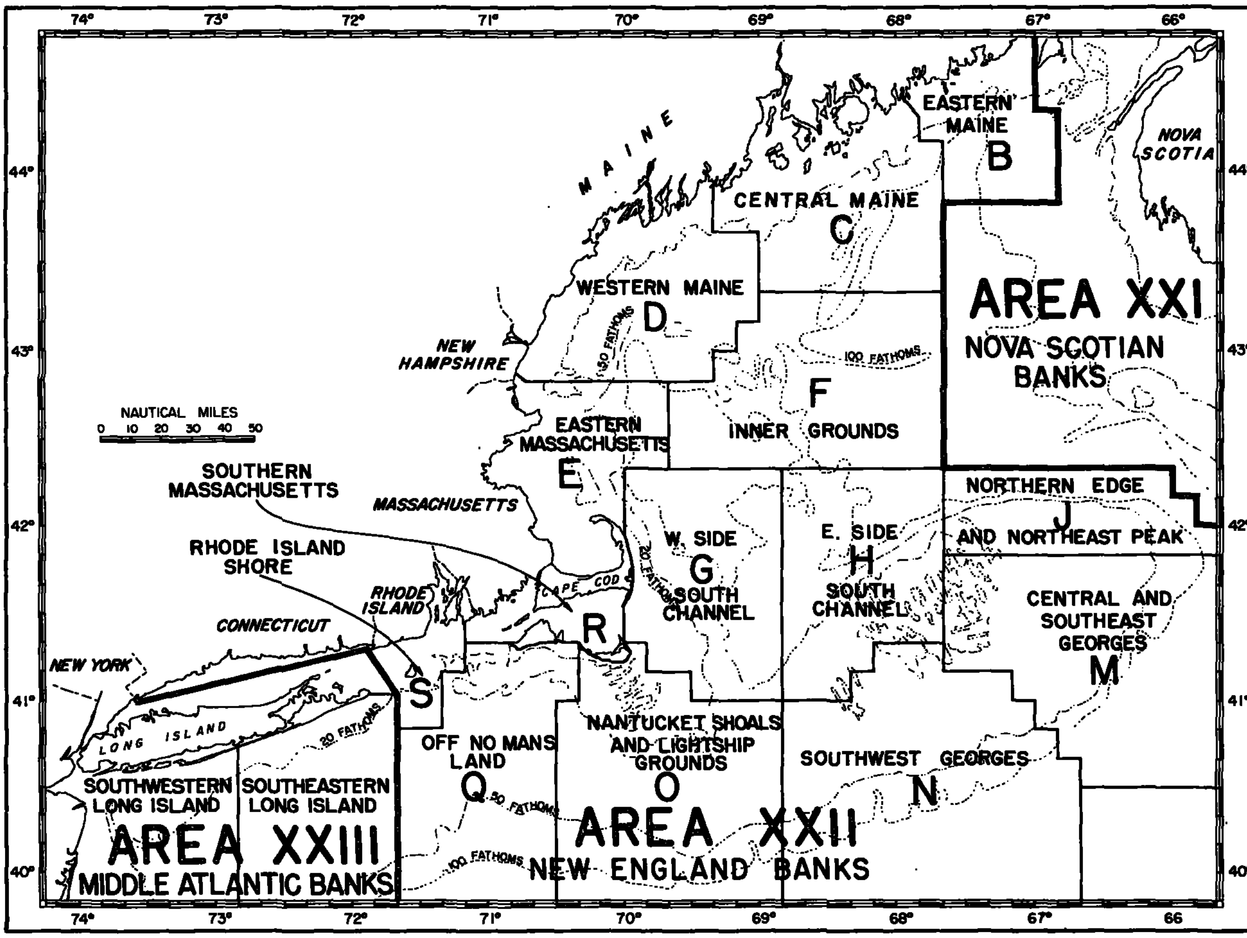

FIGURE 1.—Statistical areas on the New England Banks.

concentrations usually is indicated on the charts as sand, sand and gravel, gray sand, or sand and shell. Sand appears to be the constant ingredient, and it is significant that the distribution of the yellowtail corresponds closely to the location of the near-shore sand zone delineated by Stetson (1938). He describes the bottom sediments encountered in a section running approximately due south from Martha's Vineyard, and he states (p. 14)—

At the six-mile mark, in 27.5 meters of water * * *. Relatively coarse sands are encountered, interspersed with finer, from this point seaward until 48 meters of water is reached 18 miles from shore. This belt of coarse material, flanked on either side by finer sediment, occurs in the other traverses in the same relative position * * *. The sand is heavily stained with limonite and is much redder than the beach material * * *. From the sixteen-mile point onward the red stain disappears * * * it seems probable that the sediments throughout this zone are being strongly worked upon by bottom currents which vary greatly in velocity from place to place.

Stetson further reports that this near-shore zone of coarse sand was found in 10 to 29 fathoms in a section running slightly east of south from Block Island.

Our method of recording yellowtail-catch areas does not permit a precise statement of their depths, but the unit areas south of the center of Martha's Vineyard that produced yellowtail include charted depths to 27 fathoms, with those south southeast of Block Island running to 37 fathoms. Furthermore, the fishermen reported that very few fish were caught in less than 15 fathoms. Thus, the zones of coarse reddish sand and of yellowtail catch are in fairly good agreement, but perhaps better evidence of such a relation is to be found in the coloration of this

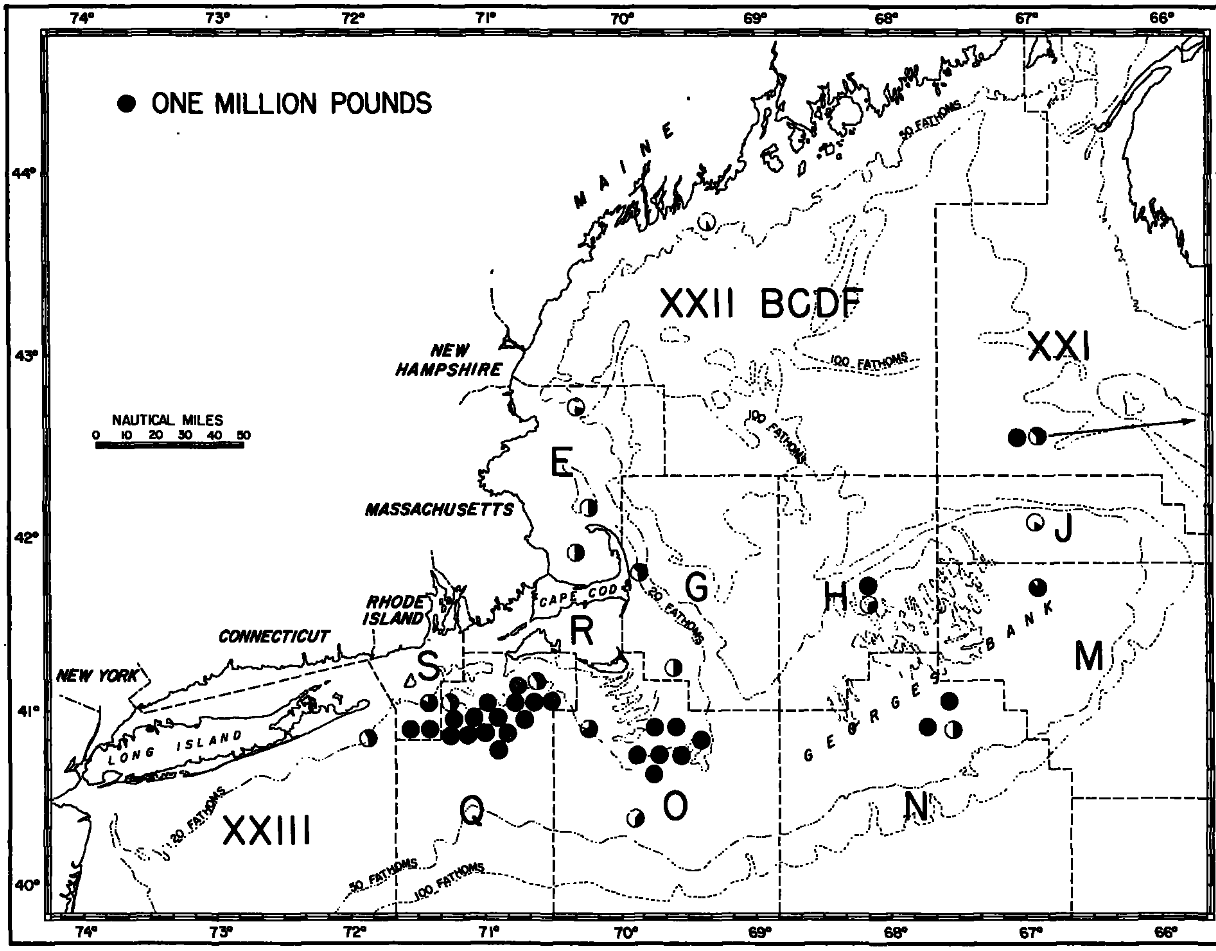

FIGURE 2.—Yellowtail flounder fishing areas and catch during 1947. Solid dots indicate 1 million pounds taken; partial dots represent fractions of 1 million pounds.

flounder which, like others of the group, adjusts its color quickly to the bottom type. Characteristically, on most grounds where it is taken, the yellowtail is speckled with rusty red spots from ½ to 1 centimeter in diameter; hence, its other common name, rusty dab.

With a preference for coarse, reddish sand in 15 to 35 fathoms of water, the yellowtail of commercial size on many of the grounds are surrounded by water depths and bottom types that may be a deterrent if not a bar to migration. The Fundian Channel, more than 100 fathoms deep, separates the Georges and Nova Scotian Banks; the South Channel with a minimum, central depth of 36 fathoms separates Georges Bank from the Nantucket Shoals region and only a narrow and tenuous strip of between 15 and 35 fathoms exists around Cape Cod and Nantucket Shoals. Thus it would appear that movement of yellowtail populations among these areas may be sparse or lacking.

MIGRATIONS

The yellowtail in northwest Atlantic waters has been described as a single species with a range from Labrador to Virginia. While morphological differences between populations of the yellowtail may exist,[1] we believe that they are slight in the fishing areas from Maine to New Jersey. Therefore, we have not attempted to show morphological differences, but we have relied on tagging to indicate the extent of intermingling and the heterogeneity of the populations.

[1] Scott (1954) has demonstrated differences in the relative size of the head, right pectoral fin, left otolith, and dorsal and anal fin-ray numbers between Nova Scotian and Cape Cod yellowtail.

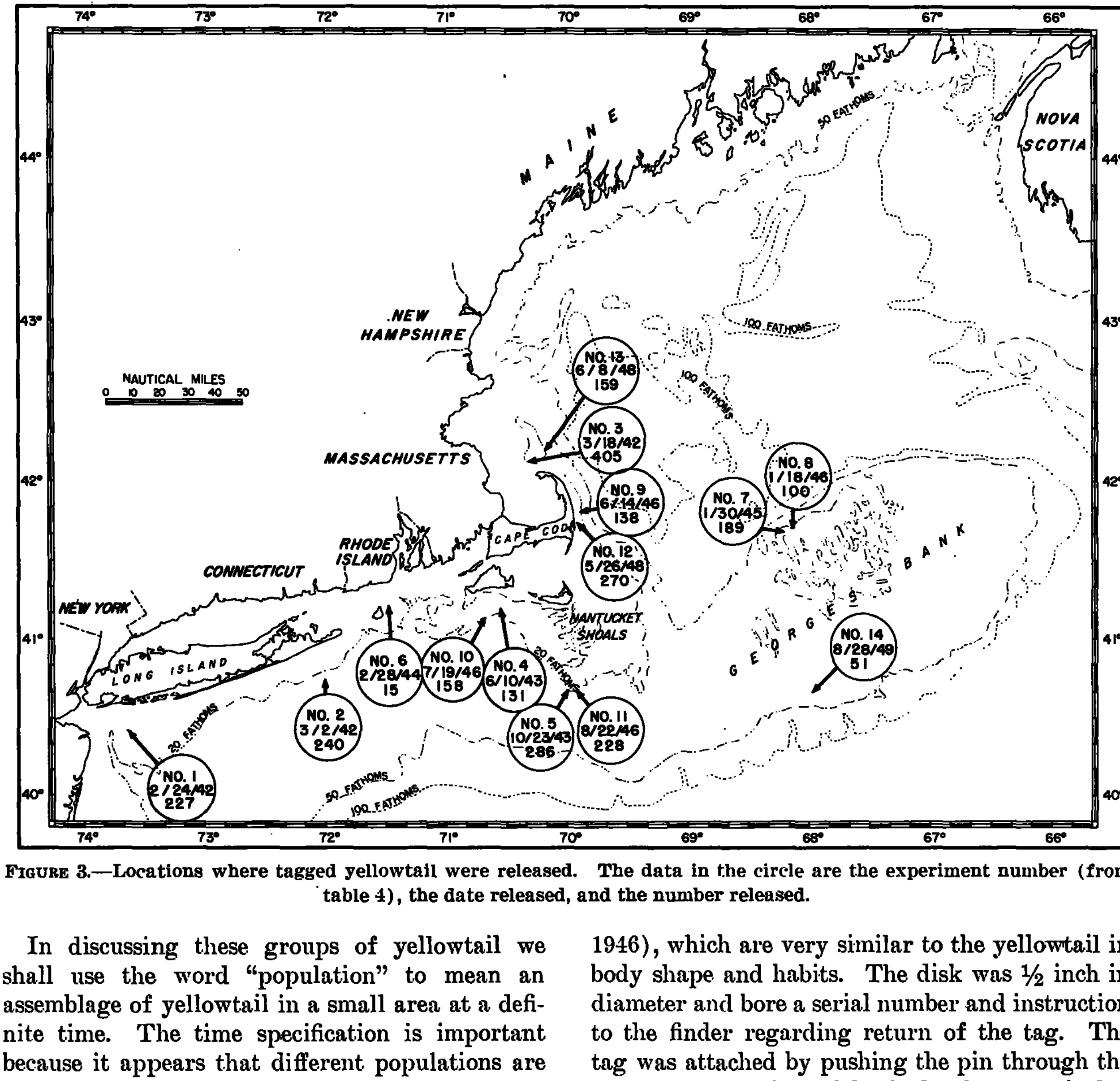

FIGURE 3.—Locations where tagged yellowtail were released. The data in the circle are the experiment number (from table 4), the date released, and the number released.

In discussing these groups of yellowtail we shall use the word "population" to mean an assemblage of yellowtail in a small area at a definite time. The time specification is important because it appears that different populations are found in an area at different times. We shall use the word "stock" to specify larger groups of yellowtail consisting of several intermingling populations all of which can be fished by a single fleet of vessels.

Between February 27, 1942, and August 31, 1949, a total of 2,597 yellowtail was tagged and released (table 4, fig. 3) on all of the major United States fishing grounds. Recaptured through December 1952 were 377, or 14.5 percent.

A tag consisting of two cellulose-nitrate disks joined by a pure nickel pin was placed on each fish selected for tagging. This tag had been successfully used with winter flounders (Perlmutter 1946), which are very similar to the yellowtail in body shape and habits. The disk was ½ inch in diameter and bore a serial number and instruction to the finder regarding return of the tag. The tag was attached by pushing the pin through the muscular part of the fish's body about 1½ inches behind the head and ¾ inch from the base of the dorsal fin. The pin was looped over with pliers leaving about ⅛ inch for growth between the disks and the body of the fish.

The finder was paid $1 for return of the tag, but this was not always enough to stimulate a busy fisherman to send in the tag. In the early part of the program a considerable proportion of the returns came from filleters and other handlers. By increasing our personal contact with the fishermen, however, we obtained more tags from them, as well as more complete information concerning the recapture.

TABLE 4.—*Returns from 2,597 tagged yellowtail flounder, by lot and locality, 1942–52*

[Roman numerals and letters refer to international areas and subdivisions as shown in figure 1]

Time of recapture	Number of fish recaptured in area—											Un-known	Total
	XXIII		XXII										
	Southwestern Long Island	Southeastern Long Island	S	Q	O	G	E	D	H	M	N		
Lot No. 1 (227 fish released 8 to 9 miles south of Jones Beach, N. Y., Feb. 24, 1942, in area XXIII, southwestern Long Island):													
Year 1942:													
February	3												3
March	9												9
April	3												3
June			4	1								3	8
July		1	1	9								1	12
August				5								4	9
September				4								1	5
October				1	3							2	6
November		1										1	2
December					1								1
Year 1943:													
January	1												1
February	1												1
April	1												1
July				3									3
August				4								1	5
September					1								1
October					1								1
Year 1944:													
January	1												1
March												1	1
May												1	1
November												1	1
Year 1945: September				1									1
Year 1946:													
January	1												1
June												1	1
Total	20	2	5	28	6							17	78
Lot No. 2 (240 fish released 16 to 20 miles southwest of Montauk Point, N. Y., Mar. 2, 1942, in area XXIII, southeastern Long Island):													
Year 1942:													
March		1	2									2	5
April		1	3									5	9
May		1	2	1								2	6
June			1	3								1	5
July				5								2	7
August				1								2	3
October				2	1							2	5
November				1									1
December												2	2
Year 1943:													
January		1		1									2
February		1	1										2
May			1										1
November												1	1
Year 1944:													
March		1											1
August												1	1
Total		6	10	14	1							20	51
Lot No. 3 (405 fish released 5 miles northwest of Race Point, Mass., Mar. 18, 1942, in area XXII, E):													
Year 1942:													
March							9					7	16
April							3					1	4
May							1					1	2
July							1						1
Year 1943: March							1						1
Total							15					9	24
Lot No. 4 (131 fish released 16 miles east southeast of No Mans Land, Mass., June 10, 1943, in area XXII, Q):													
Year 1943:													
June				1								1	2
August				2									2
September				1	1							1	3
Year 1944:													
January												1	1
April			1										1
Year 1945: August				1									1
Year 1946: January	1												1
Total	1		1	5	1							3	11

TABLE 4.—*Returns from 2,597 tagged yellowtail flounder, by lot and locality, 1942–52*—Continued

Time of recapture	Number of fish recaptured in area— XXIII: Southwestern Long Island	XXIII: Southeastern Long Island	XXII: S	XXII: Q	XXII: O	XXII: G	XXII: E	XXII: D	XXII: H	XXII: M	XXII: N	Unknown	Total
Lot No. 5 (286 fish released, off Nantucket Shoals 47 miles southeast by south of No Mans Land, Oct. 22–24, 1943, in area XXII, O):													
Year 1943: October					12							2	14
Year 1944:													
January												1	1
February												1	1
March					1								1
April			1	1									2
Year 1945:													
April												1	1
November												1	1
No date												1	1
Total			1	1	13							7	22
Lot No. 6 (15 fish released 8 miles south by east of Point Judith, Feb. 28–29, 1944, in area XXII, S):													
Year 1944:													
March			1										1
July												1	1
Total			1									1	2
Lot No. 7 (189 fish released 3 miles west of Cultivator Buoy, Georges Bank, Jan. 28–31, 1945, in area XXII, H):													
Year 1945:													
January									7				7
February									8			4	12
March									2				2
April												1	1
Year 1946: January									1				1
Year 1949: January									1				1
Total									19			5	24
Lot No. 8 (100 fish released 2 miles east of Cultivator Buoy, Georges Bank, Jan. 17–18, 1946, in area XXII, H):													
Year 1946:													
January									2			2	4
February									1				1
March									1				1
Year 1947: October									1				1
Total									5			2	7
Lot No. 9 (138 fish released 5 to 8 miles south southeast of Nauset Beach Light, June 14, 1946, in area XXII, G):													
Year 1946:													
June												2	2
July												2	2
August					1	3						1	5
September						1							1
November												1	1
December												1	1
Year 1947:													
January												1	1
March						2						2	4
April						1						3	4
May												1	1
June												1	1
August						1							1
September						1							1
October								1					1
November							1						1
Year 1948:													
January							1						1
February												1	1
April							1						1
June												2	2
December						1							1
Year 1949: April						1							1
Year 1951: March												1	1
Year 1952: May						1							1
Total					1	12	3	1				19	36

TABLE 4.—*Returns from 2,597 tagged yellowtail flounder, by lot and locality, 1942–52*—Continued

Time of recapture	Number of fish recaptured in area—												Total
	XXIII		XXII									Unknown	
	Southwestern Long Island	Southeastern Long Island	S	Q	O	G	E	D	H	M	N		
Lot No. 10 (158 fish released 14 miles southeast of No Mans Land, July 19, 1946, in area XXII, Q):													
Year 1946:													
July				7									7
August				4	3							2	9
September				3	2							2	7
October												1	1
November			1									1	2
Year 1947:													
January												1	1
August				1									1
October												1	1
Year 1948: August			1										1
Total			2	15	5							8	30
Lot No. 11 (228 fish released off Nantucket Shoals 50 miles southeast ½ mile south of No Mans Land, Aug. 21–23, 1946, in area XXII, O):													
Year 1946:													
August				16								5	21
September			1	5								7	13
October			1	4									5
November												1	1
December			2										2
Year 1947:													
January			1										1
July			3	1									4
August					1						1		2
September					1								1
December				1								1	2
Year 1948: March												1	1
Total			8	27	2						1	15	53
Lot No. 12 (270 fish released 3 miles southeast of Nauset Harbor, May 26–27, 1948, in area XXII, G):													
Year 1949:													
February						1						1	2
March												2	2
April						1						2	3
Year 1951: January							1						1
Total						2	1					5	8
Lot No. 13 (159 fish released 5 miles north 10 miles north northeast of Race Point, June 8, 1948, in area XXII, E):													
Year 1948:													
July							1						1
November												1	1
Year 1949:													
January												1	1
March							1						1
June												1	1
November							1						1
Year 1950:													
January							1						1
February												1	1
March												1	1
Year 1951: July							1						1
Total							5					5	10
Lot No. 14 (51 fish released 65 miles east and 105 miles east ¼ south of Nantucket Lightship, Aug. 28–31, 1949, in area XXII, N):													
Year 1949:													
August											2	1	3
September											1	1	2
October											1		1
November											2		2
Year 1950:													
January				1									1
February					1						1		2
March												1	1
April												1	1
June									1				1
July											1	1	2
August											1	2	3
October												1	1
Year 1952: December				1									1
Total				2	1				1		9	8	21

Fortunately, our difficulties with the tags and pins were not nearly as serious as those reported by Calhoun, Fry, and Hughes (1951, p. 310). They reported that at the end of 7 months in an aquarium "19 of the 20 tags in which the nickel pins had been used had fallen off as a direct result of pin corrosion." In our experiments with yellowtail we recovered 1 tagged specimen after it had been out 5 years and 11 months, and 58 of our 377 recaptures were made after a year at sea. Of 52 of the tags that had been out more than 1 year (all of which were available for examination), pin corrosion was evident in only 2, which were out 3 years and 5 months, and 2 years and 8 months. Of course, flounders that had lost their tags could not be distinguished in the commercial catch, but if corrosion had been a serious problem many more partly corroded pins should have been recovered. However, the finding of even 2 corroded pins indicates that some tags probably were lost and this probability must be considered in estimates of mortality from the tagging data.

The yellowtail collected for tagging were caught with otter-trawl nets from commercial vessels prior to June 1946, and subsequently from the Fish and Wildlife Service vessels *Skimmer* and *Albatross III* (except lot No. 11 released in August 1946). Naturally, only lively fish were selected for release, although with the Service vessels it was possible to make short tows and give the fish much better handling. Even when the fish were given the best of handling and appeared to be in good condition, many were slightly injured and probably some mortality occurred. Manzer (1952), who tagged Pacific coast flounder with the Petersen disk tag, found considerable mortality even under the best conditions.

Most of the yellowtail released from the Service vessels were classified in three groups according to the degree of visible injury (table 5): those with no injury apparent under casual examination (0); those with marks less severe than the following (1); those with more than three splits in fins, or with any part of a fin missing, or with red marks on the white side more than 2 millimeters wide, or with more than 2 square centimeters of scales missing from the dark side (2). All fish showing severe injury or any lethargy were rejected.

Large differences were found in the recovery rates of the three groups. Fish from the 0 group, not noticeably injured, were recovered at a rate of 19.7 percent, from the 1 group, 13.1 percent and the 2 group, only 3 percent. The chi-square value of the smaller difference between groups 0 and 1 is 4.32, a statistically significant value. In addition to such direct evidence, the low returns from one release off Cape Cod (lot No. 3, 5.9 percent), which was tagged under severe weather conditions in a heavily fished area, suggest that considerable mortality due to tagging occurred. Obviously, our methods of handling killed some of the tagged fish and, equally obvious, in future experiments only completely uninjured fish should be used even though others may be lively.

TABLE 5.—*Recaptured yellowtail classified by degree of injury at time of tagging*

[Based on lot Nos. 9, 10, 12, 13, and 14]

Degree of injury	Number tagged	Recaptured	
		Number	Percent
0	213	42	19.7
1	329	43	13.1
2	203	6	3
Total	745	91	

Evidence of a regular seasonal migration is provided by the recovery of yellowtail (lot No. 1) released off Jones Beach, N. Y., in February 1942 (table 4). These fish were recaptured on the principal fishing grounds off No Mans Land and Nantucket (fig. 4) in the summers of 1942, 1943, and 1945, and back near the point of their release in the winters of 1943, 1944, and 1946. These winter recaptures are especially significant because the majority of the landings in the winter fishery originated from the grounds off No Mans Land and Nantucket Shoals (table 3). This indicates that the fish tagged off Jones Beach are not a part of the stock found off Nantucket Shoals and No Mans Land in the winter, and suggests that the population found off Nantucket and No Mans Land in the summer differs from the winter population of the same place.

A similar pattern of migration is evident from the recaptures of yellowtail released off Montauk Point (fig. 4). These tagged fish were taken to the east of No Mans Land and Nantucket Shoals during the summer of 1942 and back off Montauk Point in the winters of 1943 and 1944. It may be significant that no fish released off Montauk Point were recaptured off Jones Beach. It appears

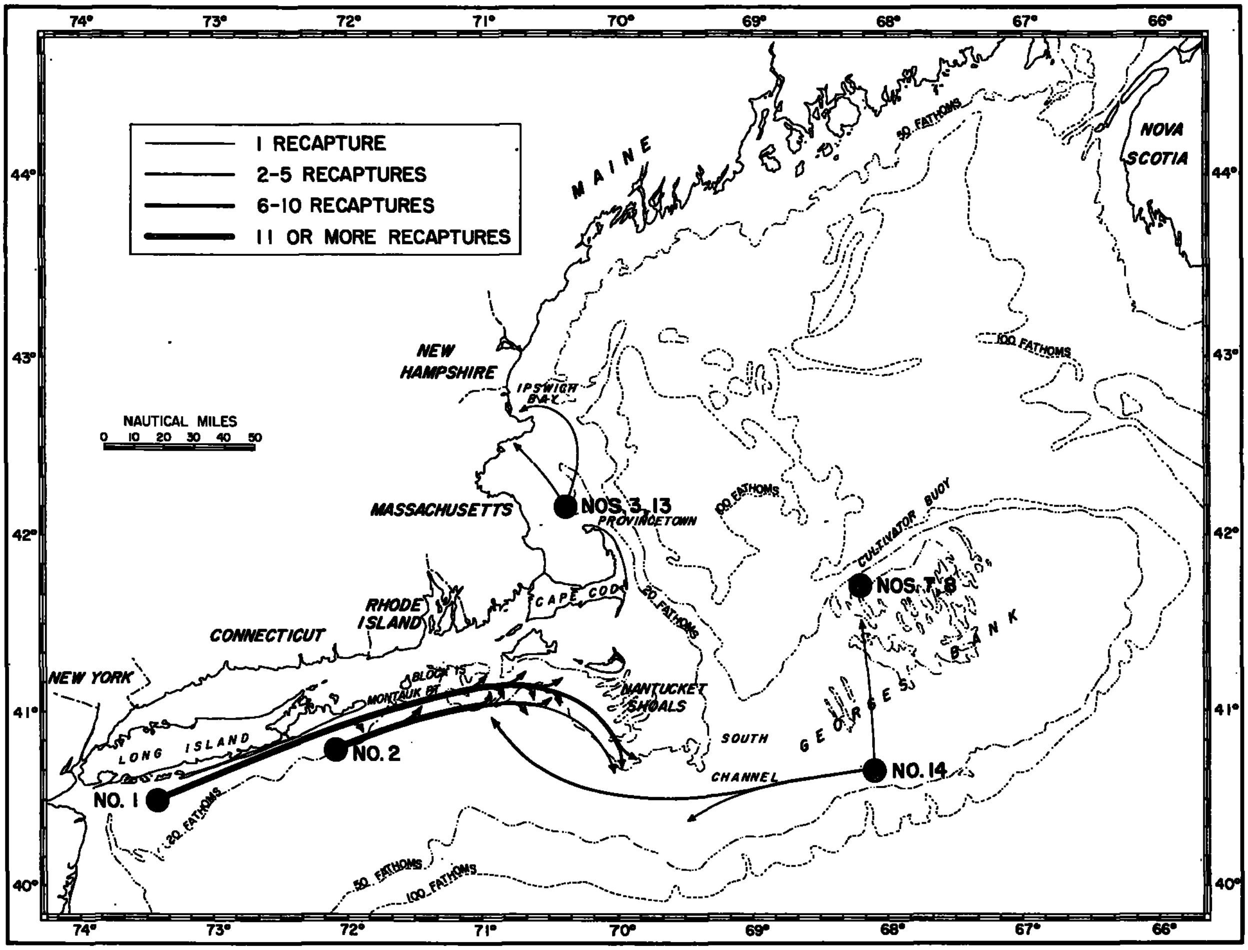

FIGURE 4.—Distant recaptures of yellowtail released off Jones Beach (No. 1), Montauk Point (No. 2), Provincetown (Nos. 3 and 13), and east of Nantucket Lightship (No. 14).

probable that the fish from Montauk Point mingled with those from Jones Beach on the grounds off southern Massachusetts during the summer and separated from them in the winter on the westward migration.

Recaptures from the yellowtail released off No Mans Land and Nantucket Shoals during the summer and fall months of 1943 and 1946 (fig. 5) were almost all made in the area where the fish had been released or in the areas between Block Island and Nantucket Shoals. Only one flounder was caught westward off Jones Beach and only one moved eastward to be caught on Georges Bank.

The yellowtail that were released off Race Point on the tip of Cape Cod (fig. 4) remained in the eastern Massachusetts area, although one was caught as far north as Ipswich Bay, just north of Gloucester. Those fish tagged off Nauset Beach ranged farther (fig. 5): one moved across Nantucket Shoals to be recaptured south of Nantucket, one was caught off Maine, and other yellowtail were taken in Cape Code Bay near Plymouth, Mass.

Those released in the Cultivator Buoy region on Georges Bank (lot Nos. 7 and 8) were recaptured in the same area, one of them 4 years later. Thus, there was no evidence of migration from this area, even though we suspect that these fish must mix to some extent with those on the other parts of Georges Bank.

The yellowtail tagged on the southwestern part of Georges Bank, east of Nantucket Lightship (fig. 4), were mostly recaptured in the area of release, but one had migrated to the Cultivator Shoals area and three moved westward to cross South Channel and were taken south of Nantucket and off No Mans Land. These three fish

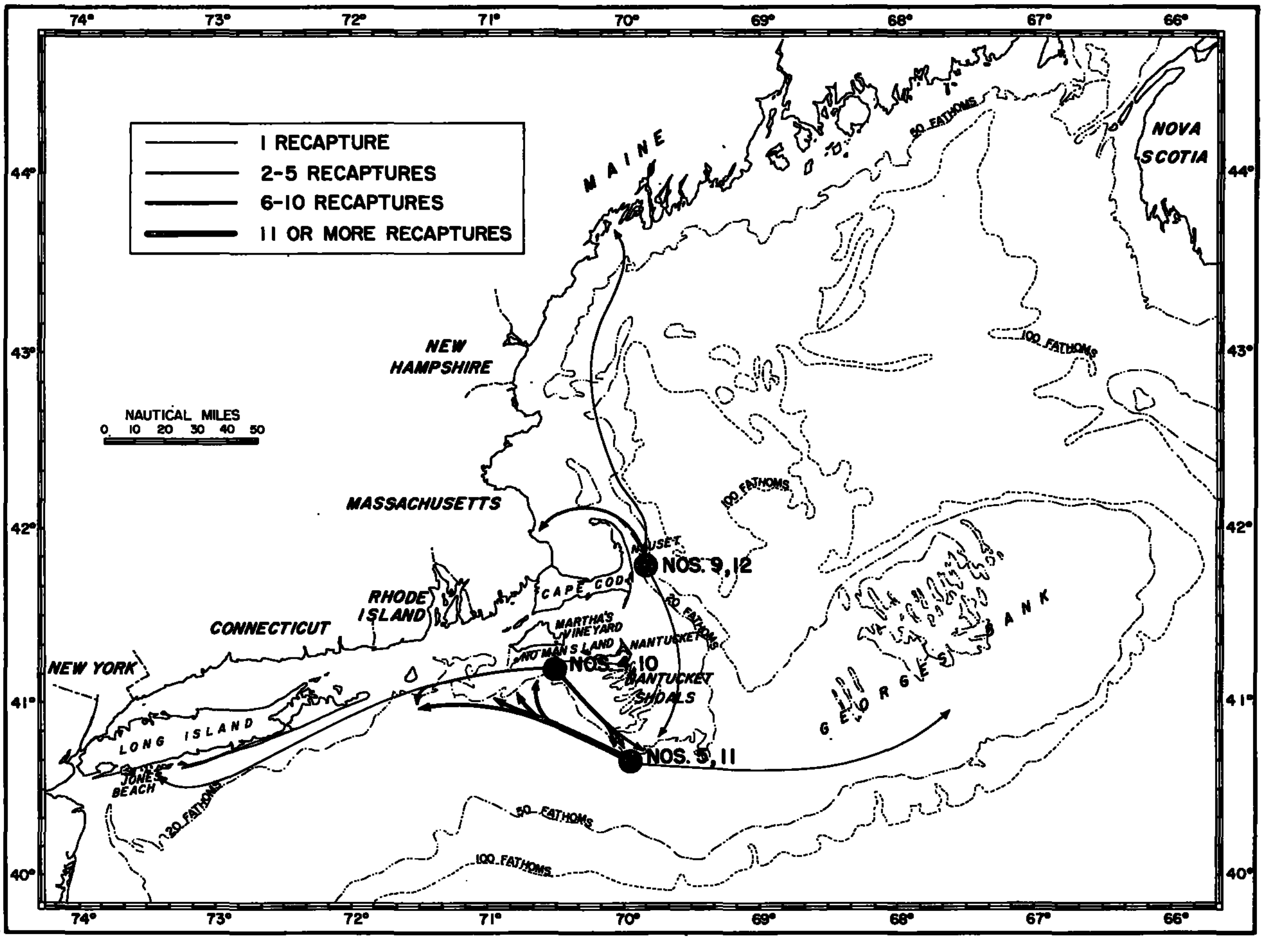

FIGURE 5.—Distant recaptures of yellowtail flounder released off No Mans Land (Nos. 4 and 10), Nantucket Shoals (Nos. 5 and 11) and off Nauset Beach (Nos. 9 and 12).

were winter returns from summer releases, and Clyde C. Taylor has suggested that they indicate a seasonal migration from Georges Bank to the southern New England grounds in the winter time. There was also one winter return from southwestern Georges Bank. It would be consistent with the returns from this one experiment to postulate a summer population on Georges Bank which moves westward to the southern New England grounds in the winter. Such an east-west migration would be similar to the seasonal movements already noted for the releases south of Long Island. It appears unlikely that such a seasonal migration involved many fish during the peak years of the fishery, because only minor quantities of yellowtail were taken on Georges Bank by the extensive otter-trawl fisheries prior to 1947.

These recaptures do indicate only a small amount of intermingling among the populations on the major fishing grounds. The Nantucket Shoals, which are shallower than the preferred depth of the yellowtail flounder, apparently limit migration across them. Considering only the tagged yellowtail released in adjacent areas, we noted that none of the 54 fish recaptured from the 514 released in subarea O were found across Nantucket Shoals, and only 1 of the 15 recaptures from the 408 fish tagged off the east side of Cape Cod was found south across the Shoals. South Channel appears to be somewhat less of a deterrent to movement because 1 fish tagged in subarea O west of the Channel was found east of it and 3 of 12 recaptures from the 51 tagged in subarea N just east of the Channel were found west of it.

In general, then, the yellowtail are to be found in relatively localized populations, which may make short, seasonal migrations. Our most distant recapture was only 170 miles from the point of release, and the majority of the recaptures were within 50 miles of their points of release. In this respect, movement of the yellowtail is not quite as localized as that of the winter flounder (Perlmutter 1946), but certainly it ranges far less than do such species as the cod, striped bass, and mackerel.

YELLOWTAIL STOCKS

The tagging data when considered together with the concentrations of fishing effort provide the basis for delineating the stock of yellowtail. A stock is defined here as the population or populations of yellowtail which occur in a fishing concentration during a year. In the following paragraphs we delineate the stocks and discuss for the minor stocks the trends in production and problems of intermingling. The discussion of the southern New England stock will be the subject of most of the rest of this report.

1. *Southern New England Stock.*—This stock is found between Nantucket Shoals and Long Island, chiefly in water 15 to 35 fathoms in depth. It appears to be limited on the southwest by unsuitable temperature conditions and on the east by the less-favorable shoal waters of Nantucket Shoals and the deep waters of South Channel. The populations intermingle to a large extent, but are not entirely homogeneous. The area is close enough to the scattered small fishing ports to enable the small trawlers to fish any concentration that they may find.

2. *Georges Bank Stock.*—This stock tends to be restricted to Georges Bank by the less-favored deep waters around the Bank. This area is accessible to medium and large trawlers, which fish the entire Bank except for a few small areas where the bottom is too rough. For many years the Georges Bank catch of yellowtail flounders was taken either in the winter in the Cultivator Shoals area by vessels seeking yellowtail or incidentally throughout the year on the rest of the Bank by vessels seeking other species of fish. Beginning in 1947, increasing quantities of yellowtail were found on southwestern Georges Bank, and in 1948 and 1949 much larger quantities were obtained on southeastern and southwestern Georges Bank (tables 3 and 6).

TABLE 6.—*Annual United States landings of yellowtail by stocks, 1942–49*

[In thousands of pounds]

Year	Southern New England	Georges Bank	Cape Cod	Northern Gulf of Maine	Nova Scotian Banks	Total[1]
1942	62,797	2,385	3,330	26	40	68,578
1943	39,777	2,784	2,831	74	321	45,787
1944	23,406	3,670	3,335	68	608	31,087
1945	22,861	2,989	2,554	30	4,734	33,169
1946	23,867	1,913	2,774	30	2,737	31,321
1947	26,706	4,976	2,387	49	1,636	35,754
1948	21,872	12,472	1,464	23	3,137	38,968
1949	10,305	16,097	2,711	46	651	29,810

[1] Slight discrepancies occur due to rounding off of the figures.

Naturally, with a catch increasing so phenomenally, the question arises as to whether it increased because the fish became more abundant in the area or because they had not been previously found. Distribution of the other trawl fisheries on Georges Bank appears to answer the question. The principal fishery here is for haddock, and according to Schuck (1951) the southeastern part of Georges Bank produced 24.4 percent of all the Georges Bank landings of haddock from 1936 to 1948, while the southwestern part produced but 6.8 percent. The haddock fishery is concentrated in somewhat deeper water than the yellowtail flounder prefers, but nevertheless enough haddock fishing occurs in almost all trawlable areas on Georges Bank that any important concentrations of yellowtail almost certainly would have been discovered. This view is further strengthened by Schuck's observation that the southwestern part of Georges Bank produced 14.7 percent of the haddock in 1944 and 18.9 percent in 1945. From the same investigator we learn that fishing effort on the southwestern part of Georges Bank fell off to 7 percent in 1946, 6.2 percent in 1947, and 4.9 percent in 1948. As the yellowtail catches did not increase until 1947, 1948, and 1949 (table 3), the increased yellowtail catches did not coincide with increased trawling for haddock, but followed it about 2 years later. Clearly the yellowtail became more abundant in the area after the haddock declined.

Since the increase in catches of yellowtail on Georges Bank coincided with a decrease in catches from the southern New England stock west of Nantucket Shoals and the tagging results show that migration may occur across the South Channel, part of the southern New England stock of yellowtail may have moved to Georges Bank. The proportion is probably small, however, because 386 yellowtail were tagged in subareas Q and O to the west of Nantucket Shoals in 1946, the year before the big increase in catch, and only 1 of the 60 fish recaptured was taken on Georges Bank. However, the winter population in Q and O may have moved to Georges Bank to be caught mostly in the summer. (See p. 182).

3. *Cape Cod Stock.*—It occurs east and north of Cape Cod, in Cape Cod Bay, and north to the vicinity of Cape Ann and Ipswich Bay. It is limited in all directions by deep water, although to the south and north there are narrow strips of water of the preferred depth. Production from this stock has been comparatively stable. It rose to a moderate peak in 1944 of about 3⅓ million pounds, declined to about 1½ million pounds in 1948, and rose again to about 2¾ million pounds in 1949. In this area, the yellowtail is a species of minor importance sought only at certain seasons by vessels out of New Bedford, Plymouth, Boston, Provincetown, and Gloucester, Mass. It is heavily fished when available, but changes in catch may be related to changes in effort because other species are sought at times in preference to it.

4. *Northern Gulf of Maine Stock.*—This stock contributes the very few yellowtail that are taken on the scattered shoal areas of the northern gulf along the coast of Maine. This extremely small catch is taken by otter trawlers and line trawlers incidentally to other species. No significance can be attached to the small fluctuations in catch, which may be caused by changes in fishing as well as by changes in the stock.

5. *Nova Scotian Stock.*—It is completely distinct from the New England stocks. Moreover, it is of slight importance to New England fishermen. United States vessels have rarely gone to the Nova Scotian Banks especially to catch yellowtail, and therefore the catch is related to the fishing for other species. The great increase in the take of yellowtail from a low of 40,000 pounds in 1942 to a high of 4,700,000 pounds in 1945 appears to have been caused by the removal of wartime restrictions. The subsequent reduction in yellowtail catches coincided with the declining market for cod in the later years, because the large catches of yellowtail were produced by vessels fishing primarily for cod.

The United States landings from these five stocks are shown in table 6.

THE SOUTHERN NEW ENGLAND STOCK

LANDINGS

The total landings from the southern New England stock are readily computed from table 3 by combining the landings from the statistical areas designated as Nantucket Shoals and Lightship Grounds, off No Mans Land, southern Massachusetts, Rhode Island shore, and Long Island. These have been combined in table 7 to show the landings, by month and quarter, for the years 1942 to 1949. The annual totals for 1940 and 1941 are also included.

TABLE 7.—*Landings of yellowtail from southern New England stock, by month and quarter, 1940–49*

[In thousands of pounds]

Month and quarter	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	Average 1942–49
January			4,881	4,905	3,701	1,323	2,123	2,641	2,009	1,162	2,843
February			3,719	3,855	3,730	1,573	1,144	737	1,260	1,402	2,178
March			6,756	4,929	3,516	3,401	3,299	2,037	1,704	884	3,316
1st quarter			**15,356**	**13,689**	**10,947**	**6,297**	**6,566**	**5,415**	**4,973**	**3,448**	**8,336**
April			5,610	2,993	2,518	652	583	1,401	1,274	406	1,930
May			2,847	1,629	1,142	454	511	1,058	1,026	216	1,110
June			4,598	2,232	977	381	1,538	1,706	1,749	424	1,701
2d quarter			**13,055**	**6,854**	**4,637**	**1,487**	**2,632**	**4,165**	**4,049**	**1,046**	**4,741**
July			5,982	3,538	2,641	1,827	2,162	2,903	3,262	477	2,849
August			7,403	5,770	2,914	2,386	1,509	1,750	1,258	527	2,940
September			5,389	4,979	151	2,560	1,696	2,662	1,677	956	2,509
3d quarter			**18,774**	**14,287**	**5,706**	**6,773**	**5,367**	**7,315**	**6,197**	**1,960**	**8,297**
October			7,886	2,166	647	3,221	3,286	3,961	1,808	519	2,937
November			4,308	1,920	829	4,073	2,765	2,645	3,025	1,325	2,611
December			3,418	861	640	1,010	3,251	3,205	1,820	2,007	2,026
4th quarter			**15,612**	**4,947**	**2,116**	**8,304**	**9,302**	**9,811**	**6,653**	**3,851**	**7,574**
Grand total[1]	36,924	47,933	62,797	39,777	23,406	22,861	23,867	26,706	21,872	10,305	28,949

[1] Slight discrepancies occur due to rounding off of the figures.

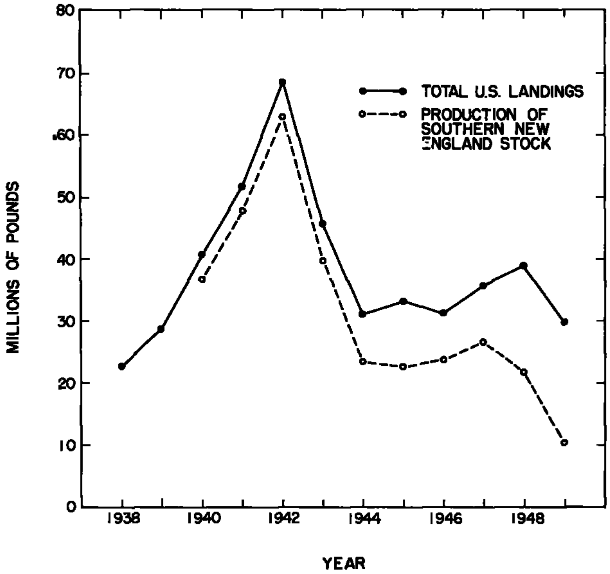

FIGURE 6.—Production of yellowtail, 1938 through 1949.

Four distinct periods in the southern New England fishery may be recognized from these data (fig. 6). First there was the increasing production to a peak of 63 million pounds in 1942, then an abrupt decline to 23 million pounds in 1944, fairly steady production from 1944 to 1947, and another abrupt decline from 27 million pounds in 1947 to 10 million pounds in 1949.[2] Since this stock has contributed the bulk of the United States yellowtail production for many years, fluctuation in its numbers is the principal cause for concern for the species.

A seasonal trend is apparent in the average catch per month (table 7). There were distinctly lower catches from April through June which, as will be shown later, are the months of the spawning season. The small variations in the average catch during the other months probably have no biological significance, being due to the seasonal weather pattern or to shifts of the fishermen to other species.

Turning from the average catch to the catches of the individual years, it is apparent that the seasonal changes in the landings have been variable. During the peak years of 1942 and 1943, there were large summer and winter fisheries with lower catches made in May and December. In 1944, the summer fishery lasted only a short time and the fall fishery was practically a failure. In 1946 and 1947, the summer landings were lower than those of the period October to December. Finally, in 1949 when a new low in the catch was reached, the landings were extremely small during all the summer months.

LENGTH COMPOSITION OF THE CATCH

Data on lengths of yellowtail in the landings were collected routinely at New Bedford from October 1942 through 1947. In addition to these routine measurements, a few were obtained irregularly at other ports. Also, some measurements were made occasionally during 1941 and the first 9 months of 1942. The total number of measurements available are listed in table 8, and detailed length frequencies are given in appendix tables C-14 and C-15, pages 244 and 245.

