Migrations and Biological Characteristics of Atlantic Mackerel (*Scomber scombrus*) Occurring in Newfoundland Waters

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Mackerel migrate to Newfoundland waters from July to November and exhibit periodic fluctuations in abundance. Recent taggings have shown extensive migrations from Newfoundland to ICNAF Statistical Area 6. Various biological characteristics of mackerel from Newfoundland waters are reported and compared with those for mackerel caught in the New England area. A consideration of tagging results, biological characteristics, and ecological factors indicates that for assessment purposes mackerel inhabiting ICNAF Subareas 3–6 should be treated as one stock rather than assessed separately as northern and southern contingents each with a separate quota.

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Le maquereau bleu émigre vers les eaux de Terre-Neuve de juillet à novembre et accuse des fluctuations périodiques d'abondance. Des marquages récents ont démontré des migrations d'envergure depuis Terre-Neuve jusque dans l'aire statistique 6 de l'ICNAF. Les auteurs mentionnent diverses caractéristiques biologiques du maquereau bleu des eaux de Terre-Neuve et les comparent avec celle du maquereau capturé dans la région de la Nouvelle-Angleterre. L'analyse des résultats du marquage, des caractères biologiques et des facteurs écologiques indique qu'aux fins de l'évaluation, le maquereau habitant les sous-aires 3–6 de l'ICNAF devrait être considéré comme un seul stock plutôt que deux, l'un septentrional et l'autre méridional, chacun avec un contingent de capture séparé.

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ATLANTIC mackerel (*Scomber scombrus*) are seasonal migrants to Newfoundland waters, appearing in abundance in July and disappearing again in October and November. Although reported from as far north as Black Island, Labrador (53°46′N) (Parsons 1970), the mackerel is basically a warmwater species and its abundance in Newfoundland waters has fluctuated in response to environmental conditions (Templeman 1966). The earliest landing records indicate that during the late 1800s there were two short periods of low abundance: 1870–72 and 1879–80 (Templeman 1966). After 1880 mackerel virtually disappeared from Newfoundland waters and did not become abundant again until the mid-1940s during a period of climatic warming. Landings declined considerably during the late 1950s, possibly due in part to the effects of a major fungus disease (Tibbo and Graham 1963). Recently mackerel have again appeared in abundance in Newfoundland waters with landings increasing from just over 300 metric tons in 1969 to nearly 1600 metric tons in 1972 (Table 1). The bulk of the landings has always been taken from coastal waters along eastern Newfoundland in ICNAF Divisions 3K and 3L (Fig. 1).

There is little published information on population characteristics of mackerel in Newfoundland waters. Most 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). Parsons and Hodder (1970) reported the occurrence of at least sporadic mackerel spawning in the southern Newfoundland area. Tagging studies (Parsons and Moores 1974) and the patterns of landings (Anderson 1973) suggested that the recent rapid expansion in mackerel landings from ICNAF Subareas 5 and 6 (381,000 metric tons in 1973) may be based partially on the northern population of mackerel. This paper presents the results of an investigation of certain facets of the biology of mackerel in Newfoundland coastal

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TABLE 1. Canadian Atlantic mackerel (*Scomber scombrus*) landings (metric tons) in ICNAF Subareas 2, 3, and 4, 1963–72.

Year	Subarea 2	Subarea 3	Subarea 4	Total	% total catch
1972		1579	20780	22359	73
1971	207	1299	22990	24496	60
1970	20	842	19097	19959	79
1969		314	17247	17561	75
1968		370	20449	20819	53
1967		54	11189	11243	99
1966		93	12728	12821	90
1965		187	11403	11590	97
1964		846	10114	10960	98
1963		373	6100	6473	98

