MATURATION AND GROWTH OF PACIFIC MACKEREL *SCOMBER JAPONICUS* HOUTTUYN

RESOURCES AGENCY
CALIFORNIA
DEPARTMENT
FISH & GAME

by

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ABSTRACT

The maturation of Pacific mackerel has never been documented clearly. Analysis of data reveals spawning can occur from March through October, but the majority takes place from April through August. During this April through August period, 22.5%, 65.7%, 75.1%, 84.7%, 84.2%, and 87.5% of the female fish were mature or maturing for Age Groups I, II, III, IV, V, and VI+ respectively.

A von Bertalanffy growth curve and a weight-length curve were calculated. The weight-length curve was found to differ significantly from a curve previously published.

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INTRODUCTION

The biology of Pacific mackerel must be clearly understood to properly manage this resource. One of the aspects of its biology which has not been clearly documented in the literature is age at first spawning. Fry (1936) states that yearling fish do not spawn, whereas most of the 2 year olds do. Fitch (1952) observed that most mackerel do not spawn until their third or fourth year.

To clearly document age at maturity, we conducted a special study on the maturation and growth of Pacific mackerel. This information will contribute to our understanding of the biology and population dynamics of this fish.

METHODS

Maturation Data

Data concerning 1958-59 through 1969-70 Pacific mackerel seasons were utilized to determine age at maturity. Information about 3,397 female Pacific mackerel was used in the study. Samples used were taken as part of a program for monitoring the California commercial mackerel catch.

Three maturity stage categories were established. If eggs were not visible with the naked eye, fish were considered immature (Stage i). If a fish had unripe yellowish eggs visible to the naked eye, it was considered to be developing (Stage g). Any fish which had large transparent ripe eggs was classified as mature (Stage G). This maturity index agrees favorably with that suggested by Holt (1959) for *Rastrelliger* (Table 1).

Growth Data

Weight-length relationships were determined by using a computer program (Abramson, 1971) which fits weight-length data to the exponential curve: $W = a\ L^b$

where: W = weight
L = length
a = constant
b = constant

A computer program also was used to fit Pacific mackerel data to the von Bertalanffy growth equation: $l_t = L_\infty\ [1\text{-}\exp\ (-kt+kt_o)]$.

where: l_t = total length at age t

L_∞ = maximum expected length

t_o = fitted length at age zero, extrapolated backward from growth pattern in later life

k = a parameter related to the matabolic rate

exp= exponential function

This program fits a curve using the least squares procedure with weights proportional to sample size (Tomlinson and Abramson, 1961).

RESULTS

Maturation

Analysis of data indicates spawning can occur from March through October, but the majority takes place from April through August. An important factor contributing to the great spread in spawning time is that eggs of an individual fish appear to mature in successive batches. Ripe translucent eggs appear irregularly in the ovary amongst still unripe ova in early stages of development. This condition also has been found in Atlantic mackerel, *Scomber scombrus* Linnaeus, (Steven, 1949) and in the genus *Rastrelliger* (Holt, 1959).

Only five fish were found in a spent condition during the entire study and all of these in October. Since eggs mature in successive batches, a spent condition would not be found in a fish until all spawning was completed. Due to this fact, we did not include spent condition in our maturity stage classification (Table 1).

All identification and examination of ovaries was done externally; therefore, the number of mature fish may have been underestimated. Steven (1949) found that Atlantic mackerel ovaries containing numerous ripe eggs in the lumen may show no external evidence of their presence.

Immature individuals were found in each age group throughout the year (Table 2). No female Pacific mackerel spawn during their first season (Age Group 0), and only 22.5% of Age Group I fish were found to be mature or maturing from April through August (Table 3). During this same period, the percentage of maturation in older age groups was 65.7%, 75.1%, 84.7%, 84.2% and 87.0% for Age Groups II, III, IV, V, and VI+ respectively. It is not definite that all individuals of any age group spawn in any given season, and the percentage of maturation is higher during some months than for the spawning season (Table 4).

We also conducted a study on maturity of male Pacific mackerel; however, our results should be considered preliminary because of the small sample size (205). Male Pacific mackerel mature earlier in life than females and appreciable amounts of ripe sperm commonly are found. No Age Group 0 males were found to be mature or maturing. During a 3 month period (May through July), the percentage of male fish mature or maturing was 88.0%, 96.6%, 100.0%, 100.0%, 100.0%, 100.0% for Age Groups I, II, III, IV, V, and VI+ respectively.

Growth

We processed lengths and weights of 1,232 fish with the resultant weight-length relationship for Pacific mackerel being $W = 0.0000013660 L^{3.39358}$. Using this formula, a 270 mm FL fish weighs 243 grams (Table 5) while a 340 mm FL fish weighs 532 grams. The calculated length-weight curve is a good fit for the data with the correlation coefficient being 0.994 (Table 6).

