A STUDY OF THE PRINCIPAL SPAWNING GROUNDS AND OF THE SPAWNING OF THE LEMON SOLE, *PAROPHRYS VETULUS* (GIRARD), IN THE GULF OF GEORGIA IN RELATION TO THE COMMERCIAL FISHERY

by

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ABSTRACT

The winter fishery for lemon sole in the gulf of Georgia depends on populations spawning in Baynes sound and Boat harbour from January to March. The peak period in 1946 was from January 24 to February 23 in Baynes sound and 10 days earlier in Boat harbour. Although some spawning took place throughout the whole of both regions, with the exception of Porlier pass, spawning was more intense in certain areas of each region. Minimum estimates of fishing intensities of 42% and 26.3% for the Baynes sound and Boat harbour regions respectively appear too heavy to maintain the fishery at its present level. During the 1947 fishing season Baynes sound was largely closed to trawling; in Boat harbour the percentage tag recovery was 6.3% as compared to 18.8% for the same period in 1946. These recoveries indicated an average annual increase in length of 7.3% or in weight of 21.9%. Lemon sole spawning in Baynes sound dispersed to parts of the gulf north of Nanoose bay, while those spawning in Boat harbour dispersed southward as far as the American boundary. Although these two populations do not mix to an appreciable extent, their composition is very similar except for a larger number of immature and small mature fish in Baynes sound. The Porlier pass population, consisting of two-thirds immature fish, differed markedly. An estimate of the amount of population change on the spawning grounds was made by comparing the variations in tag returns per period calculated on the basis of a constant number of tagged fish available and a constant weight of fish

caught each period. Stomach analysis showed that lemon sole do not feed actively during the winter and that fully matured fish feed less actively than immature or spent individuals. Worms, clams, and brittlestars formed the principal foods.

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INTRODUCTION

In 1943 an investigation of the otter trawl fishery was undertaken by the Pacific Biological Station. Hart (1946) in his "Memorandum on the Otter Trawl Fishery", in giving the reasons for undertaking this investigation, states, "An investigation of the otter trawl fishery has been set up in order to determine the nature and extent of the competition of otter trawls with other types of fishing gear and the possibilities of a continued successful otter trawl fishery. Considerations of the latter point depend upon studies of the species of fish caught, their general life history and interrelationships, the effects of catching and releasing illegal, under-sized or otherwise unwanted fish, and the effects of dragging heavy nets over the bottom."

The study of the lemon sole spawning grounds in Baynes sound and Boat harbour, carried out during January, February, and March, 1946, forms one phase of the general life history studies of trawl caught fish.

CONDITION OF THE FISHERY AND REASONS FOR THE SPAWNING GROUND SURVEYS

Hart (1946) also makes the following statements about the condition of the otter trawl fishery in the straits of

Georgia: "In general the fishery for otter trawl in the straits of Georgia is in a depleted condition. This is the result of the activity in enclosed waters over a long period of years of a substantial fishing fleet which has been able to operate fairly well throughout the year."

The lemon sole spawning grounds in this area, were made the object of study both because the exploitation of spawning lemon sole constitutes one of the main winter fisheries of this region and because of the biological interest in spawning populations. These regions form two of the few "flatfish" spawning grounds well enough known to permit study.

In this survey information was sought on a number of problems which are stated briefly below. These are enlarged upon in later sections of this report. They are:

1. Does the availability (abumdance) of the lemon sole vary during the spawning season?

2. What is the variation in the sexual development of the fish on or near the spawning grounds?

3. Does active spawning take place generally throughout the whole of a region or is there more active spawning in certain sections of a region than in others?

4. What is the duration of the spawning season?

5. What is the intensity of fishing on these spawning grounds?

6. What indications are there of mass movements of fish about or away from the spawning grounds?

7. To what regions of the gulf do the lemon sole from each spawning ground disperse after spawning?

8. Does a relationship exist between the feeding of lemon sole and the degree of sexual maturity?

REGIONS STUDIED

Major Lemon Sole Spawning Grounds

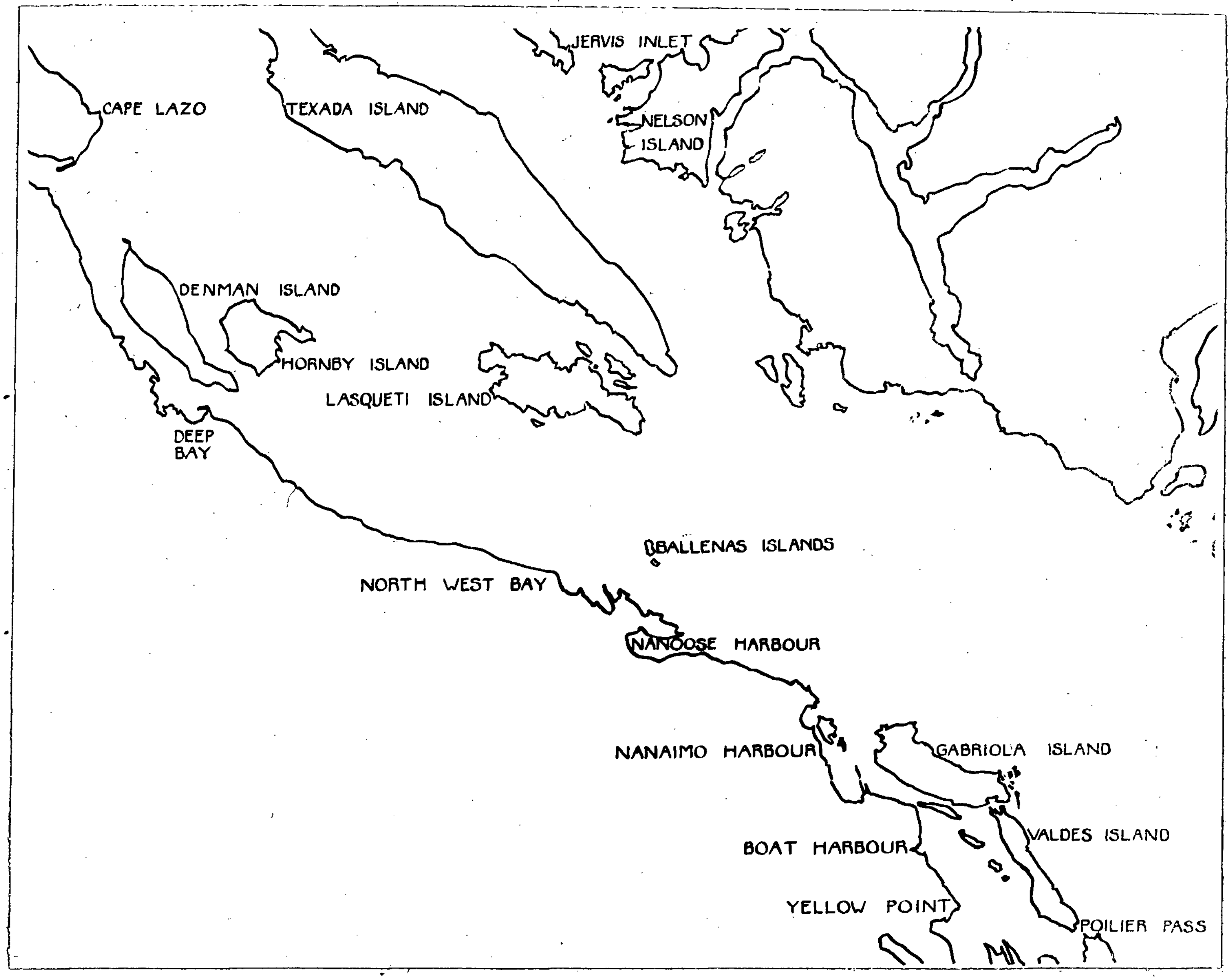
As the gulf of Georgia has been intensively prospected and fished by the trawler fleet for many years now, there is every reason to suppose that all the areas in which lemon sole concentrate in the wintertime to spawn would be utilized by the fishermen or at least known to them. Interviews with fishermen, and examination of cannery records and pilot house log books indicate that there are only three areas in the gulf of Georgia in which lemon sole are found in sufficient quantities to provide a profitable fishery. These are the Baynes sound, Boat harbour, and Point Atkinson-Fraser river areas. These regions yielded 54%, 20%, and 7% respectively of the total lemon sole landings from the gulf of Georgia for the first three months of 1946. For this reason, therefore, the Baynes sound and Boat harbour regions have been assumed to be two of the major spawning areas for lemon sole in the gulf. Although some spawning is known to take place off Point Atkinson, this area is not considered to be a major spawning area as the number of lemon sole taken there is small; as far as is known, no spawning takes place off the Fraser river mouth.

Location of the Spawning Grounds

The Baynes sound and Boat harbour regions have, for convenience, been called after the most widely known areas in each region, although such areas may actually form only a small part of the whole region. The locations of these regions are shown on Map 1, and are described below:

The Baynes sound region comprises that area between Denman and Vancouver islands, from Yellow rock light and Deep bay on the south to Comox and cape Lazo on the north. The area outside the Comox bar, south of cape Lazo, is also included in this region. Baynes sound itself constitutes that stretch of water between Vancouver and Denman islands.

The Boat harbour region is bounded on the north by Dodd narrows and on the south roughly by a line from Yellow point on Vancouver island to Blackberry point on Valdes island. This region includes the top end of Stuart channel between Vancouver island and De Courcy island and that part of Pylades channel between De Courcy and Valdes islands from Ruxton passage south to Whaleboat channel. For convenience that part of Trincomali channel in the vicinity of Porlier pass has been included in this area. Boat harbour itself is on the Vancouver island shore two and one-half miles south of Dodd narrows.



Map.1. Gulf of Georgia: Porlier Pass to Cape Lazo
Scale: $\frac{1}{649,000}$

METHODS

In making this study of the lemon sole spawning grounds and of the spawning of the lemon sole, the methods employed involved three lines of investigation:

1. Studies of the size distribution and sexual condition of the fish;

2. Tagging studies, to obtain information on fishing intensities and movements of the fish;

3. Availability studies.

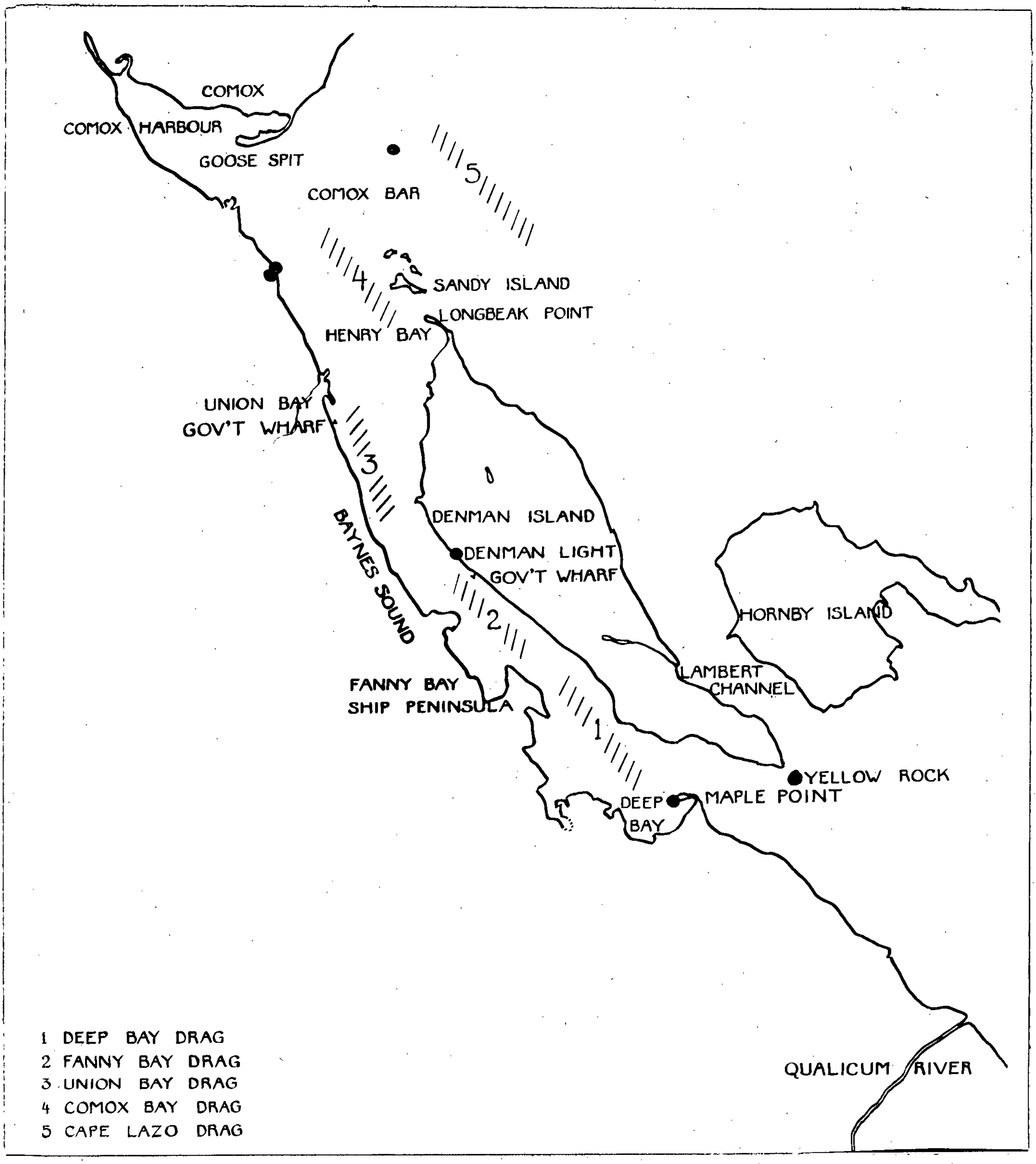
Coverage of the Regions

The investigation was forwarded during January, through the use of the chartered vessel, "Phyllis Carlyle". This vessel made five trips to both the Baynes sound and the Boat harbour regions. Her captain's knowledge of the fishing grounds in each area proved invaluable in obtaining samples from the localities most used by the fishermen.

In February two trips were made to the Baynes sound region and one to the Boat harbour region and in March one trip was made to the Baynes sound region.

In each of the major regions five "drags" were made over definable courses. In the Baynes sound region these drags have been called the "Deep bay", "Fanny bay", "Union bay", "Comox bay", and "cape Lazo" drags. The courses over which they were made are described below and are shown on Map 2.

1. Deep bay: from a point off the light at the entrance to Deep bay, down the centre of the sound to the southern tip of Ship peninsula.



Map.2. Baynes Sound Region.

Scale : $\frac{1}{263,000}$

2. Fanny bay: from a point off the northern tip of Ship peninsula, down the centre of the channel to a point off the ferry dock on Denman island.

3. Union bay: slightly westward of the centre of the sound from a point approximately opposite the government dock at Union bay, southward for a distance of about two miles.

4. Comox bay: slightly to the east of the centre of the sound from the most westerly tip of Sandy or Seal island, northward for a distance of about two miles.

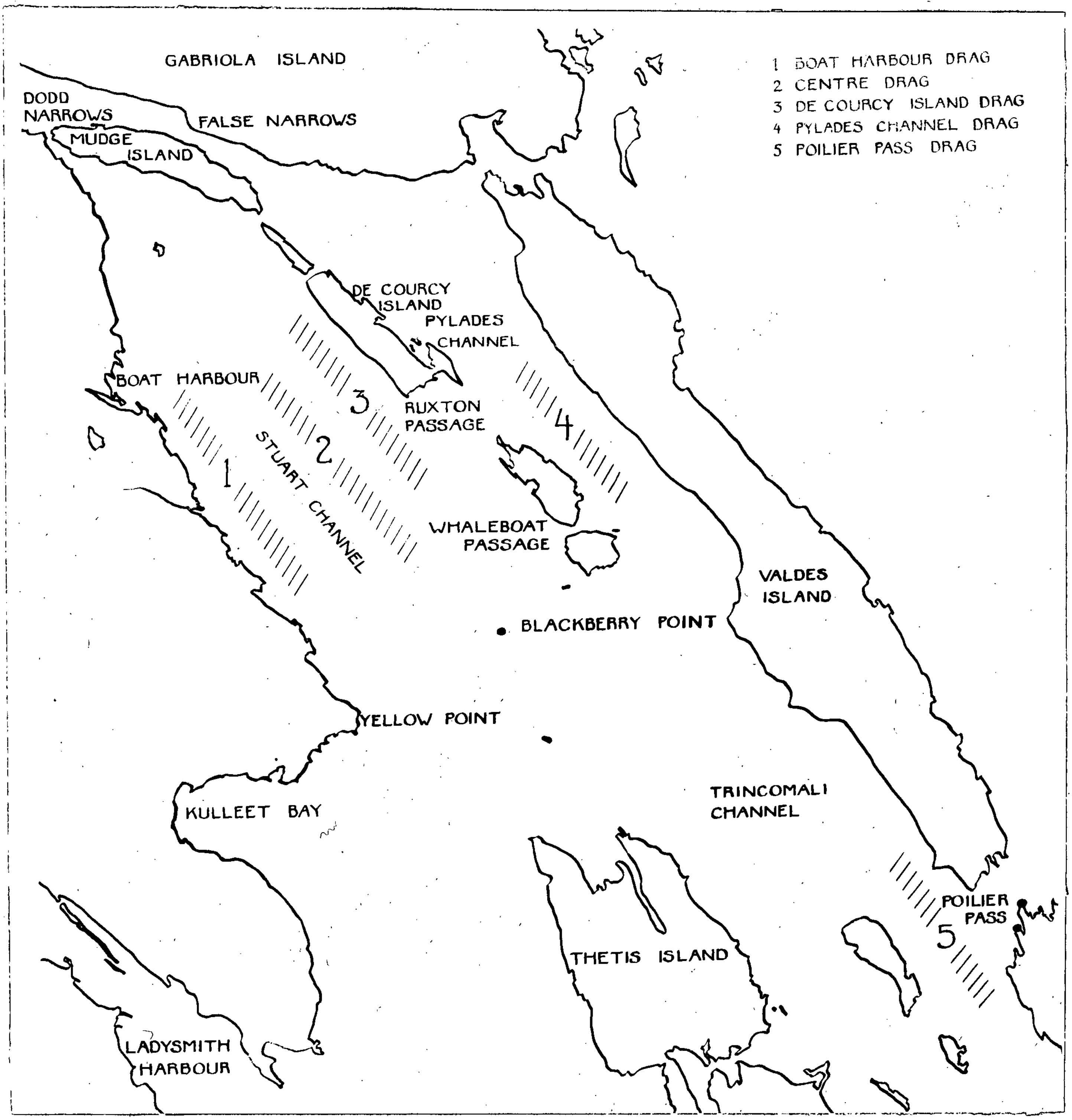
5. Cape Lazo: from a point about half a mile to the east of the light off Comox bar southward for a distance of about two miles.

The drags off Deep and Fanny bays were made in 35 fathoms of water, those off Union and Comox bays in 23 fathoms, and that off cape Lazo in 42 fathoms of water.

In the Boat harbour region the five drags have been called " Boat harbour", "centre drag", "De Courcy island", "Pylades channel", and "Porlier pass". The courses over which they were made are described below and are shown on Map 3.

The three drags of "Boat harbour", "centre drag", and "De Courcy island" are situated across the top of Stuart channel, and run parallel to each other.

1. Boat harbour: on the west side of Stuart channel, close to the Vancouver island shore, running from a point off Boat harbour in a south-easterly direction for a distance of about two miles.



Map.3. Boat Harbour Region

Scale: $\frac{1}{89,000}$

2. Centre drag: in the centre of this part of Stuart channel, running between the same two points as above.

3. De Courcy island: on the east side of Stuart channel, off the west shore of De Courcy island, running from a point opposite Boat harbour, in a south-easterly direction to a point opposite the northwestern tip of Ruxton island.

4. Pylades channel: down the eastern side of Trincomali channel from a point just north of Cardale point to a point opposite Porlier pass.

These five drags were made in approximately 35 fathoms of water.

In Tables I and II, the dates on which drags were made in the various areas are shown for the Baynes sound and Boat harbour regions respectively. On those trips made during February and March samples could only be obtained from those areas in which commercial trawlers were found fishing. The February 24th Union bay drag was made in a slightly different area than the other Union bay drags. This drag, in contrast to the others, extended to the edge of the Fanny bay area. All other drags made from commercial trawlers were in the same areas as those made from the chartered vessel. No haul was made off cape Lazo on the second trip, as the " Phyllis Carlyle" had to make an emergency run to Vancouver on the night of January 12.

TABLE I

BAYNES SOUND

	Deep bay	Fanny bay	Union bay	Comox bay	Cape Lazo
Trip 1	Jan. 4 Jan. 5	Jan. 4	Jan. 4	Jan. 5	Jan. 5
Trip 2	Jan. 12	Jan. 12	Jan. 12	Jan. 12	-------
Trip 3	Jan. 18	Jan. 18	Jan. 18	Jan. 18	Jan. 19
Trip 4	Jan. 24	Jan. 24	Jan. 25	Jan. 25	Jan. 25
Trip 5	Jan. 28	Jan. 28	Jan. 29	Jan. 29	Jan. 29
Trip 6	Feb. 13	-------	-------	-------	-------
Trip 7	Feb. 23	-------	Feb. 24	-------	-------
Trip 8	Mar. 16	-------	-------	Mar. 17	-------

TABLE II

BOAT HARBOUR

	Boat harbour	Centre drag	De Courcy island	Pylades channel	Porlier pass
Trip A	Dec.28,1945 Dec.29,1945	-------	Dec.28,1945 Dec.29,1945	Dec.29, 1945	Dec.30, 1945
Trip 1	Jan. 7	Jan. 8	Jan. 7	Jan. 8	Jan. 9
Trip 2	Jan. 15	Jan. 15	Jan. 15	Jan. 15	Jan. 14
Trip 3	Jan. 20	Jan. 20	Jan. 20	Jan. 21	Jan. 20
Trip 4	Jan. 26	Jan. 26	Jan. 26	Jan. 26	Jan. 27
Trip 5	Jan. 31	Jan. 31	Jan. 30	Jan. 30	-------
Trip 6	-------	-------	Feb. 16	-------	-------
Trip 7	-------	-------	-------	-------	-------

A trip was made to the Boat harbour region on February 27, but as no trawlers were fishing there at that time, no samples were obtained. One drag was also made off Qualicum beach, two inside Nanoose harbour, and one on the east side of Kuper island.

