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Preliminary Studies of the Juvenile Stage of the

Pacific Herring (*Clupea pallasii*)

Author

A. S. Hourston, M.A.

Pacific Biological Station

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by

A.S. Hourston, M.A.,
Pacific Biological Station,
Nanaimo, B.C.

GENERAL INTRODUCTION

During the summer of 1950 a major investigation into various aspects of the juvenile stages of the life history of the Pacific herring (Clupea pallasii) was undertaken by the Pacific Biological Station. Up to that time, more or less comprehensive studies had been initiated (and at least partially carried out) in all other phases of the life history of the Pacific herring. Studies of the adult populations have been in progress since shortly after the turn of the century. A study of spawn deposition was begun in 1928, and intensified in 1946; since 1949 various studies concerning development and mortality of the herring spawn have also been carried out. In 1947 a comprehensive investigation of the larval stage was initiated. An investigation of the juvenile stage should therefore serve to fill the last major gap in our knowledge of the life history of the Pacific herring, thus, completing the background for more specific studies.

The purpose of the juvenile herring studies is to follow the growth, distribution, movement and abundance of the herring from metamorphosis to maturity. An estimate of survival during this period should give a good indication of the probable recruitment of a year-class into the fishery at maturity. This role of prediction of the fishable stocks is an important one in fisheries management, and as such, forms the primary objective of this investigation.

More specifically the aims of this investigation are:

1. To estimate the abundance of a new year class and its

contribution to the population as a whole. This would involve an estimate of survival at various intervals during the period under study.

2. To investigate the dispersal and mixing of the schools.
3. To follow the migrations of the juveniles.
4. To study the rate of growth of young herring and compare this factor from year to year and from population for possible controlling factors.
5. To study the development of scale patterns.

With these objectives in mind a programme involving a minimum of three years of investigation was set up. For the first year, techniques and methods were to be evolved and tested in a locality close to the Pacific Biological Station (i.e. Departure Bay). Using this information an investigation would be launched on the west coast of Vancouver Island in the following year. This study would be continued as long as it was required and would form an integral part of the life history studies now being carried out there in connection with the "west coast experiment" (Tester and Stevenson, 1947). The purpose of the west coast experiment is to follow the changes which take place in a herring population subjected to practically unlimited exploitation by the fishery in comparison with populations whose exploitation is limited by annual quotas. One of the chief aspects of this investigation is a study of the causes of natural fluctuations in abundance of herring, and the life history studies form one of the most important parts of this research. Indeed it

would seem that a study of the stage in the life history immediately preceding recruitment would give the best advance indication of the amount of natural fluctuation and possibly some of its major causes.

HISTORICAL BACKGROUND

Prior to the present investigation, the only studies on this phase of the life history of the Pacific herring on record were carried out in Departure Bay from 1938 to 1940 (McHugh, 1940). Various unpublished reports give an outline of his work on juveniles during this period. This investigation involved several phases of the juvenile work, but laid emphasis on vertebral studies. These latter showed:

1. Significant differences between young herring from different bays and inlets (i.e. distinct populations) exist similar to those found for adult fish and are possibly a little more discreet.
2. Significant differences exist between young fish and adult fish captured commercially in the same general locality and the same year. This would be expected since they went through the critical formative period at different times and therefore under different conditions.
3. The proportion of abnormal vertebra was considerably higher in the young fish than in the adults. This also is to be expected since the abnormal fish are presumably less well adapted and would thus survive in smaller proportions than the normal fish.
4. Larger fish in a sample tend to have higher vertebral counts.

5. The causative agent in the types of abnormalities listed seems to be differential growth.
6. There is a significant difference in the number of abnormal vertebra in different regions (e.g. Departure Bay and Nancoose Bay). This presumably is the result of the differential toll of environmental resistance acting more strongly on the less well adapted fish.
7. Three separate populations of juveniles were found in Departure Bay.

In one of his final reports, McHugh states that the vertebral studies were too time-consuming to make further investigation advisable at that stage.

Other studies were also carried out. Stomach contents of adult spring and coho salmon, fingerling coho and chum salmon, and young and adult ling-cod showed these fish to be predators on juvenile herring. Studies of the methods of sampling using dip net (surface), beach-seine (inshore), and dynamite (offshore) showed that smaller fish form the upper and inshore positions of a school while larger fish form the deeper layers. A significant difference was found in the size of specimens from the same place and captured by different methods, and thus samples taken by different methods were not considered comparable. By comparing the size and growth of fish in samples examined, McHugh was able to distinguish the progeny of early and late spawnings in Departure Bay. He also showed that the total size attained in the first year tended to be about the same for both populations.

Some tagging experiments were carried out by McHugh using several different types of tags. From the experiments, it was concluded that small, flat, body-cavity tags, 13 x 3 x 1/2 mm., were the most satisfactory type of those tried. Tagging mortality on 70 mm. fish held in tanks was found to be 58% - 75%, and magnet recovery at the Nootka plant of ten test tags of this type was 90%.

RECENT OPERATIONS PRIOR TO 1950

In 1948 and 1949, scouting for schools of juvenile herring was carried out on the west coast during the months of May and June at the conclusion of the larval studies. This work was preliminary to the present study and subsidiary to the larva investigation, and was carried out by various members of the herring staff. Three schools were sighted in 1948, two near Nuchatilitz village in Esperanza Inlet (May 31 and June 10), and one near Union Island, Kyuquot Sound (June 10). No schools were sighted in 1949 but that year the seine boat used for the survey had to be laid off near the beginning of June, when the juveniles were probably just beginning to school up. In the Departure Bay vicinity, observations of schools during the summer of 1949 were recorded. Juvenile herring were found to be abundant from mid-June to late in August.

THE 1950 JUVENILE HERRING INVESTIGATION

One of the main purposes of the 1950 programme was to try out various methods and gear with the object of establishing a procedure for a more intensive study in the future. To this end, the following objectives were set up.