TABLE 1. Maturity Stages of *Rastrelliger* and *Scomber*

Extent of ovary in body cavity	General appearance of ovary	*Rastrelliger** Stage and State	*Scomber* Stage
About 1/3 length of cavity.	Translucent; reddish to pinkish ova invisible to naked eye.	I Immature	i
About 1/2 length of cavity.	Translucent; pinkish color; ova invisible to naked eye.	II Mature virgins and recovering spents	i
About 2/3 to full length of cavity.	Pinkish yellow color; granular opaque appearance; ova entirely opaque; no translucent or transparent ova visible.	III Ripening	g
From 2/3 to full length of cavity.	Orange to pink color; superficial blood vessels; conspicuous large translucent to transparent ripe ova visible; eggs might be extrusable.	IV Ripe	G
Shrunken to about 1/2 length of cavity; walls loose.	Remnants of disintegrating opaque and ripe ova visible; may be darkened or translucent.	V Spent	-

* From Holt, 1959.

TABLE 2. Monthly Maturity Index of Pacific Mackerel in Percent

Month	0	I	II	III	IV	V	VI+
Jan.							
i	---	100	100	100	95	94	100
g	---	---	---	---	5	6	---
G	---	---	---	---	---	---	---
Feb.							
i	---	100	100	83	78	50	100
g	---	---	---	17	22	50	---
G	---	---	---	---	---	---	---
Mar.							
i	---	97	84	50	25	20	34
g	---	3	16	45	75	80	67
G	---	---	---	5	---	---	---
Apr.							
i	---	76	28	16	4	5	24
g	---	21	69	72	91	90	70
G	---	3	3	12	5	5	6
May							
i	---	78	34	13	2	9	---
g	---	22	66	78	82	61	64
G	---	---	---	9	16	30	36
June							
i	---	77	16	25	23	23	14
g	---	23	82	72	60	77	71
G	---	---	2	3	17	---	15
July							
i	---	72	33	28	18	39	7
g	---	28	65	72	82	61	67
G	---	---	2	---	---	---	26
Aug.							
i	100	86	76	55	36	17	25
g	---	14	24	41	43	44	25
G	---	---	---	4	21	39	50
Sept.							
i	100	89	75	54	74	83	56
g	---	11	25	46	26	17	44
G	---	---	---	---	---	---	---
Oct.							
i	100	99	94	75	87	99	70
g	---	1	6	25	12	1	30
G	---	---	---	---	1	---	---
Nov.							
i	100	100	100	100	96	100	95
g	---	---	---	---	4	---	5
G	---	---	---	---	---	---	---
Dec.							
i	100	100	100	100	100	100	100
g	---	---	---	---	---	---	---
G	---	---	---	---	---	---	---

TABLE 3. Maturity Index of Female Pacific Mackerel in Percent for April Through August

Months	Age Group						
	0	I	II	III	IV	V	VI+
April-August							
i	100	77.5	34.3	24.9	15.3	15.8	13.0
g		22.2	64.5	69.9	73.1	64.2	64.8
G		0.3	1.2	5.2	11.6	20.0	22.2
Percent mature or maturing	0.0	22.5	65.7	75.1	84.7	84.2	87.0
Number examined	45	613	318	173	190	120	54

TABLE 4. Highest Percentage of Mature and Maturing Stages of Female Pacific Mackerel in any One Month

Age Group	Percentage	Month	Number Examined
I	28	July	137
II	84	June	82
III	87	May	46
IV	98	May	44
V	95	April	20
VI+	100	May	11

TABLE 5. Some Expected Weights for Given Lengths by 10 mm FL Groupings

Fork Length (mm)	Expected Weight grams	Fork Length (mm)	Expected Weight grams	Fork Length (mm)	Expected Weight grams	Fork Length (mm)	Expected Weight grams
130	20	220	122	310	389	400	924
140	26	230	141	320	433	410	1005
150	33	240	163	330	481	420	1090
160	41	250	188	340	532	430	1181
170	51	260	214	350	587	440	1277
180	62	270	243	360	646	450	1378
190	74	280	275	370	709	460	1485
200	88	290	310	380	776	470	1597
210	104	300	348	390	848	480	1716

TABLE 6. Constants and Standard Errors for the Weight-Length Relationship

a	b	Standard error of b	Standard error of the estimate	Correlation coefficient
1.36600E-06	3.39358	0.01088	39.04692	0.994

TABLE 7. Lengths at Various Ages

Age	Fitted length (mm FL)	Sample Mean length (mm FL)	Standard error of sample mean	Sample Size
I	272.96	272.44	1.121	349
II	308.34	312.35	1.113	119
III	336.05	334.75	0.789	157
IV	357.75	356.09	0.927	172
V	374.75	375.52	0.675	232
VI	388.05	388.52	1.242	108
VII	398.48	396.80	1.623	57
VIII	406.64	412.27	3.653	11

Standard error of estimate = 14.8762

TABLE 8. Estimates of Parameters for Von Bertalanffy Growth Curve

	Parameters Average maximum length cm/4	Parameters Average maximum length mm.	Metabolic rate constant k	Fitted length at age zero to
Estimates	174.45	436.12	0.244440	-3.0222
Standard errors	2.10	5.26	0.13694	0.154625

Traditionally Pacific mackerel measurements have been reported in quarter-centimeters. To facilitate future workers who may use this measurement with the exponential equation $W = a\ L^b$, the constant a should be changed to 3.06119E-05 while the constant b of 3.39358 remains the same number.