TABLE 8.—*Numbers of yellowtail measured from southern New England stock, by statistical area, 1941–47*

[See fig. 1 for chart of statistical areas]

Year and quarter	Statistical area—				Total
	New England Banks			South-western Long Island	
	O	Q-R	S		
Year 1941:					
1st quarter	-	-	-	-	-
2d quarter	-	77	-	-	77
3d quarter	-	-	-	-	-
4th quarter	-	317	-	-	317
Year 1942:					
1st quarter	-	-	504	240	744
2d quarter	-	161	684	-	845
3d quarter	-	-	-	-	-
4th quarter	455	805	-	-	1,260
Year 1943:					
1st quarter	1,221	959	-	-	2,180
2d quarter	-	1,449	137	-	1,586
3d quarter	1,024	1,751	-	-	2,775
4th quarter	-	609	-	-	609
Year 1944:					
1st quarter	172	1,354	459	-	1,985
2d quarter	-	454	-	-	454
3d quarter	207	413	-	-	620
4th quarter	513	403	100	228	1,244
Year 1945:					
1st quarter	1,481	2,098	201	-	3,780
2d quarter	-	-	402	-	402
3d quarter	701	2,223	-	-	2,924
4th quarter	1,417	1,280	202	-	2,899
Year 1946:					
1st quarter	1,202	1,351	-	-	2,553
2d quarter	-	100	-	-	100
3d quarter	1,304	805	-	-	2,109
4th quarter	2,873	1,404	-	-	4,277
Year 1947:					
1st quarter	-	1,005	187	-	1,192
2d quarter	-	803	803	100	1,706
3d quarter	1,402	367	202	-	1,971
4th quarter	301	1,008	400	-	1,709
Total	14,273	21,196	4,281	568	40,318

The routine measurements were obtained with the primary objective of having them representative of the landings. To ensure that the area of

[2] This decline continued to 7.2 million pounds in 1950 then leveled off at 4.0 in 1951, 4.8 in 1952, and about 4.5 million pounds in 1953. Total landings in United States ports declined to 23.5 million pounds in 1950, 18.4 in 1951, 16.3 in 1952, and about 13.5 in 1953.

origin was known, only the catches from vessels that fished a single area were sampled. A sample of about 100 fish was selected for measuring in as nearly random a manner as working conditions would permit. The standard practice at the port of New Bedford was to pack the fish in 125-pound boxes as they were being unloaded. The boxes were accessible to the measurers before being iced and closed, and it was convenient to measure 20 or 25 fish from each box. A sample of 100 fish was obtained from 4 or 5 boxes taken one at a time from the unloading line as needed. Usually from 1,000 to 2,000 pounds of fish were unloaded between the boxes sampled. The fish were taken from one end of each box from the top to the bottom, with a special effort to avoid any selection. In view of the difficulties of obtaining an accurately representative sample (Hayne 1951), a slight bias may have favored the large fish; but the same technique was followed throughout the investigations, and the bias, if any, should not affect the interpretation of trends in fish lengths.

Measurements were of the total length of the fish—from the tip of the lower jaw (with the mouth closed) to the end of the caudal fin. Almost all measurements were recorded on a measuring board slotted to receive an aluminum strip. The measurement was taken by pricking a hole in the strip, which was marked off in two parts to keep separate the records of the lengths of males and females. This method of measuring is very satisfactory, provides a rapid field method suitable for use when fingers are too wet or too cold to write, and is free of "digit bias," which has troubled other investigators who have measured large numbers of fish (Sette 1941). Later in the laboratory, the lengths were tallied to the half centimeter by superimposing a graduated celluloid strip over the marked aluminum strip.

It became apparent quite early in the study that the sexes differed in size composition, and commencing in October 1942 most measurements were kept separate by sex although the total sample was obtained in as random a manner as possible so that the number of each sex measured would be representative of its numbers in the landings. After opening a few fish to determine the condition of the sex organs, it was discovered that the yellowtail could be sexed easily and accurately by holding the white side to the light and looking through the fish. In this way, the outline of the ovary extending posteriorly from the mass of viscera can readily be seen even in immature females.

The program of sampling was planned to obtain a sample from nearly every vessel landing that had fished but a single area. It was expected that this would supply representative samples of the entire landings, but pressure of other duties and changes in field personnel made it impossible to maintain the program at the same level at all times. Some gaps also occurred because of the fishermen's habit of working in two or more areas when fish are scarce. This was particularly true in the yellowtail fishery, and many months when the landings from an area were low it was not possible to obtain a sample because the few landings made were always mixtures of fish from several areas. This tendency led to some undersampling of areas poorly represented in the landings at New Bedford. Furthermore, the catches from the Block Island and Long Island areas, which are fished mostly by Rhode Island and New York fishermen, were landed to a large extent in ports not covered by our sampling.

To obtain the best representation of the length composition of the yellowtail for the period October 1942 through December 1947, it would be best to weight the length frequencies by the quantities landed. This would be difficult, however, because of lack of data in numerous quarters and from some statistical areas (table 8). Therefore, we have tested the representativeness of our unweighted data in two ways: First, by comparing the distribution of measurements with the distribution of catch according to area and time, and second, by computing the effect of the maldistribution of the catch on the average length.

A comparison of the distribution of measurements with the distribution of catch shows that the discrepancies were not serious. When considered according to area, it is apparent that the areas off No Mans Land and Nantucket Shoals, which provided the bulk of the catch, were somewhat oversampled and the areas off Block Island and Long Island were somewhat undersampled (table 9). The distribution according to years showed similar discrepancies, with 1943, 1944, and 1947 being undersampled and 1945 and 1946 being oversampled. However, the distribution according to the calendar quarter shows excellent agreement, with the maximum discrepancy between measurements and landings being only 2.3 percent. The effect of these maldistributions on the average is very slight. The average size of the yellowtail measured from 1943 through 1947 was 35.87 cm. If the average lengths by area are computed separately and weighted according to the quantity landed from each area, the overall average is decreased only 0.18 cm. Similarly, if we separate the measurements according to the year and weight them according to quantities landed, the overall average is increased by only 0.14 cm. Finally, computations according to quarter show even less change, 0.03 cm. Because of these very small differences, we present the average length compositions in the ensuing pages on the basis of the actual number measured, and we consider them representative.

TABLE 9.—*Quantities of yellowtail landed and numbers measured, by area, quarter, and year, 1943–47*

	Fish landed		Fish measured	
	Thousand of pounds [1]	Percent	Number	Percent
Area:				
Subarea O	39,672	29.0	13,818	37.3
Subareas Q–R	63,011	46.1	19,836	53.5
Subarea S	24,110	17.6	3,093	8.3
XXIII	9,825	7.2	328	.9
Total [1]	136,618	99.9	37,075	100.0
Quarter:				
1st	42,914	28.2	11,690	30.5
2d	19,775	13.0	4,248	11.1
3d	39,448	25.9	10,399	27.1
4th [2]	50,092	32.9	11,998	31.3
Total [2]	152,229	100.0	38,335	100.0
Year:				
1943	39,777	29.1	7,150	19.3
1944	23,406	17.1	4,303	11.6
1945	22,861	16.7	10,005	27.0
1946	23,867	17.5	9,039	24.4
1947	26,706	19.5	6,578	17.7
Total	136,617	99.9	37,075	100.0

[1] Slight discrepancies occur because of rounding off of the figures.
[2] Includes data from 4th quarter in 1942.

The samples obtained during 1941 and 1942 were less representative than later samples; they were taken as opportunity afforded and sex data are lacking. No attempt was made to sample more heavily during the seasons with heavy landings, and the third quarter of 1942, with the heaviest landings in the history of the yellowtail fishery, was not sampled at all. Thus, these length compositions are not fully representative and reservations will be made in using them.

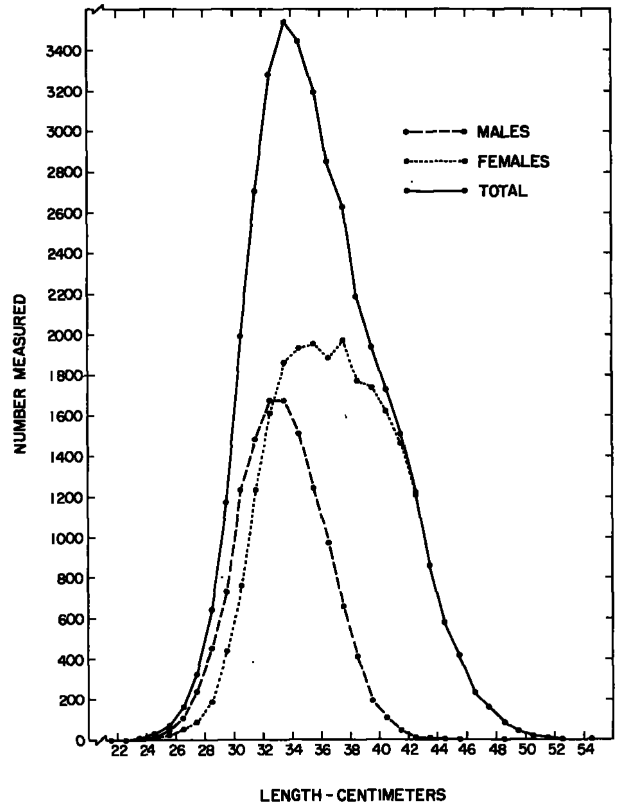

FIGURE 7.—Length composition, by sex, of the yellowtail from the southern New England stock, 1943 through 1947.

The predominance of the females in the landings from 1943 through 1947 with respect to both numbers and length is shown in table 10 and figure 7. The females accounted for 65.33 percent of the total number in the samples. The grand average length of the sexes combined was 35.87 cm.; the females averaged 37.21 cm., whereas the males averaged only 33.34 cm. It will be shown that this difference in size is caused by a difference between the sexes in rate of growth, which apparently also results in the preponderance in numbers of females in the catch. In table 10 it may be seen that above 33 cm. the females were more numerous in the landings; under 33 cm. the males were more numerous. It may be judged also from the curves in figure 7 that the fishery is fully utilizing only male yellowtail more than 33 cm. or females more than about 40 cm. in length, if we assume that this species decreases normally in numbers as it increases in size. However, if the total curve is considered, it may be judged that both sexes are fully available when more than

33 cm. long. Since the fishery did catch more males in the smaller sizes and was obviously not catching them with full effectiveness, we see no reason to suspect that the sex ratio of the unfished population is other than equal. The unequal representation in the catch may be due entirely to gear selectivity and the unequal rate of growth of the sexes.

TABLE 10.—*Length composition of yellowtail landed from the southern New England stock, by sex, 1943–47*

Total length	Number measured		
	Male	Female	Total
21.5 cm	1		1
22.5 cm	2	1	3
23.5 cm	5	5	10
24.5 cm	17	10	27
25.5 cm	44	21	65
26.5 cm	116	49	165
27.5 cm	237	84	321
28.5 cm	460	193	653
29.5 cm	729	440	1, 169
30.5 cm	1, 227	762	1, 989
31.5 cm	1, 478	1, 232	2, 710
32.5 cm	1, 673	1, 610	3, 283
33.5 cm	1, 674	1, 865	3, 539
34.5 cm	1, 517	1, 935	3, 452
35.5 cm	1, 246	1, 951	3, 197
36.5 cm	972	1, 886	2, 858
37.5 cm	660	1, 973	2, 633
38.5 cm	413	1, 774	2, 187
39.5 cm	195	1, 740	1, 935
40.5 cm	111	1, 622	1, 733
41.5 cm	44	1, 466	1, 510
42.5 cm	16	1, 209	1, 225
43.5 cm	14	861	875
44.5 cm	2	579	581
45.5 cm	1	415	416
46.5 cm		228	228
47.5 cm		163	163
48.5 cm	1	79	80
49.5 cm		40	40
50.5 cm		16	16
51.5 cm		8	8
52.5 cm		2	2
54.5 cm		1	1
Total	12, 855	24, 220	37, 075
Mean length (cm.)	33. 34	37. 21	35. 87

The average size composition during each quarter of the year (table 11, fig. 8) showed a definite seasonal change, which is in accord with the changes expected in most species of fish. The average length was greatest in the first quarter, January to March (37.40 cm.), least in the third quarter, July to September (34.37 cm.), and intermediate in the second and fourth quarters. The curves, when plotted on a percentage basis to facilitate comparison, show little change in shape. The changes appear to arise from the entrance into the fishery of young fish during the spring and summer and their subsequent growth and mortality during the winter. There is also a possibility that some of the differences arose from heterogeneity of the population, since tagging experiments indicated some segregation of

TABLE 11.—*Percent length composition, by quarter, of yellowtail landed from the southern New England stock, fourth quarter, 1942 through 1947*

Total length	1st quarter	2d quarter	3d quarter	4th quarter
21.5 cm	0. 01			0. 02
22.5 cm		0. 02	0. 01	. 12
23.5 cm	. 02	. 02	. 03	. 21
24.5 cm	. 07	. 12	. 02	. 45
25.5 cm	. 31	. 28	. 07	. 51
26.5 cm	. 68	. 99	. 30	. 38
27.5 cm	. 75	1. 58	1. 32	. 44
28.5 cm	. 97	2. 19	3. 53	. 90
29.5 cm	1. 10	3. 22	6. 14	2. 62
30.5 cm	2. 30	5. 37	8. 64	5. 63
31.5 cm	4. 32	8. 05	9. 64	7. 94
32.5 cm	5. 94	10. 66	10. 37	9. 78
33.5 cm	7. 82	11. 91	10. 11	9. 68
34.5 cm	8. 39	9. 86	9. 46	9. 68
35.5 cm	8. 54	8. 94	8. 74	8. 35
36.5 cm	8. 23	7. 27	7. 27	7. 68
37.5 cm	7. 98	5. 70	6. 65	7. 09
38.5 cm	7. 42	4. 38	4. 89	5. 72
39.5 cm	6. 06	4. 33	4. 30	5. 37
40.5 cm	6. 07	4. 07	3. 20	4. 62
41.5 cm	5. 24	3. 70	2. 36	4. 38
42.5 cm	5. 18	2. 99	1. 52	3. 05
43.5 cm	4. 13	1. 88	. 81	2. 01
44.5 cm	2. 88	1. 11	. 35	1. 44
45.5 cm	2. 29	. 73	. 17	. 87
46.5 cm	1. 34	. 31	. 06	. 48
47.5 cm	1. 04	. 14	. 03	. 28
48.5 cm	. 50	. 07	. 02	. 15
49.5 cm	. 21	. 02		. 12
50.5 cm	. 10	. 05		. 02
51.5 cm	. 06	. 02		
52.5 cm	. 02			
54.5 cm				. 01
Total	99. 97	99. 98	100. 01	100. 00
Mean length (cm.)	37. 40	35. 17	34. 37	35. 70

the southern New England stock during the winter (p. 180). However, there is no way to distinguish the two sources of variation with these data.

Segregating the length data according to statistical area for 1943 through 1947 (table 12, fig. 9) reveals a small geographical gradient in length, with the largest yellowtail coming from the more easterly area. The yellowtail from the Nantucket Shoals area averaged 36.35 cm., from off No Mans Land 35.66 cm., from off Block Island 35.23 cm., and from off Long Island 34.27 cm. These figures show statistically what is common knowledge among the fishermen, but since the figures are associated with the seasons there is no certainty that the differences are due entirely to geography. Table 3, which shows the catch by statistical subarea, indicates that the landings from the Nantucket Shoals area (O) were usually the heaviest when those from off No Mans Land (Q) were light, and vice versa. The landings from the westward, off Rhode Island (S) and Long Island (XXIII) run smaller regardless of season, but there was no clear-cut seasonal pattern in the size changes. It should be noted that in areas from Block Island to Nan-

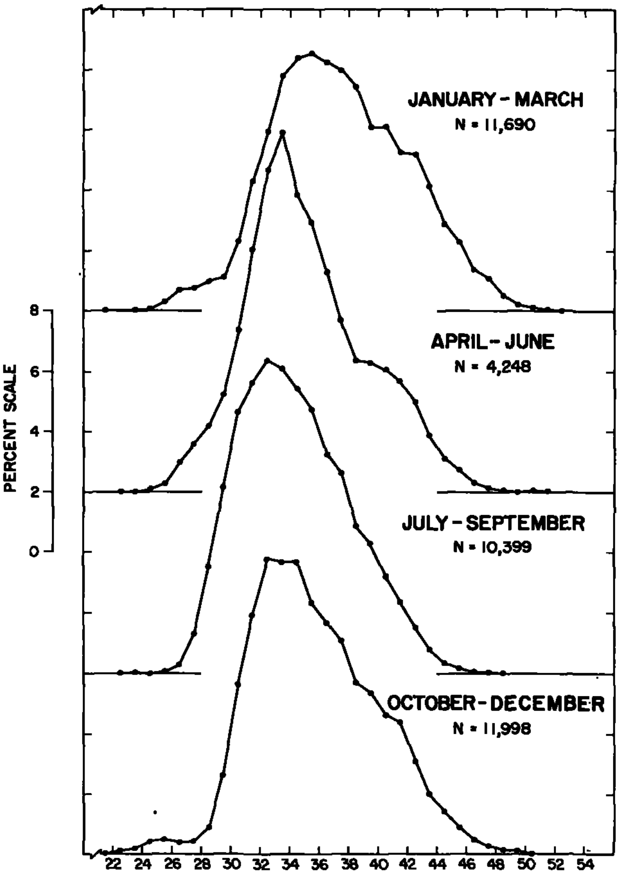

FIGURE 8.—Percent length composition, by quarter, of yellowtail from the southern New England stock, fourth quarter 1942 through 1947. (N=number of fish.)

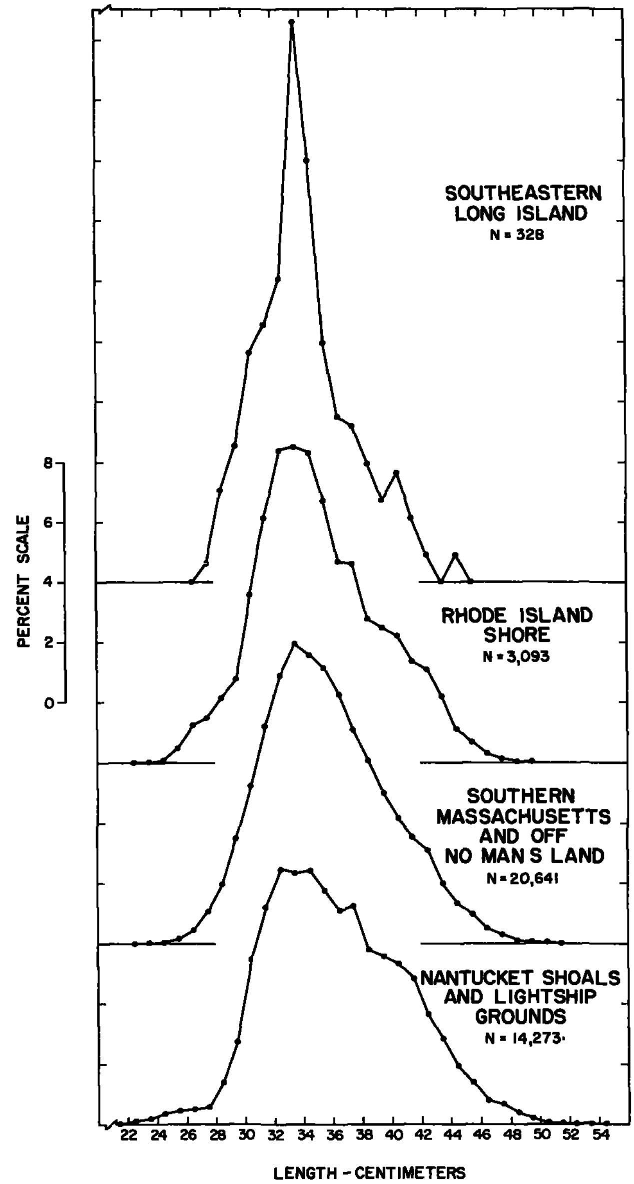

FIGURE 9.—Percent length composition, by statistical area, of yellowtail from the southern New England stock, 1943 through 1947. (N=number of fish.)

tucket Shoals for which we have adequate samples, the difference in average size (1.12 cm. maximum) was markedly less than the difference among seasons (3.02 cm. maximum).

The length compositions from 1941 to 1947 are particularly interesting (table 13; fig. 10) because they cover a period that includes the peak catch of 63 million pounds in 1942 and much of the subsequent decline. Only slight changes in the average length occurred during the period 1941–47, and there was no trend toward smaller fish in the catches, as might be expected.[3]

The yellowtail were smallest in 1942 (34.22 cm.) and largest in 1945 (36.37 cm.). Even this small difference (2.22 cm.) probably was largely the result of a change in the habits of the fishermen. The length-composition curve for 1942 (and to a lesser degree for 1941) differs appreciably from the curves for later years by including a mode of smaller fish. Very probably this mode occurred because of failure of the fishermen to cull their catches at sea. At this time the filleting industry in New Bedford was just becoming established and there were no general agreements regarding the size of fish acceptable to the trade. The fish-

[3] Such a trend apparently did develop according to reports after 1951, when the very small annual catches were largely comprised of "peewee" yellowtail.

TABLE 12.—*Percent length composition, by statistical area, of yellowtail landed from the southern New England stock, 1943–47*

[See fig. 1 for chart of statistical areas]

Total length	Subarea O	Subareas Q-R	Subarea S	Area XXIII
21.5 cm	0.01			
22.5 cm	.01	0.01	0.03	
23.5 cm	.03	.03		
24.5 cm	.09	.06	.10	
25.5 cm	.10	.18	.48	
26.5 cm	.26	.46	1.23	
27.5 cm	.45	1.06	1.52	0.61
28.5 cm	1.28	2.01	2.17	3.05
29.5 cm	2.69	3.51	2.78	4.57
30.5 cm	5.61	5.12	5.59	7.62
31.5 cm	7.30	7.16	8.15	8.54
32.5 cm	8.58	8.79	10.38	10.06
33.5 cm	8.49	9.98	10.54	18.60
34.5 cm	8.55	9.60	10.35	14.03
35.5 cm	7.86	9.15	8.73	7.93
36.5 cm	7.20	8.25	6.69	5.49
37.5 cm	7.32	7.06	6.60	5.18
38.5 cm	5.86	6.13	4.78	3.96
39.5 cm	5.70	5.04	4.49	2.74
40.5 cm	5.43	4.23	4.24	3.66
41.5 cm	4.94	3.60	3.39	2.13
42.5 cm	3.69	3.11	3.10	.91
43.5 cm	2.94	2.02	2.20	
44.5 cm	1.99	1.35	1.13	.91
45.5 cm	1.43	.99	.71	
46.5 cm	.80	.54	.32	
47.5 cm	.68	.32	.16	
48.5 cm	.40	.12	.06	
49.5 cm	.18	.07	.06	
50.5 cm	.06	.04		
51.5 cm	.04	.02		
52.5 cm	.01			
54.5 cm	.01			
Total	99.99	100.01	99.98	99.99
Mean length (cm.)	36.35	35.66	35.23	34.27

TABLE 13.—*Percent length composition, by years, of yellowtail from the southern New England stock, 1941–47*

Length	1941	1942	1943	1944	1945	1946	1947
20.5 cm		0.04					
21.5 cm		.08				0.01	
22.5 cm		.65			0.01	.01	0.02
23.5 cm		.98	0.01	0.07	.04	.02	
24.5 cm	0.25	2.08	.04	.21	.10	.03	.03
25.5 cm		2.20	.12	.28	.19	.14	.18
26.5 cm	.25	1.80	.49	.37	.54	.29	.52
27.5 cm	1.52	1.96	.91	.86	.88	.67	1.06
28.5 cm	1.27	2.29	1.58	1.35	1.74	1.78	2.23
29.5 cm	.76	3.23	2.48	2.49	3.24	3.35	3.92
30.5 cm	7.87	5.84	4.01	5.18	4.60	6.53	6.52
31.5 cm	6.85	7.90	6.35	8.55	6.42	7.56	8.56
32.5 cm	6.34	10.25	8.78	9.32	7.28	9.38	10.31
33.5 cm	7.11	9.07	9.50	10.83	8.08	9.82	10.61
34.5 cm	8.63	9.48	8.88	9.83	8.36	9.87	10.11
35.5 cm	11.17	9.27	9.31	8.92	8.44	7.79	9.11
36.5 cm	10.66	7.56	8.24	7.64	8.02	7.30	7.25
37.5 cm	9.64	6.17	7.51	7.23	7.87	6.97	5.59
38.5 cm	5.58	4.90	6.76	5.30	6.61	5.72	4.53
39.5 cm	5.84	4.21	6.10	5.18	5.52	5.16	3.92
40.5 cm	5.84	3.47	4.91	3.72	5.21	4.82	4.03
41.5 cm	3.55	2.45	4.52	3.12	4.17	4.38	3.63
42.5 cm	3.55	1.84	3.10	3.21	3.83	3.08	3.10
43.5 cm	1.52	.98	2.60	1.88	2.91	2.08	1.96
44.5 cm	.51	.65	1.40	1.84	2.03	1.35	1.17
45.5 cm	.51	.23	1.02	1.14	1.69	.78	.82
46.5 cm	.76	.37	.54	.63	1.07	.40	.29
47.5 cm			.43	.44	.64	.34	.27
48.5 cm		.04	.17	.21	.36	.16	.12
49.5 cm			.14	.14	.08	.13	.06
50.5 cm			.04	.02	.07	.03	.03
51.5 cm			.03		.03	.01	.03
52.5 cm			.01			.01	
54.5 cm				.02			
Total	99.98	99.99	99.98	99.98	100.03	99.97	99.98
Mean length (cm.)	35.86	34.15	36.12	35.69	36.37	35.67	35.22

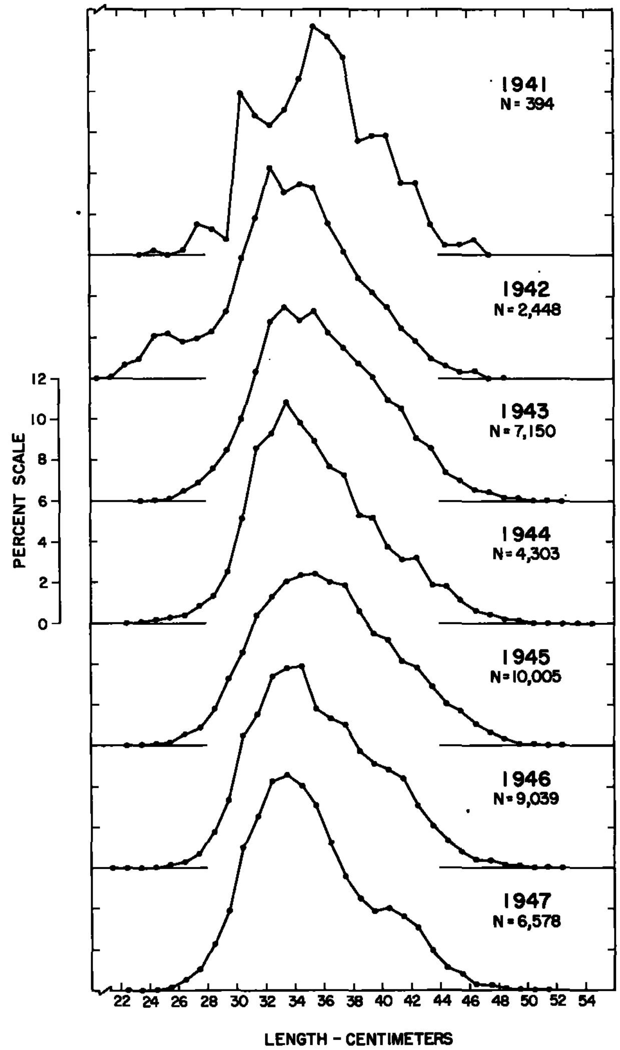

FIGURE 10.—Percent length composition, by year, of yellowtail from the southern New England stock, 1941–47. (N=number of fish.)

ermen were catching yellowtail in great quantities accompanied by few other fish, and in such situations there is an understandable tendency to ice down the entire catch and neglect the few fish that might otherwise be culled. Furthermore, these small fish were mostly from the 1941 year class, which we later found was the largest year class to occur during the period included in our study.

Another explanation of the smaller average size in 1942 might be less-representative sampling. We have previously pointed out that routine sampling began in October 1942 and, of course, a preponderance of measurements were obtained during the fall season; however, the size composition by quarters indicates that the size during the fourth quarter of the year is almost exactly the same as the average for the year. Therefore, if 1942 were an average year, insofar as the size of the yellowtail is concerned, we would expect our average (mostly during the fourth quarter) to be fairly representative of the entire year.

This lack of a decrease in the average size during a period of heavy fishing is particularly significant because it is not in agreement with theory or with actual events in closely comparable fisheries. The theory of the effect of fishing developed by Baranoff (1918) and expounded by Thompson (1937) indicates that a marked decrease in the proportion of older and larger fish is to be expected when fishing mortality increases. The development of Baranoff's theory was stimulated by observations on the plaice, which was being heavily fished in the North Sea. Russell (1942, p. 77) reported that in 1907 the relatively unfished plaice population in the Barents Sea was almost entirely mature and averaged about 48 cm. in length. At the same time in the North Sea the marketable plaice population was more than one-half immature and averaged less than 40 cm. in length even though their size at maturity was about the same as that of the Barents Sea plaice (39–40 cm.).

The European plaice and the yellowtail which it closely resembles belong to the same family, the Pleuronectidae. The plaice attains almost the same maximum size as the yellowtail, although it grows a little more slowly. The plaice appears in maximum numbers in the catch at age 4 and individuals as old as ages 10 and 11 are fairly common, whereas the yellowtail is taken in maximum numbers at age 3 (p. 209), and few individuals older than age 7 are found. Both species are subject to otter-trawl fisheries, though the North Sea plaice has been subject to a heavy fishery for 70 years or more, whereas the American yellowtail has been especially sought only since about 1938.

Despite the difference in the length of time the plaice and the yellowtail fisheries have been in operation, a nearly parallel situation is to be found in a comparison of the peak and decline of the yellowtail fishery with the peak and decline of the plaice fishery immediately after World War I. That war caused almost a complete cessation of fishing in the North Sea for about 4 years and permitted the stocks of fish to accumulate far above their prewar levels. Thursby-Pelham (1939, p. 53) has shown that the proportion of large plaice in the landings began to decline about 2 years after fishing was resumed, and reached a minimum in about 7 years.

That reduction in size of the fish did not occur in the yellowtail fishery as a result of fishing is shown in figure 11, where part of Thursby-Pelham's figure 6 has been reproduced for comparison of plaice length data with similar data from the yellowtail. We have arbitrarily established a large yellowtail category as including fish of more than 40 cm. total length and a small, as including fish of less than 30 cm. These categories differ somewhat from the large and small market categories of Thursby-Pelham, but each category forms a significant fraction of the landings. There obviously was no trend toward a decreasing proportion of large fish in the yellowtail fishery during the period of observation, 1941–49.

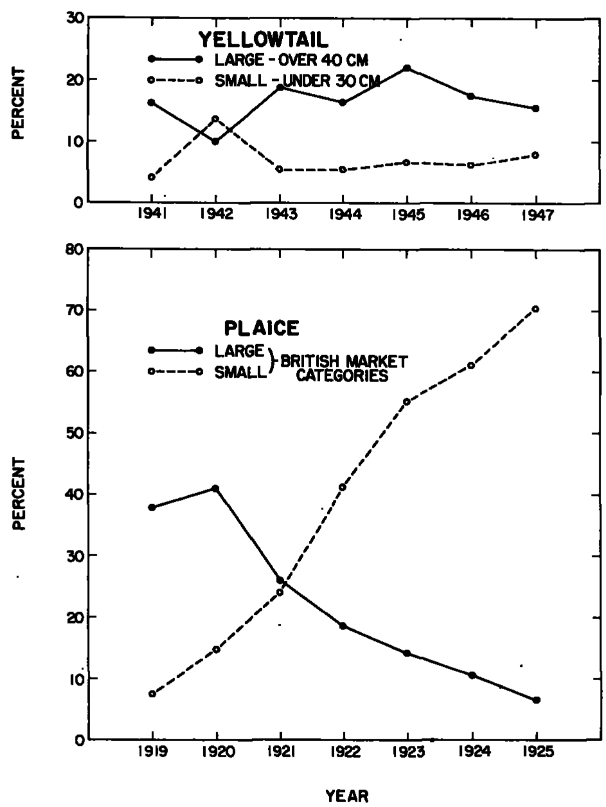

FIGURE 11.—Comparison of the trends in proportions of large and small yellowtail from the southern New England stock and of European plaice of the North Sea stock. The medium-size category has been omitted from both graphs.

This matter will be discussed further after data on abundance, age, and rate of growth have been presented.

LENGTH-WEIGHT RELATION

The regression of weight on length of the yellowtail flounder was determined (1) to provide data to convert the landings from pounds to numbers of fish, and (2) to provide data on fatness of the yellowtail which may furnish clues to changing ecological conditions. Information obtained during each quarter of 1943 provided a good basis for estimating weight from length during the several years of our study, assuming that the relation did not change from year to year. In addition, it provided a critical comparison of the differences in the length-weight relation between the sexes and among the seasons. The reduced statistical data are presented to permit further comparison with data which may be collected later.

Samples were obtained near the middle of each calendar quarter of 1943 (table 14). The fish to be weighed and measured were taken at random from the landings in the same manner as those measured for length (p. 186). Usually a sample of 50 fish was weighed and measured from a vessel that had fished in a single statistical subarea. No attempt was made to equalize the numbers of each sex.

TABLE 14.—*Numbers of yellowtail from the southern New England stock, by subarea and by sex, weighed and measured during 1943*

Date	Statistical subarea			Sex		Total
	O	Q	S	Male	Female	
Feb. 5		151				
Feb. 6	75	50		153	223	376
Feb. 19	50					
Feb. 27	50					
May 25		100				
May 31			50			
June 2		58		54	204	258
June 3	50					
Aug. 4		50				
Aug. 9		98				
Aug. 11		43		21	255	276
Aug. 12		47				
Aug. 16		38				
Nov. 8		49				
Nov. 12		50		62	141	203
Nov. 22		54				
Nov. 24		50				
Total	225	838	50	290	823	1,113

The lengths were obtained on a measuring board and the weights on balances provided with special scales graduated in 2-place logarithms to simplify the computation. The balances were of the spring type, one with a capacity of 5 pounds, the other of 1 pound. Since the weighing was done in the field it was necessary to set up the balances for each sample. Check weights were used prior to, midway through, and at the end of the weighing of a sample. The scales were adjusted at the beginning of the weighing and subsequent checks revealed no error of more than 1 percent in the weighing.

The regression of weight on length was computed with the assumption that the relation is of the form

$$W = aL^b.$$

Changing this to logarithms, of course, reduces it to

$$\text{Log } W = \text{Log } a + b \text{ Log } L,$$

which is a straight-line relation easy and convenient to compute by the standard method of minimizing the squared deviations. (The reduced logarithmic data from the observations are presented in table 15.) Plots of all the data in logarithms were made to test the assumption of linearity and as a final check on the computations. These plots showed no deviation from linearity, but they did identify two aberrant observations, which were located away from the regression line by several times the standard error of estimate. These two observations—one male and one female from the sample of August 9, 1943—were omitted from the analysis.

The several regression formulas (table 16) have been computed to permit estimating the weight from the length of the yellowtail for each sex in each quarter and for combinations of the sexes and quarters. When these formulas are used to estimate the weight of each sex at the mean length of 35.869 cm. (table 17), the females are consistently heavier than the males. The difference varies from 0.041 pound in the first quarter to 0.119 pound in the second quarter—amounts which are 4.5 percent and 14.4 percent of the average weight of the males. The greater difference (in the second quarter) reflects the greater weight of the females laden with ova. However, the samples were taken slightly after the middle of the spawning season when 67 percent of the mature females in the samples were spent (see Spawning Season, p. 216). Therefore, the differ-

TABLE 15.—*Reduced length-weight data for yellowtail from the southern New England stock, by quarters, 1943*

[n=number of specimens; Σ=summation; x=logarithm of length in decimeters; y=logarithm of weight in tenths of pounds]

Factors	1st quarter		2d quarter		3d quarter		4th quarter	
	Male	Female	Male	Female	Male	Female	Male	Female
n	153	223	54	204	21	255	62	141
Σx	82.78	103.63	27.90	110.15	10.66	137.53	32.50	81.31
$\Sigma(x-\bar{x})^2$	44.9604	77.0631	14.4832	59.7513	5.4468	74.7535	17.1322	47.1623
Σy	140.44	241.93	44.03	188.90	16.69	228.21	53.35	148.04
$\Sigma(y-\bar{y})^2$	130.9540	269.0343	36.4677	179.7234	13.5071	209.5729	46.7119	158.5402
$\Sigma(x-\bar{x})(y-\bar{y})$	76.5292	143.5529	22.9311	103.2014	8.5628	124.7938	28.2332	86.2542

TABLE 16.—*Length-weight regression formulas for yellowtail from the southern New England stock, by quarter and sex, 1943*

Quarter and sex	Number of specimens	Formula [1]
1st quarter:		
Male	153	$y=3.1558x-0.7895$
Female	223	$y=3.3838x-.8972$
Both sexes	376	$y=3\ 4102x-.9187$
2d quarter:		
Male	54	$y=2.6730x-.5657$
Female	204	$y=3.0348x-.7078$
Both sexes	258	$y=3.0567x-.7289$
3d quarter:		
Male	21	$y=2.5449x-.4971$
Female	255	$y=2.9577x-.7002$
Both sexes	276	$y=2.9409x-.6917$
4th quarter:		
Male	62	$y=2.7894x-.6017$
Female	141	$y=3.2340x-.8150$
Both sexes	203	$y=3.2377x\ \ .8229$
All quarters:		
Male	290	$y=3.0092x-.7188$
Female	823	$y=3.2353x-.8249$
Both sexes	1,113	$y=3.2310x-.8259$

[1] x=logarithm of length in decimeters; y=estimated logarithm of weight in tenths of pounds.

TABLE 17.—*Comparison of the weight of male and female yellowtail, by quarter, at the mean length of 35.869 cm.*

[In pounds]

Quarter	Male	Female	Difference	Ratio of difference to weight of males
				Percent
1st	0.914	0.955	0.041	4.5
2d	.826	.945	.119	14.4
3d	.822	.872	.050	6.1
4th	.882	.953	.071	8.0
Average	.892	.933	.041	4.6

ence between the sexes at the onset of spawning in early April is probably even greater.

The differences in the length-weight relation among quarters also are considerable. Yellowtails of the average length of both sexes are heaviest in the first quarter and lightest in the third. This is a little surprising since one would expect the females, at least, to be heaviest during the spawning season. However, as was previously mentioned, 67 percent of the females in the samples were spent, and even in this condition the average weight was only slightly less (0.010 pound) than that of the first quarter. Probably the females are their heaviest at the onset of spawning in early April.

Most of these differences are statistically significant. Covariance analysis (table 18), according to the method used by Kendall (1952, p. 239) indicates that the differences between the sexes are highly significant in each quarter except the third, which immediately follows the spawning season. It is not certain whether this lack of a significant difference is due to the small number of males (21) or to the fact that the females are recovering from spawning and have ovaries of minimal size. The differences among quarters for each sex also are highly significant.

Further consideration of the covariance analysis indicates that the slopes of the regression lines of the males, which are consistently lower than those of the females, are significantly so during the third and fourth quarters. Thus it appears that the males, in addition to being surpassed in numbers and dominated in length by the females (p. 188), become more slender compared with the females as they grow older.

These differences between the sexes and among the seasons indicate the necessity of classifying the data by sex and time of capture, if critical comparisons of condition are to be made and if the data are to be used for transforming the weight of yellowtail to numbers of fish. For the latter purpose we have segregated our data by quarters, but

TABLE 18.—*Summary of covariance analysis of length-weight data on yellowtail*

I. COMPARISON OF SEXES BY QUARTER

Source of variation	1st quarter			2d quarter			3d quarter			4th quarter		
	Degrees of freedom	Mean square	*F*	Degrees of freedom	Mean square	*F*	Degrees of freedom	Mean square	*F*	Degrees of freedom	Mean square	*F*
Deviations from individual sample regression	372	0.00184		254	0.00212		272	0.00105		199	0.00154	
Difference between regression coefficients	1	.0069	3.75	1	.0079	3.73	1	.0058	[1] 5.52	1	.0141	[2] 9.16
Difference between adjusted means	1	.0245	[2] 13.17	1	.0867	[2] 40.51	1	.0004	.38	1	.0225	[2] 13.98
Difference between samples	2	.0157	[2] 8.53	2	.0473	[2] 22.31	2	.0031	2.95	2	.0183	[2] 11.88

II. COMPARISON OF QUARTERS BY SEX

Source of variation	Male			Female		
	Degrees of freedom	Mean square	*F*	Degrees of freedom	Mean square	*F*
Deviations from individual sample regression	282	0.00168		815	0.00165	
Difference between regression coefficients	3	.0068	[1] 4.05	3	.0202	[2] 12.24
Difference between adjusted means	3	.0140	[2] 8.04	3	.0855	[2] 50.00
Difference between samples	6	.0104	[2] 6.19	6	.0528	[2] 32.00

[1] Expected less than once in 20 times by chance.
[2] Expected less than once in 100 times by chance.

since the length-weight data were from samples taken at random and include representative numbers of males and females we regard the total values for each quarter as representative and have not segregated the data by sex.[4]

The estimated weight at each length occurring in the landings has been obtained from the combined data for males and females in the preparation of table 19. This will be used in the next section to determine the number of fish landed. Figure 12 indicates the average length-weight relation. Meanwhile, it is interesting to note the range in weight of the yellowtail in the landings. When the central 98 percent was selected from the data on average length composition (table 10) to avoid the few very small or very large specimens, the "lower limit" of size was 27.3 cm. (0.38 lb.) and the "upper limit" was 46.7 cm. (2.17 lb.). The average length was 35.87 cm. (0.93 lb.). The smaller value reflects selection by the fishermen as influenced by buyers interested in filleting the fish. The buyers estimate that an average of 40 percent of the weight is recoverable as fillets. If this was true of the small fish,[5] the lower limit of desirable fillet weight would be about 0.076 pound, or just over 1 ounce. The average-size fillet weighed 0.186 pound, or about 3 ounces, and the maximum 0.434 pound, or about 7 ounces.

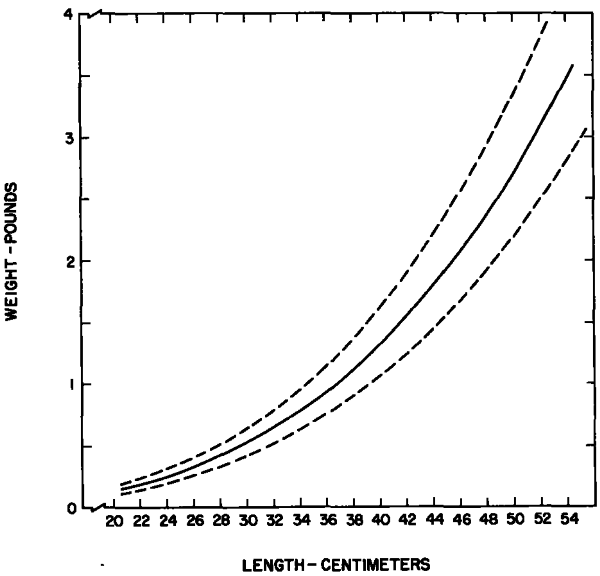

FIGURE 12.—Average length-weight relation of yellowtail landed from the southern New England stock during 1943. The dotted lines are plus and minus twice the standard error of estimate and enclose about 95 percent of the observations.

[4] We have estimated the discrepancy arising from varying proportions of the sexes by calculating the average weight of the yellowtail in the second quarter (when the greatest difference between the sexes occurs) for each sex by using the aggregate formula, and we found that the maximum difference between the sexes in average weight was 3.7 percent. Because of the small difference and the poor representation of males in the length-weight data for the second and third quarters, it appears unnecessary to compute the averages separately by sex.

[5] Small fish were disliked by the filleters because of higher cost and lower yield, but data on fillet recovery were not obtained.

TABLE 19.—*Estimated weight, by quarters, of yellowtail of each length group in the landings from the southern New England stock, during 1943*

[In pounds]

Length	1st quarter	2d quarter	3d quarter	4th quarter	Year
20.5 cm	0.14			0.15	0.15
21.5 cm	.16			.18	.18
22.5 cm	.19	0.22	0.22	.21	.20
23.5 cm	.22	.25	.25	.24	.24
24.5 cm	.26	.29	.28	.27	.27
25.5 cm	.29	.33	.32	.31	.31
26.5 cm	.33	.37	.36	.35	.35
27.5 cm	.38	.41	.40	.40	.39
28.5 cm	.43	.46	.44	.45	.44
29.5 cm	.48	.51	.49	.50	.49
30.5 cm	.54	.56	.54	.56	.55
31.5 cm	.60	.62	.59	.62	.61
32.5 cm	.67	.68	.65	.68	.67
33.5 cm	.74	.75	.71	.75	.74
34.5 cm	.82	.82	.78	.83	.82
35.5 cm	.91	.90	.84	.91	.89
36.5 cm	1.00	.98	.92	.99	.98
37.5 cm	1.09	1.06	.99	1.08	1.07
38.5 cm	1.20	1.15	1.07	1.18	1.16
39.5 cm	1.30	1.24	1.16	1.28	1.26
40.5 cm	1.42	1.34	1.24	1.39	1.37
41.5 cm	1.54	1.44	1.34	1.51	1.48
42.5 cm	1.68	1.56	1.43	1.63	1.60
43.5 cm	1.81	1.68	1.54	1.76	1.73
44.5 cm	1.96	1.79	1.64	1.89	1.86
45.5 cm	2.11	1.92	1.75	2.03	2.00
46.5 cm	2.28	2.05	1.87	2.18	2.14
47.5 cm	2.45	2.19	1.99	2.33	2.29
48.5 cm	2.63	2.33	2.11	2.50	2.45
49.5 cm	2.82	2.48	2.24	2.67	2.62
50.5 cm	3.02	2.64		2.84	2.80
51.5 cm	3.23	2.80		3.03	2.98
52.5 cm	3.44	2.97		3.23	3.17
53.5 cm	3.68			3.43	3.37
54.5 cm				3.64	3.58

CALCULATING NUMBERS OF FISH LANDED

In many of the later computations, it will be desirable to deal in numbers rather than pounds of fish to avoid a constant accounting for change due to growth.

The landings, given by quarters in thousands of pounds in table 7, may be converted to numbers of fish if we know the average weight of the fish. The average weight, W (table 20), is estimated by summing the weights of the fish measured for length as follows:

$$W=\frac{\Sigma N_L W_L}{N_T}$$

N_L=number in each length group (appendix tables C–14 and C–15, pp. 244–5), W_L=average weight of yellowtail of the corresponding length in that quarter (table 19), N_T=total number measured during the quarter. After determining the average weight of the fish, the landings in thousands of pounds are converted to number of fish (table 21).

