PACIFIC MARINE FISHERIES COMMISSION

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Bulletin 6

STATISTICAL METHODS FOR ESTIMATING CALIFORNIA SALMON LANDINGS

RESULTS FROM TAGGING A SPAWNING STOCK OF DOVER SOLE, *Microstomus pacificus*

MOVEMENTS OF PETRALE SOLE, *Eopsetta jordani*, TAGGED OFF CALIFORNIA

RESULTS OF A SAMPLING PROGRAM TO DETERMINE CATCHES OF OREGON TRAWL VESSELS
Part 1. Methods and Species Composition

DEVELOPMENT AND STATUS OF THE PINK SHRIMP FISHERY OF WASHINGTON AND OREGON

AVAILABILITY OF SMALL SALMON OFF THE COLUMBIA RIVER

Portland, Oregon

1963

PACIFIC MARINE FISHERIES COMMISSION

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FOREWORD

With this bulletin, the Pacific Marine Fisheries Commission continues the policy established in Bulletin 5 of publishing under one cover a group of papers on research of interstate interest. This volume contains articles on a variety of subjects, submitted by the fishery research agencies of all three member States. Each is a significant contribution in its field.

The Commission adheres to the principles of coordination of research along the Pacific Coast and the dissemination of research results. The papers contained herein are all of benefit to the agencies which are working cooperatively with the authors' organizations. At the same time they present to the interested public up-to-date results of the research being conducted by their scientists.

TABLE OF CONTENTS

Page

Statistical Methods for Estimating California Salmon Landings 5
Norman J. Abramson and Paul T. Jensen

Results from Tagging a Spawning Stock of Dover Sole, *Microstomus pacificus* 13
Sigurd J. Westrheim and Alfred R. Morgan

Movements of Petrale Sole, *Eopsetta jordani* (Lockington), Tagged off California 23
E. A. Best

Results of a Sampling Program to Determine Catches of Oregon Trawl Vessels.
Part 1. Methods and Species Composition 39
Robert B. Herrmann and George Y. Harry, Jr.

The Development and Status of the Pink Shrimp Fishery of Washington and Oregon 61
Austin R. Magill and Michael Erho

Availability of Small Salmon off the Columbia River 81
H. Heyamoto

Statistical Methods for Estimating California Salmon Landings

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BULLETIN 6

PACIFIC MARINE FISHERIES COMMISSION
Portland, Oregon, 1963

STATISTICAL METHODS FOR ESTIMATING CALIFORNIA SALMON LANDINGS[1]

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and
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Department of Fish and Game

INTRODUCTION

The Department of Fish and Game has sampled California's commercial troll salmon landings every year since 1952 to estimate the proportion of king and silver salmon by weight and numbers (Fry and Hughes 1952). Sampling and statistical procedures were revised in 1962 in order to measure the precision of such estimates. This paper discusses sampling problems and procedures, sampling units, stratification, and four estimators of pounds and numbers landed and accompanying standard errors. Also discussed are automated data processing techniques.

Species of salmon commonly taken by California's troll fishery are the king *(Oncorhynchus tshawytscha)* and silver *(O. kisutch)*. In some years, pink salmon *(O. gorbuscha)* make insignificant contributions to landings (Fry 1961). California fish buyers report to the Department the pounds of salmon they purchase. Of equal interest to biologists and managers is the number of each species landed.

Random sampling theory, which provides the basis for statistical estimates, involves sampling methods which are difficult to satisfy in fishery problems. Fish are available for examination only fleetingly as they pass from boat to market or processing plant. In most fishery sampling procedures, sampling is stratified by time and place of landing. With few exceptions, the size of landings at any particular time and place is not known in advance. This makes it impossible to predetermine sampling allocation among strata.

LANDING PROCEDURE

California commercial salmon landings are made from April through September at a large number of ports scattered along some 700 miles of coastline from Point Conception northward. For sampling purposes, individual ports of landing are grouped into five general port areas.

Landing of commercially-caught salmon in California usually proceeds in the following manner: As soon as a boat arrives at the dock, a power-lifted box is lowered to the deck or into the hold of the boat. The fisherman loads the box which is then raised to the dock and emptied onto a sorting table. The buying agent removes ice, if any, and sorts the fish, usually into three size groups. Silver salmon are often grouped with small kings. Placed around the sorting table are buggies which hold the sorted fish. An inter-species price difference may occasion the use of a separate buggy for silver salmon. When all of the fish have been sorted, the buggies of small, medium, and large salmon are weighed. The weights and respective prices are entered in a delivery receipt book provided by the Department of Fish and Game. The original delivery receipt is the fisherman's copy, the duplicate, or "pink ticket", is sent to the Department, and the triplicate and quadruplicate remain with the dealer. The fish are usually iced for shipment immediately after they have been weighed. Prior to 1958, landings consisted of a mixture of round and dressed fish. Since that year, all fish have been landed dressed.

SAMPLING UNITS

In a search for a suitable sampling unit, three possibilities present themselves: individual fish, dealer day (a dealer's total purchases for one day), and individual boatload.

Individual fish: For practical purposes, it is impossible to mechanically randomize sampling of individual fish. Furthermore, we cannot assume that an arbitrary selection of individual fish would be equivalent to a random sample, because the fish may be segregated by size and species when they arrive at the dock.

Dealer day: The total receipts of a dealer on a given day could, in theory, be used as a sampling unit which would assure random selection

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because the number of dealers is known in advance. Because records of each dealer's daily landings are routinely compiled by the Department's bio-statistical unit, we would have a basis for proportionally allocating sampling effort among strata of, say, small and large volume salmon buyers. Although this method would make possible the selection of a true random sample, it appears impracticable because during periods of peak landing activity, we could not obtain data from all boats without disrupting unloading procedure. A method of systematic sub-sampling within dealer day or dealer week has not yet been completely investigated, but such a modification might make dealer day or week an acceptable sampling unit.

Individual boatload: The sampling unit upon which the calculations in this paper are based is the boatload. In our procedure, samplers are instructed to sample a boat as it becomes available to be sampled or as they become available to sample it. A procedure of this type appears certain to produce a more nearly random sample than could be obtained by sampling individual fish. In addition, compilation of delivery receipts provides the total number of boatloads, making possible the use of finite population theory. However, neither number of fish nor number of boats appearing in port on a given day can be known in advance. Therefore, neither provides a basis for obtaining samples of fixed size, although the formulas we have used treat sample size as a constant.

STRATIFICATION AND SAMPLING PROCEDURE

Sampling is stratified by port-area month, and an effort is made to have at least one sampler assigned to each port area for the entire season. However, during April and May the demand for samplers sometimes exceeds the supply, and it is then necessary to have one sampler working two port areas. Although sampling effort may vary, samples are obtained each month from each general port area.

With each sample, we obtain the number of salmon of each species, aggregate weight of silver salmon, and total weight of all species. Additional information is obtained for marked fish. In some instances, samplers have been unable to obtain aggregate silver weight. In port months where this occurred, the number of samples used for weight estimation was smaller than for estimation of numbers (Table 1).

Day-boat catches are usually fewer than 20 fish and present no problem to species separation and mark examination. Ice-boat catches may exceed 200 fish and are harder to examine. An ideal method is for the sampler to go into the hold and load the box himself. He can then examine and count fish more or less at his own pace, and set marked fish aside. Boat owners will not always permit this procedure.

DATA PROCESSING PROCEDURE

During 1962, landing sampling data were recorded on IBM Port-A-Punch cards. These cards are pre-weakened so that a pencil or stylus can be used to punch out appropriate numbers. Port-A-Punch cards are damaged by moisture, but reasonable care will insure their acceptability to processing machinery. We processed over four thousand cards during the 1962 season; none was rejected because of physical damage.

Samplers are instructed to punch data into Port-A-Punch cards slowly and carefully. Although no tests have been made to check the accuracy of field punching, examination of resultant data lists revealed punching errors in less than one percent of the cards.

Port-A-Punch cards are designed for only temporary data storage. Users are advised to convert to standard 80 column data cards before any extensive processing. Repeated handling may accidentally "punch" additional numbers into the cards. In addition, Port-A-Punch columns correspond to every other column on a standard 80 column card. Complex board wiring and programming to allow for empty columns can be avoided by compressing information to adjacent columns on standard data cards. We collect Port-A-Punch cards from the samplers at the end of each month and have them converted to standard data cards. During 1962, cost of conversion and listing was one and one-half cents per card.

Monthly estimates and their standard errors were produced by a FORTRAN language computer program. Monthly production runs were made on an IBM 1620 data processing system. Diagnostic runs for comparison of estimators were made on an IBM 7090 data processing system at the Western Data Processing Center, University of California at Los Angeles.

Calculation of estimates and standard errors using the modified Hartley-Ross estimator requires an enormous number of computations. In the process of debugging our program, we calculated—with desk calculators—estimates and confidence intervals for a set of ten fictitious samples. These same samples were then processed on the computer. From a comparison of respective times, we estimate that preparation of each month's estimates would require at least six man-months of work on desk calculators. The 1620 produces them in less than one hour; the 7090 in less than one minute.

A CONSIDERATION OF ESTIMATORS

We consider four different estimators, the mean per unit, the biased ratio, the Hartley-Ross ratio, and a modified Hartley-Ross ratio, for estimating the numbers and pounds of king and silver salmon landed. Two of these estimators are unbiased. In the context of finite populations, such as we are considering, this means that the average of estimates from all possible samples of size n will equal the population parameter being estimated. The other estimators are biased but consistent. A consistent estimator, again with reference to populations of finite size, yields an estimate equal to the population parameter when the sample consists of the whole population. The bias of a consistent estimator generally decreases as the sample size increases.

In addition to unbiasedness and consistency, we must consider the dispersion of the estimates under repeated sampling. An unbiased estimator is of little value if it gives estimates which are often far from the quantity being estimated. Thus, a slightly biased estimator may be preferable to an unbiased estimator if the former exhibits less variability. Dispersion is measured by variance or mean square error depending on whether deviations are measured from the expected value of the estimate or the parameter being estimated. Variance and mean square error are, of course, equal in the case of unbiased estimates. Only estimators whose variances can be estimated from a sample are suitable for our use. It is also important that the selected estimator give reasonable results.

The estimator chosen is to be used within the framework of a stratified sampling plan where the strata are monthly port groupings, and the sampling is assumed to be random. Estimates for each stratum as well as for the totals over all strata are needed. Primary sampling units are individual boatloads as landed at the dock. These will be defined explicitly in the next section.

Notation

Because many of the symbols are used in formulas related to more than one estimator, we define the more frequently occurring ones here.

N_h	Number of sampling units in the hth stratum; $h = 1, \ldots, L$.
n_h	Number of sampling units sampled from the hth stratum.
x_{hi}	Pounds of salmon in the ith boatload from the hth stratum; $i = 1, \ldots, N_h$
y_{hi}	Number of king salmon or silver salmon, or pounds of king salmon or silver salmon in the ith boatload of the hth stratum. The definition of the symbol depends on which quantity is being estimated.
r_{hi}	y_{hi} / x_{hi}.
s^2_{xh}, s^2_{yh}	Sample variance of x or y for the hth stratum.
s_{xyh}	Sample covariance of x and y for the hth stratum.

The following equations constitute other definitions:

$$\overline{X}_h = \frac{1}{N_h} \sum_{i=1}^{N_h} x_{hi}, \quad \overline{Y}_h = \frac{1}{N_h} \sum_{i=1}^{N_h} y_{hi}, \quad X_h = N_h \overline{X}_h.$$

$$\bar{x}_h = \frac{1}{n_h} \sum_{i=1}^{n_h} x_{hi}, \quad \bar{y}_h = \frac{1}{n_h} \sum_{i=1}^{n_h} y_{hi}, \quad \bar{r}_h = \frac{1}{n_h} \sum_{i=1}^{n_h} r_{hi}.$$

X_h and N_h are known.

Mean Per Unit Estimator

Stratum totals are estimated from $\widehat{Y}_h = N_h \bar{y}_h$ and the total for all strata by $\widehat{Y} = \Sigma \widehat{Y}_h$, ($h = 1, \ldots, L$). $N_h \left(N_h - n_h \right) s^2_{yh} / n_h$ estimates the variance of $\widehat{Y}_h$ and this is summed over the L strata to obtain the variance of $\widehat{Y}$. Both the mean per unit estimator and the estimator for its variance are unbiased. It should be noted that $\widehat{Y}_h$ may yield unreasonable results because when $\widehat{Y}_h$ represents total pounds of one species, $\widehat{Y}_h > X_h$ is possible.

Biased Ratio Estimator

Ratio estimators utilize an auxiliary variable correlated with the variable of interest and for this reason they are usually more efficient than mean per unit estimators. The common or biased ratio estimator for the stratum total is $Y'_h = X_h \bar{y}_h / \bar{x}_h$ and $\left[\left(N_h - n_h \right) / \left(n_h \bar{x}_h \right) \right] \left(R'_h s^2_{xh} - s_{xyh} \right)$ is an approximation to the bias, with $R'_h = \bar{y}_h / \bar{x}_h$. The estimated variance of Y'_h is given by

$$v\left(Y'_h\right) = \frac{N_h \left(N_h - n_h \right)}{n_h \left(n_h - 1 \right)} \sum_{i=1}^{n_h} \left(y_{hi} - R'_h x_{hi} \right)^2.$$

These large-sample formulas for the bias and variance of ratio estimates were obtained by replacing parameters with their unbiased estimates in approximate population formulas. It is not known exactly how large a sample one needs to obtain good estimates from the formulas, but Cochran (1953) recommends sample sizes of at least 30 and coefficients of variation for $\bar{x}_h$ and $\bar{y}_h$ less than 0.1.

The estimated total over all strata is $Y' = \Sigma Y'_h$ and $v(Y') = \Sigma v\left(Y'_h\right)$, ($h = 1, \ldots, L$). When summing stratum estimates the bias increases relatively faster than the standard error of the estimate so that the ratio estimator should be used with caution in stratified sampling if the individual stratum estimates have a substantial bias.

Although we termed Y'_h a biased estimator, it is unbiased if sampling is from an infinite population and if the relation between y and x is a straight line through the origin.

Hartley-Ross Ratio Estimator And A Modification

Hartley and Ross (1954) introduced the unbiased ratio estimator, $\tilde{Y}_h = X_h \bar{r}_h + n_h \left(N_h - 1\right)\left(\bar{y}_h - \bar{r}_h \bar{x}_h\right) / \left(n_h - 1\right)$. Goodman and Hartley (1958) derived the exact variance of $\tilde{Y}_h$ for N very large or infinite and the variance and its unbiased estimator in the case of finite N were developed in terms of multivariate polykays by Robson (1957). Because the computational formula of the finite population unbiased variance estimator, $v(\tilde{Y}_h)$, is very long, it is not reproduced here. The reader is referred to pages 272 and 273 of Robson (1960) for the formula in standard summation notation. Again, summing the stratum estimates, $\tilde{Y}_h$ and $v\left(\tilde{Y}_h\right)$, gives the estimated total and its variance.

Examination of the formula for Y_h shows it may yield unreasonable results because it is possible to obtain $\tilde{Y}_h > X_h$ when estimating a species weight and $\tilde{Y}_h < 0$ when estimating weights or numbers. To overcome this problem we modify $\tilde{Y}_h$ to obtain the estimator Y^*_h. This is defined for number estimation by

$$Y^*_h = \begin{cases} \tilde{Y}_h \text{ if } \tilde{Y}_h \geq n_h \bar{y}_h \\ n_h \bar{y}_h \text{ if } \tilde{Y} < n_h \bar{y}_h \end{cases}$$

and for weight estimation by

$$Y^*_h = \begin{cases} X_h - n_h \bar{z}_h \text{ if } \tilde{Y}_h > X_h - n_h \bar{z}_h \\ \tilde{Y}_h \text{ if } X_h - n_h \bar{z}_h \geq \tilde{Y}_h \geq n_h \bar{y}_h \\ n_h \bar{y}_h \text{ if } \tilde{Y}_h < n_h \bar{y}_h \end{cases}$$

where $\bar{z}_h$ is the sample mean weight of the second species. Y^*_h is not unbiased but intuitively we expect its bias to be small. Clearly, $MSE\left(\tilde{Y}_h\right) > MSE\left(Y^*_h\right)$ and $E\left[v\left(\tilde{Y}_h\right)\right] > MSE\left(Y^*_h\right) > V\left(Y^*_h\right)$, where MSE, E, and V indicate mean-square error, expected value, and population variance. Because of these relationships, we may use $v\left(\tilde{Y}_h\right)$ as a conservative estimate of $V\left(Y^*_h\right)$.

RESULTS OF THE 1962 PILOT SURVEY

Because the relative variances as well as restrictions on using the different estimators depend on characteristics of the population being sampled, we will base our choice of an estimating procedure for a continuing salmon sampling program largely on information obtained from sampling the population in 1962. By so doing, we assume that the nature of the sampled population changes little from year to year.

For each of the four quantities being estimated in each of the L strata, coefficients of variation (cv.'s) of $\bar{x}_h$ and $\bar{y}_h$ were calculated. We found that a substantial majority of the cv.'s exceeded 0.1 and more than a fourth were larger than 0.25. In view of Cochran's recommendations, these large cv.'s cause us to eliminate the biased ratio estimator from further consideration. It should be noted the cv.'s were large in spite of substantial sampling fractions (Table 1).

The unbiased estimators, $\hat{Y}_h$ and $\tilde{Y}_h$, have unbiased variance estimators so the large cv.'s do not restrict their use. However, the previously cited problem of unreasonable estimates arises. Although neither $\hat{Y}_h$ nor $\tilde{Y}_h$ met our criterion that unreasonable estimates be impossible, we were interested in knowing how often they would produce unreasonable estimates in this pilot study. When used to estimate pounds of king salmon, $\hat{Y}_h$, the mean per unit estimator, exceeded X_h in 16 of the port-month strata, and the Hartley-Ross estimator, $\tilde{Y}_h$, produced unreasonable estimates in two port-month strata. In these instances the estimated pounds of king salmon exceeded X_h and the estimates of pounds and numbers of silver salmon were negative.

By a process of elimination, the modified Hartley-Ross ratio estimator appears to be the most suitable vehicle for estimating pounds and numbers landed of the two salmon species. We did not consider a modified mean per unit estimator because it seemed clear that a ratio-type estimator would be the more efficient due to an expected positive correlation between total weight of a boatload and its component species' weights and numbers. Computations from the pilot survey data bear this out. Hartley-Ross ratio estimates had smaller standard errors, in most cases dramatically smaller, in each stratum than did mean per unit estimates when king salmon numbers and pounds were the pertinent quantities. For silver salmon weights and numbers, Hartley-Ross estimates had the smaller standard errors in about two-thirds of the strata but the standard errors of the two types of estimates were much closer to each other for silver salmon than for king salmon.

When estimating totals over all strata, we found that Hartley-Ross estimates had standard errors about 90 percent as large as mean per unit standard errors for silver salmon pounds and numbers, about 45 percent as large for king salmon pounds, and approximately 20 percent as large for king salmon numbers. Thus, we give estimates of pounds and numbers computed with Y^*_h, the modified Hartley-Ross estimator, and estimated standard errors obtained from $v\left(\tilde{Y}_h\right)$, the unbiased variance estimator for $\tilde{Y}_h$ (Tables 2 and 3). The tabled standard errors will, as mentioned in the previous section, tend to be overestimates.

Y^*_h yielded estimates of king salmon landings with good precision. Cv.'s for the season totals, in both pounds and numbers, were less than 0.01 and for monthly totals by port and port totals by season, the cv.'s exceeded 0.02 in only one case (June, number of kings). Individual port-month strata, of course, had relatively larger standard errors.

Silver salmon estimates had standard errors considerably larger than those for kings, although the cv. for total pounds was a respectable 0.054 and the cv. of total number was 0.086. This greater variability for the silvers was to be expected since they were the minority species and consequently their numbers and pounds had a lower correlation with total pounds per boatload than was the case with kings. Further, the standard errors of silver weights are identical to those of king weights since the estimates of silver weights must equal $X_h - Y^*_h$, where Y^*_h represents estimated king weight, and $V\left(X_h - Y^*_h\right) = V\left(Y^*_h\right)$.

TABLE 1

Numbers of Boatloads $\left(N_h\right)$ and Samples[1] $\left(n_h\right)$ from 1962 Pilot Survey

		Crescent City	Eureka	Fort Bragg	San Francisco	Monterey
April	N_h	170	315	93	1,314	316
	n_h	27	40	22	71	39
May	N_h	285	1,681	232	2,046	786
	n_h	35	293	48	149	129
June	N_h	343	1,455	1,046	1,979	683
	n_h	105	195*	183	291	69
July	N_h	437	1,399	2,520	3,559	583
	n_h	95	164†	231	837‡	112
Aug.	N_h	1,056	702	1,505	2,834	496
	n_h	215§	41**	277	330††	100
Sept.	N_h	203	102	1,392	1,037	548
	n_h	136	9	153	149‡‡	72

[1]Tabled sample sizes are those used to estimate numbers of fish. In most strata the same samples were used for weight estimation but where sample sizes differed, the samples for weights are indicated by reference marks:

* 194 ** 37
† 79 †† 328
‡ 836 ‡‡ 148
§ 84

SUMMARY

Continuous sampling of California's commercial troll salmon landings since 1952 has produced landings estimates of species by number and weight without measures of sampling error. In 1962, sampling errors were calculated using four different estimators. A modified Hartley-Ross estimator produced the most precise estimates.

Estimated landings with associated standard errors of species by number and weight of fish were calculated for 1962 landings, using electronic data processing equipment.

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TABLE 2

King Salmon Landing Estimates from 1962 Pilot Survey[1]

		Number of King Salmon						Pounds of King Salmon					
		Crescent City	Eureka	Fort Bragg	San Francisco	Monterey	Totals	Crescent City	Eureka	Fort Bragg	San Francisco	Monterey	Totals
April	Estimated Landings	1,629	21,536	2,742	23,509	2,602	52,018	15,568	200,220	22,642	249,363	34,645	522,438
	Standard Error	32	347	68	594	152	709	0	96	37	0	0	103
May	Estimated Landings	6,118	70,032	2,091	27,083	10,858	116,182	57,347	667,632	24,424	307,579	133,311	1,190,293
	Standard Error	96	503	187	534	314	825	285	1,298	348	155	103	1,387
June	Estimated Landings	4,946	57,833	15,953	21,445	10,815	110,992	47,857	610,231	219,271	259,244	139,080	1,275,683
	Standard Error	94	2,876	571	341	293	2,968	806	7,984	1,016	298	373	8,103
July	Estimated Landings	2,870	65,560	35,890	36,400	4,672	145,392	32,287	741,935	497,140	477,900	55,170	1,804,432
	Standard Error	95	2,394	901	353	132	2,587	879	7,251	5,211	369	176	8,982
August	Estimated Landings	9,410	14,245	8,049	28,017	2,407	62,128	68,846	135,348	90,812	342,562	28,279	665,847
	Standard Error	455	1,576	210	609	88	1,765	2,648	16,261	2,522	392	0	12,072
Sept.	Estimated Landings	364	81	23,475	19,069	2,275	45,264	3,432	581	279,610	225,074	33,669	542,366
	Standard Error	19	14	962	422	45	1,052	190	100	12,663	503	0	8,971
Totals	Estimated Landings	25,337	229,287	88,200	155,523	33,629	531,976	225,337	2,355,947	1,133,899	1,861,722	424,154	6,001,059
	Standard Error of Total	485	4,106	1,466	1,195	484	4,572	2,925	15,819	10,717	810	425	19,352

[1]These estimates are from preliminary data. Late fish receipts are not included.

TABLE 3

Silver Salmon Landing Estimates from 1962 Pilot Survey[1]

		Number of Silver Salmon						Pounds of Silver Salmon					
		Crescent City	Eureka	Fort Bragg	San Francisco	Monterey	Totals	Crescent City	Eureka	Fort Bragg	San Francisco	Monterey	Totals
April	Estimated Landings	0	14	6	0	0	20	0	125	60	0	0	185
	Standard Error	0	10	4	0	0	11	0	96	37	0	0	103
May	Estimated Landings	178	1,688	111	55	3	2,035	927	9,129	625	301	18	11,000
	Standard Error	55	249	61	26	16	264	285	1,298	348	155	103	1,387
June	Estimated Landings	367	6,239	1,185	160	190	8,141	2,217	40,532	8,217	1,071	1,265	53,302
	Standard Error	128	1,239	144	46	58	1,256	806	7,984	1,016	298	373	8,103
July	Estimated Landings	2,486	14,886	5,439	289	61	23,161	17,627	103,802	43,986	2,667	479	168,561
	Standard Error	122	1,755	648	38	22	1,875	879	7,251	5,211	369	176	8,982
August	Estimated Landings	7,288	377	2,044	205	0	9,914	80,158	2,093	16,054	1,975	0	100,280
	Standard Error	462	2,769	341	42	0	2,828	2,648	16,261	2,522	392	0	12,072
Sept.	Estimated Landings	880	524	1,132	239	0	2,775	7,118	3,832	11,041	2,327	0	24,318
	Standard Error	23	17	1,605	46	0	1,606	190	100	12,663	503	0	8,971
Totals	Estimated Landings	11,199	23,728	9,917	948	254	46,046	108,047	159,513	79,983	8,341	1,762	357,646
	Standard Error of Total	498	3,513	1,771	90	64	3,967	2,925	15,819	10,717	810	425	19,352

[1]These estimates are from preliminary data. Late fish receipts are not included.

Results from Tagging a Spawning Stock of Dover Sole, *Microstomus pacificus*

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Research Division

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BULLETIN 6

PACIFIC MARINE FISHERIES COMMISSION

Portland, Oregon, 1963

RESULTS FROM TAGGING A SPAWNING STOCK OF DOVER SOLE, *Microstomus pacificus*[1]

Sigurd J. Westrheim[2]
and
Alfred R. Morgan[3]

INTRODUCTION

Dover sole *(Microstomus pacificus)* have been an important component in the Oregon otter trawl fishery since 1942 (Harry, 1956). Prior to 1951, virtually all Dover sole landed in Astoria, Oregon's principal port for this species, were caught within 30 miles north and south of the Columbia River in waters shallower than 70 fathoms. About 80-90% of the annual catch was taken during the period May through September. These fish appeared on the inshore grounds each year in the spring and disappeared in the fall. Hagerman (1952) and Harry (1956) hypothesized that Dover sole moved offshore during the winter months.

Improvements in navigational equipment since the late 1940's have permitted trawlers to explore deeper waters heretofore inaccessible to them. Deep-water stocks of Pacific ocean perch *(Sebastodes alutus)* were exploited by 1949 off Oregon (Alverson and Westrheim, 1961), petrale sole *(Eopsetta jordani)* in 1954 off Vancouver Island (Alverson and Chatwin, 1957), and Dover sole off southwest Washington in 1954. Petrale and Dover sole were available in the offshore areas primarily during the winter months, in contrast to their summer availability on the inshore grounds.

Oregon trawlers discovered a concentration of Dover sole off Willapa Bay, Washington, in 180-280 fathoms during February 1954. A substantial fishery ensued until April when the fish disappeared from this area. In October, Dover sole returned to this Willapa Deep and the fishery resumed and continued through the winter of 1954-55. All fish examined from this area were either ripe or spent indicating that the concentration was a spawning population.

Controversy arose immediately as to the desirability of permitting this new winter fishery for Dover sole to continue, particularly if these were the same fish which were available on the inshore grounds during the summer months. A tagging experiment was undertaken by the Oregon Fish Commission in early 1955 to determine, if possible, the subsequent distribution of Dover sole which spawned in Willapa Deep. This report deals with the results of the study.

MATERIALS AND METHODS

An Astoria trawler, the *Marian F*, was chartered to catch the fish for tagging. Red Petersen disc tags were affixed to the Dover sole with stainless steel pins. Actual trawling time was limited in all but one case to less than one hour per drag. Setting the net on the bottom customarily took 15 minutes whereas hauling took 60 minutes. When the catch was emptied on deck, care was taken to select for tagging only fish in good condition. These were immediately placed in a canvas tank (56 x 18 x 34 inches) containing circulating sea water, and allowed to recuperate before tagging operations began. All fish tagged were measured (fork length) to the nearest lower centimeter. Sex was not recorded because it cannot be determined externally for this species.

A standard western trawl was utilized in which the cod end had a mean mesh size of 4.6 inches (stretched measure between knots). The last 25 meshes were doubled to provide protection from chafing on the bottom.

RESULTS

Tagging was originally scheduled to take place during February, presumably at the peak of the Dover sole spawning, but unavoidable delays postponed operations until April.

Tagging was conducted on two discrete fishing grounds about 10 miles apart (Figure 1). The first, and well-known, was Willapa Deep (termed Area A) which extends from loran bearing 2H4-3795 to 2H4-3840 in 150-280 fathoms. The second, Little Willapa Deep (Area B), was located southeast from

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[2]Formerly Director of Research, Oregon Fish Commission; now Senior Scientist, Fisheries Research Board of Canada, Nanaimo, B. C.
[3]Deceased April 3, 1963.

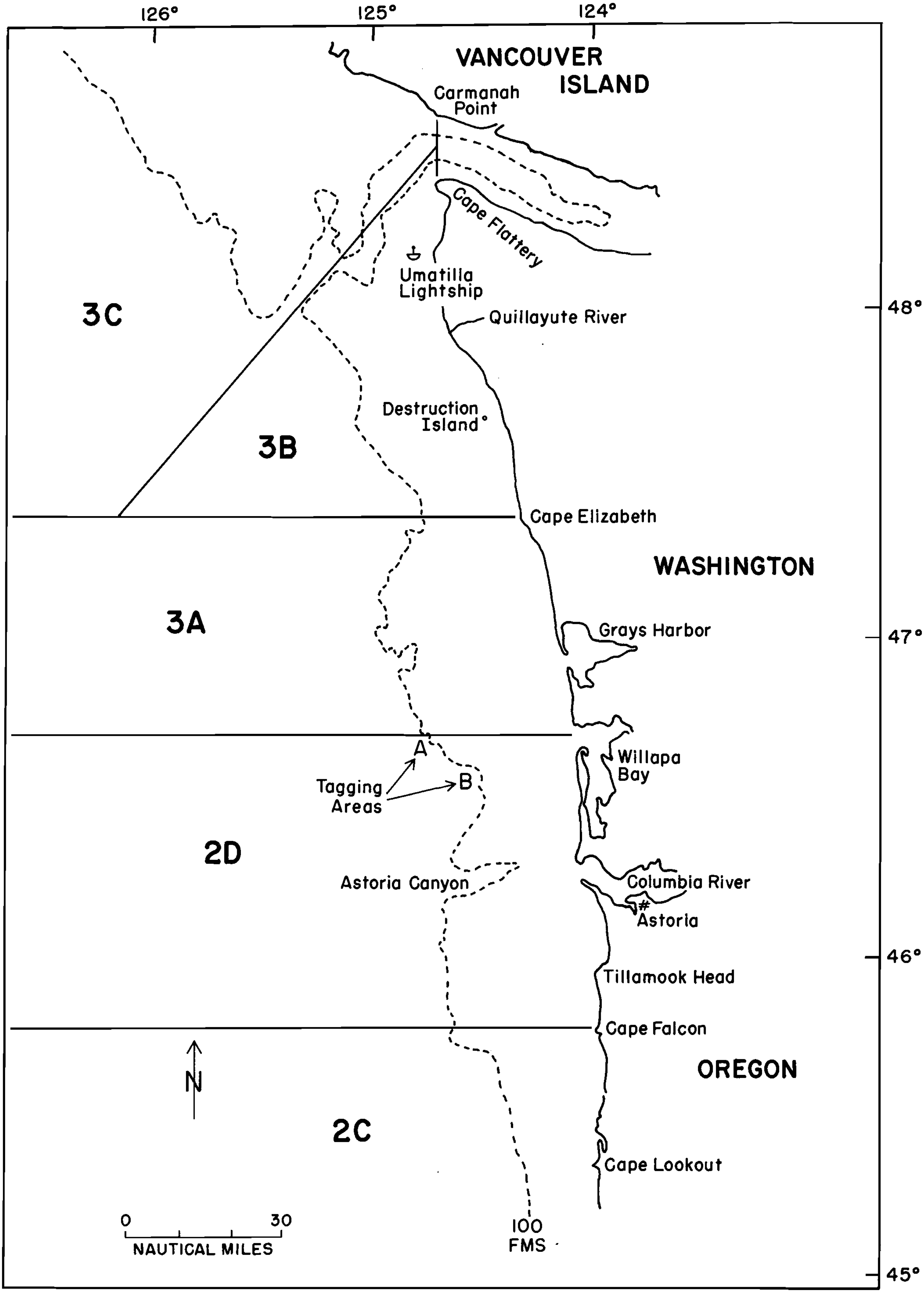

FIGURE 1. Pacific Coast from Cape Lookout to Vancouver showing tagging areas and PMFC trawl statistical areas.

Area A and was not known to most trawlers in 1955. Area B extends from loran bearing 2H4-3706 to 2H4-3745 in 180-265 fathoms. In Area A, 1,559 Dover sole were tagged and 206 (13.2%) subsequently were recovered, whereas in Area B, 847 were tagged and 54 (6.4%) were recaptured. Table 1 summarizes the numbers tagged and recovered.

Inclement weather interrupted tagging operations twice, thus creating three tagging periods: April 18, April 21-22, and April 29-30. A total of 14 tows were made from which Dover sole were tagged. Table 2 summarizes the results by tow. The numbers tagged per tow ranged from 87 to 253, and recovery rates from 1% to 25%. Considerable investigation was undertaken to seek causes for the two lowest recovery rates and the one high rate. Low rates are thought to be due to operational techniques. Sub-experiments 22-2 and 29-3 were the only ones in which the tagged fish were released while the vessel was running at cruising speed (8-9 knots) and away from the capture area. In all other cases, tagging and release took place while the vessel was trawling (2-3 knots) or drifting on the capture area. Sub-experiment 22-2 fish were released as the vessel was running toward the Columbia River in rough seas. Sub-experiment 29-3 fish were tagged and released as the vessel was running northwest to Area A to be on the grounds for trawling in the morning. No explanation can be offered for the unusually high recovery rate (25%) for sub-experiment 30-2.

TABLE 1

Numbers of Dover Sole Tagged and Recovered by Tagging Area.

Tagging Area	No. Tagged	Recoveries Through April 1962	Per Cent Recovered
Willapa Deep A	1,559	206	13.2
Little Willapa Deep B	847	54	6.4
TOTAL	2,406	260	10.8

Absence of recoveries during Period I (May 1955-April 1956) from Area B tagging is not entirely explainable. Few trawlers were familiar with this area and hence it sustained a low fishing effort compared with Area A. However, this does not explain the lack of recoveries during the summer of 1955 when appreciable numbers of tags from Area A were recaptured on inshore grounds well known to all local trawlers. These results suggest that Dover sole tagged in Area B did not move to the inshore grounds during the summer of 1955.

