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Aspects of the Biology of Atlantic Mackerel in ICNAF Subarea 4

by

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Abstract

Sette's (1950) model of migration and movements of mackerel in subarea 4 is substantiated by further tagging and analysis of monthly variations in length frequencies. The subdivision into northern and southern populations is discussed and accepted but no new substantial evidence is available. The northern population has been dominated by only two year classes (1959 and 1967) over a 13-year period. Based on egg abundance, the northern spawning stock size was estimated to be about one million metric tons in 1968. Annual total mortality appears to be low.

Introduction

The Atlantic mackerel is an abundant species in the Northwest Atlantic. The catch in all ICNAF areas has increased from 34,000 metric tons in 1967 to 373,000 metric tons in 1971. Research on various aspects of the life history and population biology of the mackerel in subarea 4 has been carried out since 1965 by the Fisheries Research Board of Canada at the Biological Station, St. Andrews, New Brunswick and at the Marine Ecology Laboratory, Dartmouth, Nova Scotia. Some of the results of these efforts are presented here.

Methods

Mackerel were sampled from the inshore commercial fishery along the Atlantic coast of Nova Scotia and the Gulf of St. Lawrence, additional samples were obtained during research cruises using baited hook, gangs of different sized gill nets and otter trawl. The fish were measured for fork length. Age determinations were made from otoliths which are reliable indicators of age of fish less than seven years old (Steven, 1950; MacKay, MS, 1967). While fish older than this could be aged, the percentage of unreadable or questionable otoliths was much higher than for younger fish.

Tagging was accomplished by obtaining live fish from trap nets or purse seines, maintaining them in a holding net, then tagging with a red Watson-Larsen tag used as a ring or barb. Tagged fish were released during late spring or summer of 1965 to 1968. Additional information on migration was obtained from analysis of monthly variations in length frequencies and interviews with personnel associated with the fishery.

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Canadian Landings

Table 1. Canadian landings* of Atlantic mackerel 1953-1972.

Year	Metric Tons	Year	Metric Tons
1953	10,966	1963	7,818
1954	12,574	1964	10,869
1955	12,780	1965	11,134
1956	10,204	1966	11,701
1957	8,950	1967	11,154
1958	7,339	1968	11,193
1959	4,296	1969	13,307
1960	5,970	1970	15,733
1961	6,417	1971	14,972
1962	7,348	1972	14,058

* From: Annual Statistical Review of Canadian Fisheries.

Most of the catch is taken in near-shore waters. During the period from 1957 to 1966, 45% of the catch was taken from the Gulf of St. Lawrence and Newfoundland waters (4R,S,T and 3) and 55% from the Atlantic coast of Nova Scotia and the Bay of Fundy (4Vn,W,X). During 1970 to 1972, 45% was taken from 4Vn,W,X. Unknown quantities of mackerel are taken as by-catch in the Gulf herring seines. Undoubtedly mackerel will become increasingly important to the mobile seiners with the decline in abundance of the Gulf of St. Lawrence herring stocks.

Catches in Newfoundland waters have been most variable (none in 1959, 1000 metric tons in 1961, hundreds of tons during the mid 1960's and 1000-2000 during 1970's) due, in part, to water temperatures and perhaps to changes in abundance.

Populations

Sette (1950), on the basis of the analysis of size composition of many samples of commercially caught mackerel collected from 1926 to 1935, separated the northwest Atlantic mackerel into northern and southern "contingents" or populations. This separation into two populations was substantiated by tagging carried out in subareas 4 and 5 during 1925-1928, (Sette, 1950, MacKay, MS 1967). An analysis of these two populations for differences in growth rates, isoenzyme pattern of lactate dehydrogenase (LDH) and malic dehydrogenase (MDH), and meristic characters yielded no obvious differences between the northern and southern groups (MacKay, MS 1967; MacKay and Garside, 1969). There are, however, two discrete spawning areas on the North American coast (Sette, 1943). The southern spawning grounds encompasses an area from Cape Hatteras to Cape Cod, with spawning commencing in mid-April in the southern part and progressing northward until June (Cape Cod region). The northern spawning area is much more restricted in time and place; it is concentrated over the Magdalen Shallows (Gulf of St. Lawrence) during early June to early July, peaking in the latter half of June (Arnold, MS 1970). Some spawning does occur in Newfoundland waters (Parsons and Hodder, 1970), and the Atlantic coast of Nova Scotia (Arnold, MS 1970). The absence of post-spawning fish and the regularity by which similar year classes occur in subarea 4 during June suggests the occurrence of a separate northern population.

