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Some biological characteristics of mackerel (Scomber scombrus) in Newfoundland waters[1]

by

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Introduction

Atlantic mackerel (Scomber scombrus) are seasonal migrants to Newfoundland waters, appearing in abundance in July and disappearing again in October and November. Although they have been reported from as far north as Black Island, Labrador (53°46'N) (Parsons, 1970) mackerel are a warm-water species and as such its spatial availability and abundance in Newfoundland waters have fluctuated in response to conducive environmental conditions (Templeman, 1966). The earliest landing records available indicate that during the late 1800's there were two short periods of minor abundance: 1870-72 and 1879-80 (Templeman, 1966). After 1880 mackerel virtually disappeared from Newfoundland waters and did not reappear in abundance until the mid-1940's during a period of climatic warming. Landings dropped off considerably during the late 1950's probably due to the effects of a major fungus disease which killed large quantities of herring and mackerel in the southern Gulf of St. Lawrence (Tibbo and Graham, 1963). In recent years (Table 1) mackerel have again appeared in abundance in Newfoundland waters with landings increasing from just over 300 m. tons in 1969 to nearly 1600 m. tons in 1972. As has been the historical case, the bulk of the landings have been taken from coastal waters in ICNAF subdivisions 3K and 3L.

There is a paucity of information on the population characteristics of mackerel in Newfoundland waters. Most of the available information is related to distribution limits (Leim and Scott, 1966; Parsons, 1970) or the occurrence of mackerel eggs, larvae and juveniles (Dannevig, 1918; Sette, 1943; Parsons and Hodder, 1970). Tagging studies (Parsons and Moores, MS 1973) together with the pattern of landings (Anderson, MS 1973) indicate that the rapid expansion in mackerel landings in ICNAF subareas 5 and 6 is at least based partially on the northern contingent of mackerel. With this perspective in mind and in view of the inadequate or conflicting data on various parameters of mackerel population dynamics, this paper presents some preliminary analysis of new information on the biological characteristics of mackerel in the Newfoundland area during 1970-73.

Methods and Materials

Random samples of mackerel were obtained directly from inshore fishermen or from processing plants and were examined fresh or after being frozen for a period of several weeks. The samples used in the following analyses were taken from catches made with random gears; purse seine, Scottish ring net, mackerel traps and cod traps with a small-meshed liner. Samples were processed for total length, whole

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weight, sex, maturity, gonad weight, degree of stomach fullness and otoliths were removed for subsequent age determination.

Total lengths were measured to the nearest millimeter from the tip of the lower jaw to the end of the longest caudal lobe directed posteriorly in line with the body. Whole weight and gonad weight were determined to the nearest gram. No significant difference was found between the lengths and weights of fish sampled fresh and those sampled after freezing and thawing, therefore no adjustment was made to length data obtained from thawed samples.

The stage of maturity was determined by gross examination of the gonads. Numerical values for each stage were designated according to the maturity scale adopted by ICNAF (ICNAF, 1964) for herring. The degree of stomach fullness was estimated on a five point scale: 0 = empty, 1 = ¼ full, 2 = ½ full, 3 = ¾ full and 4 = full.

Ages were determined from annuli patterns in otoliths which were placed whole into depressions in a black plexiglass tray according to the method of Watson (1965). Readings were made with the otolith immersed in 95% ethanol and with reflected light. Otoliths were read independently by two experienced age readers with disagreements being resolved by a third reader or by mutual agreement.

Ages were assigned by counting the number of completed summer (opaque) zones. An arbitrary birth date of January 1 was assigned to mackerel and ages were transformed into age groups. Thus fish having an otolith with one completed summer zone and caught before January 1 were assigned to the 0 age group while fish caught after January 1 with one complete summer zone were assigned to age group 1. All fish older than age 10 were classed as 11+ years of age.

Results

Length and age composition

Length and age composition data from commercial catches of mackerel by non-selective gears in Newfoundland waters (Fig. 1) indicates that the 1967 year-class has dominated the catches from 1971 onwards and contributed very significantly to the catches in 1970. The percentage contribution of this year-class peaked at about 63% in 1972 and fell to 33% in 1973. The 1966 year-class which was dominant at 39% in 1970 fell to 22% in 1971 and to less than 11% in 1973. The 1968-70 year-classes appear to be fairly weak, each year-class contributing less than 12% to the catches in 1973. The 1971 year-class comprised 16% of the samples in 1973 as 2-year-olds and would appear to be somewhat stronger than most recent year-classes. The peaks in the length frequency curves (Fig. 1) reflect the size composition of the dominant year-classes with total lengths ranging from 28 cm to 47 cm. Old fish (> 8 years old) have not formed a significant percentage of the fish examined and by 1970 the 1959 year-class, reported by MacKay (MS 1967, MS 1973) as being very strong, had all but disappeared from the catches.

Maturity composition

Analysis of maturity composition data (Table 2) indicates that during the period 1970-73 there was a consistent appearance of mackerel in spawning condition (stages 4-6) in the samples from the Newfoundland fishery. Most of the mackerel examined in June were in spawning condition whereas the percentage of ripe fish in July fluctuated from 89% in 1972 to just over 18% in 1973 and nil during 1971. With the exception of 1972 (an unusually cold year), fish in spawning condition were not present in the samples after July during which time spent and recovering spent fish dominated the catches. Most of the ripening mackerel were from samples obtained from southeastern Newfoundland (ICNAF subdivision 3Ps) and Conception Bay (3L). Farther north along the east coast of Newfoundland and particularly in Labrador, mackerel tended to appear later in the summer (usually late July-early August) and were mainly comprised of spent and recovering fish. Immature fish were not present in the catches in June but tended to increase in percentage contribution from July to August. This pattern is similar to that reported by MacKay (MS 1973) for mackerel in the Nova Scotia area.

