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Observations on the Winter Trawl Fishery for Summer Flounder, Paralichthys dentatus

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OBSERVATIONS ON THE WINTER TRAWL FISHERY FOR SUMMER FLOUNDER, *PARALICHTHYS DENTATUS*

by

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ABSTRACT

Data on the size composition of the marketable flounder landed at Hampton Roads ports were compiled in order to establish a base line to detect changes in the size composition of the summer flounder stocks. Additional data concerning location of the winter trawl fishery, catch/trip, effort, and landings were collected to determine the present status of the flounder stocks. Although data concerning the condition of the stocks are sparse, the data suggest that flounder stocks are not being overexploited. However, more complete data are necessary before a conclusive evaluation of these stocks can be made.

Spawning of summer flounder was found to be of short duration and occurred chiefly in November.

The mathematical formula describing the regression of weight on length for males was found to be $\text{Log } W = -4.51917 + 2.81601 \text{ Log } L$ and for females $\text{Log } W = -5.55030 + 3.20947 \text{ Log } L$. Females were found to grow at a faster rate than males and to a greater size.

A review of the literature concerning the aging of summer flounder was discussed and an interpretation of the growth rate was offered. The mathematical formula describing the ring-weight relationship for males was $\text{Log } W = 2.53552 + 0.45726 \text{ Log } X$ and for females $\text{Weight} = 2.1 + 377X$. The

ABSTRACT (continued)

mathematical formula describing the ring-length relationship for males was $\text{Log } L = 2.50400 + 0.16125 \text{ Log } X$ and for females $\text{Length} = 330.2 + 47.07X$ (In every instance X equals the number of rings). It was suggested that the first ring is formed on the otolith at an age of three years.

The size composition of the catch was observed to shift from smaller to larger fish during the season. This might be explained on the basis of a shift of fishing effort from inshore to offshore waters.

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INTRODUCTION

The winter trawl fishery of the Middle Atlantic Bight provides at the present time the largest source of food fishes landed in Virginia. Since the inception of this fishery, total landings have generally increased, but also have been marked by pronounced fluctuations. The decline in abundance of several of the component species as well as the concurrent decrease in the catch of the inshore pound net and haul seine fisheries has led to speculation that both the inshore and winter trawl fisheries have been over-exploiting the available stocks.

Data essential to an assessment of the effect of exploitation on the stocks were provided by Pearson (1932) who described the early development of the fishery and included pertinent catch data by weight, species, and catch per trip. Nesbit (1935) traced the development of the fishery from 1931 to 1934 and also correlated water temperatures with catches of scup (*Stenotomus chrysops*), black sea bass (*Centropristes striatus*), and summer flounder (*Paralichthys dentatus*). Despite the growing importance of this industry no biological investigations of the trawl fishery have been undertaken since 1935.

The objectives of the present study were: (1) to examine the size and age structure of the summer flounder catch landed in the Hampton Roads area and (2) to determine the changes in the catch and effort of this fishery.

Although a number of species are included in the trawl catch, summer flounder was selected for investigation for the following reasons.

1. Summer flounder ranks third in total landings.

2. Techniques for age analysis of summer flounder have been described in the literature, but similar methods have not been established for other major species in this fishery.

3. Because this species requires special gear for capture, it lends itself more easily to management techniques.

These studies were made in the Hampton Roads area inasmuch as the bulk of the winter trawl catch is landed there.

HISTORY OF THE FISHERY

The winter trawl fishery which began about 1920 when trawlers from New Jersey initiated exploratory fishing for croaker, (Micropogon undulatus), off the coasts of Virginia and North Carolina was described by Pearson (1932) and Nesbit (1935). During the 1920's small, shallow-draft, oyster and crab dredge boats, equipped with trawls joined the larger vessels. The smaller vessels were based primarily at Ocracoke Inlet, North Carolina, and fished within 10 to 20 miles of the shore whenever weather conditions permitted. In 1930 the North Carolina legislature prohibited all trawling in State waters. This regulation affected the small trawlers considerably, for weather conditions often prevented them from working outside the three mile limit. Moreover, flounder, which represented their principal catch, seemed to prefer the sandy inshore areas. Despite these factors some of the small trawlers continued to fish the offshore grounds and by the winter of 1930-31 there were about 20 small boats still operating.

Through the winters of 1928 to 1930 an increasing number of trawlers came from northern ports and fished regularly in the offshore waters. The catches of these vessels were landed chiefly at ports in the Hampton Roads area.

In the winter of 1930-31 twenty five northern vessels, in addition to the local Chesapeake Bay boats, exploited the winter stocks. The number of boats in the winter fishery increased from about 50 in the 1931-32 season to about 100 in the 1934-35 season. Of this number about one-half were equipped to fish in deep water. Since 1935 the smaller boats have left the fishery. During the 1961-62 season about 30 Hampton based vessels fished the winter stocks. Many of these trawlers fish off the New England coast during the summer.

The combined landings of scup, black sea bass, and summer flounder increased from approximately 3,500,000 pounds in 1931 to approximately 8,000,000 pounds in 1934.

Table 1 shows the annual catch of scup, black sea bass, and summer flounder for all fisheries of Virginia for the years 1929-1959 (U. S. Bur. Fish. 1931-1941, U. S. Fish & Wildl. Serv. 1942-1961). The total catch of the three major species in the winter trawl fishery (scup, black sea bass, and summer flounder) during the years 1951 through 1960 is shown in Table 2. These figures represent the landings in the Hampton Roads area during January, February, March, April, November, and December (U. S. Fish & Wildl. Serv., Market News Service Reports, 1952-1961). The average

Table 1

Annual catch of major species in Virginia from 1929-1959

Year	Scup	Black Sea Bass	Summer Flounder	Croaker	Total
1929	91,500	27,000	41,000	410,000	569,500
1930	311,517	171,366	249,464	962,780	1,695,127
1931	237,627	52,424	512,121	313,380	1,115,552
1932	1,688,966	835,405	601,761	1,593,625	4,719,757
1933	1,168,591	327,095	773,793	2,607,106	4,876,585
1934	659,500	115,900	474,300	2,837,100	4,086,800
1935	1,492,600	208,400	414,100	2,837,100	4,952,200
1936	853,200	42,300	269,900	5,753,000	6,908,400
1937	1,868,100	122,000	146,500	5,320,500	7,457,100
1938	2,301,300	230,500	438,400	2,650,300	5,620,500
1939	2,544,500	608,300	890,500	5,442,500	9,485,800
1940	3,228,700	509,900	1,022,300	6,059,000	10,819,900
1941	2,118,800	348,800	526,200	7,510,900	10,504,700
1942	2,394,500	185,500	331,400	4,596,800	7,508,200
1943	No Data Available				
1944	6,049,500	4,133,000	2,208,600	2,264,700	14,655,800
1945	4,806,000	2,267,700	1,042,100	14,126,500	22,243,300
1946	6,311,100	1,926,400	2,301,600	4,660,100	15,199,200
1947	4,801,100	3,329,000	1,191,100	7,219,400	16,540,600
1948	7,024,200	7,142,800	1,227,300	3,397,800	18,792,100
1949	5,955,400	4,195,600	1,641,800	1,623,800	13,416,600
1950	7,593,400	5,258,600	1,239,900	1,425,200	15,517,100
1951	10,054,600	8,721,900	1,488,200	1,431,700	21,696,400
1952	7,590,800	9,673,400	1,065,400	730,400	19,060,000
1953	8,357,800	6,459,100	1,263,400	749,100	16,829,400
1954	11,541,900	4,174,900	1,435,200	608,000	17,760,000
1955	13,144,100	5,039,800	1,004,400	1,663,000	20,851,300
1956	11,278,600	5,786,500	1,539,300	2,438,900	21,043,300
1957	6,321,900	3,807,800	1,185,900	2,622,100	13,937,700
1958	6,809,300	5,370,700	1,591,200	1,795,300	15,566,500
1959	11,517,800	3,065,100	2,745,700	746,900	18,075,500

Table 2

Catch of black sea bass, scup and summer flounder in winter trawl fishery from 1951-1960

Year	Scup	Sea Bass	Summer Flounder	Total
1951	7,767,600	7,979,900	930,300	16,677,800
1952	6,984,800	9,216,600	1,113,800	17,315,200
1953	7,549,300	6,358,200	1,187,100	15,094,600
1954	10,310,800	3,906,200	1,207,900	15,415,900
1955	10,631,600	4,367,500	789,200	15,788,300
1956	8,784,200	5,034,900	1,393,400	15,212,500
1957	5,549,900	3,712,000	541,000	9,802,900
1958	4,922,400	5,001,000	726,100	10,649,500
1959	9,319,500	2,748,400	1,882,300	13,950,200
1960	10,286,300	3,169,000	1,556,200	15,001,500

composite landings for these species during this decade was approximately 14.5 million pounds.

Catches shown in Table 1 for the early years of the fishery (1929-1934) are much lower than those reported by either Pearson or Nesbit. Since Pearson sampled the landings daily, it is assumed that his figures are more reliable than those of the statistical digests for that period.