Migrations

Sette (1950) has suggested, on the basis of winter catches and tag returns, that mackerel overwinter at mid-depths along the edge of the Continental Shelf from Sable Island to Cape Hatteras. Some mackerel have been taken in Canadian winter research cruises in the Emerald Bank area but there is no Canadian winter commercial fishery. The extent of mixing of the northern and southern populations in overwintering areas is unknown but Sette suggests a partial mixing of the populations in subareas 5 and 6 during late April and May.

The spring migration of the northern population involves a movement in a series of waves along the Scotian coast, from the overwintering area to the spawning ground in the Gulf of St. Lawrence. During the migration, mackerel feed extensively on euphausiids and fish larvae. The main body of fish migrates offshore; fish occasionally strike

inshore and the inshore catch (4X,W) is largely dependent on surface temperatures and availability of food. Mackerel first appear in inshore areas of 4X about May 15th with the largest catches occurring in June. The change in length frequency with time and location is indicated in Fig. 1 which presents length frequencies for 1965 and 1966, typical of those found during the eight years of this study. The fish captured late in May are larger than those captured in June in inshore regions of area 4X. The same sizes of fish are present in inshore parts of 4X and 4Vn in June as are found later in July and August in subarea 4T. In addition tagging of 135 fish in early June, 1966, in south-western Nova Scotia yielded three recaptures in the vicinity of the tagging and three recaptures 500 and 600 km northeast near the entrance of the Gulf of St. Lawrence. This scheme of spring migration to the Gulf of St. Lawrence is supported by evidence from tagging during 1925-1928 in subarea 4 and summarized by MacKay (MS 1967).

By the end of June the adults are completing spawning in subarea 4T and a few stragglers have remained in subarea 4Vn,W,X. In 1967, the majority of the population did not enter 4T but remained in subareas 4Vn,W,X; unusually late surface warming in the Gulf of St. Lawrence may have been the causative factor.

The length frequencies (Fig. 1 and MacKay, in prep.) show that immature fish reach the inshore waters of subarea 4X about July 1st and remain in many of the bays and coves throughout the summer. In years when immature fish are abundant they also occur in subarea 4T. The large scale movement of both immature and mature fish has ceased by early July. Tagging studies in St. Margaret's Bay (4X) during July of 1966, 1967 and 1968 (Table 2) substantiates this. Of 1299 fish tagged and released, 140 were recaptured, all but one within 25 km of the release sites and the one exception had moved only 60 km.

The majority of adults of the northern population remains within subarea 4T during the summer where increases in fat and somatic tissue occurs. The fish leave subarea 4T from September to November and proceed to the overwintering area.

Table 2. Tagging and recapture information on 1299 mackerel tagged within St. Margaret's Bay, Halifax Co., N. S. - 1966-1968

Area of Tagging	Date	Number	Distance and Direction from Release Site	Days at Liberty	Number Recaptured
Indian Pt. St. Margaret's Bay (4X)	July 23 1966	100	Vicinity of tagging	1-2	14[1]
			Within 15km	4-78	11
Indian Hbr. St. Margaret's Bay (4X)	July 8 1967	800	Within 3km	1-7	52
				8-16	4
			North within 15km	1-7	3
				15-21	4
				27	1
			East within 25km	1-7	3
				14	1
			West within 20km	2	5
				17	1
Indian Pt. St. Margaret's Bay (4X)	July 29 1968	399	NW within 8km	1-7	19
				8-14	7
				15-21	2
				22-27	1
			15 km S	1	1
			60 km W	46	1

[1]These fish were re-released.

Population Dynamics

The age class composition and length frequency distributions from 1965 to 1972 for the northern population are presented in Fig. 2 and Fig. 3. Although the 1959 and 1960 year classes appear to alternate in importance between 1967 and 1970, MacKay (MS 1967) has suggested that the 1960 year class is actually an artifact and that all these fish should be classified as members of the 1959 year class. Thus the 1959 year class has dominated the spawning stock until 1972. The 1967 year class was first evident in the length frequencies for 4T in the summer of 1968 but did not appear in the spawning stock until 1972 when it comprised 55 percent.

The growth rates of these dominant 1959 and 1967 year classes are compared to the average for all the non-dominant year classes in Fig. 4. It is apparent that the dominant year classes have had slower growth rates than the non-dominant year classes. This slower growth is particularly evident in the first two years.