Comparison of age compositions and mean ages of ripe and spent mackerel caught in southeastern Newfoundland during 1970-73 (Table 3) indicates that in general the older (and hence larger) fish spawn first. A similar pattern was observed in the southern Gulf of St. Lawrence (4T) mackerel populations (MacKay, MS 1967).

Growth

C 3

Average lengths-at-age of mackerel sampled in Newfoundland coastal waters during June-July and August for the years 1970-73 are shown in Table 4. There is a slight decrease in mean length-at-age from the June-July period to August both by year-class and by age. This reflects the general trend of larger and older fish spawning first (Table 3) and also the influx of immature fish in July and August (Table 2). Comparison of the size of the various year-classes at each age suggests that the dominant 1967 year-class is neither consistently larger nor smaller than adjacent year-classes. These data do not therefore support the inverse relationship between growth rate and year-class size reported by MacKay (MS 1973) for the 1959 and 1967 year-classes of mackerel in the southern Gulf of St. Lawrence.

The growth curve of mackerel in the Newfoundland area was analyzed by the von Bertalanffy (1938) growth equation according to the method of Allen (1966). Since all of the lengths were obtained during the June-August period, July was taken as the midpoint of the time interval and ages were defined as fractions of a year, e.g. age 2.6, 3.6, etc. Initially only the data shown in Table 4 were incorporated into the analyses but these produced growth parameters (L_∞ = 452 mm, K = 0.22, t_0 = -3.31) which, although providing a fairly good fit to the observed points, resulted in unreasonably large L_1 values. To overcome this, length data of 100 0-group mackerel caught in Bonne Bay, western Newfoundland (4R) on November 26, 1972, were incorporated into the analyses. The resulting von Bertalanffy growth curve is shown in Fig. 2. As can be seen, linear values calculated by the fitted curve agree well with the observed points.

A comparison of growth data of mackerel from various areas is provided in Table 5. Allocation of growth data to specific areas in subareas 5 and 6 was not possible because of the lack of information on sampling details in the original sources. Where lengths have not been defined (Isakov, MS 1973; ICNAF Redbook, Part 1, p. 94) it has been assumed that they refer to fork lengths and consequently they have been converted to total lengths using the appropriate conversion factor (Anderson, MS 1973). It would appear from Table 5 that the mackerel sampled in subareas 5 and 6 during the winter period have a growth rate very similar to the mackerel population sampled during the summer months in the Newfoundland area. This is not entirely unexpected as it is known from tagging studies (Parsons and Moores, MS 1973) that mackerel from Newfoundland migrate at least as far south as Long Island (subarea 6A) to overwinter. North Sea mackerel are smaller than their counterparts from the Northwest Atlantic and have different growth parameters (Postuma, 1972).

Analyses of length-weight data (Fig. 3) indicates that weight increases with length at a rate slightly faster than expected from the Cube law. The recovery in body condition after spawning is indicated by the greater weight-at-length of mackerel sampled in September relative to the June-July period.

Average weight-at-age

Average age-at-weight data for the periods June-July and September were compared for the years 1970-73 (Fig. 8). In general there was a decline in the average weight at age from June-July to September. The only age group showing a significant increase over the summer period was age group 2. This group is composed primarily of immature fish which are still in the rapid growth phase of the growth curve. Declining average weight values of the older age group may be attributable in part to the release of sexual products. This loss of body weight is not completely regained during the summer feeding period and is reflected in the reduced growth rate shown by mature fish.

Age and length at maturity

Analyses of maturity stage data indicates that mackerel caught in the Newfoundland area mature between ages 2 and 4 (Table 7). Females tend to mature at a slightly faster rate than males but both sexes contain only a few immature individuals at age 4 and are 100% mature at age 5. Although no age 1 fish were present in the samples used in these analyses, a few have been caught by small-meshed gillnets and these have been all immature. MacKay (MS 1967) also states that the onset of maturity occurs at age 2.

The smallest mature fish in catches of mackerel in the Newfoundland area was 32 cm and the largest immature fish was 37 cm (Fig. 4). The 50% maturity point occurred at 339 mm in the females and 347 mm in the males with the average maturity length being 343 mm. Since this mean length is based on fish sampled in June-September, the mean length or maturity at the beginning of the year (January) is probably in the range 30-31 cm. A similar conclusion was reached by MacKay (MS 1967).

Sex ratio

During the period 1970-73 there has been a significant fluctuation in the sex ratio of mackerel in the Newfoundland area (Table 6). In mature fish females tend to predominate whereas in the immature stages males have predominated. This however may be biased by the small sample sizes of immatures. In 1973 when ninety immatures were sampled the sex ratio was close to 1:1. For both matures and immatures combined the ratio of males to females for the years sampled was 1:00:1.25. MacKay (MS 1967) also found the sex ratio to be in favour of the females but only slightly so with a ratio of 1 male to 1.06 females. Steven (1952) found a similar pattern in mackerel from the English Channel and Celtic Sea.

The more rapid maturation rate of female mackerel relative to males, particularly in the younger age-group undoubtedly accounts for the predominance of females in mature fish. If one assumes that mortality is not sex specific then the convergence of the maturity curves of males and females with age implies that the proportion of males in the mature fish will increase steadily to age 5 when 100% maturity is reached for both sexes. If the stock is dominated by a strong year-class such as the 1967 year-class then the sex ratio of the stock as a whole will reflect this pattern. This therefore explains the declining predominance of mature females from 1970-72 as the 1967 year-class became fully mature at age 5 in 1972. In 1973 the relatively strong 1971 year-class as age 2 contained a relatively higher proportion of mature females than males and hence the sex ratio of mature fish again was in favour of females.