Since the inception of the fishery the landings of gray seatrout, (Cynoscion regalis), and croaker have undergone pronounced changes. Croaker in the period of 1929-42 comprised the most abundant species in the fishery and was among the three most plentiful from 1944-50. In the period 1951-60 croaker dropped to third and then the fourth most abundant species. Since 1944 scup and black sea bass landings have markedly increased and accounted for the majority of the landings. Flounder landings apparently increased from 1929-42 (Table I) and have remained relatively stable since 1951 with a mean annual catch of approximately 1.1 million pounds (Table 2).

METHODS OF THE FISHERY

The winter trawlers, employing the latest developments in electronic gear (fathometers, fish finders, radar and loran), range in length from 60 to 110 feet and have a hold capacity of 40,000 to 170,000 pounds. Generally, four to six men constitute the crew and are paid on shares. A trip varies from two to ten days with an approximate average of five days. Although the majority of the vessels are of wooden construction, a few have steel hulls and several are converted mine sweepers. The trawlers employ a sail to steady the vessel in heavy seas.

Fishing operations can be divided into two categories; those in which flounder is the principal fish landed and those in which flounder is only incidental to the main catch of scup and black sea bass. When the vessels are primarily fishing for scup and black sea bass, a standard otter trawl is used. When fishing solely for flounder, a modified trawl is utilized. This modified net is approximately 75 feet in length and consists of two wings, a belly and the cod end. The wings are attached to reinforced wooden doors which are 7 feet 6 inches long, 42 inches wide and weigh 550-575 pounds. Half-inch wire cable is attached to the inner face of the doors in such a manner that when the doors are towed the wings of the net are spread about 80 feet. The head line which is 97.6 feet in length is in advance of the foot line which is 107 feet in length. Under tow, the mouth of the net proper is approximately 50 by 4 feet. Attached to the foot line is 165 pounds of 5/8 inch link chain which is frequently wrapped with rope to prevent chafing. The chain prompts flounder to swim up until they hit the top of the net. Then, they drop back to the bottom of the net and are captured. Unlike the standard otter trawl which has 20 to 24 floats there are only three metallic floats attached to the head rope. One float is fastened to each wing and one to the top of the belly. These floats are inflated with 30 pounds of air pressure and buoy the head line about four feet above the foot line. The mesh size varies from 4 to 5 1/8 inches and is the same for all sections of the net, thus, permitting some escapement of undersized flounder.

The net is towed at approximately three knots with the average tow lasting two hours. However, tows may vary from 40 minutes to four hours depending upon the amount of flounder and trash fish in the area.

The amount of towing cable used at the various depths is listed.

Fishing depth (fathoms)	Cable length (fathoms)
10	50
15-20	75
30-35	100
40-50	125
60-80	150
80-100	200

LOCATION OF THE FISHERY

During the past winter (1961-62) the fishing grounds for flounder extended from latitude 35° 10' to 38° 20' N. and from longitude 74° 00' to 75° 20' W (Figure 1). Nesbit (1935) correlated water temperatures with the catch of the major species during the winter of 1931-34 and observed that summer flounder were found in water somewhat warmer than that occupied by scup, but not as warm as that in which black sea bass were found. Nesbit concluded that there was a zone of water between the 40 and 150 fathom contours which was warmed from surface to bottom by the Gulf Stream and that scup, black sea bass, and flounder congregated in this water. Nesbit suggested that the fishing grounds of any particular year will be determined by the location of this zone of warm water.

During November 1961 flounder were caught in depths of 15 to 25 fathoms. Catches in December and January were taken from depths of 30 to 50 fathoms in the area where the slope of the continental shelf begins to change abruptly. Flounder caught in this area were predominantly large ones.

In general, the trawlers fished further offshore as the season progressed and by February were fishing close to the 100 fathom line. The trawlers did not appear to fish further south as the season advanced, which suggests the lack of an obvious southerly migration.

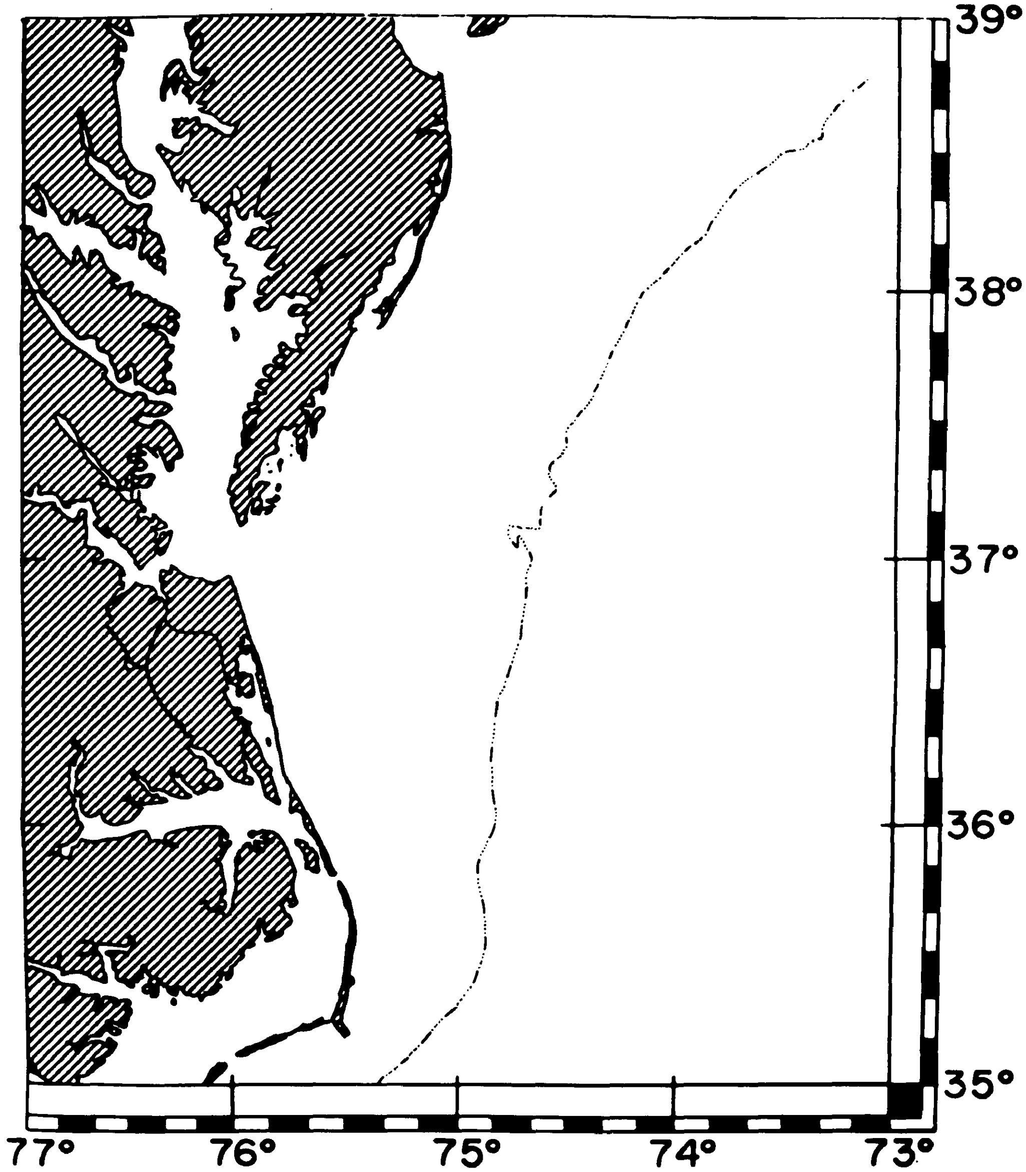

Fig. 1. Location of fishing grounds during the 1961-62 season.

MATERIALS AND METHODS

This study of the 1961-62 offshore winter trawl fishery for summer flounder was conducted from September, 1961 to April, 1962. During this time landings were sampled three or four times a week from four fishing piers which accounted for more than 65% of the Hampton flounder landings. A sample was not collected from a vessel unless the catch of flounder exceeded 1,000 pounds, because a lesser catch indicated that a standard otter trawl had been used and that flounder was not the main fish sought. Sample size varied from 60 to 400 individuals depending upon the total catch and the time required for unloading. In addition, information on the location of the fishing grounds was obtained through personal interviews with the captain or first mate of the fishing vessel.

Small flounder (under 500 grams) were weighed with a Hanson Model 1411 Dietetic scale. All larger fish were weighed with a Chatillon spring scale with a 20 pound capacity calibrated in ounces. Measurements in pounds and ounces were converted to grams. Lengths were obtained by the use of a measuring board calibrated in millimeters.

Size composition of the marketable flounder was obtained as the catch was unloaded. The unloading procedure was similar for all vessels, permitting random sampling. Periodically, subsamples of flounder were purchased for age analysis by otolith examination. Sex determination was made by gross gonadal examination. The red to orange, extended, triangular shape of the ovary rendered it easily distinguishable from the much smaller, white gonad of the male. Only twelve fish of the 359 examined could not be sexed. These fish were less than 300 mm in length and presumed to be sexually immature. Gross observations made on the condition of the gonads included notes on color, relative size, and the relative number of blood vessels on the ovary. Both gravid and spent fish were examined. Ovaries were judged to be approaching spawning condition when the eggs could be easily extruded. The ova at this time were transparent and possessed visible oil globules.