CATCH PER UNIT OF EFFORT

We determined the catch per unit-of-effort to obtain an estimate of the relative size of the population or the equivalent as defined by Marr (1951), the relative apparent abundance.[6]

TABLE 20.—*Average weight of yellowtail, by quarters, landed from the southern New England stock, 1942–47*

[In pounds]

Quarter	1942	1943	1944	1945	1946	1947
1st		1.17309	1.05247	1.26689	1.07662	1.05420
2d		.90554	.74412	.94403	.87770	.95305
3d		.86310	.80208	.76025	.78116	.75504
4th	0.83036	1.04952	.99991	1.00915	.98079	.95558

TABLE 21.—*Number of yellowtail, by quarters, landed from the southern New England stock, 1942–47*

[In thousands of fish]

Quarter	1942	1943	1944	1945	1946	1947
1st		11,669	10,401	4,970	6,099	5,136
2d		7,569	6,232	1,575	2,999	4,370
3d		16,553	7,114	8,909	6,866	9,688
4th	18,801	4,714	2,116	8,229	9,484	10,267
Total	18,801	40,505	25,863	23,683	25,448	29,461

In developing this measure of abundance, we sought one that would be stable, continuous, and representative of the fleet's activities. We desired a figure that would not vary with changes in the composition of the fleet, with seasonal changes in the weather, or with changes in the relative attractiveness to the fishermen of yellowtail and other species. Of course, this measure should be continuous and uninterrupted in order to provide data in all seasons of all the years under study. Finally, since vessels seeking yellowtail fish as a fleet and freely exchange information by radio and in port, they naturally concentrate where the fish are concentrated. Their fishing is far from randomly distributed. They avoid for months, or even years, areas where yellowtail are judged to be scattered and the risk of an unproductive trip is too great. There appears to be no possibility of obtaining a measure of abundance from this fishing activity that would be based on fishing effort distributed over the range of the stock. We, therefore, considered as an alternative obtaining a measure representative of the activities of the entire fleet.

[6] We shall use the terms in the sense defined by Marr as follows: Abundance, the absolute number of individuals in the population; availability, the degree or percentage to which a population is accessible to the fishery; apparent abundance, abundance as affected by availability; and catch per unit of effort, an index number related to the apparent abundance.

Meeting these three criteria was necessarily a compromise with the characteristics of the fishing fleet. Throughout the period of our study, yellowtail were taken entirely by otter trawlers ranging in size from about 10 to 75 gross tons. The majority of these vessels, and the most successful, were those of about 25 to 40 gross tons, which could carry a crew of 4 to 6 men and make fairly regular trips of 3 to 6 days' duration.

All of the vessels fishing for yellowtail used similar gear, but since every fisherman has his ideas of how an otter-trawl net should be rigged, probably no two were identical. Essentially, however, they used lightweight trawl nets of cotton or manila twine with head ropes ranging in length from 50 to 70 feet and with foot ropes of chain, perhaps protected by a wrapping of old rope but never with large rollers. Usually, the doors were attached on pennants from 1 to 3 fathoms from the net. Vignernon-Dahl gear was never used.

During the period of study, the yellowtail fishery was only one of the major fisheries in the area and a large proportion of the fleet turned from one fishery to another as the markets and the fish dictated. Early in the yellowtail fishery many of the fishermen who had formerly sought the winter flounder would regularly return to that fishery in the spring season from April to June. Other vessels occasionally interspersed their fishing for yellowtail with periods of fishing for whiting, scup, or other species. The larger vessels (of more than 50 gross tons) usually sought yellowtail only in the winter when the weather was too rough for them to go to Georges Bank for sea scallops or haddock, and the crews preferred to fish the nearby yellowtail grounds. Our study of yellowtail abundance was further complicated by the fact that other species of fish were sometimes abundant near the yellowtail grounds and vessels on the same trip would catch a mixture of several species.

After several attempts to select particular vessels from the fleet, which would provide a continuous record, we found that no sizeable part of the fleet had fished throughout the period studied. We therefore decided to select vessels of 26 to 50 gross tons. This range in weight included the majority of the vessels, but it eliminated the very small ones which were most affected by the seasonal weather changes and likewise the very large ones which usually entered the fishery only in periods of poor weather. Vessels in this group fished only part of the time for yellowtail flounders, and many times they landed a mixture of yellowtail and other species; consequently, we further restricted our data to landings comprised of more than 75 percent yellowtail.

Most of the vessels fished day and night while on the fishing grounds, although a few of the smaller ones fished only during daylight hours. It was decided to select as a unit of effort a day of 24 hours actual fishing on the grounds and to consider the small amount of entirely daylight fishing according to the actual time fished. Information on fishing effort was obtained almost entirely at the port of New Bedford, where the captain of each vessel landing was interviewed to determine where he had fished, what he had caught, and how long he had fished in each statistical subarea to the nearest tenth of a day.

The interviews were commenced in October 1942 and were obtained a few days each week until the early part of 1943 after which they were made daily (except for some interruptions caused by personnel changes). Prior to October 1942, a considerable number of cooperating captains had kept detailed logbook records, which made it possible for us to estimate the catch per unit of effort during the first 3 quarters of 1942.

Despite the restriction on size of the vessels, condition of the catch, and necessity of landing the catch at New Bedford, a considerable percentage of the total catch has been included in our data. The percentage of the landings included in the catch per unit-of-effort data was low (1.4) during the early months of 1942 when only logbook records were available, but rose to 16.7 percent during the last quarter of 1942 (table 22). Subsequently, it varied from 14.1 percent in 1944 to as much as 39.2 percent in 1948. In order to reduce the effect of sampling variation during the first 3 quarters of 1942 and during the second quarter of 1945, we have included the catch and adjusted days fished for trawlers of between 5 and 25 gross tons. The days fished were multiplied by 0.796, the ratio of the catch per day of the small trawlers to the catch per day of our selected group during the period 1943 to 1947. Considering the generally substantial proportion of the landings included and the fact that the New Bedford fishing fleet usually fished the concentration of yellowtail flounder wherever it was found within the range of the southern New England stock, we believe that our calculation of the catch per unit of effort is representative of that experienced by the entire fleet.

TABLE 22.—*Percent of yellowtail landings from the southern New England stock included in catch per unit-of-effort data*

Period	Percent	Period	Percent
1942:		1945	25.1
Jan.-Sept	1.4	1946	31.6
Oct.-Dec	16.7	1947	32.7
1943	24.0	1948	39.2
1944	14.1	1949	38.0

The most obvious phenomenon in the resulting catch-per-day data is the pronounced seasonal fluctuation (table 23). In every year (1942–49) the catch per day during the third quarter was greater than in any other quarter. The remaining quarters were more variable with the first, second, and fourth leading in one or more of the years. The average landing per quarter for the 8 years, 1942 through 1949, was 5,808 pounds of yellowtail per day for the first quarter; 5,242 pounds for the second quarter, 9,480 pounds for the third quarter, and 6,400 pounds per day for the fourth quarter, with an unweighted average of 6,732 pounds for the year.

This seasonal fluctuation does not hide the general downward trend of the relative apparent abundance of the yellowtail from 1942 to 1949. The trend is similar in all quarters (fig. 13). The annual average catch per day differs somewhat from the trend in the total landings (fig. 14): the change in the relative apparent abundance is not so great as the change in quantities landed. This is to be expected from the fleet's habit of concentrating on a species when it is abundant and of changing to other fisheries when it becomes scarce. Also, a considerable increase in the relative apparent abundance occurred in 1945, which was associated with a decrease in fishing effort and therefore was not accompanied by an increase in the catch.

The catch per day has been computed also in terms of numbers of fish to provide data which will be used later in the estimation of mortalities. It is of interest to note that the catch per day in terms of numbers of fish landed greatly accentuates the seasonal fluctuation because of the tendency for yellowtail to run larger in the winter fishery and smaller in the summer.

TABLE 23.—*Catch per unit of effort of yellowtail from the southern New England stock, by year and quarter, 1942–49*

[Averages not weighted]

Year and quarter	Catch (thousands of pounds) [1]	Days fished [1]	Catch per day: Pounds	Catch per day: Number of fish [2]
Year 1942:				
1st quarter [3]	702.9	84.3	8,338	-------
2d quarter [3]	301.0	43.6	6,904	-------
3d quarter [3]	731.2	39.6	18,465	-------
4th quarter	4,487.6	435.4	10,307	12,413
Average [4]	-------	602.9	11,004	-------
Year 1943:				
1st quarter	3,298.5	489.7	6,736	5,742
2d quarter	986.6	178.9	5,515	6,090
3d quarter	4,035.7	377.9	10,679	12,373
4th quarter	1,231.1	209.0	5,890	5,612
Total and average	9,551.9	-------	7,205	-------
Year 1944:				
1st quarter	1,482.3	243.4	6,090	5,786
2d quarter	226.9	44.7	5,076	6,821
3d quarter	1,433.8	178.0	8,055	10,043
4th quarter	161.0	38.6	4,171	4,171
Total and average	3,304.0	-------	5,848	-------
Year 1945:				
1st quarter	1,079.8	159.4	6,774	5,347
2d quarter [3]	50.6	8.8	5,750	6,091
3d quarter	1,736.5	181.1	9,589	12,613
4th quarter	2,863.6	310.7	9,217	9,133
Total and average	5,730.5	-------	7,832	-------
Year 1946:				
1st quarter	1,218.4	188.4	6,467	6,007
2d quarter	370.3	52.3	7,080	8,066
3d quarter	2,134.4	263.5	8,100	10,369
4th quarter	3,829.1	543.2	7,049	7,187
Total and average	7,552.2	-------	7,174	-------
Year 1947:				
1st quarter	1,482.6	259.7	5,709	5,415
2d quarter	736.6	142.8	5,158	5,412
3d quarter	2,468.5	265.1	9,311	12,332
4th quarter	4,047.2	749.6	5,399	5,650
Total and average	8,734.9	-------	6,394	-------
Year 1948:				
1st quarter	1,895.8	540.1	3,510	-------
2d quarter	1,388.3	292.0	4,754	-------
3d quarter	2,289.1	412.6	5,548	-------
4th quarter	2,997.6	591.3	5,070	-------
Total and average	8,570.8	-------	4,720	-------
Year 1949:				
1st quarter	1,692.0	594.9	2,844	-------
2d quarter	216.3	76.5	2,827	-------
3d quarter	449.5	73.8	6,091	-------
4th quarter	1,555.7	379.5	4,099	-------
Total and average	3,913.5	-------	3,965	-------
Average, 1942–49: [4]				
1st quarter	-------	-------	5,808	-------
2d quarter	-------	-------	5,242	-------
3d quarter	-------	-------	9,480	-------
4th quarter	-------	-------	6,400	-------
Grand average	-------	-------	6,732	-------

[1] Catch (in thousands of pounds) and days fished from interviewed vessels of 26 to 50 gross tons landing more than 75 percent yellowtail on each trip.
[2] Estimates based on average weights from table 20, p. 195.
[3] Includes the catch and days fished times 0.796 of trawlers from 5 to 25 gross tons. (See text, p. 196.)
[4] Unweighted average.

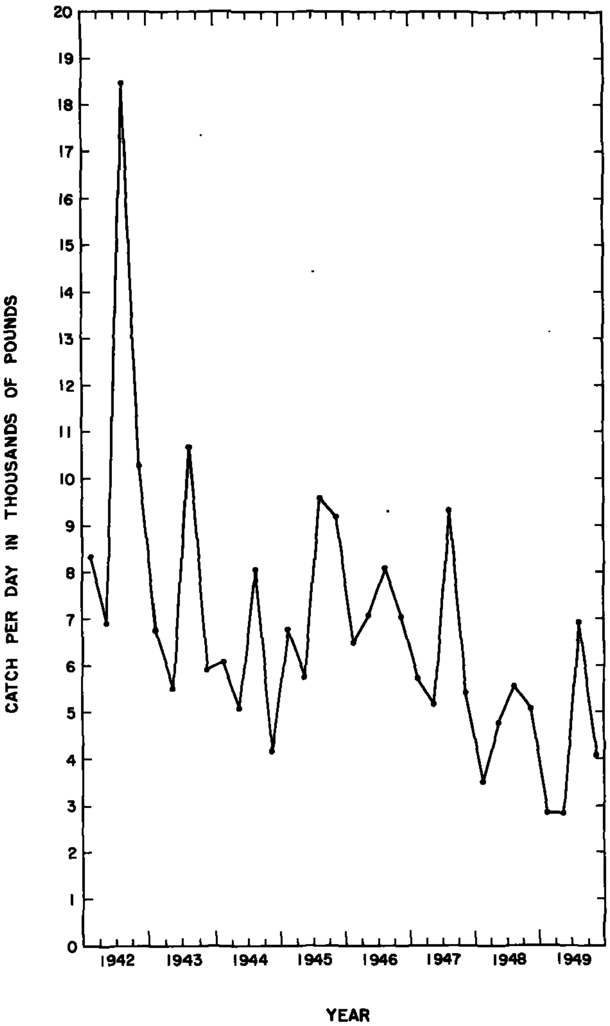

FIGURE 13.—Trend in relative apparent abundance, by quarters, of yellowtail from the southern New England stock, 1942 through 1949.

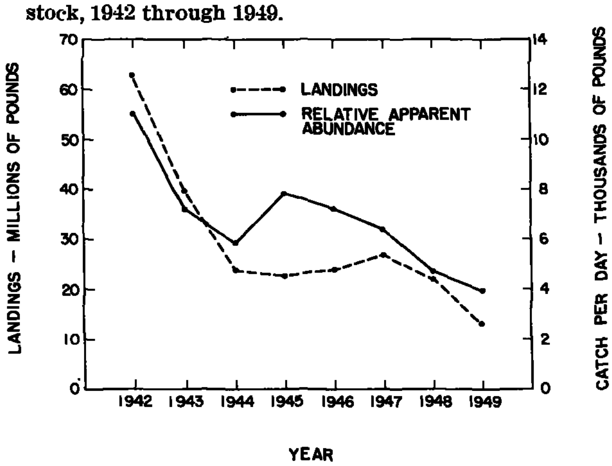

FIGURE 14.—Trends in relative apparent abundance and landings of yellowtail from the southern New England stock, 1942 through 1949.

Fishing Effort

The catch per unit of effort as computed for the selected trawlers leads naturally to an estimate of the amount of fishing for yellowtail in terms of the standard day, i. e., days fished by small otter trawlers of between 26 and 50 gross tons that landed more than 75-percent yellowtail in the catch. The data (table 24) have been computed from tables 7 and 23.

TABLE 24.—*Number of standard days fished for yellowtail on southern New England grounds, by quarters, 1942–49*

[Data computed from tables 7 and 23]

Quarter	1942	1943	1944	1945	1946	1947	1948	1949
1st	1,841	2,032	1,798	930	1,015	948	1,417	1,212
2d	1,891	1,243	914	322	372	807	852	370
3d	1,017	1,338	708	706	662	786	1,117	322
4th	1,515	840	507	901	1,320	1,817	1,312	939
Total	6,264	5,453	3,927	2,859	3,369	4,358	4,698	2,843

It is obvious immediately that the seasonal distribution of fishing effort did not parallel the seasonal distributions of catch and abundance. Usually there was more fishing for yellowtail in the first and fourth quarters of the year, less in the third quarter, and least in the second quarter. This is a reflection of a seasonal trend in the price received for yellowtail and the relative attractiveness of other fisheries. During the winter, yellowtail usually was higher in price and more easily caught than other species, but during the spring and summer the price declined as winter flounder, scup, whiting, and other species became available. The large decrease in the amount of fishing for yellowtail during the summer months between 1948 and 1949 is of interest. This occurred because of a diversion of the fleet to the newly developed "trash" fishery as described by Snow (1950).

AGE DETERMINATION

The ages of a large number of yellowtail flounder were determined for two purposes: (1) To estimate the age composition of the landings in each year and thereby obtain an estimate of the recruitment and mortality rates; and (2) to estimate the rate of growth.

Early in the investigation consideration was given to the best method of determining the age of the fish. The Petersen method of using modes in the length-frequency distribution showed little promise in the first data examined. The study of scales and otoliths was then undertaken. Both show regular growth rings, and while the otoliths may be more easily read in the larger fish, we chose the scales.[7] These are readily readable for several growth rings, are much easier to obtain from the fish, and can be handled with much less trouble in the laboratory. The choice of scales also was influenced to some extent by the fish dealers, who were accustomed to boxing and shipping fresh fish to the market. Early in the investigation a substantial part of the catch went to the consumer as whole fish, and as it was desirable to have clean, good-looking fish, several dealers refused to permit the mutilation necessary to obtain the otoliths.

It was then necessary to determine which scales were the most satisfactory to use. Careful examination of 13 different areas on the yellowtail revealed that the largest[8] symmetrical scales are located near the anterior end of the caudal peduncle on the eyed side. Scales from this area show more distinct growth rings than do those from other areas; consequently, they were used throughout the investigation. The limits of the area are not critical: scales from near the lateral line on the posterior half of the eyed side are similar in size and in clarity of growth rings.

The scales were taken from the landings in the same manner as the length measurements (p. 186), and usually they were obtained at the same time: 25 fish were measured and scales obtained, and another 75 fish were measured. The fish were measured to the nearest half centimeter. They were taken only from catches of vessels fishing in a single statistical subarea in order to make certain of their origin.

After considerable experimentation with various methods of mounting the scales on slides, it was found that they could be handled speedily and entirely satisfactorily by obtaining an impression on small strips of cellulose acetate, using a rollertype press. The strips, 2½ inches long by ½ inch wide by 0.020 inch thick, were warmed on a metal box heated by a 60-watt bulb to a temperature a little hotter than the hand could stand. Four or five scales were placed on a strip with the rough sides in contact. The scales were selected without aid of a microscope because the regenerated scales are readily distinguished with the naked eye. The only criteria for the selection of scales to be mounted were that they be symmetrical and lack regeneration. Information concerning the date, locality, length, and sex of the fish was transferred to the strip with a special celluloid ink.

The growth rings vary in character according to their position on the scale (fig. 15). The first ring, near the center, is rather indistinct at the magnification generally used when examining scales. It consists of a group of closely spaced circuli and is terminated by the first complete circulus that can be traced around the anterior portion of the scale, followed by the widely spaced circuli. This first growth ring is so narrow that it might have been considered a "natal" ring; that is, one associated with the larval stage, had it not been for our finding yellowtail that possessed this recently completed ring in the spring just before the spawning season.

Each of the succeeding three growth rings consist of a zone of widely spaced circuli enclosed by a zone of closely spaced circuli. The outer circuli of the latter are usually incomplete. The outer edge of the growth zone is marked by a prominent, complete circulus, which is concentric with the margin. The second growth ring is always very prominent. It consists of a broad zone in which the circuli are widely spaced at first but gradually come closer together at the outer edge of the ring. The third growth ring is usually about one-half the width of the second, and it, too, consists of widely spaced circuli gradually coming closer together. The fourth ring is about one-third to one-half the width of the third, has very few widely spaced circuli, and in some cases the transition from wide spacing to narrow is abrupt. The fifth and succeeding growth rings are usually very narrow and can be most easily identified if one examines the sides of the scale and attempts to trace the rings around to the apex. These include few, if any, widely spaced circuli. The outer part of the ring usually is just an interruption of the closely spaced circuli.

[7] Scott (1954) used otoliths in his studies of the yellowtail from Cape Cod and the Nova Scotian Banks. He found otoliths about as difficult to read as scales from the Cape Cod area but much easier than scales from the Nova Scotian area.

[8] The size of the scale is an important criterion because the first growth ring appears in a tiny area near the center of the scale and is completely missing from smaller scales near the head and along the edges of the fins.

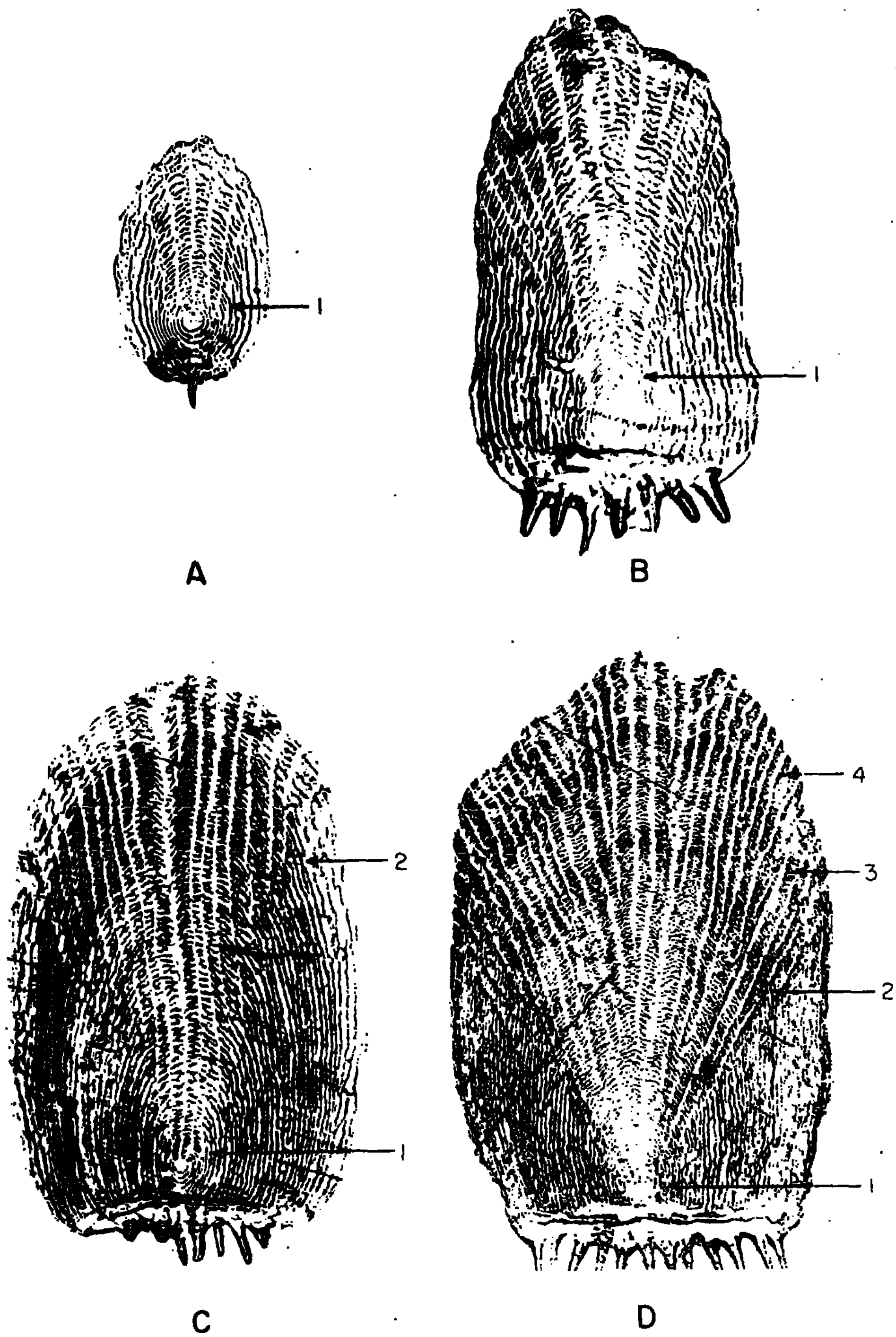

FIGURE 15.—Scales of yellowtail flounder: A, 8.2 cm. specimen, 1 annulus, April 1944; B, 16.6 cm. specimen, 1 annulus, September 1944; C, 27 cm. specimen, 2 annuli, May 1943; D, 36 cm. specimen, 4 annuli, June 1942.

In the third growth zone, frequently a very narrow ring of closely spaced circuli is visible in the midst of the widely spaced ones. This ring is less prominent than the rings of closely spaced circuli terminating the second and third growth zones. We have considered that this ring is associated with spawning and is not a true growth ring comparable to the others which we have counted. If it is a spawning mark, it would be expected to appear in subsequent growth zones, but it is not apparent because the widely spaced circuli are so few in growth zones after the third.

Examination of a series of scale samples taken throughout the year revealed that the new growth ring begins to form from January to March, and that it is apparent earliest in fish with two completed rings and later in the older fish. By the middle of March, almost all scales show the beginning of the new growth ring. Since the spawning season commences in late March, we have designated April 1 as beginning another year in the life of the fish, and in counting the growth rings, we have not included those rings completed during January, February, or March.

The consistent appearance of new growth at one season of the year is evidence that these growth rings are true annuli. Additional evidence appears from the facts (which will be developed later in this paper) that the growth rings are added systematically as growth proceeds, that a progression of modes in length-frequency data agrees closely with the length of the fish at corresponding ages estimated from the scales, and that there are consistencies in the data on age composition and in the changes in the average length of each age group which would be unlikely if the rings were not annuli. It will also be shown that there is good agreement between the mean lengths of yellowtail aged by scales during this study and those aged by otoliths by Scott (1954). Furthermore, the theoretical ultimate length computed from the lengths at each age is very close to the maximum length observed.

The age determinations used in this paper were made by Raymond J. Buller and Dexter S. Haven during a single period of a few months. The scale impressions were enlarged by a microprojector and read independently by each worker. After preliminary trials to establish a uniform technique, the two men were able to agree on the reading of more than 90 percent of the scales examined. Due to the scarcity of older scales and the difficulty of reading them, the scales aged 6 years and older were combined in one group in the first quarter and ages 7 and older in the other quarters.

Scales that were not read identically by the two readers were discarded. Since the scales become more difficult to read with increasing age of the fish, discarding them could change the proportions of older fish in the samples. Fortunately this did not happen, as indicated in figure 16 where the percentage length distributions of the yellowtail whose ages were determined from scales are compared with the percentage length distributions of the fish that were measured. Only very small differences in composition are evident, the greatest difference being a greater percentage of females in the 39- to 43-cm. group of aged fish which was compensated by a smaller percentage in the 35- to 38-cm. group. The proportion of males was almost identical—34.50 percent in the aged fish, 34.67 percent in the measured fish.

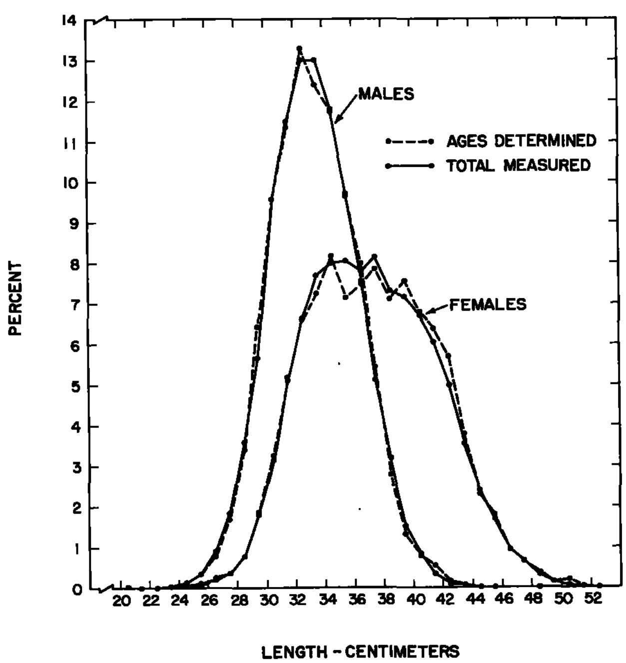

FIGURE 16.—Comparison of the percent length distributions of 7,924 yellowtail whose ages were determined from scales with 37,075 fish that were measured, 1943 through 1947.

Rate of Growth

Growth data have been developed from the attained length at time of capture of 9,204 yellowtail for which the ages were determined from scales. These fish were included in the samples collected from 1942 to 1947. The data are listed in detail in appendix D, p. 246, and summarized in table 25. The mean length of each age group in each calendar quarter during which 10 or more age determinations were obtained has been computed (table 26). It may be recalled that we have assumed that the annulus is complete on March 31, and therefore the yellowtail's year of life does not correspond to the calendar year. The first quarter in the fish's year is the second quarter in the calendar year. For example, the 2-annuli, male yellowtail that averaged 32 cm. in the fourth quarter of 1942 were actually in the third quarter of their third year of life.

The average attained length for each quarter of the yellowtail's life is plotted in figure 17. It is readily apparent from this chart that the females

TABLE 25.—*Number of age determinations of yellowtail, by sex and quarter, from the southern New England stock, 1942–47*

Year and quarter	Male	Female	Undetermined sex	Total
Year 1942:				
1st quarter	10	15		25
2d quarter			368	368
3d quarter			74	74
4th quarter	48	50	158	256
Year 1943:				
1st quarter	23	49	133	205
2d quarter	160	430	89	679
3d quarter	30	145		175
4th quarter	42	81	279	402
Year 1944:				
1st quarter	20	30	43	93
2d quarter	56	68		124
3d quarter	46	85	13	144
4th quarter	77	167		244
Year 1945:				
1st quarter	298	586		884
2d quarter	39	61		100
3d quarter	256	412		668
4th quarter	264	475		739
Year 1946:				
1st quarter	239	408		647
2d quarter	13	12		25
3d quarter	326	582		908
4th quarter	326	572		898
Year 1947:				
1st quarter	79	121		200
2d quarter	146	279		425
3d quarter	149	350		499
4th quarter	144	278		422
Total	2,791	5,256	1,157	9,204

TABLE 26.—*Mean lengths of yellowtail at time of capture, by sex and age, from southern New England stock, 1942–47*

[Computed from 10 or more age determinations]

Time of capture	Mean length (in centimeters) of—																		
	Males with—					Females with—							Undetermined sex with—						
	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli
Year 1942:																			
2d quarter														29.4	33.4	34.5	35.9	37.3	39.8
3d quarter														29.6	34	37.1			
4th quarter		32	35.3				32.6	36.1						32.3	36.2	38.8	41.3		
Year 1943:																			
1st quarter		32						38.1	41.3		46.2		27.1	32.4	35.3	37.2	40.8		
2d quarter			32.8	35.5			29.6	34.2	38.2	40.6	42.1	44.9		28.7	32.7	37.4		42.7	
3d quarter		30.2	34.2				31.7	34.6	38.8										
4th quarter		32.5	34.2				33.3	36.9	39.3					33.9	36	39.4	42.8		
Year 1944:																			
1st quarter								37.9						31	35.6				
2d quarter			31.8					33.6											
3d quarter			31.9					33.8	38.2										
4th quarter		30.6	33.8	37.4			32.4	36.6	39.9	42.1	45								
Year 1945:																			
1st quarter	27.5	33	35.6	37.5	38.5		34.8	38.1	41.2	43	45.9								
2d quarter			32	33.6				33.7	37			43.4							
3d quarter		30.4	33.4	34.5			31.7	35.7	37.4	39.9	41.8								
4th quarter		32	34.2	35.7	38.2		33.6	36.4	38.5	41.3	43.2	46.4							
Year 1946:																			
1st quarter	28	33.5	35.8	38.2		28.1	34.8	37.6	41	43.2	46.1								
3d quarter		30.2	33.8	34.9			31.5	35.2	37.7	40.1	42.4								
4th quarter		31.8	34.5	35.9	37.3		33.3	36.7	39	40.7	42.8	46							
Year 1947:																			
1st quarter		33.8	37.2			29.9	35.2	38.2	41.8	42.4	45.9								
2d quarter		29.5	32.6	35.7	37.1		31.1	34.9	37.9	40.7	42.3	44.9							
3d quarter		30.5	32.8	35	37.5		32.1	34.9	37.7	40.3	42.8								
4th quarter		32	34.3	36			33.5	36.6	38.8	41.5	42.8								
Average, 1942–47:																			
1st quarter	27.9	33.3	35.8	37.7	39.4	28.8	34.8	38	41.1	43	46		27.1	32	35.4	37.5	40.2	43.5	
2d quarter		29.1	32.5	35.2	37.2		30.4	34.2	37.9	40.6	42.2	44.5		29	33.2	34.7	36.6	38.8	39.8
3d quarter		30.3	33.1	34.9	37.1		31.7	34.8	37.7	40.1	42.4	44.3		30.1	33.9	37			
4th quarter		31.9	34.4	35.9	37.6		33.3	36.7	39	41.1	43.2	46.4		33.6	36.4	39.5	42.6	44.9	

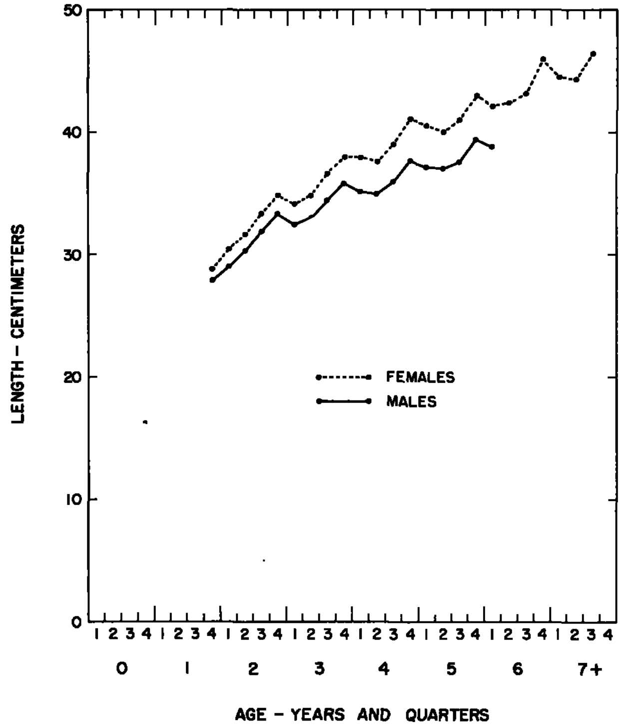

FIGURE 17.—Mean lengths of yellowtail, by ages and quarters, in the landings from the southern New England stock, fourth quarter 1942 through 1947.

grow faster than the males, as was to be expected from the observation that females attain a greater size. They were 4.5 percent longer than the males at age 2 and up to 9.1 percent longer at age 5. The lack of males prevents such comparison in the older age groups.

On the other hand, figure 17 indicates an unexpected constant seasonal cycle in the growth curve. The mean length during the fourth quarter of the fish's year of life (first calendar quarter) is usually slightly greater than during the succeeding first and second quarters, in both of which the fish are of about the same average size. One would expect slow growth in winter and rapid growth in summer, except perhaps during the spawning period from April through June. Although reduction of the mean length of an age group might occur among the younger groups because of seasonal changes in gear selectivity, it would not be expected consistently in all age groups.

The possibility of this seasonal change in average length being due to errors in reading the scales was not overlooked. If too few rings were counted in the fourth quarter of the fish's year of life and/or too many rings were counted in the succeeding first quarter, such a cycle might result. Error in reading the scales seems improbable, however, because any evidence of a new annulus forming at the edge of a scale during the fourth quarter was disregarded, and too few rings could have been read only by disregarding annuli which were counted in similar scales from second and third quarters. Most important is the similarity of the cycle in all age groups after the yearling. Since scales from the 2- and 3-year-old groups are so much easier to read than from the older age groups, we feel certain that any reading errors would have been much more common among the older fish; consequently, a change in the cycle would have occurred between the young and old groups. We, therefore, believe that reading errors are not responsible for the seasonal change in average length. Rather, the most probable explanation of this seasonal growth pattern is that different populations of flounders occurred in the landings in different quarters of the year and that these populations were growing at slightly different rates.

The differences in rate of growth of yellowtail among quarters are accentuated when the lengths are converted to weights (using the formulas from table 16), because when the fish were longer they were also correspondingly heavier. The weights (table 27) when plotted (fig. 18) show a markedly faster growth in the first quarter of the fish's year of life, intermediate and about equal growth during the second and fourth quarters, and slow growth during the third quarter. The differences, especially among females, are so great that they indicate population differences rather than seasonal differences. For example, females with three annuli were heavier in the first quarter than in the following second and third quarters, and in their next year of life were heavier in the first quarter than during the subsequent second, third, and fourth quarters. In addition, the heaviest fish were found during the coldest season when we would expect the rate of growth to be minimal.

These curves (fig. 18), which are nearly straight lines passing through the point of origin, indicate nearly equal weight increments during each year of life in the fishery. This results, in part,

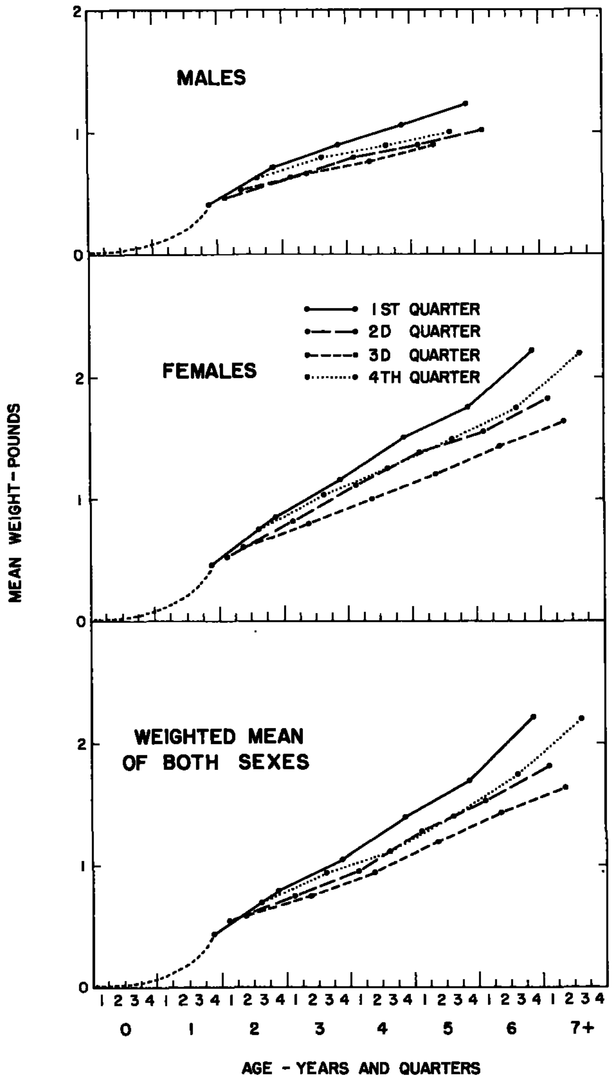

Figure 18.—Growth in weight of yellowtail from the southern New England stock caught during different calendar quarters. Dashed line indicates probable growth during early life.

from certain characteristics of the data. There is little doubt that the average weight of the yellowtail taken during the third year of life (2-annuli) is greater than the average weight of the fish remaining in the sea, because the fishery selects fish above a certain size. We shall note subsequently that growth during the first year of life is very small, as suggested by the dotted lines in figure 18. At the other end of the curve we have combined the 6-annuli and older fish in the first quarter and 7-annuli and older fish in other quarters. This combination of age groups is probably responsible for the greater growth among females in the first and fourth quarters.

Table 27.—*Mean weights and growth rates of yellowtail, by quarter, age, and sex, from the southern New England stock, 1942–47*

Number of annuli	Males		Females		Sexes combined, weighted mean	Instantaneous growth rate
	Mean weight	Number	Mean weight	Number		
1st quarter:	*Pounds*		*Pounds*		*Pounds*	
1 annulus	0.4137	51	0.4543	28	0.4281	
2 annuli	.7229	250	.8619	268	.7948	0.619
3 annuli	.9089	238	1.1607	295	1.0483	.277
4 annuli	1.0696	97	1.5129	285	1.4003	.290
5 annuli	1.2293	23	1.7634	172	1.7004	.194
6 annuli			2.2168	146	2.2168	.265
2d quarter:						
1 annulus						
2 annuli	.4724	55	.5724	95	.5357	
3 annuli	.6347	219	.8181	389	.7520	.340
4 annuli	.7854	104	1.1172	120	.9632	.248
5 annuli	.9104	33	1.3769	128	1.2813	.285
6 annuli	1.0191	3	1.5485	77	1.5286	.176
7 annuli			1.8200	41	1.8200	.174
3d quarter:						
1 annulus		3		3		
2 annuli	.5346	432	.6052	578	.5750	
3 annuli	.6694	210	.7974	366	.7507	.267
4 annuli	.7661	145	1.0010	334	.9299	.214
5 annuli	.8954	17	1.2124	216	1.1893	.246
6 annuli			1.4307	63	1.4307	.185
7 annuli			1.6280	14	1.6280	.129
4th quarter:						
1 annulus	.3792	5	.2890	5	.3341	
2 annuli	.6362	398	.7489	427	.6945	.732
3 annuli	.7854	226	1.0260	316	.9257	.287
4 annuli	.8845	166	1.2491	308	1.1214	.192
5 annuli	1.0055	52	1.4791	323	1.4134	.232
6 annuli		6	1.7386	141	1.7386	.207
7 annuli			2.1903	53	2.1903	.231
All quarters		2,733		5,191		

SUMMARY

Age groups:	*Mean instantaneous growth rate*
1–2 annuli	0.673
2–3 annuli	.291
3–4 annuli	.233
4–5 annuli	.238
5–6 annuli	.206
6–7 annuli	.173

The mean growth rate, computed from the data in table 27, will be of use to us later in population studies. Such a mean should be representative if we give proper consideration to differences between the sexes and among quarters, because we found no trends in the growth rate during the period of our study. The estimated weights for each sex in each quarter have been combined in quarterly averages through weighting the means of the sexes combined by the number of each sex in the scale samples at each age from 1943 through 1947. We then computed the instantaneous growth rate (k) for each age in the four quarters from the formula

$$e^k = 1 + b$$

in which b is the fractional increase in weight over that at the beginning of the year (after

Ricker 1945). The values for each quarter were then combined in a geometric mean for each age.

The resulting growth rates commence at 0.673 between ages 1 and 2, drop abruptly to 0.291 the next year, and then decrease to 0.173 between ages 6 and 7. The first of these growth rates is probably much too low—not only because of the gear selectivity mentioned earlier, but because the yearling group was represented only during the last half of its year of life (fourth and first calendar quarters) when the fish had already accomplished most of their season's growth. The growth rate from 2 to 3 years is probably somewhat low also because of gear selectivity.

The measurements of the fish for which we have scale readings provide valuable checks on the validity of the readings. First, the mean lengths are in close agreement, except in the older age groups, with those obtained by Scott (1954), who aged his fish by otoliths. In table 28 we have compared Scott's readings from otoliths collected during July 1946 in the New Bedford fishery with our determinations from scales collected during the entire third quarter of 1946. Agreement between scale and otolith readings is very good except among age-groups 5 to 7 where the mean lengths of the fish whose ages were determined by otoliths are somewhat less. This lack of agreement in the older groups might be attributed to the finding of a greater number of annuli on the otoliths because a slightly greater proportion of older fish were found; but we also notice that no fish of greater age were found in either sex by

TABLE 28.—*Mean lengths of yellowtail flounder, by age groups and sex, as determined from otoliths and from scales, third quarter 1946*

[In centimeters; number of specimens in parentheses]

Age group	Length of males determined from—		Length of females determined from—	
	Otoliths[1]	Scales	Otoliths[1]	Scales
1				17.5 (1)
2	29.1 (23)	30.2 (212)	30.2 (23)	31.5 (281)
3	34.0 (14)	33.8 (35)	35.0 (20)	35.2 (38)
4	34.4 (23)	34.9 (73)	37.3 (18)	37.7 (109)
5	35.3 (12)	36.8 (6)	38.8 (40)	40.1 (126)
6			38.7 (11)	42.4 (22)
7			42.0 (5)	43.7 (5)

[1] Collected in July (Scott 1954).

means of the otoliths. Moreover, the possibility remains that the scales and otoliths were obtained from somewhat different populations because of an abrupt change in the principal fishing grounds between July and August 1946 (table 3). Therefore we do not consider that these discrepancies indicate faults in the scale-reading technique.

The differences among populations within the southern New England stock, as suggested by comparison of the otolith and scale samples and by the discrepancies in attained size in different quarters, are much smaller than those between the southern New England and Nova Scotian yellowtail. Scott (1954) found that the yellowtail on Middle Ground and Western Bank areas of the Nova Scotian Banks grew much more rapidly than the Cape Cod yellowtail, except during the second and third years of life. However, in the second year the growth of the southern New England yellowtail so far exceeded the growth of the Nova Scotian fish that the attained length of the southern New England fish was the greater until about the seventh year. At this age, when the southern New England yellowtail had nearly all died, the female Nova Scotian yellowtail were just maturing. They continued to grow until the modal ages in the catch were 9 and 10 years at lengths of 44 to 47 cm. Contrast this with maturity and a modal age of 3 years at about 34 cm. in the southern New England stock.

Additional evidence of the reliability of the scale readings is available in a comparison of the attained sizes (table 26) with modes in the length frequencies of the females. We have plotted the percentages at each length as deviations from the grand mean for the years 1942 to 1947 (fig. 19). Two modes, suggestive of dominant year classes, progress from year to year. An eye-fitted line faired through one series of modes commences at 25.5 cm. in 1942, is missing in 1943, but continues to 34.5, 37.5, 41.0, and 42.5 cm. in the succeeding years. This is in good agreement with the mean attained lengths of the 1941 year class from scale readings which averaged 33.8, 37.4, 40.1, and 42.8 cm. in the third quarter (the season of heaviest landings) of the corresponding years. The shorter series of modes commences at 28.5 cm. in 1945 and continues at about 31.5 and 34 cm. in the following years. This also is in good agreement with the mean attained length of the females from the 1944

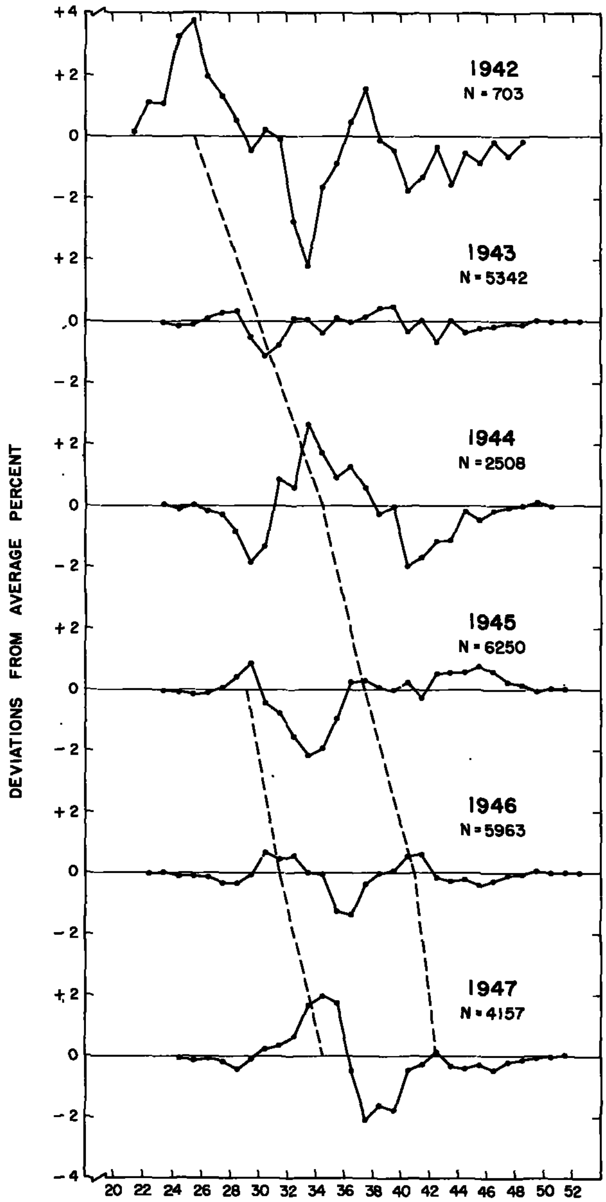

FIGURE 19.—Deviations from the mean percentage length distribution of female yellowtail from the southern New England stock, 1942–47. (N=number of fish.)

year class which were 31.5 and 34.9 cm. during the third quarters of 1946 and 1947.

It is highly significant that there was no trend in the mean length (and consequently in the growth rate) of each age group during the period of our study. The mean lengths of both males and females (table 26) for comparable quarters from 1942 to 1947 reveal no tendency toward an increasing or a decreasing growth rate among either older or younger fish. It is surprising that an increased growth rate has not occurred during this period of intense fishing in view of the both theoretical and empirical determination for many species that the growth rate increases as the stock decreases. Since we found no change in rate of growth, we conclude that the total environmental pressure remained essentially constant during the period of this study.

The rate of growth in the young yellowtail appears to be rather unusual. The proportions of the scale suggest that growth to the first annulus is only from 3 to 5 cm., whereas during the second year the fish attains a length of nearly 30 cm. Such a method of estimation is not precise, however, because some measurements of the scales from fish in the commercial catch showed that increase in size of the scales is not proportional to increase in size of the fish: the scale growth is heterogonic. For this reason and because we could not obtain appreciable numbers of juvenile yellowtail to determine the relation between scale size and fish size, we have not attempted to calculate fish lengths at early ages from scales.