1. To locate the herring at all stages from early metamorphosis onward.

2. To devise methods of capturing the herring at all of these stages.
3. To take samples at regular intervals for the purpose of studying growth and general distribution.
4. To carry out a marking (fin clipping) programme to follow the dispersal and mixing of the schools and to obtain a rough index of population abundance.
5. To tag juvenile herring with small body-cavity tags (13 x 3 x 1/2 mm.).

These objectives met with varying degrees of success and will be discussed separately.

Juvenile Herring Survey on the West Coast of Vancouver Island

As in 1948 and 1949 efforts were made in 1950 to locate and capture juvenile herring on the west coast of Vancouver Island. This study was carried out in conjunction with, and as a continuation of the larval herring studies. The survey was carried out from a seine boat (Figure 1.) operating throughout the west coast of the island and from a field station at Toquart Bay in Barkley Sound (Figure 2.). The methods employed are discussed separately below.

Dusk and Dawn Observations for Surface Schools

Herring show a tendency to appear near the surface at dusk and dawn, when their flipping and flashing may be readily observed. Scouting for this purpose was mainly carried out from an eighteen-foot scout boat (Figure 3.); observations were also made from the deck of the seiner and from the shore near the field station at Toquart Bay (Figure 4.). Between May 17

and June 11, twenty-two sets of dawn and dusk observations were made from the seine boat and five from the field station. These are recorded in Tables I and II respectively. No schools of juveniles were sighted during this period, although several large schools of adults were found. However, it is not considered probable that the juveniles had schooled up before it became necessary to conclude the west coast operations.

Attraction of Young Herring to a Light

Herring are known to be somewhat phototropic and attempts were therefore made to attract the juveniles to lights set out over the water at night. Whenever the seine boat was anchored at night, a 200 watt light was hung over the side about two feet above the water surface and an investigator stood ready with a dip net to scoop out any fish that were attracted to it (Figure 5.). At the field station two 200-watt lamps were placed on buoys at each end of a 400-foot waterproof electric cable (Figure 6.). Investigators stood by with dip nets at each lamp, one in a dinghy (Figure 7.) and one in an eighteen-foot scout boat (Figure 8.). The power for these lights was provided by a motor generator mounted on the deck of the scout boat. The mobility of this equipment made continuous night observations possible at any reasonably sheltered location near the field station. As an alternative to the electric light, gas lamps were used from both the seine boat and the field station. An investigator tended the lamp from a dinghy and stood by with a dip net (Figure 9.). Good weather and a calm sea proved to be necessary prerequisites for this work.

The first young herring caught by this method were taken about 350 feet offshore from the field station (Cabin

Point) on June 2, ten days before the west coast operations were concluded. The results of these night vigils are tabulated in Table III (seine boat group) and Table IV (field station group). Samples taken by this means are summarized in the following tabulation.

Date	Place	No. of Young Herring	Weather
June 2	Cabin Pt., Toquart Bay	15	moonlight
June 3	Cabin Pt., Toquart Bay	43	cloudy
June 6	Cabin Pt., Toquart Bay	4	cloudy
June 7	Cabin Pt., Toquart Bay	6	rain
June 8	Stopper Islands	2	cloudy
June 8	Cabin Pt., Toquart Bay	1	cloudy
June 9	Cabin Pt., Toquart Bay	25	moonlight
June 10	Between Stopper Islands and Cabin Pt.	1	clear, no moon
June 11	Cabin Pt., Toquart Bay	4	fog, light rain
June 11	Between Stopper Islands and Cabin Pt.	2	fog, light rain
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All of these herring were in the process of metamorphosis and were taken from the Toquart Bay region of Barkley Sound. Attraction to an electric light was tried twenty-nine times from the seine boat and ten times at the field station. The gfs lamps were used six times from the seine boat and twice at the field station but failed to attract any herring. The light from these lamps did not penetrate to the same extent as that from the electric lights and could not be directed straight down into the water. This may account for their failure to attract the herring.

Most of these metamorphosing herring were captured between 2300 and 0230 hours and on cloudy nights. On these occasions the lamps were placed directly above eel-grass beds,

and within 200 yards offshore. Their light penetrated the water to a depth of two to three fathoms. When the herring appeared they seemed to be swimming against a moderate current. They came singly into the light range at a depth of one-half fathom and were quickly pursued up to the surface by the school of perch which was always lurking beneath. Since they appeared singly and sporadically the herring could not have been schooled up at this stage.

All the young herring taken in this part of the investigation were less than 30 mm. long and undergoing metamorphosis. They were still more or less transparent and had a slight reddish tint anteroventrally. The body was just beginning to deepen and the pigmentation starting to take form.

After metamorphosis was complete and the juvenile herring had schooled up, three samples were taken by dip net in the daytime from other west coast regions. These samples are recorded in Table V. At that time, the juvenile herring were reported to be available in large quantities.

Juvenile Herring Investigation in Departure Bay

During 1950 efforts were made to locate, capture, mark, tag and sample the juvenile herring in Departure Bay. This investigation was begun on June 20, after metamorphosis and schooling had taken place. The last sample was taken on October 18. The work falls roughly into five categories each of which will be discussed individually.

Location and Capture

The location and capture of the juvenile herring were the primary problem of this investigation. Schools were located

by attraction to a 200 watt light or by scouting in a sixteen foot inboard power boat. Often schools of juveniles were located, but methods of capture then in use proved ineffective. In such eventualities new methods were tried out, and in this manner, several different methods or combinations of methods were employed, all with varying degrees of success. The methods used, time interval over which they were effective, and their results (number of samples taken and number of fish involved) are tabulated below.

