BIOLOGY OF THE REX SOLE, *GLYPTOCEPHALUS ZACHIRUS*, IN WATERS OFF OREGON

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ABSTRACT

Data are presented on the life history and population dynamics of rex sole, *Glyptocephalus zachirus* Lockington, collected from Oregon waters between September 1969 and October 1973. Length-weight relationships vary little between sexes or with time of year. Otolith annuli form primarily from January through May and were used for age determination. Age and length are highly correlated (r = 0.9945 for males and 0.9864 for females), with females growing faster and living longer than males. Estimates of total instantaneous mortality rate (Z) appear less variable when calculated by the catch-curve method (mean Z of 0.64 for males and 0.51 for females), than by the Jackson method. Age at 50% maturity occurs at 16 cm (about 3 yr) for males and at 24 cm (about 5 yr) for females. Spawning off northern Oregon occurs from January through June, with a peak in March-April. Fecundity is correlated (r = 0.9620) with length of fish. There were 15 recaptures (0.59%) from 2,537 fish tagged off northern Oregon during March and June 1970. Maximum movement of recaptured fish was only 53.9 km, but the low recovery precludes definite conclusions. Twenty loci were detected by starch-gel electrophoretic analysis using rex sole muscle tissue. Of these, three loci were polymorphic, but showed no discernible variation between collections from northern, central, and southern Oregon in April 1973.

Investigation into the life history of rex sole, *Glyptocephalus zachirus* Lockington, by the Oregon Department of Fish and Wildlife provided new information on this species. The broad objective was to develop knowledge of the biology and population dynamics of rex sole found off the Oregon coast which would enhance management of this species.

Specific objectives were to: 1) determine the length-weight and age-length relationships; 2) estimate the total instantaneous mortality rate by two independent methods; 3) determine relationships of maturity and fecundity with length and age, and with the spawning season; and 4) determine if rex sole off Oregon are composed of separate stocks[3] which undergo predictable movements.

The rex sole is a slender, thin flatfish belonging to the family Pleuronectidae (Starks 1918; Norman 1934), the right-eyed flounders. Of the three species of *Glyptocephalus*, rex sole is the only one reported in the eastern Pacific Ocean (Pertseva-Ostroumova 1961). Geographically distributed from southern California to the Bering Sea (Miller and Lea 1972), it is found bathymetrically to 730 m (Alverson et al. 1964). Rex sole is important in the commercial trawl fishery from California northward through British Columbia. In 1972, rex sole was the fifth most important flatfish in weight (1.54 million kg [3.4 million pounds]) in the domestic northeastern Pacific trawl food fishery. *Glyptocephalus zachirus* is also important in the domestic trawl fishery for animal food (Best 1961; Niska 1969), although this fishery has declined in recent years. On the continental shelf off the northern three-fourths of the Oregon coast, rex sole was third in biomass[4] and first in numbers of all flatfish caught with an 89-mm (3.5-inch) mesh trawl.

There is little published information on the biology of rex sole. Villadolid (1927) and Frey (1971) reported briefly on the time of spawning, size and age at maturity, and food habits for specimens captured off California. Hart (1973) summarized the life history of rex sole off Canada and suggested that the lack of information resulted in doubtful deductions. An aging study was conducted on rex sole by Villadolid (1927) who used scales. Domenowske (1966) used otoliths,

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[3]The rex sole spawning in a particular marine location (or portion of it) at a particular season, and which do not interbreed to a substantial degree with any group spawning in a different place, or in the same place at a different season (modified from Ricker 1972).

[4]Demory, R. L., and J. G. Robinson. 1973. Resource surveys on the continental shelf of Oregon. Fish Comm. Oreg., Commer. Fish. Res. Dev. Act Prog. Rep., July 1, 1972 to June 30, 1973, 19 p. (Unpubl. manuscr.).

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scales, and interopercles for aging rex sole; by comparing the age-length relationships, he concluded otoliths were the most readable structure. Vanderploeg (1973) conducted food habit studies on rex sole collected off Oregon. Porter (1964) described the larvae of rex sole, and Waldron (1972) and Richardson (1973) reported on distribution and abundance of rex sole larvae. Tsuyuki et al. (1965) conducted a general starch-gel electrophoresis study on the muscle proteins and hemoglobin of 50 species of North Pacific fish and found that rex sole differed from 10 other pleuronectids tested. Benthic distribution of rex sole was investigated by numerous workers[4] (Alverson et al. 1964; Day and Pearcy 1968; Demory 1971; Alton 1972). Limited tagging studies (Manzer 1952; Harry 1956) were conducted to determine movements of rex sole, but no tagged fish were recaptured.