First spawning normally occurs at age two (MacKay, MS 1967), however the 1967 year class were not evident in the spawning population until age four and many individuals did not spawn until age five. The first spawning for the 1959 year class may have been delayed by at least one year. Thus the slower growth rate of dominant year classes results in a delay in the age of first spawning by one to three years. In addition to the effect on growth and maturities the dominance of this northern population by only two year classes has had profound effects on the productivity and the ratio of productivity to biomass (MacKay, in preparation).

The unequal recruitment, resulting in dominant year classes, makes it difficult to determine mortality rates by the conventional fisheries techniques. The continued persistence of the 1959 year class to age 13 suggests a low total annual mortality rate. If the 1959 and 1967 year classes were equal in strength, then the age distribution observed in 1972 suggests an annual total mortality of the order of 10%.

Population Estimates

Lacking a suitable alternate method, we have resorted to available information on distribution and abundance of mackerel eggs in the Gulf of St. Lawrence to obtain a crude estimate of the spawning stock size. Because we have insufficient information on spatial and temporal distribution, confidence limits cannot be placed on the estimate.

Information on egg distribution and abundance for 1967, 1968 and 1969 was taken from Arnold (MS 1970) and Fig. 5 is an example of his survey. This is a plot of the surface distribution as sampled by a #0. 1 m ring net, during the period June 18 - June 24, 1968 on the *E. E. PRINCE*. Similar data were collected at 15 m and special tows were made to determine vertical distribution. Using these data, and supplementing them with data from vertical tows made during the same period from *M. V. BRANDAL* and *M. V. DAWSON*, we calculated average egg abundance for each block shown in Fig. 5 and used the results to estimate the total number of eggs spawned in the Gulf.

To obtain the average egg abundance for each block (column 2 of Table 3), we assumed a regular decrease in numbers from the surface to 15 m and from 15 m to 25 m with no eggs below 25 m. The total number of eggs under 1 m^2 of sea surface, estimated by geometric approximation, agreed favorably with results of vertical tows from *BRANDAL* and *DAWSON*. The grand total for the estimated number of eggs in the Gulf during the sampling period is 52×10^{12}.

Table 3. Calculation of the numbers of mackerel eggs present in subarea 4T during the period June 18 - June 24, 1968

Block Number (Figure 5)	Ave. No. Eggs per m^2 Sea Surface	Area Km^2	Total No. Eggs in Block $\times 10^9$
1a	1,544.5	4,224	6,524
1b	482.0	6,000	2,892
1c	86.6	3,224	279
1d	1.5	1,319	2
2a	1,411.3	6,896	9,732
2b	1,428.6	8,396	11,995
2c	725.5	8,620	6,254
2d	118.8	8,103	963
2e	45.8	4,310	20
3b	2,661.8	3,655	9,729
3c	530.3	4,413	2,340
3d	207.0	6,758	1,399
3e	120.5	517	62
Estimated total No. of eggs in sampling period			$52,191 \times 10^9$

Conversion of this value to total spawning requires a number of assumptions:

1. Arnold noted that 70% of the eggs collected were Stage I (less than 30 hours post spawning). We assume that 70% of 52×10^{12} or 36×10^{12} represents a one-day spawning.

2. The sampling extended over a seven-day period. We assume that sampling at each station represents peak spawning and that these may all be summed to represent a one-day peak spawning on June 21, the mid point.

3. Arnold noted that spawning took place from mid-June to mid-July. We assume normal distribution of spawning about the mid point of June 21, and base our calculations on both a 4-week and a 2-week spawning duration.

Thus, if 36×10^{12} represents the peak of spawning then for the 4-week duration it represents 5.6% (from a table of normal deviates) of the total production which is 6.4×10^{14} eggs. The second estimate, assuming only a two-week spawning (in which case 36×10^{12} represents 11.2% of the total production) is 3.2×10^{14} eggs. Finally, as an "absolute" minimum we can use the total number of eggs estimated to be present during the sampling period.

Table 4. Estimates of the numbers of mackerel eggs spawned in Subarea 4T in 1967, 1968 and 1969

	Assumed duration of spawning		
Year	4 week	2 week	Sampling period
1967	0.3×10^{14} eggs	0.15×10^{14}	0.02×10^{14}
1968	6.4×10^{14} eggs	3.4×10^{14}	0.52×10^{14}
1969	5.1×10^{14} eggs	2.6×10^{14}	0.39×10^{14}

As mentioned, above, the majority of the population did not enter and spawn in the Gulf of St. Lawrence in 1967. Sampling coverage was best in 1968.