All drags were of approximately an hour's duration, with the exception of those made by commercial trawlers. Here the duration of the drag varied from one hour to two and one-half hours. For each drag the total weight of the "lift", the weight of saleable fish, and the weight of each species of fish were recorded.

Types of Information Sought

In this study work was concentrated on the following three types of investigation:

1. Studies of the spawning condition of the fish. This part of the work was undertaken to provide information about the duration of the spawning season and the intensity of spawning in each area. A random sample of approximately 40 fish was taken from each drag and for each sample the following data were recorded:

1. The fork length of each fish.

2. The stomach contents.

3. The sex - determined by actual examination of the gonads. The sexes can also be separated by an external examination only. In the female lemon sole the ovaries are contained in pockets formed by posterior extensions of the

body cavity. These pockets lie beneath the vertebral column, one on each side, and in fully mature fish can be traced as far back as the region of the caudal peduncle. As the ovaries mature they extend farther and farther backward into these pockets. This extension of the ovary is visible, from an external examination, even in immature females and is unmistakeable in mature fish. In male lemon sole no such pockets or extension of the testes are visible.

4. The spawning condition. The spawning conditions of the female fish were rated in six numbered categories with the following brief definitions:

i. Immature - the ovary is small and undeveloped, extending posteriorly only slightly.

ii. Maturing - the ovary is developing, its posterior extension was more marked.

iii. Ripening - the ovary is well developed, distending the body walls; the posterior extension was very marked; no clear eggs are present.

iv. Ripe - the ovary was well developed with clear, mature eggs present, scattered throughout the ovary or concentrated toward the anterior end.

v. Running - eggs were extruded upon gentle pressure on the ovary.

vi. Spent - the fish had completed spawning; the ovary contained no eggs and was often streaked with blood.

Males were recognized only in categories i. and v.

2. Tagging studies. The reasons for undertaking this type of investigation were threefold:

1. To provide a means of estimating the fishing intensities. 2. To provide information about the movements of the fish over the spawning grounds.

3. To obtain information about the migration and dispersal of the lemon sole after spawning.

From each haul a second random sample of 30 to 50 fish were taken and tagged. The tags were of the standard button type used by the Pacific Biological Station's otter trawl investigation. They consist of a white disc bearing the tag number and a yellow disc bearing the address of the Pacific Biological Station. The yellow disc is placed on the eyeless, white side of the fish and the white disc on the eyed, coloured side, the discs being held in place by a nickel pin passed through the fish below the dorsal fin at a point above and slightly behind the pectoral fins. A reward of fifty cents was offered by the Pacific Biological Station for the return of these tags together with information on the place and date of recapture, the length of the fish and the condition of the fish and of the wound.

For each fish tagged the following data were recorded:

1. The tag number.

2. The fork length.

3. The sex - determined from an external examination in the manner described in the preceding section.

4. An estimate of the spawning condition - such estimates were found to be accurate only in the case of those fish falling into category (v); it was not found possible to assign fish accurately to those categories dependent on the degree of ripeness of the eggs without an examination of the gonads.

5. The weight - in some cases the weight in ounces was recorded; a spring balance which, however, proved too difficult to read accurately in rough weather, was used.

3. Availability studies. Availability studies were undertaken to provide a background against which interpretations of the fishing intensities and the movements of fish about the spawning grounds could be made.

The catches of lemon sole for Baynes sound and Boat harbour were calculated for fortnightly periods during January, February, and March, 1946. The total catch of lemon sole for the gulf of Georgia was obtained from an examination of the records of the various wholesale fish dealers in Vancouver and Victoria. With the aid of information obtained from pilot house log books, and from interviews with and letters from those captains who did not keep log books, the total catch was proportioned into the catch per period for each region.

The availability of the lemon sole in both regions, expressed in pounds of fish per hour's dragging was calculated for each period. This information was provided by an analysis of the pilot house log books. These books were issued to all trawlers in 1945 and 1946 by the Pacific Biological Station. In these books the captains recorded the number of hours fished each day, the area fished, the amount of each species caught, and information about the total weight of the lift and the weight of commercial species contained in it.

The layout of the pages contained in these books is shown in Table XXVII of the appendix. Every second sheet is perforated and removable, so that, by making a carbon copy of each entry, the captain could retain a record of his fishing and at the same time provide the Pacific Biological Station with a duplicate copy. As no compulsion was applied to make captains keep these log books, satisfactory detailed records were obtained from only approximately 30% of the trawler fleet.

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ANALYSIS OF DATA

TOTAL CATCH AND AVAILABILITY STUDIES

The survey of the Baynes sound and Boat harbour lemon sole spawning grounds was conducted during January, February, and March, 1946. Each of these months was divided into fortnightly periods and the catch and availability (average catch per hour as calculated from pilot house log book records) were determined for each period. Variations in the total catch and availability per period will reflect major changes in the abundance of lemon sole on the spawning grounds. These variations in abundance will also affect the pattern of tag recoveries and must be considered when these recoveries are used in a quantitative manner, such as in estimating the fishing intensities or in interpreting mass movements of fish to and from the spawning grounds.

This section deals primarily with the calculation and reliability of the figures obtained for the total catch and for availability of lemon sole for each period. The effects of these factors on the fishing intensities and on any consideration of mass movements of fish to and from the spawning grounds are discussed in the appropriate sections.

Total Catch

The total landings of lemon sole for January, February, and March, 1946, were obtained from the records of wholesale fish dealers in Vancouver and Victoria. The coverage of these dealers was virtually complete; in each city the records of only two small wholesalers who would handle only a comparatively small quantity of lemon sole were not examined. The figures obtained will represent approximately the total amount of sole landed during this period, and are probably the best estimate of the catch that could be made.

In every case the records examined showed the number of pounds of lemon sole landed, the date, and the name of the boat making the landing. A boat's catch would often be divided among several wholesalers. Therefore the data procured from the wholesalers were rearranged and tabulated to show the total catch for each boat for each trip. From information obtained from pilot house log books, from interviews with and letters from the skippers, and sometimes from the composition of the catch alone, the areas in which each boat had fished were determined.

The three months, January, February, and March, were divided into six periods of two weeks each, and the total catch made in each region for each period was found. A fortnight was found to be the most suitable period to use as it fitted most nearly the average time between landings for all boats, thereby largely eliminating the necessity of splitting a landing between two adjacent periods, yet still being short enough to show trends in catch and availability.

The catch in each region for each period is shown in Table III below:

TABLE III

	PERIODS					
	I	II	III	IV	V	VI
BAYNE SOUND	30,731	39,766	33,384	48,117	35,698	26,669
BOAT HARBOUR	12,448	21,775	38,494	15,568	715	1,302

Availability

As was stated earlier, in order to understand the pattern of tag recoveries, an analysis of total catch records and abundance (availability) of lemon sole for each period was necessary. The methods used in obtaining total catch records for each period were described in the preceding section. This section deals with the calculations of availability.

The availability (abundance) of lemon sole for each period is expressed as the average weight of lemon sole taken per hour's fishing, after the data have been weighted to compensate for distortions introduced by boats fishing for parts of a season and by the varying fishing efficiencies of the boats.

The computations of availability are based on pilot house log book records. These records show the number of hours fished and the estimated weight of each species taken in each location visited during the day. Unfortunately, such records were kept conscientiously and continuously by only a small proportion of the trawlers fishing these regions. However, partial records kept by certain boats were found to be sufficiently accurate to warrant their inclusion. Records from the remainder of the fleet were rejected because of apparent inaccuracies or omissions, such as the failure to record the number of hours fished. The calculations for the Baynes sound region were therefore based on the records of two boats fishing for five periods, three boats fishing for two periods, and four boats fishing for one period; and the calculations for Boat harbour were based on the records of three boats fishing for five or six periods, three boats for four periods, two boats for two periods, and four boats for one period.

The availability for a period cannot be calculated directly as the average catch per hour's fishing due to distortion introduced both by boats fishing for only parts of a season during which the availability was not constant, and also by the varying apparent fishing efficiencies of the boats. These variations in the apparent fishing efficiencies of the boats can be attributed to two causes; first, to the use by certain boats of better, more efficient gear handled by experienced crews, thereby producing a real difference in fishing efficiency; and second, to the method of recording the hours fished each day, some boats recording only the actual time the net was in the water and others the total time spent on the grounds each day, thereby producing an apparent difference in fishing efficiency.

There is, however, no reason why the catch of boats fishing only at the start of the season, when the availability was high, should influence the results more than the catches of boats fishing only towards the end of the season when the availability was obviously low, or why the catches of the apparently more efficient boats should influence the conclusions more than the catches of the less efficient boats, regardless of the cause of this variation in efficiency.

These distortions were partly compensated for by the introduction of two correction factors in weighting the data. These correction factors have been called the period factor, which makes a compensation for boats fishing for only parts of a season, and the boat factor, which makes compensation for the different fishing efficiencies of the boats. The period factors are calculated and applied first so that the boat factors are calculated from data weighted to eliminate fluctuations in availability. The boat factors are then applied to original data so that the final averages will reflect variations in availability but not variations produced by different fishing efficiencies. These causes of distortion are very similar to those for which Hart (1933) wished to compensate in calculating the catch for unit of fishing effort in the pilchard fishery. He compensated for distortions produced by boats fishing for parts of a season by a method similar to the application of the period factor, but corrected for distortions produced by companies using equipment of different fishing efficiencies by careful selection of companies representative of the different fishing policies. As the records of only a small number of boats were available, no such selection of boats representative of different fishing efficiencies could be made; therefore the method of weighting by the boat factor was used in compensating for distortions of this type.

These correction factors are calculated and applied in the following manner. The total catch and the total number of hours fished by all boats in all periods were determined. From these the seasonal average catch per hour's fishing was determined. The average catch per hour for each period was found by dividing the sum of the catches of all boats in each period by the number of hours fished in that period. The period factor, for each period, was determined by dividing the seasonal average catch per hour by the average catch per hour for that period. The daily catches of all boats in a period were then multiplied by the factor for that period. By weighting the data in this manner compensation was made for boats fishing for only parts of a season.

Next, the weighted daily catches of all boats in all periods were summed and the sum divided by the total number of hours fished during the season. This gives a weighted seasonal average catch per hour's fishing which is approximately equal to the unweighted seasonal average catch per hour. The weighted daily catches of each boat in all periods were summed and the sum divided by the total number of hours fished by that boat during the season, to give a weighted seasonal average catch per hour for each boat. The boat factor is then found for each boat by dividing the weighted seasonal average catch per hour by the weighted seasonal average catch per hour for that boat. In the case of those boats which fished for only a few days during the season, a collective correction factor was used. This was obtained by pooling the daily entries of these boats and treating them as a unit. The average value so obtained would probably allow a better correction to be made for the varying efficiencies of these boats than would individual factors based on the small catches and the few fishing hours of each boat. The unweighted daily catches of each boat were then multiplied by the factor for that boat. The daily catches thus weighted, in each period, were summed and divided by the total number of hours fished in that period. This gave an average catch per hour's fishing for each period weighted so that variations due to the different fishing efficiencies of the boats are largely compensated for but variations due to periodic fluctuations in the abundance of lemon sole remain. These figures are taken as representing the availability (abundance) of lemon sole in each period. They are shown in Table IV for the Baynes sound and Boat harbour regions.

TABLE IV

	PERIODS					
	I	II	III	IV	V	IV
BAYNES SOUND	144.2	142.9	164.3	148.7	127.0	76.9
BOAT HARBOUR	150.5	140.4	137.3	114.6	61.3	13.4

It will be noticed in the above table that:

1. In Baynes sound there was an apparent increase in availability during period III. The calculations for this period were based on the records of only one boat whose catches per hour appeared consistently high throughout the entire season. To determine whether this increase in availability

represents a significant increase or whether it was due to only partial correction of the consistently high catches per hour recorded by this boat, the mean daily catches per hour of this boat for period III were compared to its mean daily catches per hour in adjacent periods. The method used was to estimate the standard error of the differences between daily catches of, first, period III and period II, then, period III and period IV, on the hypothesis that the means of the corresponding populations were equal. In both cases the application of "t" tests showed that, were the means of the populations equal, the differences observed could have arisen by chance alone approximately 60 times out of 100. Therefore the conclusion is that the increase in availability in period III was not due to an increase in the abundance of lemon sole during this period, but rather to the relatively high adjusted catches which would obtain in such a case as this.

2. In Baynes sound there is little variation in the availability until the end of period IV, after which it drops rapidly.

3. In Boat harbour the availability drops slightly during the first three periods and then drops sharply during the last three.

4. The marked decline in availability started in Boat harbour about two weeks before it did in Baynes sound.

5. The largest catches in both areas were made in that

period immediately preceding the start of the marked decline in availability.

The fact that the marked decline in availability in Boat harbour started two weeks before it did in Baynes sound might indicate that the spawning in Boat harbour was about two weeks ahead of that in Baynes sound. This fact is also borne out by actual observations of the spawning conditions of the fish in these regions.

This marked decline in availability is attributed to fish leaving the spawning grounds rather than to the large catches made in the periods immediately preceding these declines. That such is the case is shown by the analysis of tag returns and is discussed in more detail in that section.

SPAWNING AREAS

Evidence has been presented in other sections of this report to show that the Baynes sound and Boat harbour regions form two of the major, and probably the two major, lemon sole spawning grounds in the gulf of Georgia. The evidence for this was derived from:

1. Information obtained from commercial fishermen.
2. The total catches of lemon sole for the gulf of Georgia made during the spawning season.

In this section evidence will be presented to show that spawning does not take place generally throughout all areas in these regions, but is more intense in certain areas than in others.

The data presented comes from two sources:

1. Observation of the stage of maturity of the female lemon sole. Here sampled fish only were used as the estimations of sexual maturity for tagged fish were not found to be sufficiently accurate for inclusion.

2. An analysis of the returns of tagged fish recaptured on the spawning grounds.

Each of the two major spawning grounds is considered separately.

1. <u>The Baynes sound region</u>

1. <u>Observations on the State of Sexual Maturity</u>

As was stated in the section on Methods, approximately forty fish, selected at random, were examined from each area on every trip. The spawning conditions were observed and noted in the following six categories: i. Immature, ii. Maturing, iii. Ripening, iv. Ripe, v. Running, and vi. Spent. Males were recognized only in categories i, ii, and v. Full definitions of these categories were given in the section on Methods.

In Table V are shown the number of lemon sole at each of the above stages of sexual maturity, found in the samples taken in the Baynes sound region. Where no entry appears for a trip, insufficient fish were available for precise examination of the spawning conditions.

TABLE V

BAYNES SOUND

Area	Date	Pounds of Fish per Hour's Dragging	Spawning Condition - Female I	II	III	IV	V	VI	Total Female	Spawning Condition - Male I	II	V	Total Male
Deep bay	4/1	200	9	5	20	0	1	1	36	1	0	2	3
	12/1	100	10	5	14	0	0	0	29	1	3	7	11
	18/1	150	11	6	15	1	2	2	37	0	2	2	4
	24/1	200	11	1	16	2	1	2	33	1	1	5	7
	28/1	100	6	1	20	2	0	5	34	0	0	6	6
	13/2	50	37	1	5	2	1	4	50	0	0	0	0
	23/2	---	15	0	8	0	1	18	42	1	0	7	8
	15-16/3	30	18	0	3	2	1	44	68	4	0	21	25
Fanny bay	4/1	150	9	1	13	4	2	1	30	1	0	13	14
	12/1	100	5	2	12	2	1	1	23	0	0	17	17
	18/1	200	4	5	23	4	2	0	38	0	0	2	2
	24/1	125	12	2	7	5	4	0	30	0	3	7	10
	28/1	100	4	0	14	6	6	1	31	0	1	8	9
	13/2	---	18	2	14	4	5	8	51	0	0	3	3
Union bay	12/1	20	2	1	5	0	2	0	10	1	0	1	2
	18/1	---	7	0	2	4	2	0	15	0	1	3	4
	24/2	---	4	0	2	9	12	3	30	1	0	19	20
Comox bay	5/1	100	8	1	3	1	0	1	14	6	0	0	6
	12/1	60	13	6	17	0	0	3	39	0	0	1	1
	17/3	85	14	1	0	0	0	39	54	2	0	2	4
Cape Lazo	5/1	100	1	4	2	0	1	0	8	0	3	31	34
	19/1	300	0	0	6	5	7	0	18	0	2	20	22
	25/1	125	0	0	5	7	3	1	16	0	4	19	23
	29/1	150	1	0	3	5	10	1	20	0	0	20	20

The points which are shown by this tabulation of the data are: 1. The yield of fish per hour of dragging was greatest at cape Lazo, a little less in Deep and Fanny bays, and least in Comox and Union bays. If lemon sole concentrate in certain areas to spawn the yield of fish per hour's dragging will be greater in those areas than in areas in which spawning is less intense.

2. Ripe and running females were taken in all areas.

3. Giving consideration to the fact that the Union bay February 24th sample, in contrast to the others, was taken on the edge of the Fanny bay area, ripe and running females can be said to be least abundant in Comox and Union bays and most abundant at cape Lazo and Fanny bay. Deep bay was intermediate.

4. The proportions of spent females are highest at Comox bay and at Deep bay. At the latter place the excess is great enough to be significant.

5. Chi-squared tests were applied to the data shown in this Table to determine whether observed variations in the proportions of fish at each stage of sexual maturity in the various areas were significant, or whether such variations could have arisen by chance. If such variations are significant, they would indicate that spawning is more intense in certain areas than in others. The null hypothesis set up was that the proportions of fish at each stage of sexual maturity in each area were independent of the area. Assuming

that there is no association between the area and the number of fish at each stage of sexual maturity, the numbers of fish that would be expected to occur in each cell of the table can be calculated from the marginal totals by simple proportions. Of the correctness of this procedure, Simpson and Roe (1939) state, "The numbers of observations in the two samples have nothing to do with association, nor have the total numbers of observations falling into any one category. The marginal totals, in other words, have no direct bearing on association, and in any specific problem they are to be taken as given and immutable." The chi-squared test is used, then, to determine what the probability is that deviations from the calculated expected distribution equal to those observed could have risen by chance in samples or populations in which the true proportions were those indicated by the theoretical frequencies (Simpson and Roe, 1939).

The formula for chi-squared was: chi-squared $= \frac{S(x-m)^2}{m}$, where x is the observed value and m is the expected value. The number of degrees of freedom can be found by the formula $n = (r - 1)(c - 1)$, where r is the number of rows, and c is the number of columns in the contingency table. For the number of degrees of freedom of the experiment a high value of chi-squared would refute the null hypothesis.

In the Baynes sound area tests were made on samples taken on comparable dates in Deep bay and Fanny bay, Deep bay and cape Lazo, and Fanny bay and cape Lazo. In Table VI are shown the values of chi-squared and of P obtained for these tests. In the last column of this table are shown the spawning condition classes which contributed most to the value of chi-squared.

TABLE VI

BAYNES SOUND

Areas	Value of chi-squared	D.F.	Value of P	Spawning condition category contributing most to chi-squared value
Deep bay-Fanny bay	22.4912	5	L .01	IV, V, VI
Deep bay-cape Lazo	75.6834	5	L .01	I, IV, V
Fanny bay-cape Lazo	29.4626	5	L .01	I, V

(In column 4, "L" indicates "less than")

As in some cases the observed frequencies in some cells were small (below 5), continuity corrections were applied to obtain a better estimate of P from the chi-squared distribution. This adjustment may tend somewhat to underestimate the significance, however in no case where a significant difference was indicated by the unadjusted data, did the application of this adjustment reduce the level of probability below .01. Simpson and Roe give the following reason for making this adjustment, "...the distribution of chi-squared is continuous, while that of the frequencies in a contingency table is necessarily discontinuous. The chi-squared distribution is approached as a limit by these discontinuous data, and if the frequencies are not unduly low the approach is sufficiently close to give a valid estimate of P from chi-squared, but this is not reliable if the values of the table are determined largely by the very low frequencies in it."

The adjustment is made by subtracting 0.5 from each observed frequency that is higher than the theoretical frequency, and by adding 0.5 to each observed frequency that is lower than the theoretical frequency. The calculations of the unadjusted and adjusted chi-squares are given in Table of the appendix. In all cases the value of chi-squared obtained was large enough, at the number of degrees of freedom of the test, to indicate that the chances of the observed frequencies being drawn from the same populations as the calculated frequency was less than one in one hundred. Further, the greater numbers of ripe and running females at cape Lazo and Fanny bay and of immature females at Deep bay contributed very largely to the values of chi-squared obtained. Therefore the proportions of fish to each stage of sexual maturity in an area is dependent upon the area.

The conclusion is that, though some spawning takes place throughout the whole region, it tends to be concentrated in the areas off cape Lazo and Fanny bay. This is shown both by the greater number of ripe and running females, and by the greater yields of fish per hour's dragging taken in these areas. The high proportion of spent females in the areas at either end of Baynes sound, namely, Deep and Comox bays, indicates that fish captured there are moving off the spawning grounds.