METHODS

Rex sole were collected by otter trawl off Oregon from the Columbia River south to Cape Blanco at depths of 18-200 m during September 1969-73. Most data were obtained from rex sole captured incidentally to a study of pink shrimp, *Pandalus jordani,* distribution during 1969-70.[5] Rex sole were also obtained from commercial trawl landings at Astoria, Oreg., in 1970 and 1973; at Charleston and Brookings, Oreg., in 1973; and from research vessel catches during the 1971-73 Fish Commission of Oregon (FCO) groundfish surveys.[4,6] All specimens were frozen until time of examination.

Rex sole were sexed by examination of gonads, measured for total length (TL) to the nearest centimeter, and weighed to the nearest gram. The left otolith was removed for aging studies, stored in a 50:50 solution of glycerin and water, and read using reflected light on a dark background (Powles and Kennedy 1967).

The length-weight relationship, by calendar quarters, of rex sole collected off central and northern Oregon in 1969-72 was determined by the least squares method using the logarithmic form of the equation $W = aL^b$, where W is weight in grams, L is length in centimeters, and a and b are constants.

Estimates of the lineal growth of rex sole were obtained from the age-length relationship of fish collected off northern Oregon in September-October 1969 and September 1971. A mean total length (TL) at each age was determined from these data and expressed mathematically in terms of the von Bertalanffy growth equation (Ricker 1958; Ketchen and Forrester 1966).

To obtain the calculated growth parameters, we used ages 1.5-10.5 yr for males and 1.5-12.5 yr for females.

Estimates of the instantaneous total mortality rate (Z) were made using age group data obtained from FCO groundfish cruises off northern Oregon in 1971 and 1973 and off central Oregon in 1972. Two methods, a catch curve (Ricker 1958) and the Jackson technique (Jackson 1939), were used for the analyses.

To determine maturity stages, gonads were examined according to the procedures described by Hagerman (1952), Scott (1954), and Powles (1965). Definitions used for maturity stages are listed in Table 1.

Fecundity was determined from 13 fish collected in February 1970 and measured to the nearest millimeter (TL). Both ovaries were removed from

TABLE 1.—Description of reproductive phases of rex sole gonads used in this study.

Sex	Maturity stage	Description
Females	Immature	(A): Ovaries very small (<40 mm TL), whitish in color, semitransparent, and gelatinous. No eggs discernible to the naked eye.
	Mature	(B): Ripening. Ovaries enlarging, becoming reddish-orange colored and granular in consistency, full of developing eggs that can be recognized by direct observation.
		(C): Ripe. Ovaries full of mostly reddish-orange colored granular eggs, although a few transparent ova are present. Ova can be extruded from the fish by using considerable pressure.
		(D): Spawning. Ovaries full of entirely translucent eggs which will run with slight pressure.
		(E): Spent. Ovaries flaccid, usually empty although occasionally a few eggs will remain. Ovarian membrane very transparent and saclike.
		(F): Recovering. Ovaries filling with fluid, and reddish-orange in color. No ova detectable to the naked eye.
Males	Immature	(A): Testes very small (<3 mm TL), translucent in color and not extending into the abdominal cavity.
	Mature	(B): Ripening. Testes enlarged, extending posteriorly into abdominal cavity, light brown to cream colored, but retain sperm under pressure.
		(C): Ripe and/or spawning. Testes full and cream colored. Sperm will run under no or only slight pressure.
		(D): Spent-recovering. Testes shrunken and transparent or dark brown in color.

[5]Lukas, G., and M. J. Hosie. 1973. Investigation of the abundance and benthic distribution of pink shrimp, *Pandalus jordani,* off the northern Oregon coast. Fish Comm. Oreg., Commer. Fish. Res. Dev. Act, Final Rep., July 1, 1969 to June 30, 1970, 45 p. (Unpubl. manuscr.).

[6]Demory, R.L. 1974. Resource surveys on the continental shelf of Oregon. Fish Comm. Oreg., Commer. Fish. Res. Dev. Act Prog. Rep., July 1, 1973 to June 30, 1974, 6 p. (Unpubl. manuscr.).

each fish and stored in 10% Formalin.[7] Estimates of fecundity were obtained gravimetrically, following the method described by Harry (1959).

To obtain fish for tagging, short tows of about 15 min were made in March and June 1970 off northern Oregon near the mouth of the Columbia River. Any rex sole caught were held for 15-60 min in a tank containing running seawater. Fish in good condition were tagged and released. Petersen disc (vinyl) tags, 16 mm in diameter, were attached by a stainless steel pin inserted through the musculature about ½ inch below the midbase of the dorsal fin. Fishermen were advised of the tagging program, and a $0.75 reward was offered by the FCO for each tagged rex sole returned.

Electrophoresis was used to investigate stock identification of rex sole. A preliminary electrophoretic examination was conducted using muscle tissue of 145 rex sole collected in April 1973 in three nearly equal samples taken off northern, central, and southern Oregon. Tissue extraction and starch gel electrophoresis procedures followed the methods of Johnson et al. (1972). Tests were conducted for polymorphisms in muscle protein and the five enzyme systems: aspartate aminotransferase (AAT) A-I and A-II; lactic dehydrogenase (LDH); peptidase A-I and A-II; phosphoglucomutase (PGM); and tetrazolium oxidase (TO).

