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An Evaluation of the summer flounder population in Subarea 5 and Statistical Area 6

by

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INTRODUCTION:

This paper presents a preliminary assessment of the summer flounder (fluke), *Paralichthys dentatus*.

The USA commercial fishery for summer flounder extends from Massachusetts to North Carolina (Table 1) in waters of less than 100 fathoms. In southern New England and New York waters, most are taken by an inshore summer trawl fishery. Off New Jersey most are taken by a summer and winter trawl fishery in 80 - 100 fathoms. Summer inshore trawling has declined in recent years from a time when it was equally important to the New Jersey winter fishery. In Virginia, an inshore summer trawl fishery usually lands more than the winter fishery, and about 20 per cent of the landed catch is taken by pound nets in Chesapeake Bay. In North Carolina, 90 per cent of the catch is taken in a mixed trawl fishery operating offshore in winter, the remainder is taken by minor gears in estuarine waters.

Commercial catches reported in ICNAF summaries were derived principally from U. S. monthly landing reports. The only other statistics reported to ICNAF are those of the Soviets, who have landed less than 600 tons per year in the last few years.

Recreational catch forms a significant part of the fishery (Figure 1). Statistics of recreational catch are derived from 1965 and 1970 censuses; other points are interpolated on the basis of catch ratios and projected increase of the angler population. The recreational fishery is carried on by private and charter fisherman operating close to the coast. The most recent survey indicates approximately .75 million anglers caught summer flounder, a 10 per cent increase from the similar survey of 5 years earlier (Deuel and Clark, 1968; Deuel, 1973).

Most survey statistics developed are based on semi-annual research cruises of the National Marine Fisheries Service. Survey techniques have been described by Grosslein (NEFC, Ref. 69-2).

No analysis was possible utilizing commercial effort data. Reliable statistics of the fishery effort do not exist and no detailed statistics of the recreational fishery effort are presently available other than the gross effort of participants in 1965 and 1970.

There is no evidence to suggest that discrete subgroups exist in Subarea 5 and Statistical Area 6. The time variation in availability of eggs essentially extends from Block Island, Rhode Island in September to North Carolina through February (Smith, 1973), since spawning occurs during the fall migration to offshore waters. Summer flounder make an inshore migration in early spring from overwintering areas of 50 to 100 fathoms. Once inshore, some fish move into bays, others remain in inshore ocean water, the rest move north and east. From studies of tagged fish there is some evidence of homing. There appears to be no appreciable difference in growth among areas (Poole, 1961, Eldridge, 1962, Smith, 1969). In this paper, we have treated the summer flounder population as a unit stock.

The additional biological information and our estimates were incorporated with the reported catch statistics (ICNAF 1967 - 1973) with appropriately weighted length and weight equations (Richards, 1970), age analyses from various regions (Poole, 1961; Eldridge, 1962; Smith, 1969) and unpublished study data of Mssrs. Paul Hamer, Walter Murawski (New Jersey Division of Marine Fish), Ronal Smith (U. of Delaware) and Fred Lux (Northeast Fisheries Center). We greatly appreciate the cooperative response of these colleagues in satisfying our need for information.

LANDINGS AND AGE - SIZE COMPOSITION:

Recent commercial landings reported to ICNAF have varied from 1.9 to 6.1 thousand metric tons per year. The low occurred in 1969 and the high in 1974 (Figure 1). The recreational catch was estimated at 13.4 thousand metric tons in 1965 and the 1970 catch 8.7 thousand metric tons. Although the angler data of Figure 1 are estimated for years other than 1965 and 1970, they mirror the increased catch of summer flounder witnessed by recreational fishermen in recent years. The ratio of angler catch to commercial landings ranged from 3.00 in 1965 to 3.56 in 1974.

A summary of U. S. commercial landings by state is given in Table 1. The northern segment of the commercial fishery had a persistent decline in landings from the 1950's to a low in the early 1970's, whereas the southern portion maintained a consistent level. In recent years the catch increased to former levels. Without good estimates of effort it is impossible to relate this change to increased availability or intensified fishing.

Age composition of summer flounder was derived from survey data of lengths to which was applied R. Smith's unpublished age-length information (Figure 2). Two sets of data are shown; the longer set, from 1967, indicates results from surveys in waters from 15 to 200 fathoms. The short set, from 1972, incorporates results from surveys made in shallower depths. The shift in modal values to smaller sizes is explained in the calculated age composition profiles (Figure 2) where an increase in the age 1 and 2 components was obtained from inshore catches. At least ten age groups made up the available population in recent years, 80-90 per cent comprising age groups 1-3. Based on survey statistics, there is some evidence that age group 2 was fully recruited in recent years.

The length distribution of summer flounder taken on groundfish surveys is given in Figure 3. Lengths range from 12 to 80 cm. Since 1967, modal lengths have decreased from the mid 40 cm. to a current range in the mid 20 cm. groups. The discontinuous distributions of earlier years (1967-1971) are due to smaller sample sizes. A higher proportion of smaller fish in the pooled length composition in recent years has probably resulted in part from increased survey activity in shallower waters.