Feeding habits

In the course of normal sampling the degree of stomach fullness was estimated and stomach samples were also preserved for more detailed examination. An analysis of the degree of stomach fullness (Fig. 5) shows that the majority of mackerel sampled had little or no food in their stomachs. The most extensive feeding occurred during the month of July when only 36% of the stomachs examined were empty and 16% were full. October shows the least feeding occurring as 95% of the stomachs examined were empty. June and August show feeding to a limited degree with June having 73% empty and 7% full stomachs while August has 77% empty and 1% full.

A limited number of stomachs were examined in greater detail. From these stomachs it would appear that mackerel are mainly planktonic feeders consuming primarily euphasiids and copepods. The presence of these crustaceans in stomachs has been termed as red feed and along with warm temperatures has been blamed for the rapid deterioration of mackerel caught in the summer months. It has been observed that mackerel caught in September and October, when water temperatures are colder and feeding is reduced, remain firm and stay in good condition much longer than in summer.

As well as crustaceans mackerel have been found to eat other pelagic creatures. Several samples showed heavy feeding on capelin (Mallotus villosus) during July when capelin are plentiful in inshore Newfoundland waters as they approach the beaches to spawn and thus are readily available to the mackerel. Also two samples taken in northern Newfoundland showed the mackerel to be feeding exclusively on bottle-assed squid (Rossia sp.). It would appear that although primarily plankton feeders mackerel are opportunistic feeders and will prey on larger organisms when they are available.

Discussions and Conclusions

The existence of two major spawning populations of mackerel, one in the bight between New Jersey and Long Island and the other in the southern Gulf of St. Lawrence (4T), together with the availability of an abundant mackerel resource in both the southern (Gulf of Maine) and northern (subareas 3 and 4) areas during the summer period provide substantial proof of Sette's (1950) hypotheses of mackerel stock divisions in the Northwest Atlantic. That being so and in view of the possible mixing of the two spawning contingents in subareas 5 and 6 during the over-wintering period (Sette, 1950) the critical question to be resolved before an accurate stock size estimate can be arrived at is the magnitude of the relative contribution of each component to the catches.

The southern and northern populations of mackerel have been analyzed for differences in meristics and enzyme characteristics (Sette, 1950; MacKay, MS 1967) but without success. There are, however, two features of the life history of the particular spawning contingents which should produce observable differences. The first is that the southern contingent of mackerel spawns from mid-April to mid-May (Bigelow and Schroeder, 1953) whereas the Gulf of St. Lawrence spawning usually occurs from mid-June to mid-July, a difference of 1-2 months. In view of the rapid growth of mackerel during their first year the southern mackerel should be about 50-60 mm in length by the time the northern population begins to spawn. A comparison of the length-at-age data of mackerel caught in the Newfoundland area with those sampled from the commercial fishery in subareas 5 and 6 has not revealed any such differences in growth rate. The second aspect of the population biology of Northwest Atlantic mackerel is that the two major spawning areas are widely separated in space and undoubtedly have different environmental conditions. One would not reasonably expect therefore that year-class success would be the same in both areas except by stockastic occurrences, i.e. the age structure of the two components should be different. In fact, however, age composition data of mackerel sampled in subareas 5 and 6 (Anderson, MS 1973; Paciorkowski et al, MS 1973) are essentially the same as those presented in this paper for mackerel sampled in Newfoundland waters and those presented by Stobo and Hunt (1974) for 4T mackerel. One can only conclude from these analyses, therefore, that essentially the same population of mackerel, i.e. northern spawning population was sampled in both subareas 3 and 4 and subareas 5 and 6.

The above conclusion may be explained by several hypotheses: (1) sampling data reported for subareas 5 and 6 have not been representative of the commercial catches in those areas but rather have been disproportionately weighted by samples from the northern contingent; (2) there is a complete mixing and interchange of mackerel between the major spawning areas in 4T and subarea 6, i.e. fish forming part of the northern contingent in one year may forsake that contingent and join the southern contingent in other years; (3) the commercial fishery in subareas 5 and 6 is based mainly on the northern mackerel contingent.

The first hypothesis cannot be properly evaluated here because of the lack of details on sampling operations and methods in subareas 5 and 6. One would not expect, however, that the southern population of mackerel would be consistently under-represented in the samples. In addition there is very good agreement between the age-composition data reported by both Poland and the USSR (Anderson, MS 1973) for the same subdivision.

Insofar as the second hypothesis is concerned the main bases for Sette's (1950) original hypothesis of mackerel stock division in the Northwest Atlantic was indeed differences in length and year-class composition of samples collected during the spring-summer period in the New England area and along the Canadian coast. Also as a general rule one would expect that the principle of stock identity and perpetration would be best assured by the recruitment of the progeny from the parent stock rather than that from another stock with different biological and genetic characteristics. There is some evidence from historical tagging experiments however which suggests some mixture of spawning groups may occur. Five mackerel tagged in southwest Nova Scotia in June 1927 and 1928 were recaptured in June of the following year in the Cape Cod area. Sette (1950) examined several of these fish all of which showed severe damage to the caudal peduncle, around which the tag was carried and some of the fish were in an emaciated condition. From such observation Sette concluded that these fish, being severely weakened by the tag attachment had lagged behind their more vigorous untagged companions and did not represent a general joining of the southern contingent by members of the northern contingent. This is supported by the fact that other recaptures of Canadian-tagged fish were taken at times and places appropriate for the northern contingent to have been passing through New England waters. In addition, with the exception of a single tag from Canadian waters, all recaptures of tagged mackerel released in the New England area during the summer period were recaptured in United States waters. The single exception was from a release of mixed fish containing both northern and southern mackerel (Sette, 1950).