The weight-length curve was compared to the curve determined by D. H. Fry, Jr. (Fitch, 1951). An analysis of covariance was calculated from the resulting two lines of a log transformation. There was no significant difference between the slopes of the two lines; nevertheless, there was a significant difference in elevations and variation about the regression lines (all differences at the 99% significance level). The older set of data showed more variation about the regression line.

The von Bertalanffy growth curve estimate for Age Group I fish was 273 mm FL (Table 7), while the estimate for Age Group III was 336 mm FL. The maximum expected length (L_∞) was calculated to be 436 mm FL (Table 8). These estimates are derived from data taken throughout the season and represents mean size at midseason for each age group.

DISCUSSION

Population size may account for the relative rate of growth. Davidson and Vaughan (1941) suggested that more abundant populations of pink salmon, *Oncorhynchus gorbuscha* (Walbaum), are slower growing. Witney (1961) found that growth rates of bairdiella, *Bairdiella icistius* (Jordan and Gilbert), in the Salton Sea, California, decreased as the population increased.

MacGregor (1959) found that low population levels of Pacific sardine are associated with high condition factors and, conversely, high population levels are associated with lower condition factors. The inverse correlation was interpreted as a cause and effect relation; that is, high population levels result in less available food per fish and low condition factors, while low population levels result in more available food per fish and higher condition factors.

In Pacific mackerel, the population decreased in biomass from a high during the 1931 to 1933 period to a low during the 1966 to 1970 period. The estimated total biomass for I year-old fish and older during the 1931 to 1933 period ranged from 1,040,519,000 to 1,593,966,000 pounds. The total biomass estimates for the 1966 to 1970 period ranged from 6,728,000 to less than 1,101,000 pounds. If at this later period there was a decrease in the competition within the population, then certainly the weight at size could increase.

A comparison was made between Murphy method estimates of recruits at age I and mean size at age I for twenty-nine consecutive years. The results show little correlation between estimated numbers of recruits and mean size at age I ($r = -0.208$).

Witney (1961) found that bairdiella matured later in life as the population increased and growth rates decreased. In Pacific mackerel, if growth by weight at size has increased, then this may account for the apparent increase in maturation at an earlier age.

The two studies were done over 30 years apart. An environmental or growth change may have occurred; however, the true reason for these apparent changes may be based on the manner in which the data was collected. The older data was collected only intermittently during the study period, while the newer set of data was collected throughout the year.

CONCLUSIONS

Most female Pacific mackerel (65.7%) are mature or maturing by their third year of life (Age Group II). The percentage of fish maturing continues to increase from age at first spawning until Age Group IV where it levels off at a high percentage of fish maturing within a spawning season.

The Pacific mackerel sampled during the 1966 to 1970 period had a larger mean weight at size than those fish sampled from 1931 to 1933. Fish sampled from 1958 to 1970 also appear to mature earlier in life than those caught during the early years of the fishery.

REFERENCES

Abramson, Norman J. 1971. BGC 2 - von Bertalanffy growth curve fitting, 2.(-).1.1-1.3. *In* Computer Programs for Fish Stock Assessment. F.A.O. Fish Tech. Paper (101):V.P.

Davidson, F.A., and Elizabeth Vaughan. 1941. Relation of population size to marine growth and time of spawning migration in the pink salmon *(Oncorhynchus gorbuscha)* of southeastern Alaska. Jour. Mar. Res. 4:231-246.

Fry, Donald H., Jr. 1936. A preliminary summary of the life history of the Pacific mackerel. Calif. Fish Game 22(1):30-39.

Fitch, John E. 1951. Age composition of the southern California catch of Pacific mackerel, 1939-40 through 1950-51. Calif. Dep. Fish and Game, Fish Bull. (83):1-73.

_____. 1952. The decline of the Pacific mackerel fishery. Calif. Fish Game 38(3):381-389.

Holt, Sidney J. 1959. Report of the International Training Center on the Methodology and Techniques of research on mackerel *(Rastrelliger)*. F.A.O. Report, (1095):1-129.

MacGregor, John S. 1959. Relation between fish condition and population size in the sardine *(Sardinops caerulea)*. U.S. Fish Wild. Serv., Fish. Bull. 60(166):215-230.

Steven, G.A. 1949. Contributions to the biology of the mackerel *Scomber scombrus* L. II. A study of the fishery in the southwest of England, with special reference to spawning, feeding, and fishermen's signs.

J. Mar. Biol. Assoc. U.K., 28:555-581.

Tomlinson, Patrick K., and N. Abramson. 1961. Fitting a von Bertalanffy growth curve by least squares including tables of polynomials. Calif. Dep. Fish and Game, Fish Bull., (116):1-69.

Witney, Richard R. 1961. The bairdiella, *Bairdiella icistius* (Jordan and Gilbert):105-151. *In* The Ecology of the Salton Sea, California, in relation to the Sportfishery. Calif. Dep. Fish and Game, Fish Bull., (113):1-204.