NATIVE OYSTER INVESTIGATIONS

OF

YAQUINA BAY, OREGON

Progress Report II

Covering the Period

July 4, 1939 to September 30, 1941

By

R. E. Dimick, George Egland and J. B. Long

Oregon Agricultural Experiment Station
Corvallis, Oregon

Cooperating with
The Fish Commission of the State of Oregon
and
The Lincoln County Court

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INTRODUCTION

This report presents the survey results of the oyster areas in Yaquina bay, Oregon, covering the period from July 4, 1939 to September 30, 1941. The study was inaugurated by Governor Charles A. Sprague for the purpose of ascertaining facts which might serve as a basis for rehabilitation of the oyster fishery and as a basis of management for a sustained yield of the native oyster, *Ostrea lurida* Carpenter. The investigation was a cooperative undertaking in which the Fish Commission of the State of Oregon, the Lincoln County Court and the Oregon Agricultural Experiment Station participated.

A report covering the first two and one-half months of the study was issued September 15, 1939 (Dimick and Long 1939). The salient items presented in that publication are included in this progress report.

In order that the cooperating agencies and interested persons could be informed immediately of the progress of the oyster studies at the close of the field operations in September 1941, this report was prepared. Much of the ecological data presented in tables needs to be summarized graphically and correlated with the many biological observations. When this has been done, it is expected that a bulletin covering the complete investigation will be issued.

Acknowledgements

We wish to express our sincere thanks to the many persons who assisted in the work. Everyone asked for assistance was most helpful. We are particularly indebted to Mr. and Mrs. Dow Walker, Yaquina, for the use of a houseboat laboratory and many other aids; Mr. D.C. Miller, Winant, for his general help and counsel based upon his observations of the native oyster over a long period of years as a practical oysterman; Mrs. Charles E. Hewes, Santa Monica, California, for the use of historical documents; Judge Franklin Gilkey, for his interest in the study and aid in securing needed materials; Mr. Ellsworth Rosselle, employee of the Oregon Oyster Company, for his general helpfulness; Mr. Louis A. Wachsmuth, Sr., owner of the Oregon Oyster Company, for the use of oystering equipment; the members of the Toledo Port Commission, especially Mr. C.H.Bogert, for supplying lumber used in the experimental dikes; Mr. Pete Rassmussen, Yaquina, for his assistance with equipment; Mr. M.T. Hoy, Master Fish Warden, Oregon Fish Commission, for his support and cooperation in the work.

Several students of the Fish and Game Management Department, Oregon State College, undertook and completed certain phases of the study. They were Phillip Schneider, Leo F. Schneider, Lewis Bowen, Russell Hill, Gale Welborn, Donald Stotler, and Baine Cater. Most of the pictures used in this report were taken by Dr. F.P.Griffiths, Aquatic Biologist, Oregon State College.

HISTORY OF THE YAQUINA BAY OYSTER FISHERY

A history of the oyster fishery in Yaquina Bay was compiled largely from newspaper accounts, records of the United States Bureau of Fisheries, reports of various agencies having charge of the State's fisheries at one time or another, publications of biologists who had made previous investigations of the oyster problems of the area, and by interviews and correspondence with persons having information and documents relating to past conditions of oystering in this particular estuary. From these sources, having decided chronological gaps, a trend depicting the early decline of the industry is indicated.

The Indians of the region, previous to white-settlements, apparently made a very limited use of the native oyster as food. Several shell mounds are present in locations from the mouth of the bay at Newport and South Beach to the upper limits of the oyster beds in the vicinity of Boones Point. In those kitchen midden deposits adjacent to the natural oyster beds, particularly in places such as Rocky Point where today a few oysters can be found under rocks exposed at low tide, native oyster shells are present along with the more numerous shells of the indigenous mollusks including the Bay Mussel, *Mytilus edulis*; the Cockle, *Cardium corbis*; the Little-neck clam, *Paphia staminea*; and the Horse or Gaper clam, *Schizothaeus nuttallii*. In the upper layers of these deposits, native oyster shells are more numerous; but coincident with this condition, the shells of the exotic Eastern soft-shell clam, *Mya arenaria*, are also present. The probabilities were that this clam was accidentally introduced to the bay with the first shipments of the Eastern oyster, *Ostrea virginica*, about 1878.

Apparently, the Indians collected only a few oysters for food previous to 1852, in those locations in which oysters were exposed at low tide, since most of the natural oyster beds in this estuary are in relatively deep water covered at low tide. This supposition is further substantiated in a lengthy letter by Cyrus Olney published in the Oregon Statesman, June 15, 1852, describing the findings of an exploration party to Yaquina bay in June 1852, in which he stated: "-----Of oysters in particular, we saw no signs not even a fragment of a shell about the lodges or along the beach.----"

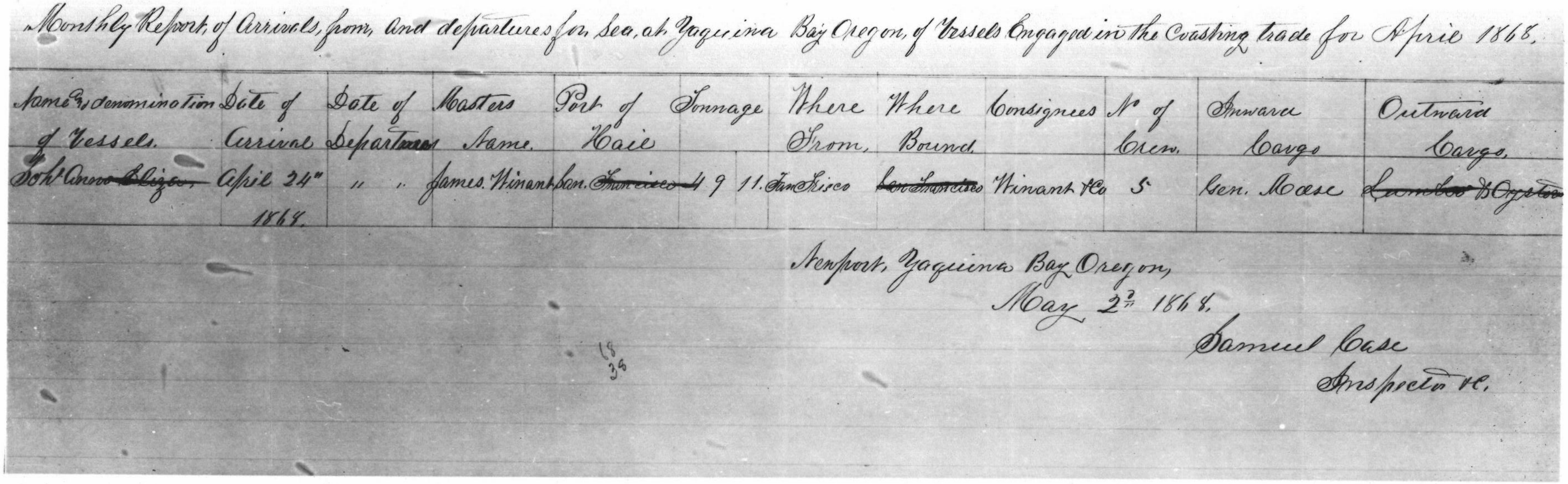
The oyster beds were first discovered by Captain Collins sometime between January 28 and the latter part of March 1852. Bancroft (1888) in his History of Oregon recorded:

> "On the 28th of January the schooner 'Juliet', Captain Collins, was driven ashore near Yaquina Bay, the crew and passengers being compelled to remain upon the stormy coast until by aid of an Indian messenger horses could be brought from the Willamette to transport them to that more hospitable region. While Collins was detained which was until the latter part of March he occupied a portion of his time exploring Yaquina bay------."

The Oregon Statesman of April 6, 1852, then published at Oregon City, Oregon territory, contained the following news article:

> "Capt. Collins, of the schooner Juliet, who visited Aquina Bay during his captivity, informs us that he found there a fine river, navigable for vessels drawing six or eight feet of water a distance of twenty miles. But from the appearance he deemed the inlet to be a bad one. He says that the river abounds with oysters, clams, and fish of all kinds. The land around is level and highly productive. The timber has been nearly all destroyed by fire. None of the land in the vicinity is claimed yet."

Oystering had begun on a commercial scale by 1862. A letter from Mrs. Charles E. Hewes, daughter of Captain James J. Winant who was the founder of the oyster fishery at Yaquina bay, stated to Mrs. D.C. Miller, present postmistress at Winant, Oregon:



Monthly Report, of Arrivals, from, and departures for, Sea, at, Yaquina Bay Oregon, of Vessels Engaged in the Coasting trade for April 1868.

Name & denomination of Vessels	Date of Arrival	Date of Departure	Masters Name	Port of Hail	Tonnage	Where From	Where Bound	Consignees	No of Crew	Inward Cargo	Outward Cargo
Schr Anna ~~Eliza~~	April 24" 1868	" "	James Winant	San ~~Francisco~~	49 11	San Frisco	~~San Francisco~~	Winant & Co	5	Gen. Mdse	~~Lumber~~ & Oysters

Newport, Yaquina Bay Oregon,
May 2d 1868.
Samuel Case
Inspector &c.

Figure 1. A copy of the custom report from Yaquina bay, April 1868.
(Courtesy of Mrs. Charles E. Hewes)

> "----in 1862, Captain Bensell in charge of fifteen soldiers of Company D, 4th. California Infantry, was detailed to protect the Winant Oyster Company from the acts of the Ludlum and Company of San Francisco, who were disposed to disregard the lease made by the United States to Winant and Company."

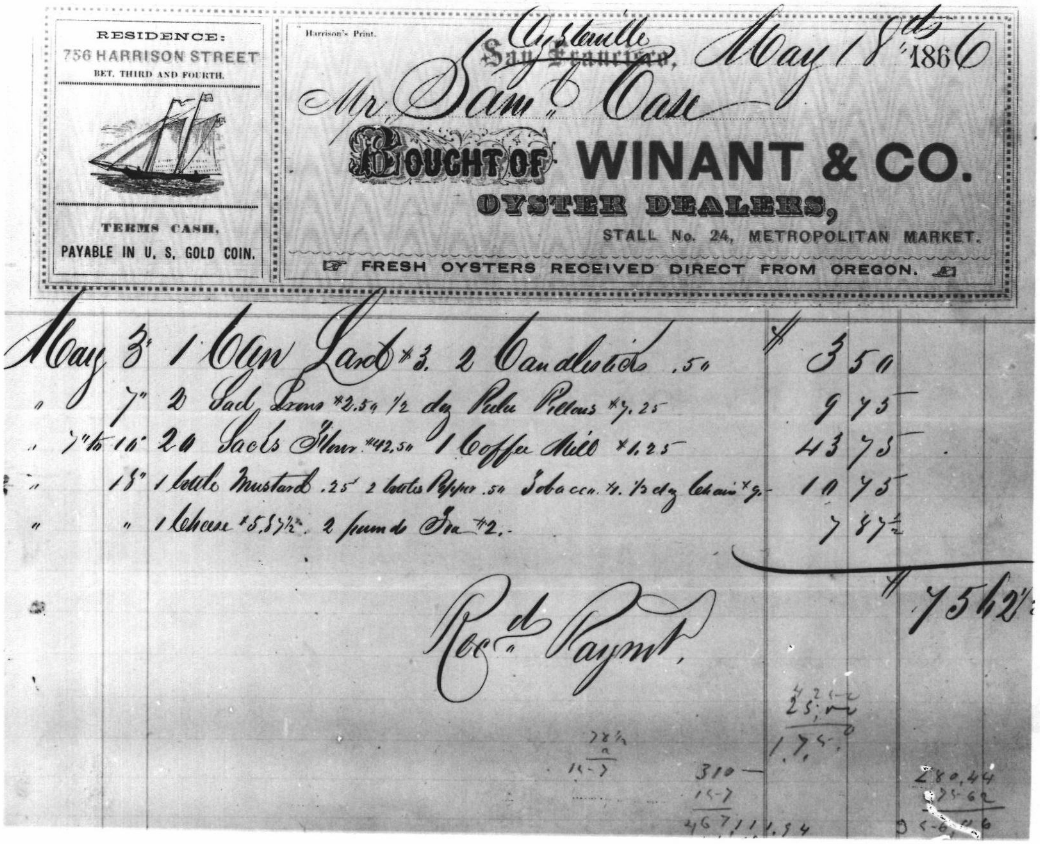
From 1862 or 1863 to some time in the early '90's, Captain Winant operated several sail-schooners from Yaquina bay to San Francisco. The principal outgoing cargoes from Oysterville on Yaquina bay were native oysters which were relaid in San Francisco bay and sold in accordance with the demand. Figure 1 is a photostatic copy of the "Monthly Report, of Arrivals from, and Departures for Sea, at Yaquina bay, Oregon, of Vessels Engaged in the Coasting Trade for April 1868" in which the outgoing cargo was "lumber and oysters." Figures 2 and 3 are copies of the statements issued by Winant and Company on portions of incoming cargoes to Yaquina bay. The statement for May 18, 1866, which was the form used by the San Francisco office of Winant and Company contained the caption "Fresh Oysters Received from Oregon."

The names of some of the schooners which were employed in the oyster trade were the Anna Doyle in the early '60's, the Sarah Louise in 1864, the Anna Eliza in 1868, the Louisa Simpson in 1872, Mischief in 1890, and the Bandorille. Two or more of the boats were wrecked in delivering oysters to San Francisco. Captain Winant, while in command of the Bandorille, was washed overboard and drowned near the mouth of the Umpqua river.

Settlement on Yaquina bay apparently resulted from oystering, for on October 1, 1864, the Oregonian stated:

> "A handsome little town is just beginning on Yaquina Bay. The principal trade now is in oysters with the San Francisco market."

In 1868, oysters were plentiful, and the several oystermen of the area organized an association for the regulation of their opera-


RESIDENCE:
756 HARRISON STREET
BET. THIRD AND FOURTH.
TERMS CASH.
PAYABLE IN U. S. GOLD COIN.

Harrison's Print.

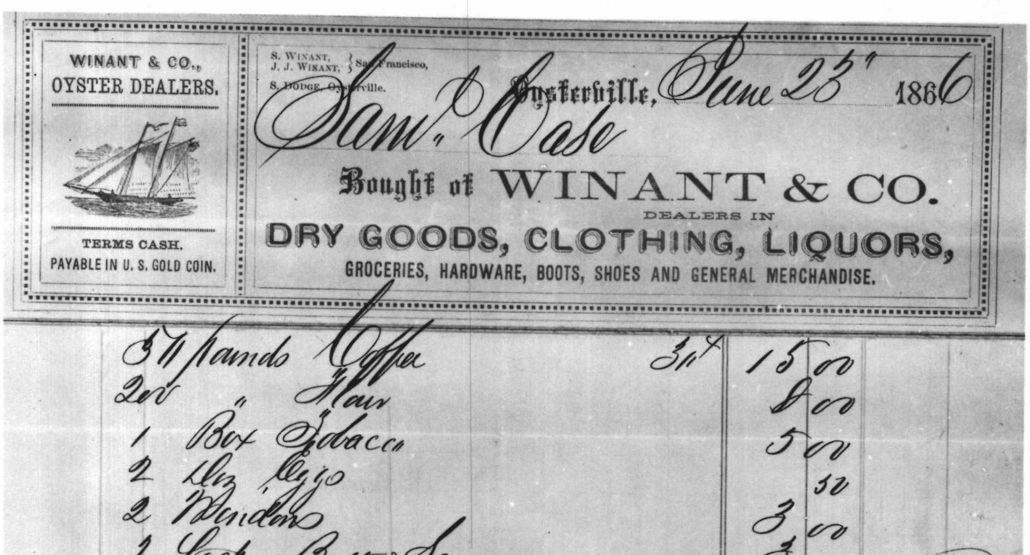
~~San Francisco~~ Oysterville, May 18th 1866

Mr. Sam'l Case

Bought of WINANT & CO.
OYSTER DEALERS,
STALL No. 24, METROPOLITAN MARKET.
FRESH OYSTERS RECEIVED DIRECT FROM OREGON.

May 3rd	1 Can Lard $3. 2 Candlesticks .50	$	3 50
" 7th	2 Sad Irons $2.50 1/2 doz Pickle Pillows $7.25		9 75
" 7th to 16th	20 Sacks Flour $42.50 1 Coffee Mill $1.25		43 75
" 18th	1 bottle Mustard .25 2 bottles Pepper .50 Tobacco $1. 1/2 doz Chairs $9.		10 75
" "	1 Cheese $5.87½ 2 pounds Tea $2.		7 87½
		$	75 62½

Rec'd Payment


WINANT & CO.,
OYSTER DEALERS.
TERMS CASH.
PAYABLE IN U. S. GOLD COIN.

S. WINANT, J. J. WINANT, San Francisco,
S. DODGE, Oysterville.

Oysterville, June 23rd 1866

Sam'l Case

Bought of WINANT & CO.
DEALERS IN
DRY GOODS, CLOTHING, LIQUORS,
GROCERIES, HARDWARE, BOOTS, SHOES AND GENERAL MERCHANDISE.

50 pounds Coffee	30¢	15 00
200 " Flour		8 00
1 Box Tobacco		5 00
2 Doz Eggs		50
2 Windows		3 00
2 Locks & Butts & Screws		3 00
	$	34 50

Figures 2 and 3. Copies of the statements issued by Winant and Company in 1866. (Courtesy of Mrs. Charles E. Hewes) tions.

> "Oysters from Yaquina Bay stand at the head of bivalves. The supply is not likely to fail soon as one enterpriser alone is taking from ten to sixteen baskets per day. There are many engaged in the oyster business at Yaquina and yet the beds present no indications of being less productive than at first." (The Oregonian, March 24, 1868.)

> "The oystermen have been in the past united in the Yaquina Bay Oystermen's Association, which in 1868, drew up certain laws regulating oystering----." (Washburn, 1900)

The first historical indication that the native oysters were becoming reduced in numbers appeared about 1878, or 16 years after the beginning of commercial oystering, when Captain Winant introduced the first Eastern oysters into the bay. It is the general procedure in the decline of a valuable wildlife resource to introduce an exotic species with the hope of supplanting the native form. This early decline is partially substantiated by two early newspaper accounts appearing in the Oregonian, March 3, 1882, and August 12, 1896.

> "Among the most important of these products at Yaquina Bay are oysters found in great supply on the shoals, throughout the bay. Captain Wyant is proprietor of an oystering headquarters on the west side of the bay. The business of oystering was carried on some years ago till the native beds were exhausted. A few years rest, however, allowed the growth of a new crop. The Yaquina oyster is about double the size of the Puget Sound oyster." (Oregonian, March 3, 1882)

> "Captain J.J. Winant, some 18 years ago while engaged in planting eastern oyster plants in San Francisco bay, concluded to try the experiment at Yaquina bay. He brought by sailing vessel two barrels of young Chesapeake bay oysters, there being about 5,000 in a barrel, and placed them near the mouth of Pools slough which empties into Yaquina bay. The plants were 8 days crossing the continent to San Francisco and after being placed in the bay for 24 hours, they were brought north being 10 days on the way. It was 19 days from the time the plants left the eastern waters before they were scattered over the bed of Pools slough. Within 18 months several bushels of oysters, considerably more than half grown were secured. Ten years after this eastern oysters were taken from the natural beds showing beyond doubt that a few

of the oysters had spawned." (Daily Oregonian, August, 12, 1896)

Apparently, the period of non-oystering just previous to 1882 did not result in a sustained annual crop of native oysters. This is substantiated by a newspaper account appearing in the Daily Oregonian, August 13, 1884, which stated :

> "In early times there was a large and profitable oyster trade from the bay, and Captain Wyman, who owns the old oyster beds six or seven miles up the bay, has planted eastern oysters on them, and confidently looks for a revival of this industry. The experiment of raising eastern oysters, though conducted on a limited scale, has proved to be satisfactory."

In 1896, Holister D. McGuire, State Fish and Game Protector, reported on the depleted condition of the oyster grounds in the 1895-96 Report of the Oregon Fish and Game Protector as follows:

> "The oyster industry of the state at the present time is of small importance judging from the amount and value of the output. The industry of Oregon is confined to Yaquina Bay, at which there are twelve private oyster beds staked as provided by law; also a small area of natural beds, from which the supply for renewing the private beds of oystermen is obtained.
>
> "Former efforts to cultivate eastern oysters in our waters failed, so far as any practical results in building up the oyster industry was concerned, although the seed planted some years ago, grew and thrived, they did not propagate.
>
> "The oyster beds have all been taken up under state law which limits the amount of bed to be held by one person to two acres. Under this law eleven or twelve have been staked. The remaining portion of the natural beds, some forty-two acres are reserved for the benefit of all citizens of the county and state and cannot be taken up and staked as private property.
>
> "A heavy freshet in Yaquina River some years ago nearly exterminated the oyster beds since which time the eighteen or nineteen men in the business had but small returns for their labors."

Professor F.L.Washburn of the State University conducted investigations at Yaquina Bay from 1896 to 1900 for the primary purpose of studying the Eastern oyster. In the 1895-96 Report of the Oregon Fish and Game Protector, he made the following comment concerning the native oyster fishery:

> "Native oysters here are not abundant on account of close culling in previous years."

Excerpts pertaining to the native oyster fishery in Yaquina Bay contained in Professor Washburn's report, which dealt mostly with his studies of the eastern oyster, published in the 1900 Annual Report of the State Department of Fisheries follows:

> "The oysters on the native beds are so closely worked that one-half sack on a tide is considered fair work, though one sack is sometimes obtained. In the past the business has been much more profitable than at present. The oysters have dwindled in numbers and size owing to persistant tonging, together with a lack of foresight on the part of the fishermen. If they could unite in a determination to forbid all tonging for two years or more on certain reserved portions of the natural beds and persist for a number of years in such a plan using care with unmarketable seed besides taking the best possible care along modern lines for catching 'spat', I believe the industry could be restored to something like it was 10 years ago, but if the present methods continue I predict the extinction of the industry before many years. There are at present less than twelve men oystering on Yaquina Bay, yet, if all of the small number depended for their living on selling oysters they would fare badly.
>
> "The oystermen have in the past united in the Yaquina Bay Oystermen's Association, which in 1868 drew up certain laws regulating oystering, which laws were made state laws by the legislature. In accordance with these laws one is obliged to have resided 12 months in the state and six months in the county, before he can tong oysters. Each oysterman can obtain from the state, for use as a private bed 2 acres of tide land, and only two."

The second scientific investigation of the oyster problems was made by Professor Sweetser in 1907 or 1908. The <u>Report of the Master Fish Warden</u> (McAllister 1908), contained the following item:

> "State Biologist Professor Sweetser has been making experiments and devoting considerable time to the oyster question, but as his funds are limited, he has not accomplished much.----I would recommend that an appropriation of $5,000 be made by our legislature, to be used by Professor Sweetser in carrying out his work, feeling that it will be the means of adding to our resources, and, in time be returned to the state a hundredfold."

On December 1, 1908, Mr. Morris Wygant completed a map of producing oyster grounds in Yaquina Bay. A copy of this map is presented in figure 4. His summary reported that at that time the area of the natural oyster grounds was 101.95 acres and the private oyster beds contained 38.8 acres.

In the 1917-18 Biennial Report of the Fish and Game Commission of the State of Oregon, Carl D. Shoemaker stated:

> "The natural restocking of the oyster beds of Oregon has fallen off to such an extent that the industry today can hardly be said to be profitable."

In 1923, the Oregon Oyster Company purchased the oystering rights on the private beds and leased the natural grounds from the Fish Commission of the State of Oregon. The following is a list of persons selling their rights in the private beds together with the prices received:

<u>Oyster Grounds in Brown's Flat</u>

J.C.Huntsucker	$200.00
V.D.Boone	$200.00
C.V. Boone and Edna J. Boone	$400.00
Joseph J. Shermer	$750.00
M.G.Shermer	$750.00
Henry Shermer	$750.00
Rachel King	$665.00
L.D.Emerson	$150.00
S.J.Shermer	$750.00
Burl King	$235.00

<u>Oyster Grounds in Lyman's Eddy</u>

Carl Knudson	$570.00
George Lewis	$200.00
D.C.Miller	$285.00
V. Boone	$400.00

In 1927, native oyster production depletion was suspected to be caused by sawdust pollution; for the Yaquina Bay News of September first of that year contained the following article:

> "Refuse from the mill of the Pacific Spruce corporation at Toledo, Oregon, has polluted the waters of the Yaquina River and also of Yaquina Bay, located between Toledo and Newport to such an extent that the oysters in the beds of those waters are being destroyed, it was charged in a suit filed yesterday in the federal court by the Oregon Oyster Company.
>
> "The oyster company, which has offices in Portland, asked that the milling company be permanently restrained from permitting sawdust, crude oil or petroleum, mill waste and other refuse to enter these waters, and that it pay $50,000 for the damages declared to have been done already.
>
> "It was declared in the complaint filed by John F. Logan and Stephen W. Matthieu, attorneys for the plaintiff company, that not only does such refuse from the mill affect the life, growth and flavor of the oyster, but prevents propagation, has destroyed large quantities and impaired the others in growth, and has become a nuisance, which has existed for the last two years. The plaintiff company asked for a judgment of $50,000 as a recompense for the profits it claims it has lost.
>
> "The oyster company claims to own outright a large amount of the land making up the oyster beds in question, and controls other tracts under lease from the state. It complains that the spruce corporation instead of abating the nuisance, has indicated that it intends to continue its present practice."

During 1927 and 1928, three biologists representing different agencies, made oyster investigations in connection with the suspected sawdust pollution problem. Dr. Harlan B. Holmes, United States Bureau of Fisheries, prepared an unpublished report entitled, "An Investigation of Sawdust Pollution in Relation to Oysters in Yaquina Bay" (quoted from Fasten, 1931). In answer to an inquiry regarding this report sent to the United States Fish and Wildlife Service, Washington, D.C., the following reply was received:

"I regret to inform you that we have no record of the report you mentioned by Mr. Harlan B. Holmes, An Investigation of Sawdust Pollution in Relation to Oysters in Yaquina Bay." (Baily, 1940)

Dr. L.E. Griffin and Dr. Nathan Fasten made separate studies of the Yaquina Bay oyster problems with particular references to sawdust pollution. Apparently, Dr. Griffin's report was never published. Dr. Fasten's study was published in the American Naturalist, October 1931, and was summarized as follows:

"1. The Yaquina oyster beds of Oregon are located in that portion of the Yaquina River lying mainly in the vicinity of Oysterville, beginning approximately six miles below the town of Toledo and extending for nearly three miles in the direction toward Newport.

"2. The oyster beds are limited in area, comprising no more than 135 acres at the most. The large bulk of the oysters consists of the native Pacific species, Ostrea lurida Carpenter. There have also been numerous plantings of the Atlantic oyster, Ostrea virginica Gmelin, but with few exceptions these have not acclimated themselves to their new locations in the Yaquina region.

"3. The Yaquina River is an exceedingly narrow and shallow stream carrying a large amount of sediment and debris. Inasmuch as this suspended material settles on the oyster beds, it becomes absolutely necessary for the oystermen to keep constant watch over their beds and give them the very best care and cultivation.

"4. The salinity and food in the vicinity of the oyster beds are adequate for the proper development of oysters. Moreover, there is an abundance of natural life in the Yaquina River, indicating that stream conditions are natural and wholesome not only for oysters, but also for those forms invariably associated with them.

"5. Untreated human sewage enters the Yaquina River from the various towns located along its banks and this is then carried by the tides back and forth over the oyster beds, making it possible for the oysters to become polluted with dangerous disease producing organisms.

"6. The oyster beds have been steadily and consistently worked for the last seventy years. A large quantity of oysters has been removed and little attention has been paid to conservation measures looking towards the building up and maintenance of the beds. The inevitable result has been that many of the beds have become exhausted and the yield of oysters has diminished to the extent where the remaining beds are threatened with extinction.

"7. Carefully planned surveys and experiments will have to be initiated to maintain, replenish and repopulate the Yaquina oyster beds if they are to be conserved for future generations."

During 1931, Mr. H.B. McMillin, then Junior Biologist, United States Bureau of Fisheries, made an investigation of the native oysters in the area. His unpublished report (1931) gives some information regarding salinity conditions, oyster spawning and setting, observations of an experimental dike, and brief recommendations for management, stressing particularly the supplying of "ample cultch to the most productive seed beds to obtain the maximum set possible."

In October 1939, the renewed lease of the Oregon Oyster Company with the Fish Commission of the State of Oregon expired. Since that time all commercial oystering has been limited to the private beds.

In a number of publications, records were found giving the amounts of native oysters marketed from Yaquina Bay for various years between 1888 and 1938. These are summarized in table 1. The reliability of the statistics are questionable, since it is not known, except for 1938, whether the pounds of oysters represent "edible meats" or oysters "in the shells". Apparently, the 1922 figures of 74,998 pounds were for oysters in the shell. Also, there is much evidence that over the years considerable amounts of native oysters have been sold locally which were not reported to the Fish Commission of the State of Oregon. However, the indications based on the reported amounts of marketed oysters are that since 1888, with the possible exception of 1923, native oyster production in Yaquina Bay has been of minor economic importance. Extremely poor years of oyster harvesting occurred in 1915, 1928 and 1932. Yet these particular dates were generally followed by years of increased marketing.

From reviewing the many laws of Oregon pertaining to oyster culture, from 1862 to the present time, the significant aspect gained is that oystering in this particular estuary has apparently been a declining resource in spite of considerable legislation over a period of many years. However, this situation has been demonstrated numerous times with other wildlife species and in many oyster beds throughout the world.

Table 1

RECORDS OF NATIVE OYSTERS MARKETED FROM YAQUINA BAY
Compiled from various sources.

Year	Pounds	Bushels	Sacks	Value	Reference
1888		4,125		$6,250	Report of the Commissioner of Fisheries for the year ending 1913, U. S. Bureau of Fisheries, Document 782, page 49.
1889		1,666		$3,125	Report of the Commissioner of Fisheries for the year ending 1913, U. S. Bureau of Fisheries, Document 782, page 49.
1890		1,470		$2,758	Report of the Commissioner of Fisheries for the year ending 1913, U. S. Bureau of Fisheries, Document 782, page 49.
1891		1,622		$3,043	Report of the Commissioner of Fisheries for the year ending 1913, U. S. Bureau of Fisheries, Document 782, page 49.
1892		1,633		$3,062	Report of the Commissioner of Fisheries for the year ending 1913, U. S. Bureau of Fisheries, Document 782, page 49.
1895		1,480		$2,220	Report of the Commissioner of Fisheries for the year ending 1913, U. S. Bureau of Fisheries, Document 782, page 49.
1896			2,000	$6,000	H. McGuire, Report Oregon Fish and Game Protector, 1897-8, page 67.
1897			1,406	$4,218	H. McGuire, Report Oregon Fish and Game Protector, 1897-8, page 14.
1899		985		$1,625	Report of the Commissioner of Fisheries for the year ending 1913, U. S. Bureau of Fisheries, Document 782, page 49.
1900			568	$1,988	F. C. Reed, Report of Oregon Department of Fisheries, 1901, page 70.
1904		992		$1,488	Report of the Commissioner of Fisheries for the year ending 1913, U. S. Bureau of Fisheries, Document 782, page 49.

Year	Pounds	Bushels	Sacks	Value	Reference
1908		1,300		$4,200	Report of the Commissioner of Fisheries for the year ending 1913, U. S. Bureau of Fisheries, Document 782, page 49.
1912		2,213		$9,050	Report of the Commissioner of Fisheries for the year ending 1913, U. S. Bureau of Fisheries, Document 782, page 49.
1915	1,547			$ 725	L. Radcliffe, Fishery Industry of the U. S. 1918, U. S. Bureau of Fisheries, Document 875, page 122.
1922	74,998			$7,500	O. E. Sette, Fishery Industries of the U. S. 1924, U. S. Bureau of Fisheries Document 997, page 278.
1923	19,200			$16,800	O. E. Sette Fishery Industries of the U. S. 1924, U. S. Bureau of Fisheries Document 997, page 336.
1924	11,070			$4,305	O. E. Sette, Fishery Industries of the U. S. 1926, U. S. Bureau of Fisheries Document 1025, page 421.
1925	9,693			$4,300	O. E. Sette, Fisheries Industries of the U. S. 1926, U. S. Bureau of Fisheries Document 1025, page 445.
1926	2,616			$2,325	O. E. Sette and R. H. Fiedler, Fishery Industries of U. S. 1927, U. S. Bureau of Fisheries Document 1067, page 503.
1927	2,700			$2,250	R. H. Fiedler, Fishery Industries of U. S. 1929, U. S. Bureau of Fisheries Documents 1067, page 569.
1928	432			$ 480	R. H. Fiedler, Fishery Industries of U. S. 1930, U. S. Bureau of Fisheries Document 1095, page 984.
1929	9,000			$6,000	R. H. Fiedler, Fishery Industries of U. S. 1930, U. S. Bureau of Fisheries Administrative Report 3, page 448.
1930	8,177			$5,310	R. H. Fiedler, Fishery Industries of U. S. 1931, U. S. Bureau of Fisheries Administrative Report 8, page 362.
1931	5,993			$2,854	R. H. Fiedler, Fishery Industries of U. S. 1932, U. S. Bureau of Fisheries Administrative Report 13, page 331.
1932	2,476			$ 964	R. H. Fiedler, Manning, J. R., Johnson, F. F., U. S. Bureau of Fisheries Administrative Report 15, page 172.
1933	4,550			$2,600	R. H. Fiedler, Fishery Industries of U. S. 1934, U. S. Bureau of Fisheries Administrative Report 20, page 267.
1934	7,800			$4,357	R. H. Fiedler, Fishery Industries of U. S. 1935, U. S. Bureau of Fisheries Administrative Report 24, page 267.