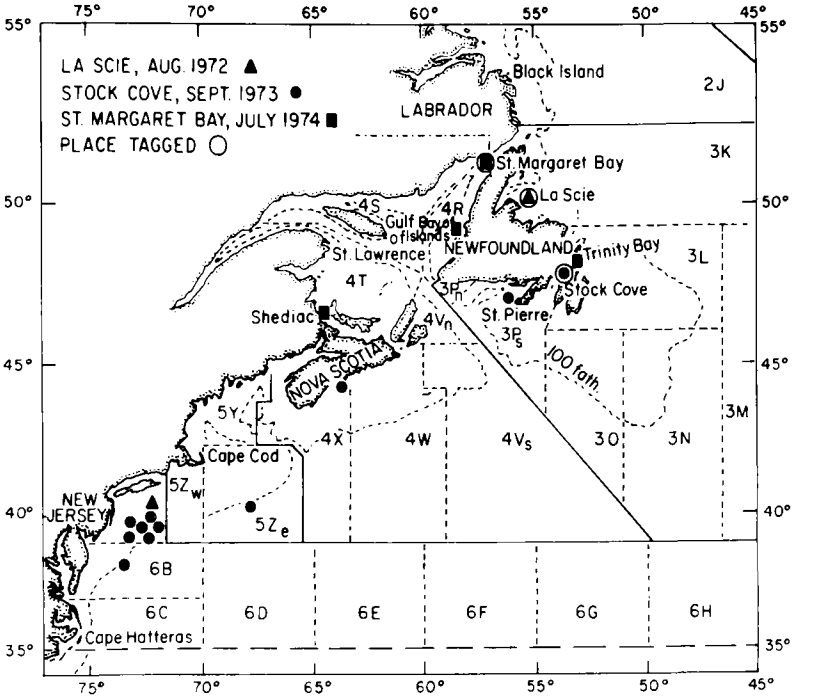

FIG. 1. ICNAF Subareas 2–6 with results of tagging studies.

waters, based on biological sampling of commercial landings and tagging studies.

Materials and Methods

Random samples of mackerel from nonselective gears (purse seines, ring nets, herring traps) were obtained from fishermen or from processing plants and were examined fresh or after being frozen for a period of several weeks. Data were obtained on total length, whole weight, sex, maturity, gonad weight, degree of stomach fullness, and otoliths were removed for 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 ($P > .05$) was found between the lengths and weights of fish sampled fresh and those sampled after freezing and thawing.

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 (Anon. 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.

TABLE 2. Mackerel taggings in Newfoundland with dates and areas of recapture.

Place tagged	Date tagged	No. tagged	Date of recapture	Place of recapture
La Scie	Aug. 30, 1972	1450	Sept. 1–25, 1972	5 tags La Scie area
			Dec. 28, 1972	40°05′N, 72°27′W(6A)
Stock Cove	Sept. 7–8, 1973	9000	Sept. 9–30, 1973	54 tags Trinity Bay area
			Oct. 30, 1973	St. Pierre (3Ps)
			Jan. 12, 1974	39°46′N, 72°37′W(6A)
			Jan. 25, 1974	39°20′N, 73°31′W(6A)
			Feb. 2, 1974	39°37′N, 72°06′W(6A)
			Feb. 15, 1974	39°46′N, 72°27′W(6A)
			Feb. 1974	(6A)
			Mar. 3, 1974	38°27′N, 73°23′W(6B)
			Mar. 30, 1974	40°23′N, 68°04′W(5Ze)
			Apr. 15, 1974	39°20′N, 72°44′W(6A)
			June 12, 1974	Indian Hr., N.S. (4X)
St. Margaret's Bay	July 27–31, 1974	6000	Sept. 16, 1974	Bay of Islands, Nfld.
			Sept. 29, 1974	Shediac, N.B. (4T)
			Sept. 1974	2 tags Trinity Bay, Nfld.

Ages were determined from otoliths placed whole into depressions in a black plexiglass tray according to the method of Watson (1965). The otoliths were immersed in 95% ethanol and read under reflected light. Otoliths were aged independently by two experienced readers with disagreements being resolved by a third reader or by mutual agreement. An arbitrary birth date of January 1 was assigned and ages were transformed into age-groups. Thus, fish having one completed summer zone on the otolith 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 10+ yr of age.

