RESEARCH BRIEFS

FISH COMMISSION OF OREGON
307 State Office Building
PORTLAND 1, OREGON

Volume Seven—Number One

JULY 1959

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FOREWORD

These short reports are intended to inform the public, industry, and other interested parties of the current studies of the Commission's staff and of the basis for conservation measures. Reports will be published from time to time when studies are sufficiently complete to provide reliable biological evidence for conclusions upon which regulations are based. Research Briefs are free and may be obtained upon request from the editor.

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Time of Spawning, Length at Maturity, and Fecundity of the English, Petrale, and Dover Soles (*Parophrys vetulus, Eopsetta jordani,* and *Microstomus pacificus,* respectively)

GEORGE Y. HARRY, JR.[1]

INTRODUCTION

During World War II, the Oregon otter-trawl fishery rapidly expanded to major importance. Because of a lack of scientific personnel, research studies waited until after the close of the war.

In 1947, a research plan was developed with the objective of providing information which would form the basis for managing the important otter-trawl fishery.

As part of the otter-trawl market sampling program for bottom fish, begun in the winter of 1947-48 at Astoria, Oregon, information was gathered on the time of spawning, length at maturity, and fecundity of the English (*Parophrys vetulus*), petrale (*Eopsetta jordani*), and Dover soles (*Microstomus pacificus*). Samples were taken from market deliveries after the small fish had been culled out at sea, leaving mostly fish larger than the generally accepted market minimum size (English sole 13 inches, petrale 14 inches, and Dover 14 inches). Total lengths were taken on a cradle-type measuring board to the nearest one-half centimeter.

TIME OF SPAWNING

Examination of the gonads established both the time of spawning and the length at maturity of the female English and petrale soles taken in the vicinity of the mouth of the Columbia River. For each sample taken during the spawning period in the winters of 1947-48 through 1950-51, the percentage of mature females which had completed spawning was calculated. Data for both species for the various seasons were combined in a single figure (Figure 1).

The spawning periods of the English and petrale soles appear to be almost identical. Spawning usually begins for both species in November, is heavy in December and January, diminishes in February, and is substantially completed by March. Some spawning continues into May, and it is not unusual to see a female petrale sole turgid with ova in mid-summer.

During the period of this study, there was no winter fishery for Dover sole. In late October, when the last samples were taken before the fish became unavailable for the winter, the females were approaching spawning condition. In early May, when Dover sole reappeared on the fishing grounds, the females had substantially completed spawning. These observations indicate that the spawning period for Dover sole is much the same as for English and petrale soles, a conclusion supported by the findings

[1] Formerly Director of Research with Oregon Fish Commission; now Assistant Regional Director for Research, U. S. Fish and Wildlife Service, Bureau of Commercial Fisheries, Alaska.

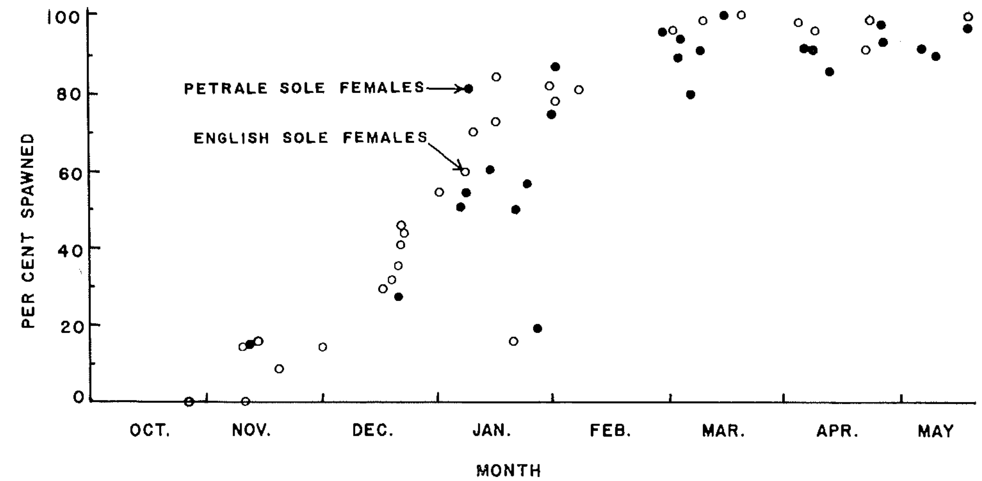

FIGURE 1. PER CENT OF FULLY SPAWNED ENGLISH AND PETRALE SOLE FEMALES.

of Hagerman (1952) that Dover sole spawn off northern California principally in December, January, and February, with some spawning in November and March as well.

LENGTH AT MATURITY

When length-frequency samples were taken, the gonads of English, petrale, and Dover soles were examined and their stage of development recorded. During the winter months, at the time of spawning, it is relatively simple to determine whether both sexes of English and petrale soles are mature. Dover sole were not available to the fishermen in the winter during the period of this study, probably because, unlike the other two species, they migrated into deeper water to spawn. Most of the data on length at maturity of the female Dover sole were gathered from May through October. Although it is not quite so easy to distinguish mature from immature females during this period, it is believed that the data are quite accurate. The mature, spent ovaries are flabby, reddish, and generally much longer than the firm, clear, immature ovaries (usually only an inch or two long). No attempts were made to distinguish the immature and mature testes of Dover sole.

From January 1948 through the winter of 1950-51, 2,090 English sole ovaries from fish between 14 and 38 cm. were examined to determine the percentage mature by length. Ovaries from many fish over 38 cm. were also examined, but since they were all mature, data were not tabulated. At 26 cm. only a small percentage of the females were mature (Figure 2). At 31 cm. approximately 50 per cent, and over 35 cm. almost all were mature. Length-frequency data established that the great majority of the female English sole landed at Astoria have spawned at least once. However, the length-frequency curves do not include small fish discarded dead at sea, many of which are immature.

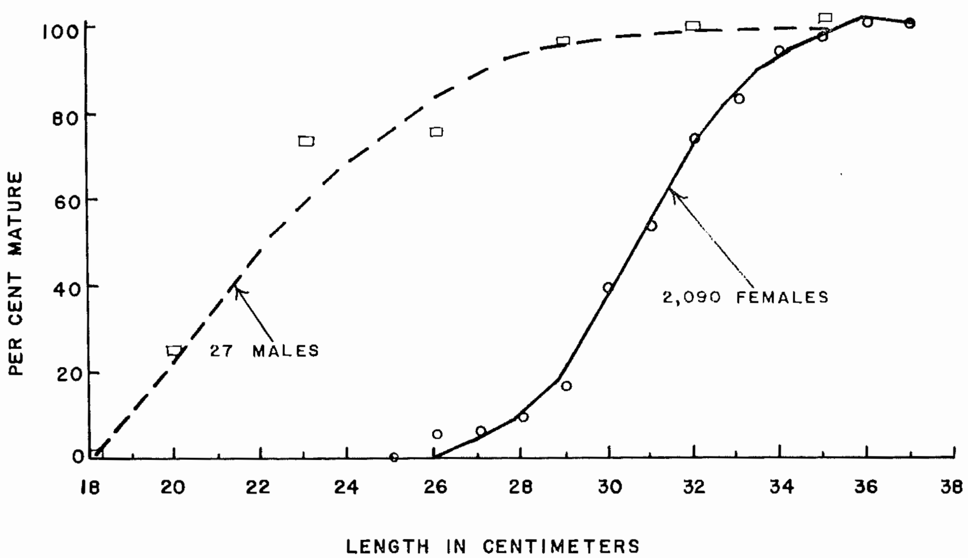

FIGURE 2. PER CENT OF ENGLISH SOLE MATURE AT EACH LENGTH.

The English sole males mature at a smaller size than the females (Figure 2). Because of the relatively few males examined, the data were grouped in class intervals of 3 cm. Some males as small as 21 cm. were mature; most were mature at 26 cm.; and practically all those over 29 cm. were mature. Because of their small average size, most mature males do not enter the commercial fishery, and therefore spawn relatively unmolested, except those caught and discarded at sea.

During the period from January 1948 through the winter of 1950-51, 1,492 petrale sole ovaries were examined for degree of maturity. The smallest mature females were about 31 cm. in length (Figure 3). At 40 cm. about half, and over 45 cm. practically all were mature. Extensive length-frequency data taken from Astoria landings indicate that about one-third of the females were less than 40 cm. in size. Again, these data disregard the small, immature females discarded dead at sea.

The condition of 267 testes of petrale sole was also recorded. Males first became mature at about 29 cm. (Figure 3). At about 36 cm. half, and over 38 cm. practically all were mature. About one-third of the males landed were less than 36 cm. in length.

The petrale sole male matures at a smaller size and younger age than the female. Consequently, mature males are more likely than females to escape capture by the otter-trawl nets.

During the May to October period of 1948 and 1949, 2,086 Dover sole ovaries from fish smaller than 49 cm. were examined. Many more ovaries of fish over 49 cm. were examined, but totals were not computed because they were all mature.

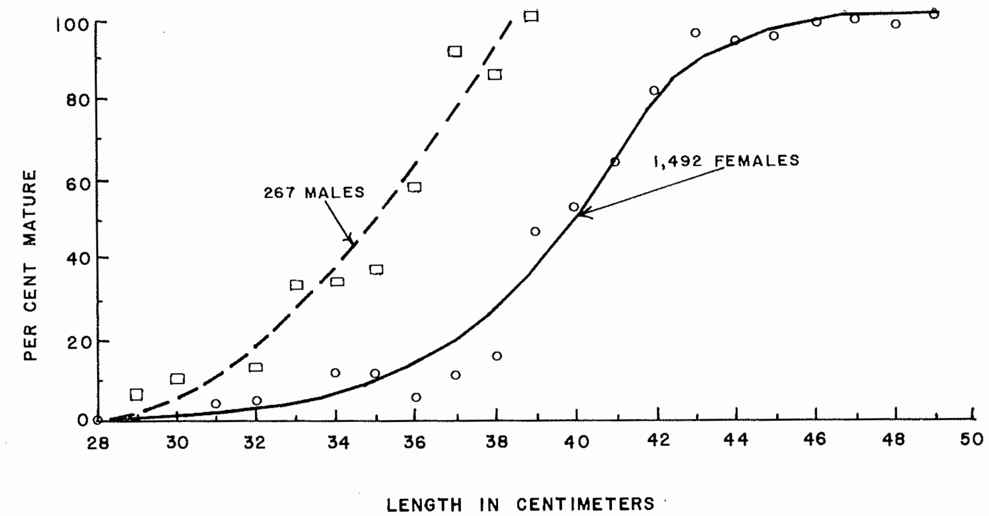

FIGURE 3. PER CENT OF PETRALE SOLE MATURE AT EACH LENGTH.

The Dover sole female first becomes mature at about 33 cm. (Figure 4). At 38 cm. approximately 50 per cent were mature, and over 42 cm. almost all were mature. These findings are similar to those presented by Hagerman (1952) for Dover sole landed at Eureka.

About 15 per cent of the females landed by the commercial fishery were smaller than 38 cm. Again, fish too small for the markets were discarded at sea.

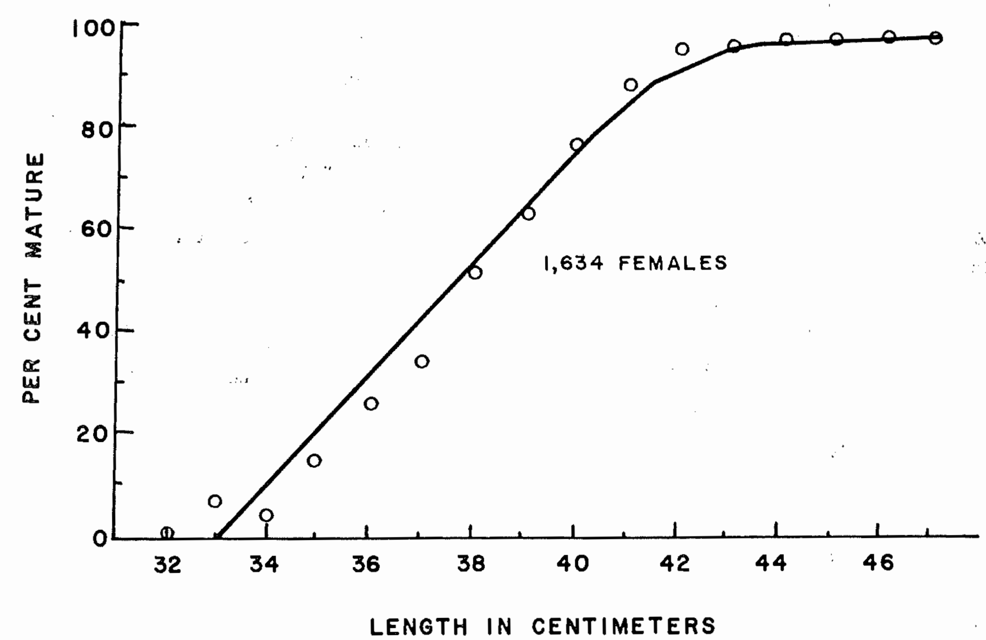

FIGURE 4. PER CENT OF DOVER SOLE MATURE AT EACH LENGTH.

FECUNDITY

Ovaries were taken in 1949 and 1950 from 15 English sole 30-43 cm. in length and 22 Dover sole 42-57 cm. in length. The Dover sole were taken in October and early November, when the fish were still in relatively shallow water (less than 100 fathoms) prior to moving into deep water to spawn. They came mostly from the area off the Columbia River, although a few were taken off Destruction Island, Washington. None of the Dover sole ovaries indicated that eggs were being extruded.

The English sole ovaries were from fish taken off the Columbia River during the spawning season, as late as February 6. Although every effort was made to select only specimens which showed no signs of egg extrusion, it is possible that some of the ova might have been lost. Agreement with ova counts by Smith (1936) supports the observation that little loss of ova had occurred through spawning prior to examination (Figure 5).

The ovaries were preserved in 10 per cent formalin until counts were made in the summer of 1951. The first step was to dry the ovaries at room temperature for one to three days, until the ova could be easily separated from the ovary with a needle. Each ovary was weighed on an analytical balance. Then a cross section was cut from the ovary and immediately weighed, after which the ova were removed. Next, loose eggs from the cross section were mixed as randomly as possible in liquid agar-agar in a petri dish. After the agar-agar solidified, a counting plate (a circular piece of black cardboard the size of the petri dish divided into six equal sectors and smaller subdivisions) was placed under the petri dish. All the Dover sole ova in the dish were counted, but because of their small size the ova of a petrale or English sole in only one-sixth of the area were counted. Counts for the latter two species were multiplied by six to obtain the total number of ova in the section. Weight of each section was then divided into total weight of the ovary, and the factor obtained was multiplied by the number of ova in the section to give the total.

Sections were made from the anterior, middle, and posterior parts of the left and right ovary from a 35½ cm. English sole. Then the total number of ova in each ovary was calculated from each section and also from the three combined sections of each ovary (Table 1).

TABLE 1. **NUMBER OF OVA IN EACH OVARY FROM A 35½ CM. ENGLISH SOLE, COMPUTED FROM COUNTS OF OVARY CROSS SECTIONS**

Section	*Left Ovary*	*Right Ovary*
Anterior	550,000	743,000
Middle	347,000	476,000
Posterior	612,000	729,000
Three combined	498,000	684,000

The large variation in totals computed from each cross section made it evident that more than one section must be counted for reliable results. However, it was thought that even three sections from each ovary might not be sufficient, so paired sections were cut from the anterior, middle, and posterior parts of left and right ovaries from a 33 cm. English sole. The totals computed from these sections are given in Table 2.

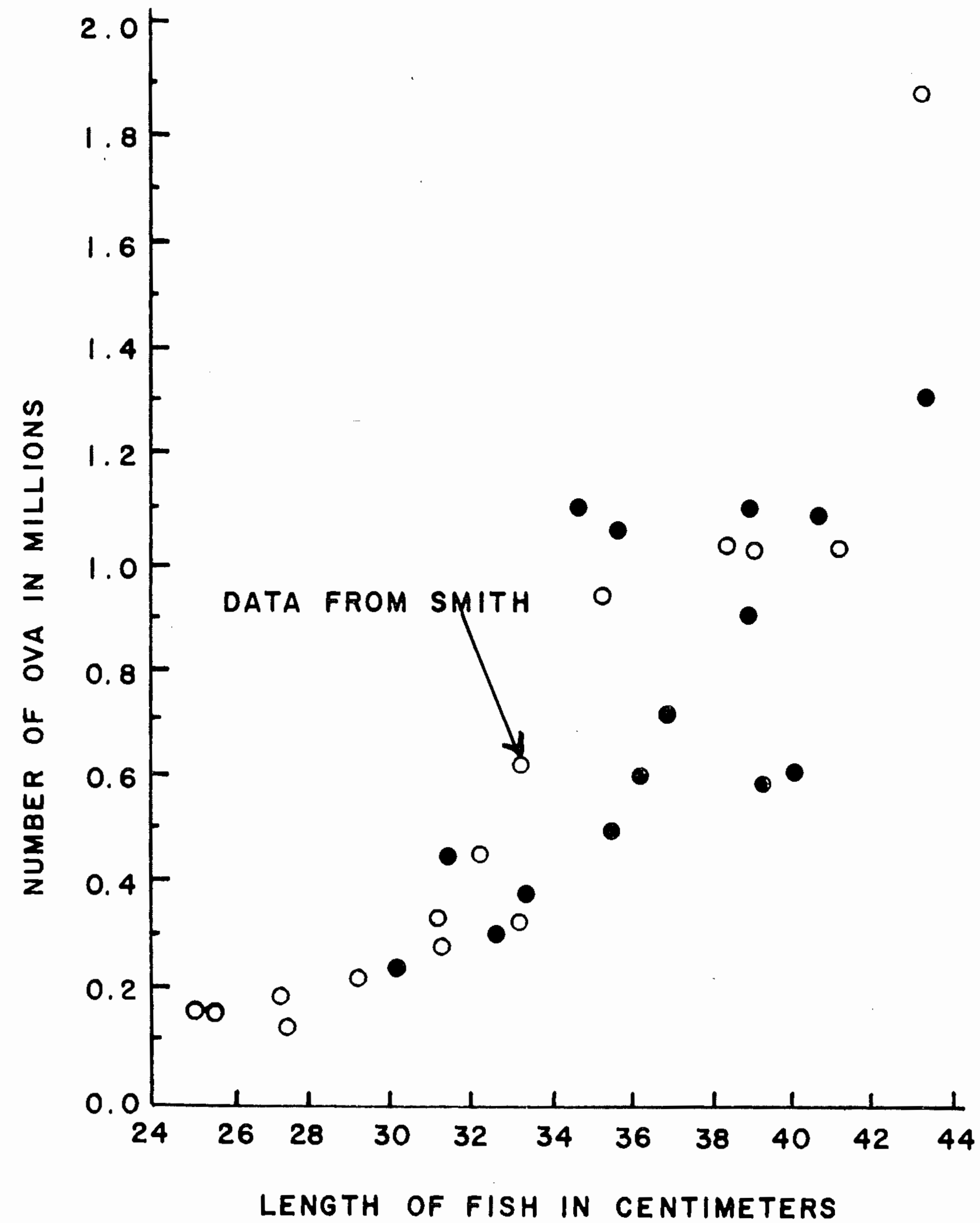

FIGURE 5. FECUNDITY DATA FOR ENGLISH SOLE.

TABLE 2. **NUMBER OF OVA IN EACH OVARY FROM A 33 CM. ENGLISH SOLE, COMPUTED FROM COUNTS OF OVARY CROSS SECTIONS**

	Left Ovary		*Right Ovary*	
Section	*Set A*	*Set B*	*Set A*	*Set B*
Anterior	219,000	233,000	266,000	280,000
Middle	244,000	178,000	245,000	249,000
Posterior	277,000	239,000	324,000	230,000
Three combined	230,000	212,000	275,000	252,000
Six combined (both sets)	221,000		264,000	

Because of the relatively small variation in ova totals computed from the three sections combined of sets A and B for both left and right ovaries, and lack of time, it was decided to limit the sampling to a single set from each of three sections of every ovary.

The numbers of ova calculated for each English and Dover sole are given in Table 3 and plotted in Figures 5 and 6. For comparison, counts by Smith (1936) for Puget Sound English sole are also plotted in Figure 5. The results are quite similar, although the smaller variation in Puget Sound data suggests that sampling procedures might have been more adequate. Smith separated all the ova from the ovary and then weighed and counted a sample (size not given) of the ova. This method is uncomplicated by the presence of ovarian membranes in the sample.

TABLE 3. **NUMBER OF OVA IN ENGLISH AND DOVER SOLES OF VARIOUS LENGTHS BASED ON COUNTS OF OVARY CROSS SECTIONS**

English Sole		*Dover Sole*	
Length of Fish (cm.)	*Number of Ova*	*Length of Fish (cm.)*	*Number of Ova*
30.0	327,600	42.5	51,900
31.5	557,300	43.0	77,700
32.5	369,000	44.0	68,400
33.0	484,400	44.5	75,700
34.5	1,266,100	45.5	58,500
35.5	638,200	45.5	80,200
35.5	1,181,800	45.5	100,600
36.0	712,300	46.5	142,900
36.5	811,300	48.0	99,100
38.5	986,900	48.5	119,900
38.5	1,251,400	49.5	122,900
39.0	706,900	51.0	137,700
40.0	751,900	51.5	183,900
40.5	1,292,900	52.0	134,100
43.0	1,566,200	52.0	191,600
		52.5	192,200
		54.0	132,100
		54.0	142,100
		54.5	148,300
		57.0	162,400
		57.5	265,800
		64.0	256,700

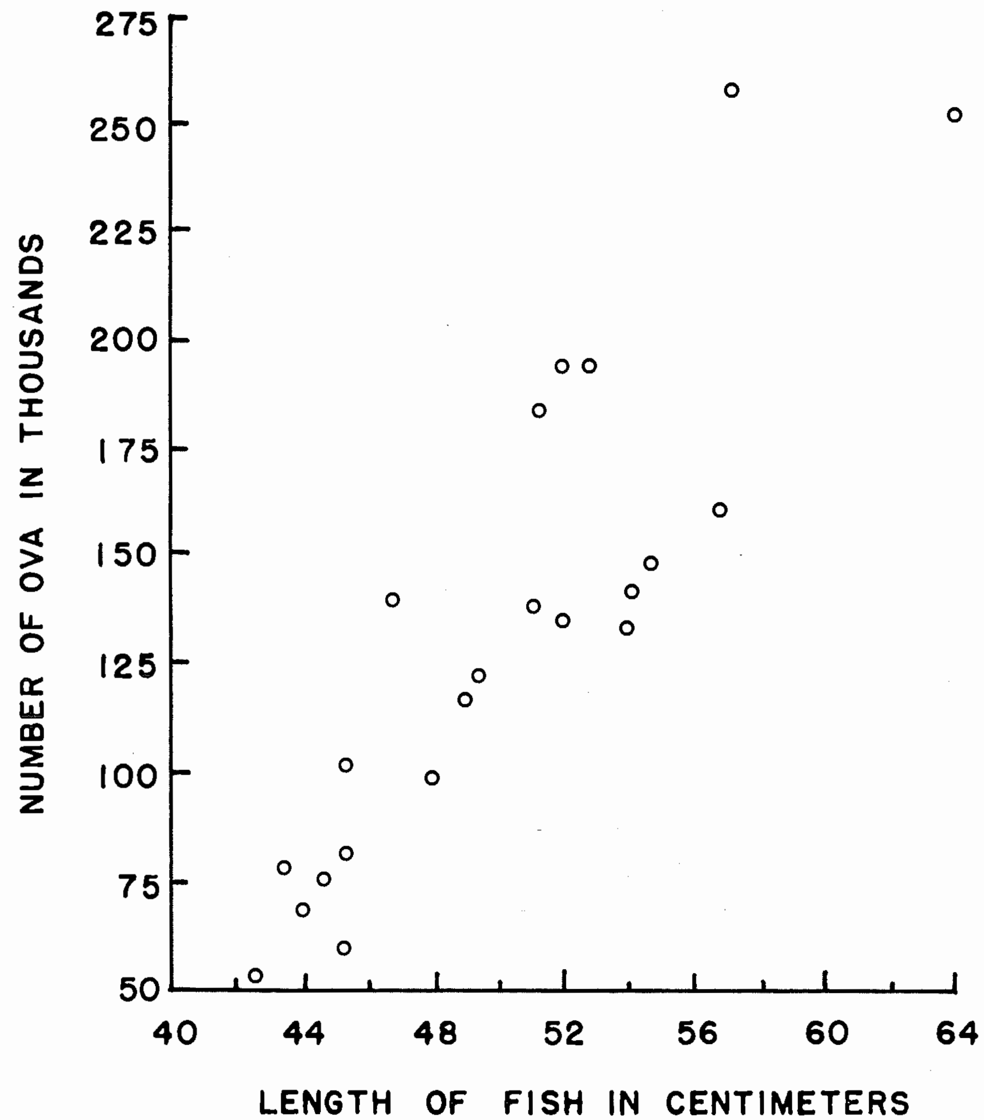

FIGURE 6. FECUNDITY DATA FOR DOVER SOLE.