Date	Pounds	Bushels	Sacks	Value	Reference
1935	8,900			$5,210	R. H. Fiedler, Fishery Industries of U. S. 1936, U. S. Bureau of Fisheries Administrative Report 27, page 215.
1936	7,900			$5,283	R. H. Fiedler, Fishery Industries of U. S. 1937, U. S. Bureau of Fisheries Administrative Report 32, page 378.
1937	9,600			$6,440	R. H. Fiedler, Fishery Industries of U. S. 1938, U. S. Bureau of Fisheries Administrative Report 37.
1938	8,700*[1]			$4,464	R. H. Fiedler Fishery Industries of the U. S. 1939, Bureau of Fisheries Administrative Report 41, page 488.

*1. "Statistics on oysters - - are based on yield of 12 per cent of edible meats - - -." Fiedler

PURPOSES OF THE INVESTIGATION.

The main purpose of this investigation has been to ascertain biological and ecological facts concerning native oysters, Ostrea lurida, in Yaquina bay, that will serve as a basis for the rehabilitation and possible extension of oyster farming in that estuary. In the first place, if restoration is to be accomplished, methods for securing an increased setting of oysters are essential. This will require a broader knowledge of spawning and the setting behavior of the native oyster in Yaquina Bay than was known previous to this study. Involved in the problem, are the analyses of the factors influencing the seasonal time of spawning, the free-swimming activities of larval oysters, and the intensity of setting in relation to seasonal time and to location. In the main, if increased production of seed oysters is to be had, then such questions as the following must be answered:

(1) Where are the locations in the bay having the greatest oyster-setting intensity?

(2) When does setting take place and when are the periods of maximal setting activity?

(3) How may the oyster "seed" be taken in large numbers?

Following the development of improved methods for collecting adequate "seed stock," it should then be advisable to determine the causes of the reduced oyster numbers in this particular bay. From such studies, involving oyster mortalities of the young as well as the older oysters, the limiting factors which have kept the oyster stocks in such depleted numbers for so many years may be ascertained.

Then, if the main causes of oyster mortalities are assigned, there is the probability that improved cultural practices may minimize such losses.

Finally, information is needed for developing new oyster production grounds which may be more advantageously farmed than the present oyster areas occurring in relatively deep water. Without the development of such oyster farms, there appears to be little opportunity for a large and profitable oyster industry on a sustained yield basis in Yaquina bay, for the many inimical conditions existing upon the present oyster grounds would be difficult to control.

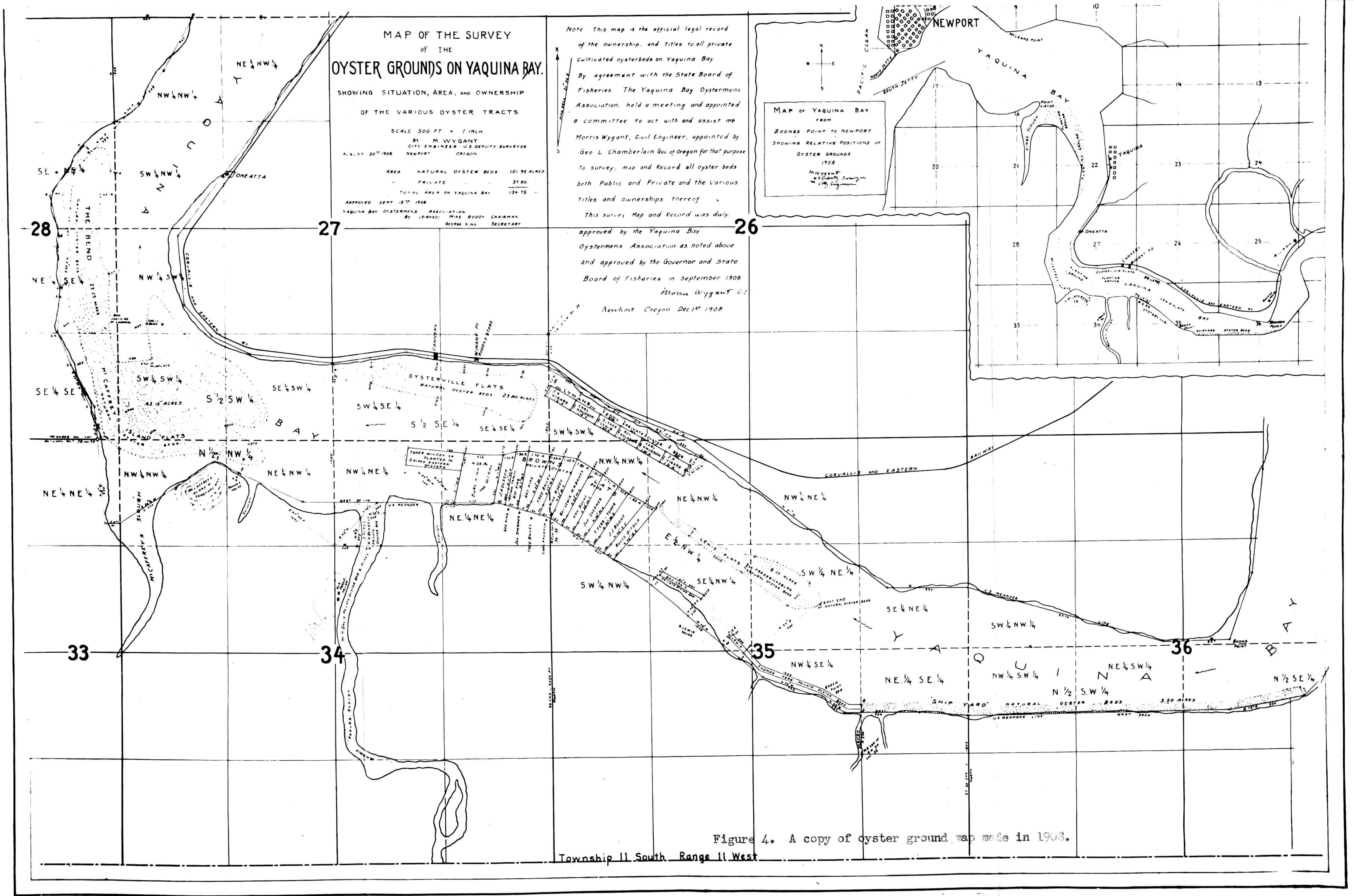
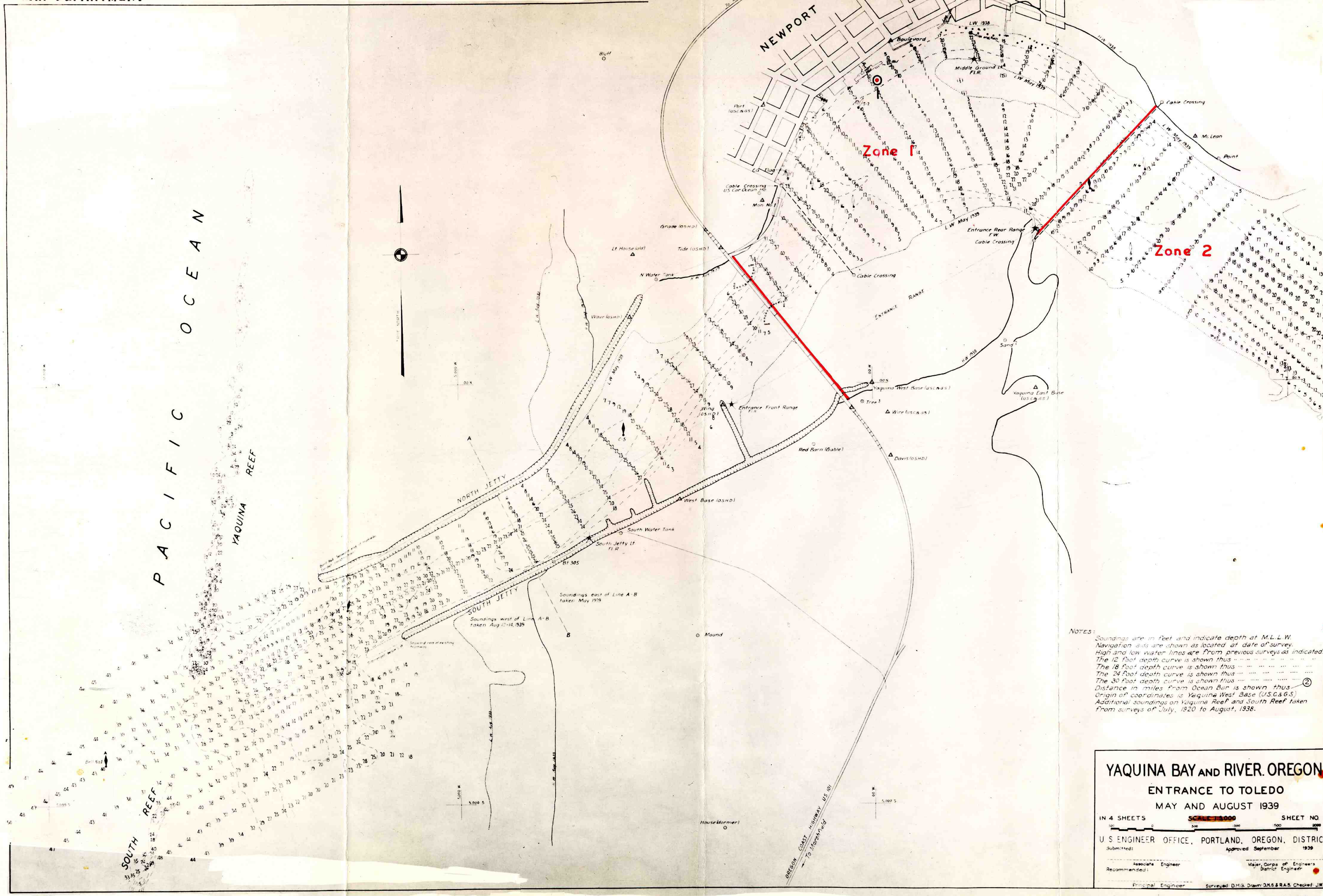


Figure 4. A copy of oyster ground map made in 1908.

WAR DEPARTMENT

CORPS OF ENGINEERS, U.S. ARMY



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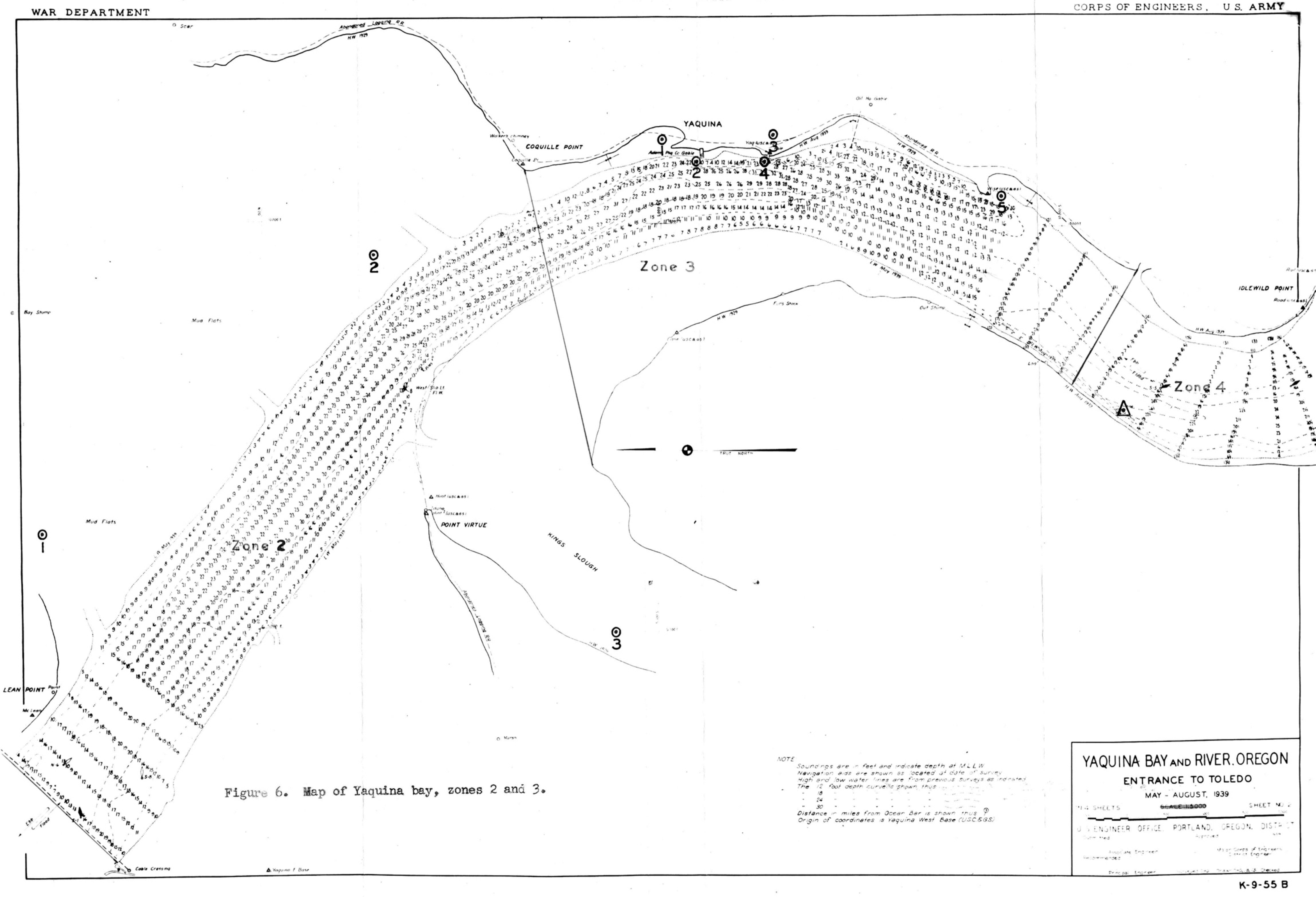

Figure 6. Map of Yaquina bay, zones 2 and 3.

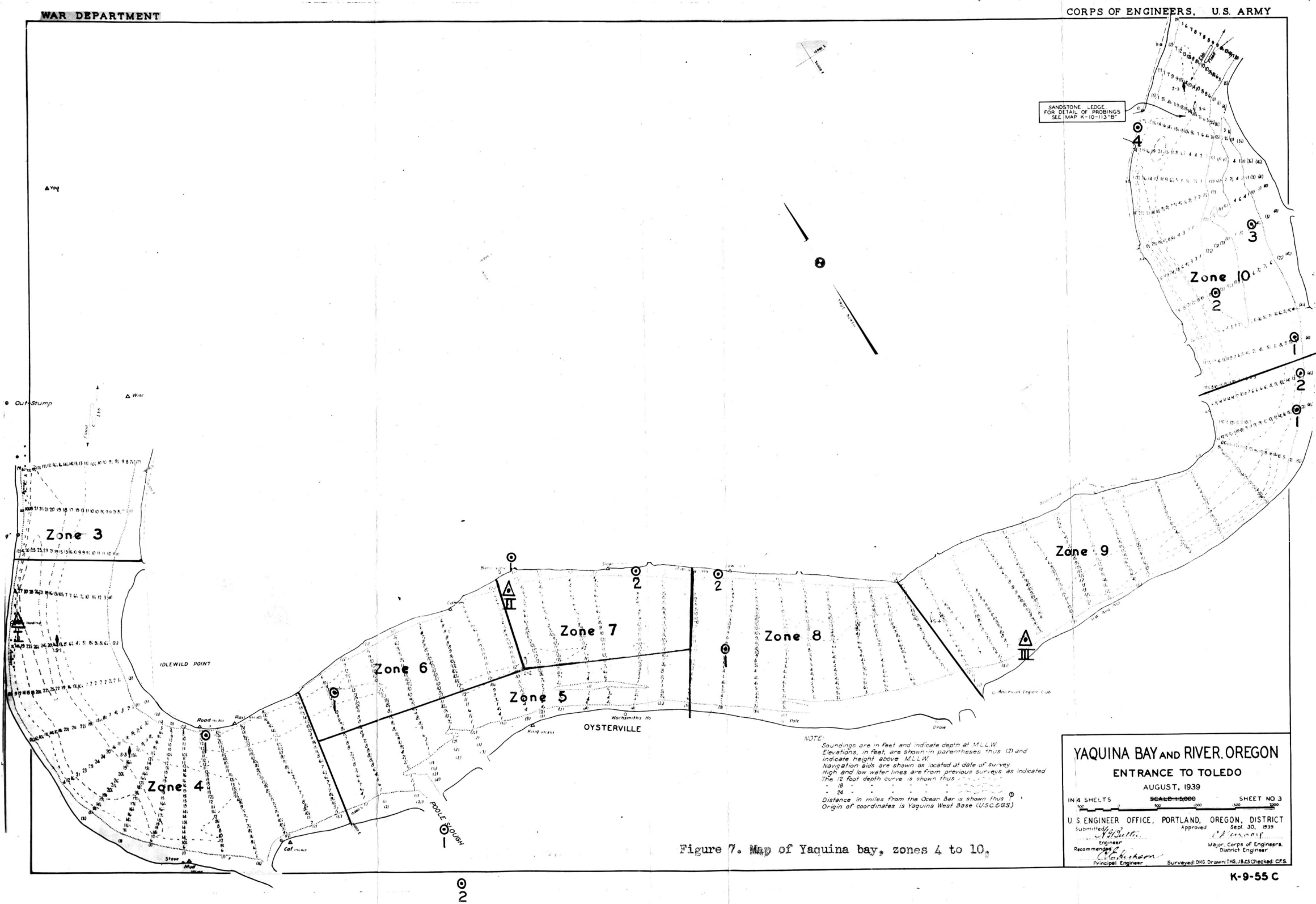

Figure 7. Map of Yaquina bay, zones 4 to 10.

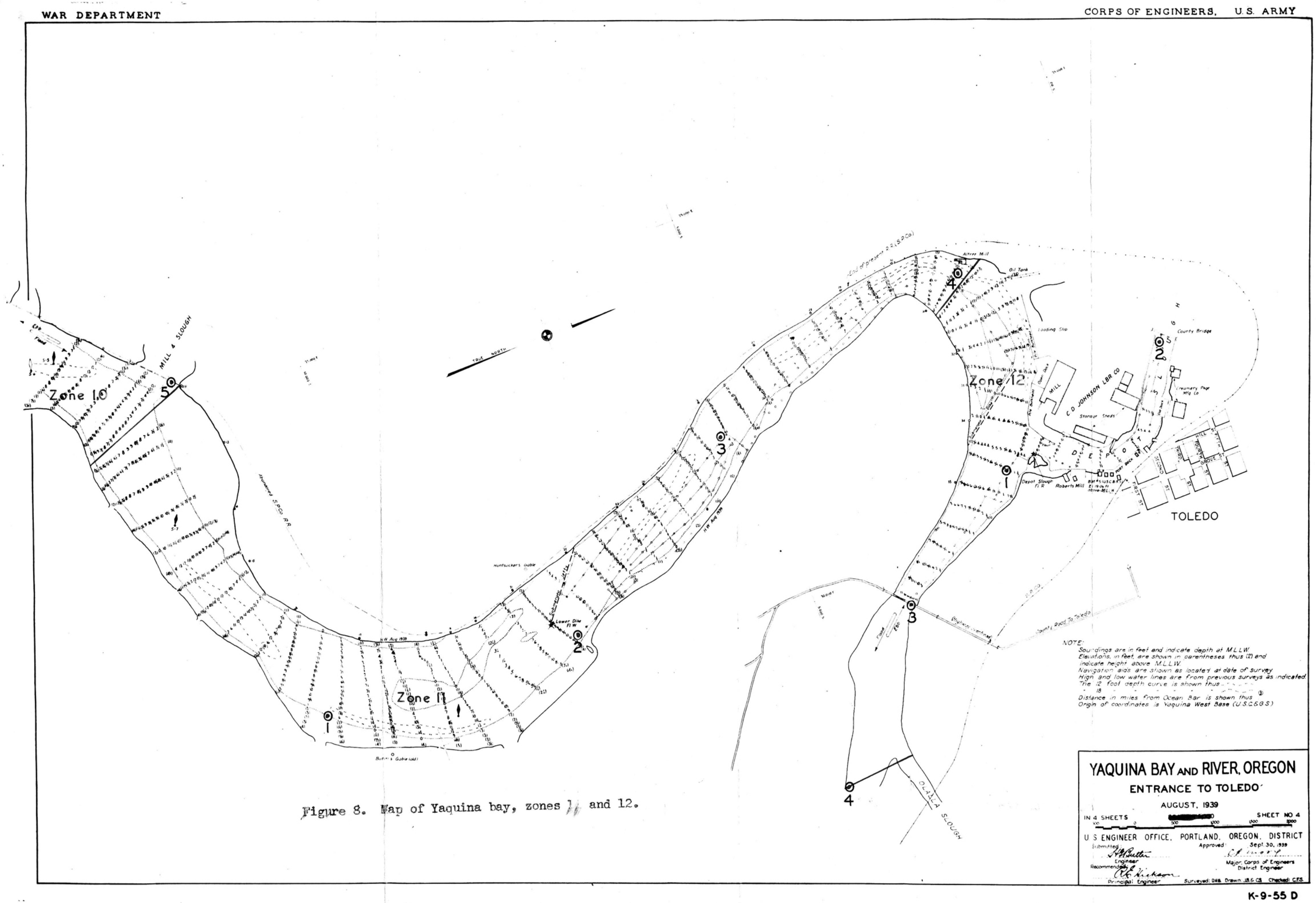

Figure 8. Map of Yaquina bay, zones 11 and 12.

GENERAL DESCRIPTIONS OF THE STUDY AREAS

The many aspects of the native oyster problem encountered in Yaquina bay, required an investigation of the entire waterway from Newport to Toledo, an approximate distance of 12 miles. Within this water area, the biological, hydrographic and edaphic conditions vary markedly. Consequently, in order to facilitate the reporting of observations and data, Yaquina bay and river from Newport to Toledo were divided into twelve zones. The boundaries of these zones were selected, as far as possible, on the basis of definite landmarks and the biological, hydrographic, and edaphic conditions which tend to make distinct each zonal area.

The twelve zones are located on the maps shown in figures 5, 6, 7 and 8. These maps were prepared by photographing copies furnished by the United States Army Engineers upon which the locations of the zones and stations were transposed. These zonal boundaries are further defined:

Zone 1 extends from the Coast Highway bridge at Newport to an upper boundary, the cable crossing, forming a line across the bay from McLean Point to the South Beach ferry landing.

Zone 2 extends from the upper boundary of zone 1 to a line which crosses from Coquille Point in a westerly direction to the point on the opposite bank forming the eastern side of the mouth of King's Slough. This zone contains King's Slough and Sally's Bend.

Zone 3 extends from zone 2 to a boundary line which directly crosses the bay from a point marked on the east shore by the lower or north bank of the entrance to Parker's Mill Slough. This line is known locally as the lower limits of the native oyster grounds. This zone includes the two small sloughs at Yaquina.

Zone 4 extends from the upper limits of zone 3 to a line which crosses the bay from the new channel light on Idlewild Point to the first unnamed slough above McCaffery's Island. This zone includes Parker's Mill Slough, the Bend and McCaffery Island Flats, and McCaffery's Slough.

Zone 5 includes the southern portion of the bay from the boundary of zone 4 to an upper line which extends directly across the river from Sommer's house on the south bank. This zone includes Brown's Flats and Poole Slough.

Zone 6 is in the northern portion of the bay, from the upper limits of zone 4 to an upstream boundary which crosses from the west side of Miller's Dock at Winant to the midstream channel buoy. This zone contains the area known as Oysterville Flats.

Zone 7 is contained in the northern portion of the bay, having the upper boundary of zone 6 as its lower boundary. The upper boundary, like that of zone 5, extends directly across from Sommer's house. This zone includes the Lyman's Eddy Private Oyster Beds.

Zone 8 extends from the upper boundaries of zones 5 and 7 to a line joining Rocky Point with McIntyre's Point (American Legion Club). The Lewis Flats and Green Point Oyster Beds are contained in this zone.

Zone 9 reaches from the upper boundary of zone 8 to a line extending from Norgard's Dock to the opening of the slough on the opposite bank. This line marks the area known locally as the upper limits of the native oyster grounds. The Shipyard's natural oyster beds is contained within this zone.

Zone 10 extends from zone 9 to a line which directly crosses the river from the up-river bank of the entrance to Mill Four Slough. Boone's and Mill Four sloughs are contained in this zone.

Figure 9.

Multnomah loading dock, used as Main Station I.

Figure 10.

Miller's dock, used as Main Station II.

Zone 11 extends from zone 10 to an up-river boundary crossing at the site of **Altree's** Mill, Toledo.

Zone 12 lies between zone 11 and an upper boundary which connects F. Lindstedt's dock with the up-river bank of Olalla slough. Depoe and Olalla sloughs are contained in this zone.

During the 1939 studies, three main stations were used. These same stations were again employed in 1940 and 1941 and were designated as Main Stations I, II, and III. Main Station III was discontinued in 1941 because construction activities ~~making~~ made its use impracticable. They are symbolized on maps as triangles with red center dots. These stations were selected because they are located in the three main portions of the native oyster grounds; namely, the lower grounds, the middle grounds, and the upper grounds. By referring to the map shown in figure 7, the locations of these three main stations may be described:

Main Station I lies near the lower boundary of zone 4 at the site of the Multnomah log-loading dock, situated on the west bank of the bay, figure 9.

Main Station II is located at Miller's Dock on the lower boundary of zone 7, figure 10.

Main Station III is in the lower part of zone 9 at the piling in front of McIntyre's Point, figure 11.

Less frequent observations and supplementary tests were made in many locations other than the main stations, and such observational points were designated as zonal stations. Their locations are symbolized on the maps in figures 5, 6, 7, and 8 as circles with red dots and are consecutively numbered for each zone. This separate sequence of numbering of the zonal stations for each zone was selected in order to avoid confusions arising from addition and discontinuance of stations within the various areas as the investigation proceeded.

Figure 11.

McIntyre's dock, used as Main Station III.

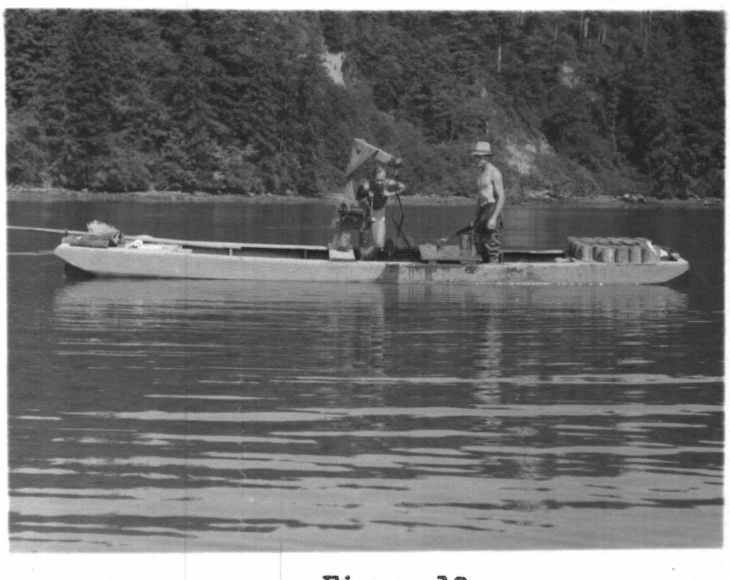

Figure 12.

Petterson dredge mounted on oyster scow.

METHODS AND EQUIPMENT

The laboratory was for a time situated at Yaquina, zone 3 station 1, but was later moved to a permanent location on the north bank of zone 8, at zonal station 2. Most of the traveling to observation points from Newport to Toledo was done in a 14 foot boat propelled by an outboard motor. An estimated 400 miles were traveled in 1939, 1000 miles in 1940, and 450 miles in 1941.

Water for salinity determination was collected with a Kemmerer water bottle. This device, which collects samples at any desired depth, was operated by sending a brass messenger down the retaining line in order to close the bottle. Specific gravity of the water samples was determined with a set of standardized hydrometers, manufactured by the Emil Greiner Company*, New York City, one with a scale ranging from 1.000 to 1.0110, a second with a scale from 1.0100 to 1.0210, and the third with a scale of 1.0200 to 1.0310. The temperature of the water sample was made at the time of each hydrometer reading and the specific gravity was corrected for a standard of 60 degrees F. Then the salinity of each sample, expressed in grains of salts contained in 1,000 grams of sea water, was determined by using the conversion tables contained in the Manual of Tide Observations, Special Publication 196, United States Coast and Geodetic Survey (1935).

A continuous record of water temperatures from April 10 to September 8, 1940, and from March 31 to September 13, 1941, were obtained by a recording thermometer installed on a float at Main Station II. The bulb of this instrument was fixed near the bottom

* These particular hydrometers were recommended by Dr. A.E. Hopkins, Oyster Biologist, United States Fish and Wildlife Service.

of the bay at the level of the oysters. In addition, occasional temperature readings were made in a number of locations with a standardized reversing thermometer which allowed the recording of temperatures at any desired water depth. Maximum and minimum thermometers were used in experimental dikes to obtain the daily extremes in water temperature.

Plankton samples were taken frequently with a net of number 20 bolting silk. Each plankton collection was made from a boat moving at slow speed for a period of five minutes. The contents were examined with a binocular microscope and an estimate was made of the relative abundance of oyster larvae present.

For the purpose of determining the seasonal intensity of oyster larval setting, cultch bags were constructed of one inch galvanized poultry netting. Each bag was marked with a numbered, monel-metal tag, so that mistakes in identity would be avoided. Approximately, 200 native oyster shells were present in each cultch bag. These bags were usually suspended from floating docks at various observation stations for different periods of time during the setting periods.

Sampling of the bottom for oysters, cultch and soil types was done with a Petterson's dredge mounted on an oyster scow, figures 12, 13 and 14. The dredge which collected a bottom surface of approximately one-half foot was lowered and raised by wire rope attached to a windlass. Occasionally collections of oysters were taken by oyster tongs.

Figure 13.

Lowering Petterson dredge.

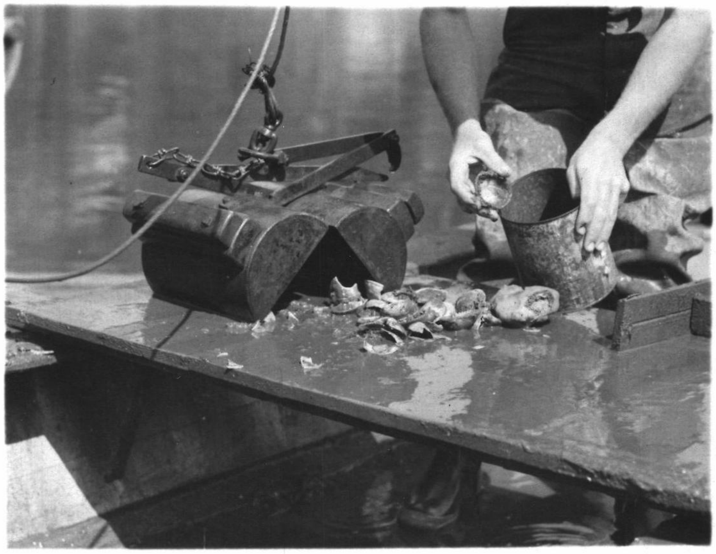

Figure 14.

Contents of dredge haul.

HYDROGRAPHIC DATA

Since successful native oyster culture in Yaquina Bay must be based upon an adequate understanding of the important hydrographic conditions existing in that estuary, frequent recordings were made of the water temperatures and salinities encountered. Some attention was given to the marked variations of these two ecological factors as influenced by tidal stages and river water discharge. Undoubtedly, the temperature and salinity conditions will determine to a large extent the success or failure of the proposed diked oyster farms. Further, these two hydrographic factors may have important effects upon the general biology of the native oyster in this particular estuary; such as present distribution, spawning, larval development, growth, condition factors, survival, and mortality.

Temperature

Temperature exercises a profound influence upon the physiological behavior of oysters. This important ecological factor affects a number of the life processes such as growth, reproduction and food ingestion. Undoubtedly, for each species of oyster, there is a zone of effective temperatures above and below which the species fails to survive. Within this zone of effective temperatures, there probably exists an optimum range in which the greatest number of oysters complete their normal development. The various life stages of an oyster, such as the egg, larval and adult phases, may possess different effective and optimum temperature ranges. Many oyster biologists have long recognized that temperature requirements vary among the different species of oysters. Perhaps the same species of oyster, living in different geographic locations, may have variations in temperature demands. Indirectly, temperature conditions influence the growth, abundance and distribution of microscopic food organisms, as well as the biologies of oyster enemies.

A summary of some of the known effects of temperatures upon *Ostrea lurida*, as observed by investigators working in other areas, follows:

(1) This species is killed by exposure to freezing and relatively high temperatures.

Hopkins (1937) reported, "Because of their susceptibility to the hot sunshine of summer and the freezing winds of winter, native oysters in Washington thrived only where they were relatively protected. Natural beds were found where the oysters were covered with water at low tide because of the slope of the tide land, or where seepage from underground would keep them moist in summer and relatively warm in winter." This investigator further stated that a great many oysters were killed in dikes at Puget Sound when the water temperature dropped to almost -2° C. (28° F.) and that the oysters in this case "were not well-covered with water of high salinity----."

(2) The native oyster will live in water temperatures as high as 30° C. (86° F.). Hopkins (1937) reported that water temperatures in the dikes at Puget Sound frequently reached 25° C. (77° F.) to 30° C. (86° F.). Apparently, the upper fatal temperature limits for the species have not been determined.