Mackerel for tagging were captured in bar seines and herring traps operated by commercial fishermen. A small-meshed holding pound, 5 m deep and supported on the surface by two diagonally secured 6-m poles, was attached to the head rope of the seine or trap and mackerel were transferred to the pound by depressing the headrope and allowing the mackerel to swim over. The actual tagging operation was conducted in small boats equipped with plastic tagging tanks capable of holding 25–50 live mackerel. Mackerel were transferred from the holding pound to the tagging tanks with a dipnet.

Two types of external tags were used — the FD-68 Anchor tag and the FT-2 Dart tag both made of #20 vinyl tubing approximately 64 mm (2½ inches) long. The FD-68 Anchor tag was applied with a tagging gun described by Dell (1968); the FT-2 Dart tag was applied with sharp-pointed hollow stainless steel applicators. Both types of tags were inserted in the dorsal region just posterior to and below the second dorsal fin.

Results

TAGGING

Three mackerel tagging experiments were carried out in the Newfoundland area during 1972–74 (Table 2). In 1972, 1450 mackerel were tagged in LaScie on August 30 (Fig. 1); 9000 mackerel were tagged in Stock Cove, Trinity Bay, on September 6–7, 1973; and 6000 mackerel were tagged in St. Margaret's Bay from July 27 to August 1, 1974.

The returns from these taggings have shown both local and long distance migrations (Table 2, Fig. 1). Six recaptures were reported from the LaScie tagging (Parsons and Moores 1974); five were from the LaScie area while the sixth was returned from ICNAF Statistical Area 6A. A total of 64 fish were recaptured from the Stock Cove tagging, 54 of which were recaptured in Trinity Bay. Of the other 10 tags, one was recaptured off St. Pierre et Miquelon in October 1973; six were recaptured in ICNAF statistical Area 6A from January to April 1974; one was recaptured in Statistical Area 6B in February; one was recaptured in Subdivision 5Ze in March; and one was recaptured off Halifax, N.S., in June. Early returns from the St. Margaret's Bay (Fig. 1) tagging show one recapture from the Bay of Islands (Fig. 1), one from Shediac, New Brunswick, and two from Trinity Bay.

The tagging results suggest that the mackerel that appear in Newfoundland waters migrate extensively. There is movement of mackerel from the west coast of Newfoundland southwards to the Gulf of St. Lawrence and eastwards to the east coast of Newfoundland via the Strait of Belle Isle. The results from the 1973 tagging confirm the long-distance migration of mackerel from the east coast of Newfoundland southward during the fall to overwintering grounds off the New England coast where they are subjected to exploitation by the international fleet. The pattern of the returns suggests that a return migration occurs during May–June.

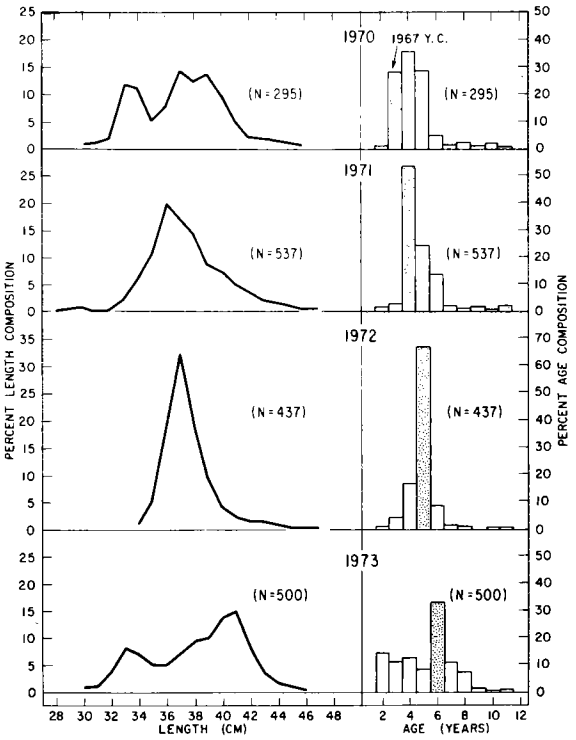

FIG. 2. Length and age compositions of mackerel caught in Newfoundland coastal waters, 1970–73.