In addition to the similarities in growth and year-class composition noted above, there is other evidence both factual and circumstantial which support the hypotheses that the northern population contributes to the bulk of the catches in subareas 5 and 6, implying as a corollary that the southern contingent is either small or is not being significantly exploited by current fisheries. Tagging data, both recent and historical, provide direct evidence of regular migrations of the northern population of mackerel to over-wintering areas off New England. During the period 1925-28 nearly 8000 mackerel were tagged during the summer period (mainly June) along southwest Nova Scotia (Sette, 1950). In addition to recaptures from Canadian waters substantial numbers (35) of the tags were recaptured during the fall-spring period from United States waters, mainly in the Cape Cod-New Jersey area (subdivision 5Zw, 6A). The general pattern of mackerel migration suggested by these historical tagging experiments was of a southward movement of northern mackerel along the Nova Scotia coast through the Gulf of Maine in the fall to over-wintering areas off the New England coast with a subsequent return migration the following spring to area as far north as the Gulf of St. Lawrence (4T). Sette (1950) considered these experiments also to confirm the less extensive migration of the southern mackerel population from the Offing of Virginia (6B) to the Gulf of Maine but not farther and of the migration of a small portion of the northern contingent from southern New England into the northern portion of the Gulf of Maine during early summer.

Recent tagging experiments corroborate the findings of those conducted during the late 1920's. Parsons and Moores (1973) report the recapture in ICNAF subdivision 6A of a single mackerel from a small number (1450) of releases in northeast Newfoundland (3K). The St. John's Biological Station conducted another tagging experiment during September 1973 in Trinity Bay, Newfoundland, where 9000 tagged mackerel were released. To date two long-distance returns have been reported from catches of Polish trawlers fishing in the Hudson Canyon (6A) area in January 1974. During the same period and in the same locality the Polish fleet also recaptured two mackerel tagged by the St. Andrews Biological Station in southwest Nova Scotia during the fall of 1973 (Stobo, personal communication). Thus it would appear that mackerel from as far north as subdivision 3K mix with those from subarea 4 in a common over-wintering area off the New England coast.

The existence of a southern over-wintering area for mackerel is indeed to be expected from the temperature requirements of the species. Sette (1950) reports observational evidence which suggest that mackerel prefer temperatures above 8°C although temperature down to 7°C are frequently tolerated; it is only rarely found in temperatures as low as 4 or 5°C. Using these guidelines the suitability of the Scotian Shelf as a major over-wintering area can be evaluated. The hydrography of the Scotian Shelf has been described by Hachey (1953) and McLellan (1954). The Cape Breton Current passing out of the Gulf of St. Lawrence generally floods the eastern portion of the Shelf but on proceeding southward is confined to an inshore bend mainly due to the Shoal banks situated on the outer part of the Shelf. In the westward portion in the region of the Scotian Gulf, the waters are strongly influenced by incursions of offshore waters which pass in over the Shelf through the Scotian Gulf. The submarine physiography of the Scotian Shelf is such however that the major effects of such incursions are confined to the Scotian Gulf area. In the Banquereau area winter temperatures range from less than 1°C at the surface to 5°C at bottom (150-200 m) (McCracken, 1965). On Sable Island Bank temperatures ranged from less than 2°C at the surface to about 4°C on bottom (75 m). On the coastal slope temperatures increased to 5.5°C at 100-150 m. On the oceanic side of Sable Island Bank water temperatures are somewhat higher depending on the influence of the Gulf stream. In the Scotian Gulf area bottom temperatures during the winter months may exceed temperatures of 8°C at bottom depths of 150 m or deeper. On Emerald Bank bottom temperatures are generally less than 8°C except on the oceanic side where slope water may increase temperature above 8°C at depths of 150 m and greater. Shoreward of the bank areas on the Scotian Shelf bottom temperatures decrease to about 2°C depending upon depth (McLellan, 1954). In summary therefore it appears that winter temperature conditions on the Scotian Shelf, with the exception of the Scotian Gulf where bottom temperatures are in the lower range of preferred temperature, are not very favourable for over-wintering concentrations of mackerel. This does not, however, exclude the possibility of over-wintering schools of mackerel in slope water on the oceanic side of the Scotian Shelf. Nevertheless mackerel catches on the Scotian Shelf during the December-April period have been extremely low despite the fact the area is traversed frequently by vessels with suitable gear.

The pattern of mackerel landings in subareas 5 and 6 also coincides with the general migration pattern of northern mackerel suggested by tag recaptures (Table 9). Landings in subarea 5 increase substantially in November and December when tag returns indicate that the northern mackerel population is moving southwards through subarea 5. Landings decrease in subarea 5 during January and February, but begin to increase again in March and peak in May after which there is a substantial decline. Landings in subarea 6 show a substantial increase in December and generally increase to a peak in March followed by an abrupt decline to less than 5000 tons from June to December. On a percentage basis landings of mackerel which come almost exclusively from subarea 5 during the summer months begin to increase from subarea 6 in November and dominate the total landings from January to April after which subarea 5 landings predominate. These landing patterns suggest a north-south movement through subarea 5 to subarea 6 during the fall period with a subsequent return to subarea 5 in April and May. Mackerel landings in the particular subdivisions of subareas 5 and 6 also exhibit the same monthly pattern. Monthly landing data for subareas 3 and 4 (ICNAF Working Paper No. 8, 1974 Mid-term Meeting) indicate a reverse pattern with landings being close to nil for the December-April period, increasing to a peak in the July-August period and subsequently declining. Thus the subarea landing patterns suggest a general southward movement of mackerel from subareas 3 and 4 through subarea 5 in late fall to over-wintering areas in subarea 6 during the January-March period after which the northward migration to the northern subareas begins.