2. Evidence from Tag Recoveries

In Table VII are shown the recoveries whose exact points of recapture are considered reliable. The areas of tagging are listed vertically and the areas of recovery horizontally.

TABLE VII

AREA OF TAGGING	AREA OF RECOVERY				
	Deep bay	Fanny bay	Union bay	Comox bay	Cape Lazo
Deep bay	22	23	7	0	1
Fanny bay	8	12	3	0	2
Union bay	1	4	1	0	2
Comox bay	5	8	5	2	2
Cape Lazo	1	0	3	1	15

It will be observed in this table that:

1. Most tags were recovered in Fanny bay and that the number recovered there is greater in each case than the number recovered from the area of tagging. This shows that there is a movement of lemon sole from both ends of Baynes sound towards Fanny bay, the area of most active spawning within Baynes sound proper.

2. There is a slight movement of fish in both directions between cape Lazo and the areas within Baynes sound proper.

As it seems fair to say that most of these fish would be moving toward spawning areas, these recoveries of tags put out during January support the belief that Fanny bay is the main spawning area in Baynes sound.

From the data derived from the state of sexual maturity of lemon sole in various areas of Baynes sound and from the recoveries of tags put out during January, the conclusion is that the 1946 spawning was most plentiful off Fanny bay and cape Lazo. However, conclusions drawn from one year only cannot be applied too generally. For instance, one trawler captain of long experience expresses the opinion that the greatest concentration of spawning fish in some years at least was in the southern part of Union bay adjacent to Fanny bay.

2. The Boat Harbour Region

1. Observations on the State of Sexual Maturity

The numbers of fish found at each stage of sexual maturity have been tabulated according to trip and area and are shown in Table VIII. The pounds of fish per hour's drag are also shown in this table.

TABLE VIII
BOAT HARBOUR

Area	Date	Pounds of Fish per Hour's Dragging	Spawning Condition - Female I	II	III	IV	V	VI	Total Female	Spawning Condition - Male I	II	V	Total Male
Boat harbour	28/12/45	300	0	0	0	2	0	0	2	0	1	22	23
	29/12	400	0	1	0	1	0	0	2	0	0	11	11
	7/1/46	113	0	0	7	5	2	0	14	0	6	26	26
	15/1	---	0	0	4	12	6	0	22	0	1	17	18
	20/1	150	0	0	1	12	7	0	20	0	0	20	20
	26/1	150	0	0	5	6	3	1	15	0	1	24	25
	31/1	150	0	0	8	8	10	1	27	0	0	13	13
Centre drag	8/1/46	266	0	0	9	5	1	0	15	0	0	25	25
	15/1	150	0	0	12	12	5	1	30	0	1	11	12
	20/1	150	2	0	9	7	8	1	27	0	1	12	13
	26/1	150	0	0	14	13	8	0	35	0	0	5	5
	31/1	60	0	0	17	5	14	5	41	0	0	15	15
De Courcy island	28/12/45	360	0	0	4	4	0	0	8	0	2	10	12
	29/12	---	0	0	8	1	0	1	10	0	1	7	8
	7/1/46	133	0	0	6	12	2	2	22	0	0	17	17
	15/1	200	0	0	7	11	6	0	24	0	0	16	16
	20/1	200	0	0	7	13	8	2	30	0	0	9	9
	26/1	200	0	0	6	15	13	0	34	0	0	6	6
	30/1	200	0	0	5	5	15	2	28	0	0	12	12
	16/2	---	1	0	9	7	19	4	40	0	0	10	10
Pylades channel	29/12/45	150	0	0	0	0	0	0	0	2	1	3	6
	8/1/46	47	5	0	20	3	0	3	31	0	3	1	4
	15/1	40	1	0	17	3	0	2	23	1	5	10	16
	21/1	80	6	3	7	0	0	2	18	3	1	6	10
	26/1	50	6	0	4	0	0	0	10	0	0	0	0
	30/1	75	5	0	8	2	3	10	28	0	0	4	4
Porlier pass	30/12/45	200	7	0	13	0	0	0	20	0	0	0	0
	9/1/46	100	26	0	10	0	0	3	39	0	0	0	0
	14/1	50	22	2	6	0	0	0	30	1	0	0	1
	20/1	20	7	4	0	0	0	1	12	1	0	0	1
	27/1	5	19	1	0	0	0	5	25	0	1	0	1

It will be noticed from this table that:

1. The yield of fish per hour's dragging was greatest in the De Courcy island, centre drag,, and Boat harbour areas and least in the Porlier pass and Pylades channel areas. Here again, if the fish are concentrating in certain areas to spawn the yield per hour's dragging will be greatest in those areas in which spawning is most intense.

2. Ripe and running females were taken all over the area except at Porlier pass. They were next least abundant at Pylades channel.

3. Immature and maturing females were most abundant at Porlier pass and next most abundant in Pylades channel.

4. The proportion of spent females is greatest in Pylades channel. This may be the result of an accumulation of fish on grounds which are less intensively fished.

5. Chi-squared tests were applied to the data shown in the table to determine whether the proportions of fish at each stage of sexual maturity was dependent upon the area. These tests were applied in the same manner as they were to the Baynes sound data. In comparing any two areas, only samples taken on comparable dates were used.

The calculations of chi-squared are given in Table of the appendix.

In Table IX on the following page are shown the values of chi-squared and of _P_ obtained for comparisons of areas in the Boat harbour region.

TABLE IX

BOAT HARBOUR

Areas	Value of chi-squared	D.F.	Value of P	Spawning condition category contributing most to chi-squared value
Boat harbour-De Courcy island	1.5370	5	.95 - .90	-----
Boat harbour-centre drag	11.1730	5	.05	III, IV
De Courcy island-centre drag	13.9332	5	.01	III, IV
Boat harbour-Pylades channel	94.4268	5	L .01	IV, V, I
Centre drag-Pylades channel	72.9966	5	1 .01	IV, V
Boat harbour-Porlier pass	147.5715	5	L .01	IV, V, I
Pylades channel-Porlier pass	44.4657	5	L .01	I, III, IV

(In column 4, "L" indicates "less than")

These chi-squared tests indicate that:

1. The distribution of sexual conditions were about the same at Boat harbour and De Courcy island.

2. The above two areas differed significantly from centre drag in their smaller proportion of ripening females and the larger proportion of ripe females.

3. Running females appeared to be fairly evenly distributed in these three areas.

4. The distributions of sexual conditions in Pylades channel differed significantly from the distributions in other areas. The smaller number of ripe and running females found in this area, as compared to Boat harbour or centre drag, caused most of these differences. The smaller number of immature females and the relatively greater number of ripening and ripe females found here caused most of the difference in Pylades channel-Porlier pass test.

5. Porlier pass differed significantly from all other areas. The large number of immature females and the small number of maturing and mature fish produced the major portions of the differences observed.

The conclusion is that, though some spawning takes place throughout the whole of this region with the exception of Porlier pass, it tends to be most concentrated in the areas of De Courcy island, Boat harbour, and centre drag. This is shown by the greater numbers of ripe and running females found in these areas. The lack of ripe and running females in Porlier pass indicates that no spawning takes place there.

2. <u>Evidence from Tag Recoveries</u>

In Table X are shown the recoveries of tags from the Boat harbour region.

TABLE X

AREA OF TAGGING	AREA OF RECOVERY				
	Boat harbour	Centre drag	De Courcy island	Pylades channel	Porlier pass
Boat harbour	22	0	6	0	0
Centre drag	31	1	3	0	0
De Courcy island	34	1	7	0	6
Pylades channel	20	0	4	0	1
Porlier pass	14	0	0	0	7

Only those tags returned by fishermen who were conscientious in giving complete and reliable tag recovery data have been included in this table. These fishermen, however, do not discriminate between the three areas lying across the top of Stuart channel, which have for convenience been called Boat harbour, centre drag, and De Courcy island, but refer to them all as Boat harbour. This explains why most tags were recovered apparently in the Boat harbour area. For those tags listed as being recovered in centre drag or De Courcy island, the actual points of recovery have been definitely established.

From this table it will be observed that:

1. The large proportion of recoveries of fish tagged

in Pylades channel were recovered in the three areas lying across the top of Stuart channel. This would indicate a definite movement of fish from Pylades channel into the top of Stuart channel. There is no evidence to show whether or not a reverse movement took place, for there was little, if any, fishing done in this area.

2. There is some evidence from tag recoveries to show that the fish in the three areas across the top of Stuart channel mix quite freely.

3. The number of recoveries of Porlier pass tags in the three Stuart channel areas and of tags from these areas in Porlier pass indicate a definite movement of lemon sole between these areas.

As in this case it again seems fair to say that most of the fish would be moving towards or away from (in the case of tags recovered in Porlier pass) the spawning grounds, the evidence from these tag returns supports the conclusions reached on the basis of the evidence derived from the examination of the state of sexual maturity of fish in the various areas.

Therefore, the conclusion is that, in the Boat harbour region, the most intense spawning occurs in the three areas lying across the top of Stuart channel. Some spawning takes place in Pylades channel, but it is less intense than that in the above three regions. No spawning takes place in the Porlier pass area.

DURATION OF SPAWNING PERIOD

In determining the duration of the spawning season, and in following the intensity of the spawning, during January frequent samples were taken from all areas in both regions. However, during February and March unfortunately only a few samples were taken at irregular intervals and from certain areas only. The examination of the ovaries of the fish taken in these samples gave some indication of the duration of the spawning season and of the period of peak spawning. Although not all the mature females on the grounds were found to be actively spawning fish, the proportions of ripe and running fish increased as the season progressed. The number of ripe and running females, and of running females only, expressed as a percentage of the total number of females in a sample, were the criteria used in estimating the period of peak spawning. These data are shown in Table XI for the Baynes sound region, and in Table XII for the Boat harbour region. In the first three columns of these tables the percentage of ripe and running females and the percentage of running females only, are shown for the three areas in which spawning was most intense, in the fourth column the percentage of ripe and running females and of running females only, taken on each trip are shown.

TABLE XI

BAYNES SOUND

Trip No.	Date (1946)	Deep bay		Fanny bay		Cape Lazo		Total for Trip	
		Sexual IV & V	Condition V T & S	Sexual IV & V	Condition V T & S	Sexual IV & V	Condition V T & S	Sexual IV & V	Condition V T & S
1	4/1	2.8%	1.3%	20.0%	4.0%	12.5%	16.6%	10.2%	3.9%
2	12/1	----	----	13.0%	3.8%	-----	-----	5.0%	2.1%
3	18/1	8.1%	5.4%	15.9%	5.5%	66.6%	26.6%	25.0%	10.6%
4	24/1	9.1%	8.8%	30.0%	13.0%	62.5%	21.9%	27.0%	12.1%
5	28/1	5.9%	1.4%	38.7%	15.6%	75.0%	40.0%	34.0%	16.4%
6	13/2	6.0%	----	17.6%	8.1%	-----	-----	12.0%	8.1%
7	23/2	2.4%	3.4%	-----	----	-----	-----	30.6%	16.5%
8	15/3	4.4%	1.5%	-----	----	-----	-----	2.5%	0.8%

Columns marked V T & S refer to the running females found among the fish tagged and the fish sampled considered together for each trip.

Columns marked IV & V refer to ripe and running females among sampled fish only.

TABLE XII

BOAT HARBOUR

Trip No.	Date	Boat Harbour Sexual Condition IV & V	Boat Harbour Sexual Condition V T & S	Centre drag Sexual Condition IV & V	Centre drag Sexual Condition V T & S	De Courcy Island Sexual Condition IV & V	De Courcy Island Sexual Condition V T & S	Total for Trip Sexual Condition IV & V	Total for Trip Sexual Condition V T & S
A	1945 28/12	-----	22.2%	-----	-----	-----	-----	36.0%	6.0%
1	1946 7/1	50.0%	22.7%	40.0%	20.0%	63.6%	34.4%	36.6%	26.8%
2	15/1	81.8%	66.6%	56.7%	31.8%	70.8%	10.0%	55.5%	25.0%
3	20/1	95.0%	69.2%	55.6%	33.3%	70.0%	33.3%	57.8%	31.5%
4	26/1	60.0%	23.0%	60.0%	32.0%	79.0%	56.5%	54.3%	31.3%
5	31/1	66.6%	22.2%	46.0%	36.0%	75.0%	61.1%	56.8%	31.8%
6	16/2	-----	-----	-----	-----	65.0%	70.5%	65.0%	70.5%

Columns marked V T & S refer to the running females found among the fish tagged and the fish sampled considered together for each trip.

Columns marked IV & V refer to ripe and running females among sampled fish only.

Further indications concerning the duration of the spawning season in each region can be obtained from the figures for availability (average catch per hour) for each period.

<u>Baynes sound region</u>

From Table XI it will be noticed that:

1. Some ripe and running females were found at the start of the period of investigation.

2. The percentage of ripe and running females increased steadily up to the end of January.

3. The percentage of ripe and running females in the samples taken on February 13 and 23 are of the same order as those for samples taken at the end of January.

4. The percentages of ripe and running females in the samples taken on March 15 and 16 are small.

5. The percentage of spent females in the samples increased steadily during the whole period under consideration.

From the above data the conclusion is that the period of peak spawning in Baynes sound in 1946 was roughly from about January 24 to February 23, though some spawning took place in the first part of January and in March. Spawning probably reached a peak slightly earlier in the cape Lazo area. In this area considerably fewer immature and maturing females were found and hence the percentages shown in Table XI are higher than for other areas in Baynes sound.

The decline in availability (see Table IV, page 16) from period V (March 1 - 15) to period VI (March 16 - 31) indicates that the fish are leaving the spawning grounds at this time and lends further weight to the conclusion that most of the spawning is completed by March.

Boat harbour region

From Table XII it will be noticed that:

1. The percentages of ripe and running females and of ripe females only in the samples from this region were considerably greater than in the Baynes sound region. This is because, in the Boat harbour region, few immature or maturing female lemon sole were found as compared to the numbers found in Baynes sound.

2. Some ripe and running females were found at the start of the investigation.

3. The percentage of ripe and running females increased steadily throughout January, possibly reaching a peak about the end of January.

4. Not enough samples were taken after the end of January to follow the course of the spawning beyond this date.

On the basis of these data the conclusion is that peak period of spawning in Boat harbour starts about January 15 and continues until the end of January, and probably into the first part of February.

There is a marked decline in availability (Table IV, page 16) in the Boat harbour region from period IV (February 16 - 28) onwards. This would indicate that the fish start to leave the grounds about the middle of February. This supports the belief that most spawning is completed in this region at least by the end of February and probably by the middle of that month. Spawning is completed a little earlier in the Boat harbour region than in the Baynes sound region.

FISHING INTENSITY

In Tables XIII and XIV are shown the returns for each period of fish tagged on each trip made to the Baynes sound and Boat harbour regions respectively. At the foot of each table is shown the unadjusted fishing intensity for that region, as indicated by these returns.

TABLE XIII

BAYNES SOUND

Trip No.	Date (1946)	Tags Used	TAGS RECOVERED						
			Periods						Tags Recovered After Mar.31
			I Jan. 1-15	II Jan. 16-31	III Feb. 1-15	IV Feb. 16-28	V Mar. 1-15	VI Mar. 16-31	
1	Jan. 7	160	11	17	14	13	2	1	3
2	Jan.12	110	4	13	9	14	3	1	5
3	Jan.18	137	-	14	11	9	7	1	2
4	Jan.24	144	-	7	18	21	9	1	4
5	Jan.28	130	-	5	8	19	5	2	6
6	Feb.13	39	-	-	0	9	4	0	2
7	Feb.23	94	-	-	-	5	9	0	5
Total		814	15	56	60	90	39	6	27

Total no. of tags out = 814. Total no. of recoveries = 266

Fishing intensity $\frac{266}{814}$ = 32.7%

TABLE XIV

BOAT HARBOUR

Trip No.	Date	Tags Used	TAGS RECOVERED						
			Periods						Tags Recovered After Mar. 31
			I Jan. 1-15	II Jan. 16-31	III Feb. 1-15	IV Feb. 16-28	V Mar. 1-15	VI Mar. 16-31	
A	1945 Dec.28 - 31	425	5	26	12	7	4	4	17
1	1946 Jan. 7	203	0	20	13	2	3	1	13
2	Jan.15	160	0	17	11	3	0	0	12
3	Jan.20	150	-	12	13	6	0	1	14
4	Jan.26	120	-	8	9	2	2	1	10
5	Jan.30	120	-	0	24	6	4	1	9
6	Feb.16	49	-	-	-	2	2	3	2
Total		1,227	5	83	82	28	15	11	77

No data on 7 recoveries: 5 from trip A, 1 from trip 1,
1 from trip 3

Effective number of tags out = 1,220.

Total no. of recoveries = 301

Total no. of recoveries to end of March = 224.

Fishing intensity:

Trip A included: $\frac{224}{1,220} = 18.3\%$

Trip A excluded: $\frac{166}{800} = 20.8\%$

The sum of tag returns, from every tagging operation, expressed as a percentage of the number of fish tagged, has been termed the fishing intensity. This will represent only approximately the true fishing mortality, that is, the rate at which fish are being removed from the grounds by the fishery, because of the effects of:

1. Natural mortality.
2. Tagging mortality.
3. Loss of tags from live fish on the grounds.
4. Loss of tags after recapture and before return.
5. Emigration of tagged fish.
6. Immigration of untagged fish.

These six factors all tend to reduce the numerator of this expression, leaving the denominator unchanged; the first three and the last two by reducing the number of live tagged fish on the grounds available to the fishermen, and the fourth by reducing the actual number of tag returns received. For these reasons the fishing intensity, as indicated, will be less than the fishing mortality rate.

As no data are available on which to evaluate the extent of the effects of any of these factors in the estimated fishing intensity, only the following general assumptions of their possible effects can be made:

1. For the comparatively short period under consideration the effects of natural mortality and the loss of tags from fish on the grounds will probably be small and could safely be ignored.

2. Tagging mortality may possibly have reduced the true fishing intensity considerably. The mortality included under this heading could arise from two sources:

1. Injuries received when the fish are caught, produced by the pressure of the fish in the net or by abrasions from the web.

2. Injuries and infections produced by the tagging operation.

If tags are either too tight or too loose they are liable to chafe and cause open sores which could conceivably cause the death of the fish. In tagging every effort was made to minimize as far as possible the effects of injuries from these sources; only apparently uninjured fish were tagged, and the tags themselves were carefully put on.

3. The loss of tags after recapture and before return remains a source of error that cannot be ignored and whose possible effect can only be approximately assessed. Some tags might have been lost through the indifference or carelessness of fishermen or cannery employees, but this number in all probability is small as every effort was made to impress on those handling lemon sole, the desirability of returning tags promptly together with the pertinent recovery data.

The method of expressing the returns as a percentage of the total number of fish tagged introduces another source of error which would also make the indicated intensity somewhat lower than the true fishing intensity. The calculation of the fishing intensity is based on the assumption that all the tags were out at the start of the season and hence all were affected equally by the fishery. In reality, the tags were put out during the course of the fishing season so that those fish tagged towards the close of the season did not have as much chance of being caught as those tagged at the start. This error can be corrected by weighting the data so that all tags appear to have an equal chance of recovery. The method used was suggested by Dr. J. L. Hart and is described below.

Table XV shows how the calculations were made for the Baynes sound region.

TABLE XV

BAYNES SOUND

Period	Column 1 Tags used	Column 2 Tags recovered	Column 3 Fish still to be caught	Column 4 Column 1 x Column 3
I	270	102	242,681	65,523,870
II	411	137	199,696	82,075,056
III	39	13	155,093	6,048,627
IV	94	14	105,398	9,907,412
Totals	814	266	702,868	163,554,965

$$\frac{\text{Total Column 4}}{\text{Total Column 1}} = \frac{163,554,965}{814} = 200,927 \text{ (Recovery susceptibility factor)}$$

$$\frac{\text{Total Column 2 x Total Catch}}{\text{Recovery susceptibility factor}} = \frac{266 \text{ x } 261,420}{200,927} = 346$$

$$\text{Adjusted Fishing Intensity} = \frac{346}{814} = 42.5\%$$

Fish were tagged in the first four periods only. The total number tagged in each period is shown in Column 1. In Column 2 are shown the number of recoveries made during the whole season from each period's tagging. The number of pounds of fish caught from the mid point of each period until the end of the season was calculated and tabulated in Column 3. Column 4 shows the product of Column 1 and Column 3. Each column was summed and the sum of Column 4 divided by the sum of Column 1. This gives a factor which represents the susceptibility of a tag to recovery. The sum of Column 2 multiplied by the total catch for the season and divided by the above factor gives the total number of tags which would have been recovered had all fish been tagged at the start of the season. This number expressed as a percentage of the total number of fish tagged represents the adjusted fishing intensity. The catch per period is expressed as occurring at the mid point of each period and the tags as if they were all out at the start of a period. The error introduced by this procedure will be small.

Before being used, the figures for the total catch for each period were adjusted so as to represent more nearly the tagged population. Fish of less than 11-12 inches in length are not accepted by the canneries, so any smaller fish caught are usually returned to the water by the fishermen. However, as random samples of the catch were taken for tagging some fish of less than 290 mm. (11 inches) were tagged.

Figure 1 shows the length frequencies of fish in the Baynes sound region; 290 mm. was taken as representing the dividing line between those fish which would be accepted by the canneries and those which would not. From this figure it was estimated that 82% of the fish were longer than 290 mm. The catch for each period was multiplied by 100/82 = 1.22.

Figure 2 shows the length frequencies for the Boat harbour region. Here 84% of the fish were longer than 290 mm. and therefore the catches from this region were multiplied by 1.19.

Table XVI shows the weighting of the tag returns for the Boat harbour region.

