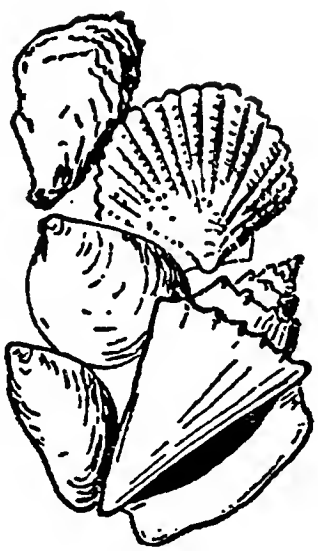
1964 PROCEEDINGS

NATIONAL SHELLFISHERIES ASSOCIATION

Volume 55



PROCEEDINGS

of the

NATIONAL SHELLFISHERIES ASSOCIATION

Official Publication of the National Shellfisheries Association; an Annual Journal Devoted to Shellfishery Biology

Volume 55
August 1964

Published for the National Shellfisheries Association by
Bi-City Ink, Bryan, Texas

1967

TABLE OF CONTENTS

OTHER TECHNICAL PAPERS PRESENTED AT THE 1964 CONVENTION

Advances in the microscopic study of larval clams . . . . REUBEN CARES

Some relationships between Pacific oyster fatness and environmental conditions. . . . . RONALD E. WESLEY

The pH tolerance of embryos and larvae of Mercenaria mercenaria and Crassostrea virginica . . . . . ANTHONY CALABRESE and HARRY C. DAVIS

Notes on glucose in the nutrition of oysters with observations on longevity. . . . . LAWRENCE GILLESPIE, ROBERT M. INGLE, and WALTER K. HAVENS

Research on oyster purification in Florida. . . . . ROBERT M. INGLE and DELANO R. CRAWFORD

Observation on the northern and southern quahog clams, their hybrids, backcrosses, and F2's . . . . . R. W. MENZEL

The effects of chemicals on the setting of oysters in Chesapeake Bay and Chincoteague Bay . . . .WILLIAM N. SHAW and GEORGE W. GRIFFITH

Chemical control of drills—its status and future . . . . . JAMES HANKS

Bureau of Commercial Fisheries surf clam studies . . . . . RUSSELL T. NORRIS

Present status of the A. E. C. program on the irradiation preservation of oysters. . . . . ARTHUR S. NOVAK

Developments in the hard clam industry in New York. . . . . WILLIAM MILLER

The status of MSX . . . . . HAROLD HASKINS and JAY D. ANDREWS

Remarks on Chytridiopsis . . . . . VICTOR SPRAGUE

Oyster mortality studies on the Pacific Coast of the United States. . . . . ALBERT K. SPARKS and KENNETH K. CHEW

The nature of "intra-cell disease" of oysters in the Pacific Northwest . . . . . J. G. MACKIN, JEROME E. STEIN, and JOHN DENISON

Multiple watery cysts in Crassostrea gigas (Thunberg) . . . . . ALBERT K. SPARKS and GILBERT B. PAULEY

Preliminary results on an investigation of the incidence of infection and effects of Mytilicola orientalis Mori in the Pacific oyster, Crassostrea gigas. . . . . KENNETH K. CHEW, ALBERT K. SPARKS, and STANLEY C. KATKANSKY

Oyster mortalities in Aransas Bay, Texas during a period of hypersaline conditions . . J. G. MACKIN, THOMAS HEFFERNAN, ROBERT HOFSTETTER, and FRANK SCHLICHT

Chromatographic studies of allopatric populations of the oyster, Crassostrea virginica . . . . . .ROBERT E. HILLMAN

A comparison of the pallial borders of bivalve mollusks. . . . . THOMAS C. CHENG

Effective temperature on the purification of hard clams contaminated with Staph. aureus phage 80 . . . . . SUN YENG FENG

Tissue graphs in the American oyster. . . . . WALTER J. CANZONIER

The effects of various antibiotics on Dermocystidium marinum in Thioglycollate cultures. . . . . .SAMMY M. RAY

Adaptation of the 48-hour oyster larvae bioassay to field waters . . . . . CHARLES E. WOELKE

The shell dredging industry and its relation to the oyster industry. . . . . .LYLE ST. AMANT and a panel: ROBERT INGLE, JAMES McPHILLIPS, JAMES L. McCONNELL, C. B. CRIBBS, and GORDON GUNTER; film by JAMES McPHILLIPS

PRELIMINARY OBSERVATIONS ON THE SEASONAL SIZE DISTRIBUTION OF MYTILICOLA ORIENTALIS MORI IN THE PACIFIC OYSTER, CRASSOSTREA GIGAS (Thunberg) AT HUMBOLDT BAY, CALIFORNIA AND YAQUINA BAY, OREGON[1,2]

Kenneth K. Chew, Albert K. Sparks, Stanley C. Katkansky, and David Hughes

ABSTRACT

Two size classes of Mytilicola orientalis were found through the year in Pacific oysters (Crassostrea gigas) in Humboldt Bay, California and Yaquina Bay, Oregon. Copepods from 2 to 5 mm were observed to be predominantly males with a few immature females in the 4 to 5 mm range. Copepods from 6 to 11 mm were found to be all females. The reproductive cycle of this parasitic copepod appears to be continuous throughout the year in the two bays, rather than periodic.

INTRODUCTION

Mytilicola is the generic name of a parasitic copepod found in the gut of molluscs. Its presence has been generally known for many years. The species found on the Pacific Coast of the United States is Mytilicola orientalis (Mori, 1935), originally described from the gut of mussels (Mytilus crassitesta) and oysters (Crassostrea gigas) from the Inland Sea of Japan. It has been known to occur in Washington waters in oysters (C. gigas and Ostrea lurida), and eastern cups (Crepidula fornicata) (Odlaug, 1946). Chew, Sparks, and Katansky (1964) were the first investigators to record M. orientalis from the California mussel, Mytilus californianus.

Although no extensive mortalities of molluscs on the Pacific Coast have ever been attributed to this copepod, Odlaug (1946) described a lowering in condition of infected oysters (O. lurida). Rankin (1943) reported infections of more than five copepods resulted in weak, watery oysters (O. lurida) and mortalities occurred with infections of 12 or more parasites. Sparks (1962) noted certain metaplastic changes in the digestive tract of C. gigas when infected

[1]This work was supported by a grant (No. EF 00346-01) from the United States Public Health Service, National Institutes of Health, Division of Research Grants.

[2]Contribution No. 222 from the College of Fisheries, University of Washington.

with M. orientalis. The normal tall columnar epithelium was reduced to a low cuboidal or squamous epithelium and the cilia were depressed or lost in areas of apposition to the copepod. Occasionally the mucosa was completely destroyed and appendages of the parasite penetrated the underlying connective tissue. An apparent tendency for development of a fibrosis of the underlying connective tissue was noted.

Wilson (1938) described Mytilicola ostreae from C. gigas that had been imported from Japan to Puget Sound. However, Odlaug (1946) stated that M. orientalis and M. ostreae are probably identical; apparently Wilson was unaware of Mori's work.

A closely related species, Mytilicola intestinalis, is found in Europe. It was first noted in the digestive tract of a mussel (Mytilus galloprovincialis) in the Gulf of Trieste by Steuer (1902). This organism was extensively studied because of the mortalities it caused in commercial mussel (M. edulis) beds. According to Korringa and Lambert (1951), the infected mussels were extremely thin and had brownish-tinged tissue, exhibited a yellowish digestive gland, and lacked the byssus. Physiological experiments by Meyer and Mann (1951) on mussels infected with M. intestinalis indicated acceleration in digestion of albumin, an increase in the utilization of oxygen, a lowered ability to absorb nutrients, and a lowered filtration capacity. These facts well account for the poor survival of the infected mussels. However, Dollfus (1951) doubts that Mytilicola is the direct cause of the mortalities and postulates that this copepod may act as a portal of entry for the true pathogen (possibly a bacterium or virus).

Hepper (1953) was able to infect artificially M. edulis, Cardium edule, Ostrea edulis, Paphia pullastia, and C. fornicata, with the infective stage of M. intestinalis. However, attempts to infect Scrobicularia plana, Chlamys varia, Pecten maximus, and Macoma balthica were unsuccessful.

Humes (1954) described another species, Mytilicola porrecta, and differentiated it from M. orientalis and M. intestinalis.

Little attention was paid to M. orientalis on the Pacific coast because no apparent mortalities of commercially important molluscs occurred in areas where it was found. It came to the attention of Public Health authorities in California during a routine bacterial examination of oysters (C. gigas). Because of the possible public health significance and of the California Department of Health's pure food certification responsibilities, it was decided, at a meeting

held in San Francisco, to study the effects of this copepod on oysters. The College of Fisheries at the University of Washington obtained support from the U. S. Public Health Service to carry out this study. The aims of this investigation are many but only the seasonal size distribution of the parasite in Humboldt Bay, California and Yaquina Bay, Oregon will be discussed in this paper.

MATERIALS AND METHODS

Experimental floating stations similar to those described by Chew (1961) were established at Humboldt Bay and Yaquina Bay in March 1963. One hundred and fifty Pacific oysters were put in a basket and eight baskets were placed in the float. Eight baskets were also placed on the bed at Humboldt Bay at the +2 tidal level with a like number of oysters, and natural bed samples were collected near the site of these baskets. Since there was no suitable intertidal location at Yaquina Bay, the bed samples were tonged from a submerged commercial oyster bed.

Samples of 12 oysters from each location (float baskets, bed baskets, and natural bed) were removed every 2 to 3 weeks. The oysters were preserved in a solution of 9 parts 95 per cent isopropyl alcohol and 1 part glacial acetic acid and left in this solution for at least two weeks before they were examined; at the end of this period the tissue was firm and dissection of the digestive tract was much easier than if fresh material was used.

Dissection commenced at the anus, the gut was opened along its entire length, and its contents examined under a low-power magnifying lens. Any copepods encountered were removed, measured (total length in millimeters, excluding egg cases), and examined for the presence of visible egg cases. Representative specimens were preserved in 4 per cent formalin for more careful determination of sexual characteristics, by examining copepods under a dissecting microscope.

RESULTS AND DISCUSSION

As shown in Figs. 1 and 2, two distinct size modes of M. orientalis were found throughout the year in Humboldt Bay and Yaquina Bay oysters. Microscopic examination of the samples revealed that those copepods from 2 to 5 mm were predominantly males, with a few

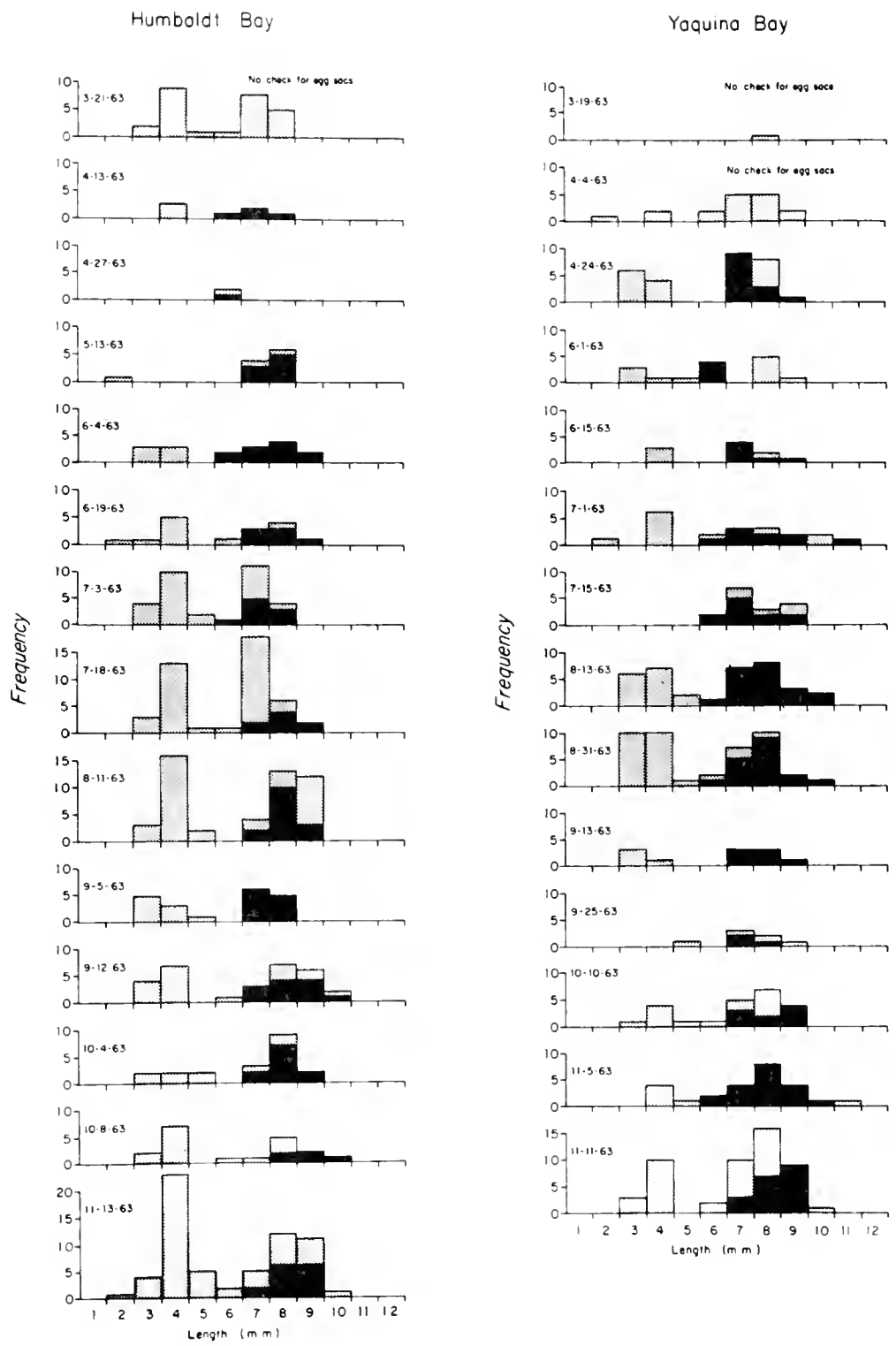


Fig. 1. Length frequency distribution of Mytilicola orientalis in Pacific oysters (Crassostrea gigas) from Humboldt Bay and Yaquina Bay for each check date from March to November 1963. Number of female copepods carrying egg sacs designated by darkened areas.

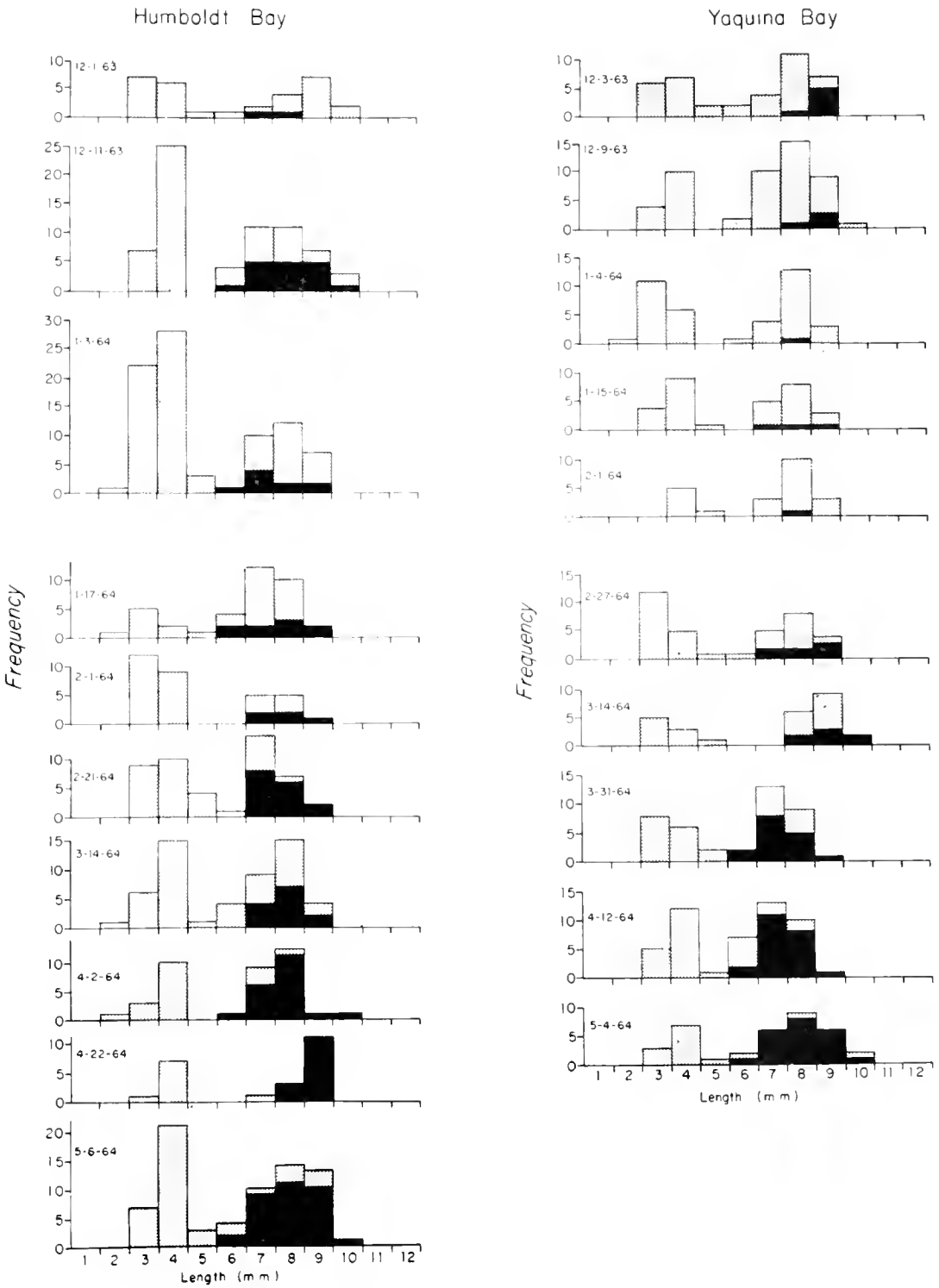


Fig. 2. Length frequency distribution of Mytilicola orientalis in Pacific oysters (Crassostrea gigas) from Humboldt Bay and Yaquina Bay for each check date from December 1963 to May 1964. Number of female copepods carrying egg sacs designated by darkened areas.

immature females in the 4 to 5 mm range. It is not known whether the 2 to 3 mm males were mature, since no histological examinations were made.

The copepods from 6 to 11 mm were females (Figs. 1 and 2). Throughout the sampling, females of approximately 6 to 7 mm were either mature with well-developed egg cases, or immature well along in development but without visible egg cases. Some of the larger females (8-10 mm) had either undeveloped egg cases, or developed cases which were sloughed or broken off after the eggs were hatched.

Heldt (1951) found reproduction in M. intestinalis to occur any time during the year when the water temperature was at least 8 to 9 C, while Korringa (1951) places the lower limit of temperature for reproduction at 6 C. Our samples revealed copepods carrying egg cases throughout the year (Figs. 1 and 2) and with few exceptions water temperatures generally exceeded 6 C. If we assume that temperature requirements for reproduction were similar for the two species, our data would suggest that the M. orientalis reproductive cycles were continuous in Humboldt Bay and Yaquina Bay, rather than periodic as previously supposed.

In Yaquina Bay, no apparent decrease in numbers of Mytilicola was observed, but the numbers of females bearing egg sacs decreased from December 1963 through February 1964 (Fg. 2). This may have been related to the low temperatures (5.5-7.1 C) in that bay. Humboldt Bay, which was considerably warmer (7.8-10 C) during the same period, revealed low numbers of females carrying egg cases in only one sample. This agrees closely with the observations of Grainger (1951) on M. intestinalis that "females carrying egg sacs were found throughout the year, but more carried them in the summer."

Work is presently under way to hatch and grow the larvae of M. orientalis to infective stages in the laboratory. Preliminary observations have already been made on the morphology and duration of nauplius and early copepodid stages.

LITERATURE CITED

Chew, K. K. 1961. The growth of a population of Pacific oysters (Crassostrea gigas) when transplanted to three different areas in the state of Washington. Ph.D. Thesis, Univ. of Washington.

Chew, K. K., A. K. Sparks, and S. C. Katkansky. 1964. First record of Mytilicola orientalis Mori in the California mussel Mytilus californianus Conrad. J. Fish. Res. Bd. Canada, 21: 205-207.

Dollfus, R. 1951. Le Cop Rouge (Mytilicola intestinalis Steuer). XIII. Le Copepode Mytilicola intestinalis A. Steuer peut-il être la cause d'une maladie epidémique des moules. Rev. Trav. Office Peches Maritime, 17 (2): 81-83.