Hagerman's fecundity estimates for 42 to 64 cm. Dover sole specimens from northern California are slightly higher than those given here.

No counts were made of petrale sole ova.

SUMMARY

The principal spawning period for English and petrale soles taken near the mouth of the Columbia River is December and January.

The lengths at which 50 per cent of the females were mature are as follows: English sole, 31 cm.; petrale sole, 40 cm; and Dover sole, 40 cm. The males mature at a somewhat smaller size.

The number of ova calculated for English sole ranged from 327,600 for a 30.0 cm. fish to 1,566,200 for a 43.0 cm. fish. For Dover sole the range was from 51,900 ova for a 42.5 cm. fish to 265,800 for a 57.5 cm. fish, although a 64.0 cm. fish contained only 256,700 ova.

ACKNOWLEDGMENT

The tedious counting of ova was done by Miss Verna Engstrom (now Mrs. Robert Engstrom Heg).

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Recent Studies in the Hydrography of Oregon Estuaries[1]

WAYNE V. BURT[2]
and
W. BRUCE McALISTER[2]

INTRODUCTION

In many respects, we know more about the oceans than about marine processes which occur along the shore and in coastal estuaries. The open sea represents a relatively unchanging environment. As such, investigations conducted over a period of years may be fitted together to describe oceanic properties which remain nearly constant. In coastal areas, variability is much greater: circulation, and physical and chemical properties of the water change rapidly, due to variation in tides, fresh-water runoff, and meteorological conditions. The different seasons may be accompanied by changes great enough to alter the physical and biological character of an estuary. Man is also continually altering the environment, and some of these changes may become permanent features of an estuary. Such utilization has created a need for greater knowledge of the processes involved in the estuarine system as affected by annual cycles and long-term changes.

The very factors which define an estuary make it a desirable site for industrial utilization. Rivers entering the estuary are sources of fresh water, a vital necessity for most modern industries. The ocean absorbs the waste and discharge from cities, towns, and industries, and the estuarial connections to the sea afford easy access to marine transportation. As markets and populations expand, we can expect growing development of coastal estuaries, bringing inevitable conflicts of interest. For example, the growth of population that accompanies industrialization increases the demand for seafood products as well as for clean recreational facilities. If the interests and requirements of all those who use the estuary are to be protected, adequate studies must be available of the original aquatic conditions in order to predict accurately the impact of changes under various alternate circumstances.

Many groups are interested in estuarine problems, including fishermen, canners, packers, marina operators, shippers, and industrial users, as well as cities requiring sources of fresh water and avenues of waste disposal. Conservation and regulatory bodies are concerned with water resources. As the resources become depleted and conflicts of utilization increase, regulatory bodies will probably exert greater and more effective control over water utilization.

A center for hydrographic study of estuarine waters has been established at Oregon State College. Investigations are under way to describe and classify Oregon estuaries according to their water properties and circulation patterns. One phase is directed toward determining the physical and chemical properties of the water, such as temperature, salinity, and

[1] This work has been supported by the Office of Naval Research, Contract Nonr 1286(02), Project NR 083-102, Oregon State College, and the Oregon Fish Commission.

[2] Department of Oceanography, Oregon State College.

dissolved-oxygen content, and relating these factors to the ecology of the estuarine system. Another phase involves the physical structure of estuaries, including the interrelation of tides, topography, and stream flow with circulation and current patterns.

This paper summarizes our present knowledge of Oregon coastal estuaries.

TYPES OF ESTUARIES

Oregon estuaries have been classified in a generally accepted system, developed by Pritchard (1955), according to circulation patterns and salinity distribution. Under this system, a given type of estuary may, and probably will, change to another type during the year as currents and salinity distribution alter. The transition from one class to another is associated with variations in width, depth, and tidal range among estuaries, and with changes in river flow in a particular estuary.

Oregon estuaries generally fall into one of three types: Type A, a two-layered or stratified estuary; Type B, partly mixed; and Type D, vertically homogenous or well mixed (Figure 1).[3]

Oregon estuaries occupy the seaward end of river valleys which have been cut through the coastal mountains, and as a result are narrower and shorter than those found on the Atlantic Coast and elsewhere.

One of the factors that determines the type of mixing pattern is the flow ratio. This is the ratio of fresh-water discharge during a half-tidal cycle of 12.4 hours to the tidal prism, which is the volume between mean high and mean low water. High river runoff, with a flow ratio value on the order of 1.0 or more, provides a large volume of fresh water at the surface that helps to maintain the sharp vertical salinity gradients of the two-layered (Type A) estuary. With smaller runoff and a flow ratio between 0.2 and 0.5, the estuary is probably partly mixed (Type B). When the river flow is low and the flow ratio less than 0.1, the estuary is probably the well mixed, vertically homogeneous Type D. Thus, a given type may change with the variation of river flow.

The tidal range can be very important. In any estuary, the energy required to mix salt and fresh water is largely supplied by tidal forces. As an approximation, the energy present in a tidal cycle may be considered proportional to the square of the tidal range. In the Mississippi Estuary on the Gulf Coast the tidal range is 0.5 feet, compared with an average of 5.5 feet in Oregon estuaries. This tenfold difference in tidal range means that the energy available for mixing in Oregon estuaries will be greater than on the Gulf Coast, thus ensuring much more mixing when other conditions are the same.

Type A: Two-Layered System

Figure 1 A shows a well-developed two-layered system, consisting of a layer of almost fresh water overlaying a layer of almost pure salt water.

[3] Pritchard's Class C estuary has not been found in Oregon and will not be considered in this paper.

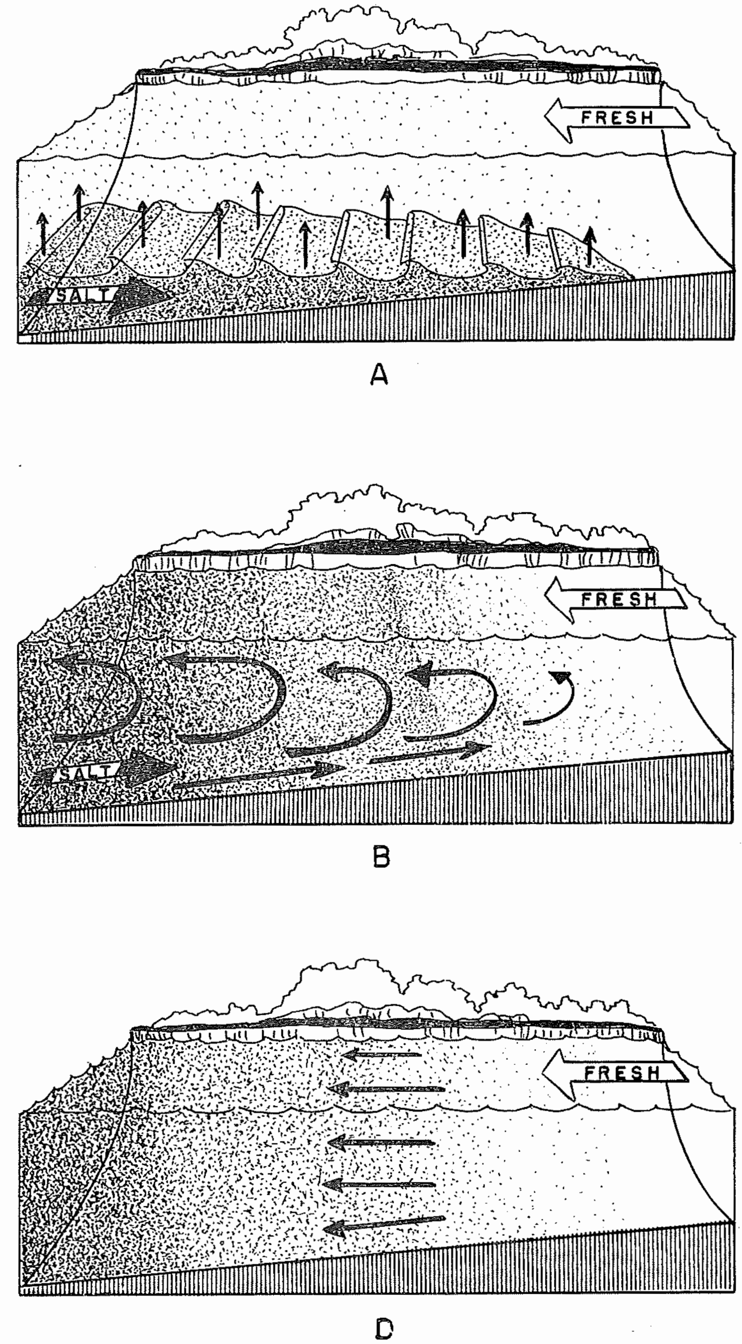

FIGURE 1. ESTUARINE CIRCULATION TYPES (ADAPTED FROM PRITCHARD, 1955): A, TWO-LAYERED SYSTEM; B, PARTLY-MIXED SYSTEM; D, WELL-MIXED SYSTEM.

Fresh water from the river inflow is spread out on the surface, while the denser salt water under-runs the fresh water, forming a salt wedge along the bottom. At the interface of salt and fresh water, some salt water mixes upward into the fresh water, where it is carried back to sea in a diluted form. Whenever the two-layered system is formed, there is a large flow of fresh water in the upper layer; even with the addition of the small amount of salt mixed from the lower layer, the upper layer remains nearly fresh. Because of vertical stability, very little or none of the lighter fresh water mixes in the denser salt layer. The layer of salt water will move back and forth with the tides but maintains a mean position. Since some of the water in the salt layer is constantly being lost to the upper, fresher layer, there must be a net upstream movement in the salt layer if it is to maintain itself.

The Mississippi Estuary is a good example of a well-developed two-layered system. There the wedge of sea water extends 150 miles upstream, while the transition from sea water to fresh water occurs in a vertical distance of several feet. In Oregon estuaries, salt wedges are usually poorly defined and rarely extend far inland from the mouth. Conditions favoring formation of a two-layered estuary include: (1) relatively small tidal ranges which do not furnish much energy for mixing; (2) high river runoff which provides a large volume of fresh water at the surface, maintaining sharp density gradients; and (3) a relatively large depth to width ratio.

None of the Oregon coastal estuaries has sufficiently low tides, great depth, and high runoff to maintain a two-layered system throughout the year; nor does tidewater in any case extend sufficiently far upstream to permit formation of a salt wedge of great extent even during periods of two-layered flow. Despite relatively high tides, several estuaries occasionally approach the two-layered system during extended periods of high runoff.

During high winter runoff the Umpqua Estuary, with a flow-ratio of 0.7, approaches two-layered flow. Figure 2 shows the vertical distribution of salinity on a cross section upstream from the ocean for the Umpqua Estuary at high water, January 26, 1956. A wedge of nearly pure ocean water with salt content of over 30‰[4] (88 per cent ocean water) enters on

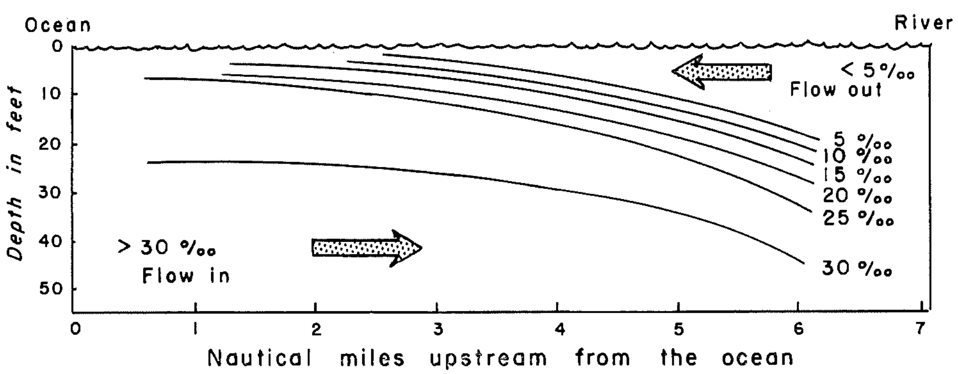

FIGURE 2. VERTICAL DISTRIBUTION OF SALINITY IN UMPQUA RIVER, CROSS SECTION RUNNING UP CHANNEL FROM THE OCEAN, HIGH WATER, JANUARY 26, 1956; ESTUARY APPROACHING TWO-LAYERED SYSTEM.

the bottom and extends upstream for over 6 miles. Nearly-fresh water with salt content under 5‰ (85 per cent fresh water) is shown moving out at the surface to within 3 miles of the mouth. At low water, the wedge was pushed completely out of the estuary by combined river and tidal flow and 3 miles upstream salt content dropped to less than 0.2‰ (99 per cent fresh water).

Figure 3, line I shows the vertical distribution of salinity at a station 6.0 miles upstream in the Umpqua at high water, January 26, 1956. Note the large increase in salt content between 20 and 30 feet.

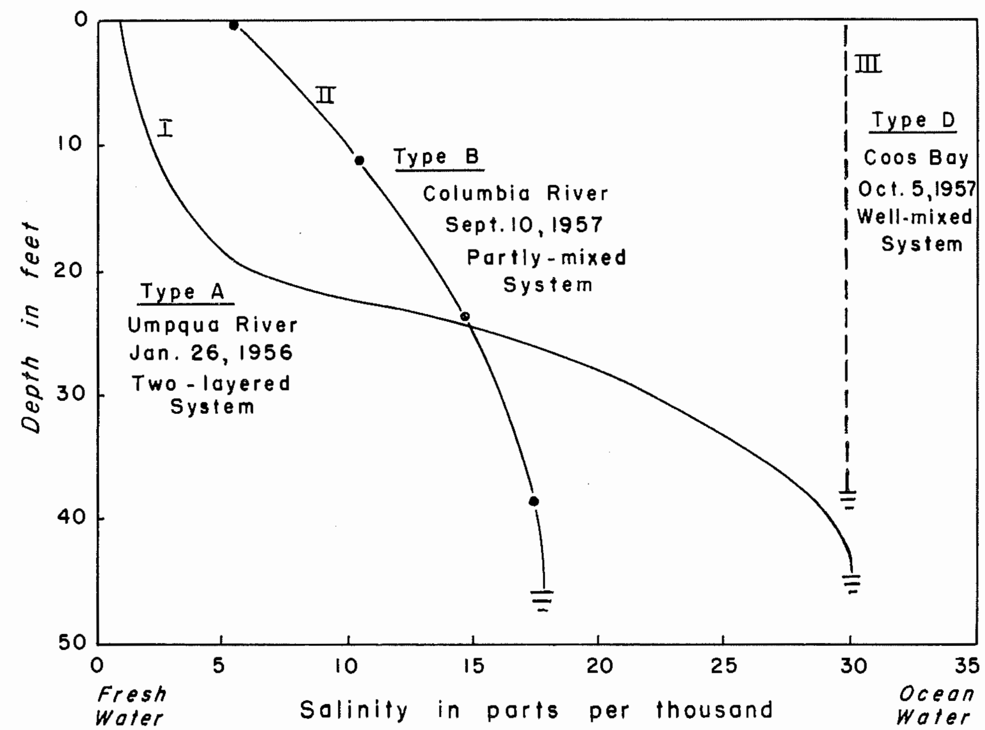

FIGURE 3. VERTICAL CHANGES IN SALINITY, SELECTED STATIONS, UMPQUA RIVER, COLUMBIA RIVER, AND COOS BAY, ILLUSTRATING TYPICAL CHANGES IN DIFFERENT TYPES OF ESTUARIES.

Figure 4, line I shows net current in the Umpqua Estuary on January 26, 1956, averaged over a tidal day of 24 hours and 50 minutes for the station 3.3 miles upstream. Note that the mean flow was downstream above 35 feet in depth, but below this level average flow was upstream despite high river flow at the time. This means that the salt wedge could transport animal and plant life as well as pollutants, sand, and silt upstream against the river flow at an average rate of nearly a half-knot or 12 nautical miles per day, although they would not be carried further than the extent of the salt wedge.

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④ The symbol ‰ refers to the salt content or salinity expressed as parts per thousand by weight of dissolved materials. Full sea water has about 34‰, or 3.4 per cent dissolved materials by weight.

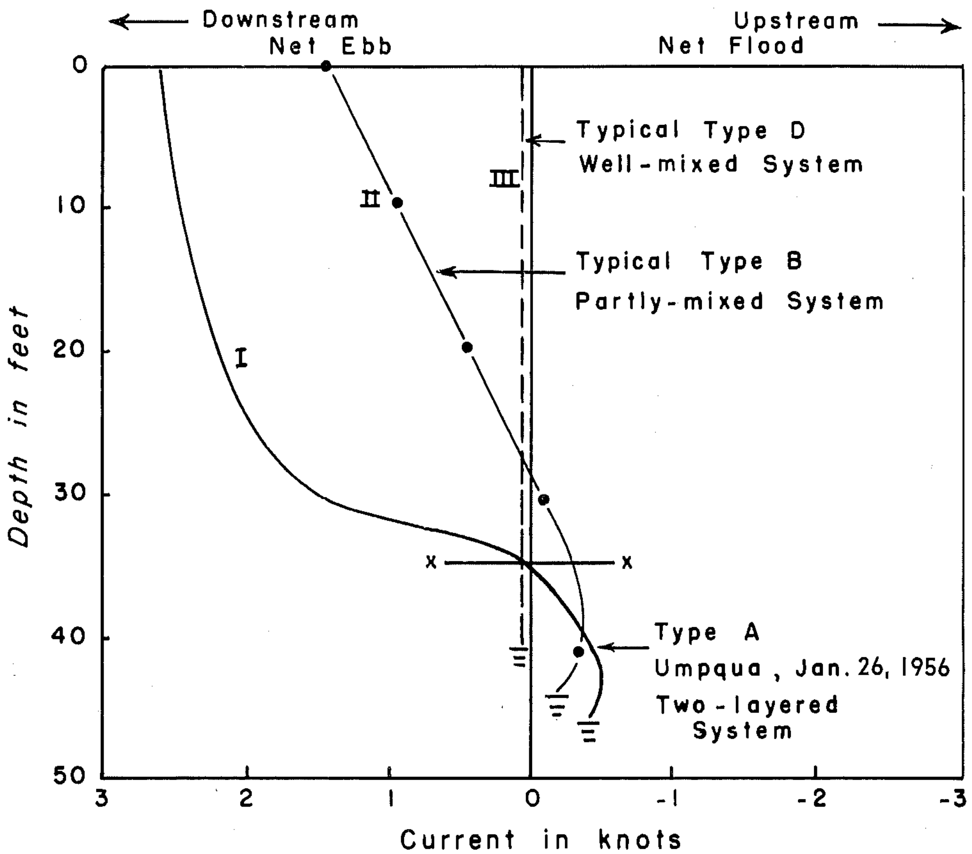

FIGURE 4. NET CURRENT AVERAGED OVER A TIDAL CYCLE, ILLUSTRATING TYPE OF AVERAGE FLOW EXPECTED IN THREE CLASSES OF ESTUARIES. LINE X——X SHOWS DEPTH OF NO NET MOTION WHERE AVERAGE CURRENT IS ZERO OVER A TIDAL CYCLE FOR LINE I.

Type B: Partly-Mixed System

As run-off becomes more moderate in the Umpqua or a similar estuary, a partly-mixed system will develop (Figure 1 B). Because of vertical mixing, the salt-water and fresh-water layers are no longer sharply defined. At any location, however, the water near the bottom is more saline than at the surface. The strongest ebb, or outflowing current, is near the surface. The strongest flood currents are found nearer the bottom and there is a net upstream flow along the bottom.

The partly-mixed pattern is common in Oregon estuaries—as in the Columbia Estuary. Figure 5 shows vertical distribution of salinity for the Columbia Estuary on a cross section running upstream from the ocean at high water, September 10, 1957. The moderate flow late in summer has permitted considerable vertical mixing. Salinity changes in both horizontal and vertical directions are gradual. The flow ratio was less than 0.5 at this time. A typical vertical salinity profile for the Columbia River is shown in Figure 3, line II.

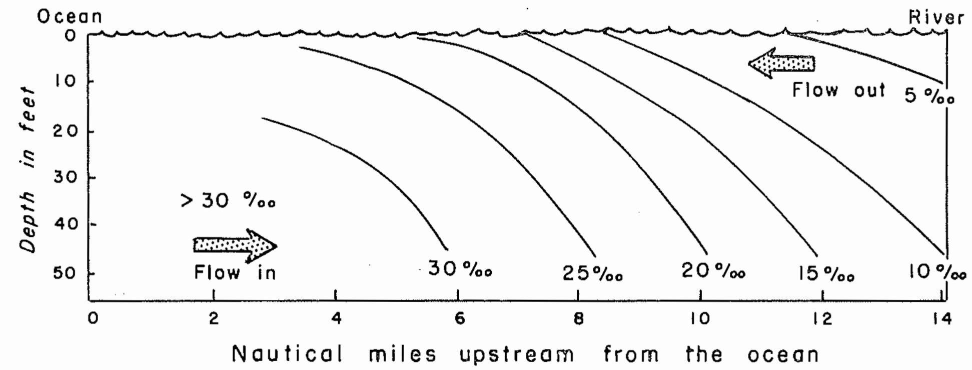

FIGURE 5. VERTICAL DISTRIBUTION OF SALINITY IN COLUMBIA RIVER, CROSS SECTION RUNNING UP MAIN CHANNEL FROM OCEAN, HIGH WATER, SEPTEMBER 10, 1957; SHOWING TYPICAL DISTRIBUTION FOR PARTLY-MIXED ESTUARY.