TABLE XVI

BOAT HARBOUR

Period	Column 1 Tags used	Column 2 Tags recovered	Column 3 Fish still to be caught	Column 4 Column 1 x Column 3
A	425	58	107,502	45,688,350
I	363	70	100,092	36,333,396
II	390	89	79,722	39,091,580
III	---	--	-------	----------
IV	49	7	11,670	571,830
Totals (Period A included)	1227	224	298,986	113,685,156
Totals (Period A excluded)	802	166	191,484	67,996,806

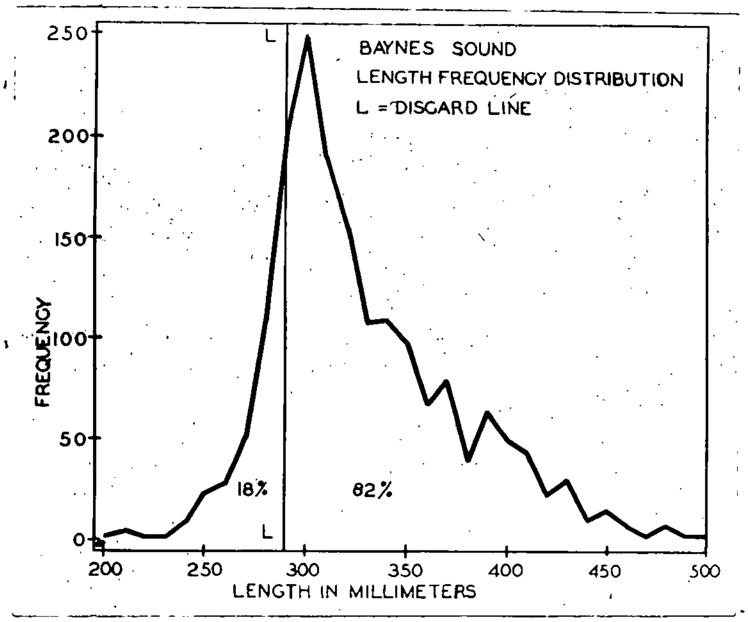

Fig.1. Length Frequency Distribution

Baynes Sound

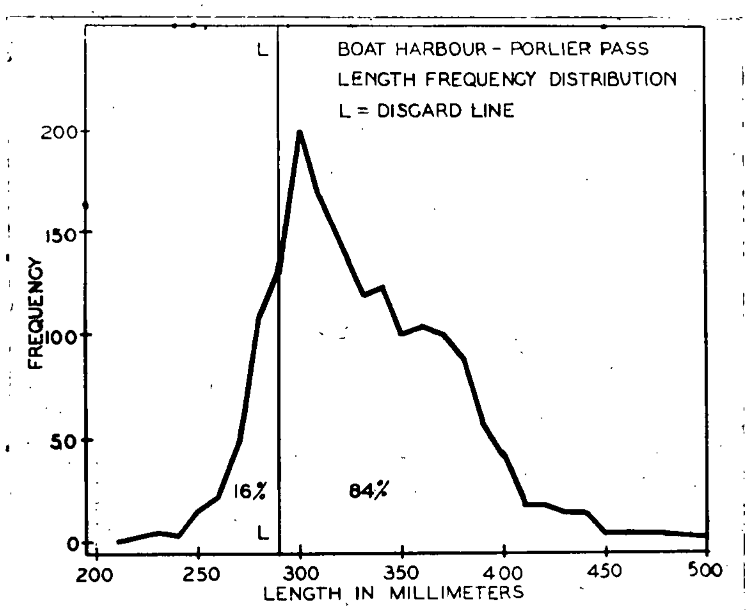

Fig.2. Length Frequency Distribution

Boat Harbour

Period A included:

$$\frac{\text{Total Column 4}}{\text{Total Column 1}} = \frac{113,685,156}{1,227} = 92,653 \text{ (Recovery susceptibility factor)}$$

Period A excluded:

$$\frac{\text{Total Column 4}}{\text{Total Column 1}} = \frac{67,996,806}{802} = 84,784 \text{ (Recovery susceptibility factor)}$$

Period A included:

$$\frac{\text{Total Column 2 x Total Catch}}{\text{Recovery susceptibility factor}} = \frac{224 \times 107,502}{92,683} = 260$$

Period A excluded:

$$\frac{\text{Total Column 2 x Total Catch}}{\text{Recovery susceptibility factor}} = \frac{166 \times 107,502}{84,784} = 210$$

Period A included:

Adjusted Fishing Intensity: $\frac{260}{1,227} = 21.2\%$

Period A excluded:

Adjusted Fishing Intensity: $\frac{210}{802} = 26.2\%$

In this area a tagging was carried out during the last three days of December, 1945; this is referred to as Period A. In weighting the recoveries from this tagging, the total catch for the season has been used, as no catch statistics were available for December, 1945. This introduced an error of 5% in the adjusted fishing intensity. The results including and excluding this sample are given in the table.

From Table XV and Table XVI it will be seen that the adjusted fishing intensity for the Baynes sound and Boat harbour regions are 42.5% and 26.2% (trip A excluded) respectively. The corresponding unadjusted percentages are 32.2% and 20.8% (trip A excluded).

The foregoing has been an analysis of the recoveries made during the 1946 spawning season. For comparison with these are the recoveries made during the 1947 spawning season in the Boat harbour region. These returns cover the months of January and February only, as on March 1 the otter trawler fishermen went on strike. Unfortunately no complete 1947 returns are available for the Baynes sound region as parts of this region were closed to trawlers in May, 1946. All the major fishing areas with the exception of cape Lazo were affected by this ruling.

In Table XVII and Table XVIII the tag returns from January, 1946, to January, 1947, are shown for the Baynes sound and Boat harbour regions respectively. Fish tagged in the Boat harbour region were not all recaptured in that area; those returns marked with an asterisk were captured in other parts of the gulf.

TABLE XVII

BAYNES SOUND

Trip	1946												1947	
No.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
1	28	27	3	3										
2	17	23	4	3							2			
3	14	20	8	1						1				
4	7	39	10	4										
5	5	27	7	3					1		1			
6	-	9	4	2										
7	-	5	9	4							1			

TABLE XVIII

BOAT HARBOUR

Area and Trip No.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
	1946												1947	
A														
Boat hbr.	30	15 1*	3 3p 2*	1p	1*		1p 1*	1p	2p 1*	2*	1 1*	1p	8 4*	2 1p 1*
Porlier	1*	3b		1p	1*			1p				1p		2b
1														
Boat hbr.	16	12 1p	1 2*		2*			1p	2p	1p	1*	1	6 2*	2 1*
Porlier	2b	3p 1b	1*	3p			2p							
2														
Boat hbr.	16 1*	11		1*		2*		2p 1*	1p	1*	1*	1	3 2*	5
Porlier		2p 1b		2p										
3														
Boat hbr.	13	11	1	1p 1*	1			2p		1	1p 2*	1 2*	2*	1
Porlier		3b 5p						1*				1* 1b	1*	
4														
Boat hbr.	8	11	2* 1	1p				1p 1*	1p	2*	1 1p 1*	1*	3	2
5														
Boat hbr.		30	3 2*	1*		1*		2p	1p	1*	1p 1*	1p		
6														
Boat hbr.		2	1 1p 3*							1p	1*		2 2*	1

KEY: Numbers with no symbol after them are fish tagged and recovered in the Boat harbour areas.
p - recovered in Porlier pass.
* - recovered in an area other than Boat hbr. or Porlier pass
b - recovered in Boat hbr., applicable to fish tagged at Porlier pass only.

During January and February, 1947, 58 tags were recovered in the Boat harbour region. This represents 6.3% of the tags remaining unaccounted for at that time. During the same period in 1946, 198 actual recoveries were made. By weighting these returns so that all tags appeared to be out at the start of the fishing season, the effective number of recoveries becomes 230. This represents 18.8% of the tags out at the start of the season. Thus there is a very marked drop in the 1947 recoveries as compared to the 1946 ones. The following factors account for this drop:

1. Tagging mortality. This factor will reduce the 1946 and 1947 returns by approximately the same amount provided the mortality occurred shortly after tagging. However, if some mortality caused by tagging occurred after March, 1946, then the 1947 returns will be reduced in comparison with the 1946 returns. A number of tagged fish recaptured about this time showed sores produced by the tag chafing. If these sores lead to the death of many fish, then tagging mortality would reduce the 1947 returns as compared to the 1946 returns.

2. Natural mortality. During the short period under consideration in 1946, the effect of natural mortality will probably be negligible. However, during the remainder of the year this factor will not be negligible and will reduce the percentage of 1947 returns in comparison to the 1946 returns. This is probably the most important factor.

3. Fishing intensity. Provided the fishing intensity

remains unchanged, this factor will not affect the percentage returns. However, if the fishing intensity was less during 1947, then it will reduce the percentage returns in 1947 as compared to 1946.

4. Failure of fish to return to the spawning grounds. If not all the fish tagged in 1946 returned to the spawning grounds in 1947, the percentage returns in 1947 will be less than in 1946. This factor should be considered, though at the present time no data is available on it.

As no adequate estimate can be made, on the basis of the data available, of any of the probable effects of any of these four factors, no attempt has been made to determine the total mortality rate or the fishing mortality rates on the basis of returns for these two years. A very rough determination could be made by plotting the logarithms of the number of returns made in January and February of each year against the year of return and extrapolating the line to zero time; however, such an estimate would be too inaccurate to be of any practical value.

Growth Rates

The data from the 1947 tag returns form a basis on which an estimate can be made of average annual growth increment of fish in the Boat harbour region. Tagged fish are measured on tagging and on recovery, and, provided both these are accurate, an estimate of the amount of growth can be made.

In determining the accuracy of the recovery measurements the criterion used was that, if a fisherman recorded some of his measurements to an eighth of an inch, then all the measurements made by him were considered accurate. The recovery lengths in inches were converted to millimeters. The lengths of the lemon sole at time of tagging were plotted against the corresponding lengths at time of recovery, and a straight line fitted to the points by the method of least squares. (Figure 3). From this line the average growth in a year of fish between 250 mm. and 425 mm. can be obtained. This line shows the average amount fish between 250 and 425 mm. increase in length a year. The average of these length increments will represent the average annual length increment of fish in the Boat harbour region. This was found to be 23.5 mm.; the range is from 27 mm. for fish of 250 mm. to 19 mm. for fish of 400 mm. If this yearly increment is expressed as a percentage of the length of the fish in 1946, the result is the average annual percentage growth rate for fish of that length. This varies from 10.8% for fish of 250 mm. to 4.5% for fish of 425 mm. It should be pointed out that the sampling here is not random in that among the smaller fish taken for tagging, there is probably definite selection of individuals which have hitherto grown more rapidly and hence have entered the fishery younger than others in their age classes. How this more rapid early growth affects their subsequent growth history is not known. Assuming, then, that the mean of the lengths plotted represents the mean length of the fish in the population, then the

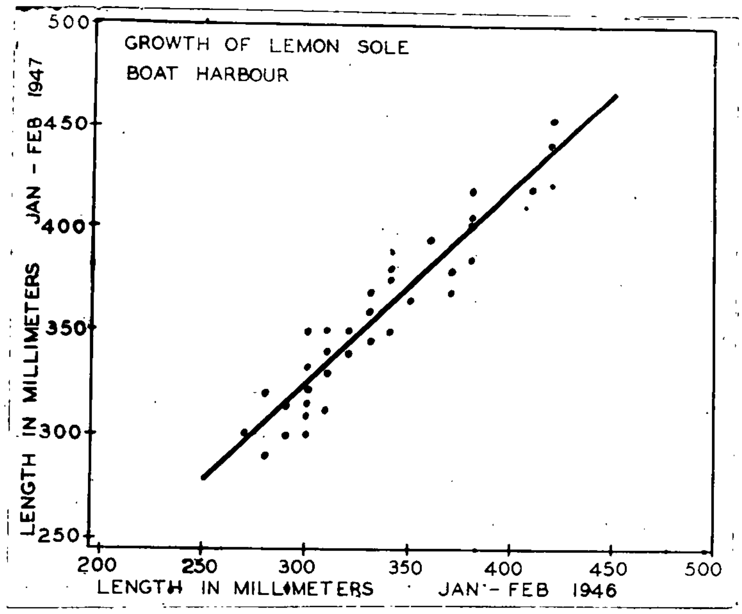

Fig.3. Growth of Lemon Sole.

Boat Harbour

average annual percentage growth rate at this mean length will be the closest estimate, under the circumstances, of the average annual percentage growth rate of the population. This value is 7.3%. The annual percentage increase in length can be converted to the annual percentage increase in weight in the following manner:

The approximate relationship between the length of a fish and its weight is given by the formula: $W = kL^3$, where W is the weight, L is the length, and k is a constant, often referred to as the coefficient of condition or the Ponderal index.

$$W_n = kLn^3$$

Now the length in year n + 1 will be: $L_{n+1} = L_n + aL_n$, where a is the average annual rate of increase in length.

Therefore, weight in year n + 1 will be

$$W_{n+1} = k(L_{n+1})^3$$

$$= k\{L_n^3 + 3L_n^2(aL_n) + 3L_n(aL_n)^2 + (aL_n)^3\}$$

Now the terms containing powers of aLn greater than one are sufficiently small to be ignored in a rough calculation.

Therefore:

$$W_{n+1} = k(L_n^3 - 3aL_n^3)$$

Now: $kL_n^3 = W_n$

Therefore: $W_{n+1} = W_n + 3aW_n$

Now, the weight in the year n + 1 will be the weight in year n plus annual weight increment.

Therefore, 3a represents the annual rate of increase in weight, and so the annual rate of increase in weight is roughly three times annual rate of increase in length.

Therefore, the average annual rate of increase in weight of the lemon sole in Boat harbour is 21.9%.

Discussion of Fishing Intensities

When the intensity of a fishery has been determined the problem arises as to whether this intensity is too great to maintain the fishery at its present level of abundance. Is the annual removal of fish by all causes balanced by the annual recruitment? Or, putting this in another way, is the intensity of the fishing such that the number of mature fish left on the grounds annually large enough to produce a sufficient number of young fish to balance the annual removal of fish at the time when these young fish enter the fishery? A second, and associated problem, also arises, namely, is this intensity one which will maintain the fishery at its most productive level?

It has been shown by many workers (Baranov 1918, Russell 1931, Thompson and Bell 1934, Thompson 1937) that a fishery may be stabilized at many different levels of yield, but that there is an optimum yield which takes full advantage of the maximum growth of the population.

No real attempt can be made to answer either of these questions on the basis of the data presented in this report. To solve these problems, the total annual mortality rates, the annual recruitment, and the annual growth rate must be known. The estimation of the annual recruitment and also of the growth rate are best determined from studies of the age distributions of the population. Such age determinations are outside the scope of this study. Growth rates can, however, be determined from tag returns provided accurate measurements are taken of the lengths of all tagged fish at the time of recapture, and provided these fish were recaptured after a long enough period to permit an estimate to be made of the annual amount of growth as fish do not grow at a constant rate throughout the year. Any estimate of the annual growth rate based on the increase in lengths shown by fish at freedom for less than a full year is liable to be inaccurate.

Thirty-five tags recovered in Boat harbour in January and February, 1947, satisfied the above conditions, and on this basis the average annual increase in weight was found to be 21.9% for lemon sole in that region.

The annual seasonal expectation of death (which includes both fishing and natural mortality rates) can be determined from either the age composition of the population, by the methods used by Baranov (1918), Jackson (1939), or Ricker (1944), or from the returns of tagged fish. Methods based on the age composition of the stock are not discussed further because, as has been stated, age determinations are outside the scope of this work.

Several methods using tag returns have been evolved: Ricker (1945) gives two methods, the first based on the tagging of fish in two successive years prior to the start of the fishing season, and the comparison of the returns in the second year from each year's tagging. The survival rate (complement of the mortality rate) equals

$$\frac{(\text{year 1 recaptures})(\text{number marked year 2})}{(\text{year 2 recaptures})(\text{number marked year 1})}$$

His second method makes use of fish tagged throughout the season instead of just prior to the season. To use this information certain assumptions were made:

1. That the seasonal distribution of marking was the same throughout both seasons.

2. That the total mortality rates were the same in both years and the same for the whole of the ranges of sizes studied.

3. That all the year's mortality (natural and fishing) takes place during the time marking goes on and that the seasonal distribution of mortality of both sorts parallels that of the marking.

Thompson and Herrington (1930) and Hart (1943) use a method based on the tagging of fish during a season and the analysis of the recoveries made in successive seasons. They assume that the total annual mortality rate is represented by the decline in actual numbers of returns each year, provided that the mortality rates and fishing efforts are constant from year to year, and that tagged fish, after recovering from the initial shock of handling, die at the same rate as the untagged fish. Thompson and Herrington obtain an estimate of the fishing mortality rate by extrapolating to zero time the line formed by plotting the logarithms of the yearly returns (expressed as a percentage of the tags available at the start of the year) against the years of recovery. Then, by assuming that their tagging mortality is negligible, they calculated the natural mortality from the total annual mortality and the fishing mortality. Hart finds the annual mortality rate from the slope of the line formed by plotting the logarithm of the tags recovered against the year of recovery.

None of the methods outlined above is suitable for calculating the mortality rates of lemon sole in the Baynes sound and Boat harbour regions as tagging was carried out for only one year and as complete returns are available for one year only. These methods also cannot be applied to determine mortality rates from the tag returns for successive two weekly periods because:

1. The mortality rates and fishing effort cannot be assumed to be constant from period to period; this is shown by the variation in the total catch and availability per period.

2. No information is available on tagging mortality or the length of time required by lemon sole to recover from the shock of handling. As the periods under consideration occur very shortly after the time of tagging, the tagged fish

cannot be assumed to die at the same rate as the untagged fish.

3. The number of recoveries per period are small and in some cases so nearly equal that the errors introduced through the chance recovery of tags in any period would distort the results considerably.

4. As neither tagging nor the resampling of the population to obtain recoveries was done at definite regular intervals, Jackson's (1939) method cannot be applied to this data.

Unless the fishing mortality rate, the natural mortality rate, the amount of annual recruitment to the population, and the annual growth rate are all known no statement can properly be made about the stability of a fishery. As was shown in the foregoing paragraphs, neither the mortality rates nor the amount of annual recruitment can be determined on the basis of the data presented. Therefore no valid statement about the stability of the fishery can be made. However, on the basis of the estimated fishing intensities and the annual rate of increase in weight calculated, an estimation of the probable state of the fishery may be made.

A fishing intensity of 26.2% during the spawning season is probably too high for the Boat harbour fishery to support and still maintain an annual recruitment that, together with a growth rate of about 22%, will balance the high total mortality rate that is suggested by the comparison of the percentage tag returns (6.3%) obtained in 1947 with the percentage tag returns (18.6%) obtained in 1946. Assuming that the growth rate is the same for Baynes sound and Boat harbour lemon sole, a fishing intensity of 42% during the spawning season appears too high for the Baynes sound fishery to support and still be in equilibrium.

Therefore, the conclusion is that fishing intensities during the spawning seasons, of 26.2% and 42.5%, for the Boat harbour and Baynes sound regions respectively, are too high.

POPULATION CHANGES

In this section an attempt is made to determine the amount of population change on the lemon sole spawning grounds of Baynes sound and Boat harbour, that is, to show whether the spawning population is stationary or is continuously changing with fish arriving to spawn and leaving throughout the season. This is done by relating, for each trip made in January and February, the number of tags out at the start of each two weekly period with the number of recoveries and the total weight of fish caught during that period. The method used was to express the tag recoveries from each tagging for each period as if a fixed number of tags, one hundred, were out at the start of each period, and a fixed weight of fish, one hundred thousand pounds, were caught in each period. By expressing the number of recoveries in this manner, the effect of the varying numbers of tags out and of the differing catches of fish made each period, on the number of tags recovered will be eliminated.

The tag recoveries, adjusted in this manner are shown in Table XIX and graphically in Figure 4 for the Baynes sound region, and in Table XX and graphically in Figure 5 for the Boat harbour region.