Age determination was attempted by examination of otoliths utilizing the techniques described by Clemens (1951) and Poole (1961). The left otolith (sagitta) was removed, marked and stored in a three percent solution of tri-sodium phosphate.

Prior to examination, otoliths were cleared for five days in glycerine. The otoliths were then placed on a glass slide and observed under 9X magnification with a binocular microscope. All measurements were made with an ocular micrometer in units equal to 0.093 mm. Measurements were taken from the left otolith along the axis of the core to the anterior margin, with the concave surface upward and the apex directed away from the observer. This was essentially the method utilized by Poole (1961) except that Poole measured from the midpoint of the core to the left side of the otolith in line with the widest edge.

Detailed records on the landings of the winter trawl fishery from 1957 to the present time were obtained through the cooperation of the Bureau of Commercial Fisheries, Market News Division of Hampton, Virginia. These individual vessel records representing over 90% of the landings in the Hampton Roads ports were analyzed for information pertinent to the investigation.

SIZE COMPOSITION OF THE CATCH

Total length measurements of 5,258 flounder were taken from October, 1961 to April, 1962. These measurements represented the marketable catch of the vessels and did not include smaller fish which may have been culled at sea. The fish were not separated according to sex.

The monthly size composition of the landings is shown by Figure 2. Modes for November, December, and January are similar, but differ from those of February and March. The mean lengths of the fish landed from November through March are respectively, 38.92, 38.91, 39.42, 43.87, and 44.49 cm. Analysis of variance indicated that the mean lengths in February and March were significantly larger, (P 0.001), than those in previous months. However, Pearson (1932) reported that a smaller class of flounder was relatively more abundant in the market catch during March and April than earlier in the season.

In an attempt to elucidate the apparent shift of size in the composition of the catch during the months of November through April the percentage of large, medium, and small flounder, as reported by Market News Division, Bureau of Commercial Fisheries, were computed for the years 1957 to 1962 (Table 3).

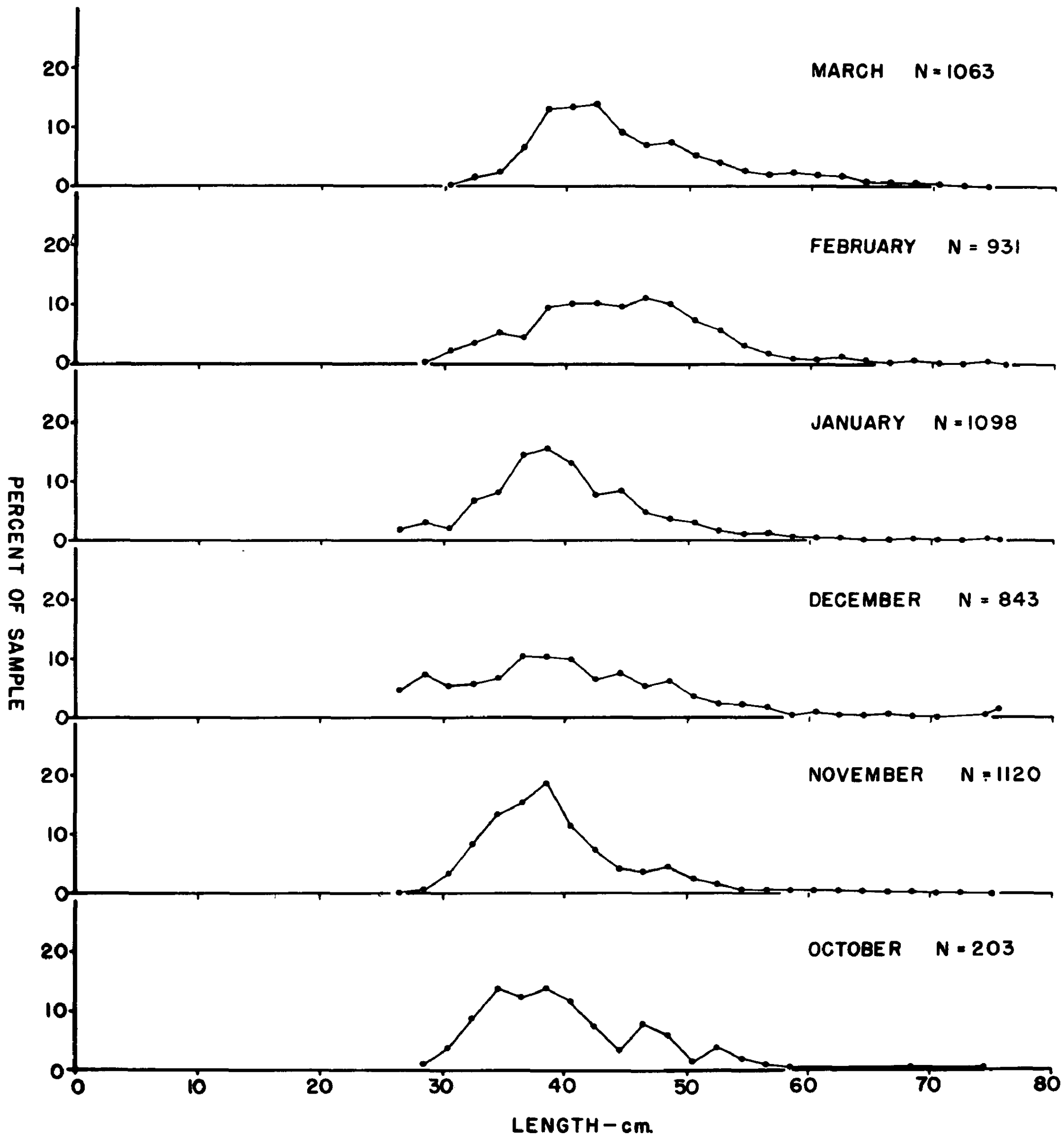

Fig. 2. Monthly size composition of flounder catch from October 1961 to March 1962.

Table 3

Size categories of summer flounder in percentage of total catch from January 1957 to April 1962

Month	% Large	% Medium	% Small	Total catch in pounds
		1957		
Jan.	50.25	28.21	21.54	156,066
Feb.	53.32	26.53	20.16	141,722
March	56.99	24.85	18.15	50,031
April	58.16	21.88	19.96	61,300
May	47.92	27.01	25.07	41,783
June	48.52	31.95	19.53	38,236
July	63.19	22.32	14.49	77,597
Aug.	49.68	18.66	31.65	74,894
Sept.	51.64	23.13	25.23	29,530
Oct.	56.10	24.18	19.71	13,955
Nov.	56.32	29.12	14.56	72,854
Dec.	56.02	26.52	17.47	125,296
		1958		
Jan.	58.65	20.66	20.69	146,007
Feb.	59.51	21.98	18.51	178,273
March	71.98	18.55	9.48	139,823
April	74.41	16.05	9.53	85,099
May	67.63	22.32	10.05	15,200
June	47.03	35.46	17.51	25,136
July	56.74	25.26	18.00	66,205
Aug.	53.20	32.80	13.99	60,995
Sept.	57.76	20.94	21.30	60,140
Oct.	52.63	23.79	23.58	43,046
Nov.	31.41	29.81	38.78	52,166
Dec.	50.11	24.23	25.66	144,477
		1959		
Jan.	53.56	22.61	23.83	318,953
Feb.	46.11	24.51	29.38	366,698
March	55.98	19.24	24.78	503,783
April	57.63	19.54	22.84	181,589
May	49.69	32.36	17.95	279,313
June	34.83	39.41	25.77	184,316
July	48.33	24.76	26.90	125,063
Aug.	35.63	23.70	40.67	164,222
Sept.	40.90	25.01	34.09	127,516
Oct.	43.53	30.31	26.16	62,749
Nov.	49.30	25.58	25.12	191,095
Dec.	51.20	27.63	21.16	411,918

Table 3 (continued)

Month	% Large	% Medium	% Small	Total catch in pounds
		1960		
Jan.	49.75	24.13	26.12	279,983
Feb.	47.68	25.22	27.10	528,052
March	77.72	12.75	9.52	149,204
April	83.62	10.50	5.88	202,186
May	36.31	36.57	27.12	168,109
June	22.56	33.47	43.97	161,383
July	49.00	23.22	27.78	74,791
Aug.	55.82	22.61	21.58	56,583
Sept.	49.51	19.34	31.14	71,396
Oct.	50.14	23.10	26.76	126,510
Nov.	45.57	27.96	26.48	228,191
Dec.	46.16	27.16	26.68	84,905
		1961		
Jan.	50.09	25.60	24.31	137,503
Feb.	71.18	18.74	10.08	181,814
March	46.53	26.78	26.68	163,316
April	43.53	20.69	35.78	68,920
May	62.36	27.90	9.74	3,706
June	35.42	35.35	29.24	11,017
July	45.48	24.18	30.34	41,832
Aug.	40.36	26.23	33.41	58,594
Sept.	41.20	22.19	36.61	83,444
Oct.	36.52	27.86	35.63	21,372
Nov.	44.27	33.60	22.13	125,890
Dec.	53.71	28.05	18.24	56,041
		1962		
Jan.	59.56	28.21	12.33	80,378
Feb.	63.20	15.05	21.75	99,872
March	62.14	27.29	10.56	196,258*
April	55.09	28.53	16.38	46,029

*Based on incomplete catch records.