Current observations were not available for September 10, 1957. Hence, a typical non-tidal circulation for a partly-mixed estuary was selected from observations in the Columbia Estuary at a different time but with similar circulation (Figure 4, line II). The average flow over a 12.4 hour tidal cycle was outward above a depth of 28 feet; below 28 feet, the flow was up the estuary at a rate of 0.3 knot, or somewhat over 7 miles per day. It should be noted that a pollutant entering an estuary of this type near the bottom may travel a number of miles upstream against the river flow before mixing completely upward into the surface layers. Thus, material entering at the bottom and near the mouth would pollute the entire estuary.

Type D: Well-Mixed System

The partly-mixed system changes under the influence of high tides, low runoff, and shallow, wide topography to a well-mixed or vertically-homogenous type (Figure 1 D). Sudden channel restrictions or obstructions which increase turbulence also tend to create a well-mixed condition, as near the mouth of the Siuslaw River. Several Oregon estuaries become vertically homogenous during late summer and early fall, the normal period of minimum runoff. At least two estuaries, Netarts Bay and Coos Bay, are essentially well mixed throughout the year.

Figure 6 shows a vertical cross section of salinity for Coos Bay, from the ocean to 14 miles upstream, October 5, 1957. For the first 10 miles, the nearly vertical lines of constant salinity are typical of a well-mixed estuary. Between 10 and 14 miles, salinity increased with depth. The flow ratio was less than 0.1 at this time. Figure 3, line III shows the typical lack of salt-content change with depth for the lower Coos Estuary in summer and early fall. With this type of salinity distribution and flow, there is a slow net drift of water outward at all depths, with the back-and-forth tidal movement superimposed upon the slow drift. Salt moves upstream against the drift by means of diffusion, enhanced by tidal mixing. The net non-tidal flow was not measured at this time, but measurements in the Yaquina Estuary with a similar salinity distribution resulted in net non-tidal flow illustrated in Figure 4, line III. Occasionally, the incoming tide may flood

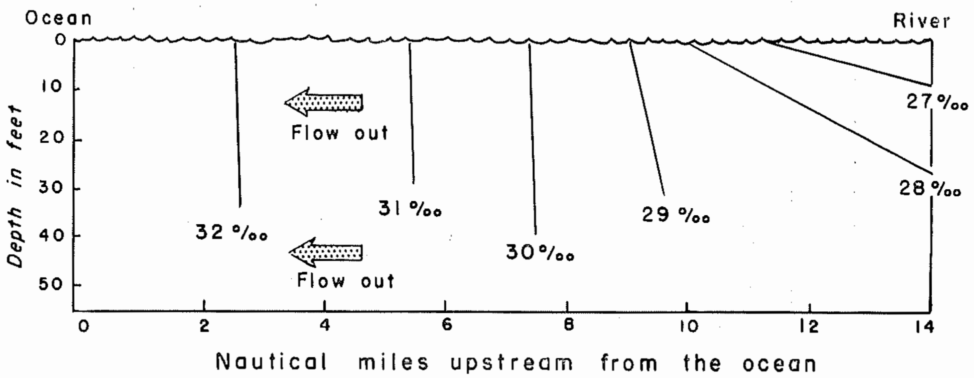

FIGURE 6. VERTICAL DISTRIBUTION OF SALINITY IN COOS BAY ESTUARY, CROSS SECTION RUNNING UP CHANNEL FROM OCEAN, HIGH WATER, OCTOBER 5, 1957; ESTUARY ESSENTIALLY WELL MIXED UPSTREAM FOR 10 MILES AND PARTLY MIXED ABOVE 10 MILES.

more strongly at the surface and over-ride the slightly less dense and less saline water at the bottom of the bay. This results in instability, which further increases turbulence and mixing to maintain the vertically-homogenous type. For a more complete discussion of this kind of tidal mixing, see Burt and Queen (1957).

CLASSIFICATION OF OREGON ESTUARIES

It is sometimes difficult to delineate estuary mixing patterns exactly at any given time, owing to gradations between the different types. Strictly speaking, Type A would have a salinity change from the surface to the bottom of nearly $34^0/_{00}$, while the vertical change in Type D would be nearly $0^0/_{00}$.

Oregon estuaries have been classified in Table 1 on the basis of salinity change from top to bottom: $20^0/_{00}$ or over, Type A; between 4 and $19^0/_{00}$, Type B; and $3^0/_{00}$ or less, Type D. Salinity change was measured at high water at the station nearest to where mean salinity was $17^0/_{00}$, or half fresh and half salt water. The location of each station in nautical miles up the channel from the ocean is also listed in Table 1, being approximately half the total distance to which any salt water penetrated when the data were collected. Large vertical changes in salt content indicate a salt-water wedge without strong vertical mixing; small changes, strong vertical mixing, and consequent absence of a well-defined salt wedge.

APPLICATION OF DATA

Results of hydrographic investigations, including physical and chemical properties and circulation patterns, may be applied to the solution of biological, ecological, and coastal engineering problems. Currents not only affect the nature and rate of sedimentation and bottom topography of the stream or estuary, but tidal mixing provides a means of transport for dissolved or suspended material upstream against the current. Departures

TABLE 1. **TYPES OF OREGON ESTUARIES DETERMINED BY SALINITY MEASUREMENTS AT HIGH WATER AT THE NEAREST STATION WHERE TOP-TO-BOTTOM SALINITY WAS 17°/₀₀**

Estuaries	*January*	*February*	*March*	*April*	*May*	*June*	*July*	*August*	*September*	*October*	*November*	*December*
Columbia	B–11		D–16	B–8			A–6		B–10 B–8			
Nehalem	B–4			A–3 B–3					B–8			
Tillamook	A–6			D–6						D–8		
Netarts	D			D								
Siletz	A–2			A–2						B–5		
Yaquina	D–8	B–9 B–2		B–8	B–8			D–12		D–16 D–16	D–10	
Alsea	B–1		B–2	B–3						B–6		
Siuslaw	A–1		B–4		A–4					D–7		
Umpqua	A–2	A–3	B–6		B–7		D–9			B–8		
Coos	D–12 B–10	D–11	D–10 B–12	D–10	D–11	D–11 B–4	D–15	D–16	D–17	D–15	B–12	D–14

from the mean must be considered as well as mean conditions themselves. In many cases, an extreme condition imposes the limiting factors upon the environment.

Biological Applications

Oysters and clams are representative of sessile animals whose distribution in estuaries appears to be affected by water properties. Figure 7 shows the distribution of two major species of clams in Yaquina Bay (Marriage, 1954), suggesting a relationship to different salinities. Lines superimposed on Figure 7 show the minimum mean salinity (5-day average) which may be expected at least 60 days during the year. The gaper clam (*Schizothaerus nuttalli,* Conrad) appears to be restricted to a minimum salinity of about $27^0/_{00}$, while the softshell clam (*Mya arenaria,* Linnaeus) is found almost to the $0^0/_{00}$ line but not to a large extent where gaper clams are found. Similar conditions may hold in Coos Bay and elsewhere in Oregon estuaries. Cause and effect relationships may not be closely inferred from such diagrams, but they can be useful for studying the ecology of various species of clams and selection of areas for clam culture.

A similar type of distribution has been found for the native oyster (*Ostrea lurida,* Carpenter) in Yaquina Bay. Dimick *et al.* (1942) showed that cultivation of this species succeeded in a relatively confined section of the bay between the 60-day mean salinity limits of approximately $10^0/_{00}$

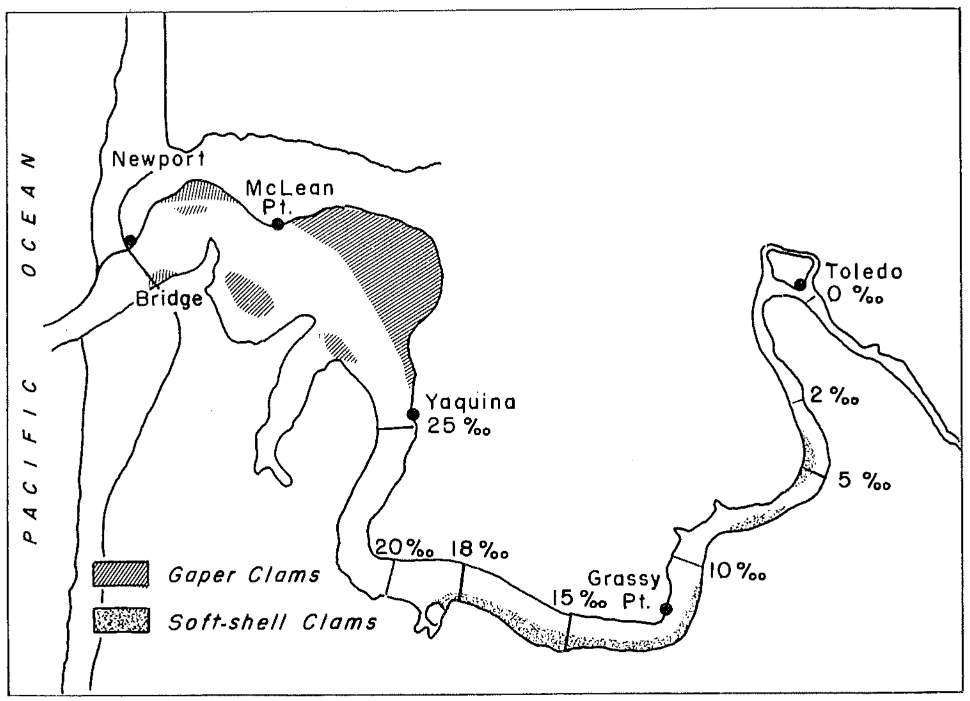

FIGURE 7. DISTRIBUTION OF GAPER AND SOFT-SHELLED CLAMS, YAQUINA RIVER ESTUARY; FIVE-DAY AVERAGE MINIMUM SALINITY EXPECTED AT LEAST 60 DAYS DURING YEAR.

and $25^{0}/_{00}$. The lower limit of salinity is related to killing of oysters by freshets in the spring, while the upper limit is probably associated with the ineffectiveness of certain predators for extended periods in waters with salinities below approximately $25^{0}/_{00}$.

Figure 8 shows the mean annual salinity cycle for stations off Empire, North Bend, and the city of Coos Bay in Coos Bay Estuary. Successful Japanese oyster (*Crassostrea gigas,* Thunberg) culture in the bay proper is limited to 2 miles on either side of the North Bend station and in South Slough. Again, the 60-day mean salinity limits for successful oyster growing are in the neighborhood of $10^{0}/_{00}$ and $25^{0}/_{00}$.

It is clear that not only should the physical and chemical properties of the water be considered in oyster culture, but circulation patterns as well. For example, the important set of oyster spawn in the James River, Virginia, was shown by Pritchard (1952) to depend upon the existence of a two-layered system. The inflowing lower layer carries the oyster spat 20 miles upstream from the large beds near the mouth of the river to localities more favorable for a large set that support a small adult population.

Fishermen at Winchester, near the mouth of the Umpqua River, advise crabbers to work at high tide when there is maximum intrusion of salt water near the bottom of the estuary. Perhaps the crabs actually come in and out of the bay with the bottom waters, or are less active and thus harder to catch when salinity of the water over them decreases with ebb tide.

In general, the ecology, distribution, and culture of other sessile and free-swimming organisms is intimately related to the changing salinity pattern as well as other hydrographic features.

Pollution and Engineering Problems

Industrial development and use of the waterway closely affect the estuarine environment. The estuary provides a source of fresh water and

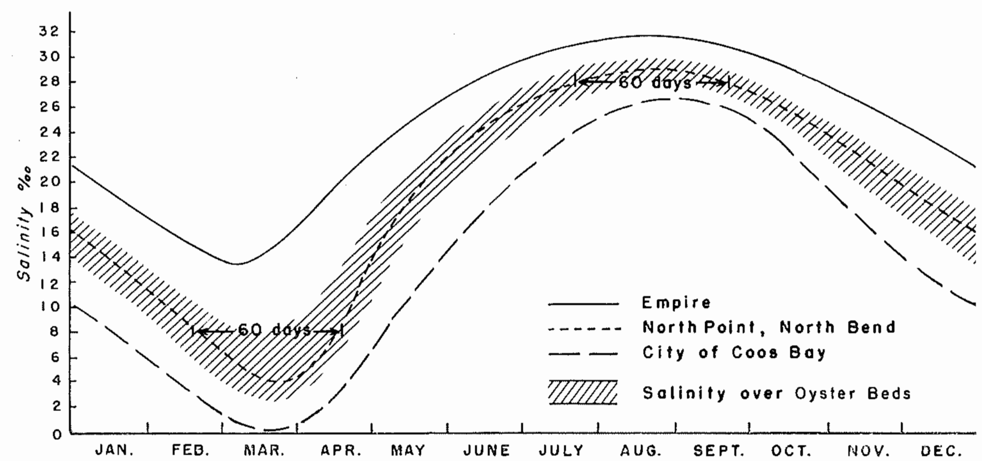

FIGURE 8. MEAN ANNUAL SALINITY CYCLE, THREE STATIONS IN COOS BAY, AND MEAN SALINITY DISTRIBUTION OVER AREAS WHERE OYSTERS ARE GROWN SUCCESSFULLY.

convenient means of waste disposal. Modern industrial plants often contribute contaminating agents which can be biologically damaging and render the water unfit for industrial and other use downstream. It is relatively more difficult to determine the effects of a pollutant discharged into an estuary than into a stream or river because of tides and tidal currents and presence of varying amounts of salt water. An intensive investigation has recently been made of the effect of introducing pollutants of different concentrations at various locations in the Yaquina River Estuary (Burt and Marriage, 1957). Figure 9, based on a theoretical study of the rates at which salt and fresh water mix in the estuary, shows the type of pollutant distribution to be expected during low flow in late summer. The vertical scale is expected concentration in pounds per cubic foot of water if one pound of pollutant were introduced each second; the horizontal scale is distance from the ocean to Elk City. The line to the left of each point and lower line to the right are expected concentrations throughout the estuary if an outfall were placed at each point. It is interesting to note that, no matter where an outfall is located, some of the material will mix back upstream through most of the estuary.

Water supply in estuaries periodically contains salt, thus reducing its usefulness for fresh-water purposes. With proper storage and utilization,

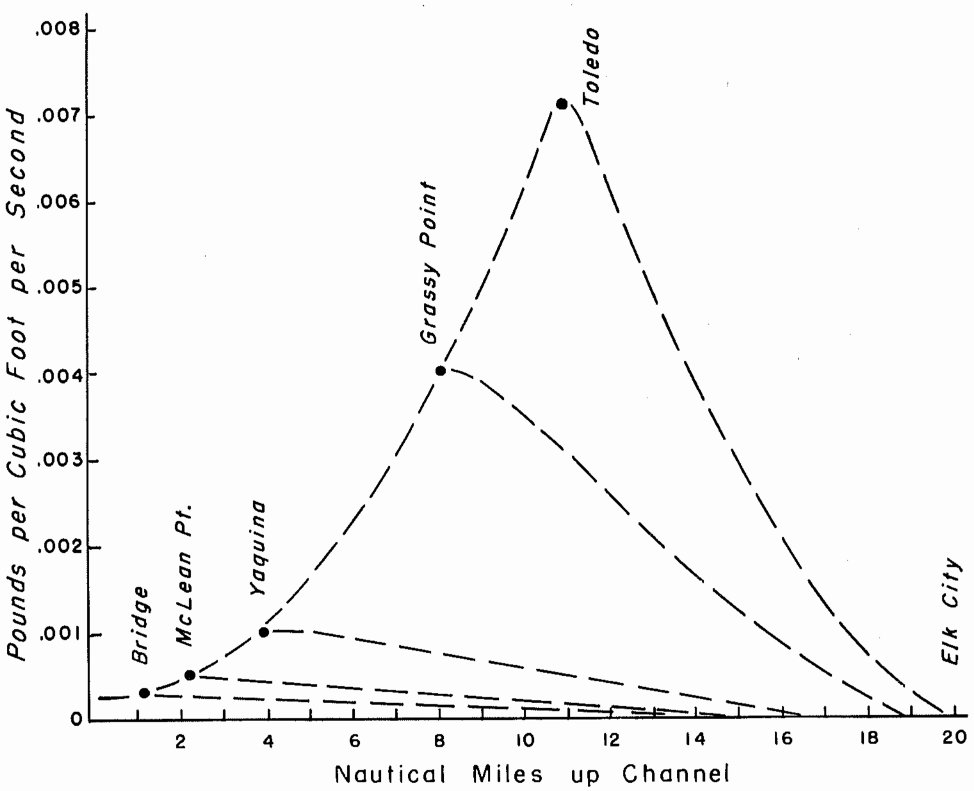

FIGURE 9. ESTIMATED DISTRIBUTION OF A POLLUTANT, YAQUINA RIVER ESTUARY, SUMMER CONDITIONS, LOW RIVER FLOW, AT LOCATION OF HYPOTHETICAL OUTFALLS.

however, estuarine waters may provide fresh water, including water for irrigation. As greater upstream use is made through diversions, the upstream distance of salt incursion may be expected to increase, thus increasing mean salinity downstream and decreasing areas where fresh water may be taken for irrigation or other purposes. Roy L. Fox (1957) of the United States Soil Conservation Service, Albany, Oregon, has suggested methods of using the Siletz Estuary for irrigation in localities where it has not been practiced before.

Knowledge of estuarine circulation is vital to proper engineering of harbor and coastal installations. If physical properties and circulation are known, reasonable prediction of results can be made. For example, prior to construction of the Santee-Cooper power project at Charleston, South Carolina, the harbor was fed by the Cooper River, a vertically-homogenous estuary. During construction, additional water was diverted into Charleston harbor from the Santee River. After this diversion, the estuary changed to a partly-mixed system with quite a different circulation pattern, resulting in shoaling and silting of the harbor. Dredging costs rose from $10,000 to $1,000,000 per year.

FUTURE PLANS

A Department of Oceanography has been established at Oregon State College as a center for hydrographic research and teaching. Research is continuing in the coastal estuaries and has begun on the waters of the continental shelf off the Oregon coast.

Hydrography can make an important contribution to our knowledge of the marine environment since species distribution, egg and larval development, reproduction, predation, and parasitism are all affected by water properties. Each year greater use is made of the estuaries, and the interests of all users must be safeguarded.

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Development of the Oregon Pellet Diet[1]

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INTRODUCTION

In 1948, personnel of the Oregon Fish Commission and Astoria Seafoods Laboratory, an agricultural experiment station of Oregon State College, embarked on a cooperative study of fish nutrition. The objectives of the project were to investigate the nutritional requirements of Pacific salmon (*Oncorhynchus* sp.) and steelhead trout (*Salmo gairdnerii*); to evaluate individual components as potential fish foods, with emphasis on the utilization of marine fishery products; and to formulate combinations of tested materials into practical and economical production-type diets.

Several feeding experiments were conducted to systematically determine the value of selected foodstuffs (Hublou *et al.*, 1955; Jeffries *et al.*, 1954; McKee *et al.*, 1951; McKee *et al.*, 1952; Wood *et al.*, 1955). A purified test diet was developed to serve as a minimum control which was a modification of the Wisconsin diet reported by McLaren *et al.* (1947) and is now known as the Oregon diet (Jeffries *et al.*, 1954). Desirable components were tested as additives to, or substitutes in, the Oregon diet. Any additional growth or improved general health over that of fish fed the Oregon diet was attributed to the added or substituted components. Those components which proved to be nutritionally beneficial, available, and relatively inexpensive were catalogued for future use in production-type diets.

It was not until 1954 that the feeding experiments included the testing of production-type diets. That year the experiment at the Sandy Laboratory of the Oregon Fish Commission included three such diets whose physical properties made it possible to form pellets that were soft and moist. The most successful 1954 production-type diet was composed of 40 per cent meal mixture, 40 per cent frozen turbot (*Atheresthes stomias*), and 20 per cent frozen yellowfin tuna liver (*Neothunnus macropterus*). The silver salmon (*O. kisutch*) readily accepted the soft pellets, their growth was good, and rate of mortality low. The dry-weight food conversion for the 38-week feeding period was 1.62 pounds of food to produce 1 pound of fish.

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From 1955 through 1958, variations of the pelleted 1954 production-type diet were tested in production feeding trials at several Oregon Fish Commission hatcheries. The results are discussed in this report with their practical application to the regular hatchery feeding program of the Oregon Fish Commission. Soft pellets composed of meals and fish or meat are referred to in this paper as Oregon pellets.

Laboratory scale diet studies not yet published have been continued along with the production feeding trials. Most of the frequent alterations of the Oregon pellet formula were a result of findings in the laboratory experiments.

PURPOSES

The purposes of the production feeding trials were to compare the results of feeding Oregon pellets under laboratory conditions with those obtained on a production scale and those produced by existing hatchery diets; to evaluate the feeding of Oregon pellets as a practical method of food presentation in salmon hatcheries; and to compare adult recoveries of marked fish fed Oregon pellets with those reared on existing hatchery diets.

METHODS AND PROCEDURE

Feeding Technique

Being a new product, the Oregon pellet required different handling methods; hence it was decided to compare it with present hatchery diets using existing feeding methods and techniques. No attempt was made to feed the same amounts of hatchery diet and Oregon pellets. The latter were initially fed ad libitum, and more recently according to a feeding chart constructed from data collected in laboratory diet experiments. The chart, which indicates the amount of food to be fed according to species, size, and prevailing water temperatures, was patterned after that reported by Burrows *et al.* (1952). In 1955 and 1956, hatchery diets were fed ad libitum, and since that time in accordance with normal hatchery procedure at the stations where the trials were being conducted.

Frequency of feeding Oregon pellets was gradually reduced from several times a day, when the fish were small, to once every other day when several months old. Hatchery diets were fed several times a day when the fish were small, and eventually only twice every other day when several months old.

Oregon pellets were fed by broadcasting over the surface of the pond. Hatchery diets were spoon-fed in all trials.

Pellet Manufacture

Oregon pellets are manufactured on a small scale as follows: the fish portion is partially thawed and then thoroughly mixed with the meals, producing a very stiff dough which is put through a meat grinder and eventually comes out in worm-like form. The "worms" are passed directly into a centrifugal blower and broken up into pellets which can be shortened by putting them through the blower again. The grinder-blower method, however, is unsuitable for large-scale pellet production because of the labor required.