RESULTS AND DISCUSSION

Length-Weight Relationships

Length and weight were closely correlated, with the derived coefficient of determination (r^2) varying from 0.9902 to 0.9988 for males and from 0.9872 to 0.9966 for females (Table 2). These coefficients of determination varied little by season, possibly because of the extended spawning period (Villadolid 1927) in the first half of the year. Based on data in Table 2, we calculated mean weights by season at representative lengths. For both sexes weight increase was greatest in the third quarter, average in the second quarter, and slowest in the first and fourth quarters (Table 3). Among mature fish, about 30 cm TL and larger, females generally were slightly heavier than males of the same length (Figure 1). A total of 950 males and 1,121 females were included in the length-weight data analyzed.

[7]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Age and Growth

Validity of the Aging Technique

Opaque or hyaline zones occur on the margin of rex sole otoliths. These zones mark the respective periods of rapid or slow growth. Examination of 265 otoliths from rex sole <27 cm TL collected off northern Oregon from September 1969 through July 1970 revealed that hyaline edges were first observed in September (Figure 2). No hyaline edges were present the previous June or July. In the fall the percentage of otoliths with a hyaline zone on their edge began to increase. By January the majority of otoliths had a hyaline zone on their edge. The percentage rapidly increased and peaked in March when 92.3% had hyaline zone margins. Conversely, opaque zones on edges were at their lowest in March, gradually increasing until June or July when all otoliths had opaque edges.

TABLE 2.—Length-weight relationship ($\log_{10} W = \log_{10} a + b \log L$) by quarterly period for male and female rex sole collected off central and northern Oregon, 1969-72.[1]

Period and sex	Number of fish	Constant log *a*	Constant *b*	Standard deviation	Correlation coefficient	Coefficient of determination
January-March:						
Male	119	−3.1447	3.5551	0.1437	0.9972	0.9944
Female	68	−3.0978	3.5095	0.1587	0.9936	0.9872
Both	187	−3.1248	3.5258	0.1539	0.9932	0.9864
April-June:						
Male	386	−2.8398	3.3557	0.1501	0.9994	0.9988
Female	356	−2.9398	3.4345	0.1488	0.9980	0.9960
Both	742	−2.8903	3.3914	0.1567	0.9984	0.9968
July-September:						
Male	350	−3.0884	3.5598	0.1461	0.9982	0.9964
Female	621	−2.9886	3.5112	0.1661	0.9983	0.9966
Both	971	−3.0631	3.5553	0.1788	0.9988	0.9976
October-December:						
Male	95	−2.9823	3.4423	0.1269	0.9951	0.9902
Female	76	−2.9795	3.4423	0.1599	0.9972	0.9944
Both	171	−2.9500	3.4252	0.1562	0.9973	0.9946

[1]Regression analysis conducted on 11- to 36-cm males and 11- to 51-cm females.

TABLE 3.—Computed mean weight per quarter at selected lengths of male and female rex sole, using regression formulas from Table 2.

Sex	Total length (cm)	Computed mean weight (g) per quarter[1] I	II	III	IV
Male	15	11	13	13	12
	25	67	71	77	68
	35	221	220	256	215
Female	15	11	13	14	12
	25	64	73	83	68
	35	210	231	271	231
	45	506	547	655	514

[1] I = Jan.-Mar.; II = Apr.-June; III = July-Sept.; IV = Oct.-Dec.

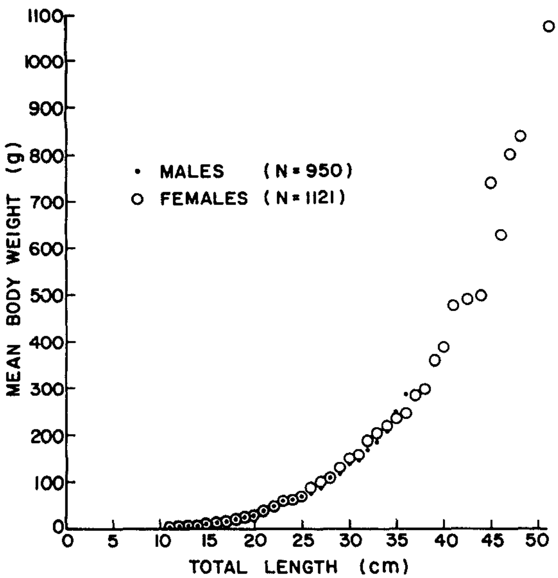

FIGURE 1.—Length-weight relationship for male and female rex sole collected off central and northern Oregon, 1969-72. Body weights obtained from an average of quarterly mean values.