The percentage of large flounder generally increased from November to April with a subsequent decline in May. However, in 1961 there was a marked increase in the percentage of large flounder in February followed by a pronounced decrease in March and April. In contrast to the usual pattern, the catch of larger fish in 1931 and 1961 appeared to be of shorter duration.

At this time it is not possible to state conclusively why this shift to larger fish occurs during the latter part of the season. However, during the past season it was noted that the increased catch of large flounder coincided with an offshore shift of fishing effort. The trawlers fished primarily in depths of 20 to 50 fathoms in December and January. During February and March they fished very close to the 100 fathom curve in depths of 50 to 100 fathoms from approximately 36° to 38° N. latitude.

It would be interesting to determine whether trawlers follow the flounder from shallow to deep water essentially fishing the same stocks throughout the season or fish a stock of larger flounder which inhabits the deeper waters throughout the winter and is unavailable to the fishery in the early part of the season. Furthermore, it would be interesting to discover whether the stock or stocks of flounder during winter months follow Heincke's Law (Wimpenny, 1953); namely, that the size and age of flounder is directly associated with the depth and distance from the coast.

SPAWNING SEASON

Gross observations of the gonads were made from October to April. Thirty six females and 111 males were examined during October. The testes were white and enlarged. The ovaries varied from medium to large and from yellow to orange in color. The eggs were not transparent and did not possess visible oil globules. During November 29 males and 40 females were examined. All of the males had large, white gonads which appeared to be ripe. Until the middle of November all of the females had large, yellow to orange gonads with profuse blood vessels. On the 17th of November the ovaries of 20 females were observed to be in either a running, partially spent, or spent condition. The eggs were transparent, possessed oil globules and were easily extruded. This was the earliest date on which fish with mature ovaries were observed. Fish in spawning condition were observed until the first week of December.

Seventy six males and 229 females were examined from the middle of December until April. In general, the testes were reduced in size, but retained their color and shape. In marked contrast to the testes, the ovaries changed appreciably in appearance. The ovaries became dark red and flaccid. Only one of the 229 females examined after the first of December was not in a spent condition. This female was taken on the 8th of January and the ovaries were large and appeared well developed. Flounder examined on the 7th of April possessed ovaries which were still flaccid. Restoration of gonadal material apparently had not commenced.

Extensive seasonal collections of eggs and larvae taken in offshore waters adjacent to the mouth of the Chesapeake Bay by the Department of Ichthyology of the Virginia Institute of Marine Science indicated that the spawning season of _P. dentatus_ was of short duration and occurred chiefly in November (Unpublished data).

Hildebrand and Schroeder (1928) observed that specimens of _P. dentatus_ taken in Chesapeake Bay during October possessed comparatively large gonads and that flounder at Beaufort, North Carolina, appeared to be fully spent by March and April. Hildebrand and Cable (1931) concluded that the height of the spawning season of _P. dentatus_ occurred during November and December in offshore waters.

LENGTH-WEIGHT RELATIONSHIP

Mathematical formulae describing the length-weight relationship of the summer flounder were calculated to provide conversions from length to weight and to compare the length-weight relationship between the sexes.

Poole (1961) demonstrated that the length-weight relationship for male and female was different and on this basis the sexes were treated separately for all statistical analyses.

A scatter diagram obtained by plotting paired length and weights on arithmetic paper indicated the length-weight relationships for both males and females were curvilinear. The same data plotted on log-log paper resolved the trend into straight lines; hence, the formula $W = aL^b$ was used to describe the relationship. Converting length and weight measurements to logarithms the formula then became $\text{Log } W = \log a + b\log L$. The elevation of intercept a and the regression coefficient b were determined by the least squares method. The mathematical formula describing the regression of weight on length for males was found to be $\text{Log } W = -4.51917 + 2.81601 \log L$ and for females $\text{Log } W = -5.55030 + 3.20947 \log L$.

Although only the regression of weight on length was computed, the coefficients of correlation ($r = 0.979$ for males) ($r = 0.972$ for females) indicate a high degree of predictability for either weight on length or length on weight.

The regressions of weight on length for male and female *P. dentatus* are shown in Figures 3 and 4.

Regression coefficients were not analyzed for significant differences between the sexes, but by inspection the curves for male and female appear to be similar for comparable ranges in weight and length. A discussion of sexual growth differences appears in a later section.

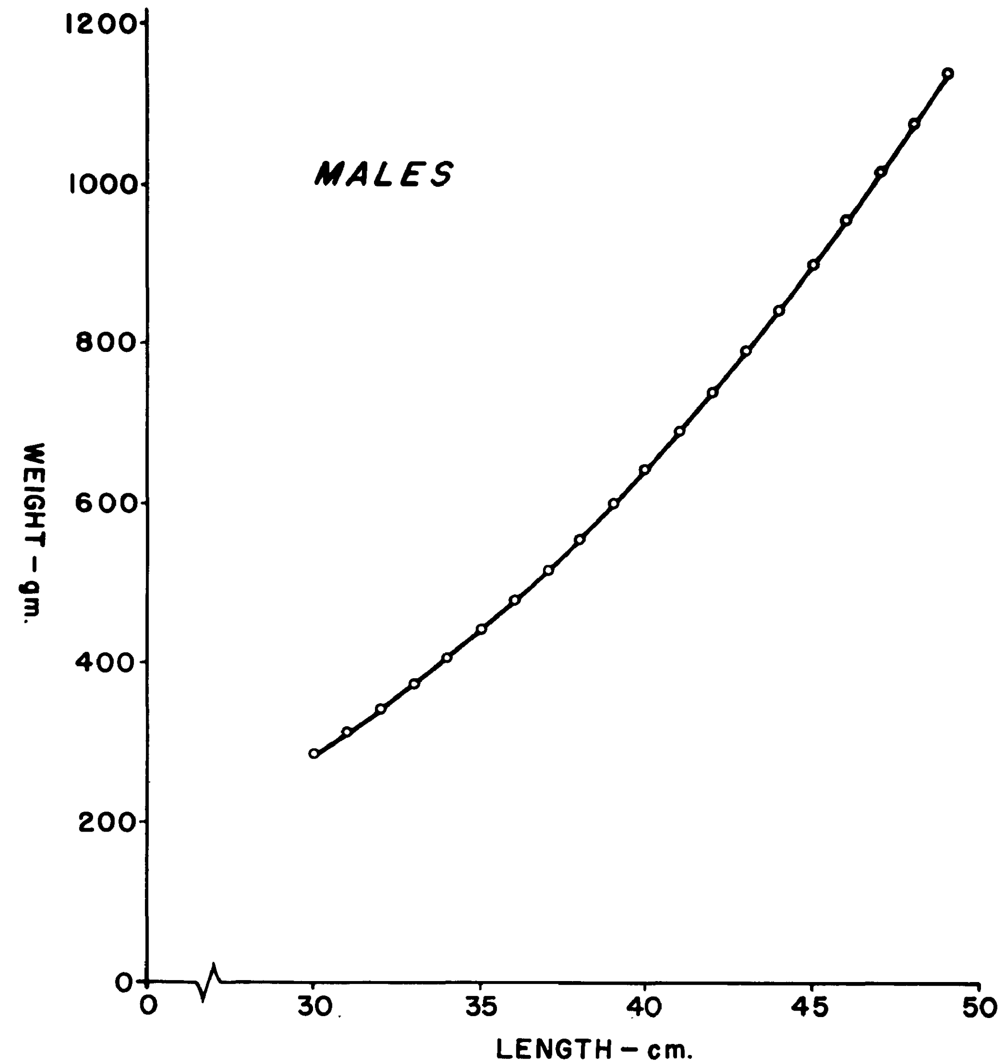

Fig. 3. Average length-weight relation of male summer flounder.