Age Composition of the Landings

The proportion of each age in the landings is readily determined from the samples (appendix D, p. 246) because all of the yellowtail used in making the age determinations except those taken during the first three quarters of 1942 were taken at random from the landings (table 25). The samples not taken at random during the early part of the investigation may not be representative and must be considered with caution. These proportions, when plotted by quarters (fig. 20) offer rather striking evidence of an alternation of the populations between winter and summer from the winter of 1942–43 to the winter of 1944–45. The distribution of age groups was similar in the fourth quarter of 1942 and the first quarter of 1943. Then a marked change to a summer pattern existed in the second and third quarters of 1943. This pattern was followed by a winter pattern in the fourth quarter of 1943 and the first quarter of 1944, a summer pattern in the second and third quarters of 1944, and another winter pattern in the fourth quarter of 1944 and the first quarter of 1945.

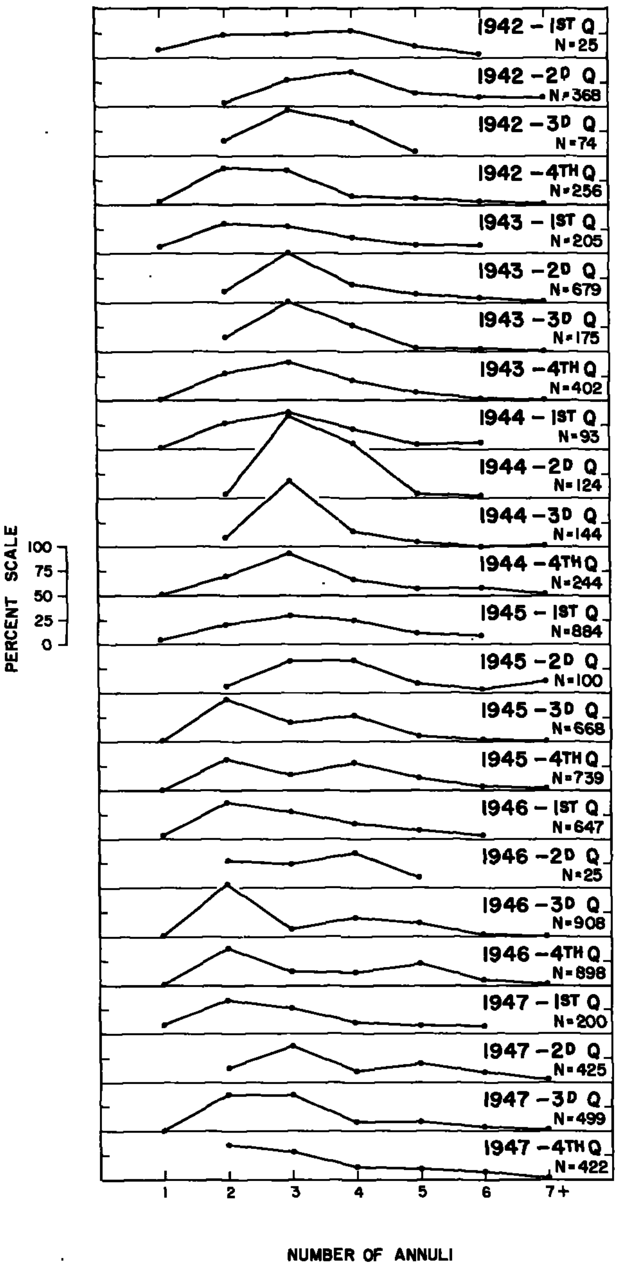

Figure 20.—Age composition of yellowtail from the southern New England stock during each quarter, 1942–47. (N=number of fish.)

An interruption in the sequence of summer and winter populations occurred in 1945. Here we find a close resemblance in the age distributions of the third and fourth quarters which persisted somewhat less clearly in the third and fourth quarters of 1946 and 1947. The change may be reflected also in the total landings, which were markedly greater in the fall months of 1945 through 1947 than in 1943 and 1944 (table 7). The first and second quarters in 1945, 1946, and 1947 have age distributions which appear to differ from those of the third and fourth quarters and also among themselves.

When we seek evidence of dominant year classes, these changes in age distributions within the southern New England stock emphasize the necessity of comparing each quarter only with the same period in other years and that with caution. When we do so for the first quarter (fig. 21) by plotting the deviations from the average age-frequency curve for the 6 years, 1942–47, we find one series of small modes as indicated by the dashed line. The series runs from the mode at the second annulus in 1943 to the mode at the fifth annulus in 1946. Recalling that the second annulus in the first quarter of 1943 was completed March 31, 1942, we identify this series of modes as representing a more abundant year class from the 1940 spawning. However, the age distribution during the first quarter was remarkably uniform, and this year class was only slightly more abundant than the others—its maximum deviation above the average being less than 9 percent.

Turning to the second quarter (fig. 21), we find little indication of a dominant year class passing through the fishery. Only two pairs of modes suggesting this appear—one from the 1941 year class in 1944 and 1945 and the other from the 1942 year class in 1946 and 1947. Since these modes are neither preceded nor followed by peaks, their interpretation as dominant year classes is dubious.

Much clearer is the succession of modes from the 1941 year class which appear as peaks from 1944 to 1947 in both the third and fourth quarters (fig. 21). Why both of these quarters in 1943 produced fewer fish from this year class, which was subsequently abundant, is of interest. Clearly the 1941 year class was not as available as other year classes at the 2-annuli stage during these quarters, nor was it more available during other quarters in 1943.

Other features of these curves are significant. The proportion of 2-annuli fish increased abruptly in 1945 in both the third and fourth quarters, and since no decrease occurred in the cull size (see length frequency data, p. 245) they must have become more available to the fishery. Significant, too, is the fact that they either did not remain

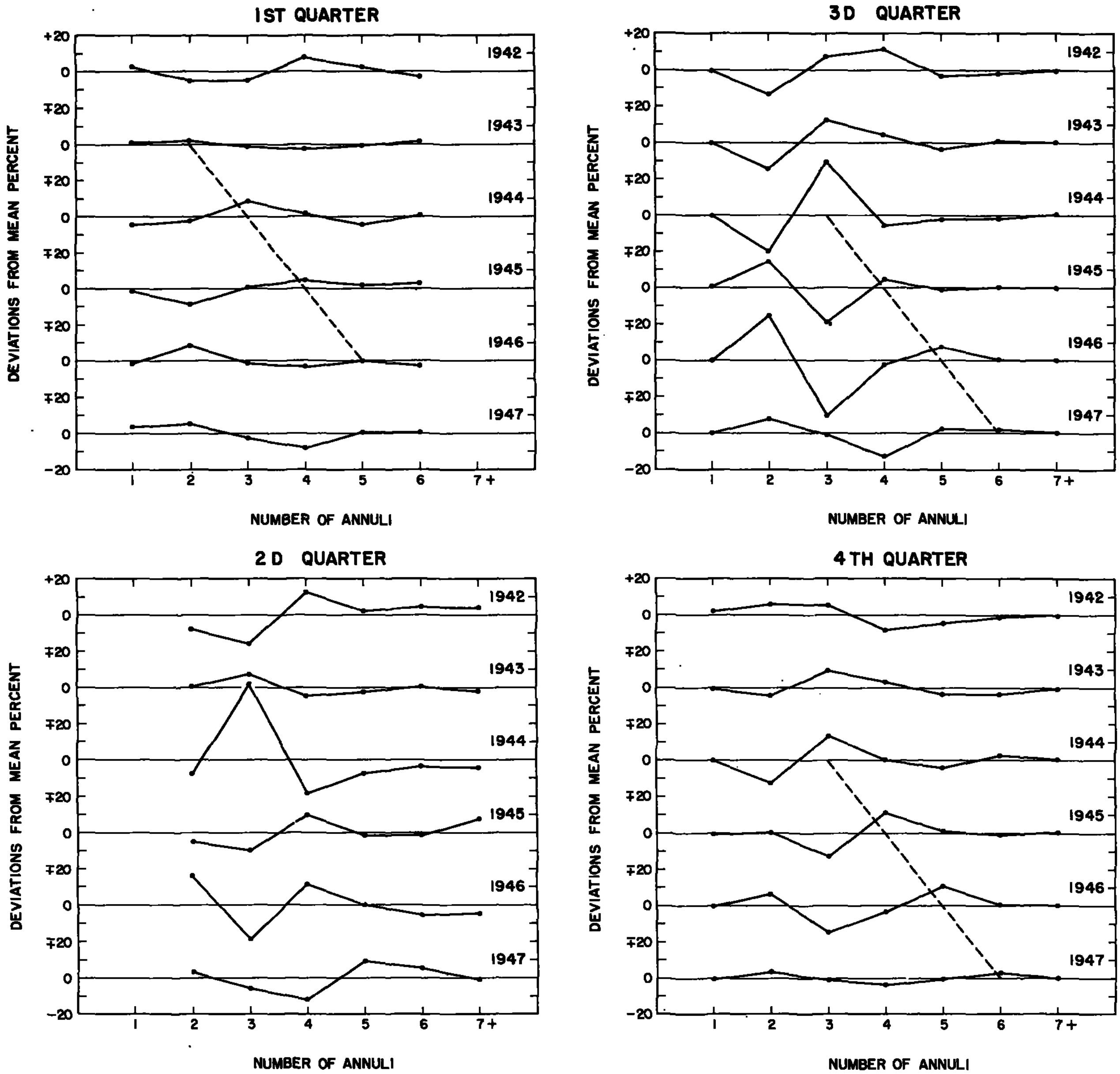

FIGURE 21.—Deviations from the mean percent age composition of yellowtail landed from the southern New England stock, 1942–47. Dashed lines indicate the series of small modes.

more available or else were mostly caught in 1945, since no similar increase in 3-annuli fish was noted in 1946 or 1947.

The data on age composition (table 29) are readily combined with the total landings in numbers of fish (table 21) to obtain an estimate of the landings of each age group in each quarter from the fourth quarter of 1942 through 1947 (table 30). These data will be used later in determining mortality. Meanwhile, we note that on the average, age-groups 2, 3, and 4 predominated, comprising 28.1, 35.5, and 19.3 percent of the catches. An exception to this might be taken for the average landings in the second quarter (the spawning season), when the 3-year-olds comprised more than half of the total; but this average is strongly influenced by the unusual sample from the second quarter of 1944, and probably is not representative. Also noteworthy is the fact that the average landings of young fish prior to age 2 years and 3 months were negligible. The youngest group strongly represented in the average catch was the group with 2 annuli in the third calendar quarter.

TABLE 29.—*Age composition, by quarters, of yellowtail landed from the southern New England stock, 1942–47*

Year and quarter	Number of fish	Percent of fish having— 1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli
Year 1942:								
1st quarter	25	8.00	24.00	24.00	28.00	12.00	4.00	------
2d quarter	368	------	4.08	27.17	36.68	13.86	9.78	8.42
3d quarter	74	------	16.22	45.94	33.78	4.05	------	------
4th quarter	256	3.12	38.67	35.55	9.38	7.42	4.30	1.56
Year 1943:								
1st quarter	205	6.34	31.22	27.80	17.56	8.78	8.29	------
2d quarter	679	------	12.52	50.37	19.59	9.28	6.04	2.21
3d quarter	175	------	15.43	50.86	26.86	3.43	2.86	.57
4th quarter	402	.25	28.11	39.30	20.90	8.46	1.99	1.00
Year 1944:								
1st quarter	93	1.08	26.88	37.63	21.50	5.38	7.53	------
2d quarter	124	------	4.03	84.68	5.64	4.03	1.61	------
3d quarter	144	------	9.72	68.06	16.67	4.86	------	.69
4th quarter	244	.82	20.08	43.03	17.62	7.79	8.20	2.46
Year 1945:								
1st quarter	884	3.85	20.25	29.64	24.77	11.65	9.84	------
2d quarter	100	------	7.00	33.00	34.00	10.00	4.00	12.00
3d quarter	668	.60	44.01	19.91	26.80	5.99	2.24	.45
4th quarter	739	.27	32.88	17.18	29.09	13.40	4.60	2.57
Year 1946:								
1st quarter	647	3.86	37.87	27.82	16.85	9.43	4.17	------
2d quarter	25	------	28.00	24.00	36.00	12.00	------	------
3d quarter	908	.11	54.30	8.04	20.04	14.54	2.42	.55
4th quarter	898	.56	38.86	15.26	14.36	22.72	6.12	2.11
Year 1947:								
1st quarter	200	9.00	34.50	26.50	12.00	10.50	7.50	------
2d quarter	425	------	15.29	37.41	12.24	20.70	11.06	3.29
3d quarter	499	.20	37.68	37.68	9.82	9.62	4.21	.80
4th quarter	422	------	36.26	28.67	13.74	10.90	8.53	1.90

TABLE 30.—*Estimated number of yellowtail of each age, landed from the southern New England stock, fourth quarter of 1942 through 1947*

[In thousands of fish. Based on tables 21 and 29]

Year and quarter	Number of fish having— 1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli	Total[1]
Year 1942: 4th quarter	587	7,270	6,684	1,764	1,395	808	293	18,801
Year 1943:								
1st quarter	740	3,643	3,244	2,049	1,025	967	------	11,669
2d quarter	------	948	3,812	1,483	702	457	167	7,569
3d quarter	------	2,554	8,419	4,446	568	473	94	16,553
4th quarter	12	1,325	1,853	985	399	94	47	4,714
Year 1944:								
1st quarter	112	2,796	3,914	2,236	560	783	------	10,401
2d quarter	------	251	5,277	351	251	100	------	6,232
3d quarter	------	691	4,842	1,186	346	------	49	7,114
4th quarter	17	425	910	373	165	174	52	2,116
Year 1945:								
1st quarter	191	1,006	1,473	1,231	579	489	------	4,970
2d quarter	------	110	520	536	158	63	189	1,575
3d quarter	53	3,921	1,774	2,388	534	199	40	8,909
4th quarter	22	2,706	1,414	2,394	1,103	378	211	8,229
Year 1946:								
1st quarter	235	2,310	1,697	1,028	575	254	------	6,099
2d quarter	------	840	720	1,080	360	------	------	2,999
3d quarter	8	3,728	552	1,376	998	166	38	6,866
4th quarter	53	3,685	1,447	1,362	2,155	580	200	9,484
Year 1947:								
1st quarter	462	1,772	1,361	616	539	385	------	5,136
2d quarter	------	668	1,635	535	905	483	144	4,370
3d quarter	19	3,650	3,650	951	932	408	78	9,688
4th quarter	------	3,723	2,944	1,411	1,119	876	195	10,267
Average, 1943–47:								
1st quarter	348	2,305	2,338	1,432	651	576	------	7,655
2d quarter	------	563	2,393	797	475	221	100	4,549
3d quarter	16	2,909	3,847	2,069	676	249	60	9,826
4th quarter	21	2,373	1,714	1,305	988	420	141	6,962
All years	385	8,150	10,292	5,603	2,790	1,466	301	28,992
Percent	1.3	28.1	35.5	19.3	9.6	5.1	1.0	------

[1] Slight discrepancies occur due to rounding off of the figures.

Good agreement appears between maximum lengths observed and Walford's (1946) ultimate length $l\infty$ for the yellowtail. This characteristic represents the length at which growth becomes zero and is computed from

$$l\infty=\frac{l_1}{1-k}$$

in which l_1 is the y intercept of a line fitting the points $(ln, ln+1)$, ln is the length at age n years and k is the slope of the line. We have used the mean attained length by quarters from table 26, fitted lines by the least-squares method to determine l_1 and k, and estimated $l\infty$, for each quarter and sex. (We have omitted females age 7 years and older from the computation because this group contains older fish and probably has a higher average mean length than a group composed only of females age 7 would have.) The results (table 31) show reasonably good agreement with the maximum size observed in the length samples which comprised 38,335 fish from the fourth quarter of 1942 through 1947. If we assume that the samples from different quarters represent different populations and the estimates of $l\infty$ contain sampling variation, it is permissible to average them. Thus, we find that the mean estimate of $l\infty$ for males is 1.1 cm. lower and for females 2.0 cm. higher than the observed measurements. Moreover, the estimates of $l\infty$ from these data, particularly for males, are probably low because the fishery undoubtedly oversamples the larger fish in the younger age groups. This results in a high value for l_1, and perhaps for l_2, and correspondingly lower values for k and $l\infty$. Nevertheless, the close agreement gives us further confidence in our age readings and length samplings.

TABLE 31.—*Ultimate length* ($l\infty$) *and maximum length found in samples of the catch* (lm), *from the southern New England stock, by quarter and sex*

[In centimeters]

Quarter	Males lm[1]	Males $l\infty$	Females lm[1]	Females $l\infty$
1st	48.5	41.0	52.5	51.7
2d	45.5	44.2	51.5	49.4
3d	42.5	47.8	48.5	61.8
4th	43.5	42.7	54.5	52.2
Mean	45.0	43.9	51.8	53.8

[1] From appendix C, pp. 244–5, recorded in centimeter groups.

SURVIVAL, MORTALITY, AND AVAILABILITY

Three methods were used to estimate survival and mortality rates, no one of which is completely satisfactory but each of which contributes something to the sum of the information. These methods are as follows: (1) Immediate fishing mortality determined from the ratio of early returns of tagged fish to total number released; (2) total mortality determined from the ratios of the numbers of tag returns in successive years; and (3) total mortality determined from the ratios of the apparent abundance of certain age groups to comparable groups in successive years.

Immediate Fishing Mortality

The recaptures of tagged yellowtail during the first 10 days after release on the principal fishing areas usually show a high mortality rate (table 32). The recapture rate may be converted to the annual fishing rate, m,[9] if we assume that the 10-day mortality is equal to the instantaneous fishing mortality rate p, where $m=1-e^{-p}$.

The calculations (table 32) yield estimates of m ranging from 0.43 to 0.97 and averaging 0.86 from the sum of returns and releases. These values can be considered minimal estimates of the annual total mortality rate a of the group tagged because natural mortality is not included. They will, of course, have been reduced by deaths due to tagging during the 10-day period, but because only lively fish were released such deaths should not have been immediate.

TABLE 32.—*Early recaptures of tagged yellowtail released on the principal fishing grounds off Nantucket Shoals and No Mans Land*

Lot	Date released	Number released	Number recaptured in first 10 days	Annual rate of fishing (m)
No. 4	June 10, 1943	131	2	0.43
No. 5	Oct. 22-24, 1943	286	14	.83
No. 10	July 19, 1946	158	7	.80
No. 11	Aug. 21-23, 1946	228	21	.97
All lots		803	44	.86

Such a high rate of exploitation for a small group of fish is subject to criticism as not being representative of the rates experienced by the population, unless availability is not uniform among all parts of the population. However, rates calculated in this way are probably indicative of the mortalities experienced by groups of fish while completely available to the fishery. All of the lots except No. 10 were released from commercial fishing vessels, and in such an operation the tagged fish probably were released over a substantial part of the area that the fleet was fishing at the time. One characteristic of the yellowtail fishery has been the appearance of concentrations of yellowtail at various places with a subsequent shift of the fleet to those areas. We have actually observed a group of about 50 vessels fishing at one time in an area of not more than 300 square miles.

At the mean rate of fishing found from the tag returns, the "half life" (the period required to catch half of the fish exclusive of any natural mortality) would be 123 days.[10] At the maximum rate of fishing (lot No. 11), the half life would be only 72 days—a period similar to the length of time fishing was frequently pursued intensively in a small area.

Mortality from Tag Returns in Successive Years

Estimates of the rate of fishing, m, derived from the early recaptures are not greatly different from estimates of the total annual mortality rate, a, derived from the tag returns in successive years.[11] If we consider the same four experiments (lot Nos. 4, 5, 10, and 11) used to estimate immediate mortality, we note that 103 yellowtail were recaptured during the first year, 11 during the next year, and 1 in the third year (table 33). Ricker (1948) has pointed out that such a series of recaptures provides direct estimates of the survival rate, $s=1-a$, simply by taking $\frac{R_2}{R_1}$, $\frac{R_3}{R_2}$, et cetera. If we do this, we find $s=\frac{11}{103}=0.11$, $a=0.89$. Between the second and third years, $a=1-\frac{1}{11}=0.91$, but this estimate, of course, is much less reliable because of the small numbers. Similar computations for the total returns in successive years from all the lots released in the southern New England stock show $s=\frac{25}{212}$, $a=0.88$ between the first year and the second after tagging.

[9] This and other symbols for mortality rates are used as defined by Ricker (1948) and Widrig (1954).

[10] The half life was computed by substituting the observed recapture rate p and 0.5 for m in the "compound interest" formula $m=1-(1\text{-}``p")^n$ and solving for n. Then, n times the period in days gives the half life.

[11] These years start with each release date and are different for each lot released.

Between the second year and third after tagging $s=\frac{6}{25}$, $a=0.76$. The value of a calculated in this way indicates the total mortality—fishing mortality and natural mortality occurring simultaneously.

TABLE 33.—*Numbers of tagged yellowtail returned in successive years after release*

Stock and lot	Number released	Date released	Number returned in—					
			1st year	2d year	3d year	4th year	5th year	6th year
Southern New England:								
No. 1	227	Feb. 24, 1942	60	12	3	2	1	
No. 2	240	Mar. 2, 1942	47	2	2			
No. 4	131	June 10, 1943	9	2				
No. 5	286	Oct. 22–24, 1943	19	2				
No. 6	15	Feb. 28–29, 1944	2					
No. 10	158	July 19, 1946	27	2	1			
No. 11	228	Aug. 21–23, 1946	48	5				
Sum			212	25	6	2	1	
Georges Bank:								
No. 7	189	Jan. 28–31, 1945	23	0	0	1		
No. 8	100	Jan. 17–18, 1946	6	1				
No. 14	51	Aug. 28–31, 1949	19	1	0	1		
Sum			48	2	0	2		
Cape Cod:								
No. 3	405	Mar. 18, 1942	24					
No. 9	138	June 14, 1946	22	8	4	0	1	1
No. 12	270	May 26–27, 1948	7	0	1			
No. 13	159	June 8, 1948	4	5	0	1		
Sum			57	13	5	1	1	1

These estimates of mortality are subject to several tagging difficulties, as well as to changes in fishing pressure. First, as has been pointed out, we probably experienced some mortality among the tagged fish shortly after the fish were released. Whenever the tagged fish were exposed immediately to a heavy fishery, as was usually the case, undoubtedly some that would have died soon were caught, thus tending to give a larger number of returns in the first year than would be experienced in the second from the same rate of fishing. The result of this would be an estimate of the annual expectation of death greater than the actual value. Secondly, loss of tags through corrosion of the pins probably took place somewhat after the immediate tagging mortality; but we judge that our losses from this cause were small (see p. 180), although we cannot accurately evaluate them. Lastly, changes in fishing pressure influenced the number of returns. This cannot be accurately evaluated because we do not know the amount of fishing pressure on each population. The fishing pressure on the southern New England stock (table 24) declined from 6,264 days in 1942 to 2,859 in 1945, increased to 4,698 days in 1948 and dropped to 2,843 days in 1949. Except for 1949, it did not change more than 30 percent in any year. Since most of our sums of returns in successive years include experiments conducted during periods of both declining and increasing fishing effort, we have chosen not to adjust our return data by the amount of fishing.

The estimates of mortality in the southern New England stock are lower than similar estimates in the Georges Bank stock for which (table 33) almost all of the tags were returned during the first year. In the Georges Bank stock, the survival rate from the first year to the second was only $\frac{2}{48}$, or an annual expectation of death of 0.96. The proportion of returns in successive years was similar in all lots. Reference to table 4 indicates that in two of the releases off Georges Bank, lots No. 7 and No. 8, a great number of returns were experienced in the first week after tagging, but in lot No. 14 the returns were well scattered through the year after tagging, and yet no different proportion was obtained in successive years.

The mortality rate computed for the Cape Cod stock is lowest of all (table 33). Here we obtain the values for the annual expectation of death of 0.77 between the first year and the second after tagging and of 0.62 between the second year and the third after tagging. These values perhaps should be even lower than this because we have included lot No. 3, which was tagged under extremely difficult weather conditions and showed no returns after the first year. If we consider only lot Nos. 9 and 13, we find an annual expectation of death of 0.50 between the first year and the second after tagging.

When we associate these mortality rates with the trends in the yellowtail fishery we find a rather confusing relationship. As would be expected, the lowest mortality rate occurred in the Cape Cod stock where production was relatively stable, but the higher rates occurred, in one instance, when production was rapidly increasing and, in the other cases, when production was seriously declining. We have no explanation for this, but it is clear that a high mortality rate from such computations is not evidence per se of a dangerous fishing rate.

Mortality and Apparent Abundance of Age Groups

The basic data for our third method of estimating total mortality are to be found in tables 23 and 29, which show the percentage age composition and the catch per day in numbers of fish of the southern New England stock. These data, when combined in table 34, provide estimates of the catch per day in numbers of each age group in each quarter from the fourth quarter of 1942 through 1947. From these data we shall select the apparent abundance of homologous groups or age classes in successive years, and this may be done more easily if the data are reorganized to show the abundance of each year class in each year (table 35).

TABLE 34.—*Catch per day in numbers of yellowtail, of each age from the southern New England stock, 4th quarter of 1942 through 1947*

[Based on tables 23 and 29]

Year and quarter	Number of fish having—							All fish [1]
	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli	
Year 1942:								
4th quarter	387	4,800	4,413	1,164	921	534	194	12,413
Year 1943:								
1st quarter	364	1,793	1,596	1,008	504	476	------	5,742
2d quarter	------	762	3,068	1,193	565	368	134	6,090
3d quarter	------	1,909	6,293	3,323	424	354	70	12,373
4th quarter	14	1,577	2,205	1,173	475	112	56	5,612
Year 1944:								
1st quarter	62	1,555	2,177	1,244	311	436	------	5,786
2d quarter	------	275	5,776	385	275	110	------	6,821
3d quarter	------	976	6,835	1,674	488	------	69	10,043
4th quarter	34	838	1,795	735	325	342	103	4,171
Year 1945:								
1st quarter	206	1,083	1,585	1,324	623	526	------	5,347
2d quarter	------	426	2,010	2,071	609	244	731	6,091
3d quarter	76	5,551	2,511	3,380	756	282	57	12,613
4th quarter	25	3,003	1,569	2,657	1,224	420	235	9,133
Year 1946:								
1st quarter	232	2,275	1,671	1,012	566	250	------	6,007
2d quarter	------	2,258	1,936	2,904	968	------	------	8,066
3d quarter	11	5,630	834	2,078	1,508	251	57	10,369
4th quarter	40	2,793	1,097	1,032	1,633	440	152	7,187
Year 1947:								
1st quarter	487	1,868	1,435	650	568	406	------	5,415
2d quarter	------	827	2,025	662	1,120	599	178	5,412
3d quarter	25	4,646	4,646	1,211	1,186	519	99	12,332
4th quarter	------	2,049	1,620	776	616	482	107	5,650

[1] Slight discrepancies occur due to rounding off of the figures.

We have computed the apparent survival, s,[12] between age groups as an average of the several years during which we observed the fishery by summing the catch per day for each year class that appears in each age group, and then determining the ratio between successive age groups (table 36). For example, in the first quarter we have computed the ratio 1.024 between age groups 2 and 3 as follows:

[12] We computed the apparent survival to avoid difficulties with apparent minus mortalities resulting from changing availability.

TABLE 35.—*Catch per day in numbers of yellowtail, by year class and quarter, from the southern New England stock, 1937–44*

Quarter and year class	Number of fish caught having—						
	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli
1st quarter:							
1937	------	------	------	------	504	436	------
1938	------	------	------	1,008	311	526	------
1939	------	------	1,596	1,244	623	250	------
1940	------	1,793	2,177	1,324	566	406	------
1941	364	1,555	1,585	1,012	568	------	------
1942	62	1,083	1,671	650	------	------	------
1943	206	2,275	1,435	------	------	------	------
1944	232	1,868	------	------	------	------	------
2d quarter:							
1937	------	------	------	------	------	------	------
1938	------	------	------	------	565	110	731
1939	------	------	------	1,193	275	244	------
1940	------	------	3,068	385	609	------	178
1941	------	762	5,776	2,071	968	599	------
1942	------	275	2,010	2,904	1,120	------	------
1943	------	426	1,936	662	------	------	------
1944	------	2,258	2,025	------	------	------	------
3d quarter:							
1938	------	------	------	------	424	------	57
1939	------	------	------	3,323	488	282	57
1940	------	------	6,293	1,674	756	251	91
1941	------	1,909	6,835	3,380	1,508	519	------
1942	------	976	2,511	2,078	1,186	------	------
1943	------	5,551	834	1,211	------	------	------
1944	------	5,630	4,646	------	------	------	------
4th quarter:							
1937	------	------	------	------	921	112	------
1938	------	------	------	1,164	475	342	235
1939	------	------	4,413	1,173	325	420	152
1940	------	4,800	2,205	735	1,224	440	107
1941	387	1,577	1,795	2,657	1,633	482	------
1942	14	838	1,569	1,032	616	------	------
1943	34	3,003	1,097	776	------	------	------
1944	25	2,793	1,620	------	------	------	------

$$s = \frac{\Sigma C3_{40} + \ldots\ C3_{43}}{\Sigma C2_{40} + \ldots\ C2_{43}}$$

in which $C3_{40}$ indicates the catch per day of 3-annuli fish of a 1940 year class, and so on. The data have been kept by quarters because of our previous observations that different populations tended to be available in different quarters.

TABLE 36.—*Mean apparent survival between age groups of yellowtail in the southern New England stock*

[Computed from abundance indexes for fourth quarter of 1942 through 1947]

Quarter	Ratio between age groups—				
	2 and 3	3 and 4	4 and 5	5 and 6	6 and 7+
1st	1.024	0.745	0.451	0.807	------
2d	3.157	.471	.454	.394	2.568
3d	1.054	.506	.376	.331	.385
4th	.637	.575	.632	.392	.376
Geometric mean	1.214	.565	.470	.451	.719
Mean instantaneous mortality rate, i	.194	.571	754	.796	.330

Several anomalies occur in the apparent survival data. The ratios greater than 1 between age-groups 2 and 3 are doubtless due to increasing availability, because, as was presented in table 30, the 3-year-old yellowtail comprised the largest fraction of the landings. We suspect also that the mean apparent survival ratio of 0.565 between age-groups 3 and 4 may be a little high for the same reason. At any rate, the survival rate seems to level off at 0.470 between age-groups 4 and 5 and at 0.451 between age-groups 5 and 6. Beyond age-group 6, the apparent survival ratio jumps again to 0.719; but this is not a good estimate because too few age determinations were used and the age-groups 6 and older were combined in the first quarter and age-groups 7 and older in the other quarters.

The year-to-year survival rate has been obtained by comparing the catch per day for age-groups 3 and older with the same group a year later (table 37). For example, the comparison of 1943–44 in the first quarter was made from the following formula:

$$s=\frac{C4_{40}+C5_{39}+C6_{38}}{C3_{40}+C4_{39}+C5_{38}+C6_{37}}$$

$C3_{40}$ are the 3-annuli fish of the 1940 year class; $C6_{38}$ are the 6-annuli fish of the 1938 year class, et cetera. Here we find a low survival rate from 1943 to 1944, a high value for the next year, and a decline from 1945 to 1947. If we compare year-classes 1942 and 1943 for the fourth quarters only, we find the survival rate is even lower than from 1943 to 1944.

TABLE 37.—*Mean apparent survival between years of yellowtail in the southern New England stock*

[Computed from abundance indexes of age groups 3 and older]

Quarter	Ratio between—				
	1942 and 1943	1943 and 1944	1944 and 1945	1945 and 1946	1946 and 1947
1st	--------	0.556	0.593	0.450	0.464
2d	--------	.144	.558	.683	.441
3d	--------	.213	.494	.557	.638
4th	0.251	.374	1.375	.533	.455
Geometric mean	.251	.283	.688	.550	.494
Mean instantaneous mortality rate, i	1.382	1.262	.374	.596	.705

Survival rates computed from the abundance indexes average substantially higher than rates computed from the tagging returns in successive years. This discrepancy may result from several factors. The tagged yellowtail may have been caught from a group whose migratory habits made it more available to the fishery and thus actually suffered a higher mortality rate than the average for the stock. Other factors which we believe had only a small effect on the computing of survival rates were the immediate tagging mortality, the continuing loss of tags, and possibly the slightly higher, continuing death rate of tagged fish. The significance of the first factor will be more obvious after we examine the relation between fishing effort and total mortality.

We sought an estimate of natural mortality, q, by modifying the method proposed by Silliman (1943), who in effect considered the relation between the total instantaneous mortality rate, i, and fishing effort, f, and then extrapolated to zero fishing to find the natural mortality. We have estimated the total instantaneous mortality rate, i, for yellowtail 3 years and older (table 37), and related it to the appropriate amount of fishing, f, (table 24). For example, i computed for the fourth quarter of 1942 to the fourth quarter of 1943, was compared with the amount of fishing from the fourth quarter of 1942 through the fourth quarter of 1943. For the succeeding annual averages, the corresponding fishing effort was con-

TABLE 38.—*Relation of total mortality rate,* i, *to amount of fishing effort,* X

[The total mortality rate, i, has been computed from the relative apparent abundance of 3-year old and older fish in quarter N and the 4-year old and older fish in quarter $N+4$. The fishing effort X has been computed for various periods as follows: X_1=effort in quarter N, X_2 in quarters N and $N+1$, X_3 in quarters N, $N+1$, and $N+2$, X_4 in quarters N, $N+1$, $N+2$, and $N+3$]

Year and quarter	i	X_1	X_2	X_3	X_4
1942–43: 4th quarter	1.38	1,515	3,547	4,790	6,128
1943–44:					
1st quarter	.59	2,032	3,275	4,613	5,453
2d quarter	1.94	1,243	2,581	3,421	5,219
3d quarter	1.55	1,338	2,178	3,976	4,890
4th quarter	.98	840	2,638	3,552	4,260
1944–45:					
1st quarter	.52	1,798	2,712	3,420	3,927
2d quarter	.58	914	1,622	2,129	3,059
3d quarter	.71	708	1,215	2,145	2,467
4th quarter	−.32	507	1,437	1,759	2,465
1945–46:					
1st quarter	.80	930	1,252	1,958	2,859
2d quarter	.38	322	1,028	1,929	2,944
3d quarter	.58	706	1,607	2,622	2,994
4th quarter	.63	901	1,916	2,288	2,950
1946–47:					
1st quarter	.77	1,015	1,387	2,049	3,369
2d quarter	.82	372	1,034	2,354	3,302
3d quarter	.45	662	1,982	2,930	3,737
4th quarter	.79	1,320	2,268	3.075	3,861

CORRELATION COEFFICIENTS

r

$i\ X_1=0.37$
$i\ X_2=0.43$
$i\ X_3=0.55$
$i\ X_4=0.68$

Regression:
$i=-0.397+0.000312\ X_4$

476995 O—59——4

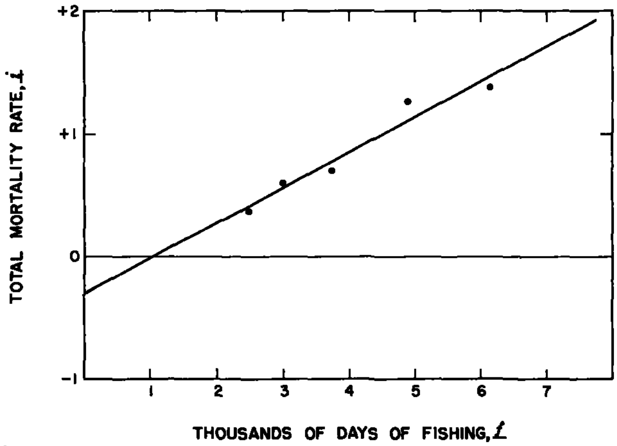

FIGURE 22.—Relation of total instantaneous mortality rate, i, and fishing effort, f, in the southern New England stock.

sidered to be from the third quarter of one year through the second quarter of the following year.[13]

When we assume a linear relation between fishing effort and mortality and compute the regression (fig. 22), we find

$$i = -0.302 + 0.288\, f$$

when f is the amount of fishing in thousands of days.

By definition $i=p+q$ and, of course, when $p=0$, $i=q$, but q must be positive. Therefore, an estimate of $i=-0.302$ with no fishing cannot be interpreted as $q=-0.302$. Since our estimate of i was based on abundance indexes computed from the fishing effort of the fleet, we immediately suspected that the availability of the fish was not constant. Not only was it not constant or even random, but there must have been an average annual increase in availability of 0.302 $+q$, if we are to accept the relation of the apparent total mortality to the amount of fishing.

Some additional evidence of increasing availability may be found in the length composition curve (fig. 7). Ricker (1948) and others have considered that the ascending left limb and dome of age-frequency curves represent groups of fish not fully available to the fishery. This applies equally well to length-frequency curves when the rate of growth in length is uniform (as it very nearly is in yellowtail in the catch). If we accept this interpretation, then clearly the males less than 33 cm. long were not fully available nor were the females less than 39 cm., although this is less clear due to the spread-out curve. If we assume that changing availabilty is a function of length rather than age, we observe that among males most 2-year-olds, about half of the 3-year-olds, and some 4-year-olds, were below the 33-cm. point of inflection (age and length-frequency data in appendix table D–2, p. 254). Even older females were below the 39-cm. size, as well as most 2- and 3-year-olds, about half of the 4-year-olds, and some 5- and 6-year-olds. Such evidence suggests that there was increasing availability to a large extent among 2- to 4-year-olds, the most abundant age groups in the fishery, and to some extent among most of the other age groups.

Not only is there evidence of increasing availability with age, but also of erratic changes in availability due to other causes. Such is indicated by the increases in catch per day of certain year classes at advanced ages (table 35). The 1940 year class (age 5, fourth quarter) and the 1943 year class (age 4, third quarter) are examples. The great variability in the rate of decline of the year classes and the erratic changes in the seasonal catch (p. 197) suggest that changes in availability are common occurrences.

There is also evidence of increasing availability with time, because 2-year-old yellowtail apparently became more available to the fishery during the period of study. We have previously noted that the 1941 year class was probably an especially good one, and this is borne out by the data in table 35 which show that this year class usually was the most abundant among the fish with 3 or more annuli, from the second quarter through the fourth. We notice, however, that it was not especially available as 2-year-olds, for in none of the quarters did it make any particularly large contribution. On the other hand, the 1943 and 1944 year classes were especially abundant as 2-year-olds during the third and fourth quarters (table 35), but the 1943 year class was scarce among the older age classes in subsequent years.

[13] We also attempted to relate the annual mortality rate for each quarter to the fishing effort. The mortality, i, was computed from the relative apparent abundance of 3-year-old and older fish in quarter N and of the 4-year-old and older fish in quarter $N+4$. Various combinations of fishing effort (table 38) were tried to find the best correlation with mortality, and the most satisfactory combination was found to be quarters N through $N+4$ ($r=0.68$). The correlation between mortality and effort in quarter N was only 0.37, which is not statistically significant. The best regression was $i=-0.379+0.312f$, with f expressed in thousands of days.

The 1944 year class was abundant as 3-year-olds but probably not later, because the total yield of the fishery continued to decline.

With this problem of changing availability, we cannot fix the total annual mortality rate or even estimate the proportions due to fishing and natural causes. We can state that among fish on the grounds completely available to the fishery the total annual fishing rate is very high as indicated by the average m of 0.86, which was computed from early tag returns. Also it is certain that the total annual mortality rate of the whole stock was considerably less during the period of study as a result of not being fully available.

REPRODUCTION

Early in the yellowtail investigation we collected material from the commercial fishery at New Bedford, Mass., to provide information on the breeding habits of the yellowtail. Data were obtained on the age and length at maturity and on the spawning season of the yellowtail landed from the southern New England stock. Attempts to collect information on the juveniles were unsuccessful;[14] however, we are able to present data on yellowtail eggs and larvae which resulted from the extensive plankton work undertaken by O. E. Sette in his study of the eggs and larvae of the mackerel.

Age and Length at Maturity

At the peak of the spawning season in May 1943, 288 yellowtail were obtained at random from the commercial landings at New Bedford, measured, sex and condition of the gonads determined, and scale samples obtained. At this time it was simple to classify the individuals according to stage of maturity and, in mature females, whether ripe or spent (table 39).

Determination of the age of these fish revealed that most individuals of both sexes mature during their second and third years, although a larger percentage of the males mature at a younger age and smaller size. Of the females aged, 52 percent were mature at 2 years, 67 percent at 3 years, and 100 percent at 4 years and older. Of the males, 84 percent were mature at 2 years, 92 percent at 3 years, and 100 percent at 4 years and older.

If we extend the results of this sample to obtain an estimate of the proportion of immature individuals in the catch during the spawning seasons in the period during which we have studied this fishery, we must assume that the proportion of immature fish found in May 1943 is representative of that obtained in other years. This seems a likely assumption inasmuch as we have already pointed out that only very slight changes in growth rate and in length composition were noted during the period of study, 1942 to 1947. Therefore, if we apply our percentages of maturity to the summarized age composition for the second quarters of the years 1942 to 1947 (appendix table D–2, p. 254), we estimate that during the second quarters 94 percent of the males and 84 percent of the females in the landings would be mature. The same percentages would apply to the landings during the spawning season, since (as will be shown in the next section) almost all of the spawning occurs during the second quarter.

The same data provide us with an estimate of length of the yellowtail at maturity, but since the majority of the males mature before they appear in the commercial catch, it is not possible to relate maturity to length with any precision. For our purpose it is adequate to know that the males do mature before entering the commercial catch and mostly before they attain the length of 26 cm. Females, however, mature after reaching commerial size and our sample appears adequate for determining the size at which they mature. The most reliable estimates can be obtained by assuming that the data form a sigmoid curve and by transforming the data to the probability integral or "probit."[15]

A line fitted to the transformed data resulted in the formula $y=-0.2176+0.1631x$ in which y equals the estimated probit and x equals the length in centimeters. The estimated probit was then transformed back to a percentage to find the points for the sigmoid curve in figure 23, and to provide the estimates that 50 percent of the female yellowtail in the landings were mature at a length of 31.98 cm. and 90 percent were mature at 40.17 cm. We may further compute the variance of the

[14] Fifty-six tows with a 1½-inch mesh shrimp trawl, at times lined with ¾-inch mesh in the cod end, were made inside the 20-fathom contour between Nantucket and Long Island at various times from July to October in 1943, 1945, and 1946. No juvenile or larval yellowtail were taken. (Data on file at the Woods Hole laboratory of the U. S. Fish and Wildlife Service.)

[15] A discussion of the use of probits for this purpose will be found in appendix F, p. 266.

TABLE 39.—*Number of mature and immature yellowtail, by length, sex, and age, from the southern New England stock, May 1943*

[I = immature; M = mature]

Length of fish	Stage of maturity of females with—										Stage of maturity of males with—									
	1 annulus		2 annuli		3 annuli		4+ annuli		Total		1 annulus		2 annuli		3 annuli		4+ annuli		Total	
	I	M	I	M	I	M	I	M	I	M	I	M	I	M	I	M	I	M	I	M
26.5 cm			2						2					1						1
27.5 cm			2		1				3				1	1					1	1
28 cm			4						4					1						1
29 cm	1		2						3				1	2					1	2
30 cm			6	2					6	2				2		3				5
31 cm			2	3	1	1			3	4				4		6				10
32 cm			3	5	5	8			8	13			2	7		9			2	16
33 cm			3	9	4	7			7	16				1	1	4		2	1	7
34 cm			1	3	2	7			3	10				1	1	4		1	1	6
35 cm			1	2	5	4		1	6	7					2	7		3	2	10
36 cm				1	6	8		2	6	11						7		4		11
37 cm				2	1	5		2	1	9				1		2		2		5
38 cm				1	4	6		4	4	11								1		1
39 cm					1	6		5	1	11						1				1
40 cm						3		11		14										
41 cm						3		7		10										
42 cm						2		9		11										
43 cm								5		5						1		1		2
44 cm								2		2										
45 cm								4		4										
46 cm								2		2										
48 cm								1		1										
50 cm								1		1										
Total	1		26	28	30	60		56	57	144			4	21	4	44		14	8	79
Percent mature				52		67		100						84		92		100		

50-percent point as $s^2=0.946$. From this it follows that the standard error $s=0.973$ and the 95-percent fiducial limits are 30.03 and 33.93 cm.

Spawning Season

Only scattered information on the spawning season of yellowtail has been available. Bigelow and Welsh (1925: p. 499) observed that spawning commences near Gloucester, Mass., by the middle of March and seemingly lasts all summer. They also found young larvae off Sandy Hook, N. J., on August 1, 1913. Perlmutter (1939) found pelagic larvae off Long Island, N. Y., in the vicinity of Montauk Point, Jones Inlet, and Fire Island Inlet, between May 16 and June 17, 1938; and between June 8 and June 17 he found bottom-living postlarval stages near Moriches Inlet, Jones Inlet, and Fire Island Inlet. The larvae observed off New York and New Jersey belonged to the southern New England stock of yellowtail flounder, but they were considerably removed from the location of the fishery during the spawning season, which was centered off No Mans Land and Block Island during our study.

During the spring of 1943 the catch from these areas, which was being landed at New Bedford, was sampled periodically and the number of each sex and the stage of maturity of the females recorded (table 40). All females were dissected and the ovaries were easily classified into the three categories of immature, mature, and spent. The inside of the immature ovary appears reddish and somewhat gelatinous to the unassisted eye, whereas the developing ova cause the mature ovary to have a granular appearance several months before spawning. After the fish spawns, the ovarian contents are watery for several weeks, usually include some unspawned eggs, and often exhibit blood clots. Table 40 records the date on which the vessel landed; the fish were captured 1 to 4 days earlier. This lag could introduce error if the ripe fish have the spawn squeezed out of them by pressure in the fish hold and so be classified as spent. However observations indicated that pressure affected only a small proportion of the fish and no correction in the date was warranted.

Estimates of the peak and duration of the spawning period were obtained by transforming the data to probits (calculations are given in appendix F, p. 266), and by fitting a line as indicated in figure 24 which resulted in the formula $y=8.281+0.04348x$, in which y equals the estimated probit and x equals the day of the year less 100. From this formula the following points were

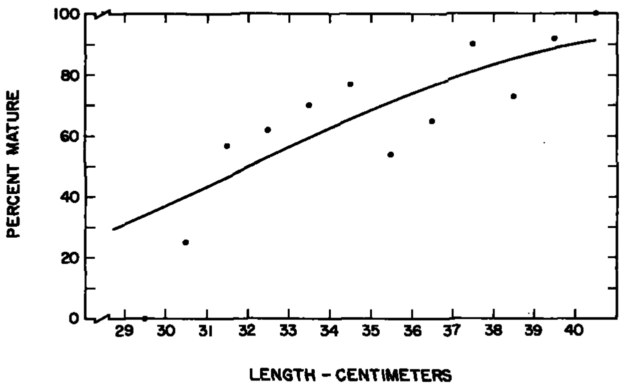

FIGURE 23.—Relation of length to percent mature of female yellowtail.