From these observations, we concluded that the hyaline margin is deposited on otoliths during each winter and spring for all sizes of rex sole. Thus, these hyaline zones are interpreted as annuli with a year's growth occurring between successive hyaline margins. These results are similar to those of Villadolid (1927) who found northern California rex sole formed a scale annulus in March through May.

Age-Length Relationship

After 3.5 yr of age, females were consistently longer than males at a given age. Females also attained an older age and longer length. Statistics for both males and females followed the von Bertalanffy growth curve, as a good fit was obtained for most age groups (Figure 3, Table 4).

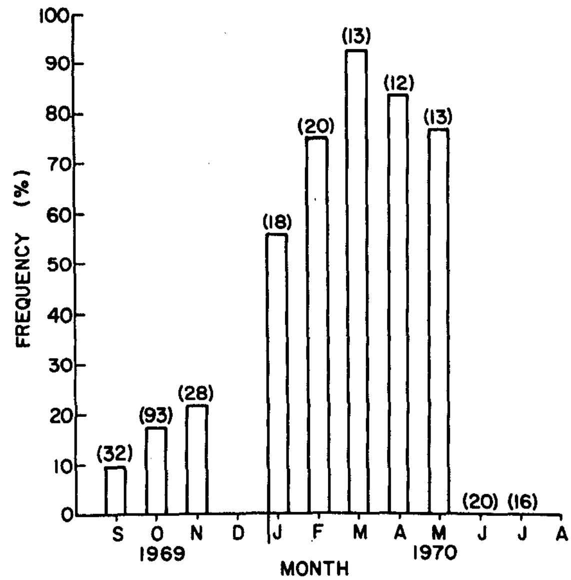

FIGURE 2.—Percent frequency of hyaline edges found on otoliths of 265 rex sole (<27 cm TL) collected off northern Oregon, September 1969-July 1970. Numbers in parentheses represent sample size.

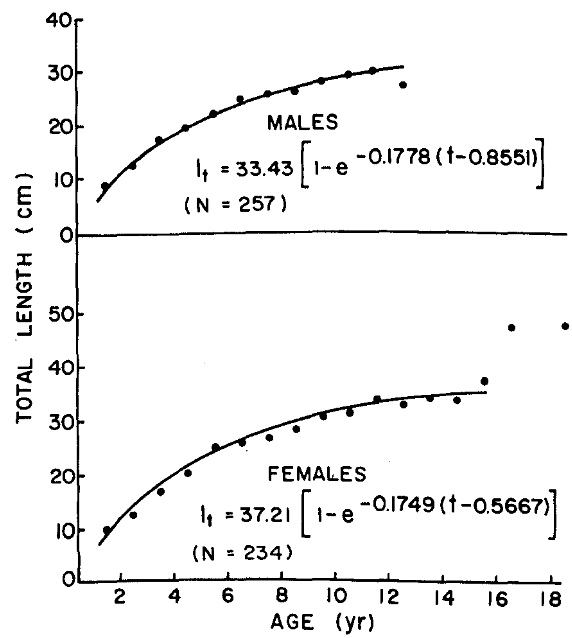

FIGURE 3.—Age-length relationship for male and female rex sole collected off northern Oregon, September-October 1969 and September 1971.

The calculated length at infinity (L_∞) of 33.43 cm for males was close to the computed mean value of 29.33 cm (Table 4). For females the L_∞ of

TABLE 4.—Computed mean length at age and mean length at age estimated by von Bertalanffy growth equation for 45 unsexed, 189 male, and 212 female rex sole collected off northern Oregon in September-October 1969 and September 1971.

	Male			Female		
Age[1] (yr)	No.	Computed mean length (cm)	Estimated mean length[2] (cm)	No.	Computed mean length (cm)	Estimated mean length[2] (cm)
1.5	[3]45	9.20	9.44	[3]45	9.20	8.91
2.5	13	12.61	13.36	7	12.71	13.44
3.5	36	17.00	16.65	33	16.64	17.25
4.5	29	19.52	19.39	11	20.45	20.45
5.5	15	21.66	21.69	19	24.95	23.14
6.5	17	24.55	23.62	14	25.64	25.39
7.5	23	25.39	25.22	9	26.33	27.29
8.5	23	25.82	26.57	17	28.05	28.88
9.5	16	27.37	27.69	24	30.37	30.21
10.5	10	28.90	28.63	28	31.03	31.34
11.5	6	29.33	29.42	20	33.35	32.28
12.5	1	27.00	30.07	14	32.45	33.07
13.5				4	33.75	33.73
14.5				2	33.50	34.29
15.5				6	37.00	34.76
16.5				1	47.00	
17.5				0	0.00	
18.5				3	47.30	

[1]These fall-caught fish were assumed to be about one-half way through the growing season, based upon otolith readings.
[2]Von Bertalanffy growth equations were based on 1- to 10-yr-old males (L_∞ = 33.43 cm, K = 0.1778, t_0 = −0.8551 yr), and 1- to 12-yr-old females (L_∞ = 37.21 cm, K = 0.1747, t_0 = −0.5667 yr).
[3]Sexes were not separated for age 1 fish (45 specimens).