LENGTH AND AGE COMPOSITION

Data from commercial catches by nonselective gears in Newfoundland waters (Fig. 2) indicate that the 1967 year-class has dominated from 1971 onwards and also contributed very significantly to catches in 1970. The percentage contribution of this year-class peaked at about 66% in 1972 and fell to 33% in 1973. The 1966 year-class that was dominant at 35% in 1970 fell to 24% 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 13% to the catches in 1973. The 1971 year-class comprised 14% of those sampled in 1973 as 2-yr-olds and would appear to be somewhat stronger than most recent year-classes. The peaks in length frequencies (Fig. 2) reflect the size composition of the dominant year-classes with total lengths ranging from 28 to 47 cm. Old fish (>8 yr old) have not formed a significant percentage of the fish examined and by 1970 the 1959 year-class, reported by MacKay (1967, 1973) as being very strong, had nearly disappeared from the catches.

MATURITY COMPOSITION

Table 3 indicates that from 1970–73 there was a consistent appearance of mackerel in spawning stages (4–6) in the Newfoundland area. 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, fish in spawning condition were not present in the samples after July when spent fish and those recovering 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, as was reported by Parsons and Hodder (1970). 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 (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 4) suggests that the older (and hence larger) fish spawn first. A similar pattern was observed in the southern Gulf of St. Lawrence (4T) mackerel population (MacKay 1967).

GROWTH

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 5. 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 4) and also the influx of immature fish in July and August (Table 3). Comparison of the mean length of the various year-classes at each age suggests that the dominant 1967 year-class is neither consistently longer nor shorter than adjacent year-classes. These data do not therefore support the inverse relationship between growth rate and year-class size reported by MacKay (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

TABLE 3. Maturity composition by month of mackerel caught in the Newfoundland area from 1970–73.

Year	Month	% at each maturity stage: Stages 1–2 (immature)	Stage 3 (maturing)	Stages 4–6 (ripening)	Stages 7–8 (recovering spent)	No. 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 4. Age composition of ripe and spent mackerel caught in the Newfoundland area during June–July, 1970–73.

Maturity condition	% at age: 1	2	3	4	5	6	7	8	9	10	10+	No. 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

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. The resulting von Bertalanffy growth curve (Fig. 3) was $L_t = 42.9\ (1-e^{-0.36(t+1.14)})$. Values calculated by the fitted curve agree with the observed points.

A comparison of growth data of mackerel from various areas is provided in Table 6. Allocation of growth data to specific areas in ICNAF Subarea 5 and Statistical Area 6 was not possible because of the lack of information on sampling details in the original sources. Where lengths have not been defined (Isakov 1973; Anon. 1973) 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 1973). Table 6 suggests that the mackerel sampled in Subarea 5 and Statistical Area 6 during the winter period are similar in size-at-age to the mackerel population sampled during the summer months in Subarea 4 (Stobo and Hunt 1974) and the Newfoundland area. The inconsistent variation in size-at-age in the older age-groups is probably due to errors in age determination rather than real differences in growth.

Analysis of length–weight data (Fig. 4) 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.

AGE AND LENGTH AT MATURITY

Analyses of maturity stage data indicate 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.

TABLE 5. Mean length-at-age of mackerel from the Newfoundland area for the period June–July (A) and August (B) 1970–73. No. of fish examined in brackets.

Year	1	2	3	4	5	6	7	8	9	10	10+
(A) June–July 1970–73											
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) August 1970–73											
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 6. Comparison of mean length of mackerel from various areas.

Age	Newfoundland Calculated (Jan.)	Newfoundland Observed (July)	Subarea 4 (calculated Jan.)[a]	New England (Jan.–Feb.)[b] (observed)	New England (Jan.–Feb.)[c] (observed)
1	231		222	232	217
2	291	318	275	284	272
3	333	363	315	341	325
4	362	374	345	353	356
5	382	389	369	366	381
6	397	399	387	374	405
7	406	413	400	402	415
8	413	421	411	424	
9	418	438	419	435	
10	421	430	425		

[a]Stobo and Hunt 1974.
[b]ICNAF Redbook, 1973, Part 1, p. 94.
[c]Isakov 1973.