Method	Time Interval	Effective	No. of Samples	No. of Juveniles
Attraction to a light at night and capture with a dip net or lift net	June 20 - July 17		17	3,758
Beach seining	July 13 - July 28		4	469
Drag seining - dusk - daytime	July 25 - Oct. 18		16 8	3,442 1,369
Herring rake	Sept 18 - Sept 20		2	4
Attraction to a light on a buoy and setting drag seine around the fish	Sept 20 - Sept 21		2	25
Purse seine	Sept 26 - Sept 30		1	208
Dynamite	Oct. 26		--	--

Hauls with a conical plankton net (bolting silk - 29 meshes to the inch) have been successful in obtaining larvae up to about the beginning of June on the west coast, but since the Departure Bay investigation was not begun until one month after this method generally ceases to be effective it was not used in this study. Thus, no metamorphosing herring were caught by this means in 1950, although some had been taken on the west coast in previous years. Attraction to a 200 watt

electric light and capture with a dip net was effective for the early juvenile stages (mid-June to mid-July). It also yielded some results during the metamorphosing period although the catch per unit effort was quite low. Daylight beach seining (i.e. pulling the seine onto a beach so that the fish are cut off from escaping from the bay by the cork line on the surface and the lead line dragging on the bottom) at low tide provided two good samples but in most sets no juvenile herring were taken. It would seem that the period covered by this method would probably be more satisfactorily sampled by drag seining (i.e. using a beach seine in deeper waters where the lead line is well above bottom and the fish are secured in a bay by hauling the lead line into a boat or onto a rock) at twilight when the fish are on the surface. The latter method proved very effective from mid-July to the beginning of September. After that time the juveniles became much swifter and more active, and consequently their location and capture presented considerable difficulty. The successful use of the drag seine became largely dependent on the weather and the state of the tide at dusk; when these conditions were adverse it was necessary to adopt other methods. A purse seine (wherein the fish are trapped by closing off the bottom like the mouth of a purse) of one-inch mesh was used successfully once, but the smaller fish escaped too easily through the mesh, thus introducing a certain amount of selectivity as well as losing a large portion of the catch. In addition, the tarred web used was very rough on those fish caught. Some small success was achieved with a herring rake. (An elongate flattened pole, about 2 in. x 1/2 in. x 15 ft.

with nails protruding from the end on one of the narrow sides. When this pole is swept through a school of small fish some are usually caught on the nails). Also, an attempt was made to attract the juveniles to a 200 watt light, set out on a buoy at night; those fish attracted were captured in a purse seine set around the buoy.

It would thus seem that the main need for this particular aspect of the investigation is to find an adequate method of locating and capturing herring during the period of metamorphosis and during the early fall.

Marking

A marking programme was carried out on the juvenile herring in the Departure Bay vicinity principally to test its feasibility and to determine approximately how extensive such a programme would have to be to ensure adequate results. It was also planned to determine a rough index of population abundance and to follow to some extent the dispersal and mixing of schools. In conjunction with this project, experiments were carried out to estimate the probable survival of the marked fish.

After a random sample had been preserved from each catch taken, the remainder of the fish were put into a "box-type" live-pen to be marked and released again. This live-pen consisted of four chambers about two feet cube with screening down either side, and was attached to the outside float at the Biological Station wharf. Fish taken at some distance from the float were transported there in a rowboat with a series of slits, one-half inch by two inches, cut in the bottom. This "boat-type" live-pen proved to be a relatively efficient means of moving the fish and in all cases mortality was quite low. Both

* live-pens are shown in Figure 10. When the boat-type live-pen was tied up at the dock, the juveniles in it survived better than did those in the box-type live-pen. Fish in both live-pens suffered a high mortality during rough weather and were subject to the attacks of birds. This latter difficulty was alleviated to some extent by attaching a door to the top of the box-type live-pen and covering the boat-type live-pen with a net; but even the net was not sufficient to provide complete protection from the attacks of gulls.

The marking process is shown in Figures 10-14. The juveniles were removed from the boat-type live-pond with a dip net (Figure 11) and transferred to an enamel basin about three-quarters full of salt water. The water was changed about every ten minutes to keep it clean and to maintain its temperature approximately at that of the bay. The hard sides of the basin were covered with netting, in order to prevent the herring from injuring themselves by hitting against the hard enamel surface (Figure 12). The juveniles were removed by hand from the shallow basin and marked by cutting off both ventral fins with a pair of clippers (Figure 13). After the first lot of fish was released, every successive clipping was also an examination for previously marked fish. An estimate of the mortality caused by the marking operation was obtained for each set of fish by keeping one out of every ten marked juveniles overnight in the box-type live-pen (Figure 14). For every marked fish kept, one unmarked control was put into the next chamber of the pen. The percentage mortality of the actual marking was taken to be the percentage mortality of the fish marked and kept overnight minus

the percentage mortality of the controls kept overnight.

In this manner, 11,914 juveniles were marked, of which it is estimated 9,209 survived the marking (approx. 75%). This estimate is for the operation only. Holding onto the fish during the operation may be responsible for some of the mortality. Also, differential mortality from the action of predators may be quite large and the herring population of Departure Bay may have been changing by immigration and emigration. In an effort to reduce marking mortality and to speed up the operations, numerous trial markings were carried out using the anaesthetics urethane and chlorbutol in various concentrations, but mortality was not significantly reduced and the time saved by the ease in working with anaesthetized fish was lost in preparing and applying the anaesthetic.

Meanwhile, ignoring the above factors, some estimate of the size of a juvenile herring population may be obtained which could serve for comparison from year to year. Schnabel's formula for estimating a population from recoveries made while marking is in progress (Ricker, 1948) seems to be best suited to the data. The results of this calculation are given in Table VII, from which it may be seen that if these figures were truly representative, there would be between 1.5 million and 17 million juvenile herring in Departure Bay. However, such an absolute estimate could scarcely be considered reliable since the mortality of the marked fish was not considered in these calculations; also immigration into the bay, emigration out of the bay, and the possibility of incomplete mixing within the bay have all been ignored in these considerations. It is however,

of value as an index of the populations size.

The number of recoveries during 1950 was insufficient to give any significant data on the dispersal and mixing of the juvenile herring in Departure Bay. All the fish marked were released at the Biological Station wharf and the four recoveries were all made within one-half mile of the wharf. There were however, at least two large schools in this vicinity both of which contained marked fish. A large majority of the catches were made in this region and consequently recoveries could not be expected from more distant localities, considering the small number of fish marked.

The fact that some recoveries were made shows that a marking programme is feasible. However, it would seem that about 100,000 juveniles would have to be marked in order to get an adequate number of recoveries.