TABLE XIX

BAYNES SOUND

No. & Date of Period	Number and Date of Trip						
	I Jan.4	II Jan.12	III Jan.18	IV Jan.24	V Jan.28	VI Feb.13	VII Feb.23
I Jan. 1-15	23.1	36.0	-----	-----	-----	-----	-----
II Jan.16-28	23.5	25.4	25.5	21.5	33.3	----	----
III Feb. 1-15	26.0	24.1	21.9	32.2	15.7	----	----
IV Feb.16-28	18.7	28.5	13.6	30.0	27.6	39.4	25.3
V Mar. 1-15	4.4	9.9	15.6	21.1	11.7	30.6	23.2
VI Mar.16-31	3.1	4.6	3.1	3.9	6.8	-----	-----

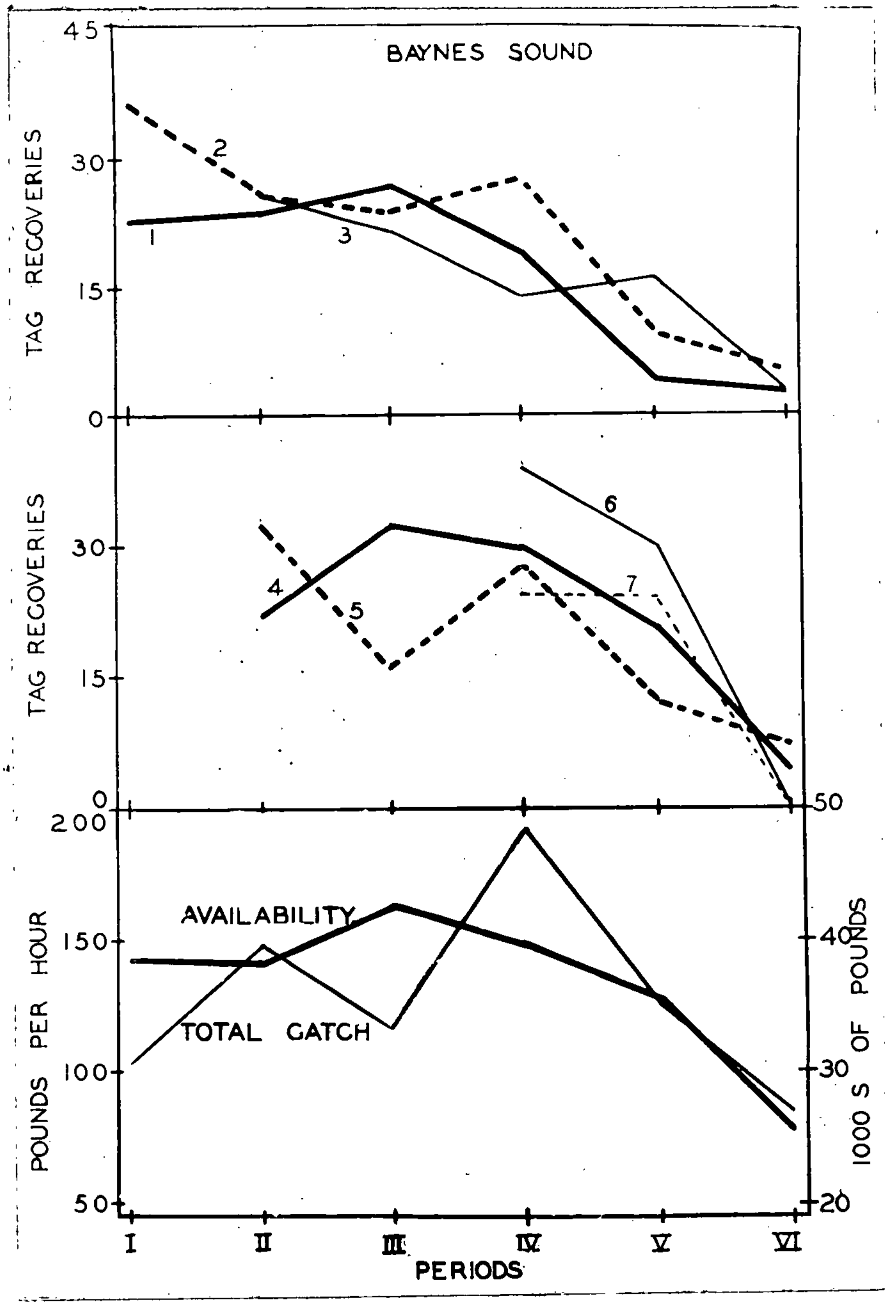

Fig. 4. Baynes Sound. Effective Tag Recoveries from each Trip Availability. Total Catch.

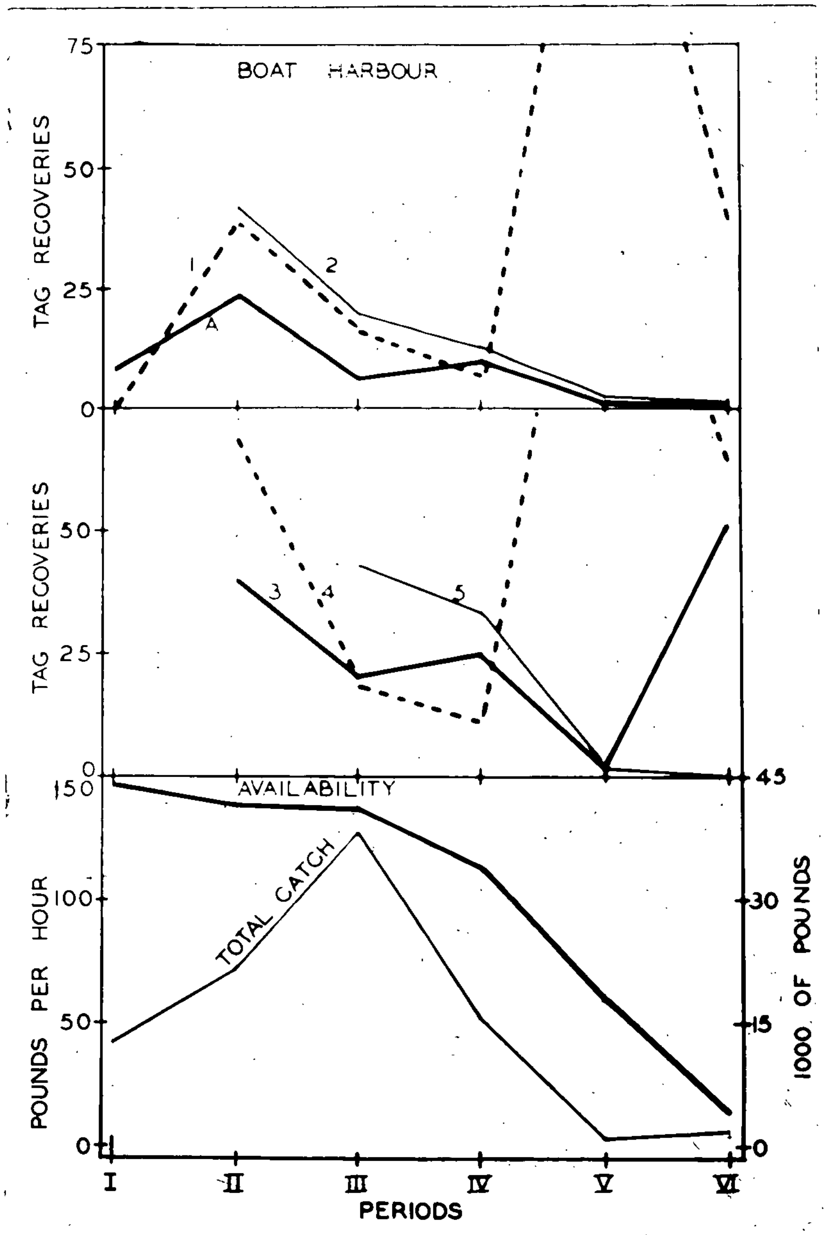

Fig.5. Boat Harbour. Effective Tag Recoveries from each Trip

Availability. Total Catch.

TABLE XX

BOAT HARBOUR

No. & Date of Period	Number and Date of Trip A Dec.28	I Jan.7	II Jan.15	III Jan.20	IV Jan.26	V Jan.30	VI Feb.16
I Jan. 1-15	8.1	----	----	----	----	----	----
II Jan.16-31	23.9	38.2	40.9	41.1	68.9	----	----
III Feb. 1-15	6.5	15.5	16.8	20.5	17.5	43.6	----
IV Feb.16-28	9.7	6.5	12.4	25.9	10.3	34.0	22.1
V Mar. 1-15	117.5	212.5	----	----	235.0	517.0	505.3
VI Mar.16-31	71.0	38.7	----	51.6	64.5	77.4	432.3

In interpreting these results the following assumptions are made:

1. The tagged fish do not school, and are distributed equally amongst the untagged population.

2. Tagging mortality is negligible or affects the fish tagged on each trip in precisely the same manner.

3. Natural mortality, during the period under consideration is nil.

4. The loss of tags after recapture and before return either affects the recoveries from each trip for each period in the same manner or is nil.

Before the results given in the tables are discussed, certain theoretical interpretations of such results are considered:

1. If no immigration or emigration takes place, that is, if the population is absolutely stationary, then the effective returns per period (that is to say, the actual returns adjusted as if one hundred tags had been out at the start of the period and one hundred thousand pounds of fish had been caught during the period) would remain constant.

2. Again, if emigration alone took place, and, providing the tagged fish were equally distributed throughout the population, then the effective return per period will again be constant, for tagged and untagged fish should leave the grounds at the same rate. In such a case fish are becoming less abundant on the grounds and this will be reflected in the lower average catch per hour for that period.

3. If immigration alone occurs during any period, then the effective returns for that period will show a decline. This is because the immigrants have lowered the ratio of tagged to untagged fish present on the ground, that is, the population has been diluted. In this case more fish will be present on the grounds and the average catch per hour for that period should show an increase.

4. If immigration and emigration take place at the same time the effective returns per period will drop. There are three possible ways in which emigration and immigration could occur together: 1. If emigration exceeds immigration. In this case the effective returns in a period would show a decrease as there would be some dilution of tags remaining on

the grounds, and the average catch per period would also show a decrease, as there would be less fish on the grounds.

2. When emigration equals immigration. Here the effective returns in a period would again show a decrease, for dilution of the stock is taking place; the average catch per period should remain constant.

3. If immigration exceeds emigration. The effective returns in a period would still show a decrease, but the average catch per period would show an increase.

Thus these three possible combinations of immigration and emigration can be separated by their effect on the average catch per hour for a period.

It will be noticed, however, that type (3) produces the same effect as immigration alone. These two may prove difficult to separate, but some clue to which it is may be given by the actual number of returns for that period, for if any emigration took place the actual number of returns might be less than had no emigration taken place.

5. The above four situations have been considered on the assumption that there was no resident or temporary non-migratory population present. Assume now that there is such a resident population present. Now, if the proportion of tagged to untagged fish in this resident population was the same as that in the migratory population, the changes produced by emigration, immigration, or various combinations of them, would be similar to those discussed in points 1 - 4. But,

if it so happened that the proportion of tagged fish in the resident population was less than that in the migratory population, then any change in the population due either to immigration or emigration, would cause a drop in the effective number of tags recovered. In this case it would be difficult to separate a case where emigration alone occurred from a case where emigration and immigration both occurred, with emigration exceeding immigration, and also a case where immigration alone occurred from a case where emigration and immigration took place with immigration exceeding emigration.

6. Movement of fish about the spawning grounds. Consideration should also be given to a case in which the factors involved produce an increase in the effective number of returns in a period. Assume that the region under consideration is made up of a number of areas, and that the fish, for some reason, tend to concentrate more in certain areas than in others, but that in the tagging operation, the same number of tags were put out in each area. The result of such tagging operations will be that the ratio of tagged to untagged fish will be greater in those areas in which the fish are less concentrated. If such a region is fished commercially, the fishing will tend to be concentrated in those areas where fish are most abundant, therefore more fish will be caught in those areas in which tags are relatively less concentrated. Now, if fish migrate from those areas in which tags are more concentrated, to those areas in which the tagged fish are relatively less concentrated, then the relative concentration of

tagged fish in these latter areas will be increased, and, therefore, on the assumption that the greater part of the catch in any period will be made in these areas, the effective number of returns for a period will show an increase. To prove that such an effect was produced by migration of this type, catch statistics for each area as well as for the whole region, would have to be available. To illustrate the effects of such migrations a hypothetical example is given below: Assume that 40 fish were tagged in each of four areas A, B, C, D, and that the following pattern of tag returns was obtained:

Area of Tagging	Area of Recovery			
	A	B	C	D
A	2	2	0	0
B	2	6	0	0
C	1	1	2	0
D	0	2	1	2

Let the catches in each area in the same period be:

A = 10,000 lbs.

B = 25,000 lbs.

C = 2,000 lbs.

D = 1,000 lbs.

Now, migration has taken place between the various areas, and hence the catch in an area will be made up of fish from that area and of fish which have migrated into it, in the proportions indicated by the tag returns.

Therefore:

For area A: Catch $= 10{,}000 = \dfrac{2a + 2b + c}{40}$

For area B: Catch $= 25{,}000 = \dfrac{2a + 6b + c + 2d}{40}$

For area C: Catch $= 2{,}000 = \dfrac{2c + d}{40}$

For area D: Catch = 1,000 = $\frac{2d}{40}$

where a, b, c, and d, represent the population of each area respectively.

Solving the above equations, the populations in each area are:

Area A:- 45,000; B:- 140,000; C:- 30,000; D:- 20,000.

Now, if no migration takes place, ratio

$\frac{\text{Tags returned}}{\text{Catch}} = \frac{\text{Fish tagged}}{\text{Population}}$, but, if there has been migration from areas where tagged fish are relatively more concentrated into an area where tagged fish were relatively less concentrated, then the ratio of $\frac{\text{Tags returned}}{\text{Catch}}$ will be greater than the ratio $\frac{\text{Fish tagged}}{\text{Population}}$ in those areas into which the fish migrated. These two sets of ratios for this hypothetical population are shown in the table below:

	$\frac{\text{Tags Returned} \times 10^5}{\text{Catch}}$	$\frac{\text{Fish Tagged} \times 10^5}{\text{Population}}$
A	50	9
B	44	29
C	60	133
D	200	200

Thus, this example illustrates that the migration of fish from an area where tagged fish are more concentrated to an area where they are less concentrated and where more fishing is done, raises the effective number of returns.

The foregoing theoretical considerations form a background against which the variations in the effective tag returns for each period in the Baynes sound and Boat harbour regions can be partially interpreted. The variations in effective returns per period for each tagging should give an indication of the population changes occurring on each of the spawning grounds.

Each region will now be considered separately:

1. The Baynes sound region.

For this region the effective returns for each trip's tagging, obtained by the method described, are given in Table XIX, page 58, and Figure 4, following page 58.

1. For any trip, the effective returns for the period during which the trip was made are not reliable. This is because the tagging was done, not at the start of the period, but at some time during it, and therefore, in adjusting for the amount of fish caught, a proportion of the catch for the period corresponding to the fraction of the period from the time of tagging to the end of the period had to be used. Such a proportion may not correspond accurately to the real weight of fish taken during that time and so will distort the results.

2. In the first four periods there appears to be considerable variation in the trends shown by the effective returns from the various tagging operations. However, in the last two periods, all the returns show a sharp decline. During these same two periods the availability also decreases sharply. In the discussion of the theoretical aspects of this problem it was shown that three types of population change will

produce a decline in effective returns associated with a decline in availability. These are:

a. a greater emigration than immigration taking place from a population in which only the migratory or spawning fish were tagged, and

b. either emigration alone, or

c. a greater emigration than immigration taking place from a population in which a resident or temporarily non-migratory population received a small proportion of tags. The changes in the Baynes sound population during periods V and VI can probably best be described by either of the last two assumptions, the second being the more likely one.

3. In view of the fact that increases in the effective numbers of returns for a period are produced by migration of fish from areas with a higher concentration of tagged fish to areas with a lower concentration, or (as the approximately same number of tags were put out in each area) from an area with relatively fewer fish to an area where more fish are present; the increases noted in the effective returns for trip I during period III, for trips II and V during period IV, and for trip III during period V, are of interest, especially as these increases occurred in periods immediately preceding the start of the sharp decline in returns. It has been shown (Table V, page 20) that the yields of fish per hour's dragging are greatest in the Deep and Fanny bay areas and further that there was a definite movement of fish from both ends of Baynes sound

towards the Fanny bay area (Table VII, page 25). Therefore the increase in effective returns noted for these trips is possibly the result of a migration to and accumulation of fish in, the Fanny and Deep bay areas prior to their leaving the spawning grounds.

4. The fact that the effective returns for trip I started to decline sharply a period before the returns for other trips would indicate that some of the lemon sole tagged earlier in the season are leaving the grounds before those tagged later in the season.

The conclusion is that the population of lemon sole present in Baynes sound during January, February, and March consisted of a small resident population as well as a much larger migratory spawning population. The evidence points to general emigration of lemon sole from this region starting about the end of February. There is some evidence that emigration may have started about the middle of February and that these early emigrants are fish that were present on the grounds earlier in the season. There was also some indication of a migration to and accumulation of fish in the Deep and Fanny bays prior to leaving the spawning grounds.

2. The Boat harbour region.

For this region the effective returns for each trip's tagging, calculated in the same manner described earlier are shown in Table XX, page 59, and Figure 5, following page 58.

1. The same reservations as were made for the Baynes sound

region must be made here concerning the effective returns from a trip for the period during which the tagging was done. The returns for trip A for period I, for trips I and II for period II, and for trip V in period III can be considered reliable, as in each case the tagging was done before the commencement of the period in question.

2. Large increases will be noticed in the effective returns for trips A, I, IV, V, and VI during period V. In period VI the effective returns for trips A, I, III, IV, V, and VI were still comparatively large but showed a considerable decrease over those for period V. In periods V and VI the total catches made were small, being less than 1/20 and 1/10 respectively of the catch made in period IV. Therefore in weighting the tag returns for these two periods the adjusted or effective returns will be disproportionately large when compared with those of other periods. In the Baynes sound region increases in effective returns were explained on the basis of a migration of fish between areas; such an explanation cannot be applied in this case as the actual returns of tags are too small to indicate a migration of the size necessary to produce such large increases in effective returns. Therefore the weighting of the returns by the disproportionately small catches made in these periods alone caused this marked increase in effective returns.

3. The variation in effective returns from the various taggings indicate that a part of the population emigrated from

the region during period III and that in the succeeding periods more of the population emigrated so that by period VI most of the migratory spawning population had probably left the grounds. It will be noticed that the effective returns for trips I and II decreased from approximately 40 in period II to 20 in period III, while the effective returns for trip V in period III were still above 40. That is to say, that, during period II from February 1 to 15, the number of effective returns from fish tagged up until January 15 decreased, as compared to the number of effective returns of fish tagged on January 30. During periods II and III the average catch per hour declined. Now, the considerations of theoretical possibilities of variation in effective returns showed that, for a decline in effective returns to be associated with a decline in average catch per hour, the assumptions had to be made either that emigration exceeded immigration or that, if emigration alone was occurring, a small proportion of fish tagged were from a resident or temporarily non-migratory population. If the first assumption were applicable, the expected number of effective returns from fish tagged on January 30 would be less than the number of effective returns for fish tagged prior to January 15 and recaptured during period II, due to the dilution of tagged fish resulting from the assumed emigration. However, as this was not so, the second assumption would appear to fit the case more nearly, that is, that some of the fish tagged prior to January 15 remained on the spawning grounds during the period from February 1 to 15, whilst others emigrated. The effective returns for trips I, II, IV, and V declined again during period IV, that is, from February 16 to 28, and the average catch per hour declined sharply during this same time. This would again indicate that only a part of the population emigrated at this time. The effective returns during periods V and VI do not lend themselves to interpretation because of the distortion in weighting introduced by the very small catches made in these periods.

The conclusion is that, in the Boat harbour region, the lemon sole did not leave the spawning ground en masse at one time but fish were continuously emigrating from the grounds during February and March. The very low average catch per hour in periods V and VI would indicate that the emigration of the spawning population was probably concluded by March.

DISPERSAL OF LEMON SOLE FROM THE SPAWNING GROUNDS

The populations of lemon sole found on the spawning grounds in Baynes sound and Boat harbour regions are largely non-resident spawning populations. Reports received from the commercial fishermen indicate that the fish start to arrive on these grounds in numbers about December and to leave in February and March; and that it is only during this period that good catches are made.

These reports are borne out by the variations in the abundance (average catch per hour for each period) of lemon sole as calculated from pilot house log book records. In both the Baynes sound and Boat harbour regions the average catch per hour drops sharply towards the end of February.

Therefore one reason for tagging lemon sole on these two spawning grounds was to obtain information as to the extent of dispersal of the fish following spawning. The points of recovery of tagged fish would indicate this, and would also show if there was an appreciable intermingling of the populations spawning on the two grounds.

In the Baynes sound region 814 fish were tagged. To date, no tags have definitely been recovered from areas outside this region. Two tags have been reported as probably having been caught in Nanoose bay, however, considerable doubt exists as to the real point of recapture of these tags. The fact that none of the fish tagged in Baynes sound have been recovered from points outside this area cannot be taken as indicating that the population is non-migratory, for the marked decline in average catch per hour observed during March definitely indicates that the fish are leaving the grounds. Further, the absence of a definite summer fishery in Baynes sound indicates that there must be, at the best, only a small resident population in this region. Therefore, these fish probably disperse to those parts of the gulf of Georgia from the Nanoose bay region northward, that is, to areas not often fished by the otter trawlers.

In the Boat harbour region 106 recoveries out of a total of 359 were made in areas outside the region of tagging. These recoveries are shown in Table XXI.

From this table it will be noticed that:

1. There is a definite migration of lemon sole in both directions between Porlier pass and the Boat harbour region. The comparatively large number of returns from Porlier pass during August and September, 1947, might indicate that the lemon sole were moving through the Porlier pass region on the way back to spawning grounds. Mr. C. B. Shannon, an experienced trawl fisherman, reports that lemon sole appear in numbers in the Porlier pass area in September, and that a month later they are to be found about six miles northward. He has also found a similar southward migration taking place in February and March.

2. From the Boat harbour spawning ground, there is a general southward dispersion of lemon sole, extending as far as the mouth of the Fraser river and the Bellingham bay-point Roberts area.

The fact that no fish tagged in the Baynes sound region were recovered to the south in the Boat harbour region and that no fish tagged in Boat harbour were recovered to the north in the Baynes sound region would indicate that the population using these two spawning grounds are separate and do not intermingle to any extent.