ESTIMATION OF POPULATION PARAMETERS:

Mortality Rate:

Of the several methods for estimating mortality in fish populations those most applicable to the present study include age composition, cohort and tagging data analyses. Age composition analysis involves estimation of the rate of decline of abundance with increasing age, i.e. ln $(C_i) = a - Zi$ where C_i is catch of age i. The virtual population method (Gulland, 1965) provides a set of instantaneous fishing mortality rates which are summarized in Table 2. Estimates of fishing and natural mortality rate including an additional mortality factor due to the tags were obtained by Paulik's method (1963). Results of the tagging analyses are based in part on the numbers of released and recaptured tags of Lux's experiments at Point Judith, Rhode Island, and Nantucket Sound in 1962. Additional tagging data were analyzed from published reports (Poole, 1961 and Murawski, 1970).

The differences in estimates of instantaneous fishing mortality rate appear to be insignificant over years (Table 2). To compare with these values, estimates derived from earlier tagging experiments (Table 3) do not suggest even longer term trend changes. F values did not consistently change as landings changed. In the observed period, as judged from relatively consistent calculated F, year classes are fully recruited to the fishery at age 2 or 3.

The estimates of instantaneous total mortality rates fall in a range from 0.56 to 0.69 (Table 2) estimated by age composition analysis. Compared to values of the virtual population procedure and age composition analysis, some indication of differences appear to exist between the two sets of mortality rates. The reason for this is not clear, but because the summer flounder fishery is not considered to be in a steady state, and also the role of the recreational fishery is such a dominant factor, it is apparent that some of the assumptions may have been violated.

An estimate of the instantaneous natural mortality rate is only available from the tagging experiments. Three independent tagging experiments led to somewhat different sets of X values ranging from 0.57 to 0.97. These appear to be extremely high for summer flounder, however, the conditions of releasing fishes, location, time, related environment, low tag returns from fishermen in some areas, mortality due to the tagging, and higher vulnerability to the fishing nets (i.e. Petersen-type tags), and other loss factors must be considered. The higher X values are only provisionally acceptable figures. More realistic estimates for M may be around 0.2 and the remaining portion of X values (M_{tag}) may be considered mortality due to the variabilities related to tagging experiments and the tag itself.

An interesting observation in the summer flounder population is the scarcity of 5 and 6 year old males and absence of any males older than age 7. Thus, the natural mortality rate of male summer flounder may increase dramatically beyond ages 4 and 5 or simply result from a consistently higher rate for all age groups.

Recruitment Rate:

Table 4 summarizes the recruitment rates for summer flounder using Allen's (1966) method under the assumptions of M = 0.2 and the total mortality rate for fully recruited and new recruits is the same. Therefore, with the assumption of M a constant, then only effects of fishing mortalities of new recruits and fully recruited fish are considered. In recent years, the age of full recruitment is younger than earlier years. The fully recruited age for summer flounder is three for 1967-1972 and two for 1973-1974.

An interesting aspect of the recruitment rate is shown in Table 4. There is an increasing proportion of new recruits in the exploited population (W) in the two-year-old age group, however, the total proportion of new recruits in the exploited population (W_t) has not shown comparable increases in recent years. Table 4 also indicates that at least 40 - 50% of the newly recruited summer flounders had not reached the maturing age of 3 years.

Growth:

The length and weight relationship of the summer flounder has been investigated by several scientists (Eldridge, 1962, Lux and Porter, 1966, and Smith, 1969). Poole (1961) studied growth in length of summer flounder in the Great South Bay, Long Island. Recently, Richards (1970) re-examined Poole's data using analog simulation and found a better fit when the lengths were shifted to a point one year older than that of the original growth curve. Using this correction he developed Bertalanffy's growth equation for summer flounder as follows:

For males:

$$l_t = 607\ (1 - e^{-0.240\ (t + 0.11)})$$

$$w_t = 2608\ (1 - e^{-0.214\ (t + 0.02)})$$

For females:

$$l_t = 943\ (1 - e^{-0.164\ (t + 0.1)})$$

$$w_t = 13431\ (1 - e^{-0.144\ (t + 0.04)})$$

The units are millimeters for the length and grams for the weight. Using these same criteria we suggest Eldridge's data should be shifted back one year (i.e. read as one year younger) to fit Richard's curve. These equations suggest the rate of growth in weight for males is greater than that of females, although theoretical maximum length and weight of females are much longer and heavier than those of males. These male values of L_∞ and W_∞ correspond to the scarcity of older male summer flounder in the fishery.

ESTIMATION OF POPULATION SIZE:

Since a good index for effective effort is not available, and availability may fluctuate considerably from year to year, there may be considerable errors involved in the age composition method of estimating mortality rates. To avoid such marked effects of changes in vulnerability, Fry (1949) used virtual population estimates in place of abundance. Chapman (1958), Gulland (1965), and Pope (1973) modified this method to obtain population sizes. Tables 5 and 6 summarize the estimates in the summer flounder population size by year class obtained using the NEFC computer program based on Gulland's method.

