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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 years) for males and at 24 cm (about 5 years) 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.

Biology of the Rex Sole, *Glyptocephalus zachirus* Lockington, in Waters off Oregon

by

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

INTRODUCTION

Rex sole, *Glyptocephalus zachirus* Lockington, is a slender, thin flatfish belonging to the family Pleuronectidae (Bailey, 1970), the right-eyed flounders. Of the three species of *Glyptocephalus*, it 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 (399 f) (Alverson *et al.*, 1964). Rex sole is important in the commercial trawl fishery from Santa Barbara, California northward through the Queen Charlotte Islands in British Columbia (Appendix Table 1). In 1972, rex sole was the fifth most important flatfish in weight (3.4 million pounds) in the domestic northeastern Pacific trawl food fishery. *G. 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 (Demory and Robinson, 1973) and first in numbers of all flatfish caught with an 89 mm (3.5 in) mesh trawl.

My study was conducted to help fill the need for more information on the general biology and population dynamics of this important flatfish. The broad objective was to develop knowledge of the biology of rex sole off the Oregon coast which would enhance management of this species. Specific objectives were: (1) to determine if length-weight and age-length are related; (2) to estimate the total instantaneous mortality rate by two independent methods; (3) to determine if maturity and fecundity are related to length and age, and to the spawning season; and (4) to determine if rex sole off Oregon are composed of separate stocks[1/] which undergo predictable movements.

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, reporting that the paucity of information necessitates deductions made in doubt. An aging study was conducted on rex sole by Villadolid (1927) who used scales. Domenowske (1966) used otoliths, scales and interopercles for aging rex sole, and by comparing the age-length relationships, he concluded otoliths were the most readable structure. Vanderploeg (1973) conducted food habit studies on rex sole collected

1/ The term stock is used here (modified from Ricker, 1972) to define the rex sole spawning in a particular marine location (or portion of it) at a particular season, which fish to a substantial degree do not interbreed with any group spawning in a different place, or in the same place at a different season.

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 (Alverson et al., 1964; Day and Pearcy, 1968; Demory, 1971; Alton, 1972; Demory and Robinson, 1973). Limited tagging studies (Manzer, 1952; Harry, 1956) were conducted to determine movements of rex sole, but no tagged fish were recaptured.

Several studies were conducted on the abnormalities and diseases of rex sole. Although rex sole are primarily dextral, a few sinistral specimens were found (Follet et al., 1960). A skin neoplasm disease was noted by Wellings et al. (1965).

METHODS

Rex sole were collected by otter trawl off Oregon from the Columbia River south to Cape Blanco at depths of 18.3-200 m (10-109.4 f) during September 1969-1973. Most data were obtained from rex sole captured incidentally to a study of pink shrimp (Pandalus jordani) distribution during 1969-1970 (Lukas and Hosie, 1973). Rex sole were also obtained from commercial trawl landings at Astoria, Oregon in 1970 and 1973; at Charleston and Brookings, Oregon in 1973; and from research vessel catches during the 1971-1973 Fish Commission of Oregon (FCO) groundfish surveys (Demory and Robinson, 1973; Demory, 1974). All specimens were frozen until time of examination.

Most rex sole were sexed by examination of gonads, measured for total length (TL) to the nearest centimeter, and weighed to the nearest gram. For aging studies the left otolith was removed, 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 1969-1972 was determined by the least squares method using the logarithmic form of the equation $W = aL^b$, where W is weight (g), L is length (cm), 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 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, I used ages 1.5-10.5 years for males and 1.5-12.5 years 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 (Appendix Table 2). Two methods, a catch curve (Ricker, 1958) and the Jackson (1939) technique, were used for the analyses.

To determine maturity stages, gonads were examined according to procedures described by Hagerman (1952), Scott (1954), and Powles (1965). Maturity stages recorded are defined in Appendix Table 3.

Fecundity was determined from 13 fish collected in February 1970 and measured to the nearest mm (TL). Both ovaries from each fish were removed and stored in 10% Formalin. 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 sea water. 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 1/2-in 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 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 0.9902-0.9988 for males and 0.9872-0.9966 for females (Table 1, Appendix Table 4). 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 1, I calculated mean weights at four representative lengths. For both sexes growth was greatest in the third quarter, average in the second quarter and slowest in the first and fourth quarters (Table 2). Figure 1 shows that among mature fish, about 30 cm and larger in length, the females appear to be slightly heavier than males of the same length. A total of 950 males and 1,121 females were included in the length-weight data analyzed.

Age and Growth

Validity of the Aging Technique

Narrow, 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 in length collected off northern Oregon from September 1969 through July 1970 revealed that hyaline

Table 1. Data to describe the length-weight relationship ($\log_{10}$ Weight = $\log_{10}$ a + b log Length) by quarterly period for male and female rex sole collected off central and northern Oregon, 1969-1972.[1]

Months 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 11-36 cm males and 11-51 cm females.

Table 2. Computed mean weight per quarter at selected lengths of male and female rex sole using regression formulas from Table 1.

Sex	Total length (cm)	Calculated mean weight (g) per quarter			
		I[1/]	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.-Jun., III = Jul.-Sep., IV = Oct.-Dec.