A laboratory model of an extruder[3] was tested and found to produce excellent pellets with a minimum of labor. Large models are available that can produce as much as 1,500 pounds of pellets per hour. Dies may be obtained for different pellet sizes; one die produces hollow pellets, which would permit the fabrication of a floating pellet. The successful use of this machine does not preclude the possibility that other pellet-making devices would be satisfactory.

Feeding Trials

Nine feeding trials were conducted at four Oregon Fish Commission hatcheries from 1955 through 1958 comparing Oregon pellets with the regular hatchery diets. In two instances a third diet was also tested. Details of the feeding trials, including the number of fish involved, are given in Appendix Tables 1-9.

The 1955 feeding experiment was conducted at Sandy Hatchery in a regular rearing pond containing silver salmon. The pond was divided into two parts, making it possible to feed pellets on one side and the regular hatchery diet on the other.

The Oregon pellet diet was altered slightly from the formula used under laboratory conditions in 1954 to make the pellets somewhat drier and easier to handle. The meal was increased by 5 per cent and tuna liver decreased by the same amount. Vitamins were included in the vitamin mixture at levels established for the Oregon diet (Jeffries *et al.*, 1954). Natural vitamins in the meals and fish were not taken into consideration except for vitamins A and D; these were not added because of their high level in tuna liver. Table 1 shows the composition of the 1955 formula.

In the 1956 experiments a further modification of the Oregon diet was tested as in 1955, using silver salmon at Sandy Hatchery and spring chinook salmon (*O. tshawytscha*) at Oakridge Hatchery.

The diet was modified as follows: skim milk was replaced with cottonseed oil meal; wheat germ meal, fish solubles, and an antioxidant[4] were added; corn oil was reduced; the percentages of all components were adjusted to compensate for the new ingredients; and tuna liver was replaced by whole albacore tuna viscera (*Thunnus germo*). In addition, thiamine was increased to allow for the possible presence of thiaminase in the tuna visceral contents (i.e., herring, *Clupea pallasii*); pyridoxine was increased to allow for possible inhibition of this vitamin by the linseed oil meal (Kratzer and Williams, 1948); menadione was added; B-12 supplement replaced a portion of the Pro-pen; and the vitamin mixture was supplemented with vitamin E. The 1955 pellets were still too moist, so the meal-fish ratio was further adjusted to include 10 per cent more meal and 10 per cent less fish; turbot was reduced from 40 to 20 per cent and tuna viscera included at 25 per cent. Composition of the 1956 formula is given in Table 2.

In the 1957 experiments the Oregon pellet formula was again altered somewhat and tested on a larger scale on silver salmon and steelhead trout at Klaskanine Hatchery, and on spring chinook and blueback salmon

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[3] Made by Ambrette Machinery Company, 156 Sixth Street, Brooklyn 15, New York.
[4] The use of this or any other commercial product in the reported work does not in any way constitute endorsement.

TABLE 1. **COMPOSITION OF 1955 OREGON PELLET DIET**

Complete Mixture (Per Cent)		*Meal Mixture (Per Cent)*		*Vitamin Mixture (Mgs. Per Pound)*	
Meal mixture	45.0	Herring meal	28.6	Ascorbic acid	18,234
Turbot, frozen	40.0	Skim milk	24.5	Biotin	30
Tuna liver, frozen	15.0	Linseed oil meal	24.5	Calcium pantothenate①	2,253
Total	100.0	Distiller solubles	8.2	Choline chloride②	292,496
		Corn oil	6.1	Folic acid	208
		Crab meal	4.1	Inositol	38,099
		Vitamin mixture	4.0	Niacin	4,140
		Total	100.0	Para-aminobenzoic acid	6,092
				Pyridoxine hydrochloride	305
				Thiamine hydrochloride	305
				Pro-pen③	91,428
				Total	453,590

① Feed grade—45%.

② Feed grade—25%.

③ Trademark of Merck and Co., Inc.; active B-12: 3 mgs. per pound; procaine penicillin activity: 2 gms. per pound.

TABLE 2. **COMPOSITION OF 1956 OREGON PELLET DIET**

Complete Mixture (Per Cent)		*Meal Mixture (Per Cent)*		*Vitamin Mixture (Mgs. Per Pound)*	
Meal mixture	55.0	Herring meal	28.5	Ascorbic acid	13,627
Tuna viscera, frozen	25.0	Linseed oil meal	22.8	Biotin	9
Turbot, frozen	20.0	Cottonseed oil meal	22.8	Calcium pantothenate[1]	1,164
Total	100.0	Crab meal	5.7	Choline chloride[2]	317,960
		Wheat germ meal	5.7	Folic acid	108
		Distiller solubles	3.8	Inositol	28,388
		Fish solubles	3.8	Menadione	90
		Corn oil	1.9	Niacin	2,870
		Vitamin mixture	4.8	Para-aminobenzoic acid	4,484
		Antioxidant (Tenox IV)	0.2	Pyridoxine hydrochloride	273
		Total	100.0	Thiamine hydrochloride	363
				Pro-pen[3]	68,133
				B-12 supplement[4]	10,089
				E supplement[5]	5,605
				Total	453,613

[1] Feed grade—45%.
[2] Feed grade—25%.
[3] Trademark of Merck and Co., Inc.; active B-12: 3 mgs. per pound; procaine penicillin activity: 2 gms. per pound.
[4] Active B-12: 20 mgs. per pound.
[5] Active E: 20,000 i.u. per pound.

(*O. nerka*) at Oakridge Hatchery. The comparison diet fed the Klaskanine steelhead consisted of Dina-Fish pellets®, a dry commercial feed. It has not been the policy of this research group to test commercially-formulated diets but, since Dina-Fish pellets were being used in relatively large quantities in Fish Commission hatcheries, it was desirable to determine their value as a complete fish food. The dry pellets were discontinued after a short time and the regular hatchery diet was fed during the remainder of the feeding trial.

The Oregon pellet was altered to include a commercial product called crab solubles (crab meal and fish solubles combined and dried together) in place of crab meal and fish solubles; the corn oil level was increased 1 per cent and crab solubles reduced accordingly; vitamin B-12 supplement replaced Pro-pen; and albacore tuna liver substituted for one-half the tuna viscera to aid in the prevention of anemia. A formula useful for rehabilitation purposes was devised in which the fish portion of the Oregon pellet diet was replaced with beef liver. This diet was fed to spring chinook at Oakridge Hatchery during the latter part of the feeding trial. Table 3 lists the components of the 1957 Oregon pellet diet.

In the 1958 experiments the Oregon pellets were fed experimentally at Oxbow Hatchery using fall chinook (*O. tshawytscha*), at Sandy Hatchery using silvers, and at McKenzie and Marion Forks Hatcheries using spring chinook. The McKenzie and Marion Forks Hatchery trials, still in progress, are not included in this report. A third diet fed the Sandy Hatchery silvers consisted of Dina-Fish pellets.

The meal mixture of the Oregon pellet formula was initially the same as in 1957, but for economic reasons tuna liver was again replaced with whole tuna viscera. Later in the year, the meal mixture was altered by first reducing linseed oil meal to less than a third of its previous level and then by completely eliminating it. The linseed oil meal was replaced with cottonseed oil meal. Initially, the meal-fish ratio was the same as in 1957, but when linseed oil meal was reduced, and then deleted, it became necessary to increase the level of meals to make a satisfactory pellet. Linseed oil meal had been included in earlier formulae partly because of its good binding qualities. The results of a laboratory experiment on silver salmon and steelhead trout, conducted in advance of the 1958 trials, indicated that the meal-fish combination could be changed satisfactorily from 55 per cent meal and 45 per cent fish to 60 per cent meal and 40 per cent fish by reducing tuna viscera 5 per cent and increasing meals accordingly. Choline chloride was reduced by approximately 9 per cent and levels of all vitamins were adjusted to correspond with the increased meal level. Table 4 shows the current Oregon pellet diet.

The level of individual vitamins in the vitamin mixture is expressed in mgs. per pound, which can be termed "potency per pound". For example, Table 4 shows that 3.8 pounds of vitamin mixture would be required to complete 100 pounds of meal mixture; each pound of vitamin mixture would contain the amount of individual vitamins indicated.

Table 5 presents the proximate analysis of the current Oregon pellet diet (Table 4) as determined at the Astoria Seafoods Laboratory.

® Manufactured by the Willis H. Small Feed Company, Eugene, Oregon.

TABLE 3. **COMPOSITION OF 1957 OREGON PELLET DIET**

Complete Mixture (Per Cent)		*Meal Mixture (Per Cent)*		*Vitamin Mixture (Mgs. Per Pound)*	
Meal mixture	55.0	Herring meal	28.7	Ascorbic acid	15,617
Turbot, frozen	20.0	Linseed oil meal	23.0	Biotin	10
Tuna liver, frozen	12.5	Cottonseed oil meal	23.0	Calcium pantothenate[1]	1,874
Tuna viscera, frozen	12.5	Crab solubles	8.6	Choline chloride[2]	364,125
Total	100.0	Wheat germ meal	5.7	Folic acid	125
or		Distiller solubles	3.8	Inositol	32,496
Meal mixture	55.0	Corn oil	2.9	Menadione	104
Beef liver (fluky), frozen	45.0	Vitamin mixture	4.2	Niacin	3,331
Total	100.0	Antioxidant (Tenox VI)	0.2	Para-aminobenzoic acid	5,206
		Total	100.1	Pyridoxine hydrochloride	313
				Thiamine hydrochloride	416
				B-12 supplement[3]	23,510
				E supplement[4]	6,507
				Total	453,634

[1] Feed grade—45%.
[2] Feed grade—25%.
[3] Active B-12: 20 mgs. per pound.
[4] Active E: 20,000 i.u. per pound.

TABLE 4. **COMPOSITION OF CURRENT OREGON PELLET DIET**

Complete Mixture (Per Cent)		*Meal Mixture (Per Cent)*		*Vitamin Mixture (Mgs. Per Pound)*	
Meal mixture	60.0	Cottonseed oil meal	44.0	Ascorbic acid	16,800
Tuna viscera, frozen	20.0	Herring meal	30.0	Biotin	11
Turbot, frozen	20.0	Crab solubles	9.0	Calcium pantothenate①	2,000
Total	100.0	Wheat germ meal	6.0	Choline chloride②	357,442
		Distiller solubles	4.0	Folic acid	135
		Corn oil	3.0	Inositol	35,000
		Vitamin mixture	3.8	Menadione	112
		Antioxidant (Tenox VI)	0.2	Niacin	3,600
		Total	100.0	Para-aminobenzoic acid	5,600
				Pyridoxine hydrochloride	340
				Thiamine hydrochloride	450
				B-12 supplement③	25,000
				E supplement④	7,100
				Total	453,590

① Feed grade—45%.
② Feed grade—25%.
③ Active B-12: 20 mgs. per pound.
④ Active E: 20,000 i.u. per pound.

TABLE 5. **PROXIMATE ANALYSIS OF CURRENT OREGON PELLET DIET**

Component	Weight	
	As Fed (Per Cent)	*Dry Weight (Per Cent)*
Moisture	32.4	......
Protein	35.4	52.4
Carbohydrate①	19.7	29.1
Fat	6.4	9.4
Ash	6.1	9.1
Total	100.0	100.0

① Carbohydrate level calculated by difference.

Marked Fish

All fish reared in the production feeding trials, except for 1955-brood spring chinook and 1956-brood blueback at Oakridge Hatchery, and 1957-brood steelhead at Klaskanine Hatchery, were marked by fin clipping.

Whenever possible, adult recoveries of marked fish were measured, sexed, and liver samples taken to determine the incidence of disease. In addition, the hatchery returnees were weighed after being spawned.

RESULTS

Feeding Trials

Recapitulation of each feeding trial is found in Appendix Tables 1-9. A brief summary of the results, compiled from these tables, is given in Table 6.

The average food conversion attained by Oregon pellets in the nine trials was 2.33 pounds of food to produce a pound of fish; 1.52 on a dry-weight basis. For existing hatchery diets, average food conversion was 5.58 as fed and 1.96 on a dry-weight basis. The food cost of producing a pound of fish with Oregon pellets ranged from $0.166 to $0.243 and averaged $0.209. For hatchery diets, the food cost was $0.390 to $0.540 and averaged $0.435. The average food cost of producing a pound of fish with Oregon pellets was less than half (48 per cent) of that for hatchery diets. Costs of Oregon pellets and hatchery diets in the feeding trials involve individual components only and exclude any allowance for handling, preparation, or shipping.

In most cases, mortality among fish fed Oregon pellets was somewhat higher than for those on hatchery diets.

Hemoglobin levels of fish reared on Oregon pellets were satisfactory, except for the 1956-brood spring chinook at Oakridge Hatchery; the level was usually somewhat higher among fish fed hatchery diets (Appendix Tables 1-9).

A third diet (Dina-Fish pellets) tested in two trials was considered unsatisfactory because of poor growth response and high mortality, and was discontinued before the end of either experiment.

Marked Fish

Recoveries of marked fish are now complete for only the 1954- and 1955-brood Sandy Hatchery silvers (Table 7). For both brood years, re-

TABLE 6. **SUMMARY OF PRODUCTION FEEDING TRIALS AT SANDY, OAKRIDGE, KLASKANINE, AND OXBOW HATCHERIES, 1955-58**

Experiment Description	*Time Fed (Weeks)*	*Food Fed (Pounds)*	*Fish Produced (Pounds)*	*Food Conversion*		*Food Cost Per Pound of Fish Produced (Cents)*	*Total Mortality (Per Cent)*
				As Fed	*Dry*		
Sandy Hatchery							
1954-Brood Silvers							
Oregon Pellets	38	1,841	801	2.30	1.35	23.2	13.2
Hatchery Diet	38	5,029	754	6.67	2.38	54.0	3.9
1955-Brood Silvers							
Oregon Pellets	37	1,452	640	2.27	1.37	16.6	5.3
Hatchery Diet	37	3,295	609	5.41	1.84	39.0	3.2
1957-Brood Silvers							
Oregon Pellets							
Starter Diet[1]	7	577	181	3.20	0.99	40.9	0.2
Pellets	33	6,000	2,674	2.24	1.52	22.0	2.2
Combined	40	6,577	2,855	2.30	1.48	23.2	2.4
Hatchery Diet	40	10,635	2,143	4.96	2.16	39.2	1.4
Dina-Fish Pellets							
Starter Diet[2]	12	2,337	580	4.03	1.75	31.0	0.7
Pellets	22	2,250	477	4.72	4.24	40.1	15.0
Combined	34	4,587	1,057	4.34	2.88	35.1	15.7
Oxbow Hatchery							
1957-Brood Fall Chinook							
Oregon Pellets							
Starter Diet[3]	5	1,021	203	5.04	1.42	67.0	0.7
Pellets	7	785	275	2.86	1.87	24.3	1.8
Combined	12	1,806	478	3.78	1.68	42.4	2.5
Hatchery Diet	11	3,611	594	6.08	1.60	51.7	1.1
Oakridge Hatchery							
1955-Brood Spring Chinook							
Oregon Pellets	26	1,204	516	2.33	1.46	17.0	0.9
Hatchery Diet	26	2,371	476	4.98	1.66	43.3	3.0

TABLE 6. **SUMMARY OF PRODUCTION FEEDING TRIALS AT SANDY, OAKRIDGE, KLASKANINE, AND OXBOW HATCHERIES, 1955-58—Continued**

Experiment Description	*Time Fed (Weeks)*	*Food Fed (Pounds)*	*Fish Produced (Pounds)*	*Food Conversion*		*Food Cost Per Pound of Fish Produced (Cents)*	*Total Mortality (Per Cent)*
				As Fed	*Dry*		
1956-Brood Spring Chinook							
Oregon Pellets④	33	3,966	1,560	2.54	1.66	23.6	8.1
Hatchery Diet	33	9,972	1,711	5.83	1.80	47.8	7.2
1956-Brood Blueback							
Oregon Pellets	9	924	380	2.43	1.59	20.7	5.2
Hatchery Diet	9	2,223	394	5.64	1.82	46.8	4.3
Klaskanine Hatchery							
1956-Brood Silvers							
Oregon Pellets	29	5,853	2,590	2.26	1.48	19.2	0.6
Hatchery Diet	29	11,376	2,001	5.69	1.95	40.4	0.7
1957-Brood Steelhead							
Oregon Pellets⑤	22	1,974	846	2.33	1.52	19.8	4.8
Hatchery Diet	16	3,539	644	5.50	1.91	39.0	0.6
Dina-Fish Pellets⑥	6	756	204	3.70	3.10	31.4	1.7
Total All Feeding Trials							
Oregon Pellets	....	23,999	10,282	2.33	1.52	20.9	....
Hatchery Diet	....	52,051	9,326	5.58	1.96	43.5	....

① An all-meat starter diet was fed for the first 7 weeks, at which time the fish averaged 311/lb. and were considered large enough to eat the pelleted diet.

② The regular hatchery diet was fed for the first 12 weeks as a starter diet, at which time the fish averaged 122/lb. and were considered large enough to eat the pelleted diet.

③ An all-meat starter diet was fed for the first 5 weeks, at which time the fish averaged 550/lb. and were considered large enough to eat the pelleted diet which had been pulverized and put through a screen with 8 meshes per inch.

④ Beef liver substituted for fish portion of pellet diet in last 7 weeks of experiment.

⑤ Experiment discontinued after 22 weeks because of sporadic fish kills among fish fed Oregon pellets.

⑥ Diet discontinued after 6 weeks due to steady increase in mortality and reluctance of fish to eat the food. The same group of fish were then fed the hatchery diet for 16 weeks until termination of the experiment.

TABLE 7. **RECOVERIES OF MARKED 1954- AND 1955-BROOD SANDY HATCHERY SILVER SALMON**

	Number of Recoveries							
	Oregon Pellet Diet				*Hatchery Diet*			
	1954 Brood②		*1955 Brood③*		*1954 Brood④*		*1955 Brood⑤*	
Place Recovered①	*Jacks*	*Adults*	*Jacks*	*Adults*	*Jacks*	*Adults*	*Jacks*	*Adults*
River, gill net and sport⑥	2	29	0	14	1	19	1	2
Hatchery	31	26	4	58	41	26	0	61
Total	33	55	4	72	42	45	1	63
Number fish liberated	14,837		15,612		15,884		17,445	
Total fish recovered	88		76		87		64	
Per cent recovery	0.59		0.49		0.55		0.37	

① Recoveries from ocean troll and sport fisheries are not included because they could not definitely be assigned to the Sandy Hatchery as the marks were duplicated by another agency.
② Marked Ad-LV.
③ Marked Ad-RMax.
④ Marked Ad-RV.
⑤ Marked Ad-LMax.
⑥ Fishery sampled, only actual recoveries reported.

coveries of Oregon-pellet-fed fish were equal to, or slightly greater than, fish fed hatchery diets. Table 8 shows average fork lengths, average weights, and sex ratios of the recoveries (Table 7). There was no appreciable difference in size or sex ratio between the two groups of marked fish for either brood year; however, the size of 1955-brood recoveries of each group appeared to be considerably smaller than for the 1954 brood. Statistical analyses indicated that returning males and females of the 1955 brood fed the regular hatchery diet, and the females of the group fed Oregon pellets, were significantly smaller than those of the 1954 brood. The returning males of the 1955 brood reared on Oregon pellets were not significantly smaller than those of the 1954 brood. Recoveries of marked 1956-brood Klaskanine Hatchery silvers are not complete, but substantial numbers returned as 2-year-olds (jacks[6]) (Table 9). Significance of the large jack recovery is debatable and no interpretation will be attempted here. The figures are given mainly to provide added data on the incidence of disease in these fish.

Disease Incidence

Numerous observations were made on the incidence of disease among fish fed Oregon pellets and hatchery diets (Appendix Tables 1-9). Kidney disease (*Corynebacterium* sp.) was found in several cases in fish reared on regular hatchery diets, but observed in fish fed Oregon pellets only in the 1954-brood Sandy silvers. Chronic gill trouble in fish fed the regular hatchery diets was greatly improved when Oregon pellets were used. It is presumed the well-bound pellets reduced gill irritation caused by leaching food.

Whenever possible, liver smears were made from recoveries of marked fish examined for incidence of tuberculosis. No tuberculosis was found in recoveries of 1954-brood Sandy silvers fed Oregon pellets, whereas 78.0 per cent of the fish reared on hatchery diets were infected (Table 10). Of the recoveries of 1955-brood Sandy silvers fed Oregon pellets, 96.5 per cent were tuberculous; the disease was found in all fish fed the hatchery diet. Of the jack recoveries of 1956-brood Klaskanine silvers fed Oregon pellets, 3.0 per cent were tuberculous compared with 92.1 per cent for fish fed the hatchery diet.

[6] Precocious fish of which the vast majority are usually males.

TABLE 8. **SIZE AND SEX RATIO OF MARKED ADULT RECOVERIES OF 1954- AND 1955-BROOD SANDY HATCHERY SILVER SALMON**

Diet	Brood	*Average Fork Length (Inches)* Male	Female	*Average Weight[1] (Pounds)* Male	Female	Sex Ratio (Male to Female)
Oregon Pellets	1954	26.4	27.5	6.5	6.0	1:0.96
	1955	25.1	25.2	5.5	4.2	1:1.06
Hatchery Diet	1954	27.4	26.9	6.9	5.5	1:0.82
	1955	24.3	24.9	4.9	4.3	1:0.85

[1] Average weights are for hatchery returns only for both brood years. The fish were weighed after being spawned.

TABLE 9. **RECOVERIES OF MARKED TWO-YEAR-OLD SILVERS OF 1956 BROOD, KLASKANINE HATCHERY**

Place Recovered	*Oregon Pellet Diet*①	*Hatchery Diet*②
Ocean troll③	10	3
River sport③	1	6
Hatchery	581	365
Total	592	374
Number fish liberated	69,068	65,653
Per cent recovery	0.86	0.57

① Marked: Ad-LV.
② Marked: D-RV.
③ Fishery sampled, only actual recoveries reported.

Data on disease, although still incomplete and inconclusive, indicate that the Oregon pellet diet may possess some advantages from this standpoint. An explanation of the lesser incidences of kidney disease and tuberculosis when Oregon pellets are fed may be found in the discussion below.

DISCUSSION

Advantages of Pellet Feeding

There are many advantages in pellet feeding. When a pellet is swallowed, the fish receives the diet as compounded and in the relative proportions of the mixture (Phillips *et al.*, 1953). There is very little loss of food in the water by leaching or disintegration, as is the case when meat diets are spoon fed. More complete food consumption is reflected in better conversion, which in turn reduces the cost necessary to produce a pound of fish.

Other advantages are elimination of food grinding and diet preparation in the hatchery and the inherent food loss encountered; labor reduction in food handling, feeding, and pond cleaning; less storage space required; decrease of water pollution; and the fish produced tend to be more uniform in size.

Not all the advantages of pellet feeding apply to Oregon pellets. For example, dry pellets may be stored at room temperature whereas Oregon pellets, with a higher moisture content and raw ingredients, must be refrigerated. Salmon and steelhead trout seem to accept Oregon pellets readily, but are often reluctant to eat dry pellets.