Because the spawners were all large fish (mainly 1959 yc) we used Sette's fecundity estimate of 400,000 eggs per female. With a sex ratio of 1.1 and an average

weight of 550 gms we derived, for 1968:

4 week	3.2×10^9 spawners; 1.7×10^6 mt
2 week	1.6×10^9 spawners; 0.9×10^6 mt
Sampling period	0.13×10^9 spawners; 0.07×10^6 mt

Summary

1. The subdivision of the Atlantic mackerel from the northwest Atlantic into a southern and northern population while not proved is accepted.

2. The migration and movements of the northern population as discerned by tagging, analysis of monthly variations in length frequencies and interviews with persons concerned with the inshore fishery all substantiate the basic scheme proposed by Sette (1950).

3. The northern population has been dominated by only two year classes over a 13-year period. These two year classes have grown more slowly and matured one to three years later than the other non-dominant year classes.

4. Data on egg abundance suggests the spawning stock of the northern population was about 1.6 billion fish or 1 million metric tons in 1968.

Literature Cited

Arnold, P. W. MS 1970. Spawning and aspects of the early life history of the Atlantic mackerel (*Scomber scombrus* L.) in the Gulf of St. Lawrence. B. Sc. Thesis, Acadia Univ., Wolfville, N. S., pp 73.

MacKay, K. T., MS 1967. An ecological study of mackerel, *Scomber scombrus* (Linnoeus) in the coastal waters of Canada. Fish. Res. Bd. Canada Tech. Rept. 31, pp 127.

MacKay, K. T. and E. T. Garside. 1969. Meristic analysis of Atlantic mackerel, *Scomber scombrus*, from the North American coastal population. J. Fish. Res. Bd. Canada 26. 2537-2540.

Parsons, L. S. and V. M. Hodder. 1970. Occurrence of juvenile and spawning Atlantic mackerel in southeastern Newfoundland coastal waters. J. Fish. Res. Bd. Canada 27: 2097-2100.

Sette, O. E. 1943. Biology of the Atlantic mackerel (*Scomber scombrus*) of North America. Part I. Early Life History. U. S. Fish & Wildlife Serv., Fish. Bull. 38(50): 149-237.

Sette, O. E. 1950. Biology of the Atlantic mackerel (*Scomber scombrus*). Part 2. Migration and habits *Ibid.* 49(51): 251-358.

Steven, G. A. 1950. Contribution to the biology of mackerel *Scomber scombrus* L. III Age and growth. J. Mar. Biol. Assoc. 30: 549-568.