Migration

The recovery area was known for 251 tagged Dover sole recovered during the period May 1955-April 1962. Of these, only 7 were recaptured more than 30 miles from the tagging area. Table 3 lists the appropriate information concerning these 7 recoveries. The most northerly recovery was 110 miles from the tagging area, off the southwest coast of Vancouver Island. The most southerly recapture was made 360 miles away, southwest of

TABLE 2

Numbers of Dover Sole Tagged and Recovered by Sub-Experiment and Time Period.

Sub-Experiment Number[1]	Release Area[2]	Nos. Tagged	Time Period Recovered[3] O	I	II	III	IV	V	VI	VII	Total	Per Cent Recovered
18-1	A	126	0	7	6	4	1	0	0	1	19	15.1
18-2	A	198	0	6	20	3	3	0	0	0	32	16.2
21-1	A	114	3[4]	4	4	2	2	2	1	0	15	13.2
21-2	A	170	1[4]	5	7	3	2	0	2	0	19	11.2
21-3	A	87	0	3	3	1	2	0	1	0	10	11.5
22-1	A	99	0	3	1	2	1	0	0	0	7	7.1
22-2	B[5]	184	0	0	0	2	0	0	0	0	2	1.1
29-1	B	253	0	0	15	6	0	2	0	1	24	9.5
29-2	B	202	0	0	17	1	2	1	1	0	22	10.9
29-3	B	208	0	0	1	1	1	2	0	1	6	2.9
30-1	A	230	0	3	7	5	2	1	0	0	18	7.8
30-2	A	225	0	15	17	11	4	5	4	1	57	25.3
30-3	A	215	0	4	9	7	1	0	0	0	21	9.8
30-4	A	95	0	3	2	1	2	0	0	0	8	8.4
TOTAL		2,406	4[4]	53	109	49	23	13	9	4	260	10.8

[1]18-1 = April 18, Tow No. 1, etc.
[2]A = Willapa Deep; B = Little Willapa Deep.
[3]Time Period O = April 1955. Periods I through VII = successive annual periods: e.g., I = May 1955-April 1956; VII = May 1961-April 1962.
[4]Recovered April 30 by tagging crew and re-released; none subsequently recaptured. Not included in other recovery totals.
[5]*Little Willapa Deep to Columbia River North Jetty—running before storm.*

Humboldt Bay, California. Only one other tagged Dover sole was recaptured south of the Astoria Canyon.

Three types of migration have been evaluated, viz., offshore-inshore, offshore-offshore, and north-south (independent of depth). Offshore-inshore migration is indicated by depth and month in Table 4. Tagged fish were recaptured in waters as shallow as 27 fathoms and as deep as 300 fathoms. Inshore (less than 120 fathoms) recoveries totaled 66, of which 58 were recaptured in the 31- to 60-fathom interval. All of these were taken during the period May-November. Offshore (deeper than 120 fathoms) recoveries totaled 185. One or more tagged fish were recaptured in offshore waters in all months except July and August. Unfortunately, neither catch nor fishing effort data are available by month and depth to weight these recoveries for quantitative measure of the offshore-inshore migration. However, it is evident that these fish do conduct such a migration on a periodic basis. No variation from this behavior was noted among the 14 sub-experiments. Similar results were obtained by Alverson (1960) utilizing fishing vessel logs of Washington trawlers.

Offshore areas yielded substantially more tags than inshore areas, possibly due to a preponderance of males among the tagged fish (see section on sex ratios). However, since the summer of 1957, the inshore grounds between Willapa Bay and Cape Elizabeth have been invaded by hake *(Merluccius productus)* and the trawlers have had to restrict their Dover sole fishing in this area in order to avoid the unmarketable hake.

Offshore-offshore migration is suggested by the limited data available in Table 5. Dover sole tagged in Area A have been recaptured in Area B and 3 other deep-water areas, although the numbers of recoveries are small. Likewise, fish tagged in Area B have been recaptured in Area A. Scant recoveries from offshore areas other than Willapa Deep are probably due in large part to the lack of fishing effort expended to locate and exploit Dover sole concentrations in other offshore grounds.

North-south distribution of the tagged Dover sole strongly suggests a northward movement from Willapa Deep as shown in Table 6. The tag recoveries have been grouped by Pacific Marine Fisheries Commission trawl area (Figure 1), together with annual Dover sole catches for 1956-60

TABLE 3

Recovery Data on Tagged Dover Sole Recaptured More Than 30 Miles from the Tagging Area.

Tagging				Recovery				
Exp. No.	Area	Length (Cm)	Sex	Date	Area	Depth (Fms.)	Dir.	Miles
18-1	A	44	?	Sept. 14, '56	Umatilla Lightship	65	N	80
29-2	B	39	F	June 29, '57	Off Tillamook Head	68	S	35
30-1	A	36	?	Nov. 3, '55	Quillayute, Washington	59	N	70
30-2	A	45	F	Oct. 20, '55	Carmanah Pt., Vancouver Island	135	N	110
30-2	A	43	?	March 15, '56	Destruction Island	240	N	50
30-2	A	37	M	Aug. 21, '56	Quillayute, Washington	42	N	70
30-4	A	42	F	April 29, '58	SW of Humboldt Bay, Calif.	295	S	360

TABLE 4

Recoveries of Tagged Dover Sole by Depth and Month, 1955-62.

	Month												
Depth (Fms.)	M	J	J	A	S	O	N	D	J	F	M	A	Total
0 - 30	—	—	—	—	2	—	—	—	—	—	—	—	2
31 - 60	5	27	9	6	5	4	2	—	—	—	—	—	58
61 - 90	1	2	—	1	1	1	—	—	—	—	—	—	6
91 - 120	—	—	—	—	—	—	—	—	—	—	—	—	—
121 - 150	5	—	—	—	—	1	—	—	—	—	—	—	6
151 - 180	—	1	—	—	2	—	2	—	—	—	—	—	5
181 - 210	—	—	—	—	1	1	8	—	22	5	7	9	53
211 - 240	5	—	—	—	—	1	15	2	—	3	3	4	33
241 - 270	7	—	—	—	—	—	21	1	3	1	11	15	59
271 - 300	—	—	—	—	—	—	2	—	3	—	—	24	29
Sub-Total	23	30	9	7	11	8	50	3	28	9	21	52	251
Unknown	1	—	—	—	1	2	—	—	—	—	4	1	9
Total	24	30	9	7	12	10	50	3	28	9	25	53	260

(PMFC, 1962). Of the 251 recoveries, 201 were attributed to Area 2D (the area of tagging). Of these, only 1 was taken south of the Astoria Canyon (midway in 2D) although for the period 1956-61, 47% of the 2D catch was taken south of the Astoria Canyon. It is apparent that the Dover sole tagged in the Willapa Deeps generally moved northward. Substantial trawl catches in Areas 1B, 2B, 3B, and 3C preclude the possibility that low recovery rates were the result of low fishing effort.

Size Composition

Size composition of tagged and recovered Dover sole from Areas A and B are compared in Figure 2. For Area A, the mean lengths were 420 and 422 mm, respectively, for tagged and recovered fish, based on size at tagging. For Area B, the corresponding values were 427 mm for tagged fish, and 434 mm for recovered fish.

Recovery rates varied by size (Table 7). Area A fish produced consistent returns (13-16%) within the 36-46-cm intervals. For intervals below 36 cm, returns were poor (0-2%), and above 46 cm, erratic (0-26%). Similar results were achieved for Area B fish, but the size range over which consistent returns were achieved was smaller, i.e., 40-46 cm.

Low recovery rates for fish less than 35 cm can be expected since a minimum size of 14 inches (35.6 cm) is imposed by the fillet plants. Hence the undersized tagged Dover sole caught in trawl nets are likely to pass unnoticed through the discarding operation at sea and will rarely be brought ashore for sale and possible detection in the fillet plants. The low or erratic returns from the larger sizes of marketable fish probably are due to the small numbers of fish tagged.

TABLE 5

Intra-Deep Water Area Exchange of Tagged Dover Sole.

Tagging Area	Numbers Tagged	Recovery Area[1] A	B	AB	C	D	E
A	1,559	121	11	6	1	1	1
B	663	3	26	13	0	0	0
BX[2]	184	0	2	0	0	0	0

[1] A = Willapa Deep
B = Little Willapa Deep
AB = Willapa or Little Willapa Deep
C = Destruction Island Deep
D = Vancouver Island
E = SW of Humboldt Bay, California
[2]Area B to mouth of Columbia River.

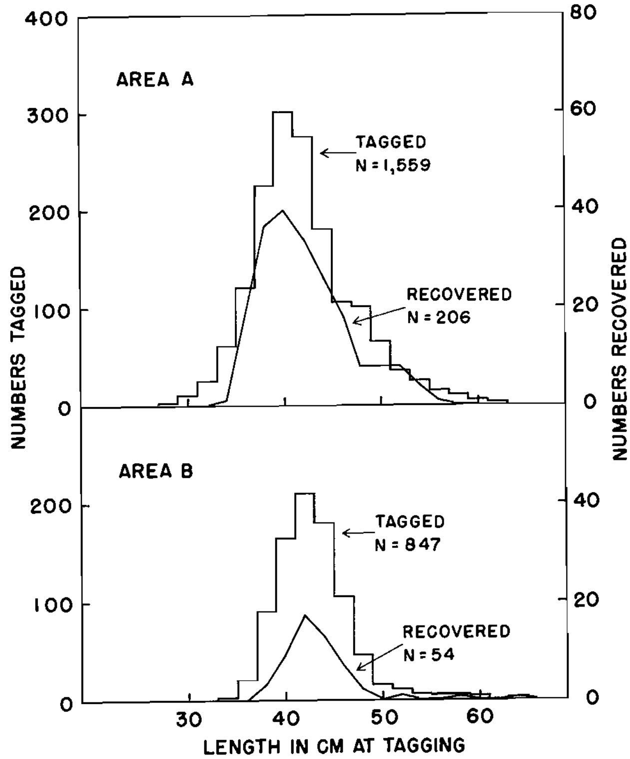

FIGURE 2. Size composition of tagged and recovered Dover sole.

TABLE 6

Dover Sole Catches (1956-60) and Tag Recoveries (1955-62) by PMFC Area.

PMFC Area	Catch (Thousands of Lbs.) 1956	1957	1958	1959	1960	Tags Recovered
3D	38.5	2,909.0	65.5	183.5	100.5	0
3C	1,423.5	1,389.0	635.5	646.5	1,167.0	1
3B	1,782.0	675.5	884.5	1,059.5	1,714.5	5
3A	272.0	685.5	125.5	198.0	211.5	43
2D[1]	1,599.0	1,933.0	1,674.0	1,756.0	2,014.0	201
2C	410.0	463.5	0	360.0	534.0	0
2B	417.0	682.0	1,042.5	2,538.5	2,344.5	0
2A	789.5	790.0	836.0	931.0	1,189.0	0
1C	3,961.0	4,293.0	3,950.5	3,670.5	5,202.0	1
1B	3,281.0	2,657.0	2,963.0	2,453.0	2,716.5	0
1A	3.0	0.5	0.5	14.0	61.5	0
Total						251

[1]Includes Willapa and Little Willapa Deeps.

Mean lengths of Dover sole landed commercially in Astoria from offshore and inshore grounds were compared with the mean lengths of tagged and recovered fish. Inshore catches had mean lengths of 430 mm in 1954 and 432 mm in 1955, whereas for offshore catches the means ranged from 422 mm in October 1954 to 442 mm in December 1954. The tagged fish, with mean lengths of 420 mm (Area A) and 427 mm (Area B), were thus similar to sole taken offshore, but smaller than fish landed from inshore areas.

Offshore recoveries from Area A had a smaller mean length (417 mm) than inshore recoveries (435 mm). No appreciable difference was evident between mean lengths of offshore (435 mm) and inshore (440 mm) recoveries from Area B tagging.

Sex Ratios

Astoria trawl landings of Dover sole have been sampled regularly since 1948 for size, sex, and age composition. Sex ratios have remained consistent for fish caught on the inshore grounds during the summer months, but not in samples from the new offshore grounds. Table 8 shows the sampling results for the period June 1954-August 1955. The sex ratio, expressed as per cent males, was remarkably constant (28-38) for fish caught on the inshore grounds during the two summers. Such was not the case for the limited sampling from the offshore grounds (Willapa Deep). Per cent males ranged from 35 in December 1954 to 93 in May 1955. A similar phenomenon was noted for petrale sole from Esteban Deep off Vancouver Island by Alverson and Chatwin (1957).

Since the May 1955 sample which contained 92.6% males was taken from fish caught April 29-30 by the tagging vessel, presumably the bulk of the tagged fish were males.

Therefore, the sex ratio of the recaptured fish was examined and Table 9 summarizes the results. The proportion of males was high for offshore recoveries from Areas A (70%) and B (86%). Inshore recoveries, however, contained fewer males from both tagging areas (Area A, 49%; Area B, 44%). Similar variations in sex ratio were observed for untagged fish from commercial landings. Females, on the other hand, were recaptured in approximately equal numbers on offshore and inshore grounds.

Variations in size composition could alter sex ratios since the females grow to a larger size than the males. Figure 3 demonstrates the difference in size composition of male and female Dover sole landed in Astoria from offshore and inshore grounds during the period June 1954-August 1955. Figure 4 shows the same comparison for recaptured tagged fish.

TABLE 7

Size Composition of Tagged and Recovered Dover Sole by Tagging Area.

Total Length[1] (cm)	Area A Tagged Nos.	Area A Recov'd Nos.	Area A Recov'd %	Area B Tagged Nos.	Area B Recov'd Nos.	Area B Recov'd %
28	1	—	0	—	—	—
30	9	—	0	—	—	—
2	24	—	0	—	—	—
4	61	1	2	2	—	0
6	121	19	16	21	—	0
8	226	37	16	90	2	2
40	300	40	13	165	10	6
2	274	35	13	209	16	8
4	180	26	14	178	14	8
6	106	17	16	103	7	7
8	100	8	8	45	2	4
50	67	8	12	13	0	0
2	34	8	24	8	1	13
4	23	6	26	5	0	0
6	17	1	6	3	0	0
8	10	—	0	3	1	33
60	5	—	0	1	0	0
2	1	—	0	0	0	0
4	—	—	—	1	1	100
Total	1,559	206	13	847	54	6

[1]At time of tagging.

TABLE 8

Sex Ratios of Dover Sole Landed in Astoria by Catch Area and Month, 1954-55.

Year	Month	Offshore Nos. Sampled	Offshore % Males	Inshore Nos. Sampled	Inshore % Males
1954	June	—	—	2,118	32.2
	July	—	—	865	28.4
	Aug.	—	—	2,181	34.5
	Oct.	742	68.6	—	—
	Dec.	643	34.8	—	—
1955	May[1]	203	92.6	—	—
	June	—	—	1,753	36.4
	July	—	—	2,290	37.7
	Aug.	—	—	1,659	35.3

[1]A sample from the April 29-30 catch of tagging vessel.

TABLE 9

Tag Recoveries by Sex and Tagging and Recovery Areas.[1]

	Tagging Area A	Tagging Area B
Offshore Recoveries		
Males	90	36
Females	38	6
% Males	70	86
Inshore Recoveries		
Males	21	4
Females	22	5
% Males	49	44

[1]Fish of unknown sex (29) and catch area (9) have been omitted.

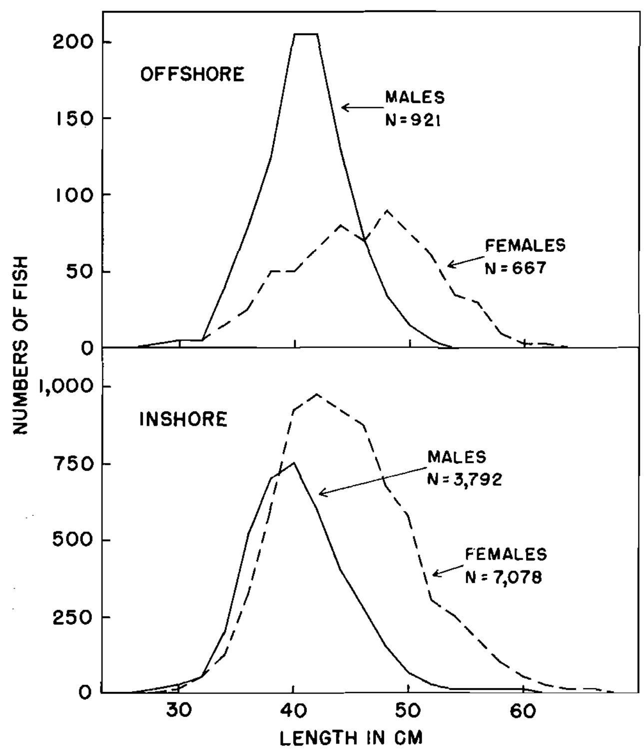

FIGURE 3. Size composition by sex of Dover sole landings from offshore and inshore grounds, 1954-55.

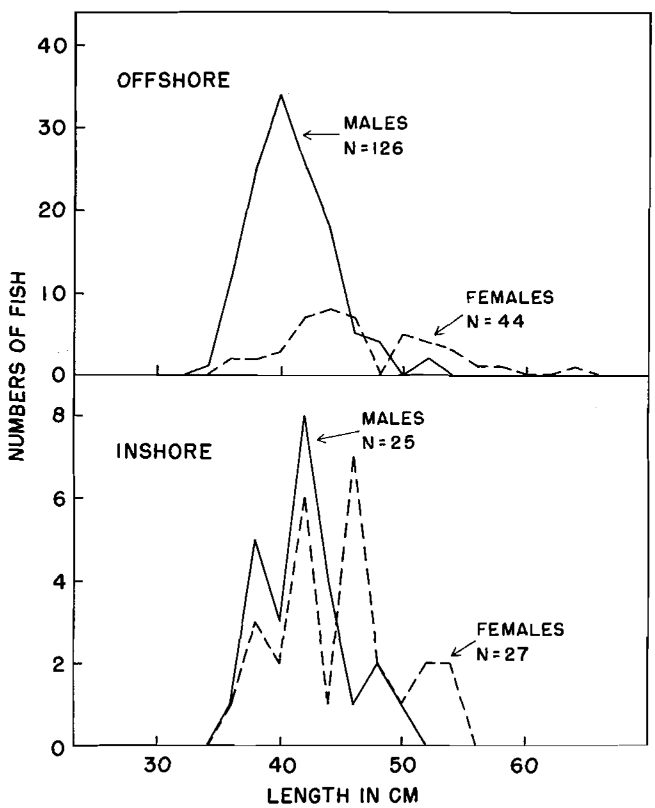

FIGURE 4. Size composition of recovered Dover sole by sex and recovery area.

In order to correct for possible effects of changing size composition, those size intervals among tagged fish which yielded consistent returns were examined. The results are as follows:

Tagging Area	Size Interval	Recovery Area	Per Cent Males
A	36-46 cm	Offshore	77
		Inshore	56
B	40-46 cm	Offshore	89
		Inshore	56

These results suggest that fewer tagged male Dover sole were available for recapture on the inshore grounds. It appears probable that this phenomenon resulted because a substantial portion of the tagged male Dover sole dispersed from the tagging area into other offshore areas and were not present on the inshore grounds.

Mortality Rate

An estimate of the total annual mortality rate, *a*, has been computed from the data in Table 2 using the technique suggested by Ricker (1958). Thus,

$$s = \frac{49 + 23 + 13 + 9 + 4}{109 + 49 + 23 + 13 + 9} = 0.48,$$

and

$$a = 1 - s = 0.52.$$

The corresponding estimate for the instantaneous rate, *i*, is 0.73.

These estimates have two important limitations. First, they are maximal since no correction can be applied for dispersion to other areas, tag loss, or recovery efficiency. Second, the values apply primarily to male Dover sole, which predominated among the recaptured fish.

CONCLUSIONS

This tagging experiment was unfortunately timed so that the spawning period was nearly over and as a result most of the fish tagged were males, which precede the females to the spawning grounds and linger on after they have left. Hence, little knowledge concerning the migration of female Dover sole utilizing the Willapa Deeps is available from this experiment.

Few Dover sole tagged in the two offshore areas migrated more than 30 miles from the tagging areas and the inshore recoveries were nearly all taken northeast of the deeps between Willapa Bay and Cape Elizabeth. This inshore area is not a major producer of Dover sole at the present time.

Male Dover sole may not all migrate to inshore grounds each summer. Indeed, it appeared that fish from Little Willapa Deep, of both sexes, did not move to inshore grounds at all during the first 12 months after tagging.

SUMMARY

1. Rapid development in 1954 of a deep-water fishery for spawning Dover sole during the winter months created some concern within the conservation agencies and the trawl industry. If the deep-water stocks were the same fish which appeared each summer on the inshore grounds, the threat of over-fishing seemed possible.
2. A tagging experiment was initiated in April 1955 to determine whether the Dover sole occupying the offshore grounds during the winter and early spring did indeed move inshore to become available to the summer inshore fishery.
3. During April 1955, 2,406 Dover sole were tagged in 2 adjacent offshore grounds with a chartered trawler.
4. Through April 30, 1962, 260 tagged fish were recaptured. In Area A (Willapa Deep) 1,559 were tagged and 206 (13%) recaptured, and in Area B (Little Willapa Deep, 10 miles southeast of A) 847 were tagged and 54 (6%) were recaptured. For an unknown reason, none of the Area B fish was recaptured during the first 12 months after tagging. Recovery rates by individual tow ranged from 1 to 25%.
5. Migration away from the tagging area was not extensive for most of the recaptured fish. Only 7 were recaptured more than 30 miles from the tagging area. Maximum migrations were 110 miles north to southern Vancouver Island and 360 miles south to northern California.
6. A seasonal offshore-inshore migration was exhibited by the tagged fish. Principal inshore recovery depths were 30-60 fathoms during June-September. Offshore recoveries were made between 180 and 300 fathoms during November-April.
7. Available data suggest a limited exchange of stocks among offshore areas from northern California to British Columbia.
8. Sex ratios indicated that most of the tagged fish were males. This was probably because the tagging took place late in the spawning season. Furthermore, most of the tagged male Dover sole probably did not move to the inshore grounds to become available to the summer fishery.
9. Total annual mortality rate was estimated to be 0.58, and total instantaneous mortality rate to be 0.73.

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Movements of Petrale Sole, *Eopsetta jordani* (Lockington), Tagged Off California

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Marine Resources Operations
California Department of Fish and Game

BULLETIN 6

PACIFIC MARINE FISHERIES COMMISSION
Portland, Oregon, 1963

MOVEMENTS OF PETRALE SOLE, *Eopsetta jordani* (LOCKINGTON), TAGGED OFF CALIFORNIA[1]

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INTRODUCTION

The petrale sole ranges from at least Los Coranodos Island, Baja California, north into the Bering Sea (Roedel, 1953, p. 59; Evermann and Goldsborough, 1907, p. 352). It is the object of a commercial fishery from Santa Barbara, California, to Hecate Strait, British Columbia. This moderately large flounder is an extremely desirable fish and has always commanded a premium price from the fresh fish markets. It has been relatively abundant in the California markets since the earliest days of the trawl fishery. Lockington (1881, p. 25) reported it was abundant in San Francisco markets every month of the year and stated it was the most abundant flatfish at Monterey with daily landings of at least 500 pounds. Presumably, the fish landed at Monterey were taken by hook and line as no trawl fishery was known at that time. The magnitude of these early landings cannot be accurately assessed, because petrale sole was normally landed and sold mixed with sand sole *(Psettichthys melanostictus)*.

Improvements in catch and effort statistics of the trawl fishery since 1934 have given a reliable measure of the importance of petrale sole. During the period 1934 through 1947, annual landings averaged about 1,500,000 pounds at California ports. This amounted to about 20 percent of the trawl catch and was second in poundage landed to English sole *(Parophrys vetulus)* (Ripley, 1949, p. 68).

Following World War II the California trawl fleet increased in number and developed large winches and equipment capable of fishing to 200 fathoms and deeper. With this improved gear the fleet quickly found new fishing areas and landings increased greatly. Most significant was the finding of petrale sole spawning concentrations during winter months at depths of 150 to 200 fathoms. These concentrations were very dense and catch rates went up accordingly. Over 5,000,000 pounds of petrale sole were landed at California ports in 1948. Annual landings for the period 1948 through 1961 averaged about 3,505,000 pounds. This increase to more than double previous annual landings, was overshadowed by the spectacular development of California's dover sole *(Microstomus pacificus)* fishery, and petrale sole dropped to third ranking, now representing only 10 percent of the trawl landings (Best, 1961b, p. 59). The trawl fishery is by far the largest producer of petrale sole, however, each year a few thousand pounds are taken with other gear. Total petrale sole landings at California ports are listed in Table 1.

TABLE 1

Petrale Sole Landings at California Ports, 1924 to 1961.

Year	Pounds	Year	Pounds
1924	66,000	1943	897,000
1925	321,000	1944	928,000
1926	356,000	1945	711,000
1927	387,000	1946	1,758,000
1928	854,000	1947	1,169,000
1929	1,064,000	1948	5,082,000
1930	2,244,000	1949	4,859,000
1931	4,244,000	1950	4,337,000
1932	1,204,000	1951	2,716,000
1933	966,000	1952	2,889,000
1934	2,451,000	1953	3,349,000
1935	1,972,000	1954	4,168,000
1936	1,113,000	1955	3,620,000
1937	1,780,000	1956	2,830,000
1938	1,987,000	1957	3,457,000
1939	2,543,000	1958	3,158,000
1940	1,572,000	1959	2,632,000
1941	874,000	1960	2,476,000
1942	596,000	1961	3,391,000

COASTAL SUBPOPULATIONS

Spawning Aggregations

Knowledge of the fishing habits of the Pacific coast trawl fleets, combined with observations of the landings, established that several separate spawning populations did exist. Using the terminology of Marr (1957, p. 1), these spawning concentrations will be considered subpopulations. Adult fish in an advanced stage of maturity were

[1]Submitted for publication May 10, 1963.

taken simultaneously from such widely separated places as Esteban Deep, off Vancouver Island, British Columbia; Willapa Deep, off the Washington coast; off Coos Bay, Oregon; off Cape Mendocino, Point Montara, and Point Sal, California.

Meristic Data

Taylor (1957) statistically compared vertebral centra and dorsal, anal, and pectoral fin rays of petrale sole collected at various places from Hecate Strait to Port San Luis, California. Using these meristic characters he concluded that there were 2 broad groups of petrale sole on the Pacific coast: a northern group, from Hecate Strait to Trinidad Head, California, and a southern group from central and southern California. He also showed that the relatively stable conditions of temperature and salinity at the depths which petrale sole spawn (150-200 fathoms) could account for this. The T-S relationship of this moderately deep water was similar from Cape Mendocino to the Columbia River and probably as far north as the west coast of Vancouver Island. The water mass south of Point Conception was of similar salinity but warmer by 1.0°C. Tagging studies and the above information on spawning aggregations show that several subpopulations exist with these 2 groups.

Tag Returns

Returns of tagged petrale sole made it clear that this flounder could and did migrate considerable distances. Hagerman (1949) reported the recovery in 200 fathoms off Eureka, during November 1948, of a petrale sole tagged by the Fish Commission of Oregon the previous April in 40 fathoms off the Columbia River. Mr. J. A. Thomson (personal communication) reported that 2 petrale tagged by the Fisheries Research Board of Canada off Vancouver Island were subsequently recovered off Rogue River, Oregon, and Crescent City, California.

Barraclough (1954) recorded movements of summer-tagged petrale sole from Hecate Strait south to Esteban Deep during the winter. Alverson and Chatwin (1957) tagged spawning petrale sole in the Esteban Deep during the winter, with subsequent recoveries from Hecate Strait area during the summer fishery. These 2 experiments confirmed the migration pattern of the Esteban subpopulation. Spawning occurs in deep water off Esteban during the winter, followed by an inshore and northerly summer feeding migration, at least as far north as Hecate Strait, a distance of 350 miles.

Following instructions of the Pacific Marine Fisheries Commission (1948, p. 34) and utilizing this background information, the Fisheries Research Board of Canada, Washington Department of Fisheries, Fish Commision of Oregon, and California Department of Fish and Game embarked upon a petrale sole tagging program to determine the amount of mixing between subpopulations. The tagging was carried out by the individual states or by co-operation between neighboring states. Coordination, planning, and recovery data were handled through the Pacific Marine Fisheries Commission. A progress report upon the early phases of these ventures was made by the Pacific Marine Fisheries Commission (1961).

This paper will report upon the program carried out by the California Department of Fish and Game, and also report the returns from early petrale sole tagging along the coast of California.

METHODS AND MATERIALS

Fishing Operations

All tagging was done aboard California Department of Fish and Game research vessels. Often the petrale sole were taken incidental to other species, and in the early cruises the number tagged was small. All fish were taken by trawling. No description of the fishing gear used on the early cruises is available.

On the 1949 cruise, fishing was with a 325-mesh western box net (Best, 1961c, p. 28) constructed of 4.5-inch cotton webbing fitted with a 6.5-inch hogring bag constructed of untreated 0.25-inch manila rope. This hog-ring bag was constructed with meshes measuring 6.5-inches when dry. Mesh measurements made during fishing showed the ropes had shrunk until the lumens of the meshes averaged only 4.75-inches.

A 10-foot beam trawl fitted with a net of 3.5-inch cotton webbing and 1.0-inch cotton cod-end was used on the 1950 cruise.

On the 1958 and 1960 cruises fishing was with a 400-mesh eastern trawl (Greenwood, 1958, p. 12) constructed of 4.5-inch no. 27 thread nylon webbing and fitted with a 3.0-inch cod-end of 120-thread cotton webbing.

Trawl hauls were limited to 20 or 30 minutes, after the gear was set, to insure the fish being in the best possible condition for tagging. After retrieving the trawl, the fish selected for tagging were held on deck in 2 live-tanks prior to tagging. Portable rubber bathtubs were used as live-tanks (Figure 1). A third tank was in reserve in case of a large catch. Using the 3 tanks, on 1 occasion 625 fish were tagged without apparent harm from overcrowding. The live-tanks received a continuous supply of fresh sea water from deck hoses.

FIGURE 1. Facilities for tagging aboard the *N. B. Scofield.* Live tanks, measuring boards and spaghetti tags ready for use. Photograph by author, December, 1960.

At the time of tagging the length of each fish was noted for use in growth studies. The fish was then released over the side of the vessel. Fish were not held in live-tanks for observation after tagging.

Tags

Petersen disc tags were used on all of the early cruises. On the 1958 and 1960 cruises all fish were tagged with vinyl spaghetti tubing (Floy Tag & Mfg. Co., type FT-4). The first time this tubing was used the legend was subject to abrasion and quickly became difficult, if not impossible, to read. Fortunately only orange tubing was used on the petrale sole and was never used again. This permitted identification of fish from this lot even though the identifying numbers had been worn off. By the 1960 cruise, these tags had been improved by adding a plastic coating, and no further trouble was encountered.

MOVEMENTS OF TAGGED PETRALE SOLE

Northern California

Crescent City area

August 1938. Tagging was conducted in shallow water off Crescent City from the *Albacore.* All species taken in the trawling operations were tagged and released. In the period August 14-17, 218 petrale sole were liberated. Eleven tags were subsequently recovered (5 percent), all from the tagging area. Within 34 days 9 recoveries had been made. Nearly a year elapsed before another recovery was made, May 31, 1939, and the final tag was returned during October 1940. Records of trawling activities show an intensive paranzella fishery took place in this area during the summer but not during the winter. Little effort was recorded from waters north of California. With this fishery it was impossible to determine if any substantial movement took place, only that the tagged fish were available on the inshore grounds off Crescent City during three successive summers.

Eureka area

August 1940. Sixty-seven petrale sole were tagged and released off the Mad River in 20 to 30 fathoms during tagging operations conducted aboard the *N. B. Scofield* from August 8-12. Only 5 tags (7 percent) were recovered from this incidental tagging. Two fish were recovered from the vicinity of Crescent City, one in October and the other in December 1940, approximately 40 miles north of the tagging area. Two other recoveries were made off Trinidad Head, in September 1940, and April 1941, some 10 miles north of the release point. The fifth and final recovery was made in a local fillet plant in May 1941, without information as to fishing locality.

During the winter of 1940-41 little fishing took place in northern California. This fishing inactivity, combined with the very small number of tags at liberty, could not be expected to show fish movement.

October 1949. The *N. B. Scofield* was again used for tagging during the period October 9-24. Fishing operations were carried out in 30 to 40 fathoms of water about 10 miles northwest of Humboldt Bay entrance. Of the 157 petrale sole tagged, 21 (13 percent) were subsequently recaptured. Through March 1950, a period of about 5 months, 12 tags were returned. Nine of these were from the general tagging area. Although large catches of fish in an advanced state of maturity were made, only 1 tag was positively recorded from the 200-fathom depth. The other returns were; 1 from the vicinity of Redding Rock, approximately 30 miles to the north, and 2 from Crescent City, about 50 miles north of the release point. These returns indicate some of the petrale sole, which concentrate for spawning in the Eureka area, move away fairly rapidly after conclusion of spawning activity.

Eight of the remaining tags were returned during the next summer from the inshore fishing grounds near the site of tagging, indicating that at least a portion of this spawning aggregation is resident in northern California. The final return was from a local market during May 1952, some 2 years and 7 months after release; no fishing information could be obtained.

July 1950. In an incidental tagging operation, 27 petrale sole were released on July 12, approximately 10 miles northwest of Humboldt Bay entrance. Four tags (15 percent) were returned: 3 from the tagging area in July and September 1950, and June 1951; the fourth from Crescent City in November 1951. Again the small number of tags released precluded any usable information.

November and December 1958. During the period November 12 to December 12, the *N. B. Scofield* (Cruise 58-S-8) made a cruise to northern California waters and tagged 876 petrale sole (Best, 1959). From November 12 to 17 fishing was carried out in 70 to 200 fathoms about 20 miles south-southwest of Crescent City. One hundred tags were released in this area. On November 25, operations were transferred to the Eureka area and the remaining 776 tags were put out in 30 to 50 fathoms about 10 miles northwest of Humboldt Bay entrance.