TABLE XXI

BOAT HARBOUR

Area of Recovery	1946 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	1947 Jan	Total	Area of Tagging	Date of Tagging
Porlier pass	2	1	4	3		1	1	9	6	1	2	3		33	Boat harbour	Jan-Feb/46
Yellow point										2		1	10	15	Boat hbr, Porlier pass	Dec/45-Feb/46
Ladysmith	1		5			1		3		2				12	Boat hbr, Porlier pass	Dec/45-Jan/46
Chemainus			5	1	1	1		1					1	10	Boat hbr, Porlier pass	Dec/45-Jan/46
Thetis island (west side)				2	1		1						1	5	Boat harbour	Dec/45-Jan/46
Active pass	1		1											2	Boat hbr, Porlier pass	Dec/45-Jan/46
Satellite ch.											1			1	Boat harbour	Jan/46
Swanson ch.	1	1	1											3	Boat harbour	Dec/45-Jan/46
Beaver point											2			2	Boat harbour	Jan-Feb/46
Pender island												1		1	Boat harbour	Jan/46
Captains pass.											1			1	Boat harbour	Jan/46
Fraser river									1	2				3	Boat harbour	Dec/45
Pt. Roberts reef				1	1									2	Boat hbr, Porlier pass	Dec/45-Jan/46
Bellingham bay				1										1	Boat harbour	Jan/46
Gabriola pass			1	6										7	Boat harbour	Dec/45-Jan/46
Boat harbour	4	4												8	Porlier pass	Jan/46

If the fishery for the spawning lemon sole in the Baynes sound and Boat harbour regions is too intense and is producing a decline in the abundance of lemon sole in these areas, this decline will be reflected in all areas to which the fish disperse after spawning. However, if the fish frequenting the Baynes sound and Boat harbour spawning grounds are separate populations which do not intermingle extensively, then a too intense fishery on one of these grounds will bring about a reduction of fish only in those parts of the gulf normally supplied by this spawning ground.

For instance, the fishing intensity in the Baynes sound region appears to be rather too high to maintain the stock at its present level of abundance. This should not cause a general depletion of lemon sole throughout the gulf but only in that part of it from Nanoose bay northward, provided the assumption is correct that this is the area over which the Baynes sound fish disperse after spawning.

POPULATION DIFFERENCES

As was mentioned in the previous section the returns of tagged fish indicated:

1. That the lemon sole found on the Baynes sound and Boat harbour spawning grounds came from two separate populations which did not intermingle appreciably.

2. That the fishing intensity was considerably higher in the Baynes sound region than in the Boat harbour region.

To see whether these two factors had produced any major differences in the composition of the populations in these regions, the length frequency distribution, the sex ratio, and the ratio of immature to mature fish, were determined for each region. Porlier pass was treated separately. The total numbers of mature and immature males and females and the percentage each represents of the total population of the region are shown in Table XXII. Figure 6 shows the length frequency distribution for immature males and females for the Baynes sound region, Figure 7 for the Boat harbour region, and Figure 8 for the Porlier pass region.

TABLE XXII

	Immature Males		Immature Females		Mature Males		Mature Females		Sex Ratio Mature Fish	
	No.	%	No.	%	No.	%	No.	%	Males	Females
Baynes sound	44	2.4	396	21.9	411	22.7	959	53.0	30%	70%
Boat harbour	31	2.2	42	2.9	476	33.1	889	61.8	35%	65%
Porlier pass	6	2.7	151	67.4	0	0	67	29.9	0%	100%

From an examination of Table XXII and Figures 6, 7, and 8, it appears that:

1. The length frequency distributions of the mature males and females are very similar in the Baynes sound and Boat harbour regions. There are more small mature females (of 300 mm. or less in length) in the Baynes sound region.

2. In the Baynes sound region a definite population of

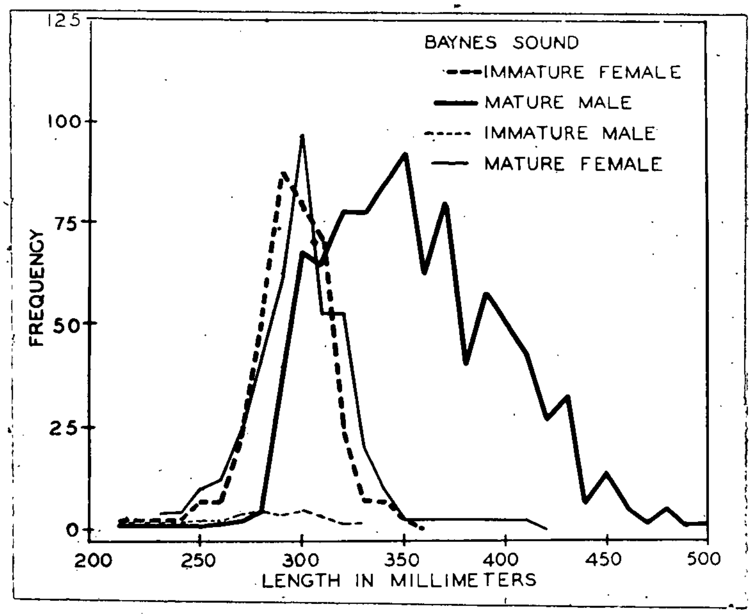

Fig.6.Length Frequencies: Immature & Mature Males & Females Baynes Sound.

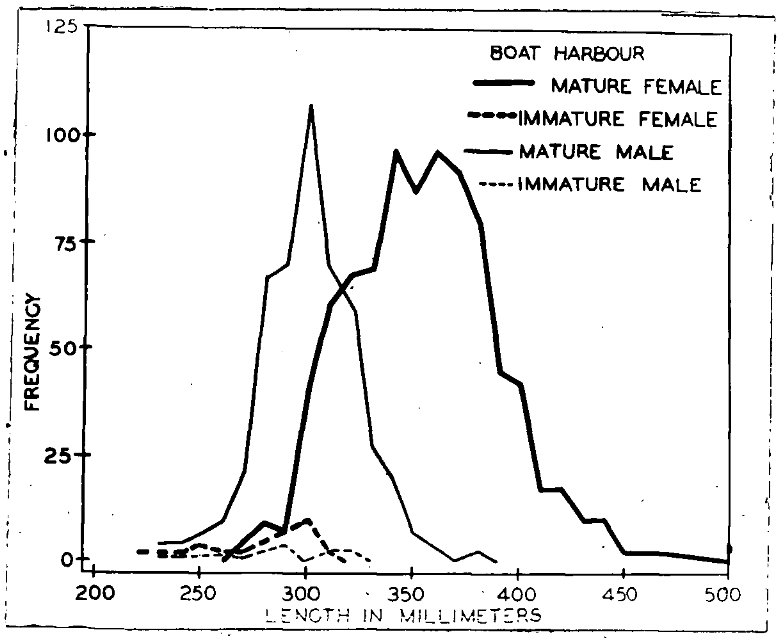

Fig.7. Length Frequencies: Immature & Mature Fish.
(Males and Females)
Boat Harbour.

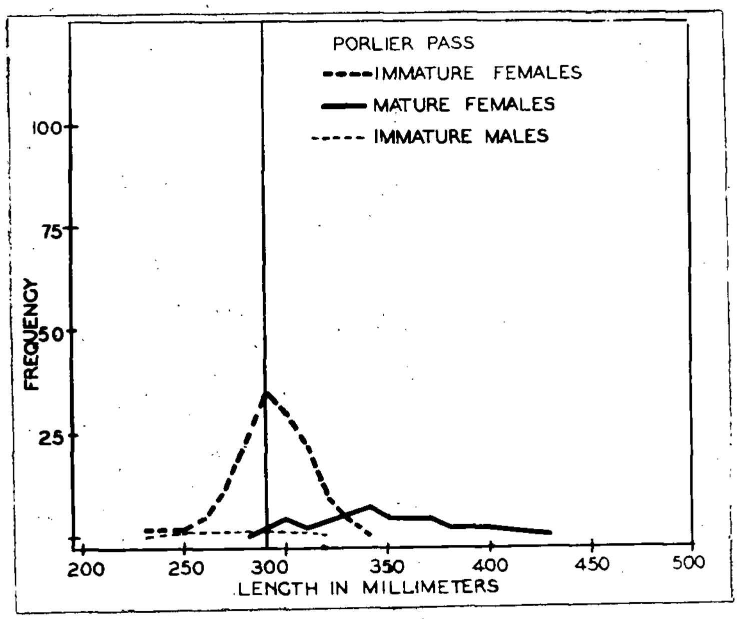

Fig.8. Length Frequencies. Immature & Mature Females
Immature Males. No Mature Males Found.
Porlier Pass.

immature females was found. It comprised 22% of the total population of this area.

3. Immature males formed 2% of the total population in both areas.

4. The sex ratio, based on the number of mature fish, was approximately the same in both regions. 32% of the mature fish in Baynes sound were males and 35% in Boat harbour.

5. In Porlier pass immature females formed 67% of the total population and mature females 32%. No mature males were found.

In summary, the Baynes sound and Boat harbour populations have important features of resemblance especially among the mature fish. They differ in the large (22%) proportion of immature females present in Baynes sound and the greater number of small mature fish there. Porlier pass differs markedly from the other areas, consisting of two-thirds immature females.

STOMACH ANALYSIS

A qualitative analysis of the stomach contents of lemon sole was made in the course of the study of the spawning of these fish in the Baynes sound and Boat harbour-Porlier pass regions.

The following tables show the results of the stomach analyses for these regions: Table XXIII for the Baynes sound region, Table XXIV for the Boat harbour areas, and Table XXV for the Porlier pass area.

TABLE XXIII
BAYNES SOUND

STOMACH CONTENTS	FEMALE: Immature	FEMALE: Maturing	FEMALE: Eggs not clear	FEMALE: Eggs clear	FEMALE: Running	FEMALE: Spent	FEMALE: Total	MALE: Immature	MALE: Running	MALE: Total	%
Empty	164	28	173	67	60	63	555	29	190	219	
Worms	30	6	24	4		18	82	4	13	17	78%
Clams	8	2	4	1		11	26	2	4	6	46%
Worms, clams	13	2	18	3		23	59	4	2	6	
Worms, clams, brittlestar	1		1			1	3			0	
Worms, brittlestar	1		1	1			3	1		1	
Clams, brittlestar			1				1			0	
Brittlestar							0		1	1	4%
Unidentifiable	1	1	5	1			8		1	1	
Miscellaneous	1				1	2	4		2	2	
Empty:											
Observed No. (x)	164	28	173	67	60	63	555	29	190	219	
Expected No. (m)	164.03	29.21	170.03	57.67	45.69	88.38		34.62	184.38		
Full:											
Observed No. (x)	55	11	54	10	1	55	186	11	23	34	
Expected No. (m)	54.97	9.79	56.98	19.33	15.31	29.62		5.38	28.62		
Total	219	39	227	77	61	118	741	40	213	253	
d (x-m)	-.03	-1.21	+2.98	+9.33	+14.31	-25.38		-5.62	+5.62		
	+.03	+1.21	-2.98	-9.33	-14.31	+25.38		+5.62	-5.62		
d^2	.0009	1.4641	8.8804	87.0489	204.7761	644.1444		31.5844	31.5844		
d^2/m: Empty	0	0.0501	0.0522	1.5094	4.4819	7.2884		0.9123	0.1713		
Full	0	0.1476	0.1559	4.5633	13.3753	21.7469		5.8707	1.1036		
Total	0	0.1997	0.2081	6.0127	17.8572	29.0353		6.7830	1.2749		

Females: chi-squared = 53.3130
df = 5
P is less than .01

Males: chi-squared = 8.0579
df = 1
P is less than .01

TABLE XXIV
BOAT HARBOUR

STOMACH CONTENTS	FEMALE Immature	FEMALE Maturing	FEMALE Eggs not clear	FEMALE Eggs clear	FEMALE Running	FEMALE Spent	FEMALE Total	MALE Immature	MALE Running	MALE Total	%
Empty	57	4	170	159	124	31	545	33	293	326	
Worms	14	4	26	1	1	5	53	2	9	11	58%
Clams	2		1				3	2	3	5	20%
Worms, clams	5		5			5	15	1	3	4	
Worms, clams, brittlestar	10	1	12	2		2	27			0	
Worms, brittlestar	14		17	1		4	36	1		1	
Clams, brittlestar	5		1				6			0	
Brittlestar	1		3				4	3	2	5	32%
Unidentifiable	1						1			0	
Miscellaneous	2		3				5	2	1	3	

	FEMALE Immature	FEMALE Maturing	FEMALE Eggs not clear	FEMALE Eggs clear	FEMALE Running	FEMALE Spent	FEMALE Total	MALE Immature	MALE Running	MALE Total
Empty:										
Observed No. (x)	57	4	170	159	124	31	545	33	293	326
Expected No. (m)	87.29	7.08	187.17	128.19	96.30	36.96		40.41	285.59	
Full:										
Observed No. (x)	54	5	68	4	1	16	148	11	18	29
Expected No. (m)	23.71	1.92	50.83	34.81	26.70	10.04		3.59	25.41	
Total	111	9	238	163	125	47	693	44	311	355
d (x-m)	-30.29	-3.08	-17.17	+30.81	+25.70	-5.96		-7.41	+7.41	
	+30.29	+3.08	+17.17	+30.81	-25.70	+5.96		+7.41	-7.41	
d^2	917.4841	9.4864	294.8089	949.2561	660.4900	35.5216		54.9081	54.9081	
d^2/m: Empty	10.5107	1.3399	1.5751	7.4051	6.7191	0.9611		1.3588	0.1923	
Full	38.6961	4.9408	5.7999	27.2696	24.7375	3.5380		15.2947	2.1609	
Total	49.2068	6.2807	7.3750	34.6747	31.4566	4.4991		16.6535	2.3532	

Females: chi-squared = 133.4929
df = 5
P is less than .01

Males: chi-squared = 19.1067
df = 1
P is less than .01

TABLE XXV
PORLIER PASS

STOMACH CONTENTS	FEMALE: Immature	Maturing	Eggs not clear	Eggs clear	Running	Spent	Total	MALE: Immature	Running	Total	%
Empty	43	4	11			3	61			0	
Worms	11	2	5			2	20			0	88%
Clams	1						1			0	45%
Worms, clams	5		4			2	11			0	
Worms, clams, brittlestar	8	1	6				15			0	
Worms, Brittlestar	10		1			1	12			0	
Clams, brittlestar	3						3			0	
Brittlestar			1				1			0	47%
Unidentifiable	1						1			0	
Miscellaneous	2						2				
Empty:											
Observed No.(x)	43	4	11	0	0	3	61	0	0	0	
Expected No.(m)	40.35	3.36	13.45			3.84					
Full:											
Observed No.(x)	41	3	17	0	0	5	66	0	0	0	
Expected No.(m)	43.65	3.64	14.55			4.16					
Total	84	7	28	0	0	8	127	0	0	0	
d (x-m)	+2.65	+0.64	-2.45			-0.84					
	-2.65	-0.64	+2.45			+0.84					
d^2	7.0225	0.4096	6.0025			0.7056					
d^2/m: Empty	0.1740	0.1219	0.4463			0.1836	0.9258				
Full	0.1609	0.1125	0.4125			0.1696	0.8555				
Total	0.3349	0.2344	0.8588			0.3532	1.7813				

Females: chi-squared = 1.7813
df = 5
P is between .70 and .50

Males: nil

In these tables, columns 1 - 6, 8, and 9, show the numbers of empty stomachs and the types of food found in full stomachs of fish at the various stages of sexual maturity; columns 7 and 10 give the totals for females and males respectively; and column 11 the percentage of full stomachs containing each of the three main types of food.

From these tables it will be observed that:

1. In the Baynes sound and Boat harbour regions approximately 75% of the stomachs examined were empty, while in the Porlier pass area only 51% were empty. It should be pointed out that in this last area the fish found were largely immature and spent females.

2. During the winter months, at least, the food of the lemon sole consists mainly of worms, clams, and brittle-stars. The worms were a species of Polychaete, but were not identified further. These worms formed the predominant food in all three regions. Small whole clams were found in the stomachs of many fish, while in others only clam siphons occurred. Brittlestars were found in many of the stomachs of those fish from the more southern parts of the gulf in which area they were found more frequently than clams.

3. As full sexual maturity was reached these fish, especially the females ceased to feed and continued to fast till spawning was completed. Of the stomachs of 414 immature and 173 spent females examined 150 and 76 respectively were full, while only 2 out of 185 stomachs of fully matured or running females contained any food.

To determine whether the differences observed in the numbers of full and empty stomachs found between fish at the various stages of sexual maturity were significant, chi-squared tests were applied to the data for females shown in these tables. In each case the P value obtained was less than .01 (with the exception of fish in Porlier pass). In order to be sure that any distortions produced by having only small numbers of fish represented at certain stages of maturity were not unduly influencing the significance of the results, the females were divided into three groups, immature, mature, and spent females, and the chi-squared tests again applied. (Tables XXVI and XXVII). Fish in sexual categories I - III were classed as immature, those in categories IV and V as mature, those in category VI as spent. The P values obtained were again considerably less than .01. This would indicate that the differences in the numbers of full and empty stomachs found as maturity was reached were significant and not due to chance selection of the fish. This last test was applied to fish from the Baynes sound and Boat harbour regions only. It could not be applied to fish from Porlier pass as no fully matured females were found there. Similar tests were applied to the data for males in the Baynes sound and Boat harbour regions. It was again demonstrated that the fully matured fish feed less actively than the immature fish. However, food was found in only 13% of the stomachs of males in the Baynes sound region and in only 8% of those in the Boat harbour region.

TABLE XXVI
BAYNES SOUND

	Immature	Mature	Spent	Total
Empty:				
Observed No. (x)	365	127	63	555
Expected No. (m)	363.26	103.36	88.38	
Full:				
Observed No. (x)	120	11	55	186
Expected No. (m)	121.74	34.64	29.62	
Total	485	138	118	741
d	+1.74	+23.64	-25.38	
	-1.74	-23.64	+25.38	
d^2	3.0276	558.8496	644.1444	
d^2/m: Empty	0.0083	5.4068	7.2884	12.7035
Full	0.0249	16.1331	21.7469	37.9049
Total	0.0332	21.5399	29.0353	50.6084

chi-squared = 50.6034; df = 2; P is less than .01

TABLE XXVII
BOAT HARBOUR

	Immature	Mature	Spent	Total
Empty:				
Observed No. (x)	173	283	28	484
Expected No. (m)	204.37	246.28	33.35	
Full:				
Observed No. (x)	66	5	11	82
Expected No. (m)	34.63	41.72	5.65	
Total	239	288	39	566
d	-31.37	+36.72	-5.35	
	+31.37	-36.72	+5.35	
d^2	984.0769	1348.3584	28.6225	
d^2/m: Empty	4.8152	5.4749	0.8582	11.1483
Full	28.4169	32.3192	5.0659	65.8020
Total	33.2321	37.7941	5.9241	76.9503

chi-squared = 76.9503; df = 2; P is less than .01

From the foregoing it appears that:

1. Lemon sole do not feed very actively during the winter. This is shown by the large proportion of empty stomachs found.

2. Fully matured fish feed less actively than immature or spent individuals.

3. The main food of the lemon sole on or near the spawning grounds were worms, clams, and brittlestars. Worms were the predominant food in both regions, clams ranked second in the more northern area, and brittlestars in the more southern.

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SUMMARY

1. The fishery for lemon sole is one of the most important winter fisheries in the gulf of Georgia.

2. This fishery is dependent upon populations of lemon sole spawning in the Baynes sound and Boat harbour regions. The fact that 80% of the total landings of lemon sole for the first three months of 1946 came from these two regions shows this.

3. The Baynes sound and Boat harbour regions are shown to be the two major lemon sole spawning grounds in the gulf of Georgia. A third small spawning ground lies off point Atkinson.

4. In both regions spawning took place from January through to March; the peak period was from approximately

January 24 to February 23 in the Baynes sound region and from January 15 to the middle of February in the Boat harbour region. The number of samples taken in February and March was not large enough to permit very accurate limits to be set to the end of the spawning period in either region.

5. Active spawning was found to be more intense in certain areas of each region than in others, although some spawning took place generally throughout the whole of both regions. The areas of Fanny bay and cape Lazo were found to be the areas of most active spawning in the Baynes sound region, while the areas of Boat harbour, centre drag, and De Courcy island formed the areas of most active spawning in the Boat harbour region. No evidence that spawning took place was found for Porlier pass.

6. The fishing intensities in the Baynes sound and Boat harbour regions were found to be 42% and 26.3% respectively for January, February, and March, 1946. These were calculated from the tag returns which were weighted so as to compensate for the fact that the tags were put out while the fishery was in progress. Fishing mortality, natural mortality, and the amount of annual recruitment cannot be calculated from the present data. However, minimum estimates can be obtained which suggest that the fishing intensities are probably too heavy to maintain the fishery at its present level of production.

7. Fifty-eight of the tags put out in the Boat harbour region were recovered from that region in January and February,

1947. This represents a percentage recovery of 6.3% as compared to 18.8% for the same period in the previous year. No tags were recovered from the Baynes sound region in this same period. This was no doubt largely accounted for by the closure to trawling of all areas with the exception of cape Lazo and Comox bay.

8. From the 1947 Boat harbour tag recoveries the average annual length increment of lemon sole was found to be 23.9 mm. representing an average annual increase in length of 7.3% or in weight of 21.9%.

9. No fish tagged in the Baynes sound region were recovered outside that area. The conclusion was that the lemon sole from this area probably dispersed over that part of the gulf of Georgia north of Nanoose bay, a part of the gulf which is not heavily fished by trawlers. Fish tagged in the Boat harbour region dispersed southward. On the eastern side of the gulf tags were recovered as far south as Bellingham bay, point Roberts, and the mouth of the Fraser river, and on the western side as far south as Active pass and Swanson channel.

10. The lack of returns of fish tagged on one spawning ground from the other grounds indicates that the populations of fish spawning on these grounds do not mix to any appreciable extent.

11. The composition of the populations spawning in Baynes sound and Boat harbour were very similar, with the exception

that there were present in Baynes sound a larger number of immature fish and of mature fish of less than 300 mm. in length. The population at Porlier pass differed from the others in consisting largely of immature fish.

12. An attempt was made to determine the changes occurring in the populations of lemon sole on each spawning ground. The returns per period were expressed as if a constant number of fish were tagged each time and a constant weight of fish caught each period. Variations in the returns per period for the Baynes sound region expressed in this manner lead to the following conclusions:

1. The population present on the ground consisted of a small resident population and a much larger migratory population.
2. A general emigration of lemon sole began about the end of February, however, some of the fish present on the ground at the start of the season had started to leave by the middle of February.
3. There was apparently a migration to and accumulation of fish in Deep and Fanny bays prior to emigration.