Estimated population size in numbers (Table 5) progressively increased in the observed period by a factor of 2.8 from 80 million in 1967 to 247 million in 1973. The fishable population size in weight (Table 6) increased by a factor of 1.6 during the same interval, from 41 to 66 thousand metric tons. This reflects the increased number of younger fish in the stimates which do not have a proportionate increment in weight, thus recent year population estimates include more younger fish than those of earlier years. This may be influenced somewhat from inshore survey coverage in recent years.

The estimated population in 1974 does not include the size of the 1-year-old age group, so the size in numbers is less than that of 1973, however, the size in weight is larger than that of 1973. This reflects the influence of strong year classes of 1970, 1971, and 1972 prevailing in the 1974 population size in weight, since the net weight contribution of these stronger year classes to the 1974 population is greater than those of the 1973 population.

YIELD ANALYSIS:

Besides the two most popular methods of yield analysis, the dynamic pool model with yield per recruit analysis and the surplus yield model with general production equation, more recent developments of yield analysis have been accomplished by Chapman (1970) and Doi (1972). Their designs have employed a reproduction mechanism to obtain the level of sustainable yield and population size.

Doi's mathematical formulations may be modified for the summer flounder fishery as follows: Let R be the number (or index) of recruits at age 1, let $s = e^{-(F + M)}$ be an annual rate of survival, and let t_c be the first age of entry to the fishery. We may assume maturity for summer flounder occurs at age 3, since Smith (1969) observed the smallest male caught with ripening testes was 30.5 cm long and the smallest female with ripening ovaries was 39.0 cm long. The ages of those male and female fish were 3 years old based on the age-length key constructed from his data.

Then the fishable stock size N (age 1-10) and the spawners S, for $t_m = 3$ and $t_c = 1$ are calculated as:

$$N = \frac{R\ (1 - s^{11})}{1 - s} \text{, and}$$

$$S = \frac{R\ s^2\ (1 - s^9)}{1 - s}$$

The reproduction rate, K, is written as

$$K = \frac{R}{S} = \frac{1 - s}{s^2\ (1 - s^9)}$$

For $t_m = 3$ and $t_c = 2$, we have

$$N = \frac{R\, s_o\, (1 - s^{10})}{1 - s}$$

where $s_o = e^{-M}$

$$S = \frac{R\, s_o\, s\, (1 - s^9)}{1 - s}$$

$$K = \frac{R}{S} = \frac{1 - s}{s_o\, s\, (1 - s^9)}$$

Although K values are easily obtainable, there is no analytical solution for s. So we compute K's and plot values of K on s (Figure 4) for various t_c values within $t_m = 3$ as a function of s. Thus, survival rates are estimated in Figure 4 by known reproduction rates.

Tables 7 and 8 present calculations of sustainable yield for summer flounder fishery with special reference to its spawner-recruit relationship and estimated parameters are described above and in Figure 4. These computations are treated with values of $t_c = 1, 2$; $t_m = 3$ and a constant $M = 0.2$. Then both maximum sustainable yield (MSY) in numbers and weights are observed at a spawner size index $S = 3.0$. The MSY in weights (Ys) are 20 and 22 thousand metric tons with fishing intensity (F) 0.45 and 0.69 and average weight per fish ($\bar{w}$) 562 and 674 grams for $t_c = 1$ and $t_c = 2$ respectively.

The present level of the estimated 1974 landings from commercial and recreational fisheries, is larger than the MSY level of 20-22 thousand metric tons.

The eight years of data points (1967-1974) generate only 6 points for a spawner-recruit relationship, since there is a 2-year time lag effect of spawners to recruits. Thus, under the circumstances, determination of this relation is particularly meager with an extrapolation from six points.

DISCUSSION AND RECOMMENDATIONS:

This analysis represents a first attempt to evaluate the summer flounder fishery in Subarea 5 and Statistical Area 6. The study indicates a lack of adequate information in several areas including the sport fishery element. A review of the information leading to our analyses is in order primarily to point out where and why certain gaps should be filled.

The historical summary of landings shows the commercial harvest is considerably less than the recreational harvest. Statistical sources do not contain paired estimates of commercial and recreational landings. Furthermore, the entry for summer flounder is often lost in a statistical clustering of "flatfish" or "other flounders." Better information of effort and age characteristics from both commercial and recreational landings is needed.

We have assumed one stock. At present this is an allowable premise, based on the uninterrupted progression of spawning (Smith, 1973) and the relatively homogeneous availability of fish. Oceanographic and other factors may affect annual survival in different geographic sections of the fishery and a regional catch composition analysis would demonstrate their characteristics and whether persistent differences occur. A discriminate function analysis of area samples would also evaluate the validity of our premise.

From our preliminary analysis we have concluded that the fishable population is one characterized by a stock fully recruited by age 3 and in recent years dominated by modal age groups of 2 or 3. A trend of increasing harvest in recent years appears to have resulted from a short series of strong year classes of 1970 to 1972. Development of a spawner-recruit curve and yield analysis suggest a sustainable catch level of 20-22 thousand metric tons in Subarea 5 and Statistical Area 6. The 1974 combined fishery harvest of 27 thousand metric tons is over our estimate of a sustainable level.

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Table 1. Annual USA commercial landings (X 1000 lbs) summer flounder by state.