37.21 cm fit observed data through age 15.5, but was far below the maximum computed mean TL of 47.30 cm. The apparent discrepancy does not invalidate the data because Knight (1968) noted that L_∞ is not the maximum obtainable length, but rather a mathematical tool needed in computations for the von Bertalanffy growth equation. This is exemplified by our collection of a 23-yr-old (±1 yr), 59-cm female rex sole off northern Oregon in February 1970, which we consider as about the maximum length and age of rex sole. Hart (1973) reported a 24-yr-old rex sole was collected off British Columbia, but no length was given.

Mortality Rate

Estimates of the total instantaneous mortality rate (Z) derived from data in Table 5 and using the catch curve method varied from 0.53 to 0.70 for males and from 0.44 to 0.55 for females (Table 6). In this analysis the natural logarithm of the numbers of males and females caught at each age was plotted against the respective age class (Figures 4, 5). The total mortality rate was the best fitted slope on the right side of the catch curve, determined by linear regression using ages ranging maximally from 6 to 16 yr (Table 5).

Estimates of Z using the Jackson method ranged from 0.43 to 0.61 for males and from 0.20 to 0.52 for females (Table 6). In this method annual survival rate (S) is:

TABLE 5.—Numbers of rex sole per age group caught during groundfish surveys off northern Oregon in 1971 and 1973 and central Oregon in 1972.

Age	Number males			Number females		
(yr)	1971	1972	1973	1971	1972	1973
2	7	14	11	0	19	26
3	50	68	75	59	70	116
4	67	142	45	102	124	56
5	270	290	337	353	207	514
6	244	663	387	329	732	613
7	375	278	881	418	501	1,217
8	380	412	432	400	560	570
9	215	274	382	366	465	596
10	320	45	106	582	108	201
11	67	123	42	138	283	94
12	76	24	72	247	32	219
13	5	14	11	69	57	30
14	10	2	0	50	10	26
15	5	7	0	20	10	0
16	2	2	0	7	3	9
18				9	3	0
21						4
Total	2,093	2,358	2,781	3,149	3,184	4,291

TABLE 6.—Estimates of the total instantaneous mortality rate (Z) of rex sole collected off northern Oregon in September 1971 and 1973 and off central Oregon in September 1972.

Year and sex	Age of maximum numbers	Ages utilized	Catch curve estimates of Z	Jackson method estimates of Z
1971:				
Male	8	8-16	0.70	0.43
Female	10	7-16	0.44	0.20
1972:				
Male	6	6-13	0.53	0.44
Female	6	6-16	0.55	0.31
1973:				
Male	7	7-13	0.68	0.61
Female	7	7-14	0.54	0.52
Mean:[1]				
Male			0.64	0.49
Female			0.51	0.34

[1]Based on simple average of Z's for the 3 yr.

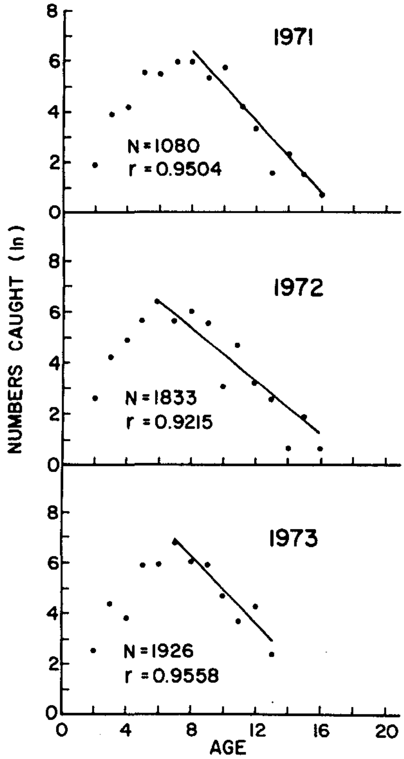

FIGURE 4.—Catch curves of male rex sole collected off Oregon in September 1971, 1972, and 1973.