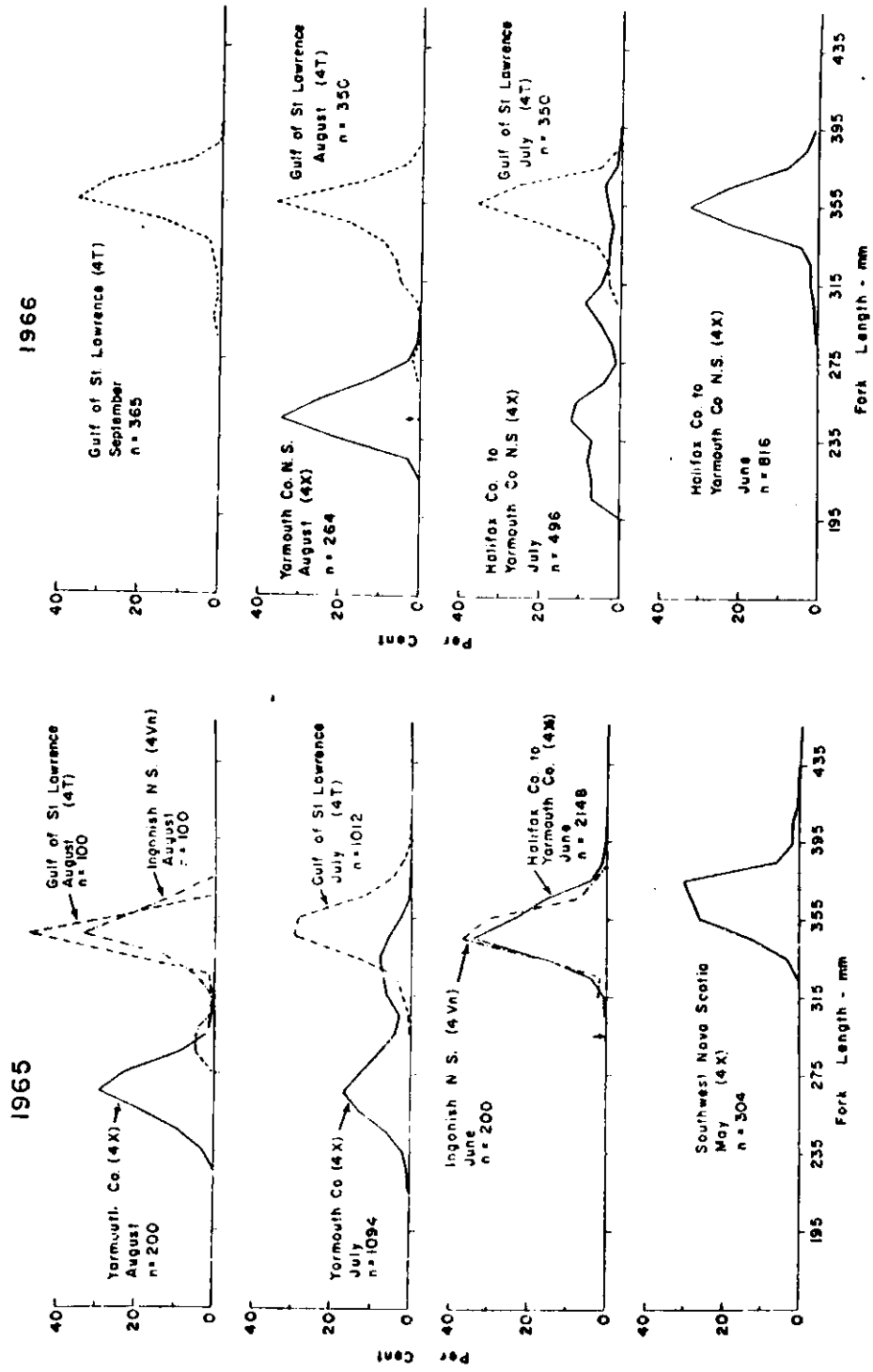

Figure 1. Length-frequency distributions of mackerel sampled in subarea 4 during 1965 and 1966, by location and by month.