Disease

In several trials the fish fed regular hatchery diets contracted kidney disease, while only one group fed Oregon pellets was found infected. Fish receiving Oregon pellets were generally given, prior to pellet feeding, regular hatchery diets which contained large percentages of untreated salmon products; the Oregon pellet diets did not include salmon products. Wood and Wallis (1955) demonstrated that kidney disease could be transmitted to young salmon by feeding infected flesh and viscera of adult salmon. The extent of kidney disease incidence in salmon products included in the hatchery diets is not known, but it would seem quite possible that the disease is transmitted orally. If this is true, one could expect less infection in fish eventually fed Oregon pellets because untreated salmon products were fed to them for relatively short periods of time.

Wood and Ordal (1958) report that in comparing the incidence of tuberculosis among wild and hatchery-reared fish, the data indicated that the disease was hatchery propagated; that hatchery stocks in Oregon were widely infected; and that the most likely method of transmission in hatcheries is by feeding untreated salmon products. The degree of infection appears to be directly correlated with duration of rearing. The reason for the difference in incidence of tuberculosis between fish reared on Oregon pellets and hatchery diets (Table 10) is thought to be the same as for kidney disease—less feeding of infected material.

Recoveries of the 1955-brood Sandy silvers fed Oregon pellets seem to dispute this theory. Possible reasons for the high incidence of tuberculosis in these fish are that they were given the regular hatchery diet for a longer period (95 days) prior to pellet feeding than the 1954-brood Sandy silvers (62 days). Also, salmon viscera included in their diet came from the Columbia River area which is known to include infected fish (Wood and Ordal, 1958), while the viscera fed the 1954 brood was from the Puget Sound area which was thought to contain few infected fish at that time,

TABLE 10. **INCIDENCE OF TUBERCULOSIS IN RECOVERIES OF MARKED SILVER SALMON OF SANDY HATCHERY 1954 AND 1955 BROODS AND KLASKANINE HATCHERY 1956 BROOD.**

			Incidence of Tuberculosis			
Diet	*Brood*	*Hatchery*	*Negative*	*Positive*	*Total Examined*	*Per Cent Tuberculous*
Oregon Pellet	1954	Sandy	49	0	49	0.0
	1955	Sandy	2	55	57	96.5
	1956	Klaskanine②	97	3	100	3.0
Hatchery	1954	Sandy	9	32	41	78.0
	1955	Sandy	0	61	61	100.0
	1956	Klackanine②	8	93	101	92.1

① Includes river (gill net and sport) and hatchery recoveries for the 1954- and 1955-brood Sandy Hatchery silvers; a sample of the hatchery recoveries only for the 1956-brood Klaskanine Hatchery silvers.
② Jacks only.

indicating that the pellet-fed fish received less of the infected material. Incidence of tuberculosis in recoveries of 1956-brood Klaskanine jack silvers shows light infection in Oregon pellet-fed fish and heavy infection in hatchery diet-fed fish. The former were not fed untreated salmon products prior to pellet feeding, but were given salmon viscera, pasteurized for 30 minutes at 160°F. No thermal death time has been reported for this specific "cold blooded" mycobacterium responsible for fish tuberculosis; consequently, it is not certain that pasteurization was successful in killing the bacteria. Another factor in explaining the incidence of tuberculosis in jack recoveries fed Oregon pellets is that while these fish were in rearing ponds, some of the adult run of the 1954 brood were released in the stream above the hatchery water intake to spawn naturally. These adult fish were heavily infected with tuberculosis (Wood, unpublished data) and could have been responsible for spreading the disease to fish in the hatchery.

Problems Encountered

Fish reared on Oregon pellets have generally been in good health but at times have sickened as a result of anemia and oxidative rancidity in stored pellets. Unexplained sporadic fish kills have also occurred. The problem of rancidity can be overcome, for the most part, by the use of antioxidants and proper food handling.

A general account of the symptoms displayed by moribund fish in one of the typical fish kills is as follows: The first sign of distress most often noted was an occasional flash by a fish that had lost equilibrium and was swimming erratically. Some fish had a dark patch about the area of the dorsal fin. Upon closer examination, breathing appeared labored, with occasional gasping followed by rapid and erratic swimming. At time of death the fish were abnormally tense, and nervous tremors were noted along lateral surfaces. Gills were often inflamed. After death, some were observed with mouths widely agape and gills flared. Results of an experiment on steelhead trout at Klaskanine Hatchery in the spring of 1958 indicated that the afflicted fish were suffering from a nutritional deficiency, or toxemia, caused by the high level of linseed oil meal in the diet. They were apparently cured by deleting the linseed oil meal.

Anemia has been found in two experiments thus far; one was thought to be caused by rancidity, and the other was a complex anemia associated with fish kills apparently due to the high level of linseed oil meal. Additional work is in progress on rancidity and anemia.

Oregon pellets are not being fed to fish smaller than 300 per pound at the present time because of a lack of information as to the efficiency of the diet in smaller fish. Until further information is available, a starter diet will be given the smaller fish. Beef liver fed in an equal amount with pasteurized salmon viscera has produced satisfactory results in this respect.

Laboratory Experiments

Several cases have been cited where the Oregon pellet formula was altered or modified by applying the results of laboratory experiments. Other tests were designed to improve the pellet by altering the method of preparation and handling. For example, it was found that pellets could be prepared, frozen, and stored for as much as nine months before feeding. Growth rate of fish fed stored frozen pellets was about the same as for those given pellets made fresh daily. Oregon pellets were also oven-dried and stored. Shortly before feeding, the dried pellets were reconstituted with water until the original moisture content was established. It was found that fish reared on these pellets had a growth rate substantially lower than those fed fresh or stored frozen pellets. Frozen pellets (regular or dried) became rancid in a relatively short time when kept in a freezer with temperatures fluctuating from 0° to 32°F.

CONCLUSIONS

Oregon pellets, altered in composition four times in the course of nine production-feeding trials, produced growth and efficiency of food conversion which compared favorably with results obtained under laboratory conditions.

It proved to be more efficient and economical to feed Oregon pellets than existing hatchery diets. Average food conversion of the Oregon pellet in nine feeding trials was 2.33 pounds of food as fed to produce one pound of fish; on a dry-weight basis, the conversion was 1.52. Food costs to produce a pound of fish with the pellets ranged from $0.166 to $0.243 and averaged $0.209. Food conversions for regular hatchery diets averaged 5.58 as fed and 1.96 on a dry-weight basis; food cost per pound of fish produced was $0.390 to $0.540 cents and averaged $0.435. These results show clearly the saving in food cost when Oregon pellets are used in place of existing hatchery diets. This is due to the reduced amount of food required and better utilization of the food fed.

Fish produced by Oregon pellets were generally in good health, but problems of food rancidity, sporadic fish kills, and anemia were encountered. The cause of each is being studied. The diet was altered to try to eliminate fish kills, and it is felt that rancidity and anemia can be avoided, for the most part, by using antioxidants and proper handling of food prior to feeding.

Oregon pellets were found to be a practical and advantageous method of food presentation. Machinery is available for producing the pellets in commercial quantities.

Recoveries of fish marked at termination of most feeding trials are still incomplete. In the two trials for which recoveries are complete, fish fed Oregon pellets were recovered in numbers at least as great as those fed the regular hatchery diets, and the size and sex ratios were about the same.

Evidence was presented which indicated that the use of Oregon pellets may reduce the incidence of disease known to be propagated by existing hatchery diets.

PRACTICAL APPLICATION OF RESULTS

During the fiscal year July 1, 1957 to June 30, 1958 the Oregon Fish Commission used 1,728,190 pounds of fish food at a total cost of $141,674.

An estimated 22 per cent of the annual food bill is for food fed to fish 300 per pound or smaller. The present Oregon pellet formula has not been used successfully for fish this small. Thus, in the fiscal year 1958, 78 per cent of the food was fed to fish of this size or larger. This amounted to approximately 1,348,000 pounds and cost about $110,500.

The average Oregon pellet food conversion in the production-feeding trials was 2.33; for the regular hatchery diets, 5.58. Applying the hatchery diet food conversion (5.58) to the amount of food fed to fish 300 per pound or larger, approximately 241,500 pounds of fish would have been produced. Using the Oregon pellet food conversion (2.33), it is found that the 241,500 pounds of fish could have been produced with 562,700 pounds of Oregon pellets; thus, only 41.7 per cent as much food in pellet form would have been required to produce the same amount of fish (by weight) as with regular hatchery diets.

Oregon pellets are currently made by private industry and sold to the Fish Commission for $0.129 per pound, boxed and frozen, f.o.b. the manufacturing plant—$0.096 for ingredients and $0.033 for preparation. Using this figure, the 562,700 pounds of Oregon pellets necessary to produce 241,500 pounds of fish would cost approximately $72,600 compared with $110,500 for 1,348,000 pounds of hatchery diet to produce the same amount of fish. This would result in a saving of approximately $37,900 (34.3 per cent) for the fiscal year 1958. In addition, shipping costs would have been lower because of the reduced amount of pellets required.

It is believed that feeding Oregon pellets would also yield substantial savings in hatchery labor by eliminating food grinding and diet preparation, and reducing food handling as well as time required for feeding and pond cleaning. Further, the loss of food inherent in diet preparation would be eliminated.

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APPENDIX TABLE 1. **FEEDING TRIAL SUMMARY, 1954-BROOD SILVER SALMON, SANDY HATCHERY**

Diet and Lot Number	*Food Fed (Pounds)*		*Fish Produced (Pounds)*	*Food Conversion*[1]		*Food Cost*[2] *(Per Pound)*	*Total Cost of Food Fed*	*Food Cost Per Pound of Fish Produced*	*Fish Size (Fish Per Pound)*		*Total Mortality (Per Cent)*
	As Fed	*Dry Weight*		*As Fed*	*Dry Weight*				*Start*	*Finish*	
Oregon Pellets (Lot A)	1,841[3]	1,083	801	2.30	1.35	$0.101	$185.94	$0.232	300	18	13.2
Hatchery Diet (Lot B)	5,029[4]	1,792	754	6.67	2.38	0.081	407.35	0.540	300	20	3.9

Observations

On May 23, 1955, fish which had been reared on the regular hatchery diet for 62 days were sampled to determine average size. Approximately 17,500 of these fish were stocked, by weight, into each half of a 20 x 80 x 4 foot concrete raceway pond which had been divided equally lengthwise, each part having an inlet and outlet. The experiment was terminated 38 weeks later on February 14, 1956. The fish of both lots were active, had good gill color, and were apparently in good general health throughout the experiment—except that Lot A had an unexplained, abnormally high death rate on three separate days in October-November which accounted for about 75 per cent of the total mortality. A few mortalities in Lot A were due to kidney disease; no kidney disease was noted in Lot B. Both groups were treated with a 1:500,000 solution of PMA for 1 hour on three occasions during the experiment. Two of the treatments were given as a prophylactic measure, the third because of an infection of the protozoan parasites *Epistylis* sp. and *Trichodina* sp. A hemoglobin check at the termination of the experiment, taken with a Klett-Summerson hemometer, showed Lot B to have a somewhat higher level of hemoglobin than Lot A; the level of both groups was considered satisfactory. Weekly average water temperatures ranged from 38° to 62°F.

[1] Pounds of food to produce a pound of fish.
[2] Diet components and cost:

Oregon Pellet Diet

Components	*Cost Per Pound*	*Per Cent*
Meal mixture	$0.173	45.0
Turbot	0.035	40.0
Tuna liver	0.060	15.0
Total	$0.101	100.0

Hatchery Diet (Composite)

Components	*Cost Per Pound*	*Per Cent*
Salmon viscera	$0.070	60.0
Dina-Fish meal or pellets	0.085	20.0
Horsemeat	0.150	5.0
Beef liver	0.140	5.0
Beef lungs	0.040	4.0
Beef spleen	0.100	4.0
Sheep cheeks	0.100	1.0
Sheep tripe	0.060	1.0
Total	$0.081	100.0

[3] Moisture content: 41.2%.
[4] Average moisture content of daily samples: 64.4%.

APPENDIX TABLE 2. **FEEDING TRIAL SUMMARY, 1955-BROOD SILVER SALMON, SANDY HATCHERY**

Diet and Lot Number	*Food Fed (Pounds)*		*Fish Produced (Pounds)*	*Food Conversion*①		*Food Cost*② *(Per Pound)*	*Total Cost of Food Fed*	*Food Cost Per Pound of Fish Produced*	*Fish Size (Fish Per Pound)*		*Total Mortality (Per Cent)*
	As Fed	*Dry Weight*		*As Fed*	*Dry Weight*				*Start*	*Finish*	
Oregon Pellets (Lot A)	1,452③	878	640	2.27	1.37	$0.073	$106.00	$0.166	162	20	5.3
Hatchery Diet (Lot B)	3,295④	1,117	609	5.41	1.84	0.072	237.24	0.390	162	24	3.2

Observations

On June 18, 1956, 17,500 fish, reared 95 days on the regular hatchery diet, were counted and weighed into each half of the pond used the previous year (Appendix Table 1). The experiment was terminated 37 weeks later on March 1, 1957. The fish of both lots were apparently in good general health throughout the experiment—except that Lot A had an unexplained, abnormally high death rate on three days in October-November. At the termination of the experiment, fish in Lot A were more vigorous. Internal examination showed the fish in Lot B to have more deposited body fat. A few mortalities in Lot B had kidney disease; no kidney disease was noted in Lot A. Weekly average water temperatures ranged from 34° to 66°F. Hemoglobin levels as determined with a Fisher Electro-Hemometer are shown below. A level of 9.0 and above was considered satisfactory.

Date	*Gms. Hemoglobin Per 100 ml. Blood*	
	Lot A	*Lot B*
July 12, 1956	10.8	11.5
September 21, 1956	9.8	10.6
October 30, 1956	11.1	10.5
March 1, 1957	9.5	9.1

① Pounds of food to produce a pound of fish.
② Diet components and cost:

Oregon Pellet Diet

Components	*Cost Per Pound*	*Per Cent*
Meal mixture	$0.110	55.0
Tuna viscera	0.010	25.0
Turbot	0.050	20.0
Total	$0.073	100.0

Hatchery Diet (Composite)

Components	*Cost Per Pound*	*Per Cent*
Salmon viscera	$0.070	47.0
Beef lungs and spleen	0.070	31.0
Dina-Fish pellets	0.085	18.0
Turbot	0.055	3.0
Salmon flesh and tuna liver	0.070	1.0
Total	$0.072	100.0

③ Moisture content: 39.6%.
④ Average moisture content of daily samples: 66.1%.

APPENDIX TABLE 3. **FEEDING TRIAL SUMMARY, 1955-BROOD SPRING CHINOOK SALMON, OAKRIDGE HATCHERY**

Diet and Lot Number	Food Fed (Pounds)		Fish Produced (Pounds)	Food Conversion(1)		Food Cost(2) (Per Pound)	Total Cost of Food Fed	Food Cost Per Pound of Fish Produced	Fish Size (Fish Per Pound)		Total Mortality (Per Cent)
	As Fed	Dry Weight		As Fed	Dry Weight				Start	Finish	
Oregon Pellets (Lot A)	1,204(3)	752	516	2.33	1.46	$0.073	$ 87.89	$0.170	235	29	9.9
Hatchery Diet (Lot B)	2,371(4)	793	476	4.98	1.66	0.087	206.28	0.433	235	31	3.0

Observations

On June 18, 1956, fish reared on the regular hatchery diet for 160 days were sampled to determine average size. Approximately 17,500 of these fish were stocked, by weight, into each half of a 20 x 80 x 4 foot concrete raceway pond divided as in Appendix Table 1. The experiment was terminated 26 weeks later on December 14, 1956. Both groups were apparently in good health throughout the experiment; however, the mortality of Lot B increased during the last month, cause undetermined. The experiment was terminated prematurely due to the danger of losing the hatchery water supply. Weekly average water temperatures ranged from 36° to 56°F. Hemoglobin levels as determined with a Fisher Electro-Hemometer are shown below. A level of 9.0 and above was considered satisfactory.

Date	Gms. Hemoglobin Per 100 ml. Blood	
	Lot A	Lot B
August 4, 1956	11.1	11.5
September 12, 1956	11.1	11.4
October 8, 1956	11.9	12.3
November 7, 1956	10.8	10.9
December 17, 1956	12.1	11.0

(1) Pounds of food to produce a pound of fish.
(2) Diet components and cost:

Oregon Pellet Diet

Components	Cost Per Pound	Per Cent
Meal mixture	$0.110	55.0
Tuna viscera	0.010	25.0
Turbot	0.050	20.0
Total	$0.073	100.0

Hatchery Diet (Composite)

Components	Cost Per Pound	Per Cent
Salmon viscera	$0.070	57.2
Miscellaneous meats	0.100	16.7
Liver	0.140	10.8
Dina-Fish meal	0.085	8.8
Tuna liver	0.070	5.1
Water (added to mix)	....	1.3
Total	$0.087	100.0

(3) Moisture content: 37.6%.
(4) Average moisture content of daily samples: 66.6%.

APPENDIX TABLE 4. **FEEDING TRIAL SUMMARY, 1956-BROOD SPRING CHINOOK SALMON, OAKRIDGE HATCHERY**

Diet and Lot Number	*Food Fed (Pounds)*		*Fish Produced (Pounds)*	*Food Conversion*[1]		*Food Cost*[2] *(Per Pound)*	*Total Cost of Food Fed*	*Food Cost Per Pound of Fish Produced*	*Fish Size (Fish Per Pound)*		*Total Mortality (Per Cent)*
	As Fed	*Dry Weight*		*As Fed*	*Dry Weight*				*Start*	*Finish*	
Oregon Pellets (Pond 21)	3,966[3]	2,590	1,560	2.54	1.66	$0.093	$368.84	$0.236	132	26	8.1
Hatchery Diet (Pond 22)	9,972[4]	3,080	1,711	5.83	1.80	0.082	817.70	0.478	132	24	7.2

Observations

On July 1, 1957, approximately 55,372 fish reared 152 days were stocked, by weight, in each of two 20 x 80 x 4 foot concrete raceway ponds. The fish were originally started on an all-meat diet and then fed pulverized Oregon pellets. Due to contamination of the food with phenothiazine, the fish became sunburned. They were then fed a variety of foods, but no raw salmon products, until the start of the experiment. A tail-fungus condition was responsible for mortality in both groups; bacterial gill disease and kidney disease were also found in Pond 22. Anemia was responsible for much of the mortality in Pond 21. As a therapeutic measure, the fish portion of the Oregon pellet diet was replaced with beef liver for the last 7 weeks of the experiment. Weekly average water temperatures ranged from 41° to 57°F. Hemoglobin levels as determined with a Fisher Electro-Hemometer are shown below. A level of 9.0 and above was considered satisfactory.

Date	*Gms. Hemoglobin Per 100 ml. Blood*	
	Pond 21	*Pond 22*
August 15, 1957	8.7	8.7
September 26, 1957	5.2	10.0
October 21, 1957	7.0	11.3
November 5, 1957	5.5	11.0
December 24, 1957	6.7	11.2
January 6, 1958	6.5	(no sample)
February 3, 1958	8.5	11.5
February 24, 1958	9.2	12.3

[1] Pounds of food to produce a pound of fish.
[2] Diet components and cost:

Oregon Pellet Diet (Composite)

Components	*Cost Per Pound*	*Per Cent*
Meal mixture	$0.118	55.0
Turbot	0.050	16.4
Tuna liver	0.070	10.3
Tuna viscera	0.010	10.3
Beef liver	0.140	8.0
Total	$0.093	100.0

Hatchery Diet (Composite)

Components	*Cost Per Pound*	*Per Cent*
Salmon viscera	$0.070	47.5
Liver	0.107	16.0
Miscellaneous meats	0.100	13.2
Lungs	0.080	9.5
Commercial feeds	0.085	8.7
Fish	0.070	2.1
Salmon eggs	0.093	1.4
Salt	0.018	0.9
Shrimp waste	0.065	0.7
Total	$0.082	100.0

[3] Moisture content: 34.7%.
[4] Average moisture content of daily samples: 69.1%.

APPENDIX TABLE 5. FEEDING TRIAL SUMMARY, 1956-BROOD BLUEBACK SALMON, OAKRIDGE HATCHERY

Diet and Lot Number	Food Fed (Pounds)		Fish Produced (Pounds)	Food Conversion[1]		Food Cost[2] (Per Pound)	Total Cost of Food Fed	Food Cost Per Pound of Fish Produced	Fish Size (Fish Per Pound)		Total Mortality (Per Cent)
	As Fed	Dry Weight		As Fed	Dry Weight				Start	Finish	
Oregon Pellets .... (Pond 39)	924[3]	604	380	2.43	1.59	$0.085	$ 78.54	$0.207	85	49	5.2
Hatchery Diet .... (Pond 38)	2,223[4]	781	394	5.64	1.82	0.085	184.51	0.468	85	53	4.3

Observations

On September 5, 1957, fish reared on the regular hatchery diet for 175 days were sampled to determine average size. There were approximately 54,000 fish in Pond 38 and 49,000 in Pond 39, which were 20 x 80 x 4 foot concrete raceway ponds. The experiment was terminated prematurely 9 weeks later on November 6, 1957, because the Oregon pellets on hand were quite rancid. The fish were already infected with bacterial gill disease; two treatments were administered during the experiment in which the fish were subjected to a PMA solution of 1:500,000 for a 1-hour period. A tail-fungus condition existed in both ponds and was thought to be the result of handling the fish during warm weather. Weekly average water temperatures ranged from 41° to 55°F. Hemoglobin levels as determined with a Fisher Electro-Hemometer at the end of the experiment are shown below. A level of 9.0 and above was considered satisfactory.

Date	Gms. Hemoglobin Per 100 ml. Blood	
	Pond 38	Pond 39
November 5, 1957	10.0	10.2

[1] Pounds of food to produce a pound of fish.
[2] Diet components and cost:

Oregon Pellet Diet

Components	Cost Per Pound	Per Cent
Meal mixture	$0.118	55.0
Turbot	0.050	20.0
Tuna liver	0.070	12.5
Tuna viscera	0.010	12.5
Total	$0.085	100.0

Hatchery Diet (Composite)

Components	Cost Per Pound	Per Cent
Salmon viscera	$0.070	58.9
Miscellaneous meats ..	0.100	12.0
Liver	0.140	10.6
Lungs	0.080	8.2
Dina-Fish meal	0.085	6.6
Salmon eggs	0.093	2.3
Salt	0.015	1.3
Total	$0.085	100.0

[3] Moisture content: 34.7%.
[4] Average moisture content of daily samples: 67.7%.