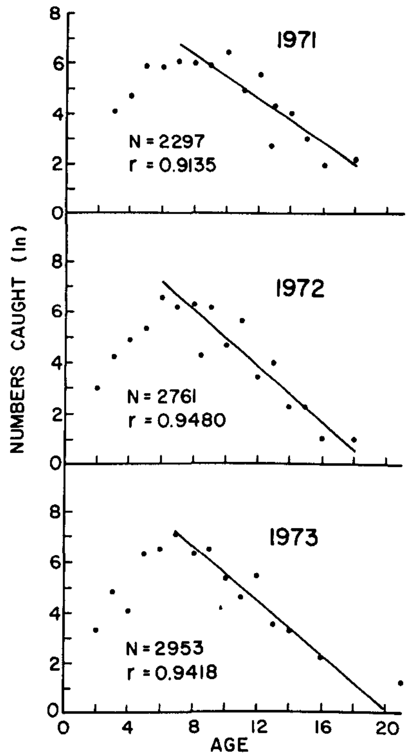

FIGURE 5.—Catch curves of female rex sole collected off Oregon in September 1971, 1972, and 1973.

$$S = \frac{N_7 + N_8 + \ldots + N_r}{N_6 + N_7 + \ldots + N_{r-1}}$$

where N is the number of fish of age group r caught. Annual mortality rate is $1 - S$ and the corresponding instantaneous rate of total mortality is obtained from the expression $S = e^{-z}$, where e and Z are derived from Ricker (1958).

The catch curve method probably gives more reliable estimates of Z than those obtained using the Jackson method. In the Jackson method the larger samples of younger fish strongly affect the estimates, with the older age groups weighted less. Thus, the Jackson method substantially underestimates the mean Z for the entire right limb of the catch curve.

Reproduction

Size at Maturity

Some males were mature at 13 cm while no females reached maturity until 19 cm (Figure 6).

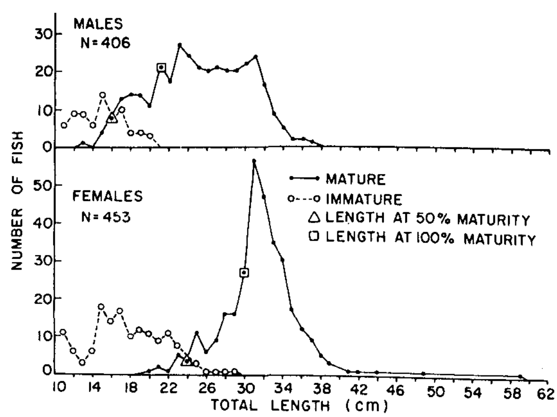

FIGURE 6.—Size composition of immature and mature rex sole, by sex, collected off northern Oregon, September 1969-July 1970.

About 50% of the males were mature at 16 cm, and all were mature at 21 cm. For females, 50% were mature at 24 cm and 100% were mature at 30 cm. Lengths at 50% and 100% maturity correspond to about ages 3 and 5 for males and 5 and 9 for females (Table 4).

The only maturity data on rex sole available from other areas is that of Villadolid (1927). He found that both males and females off San Francisco, Calif., were fully mature at age 4, which corresponded to about 21.8 cm for males and 22.8 cm for females. Possibly rex sole mature earlier in the southern portion of their range.

Spawning

Duration of the spawning period was from January through June, with a peak in March-April (Figure 7). Although samples were not obtained during August and December, the percentage of fish in each reproductive phase gives a good indication of the spawning time.

The 6-mo spawning period we found is longer than the January through April spawning reported by Villadolid (1927) for rex sole collected off central California in 1925 and 1926. Paul Reed (FCO, pers. commun.) found a prolonged spawning from January through August for 3,189 rex sole collected off northern California in 1949-54 and 1962-63. This suggests the duration of rex sole spawning varies by area and year.

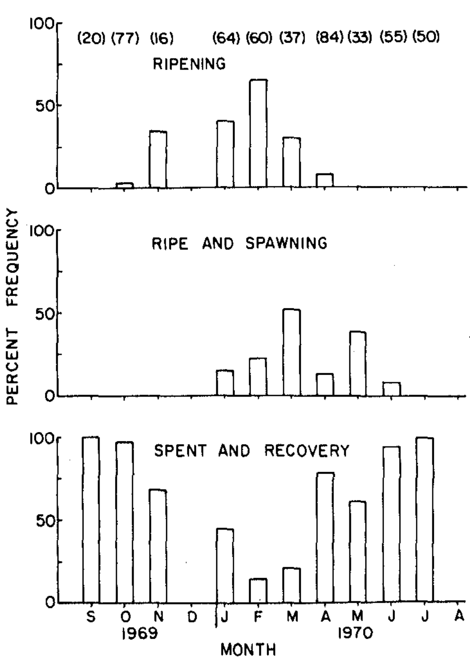

FIGURE 7.—Annual cycle of reproduction in 496 rex sole (274 males and 222 females) collected off northern Oregon, September 1969-July 1970. The number in each monthly sample is shown in parentheses.

Fecundity

Examination of 13 mature females ranging from 240 to 590 mm TL yielded fecundity estimates of 3,900 and 238,100 ova, respectively. The numbers of ova generally increased with size of the female. In 11 of 13 fish, the right ovary contained more ova than the left (100 to 12,700 more). A linear regression fitted to the fecundity-length data gave a correlation coefficient of 0.9620 (Figure 8). The formula for the regression line was $F = 5.3797 \times 10^{-7} L^{4.22667}$, where F is fecundity in number of ova and L is fish TL in millimeters.