Grainger, J.N.R. 1951. Notes on the biology of the copepod Mytilicola intestinalis Steuer. Parasitology, 41: 135-142.

Heldt, J. H. 1951. Le Cop Rouge (Mytilicola intestinalis Steuer). V. Observations sur Mytilicola intestinalis Steuer parasite des moules. Rev. Trav. Office Peches Maritime, 17(2): 33-39.

Hepper, B. T. 1953. Artificial infection of various molluscs with Mytilicola intestinalis Steuer. Nature, 172 (4371): 250. London.

Humes, A. G. 1954. Mytilicola porrecta n. sp. (Copepoda: Cyclopoida) from the intestine of marine pelecypods. J. Parasitol. 40: 186-194.

Korringa, P. 1951. Le Cop Rouge (Mytilicola intestinalis Steuer). II. Le Mytilicola Intestinalis Steuer (Copepoda Parasitica) menacé l'industrie mouliere en Zelande. Rev. Trav. Office Peches Maritime, 17 (2):9-13.

Korringa, P. and Lambert, L. 1951. Le Cop Rouge (Mytilicola intestinalis Steuer). III. Quelques observations sur la fréquence de Mytilicola intestinalis Steuer (Copepoda Parasita) dans les moules du littoral méditerranéen francais avec une note sur la présence de Pseudomyicola spinosus. (Raff. and Mont.) (Copepoda Parasita). Rev. Trav. Office Peches Maritime, 17 (2): 15-29.

Meyer, P. F. and H. Mann. 1951. Recherches allemandes relatives en Mytilicola copepode parasite de la moule existant dans les watten allemandes, 1950-1951. Rev. Trav. Office Peches Maritime, 17 (2): 63-71.

Mori, T. 1935. Mytilicola orientalis, a new species of parasitic copepoda. Dobutsugaku Zasshi (Zool. Soc. Japan), 47: 687-693.

Odlaug, T. O. 1946. The effect of the copepod Mytilicola orientalis upon the Olympian oyster Ostrea lurida. Trans. Am. Microscop. Soc., 65:311-317.

Rankin, J. S. 1943. A biological report on the conditions in the waters of Oyster Bay, Little Skookum, and Oakland Bay. July-December, 1942. Unpubl. Manuscript, 19 pp.

Sparks, A. K. 1962. Metaplasia of the gut of the oyster Crassostrea gigas (Thunberg) caused by infection with the copepod Mytilicola orientalis Mori. J. Insect Pathol., 4:57-62.

Steuer, A. 1902. Mytilicola intestinalis, n. gen., n. sp., aus dem Darm von Mytilus galloprovincialis Lamck. (Vorlaufige Mittheilung.) Zool. Anz. XXV (680):635-637.

Wilson, C. B. 1938. A new copepod from Japanese oysters transplanted to the Pacific Coast of the United States. J. Washington Acad. Sci., 28:284-288.

SURVIVAL AND GROWTH OF THE EUROPEAN FLAT OYSTER IN CALIFORNIA

Walter A. Dahlstrom

California Department of Fish and Game
Marine Resources Operations
Menlo Park, California

ABSTRACT

A shipment of European oysters from the U. S. Fish and Wildlife Laboratory, Milford, Connecticut, was planted in trays in Tomales Bay, California for studies of survival and growth. Between 6 September and 12 December 1963, nine per cent of the transplanted oysters died. Surviving oysters increased from 63 to 87 mm in average length and from 65 to 84 mm in average width. Condition of the meats was satisfactory and the oysters developed normal gonads and first spawned during April 1964. A sample of oysters released straight hinge larvae under laboratory conditions and some larvae metamorphosed to the setting stage within three weeks. It appears that the European oyster will survive, grow, and release larvae in California waters, but whether the larvae will survive and set naturally remains to be determined.

INTRODUCTION

The European oyster, Ostrea edulis, occurs along the Atlantic Coast of Europe from Norway to Spain, in the British Isles, and the western part of the Mediterranean. Introduction and subsequent natural propagation of this oyster occurred in New England. V. L. Loosanoff (1955) obtained the parent stock from Holland in 1949. Some oysters of the original shipment were left in the harbor at the U. S. Fish and Wildlife Service Laboratory at Milford, Connecticut. Others were transplanted to four localities in Maine, including Boothbay Harbor.

Subsequent progeny of the Milford stock were shipped to other places, including the shellfish laboratory of the State of Washington. Some of the set which was placed in the waters of Hood Canal had reached 77 mm in length by August 1954.

The European oyster was first introduced into California waters in May 1956. T. Imai of Tohoku University, Sendai, Japan sent 251 young oysters by air freight to H. C. Orcutt, marine biologist, California Department of Fish and Game. The oysters were planted on intertidal oyster ground of the Tomales Bay Oyster

Company, 50 miles north of San Francisco. There was high mortality at the beginning of this experiment, probably due to rigors of the transocean journey rather than environmental conditions after planting. The surviving oysters grew from an average length of 28 mm on 11 May 1956 to 50 mm in November 1956 and then to 75 mm by 1 March 1958. Only two oysters remained alive at the conclusion of the experiment in May 1958. Orcutt attributed the mortality to spring storms which destroyed the protective fencing about the experimental plot, and the subsequent effect of silt, crabs, and drilling snails.

A second introduction of the European oyster was attempted by an oyster culturist in July 1962. These oysters were shipped by air from Arcachon, France, and planted in Drakes Estero approximately 10 miles from Tomales Bay. The shipment contained about 30,000 seed oysters averaging approximately 20 mm in length. Mortality was high due to overcrowding and planting too high in the intertidal zone. On 19 October 1962 approximately 1,000 of the oysters were put in trays suspended from racks at the minus 1.5-foot tide level. By 2 December 1963, some of these oysters had reached 80 mm in length.

On 6 September 1962, 675 oysters were shipped by air from the Milford, Connecticut laboratory to San Francisco. This third shipment of O. edulis arrived in excellent condition and no mortalities were observed. The oysters were immediately taken to Tomales Bay, placed in trays, and suspended in the water from a rack. On 9 November 1962, 169 were placed on an adjacent ground plot, 300 were taken for tray experiments in Drakes Bay and San Francisco Bay, and 200 oysters were left in the trays in Tomales Bay. This report deals primarily with the observations on these oysters and environmental conditions at the Tomales Bay oyster culture site.

ECOLOGICAL CONDITIONS

The experimental oyster culture site at the Tomales Bay Oyster Company is near the head of the 13-mile long bay where temperature and salinity are greatly influenced by air temperature and fresh-water runoff. The soft mud bottom at the experimental rack is at about the minus 2-foot tide level, and the tidal interval averages 5.5 feet.

High and low water temperature means were calculated from thermograph recordings using 10-day averages (Fig. 1). The mean high values ranged from 8.2 C to 24.4 C, whereas mean low values

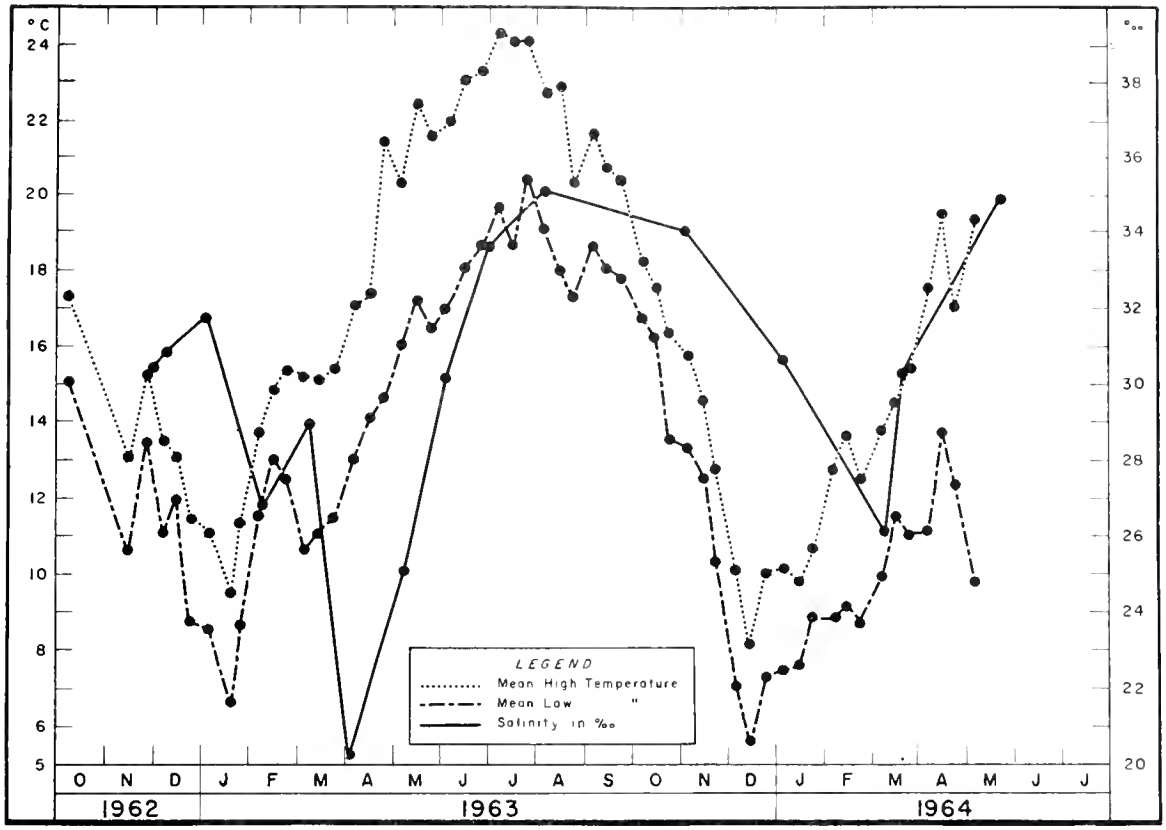


Fig. 1. Mean high and low water temperatures and salinity of Tomales Bay.

ranged from 5.7 C to 20.6 C. The highest temperatures occur from June through September, the lowest during the months of December and January.

Surface salinity samples were usually taken during flood tides. Salinities ranged from 21.0 to 35.1 o/oo. Highest salinities were recorded during summer, and the lowest during winter and spring when there was more rainfall.

The trays used in the experiment were of 0.37-inch reinforced steel rod, plastic dipped. Each measured 42 x 24 x 6 inches and was covered by 0.75-inch plastic-covered wire netting of 1 mm (19 gauge) hard-drawn bright core, plastic coated to 1.72 mm (15.5 gauge) dimensions. The trays were suspended by 0.25-inch polypropylene line from a rack. The rack was constructed of 2 x 4-inch rough redwood lumber and measured 12 x 5 feet (Fig. 2). The trays were suspended about 6 inches above the bay bottom which was at the minus 2-foot level.

Fig. 2. Hanging culture rack at low water. The trays were suspended from the ends of the rack.

SURVIVAL

Survival of the oysters on the racks in Tomales Bay has been excellent; only 18 of the 200 have died (natural mortality). During the course of the experiment, 51 oysters were sacrificed to determine condition and development. As of 13 April 1964, 131 (65 per cent) of the oysters remained in the experiment (Fig. 3). What light mortality did occur, took place between 9 November 1962, and 11 December 1963. The high survival rate can be attributed to the fact that trays were off the bottom keeping the oysters out of reach from crabs, drills, and stingrays, and relatively free from silt. A check of the ground control plot revealed 75 per cent mortality and very little growth between 9 November 1962 and 11 December 1963.

GROWTH

Samples of oysters were measured three times during the period November 1962 to 1 May 1964 (Table 1). Average length of the oysters was 57 mm when received 6 September 1962. Each sample contained 25 oysters randomly selected for length and width measurements, and 10 for depth. The most noticeable increase in length and width occurred between 9 November 1962 and 12 December 1963, when the oysters increased from 63 to 87 mm in length and from 65 to 84 mm in width. No increase in length or width took place during the winter of 1963-64, but a slight increase in depth was observed. On 21 October 1964, observations indicated that the oysters had added summer growth in all dimensions.

Table 1. Growth of European oysters held in trays at Tomales Bay, September 1962-April 1964 (all measurements in millimeters)

	Length	Increase	Width	Increase	Depth	Increase
6 Sept. 1962	57	--	--	--	--	--
9 Nov. 1962	63	6	65	--	16	--
12 Dec. 1963	87	24	84	19	25	9
13 Apr. 1964	84	-3	80	-4	28	3

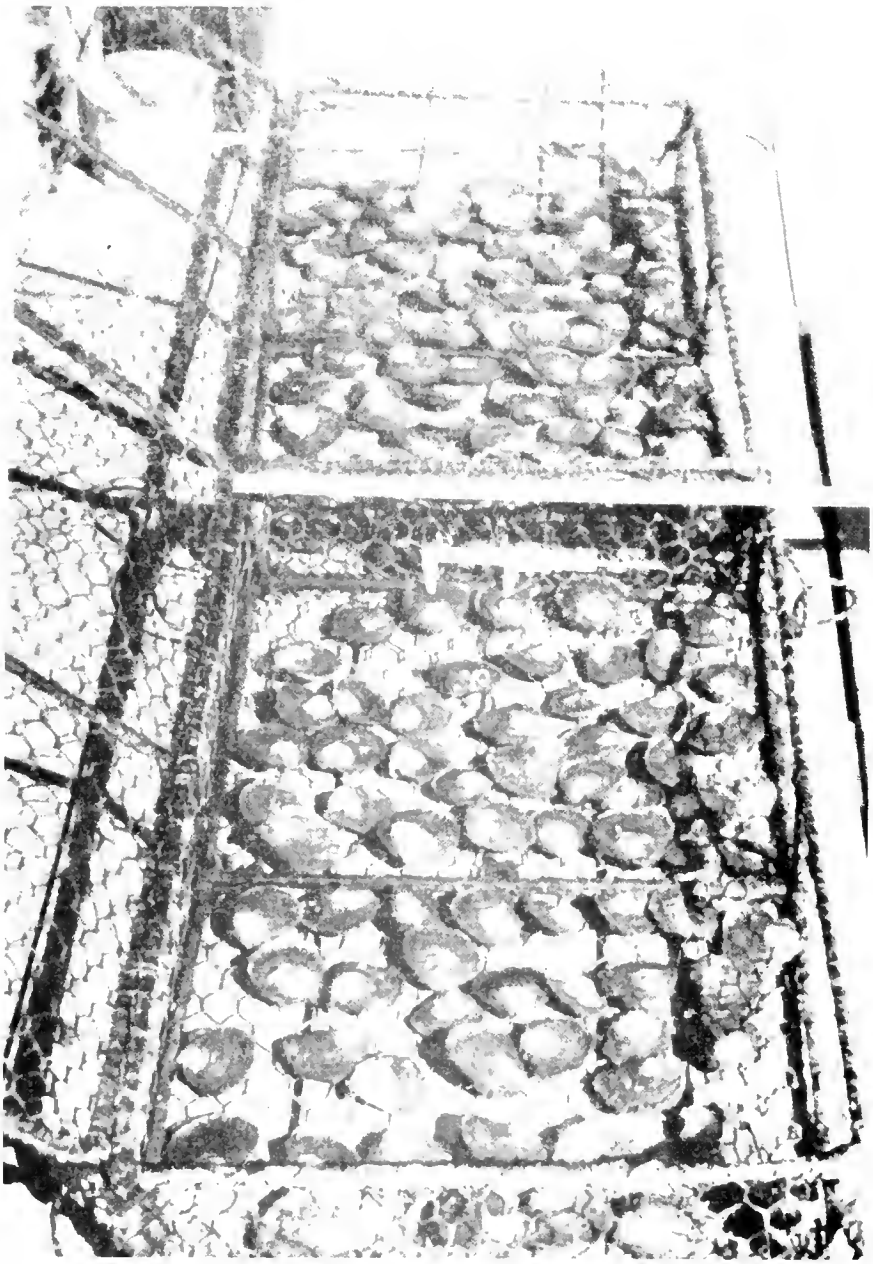


Fig. 3. Trays for holding experimental oysters. Note caliper for measuring oysters in center of the picture.

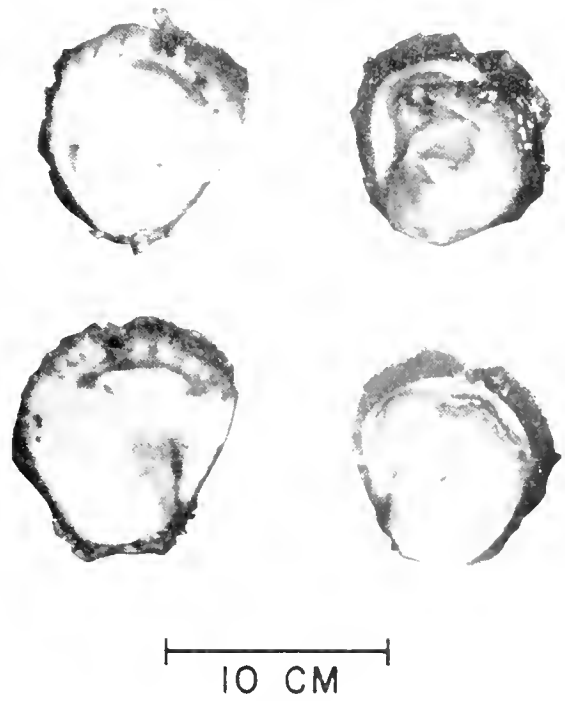


Fig. 4. Meats and shell of Tomales Bay grown European oysters approximately 15 months after planting. December 1963.

CONDITION

To determine the condition of the oysters, a sample of 20 was randomly selected during December 1963. They averaged 0.22 pounds (0.1 kilogram) each in the shell and the count per gallon of meats was 261 (Fig. 4). Condition index, after drying the meats at 50 C for 48 hours and at 100 C for 48 hours, was 10.7. The per cent solids (dry weight divided by net weight of meats) was 16.3.

Observations made during April 1964 showed that some oysters were spawning. A sample of 10 oysters taken to the Tiburon Laboratory released straight-hinge larvae the next day. Some of the larvae survived through metamorphosis to the setting stage (3 weeks).

DISCUSSION

The purpose of this study was to determine if European oyster seed would survive to marketable size and condition in California waters. It was found that this species will grow to a marketable size within two years if suspended in trays, and will survive well when thus protected from predators.

Another study is planned to determine if this species will propagate naturally in California waters where native species are not commercially abundant. It is hoped that a natural set can be obtained by the end of 1965. Shell bags and strings of shell will be placed near potential spawners. Cultivated adult Pacific oysters, Crassostrea gigas, and rocks in the vicinity will provide natural surfaces upon which the larvae may set. The California oyster industry is dependant on the Pacific oyster, but this oyster does not reproduce naturally in California and must be imported as seed from Japan.

Subsequent shipments of European oysters have been received from Milford through the courtesy and cooperation of James Hanks and H. C. Davis. Shipments were received during May 1963, November 1963, and November 1964. The May shipment was planted in both Drakes Bay and Tomales Bay, and survival and growth have been good at both localities. The entire November 1963 shipment was put in Morro Bay (about 200 miles south of San Francisco) where, during the first 6 months, 100 per cent of 685 tray oysters survived and increased in length and width an average of 25 mm. The mean length and width at shipment time was 30 mm, and after 6 months was 55 mm. The November 1964 shipment was distributed in Morro Bay, Tomales Bay, Drakes Bay, and Humboldt Bay. The Humboldt Bay planting is the first of this species in the northern part of the state. Reports of experiments with these 1964 plantings will be available in 1966.

ACKNOWLEDGMENTS

I wish to thank V. L. Loosanoff, H. G. Davis, and J. Hanks for their cooperation in supplying and arranging for the shipment of oysters. Thanks are also due to O. Johansson of Tomales Bay Oyster Company for permission to conduct the experiments on his oyster grounds.

LITERATURE CITED

Loosanoff, V. L. 1955. The European oyster in American waters. Science 121:119-121.

SOME RELATIONSHIPS BETWEEN PACIFIC OYSTER (CRASSOSTREA GIGAS) CONDITION AND THE ENVIRONMENT

Ronald E. Westley

Washington Department of Fisheries
Brinnon, Washington

ABSTRACT

A study has been carried out by the Washington Department of Fisheries to learn some of the relationships between the environment and oyster condition. Areas with an adequate supply of nutrients and high sustained phytoplankton production tended to be areas of good oyster condition whereas areas lacking in nutrients and with little phytoplankton production were areas of poor oyster condition. The water movement in the areas was important for creating an optimum environment for phytoplankton production.

Culture of the Pacific oyster (Crassostrea gigas) in Washington State is carried out primarily on the intertidal flats of various bays and inlets of Puget Sound, Grays Harbor, and Willapa Bay (Fig. 1).