Year	Mass.	R.I.	Conn.	N.Y.	N.J.	Del.	#Md.	# Va.	1-8 TOTAL
1950	3613	1036	270	3838	2514	25	(543)	(1761)	13601
51	4506	1189	441	2636	2865	20	(327)	(2006)	13988
52	4898	1336	627	3680	4721	69	(467)	(1671)	17470
53	3836	1043	396	2910	7117	53	(1176)	(1838)	18367
54	3363	2374	213	3683	6577	21	(1090)	(2257)	19578
55	5407	2152	385	2608	5208	26	(1108)	(1706)	18600
56	1448	1604	322	4260	6357	60	(1049)	(2168)	21289
57	5991	1486	677	3488	5059	48	(1171)	(1692)	19612
58	4172	950	360	2341	8109	209	1452	2039	19632
59	4524	1070	320	2809	6294	95	1334	3255	19701
60	5583	1278	321	2512	6355	44	1028	2730	19851
61	5240	948	155	2324	6031	76	539	2193	17506
62	3795	676	124	1590	4749	24	715	1914	13587
63	2296	512	98	1306	4444	17	550	1720	10943
64	1384	678	136	1854	3670	16	557	1492	9787
65	431	499	106	2451	3620	25	734	1977	9843
66	264	456	90	2466	3830	13	630	2343	10092
67	447	706	48	1964	3035	-	439	1900	8539
68	163	384	35	1216	2139	-	350	2164	6451
69	78	267	23	574	1276	-	230	1508	3929
70	41	259	23	900	1958	-	371	2146	5698
71	89	275	34	1090	1850	-	296	1707	5341
72	70	276	-	1101	1852	-	277	1856	5432
73	447	594	-	1826	3092	-	492	3228	9679
74	1600*	2516*	-*	2481*	3499	-*	706*	2733*	13535

* June - Nov.; ( ) all "flounders" together
# Chesapeake Bay included

Table 2. Estimated instantaneous fishing mortality rates for summer flounder by virtual population method with M = 0.2, and total mortality rates estimated by ln (C_i) = a - Zi where C_i is catch of age i.

	AGE											
Year	1	2	3	4	5	6	7	8	9	10+	$\bar{F}_{2-10}$	Z
1967	0.051	0.212	0.472	0.637	0.615	0.556	0.527	0.705	0.569	0.5	0.533	0.62
1968	0.036	0.383	0.460	0.402	0.436	0.434	0.482	0.647	0.744	0.5	0.499	0.59
1969	0.180	0.133	0.237	0.304	0.405	0.320	0.301	0.350	0.397	0.5	0.327	0.60
1970	0.146	0.386	0.306	0.300	0.263	0.290	0.369	0.469	0.551	0.5	0.382	0.56
1971	0.024	0.154	0.307	0.414	0.445	0.345	0.406	0.603	0.863	0.5	0.449	0.58
1972	0.247	0.611	0.335	0.337	0.350	0.392	0.239	0.355	0.414	0.5	0.393	0.67
1973	0.099	0.461	0.374	0.368	0.494	0.417	0.351	0.296	0.413	0.5	0.408	0.69

Table 3. Summary of estimated instances fishing and natural mortality rates from tagging experiments by various sources.

STUDY	SOURCE	LOCATION	TAG TYPE	Z = M + M Tag	F
1961	Hamer, Murawski (1970)	Sandy Hook, N.J.	Petersen	0.84	0.37
			Atkins	0.97	0.34
1956	Poole (1961)	Long Island N.Y.	Petersen	0.91	0.50
1962	Lux (unpub.)	Pt. Judith R.I.	Petersen	0.57	0.55
		Nantucket Mass.	Petersen	0.77	0.52

Table 4. Computation of recruitment rate for summer flounder under the assumption of M = 0.2 and total mortality for fully recruited and newly recruits is the same (i.e., Z = Z^1).

Year	Recruitment* Rate	Age 2	Age 3	Age 4-10	W_t**
1967	U	0.60	1.00	1.00	
	R	+	+	+	
	W	+	+	+	+
1968	U	0.96	1.00	1.00	
	R	1.00	0.44	0.00	
	W	0.36	0.12	0.00	0.48
1969	U	0.61	1.00	1.00	
	R	1.00	0.62	0.00	
	W	0.27	0.15	0.00	0.42
1970	U	0.79	1.00	1.00	
	R	1.00	0.20	0.00	
	W	0.40	0.03	0.00	0.43
1971	U	0.81	1.00	1.00	
	R	1.00	0.28	0.00	
	W	0.27	0.07	0.00	0.34
1972	U	0.82	1.00	1.00	
	R	1.00	0.39	0.00	
	W	0.44	0.04	0.00	0.48
1973	U	1.00	1.00	1.00	
	R	1.00	0.20	0.00	
	W	0.47	0.03	0.00	0.50
1974	U	1.00	1.00	1.00	
	R	1.00	0.16	0.00	
	W	0.41	0.03	0.00	0.44

* U = Proportion of recruits in each age group
R = Proportion of new recruits in the recruited part of each year class
W = Proportion of new recruits in the exploited stock in each age group

** Wt = Total proportion of new recruits in the exploited stock for year t

\+ Not computable unless 1966 catch data for each age groups is available.