Through January 1963, returned tags numbered

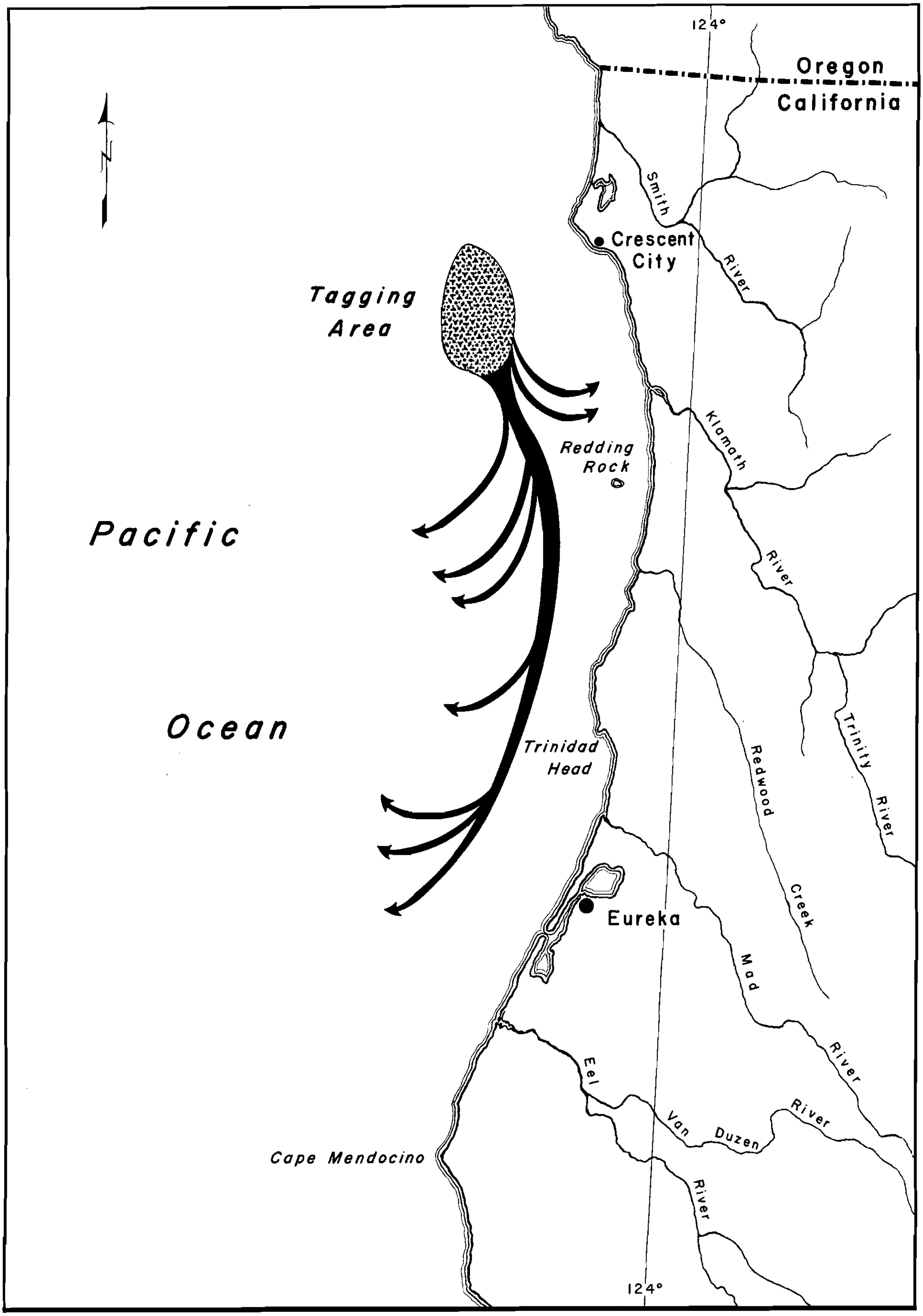

FIGURE 2. Recoveries of 9 petrale sole released off Crescent City, California, November, 1958. All fish at liberty less than 30 days.

148 (17 percent). The 100 fish released at Crescent City provided 16 recaptures (16 percent). The 776 fish released off of Eureka produced 132 recoveries (17 percent). Within 30 days after release, 9 of the Crescent City fish were recovered south of the tagging area (Figure 2). Three of the 9 were taken in deep water off of Eureka and offshore from the southern tagging area. The agreement of these 2 criteria, recovery rate and southerly movement immediately after tagging, indicate these 2 groups of fish contributed to the single spawning aggregation. Therefore, in the analysis of these data the recoveries will be treated as stemming from a single unit.

Through February 1959, the recoveries numbered 40. Fifteen of these were from water 165 to 210 fathoms deep over known spawning grounds. Although tagging was carried out in shallow water, the tagged fish contributed to the offshore spawning accumulation. Tagged petrale sole were recovered in this spawning deep each succeeding winter through 1961-62. This return to the same area for spawning denotes that homing instincts are present in petrale sole and a considerable degree of homogeneity must exist between separate spawning populations along the Pacific coast.[2]

All recoveries for which we could obtain fishing information came from either the immediate tagging area or north of it. No tags were returned from south of Cape Mendocino. A few tags were returned from the inshore grounds slightly south of the tagging area, but this was considered to be the tagging area (Figure 3). This northerly movement away from the spawning grounds after spawning agrees with the findings of Alverson and Chatwin (1957) on the Esteban Deep spawning grounds off British Columbia.

By far the largest number of fish was taken in the immediate vicinity of the tagging area. However, a definite northward movement was noted for summer recoveries. The southern and central Oregon coast contributed several returns at various times of the year, while the northern Oregon, southern Washington, northern Washington and southern Vancouver Island areas each contributed 1 return during the summer months of July to September. The single return from Vancouver Island was landed by the Canadian otter trawler, *Cape Norman,* while fishing on the southwest corner of La Perouse Bank, approximately 500 miles from the point of release. This fish was taken in early September and landed at Vancouver, B. C., on September 7, 1959, some 9 months after tagging.

Maturity was recorded whenever an entire fish was available for examination. In every case, immature specimens, both male and female, were recovered in the immediate tagging area. The specimens exhibiting migratory tendencies were all larger, mature fish. In addition, the extreme migrations were all made by female fish. In only 2 instances were tagged male petrale recorded from north of Cape Blanco, Oregon; 1 from the vicinity of Coos Bay and the other off Yaquina Bay.

In summary, petrale sole concentrate in deep water off Eureka for spawning during December, January, and February. At the conclusion of spawning, spent fish return to shallow water and rapidly disperse in a northerly direction. This summer movement is presumably a feeding migration, and is followed by a return to deep water off Eureka for spawning. The northerly migration is not undertaken by all members of this subpopulation. Some move inshore in the immediate area and presumably remain there all year. A sizable segment of this population disperses north through the coastal waters of Oregon to at least Cape Blanco. Migration to more northerly parts of Oregon, Washington, and British Columbia is limited to a rather small portion of the population. However, the number of Oregon-tagged petrale sole recovered in California indicates the movement may be greater than our experiment showed. Differential fishing effort between the southern Oregon coast (generally light) and the northern California coast (generally intense) may be the cause of this.

Fort Bragg

August 1940. During the period August 4-6, the *N. B. Scofield* tagged and released 84 petrale sole in 21 to 45 fathoms of water off the Ten-Mile River, approximately 8 miles north by west of the Noyo River entrance buoy. No recoveries were made from this tagging venture.

Central California

San Francisco

April 1939. On April 18, two petrale sole were tagged incidentally to other species in shallow water outside Drakes Bay. One of these was recovered south-southwest of Bodega Bay in 47 fathoms on September 9. This was a northerly movement of about 25 miles.

July and August 1940. Two groups of tags were put out on this cruise of the *N. B. Scofield.* Twenty-six petrale sole were released in 30 to 100 fathoms about 10 miles west of Drakes Bay on

[2]A male petrale sole tagged by the Washington Department of Fisheries in 190 fathoms off Willapa Bay, Washington, (P.M.F.C. Area 2D), February 21, 1962, was recovered January 9, 1963, from 180 fathoms off Eureka, California, (P.M.F.C. Area 1C), approximately 350 miles south. This indicates that this fish contributed to 2 separate spawning concentrations on successive years.

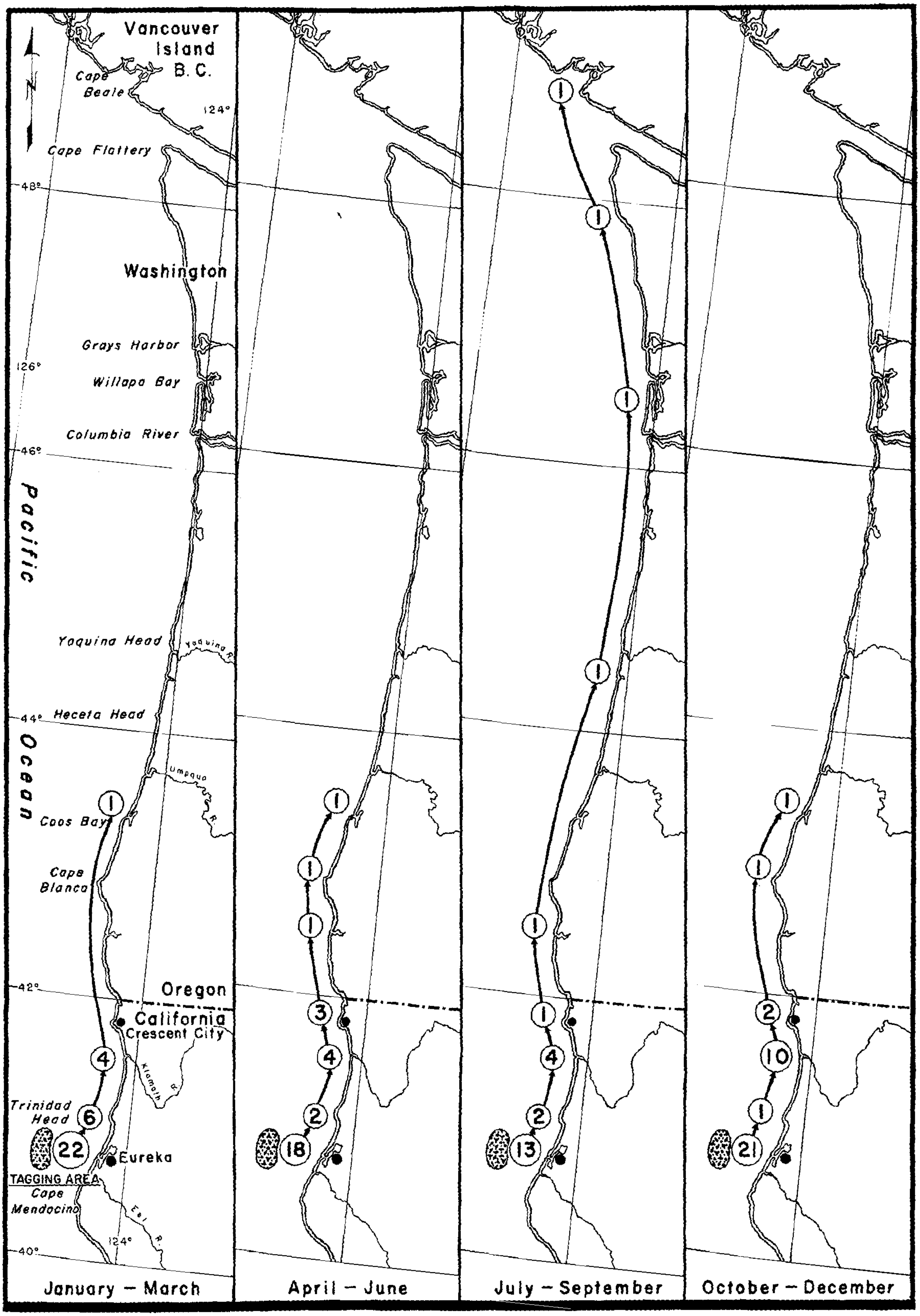

FIGURE 3. Recoveries from the 1958 petrale sole tagging in northern California. Returns have been grouped by quarter-year periods, regardless of the length of time at liberty.

July 28-30, and an additional 177 petrale sole were tagged on August 18-19 in 20 fathoms of water about 3 miles west of Double Point. For the purpose of recording their movements, these 2 groups of fish have been combined. The tagging localities were very close to each other, although some 3 weeks elapsed between the release dates. Six returns were reported from these 203 tagged fish (3 percent).

Five recoveries were made within 2 months; 3 moving south 25 miles to an area off San Francisco, and 2 in the tagging area. The 6th return was from Patricks Point some 220 miles north, on May 8, 1941, approximately 9 months after release. This single return is the only evidence of mixing among the stocks of petrale sole between the San Francisco and Eureka areas.

November 1949. On November 14, in 25-50 fathoms of water off Sharp Park, approximately 10 miles south of the San Francisco Light Vessel, 19 petrale sole were tagged. Only 1 tag was returned and it was recovered in a San Francisco market without adequate fishing information. This return was made during December 1950, after 1 year at liberty.

July 1950. On July 14, off Drakes Bay in 30 fathoms, 14 petrale sole were released from the *N. B. Scofield.* No returns were reported from this incidental tagging.

November and December 1960. The *N. B. Scofield* (Cruise 60-S-6) was utilized for tagging during the period November 17 to December 16. In this operation, 2,378 tags were released in 164 to 225 fathoms off Point Ano Nuevo and Half Moon Bay (Best, 1961a). The tagging was carried out 30 to 40 miles south-southwest of the San Francisco Light Vessel.

Tags returned were 53 (2 percent) through January 1963. Eight tags were returned from the deep-water fishing grounds during and immediately after tagging. By April and May 1961, tags were being returned from inshore areas slightly to the north. During June and July, 4 returns were reported from the general vicinity of the San Francisco Light Vessel and 1 from Santa Cruz. One return was reported from off Point Reyes, approximately 50 miles north of the tagging area, in September. During December 1961, a price dispute sharply curtailed landings and no tags were returned. January 1962, saw fishing resumed and 13 tags were returned from the tagging area in deep water. This was the best single month for tag returns from this experiment. Single tags were turned in during March and April 1962. The spawning deep produced 1 tag in December 1962, and 2 in January 1963. Additional returns are anticipated in the future.

This experiment again demonstrated the northerly migratory tendency of this species after spawning. No tags were returned from any distance south of the winter spawning areas. Although the predominant migration was to the north, it was of considerably less magnitude than that exhibited by fish tagged off of Eureka and Vancouver Island (Figure 4).

The weather during this tagging cruise was extremely adverse and the fish were subjected to rough handling. This undoubtedly contributed to the low recovery rate of 2 percent. Alverson and Chatwin (1957) also reported low recovery rates of 2.2 and 5.1 percent for petrale sole tagged in deep water. Apparently the extreme pressure change that the fish are subjected to in hauling them from 200 fathoms, the physical beating they take in the net (trawling as well as bringing in the net), additional handling to place them in live tanks, and tagging operations, all contribute to a high tagging mortality. However, fish tagged in shallow water are subjected to the same techniques, but appear to survive in far greater numbers, 17 percent for the 1958 Eureka tagging. This points to the change in pressure of 40 atmospheres as the primary cause of tagging mortality among deep-water caught petrale sole.

Monterey Bay

Very few petrale sole have been tagged in the Monterey Bay area, and these incidentally to other species.

April 1937. On April 7, in shallow water near Santa Cruz, 32 tags were released; 12 subsequently were recovered (37.5 percent). Three were taken in the tagging area within 1 month of tagging. Eight recoveries were made in the tagging area 11 to 14 months later. Unfortunately, no record was obtained of the whereabouts of the tagged individuals during the intervening year. The 12th and last return was made September 22, 1941, 4 years and 5 months later off Port Hueneme, some 250 miles south of the release point. Lack of fishing effort in this area and in the regions to the south undoubtedly masked other movements that may have occurred. The intensive fishery to the north would have uncovered the fish had they moved that way.

March 1939. Ten petrale sole were tagged on March 29-31, and 2 were recovered after having been at liberty for 6 and 22 days. No movement of any degree was noted.

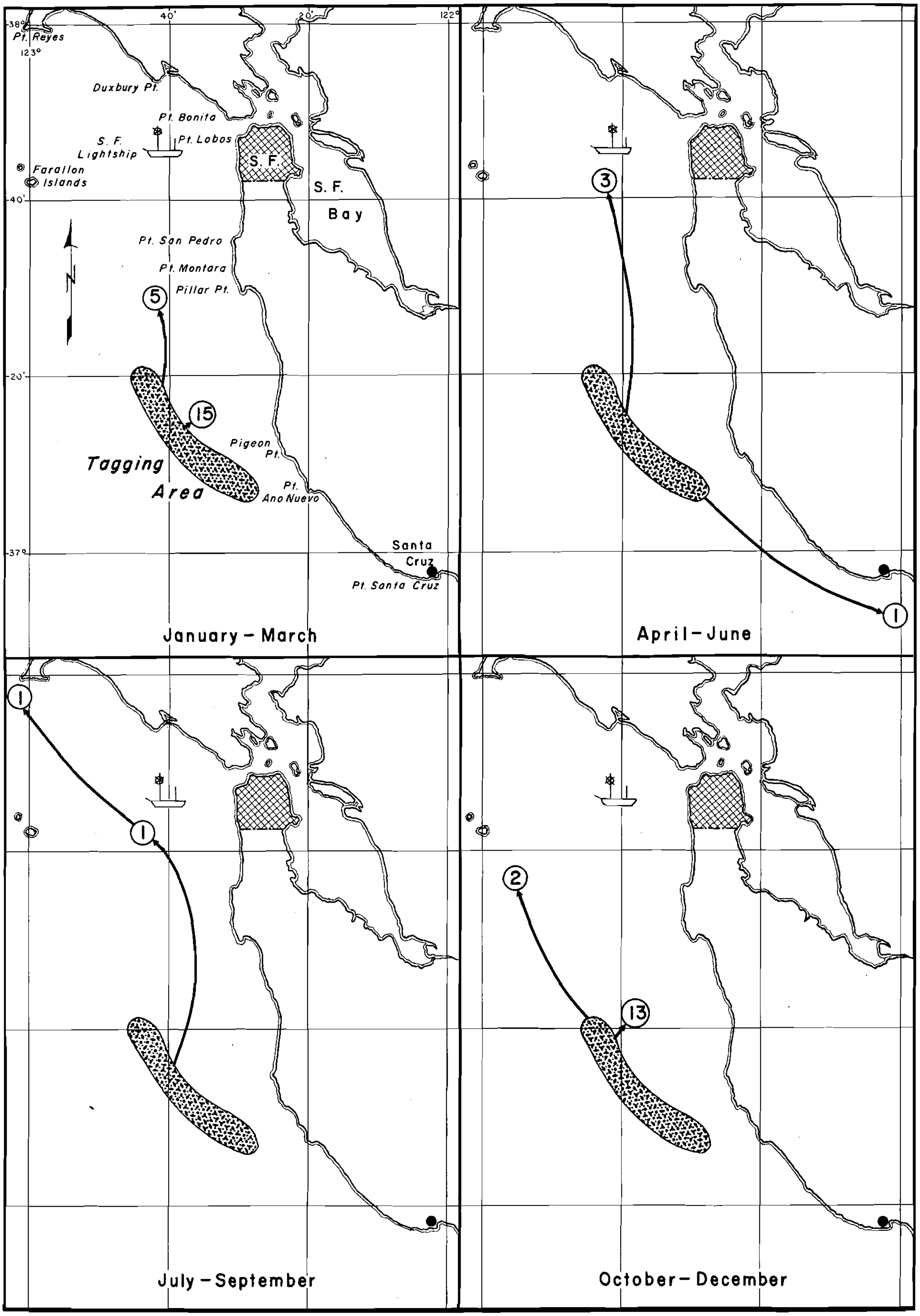

FIGURE 4. Recoveries from the 1960 petrale sole tagging in central California. Returns have been grouped at quarter-year periods, regardless of the length of time at liberty.

MIGRATION RATE

The 9 tags released off Crescent City and recovered within 30 days gave some information on the migratory rate of this species. Recovery information provided by fishermen often involves a large area fished during a trip. For computing movements, we used the given location closest to the tagging area, thus all movements are minimal.

The minimum rate of movement shown by individuals of this group was 1.0 mile per day, and the maximum was 3.8 miles. The mean rate for the entire group was 1.7 miles per day. If we had used the given fishing location farthest from the tagging location, the maximum rate of movement would be 4.1 miles per day and the mean rate 1.9 miles.

Because we used minimum distances, an average movement of 2 miles per day does not seem unreasonable for migrating petrale sole. The Oregon Fish Commission has reported movements of more than 3 miles per day (P.M.F.C., 1961, p. 44). The single fish reported as moving from Eureka to Vancouver Island covered about 500 miles in 280 days, an average of 1.8 miles per day. These are all straight-line measurements and do not take into consideration the random meanderings the fish may make.

SHRINKAGE

It was disturbing to find that practically all of the initial recoveries measured shorter than when tagged a few days previously. Obviously the several people involved in tagging recovery presented a large source of error in the measurements, and the first few negative measurements were written off to this cause. However, when 10 of 13 fish, at liberty 30 days or less, showed negative growth, it could not be blamed on measurement.

Methods of handling the recovered tagged fish also varied; some samplers obtained nearly fresh fish, some fish had been iced aboard the fishing vessel, and some had been iced and then frozen in the fillet plant.

One of the 13 fish recovered showed growth of 2 mm, 2 were unchanged, and 10 had decreased in length by 2 to 12 mm each. The mean shrinkage was 4.3 mm (Table 2).

Such shrinkage agrees with the findings of Harry (1956, p. 99) who showed in a controlled experiment that petrale sole shrank an average of 3 mm when stored in ice, and an average of 6 mm when iced at sea and frozen at the plant. Lux (1960) found a mean decrease in length of tagged and recovered yellowtail flounder *(Limanda ferruginea)* off New England of 4.03 mm, or 1.2 percent. In a controlled experiment on the same species, he found a mean shrinkage of 5.12 mm, or 1.47 percent. Every fish in this experiment shrank some. Burgner (1962, p. 258) determined the primary cause of shrinkage of red salmon smolts *(Oncorhynchus nerka)* was rigor mortis with some additional shrinkage when the specimens were preserved in 10 percent formalin.

Thus, it appears that petrale sole, in common with other fish, shrink upon death and icing aboard commercial vessels. This shrinkage of about 5 mm per fish must be considered in growth analysis.

The 13 fish we measured indicated a linear relationship of increased shrinkage with larger sizes of fish. No conclusive results could be determined from this small number of measurements.

TABLE 2

Lengths of 13 petrale sole at time of tagging and net change in length when recovered. All fish were at liberty 30 days or less.

Total Length mm	Net Change mm	Total Length mm	Net Change mm
296	−2	362	− 8
300	0	366	0
304	−4	386	−12
322	−4	390	+ 2
326	−6	424	− 4
330	−4	440	−10
334	−4		

SIZE

Combining recoveries, made after 11 to 13 months at liberty, for all experiments gave us length measurements for 8 mature female and 21 mature male petrale sole. These measurements made it possible to determine a year's length increment (Figure 5).

The females were 318 to 460 mm long when tagged. Their lengths at recovery plus the 5 mm correction for shrinkage were plotted as a growth transformation. This estimate of yearly growth is approximated by the equation $Y = 43 + 0.932X$, which gives an estimate for L_∞ of 630 mm.

The 21 males ranged from 270 to 430 mm long. These length measurements were handled in the same manner as above, and the resultant equation was $Y = 77 + 0.850X$, giving an estimate for L_∞ of 520 mm.

The largest specimens observed in our market sampling have been a 594 mm female and a 490 mm male. Cleaver (1949) reported largest observed size in Washington was 61.0 cm for females and 49.0 for males. Harry (1956, p. 54) reported maxima from Oregon to be 56.0 cm for females and 47.0 for males.

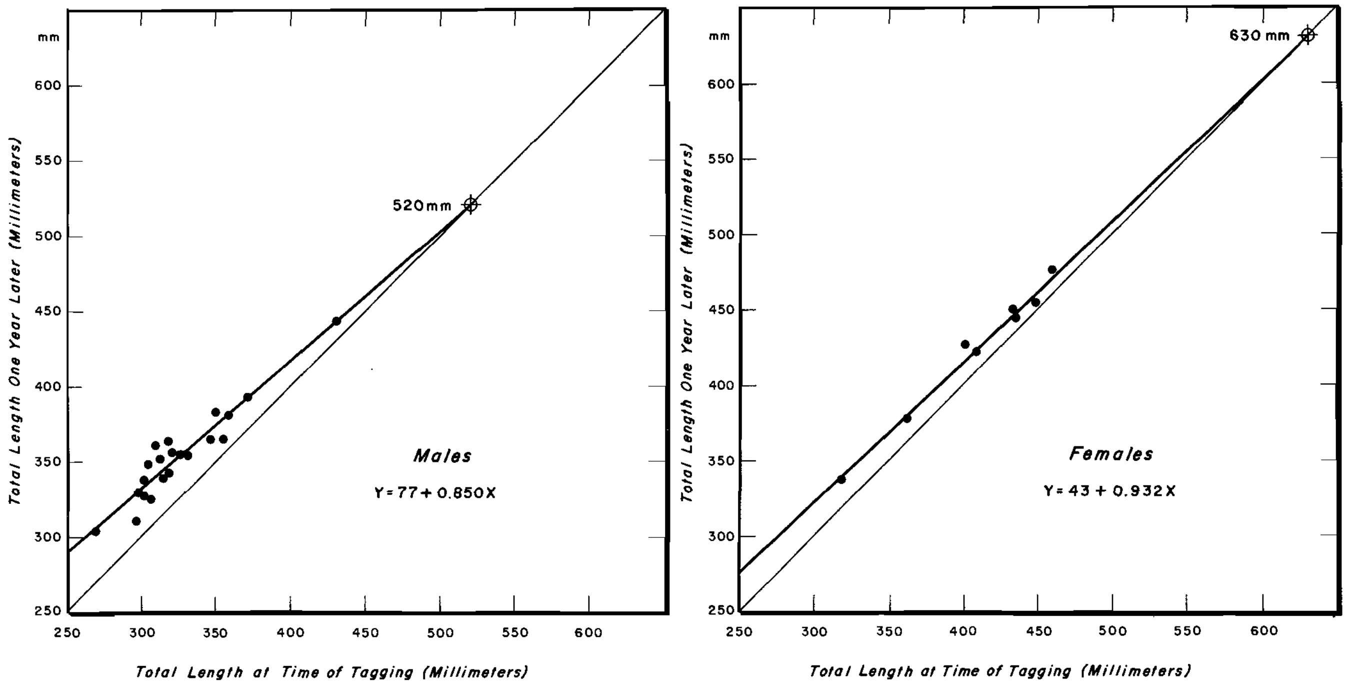

FIGURE 5. Growth of male and female petrale sole based on returns of tagged fish at liberty from 11 to 13 months.

ACKNOWLEDGMENTS

The success of the various tagging cruises has been dependent to a large degree on the cooperation of the crews of the various research vessels. I deeply appreciate this cooperation which Captain R. B. Mitchell and crew of the *N. B. Scofield* willingly gave me. I am also grateful to the members of the bottomfish investigations of the cooperating agencies for their help in collecting and forwarding information on out of state recoveries.

SUMMARY

1. Early work on spawning aggregation, meristic counts, and tag studies indicated that more than one petrale sole subpopulation existed in the eastern north Pacific Ocean.
2. During November and December 1958, 876 petrale sole were tagged and released off northern California. One hundred forty-eight (17 percent) have subsequently been returned. This subpopulation concentrates for spawning off Eureka during December to February. A considerable portion of this group moves north to at least Cape Blanco, Oregon, during the summer. Lesser numbers move north at least to Vancouver Island, British Columbia.
3. During November and December 1960, 2,378 petrale sole were tagged and released southwest of San Francisco. Fifty-three (2 percent) have subsequently been recovered. This spawning subpopulation moves north through the Gulf of the Farallons to at least Point Reyes and Cordell Bank during the summer.
4. An average migration rate of 2 miles per day was calculated for petrale sole. A maximum of 3.8 miles per day was calculated for a single fish.

5. Migratory behavior was exhibited only by mature fish, females migrating considerably longer distances than males.
6. Petrale sole recovered within 30 days of tagging had shrunk an average of 5 mm in length. The method of handling after capture influenced the amount of shrinkage.
7. Maximum expected lengths of 52 and 63 cm, for males and females respectively, were calculated from growth of individual fish at liberty 11 to 13 months. Maximum sizes observed in market samples were 49 and 59 cm for males and females.

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APPENDIX A-1

Returns from 218 Petrale Sole Tagged off Crescent City, California (P.M.F.C. Area 1C), August 14-17, 1938.

Tag No.	Recovery Date	Depth in Fathoms	Dir.	Distance in Miles	P.M.F.C. Area
2790	8/21/38	U	N	10	1C
2653	8/24/38	U	N	10	1C
3009	8/28/38	U	O	0	1C
3133	9/ 1/38	U	O	0	1C
3507	9/ 1/38	U	O	0	1C
2833	9/ 5/38	U	O	0	1C
3121	9/19/38	U	O	0	1C
3138	9/ ?/38	M	U	U	U
3573	9/ ?/38	M	U	U	U
3309	5/31/39	U	N	10	1C
3379	10/ 8/40	U	O	0	1C

P.M.F.C. Area = See P.M.F.C. Annual Report for 1961
U = Unknown
N = North
O = Tagging Area
M = Market Recovery

APPENDIX A-2

Returns from 67 Petrale Sole Tagged off Mad River California (P.M.F.C. Area 1C), August 8-12, 1940, in 20 to 30 Fathoms

Tag No.	Recovery Date	Depth in Fathoms	Dir.	Distance in Miles	P.M.F.C. Area
20803	9/13/40	U	N	10	1C
21498	10/ 8/40	U	N	30	1C
20735	12/10/40	U	N	50	1C
20745	4/17/41	U	N	10	1C
21136	5/ 6/41	M	U	U	U

P.M.F.C. Area = See P.M.F.C. Annual Report for 1961
U = Unknown
N = North
M = Market Recovery

APPENDIX A-3

Returns from 157 Petrale Sole Tagged off Humboldt Bay, California (P.M.F.C. Area 1C), October 9-24, 1949, in 30 to 40 Fathoms

Tag No.	Recovery Date	Depth in Fathoms	Dir.	Distance in Miles	P.M.F.C. Area
C 309	11/19/49	41	N	40	1C
C 930	12/20/49	M	U	U	U
C 783	12/21/49	45	S	10	1C
C 925	12/27/49	200	S	10	1C
C 485	12/28/49	M	U	U	U
C 375	1/20/50	U	O	0	1C
C 14	1/22/50	49	S	10	1C
C 200	2/ 8/50	41	N	50	1C
C 926	2/ 8/50	40	N	20	1C
C 638	2/14/50	M	U	U	U
C 546	3/21/50	U	O	0	1C
C 369	3/31/50	U	N	30	1C
C 383	4/ 4/50	40	O	0	1C
C 916	4/16/50	U	O	0	1C
C 244	5/ 5/50	40	O	0	1C
C 474	7/11/50	25	O	0	1C
C 971	8/ 1/50	M	U	U	U
C 941	8/ 5/50	M	U	U	U
C 204	9/29/50	43	S	10	1C
C 222	10/ 1/50	30	O	0	1C
C 31	5/ 4/52	M	U	U	U

P.M.F.C. Area = See P.M.F.C. Annual Report for 1961
N = North
M = Market Recovery
U = Unknown
S = South
O = Tagging Area

APPENDIX A-4

Returns from 27 Petrale Sole Tagged off Humboldt Bay, California (P.M.F.C. Area 1C), July 12, 1950, in 24 Fathoms

Tag No.	Recovery Date	Depth in Fathoms	Dir.	Distance in Miles	P.M.F.C. Area
C 2594	7/29/50	55	O	0	1C
C 2416	9/10/50	U	O	0	1C
C 2415	6/23/51	27	O	0	1C
C 2499	11/ 8/51	U	N	50	1C

P.M.F.C. Area = See P.M.F.C. Annual Report for 1961
O = Tagging Area
U = Unknown
N = North

APPENDIX A-5

Returns from 100 Petrale Sole Tagged off Crescent City, California (P.M.F.C. Area 1C), November 12-17, 1958, in 70 to 200 Fathoms

Tag No.	Recovery Date	Depth in Fathoms	Dir.	Distance in Miles	P.M.F.C. Area
63	11/23/58	40	S	13	1C
75	11/23/58	40	S	13	1C
17	11/26/58	185	S	50	1C
50	11/26/58	185	S	50	1C
93	11/29/58	58	S	40	1C
89	12/ 7/58	165	S	20	1C
57	12/ 9/58	190	S	50	1C
85	12/17/58	165	S	30	1C
88	12/17/58	165	S	30	1C
10	5/ 8/59	64	N	120	2B
8	5/15/59	48	N	10	1C
23	5/15/59	48	N	10	1C
35	6/ 6/59	50	N	40	2A
100	8/19/59	40	N	170	2C
80	8/22/59	M	U	U	U
42	8/22/60	70	O	0	1C

P.M.F.C. Area = See P.M.F.C. Annual Report for 1961
S = South
N = North
M = Market Recovery
U = Unknown
O = Tagging Area

APPENDIX A-6

Returns from 776 Petrale Sole Tagged off Humboldt Bay, California (P.M.F.C. Area 1C), Nov. 25 to Dec. 12, 1958, in 30 to 50 Fathoms