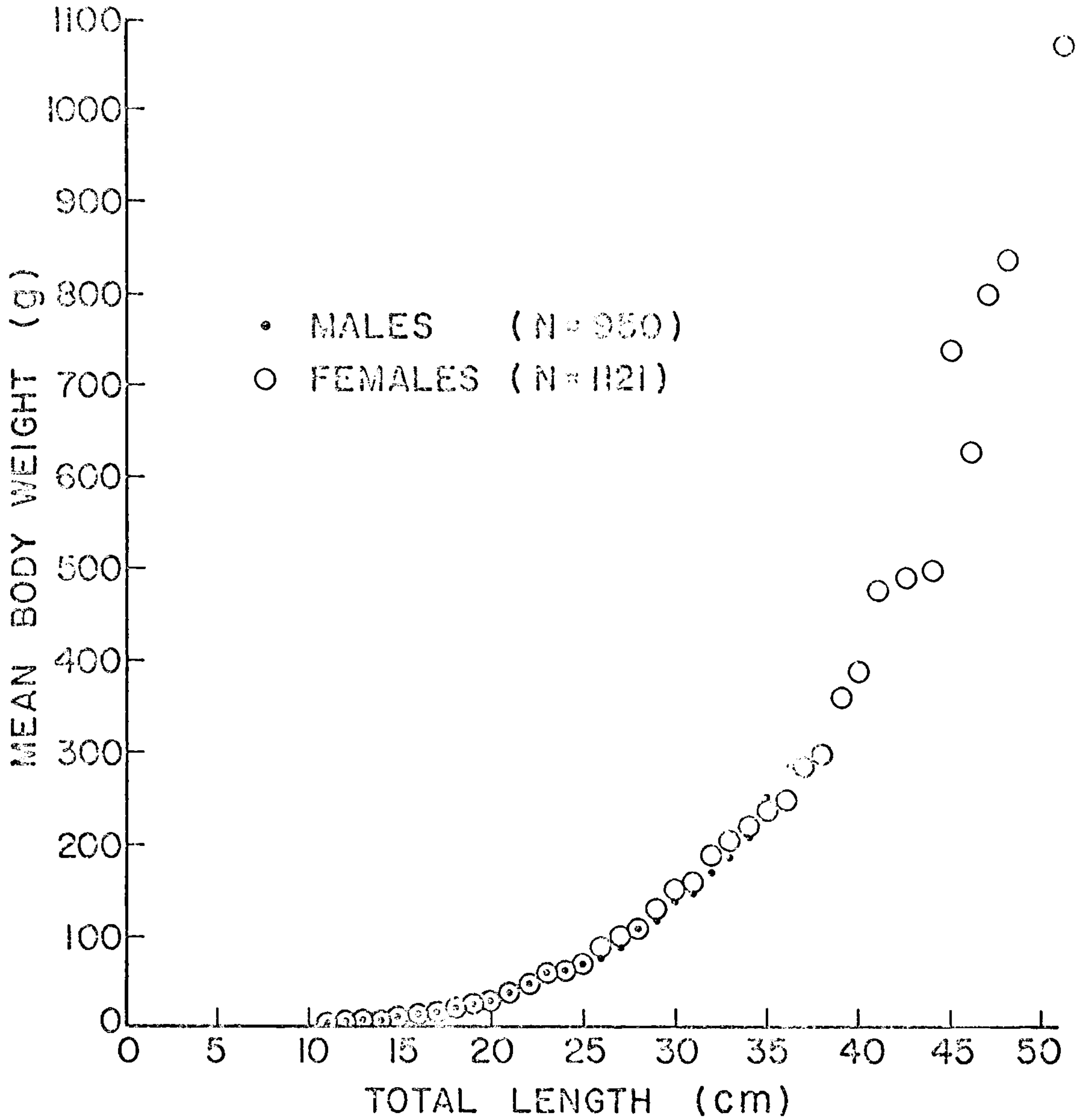

Figure 1. Length-weight relationship for male and female rex sole collected off central and northern Oregon, 1969-1972. Body weights obtained from an average of quarterly mean values.

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. The opaque margins then slowly decreased in occurrence.

From these observations I conclude 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, indicating a years' growth 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 years, females were consistently longer than males at a given age and 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 3).

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

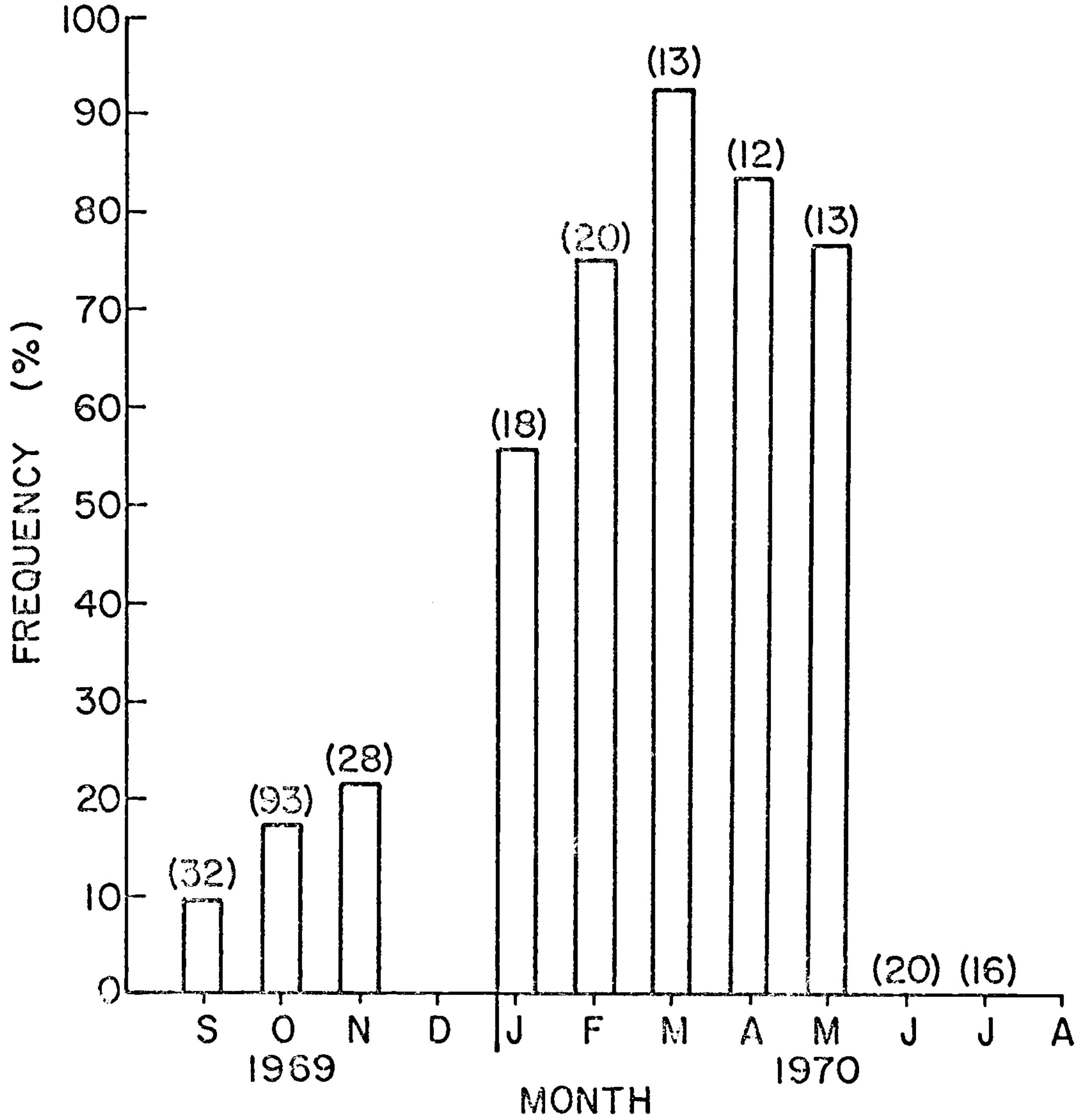

Figure 2. Percent frequency of hyaline edges found on otoliths of 265 rex sole (< 27 cm TL) collected off northern Oregon, September 1969-July 1970. Numbers in parentheses represent sample size.