Tagging

A tagging programme was included in the juvenile studies in order to estimate population size and to determine the extent of the homing tendency of the herring. The use of internal body-cavity tags which could be recovered from the fishery appears to be the only method of ascertaining to what extent the populations of adult herring which tend to return to more or less discreet spawning grounds are actually the fish which hatched in that particular locality. Norwegian workers (Rasmussen, 1950) have shown that the schooling of the Atlantic herring is a temporary phenomenon with the schools dispersing after a while and the fish later forming into new groups which may be quite different from the previous ones. If such a

On the other hand, the continued survival of the larger fish tagged would seem to indicate that if the juveniles were still available in quantity by the time they have reached a length of about 90 mm., a full scale tagging programme would be in order.

Tag-recovery

During the 1950-51 fishing season, four sets of test-tags were put through the reduction plants at Steveston, B.C. to determine the efficiency of detector and magnet recovery of this type of tag. The results of the detector lists are tabulated below.

Detector Recoveries of Juvenile Test Tags

Date	Plant	No. Used	Recoveries Number	Percentage
Nov 29/50	Imperial	10	2*	20
Nov 29/50	Imperial	12	1	8

* Detector sensitivity tuned up beyond practical operating level.

The results of the first detector recovery test cannot be included in any consideration of detector efficiency at recovery of juvenile tags since the detectors sensitivity was tuned up well beyond its practical operating level. The recovery of 8% observed on November 28 cannot be considered truly representative since it is based on the recovery of only one tag. However, it does seem likely that detector recovery of juvenile tags will be well below 10%. During the 1949-50 fishing season, detector recovery of the larger adult tags (19 x 4 x 1.6 mm.) was approximately 70% (Stevenson and Lanigan, 1951). Thus the detector

recovery of juvenile tags could only be about one tenth that of adult tags and will thus be of little value at the scale of programme planned.

The main data on population size and migration will therefore have to come from magnet recoveries. The results of four tests of magnet efficiency at the recovery of juvenile tags are tabulated below.

Magnet Recoveries of Juvenile Test Tags

Date	Plant	No. Used.	Time Lapse in Days						Recoveries	
			0	1	2	3	4	5	Total	%
Nov 29/50	Imperial	20			2			11	13	65
Dec 6/50	Imperial	20	5	6		2			13	65
Jan 12/51	Gulf of Georgia	20	3	1	2	1			7	35
Feb 5/51	Gulf of Georgia	85	72	4					76	87

Average percentage 63%

The magnet at the Imperial plant recovered 65% of the test tags passing over it while that at the Gulf of Georgia plant recovered 61% of its test tags. Thus an overall recovery of about 63% may be expected from these and comparable plants. A recovery of 90% was found by McHugh in 1940 for a similar test at the Nootka plant, but this estimate cannot be considered indicative since it involved only ten tags.

Thus the chances of recovery of juvenile tags by plant magnets are nearly 20% lower than for the adult tags. In addition, tagging mortality and natural mortality between the time of tagging and the time for recovery are bound to be considerably greater for the juveniles. It would therefore be necessary to counteract this higher mortality by tagging larger numbers of fish.

Sampling

The main purpose of the sampling programme was to study the growth and development of the herring between the stage of metamorphosis and when they migrate offshore at the end of their first summer. Ten samples of herring in the early stages of metamorphosis and two samples of fully metamorphosed juveniles were taken in Barkley Sound during this study. Fifty samples of juvenile herring, from late metamorphosis onward, were obtained in Departure Bay. Two samples were also taken in the Kyuquot area but were excluded from these considerations because of their remoteness from the locality of the rest of the study.

The age-length and age-weight relationships for the samples from Departure Bay are shown in Figure 15. Age is expressed in terms of time of capture. The trend lines have been drawn in either case to show the probable average length and weight of specimens at any time during the interval sampled. The age-weight relationship shows the customary concave-upwards curve showing that the rate of absolute increase in weight increases with age. The customary age-length relationship of a concave downwards curve was not shown by the data from this study. Rather, a linear relationship was found. Since the interval sampled during this investigation forms a comparatively small portion of the life span of the Pacific herring, it seems probable that this line represents the initial slope of the usual curve before any appreciable levelling-off has occurred.

The length-weight relationship for the Departure Bay and Barkley Sound samples is shown logarithmically in Figure 16. The data seem to compare but fall into two separate linear trends of different slope. The two lines meet at a point representing

a length of 33 mm. and a weight of 3.0 gms. (M in the figure). This corresponds approximately to the stage of completion of metamorphosis (Figure 17), when a change in this relationship might be expected. The equations of these two lines were determined to be:

Before the completion of metamorphosis
 $\log W = 1.1705 \log L - 1.3145$

After the completion of metamorphosis
 $\log W = 2.6239 \log L - 3.5020$

Thus, upon the completion of metamorphosis the rate of increase in weight becomes greater with respect to the rate of increase in length (i.e. the fish tend to put on weight more after metamorphosing). This fact is evident from the general form of the specimens above and below 32 mm. in length in Figure 17.

The comparative development of herring during metamorphosis and the early juvenile stages is shown in Figures 17-19. The major stages in metamorphosis are shown in Figure 17. The 21 mm. specimen is the normal postlarval form. The body is long, narrow and more or less transparent; the dorsal pectoral and caudal fins are developing but the gut is still attached to the bottom of the body wall. Pigmentation is confined to a few black spots arranged more or less regularly dorsal to the gut. At this stage the body begins to deepen and thicken, at the same time assuming a whitish opaqueness. The gut becomes enclosed in the body wall and the ventral and anal fins begin to become evident. This stage is represented by the 25 mm. fish in Figure 17. As the body increases in depth, the gut becomes more completely enclosed and dark pigmentation spots begin to appear in the caudal and dorsal regions (Figure 17 - the 26 mm. specimen). The mouth develops rapidly and by the time the herring is about 32 mm. long it resembles the adult form for the first time. Pigmentation

then proceeds rapidly, and by the 33 mm. stage metamorphosis is more or less complete and the herring embark upon a period of rapid growth.