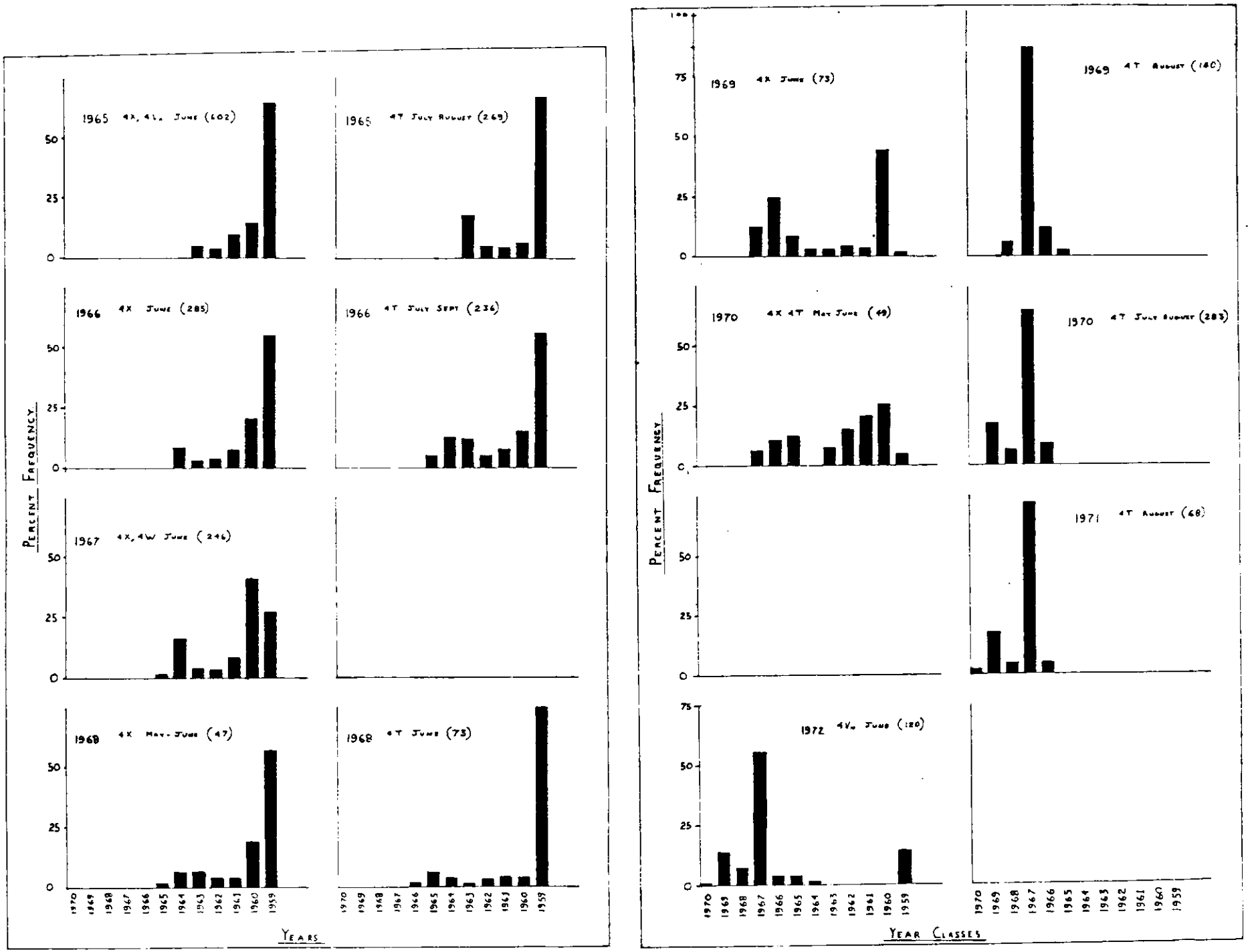

Figure 2. Percent composition of year classes of mackerel sampled from subarea 4 from 1965 to 1972.