APPENDIX TABLE 6. FEEDING TRIAL SUMMARY, 1956-BROOD SILVER SALMON, KLASKANINE HATCHERY

Diet and Lot Number	Food Fed (Pounds)		Fish Produced (Pounds)	Food Conversion[1]		Food Cost[2] (Per Pound)	Total Cost of Food Fed	Food Cost Per Pound of Fish Produced	Fish Size (Fish Per Pound)		Total Mortality (Per Cent)
	As Fed	Dry Weight		As Fed	Dry Weight				Start	Finish	
Oregon Pellets .... (Ponds 15 & 16)	5,853[3]	3,822	2,590	2.26	1.48	$0.085	$497.51	$0.192	43	18	0.6
Hatchery Diet .... (Ponds 3 & 4)	11,376[4]	3,885	2,001	5.69	1.94	0.071	807.70	0.404	53	21	0.7

Observations

On June 28, 1957, fish reared 115 days were sampled to determine average size. They were already stocked in four 20 x 80 x 4 foot concrete raceway ponds at approximately 35,000 each. The experiment was terminated 29 weeks later on January 21, 1958. All the fish were originally started on an all-meat diet and then fed pulverized Oregon pellets. Due to contamination of the food with phenothiazine, they became sunburned. They were then fed a variety of foods, but no untreated salmon products, until the start of the experiment. The fish of both groups were active and in apparent good general health through most of the experiment; however, the fish in Ponds 15 and 16 were repeatedly observed to be more vigorous. Overall mortality was very low for both groups, but towards the end of the experiment fish in Ponds 3 and 4 were dying due to kidney disease. The fish of both groups had a moderate body fat deposit. Weekly average water temperatures ranged from 42° to 60°F. Hemoglobin levels as determined with a Fisher Electro-Hemometer are shown below. A level of 9.0 and above was considered satisfactory.

Date	Gms. Hemoglobin Per 100 ml. Blood	
	Ponds 15 & 16	Ponds 3 & 4
August 7, 1957	9.9	10.6
September 23, 1957	10.9	10.2
October 3, 1957	10.5	(no sample)
October 31, 1957	10.4	10.2
November 27, 1957	11.1	10.3
January 14, 1958	8.8	8.6

[1] Pounds of food to produce a pound of fish.
[2] Diet components and cost:

Oregon Pellet Diet

Components	Cost Per Pound	Per Cent
Meal mixture	$0.118	55.0
Turbot	0.050	20.0
Tuna liver	0.070	12.5
Tuna viscera	0.010	12.5
Total	$0.085	100.0

Hatchery Diet (Composite)

Components	Cost Per Pound	Per Cent
Salmon viscera	$0.052	33.5
Tuna liver	0.070	18.0
Sheep products	0.075	16.0
Beef lungs	0.070	13.0
Dina-Fish meal	0.085	10.0
Beef spleen	0.100	5.0
Beef liver	0.140	4.0
Turbot	0.050	0.5
Total	$0.071	100.0

[3] Moisture content: 34.7%.
[4] Average moisture content of daily samples: 66.2%.

APPENDIX TABLE 7. **FEEDING TRIAL SUMMARY, 1957-BROOD STEELHEAD TROUT, KLASKANINE HATCHERY**

Diet and Lot Number	Food Fed (Pounds)		Fish Produced (Pounds)	Food Conversion[1]		Food Cost[2] (Per Pound)	Total Cost of Food Fed	Food Cost Per Pound of Fish Produced	Fish Size (Fish Per Pound)		Total Mortality (Per Cent)
	As Fed	Dry Weight		As Fed	Dry Weight				Start	Finish	
Oregon Pellets .... (Pond 7)	1,974[3]	1,289	846	2.33	1.52	$0.085	$167.79	$0.198	72	16	4.8
Dina-Fish Pellets[4] (Pond 8)	756[5]	634	205	3.70	3.10	0.085	64.26	0.314	44	30	1.7
Hatchery Diet[4] ...... (Pond 8)	3,539[6]	1,227	644	5.50	1.91	0.071	251.27	0.390	30	15	0.6

Observations

The fish had been reared on the regular hatchery diet for several months and were graded into two groups prior to the start of the experiment on September 5, 1957. There were approximately 19,000 fish in Pond 7 and 22,000 in Pond 8; both were 20 x 80 x 4 foot concrete raceway ponds. The experiment was terminated after 22 weeks on February 5, 1958 because of sporadic mortality among the fish being fed Oregon pellets. Further work was conducted on the cause of mortality after the experiment was terminated. The Dina-Fish pellet diet was discontinued after 6 weeks of feeding because of reluctance of the fish to eat the food. Mortality was steadily increasing and the fish were becoming very emaciated. The diet was then changed to the regular hatchery diet; mortality quickly subsided and remained low until the experiment was terminated. Weekly average water temperatures ranged from 41° to 59°F. Hemoglobin levels as determined with a Fisher Electro-Hemometer are shown below. A level of 9.0 and above was considered satisfactory.

Date	Gms. Hemoglobin Per 100 ml. Blood	
	Pond 7	Pond 8
October 3, 1957	10.4	11.7
October 31, 1957	11.0	12.0
November 27, 1957	11.4	13.6
January 14, 1958	10.3	(no sample)
January 21, 1958	11.3	10.6

[1] Pounds of food to produce a pound of fish.
[2] Diet components and cost:

Oregon Pellet Diet

Components	Cost Per Pound	Per Cent
Meal mixture	$0.118	55.0
Turbot	0.050	20.0
Tuna liver	0.070	12.5
Tuna viscera	0.010	12.5
Total	$0.085	100.0

Hatchery Diet (Composite)

Components	Cost Per Pound	Per Cent
Salmon viscera	$0.052	33.5
Tuna liver	0.070	18.0
Sheep products	0.075	16.0
Beef lungs	0.070	13.0
Dina-Fish meal	0.085	10.0
Beef spleen	0.100	5.0
Beef liver	0.140	4.0
Turbot	0.050	0.5
Total	$0.071	100.0

[3] Moisture content: 35.7%. Seventy-nine pounds of hatchery diet fed at 68.2% moisture.
[4] Dina-Fish pellets were discontinued on October 31, 1957. The regular hatchery diet was then fed the remainder of the experiment.
[5] Moisture content: 10.0%.
[6] Average moisture content of daily samples: 64.9%.

APPENDIX TABLE 8. **FEEDING TRIAL SUMMARY, 1957–BROOD FALL CHINOOK SALMON, OXBOW HATCHERY**

Diet and Lot Number	*Food Fed (Pounds)*		*Fish Produced (Pounds)*	*Food Conversion*①		*Food Cost*② *(Per Pound)*	*Total Cost of Food Fed*	*Food Cost Per Pound of Fish Produced*	*Fish Size (Fish Per Pound)*		*Total Mortality (Per Cent)*
	As Fed	*Dry Weight*		*As Fed*	*Dry Weight*				*Start*	*Finish*	
Oregon Pellets (Pond 4)											
Starter diet	1,021③	289	203	5.04	1.42	$0.133	$135.79	$0.670	1,135	556	0.7
Pellets	785④	513	275	2.86	1.87	0.085	66.73	0.243	556	222	1.8
Total	1,806	802	478	3.78	1.68	0.112	202.52	0.424	1,135	222	2.5
Hatchery Diet (Pond 5)	3,611⑤	951	594	6.08	1.60	0.085	306.94	0.517	1,135	231	1.1

Observations

On February 3, 1958, approximately 247,000 unfed fry were weighed into each of two 20 x 80 x 4 foot concrete raceway ponds. Fish were weighed and liberated from both ponds during the course of the experiment, terminated on April 25-30, 1958, when there were approximately 119,000 fish remaining in each pond, less mortality. The fish in Pond 4 were fed an all-meat starter diet for 5 weeks prior to feeding pulverized Oregon pellets. They did not change over to the pelleted diet readily and, as a result, lagged behind the hatchery-diet-fed fish in growth for the first month of pellet feeding; some became pinheaded, accounting for the higher mortality. During the last few weeks the fish fed Oregon pellets grew more rapidly and both groups were about the same size when the experiment was terminated. The hemoglobin level, using an improved Tallqvist hemoglobin scale, at the end of the experiment was 45 per cent for Pond 4 and 55 per cent for Pond 5. The fish in Pond 5 were more active throughout the experiment. The water supply is spring fed and a near constant 46°F. is maintained.

① Pounds of food to produce a pound of fish.
② Diet components and cost:

Starter Diet (Composite)

Components	*Cost Per Pound*	*Per Cent*
Beef liver	$0.140	43.8
Hog liver	0.140	43.8
Beef spleen	0.100	6.2
Beef lungs	0.070	6.2
Total	$0.133	100.0

Oregon Pellet Diet

Components	*Cost Per Pound*	*Per Cent*
Meal mixture	$0.118	55.0
Turbot	0.050	20.0
Tuna liver	0.070	12.5
Tuna viscera	0.010	12.5
Total	$0.085	100.0

Hatchery Diet (Composite)

Components	*Cost Per Pound*	*Per Cent*
Salmon viscera	$0.065	47.6
Beef liver	0.140	17.0
Beef spleen	0.100	13.3
Beef lungs	0.070	7.5
Shrimp waste	0.080	5.0
Horse products	0.085	4.8
Dina-Fish meal	0.065	4.1
Sheep products	0.100	0.7
Total	$0.085	100.0

③ Moisture content: 71.7%.
④ Moisture content: 34.7%.
⑤ Average moisture content of daily samples: 73.7%.

APPENDIX TABLE 9. **FEEDING TRIAL SUMMARY, 1957-BROOD SILVER SALMON, SANDY HATCHERY**

Diet and Lot Number	*Food Fed (Pounds)*		*Fish Produced (Pounds)*	*Food Conversion*①		*Food Cost*② *(Per Pound)*	*Total Cost of Food Fed*	*Food Cost Per Pound of Fish Produced*	*Fish Size (Fish Per Pound)*		*Total Mortality (Per Cent)*
	As Fed	*Dry Weight*		*As Fed*	*Dry Weight*				*Start*	*Finish*	
Oregon Pellets (Ponds 9 & 10)											
Starter diet	577③	179	181	3.20	0.99	$0.128	$ 73.86	$0.409	1,067	311	0.2
Pellets	6,000	4,052	2,674	2.24	1.52	0.098	588.00	0.220	311	28	2.2
Total	6,577④	4,231	2,855	2.30	1.48	0.100	661.86	0.232	1,067	28	2.4
Hatchery Diet (Ponds 5 & 6)	10,635⑤	4,622	2,143	4.96	2.16	0.079	840.17	0.392	1,067	36	1.4
Dina-Fish Pellets⑥ (Ponds 7 & 8)											
Starter diet⑦	2,337⑧	1,061	580	4.03	1.75	0.077	179.95	0.310	1,067	122	0.7
Pellets	2,250⑨	2,025	477	4.72	4.24	0.085	191.25	0.401	122	60	15.0
Total	4,587	3,086	1,058	4.34	2.92	0.081	371.20	0.351	1,067	60	15.7

Observations

On March 14, 1958, unfed fry were sampled to determine average size, and approximately 40,000 were stocked by weight in each of six 20 x 80 x 4 foot concrete raceway ponds. The experiment was terminated 40 weeks later on December 19, 1958.

The fish in Ponds 9 and 10 were fed an all-meat starter diet from March 14 to May 1, prior to pellet feeding. The Oregon pellet and regular hatchery diets both produced fish that were active and apparently were in good general health; the fish fed Oregon pellets were more even in size at the end; also, the deposited body fat was from moderate to heavy while the fish fed the hatchery diet had very little to moderate fat deposit. At the end of the experiment it was noted that an estimated 1 per cent of the fish in Ponds 5 and 6 were blind in one eye; a few blind fish were also noted in Ponds 9 and 10.

The fish in Ponds 7 and 8 were fed the regular hatchery diet from March 14 to June 9, prior to pellet feeding. They were reluctant to accept the dry pellet, which made feeding difficult; they never ate their entire daily ration with vigor. By July 10, dark-colored and inactive fish were observed in the group. By August 4, the mortality started increasing and remained abnormally high until the diet was discontinued on November 6. The hemoglobin level remained high throughout the experiment; some fish remained active and grew very large, but most were small and pinheaded. On September 10, Pond 7 was removed from the experiment and the fish fed an all-meat rehabilitation diet. The rate of mortality in Pond 7 dropped back to normal by November 6 while that of Pond 8, still receiving the dry pellets, was abnormally high. The lot weight gain for Pond 7 from September 10 to November 6 was 55.8 per cent while the fish in Pond 8 lost 0.7 per cent.

APPENDIX TABLE 9. **FEEDING TRIAL SUMMARY, 1957-BROOD SILVER SALMON, SANDY HATCHERY—Continued**

Weekly average water temperatures ranged from 42° to 67°F. Hemoglobin levels as determined with a Fisher Electro-Hemometer are shown below. A level of 9.0 and above was considered satisfactory.

	Gms. Hemoglobin Per 100 ml. Blood		
Date	*Ponds 5 & 6*	*Ponds 7 & 8*	*Ponds 9 & 10*
July 18, 1958	9.6	11.3	8.8
August 12, 1958	10.4	10.4	9.6
November 20, 1958	11.3	11.2⑩	10.2
January 5, 1959⑪	10.8	(no sample)	10.2

① Pounds of food to produce a pound of fish.
② Diet components and cost:

Oregon Pellet Diet

Components	*Cost Per Pound*	*Per Cent*
Starter Diet (Composite)		
Beef liver	$0.140	83.0
Beef spleen	0.070	17.0
Total	$0.128	100.0
Oregon Pellets		
Meal mixture..	$0.136	60.0
Tuna viscera ..	0.028	20.0
Turbot	0.055	20.0
Total	$0.098	100.0

Starter Diet for Ponds 7 & 8 (Composite)

Components	*Cost Per Pound*	*Per Cent*
Salmon viscera ..	$0.065	37.2
Beef lungs and spleen	0.070	26.2
Dina-Fish meal and pellets	0.085	26.0
Beef liver	0.140	8.8
Salt	0.021	1.8
Total	$0.077	100.0

Hatchery Diet (Composite)

Components	*Cost Per Pound*	*Per Cent*
Salmon viscera ..	$0.065	34.6
Beef lungs and spleen	0.070	27.0
Dina-Fish meal and pellets	0.085	18.1
Beef liver	0.140	12.7
Custom mix meal	0.092	1.9
Shrimp waste	0.065	3.7
Salt	0.021	2.0
Total	$0.079	100.0

③ Moisture content: 69.0%.
④ Moisture content: 32.5%.
⑤ Average moisture content of daily samples: 56.5%; these figures (pounds of food fed and moisture content) do not include an additional 12.0% water added before feeding.
⑥ Discontinued on November 6, 1958.
⑦ Regular hatchery diet.
⑧ Average moisture content of daily samples: 54.6%; these figures (pounds of food fed and moisture content) do not include an additional 19.2% water added before feeding.
⑨ Moisture content: 10.0%.
⑩ From Pond 8, fed Dina-Fish pellets until blood sample was taken.
⑪ Both groups still being fed respective diets at this time.

The 1955-1956 Silver Salmon Run Into the Tenmile Lakes System

ALFRED R. MORGAN
and
KENNETH A. HENRY①

INTRODUCTION

For many years it has been known that a large population of silver salmon (*Oncorhynchus kisutch*) returned each year to Tenmile Lakes and tributaries on the southern Oregon coast (Figure 1). There are also migratory populations of sea-run cutthroat trout (*Salmo clarkii*) and steelhead trout (*S. gairdnerii*) in addition to resident populations of various warm-water fish and rainbow trout. Since 1949, surveys of the Tenmile Lakes system by Oregon Fish Commission personnel have revealed greater concentrations of spawning silvers than on any other Oregon coastal stream where surveys have been conducted, in spite of the fact that some areas in the watershed which formerly produced good runs of silvers have been rendered unavailable through undesirable logging practices and stream rechanneling for irrigation. The Tenmile Lakes watershed contains 8 lakes of 3,200 acres; only 4 have runs of silvers.

A commercial fishery once existed, but the magnitude of silver runs to Tenmile Lakes was not precisely known. A reliable estimate of the size of the runs was deemed necessary for proper management of this stock of fish. Therefore, a tagging program to estimate the numbers of adult and jack silvers returning to the system was launched in the 1955-56 winter season. (Jacks are sexually mature fish—predominantly males—which return to spawn as 1+ or so-called 2-year-olds.)

At the same time, the stream surveys were intensified to measure utilization of various areas by spawning silvers as well as to recover tagged fish.

TAGGING

Tenmile Creek, outlet to the lake, flows about 4 miles due west before emptying into the Pacific Ocean (Figure 2). In some years, fall storms have formed a sand blockade at the mouth of the creek, and returning fish were partially or completely halted until the flow was great enough to break through the barrier. Since this barrier did not form in 1955, salmon could enter the stream throughout the fall season. However, no fish were observed in Tenmile Creek until the first freshet on October 9, 1955. Prior to this time there was no perceptible current in the weed-choked outlet between the lake and the mouth of Eel Creek.

The fish were captured with two types of gear—a cotton web trap and wire mesh circular fyke nets—at separate sites. A cotton trap, somewhat similar to salmon traps formerly used commercially in the Columbia River, was installed in Tenmile Creek at the old bridge just below the new location of Highway 101 (Figure 2). It was composed of two parts, lead and spiller, and constructed of heavily-tarred cotton webbing. The spiller, of 2¾-inch

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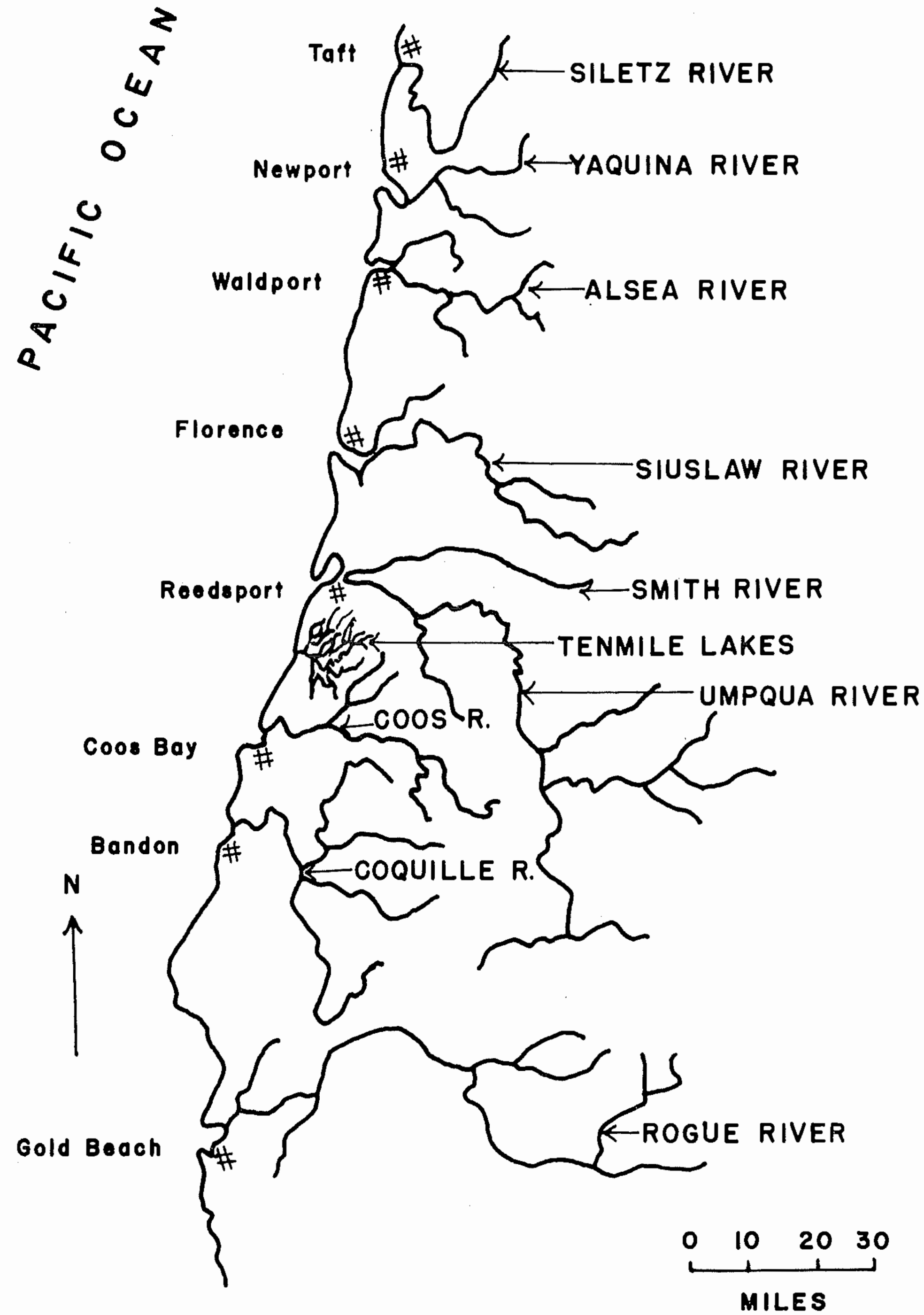

FIGURE 1. A PORTION OF THE OREGON COAST SHOWING THE LOCATION OF TENMILE LAKES.