In the Boat harbour region variations in returns per period indicate that the lemon sole did not emigrate en masse at one time but were continuously leaving the grounds during February and March. The conclusions based on this method of tag analysis should be treated with a certain amount of caution, as they are largely based on theoretical conditions and require more extensive data to substantiate them.

13. The analyses of the stomach contents of lemon sole on the spawning grounds showed that:

1. The main food of the lemon sole on the spawning grounds consists of worms, clams, and brittlestars.
2. The lemon sole do not feed very actively during the winter. Approximately 75% of the stomachs examined were empty.
3. Fully matured fish feed less actively than immature or spent individuals.

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APPENDIX

TABLE I

BAYNES SOUND PERIOD I JANUARY 1 - 15, 1946

BOAT	DATE	AREA	HOURS FISHED	CATCH	CATCH CORRECTED BY PERIOD FACTOR	CATCH CORRECTED BY BOAT FACTOR
Welcome Pass	Jan. 6	Fanny bay	9:00	1,400	1,427	1,470
	Jan. 7	Fanny bay	10:00	900	918	946
	Jan. 8	Yellow rocks	11:00	2,100	2,140	2,205
	Jan. 9	Union bay	10:00	1,500	1,530	1,575
	Jan.10	cape Lazo	6:00	700	714	735
Emma K.	Jan. 3	Union bay	6:00	700	714	693
	Jan. 4	Ship pen.	3:00	700	714	693
	Jan. 5	Comox bay	2:00	150	153	148
	Jan. 5	cape Lazo	4:00	400	408	396
	Jan. 5	Union bay	2:00	350	357	347
	Jan. 6	Fanny bay	4:00	650	663	644
	Jan. 6	Union bay	2:00	350	357	347
	Jan. 7	Union bay	6:00	900	918	891
	Jan. 7	Comox bay	2:00	300	306	297
	Jan. 8	cape Lazo	4:00	400	408	396
	Jan. 8	Union bay	2:00	200	204	198
	Jan. 9	Fanny bay	4:00	700	714	693
	Jan. 9	Union bay	2:00	200	204	198
Phyllis Carlyle	Jan. 4	Tagging	2:45	485	495	660
	Jan. 5	Tagging	2:40	210	214	286
	Jan.12	Tagging	4:00	280	286	381
Total			98:30	13,575	13,844	14,199

Period factor: 1.02

Boat factor:
- Welcome Pass 1.05
- Emma K. 0.99
- Phyllis Carlyle 1.36

TABLE II

BAYNES SOUND PERIOD II JANUARY 16 - 31, 1946

BOAT	DATE	AREA	HOURS FISHED	CATCH	CATCH CORRECTED BY PERIOD FACTOR	CATCH CORRECTED BY BOAT FACTOR
Welcome Pass	Jan.18	Yellow rocks	8:00	1,200	1,209	1,260
	Jan.19	Fanny bay	10:00	1,400	1,410	1,470
	Jan.21	Henry bay	10:00	750	755	788
	Jan.22	Yellow rocks	8:00	900	906	946
Endvour	Jan.25	Union bay	4:30	1,000	1,006	880
	Jan.26	Union bay	3:30	500	504	440
	Jan.27	Union bay	3:30	500	504	440
	Jan.27	Union bay to Denman	2:00	500	504	440
	Jan.28	Deep bay to Denman	5:00	1,500	1,510	1,320
	Jan.29	Deep bay to Denman	3:30	750	755	660
Optu	Jan.27	Comox bar	1:30	---	---	---
	Jan.27	Goose spit	3:45	225	227	230
	Jan.27	Comox bar	1:45	212	213	216
	Jan.28	Ship pen.	1:45	100	100	102
Phyllis Carlyle	Jan.16	Tagging	0:45	30	30	41
	Jan.18	Tagging	2:00	350	353	476
	Jan.19	Tagging	1:00	300	302	408
	Jan.25	Tagging	2:15	200	201	272
	Jan.24	Tagging	1:45	300	302	408
	Jan.28	Tagging	2:00	200	201	272
	Jan.29	Tagging	2:30	165	166	224
Total			79:00	11,082	11,158	11,293

Period factor:		1.006
Boat factor:	Endvour	0.88
	Phyllis Carlyle	1.36
	Welcome Pass	1.05
	Optu (Pooled)	1.02

Availability 142.9

TABLE III

BAYNES SOUND PERIOD III FEBRUARY 1 - 15, 1946

BOAT	DATE	AREA	HOURS FISHED	CATCH	CATCH CORRECTED BY PERIOD FACTOR	CATCH CORRECTED BY BOAT FACTOR
Endvour	Feb. 7	Deep bay to Denman wharf	6:00	1,500	1,140	1,320
	Feb. 8	Deep bay to Denman wharf	6:00	750	570	660
	Feb. 9	Deep bay to Denman wharf	6:00	1,000	760	880
	Feb.10	Deep bay to Denman wharf	5:30	750	570	660
	Feb.13	Deep bay to Denman wharf	5:00	1,500	1,140	1,320
	Feb.14	Deep bay to Denman wharf	2:00	500	380	440
	Feb.15	Deep bay to Denman wharf	7:00	1,000	760	880
Total			37:30	7,000	5,320	6,160

Period factor: 0.76
Boat factor: Endvour 0.88

Availability 164.3

TABLE IV

BAYNES SOUND PERIOD IV FEBRUARY 16 - 28, 1946

BOAT	DATE	AREA	HOURS FISHED	CATCH	CATCH CORRECTED BY PERIOD FACTOR	CATCH CORRECTED BY BOAT FACTOR
Endvour	Feb.16	Deep bay to Denman wharf	8:00	1,000	970	880
	Feb.17	Deep bay to Denman wharf	4:00	300	291	264
	Feb.26	Deep bay to Denman wharf	7:00	1,000	970	880
	Feb.27	Deep bay to Denman wharf	6:00	1,500	1,455	1,320
	Feb.28	Deep bay to Denman wharf	5:00	1,000	970	880
Mary Rita	Feb.18	cape Lazo	4:00	525	509	536
	Feb.23	Baynes sound	1:00	100	97	102
	Feb.24	cape Lazo	3:00	275	267	281
Phyllis Carlyle	Feb.17	Deep bay	3:30	200	194	272
	Feb.17	Fanny bay	5:30	600	582	816
	Feb.18	Fanny bay	4:00	400	388	544
	Feb.18	cape Lazo	4:00	500	485	680
	Feb.19	cape Lazo	4:00	300	291	408
	Feb.19	cape Lazo	4:00	800	776	1,088
	Feb.20	Fanny bay	7:00	300	291	408
	Feb.21	Fanny bay	1:45	50	48	68
	Feb.26	Deep bay	1:45	100	97	136
	Feb.27	Deep bay	1:15	100	97	136
	Feb.27	cape Lazo	6:00	900	873	1,225
	Feb.28	cape Lazo	7:30	800	776	1,088
Good Hope II	Feb.18	cape Lazo	3:00	150	145	153
Izumi II	Feb.25	Deep bay	2:00	700	679	378
	Feb.26	Deep bay	2:00	200	194	108
	Feb.27	Deep bay to Union bay	1:00	600	582	324
	Feb.28	Deep bay to Union bay	2:00	1,000	970	540

TABLE IV (Continued)

BAYNES SOUND PERIOD IV FEBRUARY 16 - 28, 1946

BOAT	DATE	AREA	HOURS FISHED	CATCH	CATCH CORRECTED BY PERIOD FACTOR	CATCH CORRECTED BY BOAT FACTOR
Ray Roberts	Feb.16	Deep bay and Union bay	3:30	730	308	745
	Feb.17	Union bay and cape Lazo	4:00	600	582	612
	Feb.18	cape Lazo	7:00	1,700	1,650	1,735
	Feb.19	cape Lazo	4:00	800	776	816
Reubina	Feb.25 - 28	------------	7:45	912	884	1,085
Total			124:30	18,142	17,597	18,508

Period factor: 0.97

Boat factor:
- Endvour 0.88
- Phyllis Carlyle 1.36
- Reubina 1.19
- Izumi II 0.54
- Mary Rita) Good Hope II) Ray Roberts) pooled 1.02

Availability 148.7

TABLE V

BAYNES SOUND PERIOD V MARCH 1 - 15, 1946

BOAT	DATE	AREA	HOURS FISHED	CATCH	CATCH CORRECTED BY PERIOD FACTOR	CATCH CORRECTED BY BOAT FACTOR
Endvour	Mar. 1	Denman	1:00	200	206	176
	Mar. 2	Deep bay to Denman wharf	3:30	200	206	176
	Mar. 2	cape Lazo	3:30	1,000	1,030	880
	Mar. 3	cape Lazo	4:30	400	412	352
Phyllis Carlyle	Mar. 1	Fanny bay	2:00	100	103	136
	Mar. 2	Deep bay	1:30	100	103	136
Izumi II	Mar. 5	Deep bay	2:00	1,000	1,030	540
	Mar. 6	Deep bay	1:00	400	412	216
	Mar. 7	Deep bay	2:00	---	---	---
	Mar. 7	Deep bay	2:00	500	515	270
	Mar. 8	Deep bay	2:00	400	412	216
	Mar. 9	Deep bay	2:00	400	412	216
	Mar.10	Deep bay	2:00	---	---	---
Reubina	Mar. 1 - 14	------------	34:15	3,965	4,085	4,720
Total			63:15	8,665	8,926	8,034

Period factor:		1.03
Boat factor:	Endvour	0.88
	Phyllis Carlyle	1.36
	Izumi II	0.54
	Reubina	1.19
Availability		127.0

TABLE VI

BAYNES SOUND PERIOD VI MARCH 16 - 31, 1946

BOAT	DATE	AREA	HOURS FISHED	CATCH	CATCH CORRECTED BY PERIOD FACTOR	CATCH CORRECTED BY BOAT FACTOR
Endvour	Mar.16	Deep bay to Denman wharf	3:00	100	184	88
	Mar.17	cape Lazo	3:00	100	184	88
	Mar.18	Union bay and cape Lazo	6:00	200	368	176
	Mar.19	cape Lazo	6:00	1,000	1,840	880
Phyllis Carlyle	Mar.19	Comox bar	3:30	300	552	408
	Mar.19	Comox bar	2:00	100	184	136
	Mar.19	Yellow rocks	1:00	80	147	109
Total			24:30	1,880	3,459	1,885

Period factor: 1.84

Boat factor: Endvour 0.88

Phyllis Carlyle 1.36

Availability 76.9

TABLE VII

BOAT HARBOUR PERIOD A DECEMBER 15 - 31, 1945

BOAT	DATE	AREA	HOURS FISHED	CATCH	CATCH CORRECTED BY PERIOD FACTOR	CATCH CORRECTED BY BOAT FACTOR
Phyllis Carlyle	Dec.28	Boat harbour	1:20	400	176	448
	Dec.28	Boat harbour	:45	200	88	224
	Dec.28	De Courcy Island	1:15	400	176	448
	Dec.29	Boat harbour	:30	200	88	224
	Dec.29	Pylades Channel	:35	75	33	84
Total			4:25	1,275	561	1,428

Period factor: 0.44
Boat factor: Phyllis Carlyle 1.12

Availability 323.1

TABLE VIII

BOAT HARBOUR PERIOD I JANUARY 1 - 15, 1946

BOAT	DATE	AREA	HOURS FISHED	CATCH	CATCH CORRECTED BY PERIOD FACTOR	CATCH CORRECTED BY BOAT FACTOR
Curlew M.	Jan. 4	Boat harbour	2:00	450	382.5	486
	Jan. 5	Boat harbour	8:00	1,000	850	1,080
	Jan. 6	Boat harbour	7:30	1,250	1,062.5	1,350
	Jan. 7	Boat harbour	4:30	570	484.5	615.6
B. C. Girl	Jan.14	Boat harbour	10:00	1,000	850	1,040
	Jan.15	Boat harbour	5:00	500	425	520
Chasam	Jan. 4	Boat harbour	8:00	2,000	1,700	1,940
	Jan. 5	Boat harbour	8:00	1,400	1,190	1,358
	Jan. 6	Boat harbour	4:00	700	595	679
	Jan. 7	Boat harbour	4:00	600	510	582
	Jan. 8	Boat harbour	8:00	1,000	850	970
	Jan. 9	Boat harbour	5:00	600	510	582
	Jan.10	Boat harbour	2:00	300	255	291
	Jan.14	Boat harbour	4:00	600	510	582
	Jan.15	Boat harbour	8:00	1,200	1,020	1,164
Phyllis Carlyle	Jan. 7	De Courcy island	:45	100	85	112
	Jan. 7	Boat harbour	:40	75	63.8	84
	Jan. 8	Pylades channel	:45	35	29.8	39.2
	Jan. 8	Centre drag	:45	200	170	224
	Jan.15	Centre drag	1:00	150	127.5	168
	Jan.15	De Courcy island	1:00	200	170	224
	Jan.15	Pylades channel	1:00	40	34	44.8
Total			93:55	13,970	11,874.6	14,135.6

Period factor:		0.85
Boat factor:	Curlew M.	1.08
	B. C. Girl	1.04
	Chasam	0.97
	Phyllis Carlyle	1.12

Availability

TABLE IX

BOAT HARBOUR PERIOD II JANUARY 16 - 31, 1946

BOAT	DATE	AREA	HOURS FISHED	CATCH	CATCH CORRECTED BY PERIOD FACTOR	CATCH CORRECTED BY BOAT FACTOR
Curlew M.	Jan.17	Boat harbour	7:30	815	749.8	880.2
	Jan.18	Boat harbour	7:00	825	759	891
B. C. Girl	Jan.19	Boat harbour	5:00	1,000	920	1,040
	Jan.20	Boat harbour	6:00	800	736	832
	Jan.23	Boat harbour	2:00	300	276	312
	Jan.24	Boat harbour	10:00	1,200	1,104	1,248
	Jan.25	Boat harbour	10:00	1,200	1,104	1,248
	Jan.27	Boat harbour	8:00	1,000	920	1,040
	Jan.28	Boat harbour	10:00	1,200	1,104	1,248
Chasam	Jan.18	Boat harbour	8:00	1,200	1,104	1,164
	Jan.19	Boat harbour	8:00	1,200	1,104	1,164
	Jan.23	Boat harbour	2:00	300	276	291
	Jan.24	Boat harbour	8:00	1,200	1,104	1,164
	Jan.27	Boat harbour	8:00	1,200	1,104	1,164
	Jan.28	Boat harbour	8:00	1,200	1,104	1,164
	Jan.29	Boat harbour	8:00	1,200	1,104	1,164
	Jan.30	Boat harbour	8:00	1,200	1,104	1,164
	Jan.31	Boat harbour	4:00	600	552	582
Phyllis Carlyle	Jan.20	Boat harbour	1:00	150	138	168
	Jan.20	Centre drag	1:00	150	138	168
	Jan.20	De Courcy island	1:00	200	184	224
	Jan.21	Pylades channel	:45	60	55.2	67.2
	Jan.26	Boat harbour	1:00	150	138	168
	Jan.26	Centre drag	1:00	150	138	168
	Jan.26	De Courcy island	1:00	200	184	224
	Jan.26	Pylades channel	1:00	50	46	56
	Jan.30	De Courcy island	1:00	200	184	224
	Jan.30	Pylades channel	1:00	75	69	84
	Jan.31	Boat harbour	1:00	150	138	168
	Jan.31	Centre drag	1:00	60	55.2	67.2
Total			139:15	19,235	17,696.2	19,546.6

TABLE IX (Continued)

BOAT HARBOUR PERIOD II JANUARY 16 - 31, 1946

Period factor:		0.92
Boat factor:	Curlew M.	1.08
	B. C. Girl	1.04
	Chasam	0.97
	Phyllis Carlyle	1.12
Availability		140.4

TABLE X

BOAT HARBOUR PERIOD III. FEBRUARY 1 - 15, 1946

BOAT	DATE	AREA	HOURS FISHED	CATCH	CATCH CORRECTED BY PERIOD FACTOR	CATCH CORRECTED BY BOAT FACTOR
Norpack	Feb.10 - ?	Boat harbour	14:00	2,500	2,400	1,850
Phyllis Carlyle	Feb. 7	De Courcy island & Centre drag	4:30	300	288	336
	Feb. 8	De Courcy island & Centre drag	8:30	1,200	1,152	1,344
	Feb. 9	De Courcy island & Centre drag	4:30	400	384	448
	Feb.14	De Courcy island	2:30	300	288	336
	Feb.15	Boat harbour	2:00	200	192	224
B. C. Girl	Feb. 3	Boat harbour	5:00	800	768	832
	Feb. 4	Boat harbour	5:00	900	864	936
	Feb. 5	Boat harbour	8:00	1,000	960	1,040
	Feb. 6	Boat harbour	8:00	1,200	1,152	1,248
Chasam	Feb. 4	Boat harbour	4:00	600	576	582
	Feb. 5	Boat harbour	2:00	300	283	291
	Feb. 6	Boat harbour	9:00	1,300	1,248	1,261
	Feb. 7	Boat harbour	9:00	1,200	1,152	1,164
	Feb. 8	Boat harbour	9:00	1,600	1,536	1,152
	Feb. 9	Boat harbour	9:00	1,100	1,056	1,067
	Feb.10	Boat harbour	9:00	1,200	1,152	1,164
Norma N.	Feb. 8	Boat harbour	7:00	325	312	796.3
Good Hope I	Feb.14	Gabriola channel	2:15	---	---	---
Ray Roberts	Feb. 4	Boat harbour	1:15	100	96	245
	Feb. 6	Boat harbour	2:00	400	384	980
	Feb. 7	Boat harbour	4:00	200	192	490
Total			129:30	17,125	16,440	17,786.3

Period factor: 0.96 Boat factor: Chasam 0.97 Availability 137.3

Boat factor: Norpack 0.74

Phyllis Carlyle 1.12 pooled (Norma N.) (Good Hope I) (Ray Roberts) 2.45

B. C. Girl 1.04

TABLE XI

BOAT HARBOUR PERIOD IV FEBRUARY 16 - 28, 1946

BOAT	DATE	AREA	HOURS FISHED	CATCH	CATCH CORRECTED BY PERIOD FACTOR	CATCH CORRECTED BY BOAT FACTOR
Chasam	------	Boat harbour	2:00	300	351	291
	Feb.21	Boat harbour	9:00	1,200	1,404	1,164
	Feb.22	Boat harbour	9:00	1,200	1,404	1,164
	Feb.23	Boat harbour	9:00	1,400	1,638	1,358
Good Hope II	Feb.19	Boat harbour	2:45	75	87.8	183.8
Norma N.	Feb.21	Boat harbour	4:30	85	99.5	208.3
Good Hope I	Feb.19	Boat harbour	2:00	50	58.5	122.5
Endvour	Feb.25	Boat harbour	2:00	50	58.5	122.5
Total			40:15	4,360	5,101.3	4,614.1

Period factor: 1.17

Boat factor: Chasam 0.97

Norma N.)
Good Hope I) pooled 2.45
Good Hope II)
Endvour)

Availability 114.6

TABLE XII

BOAT HARBOUR PERIOD V MARCH 1 - 15, 1946

BOAT	DATE	AREA	HOURS FISHED	CATCH	CATCH CORRECTED BY PERIOD FACTOR	CATCH CORRECTED BY BOAT FACTOR
Pearse Island	Mar. 5	De Courcy island	2:00	50	254.0	122.5
Total			2:00	50	254.0	122.5

Period factor: 5.08

Boat factor: Pearse Island (pooled) 2.45

Availability 61.3

TABLE XIII

BOAT HARBOUR PERIOD VI MARCH 16 - 31, 1946

BOAT	DATE	AREA	HOURS FISHED	CATCH	CATCH CORRECTED BY PERIOD FACTOR	CATCH CORRECTED BY BOAT FACTOR
Alco	Mar.22	Gabriola	6:00	400	2,132	224
	Mar.23	Gabriola	3:00	50	266.5	28
	Mar.28	Boat harbour	10:00	400	2,132	224
	Mar.29	Boat harbour	3:00	80	426.4	44.8
Chasam	Mar.24	outside Porlier & Gabriola passes	9:00	---	---	---
	Mar.26	Yellow point	8:00	---	---	---
Total			39:00	930	4,956.9	520.8

Period factor: 5.33

Boat factor: Alco 0.56

Availability 13.4

TABLE XIV

COMPARISON OF "ENDVOUR'S" CATCHES IN PERIOD II AND PERIOD III

PERIOD II			PERIOD III		
DAILY CATCH x_1	$x_1-\bar{x}_1$	$(x_1-\bar{x}_1)^2$	DAILY CATCH x_2	$x_2-\bar{x}_2$	$(x_2-\bar{x}_2)^2$
222.22	+10.18	103.6324	250.00	+ 54.16	2,933.3056
142.86	-69.18	4,785.8724	125.00	- 70.84	5,018.3056
142.86	-69.18	4,785.8724	166.67	- 29.17	850.8889
250.00	+37.96	1,440.9616	136.36	- 59.48	3,537.8704
300.00	+87.96	7,736.9616	300.00	+104.16	10,849.3056
214.29	+ 2.25	5.0625	250.00	+ 54.16	2,933.3056
			142.86	- 52.98	2,806.8804
$S(x_1)$ 1,272.23		$S(x_1-\bar{x}_1)^2$ 18,858.35	$S(x_2)$ 1,370.89		$S(x_2-\bar{x}_2)^2$ 28,929.88
$\bar{x}_1 = \frac{1,272.23}{6} = 212.04$			$\bar{x}_2 = \frac{1,370.89}{7} = 195.84$		

$$s^2 = \frac{1}{(N_1-1)(N_2-1)}\left\{S(x_1-\bar{x}_1)^2 + S(x_2-\bar{x}_2)^2\right\} = \frac{1}{5+6}\left\{18,858.35 + 28.929.88\right\} = \frac{47,788.23}{11}$$