Table 5. Estimated summer flounder population size in numbers (X 1000 fish), and total landings in numbers (X 1000) from commercial and recreational fisheries.

Year	Year Class 1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	Population Size Total (1000 fish)
1967	425	724	1341	2581	5962	10091	15589	22129	28727							87569
1968	198	293	648	1212	2639	4370	7963	14658	22354	30387						84722
1969		114	278	613	1400	2314	4361	7579	12482	23999	41641					94781
1970			153	354	848	1377	2382	4580	8059	17209	33515	51909				120386
1971				167	435	780	1459	2883	4887	10380	18644	36738	82187			158560
1972					150	349	796	1672	2565	5617	11232	25785	65715	111438		225319
1973						189	457	1078	1419	3242	6568	15097	29193	71239	119268	247750
1974							248	656	818	1749	3282	8557	16436	36771	88405	156922

Table 6. Estimated summer flounder population size in weight (metric ton), and total landings in weights from commercial and recreational fishes.

Year	Year Class 1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	Population Size Total (m tons)	Total Catch (m tons)
1967	2067	2884	4002	5446	8192	8174	6469	3430	718							41382	16104
1968	1188	1425	2582	3617	5568	6004	6450	6083	3465	760						37142	12256
1969		684	1352	2442	4178	4883	5992	6139	5180	3720	1041					35611	8233
1970			918	1722	3378	4109	5026	6293	6528	7142	5195	1298				41609	11421
1971				1002	2115	3108	4354	6083	6715	8408	7737	5694	2055			47271	14777
1972					900	1697	3171	4989	5412	7718	9098	10701	10186	2786		56658	16343
1973						1134	2223	4295	4234	6841	9024	12229	12115	11042	2982	66119	19720
1974							1448	3190	3259	5219	6925	11757	13313	15560	13703	74374	27995

Table 7. Calculations of sustainable yields in numbers and weights for summer flounder population with spawner recruit relationship under the assumptions of M = 0.2, $t_m = 3$, $t_c = 1$ and $\bar{w}$ = 562 grams.

S*	R*	K	s	Z	F	E	N*	Cs*	P**	Ys**
0.1	0.35	3.50	0.41	0.89	0.69	0.46	0.59	0.27	3316	1517
0.5	1.59	3.18	0.43	0.84	0.64	0.43	2.79	1.20	15680	6744
1.0	2.81	2.81	0.45	0.80	0.60	0.41	5.11	2.09	28718	11746
2.0	4.40	2.20	0.49	0.71	0.51	0.37	8.62	3.19	48444	17928
3.0	5.17	1.72	0.52	0.65	0.45	0.33	10.76	3.55	60471	19951
4.0	5.40	1.35	0.57	0.56	0.36	0.28	12.53	3.51	70419	19726
5.0	5.28	1.06	0.61	0.49	0.29	0.23	13.48	3.10	75758	17422
6.0	4.96	0.83	0.65	0.43	0.23	0.19	14.17	2.69	79635	15118
7.0	4.53	0.65	0.70	0.36	0.16	0.13	14.80	1.92	83176	10790
8.0	4.05	0.51	0.74	0.30	0.10	0.16	15.01	1.50	84356	8430
9.0	3.57	0.40	0.79	0.24	0.04	0.03	15.73	0.47	88403	2641
10.0	3.11	0.31	0.83	0.19	-	-	-	-	-	-

* Unit is 10^7 fish
** Unit is metric tons
S = spawners (index or numbers)
R = recruits (index or number)
K = reproduction rate
s = survival rate

$Z = -\ln s$

$E = \frac{F}{Z}(1-s)$

$Cs = NE$

$Ns = \frac{R\ So(1-s^{10})}{1-s}$

$\bar{w} = \frac{\sum_{i=1}^{10} Pi\ wi}{\sum_{i=1}^{10} Pi}$ = 562 grams

$P = N\bar{w}$

$Ys = C_s\bar{w}$

Table 8. Calculations of sustainable yield in numbers and weights for the Atlantic summer flounder population with spawner recruit relationships under the assumptions of $M = 0.2$, $t_m = 3$, $t_c = 2$ and $\bar{w} = 674$ grams.

S*	R*	K	s	Z	F	E	N*	C_s*	P**	Y_s**
0.1	0.35	3.50	0.26	1.35	1.15	0.63	0.39	0.25	2627	1685
0.5	1.59	3.18	0.28	1.27	1.07	0.61	1.81	1.01	12199	6807
1.0	2.81	2.81	0.30	1.20	1.00	0.58	3.29	1.91	22175	12873
2.0	4.40	2.20	0.35	1.05	0.85	0.53	5.54	2.94	37340	19815
3.0	5.17	1.72	0.41	0.89	0.69	0.46	7.17	3.30	48326	22242
4.0	5.40	1.35	0.48	0.73	0.53	0.38	8.50	3.23	57290	21770
5.0	5.28	1.06	0.54	0.62	0.42	0.31	9.38	2.91	63221	19613
6.0	4.96	0.83	0.61	0.49	0.29	0.23	10.34	2.38	69692	16041
7.0	4.53	0.65	0.67	0.40	0.20	0.17	11.09	1.88	74747	12671
8.0	4.05	0.51	0.73	0.31	0.11	0.10	11.75	1.18	79195	7953
9.0	3.57	0.40	0.79	0.24	0.04	0.03	12.60	0.38	84924	2561
10.0	3.11	0.31	0.83	0.19	-	-	-	-	-	-