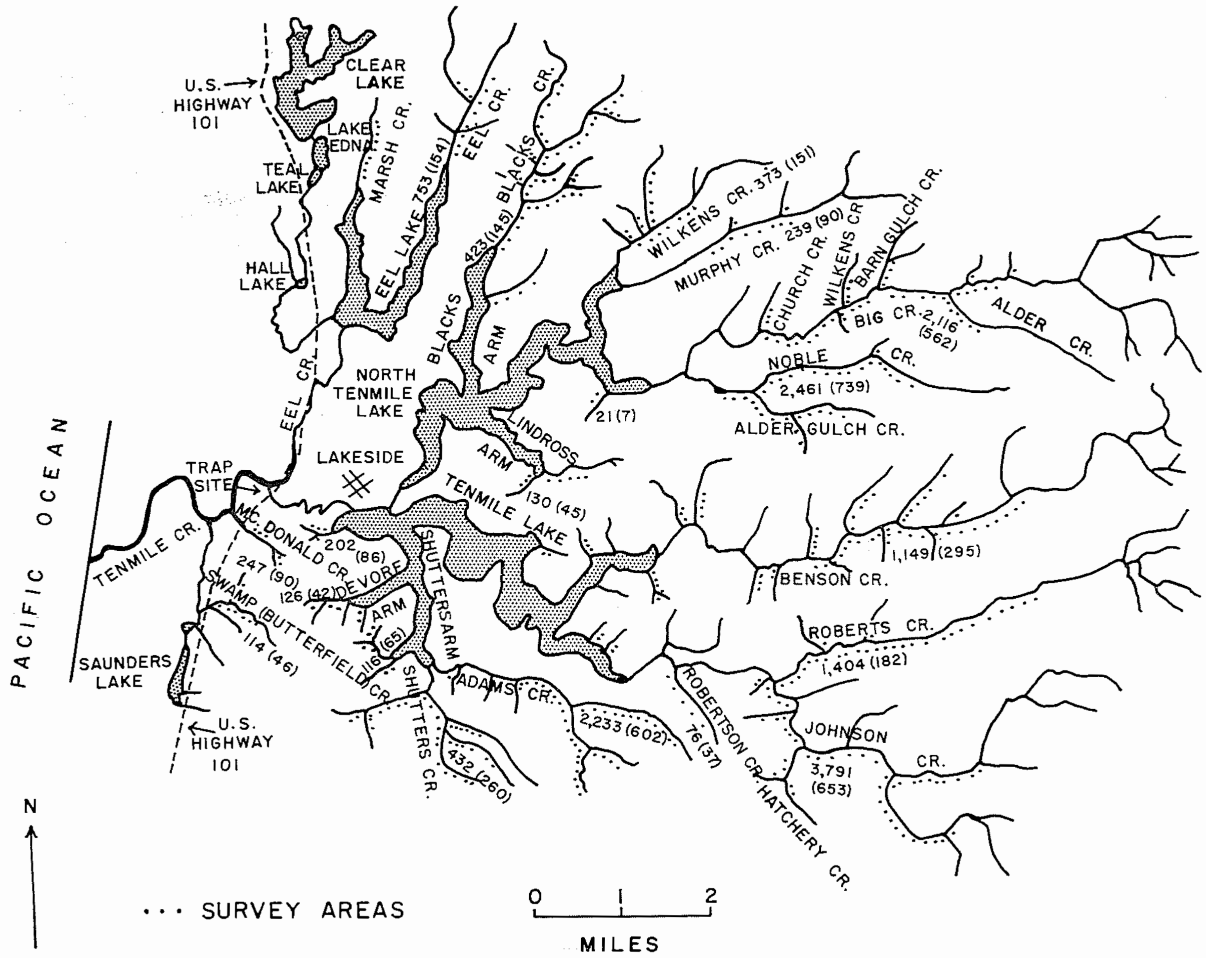

FIGURE 2. TENMILE LAKES AREA SHOWING STREAMS SURVEYED AND DEAD SILVER SALMON FOUND. NUMBERS IN ( ) ARE JACKS AND ARE INCLUDED IN TOTALS.

stretched mesh, was secured to the bridge piling. The lead was composed of 4¾-inch stretched mesh web connected to the spiller at the throat, allowing the fish to enter the spiller. The lead was secured to the bridge and a floating boom, and heavily weighted to keep it in fishing position. Often at night the lead was swung across the entire stream in an attempt to divert fish into the trap, which was put into operation on October 10, 1955. From October 11 to November 24 the trap was fished continuously with varying degrees of success.

The second tagging site was at Lakeside, approximately 1¼ miles upstream from the trap (Figure 2). Fyke nets fished at this location were constructed of pipe, and covered with 2-inch wire mesh. All three were 18 feet in length, although two of the nets were 10 feet and one 8 feet in diameter. There was a funnel-like entrance on one end, leading into a compartment which in turn led through a second funnel into another compartment. Three doors, equally spaced around the surface of the latter compartment, were used in gaining access to the captured fish (Figure 3).

FIGURE 3. TYPE OF FYKE NET FISHED AT LAKESIDE IN TAGGING STUDY.

On October 14 one large and one small fyke net were put into operation at Lakeside. On October 26 another large fyke net was added. The three nets were fished at the same site until November 25. At that time the trap was flooded out—high water made it impossible to fish more than two fyke nets at the original site—so the small net was moved downstream, just below the trap site, but was not fished successfully because of high water. The two larger nets were fished at the upper site until February 10, 1956.

The nets were fished side by side more or less parallel to the bank and stream channel (Figure 4). Between one-third and one-fifth of the channel was covered, depending on the water levels. They were located above the trap to recover tagged fish released from the trap, and to tag additional fish for recovery on the spawning grounds. However, the nets did not fish very efficiently, particularly for adult silver salmon, for unknown reasons, and few fish tagged at the trap below were recovered in them.

FIGURE 4. FYKE NETS AT MOUTH OF TENMILE LAKE.

Petersen tags were used, one numbered and one blank disk, attached to the fish's back by a nickel pin inserted through the dorsal fin at its origin. In addition, the adipose fin of each tagged fish was removed, leaving a distinct scar that was later valuable in identifying fish which had lost the tags. During the tagging, fish were measured to the nearest ½-inch, fork length, on the scale inside the tagging box. Length for each fish was recorded along with the tag number, date of tagging, tagging location, and type of gear with which the fish was captured. No attempt was made to sex the fish. In addition, scale samples were taken from a number of jack silvers of selected lengths.

Totals of 432 adult and 131 jack silvers were tagged from the cotton web trap and 443 adults and 674 jacks from the three fyke nets—875 adults and 805 jacks altogether (Table 1). The trap caught mostly adults and the fyke nets predominantly jacks (Figure 5). Because of this selectivity, it was necessary to make separate estimates of the adult and jack populations.

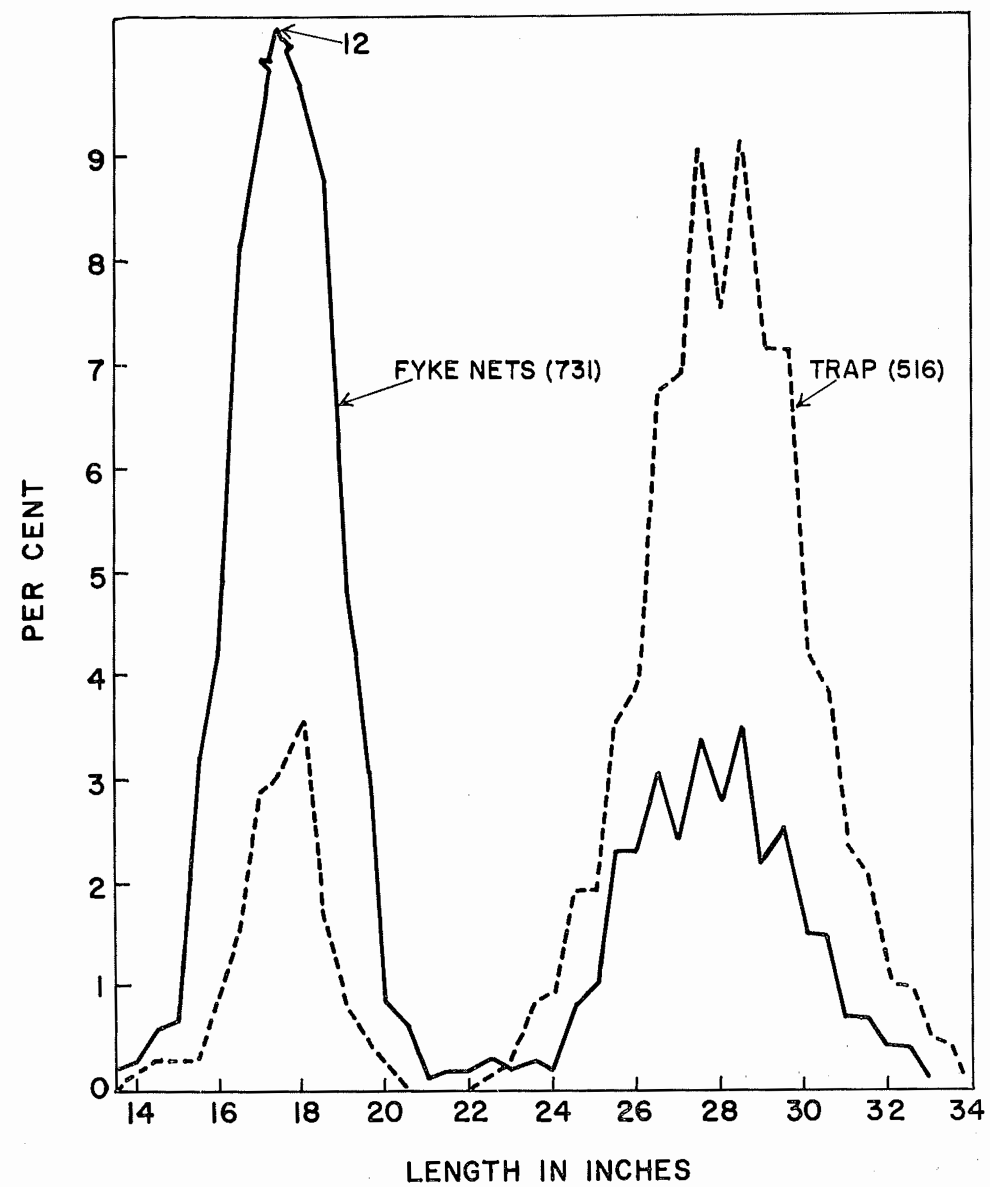

FIGURE 5. LENGTH FREQUENCY OF SILVER SALMON TAGGED IN A TRAP AND IN FYKE NETS, TENMILE LAKES, OCTOBER 16-NOVEMBER 23, 1955.

TABLE 1. **NUMBERS OF ADULT AND JACK SILVER SALMON TAGGED FROM TWO TYPES OF GEAR, WEEKLY PERIODS, AT TENMILE LAKES, 1955-1956**

	Trap			*Fyke Nets*			*Trap and Fyke Nets*		
Date	*Adults*	*Jacks*	*Total*	*Adults*	*Jacks*	*Total*	*Adults*	*Jacks*	*Total*
Oct. 10–16, 1955	10	39	49	3	9	12	13	48	61
17–23	54	35	89	11	45	56	65	80	145
24–30	106	47	153	31	85	116	137	132	269
Oct. 31–Nov. 6	38	4	42	53	101	154	91	105	196
Nov. 7–13	191	4	195	81	109	190	272	113	385
14–20	32	2	34	35	97	132	67	99	166
21–27①	1	0	1	69	104	173	70	104	174
Nov. 28–Dec. 4	......	......	......	41	50	91	41	50	91
Dec. 5–11	......	......	......	39	36	75	39	36	75
12–18	......	......	......	38	24	62	38	24	62
19–25	......	......	......	12	3	15	12	3	15
Dec. 26–Jan. 1②	......	......	......	0	0	0	0	0	0
Jan. 2– 8, 1956	......	......	......	5	5	10	5	5	10
9–15	......	......	......	12	4	16	12	4	16
16–22	......	......	......	5	1	6	5	1	6
23–29	......	......	......	6	1	7	6	1	7
Jan. 30–Feb. 5	......	......	......	1	0	1	1	0	1
Feb. 5–12	......	......	......	1	0	1	1	0	1
Total	432	131	563	443	674	1,117	875	805	1,680

① Trap was removed after November 27, 1955.
② Fishing was discontinued because of high water.

SPORT FISHERY CATCH

The Tenmile Lakes system is fished throughout the summer and fall for perch, catfish, and cutthroat and rainbow trout. When the silver salmon run appears, fishing intensity increases. The most heavily fished areas are North Tenmile and Tenmile Lakes themselves, but there is considerable activity in the outlet stream down to 1¼ miles below its confluence with Eel Creek. Trolling with various lures is the most popular and successful method, but bait fishing with salmon eggs is also practiced.

Before the silver sport fishery got under way in October, moorage operators were asked to keep a daily record of the number of boats rented, fishermen per boat, catch of tagged and untagged adult silvers and jacks, and where they were taken (above or below the lower tagging site). While all five operators did not keep complete records, they supplied useful information.

About three-fourths of the fish taken in the sport fishery were caught by trolling in the lakes and outlet; the remainder by fishing the outlet from the bank. A good minimum count of the catch by the bank fishery was obtained from one of the moorages whose facilities were used to gain access to bank and fishing sites on the outlet. The moorages returned 41 tags recovered in the sport catch in addition to the 18 tags returned by individuals.

From records kept by moorage operators, tag recoveries in the sport catch, and tagged to untagged ratios found on the spawning grounds, it was calculated that a minimum of 5,300 silver salmon (2,000 adults and 3,300 jacks) were taken in the sport fishery during the 1955-56 season.

SPAWNING GROUND SURVEYS

Methods

The tag recovery program on the spawning grounds was conducted by walking the bank of the stream, counting all live and dead adults and jacks, and recording them as tagged or untagged. In most cases, the live tagged fish were merely counted, with no attempt made to recover the tag. Occasionally, particularly in very small streams, live fish were picked up, the tags examined and numbers recorded, and then released. These data provided information on time of spawning and migration to spawning grounds, but were not used in estimating the population. To insure that dead fish were counted only once, their caudal peduncle was severed immediately behind the adipose fin. All tags on dead fish were removed and numbers recorded. All dead fish were also examined for tag scars and clipped adipose fins, and those found were counted as tag recoveries. Mutilated or decomposed fish, or those that could not be carefully examined, were not counted, whether tagged or untagged.

Areas Surveyed

Practically all Tenmile tributaries with spawning populations were surveyed at least once, and some six or eight times. Streams surveyed ranged from tiny brooklets with 1/4 c.f.s. flow to Benson and Johnson Creeks with estimated flows of 75 to 100 c.f.s. In addition to tributaries on North Tenmile and Tenmile Lakes, Eel Lake tributaries and the two tributaries flowing into Tenmile Creek were surveyed. These areas varied in length from a few yards on the tiny tributaries to 2 and 3 miles on the larger streams (Figure 2).

Numbers of Fish Observed

Spawning ground surveys to recover tags from dead fish started on November 17, 1955, when 3 live and 2 dead silvers were observed in a ¾-mile survey of Big Creek and a ⅝-mile survey of Alder Creek. On November 18, 108 live and 1 dead silver were observed in a 2¼-mile survey of Johnson Creek, and 7 live silvers in a ½-mile survey of Hatchery Creek, tributary of Johnson Creek. Since few dead fish were seen, no further surveys were made until November 26-29. Surveyors were handicapped by high water levels throughout the season. As a result, many fish may have spawned, died, and disappeared without being seen.

Table 2 shows counts of live and previously uncounted dead silvers from streams of various sizes according to the date surveyed. In some cases, the same sections on the stream were surveyed several times, although the entire section was not always covered each time. The surveys shown are not necessarily all those made of these areas since some counts and mileages were combined with those of other areas on the same stream and did not readily lend themselves to inclusion in this table. It can be seen from Table 2 that in late November and early December large numbers of fish were on the spawning grounds. Abundance continued until at least mid-January, particularly in the larger streams. Fish were observed actively spawning in Noble Creek on February 6, 1956, and in Johnson Creek on February 10, 1956. No surveys were made after these dates.

TABLE 2. **LIVE AND DEAD SILVER SALMON OBSERVED IN SELECTED SURVEYS OF TRIBUTARIES OF TENMILE LAKES ACCORDING TO TIME AND DISTANCES SURVEYED, 1955-1956**

Stream	*Distance (Miles)*	*Date*	*Live Fish*①	*Dead Fish*		*Total*①
				Adults	*Jacks*	
Alder Creek (Trib. Big Cr.)	⅝	11/17/55	1	1	0	2
	⅝	11/28/55	313	5	0	318 (178)
	⅝	12/ 9/55	297 (148)	36	4	337 (156)
	⅝	12/29/55	157	32	4	193 (57)
	⅝	1/12/56	143	59	11	213 (27)
	⅝	1/24/56	48	9	1	58 (1)
	⅝	2/ 1/56	6 (0)	12	2	20 (2)
Barn Gulch (Trib. Big Cr.)	⅜	11/28/55	254	18	12	284 (138)
	⅜	12/ 5/55	210	78	29	317 (29)
	⅜	12/ 9/55	244 (122)	41	35	320 (157)
	½	12/12/55	318	48	22	388 (199)
	½	12/29/55	97	171	45	342 (114)
	⅜	1/12/56	9	96	44	149 (44)
	½	1/24/56	8 (1)	14	1	23 (2)
Adams Creek (Left Fork)	¾	11/27/55	26	4	4	34 (4)
	1	1/19/56	42 (6)	174	58	274 (64)
	1	1/25/56	25 (4)	94	12	131 (16)
Hatchery Creek (Trib. Johnson Cr.)	¾	11/18/55	7			7 (3)
	⅞	11/29/55	393	6	10	409 (171)
	¾	12/ 6/55	423 (166)	92	48	563 (213)
	¾	12/13/55	368	135	57	560 (221)
	¾	12/16/55	426	89	37	552 (178)
	¾	12/31/55	54	177	51	282 (64)
	¾	1/11/56	23 (3)	86	30	139 (33)
Johnson Creek (Left Fork)	1	11/18/55	56	0	0	56 (23)
	1	12/ 7/55	1,150 (197)	194	30	1,374 (227)
	½	12/15/55	202	159	47	408 (83)
	1	12/31/55	206	419	22	647 (46)
	¾	1/11/56	134	82	5	221 (19)
	¾	2/10/56	3 (0)	57	3	63 (3)
Johnson Creek	1¼	11/18/55	52	0	1	53 (14)
(Main Stream and Right Fork)	1	12/ 6/55	1,050 (346)	704	346	1,318 (392)
	½	12/15/55	146	158	94	398 (115)
	1¼	12/30/55	322	468	57	847 (119)
	½	1/11/56	172	172	19	363 (64)
	1½	2/10/56	19 (0)	109	3	128 (3)
Murphy Creek	1⅛	11/30/55	231	11	7	249 (113)
	1⅛	12/10/55	272 (153)	71	68	411 (221)
	1⅛	1/31/56	1 (0)	67	15	83 (15)
Noble Creek (Trib. Big Cr.)	1	11/26/55	526	0	0	526 (230)
	1¼	12/ 4/55	361	60	8	429 (118)
	1¼	1/ 2/56	(not counted)	499	201	700 (201)
	1¼	1/ 3/56	362 (64)	230	48	640 (112)
	1½	1/10/56	237	274	51	562 (78)
	1¼	1/26/56	104	107	8	219 (16)
	1¾	2/ 6/56	13 (0)	114	2	129 (2)

① Jacks shown in ( ) are included in total and only appear for maximum adult counts for distances shown and for last surveys made. Live fish shown only for interest and not used in calculations in report.

Figure 2 shows the total number of dead adult and jack silvers found in each major area of the Tenmile system. Jacks, shown in parentheses, are included in total counts. Approximately 130 miles of stream was surveyed during the season, and 12,092 adults and 4,214 jacks were examined for tags. A total of 346 tagged silvers was recovered—250 adults and 96 jacks.

MIGRATION AND MOVEMENTS

Sport Fishery Recoveries

Table 3 shows tag recoveries of adult and jack silver salmon in the sport fishery by date recovered and date tagged. The lapse between tagging and recovery of adults in the sport fishery was 2 to 28 days, with a mean of 11.5 days. Except for two fish, all adults were taken within three weeks of the time they were tagged. It appears that adult fish generally are not susceptible to sport gear about three weeks after having entered the lake.

TABLE 3. **RECOVERIES OF ADULT AND JACK SILVER SALMON IN THE SPORT FISHERY ACCORDING TO DATE TAGGED AND RECOVERED AT TENMILE LAKES, 1955-1956**

	Adults			*Jacks*	
Date Tagged	*Date Recovered*	*Days Out*	*Date Tagged*	*Date Recovered*	*Days Out*
10–15	11–12	28	10–15	11–10	26
16	10–28	12		11–21	37
17	11– 9	23		12– 3	49
18	10–28	10	17	10–29	12
21	10–29	8		11– 5	19
22	11– 5	14	18	11– 4	17
	11– 6	15	21	10–25	4
24	11–10	17		11– 6	16
28	11– 6	9	22	11–17	26
29	11– 6	8	23	11– 5	13
31	11– 9	9		11–12	20
11– 2	11– 8	6	24	11– 5	12
5	11–17	12	27	10–31	4
	11–25	20		11–18	22
6	11–20	14	29	11–11	13
7	11–12	5	30	11–20	21
8	11–10	2		12– 3	34
9	11–11	2	31	11– 5	5
	11–24	15	11– 2	11–11	9
10	11–17	7	3	11– 5	2
	11–20	10		11–11	8
	11–29	19	6	12–15	39
11	11–22	11	7	11– 8	1
20	11–25	5		11–24	17
22	11–26	4	8	11–11	3
29	12–14	15	26	12– 3	7
Mean		11.5	Mean		16.8

The time between tagging and recovery of silver jacks in the sport fishery varied considerably, with a range of 1 to 49 days and mean of 16.8.

Tagging Gear Recoveries

During the season 29 tagged fish (adults and jacks) were recovered with tagging gear; 2 were adults tagged and recovered in the trap, both were at liberty 2 days; 11 were tagged in the trap and recovered in the fyke nets; and 16 were tagged and recovered in the nets (Table 4). Time out for fish tagged in the trap and recovered in the nets was 1 to 54 days with a mean of 17.9. Four made the 1¼-mile trip in no more than 3 days.

TABLE 4. **RECOVERIES OF ADULT AND JACK SILVER SALMON IN THE TAGGING GEAR ACCORDING TO DATE TAGGED AND RECOVERED AT TENMILE LAKES, 1955-1956**

Adults			*Jacks*		
Date Tagged	*Date Recovered*	*Days Out*	*Date Tagged*	*Date Recovered*	*Days Out*
In Trap	In Fyke Nets		In Trap	In Fyke Nets	
10–19	10–22	3	10–14	10–29	15
24	12–17	54	28	10–29	1
27	11–21	25	30	12– 6	37
28	10–31	3			
31	11–21	21	Mean		17.7
11– 7	12– 9	32			
11–12	11–13	1			
17	11–21	4			
Mean		17.9			
In Trap	In Trap		In Fyke Nets	In Fyke Nets	
11– 8	11–10	2	10–19	11– 8	20
11	11–13	2	28	11–20	23
			31	12–12	42
Mean		2.0	11– 5	12–11	36
			13	12– 8	25
			15	11–26	11
			20	12–10	20
In Fyke Nets	In Fyke Nets		21	11–27	6
				12– 3	12
12–14	1– 9	26		12– 6	15
1– 9	1–15	6		12– 8	17
				12– 9	18
Mean		16.0	11–24	11–27	3
			12– 5	12– 6	1
			Mean		17.8
Combined Mean		14.9			17.8

Recoveries in the fyke nets are weighted by a jack that was recaptured five times in 18 days (November 21 to December 9). Time between tagging and recovery in the fyke nets was 1 to 42 days with a mean of 17.8.