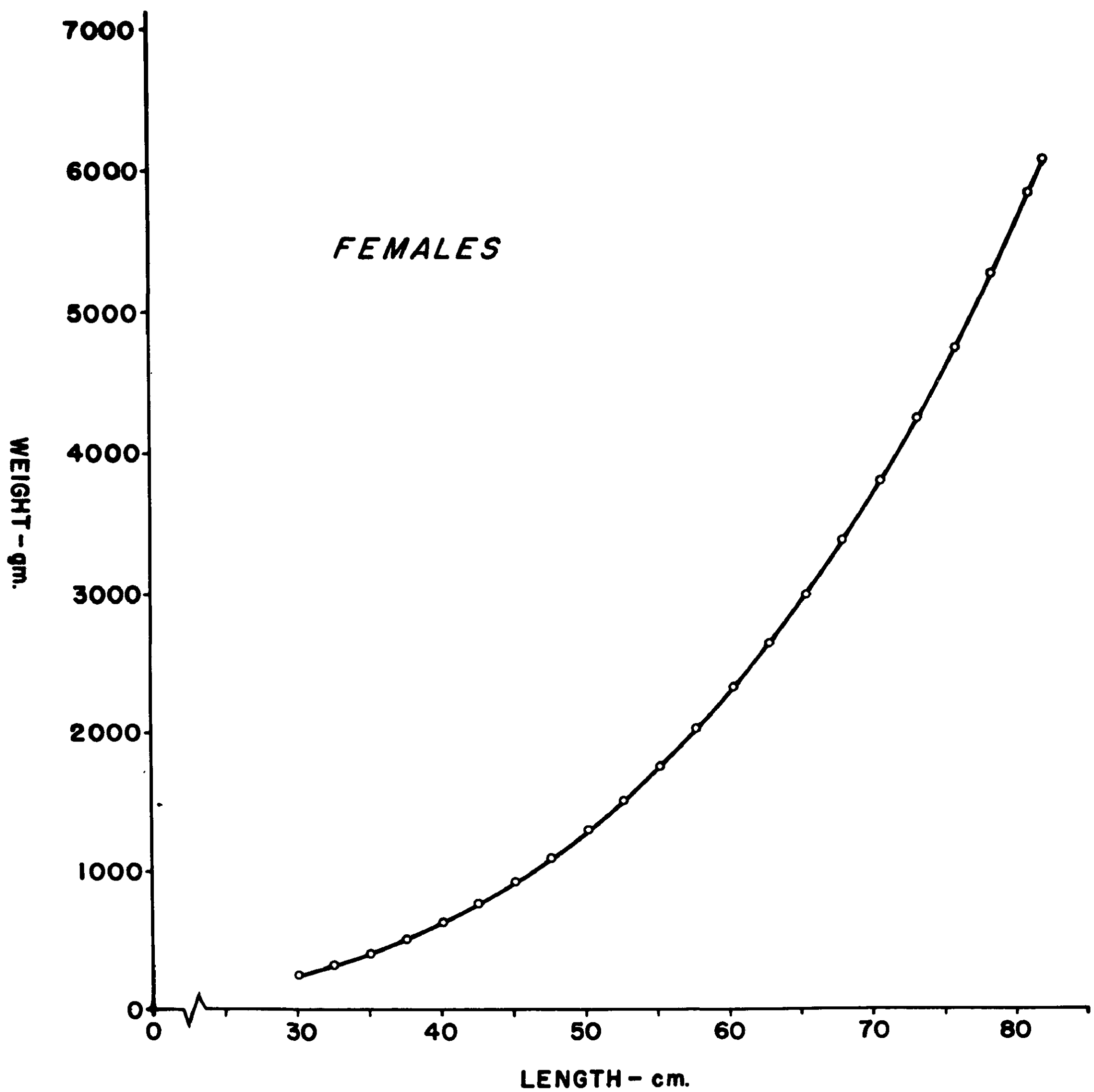

Fig. 4. Average length-weight relation of female summer flounder.

AGE AND GROWTH ANALYSIS

In order to determine the relationship between fish length and otolith length, otoliths from 326 fish were examined and measured. The ring-length as well as the ring-weight relationship was calculated for both sexes of *P. dentatus* in order to determine if age determinations could be predicted from either weight or length measurements.

Scatter diagrams obtained by plotting paired otolith radial lengths against total lengths on arithmetic paper indicated that the otolith length-total fish length relationships for males and females were linear. The elevations a and regression coefficients b were determined by the least squares method. The equation for the females was $L = 87.65 + 7.04836X$ and for males $L = 151.14 + 4.75829X$. In both instances X equals the number of rings. Thus, it became possible to estimate (back calculate) lengths for any given ring. However, it was found that when back calculations were made Lee's phenomenon became evident (Table 4). Apparently, the faster growing fish were recruited to the fishery before the slower growing individuals. In order to circumvent any error which may have been introduced by this phenomenon, fish were grouped according to the number of rings that their otoliths possessed. Thus, only those otoliths which had the same number of rings

Table 4

Length of summer flounder at time of formation of first ring as determined by back calculations of older fish

Ring Class	1	2	3	4	5	6	7
Mean size	319.2	317.87	301.60	309.21	303.12	307.21	
Mean size	377.3	349.00	324.26	326.59	319.75	311.44	324.47

were used to back calculate the length at the time of ring formation of that particular group. Based on back calculations, using only the last formed ring, the growth rate was obtained. The regression of length on number of rings for females was linear. The constants a and b were determined and the equation for females was: Length = 330.2 + 47.07X, where X equals the number of rings. The males were treated in the same manner as the females. However, when the scatter diagram of the ring-length relationship was plotted, it proved to be curvilinear. The same data plotted on log-log paper resolved the curve into a straight line; hence, the formula $L = aX^b$ was used. Converting length and number of rings to logarithms the formula then became log L = log a + b Log X. The mathematical formula describing the regression of length on number of rings for males was: Log L = 2.50400 + 0.16125 Log X, where X equals the number of rings. The data for males and females are given in Table 5 and illustrated in Figure 5. (Note--the number of rings does not correspond to the age of an individual; see the section on age interpretation). In a similar manner the ring-weight relationships of male and female flounder were computed. First, the otolith radial length-fish weight relationships were found. Then, the ring-weight regressions were computed. Since the plot of weight on number of rings

Table 5

Length-ring relationship
(millimeters)

Ring Class	1	2	3	4	5	6	7	Total
Class size	15	39	35	18	9	5		121
Mean calculated length at respective rings	319.2	356.9	381.0	399.1	413.7	426.1		
Class size	25	49	47	47	9	10	11	198
Mean calculated length at respective rings	377.3	424.4	471.4	518.5	565.6	612.6	656.9	
Standard error	4.95	3.98	3.89	5.76	10.90	11.00		
$s_{\bar{x}}\ t_{05}$	10.62	8.04	7.90	12.15	25.13	30.54		
Standard error	3.81	4.07	5.66	5.17	13.24	7.59	6.79	
$s_{\bar{x}}\ t_{05}$	7.78	8.16	11.39	10.41	31.31	17.17	15.13	

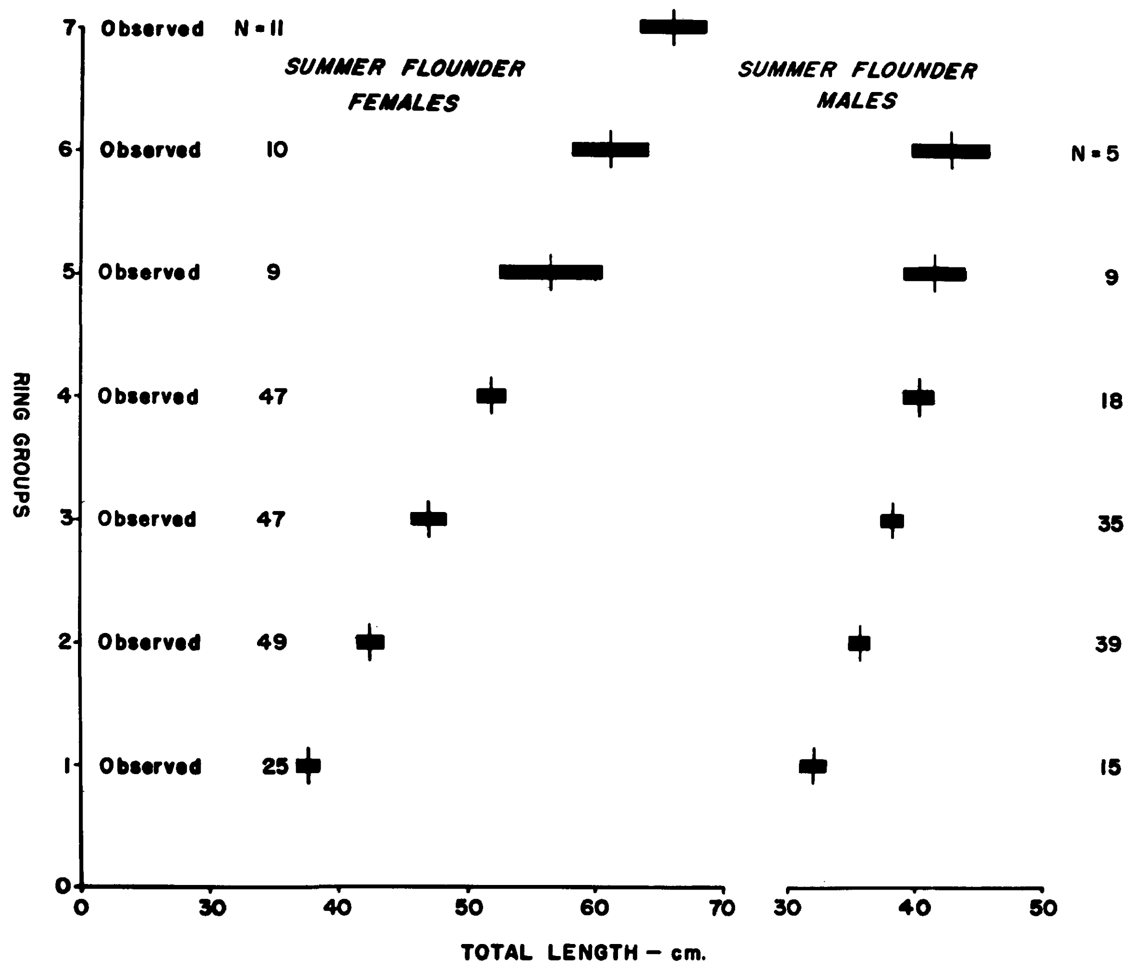

Fig. 5. Average length-ring relation for male and female summer flounder.