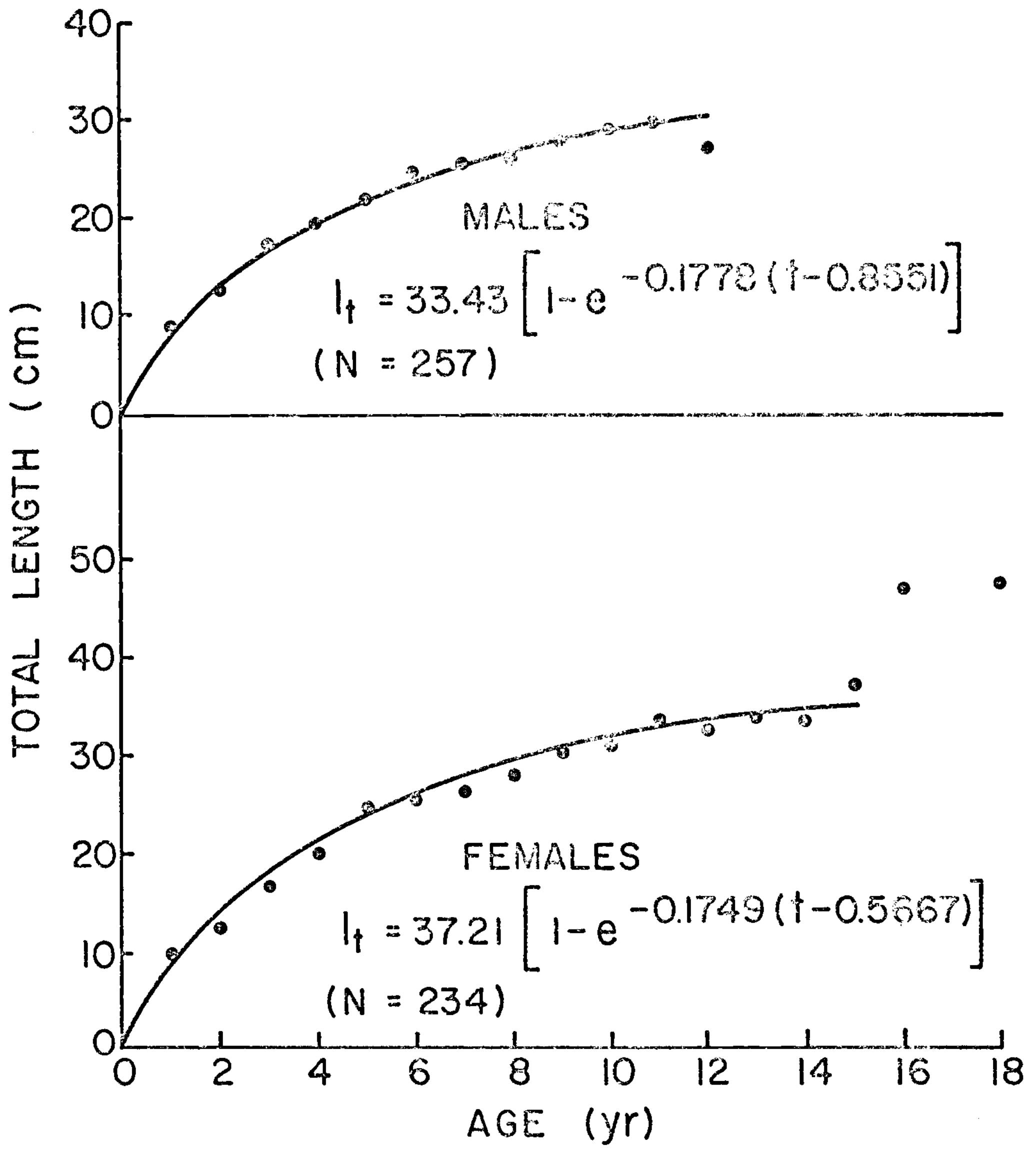

Figure 3. Age-length relationship for male and female rex sole collected off northern Oregon, September-October 1969 and September 1971.

Table 3. 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 (Years)[1]	No.	Computed mean length (cm)	Estimated[3] mean length (cm)	No.	Computed mean length (cm)	Estimated[3] mean length (cm)
1.5	45[2]	9.20	9.44	45[2]	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/ Sexes were not separated for age 1 fish (45 specimens).

3/ von Bertalanffy growth equations were based on 1-10 year-old males (L_∞=33.43 cm, K=0.1778, t_o=-0.8551 yr), and 1-12 year-old females (L_∞=37.21 cm, K=0.1747, t_o=0.5667 yr).

(Table 3). For females the L_∞ of 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 my collection of a 23 year-old (± 1 year), 59 cm female rex sole off northern Oregon in February 1970, which I consider as about the maximum length and age of rex sole. Hart (1973) reported a 24 year-old rex sole was collected off British Columbia, but no length was given.

Mortality Rate

Estimates of the total instantaneous mortality rate (Z) using the catch curve method varied from 0.53 to 0.70 for males and 0.44 to 0.55 for females (Table 4). In this analysis the natural logarithm of the numbers of males and females caught at each age group was applied to the age classes obtained (Figures 4 and 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 6-16 yr.

Estimates of Z using the Jackson method ranged from 0.43-0.61 for males and 0.20-0.52 for females (Table 4). In this method annual survival rate (S) = $\frac{N_7 + N_8 + \ldots + N_r}{N_6 + N_7 + \ldots + N_{r-1}}$

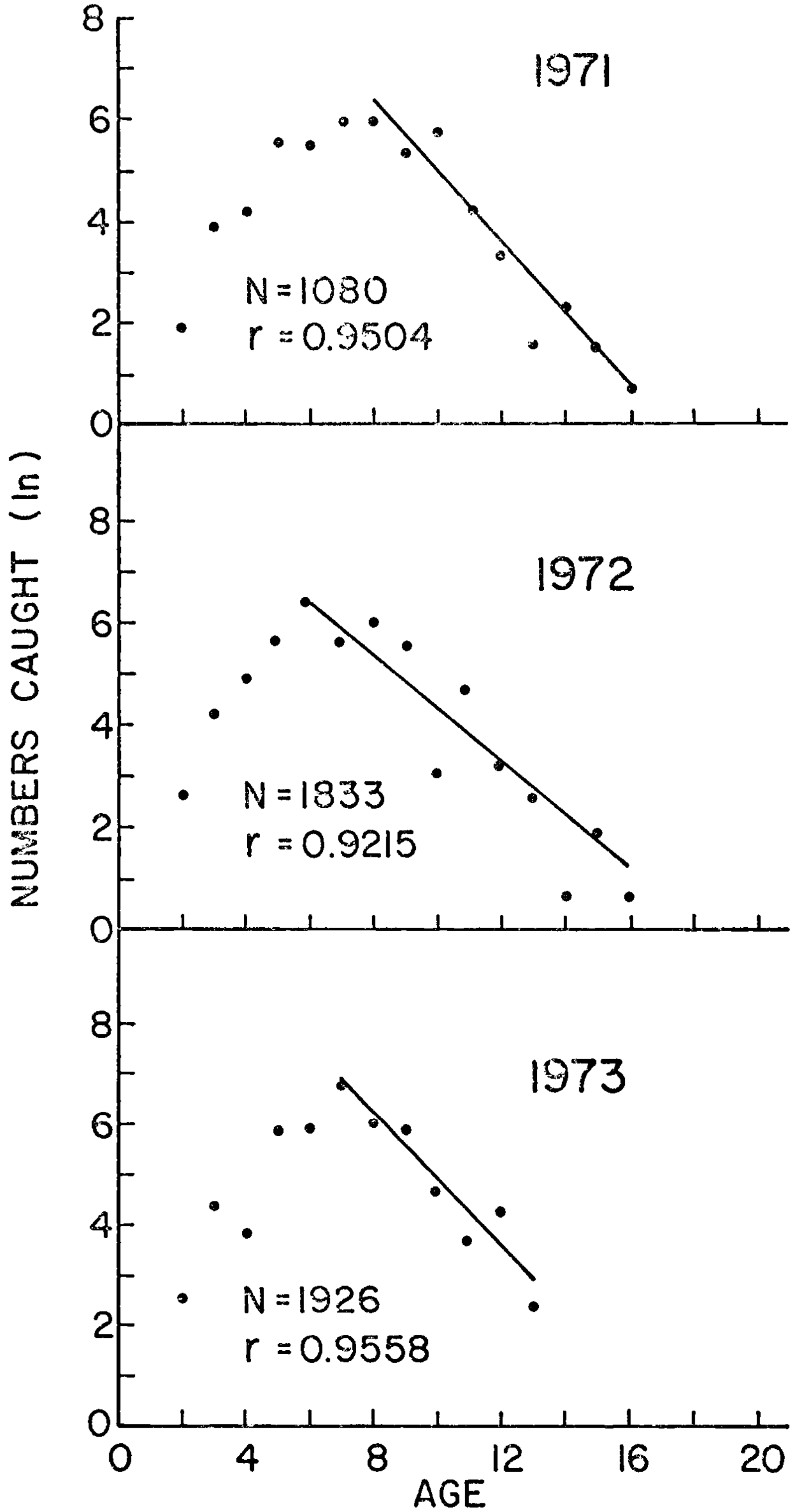

Figure 4. Catch curves of male rex sole collected off Oregon in September of 1971, 1972 and 1973.