* Unit is 10^7 fish
** Unit is metric tons

S = spawners (index or number)
R = recruits (index or number)
K = reproduction rate

s = survival rate
$Z = -\ln s$
$E = \frac{F}{Z}(1-s)$
$Cs = NE$
$Ns = \frac{R\,So(1-s^{10})}{1-s}$

$\bar{w} = \sum_{i=t}^{10} \frac{P_i w_i}{\sum_{i=t}^{10} P_i} = 674$ grams
$P = N\bar{w}$
$Ys = C_s \bar{w}$

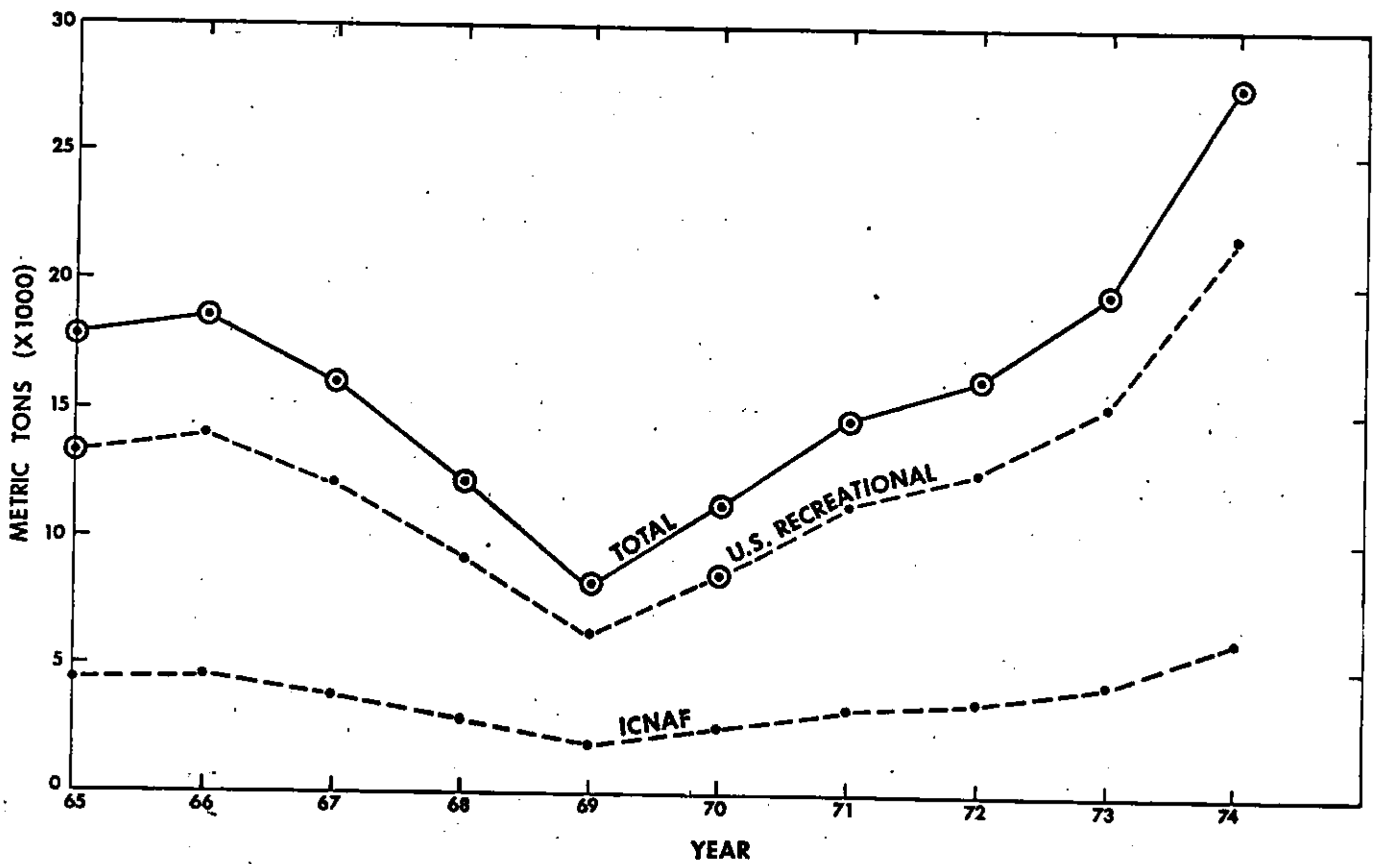

Figure 1. Landings of commercial (ICNAF, USA and USSR) and recreational fisheries for summer flounder, 1965-1974.