was linear for females, their equation was: Weight = 2.1 + 377X, when X equals the number of rings. Because the weight-ring relationship for males was curvilinear, the data were converted to logarithmic units. The formula for males was found to be: Log W = 2.53552 + 0.45726 Log X, where X equals the number of rings. These data are given in Table 6 and illustrated in Figure 6. An examination of the data show that the growth rates for male and female P. dentatus are different. The mean lengths and weights of the male regression lines are within the range of variation of the individuals that belonged to their particular ring category. However, when one compares the actual weight of the female samples with the plotted mean weights, it is at once apparent that the one ring females weighed more than their predicted weight and the three ring females weighed less than their predicted weight. These observations are not explainable at the present time. The ring-length relationship for females was in good agreement with the actual length of the female subsamples.

Table 6

Weight-ring relationship
(grams)

Ring Class	1	2	3	4	5	6	7	Total
Class size	15	34	35	17	9	5		115
Mean calculated weight at respective rings	343.2	471.2	556.9	676.0	688.2	824.9		
Class size	25	49	47	46	8	10	11	196
Mean calculated weight at respective rings	379.3	756.6	1133.0	1511.3	1888.6	2265.9	2643.3	
Standard error	11.24	12.36	13.75	28.52	22.76	70.90		
$S_{\bar{x}}\ t_{05}$	24.11	25.15	27.94	60.46	52.48	196.80		
Standard error	9.22	19.34	34.65	36.74	133.40	108.20	114.60	
$S_{\bar{x}}\ t_{05}$	19.05	38.87	69.78	73.99	315.40	244.80	255.20	

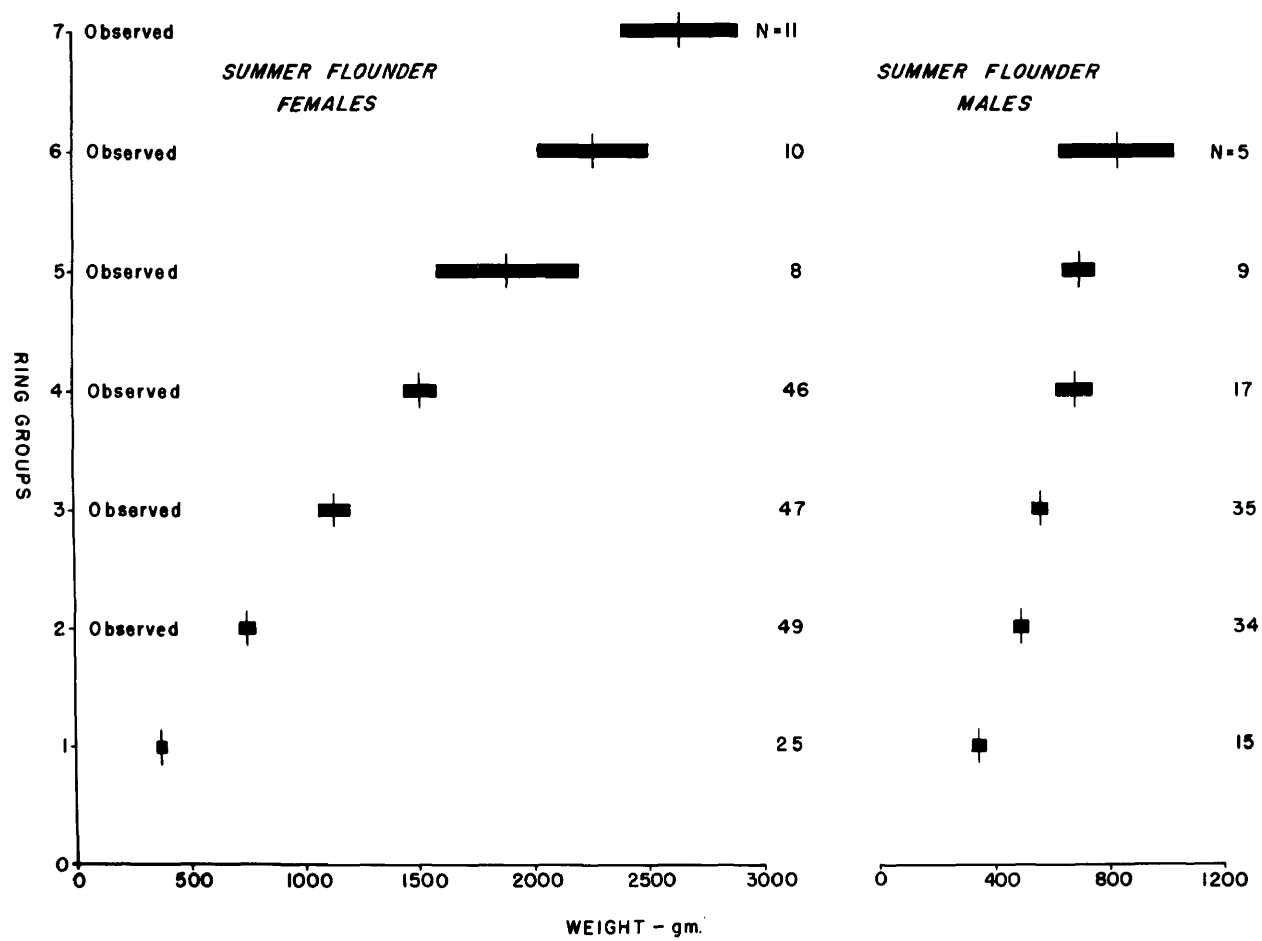

Fig. 6. Average weight-ring relation for male and female summer flounder.

AGE INTERPRETATION

Very little work has been done to determine the age and growth rate of Paralichthys dentatus. Inferences of the growth rate have been drawn from the study of length frequencies of young summer flounder (Hildebrand and Schroeder 1928) which do not correspond with the growth rate proposed by Poole (1961) who based his conclusions on examination of otoliths. It is the intent of this section to attempt to define the differences that exist in the literature and to offer an interpretation of the data which will, it is hoped, accurately portray the true growth rate.

The otolith is concave with the most opaque portion in the center. This central portion or core is surrounded by concentric hyaline bands separated by narrow opaque rings. Poole concluded that the first ring was laid down at the end of the first year of life and that successive rings represented annual growth. In the present study otoliths were examined and Poole's descriptions were confirmed. However, it appears that there is another reasonable interpretation of the data as to the age at the time of formation of the first ring. Hildebrand and Schroeder (1928) concluded, on the basis of a study of length frequencies, that summer flounder in Chesapeake Bay attained a length of 150 to 180 mm at the age of one year, 200 to 260 mm when about 1 3/4 years old, and 270 to 280 mm when slightly more than two years old. Hildebrand and Cable (1931) collected post-larval flounder of one or more species at Beaufort, North Carolina, and found that none exceeded 19 mm in February and only one exceeded 24 mm in March. These flounder, if *P. dentatus*, were hatched during November and were about four months of age in March. Collections of larval *P. dentatus* obtained during March by the Department of Ichthyology of the Virginia Institute of Marine Science indicated that larval flounder did not exceed 16 millimeters at that time. Their small size in March indicated either a slow rate of growth during the winter months or complete net escapement by the larger individuals.

The length frequency distribution of 230 flounder (Table 7) taken by experimental trawling in Chesapeake Bay during the years of 1956-1959 indicates that the mean size of juvenile summer flounder was approximately 101 mm in June, 154 mm for the months of July through September and 170 mm for the months of October through December (Massmann, unpublished data).

A sample of 29 flounder having a mean length of 94.4 mm and a mean weight of 7.71 g was obtained from the

Table 7

Length frequency distribution of summer flounder, *P. dentatus*, caught by experimental trawling by R/V Pathfinder [1]

Length (mm)	June	July-Sept.	Oct.-Dec.
53-57	1		
58-62			
63-67	2		
68-72			
73-77	1		
78-82	1		
83-87	2		
88-92	2		
93-97	4		
98-102	2		
103-107	5	2	
108-112	4	5	
113-117	5	3	
118-122	2	3	
123-127		4	1
128-132	2	9	3
133-137	1	9	1
138-142		9	4
143-147		11	1
148-152		11	6
153-157		11	5
158-162		5	10
163-167		3	6
168-172		5	9
173-177		8	4
178-182		2	4
183-187		5	4
188-192		4	5
193-197		4	2
198-202		5	2
203-207		1	1
208-212		2	3
213-217		1	1
218-222			2

[1] Data compiled from Virginia Institute of Marine Science, Special Scientific Report No. 27, 1962.