Tag No.	Recovery Date	Depth in Fathoms	Dir.	Distance in Miles	P.M.F.C. Area
134	12/ 6/58	190	O	0	1C
426	12/ 9/58	190	O	0	1C
318	12/13/58	56	O	0	1C
504	12/13/58	56	O	0	1C
627	12/13/58	56	O	0	1C
682	12/16/58	48	O	0	1C
350	12/18/58	180	O	0	1C
263	12/19/58	55	O	0	1C
345	12/19/58	55	O	0	1C
522	12/19/58	55	O	0	1C
462	12/20/58	50	O	0	1C
730	12/20/58	50	O	0	1C
745	12/20/58	50	O	0	1C
281	12/28/58	52	O	0	1C
731	12/28/58	52	O	0	1C
496	1/ 2/59	165	N	20	1C
822	1/ 2/59	165	N	20	1C
385	1/12/59	50	O	0	1C
485	1/14/59	47	O	0	1C
359	1/15/59	45	N	30	1C
428	1/15/59	68	O	0	1C
307	1/17/59	185	N	10	1C
617	1/17/59	66	O	0	1C
625	1/17/59	66	O	0	1C
242	1/21/59	39	N	40	1C
568	2/19/59	195	O	0	1C
754	2/21/59	110	O	0	1C
321	2/23/59	70	N	10	1C
623	2/23/59	125	N	10	1C
630	2/23/59	70	N	10	1C
648	2/23/59	70	N	10	1C
601	3/ 1/59	50	O	0	1C
297	3/13/59	65	O	0	1C
527	3/16/59	57	O	0	1C
602	3/22/59	68	O	0	1C
253	3/28/59	52	O	0	1C
672	3/28/59	52	O	0	1C
381	4 /1/59	56	O	0	1C
566	4/ 3/59	80	N	10	1C
789	4/ 4/59	81	O	0	1C
304	4/ 8/59	41	N	30	1C
275	4/ 9/59	70	O	0	1C
689	4/ 9/59	55	O	0	1C
309	4/10/59	65	O	0	1C
401	4/10/59	65	O	0	1C
503	4/10/59	65	O	0	1C
888	4/10/59	65	O	0	1C
307	4/21/59	65	O	0	1C
384	4/23/59	60	O	0	1C
411	4/23/59	60	O	0	1C
564	4/23/59	60	O	0	1C
854	4/23/59	60	O	0	1C
424	4/24/59	60	O	0	1C
103	4/26/59	40	N	30	1C
545	4/26/59	40	N	30	1C
758	4/29/59	52	N	130	2B
413	5/19/59	M	U	U	U
756	5/19/59	M	U	U	U
712	7/23/59	26	O	0	1C
737	8/ 1/59	26	O	0	1C
795	8/ 1/59	26	O	0	1C
415	8/ 2/59	27	O	0	1C
885	8/ 2/59	M	U	U	U
839	8/ 5/59	30	O	0	1C
777	8/ 7/59	30	N	30	1C
578	8/ 9/59	30	N	10	1C
349	8/17/59	29	N	20	1C
433	8/17/59	M	U	U	U
267	8/19/59	M	U	U	U
420	8/31/59	44	N	100	2A
108	9/ 1/59	U	N	500	3C
774	9/ 7/59	M	U	U	U
391	9/ 9/59	30	O	0	1C
130	10/13/59	38	N	30	1C
765	10/13/59	38	N	30	1C
582	10/15/59	M	U	U	U
626	10/21/59	32	N	30	1C
686	11/ 8/59	70	N	150	2B
389	11/10/59	40	N	80	2A
848	11/20/59	M	U	U	U
530	12/ 1/59	M	U	U	U
?	12/ 4/59	M	U	U	U
277	12/ 9/59	58	O	0	1C
628	12/ 9/59	58	O	0	1C
683	12/17/59	M	U	U	U
326	12/22/59	M	U	U	U
857	2/ 1/60	M	U	U	U
393	3/ 7/60	M	U	U	U
666	3/20/60	65	O	0	1C
315	3/23/60	180	O	0	1C
880	3/23/60	180	O	0	1C
802	4/ 1/60	M	U	U	U
465	4/ 4/60	70	O	0	1C
285	5/ 5/60	43	N	30	1C
141	5/21/60	M	U	U	U
706	5/23/60	65	O	0	1C
439	7/13/60	40	N	10	1C
831	7/31/60	44	O	0	1C
122	8/10/60	18	N	360	2D
?	11/ 9/60	M	U	U	U
?	11/10/60	M	U	U	U
593	12/ 8/60	40	N	30	1C
213	12/20/60	M	U	U	U
238	1/ 4/61	74	O	0	1C
271	1/ 5/61	150	O	0	1C
377	1/ 5/61	150	O	0	1C
317	1/20/61	180	O	0	1C
295	3/29/61	44	O	0	1C
?	3/ ?/61	U	N	170	2B
331	4/23/61	51	O	0	1C
486	4/23/61	M	U	U	U
171	4/24/61	M	U	U	U
236	5/ 1/61	M	U	U	U
266	7/ 8/61	M	U	U	U
?	7/17/61	U	N	400	3B
476	7/19/61	70	O	0	1C
567	8/ 4/61	28	N	10	1C
425	8/ 8/61	35	O	0	1C
496	8/ 8/61	35	O	0	1C
431	9/21/61	28	O	0	1C
364	10/14/61	125	N	70	2A
844	11/ 1/61	160	N	60	1C
907	12/23/61	180	O	0	1C
849	1/ 6/62	185	O	0	1C
614	1/29/62	200	O	0	1C
?	4/ 7/62	U	N	10	1C
632	4/17/62	66	O	0	1C
598	6/13/62	38	N	50	1C
618	8/20/62	60	N	30	1C
764	9/12/62	26	O	0	1C
540	9/22/62	38	N	30	1C
96	1/22/63	50	N	30	1C

P.M.F.C. Area = See P.M.F.C. Annual Report for 1961
O = Tagging Area
N = North
M = Market Recovery
U = Unknown

APPENDIX B-1

Returns from 203 Petrale Sole Tagged off Drakes Bay, California (P.M.F.C. Area 1B), July 28-30 and August 18-19, 1940, in 20 to 100 Fathoms

Tag No.	Recovery Date	Depth in Fathoms	Dir.	Distance in Miles	P.M.F.C. Area
23012	8/29/40	50	S	20	1B
22053	9/19/40	U	O	0	1B
19060	9/23/40	U	S	20	1B
22464	9/25/40	54	N	10	1B
22477	10/20/40	U	S	20	1B
22073	5/ 8/41	41	N	220	1C

P.M.F.C. Area = See P.M.F.C. Annual Report for 1961
S = South
U = Unknown
O = Tagging Area
N = North

APPENDIX C-1

Returns from 32 Petrale Sole Tagged off Santa Cruz, California (P.M.F.C. Area 1B), April 7, 1937, in 20 Fathoms

Tag No.	Recovery Date	Depth in Fathoms	Dir.	Distance in Miles	P.M.F.C. Area
8592	4/20/37	U	O	0	1B
8553	4/22/37	U	O	0	1B
8552	5/ 4/37	U	O	0	1B
8532	5/ 5/37	U	O	0	1B
8509	2/28/38	U	O	0	1B
8502	3/27/38	U	O	0	1B
8521	4/13/38	U	O	0	1B
8530	4/13/38	U	O	0	1B
8573	4/13/38	U	O	0	1B
8582	4/18/38	U	O	0	1B
8518	8/ 7/38	U	O	0	1B
8587	9/22/41	U	S	250	1A

P.M.F.C. Area = See P.M.F.C. Annual Report for 1961
U = Unknown
O = Tagging Area
S = South

APPENDIX B-2

Returns from 2,378 Petrale Sole Tagged off Half Moon Bay, California (P.M.F.C. Area 1B), Nov. 17 to Dec. 16, 1960, in 164 to 225 Fathoms

Tag No.	Recovery Date	Depth in Fathoms	Dir.	Distance in Miles	P.M.F.C. Area
6191	12/13/60	200	O	0	1B
7859	12/15/60	200	O	0	1B
7808	12/21/60	200	O	0	1B
8131	12/27/60	200	O	0	1B
?	12/27/60	M	U	U	U
7747	1/18/61	M	U	U	U
8225	1/18/61	200	O	0	1B
8066	3/ 6/61	67	N	20	1B
6838	3/15/61	M	U	U	U
7763	3/15/61	70	N	15	1B
7903	3/22/61	69	N	20	1B
8180	3/23/61	200	O	0	1B
8184	3/29/61	98	N	10	1B
7931	4/ 5/61	90	N	25	1B
8011	4/ 5/61	M	U	U	U
8076	4/ 7/61	M	U	U	U
7821	5/29/61	45	S	35	1B
8096	6/26/61	30	N	40	1B
7865	6/29/61	35	N	40	1B
8145	7/13/61	M	U	U	U
7998	7/18/61	40	N	60	1B
6185	7/ ?/61	M	U	U	U
6528	10/ 9/61	97	N	25	1B
6728	10/25/61	M	U	U	U
6818	10/25/61	200	O	0	1B
7704	10/25/61	200	O	0	1B
7940	10/25/61	200	O	0	1B
8248	11/ 7/61	200	O	0	1B
8220	11/ 9/61	200	O	0	1B
7006	11/12/61	200	O	0	1B
8338	11/15/61	200	O	0	1B
7971	11/16/61	200	O	0	1B
8310	11/19/61	200	O	0	1B
6653	1/ 3/62	200	O	0	1B
8236	1/ 3/62	200	O	0	1B
6719	1/ 9/62	200	O	0	1B
7788	1/ 9/62	200	O	0	1B
6508	1/10/62	200	O	0	1B
8073	1/10/62	200	O	0	1B
6417	1/16/62	200	O	0	1B
8255	1/17/62	205	O	0	1B
6146	1/18/62	210	O	0	1B
8257	1/18/62	210	O	0	1B
8281	1/18/62	210	O	0	1B
8156	1/31/62	205	O	0	1B
8282	2/ 2/62	M	U	U	U
?	2/ ?/62	M	U	U	U
?	2/ ?/62	M	U	U	U
7866	3/16/62	120	N	25	1B
6579	4/27/62	M	U	U	U
6927	12/ 5/62	190	O	0	1B
7969	1/17/63	100	N	20	1B
8150	1/17/63	M	U	U	U

P.M.F.C. Area = See P.M.F.C. Annual Report for 1961
O = Tagging Area
M = Market Recovery
U = Unknown
N = North
S = South

Results of a Sampling Program to Determine Catches of Oregon Trawl Vessels

Part I. Methods and Species Composition

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and
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Research Division
Oregon Fish Commission

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PACIFIC MARINE FISHERIES COMMISSION
Portland, Oregon, 1963

RESULTS OF A SAMPLING PROGRAM TO DETERMINE CATCHES OF OREGON TRAWL VESSELS[1]

Part 1. Methods and Species Composition

Robert B. Herrman[2]

and

George Y. Harry, Jr.[3]

INTRODUCTION

The Oregon otter-trawl fishery developed into an industry of major importance during World War II, reaching a peak in 1943 when about 30 million pounds of fish were landed. Following the war years, however, production for the fillet market declined. Recently, market conditions have achieved more stability, and the fishery now produces quantities of fish, both for human food and animal consumption, approaching former magnitudes (Figure 1).

Intermittently since 1950, personnel of the Oregon Fish Commission have sampled unsorted otter-trawl catches at sea on Oregon vessels. Goals of the sampling program included: (1) determining the species composition of sampled catches, and from these samples the composition of both the wanted fish—those landed, and the unwanted fish—those discarded; (2) determining the size composition of specific sampled catches of the three important species of sole; and (3) determining the practicality of the existing regulations imposed on the fishery in relation to the catches, gear, and grounds fished. Sampling effort was confined almost entirely to those trips where sole were the primary type of fish sought. Trips exclusively for roundfish—usually rockfish—were not sampled. This limitation on type of trip sampled was occasioned by manpower limitations.

Only those subjects enumerated under heading (1) will be discussed in this paper. A subsequent paper will deal principally with the subjects mentioned under headings (2) and (3). In addition to the more general results listed under heading (1), this paper also details the methodology associated with the development of trawl sampling at sea.

The relatively unselective nature of the gear utilized in the trawl fisheries, as well as the heterogeneous disperson of the various species on the grounds, make it necessary to have knowledge of the true catches from fishing activities. The landings of food fish seldom mirror the composition of the catches at sea either qualitatively or quantitatively (Figure 2). In former years, after the sorting of the catches, the unwanted species plus the smaller sizes of the marketed species were commonly discarded into the sea. More recently, however, increasing amounts of the discard have been retained for animal food (principally for mink). Since no indication as to the species of fish entering the mink food appears in the landing statistics, and since the amounts and kinds of fish discarded at sea are unreported, some knowledge of the composition of mink food and discard is essential to determine the degree of exploitation of each species.

Species compositions of the landings for mink food have been previously detailed in another paper (Jones and Harry, 1961), and will not be considered in the current report.

The common names which will be used in this paper are those in use in the Oregon fishery; a few may differ from those suggested for use by the American Fisheries Society (1960). A list of common and scientific names of the most abundant species is presented in Appendix Table A.

Work loads during the summer and fall months when the sampling trips were made were highly variable from year to year and no constant amount of boat sampling could be pursued. Thus, in 1951 and 1959 only 4 trips were made each year, while in 1950 12 trips were sampled. In the other years of sampling, 1953, 1960, and 1961, the numbers of trips sampled were 5, 7, and 9, respectively. Obviously, the results of these relatively few samplings of the catches cannot be applied without reservation to those of the entire Oregon fleet; not only were the number of trips sampled restricted, but also trip type, i.e., to trips primarily for sole. The intention was to determine the composition of the catches as they were made at sea, and of the discards which occur subsequent to the sorting out of the fish for human food.

Generally, fishing during the sampled trips centered off the mouth of the Columbia River from which most of the vessels sailed. Some trips, however, were made aboard vessels fishing as far south as Heceta Bank, off central Oregon, and as far north as Destruction Island, off the northern Washington coast. Depths of fishing ranged from 5 to 200 fathoms, and duration of the trips from 1 to 6 days.

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[1]In part from a thesis submitted for the Ph.D. degree at the University of Washington, 1956. Submitted for publication May 23, 1963.

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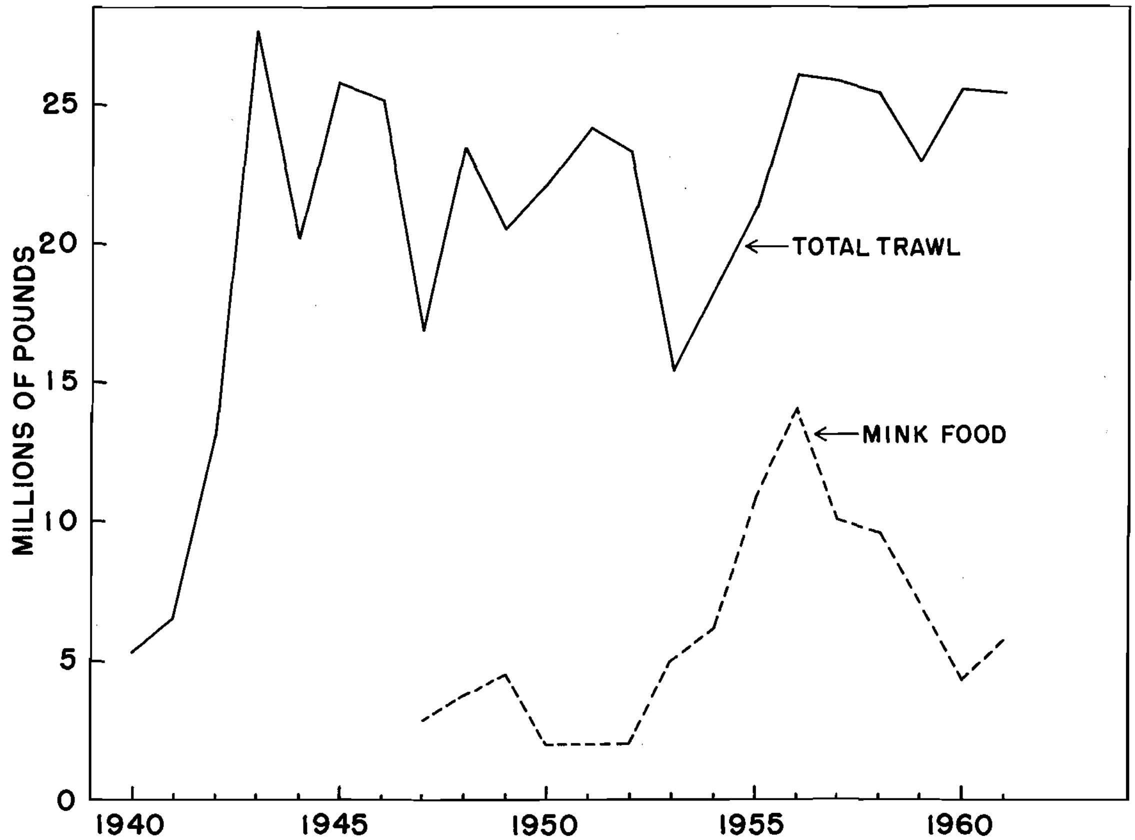

FIGURE 1. Total otter-trawl landings at Oregon Ports, 1940-61, and mink food landings, 1947-61.

FIGURE 2. Typical unsorted catch of groundfish made during a trip for sole, trawler *Eagle*, June 1960.

METHODS

General Procedure

To obtain the information desired, biologists sampled the catch as it was brought aboard commercial otter-trawl vessels, recording the frequency of occurrence of all the species encountered; in addition, all Dover, English, and petrale sole were measured. In order to have a basis for expansion of these samples to a calculated catch, one or more length-frequency samples were taken at the conclusion of each of the sampled trips from the food fish landings of the three important soles mentioned above.

Using these "boat" and "dock" length-frequency samples as a basis, the total catch of all species could be determined as follows. The dock samples of the soles were expanded numerically, first to the total landing of the particular species and then to the total catch at sea of that species. Collating these data with the species percentage compositions from the sampling aboard the vessels, the total catch of all species for each trip could be computed; species numbers were converted to pounds using average weights. By comparing the calculated poundage catches to the actual pounds landed, the amounts discarded or retained for animal food were determined.

On some occasions in addition to the food-fish samples, composition and length-frequency samples were also taken of the discard which had been retained and landed for mink food. Where most of the discard was retained for mink food, this additional sample served as a check of the calculated catch based on the food-fish samples.

In pursuing sampling aboard the vessels at sea, care was taken to interfere as little as possible with the normal operation of the vessel. For this reason no attempt was made to change the ordinary routine of fishing and fish handling, though a different procedure might have helped to obtain a larger or more representative sample. The usual practice when the catch was brought alongside was for the fish to be spilled from the net into bins on the deck of the vessel. The crew immediately began to separate out the unwanted fish, including small commercial sole. Fish which were retained were sorted into the hold and iced. As soon as the fish were spilled into the deck bins, a biologist began to sample the catch in one corner of a bin, starting at the top of the pile and working as deep into the bin of fish as time permitted. When the crew began to sort fish close to where the biologist was working the sampling was discontinued.

In all 6 years of sampling, portions of as many retained tows as practical were examined. Some tows of small volume were not sampled due to rapid sorting by the vessel crew, while some night tows went unsampled due to poor visibility. Tows composed of predominately discard species—hake, dogfish, and skate—which were dumped before being brought aboard likewise could not be sampled.

In addition to collecting the sampling data mentioned above, routine information was recorded on weather and sea conditions, areas fished, duration of the tows, volume and composition estimates of the tows, and the disposition of the fish caught. Species average weights were taken when possible for later computational use. The construction and mesh size of the cod end(s) used on the net during each trip were also noted. The average size of the mesh in the cod end was obtained by measuring every 5th mesh (stretched measure) from the pucker string at the terminal portion of the cod end forward to the intermediate portion of the net proper[4] (Figure 3).

Basic Sampling Assumptions

Qualitative and quantitative estimates of the composition of the unsorted catches and of the discards therefrom depend primarily on getting representative samples of the species composition at sea and of the lengths of the principal species of marketable sole; both at sea before sorting of the catch and at the time of unloading the catch. At sea, there are several ways in which the method of sampling might have resulted in an unrepresentative sample. The largest fish, either of one species or among various species, might tend to be at the top or at the bottom of the pile. The method of sampling from the top of the bin toward the bottom was intended as a safeguard against this type of bias. Also different species of fish, or fish of the same species but of different sizes, might tend to be distributed differently in the four corners of the bin available for sampling.

Stratification of Fish Samples by Size or Shape

In an analysis to determine whether fish were stratified in the bins according to size or shape, the data from trip 1 in 1950 were used (see also Appendix Table B). On this trip, 3,017 fish were sampled, of which the two most abundant species were petrale and rex sole (29 and 26% of the species sampled, respectively). Petrale and rex sole were used in the statistical tests mainly because the shape and size of the two species are quite dissimilar. Petrale sole is a relatively large, broad, inflexible species, while rex sole is small, narrow, and more pliable.

[4]Measurements taken during the 1950 and 1951 sampling included one knot in the measurement; in subsequent years of sampling the measurement excluded the knot. The 1950 and 1951 data have been converted to this later measurement.

FIGURE 3. Catch in cod end of trawl net showing chaffing gear and splitting strap, the pucker string concealed beneath net, trawler *Betty*, September 1961.

The incidence of each species as it was encountered in the sampling of each tow during this experiment was arranged initially into columns of 50 in the order of sampling. Thus, the first fish sampled from the top of the pile was the top species of the first column on the left, and the last fish sampled near the bottom of the pile was the bottom species in the last column to the right. Then the numbers of petrale and rex sole, respectively, were tabulated in the first 100 or 150 (depending on the total size of the sample) fish counted of all the species in each tow, and the same was done for the last 100 or 150 fish counted. If there were a change in the ratio of petrale to rex sole proceeding from the top of the bin toward the bottom, such a change should be evident in the numbers of each species in each column. The hypothesis was advanced that the ratio of petrale sole to rex sole in the samples near the top of the pile was the same as the ratio toward the bottom of the pile. This hypothesis (for data from the nine tows made during this trip) was tested using chi-square tests of independence. A significant chi-square value at the 5% level was obtained from only one of the nine tows examined in this manner. Thus, we may generally assume that stratification by species in the bins did not pose a major problem under the conditions examined.

Stratification of an Individual Species by Size

There was also the possibility that individuals of one species might be stratified according to size, either the large or small ones tending to be at the bottom. To determine if such a condition existed, the petrale sole data obtained during 1950 trip 1 were used. The mean lengths of the petrale sole were calculated for consecutive measurements in columns of 50 taken by the sampler as he proceeded downward through the catch. These measurements were summarized and their means compared for each tow using analysis of variance. The hypothesis tested was that the petrale sole mean lengths within each tow were random samples from the same population. None of the "F" values obtained in the analysis was significant at the 5% level, indicating that the petrale sole lengths within each tow came from a common population.

Variation in Species Composition at Opposite Corners of a Sampling Bin

Another possible source of bias was that all species might not be distributed evenly in the four corners of the sampled bin. In order to test for possible variation in species composition or in the size of a single species at the opposite corners of a fish bin, two biologists made a trip aboard the same vessel during the period September 9-14, 1950 (trip 12) sampling the catches independent of one another at opposite ends of the bins containing the catch (Appendix Table B). Thus if differences in species composition were present in different areas of the bin, it should be conspicuous in the compositions from the sampling of the two biologists.

In order to test statistically the sampling by each investigator at opposite corners of the bin, the hypothesis was advanced that the species composition was independent of where the sampling occurred. The summarized data from the two samplers were contrasted by a chi-square test of independence. The value obtained in this case was significant at the 5% level, indicating that the catch composition by species from the opposite ends of the bin was different.

Although there was a significant chi-square value when comparing the samples by species from opposite corners of the bin, most of the difference was supplied by petrale and rex sole. The other 13 categories (12 species and 1 miscellaneous category) in the sampling supplied a much smaller portion of the chi-square value. This difference in the proportions of rex sole and petrale sole could have been the result of personal bias, but on the other hand, the difference may have been real, possibly associated with the manner in which the fish were distributed in the net and released onto the deck. In the sampling reported here, whenever possible the corner of the bin sampled was selected in a random manner in an attempt to minimize any possible differences in the distribution by species.

Variation in Size Composition at Opposite Corners of a Sampling Bin

Data from this trip 12 in 1950 were also used to test whether there was a size difference of an individual species in opposite corners of the deck bin. Because English sole was the principal species sampled during this trip, the length-frequency distributions compiled from English sole taken at opposite corners of the bin by each of the biologists were compared statistically using a chi-square test of independence. The value obtained was not significant at the 5% level, indicating that it is likely that the two samples were drawn from a common population.

Bias in Samples of Fish Landed

In order to get a valid estimate of the species composition of the otter-trawl catches and discards, it was necessary to have not only representative samples of what was caught but also representative length-frequency samples of at least one of the three principal soles landed. The possibility of obtaining biased samples of the lengths of the soles landed from the catch was investigated using data from 5 of the 12 trips sampled in 1950. During these trips, with the exception of number 7 in which all Dover sole were discarded the first day, there was no discard of the principal sole species and the entire catch was landed. Assuming representative sampling, the length-frequency distributions of the samples taken at sea should be similar to those taken at the dock. Using a chi-square test of homogeneity, the 5 sets of data were contrasted statistically; one comparison produced a statistically significant result at the 1% level. This analysis indicates that in general the sampling was adequate, but that an occasional non-random sample was taken. If there was occasional non-random sampling for length distribution, the resultant estimates of the discard at sea were biased to some extent.

Method of Analysis

The method devised in this study to calculate the catch in numbers of Dover, English, or petrale sole at sea before sorting utilizes three basic sources of information: (1) the length-frequency distribution of the principal species of sole in the catches at sea, (2) the length-frequency distribution of the principal sole(s) landed, and (3) the length-weight relationships for the species involved. An assumption of this method is that all soles larger than a selected size which were caught were landed. The size at which all sole were assumed to be landed was 2 cm (3 cm in 1950) greater than the mode of the length-frequency distribution plotted from the market samples. There is always some doubt when sorting at sea as to whether fish close to the minimum acceptable market size should be kept or discarded. Almost all market sole 2 or 3 cm larger than the market sample mode are kept, and therefore the assumption that all sole larger than a certain size are landed is for practical purposes satisfied.

In order to calculate the numbers of the principal sole actually caught according to this method, it was necessary to know the numbers landed. To convert pounds landed to numbers landed, the length-weight relationship for the females of that species was used (in that portion of the size range where most of the fish occur the length-weight relationship is almost identical for both sexes).

The next step in the analysis was to determine the numbers of sole in the landings—and by definition in the unsorted catch—2 (or 3) cm beyond the mode in the landing. Knowing what percentage of the length-frequency distribution for the sole measured at sea was 2 (or 3) cm greater than the market (or dock) sample mode, the total catch of the species concerned was determined.

After calculating the catch at sea of the principal species of sole, the next step was to calculate the numbers of the other species caught at sea. This step is based on estimates of the numbers of Dover, English, or petrale sole caught on each trip. For example, if 1,000 English sole were caught at sea, and 100 English sole were encountered in the sampling at sea, then 10% of the catch of the English sole was sampled. It was then assumed that 10% of the catch of each of the other species was also sampled. Expanding the number of fish of each species sampled by a factor of 10 yields an estimate of the total catch of each species before sorting. The poundage catch of each species was obtained by applying the average weights taken at sea to the numerical catches; discards of unwanted fish were obtained by subtracting landing figures from those of the catch.

RESULTS

During the 6 years when sampling was pursued, the number of trips where catches were examined each year ranged between 4 and 12 (Table 1); the total number of sampled trips was 41. Gross catches in relation to the grounds on which the fishing was done will not be considered since often several grounds were explored during a trip. Treatment of the data in such a manner for all the species involved would be extremely difficult.

The average number of tows during the sampled trips has varied between 8 in 1961 and 16 tows in 1953. Generally, the length of tows approximated two hours. Most of the tows made during the trips were sampled. As mentioned, the unsampled tows were most often either sorted by the vessel crews before they could be sampled, partially or wholly dumped back into the sea, or brought aboard the vessel in darkness.

The calculated gross catches from the sampled trips for each of the years were as follows: 1950—459,671 fish; 1951—94,900 fish; 1953—168,900 fish; 1959—155,600 fish; 1960—155,000 fish; and 1961—149,700 fish. The samples from the tows which were extrapolated to the catch were usually between 5 and 14% of the calculated figures. Species compositions (from sampled tows) for these catches are shown in Table 2.

TABLE 1

Number of Trips and Tows Sampled by Year.

Year	Number of Trips	Sampled Tows	Un-sampled Tows	Dumped Tows	Average Tows per Trip	Average Hours per Tow
1950	12	125	48[1]	1	14.5	1.9
1951	4	44	6	0	12.5	1.9
1953	5	69	10[2]	1	16.0	2.2
1959	4	28	10[3]	0	9.5	2.1
1960	7	52	18[3]	3	10.4	2.4
1961	9	65	7	1	8.1	2.2

[1]Includes four tows where trawl doors crossed.
[2]Includes one tow where net was fouled and two tows where net was lost.
[3]Includes one tow where net fouled.

Although more than 30 species entered the catches, Dover, English, and petrale soles tended to dominate the flatfish catches. Other important soles in the sampled catches were arrowtooth flounder (turbot) and rex sole. While Dover, English, and petrale are well known food fish, only after 1951 has rex sole been landed as a food fish. Two other flatfish of minor importance in the catches entered the food-fish landings — sand sole and starry flounder. Hake was the most common roundfish encountered in sampling; unfortunately this species has no commercial value at present. Trips exclusively for roundfish (rockfishes) for fillet purposes were not sampled so these fishes do not constitute important portions of the catches shown in Table 2.

TABLE 2
Percentage Composition by Species of Sampled Catches.

Species	1950	1951	1953	1959	1960	1961
Pacific codfish	0.5	0.3	1.5	0.2	0.1	0.1
Spiny dogfish	0.6	0.2	0.6	0.6	0.5	0.3
Pacific hake	9.0	5.2	3.5	4.0	3.6	10.4
Pacific halibut	Tr.	Tr.	0.2	0.1	0.1	0.2
Lingcod	0.3	0.3	0.7	0.5	0.8	1.9
Ratfish	0.8	0.7	1.7	0.4	0.9	0.2
Rockfish						
Bocaccio	0.2	0	0	0.1	0.3	0.1
Black	Tr.	0.3	0	1.6	Tr.	2.3
Greenstriped	0.1	0.1	0.1	0.1	0.1	0.1
Hollywood	0	0.1	Tr.	0	0.1	0.1
Idiot	Tr.	1.1	0	0.3	1.0	0.1
Pacific ocean perch	0.1	0.7	Tr.	0.1	0.9	2.1
Orange	0.3	1.8	0.7	0.2	1.9	0.4
Yellowtail	0.3	0.3	0.6	0	0.8	1.0
Other	0	0.4	0.1	Tr.	Tr.	0.4
Sablefish	1.3	0.7	3.4	0.3	1.0	0.3
American shad	0.1	Tr.	Tr.	0	0.1	0.1
Skate	1.1	2.3	3.0	2.4	1.4	1.6
Sole						
Arrowtooth flounder	2.4	8.9	11.4	4.3	13.8	9.6
Bellingham	1.9	1.8	0.7	3.4	12.1	0.6
Dover	25.8	23.6	17.1	15.3	17.6	11.1
English	16.0	17.3	18.7	30.3	17.3	26.5
Flathead	0	0	0.2	Tr.	0.4	Tr.
Petrale	8.0	4.9	10.8	7.1	6.8	7.7
Rex	26.0	25.2	15.4	23.6	12.4	13.2
Rock	Tr.	0	Tr.	0	Tr.	0.1
Sand	Tr.	Tr.	0.3	0.2	0.7	0.3
Pacific sanddab	4.2	1.7	4.5	0.5	1.4	2.7
Slender	0.2	0.8	1.1	0.2	0.7	0.4
Starry flounder	0.6	1.3	0.3	1.4	0.3	2.2
Pacific tomcod	Not sampled		0.1	0	0.8	Tr.
Other fish	Tr.	0	0.1	Tr.	0.4	0.4
Crabs	Not sampled		3.2	2.9	1.5	3.2
Scallops	Not sampled		0.2	0	Tr.	0.1

Poundage catches and discards have been computed for each species by trip with yearly summaries presented in Table 3. Trip summaries for each year of sampling are presented in Appendix Tables B through G. Although numerical catches are also readily available for all of the species, subsequent discards (of unwanted fish) in terms of numbers are not available for all of the species involved. As a result the following discussions will be confined to catches and discards in terms of pounds. Numerical catches and discards of Dover, English, and petrale sole will be considered in Part II.

As evident from the tabular data, certain species were never considered as food fish, while only the larger sizes of other species were retained. Among the former category are such flatfish as arrowtooth flounder, Bellingham sole, and sanddab; and such roundfish as dogfish, hake, and certain rockfishes. In the food-fish category are included such soles as Dover, English, petrale, and rex; and roundfish such as lingcod, Pacific (true) cod, and sablefish. Since the small sizes of the rockfish are unavailable to the fishery because of their epipelagic distribution, no size restriction is imposed as for the soles. Mink and other animal food retained from the discards of non-food fish usually consisted of a mixture of soles and rockfish species. A more detailed presentation of the results of each of the 6 years of sampling follows.

1950 Sampling

The calculated gross catch from the 12 trips sampled during 1950 was 770,630 pounds (Table 3 and Appendix Table B); the average catch per tow amounted to 4,560 pounds (uncompleted and dumped tows omitted). The calculated catch per hour was 2,339 pounds. Dover, English, and petrale soles, in that order, composed the greatest poundages caught. Rex sole and arrowtooth flounder were also important in the unsorted catches as were two other species, hake and skate.

From the above gross catch, various portions of the catch of 11 species were retained as food fish and entered the 307,023 pounds landed. As might be expected, chief among the species were the three important soles for human food. In addition to the landings of food fish, another 38,180 pounds from the discard sorted out during two of the trips were landed for mink food. The total discard from all 12 trips amounted to 60% of the gross catch. The range for the trips was from a low of 29% to a high of 90% (Appendix Table B). The adjusted per cent discard after the removal of mink food was 55%. Hake, skate, arrowtooth flounder, and rex soles were the principal species discarded; neither rex sole nor cod were landed as food fish in 1950.

Visual estimates of catch magnitude, made by the sampler in consultation with the fishermen,

TABLE 3

Calculated Total Pounds Caught and Discarded by Year during Sampling-at-Sea Trips.

Species	1950		1951		1953		1959		1960		1961	
	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds[1] Discarded
Pacific cod	26,547	26,547	558	558	8,013	6,693	705	53	872	308	1,235	0
Spiny dogfish	7,673	7,673	995	955	6,171	6,171	12,175	12,175	4,662	4,662	1,067	1,067
Pacific hake	79,522	79,522	11,906	11,906	15,191	15,191	13,269	13,269	14,346	14,346	39,734	39,734
Pacific halibut	1,660	1,660	55	55	1,165	1,165	270	270	1,275	1,275	895	895
Lingcod	24,515	14,695	624	66	3,342	1,536	1,073	370	2,942	0	11,303	3,629
Ratfish	14,114	14,114	1,170	1,170	5,860	5,860	1,019	1,019	1,762	1,762	478	478
Rockfish												
Bocaccio	4,537	4,537	—	—	—	—	1,816	1,816	1,384	1,384	843	843
Black	1,540	48	834	0	—	—	3,609	0	138	0	12,944	1,576
Greenstriped	849	849	27	27	43	43	34	34	131	131	218	218
Hollywood	—	—	267	0	273	0	—	—	519	0	474	0
Idiot	148	148	1,018	1,018	—	—	212	212	1,186	1,186	124	124
Pacific ocean perch	4,980	4,980	905	0	—	—	62	0	1,558	0	7,069	276
Orange	18,668	2,405	5,646	0	3,036	0	600	0	9,375	0	3,214	1,868
Yellowtail	9,501	1,212	915	0	3,547	0	—	—	3,711	0	13,854	11,419
Other	—	—	720	0	54	54	30	30	54	54	1,357	1,357
Sablefish	21,169	19,544	667	226	5,544	3,460	562	160	1,232	296	3,608	2,381
American shad	3,210	3,210	—	—	—	—	—	—	316	316	225	225
Skate	84,553	84,553	3,595	3,595	9,500	9,500	6,007	6,007	3,430	3,430	15,538	15,538
Sole												
Arrowtooth flounder	44,315	44,315	24,936	24,936	37,733	37,733	14,253	14,253	49,382	49,382	24,544	24,544
Bellingham	15,882	15,882	775	775	500	500	1,814	1,814	11,580	11,580	414	414
Dover	136,781	23,363	36,571	1,203	49,496	654	53,548	16,164	47,459	5,910	34,853	5,249
English	123,162	29,241	18,793	4,852	35,584	6,484	33,298	16,979	22,813	6,777	41,595	3,866
Flathead	—	—	—	—	159	159	85	85	319	319	21	21
Petrale	84,670	23,280	7,491	2,088	23,171	1,260	13,804	4,611	13,753	2,371	12,293	1,296
Rex	46,353	46,353	12,671	12,671	14,378	5,472	18,843	11,973	9,782	1,432	11,336	2,754
Rock	36	36	—	—	—	—	—	—	8	8	130	130
Sand	210	38	602	602	591	591	147	147	969	969	366	207
Pacific sanddab	6,694	6,694	—	—	2,811	2,811	262	262	1,053	1,053	1,163	1,163
Slender	415	415	172	172	378	378	3,017	3,017	192	192	190	190
Starry flounder	8,586	8,293	2,691	2,691	1,380	1,380	174	174	1,032	0	4,884	2,745
Pacific tomcod	Not sampled		—	—	8	8	—	—	261	261	2	2
Other fish	340	0	—	—	45	45	3	3	149	149	1,043	923
Crabs	Not		Not		12,731	12,731	10,210	10,210	5,825	5,825	4,896	4,896
Scallops	sampled		sampled		120	120	—	—	13	13	24	24
Total	770,630	463,607	134,564	69,566	240,824	119,999	190,937	115,107	218,483	115,391	251,934	131,380
Discard Landed (Mink Food)		38,180		10,327		0		43,582		45,029		36,669
Per Cent Discard		60.2		51.7		49.8		60.3		52.8		52.1

[1]Portions of discard retained for mink food.

were available for 11 of the 12 trips. These visual estimates, or "hails," are a commonly used measure of catch magnitude referred to by vessel skippers. As compared to the quantitative samplings these hails present only a rough picture of catch magnitude. In 1950 these estimates placed the total unsorted catch at 661,000 pounds. This compares with the 770,630 pounds for these same trips based on the expanded catch sampling. The visual estimates also included about 35,000 pounds of principally hake and crab which were dumped back into the sea from four tows, and as a consequence were not sampled.