(3) The beginning of the spawning season in spring coincides with a rise in water temperatures. Hori (1933), working experimentally with this species in Japan, thought that 14° C. (57.2° F.) was the average temperature necessary for spawning to commence. Coe (1931) determined that 16° C. (60.8° F.) was the

average temperature required for initial spawning in Southern California waters. Hopkins (1937) came to the conclusion, after several years' study in Puget Sound, that the temperatures must reach a minimum of 13° C. (55.4° F.) or between 12.5° C. (54.5° F.) and 13° C., before spawning began in the spring.

(4) Spawning may cease when the water temperatures rise to 20° C. (68° F.) and above. Hori (1933) concluded that the maximum temperature for spawning of this species was about 20° C. However, the data supporting this finding is not clear, for it was not stated in his report if this upper critical spawning temperature was based upon average, approximate, maxima or minima temperatures.

(5) The duration of the free-swimming larval stage is dependent upon prevailing water temperatures. Hori (1933), who removed the mature larvae from the mantle chamber of gravid oysters found that at 20° C. (68° F.) the free-swimming larvae developed to full size and attached to cultch after 22 days. Hopkins (1937) concluded that in Puget Sound, where the temperatures are considerably lower than observed by Hori, "The free-swimming period is 30 or more days and varies from year to year, probably according to water temperatures".

Continuous bottom water temperatures were obtained at Main Station II from April 10 to September 9, 1940, and from March 31 to September 13, 1941. These periods of time in 1940, and 1941 included a few days previous to the initial spawning, the entire spawning and larval-setting seasons, and a number of days after spawning and setting had ceased. The location of the recording thermometer in the lower end of zone 7 was selected as being fairly representative of the general water temperatures existing over the main oyster

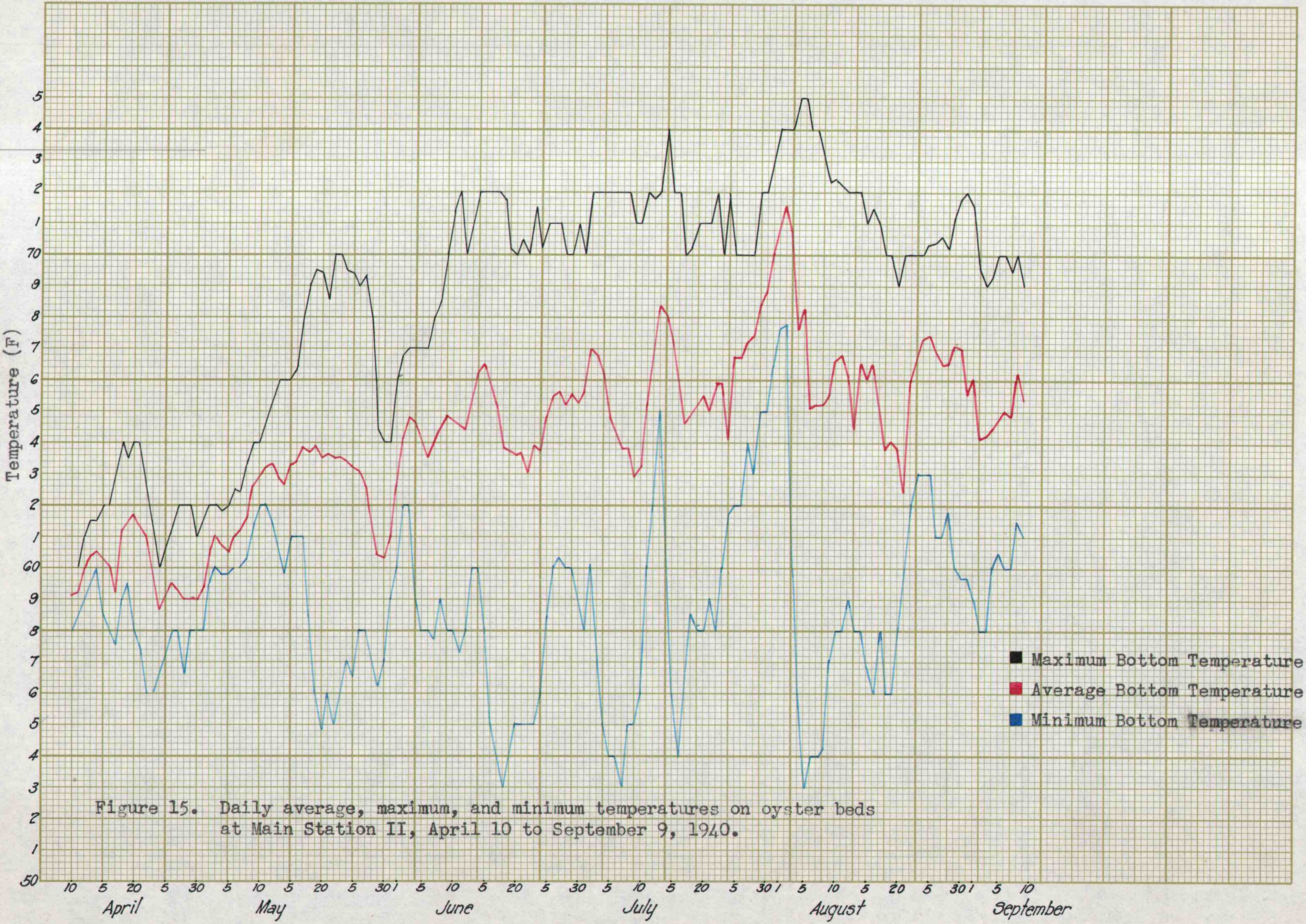

Figure 15. Daily average, maximum, and minimum temperatures on oyster beds at Main Station II, April 10 to September 9, 1940.

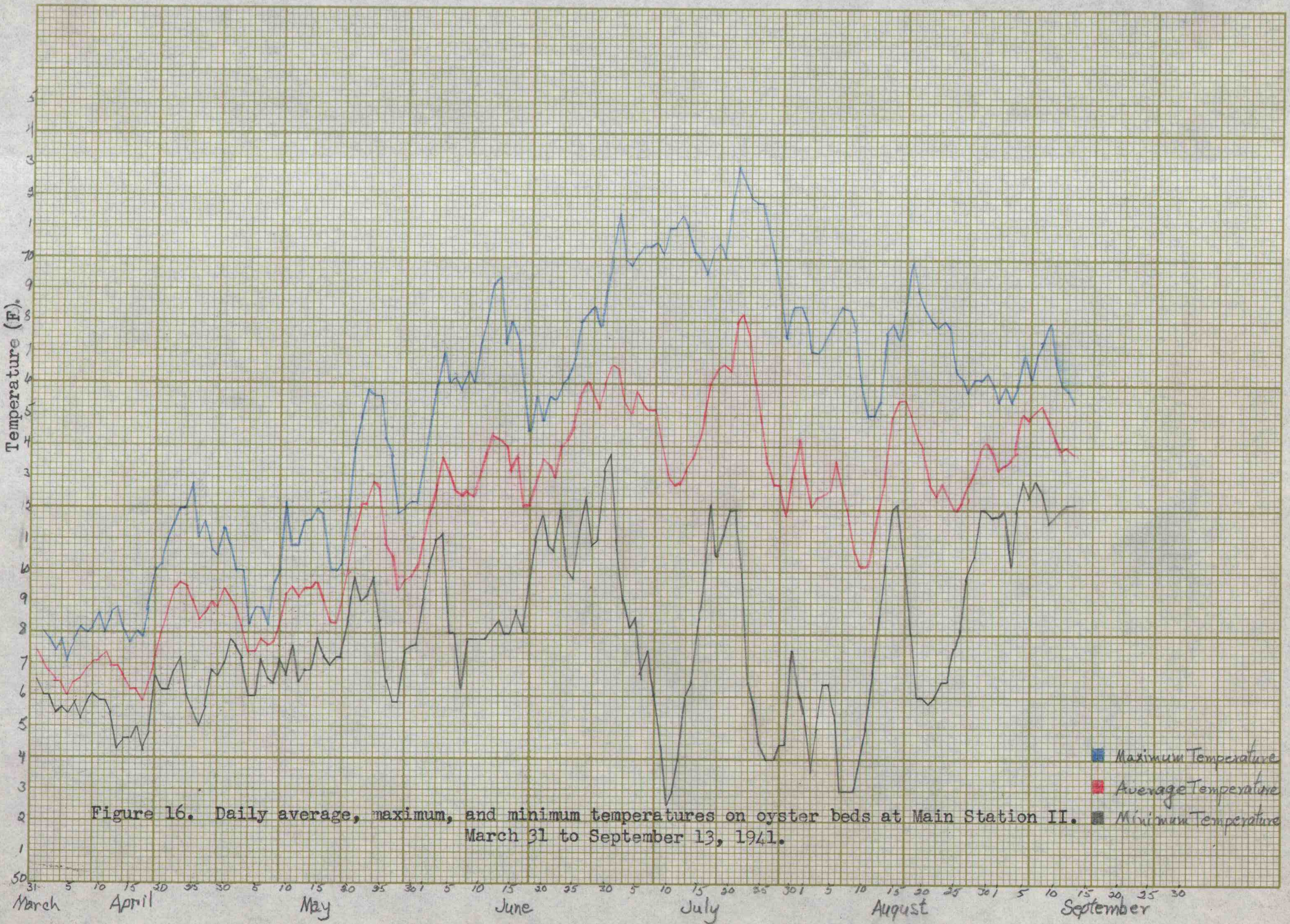

Figure 16. Daily average, maximum, and minimum temperatures on oyster beds at Main Station II. March 31 to September 13, 1941.

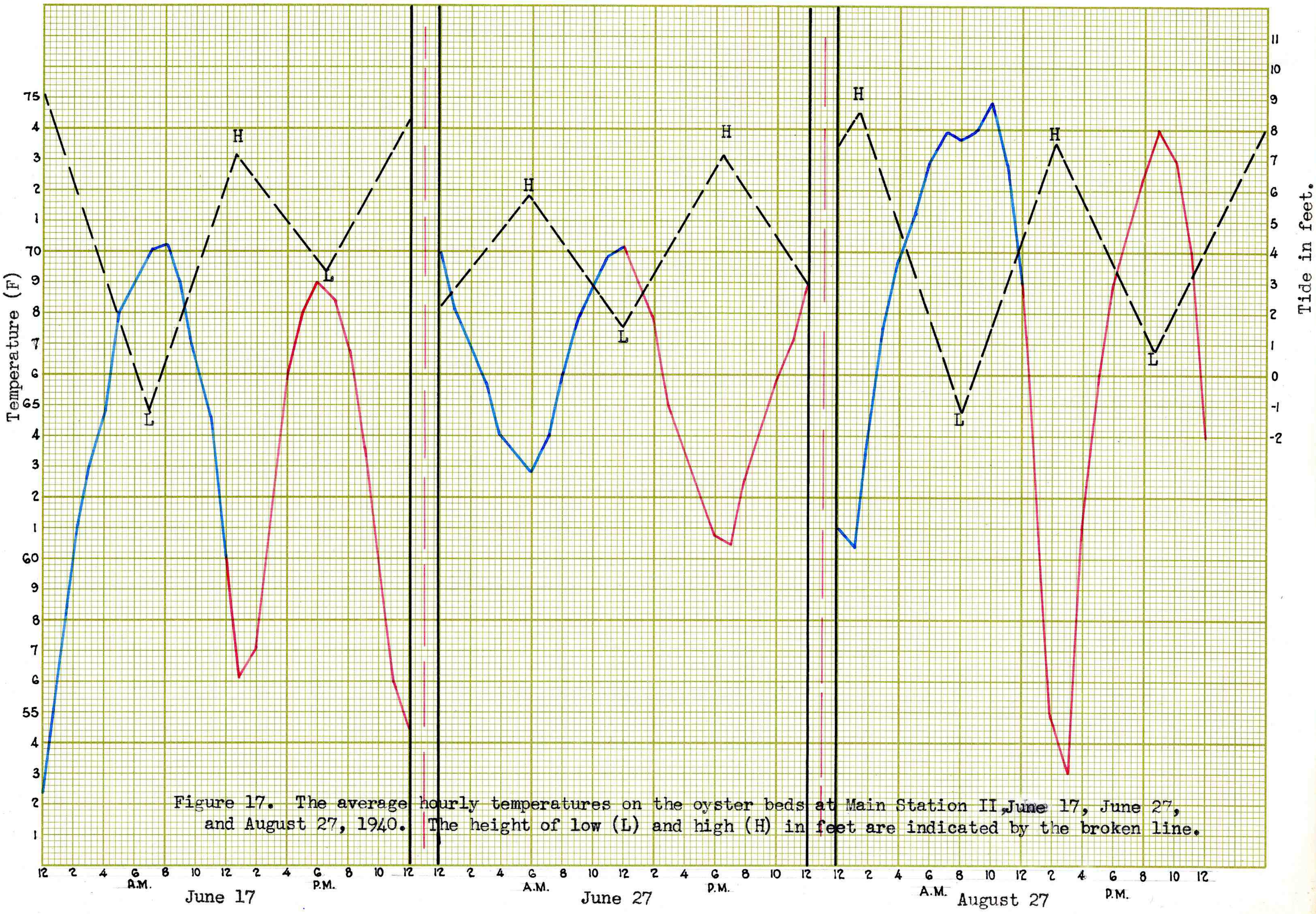

Figure 17. The average hourly temperatures on the oyster beds at Main Station II, June 17, June 27, and August 27, 1940. The height of low (L) and high (H) in feet are indicated by the broken line.

beds, for Main Station II is about midway between the lower limits of zone 4 and the upper limits of zone 9.

These temperature records were analyzed to give the average hourly maximum, minimum, and daily temperatures for each day. This data is presented graphically in figures 15 and 16 for 1940 and 1941, respectively.

In 1940, the average daily temperature on April 10 was 59.3° F., from which it rose, with slight fluctuations, until August 2 when the average temperature reached 71.63° F. From then until September 9 the trend was a general reduction in the average temperatures. During April and the first half of May 1940, the differences between daily maximum and minimum temperatures were slight. Then followed a period until the last part of August in which there were marked differences between the daily maximum and minimum temperatures, with a few exceptions occurring.

The seasonal temperature trends from March 31 to September 13, 1941, were quite similar to those recorded during the summer of 1940, with the exception that the maximum and daily average temperatures were slightly higher in 1940. The minimum temperatures were similar both years.

The average hourly temperatures from April 10 to September 9, 1940, and from March 31 to September 13, 1941, were plotted in relation to the hourly tidal stages. Since these graphs were too large for presenting in this report, figure 17 presents the average hourly temperatures in relation to tidal stages on three representative days. In Yaquina Bay during the summer the water temperatures increase as the tide ebbs and decrease as the tide floods. During the flood tide the influence of the colder ocean water causes, in general, a gradual temperature decrease until high tide is reached. Then, as the tide ebbs, the water temperatures increase, reaching the maximum at low tide or slightly after low tide. This rythmic temperature change in relation to tidal stages was found to occur throughout the periods when continuous water temperatures were recorded, regardless of the time of day that high and low tides occurred and regardless of the atmospheric temperatures. In general, the greater daily differences between maximum and minimum temperatures were evident during spring tides, as illustrated for June 17 and August 5, 1940, and less so during a neap tide, as shown for June 27, 1940.

Although continuous water temperatures were not recorded during the late fall and winter months, frequent readings were made of the surface and bottom waters at Main Station II, from November 17, 1940 to February 28, 1941. These temperatures are given in table 2 and show that in winter there is only a slight difference of a few degrees of temperature from day to day. The lowest temperature recorded was 44 degrees and the highest was 53 degrees F., representing only 9 degrees difference. Generally, the surface and bottom temperatures were identical. When differences did occur, the bottom water was generally slightly warmer than the surface waters. Rarely, the surface temperature was one degree higher than that of the bottom.

Table 2

Surface and bottom water temperatures at Main Station II,
November 17, 1940 to February 28, 1941

Date	Time	Surface Temperature -F.	Bottom Temperature - F.
Nov. 17, 1940	3:30 pm	52.0	52.5
Nov. 18, 1940	4:25 pm	52.5	52.5
Nov. 19, 1940	10:35 am	49.0	52.0
Nov. 20, 1940	10:00 am	49.0	49.5
Nov. 21, 1940	10:30 am	49.0	48.0
Nov. 22, 1940	7:35 pm	48.0	48.0
Nov. 24, 1940	11:10 am	50.0	50.0
Nov. 25, 1940	11:25 am	51.0	51.0
Nov. 26, 1940	2:00 pm	47.0	49.5
Nov. 27, 1940	5:15 pm	50.0	51.5
Nov. 28, 1940	3:20 pm	53.0	52.0
Nov. 29, 1940	9:50 am	53.0	53.0
Nov. 30, 1940	8:30 am	48.0	48.0
Dec. 1, 1940	4:40 pm	53.0	53.0
Dec. 2, 1940	9:25 am	50.0	51.0
Dec. 3, 1940	10:45 am	53.0	53.0
Dec. 4, 1940	9:15 am	52.0	52.0
Dec. 5, 1940	8:30 am	53.0	53.0
Dec. 6, 1940	9:30 am	51.0	51.0
Dec. 7, 1940	1:00 pm	52.0	52.0
Dec. 8, 1940	11:10 am	53.0	53.0
Dec. 9, 1940	3:35 pm	50.0	51.0
Dec. 11, 1940	2:45 pm	49.0	50.0
Dec. 12, 1940	3:30 pm	46.0	46.0
Dec. 14, 1940	10:45 am	44.0	46.0
Dec. 15, 1940	4:30 pm	44.0	44.0
Dec. 16, 1940	4:10 pm	44.0	44.0
Dec. 17, 1940	3:30 pm	52.0	52.5
Dec. 18, 1940	4:25 pm	52.5	52.5
Dec. 19, 1940	10:35 am	49.0	52.0
Dec. 20, 1940	10:00 am	49.0	49.5
Dec. 21, 1940	10:30 am	49.0	48.0
Dec. 22, 1940	7:35 pm	48.0	48.0
Dec. 24, 1940	11:10 am	50.0	50.0
Dec. 25, 1940	11:25 am	51.0	51.0
Dec. 26, 1940	2:00 pm	49.0	49.5
Dec. 27, 1940	5:15 pm	50.0	51.0
Dec. 28, 1940	3:20 pm	53.0	52.0
Dec. 29, 1940	9:50 am	53.0	53.0
Dec. 30, 1940	8:30 am	48.0	48.0
Jan. 1, 1941	4:30 pm	46.0	48.0
Jan. 2, 1941	4:30 pm	46.0	47.0
Jan. 3, 1941	11:50 am	44.0	46.0
Jan. 4, 1941	3:40 pm	46.0	48.0
Jan. 5, 1941	4:45 pm	47.0	48.0
Jan. 6, 1941	4:40 pm	46.0	48.0

Table 2 (Continued)

Date	Time	Surface Temperature-F.	Bottom Temperature - F.
Jan. 8, 1941	5:00 pm	48.0	48.0
Jan. 9, 1941	3:15 pm	50.0	51.0
Jan. 10, 1941	8:30 pm	48.0	48.0
Jan. 11, 1941	5:35 pm	49.0	48.0
Jan. 12, 1941	5:25 pm	49.0	49.0
Jan. 13, 1941	4:50 pm	50.0	49.0
Jan. 14, 1941	4:10 pm	50.0	50.0
Jan. 15, 1941	4:50 pm	49.0	49.0
Jan. 16, 1941	5:00 pm	49.0	50.0
Jan. 17, 1941	9:45 am	49.0	49.0
Jan. 18, 1941	3:35 pm	49.0	50.0
Jan. 19, 1941	4:00 pm	50.0	50.0
Jan. 20, 1941	3:15 pm	50.0	50.0
Jan. 21, 1941	2:50 pm	50.0	50.0
Jan. 22, 1941	3:45 pm	50.0	50.0
Jan. 23, 1941	4:25 pm	49.0	49.0
Jan. 24, 1941	4:55 pm	50.0	50.0
Jan. 25, 1941	3:00 pm	50.0	51.0
Jan. 26, 1941	6:05 pm	50.0	51.0
Jan. 27, 1941	10:40 am	49.0	51.0
Jan. 28, 1941	5:15 pm	50.0	50.0
Jan. 29, 1941	4:15 pm	52.0	52.0
Jan. 30, 1941	3:45 pm	51.0	52.0
Jan. 31, 1941	9:15 pm	50.0	50.0
Feb. 1, 1941	10:20 pm	50.0	50.0
Feb. 2, 1941	8:30 pm	49.0	50.0
Feb. 3, 1941	3:50 pm	50.0	52.0
Feb. 4, 1941	10:00 am	50.0	50.0
Feb. 5, 1941	5:00 pm	50.0	50.0
Feb. 6, 1941	5:00 pm	50.0	51.0
Feb. 7, 1941	2:15 pm	51.0	52.0
Feb. 8, 1941	5:20 pm	50.0	50.0
Feb. 9, 1941	10:00 am	51.0	52.0
Feb. 10, 1941	9:50 am	51.0	52.0
Feb. 11, 1941	9:30 am	52.0	52.0
Feb. 12, 1941	11:40 am	50.0	51.0
Feb. 13, 1941	8:45 am	48.0	49.0
Feb. 14, 1941	No record		
Feb. 15, 1941	No record		
Feb. 16, 1941	10:10 am	49.0	49.0
Feb. 17, 1941	8:00 pm	51.0	51.0
Feb. 18, 1941	4:30 pm	52.0	52.0
Feb. 19, 1941	12:30 pm	52.0	52.0
Feb. 20, 1941	12:30 pm	52.0	52.0
Feb. 21, 1941	5:15 pm	53.0	53.0
Feb. 22, 1941	11:40 am	52.0	52.0
Feb. 23, 1941	8:50 am	52.0	52.0
Feb. 24, 1941	1:00 pm	52.0	52.0
Feb. 25, 1941	2:35 pm	53.0	53.0
Feb. 26, 1941	6:00 pm	52.0	52.0
Feb. 27, 1941	3:55 pm	52.0	52.0
Feb. 28, 1941	4:00 pm	53.0	53.0

In order to ascertain whether temperature differences exist during the summer between the surface and bottom waters, recordings were made at Main Station II on August 3, 1939, and at Main Station I, two days later. These readings were made with a reversing thermometer at half-hour intervals covering a period of several hours duration at each location. Water depths from the surface were measured with a sounding chain at the time each series of surface and bottom temperatures was recorded. The results of these observations are given in tables 3 and 4.

Bottom temperatures were found to be, in most cases, slightly lower than surface water temperatures; occasionally the surface and bottom were identical. The greatest single difference between surface and bottom water temperatures of 3.7 degrees F., occurred at Main Station II, at 4 P.M., shortly after high tide, when the surface water was 58° F., and the bottom temperature was 54.3° F. In general, there were less differences between surface and bottom temperatures at Main Station I than those encountered at Main Station II, two days previously.

Table 3

Surface and bottom temperatures
at Main Station II,
August 3, 1939.

Time	Temperature -°F. Air	Surface Water	Bottom Water	Temp. Degrees Difference Surface and Bottom	Water depth -feet	Tidal Stage
9:00 am	61.2	69.0	68.9	.1	6.0	Ebb-just before low water
9:30 am	61.5	69.0	69.0	0.0	7.0	Flood-just beginning
10:00 am	65.4	68.9	68.9	0.0	7.5	Flood
10:30 am	65.2	68.5	67.3	1.2	7.5	Flood
11:00 am	65.2	67.2	66.9	.3	9.0	Flood
11:30 am	65.2	65.6	65.2	.4	9.5	Flood
12 N	66.6	63.8	63.6	.2	10.0	Flood
12:30 pm	70.3	63.6	61.4	2.2	12.0	Flood
1:00 pm	72.0	61.2	59.8	1.4	12.7	Flood
1:30 pm	70.3	59.4	58.0	1.4	13.0	Flood
2:00 pm	65.4	59.0	56.5	2.5	13.0	Flood
2:30 pm	65.4	56.0	54.7	1.3	13.4	Flood
3:00 pm	65.6	54.7	54.3	.4	13.5	Flood
3:30 pm	65.2	56.4	54.0	2.4	13.5	Flood-near high tide
4:00 pm	58.1	58.0	54.3	3.7	13.0	Ebb-just after high water
4:30 pm	59.8	57.6	54.7	2.9	12.5	Ebb
5:00 pm	59.8	60.0	59.4	.6	12.0	Ebb
5:30 pm	59.8	61.4	59.8	1.6	11.0	Ebb

Table 4

Surface and bottom temperatures at Main Station I,
August 5, 1939

Time	Temperature -° F. Surface	Temperature -° F. Bottom	Temp. Degrees Difference-Surface and Bottom	Water depth -feet	Tidal Stage
9:30 am	65.4	63.8	1.6	19.0	Ebb-just before low water
10:00 am	64.9	63.0	1.9	21.0	Flood-just after low water
10:30 am	63.8	63.0	.8	21.5	Flood
11:00 am	63.2	61.8	1.4	22.0	Flood
11:30 am	60.1	59.8	.3	23.0	Flood
12 N	56.5	56.1	.4	24.0	Flood
1:00 pm	56.1	54.7	1.4	25.0	Flood
1:30 pm	54.1	52.7	1.4	25.0	Flood
2:00 pm	50.9	50.0	.9	26.0	Flood
2:30 pm	50.3	49.0	1.3	27.0	Flood
3:00 pm	49.0	48.9	.1	27.5	Ebb-just after high water
3:30 pm	49.0	48.9	.1	27.0	Ebb-just after high water
4:00 pm	50.0	50.0	0.0	26.5	Ebb

On August 1 and 11, 1939, horizontal surface temperature readings of the water were made starting in the lower bay and proceeding up-river with the flood tides. The results of these recordings are presented in table 5. From these horizontal temperature recordings, there appears to be, at least in the summer time, and probably in late spring and early fall, a gradual increase in water temperature as the distance up the bay increases. However, the water temperature at any particular location over the oyster grounds, as proven by continuous records at Main Station II during the summers of 1940 and 1941, decreases as the tide floods and increases as the tide ebbs.

Tablo 5

Horizontal temperatures in Yaquina Bay,
August 1 and 11, 1939

Date & Time	Location	Water Temperature F Surface	Bottom	Water Depth -feet	Tide Stage
Aug. 1					
8:47 am	Zone 2-Station 2	63			Flood-just after low water
8:55 am	Zone 3-Station 5	63	63.6	14	Flood-just after low water
9:10 am	Zone 4-Main Station I	65	64.2	10	Flood
9:43 am	Zone 4-Station 1	68			Flood
10:00 am	Zone 7-Main Sta.II	69	68.7	12	Flood
10:32 am	Zone 5-Upper part	69			Flood
11:00 am	Zone 9-Main Sta.III	69			Flood
11:15 am	Zone 9-Station I	70			Flood
11:35 am	Zone 10-Station 4	70			Flood
Aug. 11					
6:20 am	Zone 3-Station 2	56	55.8		Flood
6:40 am	Zone 4-Main Stat. I	57	56.6		Flood
7:15 am	Zone 7-Main Sta.II	59	58.7		Flood
7:40 am	Zone 9-Main Sta.III	62	61.3		Flood

Data regarding water temperatures in experimental diked areas are presented in the section on dike investigations.

Salinity

The salinity factor of the environment has long been recognized as important in oyster ecology, affecting distribution, egg and larval development, larval setting, possibly reproduction, food organisms, and natural enemies. Oysters usually occur in marine waters that are modified by streams and are not generally present in locations lacking the influence of inflowing fresh water.

Amemiya (1926) has demonstrated that different optimum salinity ranges exist for the egg and larval stages for the European oyster, *Ostrea edulis*; the Japanese oyster, *O. gigas*; the Eastern oyster, *O. virginica*; and the Portuguese oyster, *O. angulata*. No such salinity studies have been reported for the Native oyster, *Ostrea* lurida. A review of the publications dealing with this species gives the following items of information regarding salinity:

(1) Hopkins (1927) in discussing salinity conditions in oyster dikes near Olympia, Washington, stated, "Because of the predominant deep water in Puget Sound and relatively small streams in the southern portion the variations in salinity are not often great-----. Low salinity never accounts for mortality in these bays-------. The day to day variation in salinity is not great----. The variation in salinity between individual samples taken at any time is relatively slight----. The bottom salinity in Oyster Bay varies during the year from about 26 to 29 parts per mille, in Mud Bay from 27 to 29.5 parts per mille."

(2) Bonnot (1936 and 1937) reporting on native oysters in Humbolt bay, California, presented two graphs of the salinity readings taken from oyster areas for the years 1935 and 1936, each of which covered the periods from May first to September 30. An inspection of the graphs showed the salt range was 20 to 35 ppm., seldom was the salinity below 25 ppm., and for most of each season between 30 to 35 ppm.

(3) E.R.Elsey (1933) in his publication on oysters in British Columbia states the following concerning salinity in Boundary bay and Ladysmith harbour, the two most important native oyster areas in British Columbia; "The salinity of bottom water in Boundary bay during late spring and summer of 1939 did not fall below 23 parts of salt ppm. and did not exceed 30 ppm. The most commonly occurring value was 25 ppm. Salinities at low tide fluctuated considerably in accordance with variations in rainfall and in quantity of river discharge. With the exception of those of a very thin surface layer,

following heavy rains, they did not fall below 20 ppm. During a period of heavy rainfall in June, 1931, salinities of Boundary bay fell to 20 ppm. at the bottom. Those of the surface water at low tide, were occasionally as low as 15 ppm. Freshening of a whole body of water to 20 ppm. has been known to occur as a result of the inflow, under the influence of prevailing winds, of Fraser river water-----. The range of salinities of high tide water in Ladysmith harbour is from 25 to 30 ppm. The average of summer salinities is slightly higher than that of Boundary Bay."

(4) H.B.McMillin (1931) in his unpublished manuscript dealing with the native oyster in Yaquina Bay stated that the salinity of the estuary was lowered by increased river discharge and that the surface salinity was less than the bottom salinity. He also reported, "The upper of the oyster beds in Yaquina Bay may be dependent on winter salinity, although further observation may indicate that other factors are responsible."

Daily salinity tests were made of samples taken from the surface and bottom waters collected at Main Station II in zone 7, covering the period of April 11, 1940 to September 5, 1941. The record for each salinity sample included the time and approximate tidal stage at which collected, and the reported rainfall for the day at Newport, Oregon (U.S. Weather Reports 1940 and 1941). Table 52 of the appendix presents this data. From an inspection of these records, coupled with other supporting salinity tests, a number of deductions concerning salinity conditions in Yaquina Bay may be made.

There was considerable variation in the amount of salinity over the oyster grounds, as measured from day to day. This daily irregularity was found related to three factors, namely: the tidal stage at which the samples were collected; the size of the tide in feet, both at high and low water; and the amount of fresh water discharged by the river and its tributaries.

In general the salinity increased as the tide flooded, bringing in the saltier water from the ocean. Conversely, the salinity decreased as the tide ebbed, because the fresh water from the river mixed with the reduced volume of ocean water. These conditions were substantiated by salinity tests at Main Station II on May 6, 1940, following a rainy period of several days duration, table 6.

Table 6

Salinity readings in parts per mille at Main Station II, May 6, 1941, showing salt variations in relation to tidal stages

Tidal Stage	Salinity Surface Water	Salinity Bottom Water
Low water	8.1	8.1
Flood .15	8.6	8.6
Flood .35	10.6	13.2
Flood .50	12.4	17.8
Flood .75	16.1	20.8
High tide	18.5	21.6
Ebb .25	15.5	18.6
Ebb .50	12.0	15.5
Ebb .75	10.2	12.4
Low tide	9.4	9.4

The larger incoming tides brought into the bay an increased volume of ocean water; and consequently, caused a higher salinity at such times in comparison with smaller high tides. Also extremely low tides allowed a greater amount of fresh water to mix with the remaining salt water over the oyster grounds than was evidenced during "hold up" low-tides.

Rainfall caused a reduction of salinity which was apparently in relation to the amount of river discharge. As the river waters increased in volume, the salinity over the oyster beds likewise decreased. At times, following heavy rainfall of several days' duration, the water over the oyster beds became practically fresh as noted on February 7, 1940; when at low tide, the surface and bottom waters at Main Station II each contained a salinity of 1.1 parts per mille. However, the salinity readings shortly after high tide on the same day were for surface 1.3 and for bottom waters 13.1 parts per mille. Frequently, when the river discharge was low, there was a several day lag between the rainfall and a recorded reduction of salinity over the oyster areas.

Usually, surface water salinities were lower than bottom salinities. This vertical difference in salinity became more pronounced during flood tide and less so at or near low water stages. Occasionally, at or near low water, both the surface and bottom salinity readings were identical. On the other hand, during periods of heavy rains resulting in marked river freshets, the surface water was practically fresh and the bottom water contained considerable amounts of salt. This was illustrated at Main Station I in zone 4, February 7, 1940, when the surface water was 1.7 and the bottom water contained a salt content of 22.2 parts per mille.

In comparing salinity readings in Yaquina Bay with those made in Puget Sound (Hopkins 1937), Humbolt Bay (Bonnot 1936 and 1937) and in British Columbia (Easley 1933), it becomes evident that oyster areas in Yaquina bay are subjected to greater variations and particularly lower salinities than are encountered in the other important native oyster areas of the Pacific Coast. This hydrographic situation may be one of the main ecological factors causing a limited oyster production in Yaquina bay over a period of years. Reduced salinities at times of marked rainfalls may result in little or no spatting in some seasons or high mortalities of mature oysters. There is a probability that the extreme low salinities encountered have resulted from increased periodic river discharge due to land clearing, forest fires, and the lack of reforestation on lands adjacent to the Yaquina river and its tributaries.

Undoubtedly, the upper limits of the native oyster grounds, as suspected by McMillin (1931), are demarked at the end of zone 9 by low salinities for extended periods of time during winter freshets. The reduced salinities on zone 10 were of sufficient duration to kill oysters during the winter of 1939-40, but not in the winter of 1940-41.