Spawning Ground Recoveries

During surveys to recover tags from dead fish on the spawning grounds, it was occasionally possible to pick up and examine tagged live fish. In this way, more reliable information was obtained on the lapse of time between tagging and appearance on the spawning grounds. Data for live tagged fish on the spawning grounds are shown in Table 5, divided into adults and jacks according to date tagged. Because the nets were at the

TABLE 5. **RECOVERIES OF LIVE TAGGED SILVER SALMON ON THE SPAWNING GROUNDS ACCORDING TO DATE TAGGED AND RECOVERED AT TENMILE LAKES, 1955-1956**

Adults			*Jacks*		
Date Tagged	*Date Recovered*	*Days Out*	*Date Tagged*	*Date Recovered*	*Days Out*
In Trap			In Trap		
10–22	12–27	66	10–12	12–14	63
31	12–29	59	30	12–31	62
11– 5	12–10	35			
	12–29	54	Mean		62.5
11– 8	12–29	51			
	1–14	67			
11– 9	12–29	50			
	12–30	51			
11–11	1–25	75			
Mean		56.4			
In Fyke Nets			In Fyke Nets		
10–28	12–30	63	10–18	12–29	72
29	12–29	61	11– 1	12–28	57
11– 7	1– 5	59	7	1–12	66
11– 9	1–10	62	11–12	12–27	45
13	12–30	47	17	12–27	40
	12–30	47	20	12–28	38
11–19	12– 4	15	27	12–30	33
24	12–30	36	29	12–29	30
12–13	12–30	17	12– 9	12–27	18
15	12–27	12	12	1–13	32
20	12–28	8			
Mean		38.8	Mean		43.1
Combined Mean		46.8			46.3

outlet of the lake, the fish caught could have been in the lake some time before being tagged. Fish caught in the trap could also have spent some time in the lake before tagging, but this is much less likely. Lapse of time between tagging and recovery alive on the spawning grounds for fish tagged from fyke nets was 8 to 63 days for adults and 18 to 72 for jacks; for fish tagged from the trap, the lapse was 35 to 75 days for adults. Only 2 jacks tagged at the trap were recovered alive, 62 and 63 days after tagging.

Of the 32 fish examined, 24 were picked up from December 27 to 31, 1955. Fish tagged as late as December 20 from the fyke nets were recovered alive on the spawning grounds, but none of those tagged at the trap after November 9.

Recoveries in all streams reflected the same tagging peaks, indicating that fish from different streams passed through the tagging area generally at the same time, and then dispersed to the various spawning grounds. Possible exceptions were fish recovered in Eel Lake and Tenmile Creek tributaries. Spawning ground surveys were made on several tributaries of Eel Lake and on McDonald and Butterfield Creeks, tributaries of lower Tenmile Creek. Tagged silvers were recovered in all these streams, and in addition, several tags were returned from Eel Lake tributaries by Oregon Game Commission biologists. Of 19 tags recovered downstream from the tagging site, 15 had been attached to fish in the fyke nets at the mouth of Tenmile Lakes; all were tagged after October 30, and 12 after November 20, 1955. The latest tagged fish (an adult) recovered downstream from the fyke nets was put out on December 20, 1955 and recovered, spawned out and dead, in a tributary of Eel Creek on January 10, 1956.

POPULATION ESTIMATES

The population estimates arrived at in this report were based on the formula $N = \frac{nt}{s}$ and the formulae of Schaefer's (1951, pp. 191-203). Numerous population estimates were available by Schaefer's method depending on how the data were grouped. Estimates of the total jack population by this method ranged from 34,887 to 38,912, and total adult population, 39,442 to 42,828. Single estimates for the combined population of adults and jacks ranged from 77,147 to 81,694. Table 6 depicts the data and procedure for one of the estimates arrived at for the jack population. The upper part of the table lists the tag recoveries by period, while the lower part lists the actual estimated population by period. The details of these computations can be obtained from Schaefer's paper.

TABLE 6. **POPULATION ESTIMATE OF JACK SILVER SALMON ENTERING TENMILE CREEK, 1955-1956①**

Recovery Period	*Tagging Period* 1	2	3	4	5	*s* *Tags recovered each sampling period*	*n* *Fish sampled each sampling period*
1	6.57	5.48	4.38	4.38	2.19	23	1,065
2	4	3	5	5	3	20	1,162
3	4.21	8.42	4.21	2.11	1.05	20	784
4	5	2	1	3	1	12	494
5	2.17	2.17	2.17	4.32	2.17	13	417
s (Tags recovered each tagging period)	21.95	21.07	16.76	18.81	9.41	88	3,922
t (Tags released each tagging period)	182	145	152	145	187	805	

TABLE 6. **POPULATION ESTIMATE OF JACK SILVER SALMON ENTERING TENMILE CREEK, 1955-1956—Continued**

Recovery Period	*Tagging Period* 1	2	3	4	5	*Total*
1	2,522②	1,746	1,839	1,563	1,951	9,621
2	1,927	1,200	2,635	2,239	3,353	11,354
3	1,368	2,271	1,497	638	792	6,566
4	1,707	567	373	952	791	4,390
5	577	479	631	1,068	1,339	4,094
Total	8,101	6,263	6,975	6,460	8,226	N = 36,025

① Tag scars proportionately distributed.

② $N_1 = 6.57 \frac{(1,065)}{(23)} \frac{(182)}{(21.95)} = 2,522.$

Using the formula $N = \frac{nt}{s}$ in which n = number of fish sampled, t = number of fish tagged, and s = number of tagged fish recovered, population estimates varied from 34,615 to 35,896 for jacks, 41,426 to 42,663 for adults, and 78,290 to 79,174 for a single combined estimate. These estimates and the appropriate confidence limits are listed in Table 7.

TABLE 7. **POPULATION ESTIMATES AND 95 PERCENT CONFIDENCE LIMITS FOR SILVER SALMON ENTERING TENMILE CREEK, 1955-1956①**

Adults *Number*	*Adults* *95% Confidence Limits*	*Jacks* *Number*	*Jacks* *95% Confidence Limits*	*Total* *Number*	*Adults and Jacks Combined* *Number*	*Adults and Jacks Combined* *95% Confidence Limits*
	36,517		29,140			70,310
41,426		35,896		77,322	78,290	
	46,950		44,490			87,406
	37,653		28,406			71,339
42,663		34,615		77,278	79,174	
	48,313		42,181			88,084

① Based on formula $N = \frac{nt}{s}$

Based on these various estimates, it appears that the 1955-56 run of silver salmon into Tenmile Creek consisted of approximately 36,000 jacks and 41,500 adults.

Production of silver salmon from the 1952 brood in Tenmile Lakes should not be limited, however, to those which returned to the natal streams. Assuming that Tenmile stocks contribute to the ocean troll fishery in the same manner as those in other Oregon coastal streams, it is estimated that about 40,000 Tenmile silvers were taken in this fishery.

Since Tenmile Creek is close to both Coos Bay and Winchester Bay, where sizeable sport fisheries exploit feeding salmon, it can be assumed that Tenmile fish also contribute to some extent to these fisheries although in an unknown amount. Considering only the ocean troll catch and returns to the lake system, production of silver salmon by the Tenmile system from the 1952 brood was estimated as at least 117,500 fish.

If the adult population had a 1:1 sex ratio, the 1955-56 run comprised about 20,800 females, each of which is capable of producing about 3,000 eggs. Therefore, the spawning potential of the 1955-56 run was approximately 62,400,000 eggs.

DISCUSSION

The gravel areas in Tenmile Lakes tributaries are mostly concentrated in one section of the stream and do not occur intermittently. Hence, schools of spawning fish tend to crowd into the same areas. Eggs of late spawners are deposited in the same gravel as those of early spawners. After November, it was common to see both live and dead eggs in the bottom of pools and floating in eddies. Further evidence of overcrowding was the large number of fish which spawned during December and January in very small streams that contained no water in February. On a survey of December 4, 1955, 40 spent, dead fish were observed in less than 100 yards on Noble Creek which was dry in February. Similar situations were observed in other small streams (Figure 6). Many thousands of silver salmon fry have been stranded in these dried-up streams.

FIGURE 6. SMALL, DRY TRIBUTARY CONTAINING SPENT DEAD SILVERS IN JANUARY.

Tenmile tributaries obviously now have smaller spawning areas than in former years. Most of the loss has resulted from re-channeling of streams by landowners to obtain better drainage and more farming areas, usually around the mouths of tributaries which are flat and make good pasture (Figures 7 and 8). Such streams have often been diverted from their natural, meandering channels into straight ditches as shown in Figure 9. This particular area, located about ¼-mile above the mouth of

FIGURE 7. UPPER FIELD AREA OF A RE-CHANNELED TRIBUTARY OF SHUTTERS CREEK. THE LOWER LIMIT FOR SPAWNING SILVERS IN THIS TRIBUTARY WAS AT THE POINT WHERE THE FIELD NARROWS ABRUPTLY, AS INDICATED BY THE ARROW.

the stream which enters the main Shutters Creek, has good spawning gravel. No spawning fish were observed here until the last 100 yards of field (center of Figure 8) was reached. In this stream the spawning area has been reduced from about ½ to ¼ mile. Such curtailment has been noted in many tributaries in the Tenmile drainage.

FIGURE 8. LOWER AREA OF FIELD SHOWN IN FIGURE 7. SPAWNING GRAVEL WAS OBSERVED IN THE UPPER HALF OF THIS AREA, BUT NO SPAWNING FISH.

Logging operations have also reduced spawning areas in the Tenmile Lakes watershed. Some tributaries are now completely inaccessible to spawning salmon, while on others heavy siltation has reduced productivity. Figures 10 and 11 show the headwaters of one stream after logging in 1955-56. Logging began a few feet above the spawning area, and no direct damage to the actual spawning ground was due to logging debris. However, siltation, heavy winter run-off, low summer flows, and high water temperatures resulted in definite but indeterminable damage to fish life.

Streams which have lost spawning areas through poor logging practices are Adams, Johnson, Shutters (not the tributary mentioned above), and Wilkens Creeks in the main Tenmile drainage; Eel Lake tributaries; and McDonald and Swamp (Butterfield) Creeks. One fork of Blacks Creek

FIGURE 9. A TYPICAL SECTION OF MANY TENMILE LAKES TRIBUTARIES FLOWING THROUGH PASTURE LAND. NOTE THE STRAIGHT CHANNEL AND SHALLOW, SWIFT FLOW.

suffered because railroad tracks were laid in the stream bed and water was diverted down each side. The other fork has several large beaver dams which affect part of the spawning area. When the surveys were made, McDonald Creek was also blocked by beaver dams and the remains of an old mill dam.

It would appear from the restricted spawning areas and concentrations of spawning fish observed, combined with very low flows and high water temperatures found in the tributaries during summer surveys, that the tremendous production of Tenmile Lakes is due mainly to good survival of fry and/or fingerlings crowded out of the tributaries into the lakes.

Studies by the Oregon Fish Commission at Spring Creek on the Wilson River showed that in 1951, when the spawning population was quite large for the amount of spawning and rearing area available, a large percentage

FIGURE 10. LOGGED-OFF AREA WHICH INCLUDES THE UPPER LIMIT FOR SPAWNING SILVERS IN A TRIBUTARY OF SHUTTERS CREEK.

of the offspring left the stream as small fry while a much smaller percentage migrated as yearlings. In 1954, there were practically no returns to Spring Creek from the large numbers of fish which had migrated as fry, and the total adults returning represented a significant percentage decrease compared with the 1951 run. An analysis of scale readings from a sample of 87 fish shows that growth of Tenmile silvers during the first winter was more than twice that of comparable Spring Creek fish.

Spawning areas in the Tenmile Lakes system appeared to be completely utilized by silver salmon. In fact, the data indicate there were many more salmon than the spawning grounds could properly accommodate and a substantial egg loss resulted.

FIGURE 11. A TRIBUTARY OF SHUTTERS CREEK TYPICAL OF COASTAL WATERSHEDS THAT HAVE BEEN LOGGED.

SUMMARY

A tagging study was conducted on Tenmile Lakes silver salmon during the 1955-56 season to obtain an estimate of the population returning to the lake.

A fixed cotton trap and three portable, wire mesh-covered fyke nets were used to capture salmon for tagging. Because of selectivity between the two types of gear, it was necessary to make separate estimates of adult and jack silver populations. During the season, 1,680 fish were tagged, 875 adults and 805 jacks.

Tenmile Lakes silvers were subjected to a comparatively light fresh-water sport fishery. From moorage reports and tag ratios it was calculated that a minimum of 5,300 fish (2,000 adults and 3,300 jacks), including 59 tagged, were taken by sport fishermen.

Stream surveys to recover tags from dead fish on spawning grounds were begun November 17, 1955 and concluded February 10, 1956. Totals of 12,092 dead adult and 4,214 dead jack silvers were examined and 346 tags were recovered—250 from adults and 96 from jacks.

A number of fish tagged at the mouth of the lake moved downstream and were recovered in Eel Lake and Tenmile Creek tributaries below Eel Creek.

Based on various estimates, depending upon how the data were grouped, the run of silver salmon into Tenmile Creek during the 1955-56 season was approximately 36,000 jacks and 41,500 adults. In addition, it was estimated that 40,000 silvers from Tenmile Lakes were taken in the ocean troll fishery. The spawning potential of the 1955-56 run was estimated at 62,400,000 eggs.

The fish were crowded on the spawning grounds and many early nests were dug up by later spawning fish causing a considerable loss of eggs. In addition, many spawning fish were crowded into small streams with only temporary water flows.

Logging and farming have had an adverse effect on fish life in the Tenmile drainage.

ACKNOWLEDGMENTS

Thanks are due to Raymond N. Breuser, Melvin D. Collins, Karl Niggol, Charles D. Snow, and David T. Vincent who helped with tagging operations and collection of data. Raymond A. Willis mounted and read scale samples taken. Cooperation of sportsmen, moorage operators, and residents of the Tenmile area is greatly appreciated.

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Occurrence of Deep-Pitted Sea-Poacher in Oregon

Occurrence of the deep-pitted sea-poacher (*Bothragonus swanii*) is considered by Schultz (1938) and Schultz and DeLacy (1936) to be rare within their established range of this fish, Vancouver Island, Puget Sound, and the Washington coast. Clemens and Wilby (1946) give the range as Washington to Queen Charlotte Strait. Considering the rarity of the species and ranges, it was considered worthwhile to report a specimen of undetermined sex taken by the author, April 28, 1951, in a tide pool at Boiler Bay, Oregon (44°50.2′ latitude, 124°03.8′ longitude). It is shown in Figure 1. Clemens and Wilby give the length of these fish as 2½ inches. The Boiler Bay specimen measured 79.6 mm. standard length, or 3⅛ inches. The fish was alive when captured, a soiled brown color, with four encircling black stripes on the body. Identification was verified by Carl E. Bond of the Department of Fish and Game Management, Oregon State College, and the specimen is now in the collection of the Biology Department of Linfield College, McMinnville, Oregon.

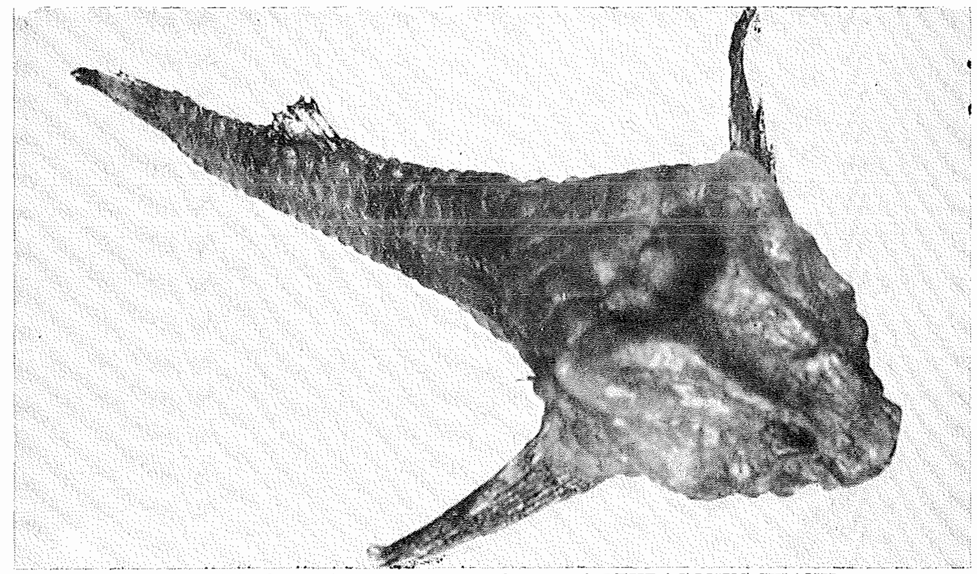

FIGURE 1. DEEP-PITTED SEA-POACHER, *BOTHRAGONUS SWANII.*

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Records of Agonid Fishes From Oregon

The tubenose poacher (*Pallasina barbata aix,* Starks) and the prickle-breast poacher, *Stellerina xyosterna* (Jordan and Gilbert), have been listed as occurring on the Oregon coast without definite locality records. Jordan and Evermann (1898) give the range of *P. barbata* as the North Pacific, south to Japan and Oregon; and the range of *P. b. aix* as Puget Sound to the Aleutians. Schultz and DeLacy (1936) list a record of *P. b. aix* from Cape Johnson on the Washington coast and refer to Jordan and Evermann (1898) for an Oregon coastal record. Hemphill and Follett (1958) have recorded a specimen from Cleone Beach, 170 miles south of the Oregon border. The scientific name of the tubenose poacher is discussed by Barraclough (1952) and Hemphill and Follett (1958).

A specimen of *P. b. aix* was collected on March 19, 1953, by James E. McCauley from an experimental trawl sample taken in Yaquina Bay, Oregon, by Oregon Fish Commission biologists and donated to the Department of Fish and Game Management, Oregon State College. It is 115 mm. in standard length with a short mental barbel of about 1 mm. Dorsal rays number VIII-8; pectoral rays, II-11; and anal rays, 12. The dorsal fins are well separated, as indicated in the figures presented by Jordan and Evermann (1898) and Barraclough (1952). Pre-pelvic plates total 4: a small pair directly in advance of the pelvics and 2 large unpaired plates anterior to these.

The range of *S. xyosterna* was reported by Jordan, Evermann, and Clark (1930) as the coast of California and Oregon; and Jordan and Evermann (1898) base their description of the species on specimens "from the Coast of Oregon, taken in 24 fathoms," but Schultz and DeLacy (1936) state that they could not verify the Oregon record.

There are 3 specimens of *S. xyosterna* in the collection at Oregon State College, Department of Fish and Game Management. The first was taken by R. L. Buchanan near the Coast Guard Station at Coos Bay, Oregon, July 11, 1941; the second by Stuart Knapp on Coos Bay bar in a surface tow net during the night of July 20, 1949; and the third by Knapp under the same conditions, July 5, 1950. The first specimen is 29.5 mm. in length; the second, received in a mutilated condition, 15.0 mm.; and the third, 15.5 mm.

The last specimen was received alive in good condition and kept in an aquarium for some time before preservation. It showed a predilection toward swimming near the surface and used its large, fan-shaped pectoral fins as the sole means of propulsion. The pectorals were worked alternately, with a wave of motion beginning at the top of each fin and progressing downward. Very little movement of the body or caudal fin could be detected.

The pectoral fins of the smaller specimens were quite large, about one-third the standard length. In the larger specimen the pectoral was less than one-fourth the standard length. Description of the species in Jordan and Evermann (1898) is based upon adult specimens up to 160 mm. and gives the pectoral length as $4\frac{2}{3}$ in length of body. Probably the ability to swim independently of the bottom is limited to juveniles, as the pectorals of older fishes are obviously not large enough to buoy up the proportionately larger and heavier bodies for extended periods. Adults of other species of agonids have been observed to move over the bottom by means of quick pectoral movements.

The sturgeon sea-poacher (*Agonus acipenserinus,* Tilesius) is listed by Schultz and DeLacy (1936) as occurring from Alaska to Puget Sound, with all the Washington-recorded recoveries in the Straits of Juan de Fuca and Puget Sound. The Oregon Fish Commission donated to Oregon State College a specimen taken at a depth of 75 fathoms by the trawler *Mary R* off the coast of southern Tillamook County, January 1, 1952. The Oregon State College Experimental Fur Farm received, on July 1, 1958, a specimen in a load of fishes taken by the trawler *Margaret E* off Waldport, Oregon. These specimens of *A. acipenserinus* represent a southerly extension of about 260 miles of the known coastwise distribution of the species.

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Occurrence of Juvenile Pink Salmon In a Coastal Stream South of the Columbia River

A record has been established recently for the occurrence of juvenile pink salmon (*Oncorhynchus gorbuscha*) from Oregon waters south of the Columbia River. The fry, 32.5 mm. in fork length, was taken by the author on April 11, 1956, along with fry chum salmon (*O. keta*) at the Oregon State College Fisheries Laboratory, Yaquina Bay.

Schultz and DeLacy (1935) in their check list of Northwest fishes do not record adult or juvenile pinks from Oregon coastal streams. In recent years, however, adult pinks have been reported from the Sixes River, Beaver Creek, a tributary of the Nestucca River (Oregon State Game Commission, 1953), and the Necanicum River (Ayers, 1955).

The captured pink fry from Yaquina Bay indicates that at least a few adult pinks straying into Oregon coastal streams propagate successfully. In addition, it also suggests an adult record from the Yaquina system inasmuch as Pritchard (1944), working in British Columbia, notes the size of pink fry at emergence from the gravel as between 30 and 35 mm. Thus, of necessity, the captured pink fry must have been spawned somewhere in the Yaquina system.

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Oregon Fish Commission Robert B. Herrmann

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Gull Food Habits on the Columbia River

In May 1955 a large concentration of gulls was observed feeding below McNary Dam on the Columbia River. Since a heavy migration of downstream-moving salmon and steelhead occurs during this season, it was assumed that the gulls were feeding on these fingerlings.

On May 11 and 12, 40 gulls and 1 tern were shot and their stomach contents examined. The species collected were: 27 California gulls (*Larus californicus*), 11 ringbill gulls (*L. delawarensis*), 2 immature Western gulls (*L. occidentalis*), and 1 Forster's tern (*Sterna forsteri*).

The diet of the gulls was surprising, since the principal food consisted of lampreys approximately 2 to 8 inches in length. Two species of lamprey were represented: ammocetes of the Pacific lamprey (*Entosphenus tridentatus*), 101 individuals, and adult brook lamprey (*Lampetra planeri*), 57 individuals. Only 5 recognizable salmonids were found, although many stomachs contained unidentified fish bones probably composed partially of salmonids. Other fish present included 3 bream (*Richardsonius balteatus*), 1 carp (*Cyprinus carpio*), and 1 stickelback (sp.). Additional food items found included insects, a crayfish claw, chunks of cauliflower, a melon seed, sand, small rocks, green vegetable matter, and a chip of green glass.

The volume of each type of food was also measured by the water displacement method. Lampreys comprised 70.8 per cent of the total volume.

This limited study indicated that for that particular time and place lampreys were the chief food item of gulls, both in number of individuals and quantity. It is realized, however, there is a possibility that the birds may have regurgitated before capture any recently eaten food, thus preventing its recovery and examination.

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Marked Pink Salmon

On July 9, 1957, Ralph Lemmi on the troller *Bear* of Astoria caught a marked pink salmon (*Oncorhynchus gorbuscha*) off the Columbia River with the adipose and right ventral fins missing. This fish, which weighed about 3 pounds dressed, had been marked at Hoodsport on Hood Canal in Puget Sound, and since pink salmon are 2 years old, was from the 1955 brood.

This is the first record of a marked pink taken in the Oregon fishery. These small salmon are quite abundant in the ocean off Oregon every odd year. It has long been assumed that most of the pink salmon come from Puget Sound streams where they have on odd-year run, and very few spawn in Oregon streams. This is the first proof of that assumption.

Oregon Fish Commission
Clackamas, Oregon

Jack M. Van Hyning