The growth of the juveniles throughout the summer months is shown graphically in Figure 15, and is illustrated by the series of specimens in Figure 18. The rapid increase, both in length and weight is especially evident for the mid period of this series (July and August). Presumably this is the height of the summer feeding period during this period. Little change in general appearance is evident during this period other than the rapid growth. A series of juveniles with increments of 6 mm. from specimen to specimen is shown in Figure 19. The only noteworthy differences in general appearance throughout the series is the tendency for the fish to take on a more robust appearance and to acquire a darker pigmentation. The latter factor may be partially due to a change in environmental conditions with the advancing season.

SUMMARY

1. A general investigation of the juvenile stage of the life history of the Pacific herring was carried out during the summer of 1950 in Barkely Sound (May-June) and Departure Bay (June-October).
2. The juveniles were located by attracting them to a light at night or scouting for them in an 18-foot scout boat. A total of seven methods of capture were employed the most effective of which proved to be attraction to a light at night and capture with a dip net (mid-June - mid-July) and drag seining (mid-July - mid-October).

3. A marking programme was carried out in Departure Bay from which, using Schnabel's formula for estimating population from recoveries made while marking is in progress, a population estimate was made. In this programme, over eleven thousand juveniles were marked, of which only four were recovered. On the basis of these results a minimum population estimate for Departure Bay was set at 1.5 million to 17 million juveniles. The recoveries were too scanty to provide reliable data on the dispersal and mixing of the young herring.

4. Five experimental taggings of juvenile herring were carried out using small internal tags. From the results of these taggings it would appear that excessive tagging mortality occurs in fish smaller than about 90 mm. in length. Even for fish of that size mortality would be relatively high but not prohibitive.

5. Recovery tests of the small internal tags show a recovery of less than 10% can be expected from the electronic detectors and a recovery of 60-70% by magnets in the plant meal bins.

6. Metamorphosis involves a period of 3 - 4 weeks and begins at a length of about 22mm. and is completed when the fish is approximately 33 mm. long.

7. The length-weight relationship changes at the completion of metamorphosis, the rate of increase in weight becoming comparatively greater than that for length. Thus when plotted logarithmically, the length-weight relationship shows two slopes meeting at the point of completion of metamorphosis.

8. Over the period of time included in this study the age-weight relationship is concave upwards but the age-length relationship tends to be linear. This line would probably represent the initial slope of the usual concave downwards trend for the age-length relationship if the whole life span of the Pacific herring were considered.

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Table I

Dawn and dusk observations for juvenile herring on the west coast
Of Vancouver Island,
 (Seine boat group)

Date	Time	Place	Observation	Weather
May 28	dawn	Nettle and Frideaux Is.	nil	clear
May 30	dawn	Refuge Cove	some isolated flips -not herring	clear
May 31	dawn	Head of Kendrick Inlet	some isolated flips -not herring	cloudy
		Kendrick Arm	nil	cloudy
June 1	dawn	Queen Cove	1 large school (pos- sibly adult herring)	bright and clear
June 2	dusk	Union Islands	nil	strong wind
	dawn	Union Islands	nil	strong wind
June 3	dusk	Quatsino Village	nil	overcast
	dawn	Quatsino Village	nil	rain
June 4	dusk	Union Islands	nil	cloudy
	dawn	Union Islands	nil	rain
June 5	dusk	Nuchatlitz	nil	overcast
	dawn	Queen Cove	nil	overcast
June 6	dusk	Queen Cove	nil	clear
	dawn	Queen Cove	nil	clear
June 7	dusk	Kendrick Arm	nil	light rain
	dawn	Kendrick Inlet	flippers from Tahsis to head of Kendrick (possibly adult her- ring)	light rain
June 8	dusk	Stopper Islands	nil	clear
	dawn	Stopper Islands	few flips - not her- ring	clear
June 9	dusk	Nettle Island	extensive flipping possible herring	clear
	dawn	Nettle and Frideaux Is.	few flips not herring	clear
June 10	dusk	Stopper Islands	few flips-probably sal- mon	clear
	dawn	Stopper Islands	nil	clear
June 11	dusk	Toquart Bay	nil	rain
	dawn	Toquart Bay	nil	rain

Table II

Dawn and dusk observations for juvenile herring in Barkley Sound
(Field station group)

Date	Time	Place	Observation
May 30	dawn	Maccosh Passage	flips observed opposite Maggie river and opposite Spillings island - adult herring; schools - salmon also jumping.
	dawn	Stopper Islands	nil
	dusk	Toquart Bay	nil
May 31	dawn	Georges Island	flips - two small schools of large herring.
	dawn	East side Snowden Island	3 large schools observed, large herring.
June 1	dusk	Stopper Islands	nil
	dawn	Mayne Bay	3 large schools of adult herring seen flipping.
	dawn	Cigarette Cove	2 schools adult herring

Table III

Attraction of juvenile herring to lights
on the west coast of Vancouver Island,
 (Seine boat group)