TABLE 40.—*Percentage of spent female yellowtail sampled from the southern New England stock during the 1943 spawning season*

Date vessel landed	Number of mature females examined	Spent		Date vessel landed	Number of mature females examined	Spent	
		Number	Percent			Number	Percent
Apr. 20	60	6	10.0	June 23	46	41	89.1
Apr. 20	62	3	4.8	June 28	50	49	98.0
Apr. 20	72	7	9.7	June 29	63	62	98.4
Apr. 20	50	9	18.0	July 4	50	50	100.0
Apr. 27	57	11	19.3	July 22	41	41	100.0
Apr. 27	66	14	21.2	July 23	25	25	100.0
May 4, 6 [1]	43	7	16.3	July 26	33	33	100.0
May 7	54	13	24.1	July 27	69	69	100.0
May 17	27	12	44.4	July 29	53	53	100.0
May 18	41	23	56.1	July 29	50	50	100.0
June 3, 7, 8 [1]	21	15	71.4	July 30	45	45	100.0
June 9	34	23	67.6				
June 16	45	41	91.1	Total	1,157	702	------

[1] Included some unusually small samples.

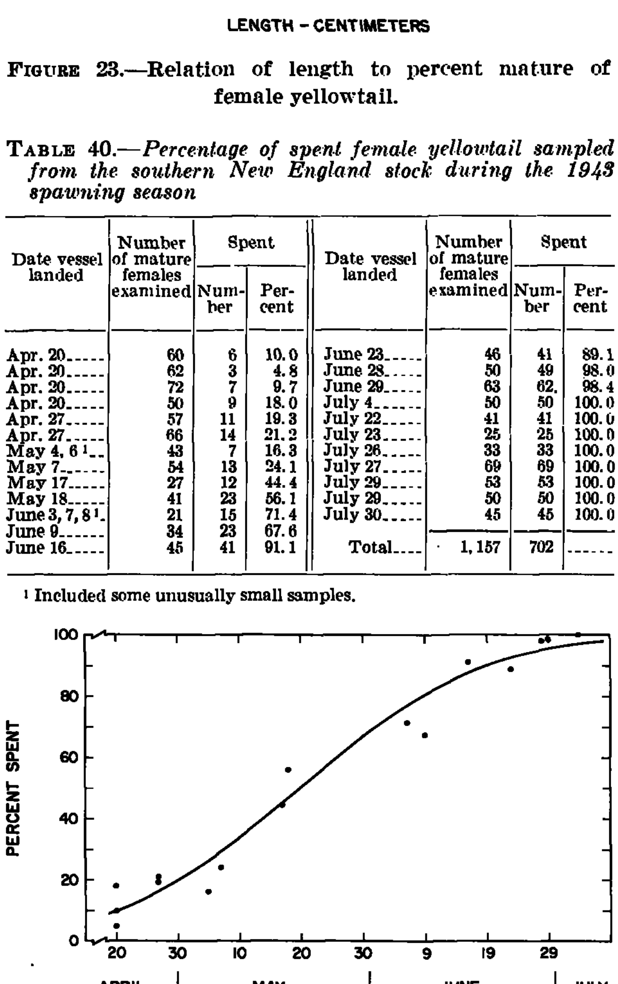

FIGURE 24.—Relation of date to percent spent in female yellowtail from the southern New England stock in 1943.

developed: (1) Ninety percent of the yellowtail spawned between April 12 and June 26; (2) the peak of spawning (the point of greater slope on a sigmoid curve) and the day on which half of the yellowtail spawned was May 20; (3) the period of heaviest spawning was from May 4 to June 4 during which 50 percent of the females became spent.

Distribution of Eggs and Larvae

Because the yellowtail shares with the mackerel the habit of spring spawning in the area between Cape Cod and Chesapeake Bay as well as the feature of pelagic eggs and larvae, we benefited from the mackerel investigations conducted by O. E. Sette (1943). The field work, from 1925 through 1932, included quantitative surveys of the distribution of mackerel eggs and larvae, and on these cruises large quantities of yellowtail eggs and larvae were taken in the plankton nets. Sette recalls that year after year the yellowtail seemed to be one of the most abundant spring spawners in the area. Quantitative data on yellowtail eggs and larvae from two cruises in April and May 1929 and on larvae only from a series of cruises in 1932 are available for analysis. In both years, a series of stations was established along section lines across the Continental Shelf. The lines were named after the nearest land feature and the stations were consecutively numbered seaward on each line from I (fig. 25).

Our task was eased by several reports that have appeared. The 1932 survey, the only one to cover adequately the range and spawning period of the mackerel (Sette 1943), included estimates of the mortality rates of the mackerel eggs and larvae and of the total number of eggs spawned. Other findings have been included in reports on the cycle of temperature by Bigelow (1933), the salinity by Bigelow and Sears (1935), and a volumetric study of the zooplankton by Bigelow and Sears (1939). A detailed account of methods used in the 1932 survey is given in Sette (1943) and the complete temperature and salinity observations for all years are reported by Bigelow (1933).

From our knowledge of the yellowtail spawning season, it appears that the period of the mackerel surveys, May 2 to July 24, 1932, covered the major part of the yellowtail spawning season (p. 217). Ninety percent of the yellowtail spawning off New Bedford in 1943 occurred between April 12 and June 26, but eggs have been taken from mid-March to September in various places (see p. 216). We would expect spawning to occur a little earlier in the warmer waters off New Jersey and a little later in the colder waters of the Gulf of Maine, north of Cape Cod.

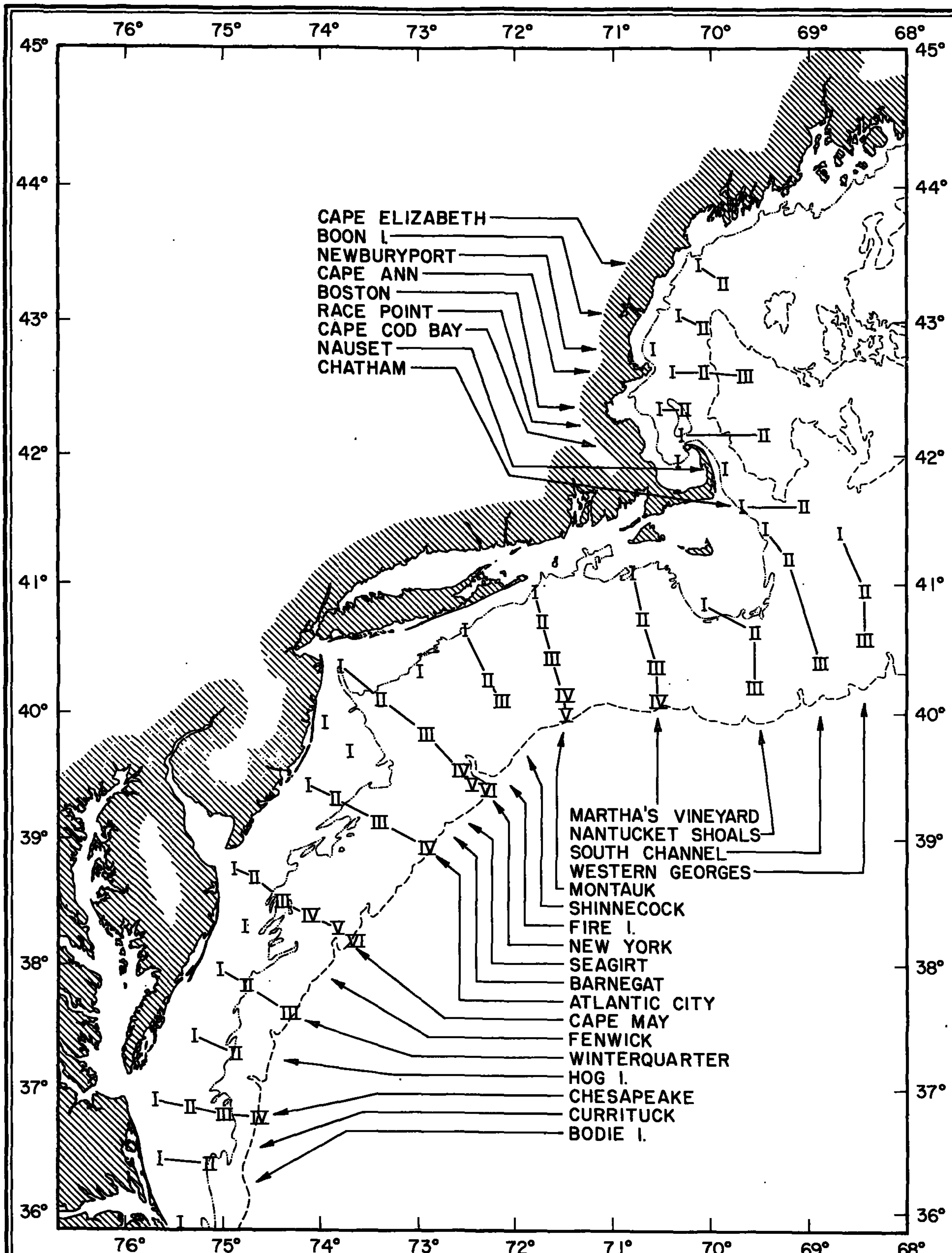

FIGURE 25.—Location of stations occupied during the 1929 and 1932 cruises.

Interpretation of the survey data would be easier if we had more information on the duration of the egg and larval stages. Bigelow and Welsh (1925) report that hatching takes place in 5 days at a temperature of 10° to 11° C. They judge further, from the stage of development, that the larvae descend to the ocean bottom when 14 mm. long, although Perlmutter (1939) reported that postlarvae caught in the bottom trawl ranged up to 12.6 mm. in length. This does not agree with Bigelow and Welsh's observation of 88 pelagic larvae 6.5 to 19 mm. long caught in a tow net off Sandy Hook on August 1, 1913. We conclude from these facts that the yellowtail may go to the bottom at lengths less than 12 mm., or even more than 19 mm., depending on conditions, but we remain ignorant of the duration of the larval period.

Horizontal distribution of eggs and larvae in 1929.—The plankton hauls during 1929 were made with nets, either 1 meter or ½ meter in diameter, towed horizontally at various levels at an average speed of 1.2 knots. The forepart of the nets had 29 to 38 meshes per linear inch, the rear part 48 to 54 meshes. For purposes of this paper, the hauls have been reduced to a standard basis of 20-minute tows with 1-meter nets.

During the April and May 1929 cruises, eggs and larvae of the yellowtail flounder were the dominant vertebrate form in the plankton (tables 41 and 42). The number of eggs taken ranged up to 37,000 at one station in April and to 79,000 in a tow in May. The eggs were taken on the April 12 to 24 cruise from the offing of Currituck, Va., to the northeasternmost stations off Block Island (fig. 26), but there was an impressive center of distribution off the coasts of northern New Jersey and Long Island. During the May 10 to 18 cruise, the southern limits of distribution of the eggs had moved about 150 miles to the northeast and a similar though less extensive movement was apparent in the principal center of the distribution, although a secondary center remained off Atlantic City. Distribution of the larvae corresponded closely to that of the eggs in both the April and May cruises though, of course, the numbers of larvae were markedly smaller.

The southern and offshore limits of the distribution of eggs in the April cruise agree well with the position of the 7°-C. isotherm at both surface

TABLE 41.—*Numbers of yellowtail eggs and larvae taken on the April 12–24 cruise in 1929*

[Weighted to basis of 20-minute tow with 1-meter net]

Locality and depth of tow	Station I		Station II		Station III		Station IV		Station V	
	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
Montauk Point:										
Surface	2,880	1	490	0	0	0	10	0	0	0
Intermediate										0
Deep	2,900	3	100	0	0	3	0	0	0	0
Shinnecock:										
Surface	8,300	39	124	0						
Deep	1,800	18	3	0						
New York:										
Surface	10,200	440	31,500	11	180	0	0	0	1	0
Intermediate							0	0	0	0
Deep	5,000	170	5,400	210	34	0	0	0	0	0
Atlantic City:										
Surface	1,600	3	24,200	0	5,600	0	0	0		
Intermediate							0	0		
Deep	730	50	400	0	170	0	0	0		
Cape May:										
Surface	0	0	1,359	0	1,170	0	0	0		
Deep	0	0	70	3	30	0	0	0		
Fenwick:										
Surface		0								
Deep	3	0								
Winterquarter:										
Surface	16	0	173	0	0	0				
Deep	40	0	280	0	0	0				
Hog Island:										
Surface	7	1	400	0						
Deep	26	0	140	3						
Chesapeake:										
Surface	0	0	11	0	273	0	0	0		
Intermediate							0	0		
Deep	0	0	90	0	100	0	2	0		
Currituck:										
Surface	50	0	48	1						
Deep	0	0	21	0						
Bodie Island:										
Surface		0								
Deep		0								

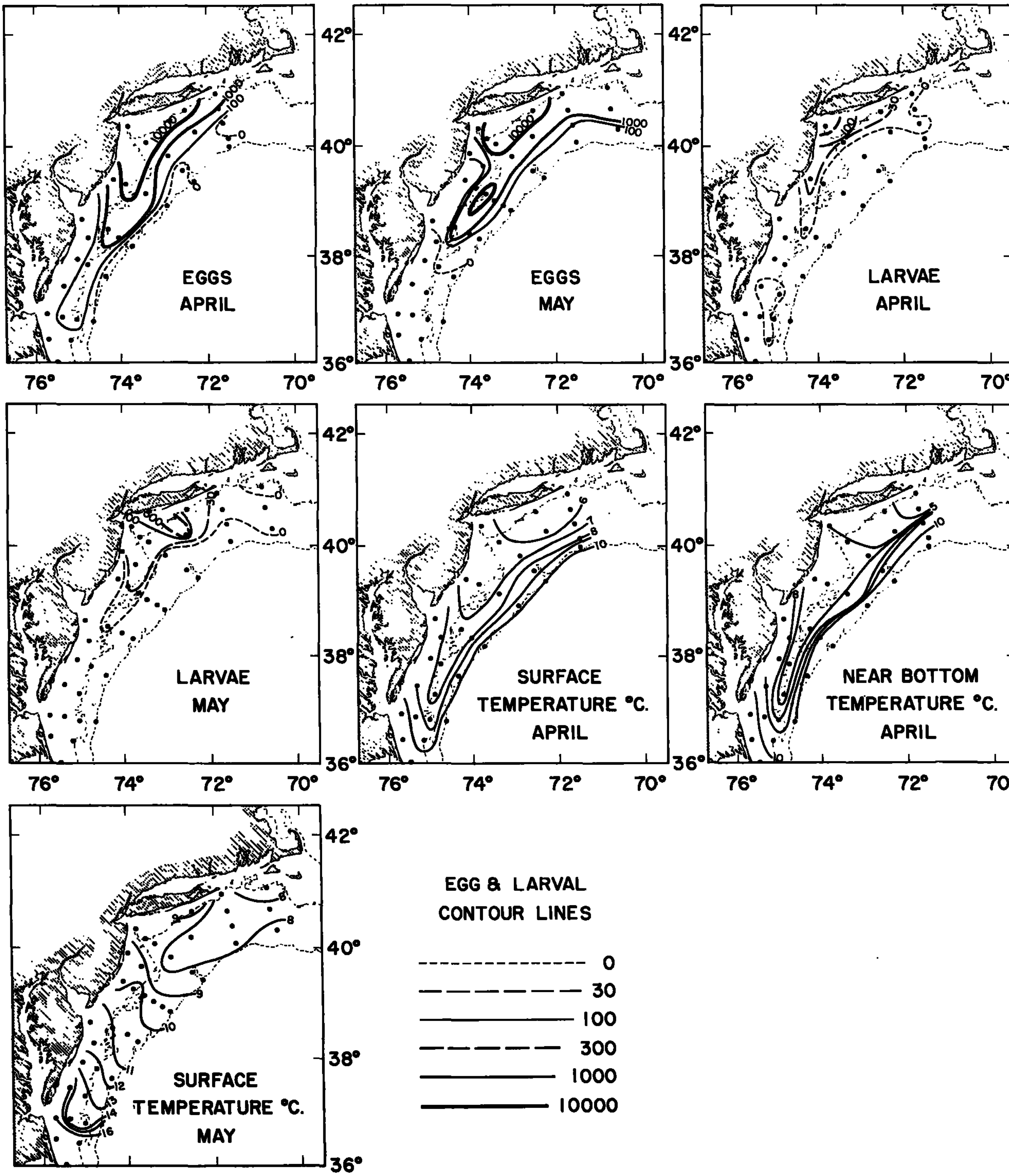

FIGURE 26.—Horizontal distribution of eggs and larvae, and surface and bottom temperatures during the 1929 cruises of April 12 to 24 and May 10 to 18. The egg and larval contour lines represent the numbers caught per standard tow of 20 minutes by a 1-meter net.

TABLE 42.—*Numbers of yellowtail eggs and larvae taken on the May 10–18 cruise in 1929*

[Weighted to basis of 20-minute tow with 1-meter net]

Locality and depth of tow	Station I		Station IA		Station II		Station IIA		Station III		Station IIIA		Station IV	
	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
Martha's Vineyard:														
Surface	3,500	0	-----	-----	7,000	0	-----	-----	0	0	-----	-----	-----	-----
Deep	1,600	0	-----	-----	900	2	-----	-----	1	1	-----	-----	-----	-----
Montauk Point:														
Surface	4,000	0	-----	-----	1,000	0	-----	-----	9	0	-----	-----	0	0
Deep	2,400	15	-----	-----	20	2	-----	-----	1	0	-----	-----	16	0
Shinnecock:														
Surface	11,000	15	-----	-----	2,000	24	-----	-----	-----	-----	-----	-----	-----	-----
Deep	3,000	65	-----	-----	350	25	-----	-----	-----	-----	-----	-----	-----	-----
Fire Island:														
Surface	-----	-----	76,000	560	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Deep	-----	-----	2,800	48	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
New York:														
Surface	2,000	1	24,000	2	32,000	7	-----	-----	157	0	-----	-----	2	0
Deep	2,400	95	-----	-----	2,700	35	-----	-----	20	0	-----	-----	0	0
Barnegat: Surface	300	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Seagirt: Surface	8	65	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Atlantic City:														
Surface	0	0	-----	-----	1,000	6	15,000	0	1,000	0	100	0	3	0
Deep	6	0	-----	-----	1,000	23	-----	-----	12	0	-----	-----	0	0
Cape May:														
Surface	8	0	8	1	2,400	0			7	0	-----	-----	11	0
Deep	0	0	-----	-----	210	0	-----	-----	3	0	-----	-----	3	0
Fenwick:														
Surface	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Deep	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Winterquarter:														
Surface	0	-----	0	-----	0	-----	-----	-----	3	-----	-----	-----	-----	-----
Deep	0	-----	-----	-----	4	-----	-----	-----	0	-----	-----	-----	-----	-----

and bottom (fig. 26). (In these shoal waters at this time of year the upper 50 meters or so are nearly isothermal.) The lowest temperature recorded in any of the stations where eggs were taken was 4.8° C. at the bottom off Montauk Point. Evidently spawning had been proceeding prior to this April cruise when temperature conditions of 5° to 7° C. prevailed.

Recalling Bigelow's observation that hatching occurred in about 5 days at 10° C., we may deduce that hatching would require between 5 and 10 days at these lower temperatures of 5° to 7° C. Since larvae were found on April 18 that were several days old, it is apparent that spawning must have started in this area in early April at the latest. Size of the larvae during the April and May cruises (tables 43 and 44) provides a clue, however, that hatching had not long preceded the April cruise. During this cruise, the larvae ranged from 2 to 6 mm. in length, the bulk of them being about 3.5 mm. These larvae were smaller than those encountered during the May cruise, when the larvae ranged from 3 to 11 mm. in length, and were mostly 4 to 6 mm.

The close agreement in distribution of eggs and larvae suggests that hatching was completed and that the larvae had assumed their bottom-dwelling existence before much of the horizontal drift occurred. If this were not so we would expect a displacement in the centers and boundaries of the egg and larval distributions. Assuming that hatching was completed and the larvae had descended to the bottom, we may then note that the southernmost contingent of eggs and larvae off Virginia and Delaware disappeared from the surface waters by the time the temperature had risen above 11° C. Presumably, the eggs found in this area on April 17 to 19 had hatched and the larvae had descended to the bottom by May 14 to 16, when these southern stations were revisited.

At a station off Fire Island where yellowtail larvae were particularly abundant on May 17 and 18, 1929, a special series of tows was made to determine vertical distribution of the larvae (table 45). It may readily be seen that at all times the greatest number was located near the 10-meter level, but considerable numbers were taken during the night at the surface and at the 5-meter level. Relatively few were taken at any time at the 20- and 35-meter levels. This suggests some diurnal dispersion upward from the 10-meter level. Considerable differences are also apparent in the number of larvae taken during the night hauls—nearly twice as many larvae being obtained in the midnight series as were taken in the noon series, whereas morning and evening series were intermediate. Since there is no evidence that larvae retreated to levels below the net, it appears likely

TABLE 43.—*Yellowtail larvae taken April 12–24, 1929*

[Roman numerals indicate the localities (see fig. 25); numbers in parentheses indicate stations established during the mackerel studies, 1925–32 (see Sette 1943)]

Station and depth of tow	Number of larvae	Length (mm.)
Montauk Point:		
Station I (20456):		
Surface	1	3.5
Deep	1	5.0
Station III (20454): Deep	1	6.0
Shinnecock:		
Station I (20448):		
Surface	39	3.5
Deep	6	3.5
New York:		
Station I (20447):		
Surface	60	3.5
Deep	13	2.5–4.0
Station II (20446):		
Surface	11	4.0
Deep	19	3.5
Atlantic City:		
Station I (20439):		
Surface	3	3.0
Deep	14	2–3
Cape May: Station II (20438): Deep	1	4.0
Hog Island:		
Station I (20424): Surface	1	4.0
Station II (20432): Deep	1	4.0
Currituck: Station II (20428): Surface	1	4.0

TABLE 44.—*Yellowtail larvae taken May 10–18, 1929*

Roman numerals indicate the localities (see fig. 25); numbers in parentheses indicate stations established during the mackerel studies 1925–32 (see Sette 1943)]

Station and depth of tow	Number of larvae	Length (mm.)
No Mans Land:		
Station I (20457): Deep	1	6.0
Station II (20458): Deep	2	5 and 8
Station III (20459): Deep	1	6.0
Montauk Point:		
Station I (20463): Deep	16	4–6
Station II (20462): Deep	2	5 and 11
Shinnecock:		
Station I (20464):		
Surface	15	4–7, mostly 4.
Deep	71	4–6, mostly 5.
Station II (20465):		
Surface	4	3.5–5.5
Deep	8	3–4
Fire Island Station I (20498)		3–9
New York:		
Station I (20470):		
Surface	1	4.0
Deep	32	3.6
Station IA (20469): Surface	3	5.0
Station II (20468):		
Surface	9	4–8, mostly 6.
Deep	13	3–8, mostly 6.
Seagirt: Station I (20471): Surface	65	4–6, mostly 5.
Barnegat: Station I (20472): Surface	1	4.0
Atlantic City: Station II (20474):		
Surface	6	5–6
Deep	7	4–7
Cape May: Station IA (20482): Surface	1	8.0

that some of the larvae were escaping the net during the daylight hours. This is borne out in that the larvae averaged slightly larger (4.3 mm.) during the midnight tows than during the morning (3.6 mm.), noon (3.9), or evening (3.8) tows.

TABLE 45.—*Vertical distribution of yellowtail larvae (off Fire Island) at station A 20498, May 17–18, 1929*

Depth of tow	Estimated number of larvae taken in tows made—				Estimated total
	Morning	Noon	Evening	Midnight	
Surface	130	0	1	430	561
5 meters	58	0	98	521	677
10 meters	914	764	876	700	3,254
20 meters	81	34	4	34	153
35 meters	37			12	49
Total	1,220	798	979	1,697	4,694

Horizontal distribution of larvae in 1932.—Several factors prevented obtaining as complete information on the yellowtail during the cruises of the mackerel investigations in 1932 as in 1929. Between the 1929 and 1932 cruises, much was learned about the distribution of the mackerel eggs and larvae and better methods of quantitatively sampling them were developed. Some stations at the southern end of the series where mackerel eggs and larvae had not been taken in 1929 were dropped, and the 1932 cruises were delayed until May 1 so as to cover the mackerel spawning season more effectively. The method of towing was changed from horizontal to oblique, and the use of two nets, one at a lower level and the other at the upper level, was introduced. Compensation was made for variations in the amount of water strained by the addition of flowmeters to the nets which made it possible to convert the catch to the standard basis of numbers of larvae or eggs per 17.07 cubic meters of water strained per meter of depth fished. Finally, with the emphasis on mackerel, the large numbers of yellowtail eggs taken could not be counted; consequently, we have available counts only of the larvae taken on the 1932 cruises. These were divided into two sizes: large, those more than 5 mm. in length; and small, those from about 2.5 to 5 mm. Details of the methods of towing and counting may be found in Sette (1943). Complete counts of yellowtail larvae are given in appendix E, page 256.

The small larvae were found in considerable numbers on every cruise (fig. 27). On cruise 1 (May 2 to 6) the center of their distribution was from southern New Jersey to Virginia, but this changed abruptly during the following week, and on cruise 2 (May 9 to 16) two principal centers of distribution were found—off southern Massachusetts and off northern New Jersey. These centers

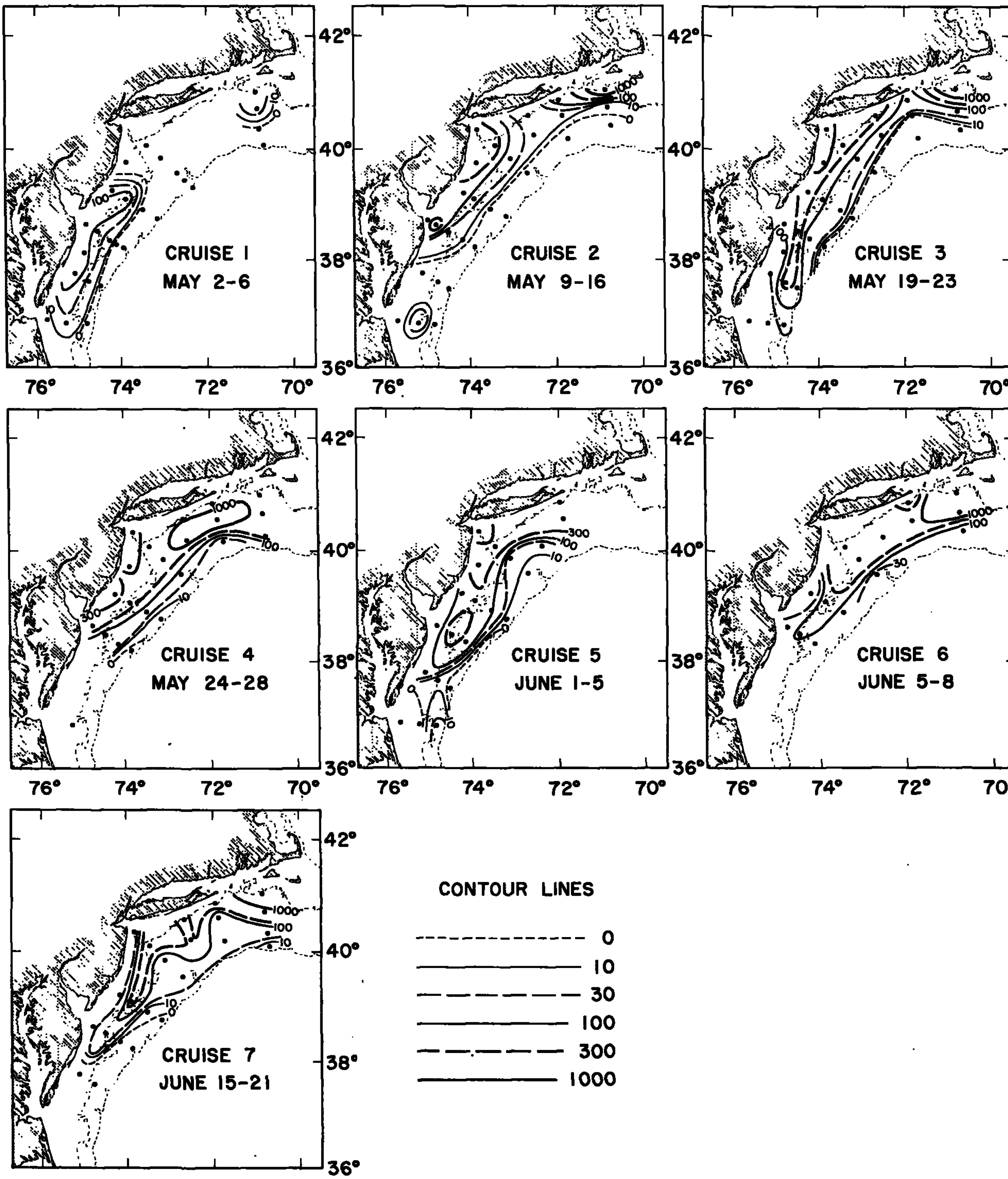

FIGURE 27.—Horizontal distribution of small yellowtail larvae during cruises in 1932. Contour lines represent the numbers taken in 17.07 cubic meters of water.

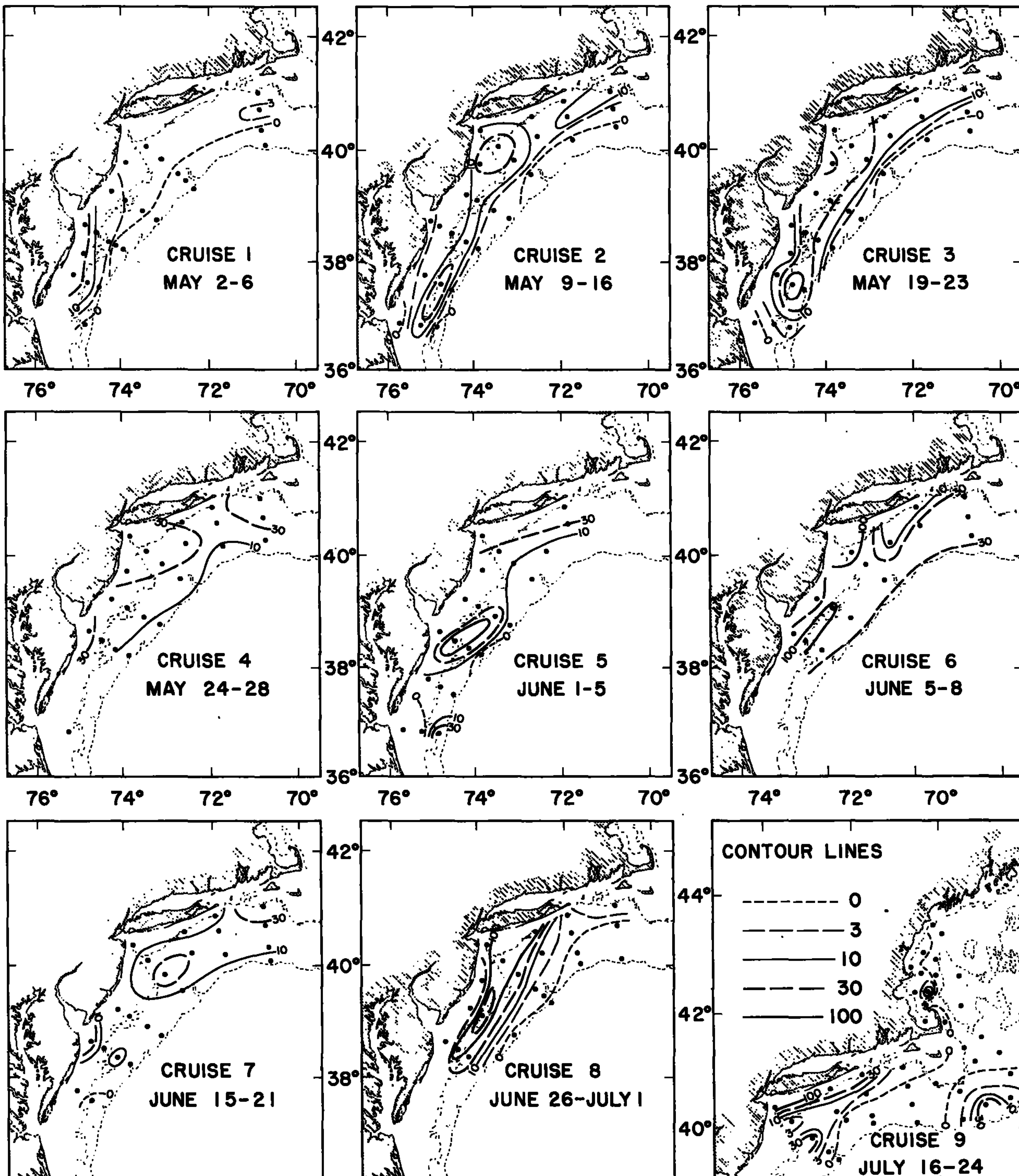

FIGURE 28.—Horizontal distribution of large yellowtail larvae during cruises in 1932. Contour lines represent the numbers taken in 17.07 cubic meters of water.

appear to have been augmented and spread out on cruise 3 (May 19 to 23), a pattern that continued to cruises 5 (June 1 to 5) and 6 (June 5 to 8). Beginning on cruise 6 and more noticeable on cruise 7 (June 15 to 19) is the reduction in the numbers of larvae found off New Jersey and Long Island as compared with those found off southern Massachusetts.

The distribution of the large larvae (fig. 28) was in most respects similar to that of the small, the principal differences being smaller numbers and the lesser variation in the catches of the large larvae. It is as though the peaks occurring in the distribution of the smaller larvae had had the opportunity to disperse somewhat.

The movement of one of the centers of distribution of the yellowtail is consistent with previous estimates of drift and, incidentally, provides an estimate of the duration of the small larval stage. In his study of the mackerel, Sette (1943) was able to identify and follow for a considerable period certain peaks in the frequency distributions of mackerel larvae, which he judged were produced by homologous groups that resulted from fluctuations in spawning. The movement during its passive phase of one of the most prominent of these groups, which he called the *S* group, was consistent with the wind movement. First found off Delaware Bay, this group moved about 60 miles south between cruises 1 and 2. The change in distribution of the small yellowtail larvae from that noted on cruise 1 and the northward movement of the southern center of large larvae observed on cruise 2 are in agreement with Sette's observations of the mackerel. This drift, coupled with the absence of small larvae at most of the stations where the southern center of large larvae was found on cruise 2, suggests further that the small yellowtail larvae progressed to the "large" stage in the 5 or 6 days intervening between the visits to the pertinent stations on cruises 1 and 2. If this were so, probably the groups of small larvae found on the later cruises had hatched from successive spawnings.

Further evidence of drift is suggested by the fact that the center of small larvae that persisted off Martha's Vineyard and/or Block Island from cruise 2 through cruise 7 was not followed by any special concentration of large larvae at these locations. We would expect a westerly or southwesterly drift to result from the prevailing coastal current—a conclusion strengthened also by Sette's discovery of a southwesterly drift of the northern center of larval mackerel off New Jersey during cruises 1 to 3. Since no special concentration of large larvae was found within a reasonable distance to the westward on cruise 3, these small larvae must have drifted north or east beyond the limits of the survey.

Further analysis of the drift of these groups of larvae appears fruitless because the yellowtail larvae were obviously more widely distributed than the mackerel which the cruises were designed to cover. In none of the cruises was the eastern limit of the yellowtail larvae included, and cruises 4, 6, and 9 (fig. 28) obviously did not cover the southwestern limits of their distribution. Furthermore, there was a considerable seaward spread of the large larvae, for on cruises 4 and 6 large larvae were found at every station that went to the edge of the Continental Shelf.

The depth distribution of yellowtail larvae found on the station off Fire Island in 1929 (table 45) was evidently not always typical of the distributions in 1932. No data from a similar special station are available for 1932, but at all of the deeper stations two levels were sampled by oblique tows. These were designed to sample the zone above the thermocline separately from the zone below. At this time the thermocline was usually about 20 meters down. On the average, more larvae were taken above the thermocline (appendix table E–3, p. 265), but at some stations all of the larvae were found below it (e. g., stations II and III off Atlantic City), and there were numerous instances of wide vertical distribution. No apparent relation existed between this distribution of the larvae and any factors of location, temperature, or time.

Temperature relationships found on these cruises (figs. 29 and 30) show the expected vernal warming with variations due to weather. The surface temperatures give evidence of a gradual seasonal increase interrupted by an invasion of cold water from the northeast at the time of cruise 2. This was compensated for by a spurt in the warming between cruises 4 and 5 followed by a gradual increase in water temperature through cruise 7. We note that the larvae were found in numbers when surface temperatures were as low as 8° C. on cruise 2 and as high as 20° C. on cruise 7.

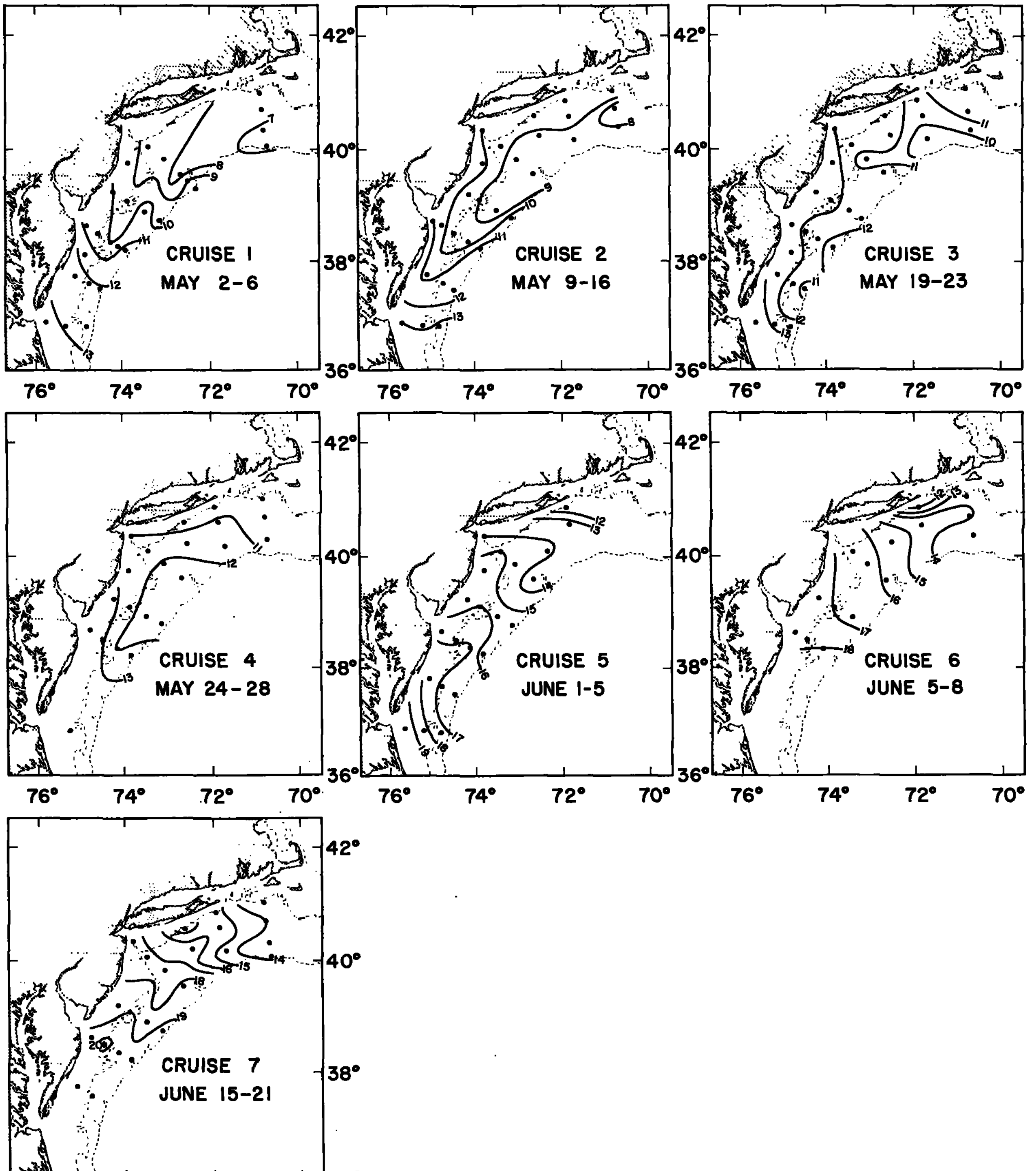

Figure 29.—Surface isotherms, 1932. (Temperature in degrees Centigrade.)

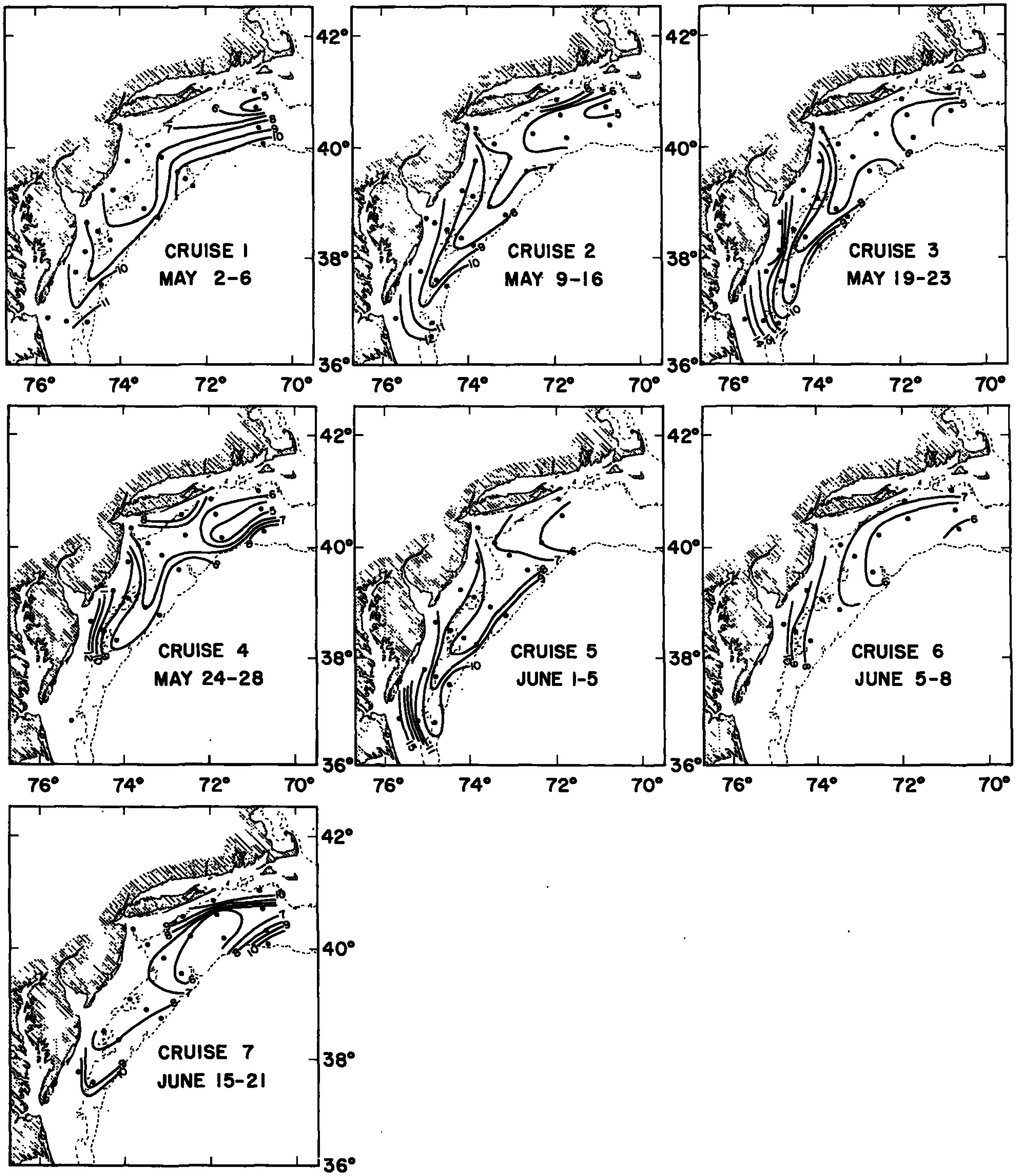

FIGURE 30.—Near-bottom isotherms, 1932. (Temperature in degrees Centigrade.)

The near-bottom temperatures, which may fairly well reflect the conditions actually pertaining during the spawning, were nearly all considerably lower than the surface temperatures. Near-bottom temperatures ranged from 4.9° C. off Martha's Vineyard on cruise 1 to about 12.3° C. on cruise 4 at the southern center of distribution of small larvae. Doubtless, spawning preceded these observations of temperature by some days, and therefore, at both ends of this range should perhaps be somewhat lower.

These temperatures give some evidence of considerable environmental changes. An invasion of warm water along the edge of the Continental Shelf south of Martha's Vineyard and Long Island occurred on cruise 1 and was strong enough to raise bottom temperatures to 10.9° C. at the edge of the shelf while the surface temperature was only 6.8°. The warming was immediately countered by cold water which persisted until after cruise 6 when at Martha's Vineyard station III the bottom temperature increased from 6.1° to 8° C. between cruises 6 and 7.

Such fluctuating temperature conditions probably occur most frequently along the edge of the Continental Shelf with the alternating invasion and retreat of the warm slope waters. The areas of gross temperature changes are not known to include the 15- to 35-fathom depth zone, which is probably inhabited by the spawning yellowtail, but Ketchum et al. (1951) found that the distribution of sea water diluted with river water in the New York bight varied greatly and could be altered suddenly by a storm. Such fluctuations in temperature must be a hazard to the larvae because of the accompanying movement of the water. The surveys show clearly that the larvae are distributed widely over the shelf and that when they descend to the bottom of the ocean they may encounter radically different bottom conditions and water temperatures. If yellowtail fry are as delicate as most fish fry, rather small differences in their environment may be fatal. Changes in temperature might even be catastrophic, as in the widespread destruction of the tilefish, which occurred along the edge of the Continental Shelf south of Block Island in March 1882 (Collins 1884). This occurrence is believed to have been caused by an invasion of cold water in an area normally warmed by the slope water during winter.

FAUNAL CHANGES ON THE YELLOWTAIL GROUNDS

In our studies of the fisheries in the New England area, we have found two examples of significant production of other species on yellowtail grounds. The first of these occurred when the landings of haddock from Nantucket Shoals rose to nearly 13 million pounds in 1928 and subsequently declined (table 46). These are the landings credited to the three principal ports in New England in the annual volumes of Fishery Industries in the United States, published by the Bureau of Fisheries and subsequently the Fish and Wildlife Service. Most of the haddock apparently came from almost exactly the depth range and location subsequently to become a major yellowtail producing area. Rounsefell (1948, fig. 6) plotted the areas fished by medium and large otter trawlers seeking haddock from 1928 to 1937. These plots show that the catches credited to the Nantucket Shoals area were centered at about latitude 40°40′ N., longitude 69°40′ W., in a depth of about 25 fathoms, although the spread of the fishing was from approximately 15 to 35 fathoms, with some tendency toward fishing shoaler waters from February through May. During most of our studies, the part of this area between 15 and 25 fathoms in depth was the second most important yellowtail producing ground (fig. 2), with production ranging from 22 million pounds in 1942 to a little over 5 million pounds in 1949.

TABLE 46.—*Landings of haddock and flounders at principal New England ports from the Nantucket Shoals, Lightship Grounds, and No Mans Land areas, 1925–49*

[In thousands of pounds]

Ports and year of landing [1]	Haddock	All flounders
Boston, Gloucester, and Portland:		
1925	6,488	No data.
1926	9,987	Do.
1927	6,246	Do.
1928	12,808	2,060
1929	4,083	1,000
1930	4,890	495
1931	2,969	609
1932	1,650	203
1933	360	114
1934	151	21
1935	116	19
1936	171	225
1937	900	1,090
1938	2,204	772
1939	1,834	2,245
1940	764	4,295
1941	489	2,501
1942	557	3,160
Boston, Gloucester, Portland, and New Bedford:		
1943	299	21,571
1944	1,728	13,869
1945	2,259	15,361
1946	2,609	18,606
1947	3,639	21,589
1948	1,775	17,996
1949	890	12,355

[1] For source see appendix A, p. 237.