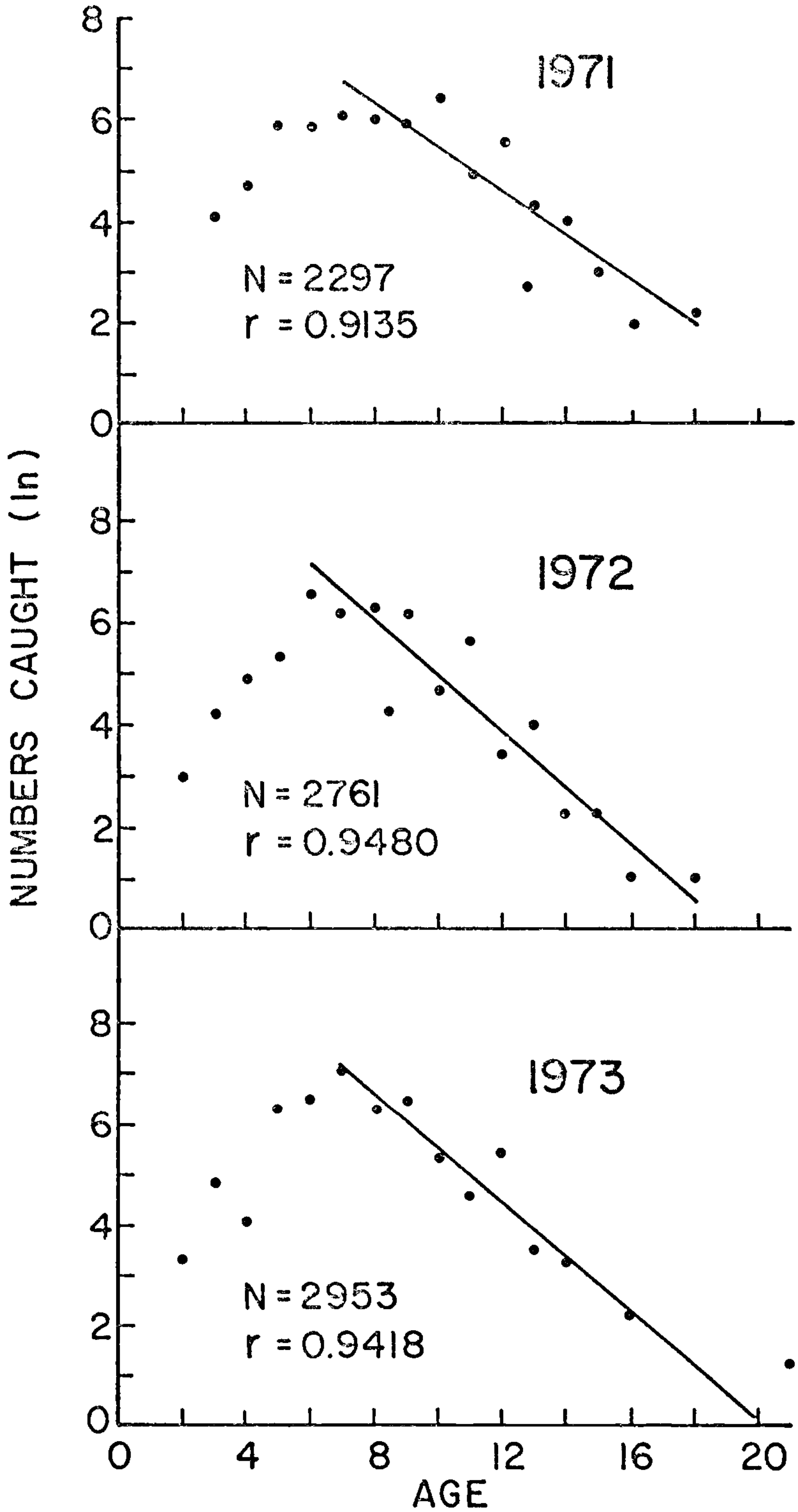

Figure 5. Catch curves of female rex sole collected off Oregon in September of 1971, 1972 and 1973.

Table 4. 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	7	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 of all years[1]				
Male			0.64	0.49
Female			0.51	0.34

[1] Based on simple average of Z's for the three years.

and 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, Appendix 2).

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). 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 2).

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, California, 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 six-month spawning period I 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. comm.) found a

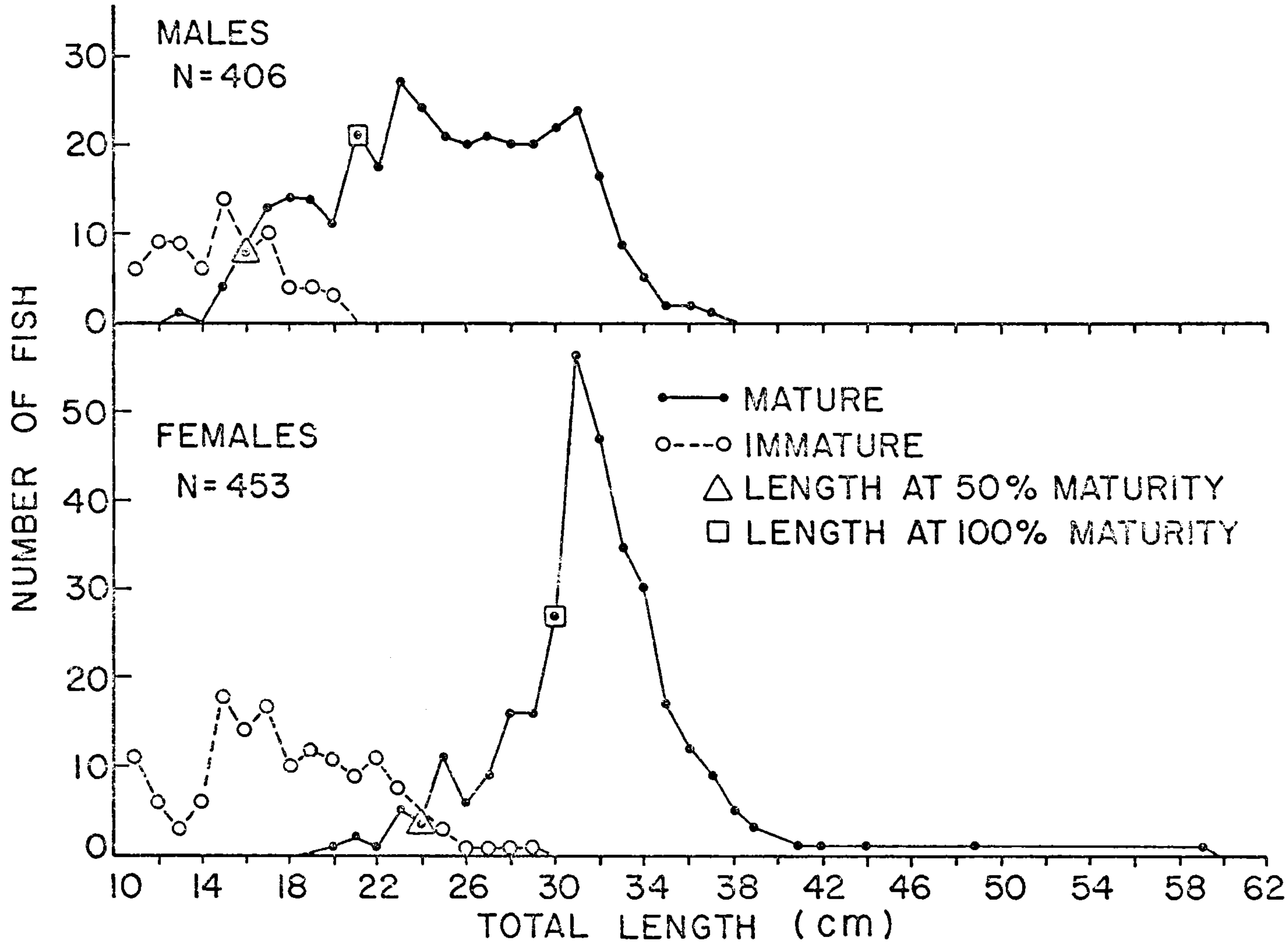

Figure 6. Size composition of immature and mature rex sole, by sex, collected off northern Oregon, September 1969-July 1970.