Evidence is also available which suggest that the northern population of mackerel, having as its major spawning area the southern Gulf of St. Lawrence could support the large catches in subareas 5 and 6. MacKay (MS 1973) on the basis of egg estimates, calculated the stock size of spawning mackerel in 4T to range from 900,000 to 1,800,000 m. tons in 1968. The lower limit of these estimates is close to the range of population sizes estimated by the Mackerel Working Group (Summ. Doc. 74/8) of mackerel in subareas 5 and 6 during the same year.

In conclusion the evidence presented above suggests that the hypothesis of a large dominant northern population of mackerel is the most plausible one to explain the similarities in biological characteristics between mackerel sampled in subareas 3 and 4 in summer and subareas 5 and 6 in winter. Until such new information is forthcoming to indicate otherwise, the authors consider this hypothesis should be a basic assumption in all stock size estimates made by the Mackerel Working Group. This implies a single mackerel assessment incorporating catch data from subareas 3 to Statistical Area 6.

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Table 1. Mackerel landings in ICNAF Subareas 2, 3 and 4, 1963-72.

	Subarea 2			Subarea 3									Subarea 4								
Year	2J	Total	Canada	3K	3L	3M	3N	3O	3PN	3PS	Total	Canada	4R	4S	4T	4VN	4VS	4W	4X	Total	Canada
1972				586	845				20	128	1579	1554 (N)	204	180	7351	2074	64	6582	4325	20780	14494(M) 204(N) 14698(T)
1971	207	207	207(N)	692	412				26	169	1299	1299 (N)	151	121	5782	1915	163	10159	4699	22990	13285(M) 151(N) 13436(T)
1970	20	20	20(N)	525	159			3	16	139	842	837 (N)	65	11	5812	2759	250	4824	5376	19097	14788(M) 65(N) 14853(T)
1969				228	12				7	66	313+ 1 Jap 314	311 (N)	30	3	3739	2085	38	6166	4990	17050 + 197 (Jap) 17247	12916(M) 30(N) 12946(T)
1968				126	51				9	184	370	186 (N)	7	487	4663	1765	42	10557	2928	20449	10925(M) 7(N) 10932(T)
1967				45					1	8	54	54 (N)	35	49	3119	2047		2176	3763	11189	11092(M) 35(N) 11127(T)
1966				70	1					22	93	83 (N)	44	29	5258	1235		2016	4146	12728	11450(M) 44(N) 11494(T)
1965					163	2				22	187	184 (N)	10	9	4622	1088		1698	3976	11403	10991(M) 10(N) 11001(T)
1964				353	405					87	846	819 (N)	11	281	5094	1070		1492	2166	10114	9956(M) 11(N) 9967(T)
1963				138	25					210	373	274 (N)		438	2326	907		751	1678	6100	6089(M)

Table 2. Maturity composition by month of mackerel caught in the Nfld. area from 1970-73.

		% at each maturity stage				
Year	Month	Stages 1-2 (imm)	Stage 3 (maturing)	Stages 4-6 (ripening)	Stages 7-8 (recovering spent)	Number examined
1970	June					
	July	1.5	10.5	68.0	20.0	200
	Aug	20.0	5.7		74.3	35
	Sept	19.4			80.6	62
1971	June	0.6	8.4	80.1	10.9	311
	July	12.2	4.9		82.9	123
	Aug	4.0			96.0	99
	Sept					
1972	June		6.0	94.0		50
	July		3.0	89.0	8.0	100
	Aug	3.0		3.0	94.0	100
	Sept	2.6			97.4	189
1973	June					
	July	10.8	27.0	18.2	44.0	148
	Aug	22.0	4.0		74.0	50
	Sept	22.3			77.7	300

Table 3. Age composition of ripe and spent mackerel caught in the Nfld. area during June-July 1970-73.

Maturity condition	% at age 1	2	3	4	5	6	7	8	9	10	10+	Number Examined	Mean Age
Ripe		0.5	8.7	46.8	23.7	13.1	3.6	1.5	1.0	0.8	0.3	389	4.69
Spent			1.6	35.2	17.2	29.5	7.4	6.6	0.8	0.8	0.8	122	5.37

Table 4. Length-at-age data of mackerel from the Newfoundland area for the period June-July (A) and August (B) 1970-73.

A)

Year	1	2	3	4	5	6	7	8	9	10	11
1970	-	-	35.4(18)	37.9(80)	38.7(73)	40.9(13)	43.7(3)	43.0(4)	45.0(1)	43.3(4)	-
1971	-	31.0(8)	35.3(7)	36.1(218)	38.4(113)	39.4(68)	41.2(6)	42.0(1)	43.5(4)	43.0(2)	43.7(10)
1972	-	-	36.0(2)	38.4(11)	38.8(71)	41.2(30)	41.9(16)	43.5(4)	44.3(6)	45.0(2)	44.6(8)
1973	-	32.0(14)	35.0(7)	36.6(18)	39.0(11)	40.3(58)	40.6(19)	41.6(14)	43.8(4)	43.0(1)	45.0(4)
Years combined	-	31.6(22)	35.3(34)	36.6(327)	38.6(268)	40.1(169)	41.4(44)	42.2(23)	44.0(15)	43.6(9)	44.3(22)

B)

Year	1	2	3	4	5	6	7	8	9	10	11
1970	-	33.0(1)	32.9(24)	36.7(6)	37.0(4)	-	-	43.0(1)	-	-	44.0(1)
1971	-	-	36.2(6)	36.2(66)	37.1(16)	43.8(4)	41.0(2)	42.0(1)	44.5(2)	42.0(1)	43.0(2)
1972	-	-	36.8(4)	37.9(14)	38.3(50)	39.4(25)	40.4(5)	40.0(1)	43.0(1)	-	-
1973	-	32.3(11)	35.0(6)	36.7(6)	38.3(4)	39.2(17)	39.0(5)	43.0(1)	-	-	-
Years combined	-	32.4(12)	34.1(40)	36.5(92)	38.0(74)	39.7(46)	39.9(12)	42.0(4)	44.0(3)	42.0(1)	43.3(3)

Table 5. Comparison of growth data of mackerel from various areas.