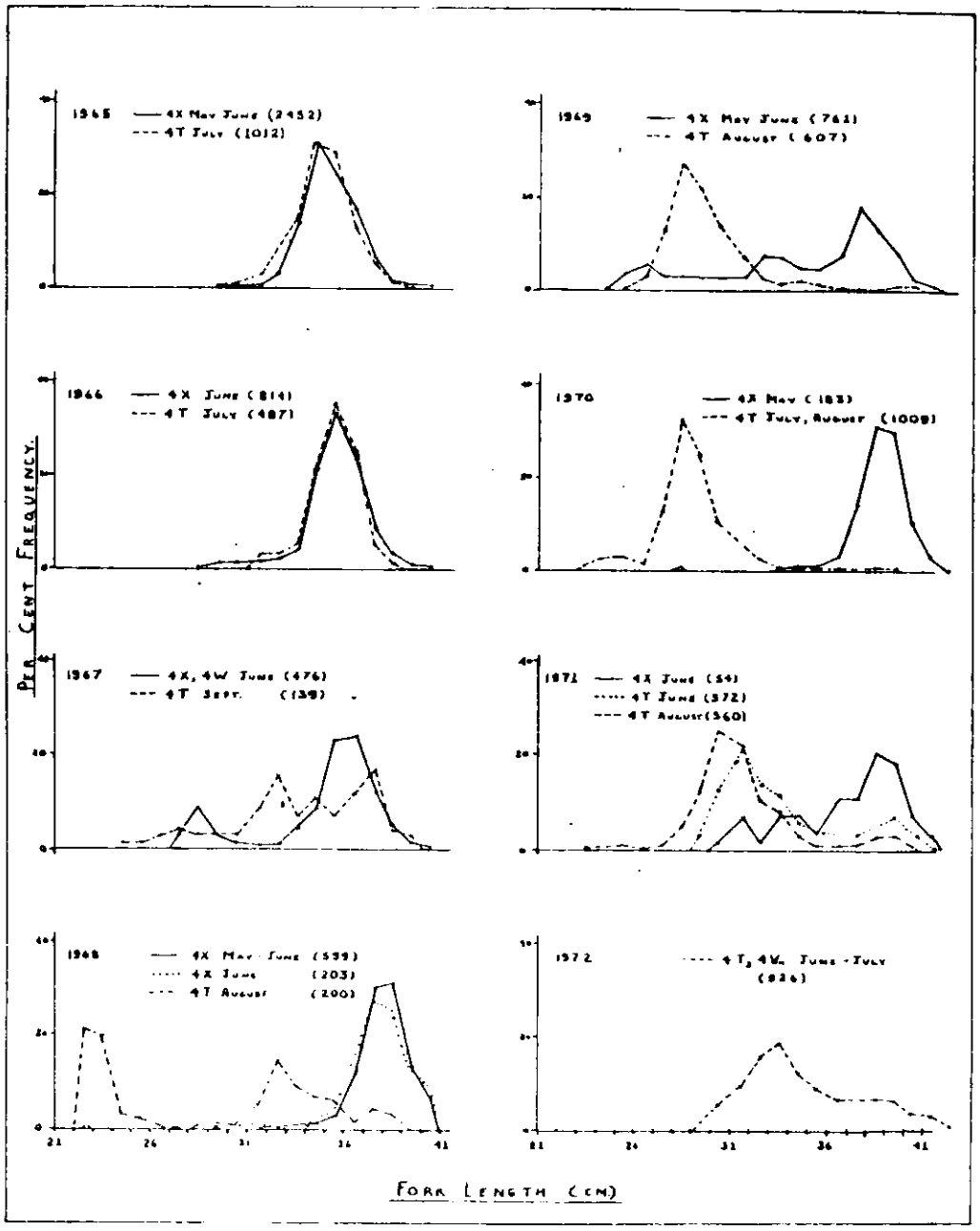

Figure 3. Length distribution of mackerel sampled in subarea 4T, 4W, and in 4X during spring and summer from 1965 to 1972.

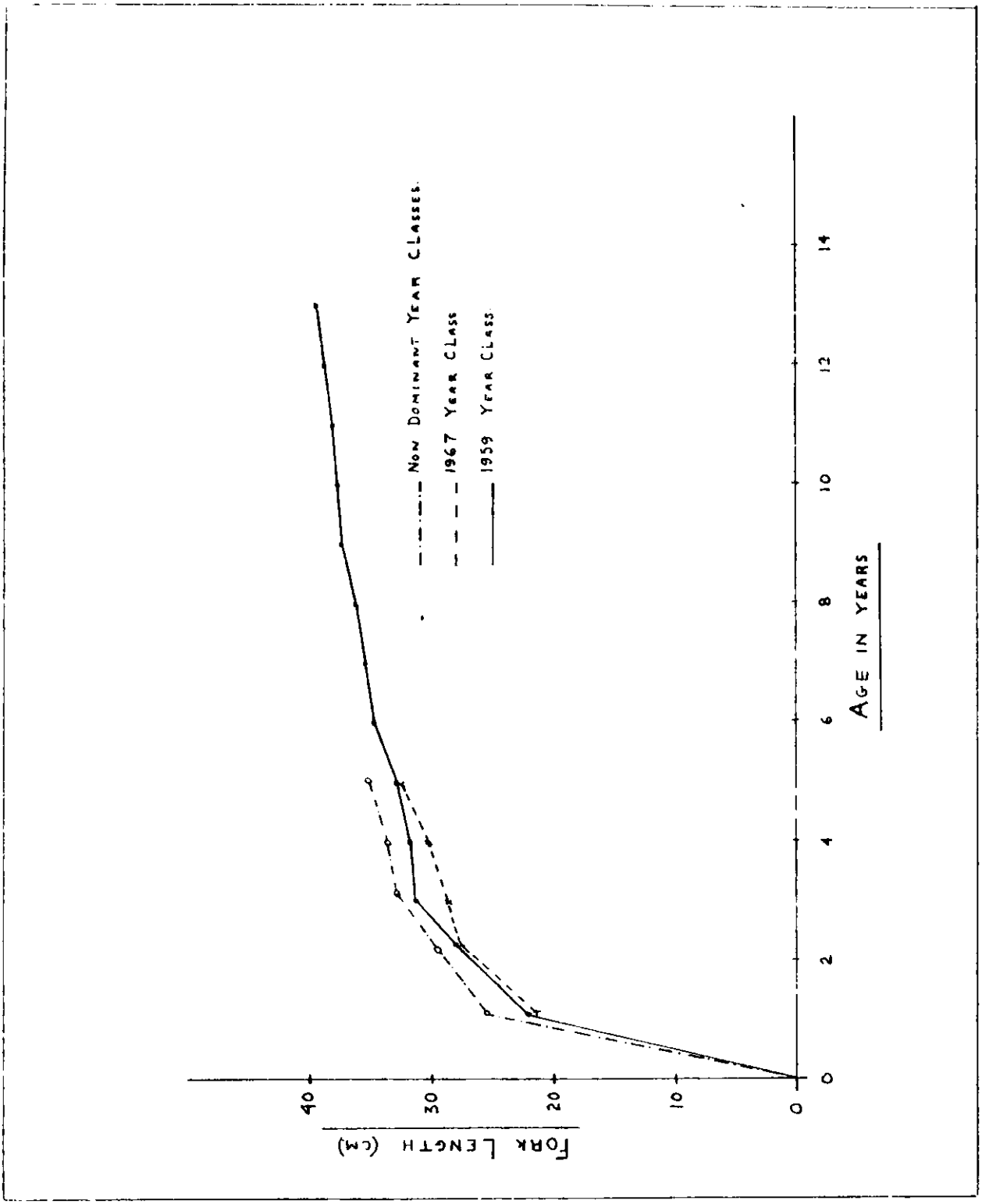

Figure 4. Growth rate of the dominant 1959 and 1967 year classes compared to the average for non-dominant year classes present in sampling from 1965 to 1972.