$N = 5 + 6 = 11$ $\qquad\qquad = 4,344.38$

$s = 65.9$

$$t = \frac{212.04 - 195.84}{65.9}\sqrt{\frac{6 \times 7}{5+6+2}} = \frac{16.20}{65.9}\sqrt{\frac{42}{13}} = \frac{16.20}{65.9}\sqrt{3.2307} = \frac{16.20}{65.9} \times 1.79 = \frac{28.9980}{65.9} = .44$$

P = between .6 and .7

TABLE XV

COMPARISON OF "ENDVOUR'S" CATCHES IN PERIOD III AND PERIOD IV

PERIOD III			PERIOD IV		
DAILY CATCH x_1	$x_1-\bar{x}_1$	$(x_1-\bar{x}_1)^2$	DAILY CATCH	$x_2-\bar{x}_2$	$(x_2-\bar{x}_2)^2$
250.00	+ 54.16	2,933.3056	200.00	+ 31.43	987.8449
125.00	- 70.84	5,018.3056	300.00	+131.43	17,273.8449
166.67	- 29.17	850.8889	142.86	- 25.71	661.0041
136.36	- 59.48	3,537.8704	75.00	- 93.57	8,755.3449
300.00	+104.16	10,849.3056	125.00	- 43.57	1,898.3449
250.00	+ 54.16	2,933.3056			
142.86	- 52.98	2,806.8804			
$S(x_1)$ 1,370.89		$S(x_1-\bar{x}_1)^2$ 28,929.88	$S(x_2)$ 842.86		$S(x_2-\bar{x}_2)^2$ 29,576.36

$\bar{x}_1 = \frac{1370.89}{7} = 195.84$

$\bar{x}_2 = \frac{842.86}{5} = 168.57$

$$s^2 = \frac{1}{(N_1-1)(N_2-1)}\left\{S(x_1-\bar{x}_1)^2 - S(x_2-\bar{x}_2)^2\right\} = \frac{1}{6+4}\left(28,929.88 + 29,576.36\right) = \frac{58,506.24}{10}$$

$N = N_1 + N_2 = 4 + 6 = 10$

$$= 5,850.62$$

$s = 76.4$

$$t = \frac{195.84 - 168.57}{76.4}\sqrt{\frac{7 \times 5}{6+4+2}} = \frac{27.27}{76.4}\sqrt{\frac{35}{12}} = \frac{27.27}{76.4}\sqrt{2.9166} = \frac{27.27}{76.4} \times 1.71 = \frac{46.63}{76.4}$$

$$= .6063$$

$P =$ between .5 and .6

TABLE XVI

CHI-SQUARED CALCULATIONS DEEP BAY - FANNY BAY

Area	Spawning Condition						
	I	II	III	IV	V	VI	Total
DB	37	13	71	5	4	10	140
FB	29	8	57	19	14	2	129
	66	21	128	24	18	12	269

Expected Values: m

	I	II	III	IV	V	VI
DB	34.32	10.92	66.56	12.48	9.36	6.24
FB	31.68	10.08	61.44	11.52	8.64	5.76

Table of x

	I	II	III	IV	V	VI
DB	+2.7	+2.1	+4.4	-7.5	-5.4	+3.8
FB	-2.7	-2.1	-4.4	+7.5	+5.4	+3.8

Table of x^2

	I	II	III	IV	V	VI
DB	7.29	4.41	19.36	56.25	29.16	14.44
FB	7.29	4.41	19.36	56.25	29.16	14.44

Table of $\frac{x^2}{m}$

	I	II	III	IV	V	VI	Total
DB	0.2124	0.4038	0.2909	4.4072	3.1154	2.3141	10.7438
FB	0.2301	0.4375	0.3151	4.8828	3.3750	2.5069	11.7474
	0.4425	0.8413	0.6060	9.2900	6.4904	4.8210	22.4912

chi-squared = 22.4912 degrees of freedom = 5

P is less than .01

Continuity Correction

Area	Spawning Condition						
	I	II	III	IV	V	VI	Total
Table of x1 corrected (x-.5)							
DB	+2.2	+1.6	+3.9	-7.0	-4.9	+3.3	
FB	-2.2	-1.6	-3.9	+7.0	+4.9	-3.3	

Table of $(x^1)^2$

	I	II	III	IV	V	VI
DB	4.84	2.56	15.21	49.00	24.01	10.89
FB	4.84	2.56	15.21	49.00	24.01	10.89

Table of $\frac{(x^1)^2}{m}$

	I	II	III	IV	V	VI	Total
DB	0.1410	0.2344	0.2285	3.9263	2.5652	1.7452	8.8406
FB	0.1528	0.2539	0.2476	4.2535	2.7789	1.8906	9.5773
	0.2938	0.4883	0.4761	8.1798	5.3441	3.6358	18.4179

chi-squared = 18.4179 degrees of freedom = 5

P is less than .01

TABLE XVII

CHI-SQUARED CALCULATIONS DEEP BAY - CAPE LAZO

Area	Spawning Condition I	II	III	IV	V	VI	Total
DB	37	13	71	5	4	10	140
CL	2	4	16	17	21	2	62
	39	17	87	22	25	12	202
Expected Values: m							
DB	27.03	11.78	60.29	15.25	17.33	8.32	
CL	11.97	5.22	26.71	6.75	7.68	3.68	
Table of x							
DB	+10.0	+1.2	+10.7	-10.3	-13.3	+1.7	
CL	-10.0	-1.2	-10.7	+10.3	+13.3	-1.7	
Table of x^2							
DB	100.00	1.44	114.49	106.09	176.89	2.89	
CL	100.00	1.44	114.49	106.09	176.89	2.89	
Table of x^2/m							
DB	3.6996	0.1222	1.8989	6.9567	10.2072	0.3474	23.2320
CL	8.3542	0.2759	4.2864	15.7170	23.0326	0.7853	52.4514
	12.0538	0.3981	6.1853	22.6737	33.2398	1.1327	75.6834

chi-squared = 75.6834 degrees of freedom = 5

P is less than .01

Continuity Correction

Area	Spawning Condition I	II	III	IV	V	VI	Total
Table of x^1 corrected $(x-.5)$							
DB	+9.5	+0.7	+10.2	-9.8	-12.8	-1.2	
CL	-9.5	-0.7	-10.2	+9.8	+12.8	+1.2	
Table of $(x^1)^2$							
DB	90.25	0.49	104.04	96.04	163.84	1.44	
CL	90.25	0.49	104.04	96.04	163.84	1.44	
Table of $(x^1)^2/m$							
DB	3.3389	0.0416	1.7259	6.2977	9.4541	0.1731	21.0311
CL	7.5397	0.0939	3.8952	14.2281	21.3333	0.3913	47.4815
	10.8786	0.1355	5.6209	20.5258	30.7874	0.5654	68.5126

chi-squared = 68.5126 degrees of freedom = 5

P is less than .01

TABLE XVIII

CHI-SQUARED CALCULATIONS FANNY BAY - CAPE LAZO

Area	Spawning Condition I	II	III	IV	V	VI	Total
FB	29	8	57	19	14	2	129
CL	2	4	16	17	21	2	62
	31	12	73	36	35	4	191
	Expected Values: m						
FB	20.93	8.10	49.28	24.30	23.63	2.70	
CL	10.08	3.90	23.73	11.70	11.38	1.30	
	Table of x						
FB	+8.1	-.1	+7.7	-5.3	--9.6	-.7	
CL	-8.1	+.1	-7.7	+5.3	+9.6	+.7	
	Table of x^2						
FB	65.61	0.01	59.29	28.09	92.16	0.49	
CL	65.61	0.01	59.29	28.09	92.16	0.49	
	Table of x^2/m						
FB	3.1347	0.0012	1.2031	1.1559	3.9001	0.1815	9.5765
CL	6.5089	0.0026	2.4985	2.4008	8.0984	0.3769	19.8861
	9.6436	0.0038	3.7016	3.5567	11.9985	0.5584	29.4626

chi-squared = 29.4626 degrees of freedom = 5

P is less than .01

Continuity Correction

Area	Spawning Condition I	II	III	IV	V	VI	Total
Table of x^1 corrected							
FB	+7.6		+7.2	-4.8	-9.1	-.2	
CL	-7.6		-7.2	+4.8	+9.1	+.2	
Table of $(x^1)^2$							
FB	57.76	----	51.84	23.04	82.81	.04	
CL	57.76	----	51.84	23.04	82.81	.04	
Table of $(x^1)^2/m$							
FB	2.7597	------	1.0519	0.9481	3.5044	0.0148	8.2789
CL	5.7302	------	2.1846	1.9692	7.2768	0.0308	17.1916
	8.4899	------	3.2365	2.9173	10.7812	0.0456	25.4705

chi-squared = 25.4705 degrees of freedom = 4

P is less than .01

TABLE XIX

CHI-SQUARED CALCULATIONS BOAT HARBOUR - CENTRE DRAG - DE COURCY ISLAND

Area	Spawning Condition									
	Female							Male		
	I	II	III	IV	V	VI	Total	I	V	Total
BH	0	0	25	43	28	2	98	2	100	102
CD	2	0	61	42	36	7	148	2	68	70
BI	0	0	31	55	44	6	136	0	60	60
	2	0	117	140	108	15	382	4	228	232
Expected Values: m										
BH	.51	0	30.02	35.91	27.71	3.85		1.76	100.24	
CD	.77	0	45.33	54.24	41.84	5.81		1.21	68.79	
DI	.71	0	41.65	49.84	38.45	5.34		1.03	58.97	
Table of x										
BH	- .51	0	- 5.02	+ 7.09	+ .29	-1.85		+ .24	- .24	
CD	+1.23	0	+15.67	-12.24	-5.84	+1.19		+.79	- .79	
DI	- .71	0	-10.65	+ 5.16	+5.55	+ .66		-1.03	+1.03	
Table of x^2										
BH	.2601	0	25.2004	50.2681	.0841	2.3225		.0576	.0576	
CD	1.5129	0	245.5489	149.8176	34.1056	1.4161		.6241	.6241	
DI	.5041	0	113.4225	26.6256	30.8025	.4356		1.0609	1.0609	
Table of x^2/m										
BH	.5100	0	.8395	1.3998	.0030	.6032		.0327	.0006	
CD	1.9635	0	5.4169	2.7621	.8151	.2437		.0516	.0091	
DI	.7100	0	2.7232	.5342	.8011	.0816		1.0300	.1799	
	3.1835	0	8.9796	4.6961	1.6192	.9285		1.1143	.1896	

Female:
chi-squared = 19.4069
df = 10
P is between .05 and .01

Male:
chi-squared = 1.3039
df = 2
P = .50

TABLE XX

CHI-SQUARED CALCULATIONS PYLADES CHANNEL - PORLIER PASS

Area	Spawning Condition									
	Female							Male		
	I	II	III	IV	V	VI	Total	I	V	Total
PC	18	3	48	6	0	7	82	16	20	36
PP	81	7	29	0	0	9	126	3	0	3
	99	10	77	6	0	16	208	19	20	39
Expected Values: M										
PC	39.03	3.94	30.36	2.37	0	6.31		17.54	18.46	
PP	59.97	6.06	46.64	3.63	0	9.69		1.46	1.54	
Table of x										
PC	-21.03	-.94	+17.64	+3.63	0	+.69		-1.54	+1.54	
PP	+21.03	+.94	-17.64	-3.63	0	-.69		+1.54	-1.54	
Table of x^2										
PC	422.2609	.8836	311.1696	13.1769	0	.4761		2.3716	2.3716	
PP	422.2609	.8836	311.1696	13.1769	0	.4761		2.3716	2.3716	
Table of x^2/m										
PC	10.8189	.2243	10.2493	5.5599	0	.0755		.1352	.1285	
PP	7.0412	.1458	6.6717	3.6300	0	.0491		1.6244	1.5400	
	17.8601	.3701	16.9210	9.1899	0	.1246		1.7596	1.6635	

Female:
chi-squared = 44.4657
df = 5
P is less than .01

Male:
chi-squared = 3.4281
df = 1
P is between .10 and .05

TABLE XXI

CHI-SQUARED CALCULATIONS CENTRE DRAG - PYLADES CHANNEL

Area	Spawning Condition I	II	III	IV	V	VI	Total
CD	2	0	61	42	36	7	148
PC	23	3	56	8	3	17	110
	25	3	117	50	39	24	258
Expected Values: m							
CD	14.35	1.72	67.16	28.70	22.39	13.78	
PC	10.65	1.28	49.84	21.3	16.61	10.22	
Table of x							
CD	-12.6	-1.7	-6.2	+13.3	+13.6	-6.8	
PC	+12.6	+1.7	+6.2	-13.3	-13.6	+6.8	
Table of x^2							
CD	158.76	2.89	38.44	176.89	184.96	46.24	
PC	158.76	2.89	38.44	176.89	184.96	46.24	
Table of x^2/m							
CD	11.0634	1.6802	0.5724	6.1634	8.2608	3.3556	
PC	14.9070	2.2578	0.7713	8.3047	11.1355	4.5245	
	25.9704	3.9380	1.3437	14.4681	19.3963	7.8801	72.9966

chi-squared = 72.9966 degrees of freedom = 5

P is less than .01

TABLE XXII

CHI-SQUARED CALCULATIONS BOAT HARBOUR - DE COURCY ISLAND

Area	Spawning Condition I	II	III	IV	V	VI	Total
BH	0	0	25	43	28	2	98
DI	0	0	31	55	44	6	136
	0	0	56	98	72	8	234
Expected Values: m							
BH	0	0	23.46	41.06	30.17	3.35	
DI	0	0	32.54	56.94	41.83	4.65	
Table of x							
BH	0	0	+1.5	+1.9	-2.2	-1.4	
DI	0	0	-1.5	-1.9	+2.2	+1.4	
Table of x^2							
BH	0	0	2.25	3.61	4.84	1.96	
DI	0	0	2.25	3.61	4.84	1.96	
Table of x^2/m							
BH	0	0	0.0959	0.0879	0.1604	0.5851	0.9293
DI	0	0	0.0691	0.0634	0.1157	0.4215	0.6697
	0	0	0.1650	0.1513	0.2761	1.0066	1.5990

chi-squared = 1.5990 degrees of freedom = 5

P is between .95 and .90

TABLE XXIII

CHI-SQUARED CALCULATIONS CENTRE DRAG - DE COURCY ISLAND

Area	Spawning Condition						
	I	II	III	IV	V	VI	Total
CD	2	0	61	42	36	7	148
DI	0	0	31	55	44	6	136
	2	0	92	97	80	13	284
Expected Values: m							
CD	1.04	0	47.93	50.54	41.68	6.77	
DI	.958	0	44.07	46.46	38.32	6.23	
Table of x							
CD	+1.0	0	+13.1	-8.5	-5.7	+.2	
DI	-1.0	0	-13.1	+8.5	+5.7	-.2	
Table of x^2							
CD	1.00	0	171.61	72.25	32.49	0.04	
DI	1.00	0	171.61	72.25	32.49	0.04	
Table of x^2/m							
CD	0.9615	0	3.5804	1.4296	0.7795	0.0059	6.7569
DI	1.0417	0	3.8940	1.5551	0.8479	0.0064	7.3451
	2.0032	0	7.4744	2.9847	1.6274	0.0123	14.1020

chi-squared = 14.1020 degrees of freedom = 5

P is between .02 and .01

Continuity Correction

Area	Spawning Condition						
	I	II	III	IV	V	VI	Total
Table of x^1 corrected							
CD	+0.5	0	+12.6	-8.0	-5.2	----	
DI	-0.5	0	-12.6	+8.0	+5.2	----	
Table of $(x^1)^2$							
CD	0.25	0	158.76	64.00	27.04	----	
DI	0.25	0	158.76	64.00	27.04	----	
Table of $(x^1)^2/m$							
CD	0.2404	0	3.3123	1.2663	0.6487	----	5.4677
DI	0.2604	0	3.6075	1.3775	0.7056	----	5.9510
	0.5008	0	6.9198	2.6438	1.3543	----	11.4387

chi-squared = 11.4387 degrees of freedom = 5

P is slightly less than .05

TABLE XXIV

CHI-SQUARED CALCULATIONS . BOAT HARBOUR - CENTRE DRAG

Area	Spawning Condition						
	I	II	III	IV	V	VI	Total
BH	0	0	25	43	28	2	98
CD	2	0	61	42	36	7	148
	2	0	86	85	64	9	246

	Expected Values: m					
BH	0.8	0	34.23	33.83	25.47	3.58
CD	1.20	0	51.77	51.17	38.53	5.42
	Table of x					
BH	-.8	0	-9.2	+9.2	+2.5	-1.6
CD	+.8	0	+9.2	-9.2	-2.5	+1.6
	Table of x^2					
BH	0.64	0	84.64	84.64	6.25	2.56
CD	0.64	0	84.64	84.64	6.25	2.56

	Table of x^2/m						
BH	0.8000	0	2.4727	2.5019	0.2454	0.7151	6.7351
CD	0.5333	0	1.5349	1.6541	0.1622	0.4723	4.3568
	1.3333	0	4.0076	4.1560	0.4076	1.1874	11.0919

chi-squared = 11.0919 degrees of freedom = 5

P = .05

Continuity Correction

Area	Spawning Condition						
	I	II	III	IV	V	VI	Total
Table of x^1 corrected							
BH	-0.3	0	-8.7	+8.7	+2.2	-1.1	
CD	+0.3	0	+8.7	-8.7	-2.2	+1.1	
Table of $(x^1)^2$							
BH	0.09	0	75.69	75.69	4.84	1.21	
CD	0.09	0	75.69	75.69	4.84	1.21	
Table of $(x^1)^2/m$							
BH	0.1125	0	2.2112	2.2374	0.1900	0.3379	5.0890
CD	0.0750	0	1.4620	1.4792	0.1256	0.2232	3.3650
	0.1875	0	3.6732	3.7166	0.3156	0.5611	8.4540

chi-squared = 8.4540 degrees of freedom = 5

P is between .20 and .10

TABLE XXV

CHI-SQUARED CALCULATIONS BOAT HARBOUR - PORLIER PASS

Area	Spawning Condition: Female I	II	III	IV	V	VI	Total	Male I	V	Total
BH	0	1	17	38	18	1	75	9	120	129
PP	81	7	29	0	0	9	126	3	0	3
	81	8	46	38	18	10	201	12	120	132
Expected Values: m										
BH	30.22	2.99	17.16	14.18	6.72	3.73		11.73	117.27	
PP	50.77	5.01	28.84	23.82	11.28	6.27		.27	2.73	
Table of x										
BH	-30.22	-1.99	-.16	+23.82	+11.28	-2.73		-2.73	+2.73	
PP	+30.22	+1.99	+.16	-23.82	-11.28	+2.73		+2.73	-2.73	
Table of x^2										
BH	913.2484	3.9601	.0256	567.3924	127.2384	7.4529		7.4529	7.4529	
PP	913.2484	3.9601	.0256	567.3924	127.2384	7.4529		7.4529	7.4529	
Table of x^2/m										
BH	30.2200	1.3244	.0015	40.0135	18.9342	1.9981		.6354	.0636	
PP	17.9998	.7904	.0009	23.8200	11.2800	1.1887		27.6033	2.7300	
	48.2198	2.1148	.0024	63.8335	30.2142	3.1868		28.2387	2.7936	

Female:
chi-squared = 147.5715
df = 5
P is less than .01

Male:
chi-squared = 31.0323
df = 1
P is less than .01

TABLE XXVI

CHI-SQUARED CALCULATIONS BOAT HARBOUR - PYLADES CHANNEL

Area	Spawning Condition									
	Female							Male		
	I	II	III	IV	V	VI	Total	I	V	Total
BH	0	1	25	46	28	2	102	3	133	136
PC	23	3	56	8	3	17	110	16	24	40
	23	4	81	54	31	19	212	19	157	176
Expected Values: m										
BH	11.07	1.92	38.97	25.98	14.92	9.14		14.68	121.32	
PC	11.93	2.08	42.03	28.02	16.08	9.86		4.32	35.63	
Table of x										
BH	-11.07	-.92	-13.97	+20.02	+13.08	-7.14		-11.68	+11.68	
PC	+11.07	+.92	+13.97	-20.02	-13.08	+7.14		+11.68	-11.68	
Table of x^2										
BH	122.5449	.8464	195.1609	400.8004	171.0864	50.9796		136.4224	136.4224	
PC	122.5449	.8464	195.1609	400.8004	171.0864	50.9796		136.4224	136.4224	
Table of x^2/m										
BH	11.0700	.4408	5.0079	15.4273	11.4669	5.5776		9.2931	1.1245	
PC	10.2719	.4069	4.6434	14.3041	10.6397	5.1703		31.5792	3.8235	
	21.3419	.8477	9.6513	29.7314	22.1066	10.7479		40.8723	4.9480	

Female:
chi-squared = 94.4250
df = 5
P is less than .01

Male:
chi-squared = 245.8203
df = 1
P is less than .01

TABLE XXVII

LAYOUT OF PILOT HOUSE LOG BOOK PAGE

TRAWL LOG RECORD BOAT......................... YEAR 1946 BOOK NO. 84

DATE	PURSE SEINE AREA	WHERE FISHING	DEPTH IN F.	TIME OF DRAGGING HR.	TIME OF DRAGGING MIN.	TOTAL CATCH LBS.	POUNDS OF PRINCIPAL FISH CAUGHT	NOTES SIZE OF SPECIES, ETC.