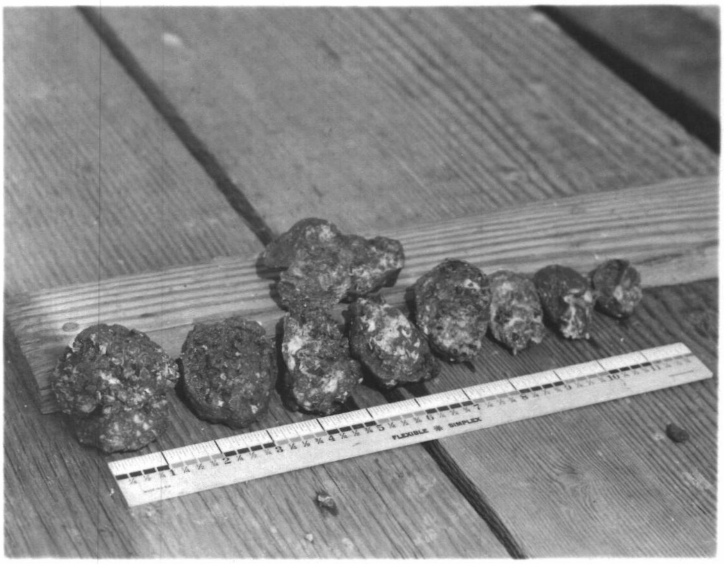

Figure 18.

Native oysters from Yaquina bay.

Figure 19.

Japanese oysters resulting from production in Yaquina bay.

Figure 20.

Eastern oysters grown in Yaquina bay from transplanted stock.

BIOLOGICAL OBSERVATIONS

Adequate knowledge of the several aspects of the bionomics of the native oyster in relation to the particular hydrographic conditions prevailing in Yaquina bay is necessary before improved cultural methods and regulations may be put into operation. Excellent studies of this oyster have been made in other locations including Puget Sound (Hopkins 1937), Humbolt Bay (Bonnot 1935, 1936, 1937), and in British Columbia (Stafford 1914, 1915, 1916, 1917, 1918); Elsey 1933). The findings of these investigators have been exceedingly helpful, but have not always been applicable to the different environmental conditions encountered in Yaquina bay.

General Life History of the Native Oyster

In order to assure a clear understanding of the experimental work presented in this report, the following general life history of the native oyster, Ostrea lurida, was compiled largely from studies made in Washington (Hopkins 1937), California (Bonnot 1935, 1936, 1937), and British Columbia (Elsey 1933), supplemented with observations from Yaquina bay.

The native oyster of the Pacific Coast, figure 18, which is also known in the Puget Sound area of Washington as the Olympia oyster, inhabits several bays or protected harbor areas from Queen Charlotte Sound, British Columbia, to San Diego Bay, California. In Oregon, this species is found in Yaquina bay, Lincoln County, and in extremely limited numbers in Netarts bay, Tillamook County. At one time, this oyster was present in tremendous numbers in Coos bay, as dredging operations for deepening the channel have uncovered large quantities of the shell. Possibly, other bays in the State produced this oyster, but, because of changed ecological conditions or because of a catastrophe such as the "big fire" of 1846 which occurred before white settlement, this species may have been extirpated from a number of areas.

The native oyster reaches a market size of 1½ to 2 inches in length in three to five years. Its smaller size readily distinguishes it from the two exotic species, the Japanese or Pacific Oyster, Ostrea gigas, and the Eastern Oyster, Ostrea virginica, found in Yaquina Bay. The muscle scar inside the native shell is clearly outlined, but lacks pigmented coloring, whereas the Eastern oyster has a distinctly outlined scar that is dark purple, and the Japanese oyster muscle scar is a light mauve but not clearly outlined. A morphological difference used to distinguish native oysters from the small Japanese oysters was in the size of ostia of the gills of these two species. The ostia of the native oyster are about twice as great in diameter as those of the latter species (Elsey 1935).

There are several structural differences among specimens of the native oyster that appears to be in response to factors of the habitat. For example,the mantle fringe of specimens from diked areas is dark and somewhat blackish, while those from deeper waters have a pinkish cast. The general appearances of the shells from Puget Sound are different in size and shape from those in Yaquina Bay. Even shell differences are apparent in oysters from various locations in Yaquina Bay. Possibly, such ecological factors as light, salinity, temperature, and encrusting organisms may account for structural variations.

The native oyster, unlike the Japenese and Eastern oysters, is hermaphroditic and regularly protandric. Each sexually mature individual passes through alternate male and female stages. Sexually mature oysters were found in Yaquina Bay during the second year of life, or at one year of age. Apparently, at first, when first reaching sexual maturity, the individual is in the male stage.

At spawning time, the eggs are discharged from gonads into an exhalent chamber from which they pass through the gill ostia into the inhalent chamber. Presumably, these eggs are fertilized by sperm brought by the outside water into the inhalent chamber, as unfertilized eggs were found in this chamber on several occasions. The eggs, embryos and larvae locate at the upper end of the inhalent chamber next to the gills and labial palps. The sperm are discharged from the gonads in sperm balls which are thought to pass into the sea water from the exhalent chamber. The action of the sea water probably causes the matrix of the sperm balls to break down, liberating the individual sperms. This spawning action of the male phase was not observed during the Yaquina bay studies.

Following fertilization, the embryonic or pre-larval development is as was described by Hopkins (1937):

> "On the day after the eggs are discharged into the brood chamber they have become blastulae. At the age of two days they are usually in the gastrula stage, and one day later they have developed the swimming organ, or prototroch, and are actively swimming trochopore larvae. Usually on the fourth day the small valves may be seen developing on the dorso-lateral surfaces a pair of clearly defined structures about 30 to 40 microns long. This may be called the first conchiferous stage----. On the fifth day the valves have become complete and enclose the larvae entirely except when swimming with the velum protruding. ------An average period of 10 days is required for development within the branchial chamber from the time eggs (diameter 100 microns to 150 microns) are extended from the gonad until the straight-hinge veliger larvae (length of valves, 180 microns are discharged)."

Contrary to McMillin's (1931) observation "in four cases segmented eggs were found in the mantle cavity of the parent along with shell larvae," all of the many gravid oysters examined during 1939, 1940, and 1941 had broods in practically the same stage of development. According to Hopkins (1937) the average size of the brood of the ordinary marketable oyster is from 250,000 to 300,000 larvae. No attempt was made to verify these reported numbers of larvae in a brood of native oysters from Yaquina bay.

The free-swimming larvae are discharged into the water, where they are carried by tidal currents back and forth over the oyster grounds for a period of about 30 days more or less. The duration of this phase of the life history is dependent upon prevailing water temperatures and food conditions. During this period the free-swimming larvae feed upon microscopic organisms which are apparently different in kind and much smaller in size than those generally ingested by the adult oysters. When the larva has grown to about 320 microns in length, it attaches by its left valve, to some solid object known as cultch. This may be a shell, stick, log, bark, rock or the like. There the "young spat" undergoes a morphological change into an organism having the structure of an adult oyster. In Yaquina bay, market-sized oysters are produced in 3 to 5 years, the average being in the 4th year of life.

A number of these life history aspects in Yaquina bay were studied during 1939, 1940 and 1941. Those receiving the most attention were the spawning periods, the activities of the free-swim-larvae, larval setting, the growth of young oysters, oyster mortalities, oyster enemies and competing organisms.

Spawning

In 1940, from April 22 to October 25, occasional samples of market-sized oysters were tonged from the Lyman's Eddy Beds in Zone 7 and examined for developing embryos and larvae. No attempt was made during that spawning season to determine the developmental stage of the embryos and larvae other than to record whether or not each oyster specimen was gravid. Table 7 summarizes the results of these observations.

Table 7

The number and percentages of gravid oysters in samples examined from zone 7 during 1940 spawning season

Date	Number of oysters in sample	Number of gravid oysters	Number of oysters not gravid	Percentage of gravid oysters
April 15	100	0	100	0
April 22	100	0	100	0
April 24	100	7	93	7
May 2	100	37	63	37.0
May 12	100	13	87	13.0
May 23	100	13	87	13.0
May 25	100	33	67	33.0
June 14	70	25	45	35.7
June 26	100	20	80	20.0
June 28	25	5	20	20.0
July 1	30	7	23	23.3
July 6	15	0	15	0
July 25	100	2	98	2.0
July 26	100	2	98	2.0
July 31	100	4	96	4.0
August 2	100	17	83	17.0
August 7	75	12	63	17.3
August 8	100	16	84	16.0
August 13	100	2	98	2.0
September 10	100	0	100	0
September 14	100	0	100	0
October 25	100	0	100	0

Although the oyster samples were collected and examined at too irregularly-spaced intervals in 1940 for exact information covering the entire period, the general trend of spawning was apparent. Gravid oysters were found from April 24 to August 13. Spawning had not begun by April 22 and ceased sometime shortly after August 13. There were apparently, two marked spawning periods. The first, from April 24 to July 1 was of greater intensity than the second, extending from July 25 to August 13.

During 1941, a systematic method of sampling oysters was followed to ascertain the trend of the spawning season. Samples of 100 market-sized oysters were tonged twice weekly from the Lewis Flats, Station I in zone 8, commencing March 31 until September 15. The larvae of the gravid oysters were examined microscopically and tabulated as to the different stages of development. Table 8 gives the results of these samples of gravid and non-gravid oysters and the number of embryos, (eggs, cell division, morula, blastula, gastrula, and trocophore) and conchiferous larvae (straight-hinge stage). Initial spawning for the year began on April 7, for eggs were present in the inhalent chamber of each gravid oyster examined on that date. Spawning continued in small waves of intensity until August 15, with an occasional gravid oyster found as late as September 15.

Table 8

The percentage of gravid and non-gravid oysters from zone 8 during the 1941 spawning season. Each sample was on 100 market-sized oysters

Date	Numbers			
	Gravid oysters	Non gravid oysters	Gravid Oysters	
			With Embryos	With Conchiferous Larvae
March 24	0	100	0	0
March 28	0	100	0	0
March 31	0	100	0	0
April 4	0	100	0	0
April 7	0	100	0	0
April 11	0	100	0	0
April 14	0	100	0	0
April 18	7	93	7	0
April 22	8	92	8	0
April 25	15	85	11	4
April 29	22	78	17	5
May 3	23	77	13	10
May 6	19	81	10	9
May 9	18	82	9	9
May 13	16	84	5	11
May 16	33	67	17	16
May 20	22	78	9	13
May 23	23	77	14	9
May 26	18	82	8	10
May 30	15	85	7	8
June 3	22	78	8	14
June 6	19	81	8	11
June 9	12	88	9	3
June 13	9	91	2	7
June 16	12	88	6	6
June 20	16	84	7	9
June 23	12	88	8	4
June 27	8	92	1	7
June 30	11	89	6	5
July 4	12	88	6	6
July 7	10	90	5	5
July 11	16	84	10	6
July 14	18	82	15	3
July 18	32	68	12	20
July 21	15	85	7	8
July 25	16	84	0	15
July 28	5	95	0	5
August 1	6	94	6	0
August 4	7	93	7	0
August 8	8	92	0	8
August 11	5	95	0	5
August 15	7	93	2	5

Table 8 (Continued)

Date	Numbers			
	Gravid oysters	Non gravid oysters	Gravid Oysters With Embryos	Gravid Oysters With Conchiferous Larvae
August 18	0	100	0	0
August 22	1	99	0	1
August 25	0	100	0	0
August 29	0	100	0	0
September 1	1	99	0	1
September 5	0	100	0	0
September 8	0	100	0	0
September 12	0	100	0	0
September 15	0	100	0	0

The Free-Swimming Larvae

Observations of the distribution, seasonal relative numbers, and general condition of the free-swimming larvae were made on numerous occasions in 1939, 1940, and 1941, by examining plankton collections taken at various locations in zones 2 to and throughout zone 12. For each plankton sample, the location and usually the approximate tidal stage was noted. An estimate was made of the abundance of oyster larvae present in each plankton haul. The terms used to describe the relative numbers were: (1) very few, if one to four larvae were present in the sample; (2) few, if five to ten larvae were found; (3) moderate, if 11 to 25 were evident; and (4) many, if 26 to several hundred were seen. The results of the seasonal plankton collections for 1939, 1940, and 1941 are given in tables 9, 10, and 11.

Table 9

Records of free-swimming larvae found in plankton samples, July 4 to September 7, 1939.

Date	Location of haul	Tidal Stage	Relative Abundance of Free-Swimming Larvae
July 4, 1939	Zone 9, Main Station III	Ebb	Many present
July 14, 1939	Zone 4, Main Station I	Flood .10	Very few present
July 14, 1939	Zone 8, Main Station III	Flood .20	Moderate numbers
July 14, 1939	Zone 5	Ebb	Moderate numbers
July 21, 1939	Zone 7	Ebb	Many present
July 21, 1939	Zone 9, Main Station III	Ebb	Moderate numbers
July 26, 1939	Zone 3, Station 2	Ebb .10	None present
July 26, 1939	Zone 9, Station I	Flood	Many present
July 26, 1939	Zone 9, Main Station III	Flood	Moderate numbers
July 26, 1939	Zone 9, Main Station III	Flood-near high water	Moderate numbers
July 26, 1939	Zone 5	Flood-near high water	Few present
July 26, 1939	Zone 4	Ebb .05	Very few present
July 26, 1939	Zone 4	Ebb .10	Very few present
July 26, 1939	Zone 4, Main Station I	Ebb .12	None present
July 27, 1939	Zone 3, Station 5	Ebb .15	None present
Aug. 2, 1939	Zone 3, Station 2	Flood .02	None present
Aug. 2, 1939	Zone 3, Station 4	Flood .05	None present
Aug. 2, 1939	Zone 4, Main Station I	Flood .05	Moderate numbers
Aug. 2, 1939	Zone 4, upper end	Flood .05	Moderate numbers
Aug. 2, 1939	Zone 4, McCaffery's Slough	Flood .08	None present
Aug. 2, 1939	Zone 8, Station 1	Flood .10	Many present
Aug. 2, 1939	Zone 5	Flood .12	Moderate numbers
Aug. 2, 1939	Zone 9, Main Station III	Flood .15	Moderate numbers
Aug. 2, 1939	Zone 9, Station 1	Flood .18	Moderate numbers
Aug. 2, 1939	Zone 10, Station 2	Flood .20	Many present
Aug. 11, 1939	Zone 9, Station 1	Ebb	Moderate numbers
Aug. 11, 1939	Zone 9, Main Station III	Ebb	Moderate numbers
Aug. 11, 1939	Zone 8, Station 1	Ebb	Few
Aug. 22, 1939	Zone 8, Station 1	Ebb-near low tide	Very few present
Aug. 22, 1939	Zone 9, Main Station III	Ebb	Very few present
Aug. 22, 1939	Zone 4, Main Station I	Flood	None present
Sept. 7, 1939	Zone 4, Main Station I	Ebb	None present
Sept. 7, 1939	Zone 8, Station 1	High tide	None present
Sept. 7, 1939	Zone 9, Main Station III	Flood	None present

Table 10

Records of free-swimming larvae found in plankton samples,
April 10 to Sept. 10, 1940.

Date	Location of haul	Tidal Stage	Relative Numbers native oyster larvae
April 10, 1940	Zone 7, Main Station II	Ebb .50	None present
April 10, 1940	Zone 7, Main Station II	Ebb .50	None present
April 17, 1940	Zone 7, Main Station II	Ebb .50	None present
May 6, 1940	Zone 9, Main Station III	Ebb .50	None present
May 7, 1940	Zone 7, Main Station II	Ebb .50	None present
May 9, 1940	Zone 9, Main Station III	Flood .50	None present
May 10, 1940	Zone 7, Main Station II	Low Tide	Very few present
May 15, 1940	Zone 7, Main Station II	Ebb .50	Very few present
May 17, 1940	Zone 7, Main Station II	Ebb .50	Very few present
May 22, 1940	Zone 7, Main Station II	Flood .30	Moderate Numbers
May 25, 1940	Zone 7, Main Station II	Flood .30	Many present
May 28, 1940	Zone 7, Main Station II	Flood .30	Many present
May 30, 1940	Zone 7, Main Station II	Ebb .50	Many present
June 3, 1940	Zone 7, Main Station II	Ebb .50	Few present
June 6, 1940	Zone 7, Main Station II	Ebb .65	Few present
June 7, 1940	Zone 9, Main Station III	High tide	Many present
June 7, 1940	Zone 10, Station 5	High tide	Many present
June 8, 1940	Zone 12, Station 4	High tide	None present
June 8, 1940	Zone 12, Station 3	Ebb .08	None present
June 8, 1940	Zone 11, Station 4	Ebb .10	Very few
June 8, 1940	Zone 11, Station 3	Ebb .15	Few present
June 8, 1940	Zone 10, Station 5	Ebb .35	Few present
June 8, 1940	Zone 9, Main Station III	Ebb .45	Very few present
June 15, 1940	Zone 7, Main Station II	Ebb .50	Very few present
June 15, 1940	Zone 9, Main Station III	Ebb .50	Very few present
June 24, 1940	Zone 7, Main Station II	Low tide	Moderate numbers
June 24, 1940	Zone 3, Station 2	Ebb .75	None present
July 2, 1940	Zone 7, Main Station II	High tide	Moderate numbers
July 6, 1940	Zone 10, Station 5	Flood .50	Few present
July 6, 1940	Zone 11, Station 2	Flood .50	Few present
July 8, 1940	Zone 7, Main Station II	Ebb .50	Few present
July 15, 1940	Zone 9, Main Station III	Flood .75	Moderate numbers
July 19, 1940	Zone 9, Main Station III	Flood .25	Moderate numbers
July 26, 1940	Zone 4, Main Station I	Ebb .65	Many present
July 26, 1940	Zone 9, Main Station III	Ebb .65	Many present
July 26, 1940	Zone 12, Station I	High tide	None present
July 26, 1940	Zone 12, Station 2	High tide	None present
July 26, 1940	Zone 12, Station 3	High tide	None present
July 26, 1940	Zone 11, Station 4	High tide	Few present
Aug. 2, 1940	Zone 7, Main Station II	Ebb .65	Moderate numbers
Aug. 7, 1940	Zone 7, Main Station II	Low Slack	Very few present
Aug. 15, 1940	Zone 7, Main Station II	Flood .65	None present
Aug. 23, 1940	Zone 7, Main Station II	Flood .20	Few present
Aug. 31, 1940	Zone 7, Main Station II	Flood .15	None present
Sept. 7, 1940	Zone 7, Main Station II	High tide	None present
Sept. 10, 1940	Zone 7, Main Station II	Flood .15	Very few present

Table 11

Records of free-swimming larvae found in plankton samples collected in Zone 7, April 13 to September 12, 1941.

Date	Tidal Stage	Relative Abundance of Free-Swimming Larvae and Remarks
April 16	Low tide	None present
April 19	Flood .35	None present
April 25	Ebb .75	None present
April 28	Flood .10	None present
May 3	Flood .15	Very few present
May 9	Low tide	Few present but all dead
May 13	Flood .20	Few present - some dead
May 16	Ebb .80	Few present - all dead
May 20	Low tide	Few present but all dead
May 23	Flood .25	Few present but all dead
May 24	Low tide	Few present but all dead
May 26	Flood .60	Moderate numbers
May 30	Ebb .60	Few present
June 2	Flood .35	Few present
June 6	Flood .50	Few present
June 9	Flood .50	Few present
June 13	Flood .35	Few present
June 16	Flood .65	Few present
June 20,	Low water	Many present
June 23	Flood .50	Few present
June 27	Flood .35	Few present
June 30	Flood .10	Few present
July 4	Low tide	Few present
July 11	Flood .30	Few present
July 14	Flood .05	Moderate numbers
July 18	Ebb .75	Few present
July 21	Low tide	Many present
July 25	Flood .30	Many present
July 28	Ebb .90	Moderate numbers
August 1	Flood .15	Very few present
August 4	Low tide	Very few present
August 8	Ebb .75	Moderate numbers
August 11	Low tide	Moderate numbers
August 15	Ebb .90	Few present
August 18	Ebb .90	Few present
August 22	Ebb .75	Very few present
August 25	Ebb .60	Very few present
August 29	Low tide	Very few present
September 1	Low tide	None present
September 5	Low tide	None present
September 8	Low tide	None present
September 12	Low tide	None present

An analysis of the data from the plankton samples revealed that the free-swimming larvae were found from the lower end of zone 4 to the upper end of zone 11. The presence of larvae in zones 10 and 11 was surprising, since the upper limits of the native oyster beds are in zone 9. On the other hand, no larvae were found below the lower limits of zone 4; but there was definite evidence that at least a few must be present at times in zones 3 and 2, since a few adult oysters growing naturally were found in both of these lower zones.

Attempts in locating free-swimming larvae in zones 12, at or near high tide, on June 8, 1940, and again on July 26, 1940, were negative. Yet, larvae were found on these dates at station 4 in zone 11 in collections made at approximately the same tidal stage as were those made in zone 12. Subsequent plankton collections in 1941 substantiated the finding that the up-river limit of the free-swimming larvae was in the vicinity of the upper end of zone 12, approximately 4 miles above the upper limits of the natural oyster beds. At or near low tide, free-swimming larvae are not present in zone 11, as evidenced by examinations of plankton samples taken on July 12, 1941, table 12.

Table 12
The results of plankton samples taken in zones 11 and 7
at or near low tide on July 12, 1941

Location of Sample	Relative numbers of free-swimming larvae
Zone 11, station 4	None present
Zone 11, station 3	None present
Zone 11, station 2	None present
Zone 11, station 1	None present
Main Station II, Zone 7	Moderate numbers

Another significant discovery from the plankton examinations was that the free-swimming larvae were most numerous over the oyster beds, zones 4 to 9 inclusive, near low tide and least in numbers near high tide. This situation, coupled with the upper-river limits of the free-swimming larvae near the end of zone 11, proved that they were carried back and forth over the oyster grounds and for several miles above the natural beds by the tidal currents. This was also substantiated by finding that the larvae were not generally as numerous in zone 6, lower 5, and 4, as in zones upper 5, 7, 8, and 9, except during periods of minus low tides.

This zonal distribution and tidal movement of the free-swimming larvae in Yaquina bay would indicate that the majority were carried up-river by the flood tide beyond the upper limits of the oyster beds and carried down-river in large numbers through zones 11 to 7 and into the upper half of zone 5, and into zones 6, lower 5, 4, and perhaps 3 and 2 in relatively small numbers. This condition may explain the present minor importance of oyster beds in zones 4 and 6. The lack of sufficient numbers of free-swimming larvae over these depleted oyster areas, in spite of an abundance of shell cultch, might contribute to the failure of these beds to "come back", as expressed by old oystermen of the region. Perhaps, if native oyster numbers in zones 4 and 6, were more numerous, the larvae originating from these locations would not be carried as far up-river as those originating in zones 7, upper 5, 8, and 9, and would then return on the ebb tide in sufficient quantities to insure an adequate set of young oysters on the depleted areas.

Of particular importance was the finding of dead larvae in the 1941 plankton samples on May 9, 13, 16, 20, and 23. Free-swimming larvae were alive and active in samples collected May

3, 24, 30 and June 2. Since there was no noticeable reduction in water temperatures just previous or during the times that dead larvae were found, an analysis of the salinity readings taken at or near low tide from Main Station II was made. This correlation between salinity and larval conditions is presented in table 13.

Table 13

Salinity readings at Main Station II, taken at or near low tide from May 3 to June 2, 1941, and the condition of free-swimming larvae found in plankton samples.

Date	Salinity ppm		Rainfall Newport	Condition of larvae
	Surface	Bottom		
May 3	18.6	19.1	.14	Alive
May 4	18.0	18.4	.60	
May 5	13.1	13.6	.25	
May 6	9.7	9.9	.12	
May 7	12.8	12.8	.01	
May 8	11.5	11.5	-	
May 9	10.2	10.2	-	All dead
May 10	12.4	12.8	-	
May 11	16.3	16.9	.03	
May 12	13.1	13.1	-	
May 13	10.3	10.5	.08	Mostly alive- a few dead
May 14	13.6	13.6	.05	
May 15	13.1	13.1	.01	
May 16	14.0	14.6	.51	All dead
May 17	9.8	9.8	1.13	
May 18	9.9	10.3	.03	
May 19	10.7	11.2	-	
May 20	10.3	12.7	-	All dead
May 21	8.4	10.2	-	
May 22	16.2	16.2	-	
May 23	13.7	13.7	-	All dead
May 24	14.8	15.2	-	Alive
May 25	13.7	13.7	-	
May 26	17.9	20.9	-	Alive
May 27	13.1	13.1	.13	
May 28	13.2	13.2	.13	
May 29	14.9	15.7	.04	
May 30	14.9	14.9	T	Alive
May 31	15.0	16.0	-	
June 1	17.9	18.2	.07	
June 2	18.3	18.3	-	Alive

Although the exact lower limits of salinity causing death of the free-swimming larvae could not be made from the daily salt samples taken at main station II, the indications were that salinities below 13 ppm might be lethal. Neither could the period of time in the lethal salinity range sufficient to cause death be ascertained. As proven by the salinity samples presented in table 6, the salt content of the water increases on the flood tide and decreases on the ebb tide; consequently the salinity in the environment of the free-swimming larvae continually varies.

In order to test this theory that the free-swimming larvae may be killed in water having a salinity below 13 ppm, controlled experiments were conducted in the laboratory, from June 20 to 30, 1941. Solutions of bay water varying in salinity values were made by adding fresh or brackish water taken from the mouth of a small creek emptying in zone 8. Oyster larvae in the last stage of development were taken from gravid oysters and placed in Petri dishes containing water of various amounts of salinity. Lids were placed over the containers so as to reduce evaporation. Each day small amounts of aerated water from the stock solutions of known density were added to test dishes. In this way, the waters to which the larvae were subjected contained sufficient oxygen, approximately the same density throughout the test period, and some food. The results of these tests were as given in table 14.

Table 14

Data concerning conditions of free-swimming larvae subjected to various water salinities
First series of tests

Case No.	Salinity of Water ppm	Condition of larvae
1	23.6	Alive and active at 10 days
2	12.0	All dead by the 4th day.
3	10.5	All dead by the 3rd day
4	9.8	All dead by the 2nd day

This experiment was repeated again on July 5, to July 14, 1941, with approximately identical results. The data on the second series of tests are given in table 15.

Table 15

Data concerning conditions of free-swimming larvae subjected to various water salinities
Second series of tests.

Case No.	ppm Salinity of water	Remarks
1	25.5	Practically all alive and active on the 10th day
2	14.2	Most all alive on the 10th day
3	10.5	All dead by 3rd day
4	9.8	All dead by 2nd day

In these tests it was noted that the free-swimming larvae in the lethal salinity solutions were markedly inactive in contrast with those placed in solutions in which larvae lived for 10 day periods. For example, those in the 10.5 ppm salinity solutions, when first placed in the water, sank at once to the bottom of the dishes and showed no apparent motion until about 24 hours, and then in limited amounts. Those in the salinity solutions of 14.2 ppm, or above, immediately undertook normal activity when placed in the water.

During each year, 1939, 1940, and 1941, free-swimming larvae were found at various times after the end of setting periods for each year. The indications were, but not proven, that the higher salinities usually encountered in August and September may have inhibited the development of the free-swimming larvae so that they are not capable of attaching to cultch. In this connection it was noted that most of the larvae in the plankton samples taken after the end of the 1941 setting period were usually in the straight-hinge stage. Free-swimming larvae nearing the setting period develop a prominent and rounded umbo on the left valve, appearing considerably different than in the early straight-hinge stage.

This apparent lack of setting in the late season free-swimming larvae cannot be attributed to low temperatures, since the temperatures were approximately the same as during the periods of normal development and setting early in the season. On August 8, 1941, free-swimming larvae collected in plankton hauls were placed in water having a salinity value of 32.5 ppm; these remained alive and active for eight days. This experiment was again repeated on August 11, 1941, in water having a salt content of 31.8 ppm and the larvae were still alive and active after eight days.

Setting

When the free-swimming larvae have completed their development, they attach to cultch and change morphologically into the adult form. Those which do not find adequate substrata perish. Consequently, this phase of the life-history becomes of paramount importance in oyster culture in securing a sufficient quantity of young oysters or "seed". The setting of the young oysters, called spat, is best effected on clean surfaces. Therefore, one of the most important operations in oyster farming is the placing of clean cultch at the correct time in the right location. This probably has not been done in the past in Yaquina bay, except in 1941. Undoubtedly, this failure to correctly plant clean shells as cultch has been one of the main reasons that the native oysters in Yaquina bay have been far below their potential productivity for a great many years.

The efficiency of cultch is greatly reduced by the accumulation of silt and organic growths on the surfaces. Hopkins (1937) from his studies of the native oyster in Puget Sound concluded "----shells had lost one-third of their efficiency as spat collectors in nine days, even during the time when the water was most free from fouling materials and organisms." The indications were that perhaps fouling of clutch in Yaquina bay is of a more serious nature than in the oyster areas of Puget Sound, for large amounts of silt are brought into or near the oyster beds by the river freshets of winter and early spring. Much of this silt is moved about markedly in the summer time by the wave action of incoming tides on the mudflats. Coupled with this silt situation there is a tremendous algal growth on the cultch of all types in the oyster beds, except those located in relatively deep water of zones 4 and 9. Further, there are a number of animal organisms, such as barnacles, tube-dwelling shrimps, bryozoans, and sponges which constitute a serious fouling problem in Yaquina bay. ? amphipod

Information available regarding the larval setting of native oysters in Yaquina bay at the beginning of operations on July 4, 1939, came from two sources:

(1) Local oystermen. The consensus was that there were usually two general setting maxima--the first occurring in late June, if the season was advanced, or if climatic temperature conditions were below normal occurring in the forepart of July. A second noticeable setting period occurring sometime in August was reported to be the normal condition. In addition, the intensity of larval

setting was believed to vary in seasonal time in the different locations on the oyster grounds.

(2) H.C.McMillin's unpublished report. This investigator, working for the United States Bureau of Fisheries, made studies of setting conditions in Yaquina bay during 1931. His complete report regarding this phase of the study follows:

> "The short period of general setting was not found in Yaquina Bay in 1931. The first set was found on July 25 when one was taken from the experimental dike, and another from the Oysterville flats at the Multnomah boom. Both were in fresh cultch bags. By August 1, a light set was down. About 90 percent of the shells were blanks (without set); seldom more than one spat could be found on one shell. Setting continued slowly; by the middle of August less than 50 per cent of the shells were blanks, and in the shipyard channel a fair set could be seen. Outside the shipyard the total set was about equal to all other oysters on the grounds. Experiments with cultch bags indicate that setting takes place at all levels in Yaquina Bay just as it does in Oyster Bay, Elkhorn Slough, and other places where it has been tried. Owing to the lateness of the light set, the results obtained from cultch bag experiments are not considered of importance."

The setting periods in 1939, 1940, and 1941 were given considerable attention. In the main, this was accomplished by placing fresh cultch bags in the water periodically at designated stations and examining the smooth surfaces of the shells for spat. The method employed was adapted from the procedures of Hopkins (1937) and Bonnot (1936 and 1937). In each fresh cultch bag there were approximately 200 to 250 clean native shells of uniform market size. These bags were usually suspended two or three feet from the water surface attached by ropes to floating docks that rose and fell with the changes in tidal levels.

The fresh cultch bags were usually changed at weekly intervals. At some stations there were two overlapping series of bags, placed on two separate days of the week. Generally, the fresh cultch bags were placed in the water well in advance of the initial setting time for the year and were maintained for some time after all spatting had ceased.

After the cultch bags were taken from the water and the shells were dry, the spat were located on the inner surface of the shells by means of a binocular microscope. Since the outer surfaces of the shells are rough, making the spat of a week-old or less difficult to locate with accuracy, the numbers were not recorded from that surface in the usual routine examination. However, the number of spat on the outer and inner surfaces of many shells were counted and the results indicated that the findings of Hopkins (1937), who used the larger Japanese oyster shells, also held in the case of the native shells in Yaquina bay. He found that 35 per cent of the larvae attached to the inner surface while 65 per cent adhered to the outer surface. These figures were used as conversion factors in this report for computing the number of spat found on shells. From this data, coupled with the spat counts on the inner surfaces of each shell, it was then possible to ascertain with a fair degree of accuracy the total number of young oysters attached to shells in the cultch bags. Usually the inner surfaces of 100 shells were examined.

Table 16

Number of spat attached to 100 native shells in weekly fresh-cultch bags at the Main Stations I, II, and III, from July 10 to September 15, 1939. Two weekly series.

Dates		Number	Main	Main	Main
Placed	Removed	of days	Station I	Station II	Station III
July 10	July 14	4	0	0	0
July 10	July 18	8	0	0	0
July 14	July 21	7	0	0	0
July 18	July 25	7	0	0	0
July 21	July 28	7	6	14	11
July 25	Aug. 1	7	54	43	163
July 28	Aug. 4	7	20	17	37
Aug. 1	Aug. 8	7	23	54	48
Aug. 4	Aug. 11	7	0	23	20
Aug. 8	Aug. 15	7	149	71	154
Aug. 11	Aug. 18	7	23	23	9
Aug. 15	Aug. 22	7	4	3	9
Aug. 18	Aug. 25	7	20	9	43
Aug. 22	Aug. 29	7	6	3	0
Aug. 25	Sept. 1	7	0	0	0
Aug. 29	Sept. 8	10	0	0	0
Sept. 1	Sept.15	14	0	0	0
	Total		305	260	494

Although observations were not begun in time to obtain complete data on the larval setting period for 1939, the indications were that no setting took place in Yaquina bay before July 25. No spat of the year could be found on cultch tonged from zones 7 and 8 before this date. Also, spat on shells suspended in water at Main Station II continuously from July 18 to September 15 were not smaller in size than those measured on tonged shells from station 1 in zone 8 on September 12. Most of these tonged shells had been in the water since early June and some had been in the water over a year's time. Since it was found that the free-swimming larvae were killed by reduced salinity in May 1941, an inspection of the weather records taken at Newport disclosed that rainfall during May and June of 1939 might have reduced the water salinity in the oyster areas sufficiently to kill all free-swimming larvae up to or shortly after June 22. Table 17 gives the daily rainfall in inches for those two months at Newport, Oregon.