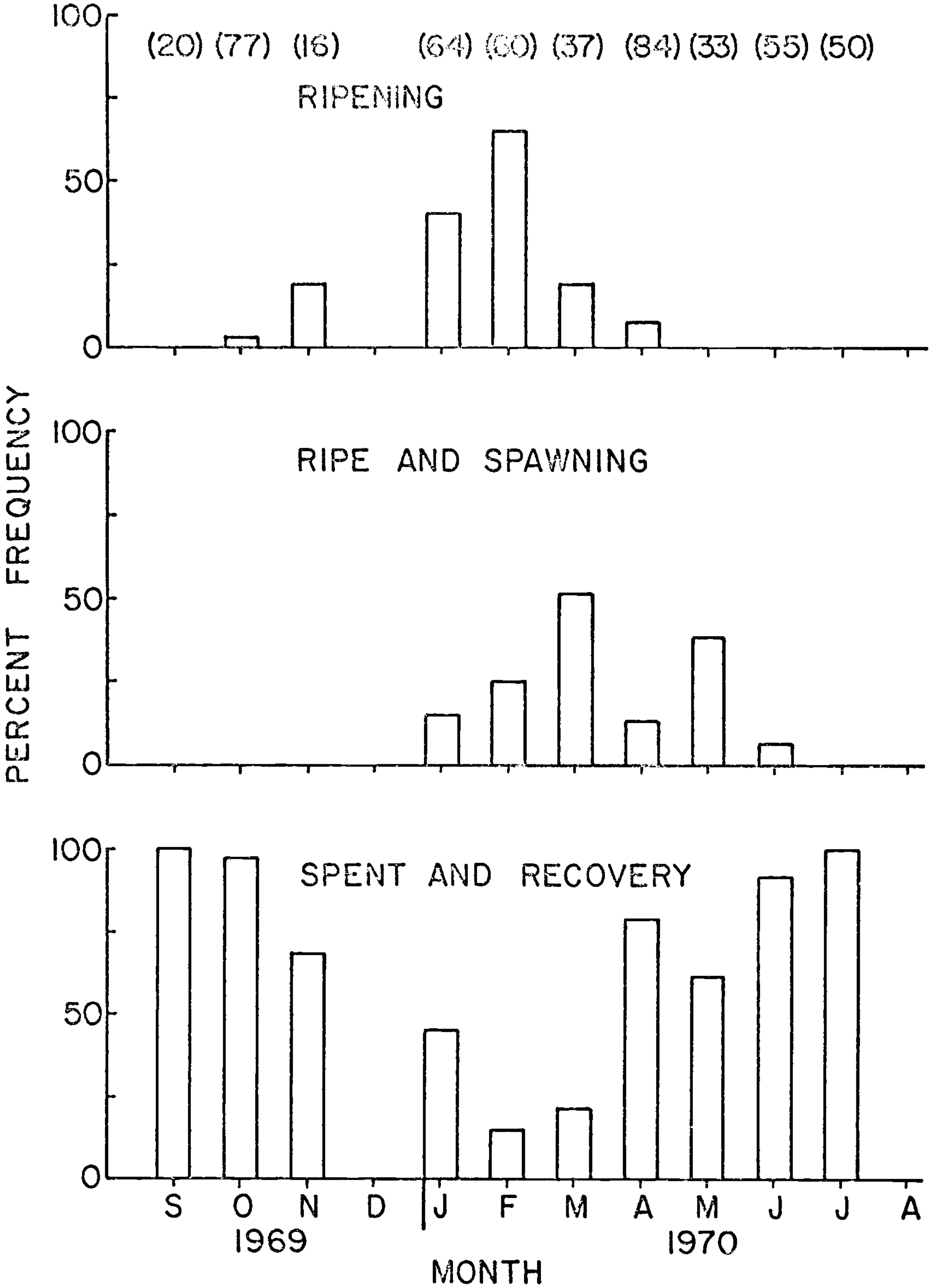

Figure 7. Annual cycle of reproduction in 496 (274 males and 222) females collected off northern Oregon, September 1969-July 1970. The number in each monthly sample is shown in parentheses.

prolonged spawning from January through August for 3,189 rex sole collected off northern California in 1949-1954 and 1962-1963. This suggests the duration of rex sole spawning varies by area and year.

Fecundity

Examination of 13 mature females ranging from 240-590 mm TL yielded fecundity estimates of 3,916-238,144 ova respectively (Table 5). The numbers of ova generally increased with size of the female. In most fish the right ovary contained more ova than the left.

Table 5. Calculated fecundity of 13 rex sole collected off northern Oregon, February 1970.

	Estimated no. of ova		
length (cm)	Left ovary	Right ovary	Both ovaries
240	1,934	1,982	3,916
264	6,201	6,058	12,259
296	5,634	5,292	10,926
299	11,654	15,182	26,836
312	9,232	10,223	19,455
319	6,403	7,541	13,944
341	14,127	13,985	28,112
341	15,664	20,717	36,381
348	14,764	19,924	34,688
358	16,740	17,206	33,946
361	16,453	17,738	34,191
485	59,002	60,146	119,148
590	112,746	125,398	238,144

A linear regression fitted to the data gave a correlation coefficient of 0.9620 (Figure 8). The formula for the

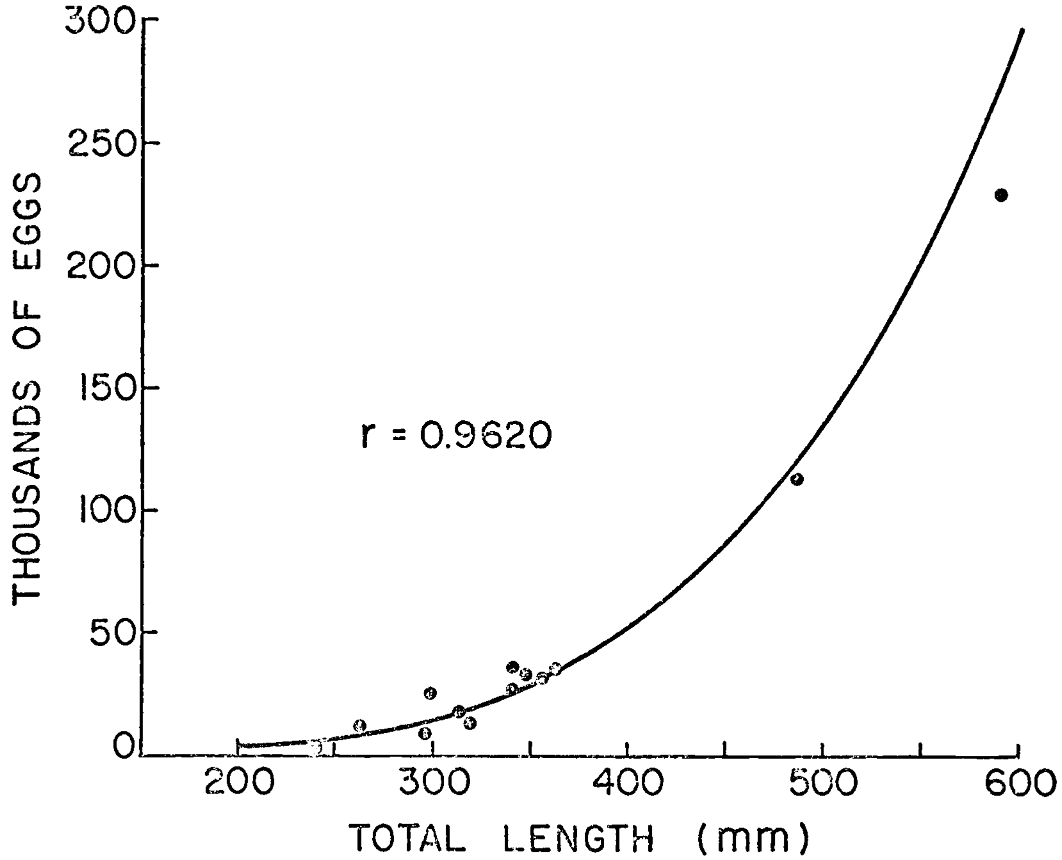

Figure 8. Fecundity-length relationship for 13 rex sole collected off northern Oregon, February 1970.

regression line was $F = 5.3797 \times 10^{-7} L^{4.22667}$, where F is fecundity expressed in number of ova and L is fish TL expressed in mm.