Oysters are sold in Washington State by the gallon of meat, therefore oyster condition has long been of concern to the commercial industry. Oysters in prime condition may yield one gallon of meat per bushel while oysters in poor condition may yield only 0.5 gallon of meat per bushel.

Although oyster condition is of considerable importance to the industry, the reasons for variation in condition are poorly understood. Several authors studying the seasonal cycle of oyster condition comment on the apparent role of the environment: Engle (1958), Haven (1962), Carriker (1959), and Shaw (1963). Medcof and Needler (1941) discuss some relationships of temperature and salinity to condition of Ostrea virginica and Medcof (1946) discusses the effect of transfer on fatness of oysters. Loosanoff and Engle (1947) point out the effect of different concentrations of micro-organisms on the feeding rate of O. virginica. Korringa (1952) states, "Further analysis of the conditions affecting fattening, especially variations in food content and fluctuations in feeding intensity, are required to increase our knowledge of this important matter, so that we may ultimately learn how to control the fattening of oysters in limited bodies of water."

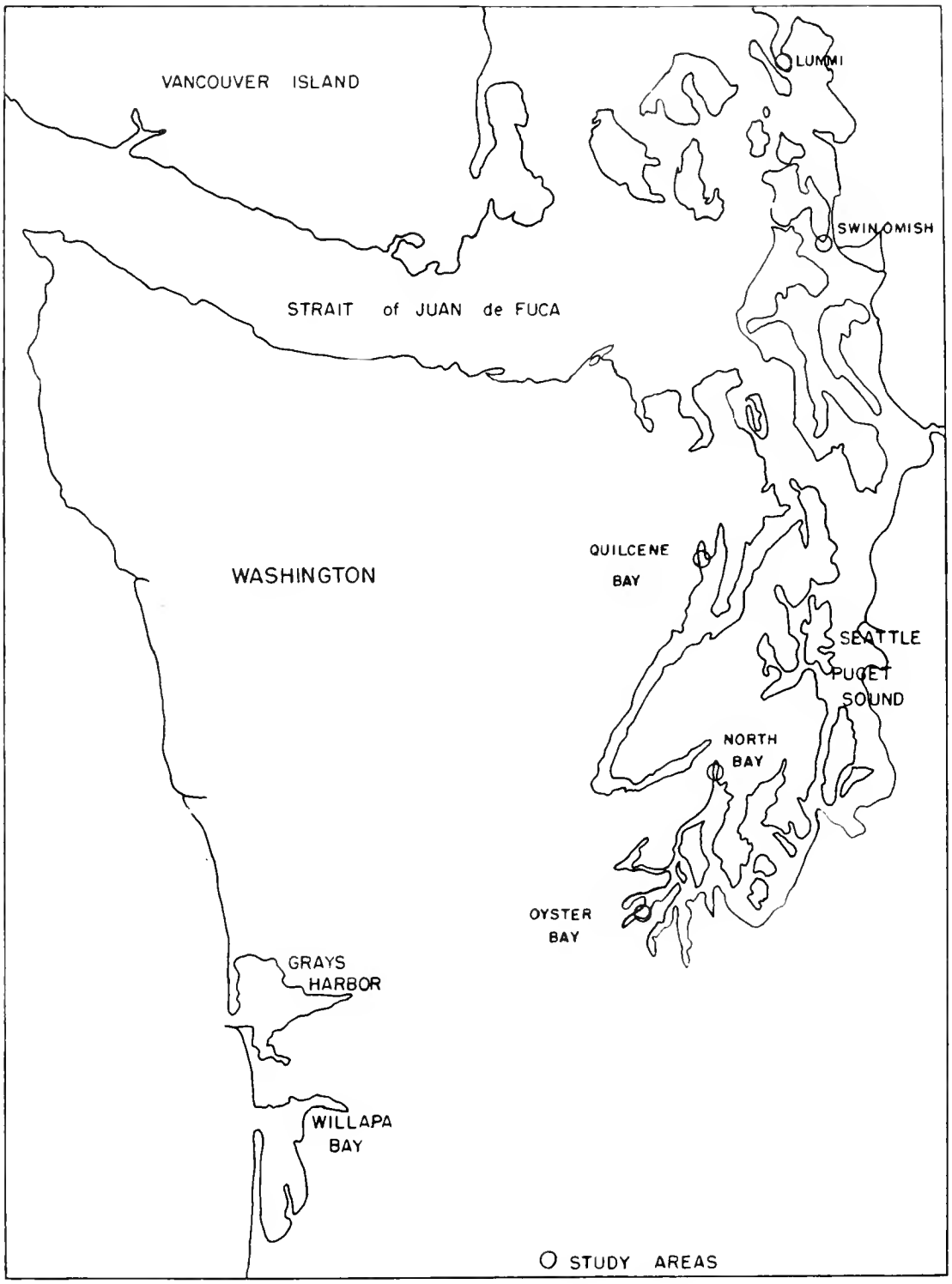


Fig. 1. Map of western Washington.

Because of the lack of information about the reasons for variation in condition or fatness of oysters, the Washington State Department of Fisheries initiated a program intended to provide information that would allow:

A. Evaluation of areas of poor and good oyster condition.

B. Understanding of change in oyster condition within an area.

C. Evaluation of effect of environmental changes on oyster condition.

D. Artificial (pond) fattening of oysters.

Work is still continuing on this project, and this must be regarded as an interim report covering the year 1963. However, it is considered worthwhile to present the available information at this time.

METHODS

There are several separate oyster areas within Washington State that each consistently produce oysters of either good or poor condition. While each of these areas has internal variation in oyster condition, this variation is generally less than the differences between areas (Westley, 1959). It was assumed that these differences in oyster condition might be related to differences in primary productivity.

Based on the available information and the above assumption, a study was set up with the objective of measuring major environmental differences between the areas of poor and good oyster condition, with emphasis on primary productivity and associated environmental factors. The feasibility of this study was increased by recent advances in methods for measuring primary production.

Water sampling and oyster condition stations were set up in each area and sampled monthly throughout the 1963 calendar year (Fig. 1). A vehicle was equipped as a mobile laboratory for the chemical analysis and filtering that had to be done in the field. In most cases water samples were collected from a 16-foot outboard motor boat at 3-foot and 10-foot depths, and oyster samples were collected on foot at low tide.

In this study measurements were made of water temperature, salinity, dissolved oxygen, pH, and alkalinity. Measurements of nutrients included inorganic phosphate, nitrite, nitrate, and silicate. The standing crop of phytoplankton was estimated by the chlorophyll method, and the photosynthetic rate by the radioactive carbon method. Samples for photosynthetic rate were incubated in situ at sample depth for two hours suspended from buoys. In general the methods used in these analyses are those presented by Strickland and Parsons (1960). Oyster condition was measured by the method presented by Westley (1961).

RESULTS

Table 1 presents the results of the environmental measurements, and Table 2 presents the results of the oyster condition index determinations. Figure 2 is a graph of the phosphate and nitrate data, Fig. 3 is a graph of the chlorophyll A photosynthetic rate measurements, and Fig. 4 is a graph of the oyster condition index measurements. Findings in the study fall into three inter-related categories: chemical, biological, and water movement. For ease of presentation these will be handled separately.

The first category, chemical, consisted of measurements of salinity, dissolved oxygen, temperature, inorganic phosphate, nitrite, nitrate, silicate, pH, and alkalinity. Of these, it appeared that nitrate and phosphate were the properties most closely related to oyster condition and the other properties measured were either present in excess, were seasonally regulative, or were unimportant. There is no intent to imply that phosphates and nitrates are the only important nutrients, but they are of major importance and do seem to be an index to the overall nutrient picture. In the remainder of this report the word "nutrient" will refer to phosphate and nitrate. In general all areas entered the spring period of 1963 with an abundant supply of nutrients (Fig. 2), and as the spring phytoplankton bloom started the amount of nutrients decreased. In the areas of poor oyster condition the nutrient levels rapidly approached zero and remained low until fall. In the areas of good oyster condition, the nutrient levels either remained at a somewhat higher level or replenishment of nutrients occurred.

It was learned that the measurable amounts of inorganic nutrients by themselves could be misleading in determining amounts available for productivity. Knowledge of utilization and replacement rates is also needed for an adequate understanding of the relationship

Table 1. Environmental measurements 1963*

Date	Temp	Sal	PO_4	NO_3	Ch A	Mg C/ M^3/hr	Light	Mg C/ M^3/hr/ Light
				OYSTER BAY				
16 Jan	6.2	25.20	2.48	32.5	1.42	0.17	4.4	0.04
12 Feb	6.8	25.51	2.48	19.0	2.61	0.73	4.2	0.17
5 Mar	6.7	24.55	2.10	19.0	1.16	0.79	8.8	0.09
9 Apr	8.7	25.17	1.75	18.5	3.25	1.63	8.8	0.18
15 May	12.6	26.72	1.15	4.1	7.65	9.08	8.6	1.06
5 June	14.3	27.93	1.55	2.1	6.72	1.18	4.1	0.29
23 July	16.6	28.46	1.98	1.3	11.81	5.52	8.6	0.64
27 Aug	19.8	28.91	2.54	7.8	2.44	5.56	12.8	0.43
2 Oct	15.8	29.23	1.77	4.7	1.30	8.34	11.7	0.71
13 Nov	10.5	25.90	2.50	21.0	4.30	0.31	2.1	0.15
17 Dec	8.5	25.95	2.58	20.0		0.34	3.7	0.10
				SWINOMISH				
25 Apr	9.7	22.70	1.39	17.0	3.17	10.28	11.0	0.93
22 May	12.1	26.54	1.53	16.0	5.24	7.86	11.0	0.71
24 June	11.6	21.16	1.31	17.0	4.63	4.63	6.0	0.77
18 July	14.3	26.89	1.70	17.0	3.77	14.22	14.0	1.02
5 Aug	12.9	27.61	1.40	15.0	7.78	8.75	12.0	0.72
3 Sept	13.9	28.07	2.02	18.1	1.76	3.60	12.0	0.30
6 Oct	11.3	28.47	2.38	20.0	2.10	1.79	11.0	0.16
4 Nov	9.7	23.11	2.00	20.5	1.87	1.15	2.0	0.57
				LUMMI				
25 Apr	10.8	25.21	1.41	14.0	1.59	1.63	10.0	0.16
23 May	12.3	27.79	0.84	6.0	1.27	2.90	12.0	0.24
25 June	14.5	20.82	0.99	3.0	1.12	2.18	10.0	0.22
18 July	18.4	20.31	0.46	25.0	1.67	3.44	11.0	0.31
6 Aug	17.2	21.63	0.31	1.6	3.20	2.67	8.0	0.33
4 Sept	15.8	25.60	1.03	3.5	1.36	1.01	5.0	0.20
6 Oct	14.0	27.21	0.98	8.0	3.86	3.13	11.0	0.28
3 Nov	9.7	23.17	1.69	18.8	1.79	0.10	3.3	0.03

Table 1. (cont.)

Date	Temp	Sal	PO_4	NO_3	Ch A	Mg C/ M^3/hr	Light	Mg C/ M^3/hr/ Light
				NORTH BAY				
15 Jan	7.0	27.65	2.61	26.3	0.97	0.37	5.2	0.07
13 Feb	7.8	26.97	2.38	17.9	1.36	0.32	7.0	0.05
6 Mar	8.0	27.52	1.89	14.6	6.16	5.52	12.0	0.46
10 Apr	10.9	25.92	1.26	9.5	4.32	3.85	11.3	0.34
16 May	13.2	27.13	0.93	3.1	3.40	3.04	13.0	0.23
4 June	15.2	25.80	1.19	1.8	3.86	14.35	8.9	1.61
24 July	15.0	28.36	1.61	8.6	5.49	7.89	8.8	0.90
28 Aug	17.5	28.29	2.11	1.9	11.55	4.69	12.7	0.37
1 Oct	16.2	28.52	1.80	1.7	13.51	16.03	10.8	1.48
14 Nov	11.0	24.84	2.47	18.0	2.73	0.63	3.9	0.16
18 Dec	8.9	28.17	2.79	19.0		0.03	1.4	0.02
				QUILCENE BAY				
14 Jan	5.8	26.08	2.15	22.0	1.47	0.53	4.4	0.01
11 Feb	7.8	25.93	2.23	18.0	1.30	0.77	11.0	0.07
4 Mar	7.7	25.83	1.64	16.5	1.25	0.57	7.5	0.08
8 Apr	8.7	27.67	0.06	2.0	7.99	4.95	5.4	0.92
14 May	12.8	26.03	0.52	2.4	1.07	1.72	9.8	0.17
3 June	16.5	24.76	0.25	1.3	1.28	2.67	11.3	0.24
22 July	16.6	27.62	0.70	1.5	3.21	4.23	13.3	0.32
26 Aug	17.5	27.25	0.58	1.4	1.41	2.11	13.0	0.16
30 Sept	16.2	28.22	0.83	1.4	4.33	3.29	12.3	0.27
15 Nov	8.9	22.65	1.79	16.8	2.75	1.23	8.7	0.14
16 Dec	7.0	25.43	2.14	17.0		0.36	4.3	0.08

* Values presented are an average of all depths and all stations for each sampling date.

Table 2. Oyster condition index data—1963

	North Bay	Oyster Bay	Quilcene Bay	Swinomish	Lummi
Jan	8.2	10.5	6.7*		
Feb	8.4	10.3	7.8*		
Mar	8.6	8.3	7.1*		
Apr	10.5	7.8	8.3*		
May	12.3	12.0	12.6*	10.2	10.2
June	11.6	14.5	7.7	13.3	7.4
July	12.6	14.0	5.2	15.0	10.2
Aug	13.1	10.6	4.8	13.8	9.6
Sept	11.8	14.2	5.1	14.9	10.4
Oct	10.4	15.3	7.7	13.5	8.9
Nov	10.9	13.5	8.9	14.2	8.9
Dec	10.4	10.8	7.0		

* 1964 Data

of the chemical nutrients to primary productivity. Instances were observed where apparently replacement equaled rate of utilization and high photosynthetic activity occurred when the measurable nutrients were quite low.

The second category, biological, includes the evaluation of the phytoplankton by measurement of the standing crop and the photosynthetic rate. In most areas phytoplankton exhibited a substantial spring bloom. Some areas had fairly high sustained phytoplankton

production through the summer and fall months while other areas had the initial spring bloom, but little productivity during the remainder of the year (except perhaps a fall bloom). It was found that the areas of high sustained phytoplankton abundance and production were the areas of better oyster condition, as might be expected. The areas of low phytoplankton abundance and production were the areas of poor oyster condition. Intensity of the spring bloom seemed unrelated to oyster condition, and in one instance the intensity of the spring bloom was greatest in an area where oyster condition is poor. Another interesting situation observed was an instance where oyster condition decreased in a "good" area during a period of extreme phytoplankton production in the fall when a decrease in oyster condition is not normally encountered.

During the study it was observed that measurement of the standing crop alone, or the photosynthetic rate alone, could be misleading and that it was necessary to have both measurements. While chlorophyll measurements by themselves do provide a great deal of information, the dynamics of the phytoplankton populations cannot be understood without information on rate of production. Also interpretation of nutrient data is sometimes difficult without knowledge of photosynthetic rate.

The third category considers information on water movement of the areas. This of course would be a major undertaking by itself; therefore, the information used for the various areas comes from other sources when available (principally the University of Washington, Department of Oceanography) or was developed as fully as possible from the available data. Water movement is recognized as being a basic step in understanding the productivity cycle in a given area since it controls the renewal of nutrients and the time-space relationship necessary for phytoplankton production (Raymont, 1963).

In the study three general types of physical environment were evaluated, with the following relationships found:

1. Deep (600 feet) stratified with little water exchange (an area of poor oyster condition).

2. Shallow (50 feet) unstratified with moderate exchange (an area of good oyster condition).

3. Shallow (50 feet) unstratified with fairly rapid exchange (an area of good oyster condition).

Except in a few instances only one area representative of each of these three types has been studied. There are, of course, several other general types of physical environment that have not yet been studied.

DISCUSSION

Some of the interrelationships between the chemical, biological, and physical conditions and oyster conditions are illustrated in the figures which present a portion of the data collected in this study. Fig. 4 presents data on oyster condition in five areas, showing Swinomish, Oyster Bay, and North Bay to be areas of good oyster condition and Lummi and Quilcene Bay to be areas of poor oyster condition. Fig. 2 presents data on nitrate and phosphate content of the water in the same areas. The nitrate data indicate no major differences between the areas except the sustained high values observed at Swinomish. The data on phosphate do show differences, with the Swinomish, Oyster Bay, and North Bay areas having fairly high sustained levels during the spring, summer, and fall while the Lummi and Quilcene Bay areas are low during the majority of the time. Fig. 3 presents data on phytoplankton from the five areas. Here also both the standing crop and the photosynthetic rate are higher in the Swinomish, Oyster Bay, and North Bay areas while low values occur in the Lummi and Quilcene Bay areas.

The available hydrographic data on these areas indicate that Quilcene Bay is part of a deep stratified area (Westley, 1956; McLellan, 1954). Oyster Bay and North Bay are unstratified with moderate exchange (Olcay, 1959; Collias, Dermody, and Barnes, 1962). Swinomish is unstratified with fairly rapid exchange and Lummi is a large shallow cove fed primarily from Bellingham Bay (Westley, Lindsay, and Woelke, 1964).

It is the writer's opinion that one of the most important points to be made from these data is the value of measuring as many aspects of the environment as possible. It is of interest to note that no single property or even category of properties would be sufficient for understanding of the various relationships and some would even be misleading. However, by considering enough factors some understanding of the environment is gained.

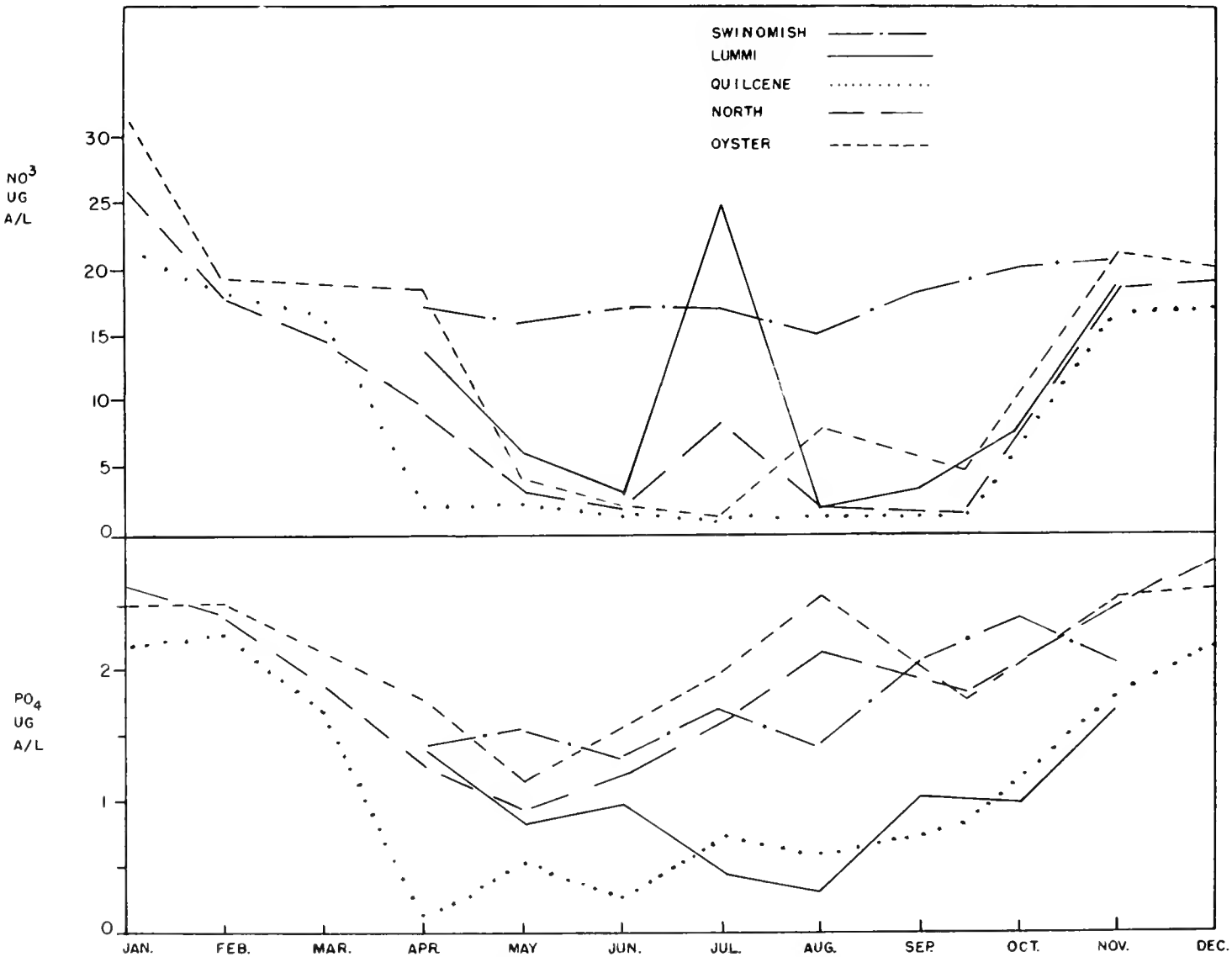


Fig. 2. Nitrate and phosphate data, 1963.