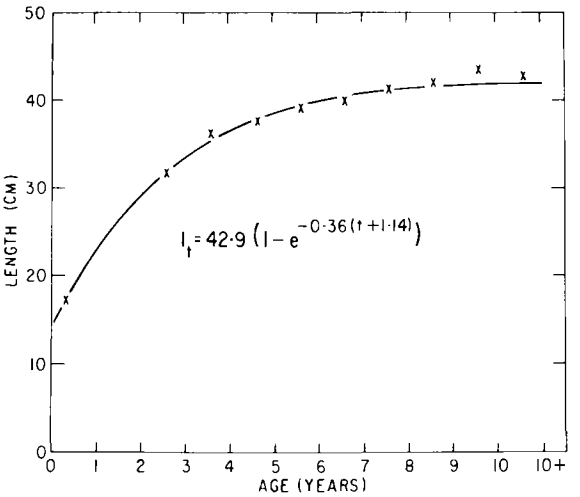

FIG. 3. Fitted von Bertalanffy growth curve of mackerel from Newfoundland waters. (x — observed mean lengths).

Although no age 1 fish were present in the samples used in these analyses, a few have been caught by small-meshed gillnets and all have been immature. The smallest mature mackerel caught in the Newfoundland area was 32 cm and the largest immature fish was 37 cm (Fig. 5). The 50% maturity point was 339 mm for females and 347 mm for males with the average length being 343 mm. Since this mean length is based on fish sampled in June–September, the mean length of maturity at the beginning of the year (January) is probably in the range of 30–31 cm.

SEX RATIO

During the period 1970–73 there has been a significant fluctuation in the sex ratio of mackerel in the Newfoundland area (Table 8). Females tend to be predominant in mature fish, whereas in the immature stages males have predominated. In 1973 when 90 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 (1967) also found proportionally more females in his samples but only slightly so with a ratio of 1 male to 1.06 females. Steven (1952) found a ratio of 1 male to 1.07 females in mackerel from the English Channel and Celtic Sea.

The more rapid maturation rate of female mackerel relative to males, particularly in the

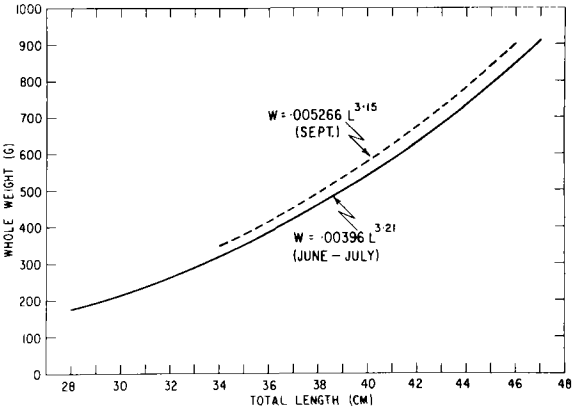

FIG. 4. Length–weight curves of mackerel samples during June–July and September.

TABLE 7. Number of mackerel examined and percentage mature by age from Newfoundland waters, 1970–73.

	Females		Males		Combined	
Age	No.	%	No.	%	No.	%
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. Sex ratio of mackerel obtained from commercial gears in Newfoundland 1970–73.