Stock Identification

Tagging Experiment

A total of 2,537 rex sole was tagged and released off the northern Oregon coast in April and June 1970. There were 15 recaptures (0.59% recovery) by July 1974, all from the June 1970 tagging (Table 6). Maximum movement was 53.9 km (29.1 n.mi.), and 788 days was the longest time at liberty. There was little depth change by recaptured fish, which were released in 42.1-153.6 m (23-84 f) and recovered by trawls in 51.2-100.6 m (28-55 f).

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.

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 I 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

Table 6. Release and recovery data on 2,537 rex sole tagged off northern Oregon, April and June 1970.

	No. tagged	No. recovered	Percent recovery	Distance traveled km	Distance traveled n.mi.	Days at Liberty
April 1970	200	0	0.00	0.0	0.0	0.0
June 1970	2,337	15	0.64	1.5	0.8	4
				17.1	9.2	4
				0.0	0.0	5
				3.7	2.0	18
				23.0	12.4	40
				14.1	7.6	189
				2.2	1.2	240
				8.0	4.3	278
				14.3	7.7	279
				0.9	0.5	294
				38.9	21.0	346
				53.9	29.1	364
				unknown		374
				3.9	2.1	450
				52.3	28.2	788
Totals	2,537	15	0.59			

in a skipping motion. This peculiar reaction might have caused a high initial tagging mortality.

Starch-Gel Electrophoretic Analysis

There were 20 loci detected from the muscle tissue of 145 rex sole, of which 13 were enzymes and 7 were muscle proteins (Table 7). Only three loci (15%) were polymorphic.

The polymorphism was found in only three of the eight systems studied or examined. Aspartate aminotransferase (AAT) staining occurred in two anodal regions (A-I and A-II). The zone II was the only polymorphic region, having A, B, C, and D alleles (Figure 9, Table 8). The enzyme peptidase also had two anodal regions. Only zone II was polymorphic, with A and B alleles (Figure 10, Table 9). A third enzyme, phosphoglucomutase (PGM) was polymorphic, having only one locus which had A^1, A, and B alleles (Figure 11, Table 10).

No discernible variation in the frequency or kinds of phenotypes found was observed between rex sole collections from off Astoria (northern), Charleston (central), or Brookings (southern) Oregon (Tables 8-10). These data are insufficient to warrant extended speculation. However, they suggest that geographic selection of rex sole off Oregon, if any, may not revolve around the genetic system included in the eight systems tested. It is important, therefore, that several other alternatives, such as testing additional genetic systems or possible use of helminth parasites as

Table 7. 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 loci	Type of alleles found	Phenotypic variation
AAT A-I	1	1	1	-	Monomorphic
AAT A-II	4	4	4	A,B,C,D	Polymorphic
LDH	1	1	1	-	Monomorphic
Peptidase A-I	1	1	1	-	Monomorphic
Peptidase A-II	2	2	2	A,B	Polymorphic
PGM	3	3	1	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, tetrazdium oxidase.

[2] Analysis of muscle proteins was non-specific, with 6 anodal (+) bands and 1 cathodal (-) band found.

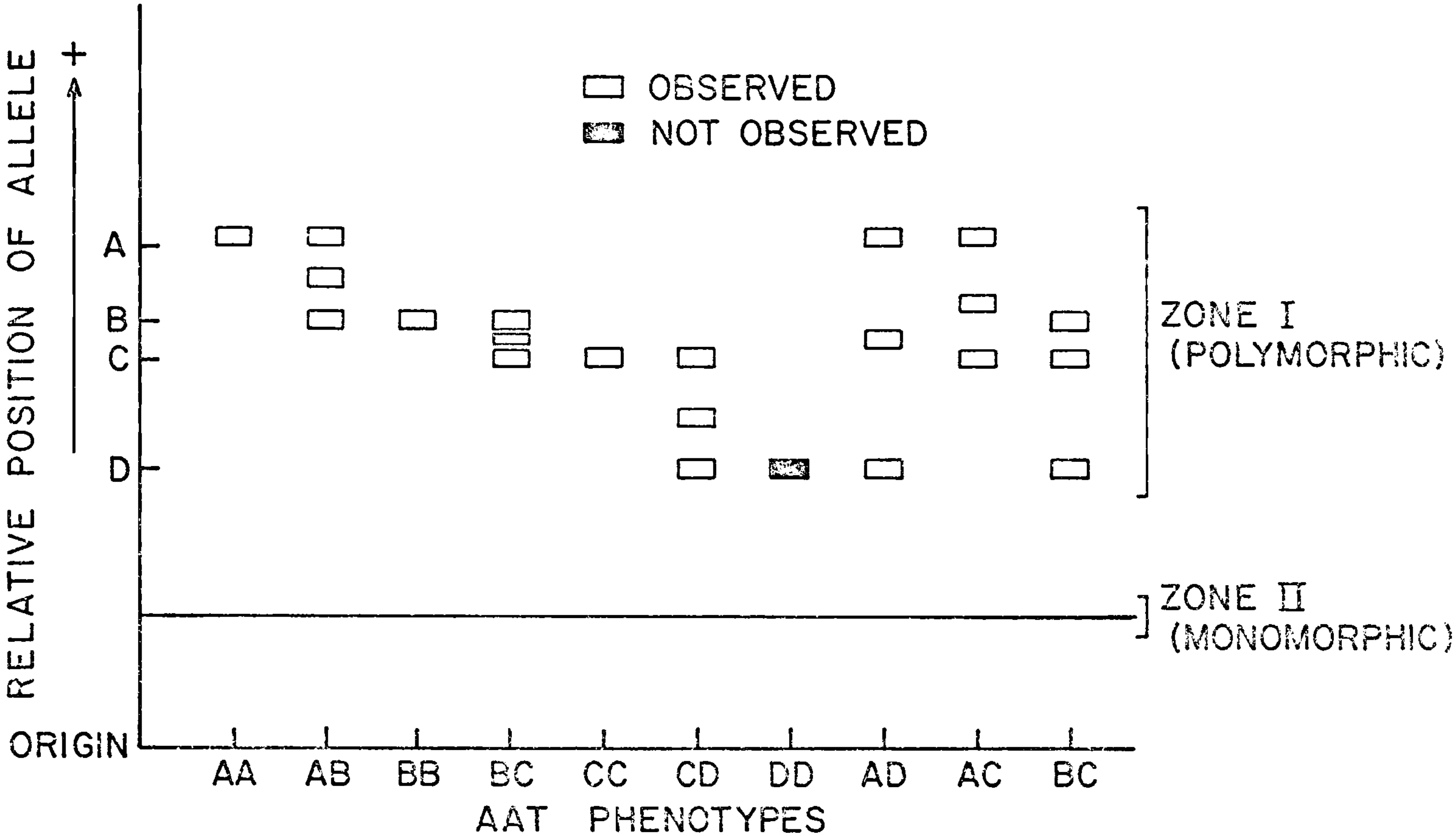

Figure 9. Diagrammatic representation of aspartate aminotransferase (AAT) phenotypes in starch gel from 145 rex sole collected off Oregon, April 1973.

Table 8. Frequencies of aspartate aminotransferase (AAT) phenotypes in 145 rex sole collected off Astoria, Charleston, and Brookings, Oregon in April 1973.