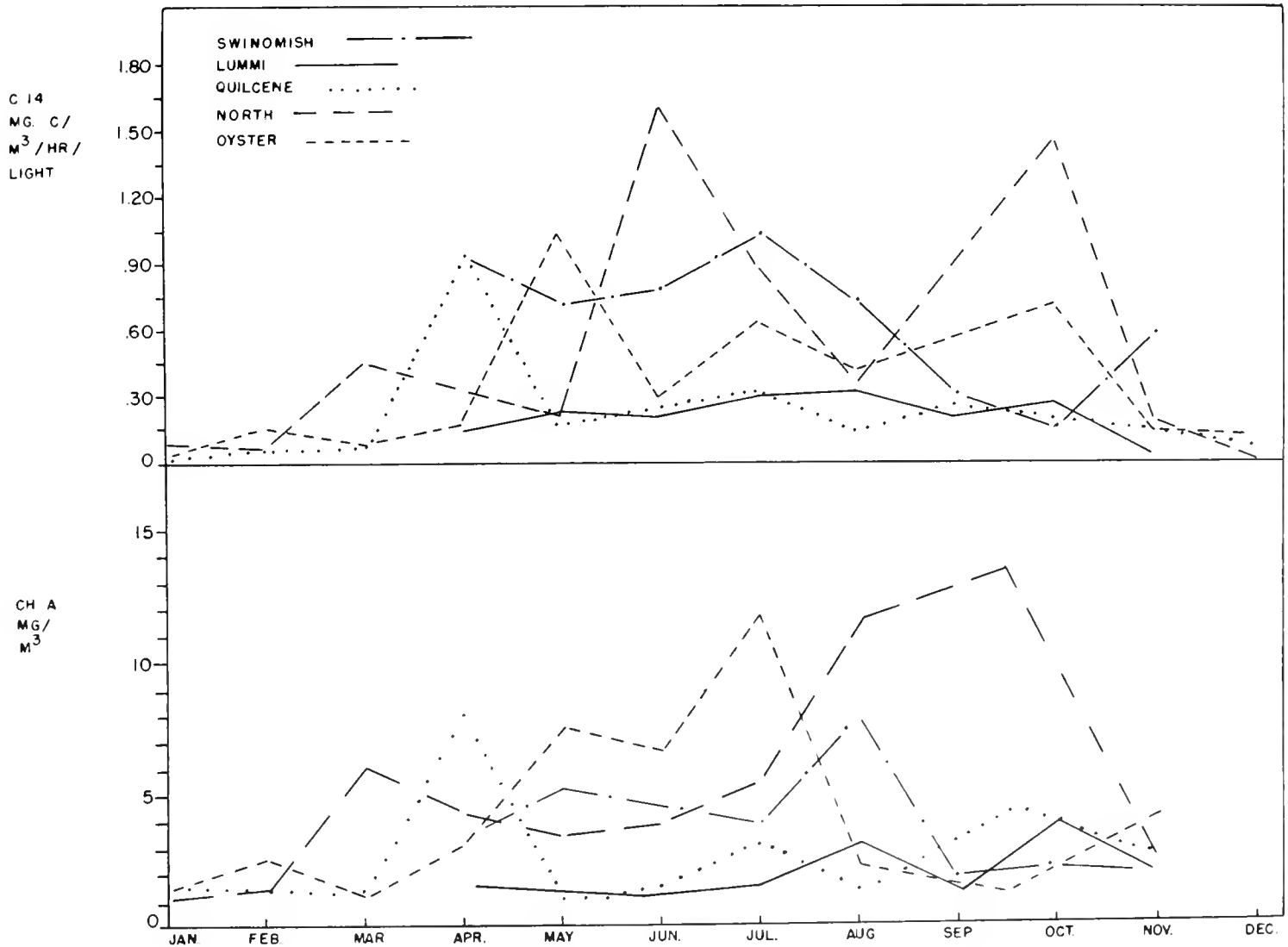


Fig. 3. Photosynthetic rate, chlorophyll A data, 1963.

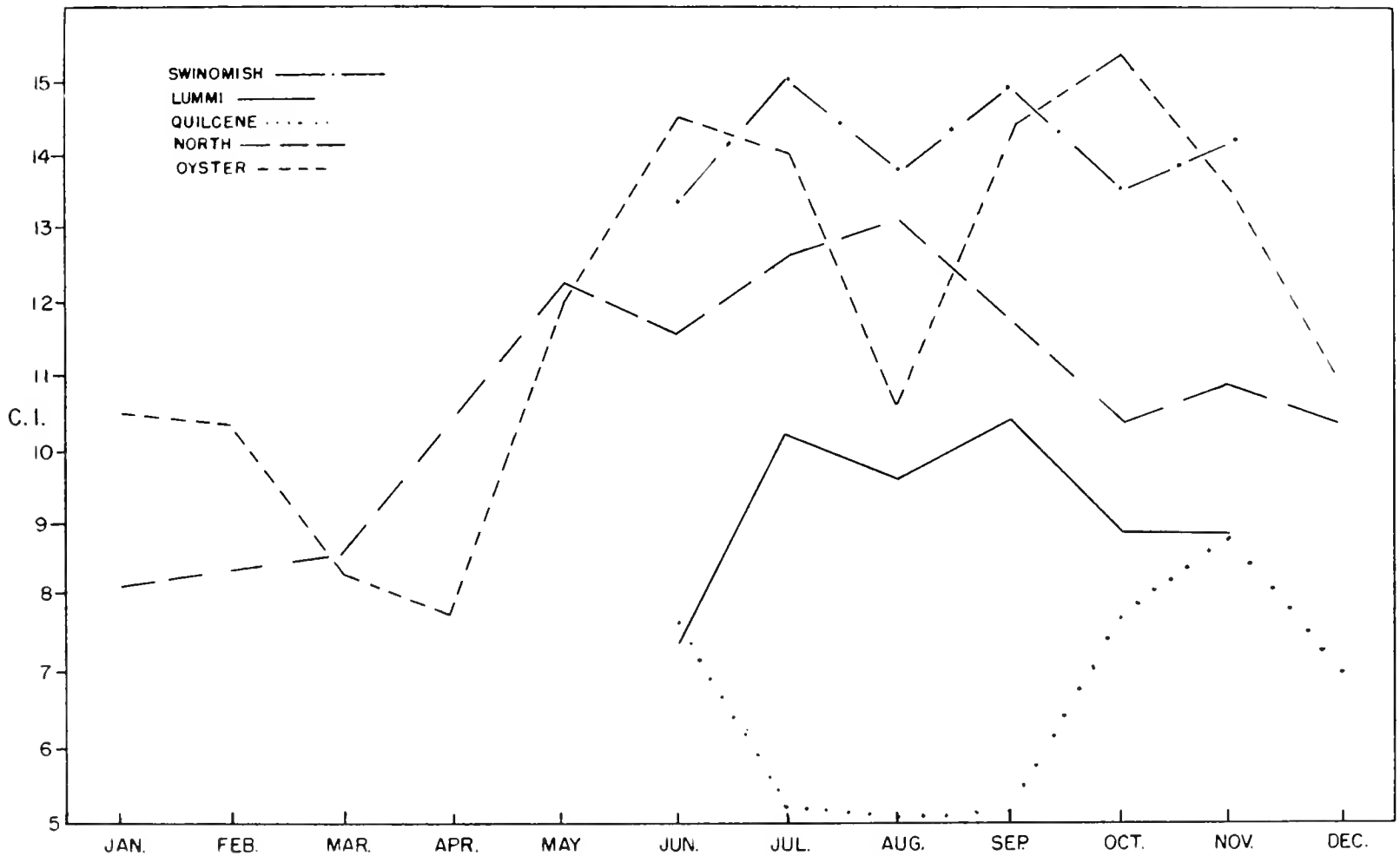


Fig. 4. Pacific oyster condition index data, 1963.

SUMMARY

A study has been made to learn some of the environmental differences between areas of good and poor oyster condition. During the study it was learned that areas with an adequate supply of nutrients and with high sustained phytoplankton production tended to be areas of good oyster condition. Areas of low nutrient concentration had little phytoplankton production, and the oysters were in poor condition. It was found that water movement in the areas was important in creating optimum conditions for good oyster condition. During the study the value of measuring many aspects of the environment was demonstrated. Some relationships have been observed, much remains to be learned.

ACKNOWLEDGMENTS

The writer wishes to gratefully acknowledge the help of Mr. Marvin Tarr who analyzed a majority of chemical samples and Drs. G. C. Anderson and C. A. Barnes of the University of Washington, Department of Oceanography, for help and advice in planning and conducting the project.

GLOSSARY OF TERMS USED IN TABLES AND FIGURES

Temp.	Water temperature in degrees Celsius.
Sal.	Salinity in parts per thousand.
PO_4	Inorganic phosphate in microgram atoms per liter.
NO_3	Nitrate nitrogen in microgram atoms per liter.
Ch. A.	Chlorophyll A in milligrams per cubic meter.
Mg C/ M^3/hr	Photosynthetic rate as measured by milligrams carbon fixed per cubic meter of sea water per hour of incubation.
Light	Amount of visible light. Measured with a Norwood incident light meter (scale 0 to 22).
Mg C/ M^3/hr/ Light	Photosynthetic rate per unit of light.

REFERENCES

Carriker, M. R. 1959. The role of physical and biological factors in the culture of Crassostrea and Mercenaria in a salt water pond. Ecol. Monographs 29:219-266.

Collias, E. E., J. Dermody, and C. A. Barnes. 1962. Physical and chemical data for southern Puget Sound. Univ. Washington Dept. Oceanog., Tech. Rept. No. 67. 151 p.

Engle, J. B. 1958. The seasonal significance of total solids of oysters in commercial exploitation. Proc. Nat. Shellfish. Ass. 48 (1957):72-78.

Haven, Dexter. 1962. Seasonal cycle of condition index of oysters in the York and Rappahannock Rivers. Proc. Nat. Shellfish. Ass. 51(1960):42-66.

Korringa, P. 1952. Recent advances in oyster biology. Quart. Rev. Biol. 27:266-365.

Lackey, J. B., G. V. Borgh, Jr., and J. Glancy. 1952. General character of plankton organisms in waters overlying shellfish-producing-grounds. Proc. Nat. Shellfish. Ass. Conv. Add. 1952:152-156.

Loosanoff, V. L. and James B. Engle. 1947. Effect of different concentrations of micro-organisms on the feeding of oysters (O. virginica). U. S. Fish and Wildlife Serv. Fish. Bull. 51(42):31-57.

McLellan, Peter M. 1954. Puget Sound and Approaches. Univ. Washington Dept. Oceanog. Vol. III. 175 p.

Medcof, J. C. and A. W. H. Needler. 1941. The influence of temperature and salinity on the condition of oysters (Ostrea virginica). J. Fish. Res. Bd. Canada. 5(3):253-257.

Medcof, J. C. 1946. Effect of relaying and transferring on fatness of oysters. J. Fish. Res. Bd. Canada. 6(6):449-455.

Medcof, J. C. 1959. Studies on stored oysters. (Crassostrea virginica). Proc. Nat. Shellfish. Ass. 49(1958):13-28.

Olcay, N. 1959. Oceanographic conditions near the head of southern Puget Sound, August 1957-September 1958. M. S. Thesis, Univ. Washington. 59 p.

Raymont, John E. 1963. Plankton and productivity in the oceans. The MacMillan Co., New York. 660 p.

Shaw, William N. 1963. Index of condition and per cent solids of raft-grown oysters in Massachusetts. Proc. Nat. Shellfish. Ass. 52(1961):47-52.

Strickland, J. D. H. and T. R. Parsons. 1960. A manual of sea water analysis. Bull. Fish. Res. Bd. Canada. No. 125. 185 p.

Westley, R. E. 1956. Retention of Pacific oyster larvae in an inlet with stratified waters. Fish. Res. Pap. Washington Dept. Fish. 1(4):25-31.

Westley, R. E. 1959. Olympia and Pacific oyster condition factor data, State of Washington 1954-1958. Mimeo. Rept. Washington Dept. Fish. Shellfish Lab. 8 p.

Westley, R. E. 1961. Selection and evaluation of a method for quantitative measurement of oyster condition. Proc. Nat. Shellfish. Ass. 50(1959):145-149.

Westley, R. E., C. E. Lindsay, and C. E. Woelke. 1964. Shellfish culture potential of Swinomish and Lummi Reservation tidelands. Washington Dept. Fish. Res. Div., Olympia. 121 p.

SEASONAL GONADAL CHANGES OF ADULT CLAMS, MERCENARIA MERCENARIA (L.), IN NORTH CAROLINA

Hugh J. Porter
University of North Carolina Institute of Marine Sciences
Morehead City, North Carolina

ABSTRACT

Hard clams, Mercenaria mercenaria (L.), from a shallow-water bed in Core Sound, North Carolina, were sampled monthly. Sections of gonads were stained with Delafield's hematoxylin and eosin and examined histologically, from September 1962 through August 1963. Major spawning was in June when water temperatures rose above 20 C, and was followed by light spawning, with a minor peak in September-October, Spawning was followed by rebuilding of follicles. Most unspawned ovocytes were gradually lost in the period December-early March. Major build-up of follicles occurred in March, and by April-May many mature ovocytes and spermatozoa were present. Follicles contained follicle cells not known from northern M. mercenaria.

INTRODUCTION

The gonadal cycles of most Lamellibranchiata are imperfectly known. Seasonal gonadal changes for Mercenaria mercenaria (L.) have been reported by Loosanoff (1937a & b) from Long Island Sound but not from more southern waters. As shown by Pfitzenmeyer (1962), Ropes and Stickney (1962), and Shaw (1964) for Mya arenaria L. the gonadal cycle for a particular species of Lamellibranchiata may vary considerably between localities.

METHODS

The studies reported here are of Mercenaria mercenaria from a clam bed in Core Sound called Whitehurst Island. This bed, in the midst of a major clam producing area, was selected because of the abundance of clams and its proximity to an offshore bed of Mercenaria campechiensis (Gmelin) (Porter and Chestnut, 1962). Concurrent studies were also made on the gonadal cycle of Mercenaria campechiensis. At low tide water depth was between zero and two feet. During the sampling period, September 1962 to August 1963, recorded salinities varied between 27 and 30%.

Samples were collected monthly. Gross gonad conditions were noted at time of sampling but, except in extreme conditions, this index was not reliable. Gonadal tissue from each of 25-30 large clams in each sample was fixed in Bouin's fixative for 24 hours. Dehydration and paraffin infiltration was patterned in part after the technique of Burton (1961). Sections were cut at five microns and stained with Delafield's Hematoxylin and an alcoholic solution of Eosin Y.

RESULTS

Development of Female Gonad Follicles

Female clams showed first definite signs of spawning in June. Spawning, indicated by localized areas of tissue containing follicles with few large ovocytes present, about five per follicle (Table 1), characterized all of the June samples. Average follicle widths (Table 2) and average number of large ovocytes per $100\mu^2$ follicle area (Fig. 1) had decreased considerably from April and May figures. Gonad sections showed heavy spawning in only two female clams and these were not completely spawned out. Small ovocytes were frequently found attached to the walls of spawned-out follicles.

Ovogenetic activity following the June spawning restored many female clams to a partially ripe condition during the July through September period. Restored females had no follicle areas with a spawned-out appearance. Average number of large ovocytes per $100\mu^2$ follicle area per clam was higher in July through September than in June (Fig. 1). During this period, 40-50% of the female clams continued to exhibit signs of having spawned though most signs were light and only about 10% heavy. Only one female during August was completely spawned out. Date of spawning for each could not be determined.

Increased signs of a gradual decline in gonad condition occurred during October and November. The drop in numbers of large ovocytes in the September-October period (Fig. 1) may have been an indication of a light spawning. By November about a third of the gonads had lost most of their ovocytes but the number of clams with apparently ripe gonads remained close to 50%.

The number of small ovocytes in the follicles began to increase during December and January (Fig. 1 and Table 1). About 50% of the female clams during this period continued to be apparently ripe. The December sample as determined from general gonad appearance,

Table 1. Average number of large and small ovocytes per follicle from female Mercenaria mercenaria (L.). Ten maximum-sized follicles examined from each clam

Sample date	Large ovocytes		Small ovocytes		Sample size
	Sample ave.	Range of indiv. clam aves.	Sample ave.	Range of indiv. clam aves.	
13 Sept. 1962	7.14	1.8-9.1	2.65	0.5-4.1	14
9 Oct. 1962	8.10	0.0-16.1	2.76	1.0-4.9	11
20 Nov. 1962	6.20	0.8-12.8	2.78	1.3-5.0	14
18 Dec. 1962	9.14	3.6-21.5	5.08	0.9-9.0	18
23 Jan. 1963	8.78	0.0-17.0	4.92	1.4-17.5	17
4 March 1963	5.31	0.0-15.0	8.84	2.7-14.6	17
1 April 1963	14.61	10.4-20.7	3.98	1.4-6.8	16
28 May 1963	10.68	6.4-15.1	2.82	0.6-5.1	10
27 June 1963	4.96	1.4-9.8	2.81	1.4-4.7	16
30 July 1963	8.62	2.7-16.0	2.21	0.6-3.9	14
29 Aug. 1963	8.70	0.0-13.0	3.58	0.0-5.7	10

Table 2. Average follicle widths from male and female Mercenaria mercenaria (L.). Ten maximum-sized follicles measured from each sampled clam

Sample date	Female			Male		
	Sample ave. (μ)	Range of indiv. clam aves. (μ)	Sample size	Sample ave. (μ)	Range of indiv. clam aves. (μ)	Sample size
13 Sept. 1962	193.5	162-238	14	181.9	150-223	11
9 Oct. 1962	253.5	187-236	11	148.3	115-205	13
20 Nov. 1962	186.7	128-240	14	153.4	113-275	7
18 Dec. 1962	274.8	193-351	18	169.1	132-221	7
23 Jan. 1963	236.5	178-332	17	178.6	150-204	5
4 Mar. 1963	238.9	176-298	17	188.0	159-213	8
1 April 1963	276.4	233-345	16	226.4	168-292	9
28 May 1963	268.4	222-309	10	212.4	160-334	15
27 June 1963	211.6	146-272	16	189.0	147-229	8
30 July 1963	255.6	188-330	14	178.5	113-223	11
29 Aug. 1963	255.5	214-288	10	172.2	127-222	13

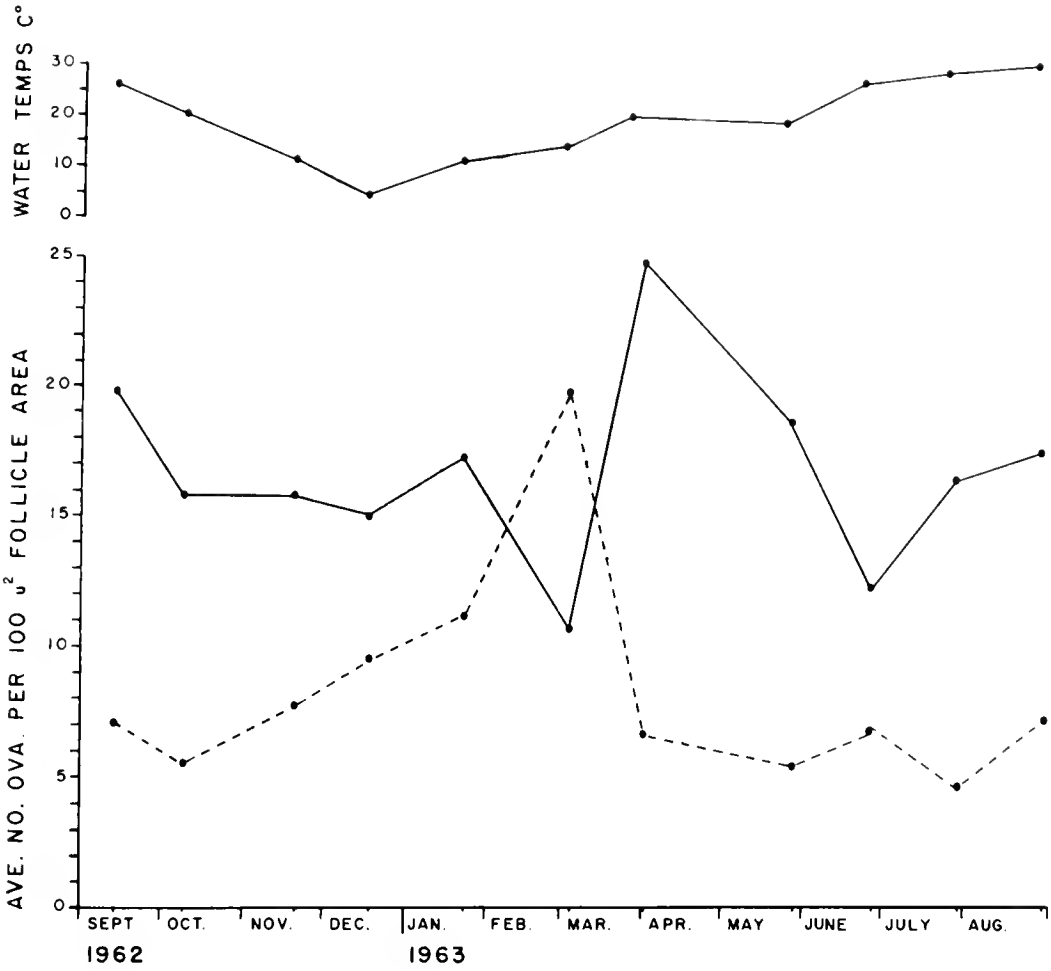


Fig. 1. Average number small and large ovocytes per $100\mu^2$ follicle area during sampling period. Dotted line represents small ovocytes and solid line represents large ovocytes. Follicle area was an approximate figure derived from the product of average follicle lengths per sample and average follicle widths per sample divided by two.

average number of ovocytes per follicle (Table 1), and follicle width (Table 2), appeared riper than in November or January. The January sample also appeared in riper condition than the November sample.