Date 1950	Place of Capture	Method of Attraction	Time	No. Caught	Weather
May 19	Nuchatlitz	200 watt light from seine boat	0245-0400	0	clear
May 18	Bowden Bay	" "	0945-1015	0	light rain
May 18	Ross Passage	" "	0200-0330	0	light rain
May 19	Chrow Island	" "	1000-1245	0	light rain
May 19	Forbes Island	" "	0130-0430	0	light rain
May 20	Hankin Island	" "	2130-0030	0	light rain
May 26	Toquart Bay (Field Station)	" "	2200-0100	0	showers
May 26	Hankin Island	" "	2230-2400	0	rain
May 26	Nettle Island	" "	0130-0400	0	overcast (1 adult)
May 29	Forbes Island	" "	2230-0115	0	moonlight
May 29	Mayne Bay	" "	-	0	moonlight
May 30	Refuge Cove	" "	2130-2300	0	moonlight
May 30	Houtla-Koutla	" "	2330-2430	0	moonlight
May 30	Refuge Cove	" "	0130-0330	0	moonlight
May 31	Flumper Bay	" "	2130-2315	0	moonlight
May 31	Kendrick Arm	" "	0030-0330	0	moonlight
June 1	Nuchatlitz	" "	2045-2345	0	clear and stars
June 1	Queen Cove	" "	0015-0345	0	moonlight
June 1	Queen Cove	gas lamp from dinghy	0045-0315	0	moonlight
June 2	Union Island	200 watt light from seine boat	2115-2300	0	clear
June 2	Union Island	gas lamp from dinghy	2215-2300	0	clear
June 3	Quatsino Village	200 watt light from seine boat	2130-0215	0	overcast
June 3	Quatsino Village	gas lamp from dinghy	2300-0230	0	overcast (88 larvae)
June 4	Union Island	200 watt light from dinghy	2130-0330	0	showers
June 4	Union Island	gas lamp from dinghy	2200-0300	0	showers
June 5	Nuchatlitz	200 watt light from seine boat	2130-2245	0	overcast
June 5	Queen Cove	" "	2315-0030	0	overcast
June 6	Queen Cove	" "	2200-0015	0	clear
June 6	Queen Cove	gas lamp from dinghy	2245-0130	0	clear
June 7	Kendrick Arm	200 watt light from seine boat	2145-0330	0	light rain
June 7	Kendrick Arm	gas lamp from dinghy	2215-2315	0	light rain
June 8	Stopper Islands	200 watt light from seine boat	2200-0330	2	clear
June 9	Nettle Island	" "	2130-0330	0	clear
June 10	Toquart Bay-Cabin Pt.	" "	2130-0330	1	clear
June 11	Toquart Bay-Cabin Pt.	" "	2130-0330	2	rain and fog

Table IV

Attraction of juvenile herring to lights
in Barkley Sound,
 (Field station group)

Date	Location	Method of Capture	Time	No. Caught	Weather
May 29	Toquart Bay-Cabin point	Gas lamp from dinghy	2300-1645	0	moonlight
June 2	Toquart Bay-Cabin point	200 watt light from scout boat	2230-0330	15	moonlight slight wind
June 2	Snowden Is. - east side	Gas lamp from dinghy	2130-0345	0	moonlight windy (fast currents)
June 3	Toquart Bay-Cabin point	200 watt light from scout boat	2100-0400	43	cloudy
June 4	Toquart Bay-Cabin point	One 100 watt light from scout boat and one 200 watt light from dinghy	2130-0345	0	cloudy
June 5	Pipestem Inlet-mouth	One 100 watt light from scout boat and one 200 watt light from dinghy	2100-0330	0	cloudy and windy (fast currents)
June 6	Toquart Bay-Cabin point	One 100 watt light from scout boat and one 200 watt light from dinghy	2100-0345	4	cloudy
June 7	Toquart Bay-Cabin point	One 200 watt light from scout boat	2200-0345	6	rain
June 8	Toquart Bay-Cabin point	One 200 watt light from scout boat	2130-0345	1	cloudy
June 9	Toquart Bay-Cabin point	One 100 watt light from scout boat and one 200 watt light from dinghy	2130-0345	25	moonlight
June 10	Toquart Bay-Cabin point	One 100 watt light from scout boat and one 200 watt light from dinghy	2100-0345	0	clear no moon
June 11	Toquart Bay-Cabin point (north side)	One 100 watt light from scout boat and one 200 watt light from dinghy	2130-0330	4	rain and fog

Table V

Juvenile herring captured on the west coast
Vancouver Island after metamorphosis and
schooling were completed

Date 1950	Place of Capture	Method of Attraction	Time	No. Caught	Weather
June 16	Kyuquot area	dip net	daytime	220	sunshine
July 1	Kyuquot area	dip net	daytime	500-	sunshine
July 5	Spring Cove	dip net	daytime	10	sunshine

Table VI

Juvenile herring samples taken in Departure Bay

Date	Location	Method of Capture	Time	No. Caught	Weather
June 20	PBS dock	Two 200 watt lights	2345-0100	400	clear-slight wind
			0200-0230	659	clear-slight wind
June 21	PBS dock	Two 200 watt lights	2230-0300	41	showers
June 22	PBS dock	Two 200 watt lights	2230-0200	367	overcast
June 23	PBS dock	Two 200 watt lights	-	300	moonlight
June 25	PBS dock	Two 200 watt lights	2230-0500	356	cloudy
June 26	PBS dock	Two 200 watt lights	2230-0400	416	cloudy
June 27	PBS dock	Two 200 watt lights	2230-0315	256	overcast
June 28	PBS dock	Two 200 watt lights	2215-0345	157	overcast
June 29	PBS dock	Two 200 watt lights	2215-0230	130	full moon
July 2	PBS dock	Two 200 watt lights	2215-0100	232	full moon
July 3	PBS dock	Two 200 watt lights	2215-0345	200	clear no moon
July 4	PBS dock	Two 200 watt lights	2215-0200	169	clear no moon
July 5	PBS dock	Two 200 watt lights	2230-0300	176	clear no moon
July 6	PBS dock	Two 200 watt lights	2300-0415	2	clear no moon
July 7	PBS dock	Two 200 watt lights	2300-0100	3	$\frac{1}{2}$ moon-muddy water
July 10	PBS dock	Two 200 watt lights	2215-0500	133	overcast
July 13	PBS dock	Two 200 watt lights	2230-0330	44	clear
July 14	Departure Bay beach	Beach seine-daytime	1030-1430	1	clear-sun- shine
July 17	PBS dock	Two 200 watt lights	1000-0030	1	dark
July 24	Off Newcastle Island -north end	Beach seine-daytime	afternoon	1	sunshine
July 25	Off Horsewell Bluff in kelp beds	Drag seine-dusk	1900-2130	400	dusk
July 26	Off Jesse Island	Drag seine-dusk	1930-2130	447	dusk
July 28	Departure Bay beach off Spit	Beach seine-daytime	1500-1600	242	overcast

Table VI (cont'd)