	Newfoundland Calculated (Jan)	Newfoundland Observed (July)	New England (Fall)[1]	New England (Jan-Feb)[2]	New England (Jan-Feb, 1970)[3]	North Sea (May 1959-69)[4]
1	231		221	232	217	201
2	291	318	289	284	272	281
3	333	363	329	341	325	322
4	362	374	353	353	356	345
5	382	389	366	366	381	349
6	397	399	374	374	405	356
7	406	413		402	415	378
8	413	421		424		378
9	418	438		435		
10	421	430				
10+	425	439				

1 - Anderson, MS (1973)
2 - ICNAF Redbook, Part 1, p. 94
3 - Isakov, MS (1973)
4 - Postuma, 1972.

Table 6. Sex ratio of mackerel obtained from commercial gears in Nfld. 1970-73.

Year	Immature No. examined	Immature % Fe	Mature No. examined	Mature % Mat	Imm + Mat No. examined	Imm + Mat % Fe
1970	14	28.6	226	71.2	240	68.8
1971	20	20.0	498	60.2	518	58.7
1972	14	0.0	773	50.8	787	49.9
1973	90	48.9	408	55.6	498	54.4
Total	138	37.7	1905	56.7	2043	55.5

Table 7. Percentage mature fish by age of Atlantic mackerel from Nfld. waters, 1970-73.

Age	Females No. examined	Females % Mat	Males No. examined	Males % Mat	Combined No. examined	Combined % Mat
2	51	31.4	41	9.8	92	22.8
3	112	93.8	72	73.6	184	85.9
4	305	96.7	257	91.8	562	94.1
5	356	100.0	305	100.0	661	100.0
6+	309	100.0	225	100.0	534	100.0

Table 8. Weight-at-age data of mackerel from the Newfoundland area for the period June-July (A) and September (B) 1970-73.

A)

Year	1	2	3	4	5	6	7	8	9	10	11
1970	-	-	356.9(19)	425.1(81)	445.6(74)	553.5(13)	730.7(3)	682.0(4)	770.0(1)	680.4(5)	-
1971	-	244.1(8)	357.4(7)	391.0(218)	464.2(113)	495.6(68)	569.7(6)	607.0(1)	725.0(4)	736.5(2)	733.2(10)
1972	-	-	339.0(2)	480.7(11)	508.4(71)	607.6(30)	645.6(16)	707.5(4)	755.2(6)	817.5(2)	792.9(8)
1973	-	265.1(14)	367.1(7)	429.4(18)	568.2(11)	606.5(58)	622.8(19)	670.6(14)	758.6(4)	717.0(1)	843.0(4)
Years combined	-	257.5(22)	358.0(35)	404.5(328)	475.0(269)	558.0(169)	631.2(44)	676.2(23)	749.0(15)	722.7(10)	774.9(22)

B)

Year	1	2	3	4	5	6	7	8	9	10	11
1970	-	-	260.0(39)	293.3(17)	383.0(5)	436.0(1)	-	-	-	-	-
1971	-	-	-	-	-	-	-	-	-	-	-
1972	-	-	417.8(9)	443.9(22)	480.9(141)	524.6(43)	600.0(16)	671.5(4)	-	902.0(1)	662.3(3)
1973	-	315.9(47)	349.0(43)	435.4(41)	572.6(26)	564.2(86)	580.5(31)	595.8(24)	575.0(1)	-	868.0(1)
Years combined	-	315.9(47)	317.7(91)	407.5(80)	491.9(172)	550.1(130)	587.1(47)	606.6(28)	575.0(1)	902.0(1)	713.7(4)

Table 9. Total mackerel landings in ICNAF areas 5 and 6 and percentage catch in each subarea by month combined for the period 1969-72.

Month	% Catch 5Y	% Catch 5Ze	% Catch 5Zw	% Catch 5NK	Area 5 Total	% Catch 6A	% Catch 6B	% Catch 6C	% Catch 6NK	Area 6 Total	Total 5 & 6	% 5	% 6
January	1.0	35.0	64.0	-	31470	72.0	17.0	11.0	-	85918	117388	27.0	73.0
February	4.0	71.0	25.0	-	11286	44.0	34.0	22.0	-	74656	85942	13.0	87.0
March	2.0	47.0	51.0	.01	19396	38.0	36.0	26.0	-	135221	154617	13.0	87.0
April	1.0	54.0	37.0	8.0	34932	40.0	57.0	3.0	-	112166	147098	24.0	76.0
May	3.0	60.0	34.0	3.0	82266	73.0	24.0	2.0	1.0	4003	116269	71.0	29.0
June	4.0	54.0	40.0	2.0	55709	50.0	6.0	-	44.0	3290	58999	94.0	6.0
July	5.0	71.0	20.0	4.0	37912	99.7	0.3	-	-	323	38235	99.0	1.0
August	5.0	77.0	14.0	4.0	33735	93.0	7.0	-	-	14	33749	99.9	0.1
September	3.0	85.0	9.0	3.0	21339	100.0	-	-	-	43	21382	99.9	0.1
October	2.0	68.0	29.0	1.0	21752	100.0	-	-	-	877	22629	96.0	4.0
November	4.0	81.0	14.0	1.0	35748	97.0	3.0	-	-	4993	40741	88.0	12.0
December	2.0	83.0	12.0	3.0	55536	99	0.4	0.6	-	43890	99426	56.0	44.0