Table 17

Rainfall records for Newport, Oregon
May and June 1939

May		June	
Date	Rainfall-inches	Date	Rainfall-inches
May 1	-	June 1	-
May 2	-	June 2	-
May 3	-	June 3	.10
May 4	.06	June 4	.66
May 5	-	June 5	.02
May 6	-	June 6	-
May 7	-	June 7	.06
May 8	-	June 8	.22
May 9	-	June 9	.04
May 10	-	June 10	-
May 11	-	June 11	-
May 12	-	June 12	-
May 13	-	June 13	-
May 14	T	June 14	-
May 15	.01	June 15	.85
May 16	.14	June 16	.14
May 17	-	June 17	.14
May 18	-	June 18	.19
May 19	.02	June 19	.19
May 20	.08	June 20	.02
May 21	.01	June 21	-
May 22	-	June 22	.02
May 23	.04	June 23	-
May 24	.04	June 24	-
May 25	.22	June 25	-
May 26	-	June 26	-
May 27	-	June 27	-
May 28	.23	June 28	-
May 29	.09	June 29	-
May 30	-	June 30	-
May 31	-		
Total Rainfall	.94	Total rainfall	2.75

Allowing about 30 days for the development of free-swimming larvae after June 22, the first larval setting could have been expected to occur about July 22. Actually initial setting commenced on July 25 or 26 in 1939. During the time that fresh cultch bags were at the three Main Stations, July 10 to September 15, 1939, setting did not begin until July 25 or 26 and ceased at all stations by August 25 or perhaps August 24, covering a period of one month.

Generally, but not always, the rate of setting was somewhat uniform at each of the three main stations on the same dates. When an increase in numbers of spat was encountered at one station, there were corresponding increases at the other two stations. Conversely, a decrease in numbers of spat was usually correlated with decreases at the other two stations. The relative importance of the three Main stations in order of importance in numbers of spat collected were III, I, and II.

Systematic observations during the summer of 1940 were made of larval setting at Main Stations I, II, and III, and at five zonal stations for the purposes of determining the seasonal duration of the setting period, the times of maximal setting, the location of greatest setting intensity. In addition, occasional observations were made at a number of other zonal stations, especially to ascertain the extent of up-river setting beyond the upper limits of the oyster grounds. Also, studies were made of setting in the intertidal zone.

The results of the 1940 spat counts from Main Stations I, II, and III are given in table 19. The fresh-cultch bags at these three locations were in two weekly series. Spat counts were made at weekly intervals from the following zonal stations: station 4 in zone 3, Yaquina public dock; station 5 in zone 3, float at Shermer's boat works; station 2 in zone 5, Shermer's float in Poole's slough; station 1 in zone 6, dolphin at lower end of Oysterville flats; station 2 in zone 9, Norgarrd's float at the upper limits of the oyster grounds. The weekly spat counts from these zonal stations are presented in table 19.

Table 18

Number of spat attached to 100 native shells in weekly fresh-cultch bags at Main Stations I, II, and III, May 31 to September 9, 1940. Two weekly series.

Dates		Number	Number of Spat		
Placed	Removed	of Days	Main Station I	Main Station II	Main Station III
May 31	June 7	7	0	0	0
June 3	June 10	7	0	0	0
June 7	June 14	7	0	0	0
June 10	June 17	7	17	11	20
June 14	June 21	7	76	177	25
June 17	June 24	7	74	76	20
June 21	June 28	7	26	120	151
June 24	July 1	7	26	110	46
June 28	July 5	7	154	180	125
July 1	July 8	7	68	248	175
July 5	July 12	7	54	68	23
July 8	July 15	7	9	14	9
July 12	July 19	7	11	23	3
July 15	July 22	7	0	14	9
July 19	July 26	7	0	0	0
July 22	July 29	7	0	3	11
July 26	Aug. 2	7	11	40	37
July 29	Aug. 5	7	51	54	37
Aug. 2	Aug. 9	7	11	63	51
Aug. 5	Aug. 12	7	0	0	0
Aug. 12	Aug. 20	7	0	0	0
Aug. 16	Aug. 23	7	0	0	0
Aug. 19	Aug. 26	7	0	0	0
Aug. 23	Aug. 30	7	0	0	0
Aug. 26	Sept. 2	7	0	0	0
Aug. 30	Sept. 6	7	0	0	0
Sept. 2	Sept. 9	7	0	0	0
	Totals		588	1201	742

Table 19

Number of spat attached to 100 native shells in weekly fresh-cultch bags, from five separate zonal stations, June 5 to August 21, 1940. One weekly series

Dates		Number	Number of Spat				
Placed	Removed	of Days	Zone 4 Station 3	Zone 3 Station 5	Zone 5 Station 2	Zone 6 Station 1	Zone 9 Station 2
June 5	June 12	7	0	0	0	0	0
June 12	June 19	7	3	9	93	20	110
June 19	June 26	7	17	17	171	25	807
June 26	July 3	7	23	29	296	60	322
July 3	July 10	7	0	0	208	31	393
July 10	July 17	7	0	0	9	11	46
July 17	July 24	7	0	0	0	0	0
July 24	July 31	7	0	0	0	0	37
July 31	Aug. 7	7	17	9	213	17	63
Aug. 7	Aug. 14	7	0	0	0	0	0
Aug. 14	Aug. 21	7	0	0	0	0	0
Totals			60	64	990	164	1,778

Since free-swimming larvae were first found in plankton samples on May 10, and were not present on May 6,7, and 9, (table 10), and since no marked salinity change occurred after May 15, (table 52), it could have been anticipated that initial setting would occur about 30 days after May 15 or on June 15. Initial setting began on June 14 or possibly on June 15 or 16.

Within the 1940 setting season, June 14 to August 5, two distinct periods occurred. The first period, from June 14 to July 17, was of considerably more intensity and duration than the later period from July 26 to August 5. Between the two setting periods, apparently no larvae were attached to cultch at any station between July 17 and July 26, a period of nine days. At some of the stations there was no larval setting from July 3 to July 31, a period of 28 days. The indications were that the non-setting period was of longer duration at down-bay stations, and progressively shorter for up-river stations. No explanation for this period of non-setting was discovered.

Definitely, station 2 in zone 9 was the most important spat-collecting location used in 1940. Station 2 in zone 5, Poole's slough, was of considerable importance, as was Main Station II.

From the use of stations 4 and 5 in zone 3, it was proven that native oyster larvae set in very limited numbers below the lower limits of the oyster grounds.

In the study of the 1941 setting season Main Stations II, III, station 2 in zone 5, and station 2 in zone 9 were employed. Main station I, formerly used in 1939 and 1940, was not available because of construction activities. Several of the zonal stations in zones 6 and 3 were discontinued in 1941 due to their relative unimportance the previous year. Tables 20 and 21 give results of the spat counts made from these stations.

Table 20

Number of spat attached to 100 native shells in weekly fresh-cultch bags at Main Stations II and III and zone 9, station 2 May 5 to September 15, 1941. Two weekly series

Dates Placed	Dates Removed	Number of Days	Number of Spat: Main Station II	Number of Spat: Main Station III	Number of Spat: Zone 9 Station 2
May 5	May 12	7	0		
May 9	May 16	7	0		
May 12	May 19	7	0		
May 16	May 23	7	0		
May 19	May 26	7	0	0	
May 26	June 2	7	0	0	
May 30	June 6	7	0	0	
June 2	June 9	7	0	0	
June 6	June 13	7	0	0	
June 9	June 16	7	0	0	0
June 13	June 20	7	0	0	0
June 16	June 23	7	9	6	3
June 20	June 27	7	30	6	14
June 23	June 30	7	11	48	63
June 27	July 4	7	34	9	20
June 30	July 7	7	74	3	42
July 4	July 11	7	197	120	116
July 7	July 14	7	148	51	134
July 11	July 18	7	26	14	37
July 14	July 21	7	17	20	20
July 18	July 25	7	114	85	103
July 21	July 28	7	74	66	138
July 25	Aug. 1	7	17	9	17
July 28	Aug. 4	7	0	0	0
Aug. 1	Aug. 8	7	0	0	0
Aug. 4	Aug. 11	7	0	0	0
Aug. 8	Aug. 15	7	0	0	0
Aug. 11	Aug. 18	7	0	0	0
Aug. 15	Aug. 22	7	0	0	0
Aug. 18	Aug. 25	7	0	0	0
Aug. 22	Aug. 29	7	0	0	0
Aug. 25	Sept. 1	7	14	3	3
Aug. 29	Sept. 5	7	9	3	3
Sept. 1	Sept. 8	7	0	0	0
Sept. 5	Sept. 12	7	0	0	0
Sept. 8	Sept. 15	7	0	0	0
		Totals	761	443	713

Table 21

Number of spat attached to 100 native shells in weekly fresh-cultch bags at Main Station II and Zone 5, station 2 May 28 to September 15, 1941. One Weekly series

Dates		Number	Number of Spat	
Placed	Removed	of Days	Main Station II	Zone 5, station 2
May 28	June 4	7	0	0
June 4	June 11	7	0	0
June 11	June 18	7	0	0
June 18	June 25	7	9	9
June 25	July 2	7	23	23
July 2	July 9	7	86	120
July 9	July 16	7	37	51
July 16	July 23	7	88	66
July 23	July 30	7	54	80
July 30	Aug. 6	7	0	0
Aug. 6	Aug. 13	7	0	0
Aug. 13	Aug. 20	7	0	0
Aug. 20	Aug. 27	7	0	0
Aug. 27	Sept. 3	7	9	-
Sept. 3	Sept. 10	7	0	-
Sept. 10	Sept. 15	5	0	-
	Totals		306	349

From the 1941 plankton examinations, table 11, it was evident that up to May 23 the free-swimming larvae had been killed by low-water salinities occurring between May 5 and May 23. On May 24, a few active swimming larvae were present in the plankton and no dead ones were found after that time. Therefore, it was expected that initial setting would begin about 30 days later or on June 23. Apparently, setting commenced on June 22 or during the early morning hours of June 23, since the shells examined on the morning of June 23 from Main Stations II, III, and station 2 in zone 9 had a few spat that appeared to have become attached only a few hours before the fresh-cultch bags were removed from the water.

Setting was continuous at all stations from June 22 or 23 to July 28. During this time two maximal setting periods were evident. The first was from July 7 to 11 and the second extended from July 21 to 25. Both of these maxima occurred during the spring tides when low tides were zero or below zero in height. This phenomenon of maximal settings being correlated with the extreme low tides had been noted during the setting seasons of 1939 and 1940. Apparently, such a tidal effect carries the free-swimming larvae in greater concentrations over the oyster grounds in zones 9 to 4 from upper river locations in zones 9, 10, and 11, than would be the case during the "hold up" low tides. From examination of relative numbers of free-swimming larvae in plankton collections, this would seem to be the situation.

In 1941, no setting occurred at any of the stations from the morning of July 28 to sometime between August 29 and September 1, a period of about one month. This non-setting period was particularly peculiar because free-swimming larvae were present in the plankton samples during that time and spawning was continuous previous to and for most of this period. The only explanation that appeared feasible was that high salinities might have inhibited setting. In support of this theory no rainfall occurred in the area from July 19 until August 22, except for .02 of an inch on August 9, which was not sufficient to affect the water salinity. Then, from August 23 to September 1, there was a period of marked rains on seven different days. The daily salinity readings from Main Station II did show a slight upward trend just previous to and during the non-setting period. Then there was a slight drop in salinity readings about the time of the late but small setting period from August 29 to September. No free-swimming larvae were found in the plankton after September 1 and no larval setting occurred after that date.

Since plankton samples revealed the presence of free-swimming larvae as far up-river as station 4 in zone 11, table 10, fresh-cultch bags were placed in several locations in zones 10, 11, and 12 at various dates during the 1940 setting season. No attempt was made to count the spat on the shells of these bags other than to record their presence or absences.

Table 22

The presence or absence of spat on shells in cultch bags placed above the upper limits of the oyster grounds in zones 10, 11, and 12. *1

Location	Date bag placed	Date bag removed	Remarks
Zone 10, Station 1	June 21	August 1	Spat present-numerous
Zone 10, Station 1	July 31	Sept. 12	Spat present
Zone 10, Station 3	June 24	July 17	Spat present-numerous
Zone 10, Station 3	June 24	June 28	Spat present
Zone 10, Station 4	June 22	June 28	Spat present
Zone 11, Station 1	June 21	July 6	Spat present
Zone 11, Station 1	July 5	Aug. 10	Spat present-numerous
Zone 11, Station 2	June 21	July 6	Spat present
Zone 11, Station 2	July 5	Aug. 10	Spat present
Zone 11, Station 3	July 5	Aug. 10	Spat present
Zone 11, Station 4	July 5	Aug. 10	Spat present-few
Zone 12, Station 1	July 5	Aug. 10	Spat absent
Zone 12, Station 3	July 5	Aug. 10	Spat absent
Zone 12, Station 4	July 5	Aug. 10	Spat absent

The results as shown in table 22 proved that setting does take place in up-river areas above the upper limits of the oyster ground, throughout zones 10 and 11 and that setting does not normally occur in any part of zone 12. Apparently, the young oysters of the year in zones 10 and 11 are usually killed by the effects of fresh or nearly fresh water at times of the heavy winter rains. This type of mortality was substantiated by placing oysters in wire bags in several locations in zones 10 and 11 during the winter of 1939-40. However, small live native oysters resulting from the 1940 setting season were found during the 1941 summer attached to the undersides

1. Note.- Most of the data comprising this table was obtained by Galo S. Welborn, senior student, Department of Fish and Game Management, Oregon State College.

of rocks at stations 4 and 5 in zone 10. The rainfall of the 1940-41 winter was far below normal as shown by records taken at Newport, Oregon, and given in table 23.

Table 23

Departures from the mean rainfall in inches at Newport, Oregon, during the winter of 1940-41. (U.S. Weather Bureau Reports)

Departures From the Monthly Mean Rainfall				
November	December	January	February	March
-2.88	-3.41	+2.41	-5.84	-5.33

For the purposes of ascertaining some of the other important setting activities of the native oyster in Yaquina bay, large eastern and Japanese oyster shells were strung on wires and submerged from floating docks. In this manner, the shells were in a horizontal position and rose and fell with tidal changes, but never rested on the bottom. On June 18, 1939, one string of these shells was placed in the water at Main Station II and another at Main Station III. Later in the season, these strung shells were removed and examined for spat on smooth surfaces of the shells. In counting the spat, each cultch shell was recorded as to depth from surface and whether the smooth surface was up or down. The results of these tabulations are given in tables 24 and 25.

Table 24

A frequency table and tabulation of the number of spat on smooth surfaces of strung shells in relation to depth and position, placed in water at Main Station II, July 18 to August 14, 1939.

Number of spat per shell	Frequency of spat occurrence on smooth surfaces of shells.					
	3 to 4 foot level		4 to 5 foot level		5 to 6 foot level	
	Up	Down	Up	Down	Up	Down
0	4	0	6	0	1	0
1	4	2	4	0	3	0
2	3	3	1	0	1	2
3	1	3	1	1	4	4
4	0	1	0	2	1	1
5	0	0	0	1	0	3
6	0	0	0	0	0	0
7	0	1	0	1	2	0
8	0	0	0	1	0	0
9	0	0	0	0	0	1
10	0	1	0	2	0	0
11	0	0	0	1	0	1
12	0	1	0	2	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
16	0	0	0	1	0	0

	3 to 4 foot level		4 to 5 foot level		5 to 6 foot level	
Number of spat on 12 shells	Up	down	Up	Down	Up	Down
	13	50	9	102	35	55
Average number of spat on 12 shells	1.08	4.16	.75	8.5	2.92	4.59

Table 25

A frequency table and tabulation of the number of spat on smooth surfaces of strung shells in relation to depth and position, placed in water at Main Station III, July 18 to August 22, 1939.

Number of spat per shell	Frequency of spat occurrence on smooth surfaces of shells					
	3 to 4 foot level		4 to 5 foot level		5 to 6 foot level	
	Up	Down	Up	Down	Up	Down
0	5	0	2	0	0	0
1	3	1	1	1	4	0
2	1	1	3	1	2	1
3	2	2	5	2	3	1
4	0	0	0	2	0	1
5	1	3	1	2	3	1
6	0	0	0	1	0	3
7	0	2	0	0	0	3
8	0	2	0	1	0	1
9	0	0	0	0	0	0
10	0	0	0	2	0	0
11	0	0	0	0	0	0
12	0	1	0	0	0	1
Number of spat on 12 shells	3 to 4 foot level		4 to 5 foot level		5 to 6 foot level	
	Up	Down	Up	Down	Up	Down
	16	66	27	61	32	73
Average number of spat on 12 shells	1.33	5.5	2.25	5.08	2.66	6.08

From these strung-shell experiments there were definite indications that the smooth sides of shells or cultch that were in an upper horizontal position in relation to the surface do not catch nearly so many spat as the smooth surfaces that were in an under horizontal position. This can be explained on the basis that the free-swimming larva generally swims in an inverted position and the "foot" used in adhering to cultch projects more or less upward. Consequently, the larvae coming up from below a surface have better opportunity of attaching than if coming downward. The fact that the larvae set with greater frequency on the under side of cultch was first noted in Puget Sound by Hopkins (1937) who stated, "Larvae set most frequently on the under horizontal surface, while the fewest catch on the upper surface." The substantiation of this setting condition in Yaquina bay should be of importance, if mechanical spat collectors are to be used in lieu of shells, which are extremely limited in the area.

Also, from these strung shell experiments, there was a slight indication that there was an increase in the amount of setting as the water depth increases from the surface. Tests were made in this connection during the 1941 setting season when, on June 28, a series of six shell bags were suspended from a float at Main Station II, two to three feet from the surface of the water. The water at the float was about 7 feet at zero low tide. Immediately under the float, another series of six shell bags were lowered to the bottom on June 30. Both series of bags were taken from the water on August 18 and the shells were examined for spat. The results are presented in tables 26 and 27.

Table 26

Number of spat attached to 100 native shells in wire bags suspended from float at Main Station II, June 28 to August 18, 1941. Series A.

Shell Bag Number	Number of Spat per 100 Shells
1 A	281
2 A	275
3 A	228
4 A	251
5 A	205
6 A	222
Total spat on 600 shells-all bags	1,456
Average number of spat on 100 shells all bags-------------------	242.6
Average number of spat per shell-----	2.42

Table 27

Number of spat attached to 100 native shells in wire bags placed on the bottom at Main Station II, June 30 to August 18, 1941. Series B.

Shell Bag Number	Number of Spat per 100 shells
1 B	986
2 B	1,237
3 B	758
4 B	792
5 B	815
6 B	775
Total number of spat on 600 shells all bags------------	5,363
Average number of spat on 100 shells -- all bags-----	893.8
Average number of spat per shell-----	8.9

This experiment in 1941 definitely proved that there was a marked increase in the efficiency of shell cultch when placed on the bottom over cultch located near the surface of the water. However, the controlling factor may be that fouling was more pronounced on shells near the surface; since shells in the floating series A were heavily coated with algae and tube dwelling shrimp and the shells from the bottom series B were relatively clean. In this connection, it was frequently noted in the collection of spat by means of shell bags, strung shells, and cement-coated structures that within a few feet of the water's surfaces there was generally much fouling. This fouling was more pronounced in some locations than others and appeared to vary at different seasonal times.

On several occasions during the setting seasons of 1940 and 1941, wire shell bags were placed at different height levels in the inter-tidal area, from high-water mark to about one foot below mean low-water. The locations used to determine if setting took place in inter-tidal areas were the mud flats of zones 7,8,9 and 10.

It was necessary to make estimates of the heights where shell bags were placed. From these studies, it was evident that setting did take place in the inter-tidal area from low-water to about four feet above. There appeared to be a positive progression of intensity in setting from the higher levels at about four feet to the minus low-water level. Perhaps setting takes place at progressively higher levels in the inter-tidal area as the distance up-river is increased. This last item could not be proven without engineering equipment and assistance.

The other uses, besides oystering, of the water from zone 4 to the end of zone 11, namely navigation and commercial fishing, necessitated the locating of areas of good larval setting at which spat could be collected without interfering with boats and drifting gill nets. A number of areas were explored, and several types of spat-collecting devices were employed. Although detailed counts of the spat collected in these many tests were made, only brief summaries of the general findings were presented in this report.

Two types of cement-coated structures were investigated as possible cultch, since there is a definite lack of shell at Yaquina bay for an adequately managed oyster industry. Cement-covered egg case cartons, used extensively in the dikes in Puget Sound, were submerged in wooden crates and suspended from floating docks at water depths ranging from three to five feet. Within a few days after placing in the water, these cartons became so heavily coated with algae and silt as to render them practically useless. Further investigation with this type of collector should be made in the lower portions of the inter-tidal areas, since it was

Figure 21.

Construction of Humbolt bay spat collector.

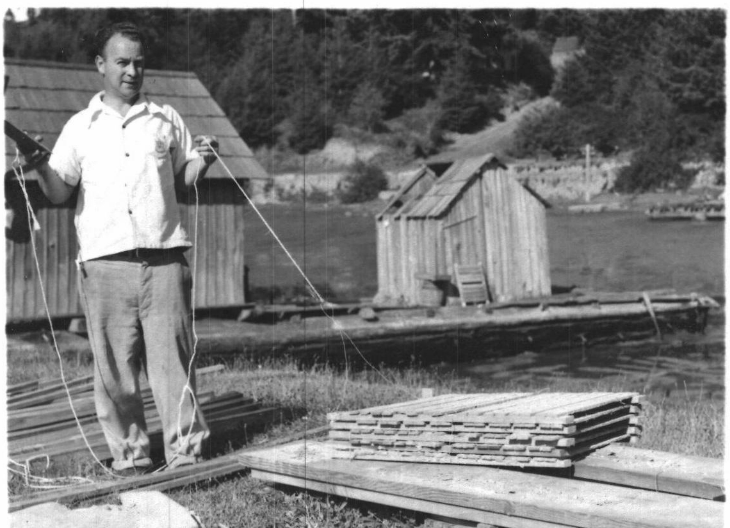

Figure 22.

A modified Humbolt bay spat collector.

Figure 23.

A shell crate collector.

Wire bag filled with native oyster shells.

Figure 25.

Wire bags with shells in a stack.

Figure 26.

Wire bags with broken Japanese oyster shells.

frequently noted that cultch of all kinds remained relatively clean of algae when placed on the mud flats.

A modified type of Humbolt bay spat collector (Bonnott 1937) figure 21 and 22 made mainly of laths and coated with cement, was used in the 1939 experiments. Of the fifteen collectors placed in various locations and marked with buoys attached to ropes only four were recovered. The loss was caused by a variety of operations such as logging, commercial fishing and navigation. An examination of these four collectors indicated that this type of a structure would be of considerable value, if located in areas where they would not be disturbed. Perhaps, they might be used in the lower portion of the inter-tidal zone.

Shell crates used in some oyster areas of the Atlantic coast, constructed of laths to form a triangular box, figure 23, were used on some of the mud flats and in shallow water in zones 9 and 10. These crates were filled with eastern and Japanese oyster shells. The native shells being too small in size usually fell out between the laths. The main disadvantage of the crate collectors was the frequency with which they were upset by the tidal currents and thus allowing the shells to become heavily coated with mud. These collectors may be improved by making the under supports longer, thus allowing for greater anchorage in the mud.

The collectors which gave the most promise were wire bags filled with shells, figure 24, 25, and 26. A description and directions for making these bags as given by Galtsoff, Prytherch and McMillin follows (1930):

> "The container consisted of a bag of chicken wire having a mesh of $1\frac{1}{2}$ to 2 inches and was filled with oyster, scallop, clam, and sea scallop shells. The wire bags had a capacity of 1 bushel and were cylindrical in shape, with a length of 36 inches and a diameter of

12 inches. The wire mesh was purchased in 24-inch rolls and then cut into pieces 3 feet long. Each piece of wire was then folded lengthwise and the ends closed either by twisting the wires together or by weaving a short piece of No. 18 annealed wire through them. The wire bags are now ready to be filled, and in this form they can be easily stored until it is time for shell planting. The filling of the bags was accomplished easily by placing them in an oblong wood box, 36" by 8" by 8", and adding sufficient shells to fill them to the top. The bags were then closed tightly by drawing and weaving the edges together with galvanized, annealed wire No. 18. The bags of shells can be handled roughly without breaking open. They can be set out singly or can be stacked in tiers several feet high, thereby greatly increasing the quantity of cultch that can be planted on a given area of bottom."

Excellent setting was obtained in 1941 with these wire bags on the bottom at Main Station II and fair set was taken on the mud flats at station 2 in zone 7.

The spreading of native shells on the bottom in zone 7 just before the maximum larval setting resulted in excellent returns in 1941, in spite of the fact that setting was below normal during this year.

The locations which appeared to be most favorable for collecting of spat were in the lower portion of zone 10, especially the shallow water portion of the eastern part of the river, known as the inside channel; Poole's Slough in the vicinity of station 2 in zone 5; Main Station II; and the lower portion of the intertidal area in zone 7, on the north bank. Undoubtedly, there are many other areas, yet undiscovered, which will be good spat-collecting grounds. On the whole, it appeared that zones 4, lower 5 (main river), and 6 were not, at the present, satisfactory as collecting areas.

Growth of Young Oysters

In the course of making spat counts during the 1940 season observations seemed to indicate that faster growth occurred in

Table 28

Comparative growths attained by young oysters taken at three different stations during the summer of 1940.

Location	Number of Oysters	Date of Placing Cultch	Date of Examining Oysters	Interval of Days Since Placing Cultch	Average Length (mm)	Average Height (mm)	Range of Length (mm)	Range of Height (mm)
Main Station II, zone 7	38	7/5/40	9/5/40	62	5.62	5.30	2.0-10.0	1.8-8.8
Main Station III, zone 9	29	7/5/40	9/2/40	59	6.38	6.30	2.8-13.0	2.4-11.2
(Mill 4) Station 4, zone 10	16	7/6/40	9/12/40	68	11.25	11.05	3.4-18.5	2.6-17.6

young oysters taken from upper portions of the bay than in those from lower regions. In order to ascertain the extent of the growth differences, length and height measurements were taken of samples of young oysters which had grown during approximately comparable intervals at each of three stations in zones 7, 9, and 10. Data pertaining to these three groups of oysters is presented in table 28.

An inspection of table 28 reveals a tendency for a faster rate of growth in oysters of zero age in those zones located farther up the bay. For instance, the average length and height of the sample of young oysters from zone 10 were 11.25 mm and 11.05 mm as compared with average measurements of 6.38 mm and 6.30 mm for zone 9, and 5.62 mm and 5.30 mm for zone 7. Likewise, increases in the ranges of length and height measurements of oysters grown up-river are seen, these ranges being 3.4 to 18.5 mm and 2.6 to 17.6 mm, respectively, for zone 10; 2.8 to 13.0 mm and 2.4 to 11.2 mm, respectively for zone 9; and 2.0 to 10.0 and 1.8 to 8.8 mm, respectively, for zone 7.

Because of the small number of oysters measured in each sample and because of the question as to whether setting occurred simultaneously in all three zones, these growth comparisons cannot be considered as entirely reliable. However, the tendencies which were indicated suggested the need for a more controlled and intensive study of growth relationships to be conducted at a future date.

Mortalities of Young Oysters

Following the setting season of 1939, various observations were made of the young oysters of the year, known as the zero-age class, for the purposes of determining the amounts of mortality taking place during definite periods of time; and, if possible, the causes of such mortalities. This study was undertaken by the checking of mortalities occurring under natural conditions and conducting tests under more or less controlled conditions.

In the study of mortalities under natural conditions, native shell cultch, which was placed on the natural oyster beds at station 1 in zone 8 during early June 1939, was tonged at different times from August 28, 1939 to May 2, 1940, for the purposes of ascertaining the following items:

(1) Number of young oysters of the zero-age class on native shells at the end of 1939 setting season.

(2) Number of young oysters of the zero-age class present at various periods during the fall, winter and spring.

(3) The seasonal trend in mortalities of the young oysters of the zero-age class during the fall, winter and spring.

The number of young oysters found on smooth surfaces only of native oyster shell collected at different times during the observations are given in tables 29 to 39. A summarization of these samples is presented in table 40.

Table 29

Number of young oysters, zero-age class, found on smooth surfaces of 100 native shells, tonged from station 1 in zone 8. August 28, 1939.

No. of young oysters per shell, smooth surface	Frequency	Total No. of young oysters
0	16	0
1	17	17
2	14	28
3	9	27
4	3	12
5	6	30
6	8	48
7	6	42
8	7	56
9	3	27
10	0	0
11	2	22
12	0	0
13	2	26
14	1	14
15	2	30
16	2	32
17	1	17
18	0	0
19	0	0
20	0	0
21	0	0
22	1	22
Totals	100	450

Average number of young oysters per smooth surface - 4.50

Table 30

Number of young oysters, zero age class, found on smooth surfaces of 100 native oysters, tonged from station 1 zone 8, September 12, 1939.

No. of young oysters per shell, smooth surface	Frequency	Total Number of Young Oysters
0	30	0
1	14	14
2	10	20
3	3	9
4	8	32
5	4	20
6	11	66
7	1	7
8	2	16
9	3	27
10	1	20
11	1	11
12	3	36
13	0	0
14	2	28
15	3	45
16	0	0
17	0	0
18	0	0
19	2	38
20	0	0
21	1	21
22	0	0
23	0	0
24	0	0
25	0	0
26	1	26
Total	100	436

(a) Average number of young oysters per smooth surface= 4.36

Table 31

Number of young oysters, zero age class, on smooth surfaces of 100 native oyster shells, tonged from station 1 in zone 8 in a drifting collection covering approximately ¼ mile upstream. October 28, 1939.

No. of Young Oysters per Shell, Smooth Surface	Frequency	Total Number of Young Oysters, Zero Age Class
0	54	0
1	17	17
2	13	26
3	5	15
4	6	24
5	3	15
6	1	6
7	0	0
8	0	0
9	0	0
10	0	0
11	0	0
12	0	0
13	0	0
14	1	14
Totals	100	117

(a) Average number of young oysters per smooth surface = 1.17

Table 32

Number of young oysters, zero age class, found on the smooth surfaces of 100 native oyster shells, tonged from station 1 in zone 8, November 5, 1939.

No. of Young Oysters per Shell, Smooth Surface	Frequency	Total Number of Young Oysters, Zero Age Class
0	49	0
1	13	13
2	13	26
3	3	9
4	9	36
5	2	10
6	5	30
7	2	14
8	2	16
9	0	0
10	2	20
Totals	100	174

(a) Average number of young oysters per smooth surface = 1.74

Table 33

Number of young oysters, zero age class, found on the smooth surfaces of 100 native oyster shells, tonged from station 1 in zone 8, December 12, 1939.

Number of Young Oysters Per Shell - Smooth Surface	Frequency	Total Number of Young Oysters, Zero Age Class
0	62	0
1	14	14
2	8	16
3	6	18
4	2	8
5	2	10
6	3	18
7	1	7
8	1	8
9	1	9
Total	100	108

Average number of young oysters per smooth surface = 1.08

Table 34

Number of young oysters, zero age class, found on the smooth surfaces of 100 native oyster shells, tonged from station 1 in zone 8, December 22, 1939.

Number of Young Oysters Per Shell - Smooth Surface	Frequency	Total Number of Young Oysters, Zero Age Class
0	57	0
1	13	13
2	10	20
3	5	15
4	4	16
5	7	35
6	2	12
7	1	7
8	1	8
Total	100	126

Average number of young oysters per smooth surface = 1.26

Table 35

Number of young oysters, zero age class, found on smooth surfaces of 200 Native oyster shells, tonged from station 1 in zone 8, February 7, 1940.

No. of young oysters per shell-smooth surface	Frequency	Total No. of young oysters, zero age class
0	104	0
1	38	38
2	24	48
3	11	33
4	8	48
5	6	30
6	2	12
7	3	21
8	2	16
9	0	0
10	0	0
11	0	0
12	1	12
13	1	13
Total	200	271 young oysters

(a) Average number of young oysters per smooth surface = 1.35

Table 36

Number of young oysters, zero age class, found on smooth surfaces of 300 native oyster shells, tonged from station 1 in zone 8, March 1, 1940

No. of young oysters per shell - smooth surface	Frequency	Total number of young oysters, zero age class
0	150	0
1	62	62
2	25	50
3	15	45
4	19	76
5	5	25
6	11	66
7	5	35
8	5	40
9	1	9
10	1	10
11	0	0
12	0	0
13	0	0
14	0	0
15	0	0
16	1	16
Totals	300	434

(a) Average number of young oysters per smooth surface = 1.44

Table 37

Number of young oysters, zero age class, found on the smooth surfaces of 1,669 native oyster shells, tonged from station 1 in zone 8, April 23, 1940.

Number of young oysters per shell-smooth surface	Frequency	Total number of young oysters, zero age class
0	978	0
1	291	291
2	188	376
3	100	300
4	53	212
5	27	135
6	7	42
7	13	91
8	6	48
9	2	18
10	1	10
11	0	0
12	2	24
13	1	13
Totals	1,669	1,560

Average number of young oysters on smooth surface per native shell = .935

Table 38

Number of young oysters, zero age class, found on the smooth surfaces of 150 native oyster shells, tonged from station 1 in zone 8, May 2, 1940.