	Immature		Mature		Imm. + Mat.	
Year	No.	% ♀	No.	% ♀	No.	% ♀
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

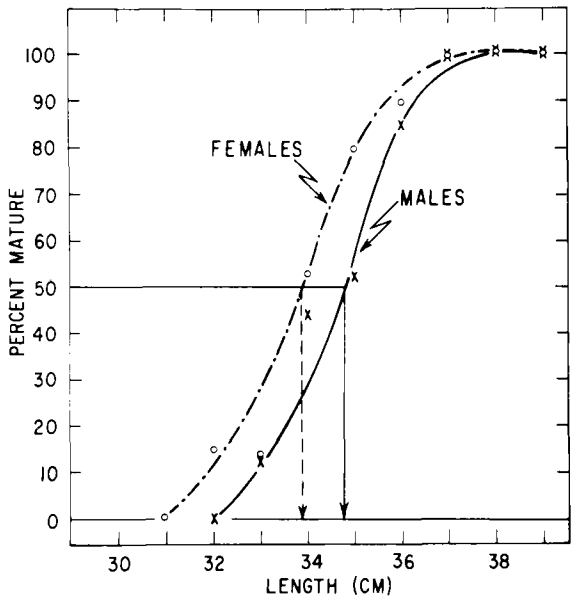

FIG. 5. Maturation ogives of male and female mackerel caught in the Newfoundland area.

younger age-groups could account 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 as 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, may explain the declining predominance of mature females from 1970 to 1972 as the 1967 year-class became fully mature at age 5 in 1972. Similarly, in 1973 the relative strong 1971 year-class at age 2 contained a relatively higher proportion of mature females than males.

FEEDING HABITS

An analysis of the degree of stomach fullness (Fig. 6) shows that most mackerel sampled had little or no food in their stomachs. The most extensive feeding was observed during the month of July when only 36% of the stomachs examined were empty and 16% were full. October shows the least observed feeding with 95% of the stomachs examined being 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 (155) was examined in greater detail (Table 9). During the summer months, June–August, mackerel feed predominantly on capelin which are plentiful in inshore waters at this time. Planktonic organisms, primarily euphausiids, are the main food item

TABLE 9. Percent occurrence of food items in mackerel stomachs.

Food item	% occurrence					
	June	July	Aug.	Sept.	Oct.	Total
Capelin	74	81	52			66
Fish remains	13	16	26		17	15
Euphausiids		2		100	66	12
Hyperiids			22			3
Decapod larvae	13					2
Copepods		1				1
Gastropod larvae					1	1

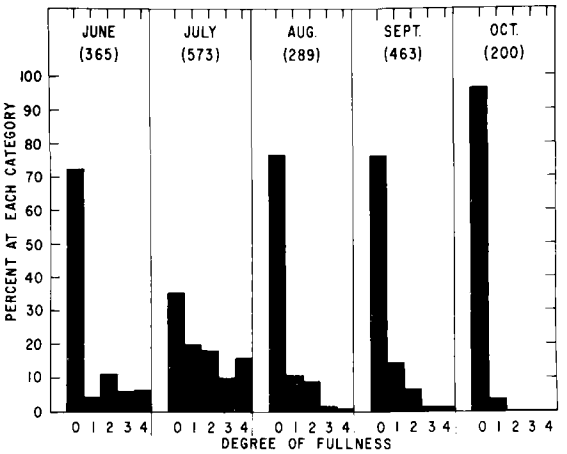

FIG. 6. Degree of fullness of mackerel stomachs collected from specimens caught in Newfoundland coastal waters.

during September–October. From this limited analysis it would appear that mackerel are opportunistic feeders that consume planktonic organisms, but also consume larger food items, such as capelin, whenever they are available.

Discussion

The existence of two major spawning areas for mackerel, one in the Bight between New Jersey and Long Island (ICNAF Divisions 6A and 5Z) and the other in the southern Gulf of St. Lawrence (ICNAF Division 4T), together with the availability of mackerel in both the southern (Gulf of Maine) and northern (Gulf of St. Lawrence) areas during the summer support Sette's (1950) hypothesis of two mackerel stocks in the northwest Atlantic. In spite of the wide separation of spawning areas, no significant differences in the meristic and biochemical characteristics of the two contingents have been found (Sette 1950; MacKay 1967). Sette (1950) stated that there may be mixing between the two mackerel contingents during the overwintering period, although the main area occupied by the northern contingent was probably north of that occupied by the southern contingent. The degree of mixing that occurs, however, has not been quantified. Recently the international fishery, which occurs in ICNAF Divisions 6A and 5Z, has been considered to be exploiting only the southern contingent, and stock assessments have been performed for this fishery without assessing the degree of intermixing (Anon. 1973).