We think that few flounders were landed from the Nantucket Shoals area in the late twenties because the fish were scarce and not just because it was the practice in the fleet to discard them. In the first place, large quantities of both haddock and yellowtail have never been caught on the same grounds at the same time in other parts of the New England Banks. Secondly, had the abundance of yellowtail in the twenties equalled that found on those grounds in 1942 when production by a small trawler reached nearly 20,000 pounds a day, it would have created so much work in sorting that fishermen not wanting the yellowtail would have moved to other areas. On the other hand, the subsequent failure of these grounds to produce haddock no doubt was due to a lack of haddock and not to a failure to fish for them. Haddock has been a much sought-after species on the New England Banks, and when vessels began to fish the grounds for yellowtail after 1940 it is certain that any significant haddock concentrations would have been discovered and fished, had they existed.

Coincident with the fishery for haddock on the grounds near Nantucket Shoals was the occurrence of yellowtail farther west off the coast of New Jersey. The presence of adults there during the spawning season is indicated by the capture of eggs and larvae in 1929 and 1932, as discussed in the preceding section. These eggs and larvae could not have been found consistently off the New Jersey coast if the spawners had been off southern Massachusetts, as they were after 1942. The residual drift of the waters on the shelf is slowly westward, but as Sette (1943) and Ketchum et al. (1951) have found, the surface water is drifted primarily by the wind. The wind direction is variable, but during May it is usually southwesterly (Sette 1943, p. 205), though it was northeast in 1932. Furthermore, the rate of drift was found by both investigators to be in the order of 10 miles a day or less. Since hatching occurs in 10 days or less and the "small" larval stage lasts only about 10 days, the spawning adults evidently were not far from the places where the eggs and larvae were found.

During the course of his mackerel investigations, 1925–32, Sette gained the impression that the yellowtail was consistently one of the principal spring spawners in the area. In 1932, the only year for which comparative data are available, the mackerel larvae were 1.97 times as numerous as yellowtail larvae in the tows of the first six cruises (Sette 1943, table 19; our appendix table E–1, p. 256). The yellowtail was the second most abundant species in the tows; consequently, the number of adults must have been large. The population of mackerel in 1932 was estimated at between 45,000,000 and 400,000,000 by Sette. We may surmise that yellowtail have similar fecundity, if we balance the slightly greater size of the egg of the mackerel against the slightly smaller size of the yellowtail. If so, the population of yellowtail was in the order of at least some tens of millions. Too, the limited migratory habits of the species indicate that it must have been a resident population, not a coastwise migrant like the mackerel.

Why such an abundant fish was not well known before 1935 is not clear, but we have mentioned that yellowtail were not marketed in those earlier years, they rarely occur within 10 miles of shore, and they are not easily caught by hooks; so it seems entirely possible that they were present but were not fished. On the other hand, any such concentration of yellowtail as was found after 1942 would have been fished, for enough small otter trawlers operated off the New Jersey coast to have found the fish if they had been there.

The second radical faunal change on the yellowtail grounds occurred after the decline in the southern New England stock. With yellowtail especially scarce in 1949 and with an expanding market for fish meal, the fishermen turned to "trash" fish, which they sold to the reduction plants. They saved everything they caught in their nets, but the principal species taken were red hake (*Urophycis chuss*), eelpout (*Zoarces anguillaris*), and several species of skates of the genus *Raja* (Sayles 1951). The principal fishing ground at the start of this fishery in 1949 was in from 10 to 20 fathoms of water south of the eastern end of Martha's Vineyard, and a secondary center was located about 15 miles southeast of this point. Both of these grounds had previously produced substantial quantities of yellowtail (fig. 2), and yet very few yellowtail were included in the catch of the trash fishery. After 1949, this fishery spread over more of the yellowtail grounds, fishermen reported.

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Such changes in the habitat of a few species of fish must be evidence of fundamental environmental changes. In seeking an explanation for the change in habitat, we note that the known geographical range of both the haddock and the yellowtail extends only a little south of the southern New England grounds, but much farther north. Bigelow and Schroeder (1953) report that haddock have been found from the deep water off Cape Hatteras north to the west coast of Greenland and the yellowtail from Chesapeake Bay to the Labrador side of the Straits of Belle Isle. We note, too, a retreat of the haddock from the grounds west of Nantucket Shoals northeasterly to Georges Bank in the early thirties, and a subsequent retreat of the yellowtail from off the New Jersey coast in the twenties to off southern New England in the early forties, and then to Georges Bank about 1949 (table 6). Perhaps these retreats have occurred because of the warming of the area (Conover 1951).

Some additional evidence from our study of the yellowtail flounder populations supports the concept of a retreat toward the northeast. We have already noted that the summer fishery weakened after 1944 and by 1949 was the smallest of all the fisheries, whereas it had been the largest in 1942 and 1943 (p. 172). Our tagging operations in 1942 and 1943 off Long Island showed that the summer fishery off No Mans Land included fish that moved west in winter and east in summer (p. 180). Perhaps it is significant that the fishery on this population was the first to fail. Perhaps, too, it is significant that old fish (5 years and older) were a smaller fraction of the landings (table 29) during the third quarter than during most other quarters even just after the peak years. Were these fish migrating from the west subject to greater environmental pressure than other groups?

We also ask why the southern New England yellowtail grew so much more slowly than Nova Scotian yellowtail (Scott 1954) except during their second and third years of life. Is this evidence of greater environmental pressure on the very young fish and those 4 years and older? Why was the life span of the southern New England yellowtail so much shorter than that of Nova Scotian fish, and why did they attain a smaller maximum size? Obviously, living conditions for the older fish from the southern New England stock must have been less favorable, but why? Perhaps the answers to these questions may be learned from a study of changing climatic conditions. Certainly here are problems deserving of more study.

EFFECTS OF THE FISHERY ON YELLOWTAIL STOCKS, 1942–49

How has the fishery affected the yellowtail flounder stocks? Although the exact effect is not known, as a result of our studies from 1942 to 1949 we can provide a working hypothesis.

Unquestionably, the fishery on the southern New England stock suffered a disastrous decline in landings and catch per unit of effort from 1942 to 1949. This decline was accompanied by the near disappearance of fishable schools of yellowtail from the usual fishing grounds on the Continental Shelf between New Jersey and Nantucket Shoals. Furthermore, extensive trawling to a depth of 200 fathoms by the *Albatross III* in 1949 revealed no concentrations of yellowtail outside the regular fishing grounds. These declining landings were accompanied by a high total mortality rate. On the other hand, there were none of the symptoms of heavy fishing, such as a declining average size, an increasing proportion of young fish in the catch, or an increasing growth rate due to the thinning of the stock.

This contradictory evidence cannot be fully explained with the limited data from so short a period of study. To it may be added the evidence of a heterogeneous stock composed of an unknown number of semi-independent populations; a mysterious absence of fish less than a year old and of yearlings from the fishing grounds; and an apparent northeasterly shift of the principal yellowtail population from off the New Jersey coast to off southern New England, where the big fishery occurred from 1941 to 1948, and then to Georges Bank.

The most striking finding from our study of the yellowtail fishery has been the changing availability, which appears, directly, in fluctuations in abundance of the fish during the year and in the abundance of year classes at different ages, and, indirectly, in the minus value of the average apparent natural mortality. It is evidence either that fishing pressure was not uniform on the southern New England stock or that the populations of yellowtail were not uniformly distributed. That both conditions exist is indicated by the irregular tag returns from certain releases and by the differences in size, age, and sex composition at different times in different statistical subareas (figs. 9 and 20, and appendix C).[16] These phenomena prevent the conventional determination of the effect of fishing on the stock because we cannot satisfy the assumption that the fishing is uniform on all parts of the stock.

The changes in availability also prevent any clear determination of the recruitment resulting from spawning. The assumption that larger recruitment results from larger spawning stocks is being challenged for many species as data become available. Likewise, we doubt that large populations of spawning yellowtail produce more young, because we have evidence that only one slightly dominant year class (1941) was produced during the years of large spawning populations (1939 to 1942, and perhaps earlier). Probably, natural conditions greatly affect the survival of the young, because the collections of eggs and larvae indicate that the young drift widely in their pelagic stages at which time they must be vulnerable to changing weather conditions, especially winds that may blow them far from suitable bottom.

Obviously, a great population of yellowtail accumulated through unknown but favorable circumstances and was ready for the fishery, which sought it increasingly after 1938. The fish were centered on a rather restricted kind of coarse red-sand bottom and extended from there beyond the scope of the fishery. We postulate that as the fishery removed them from the favorite grounds scattered groups or individuals moved in to be caught and to make way for others. The new groups of yellowtail became available as others were caught at an estimated annual rate of 35 percent (the approximate annual equivalent of an instantaneous rate of +0.30) over and above any natural mortality. This process continued until 1949, when there were no other yellowtail to move in and parts of even their favorite grounds were used by other species. Why the stock, both on and beyond the fishing grounds, was not replenished by young as the adults were removed is unknown. It appears that the fishery used up the accumulated stock during years when few young survived. Further, the unchanging growth rate indicates that the removals by the fishery did not leave better living conditions for the remaining fish.

[16] Note especially in appendix C, p. 239, the usually, but not always, greater size in subarea O compared with Q and S, the great preponderance of 86 percent females (of small size) during the third quarter 1943 in subarea Q, and the reversal of the size of females in the large samples from subareas O and Q in the fourth quarter of 1945 and the first quarter of 1946. The females averaged 38.81 cm. in length in Q and 37.07 in O at first, and then 37.46 in Q and 38.83 in O.

MANAGEMENT OF THE YELLOWTAIL FLOUNDER

We believe it is probable, although it cannot be proved, that the major changes in the yellowtail flounder fishery were not caused by overfishing although that may have hastened its decline. Many of the documented facts about the yellowtail populations are not in accord with theoretical changes caused by heavy fishing nor, with the limited data available, can we develop a theory that will, with a reasonable probability, associate fishing with the decline. Therefore, we have no answers to the fundamental questions of what sizes and numbers of fish can be expected from a given fishing effort or what measures would result in the greatest desired return from the fishery.

A negative approach to the question of protective measures is warranted because only a few practical measures have been devised to conserve an ocean fishery of this kind. These measures are all restrictive and should be adopted when they probably will increase the catch or, as Graham (1951) has suggested, fix the fishing level, methods, or seasons, and give the fishermen peace. Restriction for either of these reasons must be considered in conjunction with all of the fishing in the area, not merely for the yellowtail, which after 1945 amounted to less than half of the landings from the southern New England Banks. We have little knowledge of these other fisheries, but with what is available on them and the yellowtail we can eliminate most of the measures usually employed from further consideration.

A closed season on yellowtail appears to offer no help except that which might accrue from reduction of the total catch (to be discussed later). The period usually considered for closure is the spawning season and with the yellowtail this has been the season of poorest fishing. The fish have been consistently more available during the third quarter of the year, and while a closed season at that time would cause a greater reduction in the total catch it offers no obvious advantage in growth of the fish which might result in a greater catch after the period of restraint.

A minimum size limit may offer some small theoretical advantages, but we suspect that the practical difficulties in its application will overbalance any advantages. We cannot calculate the effect of a minimum size limit on yellowtail stocks because we do not know the natural mortality and therefore, cannot use the method developed by Ricker (1945). In principle, however, if natural mortality is low and growth rate high, it is desirable to save the fish to a larger size before capture because they will grow more than the group will lose through death. The reverse is also true: if natural mortality is high and growth rate low, the fish should be harvested as early as practicable. By the time the yellowtail enter the fishery, they have passed through the period of maximum growth in their second summer (1 annulus). When they are fully available at 3 years of age or older, the growth rate has slowed down markedly; therefore, we doubt whether even with a very moderate natural mortality, there would be a significant advantage from setting a size limit.

A second consideration that frequently enters into the establishment of a size limit is protection of the fish until they have had an opportunity to spawn. The southern New England yellowtail spawns at such an early age that during the period of our study only a negligible portion of the landings were immature; consequently, we could not advocate a size limit on this basis.

A serious limitation on the effectiveness of a size limit would ensue from the use of the otter trawl in the fishery combined with the certainty that virtually all small yellowtail, after being landed on deck and sorted in the usual manner, would die before or shortly after their return to the water. Consequently, an effective minimum size limit would have to be accompanied by a minimum mesh size, which would be most difficult to apply in a fishing fleet that seeks numerous other species of varying body shapes and minimal acceptable sizes along with the yellowtail.

There may, however, be a need to prohibit the landing of fish smaller than are acceptable for filleting. Such a need arises from the development of the trash fishery on and near the former yellowtail grounds and the possible inclusion of yellowtail among the fish destined to be reduced to fish meal. After commencement of the trash fishery, there were scattered reports of yellowtail being included in the catch, but evidently the proportion was small, for in the samples from trash-fish catches (Snow 1950) no significant quantities of yellowtail were included. If, however, an unusually successful spawning of yellowtail occurs, large quantities of young below filleting size may be attractive to the trash-fish boats. Such yellowtail would be in their most rapid period of growth and it might be more economical to allow them to remain in the sea to become available as food fish later. A prohibition against landing small fish should be effective, because the trawlers usually can avoid concentrations of such fish.

The closure of certain fishing areas has sometimes been recommended to protect spawning fish, young fish, or fish especially vulnerable to an efficient gear. Such a measure offers no solution in the yellowtail because only one kind of gear, the otter trawl, has ever caught significant quantities of them, the fish have been scarcer during their spawning season than at other times, and we have found no well-defined spawning or nursery area.

A restriction of the total catch might well have saved some of the fish and prolonged the fishery during and after the period of our study if our hypothesis of a large accumulated stock being gradually caught is correct. On the other hand, such a restriction might have meant a lowering of the total catch because the fish saved would have suffered some natural mortality that might or might not have been compensated by growth. Even a loss might have been desirable if it evened out the landings over a longer period. Advocacy of the measure for this reason requires studies beyond the scope of this report.

CONCLUSIONS

If, as appears probable, the abundance of the yellowtail is determined largely by natural causes beyond our control, no definite size or kind of catch can be expected from a given fishing effort. No action is necessary to prevent extinction of the species; the high cost of fishing them will ease the pressure in time to save a spawning nucleus. The greatest catch from the yellowtail stocks may be obtained by fishing them when available without restriction other than the inevitable economic ones, which are necessarily greater in a highly fluctuating fishery.

Such erratic catches as characterize the yellowtail fishery cause serious economic consequences among short-range vessels of the kind prevalent in the southern New England fishery. If the fluctuations in yellowtail catch cannot be smoothed out, the earnings of the fishermen would be better maintained by turning to other species—some of which replaced the yellowtail when it declined. Finding uses and markets for these species should be helpful.

Not much is known about the yellowtail and the factors influencing the size of the stocks. One of the most troublesome features of our study has been the lack of knowledge of the yellowtail populations not being taken by the fishery. The study of these apparently numerous populations and subpopulations which do not fully intermingle can be accomplished only by thorough sampling of the commercial landings and of the fish in other areas of the sea by a research vessel. Such a study should also include proper consideration of the relation of the yellowtail to its environment and to other species in the area—vertebrate and invertebrate, competing and noncompeting, predator and prey. Other aspects of its life history need to be investigated. We know little of its food habits or fecundity, the requirements and habits of the larvae and juveniles, or of other factors which may limit the size of the stock.

Adequate answers to these questions will require considerable effort; however, a satisfactory guardianship of the stocks can probably be maintained with a limited study to determine trends in total catch, abundance, and size composition of the fishery, supplemented by a watchfulness for evidence of any significant waste of young fish either through discard at sea or reduction to fish meal. Such a study will not lead to a full understanding of the causes of fluctuations in the fishery, but it can be maintained at a cost commensurate with the value of the fishery and will provide invaluable data for any future, more elaborate investigation that may become desirable.

SUMMARY

An intensive study of the yellowtail flounder (*Limanda ferruginea*) was undertaken in 1942 and continued through 1947, with additional data on landings and catch per unit of effort collected through 1951.

Following the decline in the populations of the winter flounder—mainstay of the otter-trawler fleet in southern New England—in the mid-thirties, the abundant yellowtail proved a suitable substitute. The total United States landings of this flounder rose from 23 million pounds in 1938 to 70 million in 1942, then declined to about 30 million pounds annually from 1944 through 1949. Price changes were not the cause of the declining catch.

Between 1942 and 1949, a total of 2,597 yellowtail was tagged and released at 14 points along the New England coast, covering all the major United States fishing grounds. Through December 1952, a total of 377 tags, or 14.5 percent, had been recovered. The recoveries indicated that the yellowtail occur in relatively localized populations and that they make short, seasonal migrations. The majority of the recaptures were within 50 miles of the release points and the most distant recapture was only 170 miles from the release point. Almost all the fish were recaptured in depths between 15 and 35 fathoms.

The mingling of the tagged yellowtail and the fishing concentrations indicated the existence of five more or less distinct stocks:

1. A complex southern New England stock between Nantucket Shoals and Long Island, part of which may have begun to move to Georges Bank in the summer of 1947.
2. Georges Bank stock on the shoal parts of the Bank.
3. Cape Cod stock from east of Cape Cod north to the vicinity of Cape Ann.
4. A northern Gulf of Maine stock along the coast of Maine.
5. One or more Nova Scotian stocks which are fished incidentally by United States boats seeking other species.

The bulk of yellowtail production in the United States has come from the southern New England stock, hence any fluctuations in its numbers are a cause for concern. Because of the great importance of the southern New England stock to

United States fishermen, this study was largely limited to an investigation of that stock and following comments apply to it.

1. Landings from the southern New England stock declined from 63 million pounds in 1942 to 10 million pounds in 1949. During this same period, landings from Georges Bank stock increased from 2 million pounds to 16 million.

2. Between 1943 and 1947 a total of 37,075 fish were selected randomly from the landings and measured and their sex recorded. Females were twice as numerous in the catch as males. The mean length of both sexes was 35.69 cm., with males averaging 33.34 cm. and females 37.21 cm. There was no trend toward smaller fish in the landings between 1942 and 1947; however, later reports show that such a trend developed after 1951.

3. The length-weight relation, by sex and quarter, was determined for 1,113 yellowtail taken from the landings during 1943. Regression formulas were used to estimate the weight of each sex at the mean length of 35.869 cm., and the females were consistently the heavier—this difference between the sexes probably being even greater at onset of spawning in early April. Differences in the length-weight relation among the quarters also were considerable, and yellowtail of average length of both sexes were heaviest in the first quarter of 1943 and lightest in the third.

4. Data collected by quarters on the catch by area and time fished from about 30 percent of the landings revealed that the catch per day was greatest during the third quarter of the year. Despite this seasonal fluctuation, the change in apparent relative abundance as reflected in the catch per unit of effort approximately paralleled the downward trend in the catch during the years 1942 through 1949.

5. Growth data were developed from the attained length at time of capture of 9,204 yellowtail for which the ages were determined from scales. The females attained a greater length than the males of the same age, being 4.5 percent longer than the males at age 2 and up to 9.1 percent longer at age 5. The mean lengths of both sexes for comparable quarters revealed no upward or downward trend in length and only a slight change in growth rate from 1942 to 1947. Scale readings indicated an unusual rate of growth in the young yellowtail. The first year's growth appears to be only from 3 to 5 cm., whereas during the second year the juvenile attains a length of nearly 30 cm.

6. There was no trend toward a greater proportion of young fish in the catch between 1942 and 1947. The average age composition of yellowtail in the landings, in numbers of fish, was 1.3 percent 1-year-olds, 28.1 percent 2-year-olds, 35.5 percent 3-year-olds, 19.3 percent 4-year-olds, 9.6 percent 5-year-olds, 5.1 percent 6-year-olds, and 1.0 percent 7-year-olds and older.

7. The estimated total mortality rate among yellowtail completely available to the fishery was 86 percent a year.

8. Study of the age and length at maturity of 288 fish taken at random from the landings at the peak of the spawning season in May 1943 revealed that most yellowtail of both sexes mature during their second or third year of life. Of the females aged, 52 percent were mature at 2 years and 100 percent at 4 years or more; of the males, 84 percent were mature at 2 years and 100 percent at 4 years or older. Most males mature before entering the fishery and mostly before they attain 26 cm., while 50 percent of the females in the landings were mature at 31.98 cm. and 90 percent at 40.17 cm. The catch during the spawning season in 1943 included only 6 percent immature males and 16 percent immature females.

9. Examination of the ovaries of 1,157 females sampled periodically from the landings in the spring of 1943 revealed that 90 percent of the fish spawned between April 12 and June 26, and that the peak of spawning was May 20. The period of heaviest spawning was from May 4 to June 4 during which 50 percent of the females became spent.

10. We were unable to collect either eggs or larvae of the yellowtail during our investigations, but Sette (1943) recorded considerable data relative to these stages during his mackerel investigations in 1929 and 1932. During those earlier surveys, eggs and larvae of the southern New England yellowtail were found to be abundant over most of the Continental Shelf off New York, New Jersey, and Delaware—much farther southwest than the center of the fishery during the spawning seasons from 1942 to 1949.

11. Marked faunal changes have occurred on the yellowtail grounds. The area southeast of No Mans Land at one time produced large quantities of haddock, later yellowtail, and still later "trash" fish. These changes in fish populations may be associated with fundamental ecologic changes, possibly a warming of the climate.

12. The exact effect of the fishery on yellowtail stocks is not known, but our studies indicate that as the fishery removed the yellowtail from their favored bottom new populations moved in, becoming available to the fishery at an estimated 35 percent a year, in addition to any natural mortality. Unreplenished by young, the accumulated stocks were used up by the fishery until there were no other yellowtail to move in. There is evidence that no significantly greater recruitment was produced by larger spawning populations, as but one slightly dominant year class resulted during the years of large spawning populations from 1938 to 1942.

13. We do not believe that the great decline in the catch of the southern New England stock was caused by catching too many yellowtail, too small yellowtail, or spawning yellowtail. There was no evidence of a significant waste of small fish during the period of this study. Therefore, no restrictive legislation appears needed unless there is a radical change in the conduct of the fisheries.

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APPENDIX

A. SOURCES OF DATA ON LANDINGS OF YELLOWTAIL, 1940–49

The following documents[1] supplied the information on the production of yellowtail flounder by ports.

All ports[2]

1938. Fishery Industries of the United States, 1939. Administrative Report No. 41: total production for the year, pp. 279-336; also from original records by ports and counties.

1939. Fishery Statistics of the United States, 1939. Statistical Digest No. 1: total production for the year, pp. 44-89; also from original records by ports and counties.

Portland, Maine, Boston and Gloucester, Mass.

1940–1945. Landings at Certain New England Ports, *in* Statistical Bulletin and Current Fishery Statistics series: all data by statistical subarea.

1946–1949. New England Landings, *in* Current Fishery Statistics series: all data by statistical subarea.

New Bedford, Mass.

1940. Monthly landings copied from dealers' records.

1941. Monthly landings compiled from daily reports telephoned to Boston Fishery Market News Service by the port agent of the Atlantic Fishermen's Union.

1942. Landings of Fishery Products at New Bedford, Mass., *in* Current Fishery Statistics No. 108: landings by months.

1943 (Jan.–June). Monthly landings by statistical subarea compiled from dealers' records and daily interviews.

1943 (July)–1945. Landings by Fishing Craft at New Bedford, Mass., *in* Current Fishery Statistics series: all data by month and statistical subarea.

1946–1949. New England Landings, *in* Current Fishery Statistics series: monthly landings by statistical subarea.

Provincetown, Mass.

1940–1943 (July). Monthly landings compiled from daily reports to Boston Fishery Market News Service.

Provincetown, Mass.—Continued

1943 (Aug.)–1949. Monthly landings from records of the Massachusetts Department of Conservation, Division of Marine Fisheries.

Woods Hole, Mass.

1940–1943 (July). Monthly landings compiled from daily reports to Boston Fishery Market News Service.

1943 (Aug.)–1949. Monthly landings copied from records of the Massachusetts Department of Conservation, Division of Marine Fisheries.

Chatham, Mass.

1943 (Aug.)–1949. Monthly landings copied from records of the Massachusetts Department of Conservation, Division of Marine Fisheries: landings before 1942 unavailable and yellowtail landings considered negligible.[3]

Plymouth, Mass.

1944 (Oct.)–1949. Monthly landings compiled from dealers' records: landings before this date considered negligible.[3]

Nantucket, Mass.

1944–1949. Monthly landings compiled from dealers' records: landings before 1944 considered negligible.[3]

Rhode Island.

1940. Fishery Statistics of the United States, 1941. Statistical Digest No. 7. Total production for the year.

1941. Monthly landings compiled from daily shipments into New York City as reported by the New York Fishery Market News Service.

1942. Current Fishery Statistics No. 164. Total production for the year. Proportion by month estimated from daily reports of New York Fishery Market News Service.

1943–1949. Monthly landings compiled from daily reports of the New York Fishery Market News Service. The total production reported for 1942 was 3.505 times the daily shipments to New York City. This factor was used to estimate the total landings for 1943 to 1949. Earlier years were not adjusted because processing facilities were not built until 1943.

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[1] Unless otherwise specified, all publications are those of the United States Department of the Interior, Fish and Wildlife Service, Washington 25, D. C.

[2] Although certain data on the landings of yellowtail flounder are available for the years before 1940, they are compiled by the home port of the vessel instead of the port in which the trips were landed. Thus, the data are not comparable with those of the later years. Furthermore, before 1938 all species of flounders were consolidated in the statistics.

[3] Diversion of landings to smaller ports commenced after price controls were applied in 1943.

Connecticut.

1940–1941. Twenty-fourth Biennial Report of the Connecticut State Board of Fisheries and Game, State of Connecticut, Public Document No. 19. Landings by months.

1942. New England Fisheries, *in* Current Fishery Statistics No. 164. Total production for the year. Proportion by month estimated from daily shipments into New York City.

1943–1949. Monthly landings compiled from daily shipments into New York City as reported by the New York Fishery Market News Service. The total landings for 1942 were 1.9 times the daily shipments into New York City. This factor was used to estimate the total landings for 1943–49. Earlier years were not adjusted because processing facilities were not built until 1943.

New York City, N. Y.

1940–1944. Landings by Fishing Craft at New York City, *in* Current Fishery Statistics No. 193. Landings by months.

New York City, N. Y.—Continued

1945. Landings by Fishing Craft at New York City, *in* Current Fishery Statistics No. 269. Landings by months.

1946–1949. Landings compiled by months from fishing craft weighouts as reported by the New York Fishery Market News Service.

Long Island, N. Y.

1940–1949. Total monthly shipments into New York City, as reported by the New York Fishery Market News Service; assumed to represent the entire landings.

New Jersey.

1940–1949. Monthly landings compiled from daily shipments into New York City, as reported by the New York Fishery Market News Service; assumed to represent the entire landings.

B. METHODS OF ESTIMATING CATCH BY STATISTICAL SUBAREA

Portland, Maine, Gloucester and Boston, Mass., 1938 to 1949, and New Bedford, Mass., October 1942 to 1949.

Data were collected daily from representatives of almost all vessels by the U. S. Fish and Wildlife Service and mostly published in the Service's Current Fishery Statistics series. After October 1942, more than 60 percent of the total yellowtail landings were included in the statistics.

New Bedford, Mass., January–September 1942.

Landings were assigned to statistical subareas according to information compiled from log-book records that had been kept by several of the captains fishing out of the port.

Chatham, Mass.

The fishing fleet consisted of 30 or more line trawlers, 35 to 45 feet in length, which, as a rule, fished the same nearby grounds on 1-day trips throughout the year. According to interviews with fishermen in 1946, the area fished extended from No. 6 buoy to No. 10 buoy on the western side of South Channel, in depths ranging from 15 to 30 fathoms on hard, rocky bottoms shunned by otter trawlers. All species of fish landed at Chatham were assigned to subarea G.

Provincetown, Mass.

The fleet consisted of 35 to 40 small otter trawlers, which followed a regular seasonal pattern of fishing for yellowtail. During the winter months of November to March, the fleet fished Cape Cod Bay and Massachusetts Bay, statistical subarea E, and during the rest of the year they fished east of Cape Cod on the western side of South Channel in statistical subarea G. On the basis of this information, which was gathered through interviews with captains of vessels operating out of Provincetown, the landings of yellowtail flounder have been assigned to these two subareas for the months indicated.

Plymouth, Mass.

The fleet fishing out of Plymouth consisted of less than 20 small otter trawlers which regularly fished Cape Cod Bay and Massachusetts Bay, statistical subarea E, and all landings of yellowtail flounders have been assigned to this subarea.

Woods Hole, Mass.

The regular fleet consisted of 15 or more small otter trawlers and 2 medium-sized otter trawlers that fished the same grounds fished by the New Bedford fleet of small otter trawlers. Trips were also landed there occasionally by New Bedford vessels. The landings of yellowtail flounder at Woods Hole have been assigned to statistical subareas in proportion to the landings at New Bedford by small otter trawlers.

Nantucket, Mass.

Most of the vessels landing in this port were small and medium-sized draggers that commonly fished the same grounds fished by the New Bedford fleet, and they land there or at Woods Hole occasionally. The landings at Nantucket have been assigned to statistical subareas in proportion to the landings by all otter trawlers at New Bedford.

Rhode Island, Conn., and Long Island, N. Y.

Landings at ports in these places were variously assigned to statistical subareas according to information gathered from interviews with fishermen from these ports during October and November 1946. This varied slightly from port to port and season to season, but virtually all of the fishing was west of Nantucket Shoals.

New York City, N. Y.

Landings of yellowtail flounders at this port were assigned to the subareas in proportion to the landings by all vessels at New Bedford from Georges Bank and southern New England areas. This was based on the opinion of captains of both small and medium-sized draggers landing fish at New York City.

New Jersey.

The very small amount of landings were assumed to have come from the statistical area designated Southwestern Long Island.

C. LENGTH FREQUENCIES OF YELLOWTAIL BY STATISTICAL SUBAREA, QUARTER AND SEX, 1941–47

TABLE C–1.—*Length frequencies of yellowtail: By area, quarter, and sex, southern Nova Scotia (XXI–0) and eastern Massachusetts grounds (XXII–E)*

Length of fish	Southern Nova Scotia		Eastern Massachusetts grounds						
	1945 2d quarter		1942 4th quarter	1944 3d quarter		1946 2d quarter		1947 2d quarter	
	Male	Female	Both sexes	Male	Female	Male	Female	Male	Female
26.5 cm				2					
27.5 cm			10	3	1				
28.5 cm			11	5					
29.5 cm			17	2	1			1	
30.5 cm			22	2				3	1
31.5 cm			24	5	3			5	2
32.5 cm			11	10	1	1		4	3
33.5 cm			9	10	3	1		5	5
34.5 cm	1	1	4	10	5			3	6
35.5 cm				6	2	4		4	8
36.5 cm	1			1	2	1		5	2
37.5 cm	3	2	3	1	5	2	2	1	5
38.5 cm	2	3	2	6	3	3	1	2	4
39.5 cm				3	7	4	1	1	7
40.5 cm				1	1	10	5	1	6
41.5 cm	4	5				8	5	1	2
42.5 cm	2	8		1	1	7	1		3
43.5 cm	1	10				2	6		3
44.5 cm	3	12					5		1
45.5 cm		11				2	9		3
46.5 cm		7				1	5		4
47.5 cm		5				1	4		
48.5 cm		7					1		
49.5 cm		7					1		1
50.5 cm							1		
51.5 cm		2					1		
52.5 cm		3							
Total	17	83	113	68	35	47	48	36	66
Mean length (cm.)	40.50	45.20	31.00	33.53	36.10	40.41	44.19	34.44	38.50

TABLE C-2.—*Length frequencies of yellowtail: By area, quarter, and sex, western side of South Channel (XXII-G)*

Length of fish	1945 1st quarter		1946 2d quarter	
	Male	Female	Male	Female
18.5 cm			1	
19.5 cm				
20.5 cm			1	
21.5 cm			2	
22.5 cm			4	5
23.5 cm			5	4
24.5 cm			6	3
25.5 cm			4	6
26.5 cm	2		4	5
27.5 cm			1	1
28.5 cm	1	1		1
29.5 cm	3		1	
30.5 cm	6		2	2
31.5 cm	3	1	1	1
32.5 cm	4	1	2	
33.5 cm	8	2	3	2
34.5 cm	6	3	2	1
35.5 cm	3	2	1	
36.5 cm	4	2		4
37.5 cm	10	3	1	5
38.5 cm	12	5	3	3
39.5 cm	10	9	2	2
40.5 cm	8	12	5	
41.5 cm	4	10	4	3
42.5 cm	4	5	3	7
43.5 cm	1	7	1	6
44.5 cm		7		5
45.5 cm	1	10		7
46.5 cm		5		3
47.5 cm				
48.5 cm		3		
49.5 cm		3		
50.5 cm		4		
Total	90	95	59	76
Mean length (cm.)	36.51	41.90	31.11	35.62

TABLE C-3.—*Length frequencies of yellowtail: By area, quarter, and sex, eastern side of South Channel (XXII-H)*

Length of fish	1942 4th quarter	1944				1945 1st quarter		1946 1st quarter	
		1st quarter		4th quarter					
	Both sexes	Male	Female	Male	Female	Male	Female	Male	Female
26.5 cm						1			
27.5 cm						1			
28.5 cm				1		1	2		
29.5 cm		2				1			1
30.5 cm	1	4				3	1	1	
31.5 cm	2	7	1	2		4		5	1
32.5 cm	1	17	2	2	1	14	3	4	
33.5 cm	6	16	9	6	1	19	6	9	4
34.5 cm	6	21	7	8	1	28	9	6	17
35.5 cm	13	25	15	14	1	45	17	11	19
36.5 cm	8	34	17	24	7	67	23	23	25
37.5 cm	18	21	22	22	19	50	48	25	17
38.5 cm	16	22	24	28	27	69	73	19	26
39.5 cm	13	21	31	24	45	68	90	15	20
40.5 cm	21	8	44	14	57	43	101	13	32
41.5 cm	11	5	33	9	57	29	144	14	45
42.5 cm	20	5	37	5	71	17	142	5	42
43.5 cm	23		33	3	55	8	139	1	54
44.5 cm	11	1	20	1	53	2	99		40
45.5 cm	11		19	1	39		86		40
46.5 cm	8		7		38		64	1	24
47.5 cm	7		13		36		32		16
48.5 cm	6		2		20		22		14
49.5 cm	4		3		9		11		5
50.5 cm	1		2	1	3		6		1
51.5 cm							2		1
Total	207	209	341	165	540	470	1,120	152	442
Mean length (cm.)	40.98	36.34	40.97	38.07	42.93	37.77	42.22	37.68	41.86

TABLE C-4.—*Length frequencies of yellowtail: By area, quarter, and sex, central and southeast Georges Bank (XXII-M)*

Length of fish	1942 4th quarter	1944 4th quarter		1945 3d quarter		1946 3d quarter	
	Both sexes	Male	Female	Male	Female	Male	Female
27.5 cm						1	
28.5 cm				1		2	
29.5 cm				1	1	8	1
30.5 cm	1			1		6	
31.5 cm				3		14	
32.5 cm	1			4	2	17	
33.5 cm	5	2		6	2	17	1
34.5 cm	5		2	6	4	18	3
35.5 cm	5	1	1	7	1	21	5
36.5 cm	10	1		16	4	17	9
37.5 cm	8	3	1	7	3	13	17
38.5 cm	8	5	5	9	9	10	21
39.5 cm	10	4	6	7	12	6	16
40.5 cm	6		4	2	9	3	13
41.5 cm	9	1	10	2	13	1	6
42.5 cm	8	1	14	2	11		15
43.5 cm	4	1	8		12	1	14
44.5 cm	7		13		12		6
45.5 cm	8		6		12		8
46.5 cm	5		4		9		3
47.5 cm			2		8		4
48.5 cm			2		1		1
49.5 cm			1				1
50.5 cm							1
51.5 cm		1	2				
52.5 cm					1		
Total	100	20	81	74	126	155	145
Mean length (cm.)	39.87	39.05	42.88	36.32	41.96	34.64	40.56

TABLE C-5.—*Length frequencies of yellowtail: By area, quarter, and sex, southwest Georges Bank (XXII-N)*

Length of fish	1942 1st quarter	1947			
		3d quarter		4th quarter	
	Both sexes	Male	Female	Male	Female
20.5 cm	1				
21.5 cm					
22.5 cm	1				
23.5 cm	2				
24.5 cm	5				
25.5 cm	8				
26.5 cm	4				
27.5 cm	4		1		
28.5 cm	2	1			
29.5 cm	1	4			
30.5 cm		9	1	2	
31.5 cm	1	15	4	3	
32.5 cm	2	12	1	10	2
33.5 cm	1	12	9	2	1
34.5 cm	1	19	11	5	3
35.5 cm	5	14	17	3	3
36.5 cm	3	19	21	1	2
37.5 cm	1	15	26	2	5
38.5 cm	5	10	21	1	9
39.5 cm	5	3	24	2	10
40.5 cm	3	1	35		4
41.5 cm	7	1	30		8
42.5 cm	6		22		9
43.5 cm	9		19		5
44.5 cm	9		10		3
45.5 cm	4		9		
46.5 cm	3		3		2
47.5 cm	2		2		
48.5 cm			2		3
Total	95	135	268	31	69
Mean length (cm.)	36.56	34.66	39.58	34.05	40.24

TABLE C–6.—*Length frequencies of yellowtail: By area, quarter, and sex, Nantucket Shoals and Lightship grounds (XXII–0)*

Length of fish	1942 4th quarter		1943				1944					
			1st quarter		3d quarter		1st quarter		3d quarter		4th quarter	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
21.5 cm	1	1										
22.5 cm	4	8										
23.5 cm	14	8										
24.5 cm	17	23		1							4	
25.5 cm	23	28		1							2	
26.5 cm	18	16	1		1	2		2	1		3	
27.5 cm	9	10		1	2		3		3		2	
28.5 cm	11	10	2	2	2	4	1		3		3	
29.5 cm	17	4	2		7	4	3		2		13	1
30.5 cm	8	3	12	2	18	14	6	5	13	1	18	4
31.5 cm	15	5	17	10	21	13	9	5	16	5	22	12
32.5 cm	13	10	17	22	42	25	6	6	13	3	22	11
33.5 cm	15	4	29	25	34	28	6	3	7	26	25	13
34.5 cm	7	13	23	27	27	58	10	2	5	11	16	30
35.5 cm	7	12	41	50	33	77	6	4	3	11	17	30
36.5 cm	7	11	36	50	23	76	6	6		13	5	31
37.5 cm	3	19	37	64	14	82	4	2	1	13	17	34
38.5 cm	5	15	34	76	5	65	4	7		11	6	21
39.5 cm	1	12	17	83	6	85	1	6	1	11	2	40
40.5 cm		16	16	87		78	4	10		8	2	19
41.5 cm		11	4	104	1	72		7		10	1	23
42.5 cm		9	3	83		48	2	6		8		14
43.5 cm		4	1	78		32		6		2	1	15
44.5 cm		5		49		13		5		2		11
45.5 cm		1		44		8		5		2		11
46.5 cm		2		23		3		7				3
47.5 cm				23		1		3		2		3
48.5 cm				11			1	2				3
49.5 cm				8				1				1
50.5 cm				2								1
51.5 cm				2								
52.5 cm				1								
53.5 cm												
54.5 cm												1
Total	195	260	292	929	236	788	72	100	68	139	181	332
Mean length (cm.)	29.30	32.84	35.90	40.35	33.89	38.10	34.42	39.46	31.87	37.32	33.14	38.44

TABLE C–7.—*Length frequencies of yellowtail: By area, quarter, and sex, Nantucket Shoals and Lightship grounds (XXII–0)*

Length of fish	1945						1946						1947			
	1st quarter		3d quarter		4th quarter		1st quarter		3d quarter		4th quarter		3d quarter		4th quarter	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
21.5 cm							1									
22.5 cm			1													
23.5 cm			1	1	1		1									
24.5 cm	2			1		2						2				
25.5 cm	3		1	1			2	1	1			2				
26.5 cm	12			1	1	2	1	2	1	1	1		1	1	2	
27.5 cm	10		2		3	1	4	2	9	2	2	3	10	1	1	1
28.5 cm	10	1	14	1	10	1	9	6	45	10	9	12	25	4	2	1
29.5 cm	9	2	16	7	24	11	5	2	51	34	38	50	62	23	4	2
30.5 cm	13		50	12	59	18	9	2	104	78	89	123	73	42	10	1
31.5 cm	14	6	37	25	87	44	37	4	62	112	101	166	71	90	17	6
32.5 cm	30	17	45	35	75	61	49	26	45	116	100	215	62	111	19	13
33.5 cm	33	17	42	43	78	73	52	65	39	76	68	189	44	128	9	21
34.5 cm	51	31	30	43	81	65	52	80	39	37	76	200	41	122	6	19
35.5 cm	56	38	15	40	56	78	29	60	31	27	60	155	27	122	3	17
36.5 cm	44	46	8	47	34	92	32	62	33	41	62	125	11	82	8	22
37.5 cm	59	69	2	55	11	98	25	82	12	61	42	146	6	58	5	12
38.5 cm	47	72	3	34	6	82	22	59	6	57	12	125	3	35		18
39.5 cm	18	91	1	32	4	63	15	47	2	51	8	154	2	37	2	9
40.5 cm	20	126		19	3	54	9	54		40	1	154	1	31	1	14
41.5 cm	9	93		11		46	9	67		36	2	138		32		18
42.5 cm	3	109	1	12		22	2	54		25		88		17		13
43.5 cm	2	95		6		23	2	53		8		53		17		12
44.5 cm		77		4		17		41		7		42		5		2
45.5 cm		56		2		13		24		2		21		3		6
46.5 cm		32				8		14		2		15		1		3
47.5 cm		31				4		15				11				1
48.5 cm		18				6		6		1		5		1		1
49.5 cm		4						4				7				
50.5 cm		3						1				1				
51.5 cm		2						1								
52.5 cm								1								
Total	445	1,036	269	432	533	884	367	835	480	824	671	2,202	439	963	89	212
Mean length (cm.)	35.22	40.96	32.30	36.08	33.14	37.07	34.58	38.83	32.06	35.06	33.34	36.48	31.96	35.18	32.89	37.77

TABLE C-8.—*Length frequencies of yellowtail: By area, quarter, and sex, off No Mans Land and southern Massachusetts (XXII-Q, R)*

Length of fish	1941		1942			1943							
	2d quarter	4th quarter	2d quarter	4th quarter		1st quarter		2d quarter		3d quarter		4th quarter	
	Both sexes	Both sexes	Both sexes	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
22.5 cm				1									
23.5 cm													1
24.5 cm		1		1	1	1		1					
25.5 cm						1	1	3	1		2		
26.5 cm		1				4	2	7	6	1	11		
27.5 cm	5	1		2	3			7	11	9	30	2	
28.5 cm	4	1	2	5	2	5	2	10	18	14	50	3	
29.5 cm		3	1	19	10	14	5	22	23	19	70	9	1
30.5 cm		31	2	45	26	43	5	26	46	24	69	12	6
31.5 cm	1	26	5	39	34	51	32	54	71	29	117	21	9
32.5 cm	3	22	12	73	21	54	51	52	115	45	139	22	21
33.5 cm	7	21	20	51	24	53	49	44	144	36	163	38	21
34.5 cm	7	27	31	39	34	61	40	42	99	25	162	29	29
35.5 cm	10	34	24	35	39	62	39	41	78	21	150	23	37
36.5 cm	9	33	14	25	47	46	37	31	72	13	129	19	41
37.5 cm	6	32	11	14	49	19	46	17	73	3	125	7	43
38.5 cm	3	19	18	7	35	18	46	7	66	1	109	8	40
39.5 cm	9	14	9	2	34	10	27	3	51	1	105		43
40.5 cm	5	18	5	4	17	2	30	3	53	1	47	1	26
41.5 cm	3	11	4		21	2	30		48	1	22		36
42.5 cm	3	11	1		22		27		36		3		21
43.5 cm	1	5	1		9		21	2	27		3		21
44.5 cm		2	1		7		12		15		2		9
45.5 cm		2			4		5		11				5
46.5 cm	1	2			3		2		8				3
47.5 cm							4		2				1
48.5 cm					1				1				
49.5 cm									1				1
50.5 cm									1				
Total	77	317	161	362	443	446	513	372	1,077	243	1,508	194	415
Mean length (cm.)	36.11	35.80	35.76	33.21	36.52	33.88	37.01	33.17	35.85	32.52	34.64	33.73	38.03

TABLE C-9.—*Length frequencies of yellowtail: By area, quarter, and sex, off No Mans Land and southern Massachusetts (XXII-Q, R)*

Length of fish	1944								1945					
	1st quarter		2d quarter		3d quarter		4th quarter		1st quarter		3d quarter		4th quarter	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
23.5 cm		2		1							1			
24.5 cm	2		1				1	1	1	1				
25.5 cm	3	2	1				1	1	6		2			
26.5 cm	2		2				2		14	2	6	1		
27.5 cm	5	3	8		4		3		18	1	38	3	1	1
28.5 cm	8		7	2	10	1	6		16	4	89	20		
29.5 cm	18	1	19	1	13		2	2	18	3	154	61	10	1
30.5 cm	21	16	35	5	27	3	10	7	30	10	136	69	28	2
31.5 cm	51	20	40	29	26	24	17	10	48	26	128	96	58	12
32.5 cm	48	23	40	50	26	35	23	9	59	33	140	61	66	27
33.5 cm	66	36	21	59	24	40	26	11	90	34	135	68	73	41
34.5 cm	83	43	10	34	17	38	17	14	88	35	83	127	78	47
35.5 cm	68	76	7	18	8	26	21	23	97	52	42	183	64	43
36.5 cm	66	71	10	13	4	12	7	28	85	89	13	170	34	82
37.5 cm	42	76	2	9	6	23	10	20	53	96	3	153	34	74
38.5 cm	35	57	1	8	1	9	3	24	58	130		88	11	79
39.5 cm	15	79		8	1	11	1	24	16	141	2	49	8	93
40.5 cm	7	65		5		9		17	12	122		43	1	87
41.5 cm	4	47		3		7		16	4	124		30	1	74
42.5 cm	1	67		3		7		15		132		21		64
43.5 cm	3	35		1				9	1	113		7		26
44.5 cm		38		1		1		13		67		1		27
45.5 cm		28						1		72				18
46.5 cm		11						4		56				7
47.5 cm		8						2		21				7
48.5 cm		2								11				1
49.5 cm								2		4				
50.5 cm										4				
51.5 cm										1				
Total	548	806	204	250	167	246	150	253	714	1,384	972	1,251	467	813
Mean length (cm.)	34.52	38.62	31.79	34.27	31.58	35.23	33.28	38.05	34.34	40.16	31.51	35.36	34.04	38.81

TABLE C-10.—*Length frequencies of yellowtail: By area, quarter, and sex, off No Mans Land and southern Massachusetts (XXII–Q, R)*