By early March the percentage of apparently ripe females which had been at about 50% had dropped to about 10%. A decrease in the average number of large ovocytes per $100\mu^2$ in the follicles accompanied by a corresponding sharp increase in the number of small ovocytes per $100\mu^2$ occurred in the period between late January and early March (Fig. 1). Some ovocytes were noted undergoing cytolysis. Follicle cells (Fig. 2) several layers thick and surrounding the young ovocytes were frequently found in large follicles. Some small young follicles were completely filled with the cells.

The numerous small ovocytes present in the follicles during early March had matured by early April. At this time all gonads appeared quite ripe. Some gonads contained follicles with ovocytes separated from each other by cellular partitions (Fig. 3). The ovocytes surrounded by these cells, called partition cells, sometimes appeared to be undergoing cytolysis. While noted infrequently in earlier samples, this condition was particularly evident in March and April samples. Follicle cells within the female follicles of the April sample were rarely found.

The high degree of ripeness present in April was not present in May though all but a few of the follicles still had an unspawned appearance.

Developmental Stages of Male Gonad Follicles

"Immature" (Fig. 4): Follicle expanded; lumen filled with spermatocytes; thin layer of spermatogonia between spermatocytes and follicle wall; center of lumen frequently with a small mass of spermatids and a few spermatozoa.

"Early ripe": Follicle expanded; lumen with small central area containing dense radiating bands of spermatozoa; dense areas of spermatids and then spermatocytes surrounding spermatozoa area; spermatogonia attached to follicle wall just outside circular band of spermatocytes.

"Ripe" (Fig. 5): Dense bands of radiating spermatozoa filling about one-half of follicle area; spermatid and spermatocyte layers less thick than in previous stage; spermatid band frequently thicker than spermatocyte band; similar in other respects to above stage.

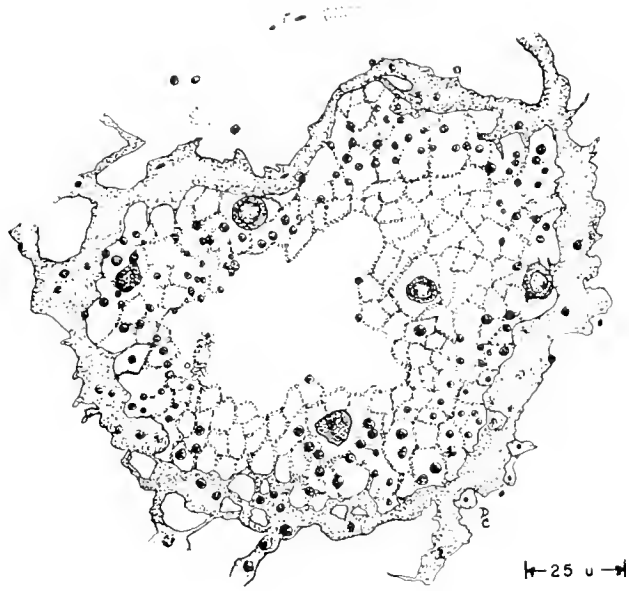


Fig. 2. Female follicle containing follicle cells (making up the reticulated mass around the small ovocytes). May 1963 sample. Gonad from which plate was drawn also contained follicles with partition cells.

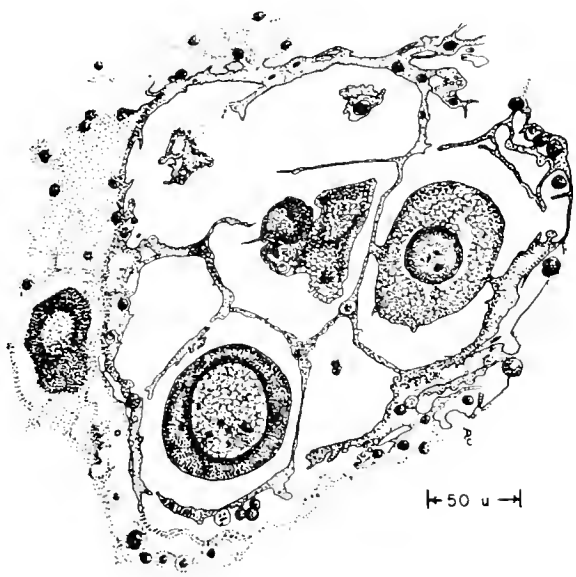


Fig. 3. Female follicle with ovocytes surrounded by partition cells (long, thin, narrow cells with follicle). Follicle from a mature-looking female in January 1963 sample.

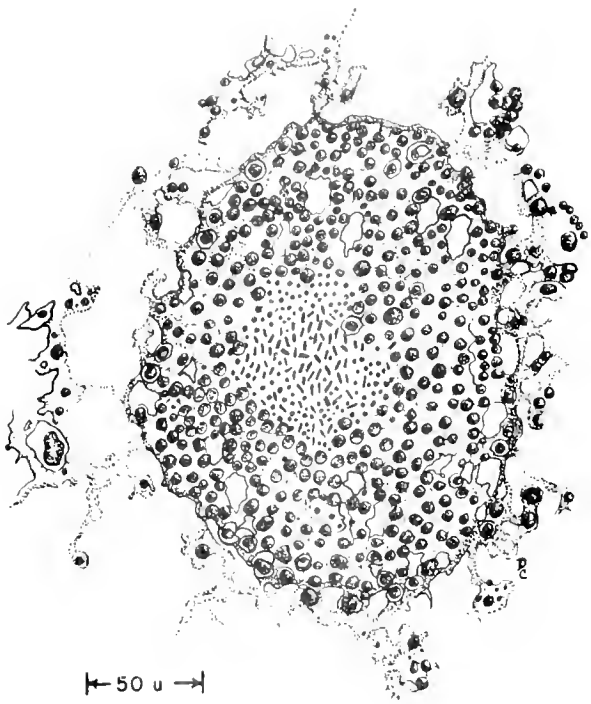


Fig. 4. "Immature" male follicle. April 1963 sample.

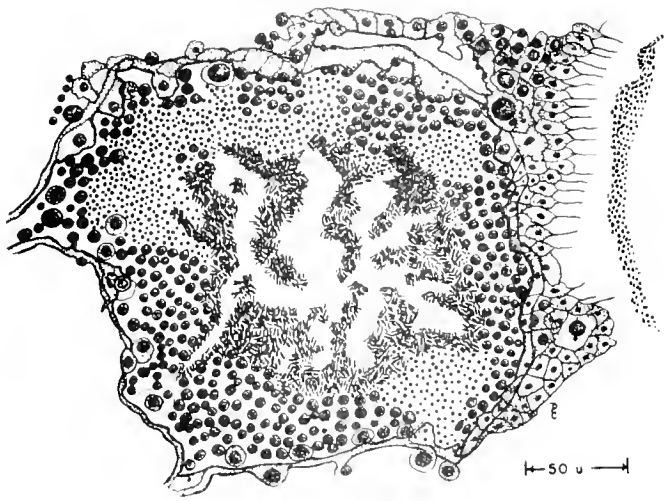


Fig. 5. "Ripe" male follicle. May 1963 sample. On upper right edge of drawing is a blood vessel. Right edge of drawing includes a portion of a gonadal duct. Between the blood vessel and the gonadal duct are a few nutritive cells.

"Spawned": Two different forms of this stage exist. "Partly spawned" state (Fig. 6) generally has an expanded follicle with a partially empty lumen surrounded by dense radiating bands of spermatozoa and peripheral layers of spermatids and spermatocytes; may have more spermatids than spermatocytes. "Spawned-out" state has nearly empty follicle with a very thin band of spermatocytes and spermatogonia along the follicle wall and a few spermatozoa and spermatids free in lumen; usually expanded but may occasionally be compressed in shape or size.

"Late ripe": Usually smaller in size than "immature" through "spawned" stages; radiating bands of spermatozoa fill most of follicle but are not as dense as in "ripe" and "spawned" stages; circular bands of spermatids and spermatocytes usually quite thin; follicle cells frequently surround the occasional spermatogonia; very probably follicles have spawned at least once and then partially redeveloped.

"Undifferentiated" (Fig. 7): Follicle usually expanded; thin band of spermatocytes surround attached spermatogonia; lumen filled with varying densities of loose spermatids and spermatozoa in irregular order.

"Inbetween" (Fig. 8): Very similar to "spawned-out" stage (may be identical to it); major difference between the two is that redevelopment of follicle has begun in the "inbetween" stage; may be in expanded, shrunken, or compressed condition; small ribbons of spermatogonia, numbers of spermatocytes, a few spermatids and spermatozoa radiate from follicle wall; ribbons particularly at base may be separated from each other by follicle cells.

Male clams showed their first major spawning in June (Fig. 9). All males showed signs of having spawned but none appeared to have spawned out.

As in the female follicles, gametogenic activity in July and August restored many of the male follicles to a ripe condition. The number of "spawned" gonads decreased and the number of "late ripe" gonads increased (Fig. 9). About 10% in each sample had had a heavy spawning.

In September and October there were some signs of spawning by male clams. Gonads from the September sample frequently exhibited "spawned" follicles. "Inbetween" follicles occurred in large numbers in both September and October samples (Fig. 9). Ten per cent of the gonads continued to show signs of heavy spawning. Two gonads in October were noted to have completely spawned out.

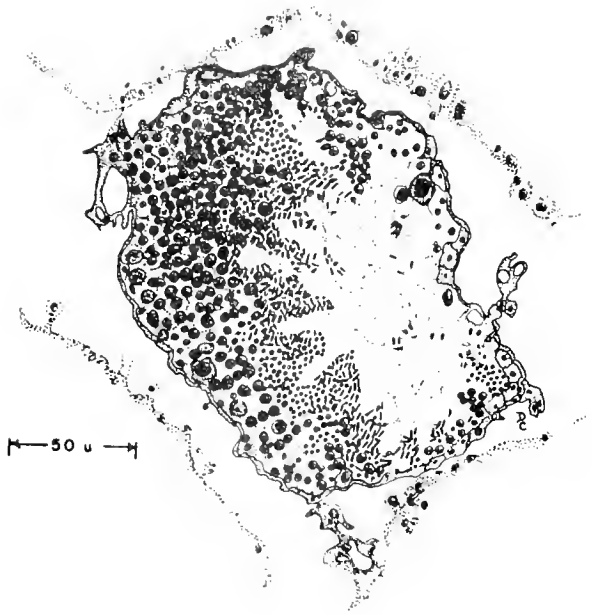


Fig. 6. "Partly spawned" male follicle. June 1963 sample. Upper right inner edge of follicle has an ovogonium.

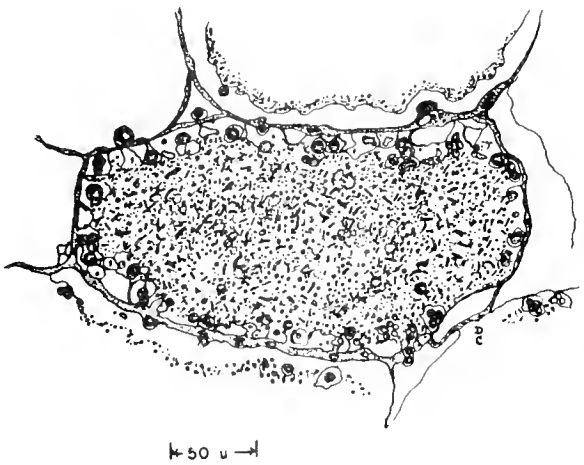


Fig. 7. "Undifferentiated" male follicle. January 1963 sample.

Fig. 8. "Inbetween" male follicle. March 1963 sample. On lower right edge of follicle is a passageway connecting the follicle to a gonadal duct. In the passageway were many loose spermatids and spermatozoa.

A second restoration of the male follicles occurred in October-December. Most gonads were in the "late ripe" stage. Numbers of "undifferentiated"and "inbetween" follicles were present (Fig. 9). Follicle cells, which occurred occasionally in all samples except April-June, were most noticeable in December.

By January most of the ribbon-like groupings of spermatozoa in the "late ripe" follicles had disappeared and been replaced by masses of spermatids and spermatozoa ("undifferentiated" stage). "Late ripe" and "inbetween" follicles were present in smaller numbers (Fig. 9).

In March renewed spermatogenetic activity in the male follicles had become noticeable. The mass of loose spermatids and spermatozoa in the follicle lumen, characteristic of the January sample, had disappeared leaving the lumens empty. Small, thin bands of spermatocytes and spermatids, characteristic of the "inbetween" stage, occurred attached to the follicle wall. Twenty-five per cent of the male gonads

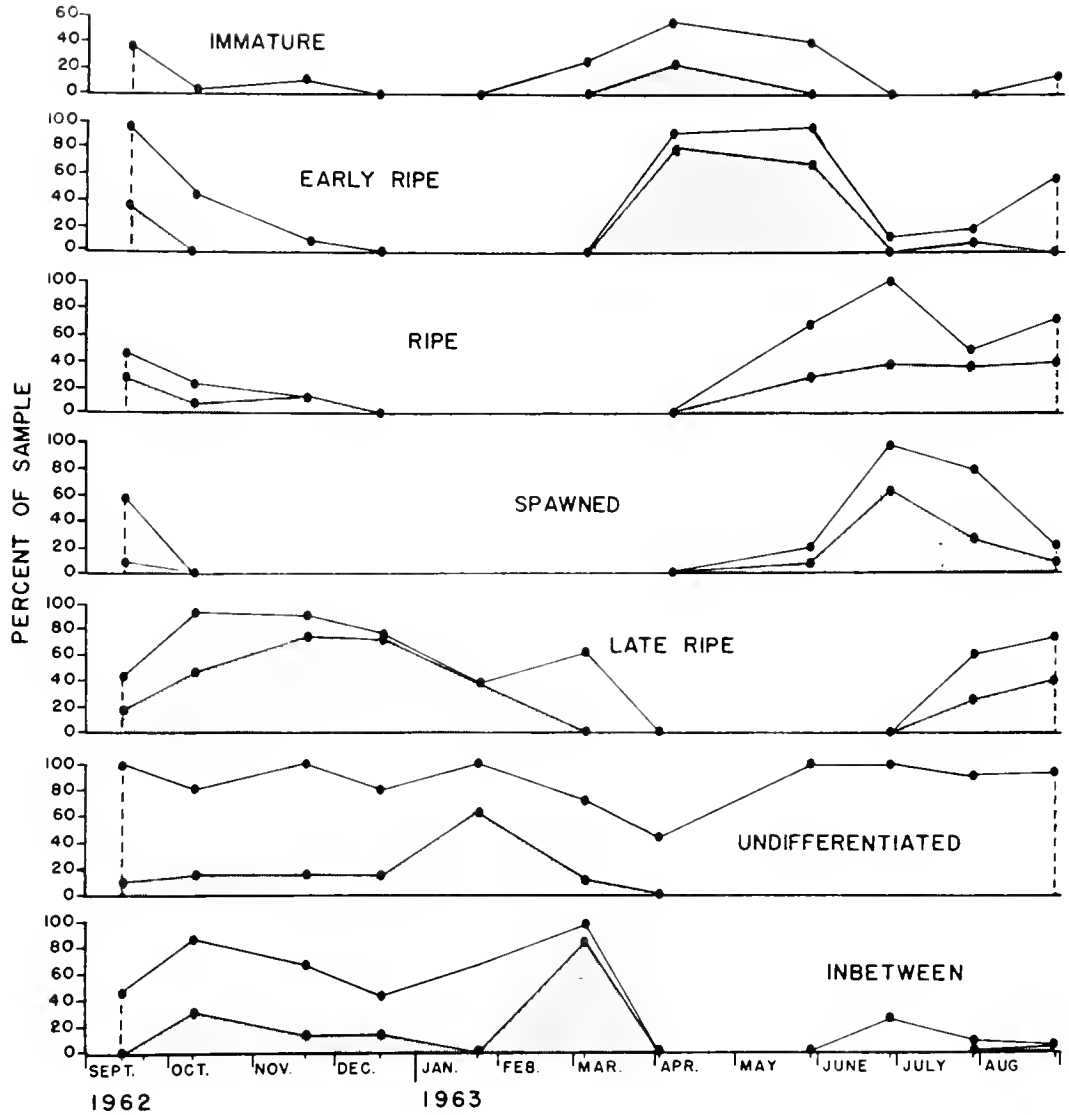


Fig. 9. Follicle stages present in male gonads during sampling period. Clear area represents percentage of gonads in a sample containing a designated follicle stage. Shaded area represents percentage of gonads in a sample with the designated follicle stage as the dominant stage.

were advanced enough in redevelopment to contain some immature follicles. "Late ripe" and "undifferentiated" follicles also occurred in many of the gonads (Fig. 9).

The early April sample showed most of the male gonads in an "early ripe" state with the remainder in an "immature" state (Fig. 9). The only other follicle type noted was "undifferentiated". This follicle type was found in fewer gonads during March and April than in any other sampled months (Fig. 9).

The May sample also contained a majority of the gonads in an "early ripe" state. Ripe gonads were present and a number of the gonads contained "immature" follicles. A small percentage of the follicles showed signs of having spawned (Fig. 9).

DISCUSSION

It has been shown by Loosanoff (1937b) that temperature is one of the major environmental factors regulating the gonadal cycle in clams. Differences exist between the temperature cycles of the Charles Island bed in Long Island Sound and the Whitehurst Island bed in Core Sound, North Carolina. Winter temperatures at Charles Island go down to 1 C (Riley, 1952), whereas at Whitehurst Island temperatures do not go much below 5 C. Summer water temperatures by Charles Island reach 22-23 C for a very short period (Loosanoff, 1937c), whereas at Whitehurst Island bed they are over 25 C for three or more months and reach 30 C for short periods. Thus, differences between clam gonadal cycles of the two areas would be expected.

Core Sound clams spawned much earlier (June) than the Long Island Sound clams (August). Spawning possibly started at about the same temperature but the Long Island spawning occurred over a short period whereas the Core Sound spawning probably occurred over a four-month period. Loosanoff (1937c) has shown that in tributaries of Long Island Sound, in shallower water than at Charles Island, spawning may start as early as June and continue at least through August, mainly due to higher water temperatures in the shallower beds. Whether or not differences in length and time of spawning or even in the gonadal development cycle occur between Whitehurst Island clams and clams from other North Carolina waters, and from greater depths, is not known. Experiments in laboratory spawning of North Carolina clams have shown that clams from other North Carolina areas were not as difficult to spawn as those from Whitehurst Island.

The major redevelopmental period of Charles Island clam gonads occurred immediately after spawning with many ripe gonads in December and January. A secondary redevelopmental period occurred in May after temperatures reached 10-15 C. The major period of redevelopment for Whitehurst Island clams was February and March when temperatures were fluctuating between 10 and 20 C. Secondary periods occurred following the June spawning and during December and January following the end of the spawning season. While gonadal buildup in the spring occurs commonly in oysters and in juvenile male clams which are in the process of changing their sex (Loosanoff, 1937a), it has not been reported in adult venerid clams. Quayle (1943) in Venerupis staminea Conrad = (Paphia staminea), Quayle (1948) in Venerupis pullastra (Montagu), and Ansell (1961) in Venus striatula (da Costa) record the major redevelopmental period to be just following spawning.