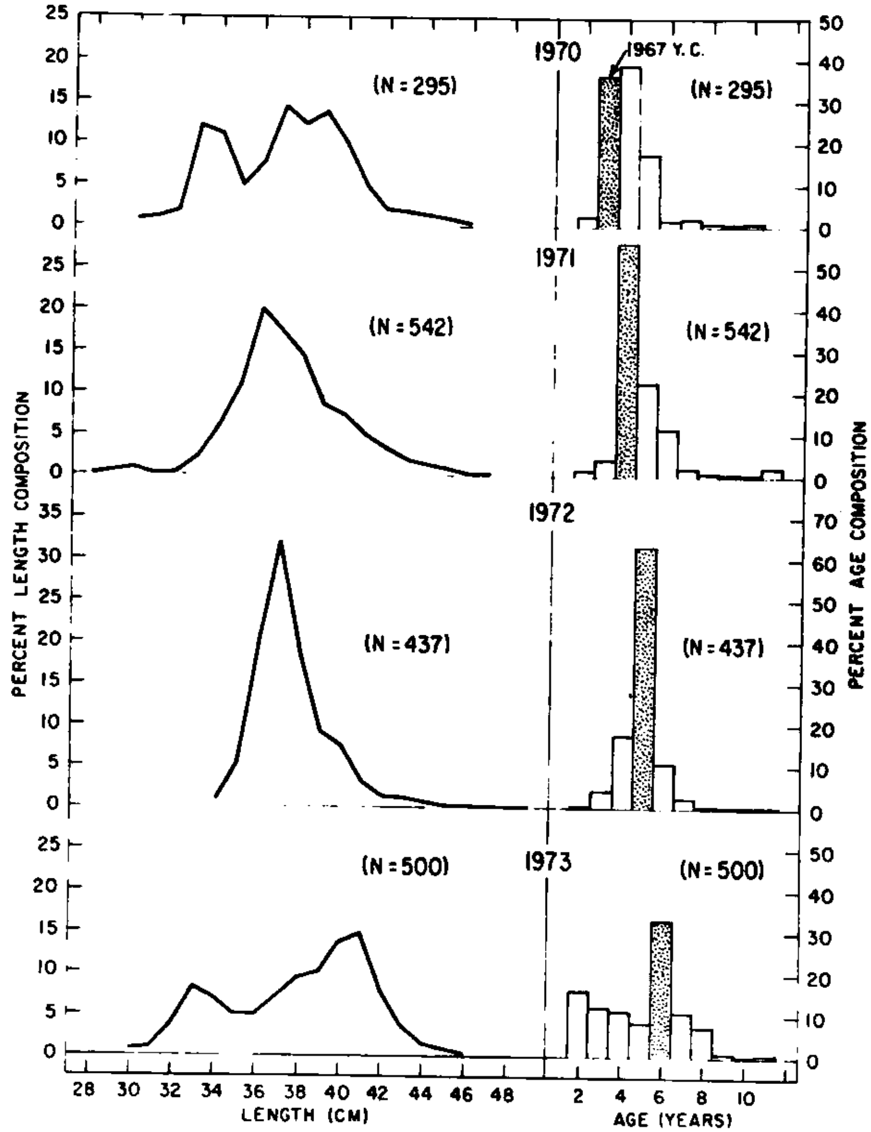
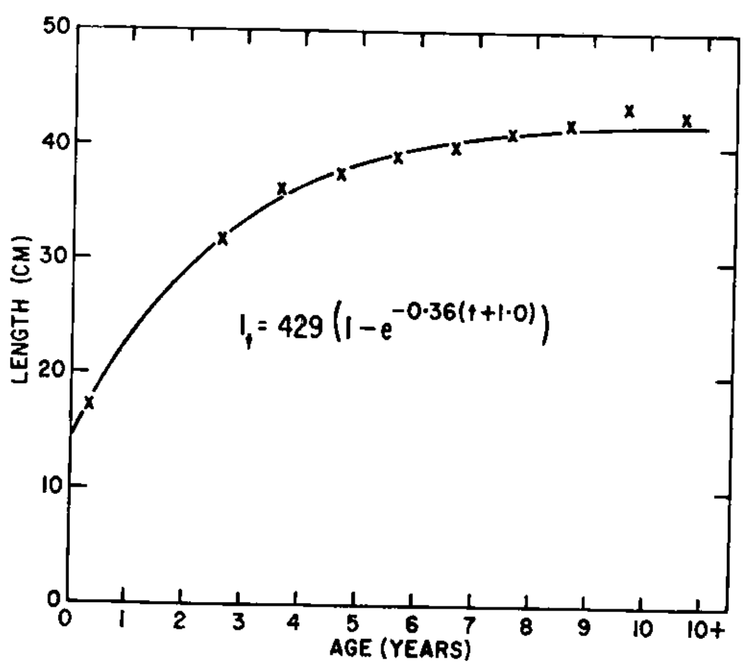


Fig. 1. Length and age compositions of mackerel caught in Newfoundland coastal waters, 1970-73.



D 2

Fig. 2. Fitted von Bertalanffy growth curve of mackerel from Newfoundland waters.