Juvenile herring samples taken in Departure Bay

Date	Location	Method of Capture	Time	No. Caught	Weather
Aug 1	Off Jesse Island	Drag seine-dusk	1930-2130	232	dusk
Aug 8	Off Jesse Island	Drag seine-dusk	1930-2100	231	dusk
Aug 10	Off Jesse Island	Drag seine-dusk	1930-2100	191	clear at dusk
Aug 15	Off Jesse Island	Drag seine-dusk	1730-2130	213	dusk
Aug 16	West of PBS dock	Drag seine-dusk	1700-2030	150	clear new moon
Aug 16	Opposite Jesse Is.	Drag seine-dusk	2030-2145	60	clear new moon
Aug 17	West of PBS dock	Drag seine-dusk	1900-2015	297	clear new moon
Aug 17	Opposite Jesse Is.	Drag seine-dusk	2015-2200	244	clear new moon
Aug 18	Opposite Black Rock	Drag seine-daytime	0900-1100	232	sunshine
Aug 22	West of PBS dock	Drag seine-dusk	1830-2030	260	-
Aug 22	Along west shore of PBS dock	Drag seine-dusk	2030-2130	36	-
Aug 23	Off Horswell bluff	Drag seine-daytime	0900-1100	201	-
Aug 24	Off Horswell bluff	Drag seine-daytime	0900-1100	196	-
Aug 25	Off buoy near lagoon	Drag seine-daytime	0900-1100	234	-
Aug 28	Off Black Rock	Drag seine-daytime	0900-1130	218	-
Aug 31	Off Black Rock	Drag seine-daytime	0930-1130	48	-
Aug 31	Jesse Island	Drag seine-dusk	1830-2030	255	-
Sept 9	Off Black Rock	Drag seine-daytime	0930-1130	197	-
Sept 18	Off White Marker	Herring rake	1600-1700	1	sunshine then fog
Sept 20	Off White Marker	Herring rake	1400-1600	3	sunshine
Sept 20	Off Black Rock	Light from power boat and drag seine net	2000-2200	1	calm, clear and moonlight
Sept 21	Mid-channel between Brandon Island and shore	Light from power boat and drag seine net	2000-2400	5	moonlight
Oct 12	Off PBS dock	Purse seine-daytime	0930-1100	44	clear
Oct 18	Off Jesse Island	Purse seine-daytime	1630-1830	104	dusk

Table VII

Estimation of the number of juvenile herring in Departure Bay from recoveries of marked fish, using Schnabel's method as outlined by Ricker (1948).

Date	B	A	C	$\frac{B}{A}$	$\frac{C}{B}$	$P = \frac{B}{C}$
	No. of Marked Fish at Large	No. of Fish in Sample	No. of Marked Fish in Sample			Population Estimate
July 16	156	31				
26	187	99				
27	286	471				
28	757	466				
Aug 1	1,223	1,286				
2	2,509	175	1	2,522,670	1	2,522,670
8	2,684	1,919		7,673,266	1	7,673,266
9	4,603	742		11,087,950	1	11,087,950
15	5,344	309		12,739,246	1	12,739,246
17	5,603	26		12,686,224	1	12,686,224
18	5,679	1,420		20,950,404	1	20,950,404
23	7,099	1,031	2	28,269,473	3	9,423,158
24	8,120	94		29,032,753	3	9,677,584
25	8,244	336		31,798,017	3	10,598,672
28	8,560	1,903		48,085,697	3	16,028,566
29	10,463	144	1	49,592,369	4	12,398,092
Sept 1	10,607	910		59,244,739	4	14,811,185
9	11,517	681		67,087,816	4	16,771,954

Poisson Limits of 95% confidence 1.0 - 10.2 16,771,954 -
1,644,309.

JUVENILE HERRING SURVEY IN BARKLEY SOUND



Figure 1. A seine boat used in the west coast juvenile survey. A scout boat is carried on deck.



Figure 2. The field station at Toquart Bay in Barkley Sound.

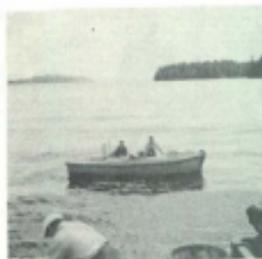


Figure 3. An 18 ft. scout boat used for scouting for juveniles.

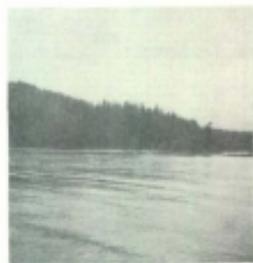


Figure 4. The shoreline at Toquart Bay field station. It was in this immediate vicinity that most of the samples of metamorphosing herring were taken.

CAPTURE OF JUVENILE HERRING IN BERELEY SOUND BY ATTRACTION TO A LIGHT.



Figure 5. A 200 watt light hanging over the side of an anchored seine boat. An investigator is standing by with a dip net to capture any fish which approach the light.



Figure 6. At the field station, power for the two 200 watt lights used to attract the herring was provided by a generator mounted on the forward deck of a scout boat. The lights were attached to buoys, one at the scout boat and the other on the end of a 350 ft. waterproof cable.



Figure 7. The light at the end of the 350 ft. cable was watched from a dinghy by an investigator with a dip net. The cable was buoyed up by corks.



Figure 8. An investigator in the scout boat ran the generator and watched for fish at the other light.



Figure 9. A Coleman gas lantern was used where electric power was not available, but was not very effective.

THE MARKING OF JUVENILE HERRING IN DEERPORE BAY



Figure 10. Juvenile herring being marked at the Biological Station float. The boat-type live-pen in the foreground contains the unmarked fish.



Figure 11. The juvenile herring are removed from the boat-type live-pen with a dip net. A series of slits were cut in the bottom of the rowboat to allow a free exchange of water.



Figure 12. The juveniles are transferred to an enamel wash basin about $\frac{2}{3}$ full of clean salt water. The netting around the sides and bottom is to prevent injury to the fish by bumping into the hard enamel surface.



Figure 13. The fish are removed singly by hand and marked by removing fins with a pair of clippers.

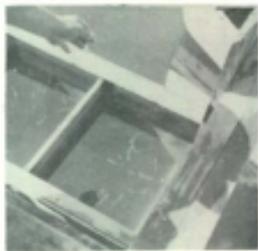


Figure 14. A certain percentage of the marked juveniles is retained in the box-type live-pen with an equal number of unmarked controls in the next compartment.