In the gonadal cycle of the female, a large proportion of the remaining ovocytes were lost during February, probably by the process of extrusion. Few signs of cytolysis were noted up to and including that time. Among other venerids studied, Quayle (1943) and Loosanoff (1937b) have mentioned that ovocytes may be extruded from clams at the termination of their spawning period. The March sample showed that while the predominant cells in the follicle were young ovocytes, a number of old ovocytes still remained. By early April the follicles consisted primarily of young mature ovocytes and a number of ovocytes from the previous year. Both Ansell (1961) and Quayle (1943) suggest that older ovocytes carried over into redeveloped follicles in venerids, and that ovocytes from a subsequent spawning would consist of two separate ovocyte year-classes.

In late May the drop in numbers of ripe ovocytes per follicle (Fig. 1) may have been caused by one or more of the following factors. 1. There may have been an early but light spawning (doubtful as water temperatures were too low for spawning). 2. Numbers of ovocytes may have been extruded from the follicles into the gonoducts for storage just prior to spawning. Stickney (1963) has reported this in Mercenaria mercenaria, Mya arenaria, and Spisula solidissima (Dillwyn). This was not demonstrable in this series as no ovarian gonoducts were recognizable. 3. Some of the drop may have been caused by cytological destruction of ovocytes from the previous year, initiated in some manner after the older ovocytes had been enclosed by the partition cells.

Follicle cells seemed to be present in the follicles of female gonads. They occurred in male tissue but were much more difficult

to differentiate from other cells as also stated by Ansell (1961). These cells may have been indifferent cells or nutritive-phagocytic cells, but they showed the characteristic vacuoles of follicle cells. Because of their large numbers they probably were not the precursors of primary ovogonia as apparently the "indifferent" cells are. Follicle cells were not mentioned in Mercenaria mercenaria by Loosanoff (1937a, 1937b) though he did mention the presence of indifferent cells and occasional nutritive-phagocytic cells interspersed among ovogonia. While the cells were about the same size as that described by Loosanoff (1937a) for the nutritive-phagocytic cells, their nuclei appeared to be slightly larger than the nutritive-phagocytic cells occurring outside the follicle walls of the Core Sound clams. Nutritive-phagocytic cells outside the follicle walls frequently were characterized by being nearly filled with orange or reddish bodies that were not well stained by either eosin or hematoxylin stains. These bodies were not seen inside the follicles. Ansell (1961) reported that immediately following spawning, the follicles of Venus striatula were sometimes filled with vacuolated cells. Quayle (1943) has also shown that following spawning the follicles in Protothaca staminea may fill up with vacuolated cells called follicle cells. These cells have been reported occurring during follicle redevelopment in Mya arenaria by Coe and Turner (1938). Stickney (1963) said that Mercenaria mercenaria lacks follicle cells. It is doubtful that Loosanoff or Stickney accidentally missed seeing follicle cells. Presence or absence of follicle cells could be caused by racial differences or by phenotypic response to environmental differences by clams from different geographical areas.

Both Quayle (1943) and Coe and Turner (1938) assumed the function of follicle cells to be nutritive. In Core Sound clams they appeared primarily in the female gonads just before the major redevelopment period as was reported by Ansell (1961) and Quayle (1943) in other venerids. At other times they were found primarily in follicles lying on the outer edges of the gonadal tissue and in small young follicles. If the function was that of nutrition to the young ovocytes during ovogenesis, it is odd that they were not present in numbers during the secondary redevelopmental periods. The presence or abundance of these cells in male follicles during December is not understood. Possibly they were easier seen at this time than at other times.

The cycle of gonadal development in male clams from the Whitehurst Island area was more complicated than previously described for other venerids.

Immature and "early ripe" phases occurred primarily during the spring months whereas in Long Island Sound they occurred during the late autumn (Loosanoff, 1937b). Quayle (1943) and Loosanoff (1937b) characterized a ripe male gonad as one in which most of the follicle was filled with bands of spermatozoa. This was characteristic of the "late ripe" stage from Whitehurst Island. "Ripe" condition from the Whitehurst Island sample had the follicle only about half filled with spermatozoa. The reason for the difference may have been that clams described by Loosanoff and Quayle had a short spawning period whereas the spawning period in the Whitehurst area was comparatively long.

A few males sampled during the latter part of the spawning season resembled that stage described by Loosanoff (1937b) as "spawned males." These fitted the Core Sound category of "spawned-out" males. Ansell (1961) stated that a spawning male was characterized by follicles containing loose spermatozoa. This fits the Core Sound "undifferentiated" follicles. Ansell (1961) did point out the difficulty of distinguishing ripe males from spawned males. The purpose of the "undifferentiated" follicle seemed to be that of preparing the spermatozoa in the follicle for extrusion or spawning. With the spermatozoa in this condition, they could be spawned or gradually extruded from the follicles.

The spawned-out appearance of the gonads in March, characteristic of the "inbetween" stage, showed that extrusion had removed most of the older spermatozoa and that spermatogenesis had begun after having apparently stopped by January. No sign of change in sex, which might occur at this time, was noted among any of the sampled clams.

ACKNOWLEDGMENTS

I wish to gratefully thank Dr. A. F. Chestnut for his review and editing of this paper, Mr. R. A. Davis and Miss Mary A. Phillips for help in the preparation of the gonadal slides and Miss Deborah Coffin for the drawing of Figs. 2-8. Without their help and the help from the other members of the Institute of Fisheries Research staff, this paper would not have been possible.

REFERENCES CITED

Ansell, A. D. 1961. Reproduction, growth and mortality of Venus striatula (da Costa) in Kames Bay, Millport. J. Mar. Biol. Ass. United Kingdom. 41: 191-215.

Burton, R. W. 1961. Routine microtechnical methods employed in the preparation of oyster tissues for histological study. Shellfish Mortality Program, U. S. Bur. Comm. Fish. Biol. Lab., Oxford, Maryland. June, 1961. 11 p.

Coe, W. R. and H. J. Turner, Jr. 1938. Development of the gonads and gametes in the soft-shell clam (Mya arenaria). J. Morphol. 62(1):91-111.

Loosanoff, V. L. 1937a. Development of the primary gonad and sexual phases in Venus mercenaria Linnaeus. Biol. Bull. 72:389-405.

Loosanoff, V. L. 1937b. Seasonal gonadal changes of adult clams, Venus mercenaria (L.). Biol. Bull. 72:406-416.

Loosanoff, V. L. 1937c. Spawning of Venus mercenaria (L.). Ecology 18(4): 506-515.

Pfitzenmeyer, H. T. 1962. Periods of spawning and setting of the soft-shelled clam, Mya arenaria, at Solomons, Maryland. Chesapeake Sci. 3(2):114-120.

Porter, H. J. and A. F. Chestnut. 1962. The offshore clam fishery of North Carolina. Proc. Nat. Shellfish Ass. 51:67-73.

Quayle, D. B. 1943. Sex, gonad development and seasonal gonadal changes in Paphia staminea Conrad. J. Fish. Res. Bd. Canada 6(2):140-151.

*Quayle, D. B. 1948. Ph.D. Thesis, University of Glasgow.

Riley, G. A. 1952. Hydrography of the Long Island and Block Island Sounds. Bull. Bingham Oceanogr. Coll. 13(3):1-39.

Ropes, J. W. and A. P. Stickney. 1962. Gametogenesis in Mya arenaria from New England. Nat. Shellfish. Ass. Abstract.

* Not seen

Shaw, W. N. 1964. Seasonal gonadal changes in female soft-shell clams, Mya arenaria, in the Tred Avon River, Maryland. Proc. Nat. Shellfish. Ass. 53:121-132.

Stickney, A. P. 1963. Histology of the reproductive system of the soft-shell clam (Mya arenaria). Biol. Bull. 125(2):344-351.

FISHING EFFICIENCY OF CLAM HACKS AND MORTALITIES INCIDENTAL TO FISHING

J. C. Medcof and J. S. MacPhail

Fisheries Research Board of Canada
Biological Station, St. Andrews, N. B.

ABSTRACT

The conventional clam hack is a reasonably efficient tool for harvesting soft-shell clams (Mya arenaria). With it the average digger harvests 60% of the market-size stock from the soil he turns. But it is very destructive. At each turning of the soil it kills nearly 50% of the unharvested clams. Each digging brings about a total reduction (harvesting and smothering) of 80% of the stock of market-size clams and a reduction of 50% of the stock of under-size clams. Frequently repeated digging of the same ground was probably the main cause of the decline in clam production in the Maritime Provinces in the 1950's. Fishing effort seems to have decreased since then and we cannot explain why the decline is continuing.

INTRODUCTION

Recent History of Clam Fishery

The annual production of soft-shell clams in the Maritime Provinces fluctuated about 9 million pounds in the period 1935-1945 (Fig. 1). Then it rose spectacularly to 23 million pounds in 1950, dropped back to 6 million in 1955, and continued a steady downward trend to 1.25 million in 1963.

Many natural factors were involved including predation by greater clam drills (Lunatia heros; Medcof and Thurber, 1958), by lesser clam drills (L. triseriata), by green crabs (Carcinides maenas; MacPhail et al., 1955), by winter flounders (Pleuronectes americanus; Medcof and MacPhail, 1952), and by herring gulls (Larus argentatus; Needler and Ingalls, 1944 and Medcof, 1949). Eelgrass (Zostera marina) has also been a deterrent. Since its decline in the 1930's (Huntsman, 1932) we have watched this plant encroaching onto tidal flats with its dense mats of roots and stems. It prevents fishing and it smothers what clams are present because it traps silt. But in some regions, particularly in Nova Scotia, clams have disappeared even in creeks and

Fig. 1. Production of soft-shell clams (in-shell weight) from the maritime provinces since 1935.

coves that were never dug, where predators were not abundant and where there were no eelgrass problems. Perhaps disease was another contributor to the decline.

Undoubtedly these natural factors played a part but we suspected from the beginning that the main cause of the decline was fishing or, more particularly, the incidental effects of fishing with conventional clam hacks. Hence, we undertook the two studies described here—fishing efficiency of clam hacks, and mortalities of clams incidental to digging with hacks.

The Clam Hack

There are many local variations in the design of hacks but they are basically the same. Fishermen working the sandy soils on the outer coast of Nova Scotia prefer hacks with slim, round tines. They usually fashion these from 5- and occasionally 6-tined manure forks (Fig. 4). In muddier regions of the Bay of Fundy, diggers prefer a hack with four flattened tines (Fig. 2).

Our studies involved hacks of different types in different parts of Nova Scotia and New Brunswick.

FISHING EFFICIENCY OF CLAM HACKS

Fishing Efficiency Tests

For this study we defined fishing efficiency as the ratio between (1) the number of legal-size clams, 2 inches (50 mm) or more in length, which a fisherman takes from the soil he digs, and (2) the number of legal-size clams that were available to him in the soil before he began digging. Digging speed is an example of other factors that would have to be considered in any industrial rating of efficiency but we have disregarded them here.

During the summers of 1951 and 1952 we conducted 16 fishing efficiency tests that involved eight different diggers, some experienced and some inexperienced, different types of soil, and different clam population densities.

Procedure. Before beginning each efficiency test, we explained its purposes to the fishermen concerned. And we believe that

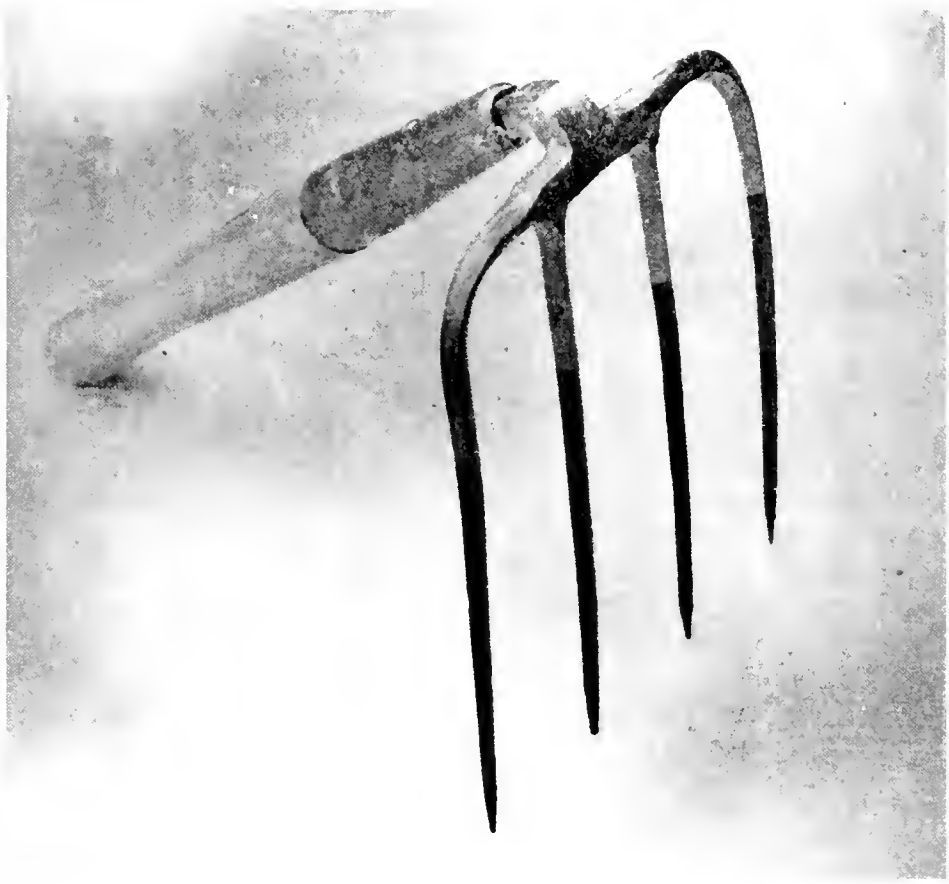


Fig. 2. Pocologan clam hack with four flattened tines commonly used in muddy soils of the Bay of Fundy region.

the digging we studied was typical of that regularly practiced by fishermen in commercial operations.

A 4-ft-square test plot was marked off on the beach. Then the digger, starting about one foot from the square, opened up the soil and prepared a perpendicular working face along one margin. These first hackfuls of soil were from outside the plot and therefore had to be separated from tailings from the test plot proper. Therefore, at this stage of proceedings, we spread a piece of burlap over the ground behind the digger. After the digging of the plot was complete, the upper eight inches of dug-over plot soil was removed with a shovel and screened.

Fig. 3. Screening clams from tailings of a fishing efficiency test plot (left foreground) at St. Andrews, N. B. A stream of water assists washing soil through screen in the cradle tray.

Fig. 4. Commercial clam digger working a hard sandy flat at Chezzetcook, N. S., with a hack fashioned from a manure fork. Large blocks of soil are left in the crooked trench burying unharvested clams in unnatural positions and at varying depths.

Screening was carried out on the beach beside the test plots using a tray set in a portable cradle (Fig. 3). The bottom of the tray was made of 1/4-inch mesh galvanized screening and the tray itself was shaken by sliding it back and forth on guides fastened to the inner sides of the cradle. A stream of water from a hose was directed onto the soil to hasten screening.

All clams less than one year old passed through the screen. Older ones remained in the tray and from these we culled and counted those of legal size to provide data for calculating fishing efficiencies.

Calculating Efficiencies

For each test the number of legal-size clams in the digger's catch and the number of legal-size screened from the soil were totaled. The efficiency was calculated by expressing the catch as a percentage of the number available.

Fishing efficiency data are summarized in Tables 1 and 2.

Discussion of Efficiencies

Table 1 shows that the efficiencies of diggers varied from 25 to 89% (average about 60%) and that three main factors affect a digger's efficiency:

1. Soil composition. Sand-silt soils (Table 1, tests 5-12) provide the easiest digging and the highest fishing efficiencies (mean 71%).

Observations of diggers showed that when enough silt is present, a forkful of sand-silt soil turns as a block. And a good digger knows how to turn clam ground in such a way that he can pick up most of the market-size clams with very little searching. He knows how to gauge the thickness of the block and how to turn it so that it will land upside-down with the bottoms (anterior ends) of the smaller market-size clams protruding from it ready to be picked out. When the block thickness is right, the larger marketable clams are also exposed and ready to be picked up. Their necks (siphon or posterior ends) protrude from the soil in the bottom of the hole from which the block was removed. In other words, a good digger takes advantage of the fact that sand-silt soils can be turned in blocks with a hack and of the fact that clams are stratified in the soil according to size—the largest being deepest (Medcof, 1950).

Table 1. Results of fishing efficiency tests in various types of soil. Some fishermen were experienced (E) and some were inexperienced (IE) in commercial fishing with clam hacks.

Fishing test		Digger		No. market-size clams		Fishing efficiency	
no.	area	no.	experience	caught	screened	%	mean
			Hard sand				
1	Chezzetcook	2	IE	38	92	29	
2	"	1	IE	99	52	66	58
3	"	3	E	157	97	62	
4	"	4	E	64	22	75	
			Sand-silt mixture				
5	St. Andrews	1	IE	102	56	65	
6	"	6	E	155	46	77	
7	"	5	E	215	162	89	
8	"	5	E	312	38	89	71
9	Chezzetcook	3	E	39	26	59	
10	"	2	IE	25	4	86	
11	St. Andrews	2	IE	28	24	54	
12	"	1	IE	33	34	49	
			Soft mud				
13	Sissiboo R.	7	E	15	14	52	
14	"	8	E	15	8	65	
			Soft mud and old shell				44
15	"	8	E	10	20	33	
16	"	7	E	3	9	25	
Averages						61%	58%

In hard sand (Table 1, tests 1-4) digging is more difficult (mean efficiency 58%). Clams are deep and soil blocks often crumble when turned. This hides many clams and lowers efficiency.

Soft, muddy soils (Table 1, tests 13-16) present a worse problem of the same kind (mean efficiency lowest of all, 44%). Although mud blocks turn easily, they tend to break up and this makes it difficult to distinguish between a freshly turned block and the worked-over ground from which clams have already been removed. Efficiencies were particularly low in tests 15 and 16 where there were many old shells in the soil. This made it hard to sort out the living clams from "dead" shells.

2. Density and composition of stock. In 10 of the 16 tests (upper part of Table 2), the density of screened clams (legal and sub-legal sizes combined) averaged 11 per square foot. In the other six tests it averaged 28. Table 2 shows that even when allowance is made for test-to-test differences in soil composition and experience of diggers, the efficiencies were considerably higher in the more densely populated ground (76% compared with 52%). Diggers worked more efficiently when clams were plentiful. The catch from each block was greater and perhaps this resulted in more careful searching. However, where clams were more abundant, diggers also picked up more sublegal-size clams (average 26% compared with 7%, Table 2). When the size-frequency mode approached the legal size limit, culling to legal size was particularly difficult and diggers tended to pick up under-size clams. This problem was usually most vexing where inexperienced diggers were involved and when population densities were highest. But even experienced diggers (test no. 3, Table 2) showed this tendency.

3. Experience and personal characteristics of diggers. Efficiencies varied greatly from person to person even in places where soil conditions were essentially the same. This was clear in tests 5-12 (Table 1) in which five different diggers were involved. Their efficiencies varied from 49 to 89% but on the average the experienced diggers had higher efficiencies (79% compared with 66%). Tests 13-16 were carried out with two experienced diggers (diggers nos. 7 and 8). Nevertheless, digger no. 8 showed higher efficiencies in both of the areas involved. Tests 7 and 8 were carried out by the same fisherman (no. 5). He was skilled and experienced and his efficiency was consistently high (89%). From all this it appears that experience improved efficiency but that there were substantial differences even among experienced fishermen. This may relate partly to differences

Table 2. Effect of density of screened clams (legal and sublegal sizes) on fishing efficiencies of experienced (E) and inexperienced (IE) clam fishermen and frequency of under-size clams in diggers' catches.

Test no.	Density of clams per sq. ft.		Fishing efficiency		Under-size clams in digger's catch		Digger	
	No.	Mean	%	Mean	%	Mean	No.	Experience
11	5.2		53.8		3.5		2	IE
16	5.3		25.0		0		7	E
12	5.8		49.3		5.7		1	IE
10	6.8		86.2		10.7		2	IE
15	8.4	11	33.3	52%	0	7%	8	E
14	9.9		65.2		0		8	E
13	15.7		51.7		6.3		7	E
1	17.6		29.2		11.6		2	IE
2	19.1		65.6		27.7		1	IE
9	19.8		59.4		2.6		3	E
4	21.6		74.4		34.0		4	E
6	22.9		77.1		26.5		6	E
5	24.4	28	64.6	76%	19.7	26%	1	IE
7	26.9		89.2		19.8		5	E
8	30.8		89.1		17.9		5	E
3	43.3		61.8		39.6		3	E
Overall means	18		61%		14%			

in digging speed—a factor we did not measure. We simply asked the men to dig as they would normally dig, either fast or slow.