York River in June, 1962. Four flounder collected in the York River in December, 1961 had a mean length of 179.5 mm and a mean weight of 58.5 g. Twelve flounder which were collected offshore by a winter trawl boat in December, 1961 had an average length of 261.5 mm and an average weight of 178 g. Either one or both samples in December, 1961 consisted of one-year-old fish. It is suggested that the great difference in weight indicated that the samples represented two different year classes.

Poole working in Great South Bay, New York collected summer flounder which had a modal length of 120 mm in July and a modal length of 230 mm in September. He concluded that these fish were of the same year class. In July his fish ranged in size from approximately 80 to 210 mm. A few fish in September were less than 160 mm, but most were between 160 to 280 mm. Although the modal length of Poole's sample in July coincides with the reports in the literature, the modal length in September does not.

The difference in interpretation concerns the size of the fish at the end of its first year of life. Poole concluded that the fish at this time was about 230 mm in length. Hildebrand and Schroeder (1928) as well as Massmann (Personal communication) concluded that the flounder is about 150 to

180 mm at the age of one year and at the end of the second year of life approached 200 to 260 mm. An examination of the weight of the flounder at their respective sizes is appropriate at this time. A flounder which is 110 mm in length weighs approximately 12 g; those 150 to 180 weigh 50 to 75 g and those 200 to 260 weigh 130 to 225 g. According to Poole, most of the flounder at about ten months of age are between 100 and 200 grams in weight. This is an 8 to 16 fold increase in weight from July to September. In order to compare the growth rate of the first year with that of successive years total lengths at the time of ring formation were converted to weight. [1] Thus, at the time of formation of rings 1, 2, and 3, the males respectively weighed 173.1, 361.7, and 585.9 grams. The females respectively weighed 181.2, 522.9, and 1,025.2 grams. The proposed growth of flounder based on Poole's interpretation and the growth rate suggested by the author are given in Table 8. The growth rates are presented in the hope that they will promote interest in the question and stimulate research which will clarify the issue. At the present time

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[1] The total lengths referred to are those of Poole's back calculations given in his abstract.

Table 8

Proposed growth rates of summer flounder

Author

Zero Rings July (8 months) Wt. in grams	Factor of increase	Zero Rings Dec. (one year) Wt. in grams	Factor of increase	Zero Rings Dec. (two years) Wt. in grams	Factor of increase
12		50-75	4-5X	130-225	3X
12		50-75	4-5X	130-225	3X

One Ring Dec. (three years) Wt. in grams	Factor of increase	Two Rings Dec. (four years) Wt. in grams	Factor of increase	Three Rings Dec. (five years) Wt. in grams	Factor of increase
379.3	2X	756.6	1.5X	1,133.0	1.4X
343.2	2X	471.2	1.2X	556.9	1.2X

Poole

Zero Rings July (8 months Wt. in grams	Factor of increase	One Ring Dec. (one year) Wt. in grams	Factor of increase	Two Rings Dec. (two years) Wt. in grams	Factor of increase	Three Rings Dec. (three years) Wt. in grams	Factor of increase
12		181.2	15X	522.9	3X	1,025.2	2X
12		173.1	14X	361.7	2X	585.9	1.6X

the author will accept his own interpretation and discuss the growth rate on that basis.

Flounder at the end of their second year of life weigh approximately 130 to 225 g and are about 200-260 mm. During the course of the study there were no individuals less than 300 mm which were judged to possess mature gonads. Therefore, it appears that flounder become sexually mature during their third summer of life and spawn during the following winter at an age of three years. At this time they deposit their first recognizable ring which becomes visible during their fourth summer. Thus, a one ring fish is actually three plus years old and two years must be added to the number of rings in order to calculate its true age.

DIFFERENTIAL GROWTH OF SEXES

A sample of 525 fish was examined to determine the size range of both sexes. Males (N = 221) ranged in size from 268 to 537 mm and females (N = 304) ranged from 293 to 808 mm. Figure 7 is a graphical representation of the size distribution and Table 9 gives the sex ratio changes with increasing size.

The data indicate that very few males exceed 500 mm in length, thus, the vast majority (approximately 95%) of the fish over 500 mm is female.

This difference in size between the sexes in similar to that reported for lemon sole (Rae, 1948), halibut (Rae, 1959) and yellowtail flounder (Royce, Buller and Premetz, 1959). In each instance, changes in the sex ratio with advancing age and size was attributed to the faster growth rate of the female. Analysis of covariance indicate that female summer flounder grow in length significantly faster than males. The possibility that the mortality rate for males in the older age groups is higher than that for females cannot be disregarded as a contributing factor to the disproportionate number of females in the larger sizes.

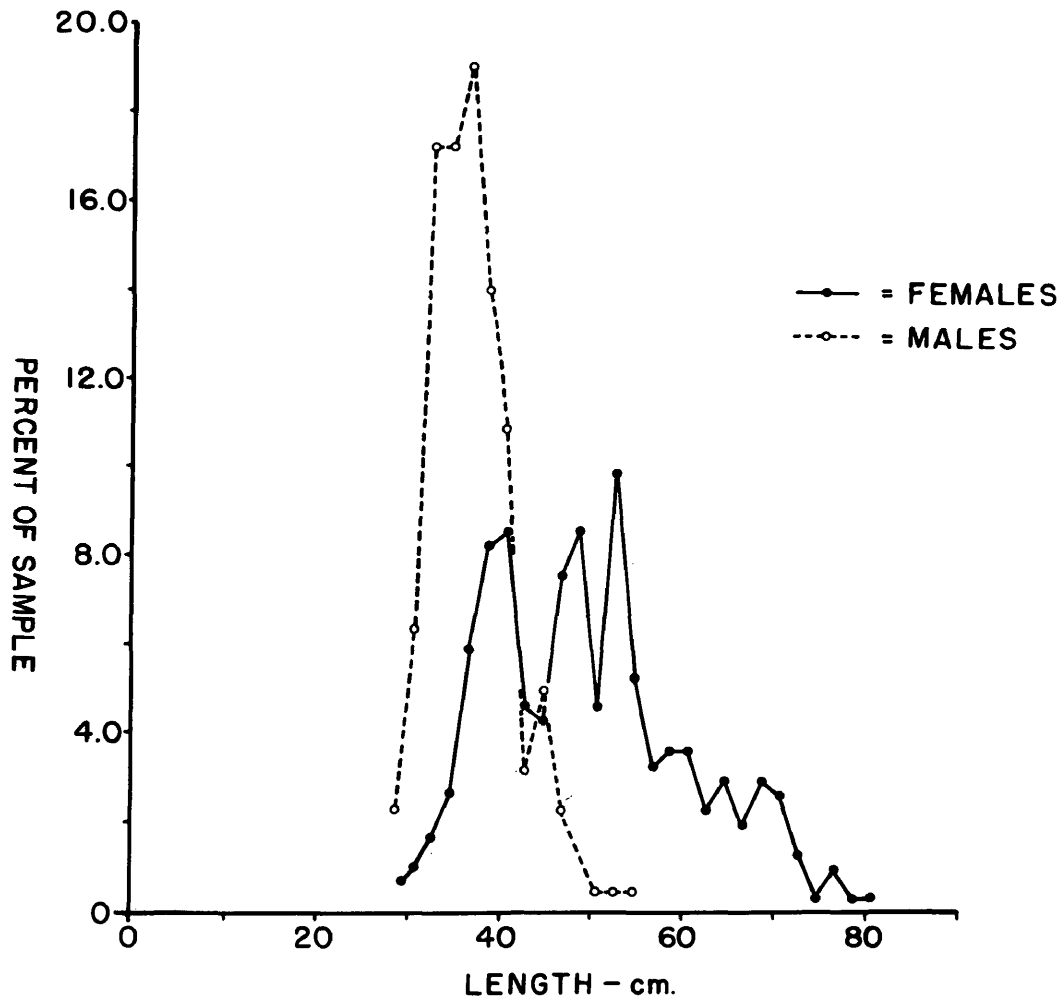

Fig. 7. Size range of male and female summer flounder landed in commercial catch.

Table 9

Size class distribution of male and female summer flounder

Length group	Male No.	Male %	Female No.	Female %	Ratio M/F
253-302	11	85	2	15	1:0.182
303-352	84	88	11	12	1:0.131
352-402	88	78	25	22	1:0.284
403-452	27	38	45	62	1:1.667
453-502	9	15	57	85	1:6.334
503-552	2	4	52	96	1:26.00
553-808	0	0	91	100	
	221		483		

AGE COMPOSITION OF SUMMER FLOUNDER LANDED IN HAMPTON ROADS AREA

The oldest male in the present study had seven rings and was judged to be nine years of age. Two of the females had eight rings; one, nine rings; and one, ten rings. Their estimated age were respectively ten, eleven, and twelve years.

The largest male examined weighed 1,559 grams and the largest female weighed 4,621 grams. Because summer flounder of a larger size are caught by trawlers, it is highly probable that a few males exceed nine years of age and that some females exceed twelve years. However, most of the males landed at Hampton are from three to eight years of age and the females are from three to twelve years of age.