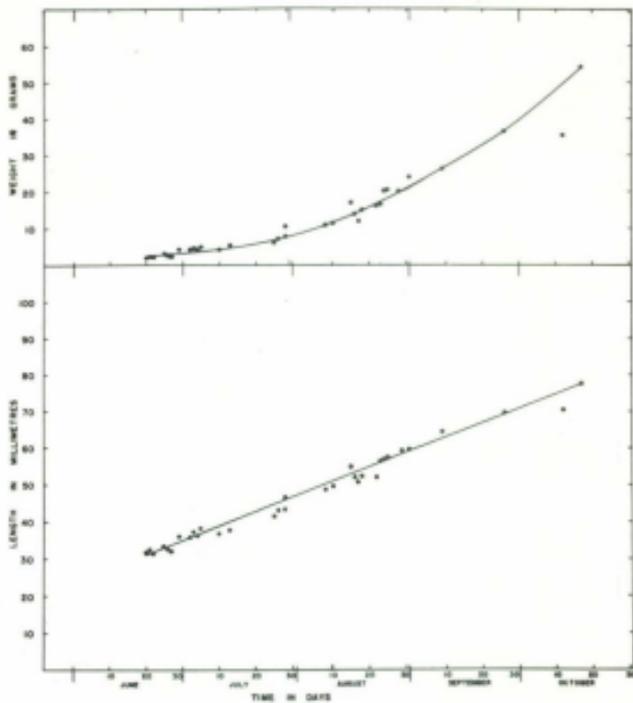


Figure 15. The age-length and age-weight relationships for juvenile herring captured in Departure Bay during 1950.

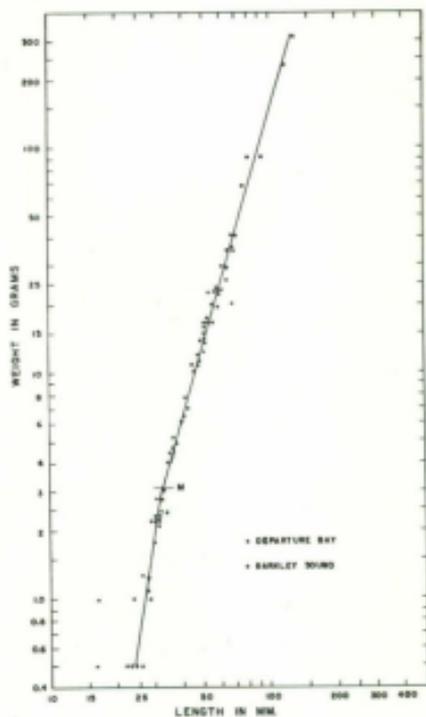


Figure 16. The length-weight relationship for metamorphosing and juvenile herring studied during the 1950 survey.

Length
in mm.

21

25

26

32

33

36

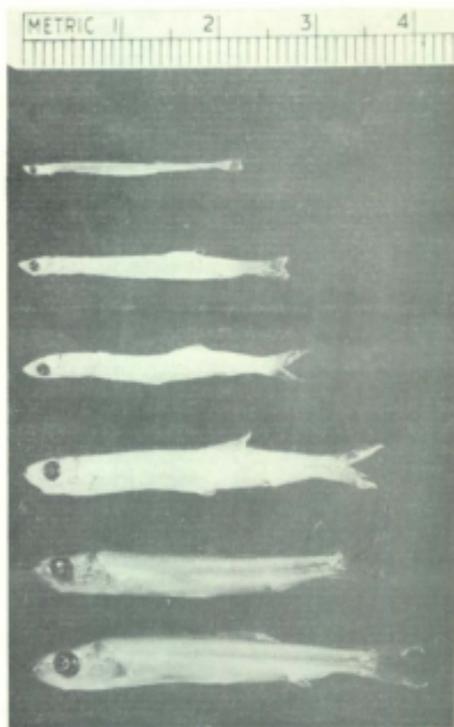


Figure 17. A series of young herring showing metamorphosis from the larva to the juvenile. The period involved is approximately between six and ten weeks after hatching.

Sample No.	Date of Capture	Length in mm.
2	June 20	31
8	June 27	32
11	July 2	36
17	July 10	37
22	July 26	43
28	Aug. 8	48
31	Aug. 15	55
42	Aug. 23	56
48	Aug. 31	58
51	Sept. 9	61
58	Sept. 26	70
59	Oct. 12	72
60	Oct. 17	74

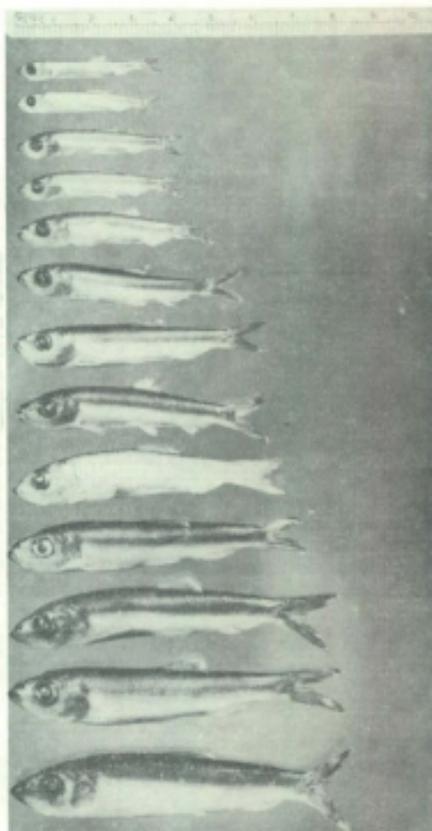


Figure 18. A series of juvenile herring showing growth and development throughout the summer months. The time interval between specimens is approximately one week in most cases. Specimens are typical ones from the larger samples taken.

Sample No.	Date of Capture	Length in mm.
13	July 2	37
23	July 25	43
28	Aug. 8	49
42	Aug. 23	55
49	Aug. 31	61
55	Sept. 20	67
59	Oct. 12	73
60	Oct. 17	79
56	Sept. 20	85



Figure 19. A series of juvenile herring showing an increment in length of approximately 6 mm. from specimen to specimen.