Number of young oysters per shell-smooth surface	Frequency	Total number of young oysters, zero age class
0	91	0
1	30	30
2	15	30
3	7	21
4	1	4
5	3	15
6	1	6
7	1	7
8	0	0
9	1	9
Totals	150	122

(a) Average number of young oysters per shell on smooth surface = .813

Table 39

Number of young oysters, zero-age class, found on the smooth surfaces of 100 native shells tonged from station 1 in zone 8, May 24, 1940.

Number of young oysters per smooth surface	Frequency	Total number of young oysters
0	63	0
1	16	16
2	8	16
3	3	9
4	2	8
5	5	25
6	2	12
7	0	0
8	0	0
9	1	9
	Totals 100	95

Average number of young oysters per 100 shells, smooth surface = .95

Table 40

A summary of the number of young oysters, zero-age class, found on smooth surfaces of native oyster shells at various dates from August 28, 1939, to May 24, 1940, tonged from station 1 in zone 8.

Date of Collection	Number of shells examined	No. of young oysters zero-age class on smooth surfaces of shells	Average number of young oysters, zero-age class, on smooth surfaces per shell
Aug. 28, 1939	100	450	4.50
Sept. 12, 1939	100	436	4.36
Oct. 28, 1939	100	117	1.17
Nov. 5, 1939	100	174	1.74
Dec. 12, 1939	100	126	1.26
Dec. 22, 1939	100	108	1.08
Feb. 7, 1940	200	271	1.35
March 1, 1940	300	434	1.44
Apr. 23, 1940	1,669	1,560	.935
May 2, 1940	150	122	.813
May 24, 1940	100	95	.95

Some of the significant findings from the observations made at station 1 in zone 8 of the mortalities of young oysters were:

(1) At the end of August 1939, there was an average of 4.5 young oysters of zero-age class per shell on smooth surface.

(2) There was a marked reduction in numbers of young oysters by the last of October 1939.

(3) By the last of April and to the last of May 1940, there was less than one young oyster of zero-age class per shell on the smooth surface.

(4) From the last of August 1939 to the last of May 1940, there had been about a 79 per cent mortality of the young oysters resulting from the 1939 setting season on the natural oyster grounds in zone 8.

(5) The suspected causes of deaths were: (a) bryozoan growth covering the young oysters, particularly in September and October; (b) smothering of young oysters by silt deposits during times of freshets; (c) an undetermined predator as evidenced by damaged valves (shells) in some of dead oysters; (d) barnacles by crowding out some young oysters.

In order to check on the mortality of young oysters of the zero-age class under more controlled conditions than the periodic counts on native oyster shells tonged from the oyster grounds, a special study was made from September 30, 1939, to May 10, 1940. Native oyster shells were tonged from the station 1 in zone 8. Young oysters recently set on these shells were counted with the aid of a binocular scope and a numbered metal tag was attached to each cultch shell. A card index file was then devised using one card for each numbered shell. Each card listed the assigned number and outline drawing of the shell and the location of all young oysters, barnacles and bryozoan growths. The shells were then placed in three separate wire bags, each bag containing shells with a different series of numbers. The bags were so constructed that the shells could be arranged in double rows. These bags with shells were lowered from Main Station II and allowed to lie on the bottom of the bay. Every effort was made to closely approach natural conditions as actually encountered on the oyster beds.

At approximately monthly intervals, bags number 1 and number 2 were raised; the shells were washed in salt water and examined. The live and dead oysters were counted on each shell and the probable causes of mortality listed. The examined shells were then placed in their respective bags and returned to the bottom of the bay. Bag number 3 was allowed to remain lying on the bottom throughout the study period and was raised only once on April 10, 1940, when the young oyster mortality was checked. The purposes of this study were:

(1) To determine the total mortality of young oysters occurring from the time shortly following setting until spring.

(2) To ascertain some of the major causes of young oyster mortality during the first year of life so that cultural methods for controlling such inimical factors may be developed.

When the young oysters in bags 1 and 2 were checked at the end of the first month, the shells used as cultch were found to be heavily coated with barnacle and bryozoan growths, and the mortality of the young oysters was found to be quite high, 11.4 per cent in bag number 1, and 18.1 per cent in bag number two. The bryozoan growth appeared to grow most rapidly during the late summer and fall months, and, like the barnacles, did not increase greatly in size under conditions of lower water temperatures and lower salinities experienced in the winter months. Then, after the first two months, the percentage of young oyster mortality in bags 1 and 2 fell to a low level which was almost constantly maintained until the end of the study.

During the winter freshet periods, the water over the entire oyster grounds was extremely dirty, due to tremendous amounts of silt. When bags 1 and 2 were lifted from the bottom of the bay during the winter months, the shells were generally heavily coated with silt. The shells in these two bags, however, were always washed and, apparently, the temporary silt had only a slight effect upon the mortality of the young oysters. On the other hand, bag number 3 was allowed to remain on the bottom of the bay for the full period, from September 30, 1939 to April 10, 1940, and when finally raised, both the bag and shells were heavily covered with silt and mud. Oyster mortality in this bag for the period of study amounted to 74.1 per cent.

In these controlled studies, some mortalities of young oysters were noted which were apparently caused by predators, for the shells of the young oysters were sometimes crushed or cracked. Although no definite proof of predatory species involved was established, the yellow Shore Crab, *Hemigrapus oregonensis* (Dana) was suspected. In addition to the finding of numbers of this crab in bags when raised, a fish (Blenny) species undetermined, was found frequently among the shells. However, only a small percentage of young oyster mortality was believed to be due to predators.

A summary of data obtained from these mortality studies of young oysters, zero age class, in bags 1,2, and 3 follows:

Bag No. 1 - Raised at approximately monthly intervals.

Total number of native shells used as cultch---------- 96

Total number of young oysters present on September 30, 1939--------------------------------371

Total number of young oysters dying during the period of September 30, 1939, to May 10, 1940 ---------------------------------------111

Total percentage of mortality of young oysters during the period studied------------------------ 29.9%

Bag No. 2 - Raised at approximately monthly intervals.
Total number of native shells used as cultch---------- 86
Total number of young oysters present on October 14, 1939---------------------------------211
Total number of youngoysters dying during the period October 14, 1939 to April 24, 1940-------- 81
Total percentage of mortality of young oysters during the period studied------------------------ 38.3%

Bag No. 3 - Not raised until end of experiment.
Total number of native shells used as cultch---------- 53
Total number of young oysters present on September 30, 1939---------------------------------112
Total number of young oysters dying during the period September 30, 1939 and April 10, 1940---- 83
Total percentage of mortality of young oysters during the period studied------------------------ 74.1%

Frequent handling of the shells in bags 1 and 2 for the purpose of counting the young oysters may have caused slight damage or injury to young oysters, resulting in some mortality. It had been hoped that a control for handling mortality would be provided by bag number 3, which was checked only once near the end of the study. However, due to the extremely high percentage of young oyster mortality in this bag, resulting largely from smothering effects of silt coating the shells and young oysters, its value as a control for measuring the effects of handling on mortality, was lost. Rust from wire bags occasionally lightly coated some of the young oysters. The mortality, if any, caused by such rust could not be detected.

In order to carry on this study of the mortality of young oysters in Yaquina bay, which appears now to be a major limiting factor in a large sustained yield of the native oyster in that estuary, further investigations should be conducted. Results of these or future studies should be made more accurate by commencing the investigations immediately following the setting season. Wire bags should be painted so as to reduce rusting. Wire, attaching a numerical band to each native shell, should be of monel metal or rustless steel. A greater number of samples should be studied and located in all parts of the oyster grounds; controls should be established to measure the mortality effects of handling; a specific study should be made of measuring the independent effects of bryozoans, barnacles, silt, and predators in which each of the other inimical factors are eliminated as far as possible.

Tentative conclusions from these mortality studies of young oysters are as follows:

(1) Principal mortality of the young oysters in Yaquina bay under natural conditions is probably due to the silting over of cultch and young oysters during the times of extreme winter freshets. This may not hold true in oyster beds located in channels where strong water currents may assist in keeping cultch clean of silt and mud.

(2) In order to prevent excessive mortality of young oysters from the effect of silt, oysters and cultch should be lifted by tonging or cultivated in some manner so as to free shells of heavy coating of silt and mud.

(3) A marked mortality of young oysters occurs during the first two months after the end of the setting period, due to bryozoan growth which covers the young oysters.

(4) Other, perhaps less serious causes of young oyster mortality are competition and crowding by barnacles and predator damage.

Natural Enemies

Unlike many of the other Pacific coast oyster producing areas, important exotic predators and competing organisms have not become established in Yaquina bay with past introductions of the Eastern and Japanese oysters. Extensive dredging operations over all of the oyster grounds in 1940 and 1941 failed to reveal the presence of the Eastern oyster drill, Urosalpinx cinereus; the Japanese oyster drill, Tritonalia japonica; or the Atlantic slipper shell, Crepidula fornicata. Relayed Eastern oysters from the Atlantic coast frequently showed the effects of the attacks of a boring sponge previous to shipment, but there was no evidence found that this shell parasite had been introduced into the area. This lack of exotic inimical organisms was surprising, since little or no inspection has in the past been employed with the introduction of oysters. Perhaps, the extremely low water salinities present over the oyster grounds at various times during the winter have been the limiting factor in the establishment of such oyster pests as drills and slipper shells.

The Red Crab, Cancer productus Randall, figure 27, known locally as the China Crab, was found to be an important predator of the native oyster. On several occasions, oysters were placed on the sandy bottom of station 2 in zone 2 and on the bottoms at stations 2 and 4 in zone 3, just below the low tide level. Invariably, these were destroyed after twenty-four hours in the water. Figure 28 shows a typical illustration of a damaged oyster shell. In order to definitely prove that this crab destroyed oysters, the following experiment was performed during the summer of 1940.

A round wire cage having a 30 inch bottom diameter was constructed and placed in a sunken float box in about three feet of water. Approximately, thirty-five freshly tonged oysters, ranging in length from one-half to two and one-half inches, were placed in the bottom of the cage. Five Red Crabs were then released in this

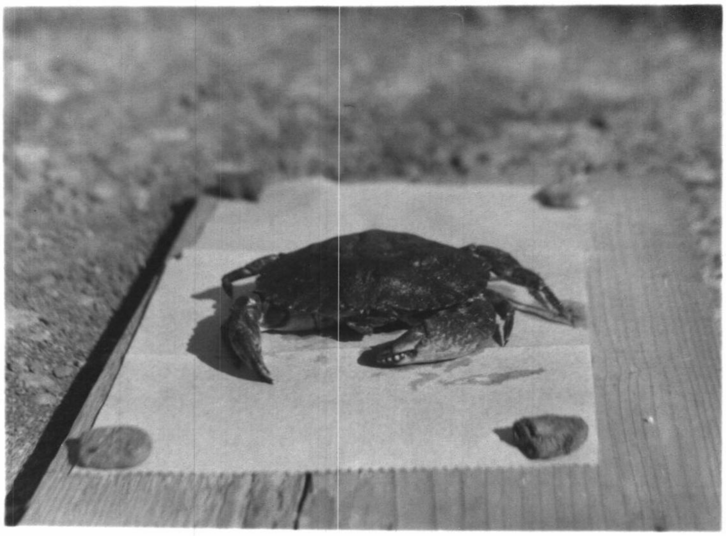

Figure 27.

Red crab, <u>Cancer</u> <u>productus</u>, and important predator of native oysters in zones 2 and 3.

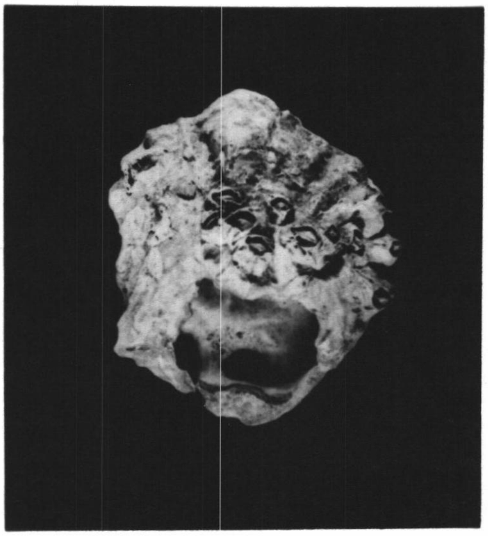

Figure 28.

Damaged native oyster shell by the Red crab.

container. Two of these crabs were large, measuring about five inches across the carapaces, and three were smaller, being about three and one-half inches wide. After 36 hours, the contents of the basket were examined. The shells of every oyster had been cracked and the flesh removed. Many of the shells were broken into small pieces. Since the top and bottom of the container were securely fastened and the wire mesh used in the cage was ½ inch in diameter, no other species of organism capable of destroying the oysters could have entered the container.

Ecologically this crab is restricted to certain areas in Yaquina bay, for structurally it lacks the equipment necessary for straining small particles such as silt from its respiratory water. Consequently, the Red Crab is never plentiful in the muddy areas of the bay, being found in zones 1 to 3. Occasionally it moves into zone 4, and then when the water is exceptionally free of fine debris and very rarely, a few specimens are carried into zones 5,6,7 and 8 by drifting gill nets. Undoubtedly, this crab is the limiting factor for native oysters in zones 2 and 3. Where the natural oyster beds stop down-bay near the end of zone 4, the usual up-bay movement of the crab is delineated. There are a few native oysters in zones 2 and 3, but only in locations in which the Red Crab cannot attack them, such as on the undersides of large rocks. On several occasions, native oysters were transplanted at stations 1 and 2 in zone 2 and at stations 2, 4 and 5 in zones 3 in bags made of one-inch wire mesh. In these containers, protected from the crab, the oysters made excellent body growths and possessed fine flavor. Until control measures for the Red Crab are devised, the extensive tidal flats in zone 2 cannot be successfully developed into dike oyster farms. Otherwise, there is every reason to expect that most of the tidal lands in zones 2 and 3 would make excellent diked areas for producing native oysters.

The Hairy-shore crab, Hemigrapus oregonensis (Dana), which is present in large numbers on the tidal flats from zone 1 into the lower part of zone 11 at least, is apparently an important predator of spat and of small-sized oysters. This crab extends into the water some distance below the zero low-water mark but is not numerous in the deeper water areas. Frequently, small oysters of the year present in the intertidal area of zones 4 to 9 were found destroyed by a predator. On several occasions, oysters or spat about two weeks old were marked on cultch and placed in tidal pools in which this crab was abundant. Usually, the spat were destroyed in a few days, except those in protected situations such as the under side of the hinge of shells. Then spat which had been marked on cultch were placed in a tidal pool and the activities of the crab were noted. Crabs were then seen to pinch off the young oysters and feed on them. The indications are that the Hairy-shore crab is the main reason that native oysters are not numerous in the lower part of the inter-tidal area adjacent to the oyster grounds. Perhaps, the crab may cause considerable mortality to small-sized oysters and spat on some of the oyster beds such as those located in zone 7, which are near to shore and in relatively shallow water. Possible control measures for this crab should be studied at once.

The tube-dwelling amphipod, Corophium spinicorne, found in zones 2 to 11 and perhaps in other locations, is an important fouling organism of cultch. This amphipod constructs small mud or fine sand tubes upon cultch, particularly shells, and thus greatly reduces the spat-catching efficiency of shells that have been in the water a period of 20 or more days. Shells that were in the water one week during the setting periods were not usually affected by this organism. Consequently, exact timing in the placing of cultch in relation to maximum larval setting will minimize the inimical effects of the tube-dwelling amphipod.

The Mud-shrimp, Upogebia pugettensis (Dana), an important pest in the dike areas of Puget Sound, covering oysters with mud and causing leakages in the dikes, was found only in the mud flats of zone 2 in the vicinity of station 3.

The Native Whelk or Drill, Thais lamellosa (Gmelin) was found in zones 1 to 8. The indications were that this indigenous drill was of minor importance as a predator of native oysters. A critical examination of native oysters and shells taken from station 1 in zone 8, February 7, 1940, showed that of 667 oysters, one year or older, examined, three had been killed by the Native Whelk.

Barnacles of several species, as yet undetermined specifically, were found to be important fouling organisms on cultch. Also, there was considerable evidence that these organisms frequently crowded out young oysters of the year. The efficiency of shells used as cultch was markedly reduced in a year's time in the water because of the excessive barnacle growth. Barnacle setting in zones 3 to 10 was greatly reduced in 1941 as compared to 1939 and 1940, as evidenced by the numbers found in the weekly fresh-cultch bags.

Starfish, Pisaster sp., considered one of the most important predators of oysters in other geographic locations, were of minor importance on the native oyster beds in Yaquina bay. Starfish were present in zones 1 to 3, and occasionally were found in the lower limits of the oyster grounds in the vicinity of Main Station I.

If oyster beds are developed in zones 2 and 3, starfish are apt to be important pests in those areas.

An undetermined sponge was found occasionally encrusting cultch shells in zones 4 to 8. The only area of serious fouling caused by this organism was in zone 4.

In the collecting of spat by means of suspended shell bags, strung shells and various types of near-surface collectors, a definite fouling problem was encountered. These collectors, in a few days' time, were frequently coated with an algal growth, Entomorpha sp. In addition, this algae served as a collector of silt and other foreign material so that soon the collectors, usually shells, were so heavily coated as to be of practically no value.

This algae, extending in range over the whole of the native oyster area, is especially prevalent in the summer months, June, July and August, when most of the spatting in the Yaquina bay area takes place.

It seems quite probable, therefore, that this algae tends to become a limiting factor on setting of oyster larvae in the upper surface areas of Yaquina bay.

Three strings of Eastern and Japanese oyster shells were hung from Main Station II on August 15, 1939. A board from the floor was removed and two of these strings were hung in the current under the dock where they received no direct light. The third string was hung in the usual manner at the end of the dock, in the current, and exposed to sunlight.

After two weeks the shells were examined. The shells receiving no sunlight appeared almost as clean as when put down, but the string exposed to direct sunlight was badly fouled. On September 15, 1939, all three strings were lifted for final inspection. The two strings which had received no sunlight proved to be remarkably clean and free from fouling organisms and materials. The string hung in the sunlight was coated to such an extent as to preclude larval setting.

In explanation it may be concluded that the algae requiring a certain amount of sunlight in the essential process of food manufacturing was unable to survive in the semi-darkness under the dock. On the other hand the third string which was hung in the sunlight afforded optimum conditions for algal growth.

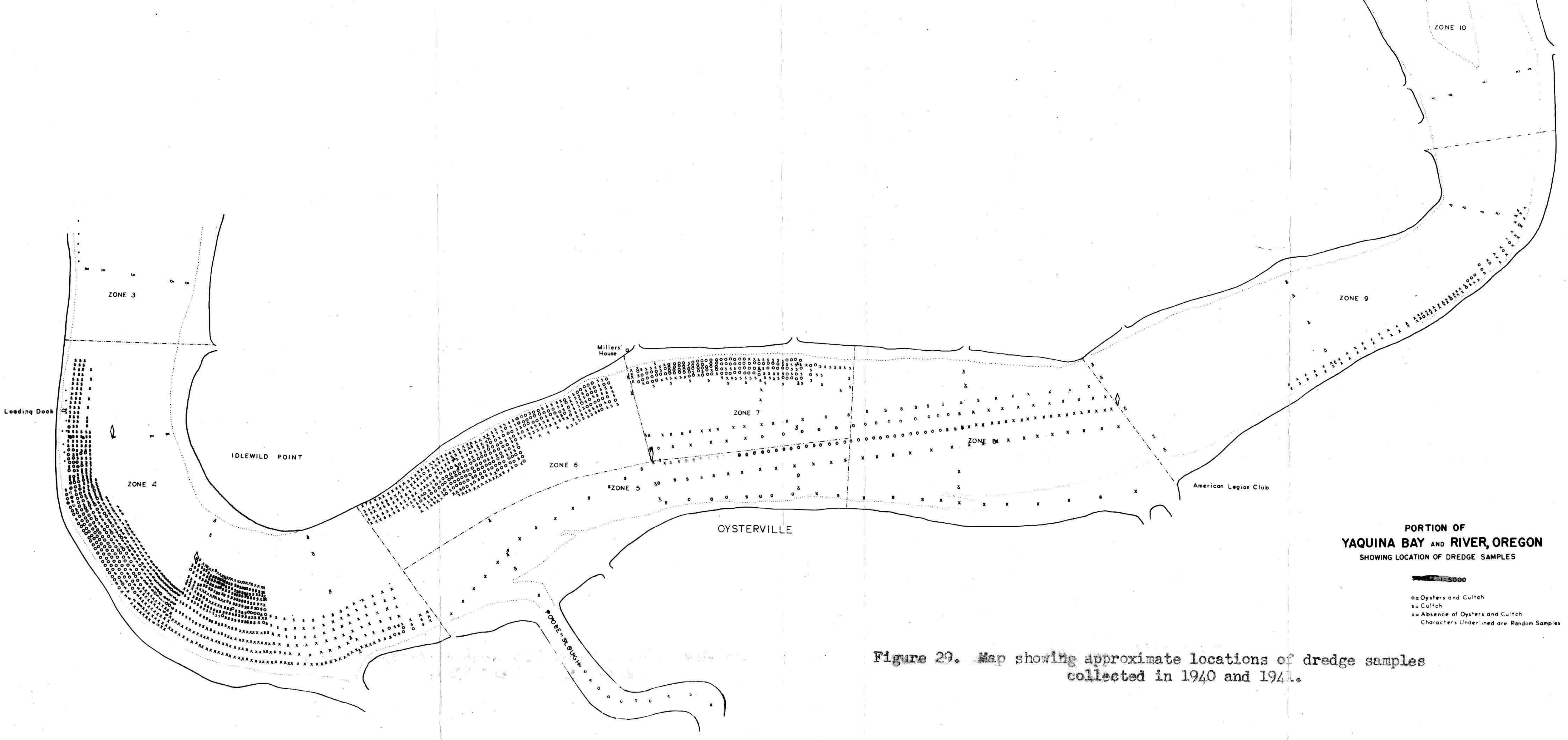

Figure 29. Map showing approximate locations of dredge samples collected in 1940 and 1941.

OYSTER NUMBERS AND GENERAL CONDITION OF THE VARIOUS BEDS

Since almost all of the native oysters in Yaquina bay are covered by water ranging from about 3 to 25 feet at low tide, the general conditions of the various beds were studied by sampling the bottoms with a Petterson dredge. The main purposes of these dredging operations were to determine the relative numbers and sizes of oysters present, the approximate extents of the beds, the cultch conditions, and the bottom types most frequently associated with oyster production.

Most of the sampling was confined in 1940 and 1941 to those oyster production areas shown on the "old oyster map", figure 4, existing in 1908. Some random dredging was done in locations outside of the known oyster beds, but the bulk of work was conducted upon areas known as The Bend and McCaffery Island Flats in zone 4; the Brown Flats in zones 5 and partly in zone 7; Poole's Slough in zone 5; the Oysterville Flats in zone 6; Lyman's Eddy Beds in zone 7; the Lewis Flats in zone 8; the Green Point Beds (the George Lewis and Thomas Ferr Private Beds) in zone 8; and the Shipyard Natural Beds in zone 9. Figure 29 presents the approximate locations of all the dredge samples taken in 1940 and 1941. Without engineering assistance, the exact points of these samples could not be accurately determined and approximations were established by the following procedures:

(1) Flags were placed on laths approximately at 100-foot intervals along the high-tide line adjacent to the area to be sampled.

(2) In the cases of several grounds, where the absence of adequate land marks made impossible an accurate estimation of distances from shore, ~~buoys were placed about 200 feet from the shore,~~ buoys were placed about 300 feet from the shore at convenient intervals along the extent of the oyster bed.

(3) In most cases, beginning 50 feet from the low-tide line at a point opposite the first flag, rows of dredge samples spaced usually at 50 feet and occasionally 100 or more feet apart, were taken parallel or nearly parallel to the shore. Distances between samples in the rows were usually 50 or 100 feet apart, some were taken at greater or lesser intervals.

(4) Usually, but not always, dredging upon each oyster area was continued in all directions until one or more successive samples indicated that the limits of the bed had been passed.

A total of 2,681 dredge samples were taken upon the various oyster beds, 2,473 in 1940 and 208 in 1941. In addition, there were about 60 random or transect samples. The contents of each dredge haul was recorded on a form sheet. This included a record of the bottom type, classification of the cultch and oysters as to kind and amount, the sizes of the oysters, and associated organisms. Although a complete analysis of the data obtained has not as yet been made, the main findings concerning the general conditions of oyster grounds as a whole and each oyster bed separately are evident from present tabulations.

<u>Bottom Types</u>

The edaphic classification of the bottoms encountered were graded upon six types, namely: soft-mud, mud, sandy-mud, muddy-sand, sand and muddy-gravel. <u>Soft-mud</u> was distinguished from <u>mud</u> by the soft and ooze-like condition of the former. Sandy-mud contained a predominance of mud over sand, while muddy-sand showed more sand than mud. The type of bottoms as recorded for 2,657 dredge samples taken from the various oyster beds is presented in relation to presence or non-presence of oysters in table 41. An analysis of data reveals that two bottom types, namely, muddy-sand and sandy-mud with 1,851 samples were the most prevalent bottom types found upon the oyster beds in Yaquina bay. Muddy-sand represented 44.29 per cent and sandy-mud 24.6 per cent of the total bottom types recorded. The remaining 806 samples were taken on sand (15.35 per cent), soft-mud (7.41 per cent), mud (4.85 per cent), and muddy-gravel (2.7 per cent).

Table 41

The occurrence or non-occurrence of oysters in relation to bottom types on the oyster beds in zones 4 to 9, based upon 2,657 dredge samples.

	Bottom Types						
	Soft-mud	Mud	Sandy-mud	Muddy-sand	Sand	Muddy-gravel	Totals All Types
Samples without oysters	186	104	481	817	377	66	2,031
Samples with oysters	11	25	173	380	31	6	626
Total dredge hauls per bottom type	197	129	654	1,197	408	72	2,657

Much of the area in zones 4 to 9 outside of the oyster beds was composed of either sand or soft-mud bottoms, as revealed by random dredge hauls. The presence of these types and the lack of sandy-mud or muddy-sand explains the reason why much of the area within the limits of the oyster grounds, zones 4 to 9, was not productive of oysters.

Of particular significance was the absence of oysters on considerable amounts of favorable bottom, muddy-sand and sandy-mud, upon the various oyster beds. There were 1,605 samples taken on these two types of bottom and only 411 contained oysters. The probable explanations were that there was an absence of cultch or cultch was "dirty" or ineffective, and, perhaps larval setting was not of sufficient intensity in some locations.

Cultch

In the 2,681 dredge samples taken from the oyster beds, 2,108 contained cultch much of which was covered with silt and organic growths. Only 643 of the dredge samples having cultch contained oysters table 42. This condition indicated that a considerable portion of the cultch was too dirty for efficient larval setting. Particularly was this so on The Bend and McCaffery Island Flats in zone 4, and to a slightly lesser extent on the Oysterville Flats in zone 6.

Table 42

The number of oyster samples in 2,108 dredge hauls that contained cultch in 1940 and 1941.

Location		Number of Dredge Samples		
Oyster Bed	Zones	With oysters	With cultch only	Total
The Bend and McCaffery Island Flats	4	200	873	1,073
Poole's Slough	5	9	9	18
Brown Flats	5 & 7	18	26	44
Oysterville Flats	6	214	384	598
Lyman's Eddy Private Beds	7	162	154	316
Lewis Flats	8	21	9	30
Green Point Beds	8	0	3	4
Shipyard Beds	9	11	15	26
Totals		643	1,465	2,108

Table 43

The amount of cultch from 2,108 dredge hauls made on the various oyster beds in 1940 and 1941.

Location: Oyster Bed	Zones	No. Samples with Cultch	Kind of Cultch and Numbers: Native Oyster	Little-neck Clam	Cockle	Soft-shell Clam	Native Whelk	Bay Mussel	Gaper Clam	Eastern Oyster	Japanese Oyster	Total All Kinds
The Bend and McCaffery Island Flats	4	1,073	19,396	7,115	1,320	924	356	61	77	51	10	29,310
Poole's Slough	5	18	113	3	10	6	1	0	0	1	4	138
Brown Flats	5 & 7	44	541	2	65	16	2	4	0	0	1	631
Oysterville Flats	6	598	4,304	113	482	59	61	135	1	5	3	5,163
Lyman's Eddy Beds	7	316	2,891	57	303	42	29	13	2	6	3	3,346
Lewis Flats	8	30	357	3	44	5	0	3	0	0	0	412
Green Point Beds	8	3	12	0	1	1	0	0	0	0	0	14
Shipyard Beds	9	26	210	0	1	9	0	1	0	1	1	223
Total Numbers		2,108	27,824	7,293	2,226	1,062	449	217	80	64	22	39,237
Percentages			70.91	18.58	5.64	2.70	1.14	.55	.20	.16	.05	

A classification of the kinds of shells found in the dredge samples is given in table 43, which discloses that the native oyster shells were the predominant type of cultch. The shells of the little-neck clam, cockle, and Eastern soft-shell clam were of secondary importance; and those of the native whelk, bay mussel, gaper clam, Eastern oyster and Japanese oyster of minor significance.

A comparison of the average amount of cultch dredged from the various oyster beds is shown in table 44. This table reveals that the greatest amount of cultch was found in The Big Bend and McCaffery Island Flats in zone 4, with successively less cultch on the Brown Flats, Lewis Flats, Lyman's Eddy Beds, Oysterville Flats, Shipyard Beds, Poole's Slough, and Green Point Beds.

Table 44

The average amount of cultch per sample from the various oyster beds in 1940 and 1941, based upon dredge hauls having cultch.

Location: Oyster Bed	Zones	Average number of shells per dredge haul.
The Bend and McCaffery Island Flats	4	27.31
Poole's Slough	5	7.66
Brown Flats	5 & 7	14.34
Oysterville Flats	6	8.63
Lyman's Eddy Beds	7	10.58
Lewis Flats	8	13.73
Green Point Beds	8	4.66
Shipyard Beds	9	8.57
Average number of shells all beds per dredge haul.		18.61

Table 45

The average number of oysters per dredge haul from the various beds in 1940 and 1941.

Location Oyster Bed	Zone	Number of Dredge Hauls with Cultch	Average Number of Oysters per Dredge Haul	Number of Dredge Hauls Having Oysters	Average Number of Oysters in Hauls Having One or More Oysters
The Bend and McCaffery Island Flats	4	1,073	.43	200	2.32
Poole's Slough	5	18	5.00	9	10.00
Brown Flats	5 & 7	44	9.59	26	16.23
Oysterville Flats	6	598	1.11	214	3.11
Lyman's Eddy Beds	7	316	3.95	162	7.71
Lewis Flats	8	30	18.73	21	26.47
Green Point Beds	8	3	00.00	0	00.00
Shipyard Beds	9	26	4.42	11	10.45
Totals		2,108		643	

Oyster Numbers and Sizes

Table 45 presents the average number of oysters per dredge haul from the various beds in 1940 and 1941. The average number per haul based upon total samples containing cultch showed that the Lewis Flats in zone 8 contained the largest number of oysters per unit area of cultch, with an average of 18.75 oysters per dredge sample. The relative importance of the other beds in descending order follow: Brown flats; Poole's Slough, Shipyard Beds, Lyman's Eddy Beds, Oysterville Flats, The Bend and McCaffery Island Flats, and the Green Point Beds, This order remained unchanged, except for Poole's Slough and the Shipyard Beds, when the average number of oysters per dredge haul was computed upon the basis of those samples containing one or more oysters as given in the last column of table 45. Definitely, it may be stated from this data that the following oyster beds are in exceedingly depleted condition: Green Point Beds, The Bend and McCaffery Island Flats, and the Oysterville Flats. The Shipyard beds, Lyman Eddy Beds, and Poole's Slough were apparently in only fair condition from the standpoint of oyster numbers in relation to a unit area of cultch.

The approximate sizes of the oysters by beds and for the grounds as a whole, as represented in the dredge hauls, are tabulated in table 46. A significant item apparent from this data is that the two most important beds, the Lewis Flats and the Brown Flats, have a large proportion of oysters one and ~~one-half~~ three-fourths inches or less in size. On the other hand, the two depleted beds, The Bend and McCaffery Island Flats and the Oysterville Flats, have a large proportion of oysters over one and three-fourths inches in size. These two areas have had little or no harvesting in recent years.

Conditions of the Various Beds

Summaries covering the general conditions of each oyster bed as observed from the sample dredging operations follow:

The Bend and McCaffery Island Flats contain relatively few oysters, but an exceedingly large amount of cultch, extending over a considerable area of favorable bottoms, muddy-sand and sandy-mud. Most of the cultch is fouled with silt and organic growth and is of little value.

Poole's Slough, as an oyster bed, is at the present time of minor importance as an oyster-producing area, since most of the bottom is of soft mud. In a few portions, where the bottom is hardened sufficiently to support cultch, oyster production is good. Hardening the soft-mud portions with sand and the application of clean shell would greatly improve this area for oysters. Good larval setting takes place in the region of station 2. The oyster meats from this bed frequently have a yellowish cast.

Table 46

The approximate sizes and numbers of oysters taken in 643 dredge hauls from the various cyster beds in 1940 and 1941. Sizes based on the long-axis of the oyster. Percentages by size groups for each bed given in parenthesis.