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

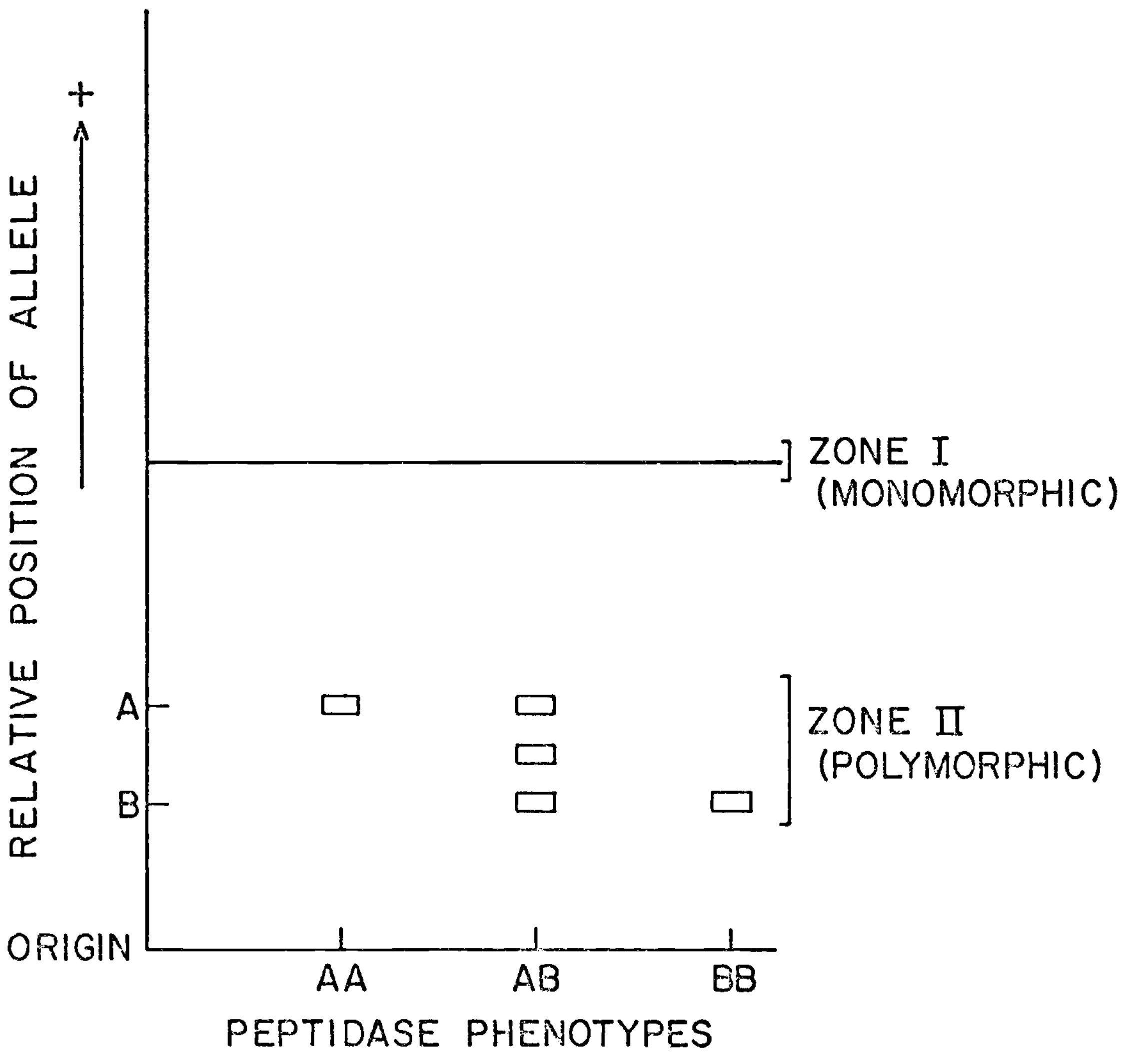

Figure 10. Diagrammatic representation of peptidase phenotypes in starch gel from 137 rex sole collected off Oregon, April 1973.

Table 9. Frequencies of peptidase anodal zone II phenotypes in 137 rex sole collected off Astoria, Charleston, and Brookings, Oregon in April 1973.

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

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

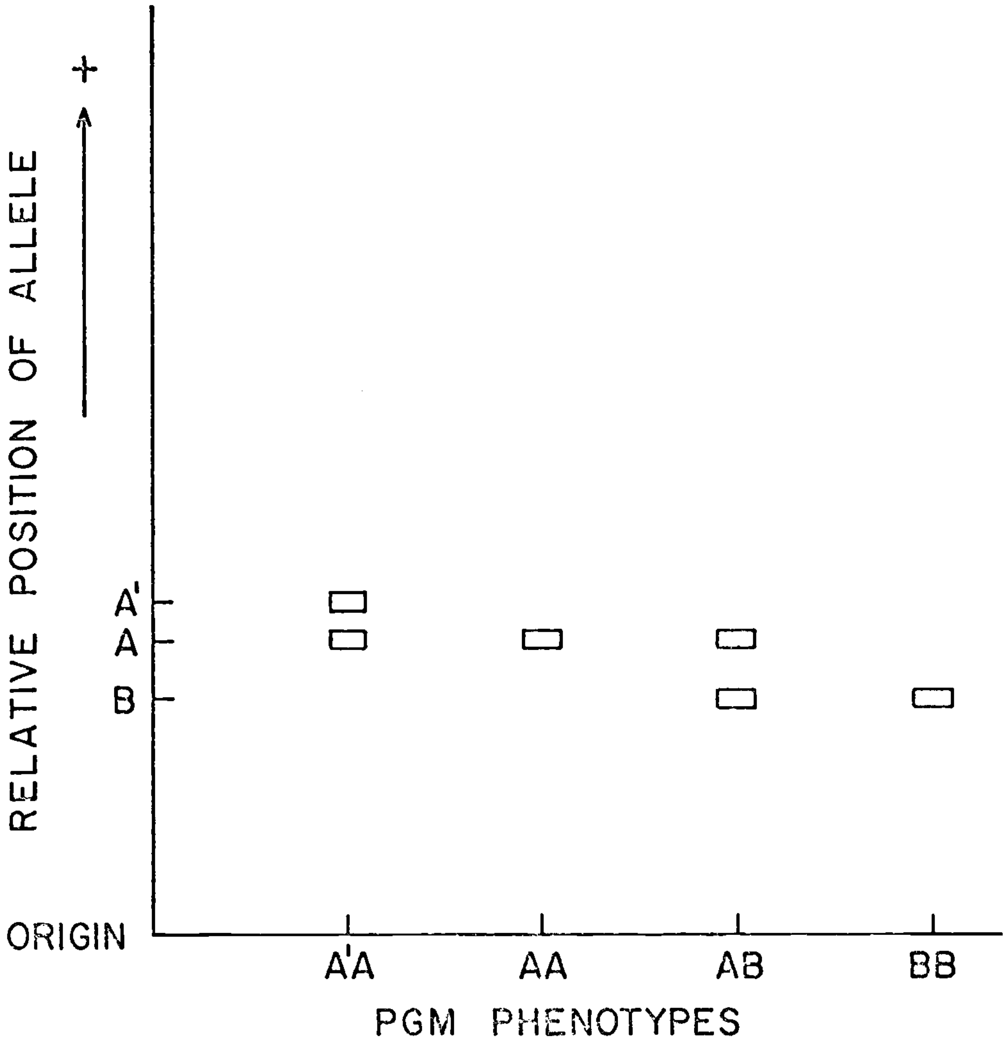

Figure 11. Diagrammatic representation of phosphoglucomutase (PGM) phenotypes in starch gel from 145 rex sole collected off Oregon, April 1973.

Table 10. Frequencies of phosphoglucomutase (PGM) phenotypes in 145 rex sole collected off Astoria, Charleston, and Brookings, Oregon in April 1973.