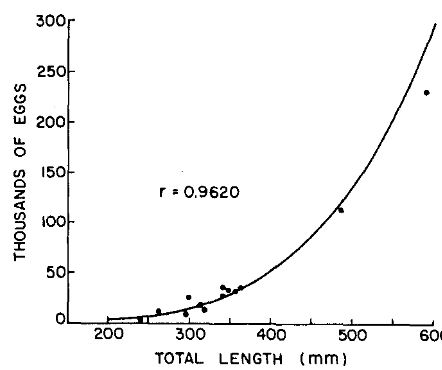

FIGURE 8.—Fecundity-length relationship for 13 rex sole collected off northern Oregon, February 1970.

Stock Identification

Tagging Experiment

A total of 2,537 rex sole were tagged and released off the northern Oregon coast in April (200) and June 1970 (2,337). There were 15 recaptures (0.59% recovery) by July 1974, all from the June 1970 tagging (Table 7). Maximum movement was 53.9 km, and 788 days was the longest time at liberty. There was little change in the depth range occupied by recaptured fish, which were released in 42-154 m and recovered by trawls in 51-101 m.

These results suggest only limited movement by rex sole. However, tag returns were too few to justify definite conclusions. This low recovery is similar to reports of rex sole tagged off British Columbia (Manzer 1952 [90 tagged]) and Oregon (Harry 1956 [19 tagged]) from which no fish were recovered.

TABLE 7.—Release and recovery data on 2,537 rex sole tagged off northern Oregon, April and June 1970.

Date	Number tagged	Number recovered	Percent recovery	Distance traveled (km)	Days at liberty
April 1970	200	0	0.00	0.0	0.0
June 1970	2,337	15	0.64	1.5	4
				17.1	4
				0.0	5
				3.7	18
				23.0	40
				14.1	189
				2.2	240
				8.0	278
				14.3	279
				0.9	294
				38.9	346
				53.9	364
				unknown	374
				3.9	450
				52.3	788
Total	2,537	15	0.59		

The low returns possibly were caused by rex sole not surviving the tagging process. Manzer (1952) reported rex sole reacted badly to capture and tagging. Most tagged rex sole released at the ocean surface did not immediately descend. Instead, unlike most other flatfish species, they curled into a semicircle and moved across the water surface in a skipping motion. This peculiar reaction might have resulted in a high initial tagging mortality from predation. It may also indicate a stress condition from which fish did not recover.

Starch-Gel Electrophoretic Analysis

There were 20 loci detected in the muscle tissue of 145 rex sole. Of these loci 13 were enzymes and 7 were muscle proteins (Table 8). Only three of the loci (15%) were polymorphic.

The polymorphism was found in only three of the eight systems studied or examined. AAT staining occurred in two anodal regions (A-I and A-II). Zone II was the only polymorphic region, having A, B, C, and D alleles (Figure 9, Table 9). The enzyme peptidase also had two anodal regions. Only zone II was polymorphic, with A and B alleles (Figure 10, Table 10). A third enzyme, PGM, was polymorphic, having only one locus which had A[1], A, and B alleles (Figure 11, Table 11).

No discernible variation in the frequency or kinds of phenotypes found was observed between rex sole collections from off Astoria (northern),

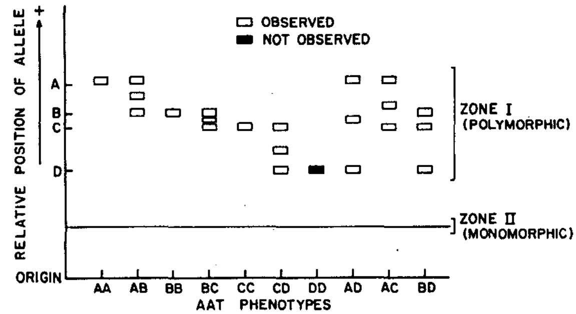

FIGURE 9.—Diagrammatic representation of aspartate aminotransferase (AAT) phenotypes in starch gel from 145 rex sole collected off Oregon, April 1973.

TABLE 9.—Frequencies of aspartate aminotransferase (AAT) phenotypes in 145 rex sole collected off Astoria, Charleston, and Brookings, Oreg., in April 1973.

Item	Astoria	Charleston	Brookings
Sample size	52	43	50
Date	5, 9 April	30 April	8 April
AAT phenotypes:			
AA	3	8	6
AB	18	3	10
BB	9	10	11
BC	12	12	9
CC	3	2	3
CD	1	0	0
DD	0	0	0
AD	1	1	0
AC	4	6	9
BD	1	1	2
Frequency of alleles:			
A	0.28	0.30	0.31
B	0.47	0.42	0.43
C	0.23	0.26	0.24
D	0.02	0.02	0.02

TABLE 8.—Results of electrophoretic tests of muscle tissue samples from 145 rex sole collected off Oregon, April 1973.