CLAM MORTALITIES INCIDENTAL TO FISHING

Needler and Ingalls (1944) studied simulated commercial digging operations and showed that the disturbance of soil, involved in harvesting market-size clams, killed approximately half the undersize clams in the dug ground. This mortality incidental to fishing was highest in summer, higher at intermediate than at low beach levels, and higher for small than for large clams. But the Sissiboo River soil, in which the Canadian work was done, is not typical of our region. It is a heavy clay-mud mixture containing much old shell. We did not know whether the Sissiboo findings applied generally so before undertaking further studies of clam harvesting we carried out mortality tests in different kinds of soil.

Mortality Tests

We made seven mortality tests working at intermediate beach levels and mostly in spring and autumn. We worked in areas and in soil types that we considered typical of clam flats in the maritime provinces. Two of the seven tests were made at St. Andrews, N. B., in sand-gravel-silt soils (March-April and August-September 1952); one at Pocologan, N. B., in sand-silt mixtures (August 1952); two at Chezzetcook, N. S., in sandy soil (September-October 1952 and May-June 1953); and two at Sissiboo River, N. S., in clayey soils (June-July 1945).

Mortalities were deduced by comparing abundance of undersize clams in plots that were being dug for the first time with abundance in adjacent plots that had been recently dug once before by fishermen who were harvesting market-size clams with clam hacks.

Procedure

Preparatory to each test, a 20-ft-square plot was staked off at an intermediate beach level in an area where siphon-hole counts indicated a fairly uniform population of clams. Each plot was then subdivided into four 10-ft squares. A commercial clam digger was then asked to dig, as he would normally dig, through two diagonally opposite squares (thereafter called "dug" squares) and harvest the market-size clams. The other two squares ("undug") in each plot were left untouched at that time.

The plots were then left for at least two weeks under the supervision of a Department of Fisheries guardian who made sure that they were not molested. Meats of clams killed by the harvesting operations in dug squares rotted in this period and this made it possible to distinguish between living and dead, under-size clams in subsequent examinations. After the two weeks a 4- or 5-ft-square sampling area was marked out in approximately the center of each of the four 10-ft squares (dug and undug) of the test plots. The soil from each sampling area was then removed with shovels and screened in the same way that we screened the tailings from test plots used in the fishing efficiency tests reported above.

All the living under-size clams recovered by screening in the 1952-1953 tests were counted and their shell lengths were measured in 5mm groups. The numbers and sizes of the pooled samples from diagonally opposite pairs of sampling areas are shown in Table 3. A count was also kept of the market-size clams screened from undug sampling areas.

The two 1945 mortality tests carried out on Sissiboo River flats (Medcof & MacPhail, 1951) were similar to the others but the sampling areas were only 2 1/2 feet square and involved clams that apparently belonged to a single year-class (believed to have settled in 1943). Their sizes ranged from 1/2 to 1 inch (12-25 mm, mean 19 mm). And a fine-mesh window screen was used in these tests to avoid loss of the smallest clams. Market-size clams were scarce in these plots and their counts are not recorded (Table 3).

Both Sissiboo tests were carried out on a flat which the Department of Fisheries had reserved for experimental purposes. The first plot was laid out at half-tide level in an area that had not been dug since 1942. The soil there had been removed in 1940 and replaced by screened clay-silt. The second plot was somewhat lower on the beach where the soil was the native heavy compact clay containing some stones and much old dead shell.

Calculating Mortalities

We assumed that the clam populations in the four sampling areas of each plot were identical before the experiment began. For each test the counts of under-size clams from undug plots were summed and the counts from the dug plots were also summed. The difference between the sums was taken as a measure of the mortality

Table 3. Size-comparison and count of living under-size clams screened from sampling areas, and mortality % of under-size clams, [no. in undug (UD) —no. in dug (D)] ÷ [no. in dug] caused by harvesting market clams with hacks in seven mortality tests. Counts of market-size clams screened from undug sampling areas in the five 1952-1953 tests are also shown.

Length of clams	St. Andrews Mar.-Apr.		St. Andrews Aug.-Sept.		Pocologan Aug.		Chezzetcook Sept.	Chezzetcook Oct.	Chezzetcook May-June	
mm	D	UD	D	UD	D	UD	D	UD	D	UD
5-10			5							
10-15			232	485						
15-20			207	422						
20-25	2	3	29	30	2	1				
25-30	4	5	2	4						
30-35	10	31	7	20	1	0	48	52	7	4
35-40	27	59	18	59	10	24	553	820	41	62
40-45	47	86	22	93	64	105	1,115	1,814	139	295
45-50	28	76	32	177	107	185	738	1,220	199	419
Count of under-size	118	260	554	1,290	184	315	2,454	3,906	386	780
Mortality of under-size	55%		57%		42%		37%		51%	
Count of market-size	-	140	-	108	-	292	-	413	-	175

Sissiboo tests 1945	Compact Soil June-July		Screened Soil July	
Count of under-size	25	63	1,153	1,777
Mortality	60%		35%	

Average mortality for seven tests 48%

incidental to digging. In Table 3 this difference is expressed as a percentage of the sum of the counts from the undug areas.

Discussion of Mortalities

We found fewer under-size clams in the dug than in the undug sampling areas (Table 3), but the dug plots contained many newly dead shells. Their inner faces were still glossy. There is no question, therefore, that the harvesting operation killed these clams. They were not washed away after digging to populate other parts of the flat.

Table 3 shows that soil characteristics influence this mortality. It was highest (60%) in the compact native clayey Sissiboo soil with much shell and lowest (35%) in the even-textured loose, clay-silt soil on the same flat. Allowing for seasonal variations (Needler and Ingalls, 1944), it appears that mortalities were also high (55 and 57%) in the sand-gravel-silt soils at St. Andrews which are typical of the Bay of Fundy region. They were intermediate both for sandy soils at Chezzetcook (37 and 51%) and for sand-silt soils at Pocologan (42%). In a general way these results agree with Glude's (1954) involving artificially buried clams. He found that survival was best in silty sand, intermediate in pure sand, and poorest in silt.

Taken together our studies show that turning the soil with hacks kills half (48%) the under-size clams in it (Table 3) and this proves that Needler and Ingalls' findings for the Sissiboo River flats apply generally to clam areas of the maritime provinces.

The artificial burial tests by Needler and Ingalls (1944) and the more careful tests by Glude (1954) led us to expect heavier mortalities among the smaller than among the larger under-size clams involved in our commercial-type digging tests. But there is no clear evidence of this in Table 3. Many of our series of size-composition data are too short to bear critical analysis but the longest (St. Andrews, August-September) indicate that the reverse may even be true. From available data we can only say that the destructive effect of digging with hacks affects all sizes of clams to about the same extent. We have shown that diggers (efficiency 60%) leave 40% of the stock of market-size clams in the soil and we conclude that half of these (20% of the original stock) also die from the effects of digging.

It is important to know how harvesting operations kill clams that are left in the soil. One common explanation is that it leaves most clams exposed on the surface where they are killed by freezing

or "sun scalding" or by predators. Another is that harvesting kills many clams by damaging their shells.

During eight of the fishing efficiency tests reported above, we gathered information that bears on these explanations. We counted all the clams that were on the surface after diggers had finished their work and made a separate count of those with broken shells or with damage to soft parts that seemed likely to be lethal. The results (Table 4) show that only 13% of all the clams left behind in tailings of efficiency test plots were at the surface. Thus, even if all the surfaced clams had been destroyed this would have accounted for only a small part of the 48% mortality incidental to harvesting.

Some clams left on the surface do perish. Gulls swallow small clams whole (Medcof, 1949) and sometimes they cough up the shells as "gull pellets." In summer they drop large clams onto rocks or the hard beach to crack the shells. In winter when clams are numb with the cold and gaping, gulls can eat the large ones quickly without cracking the shells (Needler and Ingalls, 1944). Inspection shows that in spite of this predation many able-bodied clams are still left on the surface and it is reasonable to suppose that many survive. Flounders and other fishes take their toll of these when the tide rises but whole clams burrow quickly (Medcof, 1961) to safe depths.

Clams are tough. They burrow back into the soil after hours of exposure to the hot summer sun on dry beaches. Besides, we have seen them "come to" after freezing hard on beaches in winter. We have also seen clams in soil that was frozen into ice cakes tumble out onto beaches when the cakes melted and dig in after a few minutes in the rising tide. Friedman (1933) showed that they can survive freezing for up to seven weeks.

Thus, a high proportion of the clams that diggers leave exposed on the surface probably survive. Exposure in itself is probably only a minor source of mortality.

Table 4 also shows that 14% of those clams that were left on the surface were physically damaged by harvesting operations. Some were market-size and apparently rejected by the diggers who removed most of the market sizes. Thus, it is reasonable to assume that the damage rate among the clams buried in the tailings did not exceed 14% and was probably less. Glude (1954) showed that less than 1% of clams with broken shells survive. From this we conclude that

Table 4. Observations on fishing efficiency plots after fishermen finished their work, showing the relative numbers of clams left on the surface and the proportion of these that were physically damaged.

Test plot no.	Clams on soil surface Total no.	Damaged no.	Damaged total %	Clams on surface Total left in plot (surface & buried)	%
1	24	4	17	238	10
2	16	1	6	168	10
3	77	13	17	432	18
4	26	5	19	248	11
5	51	4	8	264	19
6	16	2	13	156	10
7	27	3	11	162	17
8	10	2	20	112	9
Total or average	247	34	14%	1,780	13%

harvesting kills some clams by physical damage but that this too accounts for only a small part of the 48% mortality incidental to harvesting.

Our description of fishermen's methods of digging (see Discussion of Efficiencies) explains how clams get buried deep in the soil during harvesting and how a great many are left upside-down. Kerswill (1941) describes the difficulty small, deeply-buried quahaugs experience in regaining their normal soil-depth positions. They are able to travel in only one direction—foot first. They must move upside down to the surface, then right themselves and finally burrow

down right-side-up to preferred depths. He watched them do this in test tubes and in aquaria.

If small clams, buried upside-down, must right themselves in the same way as quahaugs, it is understandable that many of the smaller (weaker) ones could exhaust themselves and perish in this effort. The difficulty for clams that are buried deep but upright would be less if they could push themselves up in the soil. Their behavior has not been studied but we think they may be able to push themselves up because Needler and Ingalls (1944) and Glude (1954) report higher survivals for clams that are buried upright than for those buried upside-down.

We believe that exhaustion and smothering of buried clams is the main cause of the 48% mortality that attends harvesting operations.

GENERAL DISCUSSION

Clams are sedentary animals and slow-growing in our areas. Most of them are at least six years old when they reach market size and nearly all of them live on intertidal beaches where they are accessible to diggers. When they are large enough and abundant enough to invite harvesting they are soon dug. In sportsmen's terms clams are "sitting ducks."

When the ground marketable clams are living in is turned, 60% of them are harvested and half of the 40% that are left behind apparently die from incidental effects of harvesting. In other words, a single digging of the soil reduces the stock of marketable clams by 80%.

Under-size clams are normally far more abundant than the market sizes (Catch data, Table 3). But fishermen see relatively few of them because most of them are buried deep in the tailings. Whether they see them or not, fishermen destroy half of these every time they turn the soil.

These fishing mortality rates seem high but because of the peculiar methods of harvesting, there are virtually no standards for comparison to aid us in thinking about the problems of clam exploitation and clam population dynamics. Nevertheless, we are inclined to attribute the great decline in our clam industry in the 1950's (Fig. 1) to the slow growth of clams, the high efficiency of hacks, and the high mortality of clams incidental to harvesting.

During the late 1950's and early 1960's prices to fishermen increased but clam landings continued to decline. The picture is not clear but fishing effort and catch per unit of effort are said to have declined too. From this we deduce that clam abundance declined. And general observations of beds suggest that there has been little or no increase until the last year or two.

We are confident that heavy digging caused the sudden decline in clam production in the 1950's. We believe that digging also caused the continued low production because, even though clams do grow slowly, there has been enough time for the beds to re-establish themselves. We have observed recently that as soon as beds or parts of beds begin to recover they are immediately harvested. Thus it seems that during early stages of recovery even small amounts of digging with hacks are enough to offset the gains.

There may have been other causes for the slow recovery but, if there were, we think they were subordinate. We have been asked, for instance, whether the heavy digging of the 1950's destroyed clam-favorable soil conditions that require a long time to return to normal. We have also been asked whether the climatic change (warming) in the 1940's and 1950's (Lauzier, 1964) was responsible for the delayed recovery of clam stocks.

We have not answered these questions and we are not sure that they can be answered. But we have developed and encouraged the use of better methods of harvesting (MacPhail, 1961; Medcof and MacPhail, 1964). These new methods are more efficient than fishing with hacks and they are much less destructive of the unharvested stocks. Their use should hasten the recovery of clam stocks.

ACKNOWLEDGMENTS

We thank Mr. Loran Baker, Area Director of Fisheries (Maritimes Area) for establishing government reserved flats where experiments could be carried out and for supplying guardians to protect them. We also thank Mrs. R. Lord for helping analyze our data and, of course, we thank the fishermen who participated in field tests.

Friedman, M. H. 1933. The freezing and cold storage of live clams and oysters. Biol. Bd. Canada, Ann. Rept. for 1932: 23-24.

Glude, John B. 1954. Survival of soft-shell clams, Mya arenaria, buried at various depths. Maine Dept. Sea & Shore Fisheries, Res. Bull., No. 22, 26 pp.

Huntsman, A. G. 1932. Disease in eel grass. Biol. Bd. Canada, Atlantic Prog. Rept., No. 5: 11-14.

Kerswill, C. J. 1941. Some environmental factors limiting growth and distribution of the quahaug, Venus mercenaria L. Fish Res. Bd. Canada, MS Rept. Biol. Sta., No. 187, 104 pp.

Lauzier, L. M. 1964. Long-term temperature variations in the Scotian shelf area. Intern. Comm. Northwest Atlantic Fish., Environmental Symposium, Rome, 1964, Contrib. No. H-3, 17 pp.

MacPhail, J. S. 1961. A hydraulic escalator shellfish harvester. Bull. Fish. Res. Bd. Canada, No. 128, 24 pp.

MacPhail, J. S., E. I. Lord and L. M. Dickie. 1955. The green crab—a new clam enemy. Fish. Res. Bd. Canada, Atlantic Prog. Rept., No. 63: 3-12.

Medcof, J. C. 1949. "Puddling"—a method of feeding by herring gulls. The Auk, 66: 204-205.

Medcof, J. C. 1950. Burrowing habits and movements of soft-shelled clams. Fish. Res. Bd. Canada, Atlantic Prog. Rept., No. 50: 17-22.

Medcof, J. C. 1961. Effect of hydraulic escalator harvester on under-size, soft-shell clams. 1959 Proc. Nat. Shellfish. Ass., 50: 151-161.

Medcof, J. C. and J. S. MacPhail. 1951. 1945 Investigations—clams and oysters. Fish. Res. Bd. Canada, MS Rept. Biol. Sta., No. 414, 91 pp.

Medcof, J. C. and J. S. MacPhail. 1952. The winter flounder—a clam enemy. Fish. Res. Bd. Canada, Atlantic Prog. Rept., No. 52: 3-8.

Medcof, J. C. and J. S. MacPhail. 1964. A new hydraulic rake for soft-shell clams. 1962 Proc. Nat. Shellfish. Ass., 53:11-31.

Medcof, J. C. and L. W. Thurber. 1958. Trial control of the greater clam drill (Lunatia heros) by manual collection. J. Fish. Res. Bd. Canada, 15(6):1355-1369.

Needler, A. W. H. and R. A. Ingalls. 1944. Experiments in the production of soft-shelled clams (Mya). Fish. Res. Bd. Canada, Atlantic Prog. Rept., No. 35:3-8.

THE EFFECT OF SCOTER DUCK PREDATION ON A CLAM POPULATION IN DABOB BAY, WASHINGTON

John B. Glude [1]

Presented at Pacific Coast Oyster Growers Association
Annual Meeting, Vancouver, B.C., August 22, 1963

ABSTRACT

Examination of stomach contents of scoter ducks, Melanitta deglandi, Melanitta perspicillata, and Oidemia americana at Dabob Bay, Washington, showed that these ducks were feeding largely on the commercially valuable Japanese little neck or Manila clam. Tapes japonica (Venerupis semidecussata). This introduced clam is abundant and lives close to the surface of intertidal flats where it is more accessible to diving ducks than most native mollusks. Sampling on Dabob Bay clam flats suggested a decline in the number of small Manila clams during the period when scoter ducks were feeding on them. Population estimates by U. S. Bureau of Sport Fisheries and Wildlife personnel indicate that scoter ducks have increased in recent years. It is recommended that the bag limit for scoter ducks be increased in parts of Puget Sound where commercial shellfish beds are located.

INTRODUCTION

Commercial clam beds are located throughout Puget Sound on beaches which are exposed at low tide. The high tidal range of 9 to 15 feet uncovers thousands of acres of intertidal zone where clams are dug with shovels, spades, or forks.

Clam beds located at the north end of Dabob Bay, an extension of Hood Canal near Quilcene, Washington, have been dug by commercial diggers for many years. These beds have produced large quantities of Japanese little neck or Manila clams, Tapes (Venerupis) japonica (= semidecussata).

In the winter 1960-1961 season, diggers discovered that clams in Dabob and Tarboo bays were less abundant than previously. After a short time the diggers moved to other locations since the clams were so scarce that they could not obtain enough to make digging worthwhile. Diggers also reported that scoter ducks were

[1] U. S. Bureau of Commercial Fisheries, 6116 Arcade Building, Seattle, Washington.

much more abundant than usual in the area throughout that winter. A local resident observed large rafts of these ducks diving at high tide over the beds and apparently feeding on clams.

In Autumn 1961, diggers tried the Dabob Bay beds again and finding few market-sized clams present, left to find more productive beds. Scoter ducks were abundant again during the winter of 1961-1962, and were reported to be feeding on clams.

A study was begun in the fall of 1962 to determine whether depredations by scoter ducks were responsible for the shortage of clams in Dabob Bay. The study consisted of two parts: (1) observations of the clam population in late summer before the ducks arrived and periodically thereafter throughout the winter, and (2) examination of the gizzard contents of ducks, at intervals, to determine their feeding habits.

The cooperation and assistance of Richard N. Steele, owner of the tidelands, made this study possible. Richard E. Griffith of the Bureau of Sports Fisheries and Wildlife in Portland, Oregon, provided important information on duck population estimates and hunting seasons.

CLAM POPULATION STUDIES

The clam population on a bar exposed at low tide, at the entrance to the inner bay (Fig. 1), was estimated by examining one-square-foot samples taken at random, periodically, throughout the study. In the first samples taken September 3, 1962, and the final samples taken June 22, 1963, the top one inch of the sediment in a one-square-foot area was removed and placed in a container with a bottom made of plastic window screen having mesh openings of 2 to 3 mm (less than 1/8 inch). The sample was then washed thoroughly so that most of the sand passed through the screen leaving the clams in the container. The underlying six inches of sediment was then removed from the sample area and washed through a galvanized wire screen with mesh openings of 6 mm (1/4 inch). All clams were then removed, counted, and sorted into size groups as shown in Table 1.

Other samples were taken in the same manner except that the top one inch of sediment was examined without washing it through a fine mesh screen. This may have resulted in failure to observe some of the clams under 1/4 to 3/8 inch in length but should have given an accurate count of all clams above that size. The length of each clam was measured to the nearest millimeter with vernier calipers.