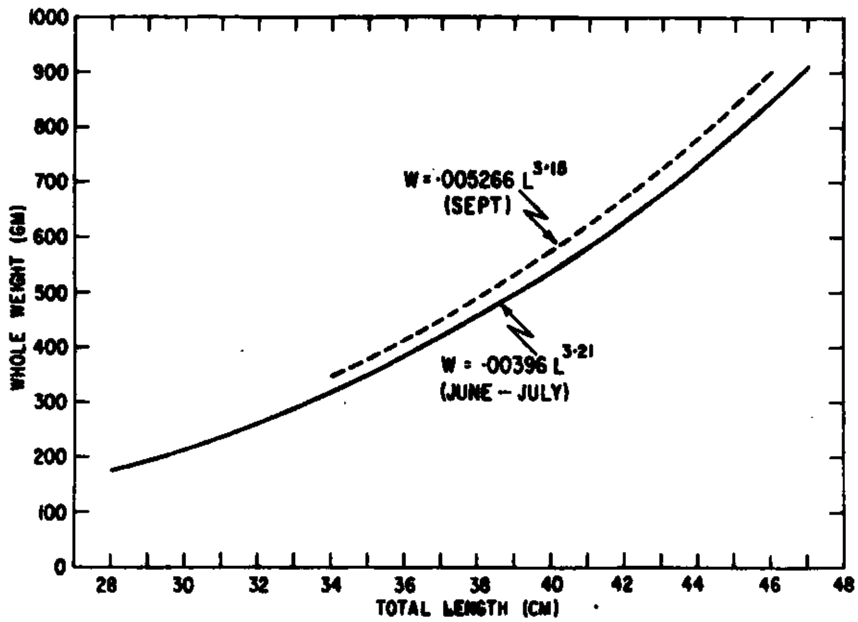


Fig. 3. Length-weight curves of mackerel samples during June-July and September.

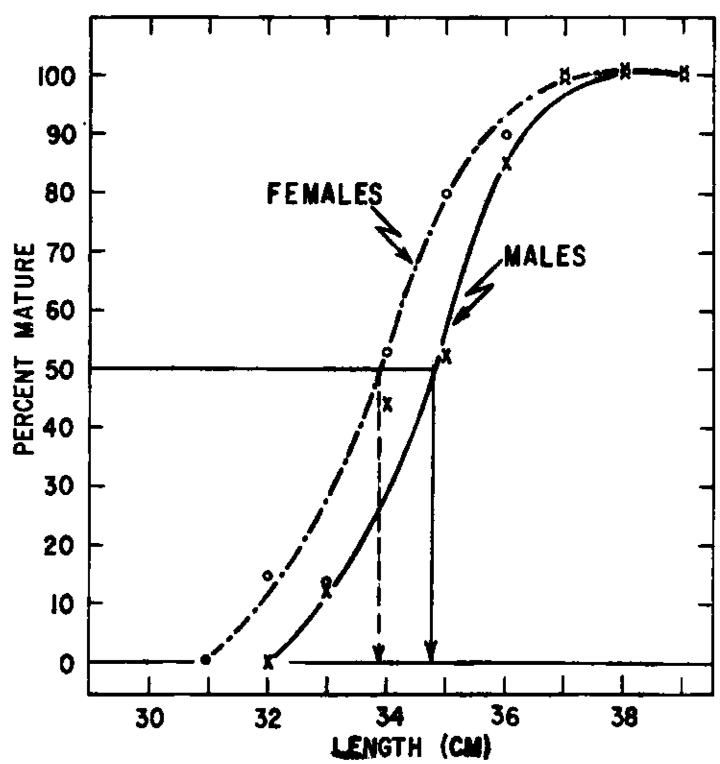


Fig. 4. Maturation ogives of male and female mackerel caught in the Newfoundland area.

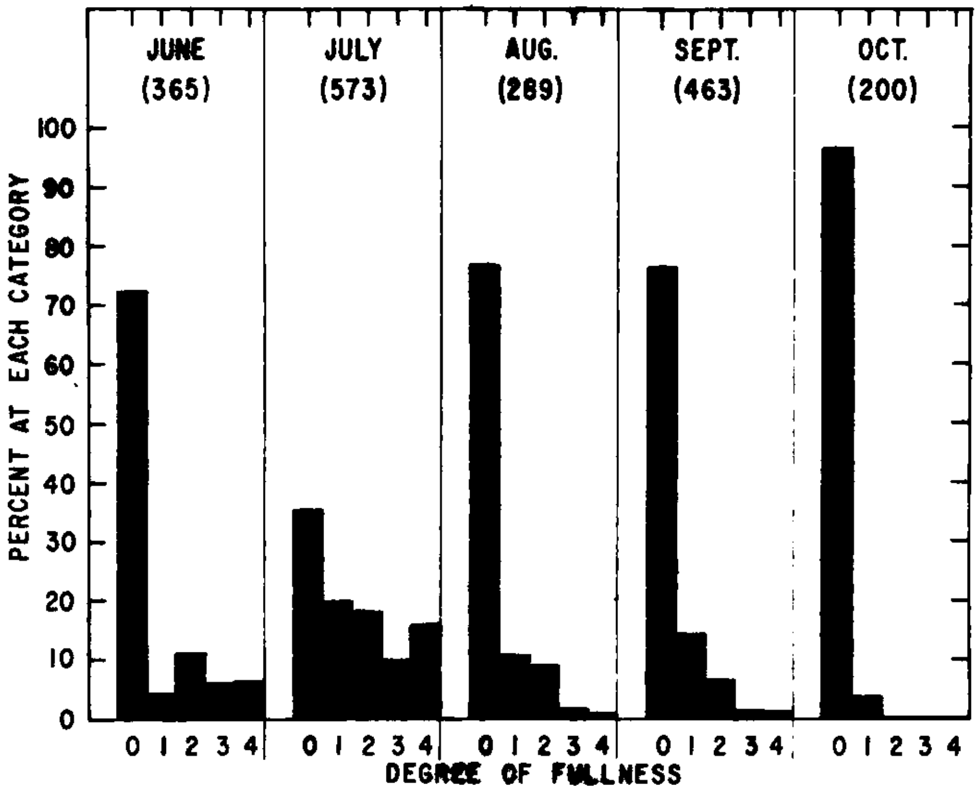


Fig. 5. Degree of fullness of mackerel stomachs collected from specimens caught in Newfoundland coastal waters.