Tagging studies reported here show that mackerel from the Newfoundland area have contributed to the international mackerel fishery off New England during the winter. During the same period and in the same general locality the international fleet recaptured 20 mackerel tagged by the St. Andrews Biological Station off southwest Nova Scotia during the fall of 1973 (W. T. Stobo personal communication). During the period 1925–28 nearly 8000 mackerel were tagged during the summer period (mainly June) along southwest Nova Scotia (Sette 1950), 35 of which were recaptured during the fall–spring period from United States waters, mainly in the Cape Cod–New Jersey area (ICNAF Divisions 5Z and 6A). During the same period 8500 mackerel were tagged in United States waters with only one recapture being recorded in Canadian waters. This single capture was from a release of mixed fish containing both northern and southern contingent mackerel (Sette 1950). These results indicate that mackerel from as far north as Division 3K mix with those from Subarea 4 in a common overwintering area off the New England coast.

The existence of a southern overwintering area for mackerel is indeed to be expected from the temperature requirements of the species. Sette (1950) reports observational evidence that suggests that mackerel prefer temperatures above 8 C, although temperatures down to 7 C are frequently tolerated; they are only rarely found

TABLE 10. Percent total catch, 1969–72, by month for divisions in Subareas 5 and 6 and Subareas 5 and 6 combined. (The combined percentage includes catches not allotted to specific divisions.)

Month	5Ze	5Zw	6A	6B	6C	% catch for SA5+6
Jan.	1.2	2.2	6.6	1.6	1.0	12.5
Feb.	0.9	0.3	3.5	2.7	1.8	9.2
Mar.	1.0	1.1	5.5	5.2	3.8	16.5
Apr.	2.0	1.4	4.8	6.8	0.4	15.7
May	5.3	3.0	0.3	0.1	—	12.4
June	3.2	2.4	0.2	—	—	6.3
July	2.9	0.8	—	—	—	4.1
Aug.	2.8	0.5	—	—	—	3.6
Sept.	1.9	0.2	—	—	—	2.3
Oct.	1.6	0.7	0.1	—	—	2.4
Nov.	3.1	0.5	0.5	—	—	4.4
Dec.	4.9	0.7	4.6	—	—	10.6

in temperatures as low as 4 or 5 C. From the hydrography of the Scotian Shelf (Hachey 1953; McLellan 1954a, b; McCracken 1965), 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 favorable for overwintering concentrations of mackerel. This does not, however, exclude the possibility of schools overwintering 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 that the area is traversed frequently by vessels with suitable gear for catching mackerel.

The pattern of mackerel landings in Subareas 5 and 6 (Table 10) supports the general migration pattern of northern mackerel as suggested by tag recaptures. The migratory pattern based on catch data suggests that there is an influx of mackerel into Subdivision 5Ze during November. During December mackerel apparently continue to move through division 5Ze and into Division 6A. From January to April the bulk of the mackerel are caught in Divisions 6A and 6B. In May and June the mackerel apparently move north from 6B through 6A and 5Ze. The catches show a marked decline from June to October as the northern contingent presumably moves out of the New England area.

In summary, tagging studies both recent and historical, similarities in growth, seasonal patterns of fishing activity and also ecological considerations suggest strongly that a large proportion of the so-called northern contingent of mackerel migrate southwards during the fall to overwinter in the offing of New England where they are exploited with the southern contingent in a mixed fishery. The relative contribution of each contingent to the international fishery is not known, but crude estimates of biomass levels of mackerel in the southern Gulf of St. Lawrence from population fecundity studies (MacKay 1973) suggest that the northern contingent is large. The so-called northern population of mackerel contributes at least partially and perhaps substantially to the international winter fishery in ICNAF Subareas 5 and 6. In the absence of precise information on the relative contribution of each contingent to this fishery, it would be prudent to incorporate all fisheries for mackerel in Subareas 3–6 into a single assessment.

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