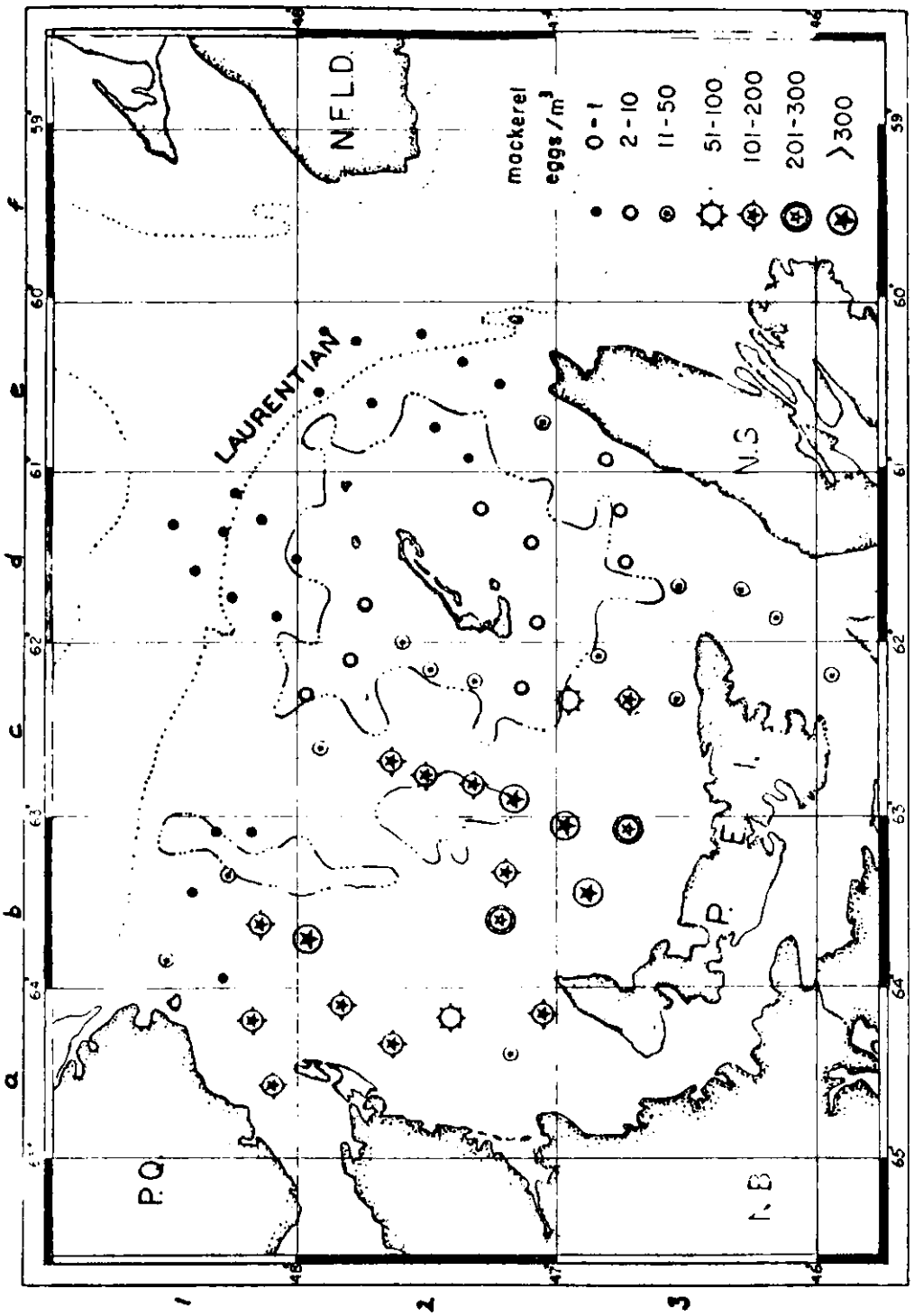

Figure 5. Surface distribution of mackerel eggs June 18 to June 24, 1968 (taken from Arnold MS 1970).