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

biological tags, be investigated for a more extensive evaluation of the population structure of rex sole off Oregon.

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APPENDICES

Appendix Table 1. Food fish landings of rex sole in thousands of pounds, by state and in British Columbia, 1924-1972.[1]

Year	United States of America			Canada	
	California[2]	Oregon[3]	Washington[4]	British Columbia[5]	Total Landings
1924	121				121
1925	149				149
1926	457				457
1927	693				693
1928	767				767
1929	1,001				1,001
1930	954				954
1931	784				784
1932	534				534
1933	564				564
1934	715				715
1935	629				629
1936	515				515
1937	451				451
1938	509				509
1939	666				666
1940	593				593
1941	371				371
1942	384	14			398
1943	495	570			1,065
1944	406	117			523
1945	296	70		91	457
1946	448	49		159	656
1947	289	15		65	369
1948	891	131		119	1,141
1949	976	224		161	1,361
1950	1,064	253		235	1,552
1951	1,321	273	3	234	1,831
1952	1,185	324	18	180	1,707

Appendix Table 1. (continued)

Year	United States of America California[2]	Oregon[3]	Washington[4]	Canada British Columbia[5]	Total Landings
1953	1,019	400	6	89	2,514
1954	1,183	954	8	21	2,166
1955	1,095	766	27	130	2,018
1956	1,147	418	38	52	1,655
1957	1,234	565	7	40	1,846
1958	1,423	666	30	30	2,149
1959	1,443	864	19	9	2,335
1960	1,107	1,280	14	12	2,413
1961	1,209	988	22	27	2,246
1962	1,408	1,333	33	19	2,783
1963	1,565	1,033	46	9	2,653
1964	1,409	806	67	21	2,303
1965	1,491	985	107	19	2,602
1966	1,635	1,498	88	21	3,242
1967	1,762	1,219	131	42	3,154
1968	1,929	1,075	19	19	3,042
1969	2,253	1,215	14	107	3,589
1970	1,743	1,074	27	372	3,216
1971	1,469	839	59	424	2,791
1972	1,662	1,314	101	359	3,436

1/ Data obtained from pers. comm. of Messrs. Tom Jow, California Department of Fish and Game; Janice Smith, Canada Department of the Environment; and Ward *et al.* (N.D., (N.D.).

2/ California animal food landings not recorded separately from food fish until 1961.

3/ Oregon landings of rex sole not tabulated prior to 1942.

4/ Washington rex sole landings not reported prior to 1951.

5/ British Columbia rex sole landings not tabulated prior to 1945.

Appendix Table 2. Absolute numbers of rex sole per age group caught during groundfish surveys off northern Oregon in 1971 and 1973 and central Oregon in 1972.

Age (years)	No. males			No. females		
	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	1217
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
17				0	0	0
18				9	3	0
19						0
20						0
21						4
Total	2093	2358	2781	3149	3184	4291

Appendix Table 3. Description of reproductive phases of rex sole gonads used in this study.

I. Females - six stages

Immature: A. Ovaries very small (<40 mm TL), opaque in color and gelatinous. No eggs discernable 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 sac-like.

F. Recovering. Ovaries becoming firm and reddish-orange colored. No ova detectable to the naked eye.

II. Males - four stages

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.

Appendix Table 4. Length frequency and mean weight (gm) per quarterly period of male and female rex sole captured off central and northern Oregon, 1969-1972.

Total length (cm)	January-March				April-June				July-September				October-December			
	Males		Females		Males		Females		Males		Females		Males		Females	
	No.	$\overline{W}$	No.	$\overline{W}$	No.	$\overline{W}$	No.	$\overline{W}$	No.	$\overline{W}$	No.	$\overline{W}$	No.	$\overline{W}$	No.	$\overline{W}$
11	3	4.00	6	4.00	4	4.75	0	0.00	2	4.50	2	4.50	0	0.00	3	5.00
12	1	5.00	0	0.00	8	5.50	3	6.33	0	0.00	0	0.00	4	6.25	2	6.00
13	3	7.00	1	6.00	18	8.06	9	7.67	1	7.00	0	0.00	5	7.00	1	6.00
14	1	7.00	0	0.00	20	10.25	15	8.70	1	10.00	0	0.00	0	0.00	1	9.00
15	1	9.00	2	10.00	26	12.58	18	10.67	1	10.00	5	12.40	10	9.00	6	11.33
16	4	15.75	3	14.33	10	15.80	11	16.36	2	15.50	3	16.00	7	14.43	7	14.29
17	7	17.00	3	16.33	26	19.88	13	19.12	4	21.00	6	21.17	10	17.30	6	17.17
18	5	21.60	1	19.00	29	23.66	20	24.90	8	27.75	3	27.33	7	22.29	6	21.67
19	2	25.00	4	18.25	40	27.90	23	28.78	6	31.83	3	35.00	10	26.70	5	26.40
20	4	28.75	3	31.00	38	32.70	33	34.91	11	34.91	8	40.25	6	30.00	2	26.00
21	6	39.33	3	34.00	34	38.82	31	41.29	12	43.00	9	46.56	5	38.80	1	36.00
22	7	43.00	3	34.67	36	47.14	23	47.57	23	48.35	14	48.43	4	49.50	4	47.25
23	12	46.25	2	42.50	19	52.95	16	55.62	25	58.80	15	65.67	4	52.75	3	49.33
24	12	61.00	1	66.00	17	63.29	20	65.15	34	65.88	15	69.13	5	61.20	1	60.00
25	8	62.88	5	71.40	9	73.89	21	75.62	27	74.67	16	76.75	4	68.50	3	67.67
26	9	76.67	4	70.50	13	82.00	13	84.38	37	85.70	31	103.65	4	71.75	0	0.00
27	12	86.92	3	93.33	9	90.33	15	91.40	37	94.30	33	111.88	2	90.50	3	92.67
28	9	102.56	3	107.67	8	113.38	16	111.19	25	110.32	33	139.27	0	0.00	3	100.00
29	3	110.00	4	128.30	9	121.11	12	123.50	19	127.16	44	150.32	2	121.50	4	111.50
30	3	134.67	3	136.67	7	128.00	14	128.64	9	145.33	55	171.58	3	144.33	0	0.00
31	4	149.25	4	150.75	3	152.67	9	148.00	15	172.13	73	181.41	1	118.00	4	147.00
32	1	181.00	2	159.50	2	149.50	9	189.67	14	199.64	65	212.11	2	148.00	1	186.00
33	2	156.50	5	176.80	0	0.00	5	204.60	13	217.23	61	233.51	0	0.00	3	195.00
34	0	0.00	1	184.00	1	199.00	3	213.00	11	222.00	45	250.20	0	0.00	2	220.00
35	0	0.00	1	227.00	0	0.00	1	248.00	10	250.80	30	251.37	0	0.00	2	205.00
36	0	0.00	0	0.00	0	0.00	1	234.00	3	292.00	17	310.29	0	0.00	1	207.00
37	0	0.00	1	290.00	1	251.00	1	283.00	0	0.00	9	323.00	0	0.00	2	253.50
38	0	0.00	0	0.00	0	0.00	1	246.00	0	0.00	9	346.22	0	0.00	0	0.00
39	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	4	364.25	0	0.00	0	0.00
40	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	387.00	0	0.00	0	0.00
41	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	479.00	0	0.00	0	0.00
42	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	490.00	0	0.00	0	0.00
43	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
44	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	495.00	0	0.00	0	0.00
45	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	743.00	0	0.00	0	0.00
46	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	634.00	0	0.00	0	0.00
47	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	803.50	0	0.00	0	0.00
48	0	0.00	0	0.00	0	0.00	0	0.00	0.	0.00	2	838.50	0	0.00	0	0.00
49	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
50	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
51	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	1079.00	0	0.00	0	0.00
Total	119		68		386		356		350		621		95		76	