Length of fish	1946								1947							
	1st quarter		2d quarter		3d quarter		4th quarter		1st quarter		2d quarter		3d quarter		4th quarter	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
22.5 cm								1								
23.5 cm							1									
24.5 cm					1											2
25.5 cm	4	3							1	1	1				2	
26.5 cm	7	6	3	1	3				5	2	3				1	
27.5 cm	12	4	3		14	3	3		13	1	3	2	2	1	3	2
28.5 cm	3	2	3	3	32	18	8	1	20	10	11	1	9	3	10	
29.5 cm	8	4	4	7	30	41	25	4	10	7	20	10	8	17	26	9
30.5 cm	21	2	4	3	28	50	63	14	19	10	28	15	16	40	47	25
31.5 cm	35	9	3		16	39	66	33	38	12	32	27	25	30	48	39
32.5 cm	75	29	2		27	27	88	49	42	17	42	29	19	32	68	58
33.5 cm	100	80	6	1	41	13	94	64	58	30	34	46	12	30	49	49
34.5 cm	92	93	6		47	15	88	67	43	43	32	41	7	32	45	52
35.5 cm	79	82	4	5	24	29	68	51	40	49	28	56	7	24	35	55
36.5 cm	71	71	2	5	17	34	60	45	44	44	38	33	5	16	20	61
37.5 cm	44	64		9	8	56	37	44	39	45	20	28		6	19	48
38.5 cm	25	52		4	2	67	19	67	26	47	14	24	2	7	10	51
39.5 cm	10	50		9		42	9	69	8	42	13	32		2	2	23
40.5 cm	6	46		2		44	4	76	7	51	1	32	1	7	1	30
41.5 cm		42		7		17		78	4	40	1	30		4		43
42.5 cm		49		3		10	3	44	1	49		26		3		31
43.5 cm		32		1		8		31	1	23		20				16
44.5 cm		18				1		13	1	23		12				14
45.5 cm		12				1		11		15		10				8
46.5 cm		2						3		6		3				2
47.5 cm		3						2		10		2				2
48.5 cm		2						1		4		1				
49.5 cm		1								2						2
50.5 cm		1								1		1				
51.5 cm										1		1				
Total	592	759	40	60	290	515	636	768	420	585	321	482	113	254	386	622
Mean length (cm.)	34.27	37.46	31.75	36.55	32.30	35.63	33.78	37.76	34.13	38.44	33.73	37.15	32.15	33.52	33.03	36.69

TABLE C-11.—*Length frequencies of yellowtail: By area, quarter, and sex, Rhode Island shore (XXII–S)*

Length of fish	1942		1943		1944				1945					
	1st quarter	2d quarter	2d quarter		1st quarter		4th quarter		1st quarter		2d quarter		4th quarter	
	Both sexes	Both sexes	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20.5 cm	1													
21.5 cm														
22.5 cm	3													
23.5 cm	2													
24.5 cm	9										3			
25.5 cm	3				1	1			1	1	4			
26.5 cm	8	2			4				3	1	11			
27.5 cm	12	12	1	2	3	2					10			
28.5 cm	14	14		1	6		2	1	1		6		1	
29.5 cm	23	6		1	11	3	4	1			3		3	2
30.5 cm	38	23	2	8	23	9	1	1	5		9	2	14	3
31.5 cm	42	56		9	32	25	2	4	6	3	18	4	22	8
32.5 cm	58	76	7	16	34	20	2	3	11	10	20	12	13	13
33.5 cm	42	86	3	12	28	22	8	2	17	3	30	8	11	12
34.5 cm	34	105	2	11	31	20	7	4	12	6	27	14	8	11
35.5 cm	36	98	4	10	27	14	4	5	11	6	18	25	8	12
36.5 cm	37	58	6	10	14	16	5	9	5	11	7	30	2	4
37.5 cm	29	37		7	10	20		10	10	11	10	27	2	20
38.5 cm	33	25		8	8	19		5	5	14		25	3	4
39.5 cm	23	31		5	1	13	1	4	1	13		13		7
40.5 cm	28	20		7	2	7		1		13		15	1	5
41.5 cm	13	15		3		11		1		5		17		3
42.5 cm	4	10		1		8		4		4		14		1
43.5 cm	6	5		1		4		5	1	4		8		5
44.5 cm	2	2				3		3		2	1	6		1
45.5 cm	2	1				2				3	1	3		1
46.5 cm	2	2				2				1		1		2
47.5 cm						1				1				
48.5 cm						1								
49.5 cm						1		1						
Total	504	684	25	112	235	224	36	64	89	112	178	224	88	114
Mean length (cm.)	34.01	34.90	33.86	35.04	33.21	36.16	33.53	37.52	34.15	38.00	32.52	37.97	32.85	36.22

TABLE C-12.—*Length frequencies of yellowtail: By area, quarter, and sex, Rhode Island shore (XXII–S)*

Length of fish	1947							
	1st quarter		2d quarter		3d quarter		4th quarter	
	Male	Female	Male	Female	Male	Female	Male	Female
22.5 cm			1					
23.5 cm								
24.5 cm								
25.5 cm	1	2	2				1	1
26.5 cm	4	6	9					
27.5 cm	4	2	14	5	4			
28.5 cm	4	1	22	7	9	4	2	
29.5 cm	2	2	14	11	3	16	10	
30.5 cm	5	1	32	6	7	24	18	3
31.5 cm	10	5	38	8	6	15	26	11
32.5 cm	8	8	42	20	13	17	38	14
33.5 cm	4	14	37	43	8	14	31	19
34.5 cm	7	8	24	62	4	14	27	21
35.5 cm	6	7	24	52	4	5	11	17
36.5 cm	3	7	25	22	2	7	15	7
37.5 cm	5	11	17	18	1	4	7	14
38.5 cm	2	4	4	21		4	2	20
39.5 cm	2	3	6	39		6	5	20
40.5 cm		14	2	45		4	2	13
41.5 cm		7		46		3	1	8
42.5 cm		5		44		3		12
43.5 cm		8		20		1		11
44.5 cm		1		11				7
45.5 cm		2		6				4
46.5 cm		1		1				2
47.5 cm		1		2				
48.5 cm				1				
Total	67	120	313	490	61	141	196	204
Mean length (cm.)	32.59	36.52	32.64	37.60	31.78	33.52	33.41	37.53

TABLE C-13.—*Length frequencies of yellowtail: By area, quarter, and sex, off Southeastern Long Island (XXII–I)*

Length of fish	1942 1st quarter	1944 4th quarter		1947 2d quarter	
	Both sexes	Male	Female	Male	Female
24.5 cm	3				
25.5 cm					
26.5 cm	3				
27.5 cm	1	1		1	
28.5 cm	1	7	1	1	1
29.5 cm	4	13		1	1
30.5 cm	10	17	1	2	5
31.5 cm	18	19		2	7
32.5 cm	27	21	6	1	5
33.5 cm	40	28	15	3	15
34.5 cm	32	18	13		15
35.5 cm	21	9	7	4	6
36.5 cm	10	1	12		5
37.5 cm	17		12		5
38.5 cm	14		9		4
39.5 cm	14		4	1	4
40.5 cm	8		4		8
41.5 cm	7		5		2
42.5 cm	5		3		
43.5 cm	3				
44.5 cm	2		2		1
Total	240	134	94	16	84
Mean length (cm.)	35.03	32.28	36.51	32.75	35.24

TABLE C-14.—*Length frequencies of yellowtail: By area, quarter, and sex, from the southern New England stock*

Length of fish	1942		1943								1944							
	4th quarter		1st quarter		2d quarter		3d quarter		4th quarter		1st quarter		2d quarter		3d quarter		4th quarter	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
21.5 cm	1	1																
22.5 cm	5	8																
23.5 cm	14	8								1		2		1				
24.5 cm	18	24	1	1	1						2		1				5	1
25.5 cm	23	28	1	2	3	1		2			4	3	1				3	1
26.5 cm	18	16	5	2	7	6	2	13			6	2	2		1		5	
27.5 cm	11	13		1	8	13	11	30	2		11	5	8		7		6	
28.5 cm	16	12	7	4	10	19	16	54	3		15		7	2	13	1	18	2
29.5 cm	36	14	16	5	22	24	26	74	9	1	32	4	19	1	15		32	4
30.5 cm	53	29	55	7	28	54	42	83	12	6	50	30	35	5	40	4	46	13
31.5 cm	54	39	68	42	54	80	50	130	21	9	92	50	40	29	42	29	60	26
32.5 cm	86	31	71	73	59	131	87	164	22	21	88	49	40	50	39	38	68	29
33.5 cm	66	28	82	74	47	156	70	191	38	21	100	61	21	59	31	66	87	41
34.5 cm	46	47	84	67	44	110	52	220	29	29	124	65	10	34	22	49	58	61
35.5 cm	42	51	103	89	45	88	54	227	23	37	101	94	7	18	11	37	51	65
36.5 cm	32	58	82	87	37	82	36	205	19	41	86	93	10	13	4	25	18	80
37.5 cm	17	68	56	110	17	80	17	207	7	43	56	98	2	9	7	36	27	76
38.5 cm	12	50	52	122	7	74	6	174	8	40	47	83	1	8	1	20	9	59
39.5 cm	3	46	27	110	3	56	7	190		43	17	98		8	2	22	4	72
40.5 cm	4	33	18	117	3	60	1	125	1	26	13	82		5		17	2	41
41.5 cm		32	6	134		51	2	94		36	4	65		3		17	1	45
42.5 cm		31	3	110		37		51		21	3	81		3		15		36
43.5 cm		13	1	99	2	28		35		21	3	45		1		2	1	29
44.5 cm		12		61		15		15		9		46		1		3		29
45.5 cm		5		49		11		8		5		35				2		12
46.5 cm		5		25		8		3		3		20						7
47.5 cm				27		2		1		1		12				2		5
48.5 cm		1		11		1					1	5						3
49.5 cm				8		1				1		2						4
50.5 cm				2		1												1
51.5 cm				2														
52.5 cm				1														
53.5 cm																		
54.5 cm																		1
Total	557	703	738	1,442	397	1,189	479	2,296	194	415	855	1,130	204	250	235	385	501	743
Mean length (cm.)	31.84	35.16	34.68	39.16	33.22	35.77	33.20	35.83	33.73	38.03	34.15	38.21	31.79	34.27	32.16	35.98	32.98	37.98

TABLE C-15.—*Length frequencies of yellowtail: By area, quarter, and sex, from the southern New England stock*

Length of fish	1945								1946								1947							
	1st quarter		2d quarter		3d quarter		4th quarter		1st quarter		2d quarter		3d quarter		4th quarter		1st quarter		2d quarter		3d quarter		4th quarter	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
21.5 cm									1															
22.5 cm					1											1			1					
23.5 cm					2	1	1		1						1									
24.5 cm	3	1	3			1		2					1			2								2
25.5 cm	10	1	4		3	1			6	4			1			2	2	3	3				3	1
26.5 cm	29	3	11		6	2	1	2	8	8	3	1	4	1	1		9	8	12		1	1	3	
27.5 cm	28	1	10		40	3	4	2	16	6	3		23	5	5	3	17	3	18	7	16	2	4	3
28.5 cm	27	5	6		103	21	11	1	12	8	3	3	77	28	17	13	24	11	34	9	43	11	14	1
29.5 cm	27	5	3		170	68	37	14	13	6	4	7	81	75	63	54	12	9	35	22	73	56	40	11
30.5 cm	48	10	9	2	186	81	101	23	30	4	4	3	132	128	152	137	24	11	62	26	96	106	75	29
31.5 cm	68	35	18	4	165	121	167	64	72	13	3		78	151	167	199	48	17	72	42	102	135	91	56
32.5 cm	100	60	20	12	185	96	154	101	124	55	2		72	143	188	264	50	25	85	54	94	160	125	85
33.5 cm	140	54	30	8	177	111	162	126	152	145	6	1	80	89	162	253	62	44	74	104	64	172	89	89
34.5 cm	151	72	27	14	113	170	167	123	144	173	6		86	52	164	267	50	51	56	118	52	168	78	92
35.5 cm	164	96	18	25	57	223	128	133	108	142	4	5	55	56	128	206	46	56	56	114	38	151	49	89
36.5 cm	134	146	7	30	21	217	70	178	103	133	2	5	50	75	122	170	47	51	63	60	18	105	43	90
37.5 cm	122	176	10	27	5	208	47	192	69	146		9	20	117	79	190	44	56	37	51	7	68	31	74
38.5 cm	110	216		25	3	122	20	165	47	111		4	8	124	31	192	28	51	18	49	5	46	12	89
39.5 cm	35	245		13	3	81	12	163	25	97		9	2	93	17	223	10	45	20	75	2	45	9	52
40.5 cm	32	261		15		62	5	146	15	100		2		84	5	230	7	65	3	85	2	42	4	57
41.5 cm	13	222		17		41	1	123	9	109		7		53	2	216	4	47	1	78		39	1	69
42.5 cm	3	245		14	1	33		87	2	103		3		35	3	132	1	54		70		23		56
43.5 cm	4	212		8		13		54	2	85		1		16		84	1	31		40		18		39
44.5 cm		146	1	6		5		45		59				8		55	1	24		24		5		23
45.5 cm		131	1	3		2		32		36				3		32		17		16		3		18
46.5 cm		89		1				17		16				2		18		7		4		1		7
47.5 cm		53						11		18						13		11		4				3
48.5 cm		29						7		8				1		6		4		2		1		1
49.5 cm		8								5						7		2						2
50.5 cm		7								2						1		1		1				
51.5 cm		3								1								1		1				
52.5 cm										1														
Total	1,248	2,532	178	224	1,241	1,683	1,088	1,811	959	1,594	40	60	770	1,339	1,307	2,970	487	705	650	1,056	613	1,358	671	1,038
Mean length (cm.)	34.64	40.39	32.52	37.97	31.68	35.55	33.50	37.80	34.39	38.18	31.75	36.55	32.15	35.28	33.56	36.81	33.92	38.11	33.18	37.20	31.97	34.70	33.12	37.07

D. LENGTH AND AGE FREQUENCIES OF YELLOWTAIL FROM THE SOUTHERN NEW ENGLAND STOCK, BY QUARTER AND SEX, 1942–47

TABLE D-1.—*Length and age frequencies of yellowtail: Southern New England stock, by year, quarter, and sex*

[Age determinations during first quarters were not made for yellowtail with more than 6 annuli]

Length of fish	Male						Female							Sex undetermined						
	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli
1942																				
First quarter:																				
25.5 cm	1																			
26.5 cm																				
27.5 cm																				
28.5 cm	1																			
29.5 cm																				
30.5 cm																				
31.5 cm																				
32.5 cm			1					3												
33.5 cm			1																	
34.5 cm		1		1				1												
35.5 cm		1																		
36.5 cm			1							1										
37.5 cm				1					2											
38.5 cm					1				1	2										
39.5 cm										2										
40.5 cm																				
41.5 cm																				
42.5 cm											2									
43.5 cm																				
44.5 cm																				
45.5 cm												1								
Total	2	2	3	2	1			4	3	5	2	1								
Mean length (cm.)	27.0	35.0	34.2	36.0	38.5			33.0	37.8	38.5	42.5	45.5								
Second quarter:																				
26.5 cm																	2			
27.5 cm															5	1	1			
28.5 cm															2	2	1			
29.5 cm															3	2				
30.5 cm															1	6	4			
31.5 cm															3	13	8	1		
32.5 cm																24	12	4		
33.5 cm															1	11	26	5	2	1
34.5 cm																20	32	8	5	1
35.3 cm																11	25	7	4	2
36.5 cm																3	8	12	7	3
37.5 cm																4	3	6	6	3
38.5 cm																2	7	3	2	4
39.5 cm																1	3	3	2	2
40.5 cm																	2	1	6	2
41.5 cm																		1	2	4
42.5 cm																				3
43.5 cm																				4
44.5 cm																				1
45.5 cm																				1
Total															15	100	135	51	36	31
Mean length (cm.)															29.4	33.4	34.5	35.9	37.3	39.8
Third quarter:																				
26.5 cm															1					
27.5 cm															3					
28.5 cm															1					
29.5 cm															2					
30.5 cm															1	1				
31.5 cm															3	3				
32.5 cm																5				
33.5 cm															1	8	3			
34.5 cm																9	1	1		
35.5 cm																5	3			
36.5 cm																1	3			
37.5 cm																	7			
38.5 cm																2	4	2		
39.5 cm																	3			
40.5 cm																	1			
Total															12	34	25	3		
Mean length (cm.)															29.6	34.0	37.1	37.2		

TABLE D-1.—*Length and age frequencies of yellowtail: Southern New England stock, by year, quarter, and sex*—Continued

Length of fish	Male						Female							Sex undetermined						
	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6K annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7K annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7K annuli
1942—Con.																				
Fourth quarter:																				
21.5 cm														1						
22.5 cm							1								1					
23.5 cm																				
24.5 cm														1						
25.5 cm							1								1					
26.5 cm														2	1					
27.5 cm														1	1					
28.5 cm															3					
29.5 cm	1							1							4					
30.5 cm		9						3							6	1				
31.5 cm		3													10	1				
32.5 cm		4	2					2	2						9	2				
33.5 cm		5	4					2	2						11	4				
34.5 cm		1	4					2	3						12	7				
35.5 cm		1	2	1					1						1	7	1			
36.5 cm			6					1	3						2	10		1	1	
37.5 cm			2						6						3	9	3			
38.5 cm				1					2	1						5	3	1		
39.5 cm			1						1							2	4	1		
40.5 cm					1					2	3	1					2			
41.5 cm										4	2					1	1	5		
42.5 cm										1		1				1		3		
43.5 cm												1						1	3	
44.5 cm																		1	3	
45.5 cm												1								1
46.5 cm																				1
47.5 cm																				1
48.5 cm																				1
Total	1	23	21	2	1		2	11	20	8	5	4		5	65	50	14	13	7	4
Mean length (cm.)	29.5	32.0	35.3	37.0	40.5		24.0	32.6	36.1	41.0	40.9	43.0		25.3	32.3	36.2	38.8	41.3	42.9	47.0
1943																				
First quarter:																				
19.5 cm															1					
20.5 cm																				
21.5 cm																				
22.5 cm																				
23.5 cm														1						
24.5 cm																				
25.5 cm														3	1					
26.5 cm														2	1					
27.5 cm														2						
28.5 cm														1						
29.5 cm														3	3	1				
30.5 cm	1	5	1												6	1				
31.5 cm		1						2							9	2				
32.5 cm		1													5	2	2			
33.5 cm		2	1					2	1						6	5	2			
34.5 cm			1					1							6	8				
35.5 cm				1				1	1						3	5	3			
36.5 cm		1						2							3	7	2	1		
37.5 cm			2	3					2	1					1	7	1			
38.5 cm					1				3						1	3	3			
39.5 cm				1					1		1							3	1	
40.5 cm				1					1	4						1	4	2		
41.5 cm									1	4	3							1		
42.5 cm										2		2					1	1	3	
43.5 cm											1	1						1		
44.5 cm											1							1		
45.5 cm										1	1	2							1	
46.5 cm												3								
47.5 cm												1								
48.5 cm												1								
49.5 cm												2								
Total	1	10	5	6	1			8	10	12	7	12		12	46	42	18	10	5	
Mean length (cm.)	30.5	32.0	34.7	38.0	38.5			34.1	38.1	41.3	42.5	46.2		27.1	32.4	35.3	37.2	40.8	42.5	
Second quarter:																				
24.5 cm															1					
25.5 cm															1					
26.5 cm		1						5							1					
27.5 cm		2						6	1						3					
28.5 cm		2	1					10	1						5					
29.5 cm		1	4					10	4						3					
30.5 cm		2	11					12	6						2	7				
31.5 cm			20	1				8	16						3	5				
32.5 cm			22	6				6	34	1						13				
33.5 cm		1	14	2					49							5				
34.5 cm			7	9					26	2						3	1			
35.5 cm			7	11	1				31	4						2	2			
36.5 cm			6	10	3				22	18	1					2	1	1		
37.5 cm			1	6	2				12	9	7						2	2	1	
38.5 cm					1	1			7	14	5	2					3			

TABLE D-1.—*Length and age frequencies of yellowtail: Southern New England stock, by year, quarter, and sex*—Continued

Length of fish	Male						Female							Sex undetermined						
	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli
1943—Con.																				
Second quarter—Con.																				
39.5 cm			1	2					2	15	2	4					2		1	
40.5 cm				1						4	11	4	1						3	
41.5 cm										3	10	2	1					2	1	
42.5 cm										4	5	4	3					1	1	
43.5 cm					1						3	6	1					2	2	
44.5 cm											3		1						2	
45.5 cm												3	3						1	
46.5 cm												1	2						1	
47.5 cm													1						1	
48.5 cm													1							
49.5 cm																				
50.5 cm													1							
Total		9	94	48	8	1		57	211	74	47	26	15		19	37	11	8	14	
Mean length (cm.)		29.2	32.8	35.5	37.8	38.5		29.6	34.2	38.2	40.6	42.1	44.9		28.7	32.7	37.4	40.5	42.7	
Third quarter:																				
27.5 cm		1						1												
28.5 cm		2						1												
29.5 cm		4						1												
30.5 cm		2						2	1											
31.5 cm		2	1					2	8											
32.5 cm		1	2					4	11											
33.5 cm		1	4						9											
34.5 cm			3		1			2	15											
35.5 cm			3					1	15	2										
36.5 cm				2					5	7										
37.5 cm									6	4										
38.5 cm			1						2	11	1									
39.5 cm									3	13	1									
40.5 cm										2		1								
41.5 cm										5	1									
42.5 cm										1		2								
43.5 cm											1	1								
44.5 cm											1									
45.5 cm																				
46.5 cm												1								
47.5 cm													1							
Total		13	14	2	1			14	75	45	5	5	1							
Mean length (cm.)		30.2	34.2	36.5	34.5			31.7	34.6	38.8	41.5	43.1	47.5							
Fourth quarter:																				
23.5 cm							1													
24.5 cm																				
25.5 cm																				
26.5 cm																				
27.5 cm																				
28.5 cm		1													1					
29.5 cm		1													3					
30.5 cm		3	1					2							2	1				
31.5 cm		2	1					4							13	1				
32.5 cm		3	2					1		1					7	10				
33.5 cm		2	5					2	2						18	6				
34.5 cm		1	4					3							13	12	2			
35.5 cm		1	4	2				2	5						11	23	3	1		
36.5 cm		2	3	2					10	1					7	14	3			
37.5 cm				2					8	2					3	21	5			
38.5 cm								1	4	5					4	10	13			
39.5 cm									3	4						7	6	1		
40.5 cm										7							9	4		
41.5 cm										2	1					1	9	4		
42.5 cm										1	1						2	4		
43.5 cm											2		1				1	3	1	
44.5 cm											2	2					1	5	1	
45.5 cm											1						1	4		
46.5 cm																		1	3	1
47.5 cm																				
48.5 cm																			1	1
49.5 cm																				1
Total		16	20	6			1	15	32	23	7	2	1		82	106	55	27	6	3
Mean length (cm.)		32.5	34.2	36.5			23.5	33.3	36.9	39.3	43.6	44.5	43.5		33.9	36.0	39.4	42.8	46.0	48.2
1944																				
First quarter:																				
24.5 cm															2					
25.5 cm																				
26.5 cm																				
27.5 cm	1														1					
28.5 cm															1					
29.5 cm															1					
30.5 cm															1					
31.5 cm		1													4					
32.5 cm		1													4	2				

TABLE D-1.—*Length and age frequencies of yellowtail: Southern New England stock, by year, quarter, and sex*—Continued

Length of fish	Male						Female							Sex undetermined						
	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli
1944—Con.																				
First quarter—Con.																				
33.5 cm		1	1												2	1				
34.5 cm		1	2												1	1	1			
35.5 cm			3					1	5						1	3	1	1		
36.5 cm		1		2				1								3	1			
37.5 cm			3	1					1											
38.5 cm				1					2							1	2			
39.5 cm									4	2						1	1	2		
40.5 cm				1					2	2										
41.5 cm											1						1			
42.5 cm										2		1					1			
43.5 cm												1							1	
44.5 cm										1	1									
45.5 cm												2								
46.5 cm												1								
47.5 cm																				
48.5 cm																			1	
Total	1	5	9	5				2	14	7	2	5			18	12	8	3	2	
Mean length (cm.)	27.5	33.7	35.7	37.9				36.0	37.9	41.4	43.0	44.7			31.0	35.6	38.4	38.2	46.0	
Second quarter:																				
28.5 cm		1																		
29.5 cm		1	4																	
30.5 cm		2	12						2											
31.5 cm			11					1	5											
32.5 cm			12						13											
33.5 cm			3						16											
34.5 cm			4						14											
35.5 cm				2					5		1									
36.5 cm			1	2					3											
37.5 cm										2										
38.5 cm					1					1										
39.5 cm											2									
40.5 cm												1								
41.5 cm																				
42.5 cm											1									
43.5 cm												1								
Total		4	47	4	1			1	58	3	4	2								
Mean length (cm.)		29.8	31.8	36.0	38.5			31.5	33.6	37.8	39.2	42.0								
Third quarter:																				
28.5 cm		1							1						2					
29.5 cm		1	3																	
30.5 cm		2	7					1	3						1					
31.5 cm			9					1	7						1	1				
32.5 cm		1	9					1	9							1				
33.5 cm			4						13						1	1				
34.5 cm			4	1					11						1	2	1			
35.5 cm									7	2										
36.5 cm				1					2	2										
37.5 cm				2					2	3										
38.5 cm										7							1			
39.5 cm				1					1	1	4									
40.5 cm											2									
41.5 cm										1	1									
42.5 cm									1	1										
43.5 cm																				
44.5 cm																				
45.5 cm																				
46.5 cm																				
47.5 cm													1							
Total		5	36	5				3	57	17	7		1		6	5	2			
Mean length (cm.)		30.3	31.9	37.1				31.5	33.8	38.2	40.1		47.5		31.2	33.3	36.5			
Fourth quarter:																				
20.5 cm	1																			
21.5 cm																				
22.5 cm																				
23.5 cm																				
24.5 cm																				
25.5 cm																				
26.5 cm																				
27.5 cm	1	1																		
28.5 cm		5																		
29.5 cm		6						3												
30.5 cm		5						3												
31.5 cm		3	3					4	1											
32.5 cm		3	8					4	1											
33.5 cm		1	11	1				3	1											
34.5 cm		1	7	1				4	12											
35.5 cm		1	7	1				2	12	1										
36.5 cm			2	1					12	1										
37.5 cm				2					9	1										
38.5 cm				2					10	4										

TABLE D-1.—*Length and age frequencies of yellowtail: Southern New England stock, by year, quarter, and sex*—Continued

Length of fish	Male						Female							Sex undetermined						
	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli
1944—Con.																				
Fourth quarter—Cont.																				
39.5 cm					1				7	13										
40.5 cm				1					2	6	2									
41.5 cm				1						3	7									
42.5 cm										3	6	1								
43.5 cm											2	2								
44.5 cm										1	1	8	2							
45.5 cm												5								
46.5 cm												2	1							
47.5 cm												2								
48.5 cm																				
49.5 cm													1							
50.5 cm													1							
51.5 cm													1							
Total	2	26	38	10	1			23	67	33	18	20	6							
Mean length (cm.)	24.0	30.6	33.8	37.4	39.5			32.4	36.6	39.9	42.1	45.0	47.8							
1945																				
First quarter:																				
24.5 cm	1																			
25.5 cm	3						1													
26.5 cm	7	1					1	1												
27.5 cm	7						1													
28.5 cm	7	2					1													
29.5 cm	3	7					1													
30.5 cm		5						2												
31.5 cm	1	15	2					3												
32.5 cm		17	6	1				18	2											
33.5 cm		10	15	1				11	2											
34.5 cm		12	13	4	1			19	4											
35.5 cm		15	29	6				8	12	1										
36.5 cm		3	22	14				12	31	3										
37.5 cm		3	12	9	3			5	26	8	1									
38.5 cm			6	13	3			4	19	9										
39.5 cm			3	7				2	32	22	1									
40.5 cm				2	2			4	14	27	6									
41.5 cm				3	1				8	26	10	1								
42.5 cm				1					2	39	30	2								
43.5 cm									1	16	26	9								
44.5 cm									1	3	10	8								
45.5 cm										3	5	28								
46.5 cm										1	2	19								
47.5 cm											2	13								
48.5 cm												3								
49.5 cm																				
50.5 cm												4								
Total	29	90	108	61	10		5	89	154	158	93	87								
Mean length (cm.)	27.5	33.0	35.6	37.5	38.5		27.5	34.8	38.1	41.2	43.0	45.9								
Second quarter:																				
25.5 cm		1																		
26.5 cm		2																		
27.5 cm		2																		
28.5 cm		1																		
29.5 cm		1	1																	
30.5 cm			3						2						2					
31.5 cm			2	2					3											
32.5 cm			6	1					5											
33.5 cm			1	9					2											
34.5 cm				4					1	2										
35.5 cm			1	1					1	4										
36.5 cm					1				2	2										
37.5 cm									3	4	1									
38.5 cm										3										
39.5 cm										2	1	1	1							
40.5 cm											1	1	1							
41.5 cm											4	1								
42.5 cm											2	1	3							
43.5 cm													2							
44.5 cm													2							
45.5 cm													2							
46.5 cm													1							
Total		7	14	17	1				19	17	9	4	12							
Mean length (cm.)		27.4	32.0	33.6	36.5				33.7	37.0	40.9	41.0	43.4							
Third quarter:																				
23.5 cm	1																			
24.5 cm							1													
25.5 cm	1																			
26.5 cm		1					1													
27.5 cm		8																		
28.5 cm		13						4												
29.5 cm		36						20												
30.5 cm		38	1					29												

TABLE D-1.—*Length and age frequencies of yellowtail: Southern New England stock, by year, quarter, and sex*—Continued

Length of fish	Male						Female							Sex undetermined						
	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli
1945—Con.																				
Third quarter—Cont.																				
31.5 cm		28	4	2				36												
32.5 cm		15	18	8				29	1											
33.5 cm		5	24	9				17	6	1										
34.5 cm			12	11				11	17	8										
35.5 cm		1	4	8				23	20	16										
36.5 cm			1	2					12	26	1									
37.5 cm				3					7	43	8									
38.5 cm				1					4	21	4									
39.5 cm				1					2	14	7	1								
40.5 cm										3	8	4								
41.5 cm											8	4	1							
42.5 cm										2	2	3	2							
43.5 cm											1	2								
44.5 cm												1								
45.5 cm											1									
Total	2	145	64	45			2	149	69	134	40	15	3							
Mean length (cm.)	24.5	30.4	33.4	34.5			25.5	31.7	35.7	37.4	39.9	41.8	42.2							
Fourth quarter:																				
26.5 cm	1																			
27.5 cm		1																		
28.5 cm			1																	
29.5 cm		8						2												
30.5 cm	1	19						6												
31.5 cm		29	4					16												
32.5 cm		24	8	1				27	2											
33.5 cm		17	18	10				29	3											
34.5 cm		6	16	19	1			31	6											
35.5 cm		3	7	20				11	10	1										
36.5 cm			9	9	2			12	21	17	1									
37.5 cm			1	10	3			2	11	35	1	1								
38.5 cm			1	5	1				6	34	1									
39.5 cm				2	4				1	34	11	1								
40.5 cm				1		1			2	10	22	1								
41.5 cm					1					5	24	2								
42.5 cm										2	17	8	1							
43.5 cm											6	12	1							
44.5 cm											3	3	2							
45.5 cm											1	4	4							
46.5 cm												1	3							
47.5 cm													3							
48.5 cm													5							
Total	2	107	65	77	12	1		136	62	138	87	33	19							
Mean length (cm.)	28.5	32.0	34.2	35.7	38.2	40.5		33.6	36.4	38.5	41.3	43.2	46.4							
1946																				
First quarter:																				
23.5 cm	1																			
24.5 cm																				
25.5 cm	2																			
26.5 cm	2						3													
27.5 cm	2	1					2	1												
28.5 cm	2						4													
29.5 cm	3						1													
30.5 cm		2	1					1												
31.5 cm	1	14	1				1	1												
32.5 cm	1	26	3					7	1											
33.5 cm		27	10					28	6											
34.5 cm		23	14					39	2											
35.5 cm		10	18					27	9											
36.5 cm		7	17	5				19	15											
37.5 cm			13	6				9	20	4										
38.5 cm			8	3				3	21	7	1									
39.5 cm			2	1	1				9	9	1									
40.5 cm				3	2				4	26	1									
41.5 cm				1	4				3	19	9									
42.5 cm					2				3	15	9									
43.5 cm										9	16	4								
44.5 cm										1	10	4								
45.5 cm											2	8								
46.5 cm											2	2								
47.5 cm												5								
48.5 cm												1								
49.5 cm											1	1								
50.5 cm												2								
Total	14	110	87	19	9		11	135	93	90	52	27								
Mean length (cm.)	28.0	33.5	35.8	38.2	41.3		28.1	34.8	37.6	41.0	43.2	46.1								

TABLE D-1.—*Length and age frequencies of yellowtail: Southern New England stock, by year, quarter, and sex*—Continued

Length of fish	Male						Female							Sex undetermined						
	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli
1946—Con.																				
Second quarter:																				
26.5 cm		1																		
27.5 cm		1																		
28.5 cm		1						3												
29.5 cm		1																		
30.5 cm																				
31.5 cm																				
32.5 cm			1																	
33.5 cm			4																	
34.5 cm				2																
35.5 cm				2						2										
36.5 cm										2										
37.5 cm									1	1										
38.5 cm																				
39.5 cm											1									
40.5 cm											1									
41.5 cm											1									
Total		4	5	4				3	1	5	3									
Mean length (cm.)		28.0	33.3	35.0				28.5	37.5	36.3	40.5									
Third quarter:																				
17.5 cm							1													
18.5 cm																				
19.5 cm																				
20.5 cm																				
21.5 cm																				
22.5 cm																				
23.5 cm																				
24.5 cm																				
25.5 cm								1												
26.5 cm		4						1												
27.5 cm		9						3												
28.5 cm		33						11												
29.5 cm		50						29												
30.5 cm		63						60												
31.5 cm		28	2	2				71												
32.5 cm		14	8	12				57	3											
33.5 cm		9	9	8				30	6	2										
34.5 cm			11	14	1			12	10	2										
35.5 cm		2	4	16	1			4	10	8	1									
36.5 cm			1	12	1			1	4	19	1									
37.5 cm				8	1			1		33	7									
38.5 cm				1	2				4	28	20									
39.5 cm										12	35	1								
40.5 cm									1	3	26	3								
41.5 cm											24	5								
42.5 cm										1	10	5	2							
43.5 cm										1	1	4	1							
44.5 cm												4	1							
45.5 cm													1							
46.5 cm											1									
Total		212	35	73	6		1	281	38	109	126	22	5							
Mean length (cm.)		30.2	33.8	34.9	36.8		17.5	31.5	35.2	37.7	40.1	42.4	43.7							
Fourth quarter:																				
23.5 cm	1																			
24.5 cm							3													
25.5 cm		1																		
26.5 cm																				
27.5 cm		1																		
28.5 cm		3					1	1												
29.5 cm		14																		
30.5 cm		36	1					10												
31.5 cm		47	2					24												
32.5 cm		39	7		1			33	2											
33.5 cm		21	13	5				46	2											
34.5 cm		13	10	14	1	1		39	10											
35.5 cm		1	10	9	5			11	19											
36.5 cm		3	10	17	5			4	15	5	1									
37.5 cm			2	8	11			2	17	16	7									
38.5 cm				4	5	1			8	16	11	2								
39.5 cm						1			5	16	29	3								
40.5 cm					1				2	12	51	1								
41.5 cm					1				1	4	44	9								
42.5 cm					1					2	21	11	1							
43.5 cm										1	7	15	3							
44.5 cm									1		2	6	4							
45.5 cm												4	4							
46.5 cm												1								
47.5 cm													1							
48.5 cm													4							
49.5 cm													1							
50.5 cm													1							
Total	1	179	55	57	31	3	4	170	82	72	173	52	19							
Mean length (cm.)	23.5	31.8	34.5	35.9	37.3	37.5	25.5	33.3	36.7	39.0	40.7	42.8	46.0							

TABLE D-1.—*Length and age frequencies of yellowtail: Southern New England stock, by year, quarter, and sex*—Continued

Length of fish	Male						Female							Sex undetermined						
	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli
1947																				
First quarter:																				
26.5 cm							1													
27.5 cm							1													
28.5 cm	3																			
29.5 cm	1	1					5													
30.5 cm	1						3													
31.5 cm	1	4																		
32.5 cm		5					1	1												
33.5 cm		6			1		1	8												
34.5 cm		14	1					7												
35.5 cm		3	8					9	1											
36.5 cm		2	5	4				4	4	1										
37.5 cm			6	1	1			4	7											
38.5 cm			6						5	1	1									
39.5 cm									4	1	1	1								
40.5 cm			3					1	2	5	3									
41.5 cm					1				1	3	1									
42.5 cm				1						1	6									
43.5 cm										1	2	4								
44.5 cm										3	3	1								
45.5 cm										1		1								
46.5 cm										1		3								
47.5 cm											1	1								
48.5 cm												2								
49.5 cm																				
50.5 cm												2								
Total	6	35	29	6	3		12	34	24	18	18	15								
Mean length (cm.)	29.5	33.8	37.2	37.7	37.5		29.9	35.2	38.2	41.8	42.4	45.9								
Second quarter:																				
26.5 cm		1																		
27.5 cm		7						3												
28.5 cm		6																		
29.5 cm		6	1					7												
30.5 cm		4	13					5												
31.5 cm		3	6					7	4											
32.5 cm		3	16					7	7											
33.5 cm		1	13	2				3	18											
34.5 cm			7	9	2			2	29											
35.5 cm				7	5				17	2										
36.5 cm			3	8	4				17	1										
37.5 cm				4	5				6	8	1									
38.5 cm					3	1				6	7									
39.5 cm				1	4	1				4	8	3								
40.5 cm									1		26	5								
41.5 cm									1		13	11								
42.5 cm											7	12	3							
43.5 cm											2	7	1							
44.5 cm												6	4							
45.5 cm												1	4							
46.5 cm													1							
47.5 cm											1									
48.5 cm																				
49.5 cm																				
50.5 cm																				
51.5 cm													1							
Total		31	59	31	23	2		34	100	21	65	45	14							
Mean length (cm.)		29.5	32.6	35.7	37.1	39.0		31.1	34.9	37.9	40.7	42.3	44.9							
Third quarter:																				
27.5 cm		1																		
28.5 cm		8						1												
29.5 cm	1	12						12												
30.5 cm		16	6					19												
31.5 cm		12	10					35												
32.5 cm		7	18	1				26	8											
33.5 em		1	15	4				17	19											
34.5 cm			11	6	1			17	39											
35.5 cm			1	4	1			3	38											
36.5 cm				4	2				20	5										
37.5 cm					2			1	2	16										
38.5 cm				1	2				1	6	6									
39.5 cm					1					1	9									
40.5 cm					1					1	9	2								
41.5 cm											13	4								
42.5 cm											1	6								
43.5 cm												5	2							
44.5 cm												2	1							
45.5 cm												2								
46.5 cm																				
47.5 cm																				
48.5 cm													1							
Total	1	57	61	20	10			131	127	29	38	21	4							
Mean length (cm.)	29.5	30.5	32.8	35.0	37.5			32.1	34.9	37.7	40.3	42.8	45.0							

TABLE D-1.—*Length and age frequencies of yellowtail: Southern New England stock, by year, quarter, and sex*—Continued

Length of fish	Male						Female							Sex undetermined						
	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli
1947—Con.																				
Fourth quarter:																				
28.5 cm								1												
29.5 cm		6						3												
30.5 cm		6						3												
31.5 cm		26	2					6												
32.5 cm		17	11	1				20	1											
33.5 cm		10	8	1	1			19	2											
34.5 cm		3	13	1				18	10											
35.5 cm		2	7	5	2			5	14	2										
36.5 cm			4	4		1		4	16	3										
37.5 cm			2	3	4			1	14	5										
38.5 cm			1					2	11	12										
39.5 cm				1				1	3	14	3									
40.5 cm					1				2	3	8	3								
41.5 cm						1				2	19	4								
42.5 cm										1	5	12								
43.5 cm											1	10								
44.5 cm											2	5	1							
45.5 cm													3							
46.5 cm													1							
47.5 cm																				
48.5 cm													1							
49.5 cm													2							
Total		70	48	16	8	2		83	73	42	38	34	8							
Mean length (cm.)		32.0	34.3	36.0	36.9	39.0		33.5	36.6	38.8	41.5	42.8	46.9							

TABLE D-2.—*Length and age frequencies of yellowtail: Summary, by quarter and sex, 1942–47*

Length of fish	Male						Female							Sex undetermined						
	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli
First quarter: [1]																				
19.5 cm															1					
20.5 cm																				
21.5 cm																				
22.5 cm																				
23.5 cm	1													1						
24.5 cm	1														2					
25.5 cm	6						1							3	1					
26.5 cm	9	1					5	1						2	1					
27.5 cm	10	1					4	1						2	1					
28.5 cm	13	2					5							1	1					
29.5 cm	7	8					7							3	4	1				
30.5 cm	2	12	2				3	3							7	1				
31.5 cm	3	35	3				1	6							13	2				
32.5 cm	1	50	10	1			1	29	3						9	4	2			
33.6 cm		46	28	1	1		1	49	9						8	6	2			
34.5 cm		51	31	5	1			67	6						7	9	1			
35.5 cm		29	58	7				46	28	1					4	8	4	1		
36.5 cm		14	45	25				38	50	5					3	10	3	1		
37.5 cm		3	36	21	4			18	58	13	1				1	7	1			
38.5 cm			20	17	5			7	51	19	2				1	4	5			
39.5 cm			5	9	1			2	50	36	4					1	1	5	1	
40.5 cm			3	7	4			5	23	64	10					1	4	2		
41.5 cm				4	6				13	52	24	1					1	1		
42.5 cm				2	2				5	59	47	5					2	1	3	
43.5 cm									1	26	45	19						1	1	
44.5 cm									1	8	25	13						1		
45.5 cm										5	8	42							1	
46.5 cm										2	4	28								
47.5 cm											3	21								
48.5 cm												7							1	
49.5 cm											1	3								
50.5 cm												8								
Total	53	252	241	99	24		28	272	298	290	174	147		12	64	54	26	13	7	
Mean length (cm.)	27.9	33.3	35.8	37.7	39.4		28.8	34.8	38.0	41.1	43.0	46.0		27.1	32.0	35.4	37.5	40.2	43.5	
Second quarter:																				
24.5 cm															1					
25.5 cm		1													1					
26.5 cm		5						5							1		2			
27.5 cm		12						9	1						8	1	1			
28.5 cm		11	1					13	1						7	2	1			
29.5 cm		10	10					17	4						6	2				
30.5 cm		8	39					17	10						3	13	4			
31.5 cm		3	39	3				16	28						6	18	8	1		
32.5 cm		3	57	7				13	59	1						37	12	4		
33.5 cm		2	35	13				3	85						1	16	26	5	2	1

[1] Age determinations during first quarter were not made for yellowtail with more than 6 annuli.