1951 Sampling

Dover sole, arrowtooth flounder, English sole, and petrale sole, in that order, were the most important soles in 134,564 pounds (2,691 pounds per tow) of fish calculated caught in the 4 trips sampled in 1951 (Table 3 and Appendix Table C). The catch per hour towed was 1,395 pounds. Hake made up the greatest poundage for a single species of roundfish. From the above catch, 64,998 pounds were calculated to have been retained and landed as food fish. Again the 3 market soles were most important among the 11 species landed as food fish. Also, this year as in 1950, rex sole and cod were not sought as food fish.

The combined discards from the 4 trips sampled were 52% of the gross catch. The range for the 4 trips was from 50 to 75% (Appendix Table C). Arrowtooth flounder, rex sole, undersize English sole, and hake composed the major poundage of discarded species. A portion of the discard, 10,327 pounds from 1 trip, was retained and landed for animal food.

The qualitative visual estimates placed the 1951 gross catch at 216,000 pounds compared to 134,564 pounds based on sampling. The visual estimates included 41,500 pounds of scrapfish (predominately hake) not available to sampling from dumped portions of tow. Hake were also presorted out of a number of other undumped tows and probably did not enter the samples in true proportion.

1953 Sampling

The principal species caught during the sampled trips in 1953 included Dover sole, arrowtooth flounder, English sole, and petrale sole, in that order, and hake (Table 3 and Appendix Table D). This ranking is the same as that encountered in 1951. The calculated gross catch from the 5 trips was 240,824 pounds; this amounted to 3,168 pounds per tow (uncompleted and dumped tows omitted). The gross catch per hour of towing for the sampled trips was 1,440 pounds. In the 120,825 pounds sorted from the catches of 9 species and landed for food fish the 3 market soles again dominated and in the same order as during the 2 previous years of sampling. In 1953 both rex sole and cod were marketed as food fish.

Visual estimates placed the combined gross catch at 287,000 pounds. Again, the visual estimates included fish not available to sampling: 1,500 pounds of undersize sablefish from a dumped portion of a tow plus 1 wholly dumped tow containing approximately 15,000 pounds of Bellingham sole. Skates were presorted out of a number of tows, but since sampling during 1953 was confined to a special box within the deck bin where presorting presumably did not occur, the sampling should be unbiased in this respect.

The combined discards from the trips sampled in 1953 were 50% of the calculated gross catch; the range for the 5 trips was 36% and 64% (Appendix Table D). Principal among the discard species were arrowtooth flounder and undersize English and rex sole. Roundfish important in the discard included dogfish, hake, and skate; although true cod are indicated in the discard column of the table, probably none was discarded. Note the large amount of crab which, because of regulation, could not be landed. None of the discard was retained and landed for animal food from the sampled trips in 1953.

1959 Sampling

The total gross catch calculated from 4 trips in 1959 was 190,937 pounds; not included in this figure are fish from 4 unsampled ocean perch and rockfish tows in the first and second trips. Excluding these unsampled catches and 1 tow where the net fouled, the average catch per tow was calculated to be 5,785 pounds with a gross catch per hour of 2,767 pounds. Poundage breakdowns in the catches and discards for the 4 trips in 1959 are presented in Table 3 and Appendix Table E. From the combined trip data, greatest poundage catches of sole were of Dover, English, rex, arrowtooth, and petrale; dogfish and hake contributed the largest poundages of roundfish. Visual estimates were made during only 3 of the 4 trips so they are not presented. Based on calculation, 75,830 pounds were retained from the gross catches for food fish; the actual landing figure also included an additional 28,000 pounds of ocean perch and rockfish which, as previously mentioned, did not enter the sampling. Dover, English, petrale and rex soles contributed the greatest poundage to the landings of food fish, although various amounts of 6 other species were landed.

Discards of non-food fish during the 4 trips averaged 60% with the range from 35 to 69% (Appendix Table E). Portions of the discard amounting to 43,582 pounds were retained in 3 of the trips and landed for mink food, however. This reduced the over-all discard into the sea to 37%. Species composing the discard included arrowtooth flounder and undersize Dover, English, and rex soles; roundfish discard included dogfish and hake, neither of which are accepted in the mink food landings. Again, the amount of crab caught and discarded was considerable.

1960 Sampling

In 1960, 218,483 pounds were calculated to have been caught during the 7 sampled trips; catches of all species and discard of non-food fish by sampling trip are presented in Table 3 and Appendix Table F. The gross catch per tow for the 68 completed tows (excluding 1 unsampled tow for rockfish) was 3,213 pounds or 1,338 pounds per hour towed. Soles contributing major poundages this year included arrowtooth, Dover, English, petrale, and Bellingham (this last species from a single trip); as in past years, hake was the roundfish contributing the greatest poundage. The calculated gross catch, 218,000 pounds, may be contrasted to the figure obtained by pooling visual estimates of the catches, 242,000 pounds. The latter figure included some fish not available to sampling: about 10,000 pounds of Bellingham sole, hake, halibut, turbot, and skates from 3 dumped tows; and about 35,500 pounds, predominately hake, from presorted or partially dumped tows.

The poundage retained as food fish after sorting at sea amounted to 103,092 pounds, excluding 1 unsampled tow of rockfish amounting to 5,500 pounds. Thirteen species entered the landings of food fish; most important among these were the three principal market soles and orange rockfish.

The average discard from the 7 trips was 53% of the gross catch; the range was from 38 to 68% (Appendix Table F). The actual discard into the sea was reduced to 29% since 53,000 pounds of the discard was landed as mink food from 4 of the 7 trips. Arrowtooth flounder, Bellingham sole, and hake composed the largest species poundage in the discard; hake were not retained for mink food.

1961 Sampling

Nine trips were sampled during the summer and fall of 1961; the gross catch from these trips totaled 251,934 pounds. The catch per tow was 3,499 pounds; the calculated gross catch per hour was 1,590 pounds (Table 3 and Appendix Table G). In the poundage catches the most important soles were English, Dover, arrowtooth, petrale, and rex, in that order. Hake, skate, and lingcod were calculated to have contributed the greatest poundages of roundfish to the catches. The estimated catches based on visual observations were in excess of 297,700 pounds. Hake, rockfish, and skate were presorted from a number of tows prior to sampling during 1 trip and undoubtedly contributed to the difference between the estimated and calculated catch.

The retention of food fish from the catches amounted to 120,554 pounds excluding the presorted rockfish which did not enter the samples in true proportion. Species contributing greatest poundages to the food-fish catch were English, Dover, petrale, and rex soles in that order; roundfish were lingcod and market species of rockfish. Portions of the catches of at least 15 species were retained and landed for food fish.

In the discard, which totaled 131,380 pounds, largest poundages by species were hake, arrowtooth flounder, skate, and orange rockfish. The latter species was discarded because of unfavorable market conditions for rockfish prevailing during 1 of the trips. The average discard for the 9 trips was 52%, but when the amount retained and landed for mink food is removed (36,669 pounds), the actual discard at sea is reduced to 36%. By trip the unadjusted discard ranged from 27 to 74% (Appendix Table G). No hake and only a small amount of skate entered the mink food landed from 8 of the 9 trips.

DISCUSSION

During the 6 years of sampling, arrowtooth flounder and Dover, English, and petrale soles contributed major poundages to the sampled catches. In all but 1 of the years Dover sole consistently contributed the greatest poundage for a single species. Since the trips were primarily for the food-fish sole on grounds where they were most abundant, it is to be expected that the catches were predominately of the latter 3 species. Large poundage of rex sole were also taken in a few of the years. This species is quite important numerically; on poundage basis, however, they are of less importance because of their small size. Generally in the later years of sampling more species entered the food-fish landings, reflecting a more stabilized market in contrast to the somewhat precarious one prevailing late in the 1940's. Hake composed the largest poundage of roundfish; in addition, often large quantities of hake were dumped or presorted out before sampling began. Other species of less importance were dogfish and skate. Certainly larger poundages of scrapfish could have been taken if suitable markets existed. Roundfish which entered the landings of food fish included true cod (after 1951), lingcod, rockfish (including Pacific ocean perch), and sablefish.

In examining the gross catches per tow for these years there can be found no sustained upward or downward trend. Such a trend could indicate that abundance of fish on the grounds had or had not changed materially during the period. Since fishermen might tend to compensate for decreases in abundance of fish by altering time of towing, catch per hour was also scrutinized. Here again no sustained upward or downward trend in catch was evident over the period sampled.

The visual estimates of the gross catches, or hails, were presented primarily to obtain an idea of the magnitude of the dumped and presorted portions of tows. Since these observations were qualitative at best, they were less precise than the data obtained through the quantitative sampling.

The sampling of gross catches at sea during these years has revealed much information not available from simply scrutinizing landings at the dock. Most obvious is the fact that on the average less than half the fish caught during the sampling trips were retained for human food. During the 12-year period which the sampling spanned there has been a trend for the market to accept a wider variety of species for human food and also for use of greater amounts of non-food fish for animal food. Certain species, notably dogfish, hake, and skate, have as yet not been utilized to any extent for animal food or other uses.

Amounts of non-food fish during the trips ranged from 22 to 90% of the gross catches during the 6 years. The average unweighted discard rate for all trips was about 55%. The 2 most abundant species in the discard were arrowtooth flounder and hake; the sole was landed as mink food in later years while hake was not. Though not considered specifically in this report, some general comments might be of interest concerning the magnitude of the discard of food-fish sole. From the sampled trips, 26% of the poundage of English sole was discarded, 21% of the petrale poundage, and 13% of the Dover sole poundage. The lower rate for Dover sole may be explained partially at least by the fact that the submarket sizes are not abundant on the grounds fished. While the amounts of fish involved in the above rates do reflect a loss to the food-fish industry, it is encouraging to note that discards of fish in later years were much lower than the gross discards indicated since various amounts were landed as mink food rather than being thrown back into the sea dead.

There was some difference between the amount of fish entering the discard on trips where mink food was retained and the amount on trips where none was saved, perhaps reflecting preferential sorting of marketable food fish into the discard retained for animal food. A "t" test statistical comparison of the means of the 2 trip types was not significant at the 5% level, however. Discard rates for trips where mink food was saved averaged 57% while the average discard for the other trips was 53%. However, if such non-mink food species as dogfish, hake, halibut, large skate, small sablefish, and crabs were removed from consideration, the relationship changed, although not significantly. During the 18 trips where mink food was retained, the adjusted average discard of non-food fish was 48%, while the corresponding rate from the 23 trips where none was retained was 39%. A comparison of the 2 values by a "t" test showed the difference between the 2 figures was not statistically significant at the 5% level.

SUMMARY

1. Sampling aboard Oregon trawl vessels was pursued during the years 1950, 1951, 1953, 1959, 1960, and 1961. Purpose of the study was to determine the quantitative and qualitative composition of the catches during trips primarily for marketable species of sole.

2. Gross poundage catches during the sampled trips ranged between 2,690 and 5,780 pounds per tow or 1,290 to 2,770 pounds per hour of towing.

3. Of the more than 30 species of fish in the catches, Dover, English, and petrale sole predominated, comprising between one-third and one-half of the fish encountered in the sampling. Trips exclusively for rockfish were not sampled so importance of these species is reduced.

4. From the sampled trips, all or portions of the catches of from 9 to 15 species were retained and landed for human food. Quantitatively, however, this amount was less than half the gross poundage catch, and the amount of nonfood fish taken incidental to that retained for food averaged 55%.

5. In recent years increasing amounts of certain fish formerly not sought either as human food or mink food have been retained and landed, reducing the amount of these fish discarded into the sea.

6. No statistical differences were apparent in the amount of non-food fish caught by boats landing mink food as contrasted to boats not landing mink food.

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APPENDIX TABLE A

Common and Scientific Names of Fishes and Shellfish Caught during Sampling-at-Sea Trips.

Common Name[1]	Scientific Name
Pacific cod	*Gadus macrocephalus*
Pacific hake	*Merluccius productus*
Pacific halibut	*Hippoglossus stenolepis*
Lingcod	*Ophiodon elongatus*
Ratfish	*Hydrolagus colliei*
Rockfish	
Black	*Sebastodes melanops*
Bocaccio	*Sebastodes paucispinis*
Greenstriped	*Sebastodes elongatus*
*Hollywood (flag rockfish)	*Sebastodes rubrivinctus*
*Idiot (shortspine channel rockfish)	*Sebastolobus alascanus*
Pacific ocean perch	*Sebastodes alutus*
*Orange (canary rockfish)	*Sebastodes pinniger*
Yellowtail	*Sebastodes flavidus*
Other	*Sebastodes* sp.
Sablefish	*Anoplopoma fimbria*
American shad	*Alosa sapidissima*
Skate	*Raja* sp.
Sole	
Arrowtooth flounder, turbot	*Atheresthes stomias*
*Bellingham (butter sole)	*Isopsetta isolepis*
Dover	*Microstomus pacificus*
English	*Parophrys vetulus*
Flathead	*Hippoglossoides elassodon*
Petrale	*Eopsetta jordani*
Rex	*Glyptocephalus zachirus*
Rock	*Lepidopsetta bilineata*
Sand	*Psettichthys melanostictus*
Pacific sanddab	*Citharichthys sordidus*
Slender	*Lyopsetta exilis*
Starry flounder	*Platichthys stellatus*
Spiny dogfish	*Squalus acanthias*
Pacific tomcod	*Microgadus proximus*
Crabs	mainly *Cancer magister*
Scallops	*Pectin caurinus*

[1]With the exception of the names denoted by asterisks, all names are those sanctioned by American Fisheries Society (1960). AFS names are in this case in parentheses.

APPENDIX TABLE B
Sampling at Sea 1950.

Species	Trip No. 1		Trip No. 2	
	Pounds Caught	Pounds Discarded	Pounds Caught	Pounds Discarded
Pacific cod	—	—	7,880	7,880
Spiny dogfish	—	—	41	41
Pacific hake	423	423	6,465	6,465
Pacific halibut	60	60	600	600
Lingcod	490	0	7,020	4,805
Ratfish	8,060	8,060	—	—
Rockfish				
Bocaccio	2,525	2,525	—	—
Black	—	—	—	—
Greenstriped	98	98	—	—
Hollywood	—	—	—	—
Idiot	—	—	—	—
Pacific ocean perch	—	—	—	—
Orange	3,551	0	690	0
Yellowtail	48	0	1,988	0
Other	—	—	—	—
Sablefish	410	0	—	—
American shad	147	147	—	—
Skate	5,318	5,318	19,229	19,229
Sole				
Arrowtooth flounder	3,218	3,218	1,640	1,640
Bellingham	—	—	11,164	11,164
Dover	19,605	7,125	900	900
English	2,779	2,779	29,036	4,539
Flathead	—	—	—	—
Petrale	20,418	2,822	3,852	3,014
Rex	8,436	8,436	791	791
Rock	36	36	—	—
Sand	—	172	0	—
Pacific sanddab	480	480	1,577	1,577
Slender	293	293	—	—
Starry flounder	—	—	293	0
Pacific tomcod	Not sampled		Not sampled	
Other fish	—	—	340	0
Crabs	Not sampled		Not sampled	
Scallops				
Total	76,395	41,820	93,678	62,645
Discard Landed (Mink Food)		0		0
Per Cent Discard		54.7		66.9

[1]Portions of discard retained for mink food.
[2]Subject to presorting prior to sampling.

APPENDIX TABLE B
Sampling at Sea 1950—Continued

	Trip No. 3		Trip No. 4		Trip No. 5		Trip No. 6		Trip No. 7		Trip No. 8	
	Pounds Caught	Pounds Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds Discarded	Pounds Caught	Pounds Discarded
	—	—	—	—	900	900	267	267	8,570	8,570	2,810	2,810
	—	—	—	—	7	7	—	—	317	317	67	67
	1,493	1,493	2,553	2,553	6,393	6,393	4,891	4,891	3,008	3,008	6,743	6,743
	—	—	415	415	5	5	—	—	—	—	280	280
	660	649	290	0	60	0	415	0	1,980	0	4,490	4,490
	2,056	2,056	58	58	—	—	208	208	264	264	1,516	1,516
	—	—	—	—	—	—	267	267	—	—	—	—
	—	—	84	0	—	—	—	—	64	0	900	0
	—	—	42	42	—	—	563	563	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	148	148	—	—	—	—
	—	—	—	—	—	—	4,980	4,980	—	—	—	—
	335	0	1,260	0	13	0	652	0	328	0	7,819	0
	400	0	2,168	0	103	0	1,156	1,156	385	0	1,716	0
	—	—	—	—	—	—	—	—	—	—	—	—
	232	219	7,416	7,416	90	0	7,767	7,431	3,130	2,983	674	523
	—	—	—	—	—	—	—	—	—	—	—	—
	15,251	15,251	2,198	2,198	576	576	2,876	2,876	9,014	9,014	4,042	4,042
	9,633	9,633	3,713	3,713	823	823	1,215	1,215	3,696	3,696	7,323	7,323
	—	—	83	83	—	—	—	—	936	936	—	—
	32,614[2]	0	1,229	1,229	8,370	3,567	1,802	1,802	16,532	738	15,029	3,739
	370	370	5,178	3,605	19	0	679	126	21,727	0	928	2,261
	—	—	—	—	—	—	—	—	—	—	—	—
	1,479	813	8,584	3,190	178	55	1,086	216	4,086	2,494	2,289	673
	4,428	4,428	4,125	4,125	4,063	4,063	800	800	1,532	1,532	9,084	9,084
	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	3,581	3,581	182	182	59	59	247	247	152	152
	—	—	—	—	4	4	—	—	—	—	118	118
	—	—	—	—	—	—	—	—	30	30	106	106
	Not sampled		Not sampled		Not sampled		Not sampled		Not sampled		Not sampled	
	—	—	—	—	—	—	—	—	—	—	—	—
	Not sampled		Not sampled		Not sampled		Not sampled		Not sampled		Not sampled	
	58,951	24,912	12,977	32,308	21,786	16,575	29,831	27,005	75,846	33,829	74,439	43,927
		0		20,201		0		17,979		0		0
		42.3		74.9		76.1		90.5		44.6		59.0

APPENDIX TABLE B

Sampling at Sea 1950—Continued

Trip No. 9		Trip No. 10		Trip No. 11		Trip No. 12		Total	
Pounds Caught	Pounds Discarded	Pounds Caught	Pounds Discarded	Pounds Caught	Pounds Discarded	Pounds Caught	Pounds Discarded	Pounds Caught	Pounds[1] Discarded
—	—	6,120	6,120	—	—	—	—	26,547	26,547
—	—	1,423	1,423	262	262	5,556	5,556	7,673	7,673
450	450	45,510	45,510	60	60	1,533	1,533	79,522	79,522
—	—	185	185	—	—	115	115	1,660	1,660
600	100	5,370	1,738	360	133	2,780	2,780	24,515	14,695
—	—	—	—	678	678	1,274	1,274	14,114	14,114
—	—	—	—	240	240	1,505	1,505	4,537	4,537
—	—	444	0	—	—	48	48	1,540	48
—	—	—	—	146	146	—	—	849	849
—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	148	148
—	—	—	—	—	—	—	—	4,980	4,980
—	—	1,615	0	—	—	2,405	2,405	18,668	2,405
—	—	1,481	0	—	—	56	56	9,501	1,212
—	—	—	—	—	—	—	—	—	—
—	—	—	—	872	394	578	578	21,169	19,544
—	—	2,889	2,889	36	36	138	138	3,210	3,210
2,650	2,650	24,893	24,893	6,288	6,288	2,218	2,218	84,553	84,553
1,587	1,587	9,596	9,596	—	—	1,871	1,871	44,315	44,315
58	58	3,586	3,586	—	—	55	55	15,882	15,882
11,600	0	4,782	2,032	21,075	0	3,243	2,231	136,781	23,363
7,126	106	45,457	13,979	34	0	1,476	1,476	123,162	29,241
—	—	—	—	—	—	—	—	—	—
3,905	775	19,192	6,570	1,149	0	18,452	2,658	84,670	23,280
397	397	10,167	10,167	1,127	1,127	1,403	1,403	46,353	46,353
—	—	—	—	—	—	—	—	36	36
—	—	38	38	—	—	—	—	210	38
108	108	239	239	7	7	62	62	6,694	6,694
—	—	—	—	—	—	—	—	415	415
160	160	7,953	7,953	—	—	44	44	8,586	8,293
Not sampled		Not sampled		Not sampled		Not sampled		Not sampled	
—	—	—	—	—	—	—	—	340	0
Not sampled		Not sampled		Not sampled		Not sampled		Not sampled	
28,641	6,391	190,940	136,918	32,334	9,371	44,812	28,006	770,630	463,607
	0		0		0		0		38,180
	22.3		71.7		29.0		62.5		60.2

APPENDIX TABLE C

Sampling at Sea 1951.

Species	Trip No. 1		Trip No. 2		Trip No. 3		Trip No. 4		Total	
	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds Discarded	Pounds Caught	Pounds Discarded	Pounds Caught	Pounds Discarded	Pounds Caught	Pounds[1] Discarded
Pacific cod	—	—	—	—	558	558	—	—	558	558
Spiny dogfish	390	390	—	—	143	143	422	422	955	955
Pacific hake	1,580[2]	1,580	4,400	4,400	1,838	1,838	4,088	4,088	11,906	11,906
Pacific halibut	—	—	—	—	—	—	55	55	55	55
Lingcod	360	0	66	66	134	0	64	0	624	66
Ratfish	—	—	326	326	758	758	86	86	1,170	1,170
Rockfish										
Bocaccio	—	—	—	—	—	—	—	—	—	—
Black	540	0	294	0	—	—	—	—	834	0
Greenstriped	—	—	—	—	14	14	13	13	27	27
Hollywood	—	—	—	—	267	0	—	—	267	0
Idiot	240	240	65	65	713	713	—	—	1,018	1,018
Pacific ocean perch	—	—	—	—	819	0	86	0	905	0
Orange	4,422	0	294	0	801	0	129	0	5,646	0
Yellowtail	—	—	684	0	137	0	96	0	915	0
Other	—	—	586	0	134	0	—	—	720	0
Sablefish	150	150	196	0	245	0	76	76	667	226
American shad	—	—	—	—	—	—	—	—	—	—
Skate	359	359	1,386	1,386	1,629	1,629	221	221	3,595	3,595
Sole										
Arrowtooth flounder	7,491	7,491	6,846	6,846	7,350	7,350	3,249	3,249	24,936	24,936
Bellingham	29	29	297	297	449	449	—	—	775	775
Dover	7,690	275	18,067	449	9,095	0	1,719	479	36,571	1,203
English	7,029	2,515	5,986	1,532	3,731	0	2,047	805	18,793	4,852
Flathead	—	—	—	—	—	—	—	—	—	—
Petrale	1,825	432	746	0	3,749	1,323	1,171	333	7,491	2,088
Rex	5,099	5,099	5,134	5,134	1,571	1,571	867	867	12,671	12,671
Rock	—	—	—	—	—	—	—	—	—	—
Sand	—	—	—	—	—	—	—	—	—	—
Pacific sanddab	48	48	130	130	134	134	290	290	602	602
Slender	—	—	163	163	—	—	9	9	172	172
Starry flounder	—	—	408	408	2,283	2,283	—	—	2,691	2,691
Pacific tomcod	Not sampled		Not sampled		Not sampled		Not sampled		Not sampled	
Other fish	—	—	—	—	—	—	—	—	—	—
Crabs	Not sampled		Not sampled		Not sampled		Not sampled		Not sampled	
Scallops										
Total	37,252	18,608	46,074	21,202	36,550	18,763	14,688	10,993	134,564	69,566
Discard Landed (Mink Food)		10,327		0		0		0		10,327
Per Cent Discard		49.9		46.0		51.3		74.8		51.7

[1]Portions of discard retained for mink food.

[2]Subject to presorting prior to sampling.

APPENDIX TABLE D

Sampling at Sea 1953.

Species	Trip No. 1		Trip No. 2		Trip No. 3		Trip No. 4		Trip No. 5		Total	
	Pounds Caught	Pounds Discarded	Pounds Caught	Pounds Discarded	Pounds Caught	Pounds Discarded	Pounds Caught	Pounds Discarded	Pounds Caught	Pounds Discarded	Pounds Caught	Pounds Discarded
Pacific cod	1,225	1,225	4,918	3,598	1,421	1,421	200	200	249	249	8,013	6,693
Spiny dogfish	176	176	1,177	1,177	1,580	1,580	371	371	2,867	2,867	6,171	6,171
Pacific hake	1,480	1,480	1,700	1,700	6,593	6,593	1,140	1,140	4,278	4,278	15,191	15,191
Pacific halibut	335	335	455	455	—	—	285	285	90	90	1,165	1,165
Lingcod	242	0	1,268	1,268	82	0	342	0	1,408	268	3,342	1,536
Ratfish	242	242	2,900	2,900	1,542	1,542	1,140	1,140	36	36	5,860	5,860
Rockfish												
Bocaccio	—	—	—	—	—	—	—	—	—	—	—	—
Black	—	—	—	—	—	—	—	—	—	—	—	—
Greenstriped	8	8	14	14	—	—	—	—	21	21	43	43
Hollywood	—	—	273	0	—	—	—	—	—	—	273	0
Idiot	—	—	—	—	—	—	—	—	—	—	—	—
Pacific ocean perch	—	—	—	—	—	—	—	—	—	—	—	—
Orange	645	0	951	0	729	0	342	0	369	0	3,036	0
Yellowtail	969	0	816	0	366	0	342	0	54	0	3,547	0
Other	54	54	—	—	—	—	—	—	—	—	54	54
Sablefish	161	161	2,084	0	649	649	798	798	1,852	1,852	5,544	3,460
American shad	—	—	—	—	—	—	—	—	—	—	—	—
Skate	1,692	1,692	2,927	2,927	1,219	1,219	3,254	3,254	408	408	9,500	9,500
Sole												
Arrowtooth flounder	4,317	4,317	14,001	14,001	10,344	10,344	2,402	2,402	6,669	6,669	37,733	37,733
Bellingham	6	6	435	435	59	59	—	—	—	—	500	500
Dover	4,509	0	17,382	0	17,621	0	6,915	654	3,069	0	49,496	654
English	1,167	0	12,522	4,407	5,418	0	10,349	2,077	6,128	0	35,584	6,484
Flathead	—	—	159	159	—	—	—	—	—	—	159	159
Petrale	3,647	0	2,894	994	1,297	52	14,374	0	959	214	23,171	1,260
Rex	915	915	2,198	2,198	5,253	0	5,385	1,732	627	627	14,378	5,472
Rock	—	—	—	—	—	—	—	—	—	—	—	—
Sand	13	13	—	—	122	122	456	456	—	—	591	591
Pacific sanddab	559	559	743	743	130	130	935	935	444	444	2,811	2,811
Slender	13	13	45	45	114	114	114	114	92	92	378	378
Starry flounder	—	—	—	—	1,380	1,380	—	—	—	—	1,380	1,380
Pacific tomcod	3	3	5	5	—	—	—	—	—	—	8	8
Other fish	27	27	—	—	16	16	—	—	2	2	45	45
Crabs	706	706	—	—	6,304	6,304	3,350	3,350	2,371	2,371	12,731	12,731
Scallops	—	—	—	—	—	—	120	120	—	—	120	120
Total	23,111	11,932	69,867	37,026	62,239	31,525	52,614	19,028	31,993	20,488	240,824	119,999
Discard Landed (Mink Food)		0		0		0		0		0		0
Per Cent Discard		51.6		53.0		50.7		36.2		63.9		49.8

APPENDIX TABLE E

Sampling at Sea 1959.

Species	Trip No. 1		Trip No. 2		Trip No. 3		Trip No. 4		Total	
	Pounds Caught	Pounds Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds[1] Discarded
Pacific cod	—	—	270	0	382	0	53	53	705	53
Spiny dogfish	10,543	10,543	754	754	475	475	403	403	12,175	12,175
Pacific hake	3,408	3,408	3,003	3,003	5,740	5,740	1,118	1,118	13,269	13,269
Pacific halibut	—	—	195	195	—	—	75	75	270	270
Lingcod	—	—	485	0	218	0	370	370	1,073	370
Ratfish	390	390	465	465	72	72	92	92	1,019	1,019
Rockfish										
Bocaccio	1,816	1,816	—	—	—	—	—	—	1,816	1,816
Black	—	—	231[2]	0	327	0	3,051	0	3,609	0
Greenstriped	20	20	—	—	—	—	14	14	34	34
Hollywood	—	—	—	—	—	—	—	—	—	—
Idiot	—	—	—	—	73	73	139	139	212	212
Pacific ocean perch	—[2]	—	—	—	51	0	11	0	62	0
Orange	195	0	—	—	219	0	186	0	600	0
Yellowtail	—	—	—	—	—	—	—	—	—	—
Other	—	—	—	—	—	—	30	30	30	30
Sablefish	454	160	—	—	—	—	108	0	562	160
American shad	—	—	—	—	—	—	—	—	—	—
Skate	1,545	1,545	2,633	2,633	1,673	1,673	156	156	6,007	6,007
Sole										
Arrowtooth flounder	2,727	2,727	3,252	3,252	4,482	4,482	3,792	3,792	14,253	14,253
Bellingham	—	—	734	734	592	592	488	488	1,814	1,814
Dover	41,879	14,810	303	0	1,943	958	9,459	396	53,548	16,164
English	4,061	3,934	14,597	6,962	12,467	6,083	2,173	0	33,298	16,979
Flathead	65	65	20	20	—	—	—	—	85	85
Petrale	2,393	391	8,030	2,580	3,034	1,640	347	0	13,804	4,611
Rex	8,307	8,307	3,099	0	6,196	3,666	1,241	0	18,843	11,973
Rock	—	—	—	—	—	—	—	—	—	—
Sand	—	—	39	—	—	—	108	108	147	147
Pacific sanddab	52	52	108	108	102	102	—	—	262	262
Slender	—	—	968	968	1,093	1,093	956	956	3,017	3,017
Starry flounder	156	156	—	—	15	15	3	3	174	174
Pacific tomcod	—	—	—	—	—	—	—	—	—	—
Other fish	—	—	—	—	—	—	3	3	3	3
Crabs	3,952	3,952	4,962	4,962	842	842	454	454	10,210	10,210
Scallops	—	—	—	—	—	—	—	—	—	—
Total	81,963	52,276	44,148	26,675	39,996	27,506	24,830	8,650	190,937	115,107
Discard Landed (Mink Food)		0		14,365		21,885		7,332		43,582
Per Cent Discard		63.8		60.4		68.8		34.8		60.3

[1]Portions of discard retained for mink food.
[2]Some tows specifically for rockfish not sampled.

APPENDIX TABLE F
Sampling at Sea 1960.

Species	Trip No. 1		Trip No. 2		Trip No. 3		Trip No. 4		Trip No. 5		Trip No. 6		Trip No. 7		Total	
	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds[1] Discarded
Pacific cod	140	0	95	0	—	—	63	0	308	308	266	0	—	—	872	308
Spiny dogfish	1,547	1,547	527	527	1,372	1,372	—	—	—	—	98	98	1,118	1,118	4,662	4,662
Pacific hake	795[2]	795	3,860[2]	3,860	2,338	2,338	2,125	2,125	3,868	3,868	800[2]	800	560	560	14,346	14,346
Pacific halibut	200	200	—	—	—	—	275	275	110	110	605	605	85	85	1,275	1,275
Lingcod	238	0	—	—	120	—	110	0	1,370	0	1,036	0	68	0	2,942	0
Ratfish	—	—	1,260	1,260	113	113	—	—	—	—	—	—	389	389	1,762	1,762
Rockfish																
Bocaccio	—	—	108	108	240	240	—	—	—	—	—	—	1,036	1,036	1,384	1,384
Black	—	—	—	—	—	—	—	—	—	—	138[3]	0	—	—	138	0
Greenstriped	—	—	—	—	121	121	—	—	—	—	—	—	10	10	131	131
Hollywood	—	—	95	0	—	—	—	—	—	—	—	—	424	0	519	0
Idiot	—	—	433	433	649	649	18	18	—	—	—	—	86	86	1,186	1,186
Pacific ocean perch	—	—	41	0	1,517	0	—	—	—	—	—	—	—	—	1,558	0
Orange	3,696	0	489	0	816	0	222	0	3,117	0	—	—	1,035	0	9,375	0
Yellowtail	120	0	1,056	0	180	0	165	0	1,524	0	45	0	621	0	3,711	0
Other	—	—	—	—	—	—	—	—	—	—	—	—	54	54	54	54
Sablefish	40	0	298	0	362	0	148	18	22	0	—	—	362	278	1,232	296
American shad	—	—	—	—	—	—	—	—	—	—	273	273	43	43	316	316
Skate	541	541	1,566	1,566	77	77	126	126	376	376	129	129	615	615	3,430	3,430
Soupfin shark	—	—	—	—	—	—	—	—	—	—	90	90	—	—	90	90
Sole																
Arrowtooth flounder	714	714	13,569	13,569	3,531	3,531	7,542	7,542	7,689	7,689	1,509	1,509	14,828	14,828	49,382	49,382
Bellingham	11,303	11,303	—	—	—	—	115	115	—	—	162	162	—	—	11,580	11,580
Dover	213	—	18,856	1,022	6,327	771	6,499	2,725	10,469	454	61	61	5,034	877	47,459	5,910
English	11,295	5,143	126	126	840	204	778	472	1,776	283	6,354	0	1,644	549	22,813	6,777
Flathead	—	—	230	230	23	23	—	—	66	66	—	—	—	—	319	319
Petrale	565	270	805	195	610	208	4,319	176	2,059	508	2,082	324	3,313	690	13,753	2,371
Rex	139	139	2,614	62	1,999	714	1,562	362	2,497	0	816	0	155	155	9,782	1,432
Rock	—	—	—	—	8	8	—	—	—	—	—	—	—	—	8	8
Sand	40	40	—	—	649	649	—	—	265	265	15	15	—	—	969	969
Pacific sanddab	—	—	—	—	—	—	917	917	—	—	122	122	14	14	1,053	1,053
Slender	8	8	130	130	15	15	15	15	4	4	3	3	17	17	192	192
Starry flounder	636	0	—	—	—	—	—	—	—	—	396	0	—	—	1,032	0
Pacific tomcod	254	254	—	—	—	—	4	4	—	—	3	3	—	—	261	261
Other fish	—	—	27	27	17	17	2	2	7	7	3	3	3	3	59	59
Crabs	—	—	342	342	—	—	777	777	2,274	2,274	2,432	2,432	—	—	5,825	5,825
Scallops	—	—	—	—	—	—	—	—	13	13	—	—	—	—	13	13
Total	32,484	20,954	46,527	23,457	21,924	11,050	25,782	15,669	37,814	16,225	17,438	6,629	31,514	21,407	218,483	115,391
Discard Landed (Mink Food)		17,871		2,306		7,133		0		0		0		17,719		45,029
Per Cent Discard		64.5		50.4		50.4		60.8		42.9		38.0		67.9		52.8

[1]Portions of discard retained for mink food.
[2]Subject to presorting prior to sampling.
[3]Some tows specifically for rockfish not sampled.