Protein[1]	No. of bands in starch gel	Proposed no. of loci	Proposed no. of alleles per locus	Type of alleles found	Phenotypic variation
AAT A-I	1	1	1	—	Monomorphic
AAT A-II	4	1	4	A,B,C,D	Polymorphic
LDH	1	1	1	—	Monomorphic
Peptidase A-I	1	1	1	—	Monomorphic
Peptidase A-II	2	1	2	A,B	Polymorphic
PGM	3	1	3	A[1],A,B	Polymorphic
TO	1	1	1	—	Monomorphic
Muscle proteins[2]	7	7	1	—	Monomorphic

[1]AAT (aspartate aminotransferase); LDH (lactate dehydrogenase); PGM (phosphoglucomutase); TO (tetrazolium oxidase).
[2]Analysis of muscle proteins was nonspecific, with 6 anodal (+) bands and 1 cathodal (−) band found.

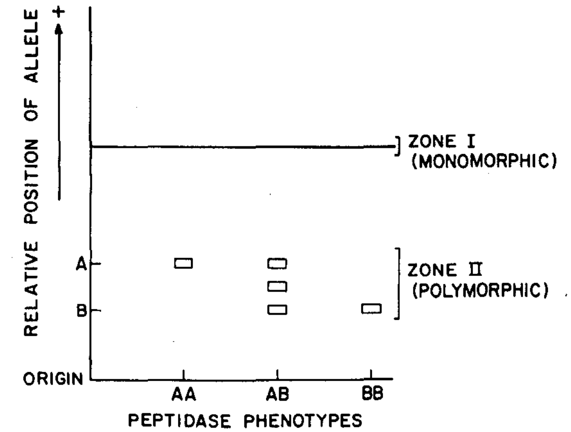

FIGURE 10.—Diagrammatic representation of peptidase phenotypes in starch gel from 137 rex sole collected off Oregon, April 1973.

TABLE 10.—Frequencies of peptidase anodal zone II phenotypes in 137 rex sole collected off Astoria, Charleston, and Brookings, Oreg., in April 1973.

Item	Astoria	Charleston	Brookings
Sample size[1]	50	43	44
Date	5, 9 April	30 April	8 April
Peptidase phenotypes:			
AA	10	10	13
AB	30	17	22
BB	10	16	9
Frequency of alleles:			
A	0.50	0.43	0.55
B	0.50	0.57	0.45

[1]An additional two rex sole from the Astoria sample and six fish from the Brookings sample did not develop distinct patterns and hence are not included.

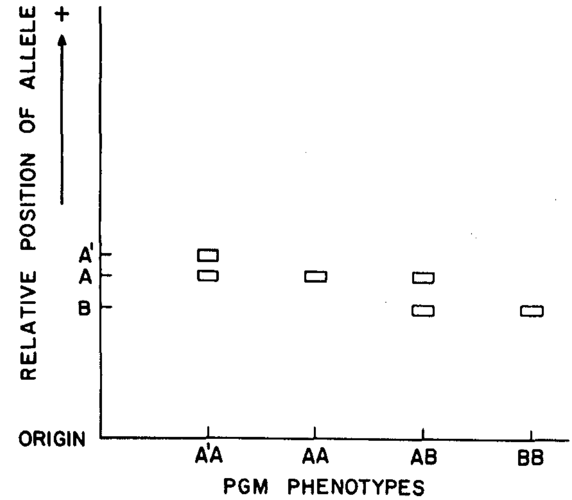

FIGURE 11.—Diagrammatic representation of phosphoglucomutase (PGM) phenotypes in starch gel from 145 rex sole collected off Oregon, April 1973.

TABLE 11.—Frequencies of phosphoglucomutase (PGM) phenotypes in 145 rex sole collected off Astoria, Charleston, and Brookings, Oreg., in April 1973.

Item	Astoria	Charleston	Brookings
Sample size	52	43	50
Date	5, 9 April	30 April	8 April
PGM phenotypes:			
A[1]A	0	0	1
AA	51	42	49
AB	0	1	0
BB	1	0	0
Frequency of alleles:			
A[1]	0.00	0.00	0.01
A	0.98	0.99	0.99
B	0.02	0.01	0.00

Charleston (central), or Brookings (southern) Oregon (Tables 9-11). These data are insufficient to warrant extended speculation. However, they suggest that geographic selection or variation in rex sole off Oregon, if any, may not revolve around the genetic system included in the eight systems tested. Other alternatives, such as testing additional genetic systems or possible use of helminth parasites as biological tags, should be investigated to provide a more extensive evaluation of the population structure of rex sole off Oregon as a possible adjunct to effective management decisions.

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