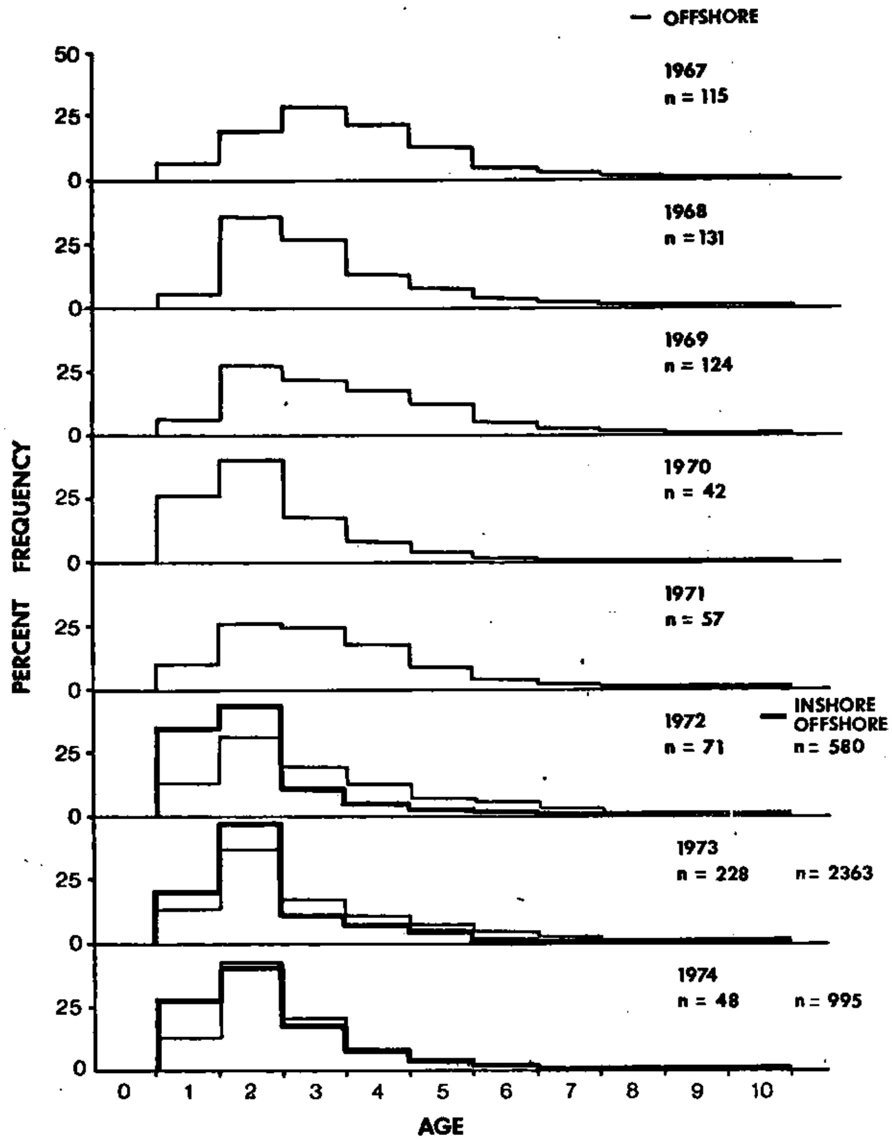

Figure 2. Age composition of summer flounder available in Subarea 5 and Statistical Area 6. Offshore includes catches made in waters deeper than 15 fm. Inshore - offshore catches include those from shallower water surveys conducted since 1971.