APPENDIX TABLE G
Sampling at Sea 1961.

Species	Trip No. 1		Trip No. 2		Trip No. 3		Trip No. 4		Trip No. 5		Trip No. 6		Trip No. 7		Trip No. 8		Trip No. 9		Total	
	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds[1] Discarded	Pounds Caught	Pounds Discarded	Pounds Caught	Pounds[1] Discarded
Pacific cod	—	—	432	0	84	0	—	—	—	—	136	0	—	—	583	0	—	—	1,235	0
Spiny dogfish	53	53	—	—	39	39	128	128	—	—	31	31	34	34	104	104	678	678	1,067	1,067
Pacific hake	557	557	615	615	3,437	3,437	335	335	43	43	2,654	2,654	192	192	19,362[1]	19,362	12,539	12,539	39,734	39,734
Pacific halibut	—	—	65	65	—	—	55	55	—	—	465	465	—	—	—	—	310	310	895	895
Lingcod	225	0	1,014	0	659	399	190	0	370	311	4,086	0	430	0	1,371	1,061	2,958	1,858	11,303	3,629
Ratfish	—	—	—	—	—	—	—	—	56	56	41	41	—	—	195	195	186	186	478	478
Rockfish																				
Bocaccio	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	843	843	843	843
Black	—	—	—	—	902	452	3,075	0	—	—	1,101	0	—	—	6,236[1]	0	1,630	1,124	12,944	1,576
Greenstriped	—	—	13	13	—	—	—	—	143	143	—	—	—	—	—	—	62	62	218	218
Hollywood	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	474	328	474	328
Idiot	—	—	—	—	—	—	—	—	53	53	40	40	—	—	—	—	31	31	124	124
Pacific ocean perch	—	—	93	0	—	—	—	—	112	112	—	—	—	—	—	—	6,864[2]	164	7,069	276
Orange	—	—	135	135	—	—	—	—	270	175	474	0	73	0	—	—	2,262	1,558	3,214	1,868
Yellowtail	537	0	9,912	9,912	—	—	—	—	363	260	499	0	55	0	682	0	1,806	1,247	13,854	11,419
Other	—	—	—	—	—	—	—	—	—	—	39	39	—	—	—	—	1,318	1,318	1,357	1,357
Sablefish	215	0	305	89	—	—	—	—	513	351	440	176	126	0	—	—	2,009	1,765	3,608	2,381
American shad	66	66	—	—	—	—	—	—	—	—	159	159	—	—	—	—	—	—	225	225
Skate	1,801	1,801	718	718	212	212	905	905	182	182	4,000	4,000	138	138	3,842[1]	3,842	3,740	3,740	15,538	15,538
Sole																				
Arrowtooth flounder	1,800	1,800	1,201	1,201	151	151	24	24	1,379	1,379	2,510	2,510	9,670	9,670	1,660	1,660	6,149	6,149	24,544	24,544
Bellingham	—	—	—	—	20	20	154	154	—	—	—	—	7	7	109	109	124	124	414	414
Dover	11,107	44	4,024	639	6	6	—	—	3,755	0	1,430	460	1,734	262	4,677	706	8,120	3,132	34,853	5,249
English	4,136	730	2,103	650	591	346	355	215	248	166	632	265	670	300	26,398	0	6,462	1,194	41,595	3,866
Flathead	—	—	—	—	—	—	—	—	—	—	—	—	21	21	—	—	—	—	21	21
Petrale	899	109	409	0	124	0	33	0	142	82	4,747	0	1,613	680	2,695	250	1,631	175	12,293	1,296
Rex	2,728	889	2,267	206	181	43	—	—	880	565	1,148	0	1,682	733	904	0	1,546	1,318	11,336	3,754
Rock	—	—	—	—	—	—	—	—	—	—	—	—	—	—	130	130	—	—	130	130
Sand	—	—	—	—	40	0	143	77	—	—	53	0	99	99	—	—	31	31	366	207
Pacific sanddab	70	70	172	172	39	39	4	4	—	—	221	221	430	430	167	167	60	60	1,163	1,163
Slender	108	108	10	10	2	2	52	52	—	—	7	7	11	11	—	—	—	—	190	190
Starry flounder	—	—	922	922	669	0	2,623	1,656	—	—	75	75	26	26	163	0	406	66	4,884	2,745
Pacific tomcod	—	—	—	—	1	1	—	—	—	—	1	1	—	—	—	—	—	—	2	2
Other fish	13	13	20	20	—	—	—	—	—	—	73	73	7	7	—	—	930	810	1,043	923
Crabs	455	455	449	449	663	663	417	417	52	52	1,406	1,406	159	159	551	551	744	744	4,896	4,896
Scallops	22	22	—	—	—	—	—	—	2	2	—	—	—	—	—	—	—	—	24	24
Total	24,792	6,717	24,879	15,816	7,820	5,810	8,493	4,022	8,563	3,932	26,468	12,623	17,177	12,769	69,829	28,137	63,913	41,554	251,934	131,380
Discard Landed (Mink Food)		1,392		13,880		620		>2,182		1,910		1,845		11,000		3,840		0		36,669
Per Cent Discard		27.1		44.6		74.3		47.4		45.9		60.0		74.3		40.9		65.0		52.1

[1]Portions of the discard were retained for mink food.
[2]Several allied species included.

The Development and Status of the Pink Shrimp Fishery of Washington and Oregon

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THE DEVELOPMENT AND STATUS OF THE PINK SHRIMP FISHERY OF WASHINGTON AND OREGON[1]

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and
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INTRODUCTION

The pink shrimp *(Pandalus jordani)* was known to be abundant off the Washington coast as early as 1904 (Rathbun, 1904). Although shrimp had sustained commercial fishing in Puget Sound since about 1888 (Smith, 1937), no commercial shrimp fishery developed off the coast of Washington and Oregon until 1956 and 1957, respectively. This time lag was due to the impracticability of capturing and processing these small shrimp. Exploratory charter cruises by the Oregon Fish Commission in 1951 and 1952 showed the shrimp to be present in numbers off the Oregon coast. Subsequent cruises by the U. S. Bureau of Commercial Fisheries vessel *John N. Cobb* off Washington in 1955-56 and Oregon in 1957 revealed the commercial potential of the beds and demonstrated the suitability of Gulf shrimp trawls for capturing these animals.

As a result of these cruises and the introduction of peeling machines in the Pacific Northwest, the industry expanded rapidly in 1957 and reached a peak in 1958. A total of 7.9 million pounds of whole shrimp was landed in Washington and Oregon in 1958. The catch declined to 5.2 million pounds in 1959, 2.4 million pounds in 1960, and then increased slightly to 2.9 million pounds in 1961. This increase was due to increased interest and landings in the southern Oregon area where shrimp were processed by a hand-picking method.

There has been much discussion concerning causes of fluctuations of the shrimp fishery. Interested persons have given many reasons including overfishing, predation, oceanographic conditions, and cyclic fluctuation. This report recalls the development of the fishery and presents scientific data gathered by the staffs of the Washington Department of Fisheries and Oregon Fish Commission.

DESCRIPTION AND LIFE HISTORY OF PINK SHRIMP

The commercial shrimp fishing industry off the coasts of Washington and Oregon is dependent upon a single pandalid species known locally as "pink shrimp" or "ocean pink shrimp." This species is small in comparison to the shrimp and prawns caught in the warmer waters of the southeastern United States and coasts of Latin America. Size of adult pink shrimp landed commercially averages between 3 and 5 inches total length (between 70 and 150 whole shrimp per pound). Count per pound varies greatly as different size or age classes appear in the catch.

Concentrations of pink shrimp are found in depths of 40 to 100 fathoms on bottoms composed of green mud and green mud and sand (Pruter and Harry, 1952). Washington and Oregon appear to be near the center of this species' geographical range—southern California to central Alaska.

Berkeley (1930) found that the five commercial species of the family Pandalidae in British Columbia waters were protandrous hermaphrodites. The shrimp mature first as males, then undergo a sex reversal and complete their life cycle in the role of females. This appears to hold true for the population of shrimp off Washington and Oregon with certain aberrations noted in 1955 and 1956 by Tegelberg and Smith (1957). They noted 18-month-old females bearing eggs in the fall indicating that the shrimp either matured directly as females or functioned as males at less than one year of age. Instances have been noted in Oregon where some shrimp continued as males through the second winter while the majority of the year class transposed to females and became gravid.

EXPLORATORY FISHING

Many years before commercial fishing for ocean pink shrimp started on the Pacific coast there were indications that large quantities of shrimp were available in the offshore areas. Trawl fishermen often told of their nets coming up with the wings "pink" with shrimp. Harvesting of this resource first began in April 1951 when landings were made in Morro Bay, California. Several months later the Oregon Fish Commission desired to define the available shrimp resources off Oregon and consequently initiated a research study to assess the magnitude and boundaries of their shrimp areas.

[1]Submitted for publication May 23, 1963.

The first of these exploratory shrimp cruises were on chartered commercial boats in the fall of 1951 and spring of 1952 and were made from the Rogue River north to the Columbia River (Pruter and Harry, 1952). Eighty tows were made using a 10-foot beam trawl, and concentrations of shrimp were found between 60 and 80 fathoms on areas of green mud and green mud and sand. Shrimp were found on almost all tows with the heavier catches coming off Coos Bay, Cape Lookout, and the Columbia River (Figure 1).

No other exploration was undertaken until the fall of 1955 when the Bureau of Commercial Fisheries vessel *John N. Cobb* explored an area off Washington between Cape Johnson and Ocean Park in depths ranging from 21 to 116 fathoms (Schaefers and Johnson, 1957). A 20-foot beam trawl with 1¼-inch stretched mesh netting and a small otter trawl with a 1¼-inch stretched mesh cod end were used in these fishing operations. Shrimp were found over a wide area of depths between 50 and 100 fathoms. The beam trawl produced clean catches of shrimp at a rate of up to 150 pounds per hour. The otter trawl, on the other hand, produced catches of up to 600 pounds of shrimp per hour and caught considerable quantities of bottom fish. Shrimp were found to be scattered over the entire cruise area with catches of 100 pounds per hour or more coming from the areas off Willapa Bay, Grays Harbor, Cape Elizabeth, and the Queets River.

A 1956 spring cruise was conducted using the same boat in the area between Long Beach and Destruction Island, principally at depths of 50 to 100 fathoms (Schaefers and Johnson, 1957). In addition to the nets used previously, a 40-foot Gulf of Mexico shrimp trawl with a 1½-inch mesh cod end was used. This net produced catches of shrimp as high as 2,200 pounds per hour. Areas showing the most promise for commercial shrimping operations were between the mouth of the Moclips River and Conner Creek, in 69 to 79 fathoms, and northwest of Grays Harbor in 57 to 87 fathoms.

The next exploratory work was done in the fall of 1957 when the Oregon Fish Commission chartered the Astoria vessel *Rose Ann Hess* to explore for shrimp from Astoria Canyon to Cape Falcon and to test the suitability of using the Gulf-type semi-balloon shrimp trawl in this area. Oregon gear regulations at the time of this cruise allowed only beam trawls to be used for the taking of shrimp. The semi-balloon trawl worked well and caught more shrimp per hour than the beam trawl but also caught more incidental fish. The incidental fish catch was not considered injurious to the stocks as very few English sole *(Parophrys vetulus)* or petrale sole *(Eopsetta jordani)* were captured and

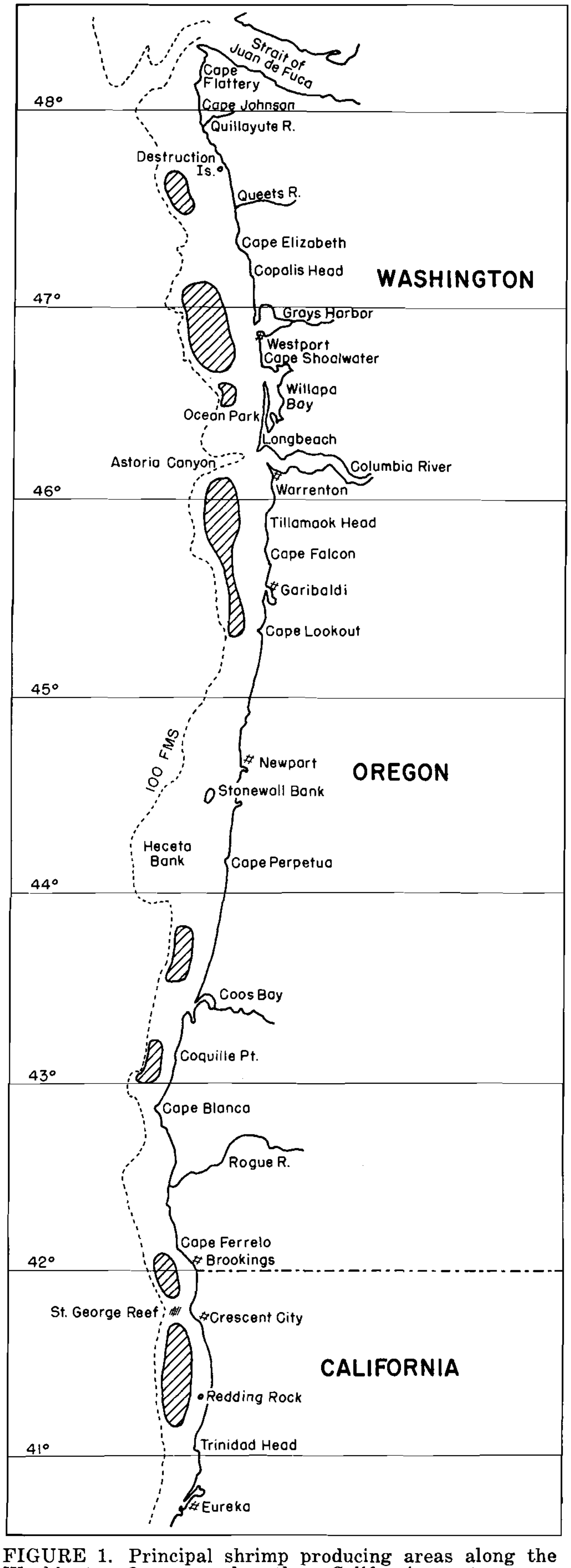

FIGURE 1. Principal shrimp producing areas along the Washington, Oregon, and northern California coast.

the majority of the Dover sole *(Microstomus pacificus)* and rockfish (*Sebastodes* sp.) caught were of marketable size. Quantities of rex sole *(Glyptocephalus zachirus)* were caught, but the possibility of harmful reduction of this abundant species did not seem to warrant limiting the shrimp production by continuing to allow only beam trawls to be fished. Shrimp trawls were soon made legal, increasing the production of shrimp from the developing fishery.

Several cruises were conducted by the *John N. Cobb* in 1958, the first being in March and April between the Columbia River and Cape Falcon. The best concentrations of shrimp were found off Tillamook Head in depths of 70-82 fathoms.

A new area previously unexploited by the commercial fleet was located by the *John N. Cobb* during the cruise which ended in May 1958 (Alverson, McNeely, and Johnson, 1960). This area, located between the Quillayute River and Destruction Island at depths of 60 to 68 fathoms, produced shrimp at the rate of 400 to 1,500 pounds per hour. Shrimp were also located about 20 miles west of Cape Flattery at depths of 68 to 107 fathoms. Catches as high as 630 pounds per hour were taken here along with considerable amounts of fish. The third 1958 *Cobb* cruise in June extended the area of exploration south to Newport, Oregon. The best catches on this cruise were made off Cape Lookout in depths from 90 to 114 fathoms. Catches of commercial quantities were also made between Cape Lookout and Newport in depths from 90 to 114 fathoms. The areas which showed promise on the exploratory cruises were being utilized by commercial fishermen at the same time with good results.

The object of the fourth and last 1958 *Cobb* cruise, which took place in October and November, was to determine the varieties and abundance of shrimp in deep-water areas and assess their commercial potential. The results were not encouraging as a total of 50 tows in water ranging up to 275 fathoms deep failed to indicate any large quantities of shrimp.

The latest exploratory cruise off Oregon or Washington took place in September, October, and November 1960 in waters off the south-central Oregon coast (Ronholt and Magill, 1961). A total of 54 tows with a 43-foot Gulf of Mexico-type shrimp trawl were made in 50 to 105 fathoms between Coquille Point and Stonewall Bank. Catches ranged from 0 to 1,300 pounds of shrimp per hour.

During all cruises off Washington and Oregon biological data were collected and analyzed. Bottom soundings and bathythermograph casts were also made and oceanographic data recorded.

HISTORY OF COMMERCIAL FISHING

Washington

The Washington coastal pink shrimp fishery began in 1956. The first shrimp landed from Washington coastal waters were caught by a 40-foot converted troller using a California-type beam trawl. During the first three months of the fishery, approximately 22,500 pounds of shrimp were landed and processed in a hand-picking operation. The winter closure on ocean shrimp fishing was lifted by the Washington Department of Fisheries for the winter of 1956-57 to encourage the development of the fishery.

Two factors were responsible for the growth of the fishery during the winter of 1956-57. First was the introduction of the semi-balloon Gulf of Mexico shrimp trawl to the west coast. This type of trawl was first used in the southern United States between 1912 and 1915 and was the standard net in use in that area by 1917 (Anderson, Lindner, and King, 1960). It is capable of taking large quantities of shrimp with less incidental fish than the otter trawl. Shrimp and otter trawls are preferred over beam trawls because they are easier to handle and are much less bulky and awkard. The second factor was the installation at Westport, Washington, of the first peeler machine on the west coast. This machine is capable of processing 1,000 to 1,200 pounds of raw shrimp per hour with a meat re-recovery of about 20% of the original heads-on weight. This is compared to a yield of about 25% in hand-picking operations (Stern, 1958). Most shrimp peeled by machine are canned since the product is not as attractive as hand-peeled shrimp.

Only one processing plant was in operation throughout 1956 and until the fall of 1957 when additional plants in Bay Center and Hoquiam went into production. By June 1958 the number of plants operating in Washington had increased to five with the addition of plants in Aberdeen and South Bend. The number of peeling machines in operation reached 11 with the addition of these 2 plants. Two processors left the fishery in the fall of 1958 as catches began to decline and the number of boats decreased. Several peeling machines were moved to Alaska where the shrimp fishery was expanding. Three processors operated a total of 6 peeling machines during 1959. By the end of 1960 and throughout 1961 only 2 processors and 3 peeler machines remained in the Washington shrimp fishery.

The boats engaged in the shrimp fishery are mainly combination boats, 50 to 80 feet in length, capable of fishing for crabs, salmon, albacore, and bottom fish. Conversion to shrimp fishing for most of these vessels is a relatively simple process, hence these boats may enter the fishery during slack periods or closed seasons in the other fisheries. The number of boats entering the fishery depends upon the abundance and availability of shrimp. Most of the vessels are well equipped with loran, depth sounder, and radio equipment and several were equipped with radar in 1960.

Until the introduction of shrimp peeling machines late in 1956 the fishery was limited by the amount of shrimp that could be handled in a hand-picking operation. Once the peelers were put into operation the industry became anxious for additional boats to enter the fishery. During the first 3 months of 1957 there were only 2 boats fishing. This number increased to a high of 9 boats in October 1957. Twelve boats made a total of 176 landings in 1957. The number of boats fishing increased rapidly in 1958 until June when a monthly high of 24 boats made landings. A total of 33 Washington and 8 Oregon boats made 561 landings in Washington in 1958. Eighteen boats made 246 landings in Washington in 1959. A further decline occurred in 1960 when 11 boats made a total of 175 landings. This decline continued into 1961 when only 7 boats made 104 landings.

Oregon

The development of the shrimp fishing industry in Oregon paralleled that in Washington in that it increased rapidly to a peak and then declined. Gear restrictions had an initial effect on the development in that only beam trawls were legal until 1958. Gear restrictions were not the only deterrent to early shrimp fishing in Oregon as the state poundage fees before 1958 were high, and this had a dampening effect on the producers' enthusiasm to buy shrimp. Relaxing the poundage fee to 0.1 cent per pound and permitting the use of shrimp trawls with meshes of 1¼ to 2 inches (taut measure, knot to knot) gave the fishermen more incentive to fish for shrimp.

Several tons of shrimp were landed at Coos Bay and Garibaldi in 1952 and picked by hand, however, the hand-picking process was not profitable and operations were discontinued. When it was evident in 1957, by the production in Washington, that the pink shrimp were abundant enough to support a fishery which could develop into a stable industry, 2 Warrenton plants installed 2 shrimp peeling machines each. With machines the margin of profit goes up as production increases, therefore producers encourage boats to fish.

The size of the Oregon commercial shrimp fleet varies considerably from year to year. A total of 18 boats fished from Warrenton in 1958, 14 in 1959, and 5 in 1960 and 1961. Two boats fished from Coos Bay in 1960 and five in 1961, while farther south at Brookings three boats fished in 1960 and two in 1961. Desire to fish for shrimp is determined by the availability and the price of the shrimp, the availability and price of other fish, and agreements between the producers and fishermen. As mentioned earlier, the conversion to shrimp trawling is relatively simple, so the fluctuation in numbers of vessels fishing for shrimp is relative to abundance or availability of shrimp and other species.

FISHING AREAS

Grounds capable of producing shrimp are available in the offshore areas the entire length of the 2 states. The approximate position and borders of the producing grounds are shown in Figure 1. As shrimp prefer certain bottom types and depths between 50 and 100 fathoms, the concentrations would necessarily be confined to specific areas known as beds. Areas that have been fished heavily are off Destruction Island, Grays Harbor, Willapa Bay, Tillamook Head, Cape Lookout, Coos Bay, and Brookings. These areas will be treated individually from north to south.

The most northerly shrimp fishing ground is off Hoh Head between the mouths of the Quillayute and Queets rivers. This area is commonly called the Destruction Island area and was first fished in 1958. This area is only fished intermittently due to its small size, about 175 square miles, and its distance of 80 miles from the nearest processing plant. Most of the fishing is carried on between the 50 and 80 fathom curves.

The largest and most important bed off Washington is the area west of Grays Harbor between Copalis Head and Cape Shoalwater. This bed encompasses an area of approximately 325 square miles, however, natural obstructions such as reefs and rocks make some locations within the bed unfishable. Most of the fishing here is carried on at depths between 60 and 80 fathoms. This bed has been the mainstay of the Washington fleet, producing between 76 and 94% of the yearly landings, and 600,000 pounds were harvested from this area by Oregon boats in 1959 through 1961.

South of Grays Harbor and southwest of the mouth of Willapa Bay is located the southernmost Washington bed known as the Willapa Bay area. This area is smaller than the previous areas having only 40 square miles of fishable bottom and is bordered on the west by an area of deep water called the Willapa "finger." It is situated near the processing plants in Willapa Bay, but due to the inconsistent nature of shrimping it is fished only intermittently. Boats from Astoria and Warrenton fish this area but the catches comprise only a small percentage of their landings.

The most northerly and also largest shrimp bed off Oregon lies between the Astoria Canyon and Cape Lookout. This is an elongated area between 60 and 90 fathoms and covers about 300 square miles. Warrenton boats fish this bed almost exclusively, excepting a few trips made yearly by boats from Grays Harbor. From 50 to 99% of the Warrenton landings come from this bed.

The next bed south that has been exploited to any degree off Oregon lies west and north of Coos Bay. It is a smaller area than the one southwest of the Columbia River, encompassing about 75-100 square miles. The fishing in this area is done by boats from the port of Coos Bay with an occasional trip by a Warrenton vessel. During the 1960 cruise of the *John N. Cobb* an area was discovered off Coquille Point in 80-100 fathoms. By the end of 1961 fishermen had made only occasional tows on this area.

On the southern extreme of the Oregon coast lies an area called the Brookings shrimp bed consisting of about 40 square miles of fishing area. It has been fished only since 1959 and almost entirely by boats from the port of Brookings. The area extends from Cape Ferrelo on the north to about St. George's Reef on the south in 40 to 90 fathoms. This area is actually contiguous with the northern California shrimp bed which extends south to Redding Rock (Dahlstrom, 1961). Boats out of Brookings catch from 12 to 40% of their landings in this area while the remainder is caught to the south in the area off California.

There are several areas along the Oregon-Washington coastline that would be suitable for shrimp fishing but are not fished because of the distance from processors or the lack of time and money for exploration. One of these areas lies just south of Heceta Bank where shrimp have occasionally been taken. No processing plants exist in Newport and the boats from Astoria and Coos Bay find it more profitable to fish in areas closer to home. Another area of interest lies southwest of Cape Blanco. This area is within easy reach of the boats out of Coos Bay and Brookings.

CATCH STATISTICS

Catch statistics on the coastal pink shrimp fishery in Washington and Oregon are gathered mainly from two sources: log book-interview data and fish-receiving tickets. In Washington total poundage figures are taken from fish-receiving tickets which buyers are required to fill out upon receipt of any fish or shellfish. These tickets list the name of the vessel, date of delivery, general area fished, days fished, and total poundage. Incidental fish poundage is listed on separate tickets. The Oregon system is similar. In both states log book data and interviews are used to provide information on pounds caught per hour by area. Coverage of the Washington boats has ranged from about 27% in 1957 to 100% in 1961. The coverage of Oregon boats was almost nil in 1957 and increased to nearly 100% in 1961. Data on effort and area fished by boats landing at Brookings are sometimes incomplete, since several of these boats are California vessels not encountered when they are delivering their loads. The log book data are desirable in that they provide more detailed and accurate information than the interview system which is just an oral log from the skipper. When fishermen are reluctant to provide log book data the interview system is employed.

The production of shrimp from the various areas has shown great fluctuation. Individual areas or beds are fished heavily one year or perhaps for a few months, then deserted in favor of a more lucrative or productive area.

For example, the Destruction Island ground produced over 80% of its total 1956-61 landings in 1958 (Table 1). This was a time when interest was high and good catches were coming from that area. After the high of 1,011,000 pounds in 1958 the catch from the Destruction Island area dropped to 91,500 pounds in 1959 and 88,500 pounds in 1960. There was some increase in fishing on this ground in 1961 when 162,500 pounds were logged as having been caught between Cape Flattery and Cape Elizabeth.

The mainstay of the Washington fishery and an area of occasional high catches by Oregon vessels has been off Grays Harbor. Production from this area in 1957 was 2.3 million pounds. In 1958 the poundage rose to 4.1 million pounds, due mainly to an excellent spring fishery and a large increase in number of boats. The catch in 1959 fell to 2.2 million pounds, and in 1960 totaled only 0.9 million pounds, but then increased slightly to 1.4 million pounds in 1961.

The Willapa area between the mouth of Willapa Bay and the Columbia River has supported a minor fishery since 1957 when 123,500 pounds were landed. The catch during 1958 rose to 239,000 pounds and dropped slightly to 217,000 pounds in 1959. The catch from the Willapa area in 1960 was 107,500 pounds, increasing to 150,500 pounds in 1961.

The area from the Columbia River south to Cape Perpetua was fished heavily during 1958 and 1959 by boats from both states. Landings in 1957 were small at 0.1 million pounds, all by Oregon boats. Landings increased to 2.6 million pounds in 1958 and 1959, then decreased to 1.2 million pounds in 1960 and 0.5 million pounds in 1961. Washington boats fish this area annually but the majority of the poundage is caught by boats from Warrenton.

Between Cape Perpetua and Cape Blanco lies an area known as the Coos Bay bed. It is fished regularly by Coos Bay and Charleston vessels with an occasional trip by a Warrenton boat. Significant landings began in 1957 with 287,000 pounds and then fell off to only 400 pounds in 1958. The shrimp landed in 1957 were caught by California beam trawlers and then trucked to California where they were hand picked. In 1959 a processing plant opened in Charleston and landings of 53,500 pounds were hand picked there. Poundages landed in 1960 totaled 82,500 and increased to 420,000 in 1961. This area accounted for over one-third of the state's landings in 1961.

The southernmost area in Oregon is the Brookings grounds. Production from this area has not been spectacular, although the landings at Brookings are much more than the value shown in Table 1. This is because much of the poundage landed at Brookings is caught south of the Oregon-California border. Recently some of the boats have been prospecting a small area northwest of Brookings.

Considerable time and effort have gone into the collection and calculation of catch-per-hour data. These data act as an indicator to show the trends in availability or abundance of shrimp. Average catch-per-hour values by month for the Washington coast are shown in Table 2 for the years 1957-61. As the fishery started in 1957 the catch-per-hour ranged from 750 pounds in April to 1,040 pounds in June. After the June high, fishing success dropped steadily to a low of 550 pounds-per-hour in October. Catch-per-hour climbed to 820 pounds in February 1958 and except for slight rises in April and June declined steadily to a low of 200 pounds-per-hour in December. Catch-per-hour stayed at a low level during the first four months of 1959 but rose to over 600 pounds-per-hour in May. After slight drops in June and July an unexpected rise to 550 pounds-per-hour took place in August 1959. The catch-per-hour stayed above 450 pounds for the remainder of the year except for October when it fell to 360 pounds. The 1960 catch-per-hour reached a peak in March at about 470 pounds and except for slight rises in July and October declined steadily to an all time low of less than 200 pounds in December 1960.

The trend in catch-per-hour of the Washington shrimp fishery has been downward until 1961 when a slight increase occurred. The weighted yearly figures as shown in Table 2 for the years 1957 through 1961 were 730, 469, 462, 311, and 436 pounds, respectively. It is doubtful that the fishery would operate with less catch-per-hour than that experienced in 1960. Catch-per-hour is normally highest during the first half of the year, declining after June or July. The 1959 season was unusual in that the catch-per-hour averaged lower from January through July than for the remainder of the year.

Catch-per-hour for Oregon boats landing at Warrenton from 1958-61, shown in Table 3, demonstrates basically the same history as Table 2. The catch-per-hour values in 1958 started in the spring

TABLE 1

Catch of Pink Shrimp off Washington and Oregon in Pounds by Area and Year.

Area	1956	1957	1958	1959	1960	1961
Cape Flattery to Cape Elizabeth	—	8,500	1,011,000	91,500	88,500	162,500
Cape Elizabeth to Willapa Bay	40,000	2,318,000	4,140,000	2,168,500	886,500	1,407,000
Willapa Bay to Columbia River	—	123,500	239,000	217,000	107,500	150,500
Columbia River to Cape Perpetua	—	116,500	2,553,000	2,556,000	1,220,500	479,000
Cape Perpetua to Cape Blanco	—	287,000	500	53,500	82,500	420,000
Cape Blanco to Ore.-Calif. Border	—	—	—	100,000	161,000	67,000
Total	40,000	2,853,500	7,943,500	5,186,500	2,546,500	2,686,000

at 674 pounds and decreased in the fall to less than 300 pounds. In 1959 the catch-per-hour figures fluctuated throughout the year, as did the Washington landings, with the high month being January. Catch-per-hour in 1960 was generally low with a high of 399 pounds in May and less than 300 in late summer. Next year, 1961, the catch-per-unit of effort increased somewhat. Although the catch-per-hour of fishing and total catch were down from the 1958-59 high, several boats continued to fish in 1960 and 1961. The fishery in southern Oregon and central Oregon differs from northern Oregon in that the landings have shown an increase from 1959 to 1961. Catch-per-hour at Brookings in 1959 was 487 pounds, in 1960 it had increased to 492 pounds, and in 1961 to 806 pounds. The high figure in 1961 was due partially to a lesser number of boats fishing.

TABLE 2

Catch-Per-Hour in Pounds by Month for Boats Landing in Washington.

Month	1957	1958	1959	1960	1961	Monthly Average
Jan.	—	625	—	—	85	355
Feb.	—	820	230	420	—	470
March	940	520	260	470	—	550
April	750	630	340	340	686	551
May	780	450	630	310	663	567
June	1,040	520	420	300	561	570
July	870	390	350	350	434	479
Aug.	680	370	550	300	285	437
Sept.	—	370	460	200	365	349
Oct.	550	310	360	240	495	391
Nov.	680	250	600	210	361	420
Dec.	—	200	450	180	—	277
Weighted Average	730	469	462	311	436	

TABLE 3

Catch-Per-Hour in Pounds by Month for Boats Landing at Warrenton, Oregon.

Month	1958	1959	1960	1961	Monthly Average
Jan.	—	659	—	—	659
Feb.	—	474	—	—	474
March	—	524	325	—	425
April	674	608	370	331	496
May	677	582	499	456	523
June	622	427	320	416	446
July	644	435	220	323	405
Aug.	345	596	285	269	374
Sept.	288	517	219	231	314
Oct.	319	415	284	—	339
Nov.	374	538	90	—	334
Dec.	508	—	—	—	508
Weighted Average	495	525	279	338	

INCIDENTAL FISH CATCHES

As shrimp fishing operations are carried on in areas where finfish are present, it is expected that some fish will be caught accidentally in the shrimp trawl. Regulations governing the landing of these incidentally caught fish have been changed from time to time in the states and have not always been comparable.

At the start of the Washington fishery in 1956 and through September 1957 no incidental fish could be landed legally from a boat fishing with a shrimp trawl. This led to complaints by the fishermen that during their regular fishing operations fish were unavoidably taken. Since these fish suffered high mortality when brought to the surface, the fishermen requested that they be allowed to market them to avoid wastage. In October 1957, Washington lifted the restriction and permitted the sale of incidental food fish taken in shrimp trawls.

The relaxation of the incidental fish restrictions brought about additional complications. Most boats would move out of an area when large quantities of bottom fish were encountered, however some boats continued to fish in such areas and thus abused the privilege of selling fish caught with a small-mesh net. This led in July 1958 to establishment by Washington of a 500-pound per landing limit for incidentally caught bottom fish. In January 1959 the limit in Washington was increased to 3,000 pounds upon recommendation of the Pacific Marine Fisheries Commission advisory committee.