Location of Oyster Bed	Zones	Year	Number of Oysters by Size Groups in Inches .25-.75	.76-1.25	1.26-1.75	1.76-2.25	2.26-2.75	2.76-3.25	3.26-3.75	Total Oysters-- all sizes
The Bend and Mc- Caffery Island Flats	4	1940	28 (6.02)	115 (24.73)	134 (28.83)	131 (28.17)	52 (11.18)	5 (1.06)	-	465 (99.99)
Poole's Slough	5	1941	21 (23.33)	32 (35.55)	27 (30.0)	8 (8.88)	2 (2.22)	-	-	90 (99.98)
Brown Flats	5 & 7	1941	51 (12.08)	159 (37.67)	151 (35.54)	57 (13.50)	4 (0.94)	-	-	422 (99.73)
Oysterville Flats	6	1940	152 (22.82)	108 (16.20)	114 (17.11)	146 (21.92	113 (16.97)	31 (4.64)	2 (.30)	666 (99.96)
Lyman's Eddy Beds	7	1940	405 (31.60)	192 (15.36)	257 (20.56)	288 (23.04)	92 (7.36)	16 (1.28)	-	1,250 (99.20)
Lewis Flats	8	1941	103 (18.32)	178 (31.67)	168 (29.89)	88 (15.65)	23 (4.09)	2 (.35)	-	562 (99.97)
Green Point Beds	8	1941	0	0	0	0	0	0		0
Shipyard Beds	9	1940	17 (14.78)	51 (44.34)	22 (19.13)	13 (11.30)	12 (10.43)	-	-	115 (99.98)
Total oysters-all beds			777	835	873	731	298	54	2	3,570
Percentages			(21.76)	(23.38)	(24.45)	(20.47)	(8.34)	(1.51)	(.05)	(99.96)

The Oysterville Flats have a small oyster population in relation to the fairly large acreage of satisfactory bottom. The probable reasons are that there is a lack of sufficient cultch, the remaining cultch is fouled with silt and organic growths and larval setting is light.

The Brown Flats composed of thirteen of the old private beds is particularly productive of oysters at the outer edge of the area in line with the two channel buoys located in zones 5 and 8. Inshore from this productive area and south of the channel buoy, native oysters are scarce, except in a few isolated small spots. There are indications that deposits of soft-mud in recent years may be responsible for the present non-productive locations.

Lyman's Eddy Beds, composed of six old private plots, appear to be limited in a narrow inside channel having satisfactory bottom types. The outside extent of this bed is demarked by a sand bar. Considerable amounts of clean shells were placed on this bed in 1940 and 1941 by the Oregon Oyster Company. An excellent larval setting generally takes place in the location. If the cultch and oysters are cleaned of silt deposits by tonging following winter and early spring freshets, satisfactory oyster production may be expected from this area.

The Lewis Flats are extremely productive at the present time, but they are limited in extent. The bed lies in a narrow belt in line with the two channel buoys and extends outward at the end of zone 8. The inshore limits of this bed to the south are bounded by a soft-mud deposit. The up-stream limits of the bed are determined by a sand bar and the outside margin to the north is bordered by sand and the navigation channel.. Apparently, this bed just previous to the beginning of the oyster studies in 1939 received a considerable amount of clean cultch, for there is now a good crop of oysters in the third year of life. There are indications that many of the larger-sized oysters have been harvested in recent years. Clean cultch is now needed on this grounds and should be equally distributed upon the favorable bottoms.

The Green Point Beds, once private areas, are now devoid of oysters. The present bottom is of soft-mud and does not have sufficient firmness to support cultch.

The Shipyard Beds, which are in relatively deep water, are limited in extent by sand bars. Definitely this bed needs cultch for most of the oysters collected were growing in large clusters.

Figure 30.

Diked lagoon at Yaquina, station 3 in zone 3.

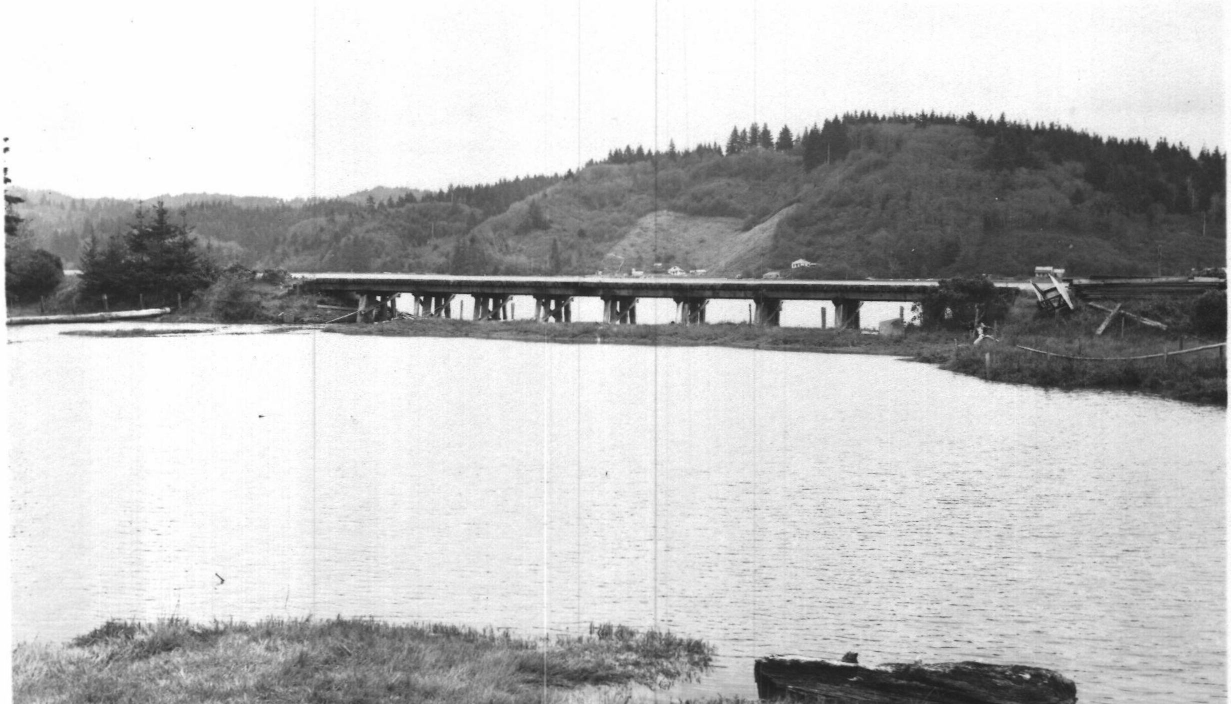

Figure 31.

Diked lagoon at Winant, station 1, in zone 7.

DIKE INVESTIGATIONS

A highly successful method of native oyster farming has been developed in Puget Sound, near Olympia, Washington, and recently in Humbolt bay, California, in which dikes were constructed on the tidal flats. The retaining walls of these structures, formerly constructed of concrete and now of creosoted lumber, keep several inches of water over the beds at low tide, thus protecting the oysters from freezing weather and excessively warm temperatures of summer. Frequently, from one to five acres may be enclosed in a dike. The bottom is usually hardened with gravel.

A considerable portion of the investigation was given to studying the feasibilities of such structures in Yaquina bay. Three experimental dikes were constructed in zones 3 and 7, two of which are shown in figures 30 and 31. Oysters were transplanted in these structures; daily water temperatures, determined by a maximum and minimum thermometer, and salinities were recorded, tables 48, 49, 50, 51 and 53 of the appendix, and the general conditions of oysters were noted from time to time. Since this phase of investigation is far from completed and needs further study, only the significant observations obtained to date are presented in this report.

Diked areas above the 5½ to 6-foot zero tide level are not likely to be successful dike locations. In such areas, the small high tides of less than 5½ feet do not re-cover the dikes with water for periods of several days in the summer. Consequently, the water temperatures may become too warm for oysters, as observed in the experimental dike at station 1 in zone 7, on July 15 and 16, table 50.

The oysters, following this warm water period, were in a markedly weakened condition. Further, little or no larval setting could be expected to occur in dikes at these higher levels.

The several small sloughs or lagoons found in zones 3 to 9 probably cannot be made into satisfactory diked areas. They are fed by small creeks which, during the rainy periods, result in reduced salinities for several days' duration in the lagoons which would likely be unfavorable to oysters.

Dikes constructed in the inter-tidal areas of zones 4 to 8, and perhaps zones 3 and 9, below the five or five and one-half foot level will probably sustain oysters which will make a satisfactory growth in shells and meats. The water temperatures in the experimental dike located at station 2 in zone 7, at about the 4-foot level, remained favorable for oysters throughout the spring and summer of 1941, table 49. The water salinities in this dike, table 53, likewise were satisfactory, even during rainy periods of several days. The daily salinity readings disclosed that the salt content of water was generally higher than at low tide over the oyster grounds. The explanation appears to be that this dike filled with water on the flood tide which has a higher salt content than the water over the oyster grounds at low tide. Also, this dike became uncovered before the low tide was reached on the native oyster grounds.

The main problem in the construction of dikes in Yaquina bay will be encountered in the finding of satisfactory material for the hardening of the soft-mud bottom. There is no available gravel in the region. Shale banks are numerous, adjacent to the oyster areas, and several experimental plots were hardened satisfactorily with this material, station 1 in zone 3. However, sufficient time has not elapsed so that the durability of such bottoms may be ascertained at this time. It is expected that test plots will be made of a variety of hardening materials in the near future, including sand, broken shell, slabwood, asphalt roofing paper and the like.

Another problem which will be encountered in diked areas is likely to be the accumulation of excessive amounts of silt over the oysters. As the soft-mud on the entire tidal area down to and slightly below the zero low-water mark becomes hardened in dike construction, there will probably be less silt stirred up in the water by the small waves of the incoming tide.

If these two main problems of hardening bottom and of controlling silt deposits can be solved, there is now every reason to believe that diked oyster farms will be successful in the inter-tidal areas of zones 4 to 8, and perhaps in zones 3 to 9. However, at the present time there is no definite data which can support a positive recommendation assuring the success of oyster dikes in Yaquina bay. Further study is needed.

MISCELLANEOUS OBSERVATIONS

A number of additional observations were made of the general oyster problems which may have an important bearing on the future management of the beds. In several instances, these miscellaneous items did not receive a thorough study other than to note their significance.

Shipping Oysters in the Shell

From an early date, the general practice in the marketing of native oysters has been to ship them in the shell to distant points. The main reason for this is that the oysters can be kept fresh for longer periods of time than would be the case if shipped in a shucked condition. The result has been a depletion of shells for cultch purposes that should have been returned to the grounds. This situation has been somewhat corrected in the last few years, for several freight carloads of native oyster shell from Olympia and Portland were placed on some of the oyster beds--Lyman's Eddy Beds, The King Flats, and Lewis Flats - in 1939, 1940 and 1941. During these three years, a great many more shells have been returned to the beds than have been shipped away.

The shipping of oysters in shells has another detrimental effect in that many small oysters of the year (spat), which should have been returned immediately to the beds, adhere to the marketed oysters. In this connection, it was observed on several occasions that men culling the oysters paid practically no attention to the small oysters attached to larger shells. The destruction of many of these small oysters would result from any culling process because their shells are extremely fragile.

On March 7, 1940, oysters were tonged from station 1 in zone 8. These were culled and a group of market-sized oysters were selected at random and examined carefully for small-sized oysters (spat). The results are given in table 47.

Table 47

The number of young oysters, zero-age class, on 662 adult oysters collected from Lewis Flats by tonging March 7, 1940.

Number of Young Oysters per Adult Oyster	Frequency or Number of Cases	Total Number of Young Oysters
0	204	0
1	187	187
2	102	204
3	43	129
4	36	144
5	14	70
6	17	102
7	8	56
8	5	40
9	2	18
10	2	20
11	2	22
Totals	662	992

On the 662 market-sized oysters there were found 992 small-sized oysters which were about six months old, the average being 1.59 spat oysters for each market-sized oyster, Perhaps the shipment of market oysters in the shell to distant points may have been one of the important reasons for the early decline of the fishery. Opening of oysters at Yaquina bay and immediately returning the shell to the grounds certainly would be an important cultural practice in the conservation of beds.

Poaching

Throughout the period of the investigation, frequent rumors were heard of the illegal taking of oysters from several of the oyster beds. Occasional reports were circulated that Yaquina bay native oysters were being sold in Newport and Toledo. One market in Corvallis advertised these oysters for sale in 1941.

Particularly, since dredging operations for channel improvements were begun on September 10, 1941, increased poaching activities were reported current in the region. The attitude of some of the persons familiar with oyster areas appeared to be, "If the dredge is going to destroy the beds, we might as well have the oysters."

Definite evidence was found that many of the oysters too small for market and cultch with spat collected by poaching were disposed of in locations not favorable for growth. Consequently, the greatest damage to beds as a whole by poaching activities is probably the destruction of the young growth which is many times more numerous than large-sized oysters.

An important sociological problem is involved in these poaching activities and should receive considerable attention by all parties interested in the management of these oyster beds. Some of the inhabitants of Lincoln county, and of the environs of the oyster grounds in particular, believe that they are taking that which is their just right. Many of the people of the towns think that the residents of the county should have the opportunity of utilizing the oysters which are naturally produced in their county. A frequent remark heard from residents of Newport was, "When are you going to open the beds so we can have a mess of oysters?"

Until this local sociological problem is corrected, there appears little hope of abating the poaching activities or in encouraging persons to develop new oyster lands. This situation is a community problem which needs intelligent leadership in re-creating a natural resource now "on its last legs." There have been over the years far too many opinions involved in this whole affair instead of constructive action in a working program for the production of oysters on a sustained annual yield basis.

Pollution

Although no bacterial tests were conducted on oysters or of the water from the oyster grounds, a pollution problem is apparently present, for untreated human sewage enters the water at Newport in zone 1 and at Toledo in zones 12 and 11. In addition, there are several boat houses over the oyster grounds during the salmon fishing season from which such sewage enters the water. This waste is not detrimental to the growth and condition of the oysters, but may become a focal point in the spreading of certain human diseases which are suspected of being transmitted by oysters from contaminated waters. There has been no evidence up to the present time that any human disease has resulted from Yaquina bay oysters; yet, there is a potential danger that such might be the case at some time in the future.

If the Yaquina bay oyster beds are developed into large-scaled production areas in which oysters are shipped to distant points, this human sewage problem will have to be corrected.

Channel dredging operations

On a trip to Winant, September 14, 1941, local residents reported that the government dredge "Pacific" operated over part of the oyster beds from September 10 to September 12, and that dredging materials were discharged below the lower limits of the oyster grounds in zone 3 off station 5. They were quite certain that the Lewis Flats and part of the Brown Flats had been destroyed, as dredging was reported to have taken place mainly between the two channel buoys.

This condition, if correct, was exceedingly serious; since the Lewis Flats in zone 8 and a portion of the Brown Flats between the two channel buoys constituted the most productive areas now existing in the bay. Mr. M. T. Hoy, Master Fish Warden, Oregon State Fish Commission, was informed by letter of the seriousness of the situation and he immediately contacted the dredge officials at Newport. They informed Mr. Hoy that they would gladly cooperate in not discharging dredging material on any of the oyster beds.

A survey of the reported damage to the Lewis Flats and Brown Flats was conducted on September 20. On arrival at Winant, about 8 A.M., the dredge was observed to be operating in the lower end of zone 9 or the upper part of zone 8. Shortly, a cargo of dredge materials was discharged below the lower limits of the oyster grounds. Of particular significance was the condition of water over the oyster beds. Before the cargo was discharged, the water was not noticeably dirty, but in several minutes the water became exceedingly muddy. The silt was carried up-river by the flood tide.

The dredge returned to the upper portion of zone 8 and apparently operated for a short time, but not on oyster land. About 10 A.M. the "Pacific" went down-river and did not return to the oyster grounds that day.

Systematic sampling of the oyster beds with a Petterson dredge on September 20 over areas studied in June and August 1941 revealed the following condition:

(1) The oysters between the two channel buoys and to the south of this line in zones 5 and 8 had not been destroyed.

(2) Oysters about 100 feet north of the line paralleling the two channel buoys in zones 7 and 8 had not been destroyed.

(3) Oysters located about 125 to 150 feet to the north of the buoy line had been destroyed. This area extended up-river about in front of the Oregon Oyster Company house to a distance of about 1800 feet, more or less. The most serious destruction was done on the lower north portion of the Lewis Beds.

(4) There was a noticeable soft-mud deposit over the oyster beds in zones 5, 7, and 8. Presumably, this deposit resulted from dredging operations.

(5) In several locations in which the Pacific operated in zones 7 and 8, large numbers of old oyster shells were uncovered. Many of these were of large size, having both shells (valves) in normal position. This condition showed that deposits of sand and mud in times past have smothered tremendous quantities of oysters.

During the afternoon, the water over the oyster grounds became exceedingly muddy. The silt was carried from up-river by the ebb tide. Muddy water was also noted in Depoe Slough at Toledo at 5:15 P.M. The Yaquina river at Chitwood and Eddyville was not muddy. Therefore, it was presumed that the muddy water condition resulted from the Pacific which had been reported operating at Toledo the day before.

The general conclusions from the survey follow:

(1) Some damage to oysters has resulted in zones 7 and 8. This area was at the north edge of the beds.

(2) The majority of oyster beds in zones 5, 7, and 8 were still intact.

(3) Silt or mud deposits <u>may cause</u> a heavy mortality of young oysters that were from the 1941 setting season. If silting continues for some time, large oysters may be killed.

(4) Cultch on beds in zones 5, 7, 8 and possibly in other locations may become useless by silt deposits.

The following recommendations were transmitted to Mr. Hoy:

(1) Dredging should not be undertaken on zones 5, 7, and 8, south of the operations thus far accomplished.

(2) If possible, dredge dischargings should be made outside the harbor. Should this not be feasible, dischargings should be done below the lower limits of the oyster grounds during the first half of the ebb tide.

(3) Under no circumstances should dredge materials be deposited in the deep water of The ~~Big~~ Bend Bed (zone 4) or in the Shipyards (zone 9).

(4) Following channel dredging, all oyster beds in zones 5, 7 and 8, and perhaps in zone 6 should be tonged, for the purposes of cleaning and lifting cultch and oysters from the accumulation of soft mud.

<u>The Japanese Oyster</u>

The exotic Japanese oyster, <u>Ostrea gigas</u>, was found in limited numbers in Yaquina bay, mostly on the Kings Flats and in Poole's Slough, zone 5. A few large-sized specimens were located attached to the undersides of rocks in the inter-tidal areas of zones 4 to 10, proving that a small amount of reproduction takes place in some years.

The first Japanese oysters were introduced into the area about 1894 by Dr. M. H. Davis, according to Mrs. Dow Walker, Yaquina, who is a daughter of Dr. Davis. At that time spat was not obtainable and large-sized adult oysters were shipped from Japan, costing one dollar apiece. This early shipment was placed at the mouth of Poole's Slough and is reported to have grown to large size. No record of any reproduction from this planting has been found.

In recent years, seed oysters from Japan have been set out in several locations. Extensive plantings were made on the tidal lands of zone 2. Very few of these are now present. Perhaps, poaching and the depredations of the Red Crab may have been responsible for their disappearance.

Plantings of seed oysters have been made by the Oregon Oyster Company in zone 5 and by several persons in Poole's Slough previous to 1939. Since that time, no Japanese oyster plantings were noted.

During 1939 and 1940, a few swimming larvae of this species were present in some of the plankton collections and a small number of spat were found on cultch in the inter-tidal area of zones 5 to 10. No indication of reproduction was found in 1941.

The Eastern Oyster

From very early times, seed oysters of the Eastern oyster, Ostrea virginica, from the Atlantic coast, have been re-laid in zones 5 and perhaps in zones 6 and 7. The Oregon Oyster Company has made frequent plantings of this oyster in 20 to 30-barrel lots, in recent years, in zone 7 where they were held for several months until needed for market.

Most of the early research work with oysters in Yaquina bay was devoted to the problem of reproduction. The remains of specially-built breeding tanks can be seen at Poole's Slough. There were occasional reports, years ago, of suspected natural reproduction. From the water temperature records taken during the summers of 1940 and 1941, figures 15 and 16, it is not likely that this species will spawn successfully in Yaquina bay. The required minimum temperature below which little or no spawning occurs is about 68 degrees F. (Churchill, 1920; Gutsell, 1924; Nelson, 1928; Prytherch, 1929; and others.) The temperature at high tide seldom reaches the critical minimum in the area, and, if so, only for short intervals during the entire summer season.

Eggs were found in a few female oysters during the summers of 1939 and 1940, but free-swimming larvae were never observed in plankton collections, nor were spat present on cultch.

According to Mr. Rosselle, former employee of the Oregon Oyster Company, the mortality of Eastern oysters held for market in zone 7 usually averaged about five per cent. However, in 1939, and again in 1940, about 50 per cent of the Eastern oysters remaining on this ground died by late summer. The reason for this loss was not determined. It was suspected, but not proven that a weakened condition may be caused in the oysters during transit from the Atlantic coast and as the water temperature rises near the spawning temperature in Yaquina bay, eggs are produced in the oyster, but not spawned. This physiological reaction may put an extra demand on the vitality of the female oysters causing death. This theory concerning Eastern oyster mortalities in Yaquina bay has some foundation in the causes of reported deaths of re-laid European oysters in England. Orton (1937) stated, "It is an interesting fact that heavy mortality among re-laid oysters may occur in the first or still more in the second summer after re-laying. All these observations point to the occurrence of severe weakening in the spawning process which, with other predisposition to weakness, may result in death. - - - Loss of leucocytes is no doubt one contributing cause of bad condition following the transport of oysters for relaying."

Throughout the period of investigation every effort was made to be unbiased, yet to take into consideration the attitudes, beliefs and prejudices of all concerned. The main objective has been to harmonize the biological findings into a workable plan which, if followed, could develop a now depleted natural resource into a profitable enterprise to the community and the State. In presenting and considering recommendations for the future development and management of the Yaquina bay native oyster beds, certain definite conclusions should first be recognized by all individuals and agencies concerned. Without such a common understanding of the fundamental conditions existing and without a definite plan of constructive action, this report becomes just another oyster investigation. These conclusions follow:

(1) The stock of oysters in Yaquina bay is at the present time extremely depleted and the natural beds will never support on a sustained yield basis an unregulated and unlimited fishery.

(2) The present depleted oyster numbers and inadequate cultch conditions, coupled with inimical environmental happenings, are not sufficient to produce adequate spat-falls for the natural rehabilitation of the oyster beds. Without improved cultural practices, based upon biological information, increased oyster production is not likely to take place.

(3) Qualified supervision of the oyster beds should be established on the area at once in order to enforce regulations and to oversee that cultural operations are in keeping with life history phases of the oyster.

(4) The present production of oysters and the production in the next few years will not be sufficient to provide the funds needed for supervision, research and cultural improvements.

(5) A definite local sociological problem exists which must be corrected before concerted community action may be utilized in the development of the resource.

<u>Rehabilitation of the natural beds</u>

Efforts should be made to improve the four main natural beds, namely: the Big Bend and McCaffery Island Flats, the Shipyard Beds, the Oysterville Flats, and the Lewis Flats. The logical procedure appears to be the laying of clean cultch timed with maximal setting activities, and the tonging or harrowing of the beds for the purpose of reducing silt accumlations on cultch.

In the case of cultching operations, clean shell should be on hand before the beginning of the 1942 larval setting season. Shell can be spread directly onto the bottoms of the Shipyard Beds and the Lewis Flats, because adequate spatting may be generally expected in these two locations. Care should be exercised in the case of Lewis Flats not to smother the present excellent stocks of oysters immediately in line with the channel buoys, but the shells should be placed on favorable bottom now devoid of clean cultch.

Cultch for both the Oysterville Flats and The Bend and McCaffery Island Flats should be placed in wire bags, figure 26, in either zone 7 or 10. Then following the larval setting season, this cultch with young oysters may be re-laid on suitable bottoms of these two beds. There is a possibility that after the oyster stocks are built up an increased larval setting will take place on Oysterville Flats and The Bend and McCaffery Island Flats.

There is a decided lack of available shell for this work in the area. Possible sources of cultch are:

(1) The shell bar in the lower bay located on the north side of the zonal line between zones 1 and 2. The shell should be cleaned by exposure on the bank during the rainy season.

(2) The ineffective cultch in The Bend and McCaffery Island Flats. Some of this shell could be dredged and exposed to rain and sunshine for a period of time.

(3) Clam and Japanese oyster shells from the markets at Newport. These shells are now being discarded off the wharfs.

(4) Japanese oyster shell from Coos bay or Tillamook bay. Considerable amounts of shell are now available at these two locations. Also, there are large amounts of native oyster shell in good condition under the south approach to the Coos bay highway bridge.

Tonging of oysters or perhaps a harrow of some sort might be used to clean the cultch of silt following freshets. This operation should be done during ebb tide so that the silt is carried below the oyster grounds.

Development of Privately-operated Beds

In the correcting of the sociological situation involved in the oyster problem, it is suggested that consideration be given to allowing the people who are now residents of Lincoln county and who were formerly engaged in oystering in Yaquina bay certain definite lands for oyster-farming purposes. As a further suggestion, the Oysterville Flats could be subdivided into eight or ten $2\frac{1}{2}$ or 3-acre tracts. These plots could be allotted at a public drawing. Continued operation of these areas should be determined upon the basis of the operators abiding by the rules and regulations suggested by an oystermen's association and approved by the Oregon Fish Commission. This arrangement might result in the rehabilitation of a now depleted oyster bed. Also, increased numbers of oysters in this locality will probably insure an enhanced spat fall on the other beds.

Although there is no present data definitely proving that diked oyster farms will be successful in the area, there are reasonable indications from the incomplete study thus far made that such structures might be used to advantage in the development of now unproductive tidal lands into oyster farms. It is therefore recommended that a small diked area of not less than one-half acre be used for demonstration purposes and future research work. If this plan is adopted, financial provision should be made for obtaining adequate care and operation of the dike.

In the north portion of zone 8 and lands comprising the now extinct Green Point Beds, there are considerable extents of soft-mud bottoms below low tide, which, if hardened with sand and shell, might be developed into new oyster areas. This land could be subdivided into tracts to be developed by people interested in engaging in oyster farming.

Harvesting Regulations

Several regulations in regard to harvesting appear advisable. There should be no tonging for market purposes on any of the beds during the spawning season, for there were some indications that such action may cause a considerable amount of abortion among gravid females. Also, during the spawning season, the oysters are not in "good flesh." The dates of this closed period should be from April 1 to August 15. An occasional gravid female may be found after September 1, even into October, but the broods from such late spawners would be of no significance in the conservation of the beds.

If supervised culling of oysters were possible, it would be advisable to establish size limits for market oysters by beds to insure against over-cropping. Another desirable practice in this connection would be the opening of oysters adjacent to oyster grounds and returning the shells along with the small-sized oysters to proper locations. Care should be taken to keep all tonged material in sink floats until culled, for exposure to high air temperatures may kill some of the small-sized oysters.

Under no circumstances should the natural beds be harvested unless there is a surplus number of market-sized oysters. Therefore, definite amounts to be harvested should be established before the tonging season begins. When the quota has been reached, all harvesting should stop at once.

Especially for the next several years, weekly reports of oysters harvested both on the private and natural beds should be required. Only in this way, may a check be had of the oyster production by beds.

Miscellaneous Recommendations

The cultivation of natural beds in order to clean cultch of silt following freshets would no doubt be an excellent cultural practice. Just how this could be accomplished without too great an expense is a question. Perhaps, operators of private beds could contribute work to such an undertaking, for increased oyster production on the natural oyster beds will mean larger spat-falls on all the beds, including the privately-operated areas.

All introductions of oysters from other locations should be thoroughly inspected before being placed in Yaquina bay. The area apparently has no introduced oyster pests at the present time.

The inside channel near the east bank of zone 10 should be set aside as a spat-catching grounds and should have priority for this purpose over salmon fishing with gill nets.

In this section are included several tables dealing with water temperatures and salinity readings which were omitted from the main body of the report.

Table 48

Daily minimum and maximum water temperatures in diked-lagoon, station 3 in zone 3 and from Main Station II, July 23 to August 22, 1940. Temperature degrees in fahrenheit.

Date	Station 3 in zone 3		Main Station II	
1940	Minimum	Maximum	Minimum	Maximum
July 23	61	76.0	60.0	70.0
July 24	60	82.0	61.8	70.0
July 25	62	79.0	62.0	70.0
July 26	62	70.0	62.0	70.0
July 27	62	82.0	64.0	70.0
July 28	62	80.0	63.0	70.0
July 29	64	75.0	65.0	72.0
July 30	67	79.0	65.0	72.0
July 31	67	78.0	66.5	73.0
August 1	64	82.0	67.7	74.0
August 2	65	80.5	67.8	74.0
August 3	64	78.0	60.0	74.0
August 4	61	76.0	56.0	75.0
August 5	58	78.0	53.0	75.0
August 6	57	72.0	54.0	74.0
August 7	53	82.0	54.0	74.0
August 8	54	76.0	54.3	73.0
August 9	56	82.0	57.0	72.3
August 10	58	82.0	58.0	72.4
August 11	56	80.0	58.0	72.0
August 12	55	75.0	59.0	72.0
August 13	55	73.0	58.0	72.0
August 14	54	80.0	58.0	72.0
August 15	54	79.0	56.8	71.0
August 16	55	78.0	56.0	71.5
August 17	54	80.0	58.0	71.0
August 18	56	74.0	56.0	70.0
August 19	54	66.0	56.0	70.0
August 20	55	74.0	58.0	69.0
August 21	58	78.0	60.0	70.0
August 22	58	74.0	62.0	70.0

Table 49

Daily minimum and maximum water temperatures taken in the experimental dike at station 2 in zone 7, March 17 to September 9, 1941.

Date of Reading	Time of Reading	Minimum Temperature F.	Maximum Temperature F.
March 19	-	54	62
March 20	-	53	59
March 21	-	52	61
March 22	-	52	64
March 23	-	52	60
March 24	-	50	61
March 25	-	52	61
March 26	-	53	58
March 27	-	53	60
March 28	-	53	58
March 30	-	53	59
March 31	-	53	61
April 1	-	54	61
April 2	-	53	58
April 3	-	53	57
April 4	-	53	56
April 5	-	53	58
April 6	-	53	59
April 7	-	54	63
April 8	-	54	63
April 9	-	54	61
April 10	-	54	63
April 11	-	54	60
April 12	-	54	61
April 13	-	54	62
April 14	-	54	61
April 15	-	54	61
April 16	-	53	61
April 17	-	53	60
April 18	-	53	63
April 19	-	55	68
April 20	2 P.M.	55	68
April 21	3 P.M.	53	69
April 22	4:30 P.M.	56	69
April 23	5:30 P.M.	55	66
April 24	5:30 P.M.	55	66
April 25	5:30 P.M.	55	65
April 26	9:10 P.M.	55	64
April 27	10 A.M.	56	65
April 28	10 A.M.	55	66
April 29	11 A.M.	55	64
April 30	12:05 P.M.	54	63
May 1	10:30 A.M.	54	66
May 3	1:30 P.M.	54	64
May 4	1:30 P.M.	54	64
May 5	1:30 P.M.	54	63
May 6	2:30 P.M.	53	64
May 7	1:45 P.M.	54	63
May 8	3:30 P.M.	54	64
May 9	4:30 P.M.	55	63
May 10	7 P.M.	55	66

Table 49 continued.

Date of Reading	Time of Reading	Minimum Temperature F.	Maximum Temperature F.
May 11	6 P.M.	56	65
May 12	10 A.M.	53	72
May 13	10:30 A.M.	55	72
May 14	10:30 A.M.	55	72
May 15	10:30 A.M.	55	70
May 16	11:45 A.M.	55	73
May 17	2:15 P.M.	55	73
May 18	1:15 P.M.	55	72
May 19	12:10 P.M.	55	73
May 20	3:15 P.M.	55	73
May 21	3:45 P.M.	56	73
May 22	3 P.M.	58	74
May 23	4:45 P.M.	56	74
May 24	5:15 P.M.	57	73
May 25	6:45 P.M.	56	73
May 26	9:45 P.M.	56	70
May 27	9 A.M.	54	65
May 28	9:45 A.M.	53	65
May 29	9:15 A.M.	56	64
May 30	8:20 A.M.	55	63
May 31	10:30 A.M.	56	66
June 1	10 A.M.	57	69
June 2	12:05 P.M.	59	72
June 3	1 P.M.	61	74
June 4	1:45 P.M.	59	68
June 5	4 P.M.	60	75
June 7	5 P.M.	60	74
June 8	5:15 P.M.	59	73
June 9	10:30 A.M.	58	71
June 11	10 A.M.	60	69
June 12	10 A.M.	60	72
June 13	8 A.M.	62	68
June 16	1:30 A.M.	60	73
June 17	1:30 P.M.	60	67
June 18	2:30 P.M.	52	74
June 26	9 A.M.	54	75
June 27	1:20 P.M.	54	75
June 28	11:15 A.M.	54	76
June 29	10:45 A.M.	53	77
June 30	11:30 A.M.	53	79
July 2	11:45 A.M.	63	79
July 3	2:15 P.M.	62	79
July 4	2:30 P.M.	60	79
July 5	5 P.M.	59	78
July 6	4:30 P.M.	50	75
July 7	8:30 A.M.	53	73
July 8	7:30 A.M.	55	76
July 9	9:20 A.M.	55	77
July 10	7 A.M.	55	70
July 11	7 A.M.	54	72
July 12	8 A.M.	55	69
July 13	11 A.M.	56	73
July 14	10:15 A.M.	60	74
July 15	12:30 A.M.	60	75

Table 49 continued.