TABLE D-2.—*Length and age frequencies of yellowtail: Summary, by quarter and sex, 1942–47*—Continued

Length of fish	Male						Female							Sex undetermined						
	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli	1 annulus	2 annuli	3 annuli	4 annuli	5 annuli	6 annuli	7+ annuli
Second quarter—Con.																				
34.5 cm			18	24	2			2	70	4						23	33	8	5	1
35.5 cm			8	23	6				54	12	1					13	27	7	4	2
36.5 cm			10	20	8				44	23	1					5	9	13	7	3
37.5 cm			1	10	7				22	24	9					4	5	8	7	3
38.5 cm					4	2			7	24	12	2				2	10	3	2	4
39.5 cm			1	3	4	1			2	21	14	8	1			1	5	3	3	2
40.5 cm				1					1	4	39	11	2				2	1	9	2
41.5 cm									1	3	28	14	1					3	3	4
42.5 cm										4	15	17	9					1	1	3
43.5 cm					1						5	14	4					2	2	4
44.5 cm											3	6	7				1		2	1
45.5 cm												4	9						1	1
46.5 cm												1	4						1	
47.5 cm											1		1						1	
48.5 cm													1							
49.5 cm																				
50.5 cm													1							
51.5 cm													1							
Total		55	219	104	32	3		95	389	120	128	77	41		34	137	146	59	50	31
Mean length (cm.)		29.1	32.5	35.2	37.2	38.8		30.4	34.2	37.9	40.6	42.2	44.5		29.0	33.2	34.7	36.6	38.8	39.8
Third quarter:																				
23.5 cm	1																			
24.5 cm							1													
25.5 cm	1							1												
26.5 cm		5					1	1							1					
27.5 cm		19						4							3					
28.5 cm		57						17							3					
29.5 cm	1	103	3					62	1						2					
30.5 cm		121	14					111	4						2	1				
31.5 cm		70	26	4				145	15						4	4				
32.5 cm		38	55	21				117	32							6				
33.5 cm		16	56	21				64	53	3					2	9	3			
34.5 cm			41	32	3			42	92	10					1	11	2	1		
35.5 cm		3	12	28	2			11	90	28	1					5	3			
36.5 cm			2	21	3			1	43	59	2					1	3			
37.5 cm				13	3			2	17	99	15						7			
38.5 cm			1	3	4				11	73	31					2	5	2		
39.5 cm				2	1				6	41	56	2					3			
40.5 cm					1				1	9	45	10					1			
41.5 cm										6	47	13	1							
42.5 cm									1	5	13	16	4							
43.5 cm										1	3	12	3							
44.5 cm											1	7	2							
45.5 cm											1	2	1							
46.5 cm											1	1								
47.5 cm													2							
48.5 cm													1							
Total	3	432	210	145	17		2	578	366	334	216	63	14		18	39	27	3		
Mean length (cm.)	26.2	30.3	33.1	34.9	37.1		25.5	31.7	34.8	37.7	40.1	42.4	44.3		30.1	33.9	37.0	37.2		
Fourth quarter:																				
20.5 cm	1																			
21.5 cm														1						
22.5 cm							1													
23.5 cm	1						1								1					
24.5 cm							3							1						
25.5 cm		1					1													
26.5 cm	1													2	1					
27.5 cm	1	3												1	1					
28.5 cm		9	1				1	2							2					
29.5 cm		35						8							6					
30.5 cm	2	69	2					25							6	1				
31.5 cm		116	12					57	1						19	2				
32.5 cm		89	36	2	1			85	6	1					17	11				
33.5 cm		55	57	17	1			101	12						27	8				
34.5 cm		29	54	35	2	1		97	40						24	16	2			
35.5 cm		9	39	37	7			33	63	4					23	30	3	1		
36.5 cm		6	30	34	7	1		20	75	27	2				8	21	4			
37.5 cm			11	25	18			6	62	59	8	1			5	31	5	1	1	
38.5 cm			4	11	6	1		3	45	71	12	2			7	19	16			
39.5 cm				4	5	1		1	21	82	43	4				12	9	2		
40.5 cm			1	2	2	1			9	38	83	5				2	13	5		
41.5 cm				1	3	1			1	18	98	16				1	11	4		
42.5 cm					1					13	52	32	2			1	3	9		
43.5 cm										2	18	40	5			1	1	6	1	
44.5 cm									1	1	10	25	8				1	6	4	
45.5 cm											2	13	8				1	5	3	2
46.5 cm												5	4					1	3	1
47.5 cm												2	4							2
48.5 cm													9						1	2
49.5 cm													2							
50.5 cm													2							
51.5 cm													1							
Total	6	421	247	168	53	6	7	438	336	316	328	145	45	5	147	156	69	40	13	7
Mean length (cm.)	26.5	31.9	34.4	35.9	37.6	38.5	24.8	33.3	36.7	39.0	41.1	43.2	46.4	25.3	33.6	36.4	39.5	42.6	44.9	47.1

E. YELLOWTAIL LARVAE TAKEN IN 1932

TABLE E-1.—*Yellowtail larvae caught during cruises 1 to 7 of the* Albatross II, *in 1932*

[Numbers in parentheses indicate stations for which complete data are available in Sette 1943, pp. 216–219; fractions indicate part of haul sorted for small and large larvae; adjusted totals represent number of larvae per 17.07 square meters of sea surface; see Sette (1943, pp. 211–215) for method of computing]

Station and haul	Count of larvae		Total larvae	
	Small	Large	Small	Large
CRUISE 1				
Martha's Vineyard:				
Station I (21327), May 2:				
Upper haul:				
112/1500	4		54	
1388/1500		2		2
Adjusted total			38	1
Station II (21328), May 2:				
Upper haul:				
112/1500	6		80	
1388/1500		7		8
Lower haul:				
112/1500	3		40	
1388/1500		1		1
Adjusted total			76	7
Station III (21329), May 3:				
Upper haul:				
112/1500	0		0	
1388/1500		0		0
Lower haul:				
56/1500	0		0	
1444/1500		0		0
Adjusted total			0	0
Station IV (21330), May 3:				
Upper haul:				
112/1500	0		0	
1388/1500		0		0
Lower haul:				
56/1000	0		0	
1444/1500		0		0
Adjusted total			0	0
New York:				
Station II (21335), May 4:				
Upper haul:				
40/1600	0		0	
Remainder		1		1
Lower haul:				
60/2400	0		0	
Remainder		0		0
Adjusted total			0	1
Station III (21334), May 3:				
Upper haul:				
100/2000	0		0	
Remainder		0		0
Lower haul:				
80/1600	0		0	
Remainder		1		1
Adjusted total			0	1
Station IV (21333), May 3:				
Upper haul:				
160/1600	0		0	
Remainder		0		0
Lower haul:				
240/1200	0		0	
Remainder		0		0
Adjusted total			0	0
Station V (21332), May 3:				
Upper haul:				
200/2000	0		0	
Remainder		0		0
Adjusted total			0	0
Station VI (21331), May 3:				
Upper haul:				
112/1000	0		0	
880/1000		0		0
Lower haul:				
112/1500	0		0	
1388/1500		0		0
Adjusted total			0	0
CRUISE 1—Continued				
Barnegat:				
Station I (21336) May 4:				
Upper haul:				
240/2400	0		0	
Remainder		0		0
Adjusted total			0	0
Atlantic City:				
Station I (21337), May 4:				
Upper haul:				
120/1200	13		130	
Remainder		7		7
Adjusted total			91	5
Station II (21338), May 4:				
Upper haul:				
60/1000	12		200	
Remainder		2		2
Lower haul:				
80/1600	11		220	
Remainder		3		3
Adjusted total			260	3
Station III (21339), May 4:				
Upper haul:				
200/4000	0		0	
Remainder		2		2
Lower haul:				
80/1600	0		0	
Remainder		0		0
Adjusted total			0	1
Station IV (21340), May 4:				
Upper haul:				
80/1600	0		0	
Remainder		0		0
Lower haul:				
80/1600	0		0	
Remainder		0		0
Adjusted total			0	0
Cape May:				
Station II (21345), May 5:				
Upper haul:				
100/2000	34		680	
Remainder		104		104
Adjusted total			476	73
Station III (21344), May 5:				
Upper haul:				
160/1500	1		9	
Remainder		0		0
Lower haul:				
200/2000	9		90	
Remainder		16		16
Adjusted total			62	10
Station IV (21343), May 5:				
Upper haul:				
100/1000	2		20	
Remainder		4		4
Lower haul:				
160/1500	2		19	
Remainder		2		2
Adjusted total			24	4
Station V (21342), May 5:				
Upper haul:				
80/1600	0		0	
Remainder		0		0
Lower haul:				
100/2000	0		0	
Remainder		0		0
Adjusted total			0	0
Station VI (21341), May 5:				
Upper haul:				
100/2000	0		0	
Remainder		0		0
Lower haul: All		0		0
Adjusted total			0	0

TABLE E-1.—*Yellowtail larvae caught during cruises 1 to 7 of the* Albatross II, *in 1932*—Continued

Station and haul	Count of larvae		Total larvae	
	Small	Large	Small	Large
CRUISE 1—Continued				
Fenwick:				
Station I (21346), May 5:				
Upper haul:				
180/1800	24		240	
Remainder		46		46
Adjusted total			168	32
Winterquarter:				
Station I (21347), May 5:				
Upper haul:				
80/1500	19		356	
Remainder		78		78
Adjusted total			249	55
Station II (21348), May 5:				
Upper haul:				
260/3000	0		0	
Remainder		17		17
Lower haul:				
200/1500	6		45	
Remainder		26		26
Adjusted total			28	26
Station III (21349), May 5:				
Upper haul:				
160/3000	0		0	
Remainder		2		2
Lower haul:				
260/2000	0		0	
Remainder		2		2
Adjusted total			0	2
Chesapeake Bay:				
Station I (21352), May 6:				
Upper haul:				
300/1000	3		10	
Remainder				
Adjusted total			7	
Station II (21351), May 6:				
Upper haul:				
1000/3000	13		39	
Remainder				
Adjusted total			27	
Station III (21350), May 6:				
Upper haul:				
500/2000	0		0	
Remainder				
Lower haul:				
1/10	0		0	
All		0		0
Adjusted total			0	0
CRUISE 2				
Martha's Vineyard:				
Station I (21381), May 16:				
Upper haul:				
56/1500	59		1,580	
1444/1500		14		15
Lower haul:				
56/1250	33		737	
1194/1250		11		12
Adjusted total			1,426	16
Station II (21380), May 16:				
Upper haul:				
56/1500	0		0	
1444/1500		1		1
Lower haul:				
56/1000	2		4	
944/1000		0		0
Adjusted total			3	1
Station III (21379), May 16:				
Upper haul:				
56/2000	0		0	
1944/2000		0		0
Lower haul:				
56/1500	0		0	
1444/1500		0		0
Adjusted total			0	0
CRUISE 2—Continued				
Montauk Point:				
Station I (21375), May 15:				
Upper haul:				
56/1000	9		161	
944/1000		7		7
Adjusted total			113	5
Station II (21376), May 15:				
Upper haul:				
56/1000	1		18	
944/1000		16		19
Lower haul:				
56/1000	0		0	
944/1000		2		2
Adjusted total			11	12
Station III (21377), May 15:				
Upper haul:				
56/1500	0		0	
1444/1500		0		0
Lower haul:				
56/1500	0		0	
1444/1500		0		0
Adjusted total			0	0
Shinnecock:				
Station I (21374), May 15:				
Upper haul:				
112/1000	1		9	
888/1000		1		1
Lower haul:				
56/1000	0		0	
944/1000		5		5
Adjusted total			5	4
Station II (21373), May 15:				
Upper haul:				
56/1000	0		0	
944/1000		0		0
Lower haul:				
56/1000	2		36	
944/1000		2		2
Adjusted total			23	2
New York:				
Station I (21369), May 14:				
Upper haul:				
56/1000	33		590	
944/1000		15		16
Adjusted total			413	11
Station II (21370), May 14:				
Upper haul:				
56/2250	16		643	
2194/2250		75		77
Lower haul:				
56/1250	33		736	
1194/1250		38		40
Adjusted total			854	72
Station III (21371), May 14:				
Upper haul:				
56/1000	3		54	
944/1000		29		31
Lower haul:				
56/1000	4		71	
944/1000		9		10
Adjusted total			78	25
Station IV (21372), May 15:				
Upper haul:				
112/2000	0		0	
1888/2000		0		0
Lower haul:				
112/1500	0		0	
1388/1500		0		0
Adjusted total			0	0
Barnegat:				
Station I (21368), May 14:				
Upper haul:				
28/1000	33		1,180	
972/1000		48		49
Adjusted total			826	34

TABLE E-1.—*Yellowtail larvae caught during cruises 1 to 7 of the* Albatross II, *in 1932*—Continued

Station and haul	Count of larvae		Total larvae	
	Small	Large	Small	Large
CRUISE 2—Continued				
Atlantic City:				
Station I (21367), May 14:				
Upper haul:				
56/1500	9		241	
1444/1500		11		11
Adjusted total			169	8
Station II (21366), May 14:				
Upper haul:				
56/1000	3		54	
944/1000		18		19
Adjusted total			39	13
Station III (21365), May 14:				
Upper haul:				
56/1500	0		0	
1444/1500		1		1
Lower haul:				
56/1500	0		0	
1444/1500		1		1
Adjusted total			0	2
Station IV (21364), May 14:				
Upper haul:				
56/1500	0		0	
1444/1500		1		1
Lower haul:				
56/1500	0		0	
1444/1500		1		1
Adjusted total			0	2
Cape May:				
Station I (21359), May 13:				
Upper haul:				
56/1000	2		36	
944/1000		3		3
Adjusted total			25	2
Station II (21360), May 13:				
Upper haul:				
56/1000	40		714	
944/1000		11		12
Adjusted total			500	8
Station III (21361), May 13:				
Upper haul: [1]				
56/1000	2		36	
944/1000		7		7
Adjusted total			25	5
Station IV (21362), May 13:				
Upper haul:				
56/1000	0		0	
944/1000		0		0
Lower haul:				
56/1000	1		18	
944/1000		24		25
Adjusted total			11	16
Station V (21365), May 13:				
Upper haul:				
112/2000	0		0	
1888/2000		0		0
Lower haul:				
112/2000	0		0	
1888/2000		1		1
Adjusted total			0	1
Winterquarter:				
Station I (21358), May 10:				
Upper haul:				
56/1500	0		0	
1444/1500		7		7
Adjusted total			0	5
Station II (21357), May 10:				
Upper haul:				
56/1500	0		0	
1444/1500		0		0
Lower haul:				
56/1500	0		0	
1444/1500		61		63
Adjusted total			0	40

[1] Part of this haul may have been lost.

TABLE E-1.—*Yellowtail larvae caught during cruises 1 to 7 of the* Albatross II, *in 1932*—Continued

Station and haul	Count of larvae		Total larvae	
	Small	Large	Small	Large
CRUISE 2—Continued				
Winterquarter—Continued				
Station III (21356), May 10:				
Upper haul:				
56/1000	0		0	
944/100		1		1
Lower haul:				
56/1000	0		0	
944/1000		3		3
Adjusted total			0	3
Chesapeake Bay:				
Station I (21353), May 9:				
Upper haul:				
56/1000	0		0	
944/1000		0		0
Adjusted total			0	0
Station II (21354), May 9:				
Upper haul:				
56/1500	4		107	
1444/1500		37		38
Adjusted total			75	27
Station III (21355), May 9:				
Upper haul:				
56/1500	0		0	
1444/1500		0		0
Lower haul:				
56/1500	0		0	
1444/1500		0		0
Adjusted total			0	0
CRUISE 3				
Martha's Vineyard:				
Station I (21382), May 19:				
Upper haul:				
56/1000	76		1,357	
944/1000		14		15
Lower haul:				
56/1000	19		339	
944/1000		28		30
Adjusted total			1,131	28
Station II (21383), May 19:				
Upper haul:				
56/1000	2		36	
944/1000		0		0
Lower haul:				
56/1000	2		36	
944/1000		3		3
Adjusted total			45	2
Station III (21384), May 19:				
Upper haul:				
56/1500	0		0	
1444/1500		0		0
Lower haul:				
56/1250	0		0	
1194/1250		0		0
Adjusted total			0	0
Montauk Point:				
Station I (21387), May 20:				
Upper haul:				
56/1500	0		0	
1444/1500		0		0
Lower haul:				
56/1500	5		134	
1444/1500		30		31
Adjusted total			84	20
Station II (21386), May 20:				
Upper haul:				
56/1000	0		0	
944/1000		13		14
Lower haul:				
56/1250	0		0	
1194/1250		10		10
Adjusted total			0	15

TABLE E-1.—*Yellowtail larvae caught during cruises 1 to 7 of the* Albatross II, *in 1932*—Continued

Station and haul	Count of larvae		Total larvae	
	Small	Large	Small	Large
CRUISE 3—Continued				
Montauk Point—Continued				
Station III (21385), May 20:				
Upper haul:				
56/1000	0		0	
944/1000		0		0
Lower haul:				
56/1250	0		0	
1194/1250		0		0
Adjusted total			0	0
Shinnecock:				
Station I (21388), May 20:				
Upper haul:				
56/1250	32		714	
1194/1250		33		35
Adjusted total			500	24
Station II (21389), May 20:				
Upper haul:				
56/1000	0		0	
944/1000		8		9
Lower haul:				
56/1000	3		54	
944/1000		12		13
Adjusted total			34	14
New York:				
Station I (21393), May 21:				
Upper haul:				
56/1250	46		1,127	
1194/1250		66		69
Lower haul:				
56/1500	23		616	
1444/1500		86		89
Adjusted total			1,072	98
Station II (21392), May 21:				
Upper haul:				
56/1250	32		714	
1194/1250		45		47
Lower haul:				
56/1500	30		804	
1444/1500		93		97
Adjusted total			940	90
Station III (21391), May 21:				
Upper haul:				
56/1500	5		134	
1444/1500		73		76
Lower haul:				
56/1250	0		0	
1194/1250		15		19
Adjusted total			81	58
Station IV (21390), May 20:				
Upper haul:				
56/1500	0		0	
1444/1500		0		0
Lower haul:				
56/1000	0		0	
944/1000		0		0
Adjusted total			0	0
Barnegat:				
Station I (21394), May 21:				
Upper haul:				
56/2000	57		2,034	
1944/2000		36		37
Adjusted total			1,424	26
Atlantic City:				
Station I (21395), May 21:				
Upper haul:				
56/1250	21		469	
1194/1250		61		64
Adjusted total			328	45
Station II (21396), May 21:				
Upper haul:				
56/1500	6		161	
1444/1500		5		5
Lower haul:				
56/1250	3		67	
1194/1250		56		59
Adjusted total			140	41

TABLE E-1.—*Yellowtail larvae caught during cruises 1 to 7 of the* Albatross II, *in 1932*—Continued

Station and haul	Count of larvae		Total larvae	
	Small	Large	Small	Large
CRUISE 3—Continued				
Atlantic City—Continued				
Station III (21397), May 21:				
Upper haul:				
56/1500	2		54	
1444/1500		7		7
Lower haul:				
56/1250	1		22	
1194/1250		4		4
Adjusted total			47	7
Station IV (21398), May 22:				
Upper haul:				
168/2000	0		0	
1832/2000		2		2
Lower haul:				
56/1500	0		0	
1444/1500		0		0
Adjusted total			0	1
Cape May:				
Station II (21402), May 22:				
Upper haul:				
56/750	2		27	
694/750		10		11
Adjusted total			19	8
Station III (21401), May 22:				
Upper haul:				
56/1500	15		402	
1444/1500		76		79
Lower haul:				
56/1250	17		380	
1194/1250		29		30
Adjusted total			570	66
Station IV (21400), May 22:				
Upper haul:				
112/1500	0		0	
1388/1500		0		0
Lower haul:				
56/1500	3		80	
1444/1500		39		41
Adjusted total			50	26
Station V (21399), May 22:				
Upper haul:				
112/1500	0		0	
1388/1500		0		0
Lower haul:				
56/1500	0		0	
944/1500		1		1
Adjusted total			0	1
Fenwick:				
Station I (21403), May 22:				
Upper haul:				
56/1000	7		125	
944/1000		5		5
Adjusted total			87	4
Winterquarter:				
Station I (21404), May 22:				
Upper haul:				
180/1800	4		40	
Remainder		30		30
Adjusted total			28	21
Station II (21405), May 22:				
Upper haul:				
300/3000	74		740	
Remainder		255		255
Adjusted total			518	179
Station III (21406), May 22:				
Upper haul:				
160/1600	15		150	
Remainder		127		127
Lower haul:				
56/1250	6		134	
1194/1250		26		30
Adjusted total			176	96

TABLE E-1.—*Yellowtail larvae caught during cruises 1 to 7 of the* Albatross II, *in 1932*—Continued

TABLE E-1.—*Yellowtail larvae caught during cruises 1 to 7 of the* Albatross II, *in 1932*—Continued

Station and haul	Count of larvae		Total larvae	
	Small	Large	Small	Large
CRUISE 3—Continued				
Chesapeake Bay:				
Station I (21409), May 23:				
Upper haul:				
40/1600	0		0	
Remainder		0		0
Adjusted total			0	0
Station II (21408), May 23:				
Upper haul:				
300/3000	1		10	
Remainder		3		3
Adjusted total			7	2
Station III (21407), May 23:				
Upper haul:				
300/3000	0		0	
Remainder		1		1
Lower haul:				
56/1250	3		67	
1194/1250		9		9
Adjusted total			42	7
CRUISE 4				
Martha's Vineyard:				
Station I (21431), May 28:				
Upper haul:				
56/1500	50		1,340	
1444/1500		63		65
Lower haul:				
56/1750	3		94	
1694/1750		26		27
Adjusted total			873	57
Station II (21430), May 27:				
Upper haul:				
56/1500	25		669	
1444/1500		48		50
Lower haul:				
56/1000	30		536	
944/1000		7		7
Adjusted total			744	35
Station III (21429), May 27:				
Upper haul:				
84/1500	3		536	
1416/1500		32		34
Lower haul:				
56/1000	0		0	
944/1000		0		0
Adjusted total			325	21
Montauk Point:				
Station I (21426), May 27:				
Upper haul:				
56/1000	52		928	
944/1000		22		23
Adjusted total			650	16
Station II (21427), May 27:				
Upper haul:				
28/1250	78		3,481	
1222/1250		16		16
Lower haul:				
56/1250	11		245	
1194/1250		10		11
Adjusted total			2,269	17
Station III (21428), May 27:				
Upper haul:				
56/1000	1		18	
944/1000		0		0
Lower haul:				
56/1000	1		18	
944/1000		10		11
Adjusted total			22	7
Shinnecock:				
Station I (21425), May 27:				
Upper haul:				
28/1500	25		1,340	
1472/1500		36		37
Adjusted total			938	26
CRUISE 4—Continued				
Shinnecock—Continued				
Station II (21424), May 27:				
Upper haul:				
28/1250	48		2,143	
1222/1250		72		74
Lower haul:				
56/1000	7		125	
944/1000		16		17
Adjusted total			1,381	56
New York:				
Station I (21420), May 26:				
Upper haul:				
56/1500	55		1,473	
1444/1500		82		85
Adjusted total			1,032	60
Station II (21421), May 26:				
Upper haul:				
28/1000	3		107	
972/1000		21		22
Lower haul:				
56/1500	45		1,205	
1444/1500		37		38
Adjusted total			761	37
Station III (21422), May 26:				
Upper haul:				
56/1300	9		241	
1444/1500		25		26
Lower haul:				
56/1250	20		446	
1194/1250		26		27
Adjusted total			478	32
Station IV (21423), May 26:				
Upper haul:				
56/1250	4		89	
1194/1250		33		35
Lower haul:				
56/1000	1		18	
944/1000		1		1
Adjusted total			65	21
Barnegat:				
Station I (21419), May 26:				
Upper haul:				
56/1300	73		1,955	
1444/1500		53		55
Adjusted total			1,369	49
Atlantic City:				
Station I (21418), May 26:				
Upper haul:				
56/1500	8		214	
1444/1500		17		18
Adjusted total			150	13
Station II (21417), May 26:				
Upper haul:				
56/1500	18		482	
1444/1500		13		14
Lower haul:				
56/1000	21		375	
944/1000		17		18
Adjusted total			530	120
Station III (21416), May 25:				
Upper haul:				
112/1500	5		67	
1388/1500		14		15
Lower haul:				
56/1000	0		0	
944/1000		3		3
Adjusted total			41	12
Station IV (21415), May 25:				
Upper haul:				
168/1500	1		9	
1332/1500		5		6
Lower haul:				
56/1250	0		0	
1194/1250		1		1
Adjusted total			6	4

TABLE E-1.—*Yellowtail larvae caught during cruises 1 to 7 of the* Albatross II, *in 1932*—Continued

Station and haul	Count of larvae: Small	Count of larvae: Large	Total larvae: Small	Total larvae: Large
CRUISE 4—Continued				
Cape May:				
Station II (21411), May 25:				
Upper haul:				
56/1250	48		1,072	
1194/1250		42		44
Adjusted total			750	31
Station III (21412), May 25:				
Upper haul:				
56/750	3		40	
694/750		12		13
Lower haul:				
56/1000	2		36	
944/1000		14		15
Adjusted total			47	17
Station IV (21413), May 25:				
Upper haul:				
112/1250	0		0	
1138/1250		0		0
Lower haul:				
56/1500	2		54	
1444/1500		16		17
Adjusted total			34	11
Station V (21414), May 25:				
Upper haul:				
112/1000	0		0	
888/1000		0		0
Lower haul:				
56/1000	0		0	
944/1000		1		1
Adjusted total			0	1
Chesapeake Bay:				
Station II (21410), May 24:				
Upper haul:				
112/1250	0		0	
1138/1250		1		1
Lower haul:				
112/750	0		0	
638/750		1		1
Adjusted total			0	2
CRUISE 5				
Montauk Point:				
Station I (21432), June 1:				
Upper haul:				
56/1500	45		1,205	
1444/1500		18		19
Lower haul:				
280/2650	6		57	
2370/2650		62		69
Adjusted total			767	55
Station II (21433), June 1:				
Upper haul:				
56/2000	19		658	
1944/2000		39		40
Lower haul:				
112/1250	40		446	
1138/1250		8		9
Adjusted total			681	30
Shinnecock:				
Station III (21434), June 2:				
Upper haul:				
56/1250	1		22	
1194/1250		2		2
Lower haul:				
112/1250	0		0	
1138/1250		6		7
Adjusted total			13	5
New York:				
Station I (21438), June 2:				
Upper haul:				
56/1500	55		1,473	
1444/1500		62		64
Adjusted total			1,032	45

TABLE E-1.—*Yellowtail larvae caught during cruises 1 to 7 of the* Albatross II, *in 1932*—Continued

Station and haul	Count of larvae: Small	Count of larvae: Large	Total larvae: Small	Total larvae: Large
CRUISE 5—Continued				
New York—Continued				
Station II (21437), June 2:				
Upper haul:				
56/1500	0		0	
1444/1500		0		0
Lower haul:				
56/1500	38		1,018	
1444/1500		43		45
Adjusted total			642	28
Station III (21436), June 2:				
Upper haul:				
84/1250	0		0	
1166/1250		1		1
Lower haul:				
112/1500	2		27	
1388/1500		14		15
Adjusted total			17	10
Station IV (21435), June 2:				
Upper haul:				
112/1000	1		9	
888/1000		1		1
Lower haul:				
112/1250	0		0	
1138/1250		1		1
Adjusted total			6	1
Barnegat:				
Station I (21439), June 3:				
Upper haul:				
112/1500	51		683	
1388/1500		36		39
Adjusted total			478	27
Atlantic City:				
Station I (21440), June 3:				
Upper haul:				
112/1250	14		156	
1138/1250		36		40
Adjusted total			109	28
Station II (21441), June 3:				
Upper haul:				
112/1000	0		0	
888/1000		0		0
Lower haul:				
112/1250	33		368	
1138/1250		34		37
Adjusted total			232	23
Station III (21442), June 3:				
Upper haul:				
112/1250	0		0	
1138/1250		2		2
Lower haul:				
112/2250	10		201	
2138/2250		111		117
Adjusted total			127	75
Station IV (21443), June 3:				
Upper haul:				
112/1500	0		0	
1388/1500		0		0
Lower haul:				
112/1500	1		13	
1388/1500		1		1
Adjusted total			8	1
Cape May:				
Station II (21447), June 4:				
Upper haul:				
112/1500	3		40	
1388/1500		39		42
Adjusted total			18	19
Station III (21446), June 4:				
Upper haul:				
112/1500	7		94	
1388/1500		22		24
Lower haul:				
56/1500	22		589	
1444/1500		440		457
Adjusted total			428	302

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TABLE E-1.—*Yellowtail larvae caught during cruises 1 to 7 of the* Albatross II, *in 1932*—Continued

TABLE E-1.—*Yellowtail larvae caught during cruises 1 to 7 of the* Albatross II, *in 1932*—Continued

Station and haul	Count of larvae		Total larvae	
	Small	Large	Small	Large
CRUISE 5—Continued				
Cape May—Continued				
Station IV (21445), June 3:				
Upper haul:				
112/1500	19		254	
1388/1500		23		25
Lower haul:				
168/1750	12		125	
1582/1750		110		122
Adjusted total			233	92
Station V (21444), June 3:				
Upper haul:				
112/2750	0		0	
2638/2750		0		0
Lower haul:				
168/1500	0		0	
1332/1500		0		0
Adjusted total			0	0
Winterquarter:				
Station I (21448), June 4:				
Upper haul:				
28/1250	1		45	
1222/1250		6		6
Adjusted total			45	6
Station II (21449), June 4:				
Upper haul:				
112/1500	0		0	
1388/1500		0		0
Lower haul:				
112/1250	1		12	
1138/1250		2		2
Adjusted total			8	1
Station III (21450), June 4:				
Upper haul:				
112/1500	0		0	
1388/1500		0		0
Lower haul:				
336/3000	0		0	
2664/3000		3		3
Adjusted total			0	2
Chesapeake Bay:				
Station I (21453), June 5:				
Upper haul:				
56/1500	0		0	
1444/1500		0		0
Adjusted total			0	0
Station II (21452), June 5:				
Upper haul:				
112/2000	0		0	
1888/2000		0		0
Adjusted total			0	0
Station III (21451), June 4:				
Upper haul:				
112/1500	6		80	
1388/1500		44		48
Lower haul:				
112/1000	2		18	
888/1000		16		18
Adjusted total			60	41
CRUISE 6				
Martha's Vineyard:				
Station I (21468), June 8:				
Upper haul:				
28/1500	27		1,446	
1472/1500		8		8
Lower haul:				
56/1500	55		1,474	
1444/1500		43		45
Adjusted total			1,807	34
Station II (21467) June 8:				
Upper haul:				
28/1500	41		2,197	
1472/1500		90		92
Lower haul:				
56/1500	15		268	
1444/1500		42		44
Adjusted total			1,503	84
CRUISE 6—Continued				
Martha's Vineyard—Continued				
Station III (21466), June 8:				
Upper haul:				
28/1250	2		89	
1222/1250		44		45
Lower haul:				
84/1250	0		0	
1166/1250		8		9
Adjusted total			54	33
Montauk Point:				
Station I (21464), June 7:				
Upper haul:				
56/1500	1		18	
1444/1500		1		1
Lower haul:				
84/1250	18		268	
1166/1250		3		3
Adjusted total			180	3
Station II (21465), June 7:				
Upper haul:				
28/1250	28		1,250	
1222/1250		29		30
Lower haul:				
112/1500	10		134	
1388/1500		25		27
Adjusted total			907	35
Shinnecock:				
Station II (21463), June 7:				
Upper haul:				
56/1000	32		571	
944/1000		6		6
Lower haul:				
112/1250	56		625	
1138/1250		7		8
Adjusted total			741	8
New York:				
Station II (21460), June 6:				
Upper haul:				
56/1250	24		536	
1194/1250		110		115
Lower haul:				
112/1250	26		290	
1138/1250		216		237
Adjusted total			508	219
Station III (21461), June 7:				
Upper haul:				
56/1500	21		562	
1444/1500		113		117
Lower haul:				
112/1500	27		362	
1388/1500		29		31
Adjusted total			569	91
Station IV (21462), June 7:				
Upper haul:				
112/1250	4		45	
1138/1250		27		30
Lower haul:				
112/2250	0		0	
2138/2250		51		54
Adjusted total			27	52
Atlantic City:				
Station I (21459), June 6:				
Upper haul:				
56/1000	2		36	
944/1000		38		40
Adjusted total			25	28
Station II (21458), June 6:				
Upper haul:				
112/1000	0		0	
888/1000		0		0
Lower haul:				
112/1500	24		321	
1388/1500		151		163
Adjusted total			202	103

TABLE E-1.—*Yellowtail larvae caught during cruises 1 to 7 of the* Albatross II, *in 1932*—Continued

Station and haul	Count of larvae		Total larvae	
	Small	Large	Small	Large
CRUISE 6—Continued				
Atlantic City—Continued				
Station III (21457), June 6:				
Upper haul:				
168/1500	0		0	
1332/1500		0		0
Lower haul:				
112/2000	8		143	
1888/2000		105		111
Adjusted total			91	70
Cape May:				
Station II (21454), June 5:				
Upper haul:				
56/1000	4		71	
944/1000		57		60
Adjusted total			50	42
Station III (21455), June 5:				
Upper haul:				
56/1000	9		161	
944/1000		153		162
Lower haul:				
56/2000	1		36	
1944/2000		17		73
Adjusted total			121	144
Station IV (21456), June 6:				
Upper haul:				
56/1000	1		18	
944/1000		45		48
Lower haul:				
56/1000	3		54	
944/1000		21		22
Adjusted total			45	43
Cape May: [1]				
Station II (21454), June 5:				
Upper haul: All		339		339
Station III (21455), June 5:				
Upper haul: 168/3500		160		3,332
Station IV (21456), June 6:				
Upper haul: 84/1000		55		655
CRUISE 7				
Martha's Vineyard:				
Station I (21490), June 19:				
Upper haul:				
28/1250	45		2,009	
1222/1250		91		93
Lower haul:				
56/1000	34		607	
944/1000		43		46
Adjusted total			1,596	85
Station II (21491), June 19:				
Upper haul:				
112/2000	31		552	
1888/2000		20		21
Lower haul:				
112/1500	68		910	
1388/1500		22		24
Adjusted total			908	28
Station III (21492), June 19:				
Upper haul:				
56/1500	0		0	
1444/1500		11		11
Lower haul:				
112/1500	4		54	
1388/1500		11		12
Adjusted total			34	14
Station IV (21493), June 20:				
Upper haul:				
112/1000	0		0	
888/1000		1		1
Lower haul:				
112/1250	1		11	
1138/1250		3		3
Adjusted total			7	3

[1] Oblique upper haul with 2-meter net.

TABLE E-1.—*Yellowtail larve caught during cruises 1 to 7 of the* Albatross II, *in 1932*—Continued

Station and haul	Count of larvae		Total larvae	
	Small	Large	Small	Large
CRUISE 7—Continued				
Montauk Point:				
Station I (21489), June 19:				
Upper haul:				
20/1000	1		50	
980/1000		2		2
Lower haul:				
20/1200	11		660	
1180/1200		5		5
Adjusted total			446	4
Station II (21488), June 19:				
Upper haul:				
112/1250	0		0	
1138/1250		0		0
Lower haul:				
168/1500	6		54	
1332/1500		21		24
Adjusted total			34	15
Station III (21487), June 19:				
Upper haul:				
112/1500	4		54	
1388/1500		27		29
Lower haul:				
112/1500	1		13	
1388/1500		1		1
Adjusted total			41	18
Shinnecock:				
Station I (21485), June 18:				
Upper haul:				
40/1500	10		375	
1460/1500		10		10
Adjusted total			262	7
Station II (21486), June 18:				
Upper haul:				
112/1000	16		143	
888/1000		18		20
Lower haul:				
112/1500	25		335	
1388/1500		23		25
Adjusted total			298	28
New York:				
Station I (21484), June 18:				
Upper haul:				
56/1000	0		0	
944/1000		2		2
Adjusted total			0	1
Station II (21483), June 18:				
Upper haul:				
112/1000	13		116	
888/1000		11		12
Lower haul:				
112/1500	44		589	
1388/1500		27		29
Adjusted total			441	25
Station III (21482), June 17:				
Upper haul:				
250/1500	8		48	
1250/1500		70		84
Lower haul:				
250/1000	28		112	
750/1000		7		9
Adjusted total			56	57
Station IV (21481), June 17:				
Upper haul:				
300/1500	3		15	
1200/1500		8		10
Lower haul:				
100/2000	3		60	
1900/2000		14		15
Adjusted total			47	10

TABLE E-1.—*Yellowtail larvae caught during cruises 1 to 7 of the* Albatross II, *in 1932*—Contintinued

Station and haul	Count of larvae		Total larvae	
	Small	Large	Small	Large
Cruise 7—Continued				
Atlantic City:				
Station I (21469), June 15:				
Upper haul:				
100/1500	0		0	
1400/1500		4		4
Adjusted total			0	3
Station II (21477), June 17:				
Upper haul:				
168/1500	1		9	
1332/1500		1		1
Lower haul:				
250/1500	81		486	
1250/1500		11		13
Adjusted total			312	4
Station III (21478), June 17:				
Upper haul:				
120/1200	0		0	
1080/1200		0		0
Lower haul:				
400/2000	1		5	
1600/2000		1		1
Adjusted total			3	1
Station IV (21479), June 17:				
Upper haul:				
112/1000	0		0	
888/1000		1		1
Lower haul:				
250/1500	0		0	
1250/1500		0		0
Adjusted total			0	1
Cape May:				
Station II (21470):				
Upper haul:				
56/1500	1		27	
1444/1500		49		51
Adjusted total			19	36
Station III (21476), June 16:				
Upper haul:				
300/1500	0		0	
1200/1500		0		0
Lower haul:				
300/1500	17		85	
1200/1500		62		77
Adjusted total			54	4
Station IV (21475), June 16: [3]				
Upper haul:				
112/1500	0		0	
1388/1500		4		4
Lower haul:				
112/2000	0		0	
1888/2000		21		22
Adjusted total			0	16
Station V (21474), June 16: [4]				
Lower haul		1		1
Adjusted total				1
Winterquarter:				
Station I (21471), June 16:				
Upper haul:				
28/1500	0		0	
1472/1500		4		4
Adjusted total			0	3
Station II (21472), June 16:				
Upper haul:				
28/1250	0		0	
1222/1250		0		0
Lower haul:				
112/1250	0		0	
Remainder		0		0
Adjusted total			0	0

[3] An estimated three-quarters of the upper haul was lost, therefore the counts are multiplied by 4.

[4] No fish larvae in 15 liters of the upper haul; only one *L. ferruginea* larva in 8 liters of the lower haul.

TABLE E-2.—*Yellowtail larvae caught during cruises 8 and 9 of the* Atlantis, *in 1932*

[Numbers in parentheses indicate stations for which complete data are in Sette (1943, pp. 216-219); fractions indicate parts of haul sorted for small and large larvae]

Station and haul	Date	Count of larvae	Estimated total larvae	Adjusted total [1]
CRUISE 8				
Martha's Vineyard: [2]				
Station:				
I (1283): All	July 1	51	51	7
II (1282): All	do	3	3	0
IV (1280): All	do	0	0	[3] 0
Montauk Point:				
Station:				
I (1276): All	June 30	42	42	2
II (1277): All	do	16	16	[3] 2
III (1278): All	do	3	3	[3] 0
IV (1259): All	June 25	0	0	0
VI (1279): All	June 30	1	1	[3] 0
Shinnecock:				
Station:				
I (1275): 112/1000	June 29	106	946	133
II (1274): All	do	63	63	16
New York:				
Station:				
I (1270): All	June 28	521	521	71
II (1271): 196/2000	June 29	301	3071	270
III (1272): All	do	430	430	32
IV (1273): All	do	7	7	[3] 1
V (1260): All	June 26	12	12	1
VI (1261): All	do	0	0	0
Barnegat: Station I (1269): All	June 28	197	197	26
Atlantic City:				
Station:				
I (1262): All	June 26	195	195	26
II (1263): 168/1800	do	241	2581	661
IV (1265): All	June 27	1	1	0
Cape May:				
Station:				
II (1266): All	do	107	107	13
III (1267): 250/1250	do	130	650	127
IV (1268): 1/10	do	31	310	25
CRUISE 9				
Cape Elizabeth:				
Station I (1323): All	July 23	1	1	[4] 0
Boon Island:				
Station:				
I (1322): All	do	3	3	[4] 1
II (1325): All	July 24	0	0	[4] 0
Newburyport:				
Station I (1321): All	July 23	4	4	[4] 1
Cape Ann:				
Station:				
I (1320): All	July 23	6	6	[4] 1
II (1319): All	do	0	0	0
III (1326): All	July 24	0	0	[4] 0
Boston:				
Station:				
I (1317): All	July 22	12	12	[4] 2
II (1318): All	do	52	52	15
Cape Cod Bay:				
Station I (1316): All	do	9	9	1
Race Point:				
Station:				
I (1315): All	do	2	2	0
II (1327): All	July 24	0	0	[4] 0
Nauset: Station I (1314): All	July 22	4	4	[4] 1
Chatham: Station II (1328): All	July 24	1	1	0
South Channel:				
Station:				
I (1312): All	July 22	0	0	[4] 0
II (1311): All	July 21	0	0	[4] 0
IV (1307): All	do	110	110	75
Western Georges Bank:				
Station:				
I (1310): All	do	2	2	[4] 0
II (1309): All	do	0	0	[4] 1
III (1308): All	do	25	25	5
Nantucket Shoals:				
Station:				
I (1304): All	July 20	8	8	[4] 2
II (1305): All	do	11	11	[4] 2
III (1306): All	do	22	22	[4] 4

See footnotes at end of table.

TABLE E-2.—*Yellowtail larvae caught during cruises 8 and 9 of the* Atlantis, *in 1932*—Continued

Station and haul	Date	Count of larvae	Estimated total larvae	Adjusted total [1]
Martha's Vineyard:				
Station:				
I (1303): All	do	37	37	4
II (1302): All	do	4	4	1
III (1301): All	July 19	0	0	[4] 0
IV (1300): All	do	0	0	[4] 0
Montauk Point:				
Station:				
I (1288): 40/1000	July 16	25	625	63
II (1289): All	July 17	10	10	[4] 2
III (1290): All	do	2	2	0
IV (1291): All	do	0	0	[4] 0
Shinnecock:				
Station:				
I (1294): 60/1000	July 18	71	1183	59
II (1293): All	July 17	26	26	[4] 5
III (1292): All	do	2	2	[4] 0
New York:				
Station:				
I (1295): 100/1000	July 18	113	1130	[4] 229
II (1296): All	do	10	10	1
III (1297): 100/1000	do	16	160	[4] 32
IV (1298): All	do	3	3	[4] 1
V (1299): All	July 19	0	0	[4] 0

[1] Represents the number of larvae per 17.07 square meters of sea surface. See Sette (1943, pp. 211–215) for method of computing.
[2] Oblique hauls to surface with 2-meter net.
[3] Adjustment data are not available from Sette (1943) and these tows have been adjusted by the average of the other values, 0.136.
[4] Adjustment data are not available from Sette (1943) and these tows have been adjusted by the average of the other values, 0.203.

TABLE E-3.—*Summary of standard catches of small larvae in upper and lower hauls at certain stations on cruises 1 through 7 in 1932*

Station	Cruise 1		Cruise 2		Cruise 3		Cruise 4		Cruise 5		Cruise 6		Cruise 7	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Martha's Vineyard:														
Station:														
I			1,106	320	950	181	938	−65			1,013	794	1,406	190
II	56	20	0	3	25	20	468	276			1,538	−35	386	522
III	0	0	0	0	0	0	375	−50			62	−8	0	34
IV	0	0											0	7
Montauk Point:														
Station:														
I					0	84			843	−76	13	167	35	411
II			13	−2	0	0	2,437	168	461	220	875	32	0	34
III			0	0	0	0	13	9					38	3
Shinnecock:														
Station:														
I			6	−1										
II			0	23	0	34	1,501	−120			400	341	100	198
III									15	−2				
New York:														
Station:														
I					789	283								
II	0	0	450	404	500	440	75	686	0	642	375	133	81	360
III	0	0	38	40	94	−13	169	259	0	17	393	176	34	22
IV	0	0	0	0	0	0	62	3	6	0	31.5−	−4	10.5	37
V	0	0	0	0										
VI	0	0	0	0										
Atlantic City:														
Station:														
II	140	120	39		113	27	337.5+	192	0	232	0	202	6	306
III	0	0	0	0	38	9	47	−6	0	127	0	91	0	3
IV	0	0	0	0	0	0	6	0	0	8			0	0
Cape May:														
Station:														
III	6	56	25		381	189	28	19	66	362	113	8	0	54
IV	14	10	0	11	0	50	0	34	178	55	13	32	0	0
V	0	0	0	0	0	0	0	0	0	0				
VI	0	0												
Winterquarter:														
Station:														
II	0	28	0	0					0	8			0	0
III	0	0	0	0	105	71			0					
IV									0	0				
Chesapeake Bay:														
Station:														
II							0	0						
III	0	0	0	0	0	42			56	4				

F. PROBIT ANALYSIS

In the section on reproduction, we dealt with two lots of data which can be analyzed by probit transformation. These data consist of samples of yellowtail that are used to determine (1) length of the fish at maturity and (2) the date of spawning. Since the technique of probit analysis is not commonly employed in fishery research, yet it has been thoroughly tested, an explanation of its use in this study is in order.

Probit analysis has been used almost exclusively in analyzing the results of biological assay of chemicals tested on experimental animals, although psychophysicists have used closely related methods. It is the most thoroughly developed method known for the analysis of quantal (all or nothing) response data, such as occurs in tests of a chemical in which different concentrations cause varying proportions of the experimental animals to die. Developed largely from the studies of C. I. Bliss, probit analysis was brought to its most definitive form by Finney (1952), on whose work this discussion is based.

Our yellowtail data may be considered as analogous to such doseage-response data. In determining length of the fish at maturity, the state of maturity or immaturity is the quantal response to the stimulus of growth. For the description of the spawning season, the females are ripe or spent in varying proportions as they are stimulated by the vernal change in environment.

The probit of a proportion P is defined as the abscissa which corresponds to a probability P in a normal distribution with mean 5 and variance 1; in symbols the probit of P is Y where

$$P=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{Y-5}e^{-\frac{1}{2}u^2}du$$

The transformation from percentage to probit changes the usual sigmoid curve of percentage response against stimulus to a straight line of the type

$$Y=a+bX$$

in which Y is the probit and X is the stimulus.

In the analysis of bioassay results, the typical distribution curve of dosage X is decidely skewed with a long tail on the right caused by the high tolerance of a few animals (usually insects). Such a curve can usually be normalized by transformation to common logarithms, and this has become standard practice in bioassay. In our spawning data, however, we have no evidence that such a transformation is necessary. A satisfactory fit is obtained by using the measures of time and length directly.

Probit regression lines may be fitted by eye if there is little scatter of the points and an accurate measure of the precision of the estimates is not needed. Such a procedure is easy and rapid, but it requires familiarity with the data and expected results. The arithmetic method of fitting is, unfortunately, rather laborious, because a solution of maximum likelihood is required. This results from the increasing variance as the proportion P approaches 0 or 1. The values of the probit Y must be weighted according to the expected Y and also according to the number of observations used in obtaining the proportion P. The expected Y is obtained from the eye-fitted line and the weighting coefficients have been tabulated by Fisher and Yates (1948, table 11).

In our analysis of the spawning period, the computations for the regressions of percentage of spent fish against the date for the female yellowtail have been made as indicated in table F–1,

TABLE F–1.—*Probit analysis of the spawning period of yellowtail, in 1943*

Date	x [1]	n	Percent spent [2] P	Provisional probit Y	nw	Working probit y
Apr. 20	10	60	10.0	3.7	20.15	3.719
Apr. 20	10	62	4.8	3.7	20.82	3.415
Apr. 20	10	72	9.7	3.7	24.18	3.701
Apr. 20	10	50	18.0	3.7	16.79	4.186
Apr. 27	17	57	19.3	4.0	25.00	4.142
Apr: 27	17	66	21.2	4.0	28.95	4.220
May 4, 6	25	43	16.3	4.3	22.86	4.047
May 7	27	54	24.1	4.4	30.12	4.300
May 17	37	27	44.4	4.9	17.13	4.859
May 18	38	41	56.1	4.9	26.01	5.154
June 3, 7, 8	57	21	71.4	5.8	10.55	5.544
June 9	60	34	67.6	5.9	16.03	5.374
June 16	67	45	91.1	6.2	16.66	6.334
June 23	74	46	89.1	6.6	10.93	6.111
June 28	79	50	98.0	6.8	9.00	7.002
June 29	80	63	98.4	6.8	11.34	7.052
July 4	85	50	100.0	7.0	6.56	7.421

SUMMARY OF REGRESSION COMPUTATIONS

$$\begin{aligned}
\Sigma\, nw &= 313.08\\
\Sigma\, nwx &= 10,407.47\\
\bar{x} &= 33.242\\
\Sigma\, nw(x-\bar{x})^2 &= 177,838.04\\
\Sigma\, nwy &= 1,479.3402\\
\bar{y} &= 4.726\\
\Sigma\, nw(y-\bar{y})^2 &= 355.9088\\
\Sigma\, nw(x-\bar{x})(y-\bar{y}) &= 7,731.7693
\end{aligned}$$

[1] x=day of the year minus 100.
[2] From table 40, p. 217.

which follows Finney (1952, p. 52). These computations lead to

$$\hat{Y}=3.281+.04348X$$

in which $\hat{Y}$ is the estimated probit and X the day of the year minus 100.

The goodness of fit was estimated by χ^2 from

$$\chi^2=\Sigma nw(y-\bar{y})^2-\frac{[\Sigma nw(x-\bar{x})(y-\bar{y})]^2}{\Sigma nw(x-\bar{x})^2}$$

$$\chi^2=19.76$$

With 16 degrees of freedom this value for χ^2 will be exceeded by chance about once in five times. We judge, therefore, that our curve (fig. 24) is a satisfactory fit and our assumption that no transformation of X was needed is justified.

The variance of x about the 50-percent point was estimated from

$$V(m)=\frac{1}{b^2}\left[\frac{1}{\Sigma nw}+\frac{(m-\bar{x})^2}{\Sigma nw(x-\bar{x})^2}\right]$$

$$V(m)=1.808 \qquad \sqrt{V(m)}=1.345$$

in which m is the 50-percent point, $\bar{x}$ mean observed x, and b the slope of the regression line. The 95-percent fiducial limits are 50-percent point of

$$x\pm1.96\sqrt{V(m)}$$

or

$$34.77\pm2.64$$

If we consider that our day began at noon, then we may say that the peak of spawning (in the fish as landed) probably occurred on May 19 and the odds are 19 to 1 that it occurred between May 16 and 21.

Using similar computations (appendix table F–2) for the data on length at maturity of the female yellowtail, we find

$$\hat{Y}=-0.2176+0.1631x$$

in which $\hat{Y}$ is the estimated probit and x is the total length in centimeters.

$$\chi^2=13.15,\ df=10,\ P=0.2$$

again indicating satisfactory fit. The standard error of the 50-percent point,

$$\sqrt{V(m)}=0.9727$$

and 95-percent fiducial limits of the 50-percent point (31.98 cm.) are 30.07 and 33.89 cm.

TABLE F–2.—*Probit analysis of the length at maturity of female yellowtail, in 1943*

Length X	n	Percent mature[1] P	Provisional probit Y	nw	Working probit y
29.5 cm	3	0	4.28	1.58	3.51
30.5 cm	8	25	4.49	4.63	4.33
31.5 cm	7	57	4.70	4.31	5.19
32.5 cm	21	62	4.90	13.32	5.30
33.5 cm	23	70	5.11	14.57	5.51
34.5 cm	13	77	5.32	7.97	5.70
35.5 cm	13	54	5.53	7.46	5.06
36.5 cm	17	65	5.73	8.89	5.34
37.5 cm	10	90	5.94	4.58	6.23
38.5 cm	15	73	6.15	5.81	5.44
39.5 cm	12	92	6.36	3.79	6.40
40.5 cm	14	100	6.57	3.46	7.07

SUMMARY OF REGRESSION COMPUTATIONS

$\Sigma nw=$ 80.37
$\Sigma nwx=$ 2,794.267
$\bar{x}=$ 34.77
$\Sigma (x-\bar{x})^2=$ 610.9173
$\Sigma nwy=$ 438.3684
$\bar{y}=$ 5.454
$\Sigma nw(y-\bar{y})^2=$ 29.407998
$\Sigma nw(x-\bar{x})(y-\bar{y})=$ 99.6630

[1] From table 39, p. 216.

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