Table 4 shows a breakdown of landings by species for each period of the Washington regulation. The landings of rockfish and lingcod *(Ophiodon elongatus)* totaled 485,500 pounds or 72% of the total finfish poundage during the unrestricted period October 1957-July 1958. During the 500-pound limit period, rockfish and lingcod landings totaled only 6,475 pounds or 25% of the poundage. This is because lingcod and rockfish, although more abundant on the shrimp grounds, do not bring as high a price to the fishermen as sablefish *(Anoplopoma fimbria)* and petrale sole. Therefore, when the landings are limited the fishermen tend to keep only the more valuable species.

A comparison of the pounds of incidental fish per shrimp landing is shown in Table 5 for the three regulation changes. The 426 shrimp landings during the unrestricted period produced 5,832,225 pounds of shrimp at a rate of 13,691 pounds per landing and 676,601 pounds of fish at 1,588 pounds per landing. During the period of the 500-pound limit, bottomfish landings dropped sharply to 25,598 pounds and the catch-per-landing dropped to 164 pounds. At this time shrimp were caught at an average rate of 8,007 pounds per landing. Since the establishment in January 1959 of a 3,000-pound limit, 626,331 pounds of bottomfish have been landed at an average rate of 1,193 pounds per landing. At the same time shrimp were being caught at a rate of 11,733 pounds per landing.

As the Oregon shrimp fishery was about a year later in developing than that of Washington, the problems encountered in regulating incidental fish catches were not as great. The Oregon Fish Commission allowed the incidental catch to be landed. Of the 100 food fish landings coincidental with shrimp trips during the no restriction period, 28 were in excess of 3,000 pounds. Oregon also adopted the PMFC recommended limit of 3,000 pounds per shrimp trip in 1959. Table 6 has the breakdown by species landed during the period 1958-61 at Warrenton.

Rockfish have consistently been predominant in landings of incidental species, with Dover sole comprising the second largest poundage. There does not appear to be any deliberate attempt by the shrimp fishermen to catch bottomfish.

In addition to the fish landed, many commercially non-important fish are caught and discarded at sea. Examples of these are hake *(Merluccius productus)*, dogfish *(Squalus acanthias)*, ratfish *(Hydrolagus colliei)*, and turbot *(Atheresthes stomias)*. Some of these species are now being landed in small quantities by shrimp fishermen for mink food.

TABLE 4

Species Composition for Washington Incidental Fish Landings by the Shrimp Fishery During Varying Regulation Periods.

	Oct. '57-July '58 Unrestricted Landings		July '58-Jan. '59 500-Pound Limit		Jan. '59-Dec. '61 3,000-Pound Limit	
Species	Pounds	Per Cent	Pounds	Per Cent	Pounds	Per Cent
Rockfish	292,940	43.3	4,575	17.9	362,059	57.8
Lingcod	192,563	28.4	1,900	7.4	97,786	15.6
Petrale sole	49,815	7.4	4,322	16.9	38,125	6.1
Dover sole	46,627	6.9	2,680	10.5	81,072	12.9
Pacific cod[1]	41,209	6.1			593	.1
English sole	21,677	3.2	790	3.1	1,875	.3
Sablefish	20,511	3.0	7,616	29.7	44,491	7.1
Rex sole	1,151	.2			209	.1
Miscellaneous	10,108	1.5	3,715	14.5	121	.1
Total	676,601		25,598		626,331	

[1]*Gadus macrocephalus*

TABLE 5

Comparison of Washington Shrimp Landings and Incidental Fish Landings During Regulation Changes.

Regulation	Number of Shrimp Landings	Shrimp Poundage	Fish Poundage	Pounds per Shrimp Landing: Shrimp	Pounds per Shrimp Landing: Fish
No Limit	426	5,832,255	676,601	13,691	1,588
500-Pound Limit	155	1,241,098	25,598	8,007	164
3,000-Pound Limit	525	6,159,874	626,331	11,733	1,193

TABLE 6

Species Composition of Incidental Fish Landed in Warrenton, Oregon by Shrimp Trawlers, 1958-61.

	1958		1959		1960		1961	
Species	Pounds	Per Cent	Pounds	Per Cent	Pounds	Per Cent	Pounds	Per Cent
Rockfish	108,834	50.7	62,223	48.7	33,517	38.9	55,018	51.8
Dover sole	40,123	18.7	37,980	29.7	31,583	36.6	25,996	24.5
Pacific Ocean Perch	23,354	15.1	1,513	1.2	3,105	3.6	—	—
Lingcod	12,064	5.6	9,111	7.1	2,242	2.6	10,499	9.9
Pacific cod	7,523	3.5	—	—	78	.1	—	—
Rex sole	5,050	2.4	5,792	4.5	8,403	9.7	1,755	1.7
Sablefish	4,383	2.0	805	.6	1,253	1.5	2,674	2.5
Petrale sole	3,781	1.8	10,100	7.9	4,030	4.7	7,076	6.7
English sole	531	.2	347	.3	—	—	806	.8
Mink food	—	—	—	—	2,000	2.3	2,424	2.3
Total	214,643		127,871		86,212		106,248	

Biological studies of the family Pandalidae have been carried on extensively during the last half century. Berkeley (1930) studied the five commercially important pandalids of British Columbia. Extensive studies of *Pandalus borealis* have been carried on in Denmark, Sweden, and Norway. Scattergood (1952) reported on the *P. borealis* fishery in Maine.

The coastal fisheries for pink shrimp are of such recent nature that little biological data have been published on this species. Tegelberg and Smith (1957) reported observations on the distribution and biology of the pink shrimp off the Washington coast and Rubtzoff (1955) reported on the life history in California. Pruter and Harry (1952) studied *P. jordani* off the Oregon coast. Butler (1959) reported on the possibility of a commercial fishery for this species developing off the coast of Vancouver Island, and Smith (1937) treated the species briefly in reviewing the Puget Sound shrimp fishery.

Size Composition

Samples of shrimp examined for length, sex and per cent egg-bearing females have been taken from commercial landings and exploratory cruises. Oregon samples were from the area between the Columbia River and Cape Perpetua while the Washington samples were from the Grays Harbor area.

Prior to May 1958, Washington measurements were recorded as length in mm from the posterior margin of the eye socket to the tip of the telson. Measurements after May 1958 were recorded as the length in mm from the posterior margin of the eye socket to the dorsal posterior margin of the carapace. This measurement was used by Rasmussen (1953) in studying the growth of *P. borealis* in Norway and Rubtzoff (1955) in studying *P. jordani* off the coast of California. The change to this method of measurement was made since the carapace is a firm structure and allows more precise measurements. Vernier calipers were used in taking these measurements to the nearest tenth of a mm. Washington measurements prior to May 1958 were converted to carapace length for this report. The carapace length (C) and the eyestalk to telson length (E) were found to be linearly related ($r = 0.99$ $P = .01$ with 54 observations) allowing conversion with the formula $C = 0.29 + 0.247\,E$.

It is apparent from the length-frequency distribution in Figure 2 that a dominant year class was present in the area off Grays Harbor when the fishery began in 1956. The dominance of this group (from the 1954 larval release) can be followed in the length frequencies from March-April 1956 through October-December 1957. Unfortunately, personnel limitations prevented sampling of the Washington catch during the peak of the 1958 season. The next samples, taken in July-September 1958, revealed a decrease in strength of the 1954 year class. No age group has appeared as dominant in the catch since 1957. The commercial fleet experienced excellent fishing in the Grays Harbor area in 1957 and early 1958. The fishery at that time was primarily on the 1954 year class.

Length-frequency distributions of shrimp from the area between the Columbia River and Cape Perpetua are shown in Figures 3 and 4. Although the shrimp fishing areas off Oregon are independent of those off Washington, the shrimp react similarly in growth and transition processes. Therefore, the following description, although shown graphically from Oregon shrimp beds, can also be applied to the shrimp caught off Washington.

The incoming year class can be seen entering the fishery in February-April at about 12 months of age, and a size of 10 to 12 mm carapace length. Shrimp at this time are immature and grow rapidly all summer and function as mature males in the fall (at the age of about 18-20 months). The following summer when the shrimp are between 2 and 2½ years old they pass through a sexual transition and become females. Head roe (maturing ovaries visible beneath the carapace) become evident on these new females in about August and by October or November the shrimp are carrying their ova externally. Ova are carried throughout the winter and larval release occurs from February to May. These female shrimp live to spawn again and possibly some spawn for the third time. Natural mortality is not known, but it can be demonstrated that the majority spawn more than once (by following a group of females after the first spawning throughout the summer and noting that there is no abrupt drop-off in the size of the year class). It is doubtful that many individuals live past the fourth year, but this is not easy to demonstrate as the sizes of individual age groups overlap and are difficult to define.

The pattern of growth and development in the Brookings and Coos Bay areas is considerably different than in northern Oregon and Washington. Young shrimp appear to function as males at about 8 months of age. A segment of these shrimp will pass through the transitional period the following summer when 12 to 18 months old. The remainder function as males the second winter and reverse sex the following summer at 24 to 30 months. It can be noted in Figure 5 that the shrimp are larger in Brookings and are undergoing transition as 1-year-

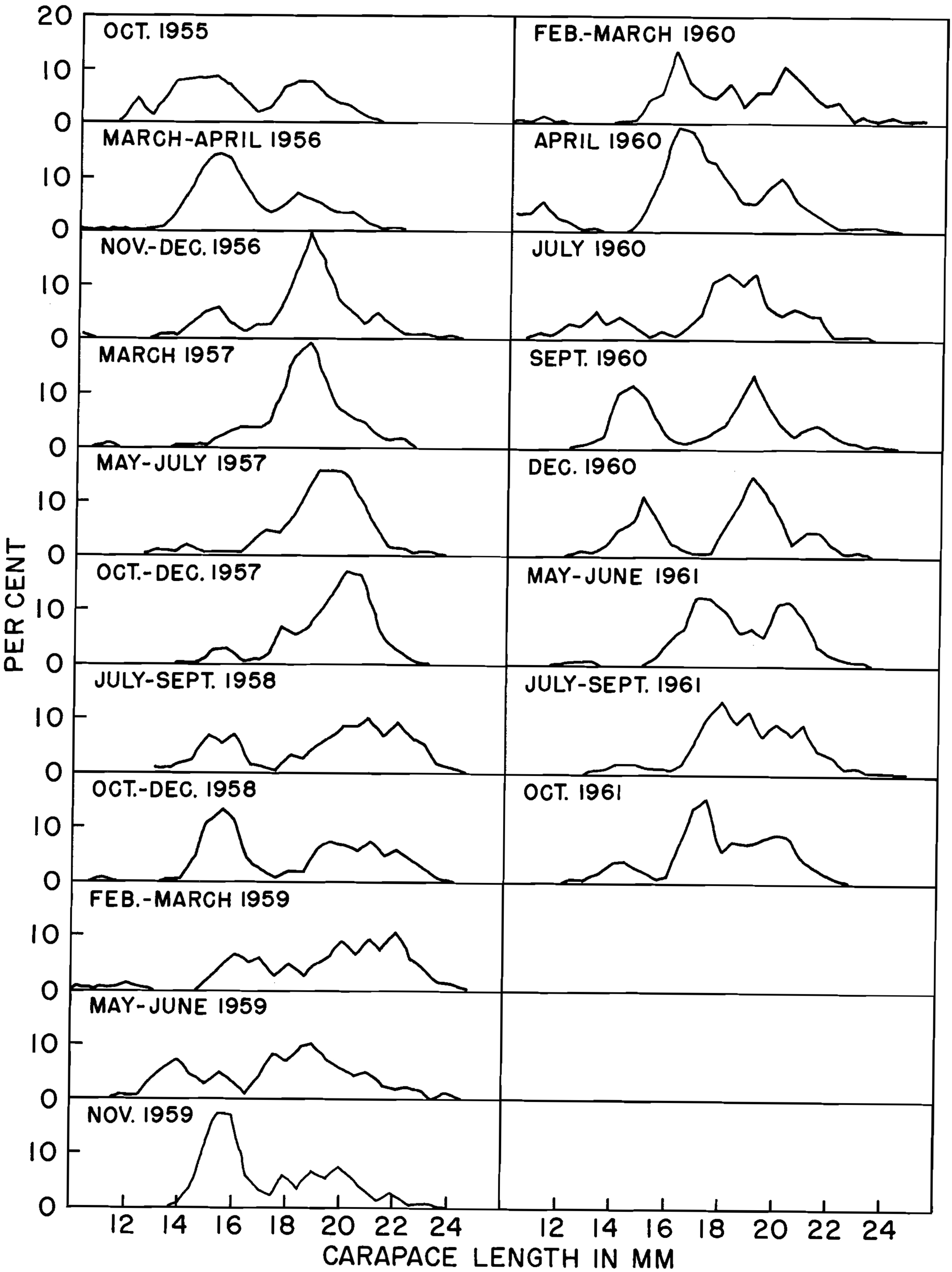

FIGURE 2. Pink shrimp length-frequency distributions from Washington coastal areas, 1955-61.

olds. No 1-year-olds are transposing in the northern shrimp and the 2-year-olds are in the midst of this process.

The count-per-pound of shrimp landed in Brookings is comparable to that at Warrenton although the modal size of comparable age groups is larger in Brookings. Landings at Brookings consist mainly of large 1- and 2-year-old shrimp while the Warrenton landings are of 1-, 2-, and 3-year-olds.

Age Composition and Sex Ratio

Changes in sex ratio are quite pronounced during the period of transition as the males transpose to females. In general, the sex ratio can be correlated with age. That is, the zero (less than 12 months) and first (12-24 months) year shrimp are males, the second (24-36 months) year shrimp are male-transitional-females, and the third year and older shrimp are females.

In Figures 2, 3, and 4 the age groups can be easily recognized by following a year class mode through the season. The percentage of males to females varies throughout the year from about 70% females and 30% males in the spring to about 60% males and 40% females in the fall. A year round average would approximate 50:50. As the individual females are larger than the males, they comprise about 70% of the poundage.

Growth

The modal progressions of several year classes are plotted in Figure 6 for the Grays Harbor area. There is considerable variation in size between year classes at a given age. The modes of the 1954-, 1957-, and 1958-year classes at 2 years of age were 15.0, 17.1, and 16.2 mm carapace length, respectively. At 2½ years the approximate modes were 17.6, 19.0, and 19.5 mm, respectively. At 3 years, the 1954 year class peaked at 18.5 mm and the 1957 year class at 20.0 mm.

The growth rate of shrimp in northern Oregon is shown in Figure 7 by plotting the monthly mode of each year class in landings from February 1958 through December 1961. The growth rate is the

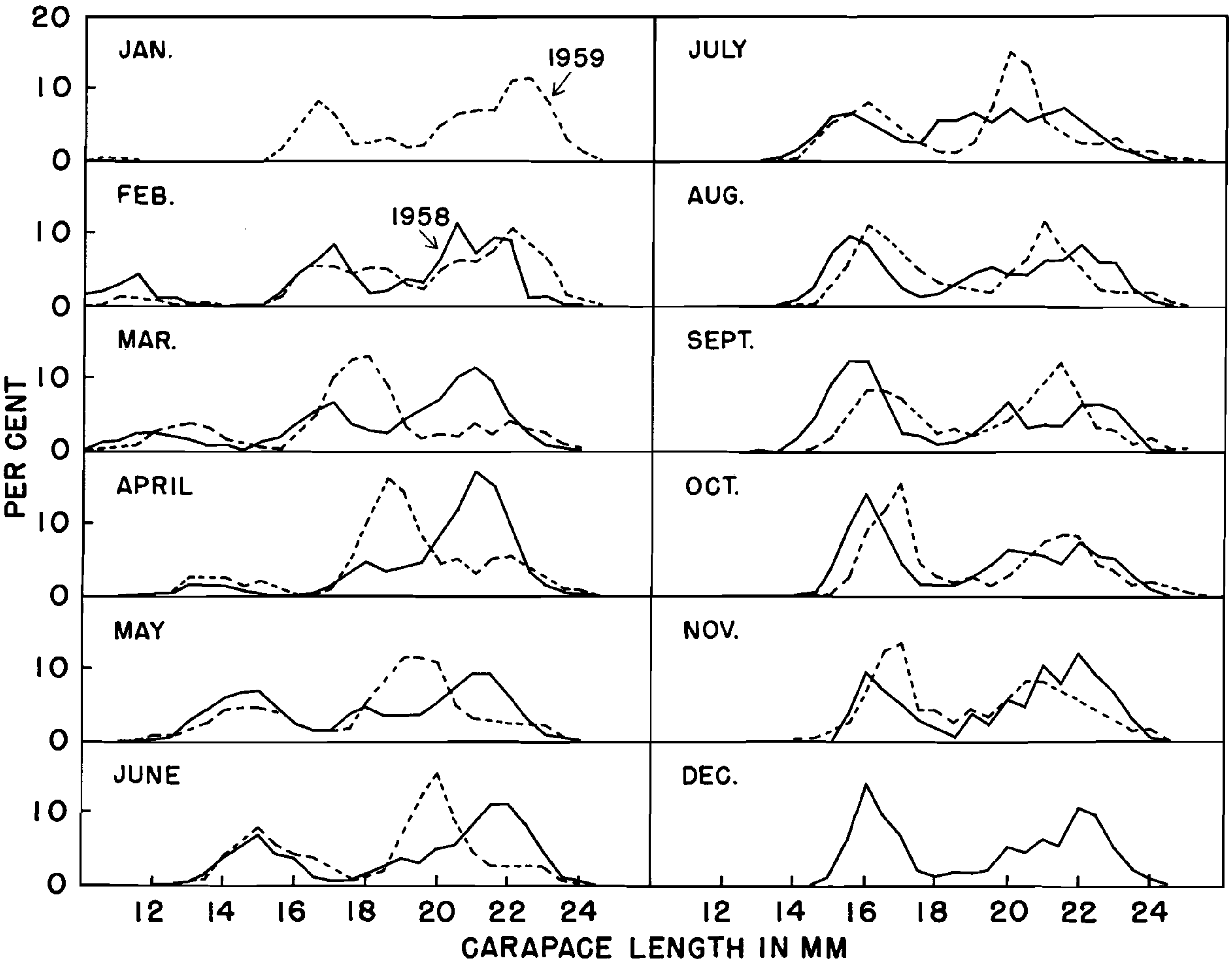

FIGURE 3. Pink shrimp length-frequency distributions from northern Oregon, 1958-59.

most rapid during the first 18 months. When shrimp reach egg bearing size no growth is apparent during the winter months as no molting can take place while the eggs or larvae are being carried externally.

Growth of shrimp in southern Oregon is more rapid than in the northern areas. Figure 5 can again be examined to compare modal size at similar times of the year.

Egg Bearing

Female pink shrimp are considered gravid when the eggs or larvae are being carried externally. The approach of the gravid condition is apparent in the fall when maturing ovaries are visible within the carapace. A seasonal comparison of the percentage of gravid females is shown in Figure 8 for the Grays Harbor and northern Oregon areas.

External egg bearing generally commences in the Grays Harbor area in early October. Approximately 40 to 60% of the females in commercial samples are gravid by the first week in November and 100% are gravid by December 1. In the northern Oregon area, egg bearing commences somewhat earlier. Approximately 50% of the mature females are gravid by the middle of October and over 75% by the first week in November.

Larval release in the northern Oregon area also begins earlier than in the Grays Harbor area, generally terminating before the first of April. Washington shrimp samples for the years 1956 through 1960 indicate considerable variation in the timing of larval release. The termination of larval release varied approximately one month between 1956 and 1959; the 1958 and 1959 seasons terminating earlier than the 1956 and 1957 seasons. No samples during the egg bearing season are available for the Coos Bay or Brookings areas.

Count-Per-Pound

The size of pink shrimp is computed by the number of individual whole shrimp required to weigh a pound — termed count-per-pound. The monthly average count-per-pound of shrimp off the Columbia River ranged from 80 to 122 (Table 7), with individual samples ranging from 70 to 220. Land-

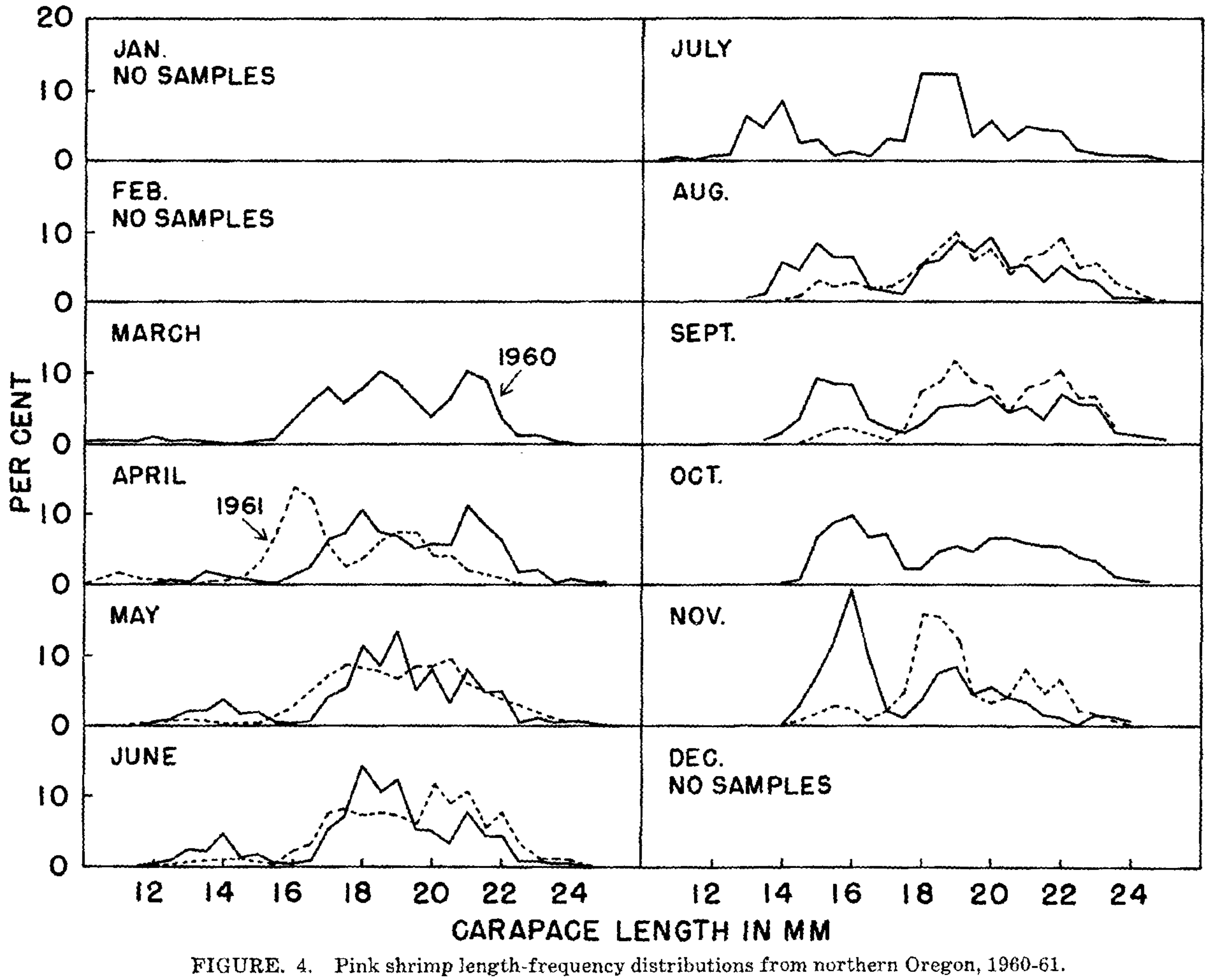

FIGURE. 4. Pink shrimp length-frequency distributions from northern Oregon, 1960-61.

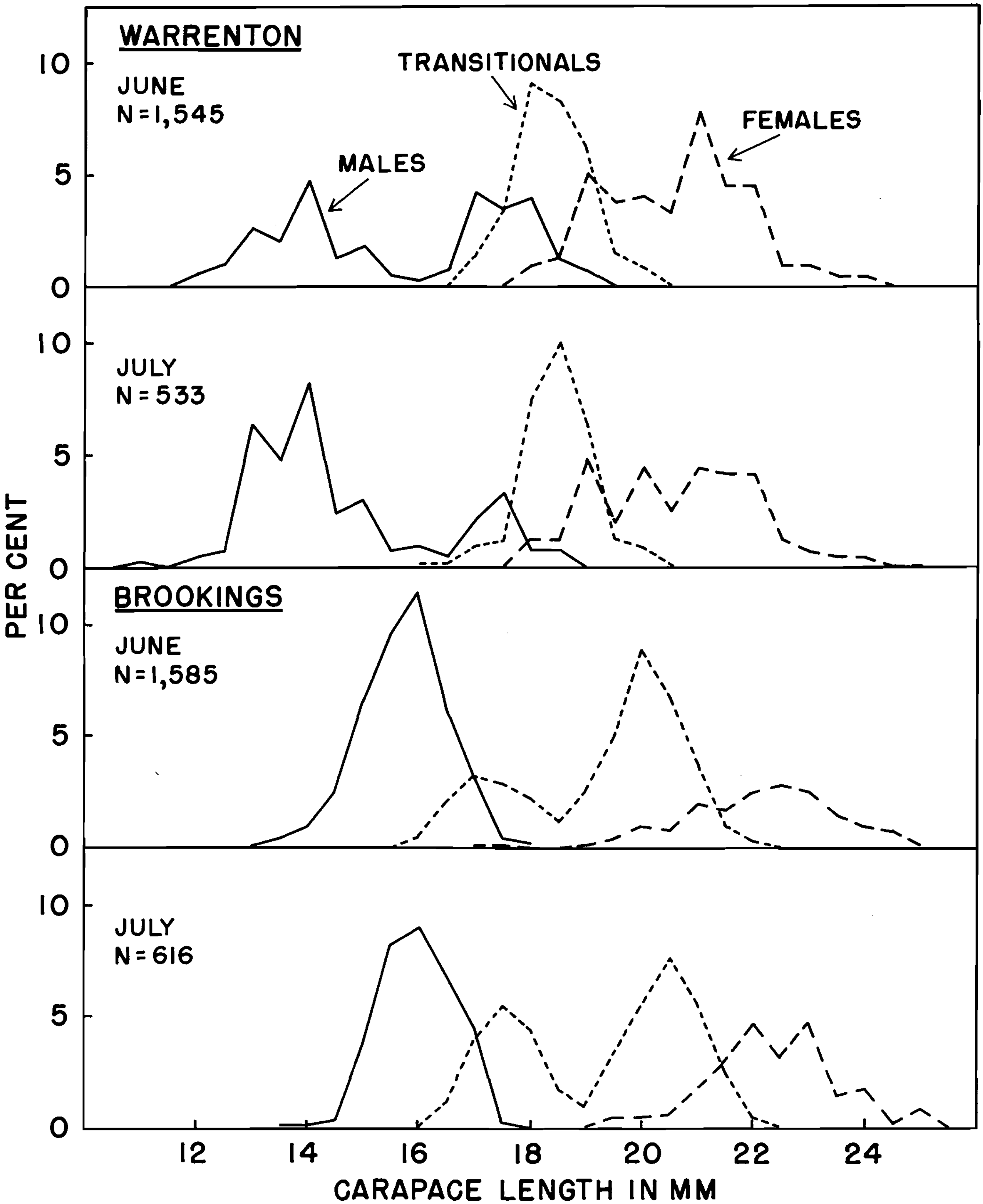

FIGURE 5. Comparison of length-frequency distributions from Warrenton and Brookings, Oregon, 1960.

ings have a tendency to contain more shrimp per pound during the months when the first-year males are entering the fishery, and contain less shrimp per pound in the fall when the second-year males and third-year females make up the bulk of the catch.

TABLE 7

Count-Per-Pound (Heads on) of Pink Shrimp Taken off Northern Oregon.

Month	1958	1959	1960	1961
January	—	80.6	—	—
February	—	86.7	—	—
March	103.3	116.8	108.1	—
April	112.6	100.7	107.5	125.1
May	112.1	111.8	110.0	105.2
June	102.1	105.3	112.1	99.2
July	101.8	100.3	122.0	85.6
August	102.4	103.5	109.6	90.2
September	115.0	95.2	100.0	85.0
October	105.8	94.6	100.4	—
November	89.6	96.7	118.7	—
December	98.2	—	—	—

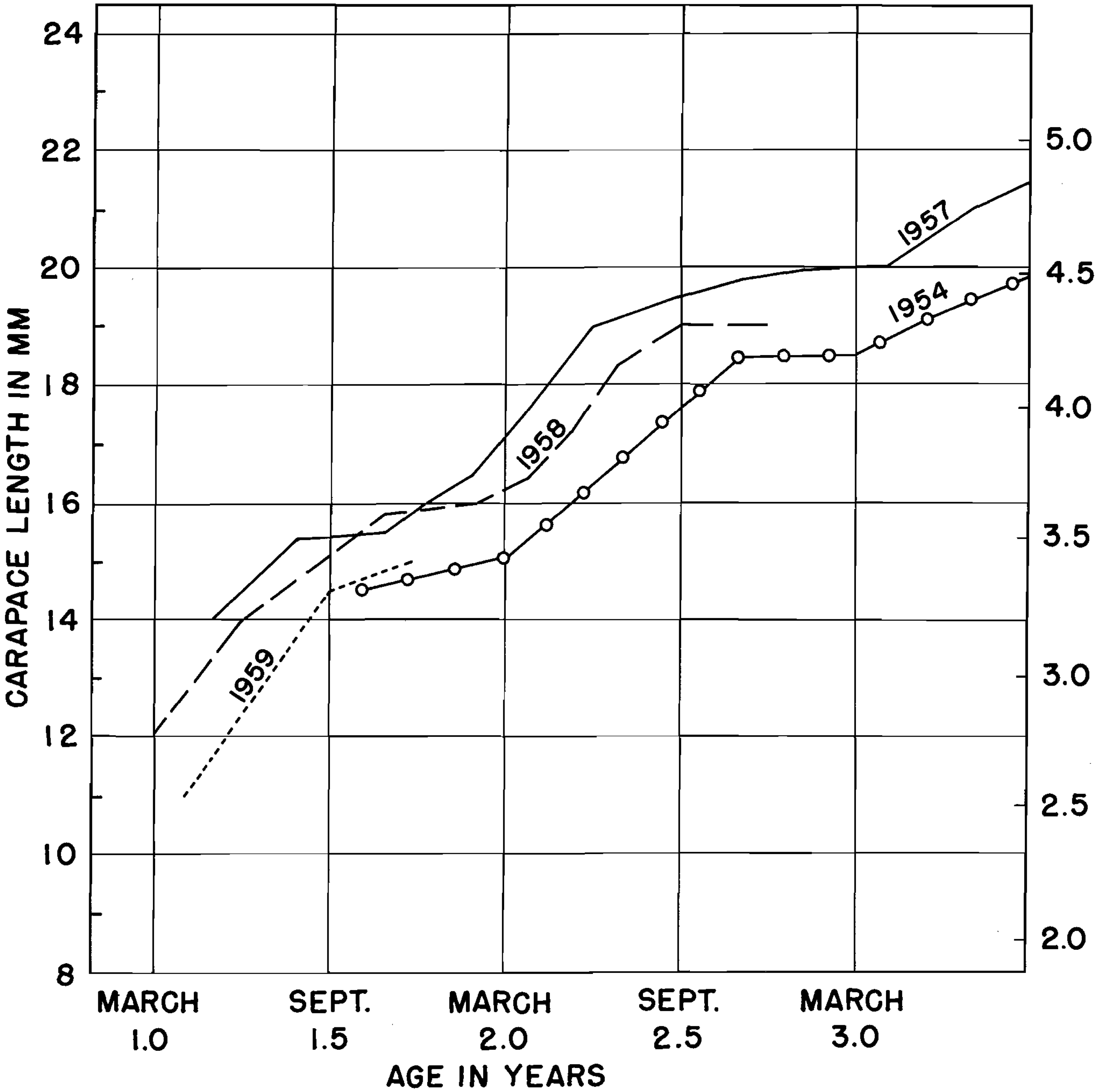

FIGURE 6. Growth of pink shrimp off the Washington coast for the 1954-, 1957-, 1958-, and 1959-year classes.

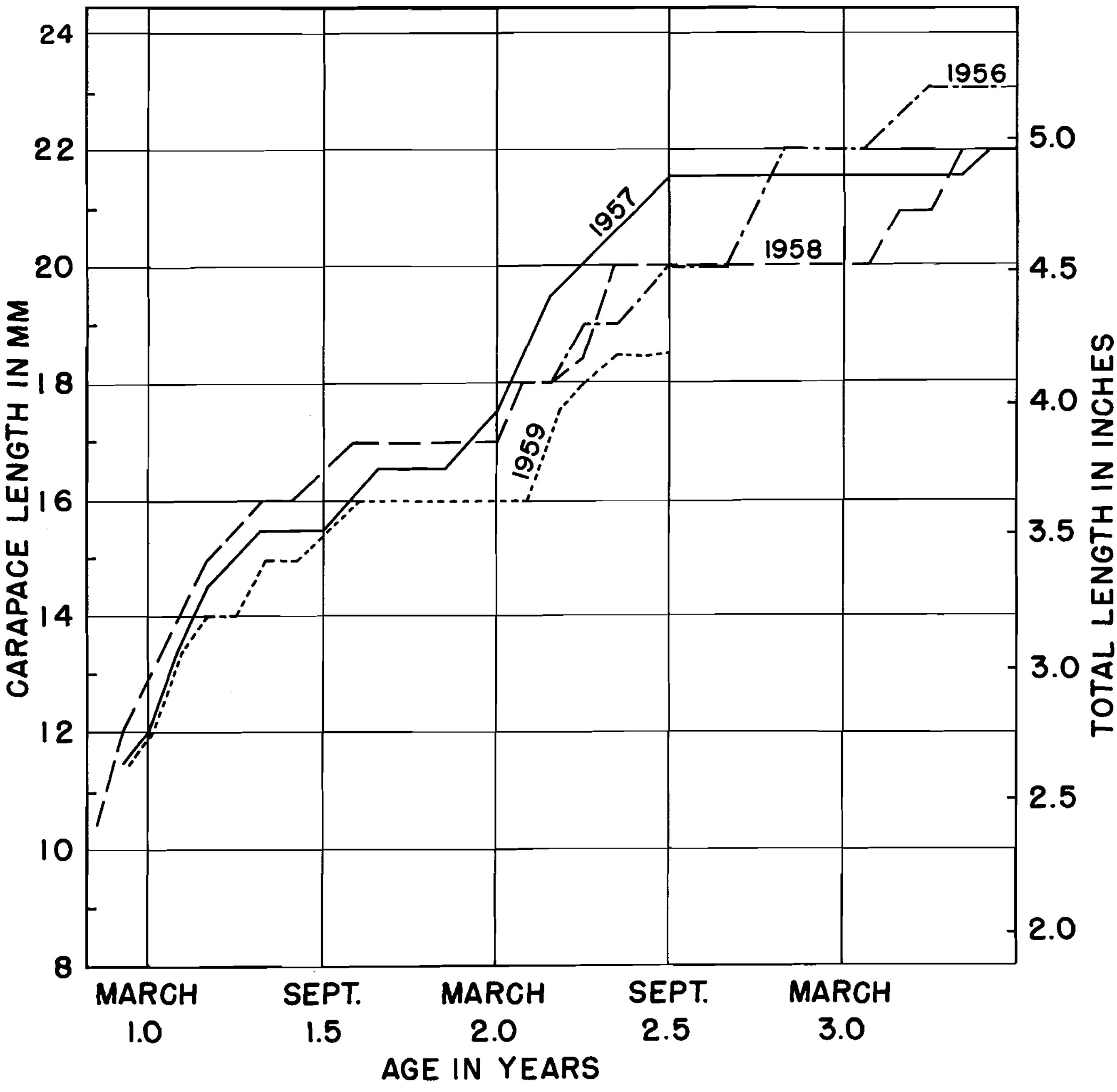

FIGURE 7. Growth of pink shrimp off the northern Oregon coast for the 1956-, 1957-, 1958-, and 1959-year classes.