Date of Reading	Time of Reading	Minimum Temperature F.	Maximum Temperature F.
July 21	5:15 P.M.	59	75
July 22	7:15 A.M.	62	73
July 23	7:30 A.M.	61	73
July 24	8:15 A.M.	56	71
July 25	8:15 A.M.	56	71
July 26	10:15 A.M.	55	70
July 27	10:30 A.M.	55	70
July 28	9:15 A.M.	55	72
July 29	10 A.M.	55	72
July 30	11:20 A.M.	56	73
July 31	12:05 P.M.	55	75
August 1	1:25 P.M.	56	73
August 5	-	56	69
August 6	-	56	70
August 7	7:15 A.M.	52	68
August 8	7:45 A.M.	51	69
August 9	8:15 A.M.	58	64
August 10	8:20 A.M.	66	54
August 11	9:15 A.M.	53	67
August 12	10 A.M.	56	67
August 13	11 A.M.	57	72
August 14	12:30 P.M.	56	71
August 20	-	56	71
August 21	-	56	69
August 22	6 P.M.	56	70
August 23	6 P.M.	56	69
August 24	8 A.M.	56	69
August 25	8:15 A.M.	56	69
August 26	9:10 A.M.	59	65
September 4	7:15 A.M.	60	64
September 5	9:20 A.M.	60	63
September 8	7 P.M.	63	65
September 9	9:15 A.M.	63	66

Table 50

Daily minimum and maximum water temperatures taken in experimental diked-lagoon at station 1 in zone 7, May 20 to July 15, 1941.

Date of Reading	Time of Reading	Minimum Temperature F.	Maximum Temperature F.
May 20	3 P.M.	58	76
May 21	3:45 P.M.	68	79
May 22	3:15 P.M.	63	81
May 23	4:15 P.M.	59	88
May 24	5:15 P.M.	60	84
May 25	6:45 P.M.	66	83
May 26	10 A.M.	58	81
May 27	9:15 A.M.	56	75
May 28	8:30 A.M.	55	75
May 29	9:15 A.M.	56	73
May 30	8:30 A.M.	59	74
May 31	10:30 A.M.	59	69
June 1	10 A.M.	60	74
June 2	11:30 A.M.	66	73
June 3	1:15 P.M.	65	85
June 4	2 P.M.	73	88
June 5	3:45 P.M.	62	86
June 6	4 P.M.	60	76
June 7	5 P.M.	60	76
June 8	5:15 P.M.	59	74
June 9	10:15 A.M.	58	71
June 10	9 A.M.	59	66
June 11	10 A.M.	59	78
June 12	10 A.M.	59	77
June 13	8:15 A.M.	59	77
June 14	7:20 A.M.	59	78
June 15	7:45 P.M.	62	85
June 16	3:30 P.M.	66	83
June 17	1:30 P.M.	60	79
June 18	2:30 P.M.	60	76
June 19	3 P.M.	60	73
June 21	6 P.M.	62	75
June 23	9:15 A.M.	59	71
June 24	7:30 P.M.	62	77
June 25	9 A.M.	62	74
June 26	9 A.M.	63	75
June 27	1:20 P.M.	63	75
June 28	11:15 A.M.	63	76
June 29	10:45 A.M.	62	74
June 30	11:15 A.M.	65	78
July 1	2:35 P.M.	62	92
July 2	11:30 A.M.	64	91
July 5	5 P.M.	59	89
July 6	4:30 P.M.	60	86
July 7	9 A.M.	58	85
July 8	7:20 A.M.	59	84
July 9	7:15 A.M.	57	85

Table 50 continued.

Date of Reading	Time of Reading	Minimum Temperature F.	Maximum Temperature F.
July 10	7 A.M.	56	86
July 11	7 A.M.	56	84
July 12	8 A.M.	55	80
July 13	11 A.M.	56	82
July 14	10:15 A.M.	60	98
July 15	10:30 A.M.	60	97
July 16	10:30 A.M.	60	97

Table 51

Bottom-water salinity, in parts per mille, recorded in the diked-lagoon station 3 in zone 3, July 24 to August 20, 1940.

Date	Tidal Stage	Salinity ppm.	Rainfall-Newport
July 24	Ebb	33.3	None
July 25	Ebb	33.3	.04
July 26	Ebb	17.4	.62
July 27	Ebb	17.4	.13
July 28	Ebb	26.7	.01
July 29	Ebb	23.7	.30
July 30	Ebb	33.4	None
July 31	Flood	33.4	None
August 1	Flood	33.4	.05
August 2	Flood	28.2	None
August 3	Flood	31.5	None
August 4	Flood	32.8	None
August 5	Ebb	32.8	None
August 6	Ebb	31.9	None
August 7	Ebb	33.2	None
August 8	Ebb	32.7	.01
August 9	Ebb	33.2	None
August 10	Ebb	32.5	None
August 11	Flood	32.7	None
August 12	Flood	25.9	None
August 13	Flood	33.0	None
August 14	Flood	33.4	None
August 15	Flood	33.2	None
August 16	Flood	33.8	None
August 17	Ebb	33.2	None
August 18	Ebb	32.9	None
August 19	Ebb	26.7	T
August 20	Flood	33.2	None

Table 52

Salinity readings of water samples collected at Main Station II, April 11, 1940, to ~~date~~, September 5, 1941.

Date	Tidal Stage	Salinity p.p.m. Surface	Bottom	Rainfall--inches Newport, Oregon
1940				
April 11	F .16	8.0	10.3	None
April 12	F .90	8.2	8.8	T
April 13	E .67	10.6	11.1	.10
April 14	E .60	11.0	11.4	.03
April 15	E .50	13.1	17.1	None
April 16	E .60	12.8	17.3	None
April 17	E .25	17.5	26.5	.04
April 18	E .08	24.6	27.8	None
April 19	F .90	27.1	27.7	None
April 20	F .50	17.0	17.8	.01
April 21	F .67	22.0	23.0	None
April 22	F .50	23.8	23.8	.01
April 23	F .50	19.4	19.7	.04
April 24	F .40	14.2	14.4	T
April 25	F .08	10.8	11.4	None
April 26	LS	12.8	12.8	None
April 27	E .80	15.0	15.0	.27
April 28	E .75	13.7	14.1	.37
April 29	E .70	16.3	17.6	None
April 30	E .50	19.0	25.6	.99
May 1	E .33	16.5	24.7	T
May 2	E .33	19.4	26.0	.16
May 3	E .25	23.7	26.3	.25
May 4	F .73	20.5	25.6	.60
May 5	F .50	17.9	20.0	.08
May 6	F .50	12.4	17.8	None
May 7	F .70	19.2	21.6	None
May 8	F .45	10.1	13.2	None
May 9	F .35	8.2	9.6	None
May 10	F .16	6.4	6.6	.01
May 11	F .15	6.7	6.8	None
May 12	F .08	7.3	7.5	None
May 13	LS	9.2	9.2	None
May 14	E .73	12.6	12.7	.09
May 15	E .65	14.9	16.0	T
May 16	E .50	16.7	18.0	None
May 17	E .60	20.6	21.4	None
May 18	HS	27.1	28.5	None
May 19	F .60	24.0	25.9	None
May 20	F .70	25.1	25.5	None
May 21	E .33	27.1	27.1	None
May 22	F .50	18.3	18.4	None
May 23	F .16	11.5	11.9	None
May 24	F .25	15.4	16.0	T
May 25	F .16	16.9	17.3	None
May 26	LS	16.0	16.0	None
May 27	LS	16.1	16.7	None
May 28	E .66	18.8	19.2	None

Table 52 continued.

Date	Tidal Stage	Salinity p.p.m. Surface	Bottom	Rainfall--inches Newport, Oregon
May 29	F .05	17.4	20.6	None
May 30	E .50	21.6	25.5	.14
May 31	E .33	25.2	26.8	.08
June 1	E .16	26.5	29.1	None
June 2	HS	27.3	29.1	.05
June 3	HS	27.8	28.6	None
June 4	F .75	28.6	28.6	None
June 5	F .73	28.4	30.8	None
June 6	F .60	25.1	25.1	None
June 7	F .50	20.9	21.2	.04
June 8	F .33	19.4	19.6	None
June 9	F .08	17.8	17.8	None
June 10	F .16	17.6	17.6	None
June 11	LS	20.5	21.0	None
June 12	F .50	23.3	23.3	.02
June 13	E .60	23.9	24.4	.02
June 14	E .50	23.1	23.4	None
June 15	E .25	28.8	29.9	None
June 16	HS	30.4	31.4	None
June 17	F .75	29.7	29.7	None
June 18	F .66	27.7	27.8	None
June 19	F .66	29.0	29.0	None
June 20	F .50	25.9	26.0	None
June 21	F .66	28.4	29.0	None
June 22	F .50	29.7	29.7	None
June 23	F .16	21.3	21.7	None
June 24	F .50	27.2	27.6	.01
June 25	F .48	31.9	32.3	None
June 26	F .75	24.8	25.1	None
June 27	F .07	24.7	26.4	None
June 28	E .75	25.1	25.4	None
June 29	E .73	28.0	30.2	None
June 30	E .08	31.6	31.6	None
July 1	E .25	31.4	31.6	None
July 2	E .08	30.4	31.8	.02
July 3	HS	31.5	31.8	None
July 4	F .83	32.8	33.4	None
July 5	F .75	27.6	27.7	None
July 6	F .75	32.3	33.3	None
July 7	No samples taken			None
July 8	LS	26.1	26.1	None
July 9	LS	26.1	26.5	None
July 10	E .75	28.1	28.4	None
July 11	E .75	30.6	30.7	None
July 12	E .50	28.9	29.0	T
July 13	F .66	33.2	33.6	.01
July 14	No samples taken			None
July 15	E .15	32.0	32.9	None
July 16	E .73	30.3	30.4	None
July 17	F .67	31.6	32.9	None
July 18	F .70	31.0	32.1	None
July 19	LS	27.6	28.9	None
July 20	LS	28.1	29.5	.04

Table 52 continued.

Date	Tidal Stage	Salinity p.p.m. Surface	Bottom	Rainfall--inches Newport, Oregon
July 21	No samples taken			None
July 22	LS	27.8	28.1	None
July 23	LS	28.6	29.3	None
July 24	E .16	28.0	28.0	None
July 25	E .70	29.8	30.3	.04
July 26	LS	28.0	29.3	.62
July 27	E .50	29.7	31.0	.13
July 28	No samples taken			.01
July 29	F .90	29.7	33.0	.30
July 30	F .30	30.8	32.0	None
July 31	F .05	29.8	30.3	None
August 1	F .48	31.1	31.2	.05
August 2	F .75	31.0	31.0	None
August 3	E .83	29.5	29.7	None
August 4	No samples taken.			
August 5	LS	27.3	27.4	None
August 6	HS	33.3	33.7	None
August 7	F .33	27.3	27.8	None
August 8	F .67	32.3	32.3	.01
August 9	E .83			None
August 10	E .83	29.8	29.8	None
August 11	No samples taken			None
August 12	E .45	31.8	31.9	None
August 13	E .33	31.6	31.6	None
August 14	E .25	32.7	33.2	None
August 15	F .66	30.2	30.3	None
August 16	F .55	30.6	30.7	None
August 17	F .83	32.7	32.9	None
August 18	No samples taken			None
August 19	F .50	30.7	30.7	T
August 20	F .60	31.2	31.4	None
August 21	F .50	31.4	31.4	None
August 22	F .25	29.9	29.9	None
August 23	F .30	30.2	30.6	None
August 24	F .25	30.6	30.6	None
August 25	No samples taken			None
August 26	LS	29.9	30.7	.05
August 27	E .75	31.4	31.4	.04
August 28	LS	31.4	31.4	None
August 29	E .75	31.8	31.8	None
August 30	E .25	32.8	32.8	None
August 31	E .50	31.2	31.5	T
September 1	No samples taken			.05
September 2	F .83	33.0	33.0	.02
September 3	F .80	32.7	32.7	None
September 4	F .60	31.4	31.5	T
September 5	F .50	31.4	31.6	None
September 6	HS	32.8	32.8	None
September 7	E .25	33.0	33.0	.18
September 8	No samples taken			.04
September 9	E .45	32.0	32.4	.04
September 10		32.1	32.4	None
September 11		31.8	31.8	None
September 12		32.3	32.5	None

Table 52 continued.

Date	Tidal Stage	Salinity p.p.m. Surface	Bottom	Rainfall--inches Newport, Oregon
Sept. 13		31.6	31.9	None
Sept. 14		33.2	33.2	T
Sept. 15	No samples taken.			None
Sept. 16	No samples taken.			None
Sept. 17	No samples taken.			.22
Sept. 18	No samples taken			.18
Sept. 19	F .33	31.0	31.1	None
Sept. 20	F .41	30.8	31.0	None
Sept. 21	F .25	30.4	30.8	None
Sept. 22	E .91	30.8	31.0	None
Sept. 23	E .91	30.8	31.0	None
Sept. 24	HS	32.5	32.8	None
Sept. 25	F .83		32.3	None
Sept. 26	F .80	32.1	32.4	.42
Sept. 27	E .48	31.4	31.6	.59
Sept. 28	No samples taken			.10
Sept. 29	US	32.0	32.0	None
Sept. 30	E .83	29.8	30.2	None
October 1	E .80	29.9	29.9	.05
October 2	E .67	30.4	31.2	T
October 3	E .70	32.0	32.4	.17
October 4	E .58	31.6	32.4	.05
October 5	E .58	31.8	31.9	None
October 6	F .16	29.8	30.6	None
October 7	F .65	31.6	31.6	None
October 8	F .75	31.8	31.8	None
October 9	F .73	31.6	31.6	.02
Oct. 10	LS	30.2	30.7	.16
Oct. 11	LS	29.3	30.6	.04
Oct. 12	E .64	30.4	30.7	.09
Oct. 13	F .92	31.4	32.1	.01
Oct. 14	E .68	31.1	32.1	None
Oct. 15	F .58	31.1	31.1	None
Oct. 16	F .41	30.4	32.1	.20
Oct. 17	F .58	31.1	32.8	.26
Oct. 18	F .16	31.1	31.1	T
Oct. 19	F .58	30.8	31.1	T
Oct. 20	E .25	32.1	32.4	.66
Oct. 21	E .25	28.9	29.0	.03
Oct. 22	F .75	29.9	31.4	.03
Oct. 23	E .70	30.3	30.3	1.04
Oct. 24	LS	28.0	28.8	.71
Oct. 25	E .53	30.0	30.2	.02
Oct. 26	LS	26.7	27.2	None
Oct. 27	E .53	29.8	29.8	None
Oct. 28	E .69	28.8	30.7	.15
Oct. 29	F .67	31.8	32.0	.82
Oct. 30	E .42	32.7	33.7	.25
Oct. 31	E .34	33.3	33.6	.59
Nov. 1	E .50	30.0	30.2	.50
Nov. 2	E .41	28.1	31.4	.02
Nov. 3	F .16	24.7	25.2	None
Nov. 4	F .16	23.9	31.0	.07

Table 52 continued.

Date	Tidal Stage	Salinity p.p.m. Surface	Bottom	Rainfall--inches Newport, Oregon
November 5	No samples taken			.11
November 6	E .58	28.0	28.0	.35
November 7	F .25	23.5	26.4	.60
November 8	LS	20.4	21.4	.72
November 9	E .33	26.7	28.1	.24
November 10	E .91	14.8	14.8	.23
November 11	FS	18.0	28.1	.40
November 12	E .91	11.8	12.2	None
November 13	E .75	15.8	15.8	None
November 14	E .25	25.9	26.7	None
November 15	E .45	21.0	22.0	None
November 16	E .58	22.0	22.6	None
November 17	E .33	25.2	26.3	.47
November 18	E .40	23.3	25.0	T
November 19	F .25	17.0	23.4	None
November 20	LS	19.1	20.3	.48
November 21	E .91	18.2	18.3	.09
November 22	E .30	21.4	22.0	None
November 23	No samples taken			.16
November 24	E .50	26.3	26.3	.48
November 25	E .40	26.3	26.8	.10
November 26	E .58	23.4	23.4	None
November 27	LS	15.0	15.0	.87
November 28	E .50	23.4	23.4	1.28
November 29	F .50	24.3	26.0	.34
November 30	F .25	6.3	8.5	None
December 1	E .50	16.3	18.6	.01
December 2	F .08	5.0	13.2	T
December 3	F .16	6.0	12.7	.61
December 4	E .83	11.1	11.1	.04
December 5	E .50	20.6	20.6	.27
December 6	E .50	17.3	18.0	T
December 7	E .91	13.9	14.1	None
December 8	E .67	17.3	22.2	.11
December 9	HS	13.6	14.6	None
December 10	No samples taken			None
December 11	E .67	16.9	17.0	None
December 12	E .67	19.7	19.7	None
December 13	E .67	20.6	20.6	None
December 14	F .80	23.4	29.5	None
December 15	E .50	23.7	23.7	None
December 16	E .33	26.4	26.5	.01
December 17		27.2	27.2	.38
December 18	F .15	19.1	24.3	.27
December 19	LS	19.2	19.2	1.00
December 20	HS	26.4	27.2	1.23
December 21	E .50	16.0	19.6	.13
December 22	E .67	11.3	16.0	.17
December 23	F .35	8.8	12.7	.48
December 24	F .25	9.3	11.4	.28
December 25	LS	9.4	9.4	.40
December 26	E .80	10.7	11.1	.91

Table 52 continued.

Date	Tidal Stage	Salinity p.p.m. Surface	Bottom	Rainfall—inches Newport, Oregon
December 27	E .83	6.2	6.2	.01
December 28	E .75	8.4	8.4	None
December 29	E .33	15.3	16.1	None
December 30	E .40	13.9	14.3	.20
December 31	E .30	16.9	23.4	.04
1941				
January 1	E .35	14.5	18.8	None
January 2	E .16	15.6	24.1	None
January 3	F .33	8.1	13.8	.33
January 4	F .75	13.0	23.4	.08
January 5	F .75	15.9	22.3	.33
January 6	F .50	10.8	18.2	.14
January 7	No samples taken			.08
January 8	F .25	11.8	14.1	None
January 9	E .80	14.5	14.5	None
January 10	F .50	15.3	17.1	None
January 11	E .91	12.9	12.9	None
January 12	E .85	16.0	16.0	.43
January 13	E .58	18.6	18.6	None
January 14	E .50	21.2	21.4	.43
January 15	E .50	20.6	21.4	.30
January 16	E .41	21.6	22.0	.77
January 17	LS	9.7	9.7	.99
January 18	F .86	5.5	19.9	.67
January 19	F .80	1.8	17.0	None
January 20	F .42	1.6	6.6	None
January 21	F .84	2.8	4.2	.06
January 22	F .06	4.2	4.2	.09
January 23	F .08	6.3	6.3	.31
January 24	LS	7.2	7.3	1.01
January 25	E .70	13.7	14.0	1.04
January 26	No samples taken			.15
January 27	F .29	1.6	1.8	None
January 28	E .43	5.4		None
January 29	E .30	7.9	8.1	None
January 30	E .04	13.3	18.0	.29
January 31	E .95	19.4	21.6	.34
February 1	E .97	6.3	6.3	.46
February 2	E .77	7.3	7.3	.01
February 3	E .72	9.0	9.2	None
February 4	E .52	9.4	11.0	None
February 5	F .50	13.3	14.4	None
February 6	F .32	14.0	16.9	.01
February 7	E .94	12.9	21.6	.02
February 8	F .06	16.7	16.7	.53
February 9	F .91	13.2	13.2	.56
February 10	F .77	22.0	28.0	.18
February 11	F .57	14.8	28.4	.01
February 12	F .80	21.7	24.4	.02
February 13	F .79	24.6	26.0	None
February 14		12.6	12.6	None
February 15	No samples taken			None
February 16	E .99	12.3	14.0	None

Table 52 continued.

Date	Tidal Stage	Salinity p.p.m. Surface	Bottom	Rainfall--inches Newport, Oregon
February 17	E .50	21.8	22.5	None
February 18	F .44	22.0	22.6	None
February 19	E .84	16.3	16.3	None
February 20	E .60	18.7	18.7	None
February 21	F .20	14.6	15.0	None
February 22	E .34	19.9	25.0	None
February 23	F .83	20.6	26.0	.13
February 24	E .33	29.0	29.7	.05
February 25	E .35	26.5	27.4	None
February 26	E .76	20.1	20.1	.14
February 27	E .38	26.3	27.2	.26
February 28	E .36	27.4	28.4	.28
March 1	E .42	24.7	25.1	.22
March 2	E .50	22.7	23.8	.07
March 3	E .83	18.0	18.0	.01
March 4	E .30	16.1	19.6	None
March 5	F .09	13.5	18.6	None
March 6	E .17	17.0	17.0	None
March 7	E .37	19.2	26.5	None
March 8	F .36	18.4	20.3	None
March 9	E .74	20.5	20.5	None
March 10	E .60	23.9	23.9	None
March 11	F .89	28.0	28.5	None
March 12	F .77	28.2	28.5	None
March 13	E .06	22.9	22.9	None
March 14	F .12	17.0	17.3	None
March 15	No samples taken			None
March 16	F .13	17.0	17.0	None
March 17	F .44	21.8	22.0	.28
March 18	E .84	22.0	22.0	.71
March 19	E .84	22.1	22.1	.17
March 20	E .85	17.9	17.9	.02
March 21	F .89	16.9	17.1	.10
March 22	E .79	18.3	18.3	.16
March 23	F .03	16.3	16.3	None
March 24	F .04	16.3	17.6	None
March 25	F .11	17.6	17.6	None
March 26	E .83	19.5	19.5	None
March 27	F .11	17.0	17.8	None
March 28	F .28	20.0	22.1	None
March 29	F .84	19.6	19.6	.13
March 30	E .84	20.9	20.9	.21
March 31	F .07	17.3	17.6	.02
April 1	F .10	17.9	19.0	.01
April 2	F .11	22.9	23.8	.27
April 3	F .13	21.6	22.6	.12
April 4	F .26	19.1	21.7	1.03
April 5	F .55	20.3	20.5	.35
April 6	F .53	16.9	16.9	.15
April 7	E .81	14.4	14.6	.02
April 8	E .88	13.9	13.9	.22
April 9	E .97	13.6	13.7	.08
April 10	E .98	16.1	16.1	None
April 11	E .80	17.8	17.9	None

Table 52 continued.

Date	Tidal Stage	Salinity p.p.m. Surface	Bottom	Rainfall—inches Newport, Oregon
April 12	E .01	16.0	16.2	None
April 13	E .70	17.4	18.3	None
April 14	E .05	27.3	28.0	.17
April 15	F .05	24.6	24.8	.26
April 16	F .55	11.5	12.3	.36
April 17	E .95	13.7	14.1	None
April 18	E .80	14.4	14.6	None
April 19	F .12	14.1	14.2	None
April 20	E .95	17.8	20.1	None
April 21	E .97	17.1	21.2	None
April 22	F .02	16.5	17.0	None
April 23	F .04	14.9	15.0	None
April 24	LS	15.7	16.2	None
April 25	E .92	16.5	16.5	None
April 26	F .32	18.4	18.6	None
April 27	F .43	18.0	18.0	None
April 28	F .35	18.0	18.2	None
April 29	F .40	17.0	17.3	.23
April 30	F .40	21.0	21.3	.02
May 1	F .05	17.3	17.5	.18
May 2	E .70	18.0	18.3	.67
May 3	F .20	18.6	19.1	.14
May 4	F .12	18.0	18.4	.60
May 5	LS	13.1	13.6	.25
May 6	LS	9.7	9.9	.12
May 7	E .70	12.8	12.8	.01
May 8	E .75	11.5	11.5	None
May 9	E .98	10.2	10.2	None
May 10	F .10	12.4	12.8	None
May 11	F .50	16.3	16.9	.03
May 12	F .35	13.1	13.1	None
May 13	F .25	10.3	10.5	.08
May 14	F .18	13.6	13.6	.05
May 15	F .24	13.1	13.1	.01
May 16	LS	14.0	14.6	.57
May 17	F .25	9.8	9.8	1.13
May 18	LS	9.9	10.3	.03
May 19	E .75	10.7	11.2	None
May 20	F .08	10.3	12.7	None
May 21	E .99	8.4	10.2	None
May 22	E .75	16.2	16.2	None
May 23	E .80	13.7	13.7	None
May 24	E .85	14.8	15.2	None
May 25	LS	13.7	13.7	None
May 26	F .55	17.9	20.9	None
May 27	F .16	13.1	13.1	.13
May 28	F .10	13.2	13.2	.13
May 29	LS	14.9	15.7	.04
May 30	E .95	14.9	14.9	T
May 31	E .90	15.0	16.0	None
June 1	E .92	17.9	18.2	.07
June 2	E .96	18.3	18.3	None
June 3	E .05	16.5	16.7	None
June 4	LS	19.1	19.1	None

Table 52 continued.

Date	Tidal Stage	Salinity p.p.m. Surface	Bottom	Rainfall—inches Newport, Oregon
June 5	F .10	17.05	17.3	.15
June 6	F .10	18.7	19.7	.10
June 7	F .05	18.0	19.4	.23
June 8	E .90	19.6	19.6	.02
June 9	F .55	20.1	20.4	None
June 10	F .25	12.8	14.1	None
June 11	F .15	17.6	18.3	None
June 12	F .12	13.2	14.4	.02
June 13	E .83	20.5	21.0	None
June 14	E .52	24.7	25.2	None
June 15	E .15	27.8	27.8	.03
June 16	F .50	24.3	24.8	T
June 17	F .05	22.9	22.9	.05
June 18	F .05	22.1	22.2	.21
June 19	F .03	23.3	23.4	.21
June 20	E .42	22.4	24.3	None
June 21	F .25	22.9	24.7	None
June 22		22.4	29.5	.31
June 23	F .50	21.0	24.1	T
June 24	F .20	21.2	25.1	.15
June 25	F .25	20.4	21.0	.21
June 26	F .25	19.1	20.5	None
June 27	F .75	18.7	18.8	None
June 28	F .30	20.1	20.1	T
June 29	F .12	19.1	19.2	T
June 30	LS	20.4	20.4	None
July 1	F .45	24.6	24.7	None
July 2	E .85	21.4	21.4	None
July 3	F .10	22.0	24.2	None
July 4	F .10	23.0	26.4	None
July 5	F .20	24.0	24.8	None
July 6	E .96	24.8	25.9	None
July 7	F .50	24.7	24.7	.07
July 8	F .10	19.5	19.6	None
July 9	F .25	21.4	21.4	None
July 10	E .90	24.2	24.3	None
July 11	E .77	25.2	26.3	None
July 12	E .79	24.4	24.6	None
July 13	F .15	23.0	24.0	None
July 14	E .96	25.0	25.0	None
July 15	E .88	26.7	27.2	None
July 16	E .80	27.6	28.0	.05
July 17	F .03	26.5	27.4	None
July 18	E .80	27.8	28.6	None
July 19	LS	27.8	28.0	.04
July 20	F .10	28.9	29.5	None
July 21	F .10	25.6	29.8	None
July 22	F .25	25.8	26.0	None
July 23	F .25	25.6	26.3	None
July 24	F .16	23.8	23.8	None
July 25	F .10	24.4	24.7	None
July 26	F .03	27.7	27.8	None
July 27	F .23	27.7	28.1	None
July 28	F .15	26.8	27.1	None

Table 52 continued.

Date	Tidal Stage	Salinity p.p.m. Surface	Bottom	Rainfall--inches Newport, Oregon
July 29	LS	27.6	27.6	None
July 30	LS	28.5	28.5	None
July 31	LS	28.2	28.5	None
August 1	LS	28.0	28.4	None
August 2	LS	28.4	28.9	T
August 3	F .62	32.9	32.9	.06
August 4	E .97	29.0	29.1	None
August 5	F .10	26.0	26.0	None
August 6	F .15	26.1	26.8	None
August 7	F .05	26.5	26.7	None
August 8	F .05	26.4	26.9	None
August 9	F .04	27.7	27.8	.02
August 10	E .97	27.6	28.0	None
August 11	LS	28.9	28.9	None
August 12	LS	29.4	29.8	None
August 13	F .05	29.9	30.3	None
August 14	F .15	30.0	30.4	None
August 15	LS	30.0	30.4	None
August 16	LS	29.7	29.7	None
August 17	F .45	31.8	32.5	None
August 18	LS	30.6	30.6	None
August 19	LS	30.4	30.7	None
August 20	E .95	29.7	29.9	None
August 21	E .98	31.1	31.4	None
August 22	E .95	30.6	30.6	None
August 23	E .80	29.1	29.3	.07
August 24	F .03	29.9	30.0	.43
August 25	LS	28.1	28.1	.17
August 26	LS	28.9	28.9	.60
August 27	F .04	29.1	29.4	T
August 28	F .04	29.1	29.3	None
August 29	F .04	29.8	29.9	None
August 30	E .98	29.7	29.7	.18
August 31	F .05	29.7	29.7	.14
Sept. 1	F .32	29.1	29.1	.03
Sept. 2	F .04	28.2	28.4	1.18
Sept. 3	F .02	27.8	27.8	.23
Sept. 4	F .20	26.4	26.8	T
Sept. 5	F .25	25.0	25.2	.06

Table 53

Daily salinity in experimental dikes at stations 1 and 2 in zone 7 as compared to bottom salinity at Main Station II near low tide.

Date 1941	Salinity p.p.m Station 1 (Dike)	Station 2 (Dike)	Main Station II
March 18	28.9	24.0	22.0
19	25.4	23.4	22.1
20	23.5	22.2	17.9
21	23.5	22.1	17.1
22	23.8	20.9	18.3
23	---	21.3	16.3
24	19.6	21.3	17.6
25	25.9	22.2	17.6
26	20.6	22.7	19.5
27	24.2	22.6	17.8
29	28.0	23.7	19.6
30	28.1	23.7	20.9
31	27.4	23.1	17.6
April 1	25.0	18.3	19.0
2	27.8	23.7	23.8
3	25.2	22.2	22.6
4	20.8	18.6	21.7
5	25.6	20.0	20.5
6	25.9	21.4	16.9
7	20.9	19.1	14.6
8	22.5	20.3	13.9
9	20.5	14.5	13.7
10	20.1	18.4	16.1
11	21.4	20.3	17.9
12	17.9	21.0	16.2
13	18.2	17.4	18.5
14	29.4	27.7	28.0
15	26.9	26.0	24.8
16	21.8	22.0	12.3
17	22.1	20.9	14.1
18	9.8	19.6	14.6
19	6.0	20.1	14.2
20	5.4	19.6	20.1
21	5.6	20.3	21.2
22	6.0	20.5	17.0
23	5.8	21.0	15.0
24	3.2	22.5	16.2
25	24.0	22.4	16.5
26	24.7	17.3	18.6
27	24.2	17.9	18.0
28	26.7	17.6	18.2
29	27.1	24.2	17.3
30	27.1	21.3	21.3
May 1	26.9	23.5	17.5
2	24.2	no sample	18.3
3	21.4	22.9	19.1
4	16.3	20.6	18.4

Table 53 (Continued)

Date 1941	Station 1 (Dike)	Salinity p.p.m Station 2 (Dike)	Main Station II
May 5	19.4	16.5	13.6
6	17.6	14.8	9.9
7	12.8	14.1	12.8
8	12.2	14.9	11.5
9	23.7	16.5	10.2
10	14.0	15.3	12.8
11	27.6	19.5	16.9
12	26.7	No sample	13.1
13	26.0	No sample	10.5
14	26.7	No sample	13.6
15	25.5	No sample	13.1
16	24.0	23.3	14.6
17	9.0	16.7	9.8
18	7.5	15.8	10.3
19	7.0	15.6	12.7
20	6.3	14.5	12.7
21	4.8	9.0	10.2
22	10.2	16.1	16.2
23	17.9	17.6	13.7
24	15.7	16.3	15.2
25	17.3	17.1	13.7
26	24.6	20.9	20.9
27	24.4	22.4	13.1
28	24.2	23.4	13.2
29	23.4	23.8	15.7
30	22.6	22.5	14.9
31	23.3	22.6	16.0
June 1	22.9	22.0	18.2
2	22.1	22.9	18.3
3	18.2	22.7	16.7
4	23.0	22.4	19.1
5	20.1	20.0	17.3
6	26.1	No sample	19.7
7	28.5	20.0	19.4
8	29.0	19.6	19.6
9	29.0	21.4	20.4
10	24.8	26.9	14.1
11	28.2	25.2	18.3
12	29.5	26.8	14.4
13	27.8	26.7	21.0
14	27.7	No sample	25.2
15	28.4	No sample	27.8
16	27.2	25.5	24.8
17	27.7	No sample	22.9
18	26.5	No sample	22.2
19	27.2	No sample	23.4
21	27.7	No sample	24.7
22	28.0	No sample	29.5
24	28.0	No sample	25.1

Table 53 (Continued)

Date 1941	Station 1 (Dike)	Salinity p.p.m Station 2 (Dike)	Main Station II
June 25	24.4	21.8	21.0
26	25.6	25.0	20.5
27	26.9	26.5	18.8
28	28.5	26.1	20.1
29	28.5	26.4	19.2
30	28.1	26.8	20.4
July 1	29.3	No sample	24.7
2	29.4	25.9	21.4
3	No sample	25.4	24.2
5	30.5	26.4	24.8
6	30.6	27.7	25.9
7	30.7	29.5	24.7
8		29.7	19.6
9		30.7	21.4
10		29.8	24.3
11		30.8	26.3
12		30.3	24.6
13		30.2	24.0
14		29.1	25.0
15		28.6	27.2
16		28.5	28.0
19		28.8	28.0
21		30.3	29.8
22		30.3	26.0
23		30.6	26.3
24		31.0	23.8
25		31.1	24.7
26		31.2	27.8
27		31.2	28.1
28		30.0	27.1
29		30.3	27.6
30		31.1	28.5
31		30.7	28.5
August 1		29.1	28.4
5		31.8	26.0
6		32.1	26.8
7		31.8	26.7
8		32.7	26.9
9		31.1	27.8
10		32.1	28.0
11		31.8	28.9
12		30.7	29.8
13		30.7	30.3
14		30.7	30.4
20		31.0	29.9

Table 53 (Continued)

Date 1941	Station 1 (Dike)	Salinity p.p.m Station 2 (Dike)	Main Station II
August 21		31.9	31.4
August 22		32.8	30.6
August 23		31.6	29.3
August 24		32.0	30.0
August 25		31.1	28.1
August 26		31.6	28.9
September 4		29.0	26.8
September 5		28.9	25.2

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