Flounder landed in the Hampton Roads area are graded into four size categories; small, medium, large, and jumbo. The respective weights of the categories are: small--1/2 to 3/4 pound (267-340 g), medium--3/4 to 1 1/2 pound (340-680 g), large--1 1/2 to 4 pounds (680-1814 g) and jumbo--those above 4 pounds. The regression of weight on number of rings indicated the following age composition of the size categories: small, three-year-old males and females (first ring being laid down that winter); medium, males of four, five and six years as well as four-year-old females; large, males of seven, eight, and nine years as well as five, six, and seven-year-old females. Most of the large flounder were females and practically all jumbo flounder were females eight years of age and older.

If this interpretation of age is correct and if only one stock of flounder is being exploited, then, the catch/unit of effort of fish in the small category which is primarily made up of one year class may provide a basis for estimating the strength of the year class just entering the fishery.

THE EFFECT OF THE FISHERY ON FLOUNDER STOCKS

The fluctuations in the summer flounder catch from 1951 to 1960 are given in Table 2. The average flounder catch for the ten years was about 1.1 million pounds.

The total catch of flounder and the number of trips per month for January, February, March, April, November, and December during the years of 1957-1961 and the winter of 1930-31 are shown in Table 10.

Since effort has varied from year to year and is liable to do so in the future, a standard unit of effort is necessary to detect changes in the apparent abundance of the flounder stocks. The catch/trip was selected as the unit. A more refined unit could not be adopted since records of number of tows or time spent actually fishing were not kept. The limited supplies of ice, food, and fuel that could be stored on the trawlers limited their fishing time. The depletion of these supplies was directly proportional to the running time of the vessel to the fishing ground and the amount of time that was spent in search of flounder concentrations that were profitable to fish. On occasion, adverse weather conditions forced them into port. On the assumptions that adverse weather conditions were fairly constant from one season to the next and that storage facilities of the

Table 10

Status of fishery

Data	1930-31	1957	1958	1959	1960	1961
Total catch (thousands of lb.)	1,072	541	726	1,882	1,556	847
Total # of Trips	316	422	423	589	629	372
Catch/trip (lbs.)	3,392	1,282	1,681	3,196	2,474	2,278

vessels did not change appreciably from 1957-1962, it was felt that the catch/trip was the best indication of the apparent abundance of the stocks.

The number of trips per season increased from 1957 to 1960 and then declined sharply in 1961. The catch/trip increased from 1957 to 1959 and dropped slightly during 1960 and 1961. The total catch per year increased from 1957 to 1959. There was a slight decline in 1960 and a pronounced decline in 1961. The catch/unit of effort indicated that the apparent abundance of flounder was greatest in 1959 and least in 1957. The sharp decrease in total catch from 1960 to 1961 appeared to be the result of a decline in fishing effort.

It is difficult to make an assessment of the change in the abundance of the stocks because of the paucity of published data concerning size distribution and catch/unit effort of flounder. Prior to 1951, there was only one reliable report concerning the total catch of flounder for a season. This was 1,071,795 pounds for the winter of 1930-31 (Pearson) which was of the same magnitude as the average landings for the years 1951-1960 (Table 2). Pearson also supplied the only catch/trip data prior to 1951. Although his figure is higher than four of the five recent years, the figure for 1959 is of the same magnitude. Moreover, during the 1930-31 season the modal length for fish during December, January, and February was 40 cm while March and April fish had a modal length of approximately 35 cm (Pearson 1932). These statistics are of the same magnitude as the mean lengths of summer flounder landed during the 1961-62 season. In fact, the figures for 1961-62 are somewhat higher than those reported by Pearson. The statistics suggest that the mean size of the catch has not decreased since the inception of this fishery. Although the available data are limited, both the size composition of the catch and the catch/trip data suggest that the stock or stocks of summer flounder which are available to the fishery have not been overexploited. However, until the stocks are defined and mortality rates and recruitment determined, this conclusion can not be considered as final.

SUMMARY

1. Data on the size composition of the marketable flounder landed at Hampton Roads ports were compiled in order to establish a base line to detect changes in the size composition of the summer flounder stocks.
2. Data concerning location of the fishery, catch/trip, units of effort and landings were compiled to determine the present status of the flounder stocks.
3. Spawning of summer flounder was found to be of short duration and to occur chiefly in November.
4. The mathematical formula describing the regression of weight on length for males was found to be Log W = -4.51917 + 2.81601 Log L and for females Log W = -5.55030 + 3.20947 Log L.
5. Females were found to grow at a faster rate than males and to a greater size.
6. The size composition of the catch was observed to shift from smaller to larger fish during the season. This might be explained on the basis of a shift of fishing effort from inshore to offshore waters.
7. A review of the literature concerning the aging of summer flounder was discussed and an interpretation of the growth rate was offered. The mathematical formula

describing the ring-weight relationship for males was Log W = 2.53552 + 0.45726 Log X and for females Weight = 2.1 + 377X. The mathematical formula describing the ring-length relationship for males was Log L = 2.50400 + 0.16125 Log X and for females Length = 330.2 + 47.07X (In every instance X equals the number of rings). It was suggested that the first ring formed on the otolith represented three years of age.

8. An estimate of the age structure of the marketable flounder was made.

9. Although the available data are limited, both the size composition of the catch and the catch/trip data suggest that the stock or stocks of summer flounder which are available to the fishery have not been overexploited. However, until the stocks are defined, mortality rates and recruitment determined, this conclusion can not be considered as final.

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APPENDIX

Table I

Monthly size composition of summer flounder landed at Hampton, Virginia

mm.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
228-32				1		
233-37			1	1		
238-42						
243-47			3	3		
248-52		1	13	2		
253-57			6	8		
258-62		1	14	5		
263-67			21	8		
268-72		1	16	7	1	
273-77			17	8		
278-82		4	14	8		
283-87	2	3	15	10		
288-92	1	7	15	7	4	
293-97	2	7	11	4	4	1
298-02	2	8	8	5	7	2
303-07	3	17	10	6	7	
308-12	2	21	13	22	5	2
313-17	6	24	11	18	8	5
318-22	8	20	12	20	11	5
323-27	2	30	11	14	10	5
328-32	2	33	12	9	13	5
333-37	5	41	12	30	7	6
338-42	12	37	10	23	10	7
343-47	9	41	22	26	18	10
348-52	6	34	15	28	7	9
353-57	8	47	24	46	9	23
358-62	9	50	18	33	16	19
363-67	2	42	30	51	11	21
368-72	12	68	21	36	17	37
373-77	2	53	22	50	24	32
378-82	9	46	23	41	24	36
383-87	5	43	20	45	27	35
388-92	8	38	19	28	26	33
393-97	6	32	25	48	19	28
398-02	5	23	17	28	23	50
403-07	5	34	23	41	26	34
408-12	8	26	16	24	18	47
413-17	1	19	12	26	19	47
418-22	5	23	13	12	28	29

Table I (continued)

mm.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
423-27	1	15	14	24	29	26
428-32	3	12	15	26	19	25
433-37	2	14	19	24	26	25
438-42	1	9	14	21	33	30
443-47	1	12	16	21	13	18
448-52	4	12	10	11	28	22
453-57	3	9	12	12	23	17
458-62	4	13	13	13	23	20
463-67	5	9	9	17	30	17
468-72	4	19	13	11	21	19
473-77	4	9	13	14	25	16
478-82	2	9	12	4	22	24
483-87	2	14	14	13	26	22
488-92		8	8	6	13	14
493-97	1	11	8	9	17	14
498-02	2	5	9	12	21	15
503-07		6	6	6	17	14
508-12	5	8	5	3	18	8
513-17	1	4	2	5	16	12
518-22	2	3	6	5	12	4
523-27		4	7	7	8	20
528-32		1	4	2	10	4
533-37	4	6	10	5	11	10
538-42		2	3		4	9
543-47			2	5	4	7
548-52		2	7	3	4	8
553-57	1	2	1	3	7	4
558-62	1	2	6	4	2	5
563-67		3	1	3	5	6
568-72	1	3		1	3	4
573-77				2		7
578-82		1	1	4	2	14
583-87		1	1	1	4	1
588-92			1	1	1	4
593-97		2	4	1	4	6
598-02		1	1	1	1	7
603-07			1	1	2	3
608-12		4	1		3	5
613-17				1	1	9
618-22		2	1	4	4	4
623-27					3	2
628-32					2	1
633-37		2				4
638-42		2		1	1	2

Table I (continued)

mm.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
643-47			1		3	3
648-52			1			2
653-57		1	1	1	1	3
658-62			1		1	2
663-67						2
668-72			1		1	
673-77		1		1		2
678-82				1	2	1
683-87	1	1				4
688-92				1		
693-97		1				3
698-02			1		1	1
703-07						
708-12					1	1
713-17				1		1
718-22						
723-27		1				
728-32						
733-37					1	1
738-42	1		2	1	1	
743-47					1	
748-52		1		1		
753-57						
758-62					1	
806-822				1		1