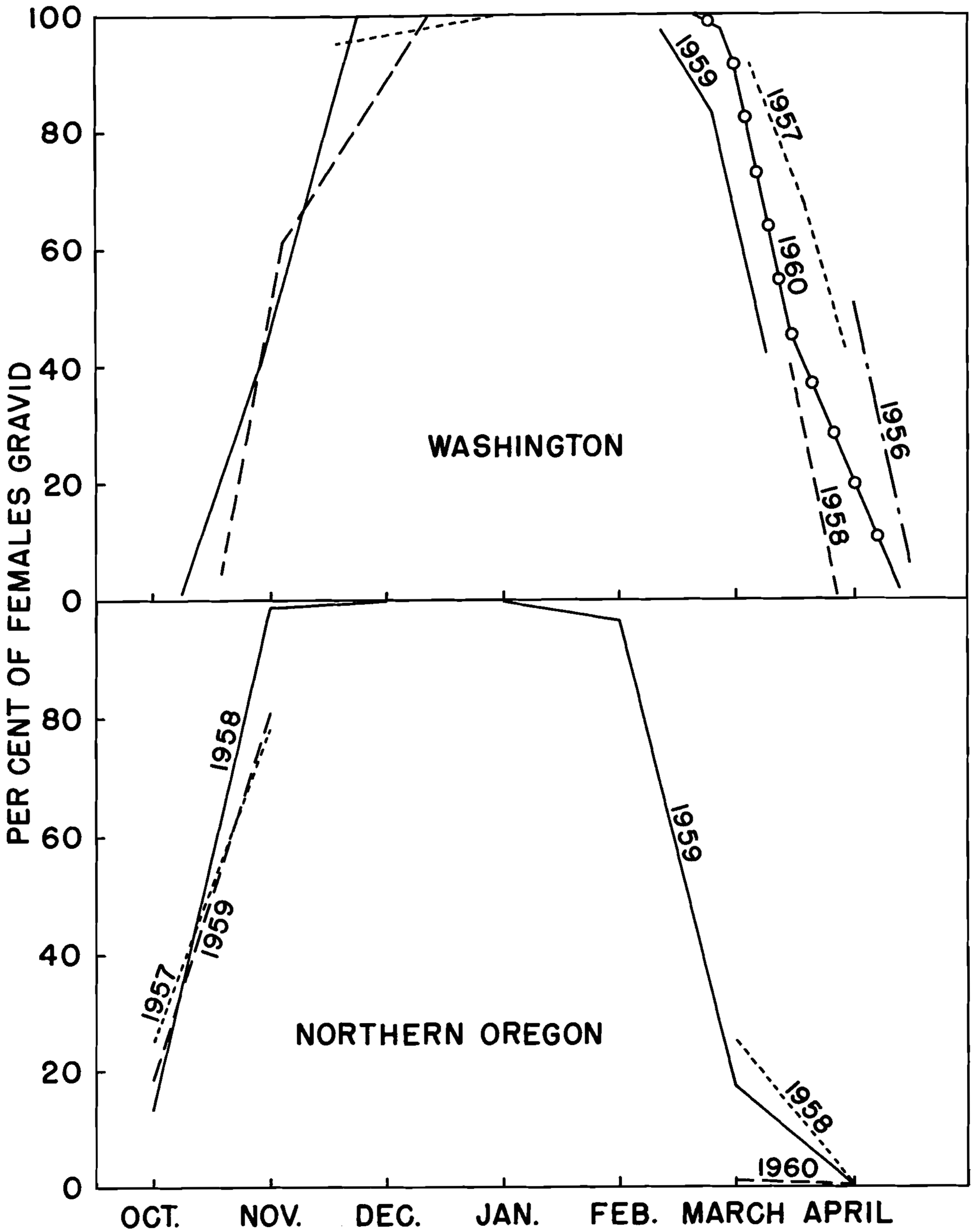

FIGURE 8. Percentage of pink shrimp gravid by month for Washington and northern Oregon.

REGULATIONS

Washington originally had a winter closure on shrimp fishing which was lifted in 1956 to allow the new fishery to develop. With the exception of the 1957-58 winter in Washington, very nominal landings have been made in each state during the winter months due to adverse weather conditions. It is lawful to fish for shrimp the entire year in these states.

Gear regulations are liberal; any kind of a trawl is permissible providing the mesh size is between 1¼ and 2 inches in Oregon (taut measure between knots) and 1½ and 2 inches in Washington. Washington regulations require that the maximum distance between the doors and the wings of the net is not to exceed one-half the over-all length of the vessel, while Oregon requires this distance to be no more than 20 feet. This regulation eliminates the long dandyline gear which tends to herd bottom fish into the net.

Regulations concerning the landings of incidental fish have been changed several times in Washington during the course of the fishery. Both states now have adopted the 3,000-pound-per-trip limit proposed by the Pacific Marine Fisheries Commission in 1958.

PRESENT STATUS OF THE RESOURCE

The coastal shrimp fishery between the Strait of Juan de Fuca and the Oregon-California border has operated virtually unrestricted since its beginning in 1956. It now appears that the main shrimp beds in this area have been located and exploited. A decline in shrimp abundance and/or availability is indicated by a decrease in total catch and catch-per-hour.

Scattergood (1952) in discussing the probable reasons for the decline of the *P. borealis* fishery in Maine commented on several factors which might contribute to such a decline: cyclic fluctuations in the shrimp population, migrations to areas unexploited by the commercial fishery, overfishing, damage to shrimp stocks by fishing operations on other species, oceanographic changes, natural mortality, and increased predation. Dow (1963) for the same species observed a relationship between March sea water temperatures at Booth Bay Harbor and Maine landings two years later.

Pink shrimp may be particularly susceptible to overfishing since the large shrimp which are most available to the fishery are all females. A reduction in the female pink shrimp population could conceivably affect the reproductive capacity and abundance of the stocks.

Cyclic fluctuations in the shrimp population could have an important effect on the fishery. The presence of a dominant year class of shrimp was revealed in periodic sampling of the Washington shrimp population starting in October 1955. This group of shrimp (from the 1954 larval release) was responsible for the excellent fishing in Washington in 1957 and early 1958. By fall of 1958 the representation of this year class in the catch was greatly reduced. No year class since has approached the strength of the 1954 class in the commercial catch.

Changes in oceanographic conditions on the continental shelf could affect the availability or abundance of the shrimp stocks. At times the fishermen have remarked about strong currents on the shrimp grounds. Such currents could affect the distribution of the shrimp, causing them to scatter rather than concentrate in certain areas. Also, conditions for the survival of shrimp larvae may be variable and account for fluctuations in the population.

Little is known about natural enemies of the pink shrimp, but predation could play an important part in their abundance. At certain times such species as hake, dogfish, and smelt become so numerous on shrimp beds that fishing operations must be shifted to other areas. If these species are preying on or competing with shrimp, the effects on the stocks in specific areas could be significant.

The initial burst of interest in the shrimp industry in Washington and Oregon appears to have been out of proportion to the maximum sustainable yield from the offshore areas. The industry now appears to be stabilizing at a level whereby the plant and boat capacities will be in balance with the resource and markets.

SUMMARY

1. The commercial fishery for pink shrimp *(Pandalus jordani)* began off the Washington coast in 1956 and off the Oregon coast in 1957. The industry expanded rapidly after the introduction of shrimp trawls and peeling machines to a peak of 51 boats and 7 peelers in 1958, then declined to 19 boats and 4 peelers in 1961.
2. Pink shrimp range in size from 70 to 220 per pound (heads on) and are caught in quantity on bottom types of green mud and green mud and sand at depths of 40 to 100 fathoms.
3. Shrimp explorations indicated the most prom-

ising areas for commercial fishing were off Destruction Island, Grays Harbor, Tillamook Rock, Cape Lookout, and Coos Bay.

4. Washington's primary fishing area is located off Grays Harbor and annually has produced over 76% of the poundage caught off Washington. The major shrimp producing area off northern Oregon lies between the Columbia River and Cape Lookout.
5. Shrimp production from Washington and Oregon waters from 1958 to 1961 has fluctuated between 2.5 and 7.9 million pounds, with the lesser catches occurring in the later years.
6. Quantities of bottom fish are occasionally taken in shrimp hauls and a limit of 3,000 pounds per landing of incidental fish is imposed by both states.
7. Growth of a year class can be determined by following modal progression in length-frequency samples. The pattern of pink shrimp growth and development is more rapid in southern Oregon than in the northern Oregon and Washington areas.
8. The 1954 year class dominated the Washington landings in 1956 and 1957. Subsequent measurements have not shown single year class dominance.
9. Shrimp growth is accelerated during the spring and summer months. No growth is noted for gravid females, since molting cannot occur while ova are being carried externally.
10. Pink shrimp are protandrous hermaphrodites and change from males to females during their second year. Sex ratios vary through the season as the sexes change.
11. Maturing ova become visible under the carapace during August, and are being carried externally by October and November. Larval release occurs from February through April, with northern Oregon shrimp usually releasing somewhat earlier than Washington.
12. There are no closed seasons for the Washington and Oregon coastal shrimp fishery, and gear restrictions are limited to mesh size and distance between the doors and wings of the net.
13. The known shrimp areas off Washington and Oregon have been located and exploited. Catch-per-unit of effort data point to a decline in shrimp abundance and/or availability in certain areas.

ACKNOWLEDGMENTS

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Availability of Small Salmon Off the Columbia River

H. HEYAMOTO

BULLETIN 6

PACIFIC MARINE FISHERIES COMMISSION
Portland, Oregon, 1963

AVAILABILITY OF SMALL SALMON OFF THE COLUMBIA RIVER[1]

H. Heyamoto[2]

INTRODUCTION

The Washington offshore troll salmon fishery is regulated through seasonal and minimum size regulations. There are certain inherent difficulties in regulating a fishery of this type. Seasonal closures are inadequate because some stocks of fish may be exploited more heavily than others, and minimum size restrictions have their shortcomings because of the problems associated with natural and hooking mortalities. Furthermore, the selection of larger fish without regard for sexual maturity of fish under the minimum size limit could result in detrimental genetic effects on future populations through cropping of the faster growing fish. Because of these objections to the present regulations, and before further restrictions on the fishery are to be considered, other means of conservation should be investigated.

It has been suggested that a more effective means of conservation could be accomplished by closing areas in which immature salmon congregated during all or part of the year. If these areas do exist, a major problem still remains and that is in delineating and effectively closing them to fishing. A "nursery" area often mentioned by troll fishermen is one off the southeast coast of Washington and commonly referred to as the "North Head" area. To investigate this area a commercial troll vessel and fisherman were chartered. The purpose of the study was to obtain the length composition of all salmon available to trolling gear in the "North Head" area, and to obtain a ratio of legal to illegal size fish during specified time periods. The existing regulation for legal size troll chinooks *(Oncorhynchus tshawytscha)* is 26 inches or over, and for silvers *(Oncorhynchus kisutch)* it is 22 inches, both total lengths.

A secondary aim of the project was to tag and release all fish in good condition to obtain information from any subsequent recoveries on migration patterns.

METHODS AND MATERIALS

A troller who had fished for many years out of Ilwaco was contacted and arrangements made to charter his boat and services for two consecutive days every other week throughout the 1957 fishing season. The plan was to fish the "North Head" area both days on alternate weeks and at the end of the season compare the length distributions of the catch by month. It was discovered, however, that the fishing in this area was extremely poor, and that the other boats were fishing elsewhere. The schedule was altered to fish north of the Columbia River the first day, and, if fishing was poor, to fish the south side the following day. (See Figure 1 for fishing areas.) The fishing on the north side did not improve measurably throughout the summer; therefore, the south side, where the main portion of the fleet from Ilwaco and Astoria was operating, was fished on the second day whenever weather conditions permitted. A total of eight trips to the north side and six to the south side was made during the course of the investigation, which started in May and ended in August. Two attempts were made in September, but due to inclement weather conditions limited fishing was accomplished on the first trip; and the second trip, which was scheduled for two weeks later, was cancelled.

Petersen disk tags (14 millimeters in diameter) and stainless steel pins were used for tagging. The tags were affixed immediately below the dorsal fin. To facilitate tagging, a live-box was constructed of ⅜-inch marine plywood reinforced with 1 by 2's and coated with Weldwood glue. The box was 18 inches deep, 24 inches wide, and 44 inches long. A canvas tagging cradle was built inside the box just above the water line. The live-box proved useful in that fish of doubtful condition were placed in the box before and after tagging to revive before releasing. An undersirable feature of the live-box, however, was that the water splashed about considerably from boat movement. Baffles were added, and together with the canvas tagging cradle, they aided greatly in reducing the amount of splashing.

The method of fishing and gear normally employed by fishermen was not altered during the

[1]Submitted for publication May 24, 1963.

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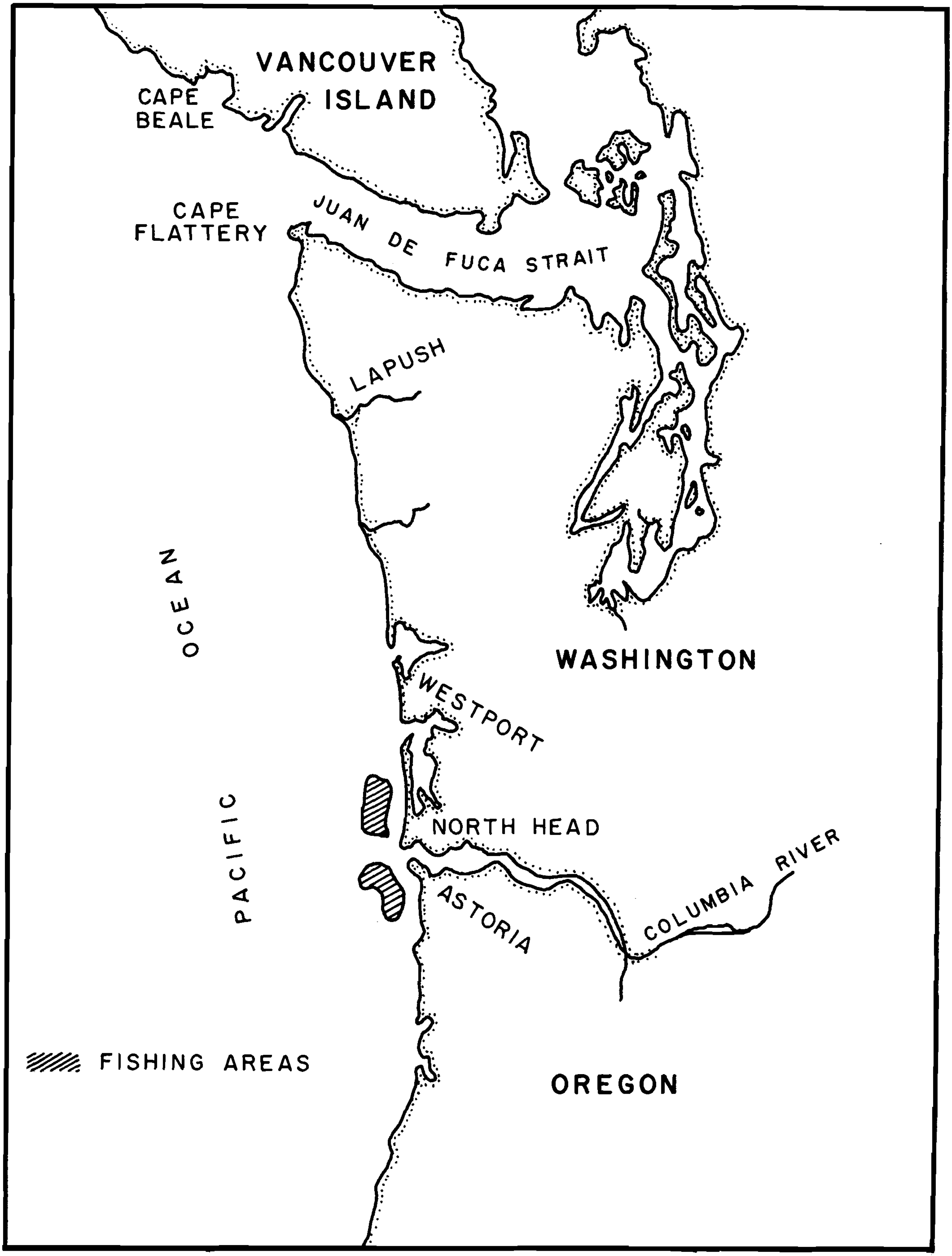

FIGURE 1. Map showing fishing areas.

course of the investigation. A variety of spoons and plugs and plastic squid with flashers were used as lures.

The depth of the water fished in both areas was from 12 to 40 fathoms, with most of the fishing being done in 20 to 30 fathoms of water.

RESULTS

North Side

In 8 one-day trips to the north side area only 22 chinooks and 64 silvers were caught and measured. Of these totals, 17 chinooks and 56 silvers were tagged and released. Fishing was very poor throughout the spring and summer. On most of the charter days no other boats were fishing in the area, although a few boats fished for silvers in late July and August. Most of the fishing was confined to the area off North Head to approximately off Klipsan Beach. Little fishing was done inside the 15-fathom curve because of the possibility of entangling lines with crab pot gear. For this reason other boats did not enter this area either.

Chinooks. The top part of Figure 2 shows the length frequencies of the chinooks caught during the investigation of the North Head area. So few fish were caught that it would be meaningless to show the lengths by month; therefore, they were grouped for the entire fishing period. Table 1, however, shows the legal to sub-legal size chinooks by month. All measurements were taken in centimeters and fork length, and conversions to total length measurements were necessary to divide legal from sub-legal sized fish. The following formula was taken from a report by Van Hyning (1951):

Tail extended

$$\text{T.L. (cm.)} = 1.71728 + 1.05625 \text{ F.L. (cm.)}$$

Using this formula the centimeter fork length for a 26-inch chinook salmon is 60.897.

TABLE 1

Number of Legal and Sub-Legal Size Chinooks Taken in the North Head Area from May through August, 1957

Size	May	June	July	Aug.	Total	Percent
Sub-legal	2	1	13	2	18	82
Legal	1	2	1	0	4	18
Total	3	3	14	2	22	100

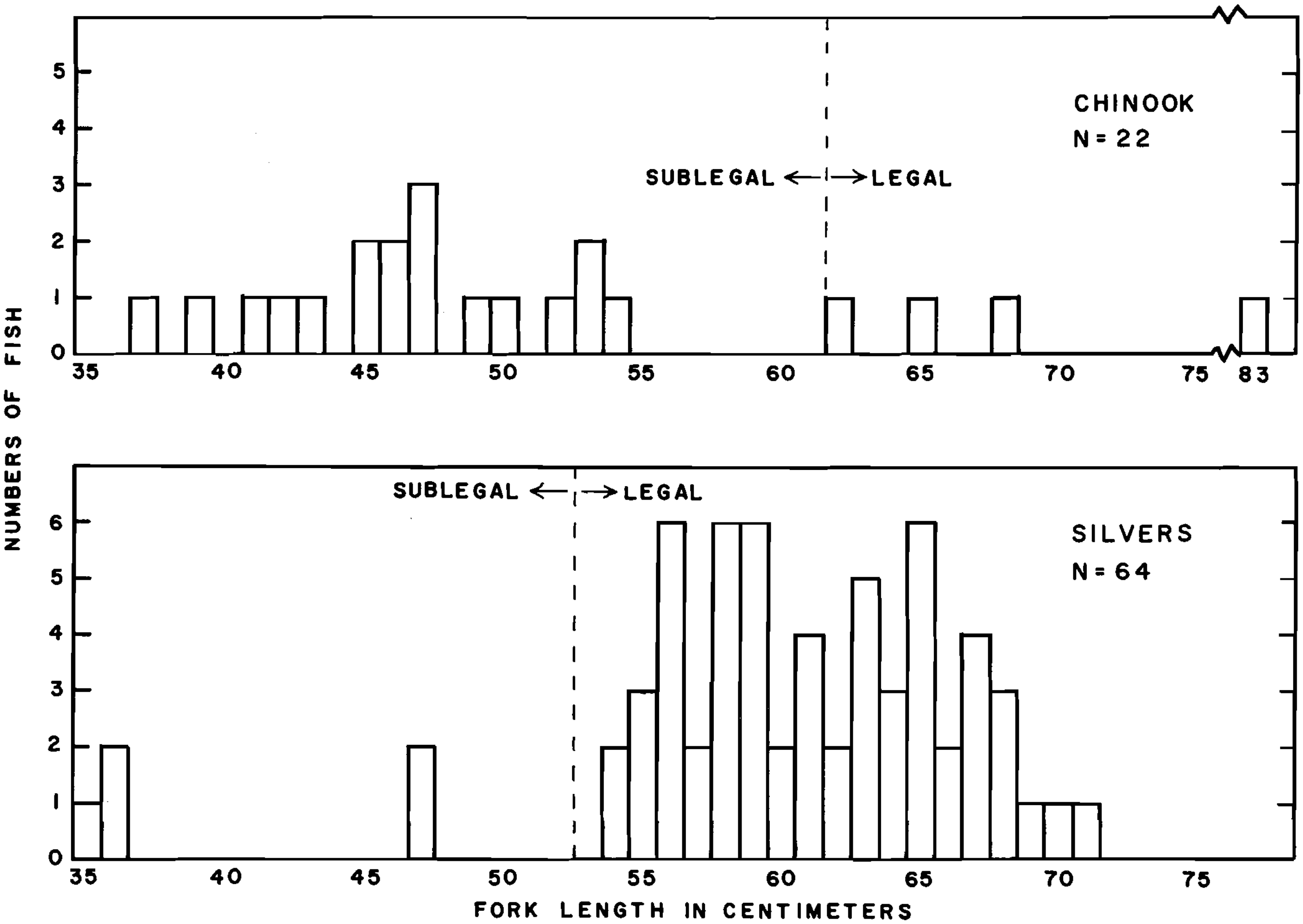

FIGURE 2. Length frequency distribution of chinooks and silvers caught north of the Columbia River.

Of the total of 22 chinooks caught, 18 or 82 percent were of sub-legal size.

Silvers. The bottom section of Figure 2 shows the length frequencies of the silvers taken during eight trips to the North Head area. The formula used in converting centimeter fork length to tail extended total length was from the same reference as cited for the chinook conversion. The formula used was:

$$\text{Tail extended T.L. (cm.)} = 1.78433 + 1.03706 \text{ F.L. (cm.)}$$
$$\text{22-inch T.L.} = 52.162 \text{ cm. fork length}$$

The total number of silvers caught was 64 of which 5 were of sub-legal size (less than 22 inches total length). The breakdown by month appears in Table 2.

TABLE 2
Number of Legal and Sub-Legal Size Silvers Taken in the North Head Area from May through September, 1957

Size	May	June	July	Aug.	Total	Percent
Sub-legal	—	0	1	4	5	8
Legal	—	10	17	32*	59	92
Total	—	10	18	36	64	100

*One in September.

Only eight percent of the silvers taken in this area were of sub-legal size, and of the five fish under the minimum size limit, one was taken in July and four in August. Some of the sub-legal size fish taken in August were examined for sexual maturity and it was found that they were precociously developed males, and therefore assumed to be "jacks."

South Side

The fishing in this area was in the vicinity of the Columbia River lightship and southward, occasionally as far south as Seaside. Most of the fishing was in 20 to 30 fathoms of water.

In 6 trips to the south side, a total of 61 chinooks, 60 silvers, and 3 pinks *(O. gorbuscha)* were tagged and released.

Chinooks. The top part of Figure 3 shows the length frequencies of the chinooks taken during the fishing on the south side. A major portion of the catch was under the legal size limit of 61 centimeters fork length.

Table 3 shows the size distribution by month. Of the 61 fish total, 50 or 82 percent were of sub-legal size. Most of the fish were caught in June and over 90 percent of these were under the legal size limit of 26 inches.

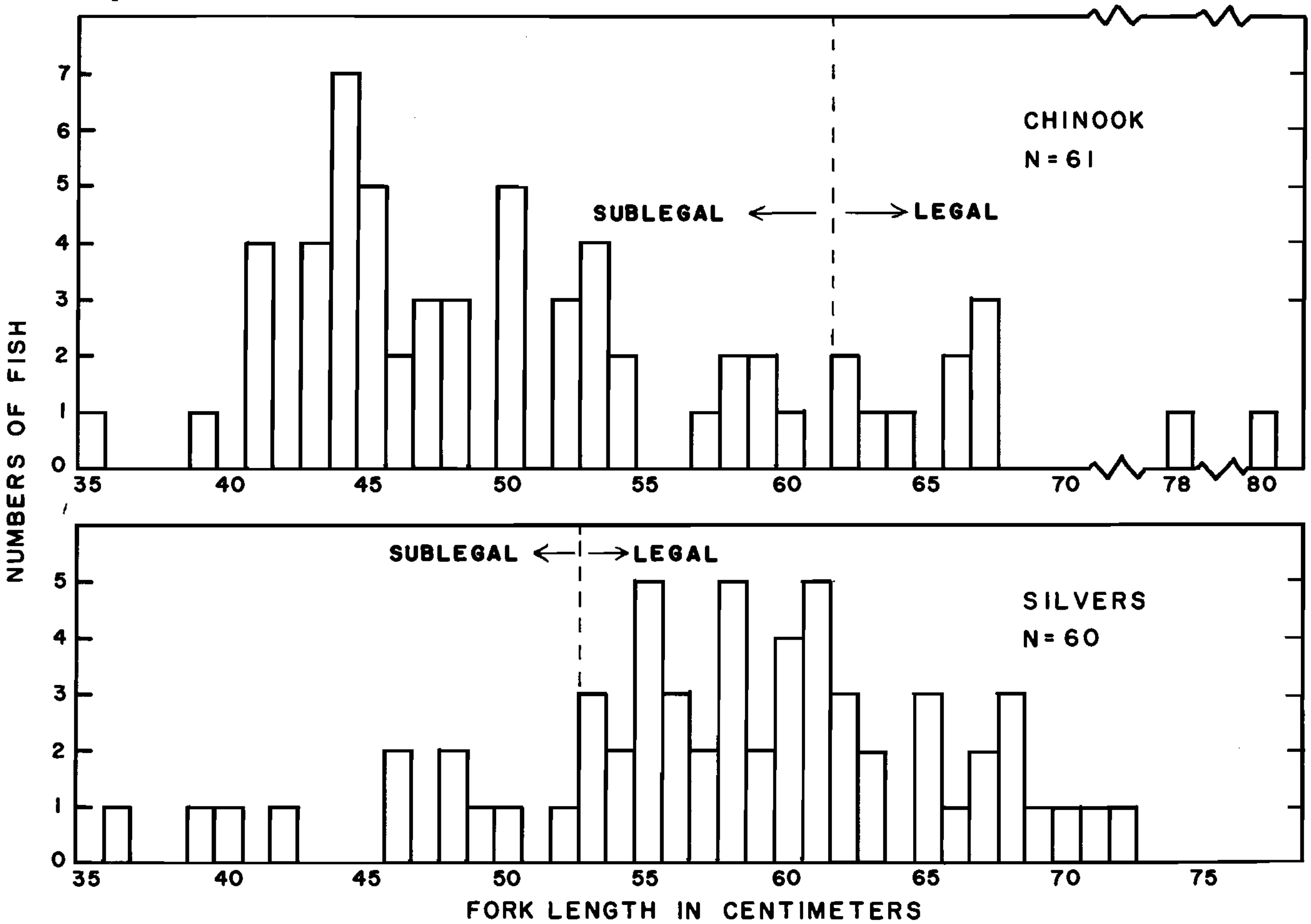

FIGURE 3. Length frequency distribution of chinooks and silvers caught south of the Columbia River.

TABLE 3

Number of Legal and Sub-Legal Size Chinooks Taken in the South Side Area from May through August, 1957

Size	May	June	July	Aug.	Total	Percent
Sub-legal	1	42	3	4	50	82
Legal	4	4	1	2	11	18
Total	5	46	4	6	61	100

Silvers. The bottom part of Figure 3 shows the length frequencies of the silvers caught on the south side during the six trips. The total number caught was 60 of which 10 were of sub-legal size. The numbers of silvers below and above the minimum size limit of 22 inches are shown in Table 4.

TABLE 4

Number of Legal and Sub-Legal Size Silvers Taken in the South Side Area from May through August, 1957

Size	May	June	July	Aug.	Total	Percent
Sub-legal	0	7	0	3	10	17
Legal	2	25	11	12	50	83
Total	2	32	11	15	60	100

Of the total of 60 silvers caught, 10 or 17 percent were of sub-legal size. Seven of the ten were taken in June when some small fish are expected in the fishery. The three in August were assumed to have been "jacks."

TAGGING

Although the primary purpose of the investigation was to obtain information on size distribution of chinooks in the Columbia River area, all fish appearing in good condition were tagged and released. A total of 71 chinooks were tagged, with 10 recoveries to date for a percentage recovery of 14.1 percent; 110 silvers, with 18 recoveries for 16.4 percent; and 3 pinks, with 2 recoveries for 66.6 percent.

It was expected that the percent recovery of silvers and pinks would be greater than for the chinooks because these fish were in their final year of life and would be subjected to intense commercial and sports fisheries during migration to their native streams. The tagged chinooks were immature and would have an additional year or more in the ocean which would increase the probability of tag loss, and also they would not be subjected to any net fishery the first year. Many were also under the minimum size for the troll fishery, although some were of legal size in the sport fishery. There was one report of a troll fisherman returning a tagged chinook to the water in the tagging area because the fish was of illegal size. He did not record the tag number.

North Side

Table 5 shows the numbers of chinooks and silvers tagged by month and the numbers recovered for the North Head area.

Chinooks. A total of 17 chinooks was tagged and to date only 1 recovery has been reported. The lone chinook recovery from the June tagging was reported by a British Columbia cannery worker on August 15.

Silvers. Six recoveries were made from the 56 tagged silvers released, for a 10.7 percent return. The one recovery from the June tagging and one of the two from the July tagging were taken in the Strait of Juan de Fuca by Canadian fishermen. The other recovery from the July tagging was taken off the mouth of the Columbia River by a sport fisherman. Of the three recoveries from the August tagging, one was taken by an ocean sport fisherman off the Columbia River, one was taken by a gillnetter in the Columbia, and the other one was reported from the Cowlitz River. The type of gear was not specified for the latter recovery.

TABLE 5

Numbers of Chinooks and Silvers Tagged and Recovered by Month for the North Head Area from May through August, 1957

	Chinooks		Silvers	
	Number Tagged	Number Recovered	Number Tagged	Number Recovered
May	2	0	0	0
June	8	1	12	1
July	7	0	11	2
August	0	0	33	3
Total	17	1	56	6
Percent		5.8		10.7

South Side

The numbers tagged and recovered for the south side area are shown in Table 6.

TABLE 6

Numbers of Chinooks and Silvers Tagged and Recovered by Month for the South Side Area from May through August, 1957

	Chinooks		Silvers	
	Number Tagged	Number Recovered	Number Tagged	Number Recovered
May	5	2	2	0
June	39	5	31	9
July	4	0	10	1
August	6	2	11	1
Total	54	9	54	11
Percent		16.66		20.37

Chinooks. From the 54 chinooks tagged, 9 have been recovered for a 16.66 percent return. Of the two from the May tagging, one was taken off Cape Flattery in early September, and the other off Esperanza, Vancouver Island, in July, 1958. From the June tagging, two were recovered off Westport in July, one off Lapush in August, and two off the Columbia River in August. From the August tagging, one was recovered off Cape Beale by a troller in June, 1958, and the other by a sport fisherman off Westport in July, 1958.

Silvers. Fifty-four silvers were tagged in the south side area and eleven recoveries have been recorded to date for a percentage return of 20.37. Nine of the eleven recoveries were from the June tagging. The sport fishery accounted for three of the nine recoveries; one off Willapa Bay and two off Grays Harbor. The troll fishery accounted for three recoveries, one each off the Columbia River, Grays Harbor, and Point Grenville which is approximately 25 miles north of Grays Harbor. Two were taken in the gillnet fishery, one in the Columbia and one in Willapa Bay. One was reported by a cannery worker in British Columbia and the type of gear by which the fish was taken was not given. The two remaining recoveries were taken by the sport fishery. The one recovery from the July tagging was taken off the Columbia River, and one from the August tagging was caught in the Wallowa River in eastern Oregon. The Wallowa River is a tributary of the Grande Ronde which flows into the Snake River.

Pinks. During one trip in late July, three pink salmon were caught, tagged, and released. Two of the three were subsequently caught by gill net gear. One was taken at Port Susan in Puget Sound and the other was taken in the Fraser River.

CONCLUSIONS

Chinooks

Although not many chinooks were caught in the North Head area, 82 percent of the catch was of sub-legal size. It would seem that the high percentage of small chinooks in this area would be sufficient to term it a small fish or nursery area; however, if the North Head area, such as was investigated, had been closed during the year of tagging, the net saving would have been very small because of the scarcity of fish. There is some evidence, however, that conditions were not normal during that season. There generally is a fairly good fishing period during the early part of the season in this area which did not materialize, but whether or not this would alter the size composition is speculative.

The area south of the Columbia River which was investigated on the second day of each trip because of poor fishing on the North Head side, also showed an 82 percent catch of sub-legal size chinooks.

If both of these areas were considered "nursery" areas for salmon, the problem of area delineation would be difficult and would require a more intensive study by time and space than the investigation just concluded. Another complicating factor would be in determining the possible variations occurring within areas from year to year.

The returns of chinooks tagged in the two areas showed similar movement in that the immature or small fish moved northward.

Silvers

Silvers were available in both areas during the test fishing period, with better success on the south side. During August "jacks" appeared in the fishery in both areas. The minimum size regulation prevented this group of silvers from being taken although they were precociously developed and would not remain in the ocean another year.

The returns from silvers tagged in the two areas, as in the case of the chinook, displayed similar movement patterns. The returns from the June and July tagging were from areas to the north, and the August tagging returns came from the Columbia River and its tributaries.

The two returns from the three pink salmon tagged showed northerly movement. One was taken in Port Susan in Puget Sound and the other in the Fraser River in Canada.

ACKNOWLEDGMENTS

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