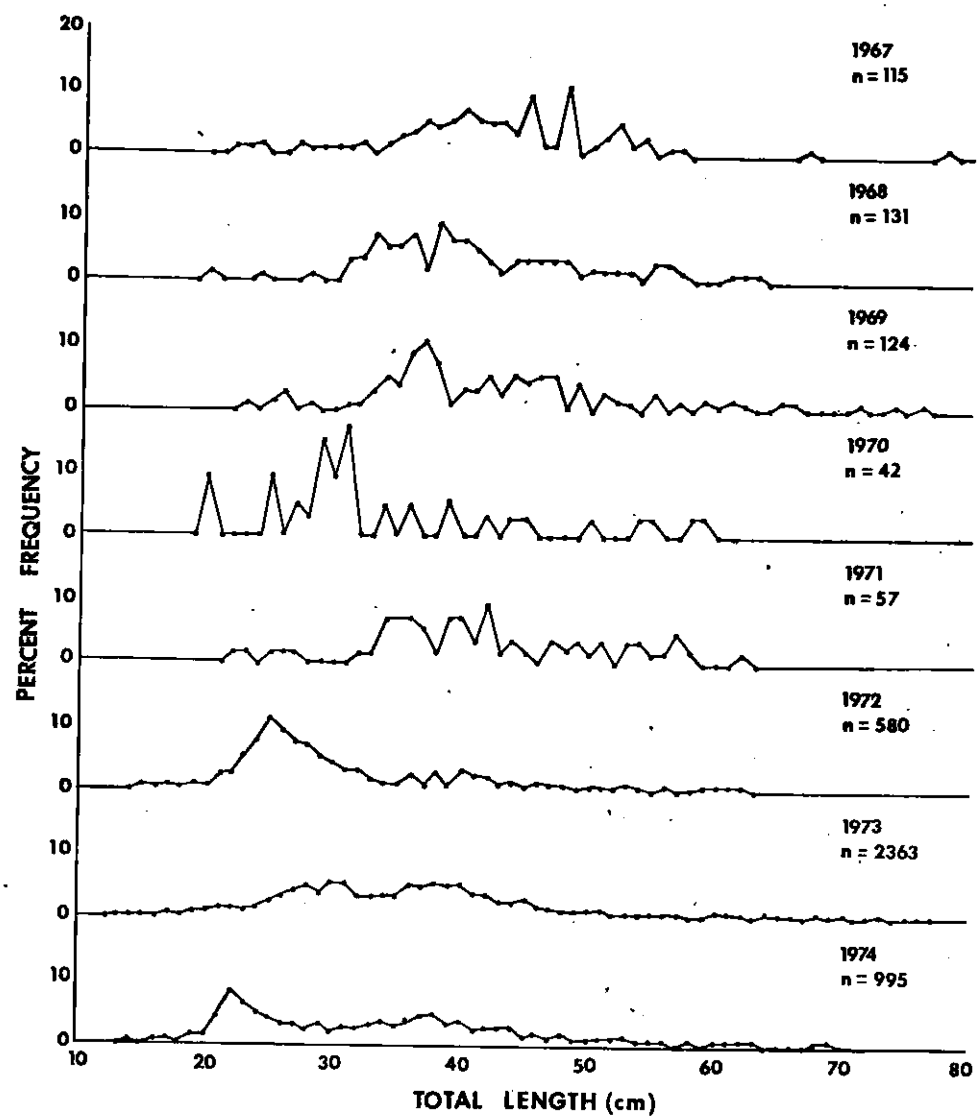

Figure 3. Size distribution of summer flounder obtained by bottom trawl - Subarea 5 and Statistical Area 6.

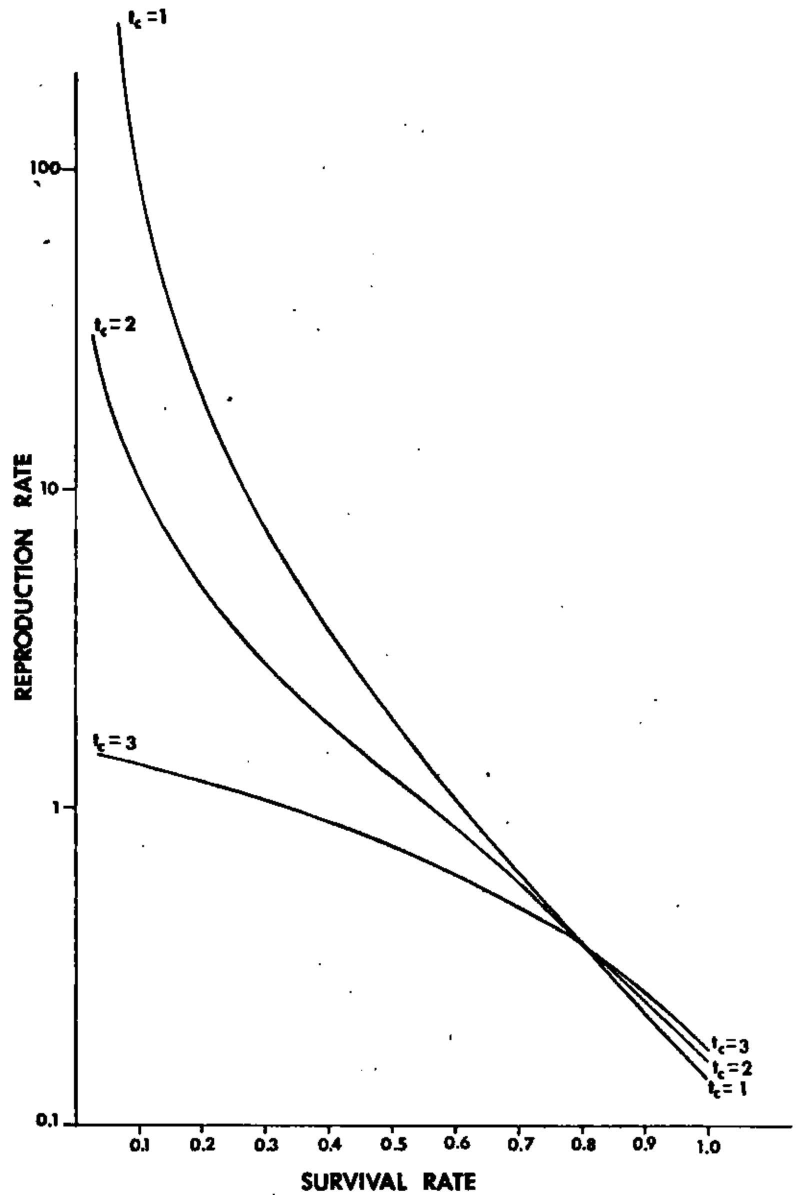

Figure 4. Relationship between reproduction rates and survival rates under the assumption of maturity age tm = 3 and with the various ages entering the fishery tc = 1, 2, and 3.