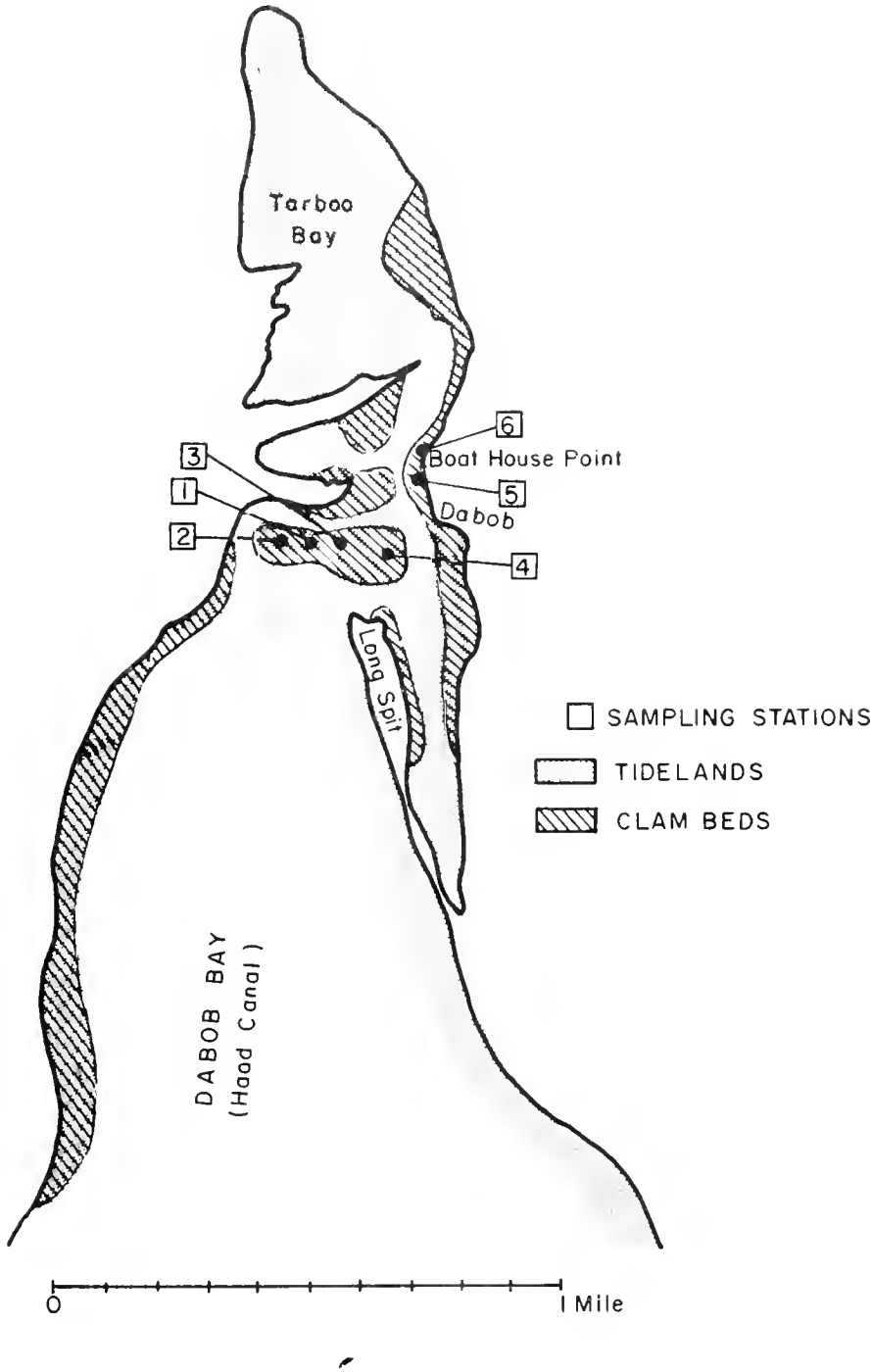


Fig. 1. Location of clam population samples in Dabob Bay near Quilcene, Washington.

Table 1. Abundance and size of Manila clams, Tapes japonica (= semidecussata), in one-square-foot samples taken at Dabob Bay, 1962-63

Date collected	Sampling station (Fig. 1)	3/16-1/2" 5-12mm	1/2-3/4" 13-19mm	3/4-1" 20-25mm	over 1" over 25mm	Total no.	Remarks
1 Sept. '62	1	25	8	8	1	42	
1 Sept. '62	2	25	16	2	-	43	
7 Dec. '62	1	1	1	11	17	30	Plus 3 Mya 15,15,20mm
7 Dec. '62	2	1	11	2	33	47	
2 Feb. '63	1	-	4	11	5	20	
2 Feb. '63	2	-	12	5	12	29	Plus 1 Mya 61mm
2 Feb. '63	3	1	7	4	13	25	Plus 5 Mya 15,15,15,14, 18mm
2 Feb. '63	4	2	13	1	14	30	Plus 1 Macoma 8mm
2 Feb. '63	5	-	-	-	18	18	
2 Feb. '63	6	-	-	1	7	8	Plus 3 Mya 54,55, 46mm & 1 Macoma, 16mm
22 June '63	1	304[1]	0	8	21	29[5]	
22 June '63	2	144[1]	0	5	24	29[5]	Plus 5 Macoma 18,16,9,9,10mm
22 June'63	2	[3]	1	19	28	48[5]	Plus 1 Venerupis staminea, 26mm; 2 Mya, 18,19mm; 11 Macoma, 24, 24,18,26,21,32, 21,20,27,25mm
22 June'63	3	236[4]	4	14	35	53[5]	Plus 3 Mya 15,19,22mm

[1] Estimated number of clams, size range 4-10mm
[2] Estimated number of clams, size range 4-11mm
[3] Sample was not sorted through fine mesh.
[4] Estimated number of clams, size range 2-7mm
[5] Excluding 2-11mm clams

In the first samples taken in September 1962, 59 per cent of the clams were in the 3/16 to 1/2-inch (5 to 12mm) size group. In later samples only one or two clams of this size range were found. This difference may be partially explained by the change in the sampling method but it was felt that more clams of this size would have been found in later samples if they had been as abundant as they were in September.

The June samples contained large numbers of 1962 year-class clams which had survived the winter at sand-grain size and which had grown to 1/8 to 3/8-inch size during the spring.

The September samples averaged 12 clams, 1/2 to 3/4-inch (13 to 19mm) per square foot. December and February samples in the same area averaged less than 9 clams and June samples averaged only one clam of this size per square foot.

Clams 3/4 to 1 inch (20 to 25mm) in length remained at about the same abundance throughout the winter but were more numerous in the June samples. Clams over 1 inch in length were scarce in the initial samples but constituted an increasing proportion of the population later in the winter. Final samples averaged 27 clams of this size per square foot, a commercial level of abundance.

In general, samples indicated a decrease in the 5 to 12mm and 13 to 19mm size groups during the winter. Some increase occurred in the larger size groups during the spring period of rapid growth as might be expected.

Only one clam under 1 inch in length was found in the two-square-foot samples taken at Boat House Point in February (Fig. 1). Although the late summer samples from this area were not available for comparison, it appears likely that the smaller size groups had decreased in abundance in this area as they had in the Bar area.

DUCK FEEDING STUDIES

Scoter ducks, Melanitta and Oidemia, normally winter in Puget Sound and are often present in large numbers from November to March. Scoters were collected for feeding studies seven times from November 11, 1962 to March 2, 1963, at Long Spit, Dabob Bay, as authorized by Federal and State collectors' permits. Most of the ducks were shot as they flew across the sand spit on their way to the clam beds located in the inner bay, shown as Tarboo Bay in

Fig. 1. A few were shot from one of the points of land inside of Tarboo Bay and some were shot as they left the inner bay flying toward Dabob Bay. Scoters were abundant throughout the winter and samples were obtained readily.

The gizzard was removed from each duck and the contents placed in plastic containers for later examination. The esophagus of each duck was felt to determine whether any foods had been ingested but had not yet reached the gizzard. In this way several live clams were located.

The gizzards of all 64 white-winged scoters collected contained pieces of Manila clam shells (Table 2). From the volume of shell pieces, it was estimated that the gizzards contained an average of 4.9 clam shells. It is not known how long a feeding period the gizzard contents represented, but the examinations provided conclusive evidence that white-winged scoters feed extensively on clams in this area. Live clams up to one inch in length were found in the gizzard or esophagus of white-winged scoters. From the size and thickness of the pieces of clam shells it was estimated that most of the clams consumed were less than one inch in length.

In addition to pieces of Manila clam shell, the gizzard of one white-winged scoter contained shells of 102 small snails, Nassarius mendicus, up to 3mm in length. The contents of most of the snail shells had been digested but one contained a hermit crab. Therefore, it is not known whether the duck was feeding on snails or on hermit crabs. At least one other gizzard contained small snail shells, Nassarius and Polinices, and another contained a small butter clam shell.

Gizzards of 21 surf scoters were examined and 18 contained pieces of Manila clam shells (Table 3). The average content was estimated to represent 2.0 clam shells. Shells or byssuses of blue mussels, Mytilus edulis, were found in 8 gizzards. One surf scoter had eaten a small softshell clam, Mya arenaria. It appeared from these samples that this species feeds predominately on Manila clams in this area, but also eats blue mussels. Even though surf scoters are smaller than white-winged scoters and have less powerful gizzards, one contained a Manila clam estimated from the shell pieces to be 1.375 inches (34.8mm) in length.

Four American scoters were collected and the gizzards of three contained pieces of Manila clam shells. From the volume of

Table 2. Gizzard contents of white-winged scoters, Melanitta deglandi, collected at Dabob Bay, 1962-63.

Date collected	Number of ducks	Est. aver. no. Manila clam shells	Other items	Remarks
11 Nov.'62	15	5.5	pea gravel	1 duck had live 1 inch clam in esophagus; 1 duck had live 3/4 inch clam in gizzard
8 Dec.'62	12	4.0	-	
8 Dec.'62	1	1	102 small snails	Nassarius mendicus to 3mm long
15 Dec.'62	8	3.9	-	
12 Jan.'63	11	9.0	1 snail	Polinices, 20mm long
			1 snail	Nassarius mendicus, 3mm long
			1 small butter clam	Saxidomus
2 Feb.'63	16	3.0	-	
2 Mar.'63	1	3.0	-	
Total	64			
Average		4.9		

Table 3. Gizzard contents of surf scoters, Melanitta perspicillata, collected at Dabob Bay, 1962-63.

Date collected	Number of ducks	Est. aver. no. Manila clam shells	Other items	Remarks
11 Nov.'62	1	-	Pea gravel & shells of 4 blue mussels	Mytilus edulis
8 Dec.'62	5	1	-	
8 Dec.'62	2	1	Byssuses & shells from several blue mussels	Mytilus edulis
15 Dec.'62	1	10	-	1 live clam 27mm, 3 partially digested clams—one 23mm
15 Dec.'62	1	-	10 small blue mussel shells	Mytilus edulis
15 Dec.'62	1	3	1 soft shell clam	Mya arenaria 25mm long
15 Dec.'62	1	1	-	
12 Jan.'63	3	2.3	2 small snails; 1 blue mussel	One probably Polinices; Mytilus edulis
2 Feb.'63	1	-	2 clams	Probably Macoma
2 Feb.'63	1	4		1 clam 34.8mm long
2 Feb.'63	3	2	-	
2 Mar.'63	1	3	Byssuses from 12 mussels	
Total	21			
Average		2.0		

shell pieces it was estimated that each contained an average of 1.75. One American scoter had eaten only barnacles; two had eaten small snails; and one had consumed blue mussels (Table 4). It appears that American scoters feed on a variety of animal foods and are probably less serious predators on commercial clam beds than either the surf or white-winged scoters. The small number examined prevented detailed analysis of their feeding habits.

Table 4. Gizzard contents of American scoters, Oidemia americana, collected at Dabob Bay, 1963

Date collected	Number of ducks	Est. aver. no. Manila clam shells	Other items	Remarks
12 Jan.'63	2	2	2 snails	Nassarius mendicus 14 & 9mm long
2 Feb.'63	-	-		
2 Mar.'63	1	-	Shells of 10 barnacles	
2 Mar.'63	1	3	Byssuses & shells from about 12 blue mussels	Mytilus edulis
Total	4			
Average		1.75		

White-winged scoters, with their large, powerful gizzards, were the most serious clam predators of the three species of scoters. Surf scoters were very abundant but fed on other mollusks in addition to Manila clams. Because of their large numbers and the fact that they appeared to be able to consume clams up to at least 1 3/8 inches in length, surf scoters also must be considered as serious clam predators.

DISCUSSION AND CONCLUSIONS

The Manila clam, Tapes (Venerupis) japonica (= semidecussata), was introduced accidentally from Japan along with seed oyster shipments many years ago. This species has thrived in the Pacific Northwest and has spread throughout Puget Sound, Grays Harbor, Willapa Bay, and part of British Columbia. The Manila clam is similar in appearance to the native little neck or rock clam, Venerupis staminea, but differs in two significant ways. First, the Manila clam occurs over a greater part of the intertidal zone, extending to a higher tidal level than does the native little neck clam. Second, the Manila clam lives closer to the surface of the sediments than does the native little neck clam. For these two reasons it appears that the Manila clam is more susceptible to predation by ducks than the native little neck clam. Both of these clams are more susceptible to predation than the butter clam which lives even deeper in the sediments than the native little neck clam and also occurs at a lower tidal level. Most Manila clams less than one inch in length occur in the top four inches of sediment, and apparently scoters are able to dig deeply enough to obtain clams in this size range. Fig. 2 shows the beach in front of Boathouse Point, which was completely pitted from feeding activities of scoters. Rafts of scoters were frequently observed diving in this area at high tide, and the beach became more pitted as the winter progressed. These observations indicate that ducks had dug the pits searching for clams. This is the area in which very few clams less than one inch in length were observed.

It is well known that scoters feed on shellfish. Cottam (1939) states, "Like the eiders, with which they have much in common in food habits, the scoters are expert divers, feeding primarily—except during the breeding season—on marine foods, predominantly mollusks; consequently, all have been vigorously condemned by the shellfishermen."

Cottam examined stomachs from 819 white-winged scoters and found that 75.34 per cent contained mollusks. He found Olympia oysters up to 51mm (2 inches) in diameter in scoter stomachs but reported that the little neck or rock clam, Venerupis staminea, was the most important single food of white-winged scoters collected on the West Coast.

Cottam found from examination of stomachs of 168 surf scoters that 60.8 per cent contained mollusks. However, most of

Fig. 2. Clam bed at Boat House Point, Tarboo Bay, at low tide showing extensive pitting caused by feeding activities of scoters.

these were mussels and the non-commercial clam Macoma. He concluded: "The fact that few commercial shellfishes were consumed indicates that shellfish depredations by the surf scoter are uncommon and exceptional."

Cottam's report gives no indication of the location at which scoters were collected in the Pacific Northwest.

Cottam found mollusks in 65.19 per cent of the 124 stomachs of American scoters that he examined and concluded: "There is no question but that this species along with the other members of its tribe is capable of serious injury over planted commercial shellfish beds."

Cottam's studies were carried out before the introduced Manila clam, Tapes (Venerupis) semidecussata, became sufficiently abundant to be used commercially. During recent years the Manila clam has become the most important commercial clam in many places. Since this species is more susceptible than the native rock clam to predation by ducks, the feeding activities of scoters have assumed new importance.

The present study clearly demonstrated that scoter ducks fed largely upon Manila clams in Dabob Bay during the winter of 1962-63. It also showed that a decrease in the smaller sizes of clams occurred during this period. Therefore, it is concluded that feeding activities of scoters caused a marked decrease in the clam populations of Dabob Bay. The loss of smaller clams would be expected to reduce the numbers of market-sized clams the following winter to the extent that commercial digging might become uneconomical.

Table 5 shows the changes which have occurred in the duck hunting seasons in the State of Washington from 1938 to 1962. Bag limits which include scoters along with the more desirable species have generally decreased from 10 per day in 1938 to 1945 to 4 in recent years. The number of days of shooting has generally increased from a range of 45 to 60 in the pre-World War II years to over 90 in the period 1957-1960. Seasons were shortened to 75 days in 1961 and 1962.

The abundance of ducks of various species is estimated annually by the Bureau of Sport Fisheries and Wildlife. Scoter populations in the State of Washington (Table 5) have generally increased from a range of 7,000 to 38,500 in the ten years from

Table 5. Duck hunting seasons and estimated scoter population in the State of Washington

Year	Daily bag[1]	Season dates	Number of days	Estimated scoter population[2]
1938	10	15 Oct.-28 Nov.	45	
1939	10	22 Oct.-5 Oct.	45	
1940	10	16 Oct.-14 Dec.	60	
1941	10	16 Oct.-14 Dec.	60	
1942	10	15 Oct.-23 Dec.	70	
1943	10	15 Oct.-23 Dec.	70	
1944	10	14 Oct.-1 Jan.	80	
1945	10	13 Oct.-31 Dec.	80	
1946	7	26 Oct.-9 Dec.	45	
1947	4	21 Oct.-3 Nov. 16 Dec.-29 Dec.	28	
1948	5	15 Oct.-31 Oct. 23 Dec.-8 Jan.	34	13,062
1949	5	4 Nov.-23 Dec.	50	38,500
1950	6	3 Nov.-27 Dec.	55	10,112
1951	6	26 Oct.-24 Dec.	60	6,915
1952	6	17 Oct.-25 Dec.	70	15,242
1953	7	17 Oct.-30 Dec.	75	9,635
1954	6	16 Oct.-3 Jan.	80	19,398
1955	6	15 Oct.-2 Jan.	80	14,870
1956	6	13 Oct.-31 Dec.	80	11,395
1957	5	13 Oct.-15 Jan.	95	14,869
1958	5	12 Oct.-14 Jan.	95	58,762
1959	5	7 Oct.-8 Jan.	94	56,094
1960	4	8 Oct.-5 Jan.	90	35,192
1961	4	14 Oct.-27 Dec.	75	59,241
1962	4	13 Oct.-26 Dec.	75	65,748
1963				64,635

[1] Includes scoters among other species.

[2] Includes all three species. Based upon winter population surveys by Bureau of Sport Fisheries and Wildlife (personal communication from Richard E. Griffith, May 31, 1963).

1948 to 1957, to over 64,000 in 1962 and 1963. Census methods were modified during this period so the estimates for earlier years are not strictly comparable with recent counts.

The most conservative interpretation of Table 5 would be that scoter populations in this state are at a high level, justifying measures to increase hunting pressure on these species.

It is therefore recommended that a predator control season and a special bag limit be established for scoters in Dabob Bay and in other parts of Puget Sound where commercial shellfish beds are located. A bonus of, say, four scoters in addition to the bag limit of other species during the regular open season would help to reduce scoter populations. Also, an extended season through January and February with a daily bag limit of 4 to 8 scoters could be established for areas in which scoters were abundant. This would provide duck hunters with the opportunity to continue hunting for an additional two months and should reduce the complaints about recent small bag limits.

Furthermore, control of scoter populations would reduce predation on commercial clam beds and should result in increased incomes to clam diggers and tideland owners in certain areas.

LITERATURE CITED

Cottam, Clarence. 1939. Food habits of North American diving ducks. U. S. Dep. Agri. Tech. Bull. 643, 139 p.

RESEARCH NOTE

A NEW CRAB HOST OF THE GREGARINE NEMATOPSIS OSTREARUM[1]

Nematopsis ostrearum, a gregarine which alternates between oysters and crabs as hosts, was described by Prytherch (1940, Jour. Morph. 66: 39-65) from two species of mud crabs, Panopeus herbsti Milne Edwards and Eurypanopeus depressus (Smith), and the oyster, Crassostrea virginica (Gmelin). Grassé (1953, Traité de Zoologie, Vol. I, p. 642) also lists an unnamed species of Menippe (but this is an error —Ed.). Sprague (1949, J. Parasitol. 35: 42) showed that in the Gulf of Mexico Prytherch's Nematopsis ostrearum actually comprised two species, N. ostrearum sensu stricta, with cysts occurring most abundantly in the mantle of oysters, and a new species, N. prytherchi Sprague, with larger spores and cysts found mainly in the gills. N. prytherchi, whose definitive host is Menippe mercenaria, has not been found in Chesapeake Bay. Sprague added a third crab host for N. ostrearum in the Gulf area, Eurytium limosum (Say).

Feng (1957, M.A. Thesis, College of William and Mary) observed gregarines resembling Nematopsis in the xanthid crab Neopanope texana sayi (Smith). In the summer of 1960 an experiment was performed to determine whether gregarines from this crab could infest oysters.

Specimens of N. texana sayi were fed pieces of mantle from oysters infected with N. ostrearum. In the course of the experiment three crabs were sacrificed and found to contain trophozoites and chains. Oysters essentially free of Nematopsis were collected from a low-salinity bed previously shown by Feng to have very low incidence of the parasite. Ten of these oysters were examined to confirm low incidence of Nematopsis. Ten oysters were placed in an aquarium with the crabs and ten controls were held in a separate aquarium without crabs. Both aquaria were aerated and received running water from the York River to keep the oysters feeding. The experiments were done in mid-summer at high water temperatures.

After 40 days, 8 x 5 mm rectangles of the mantle margin of both lots of oysters were examined for Nematopsis cysts according to the procedure recommended by Feng (1958, Proc. Nat. Shellfish. Ass. 48:162-173). The ten oysters in the aquarium with the crabs were all

---

[1] Contribution No. 206, Virginia Institute of Marine Science.

heavily infected and partial counts indicated from 60 to 400 cysts per mm^2 whereas the control group had only 0 to 4 cysts in the whole 8 x 4 portion of the mantle and seven of the control oysters had no cysts. It appears, therefore, that Neopanope texana sayi is another decapod host of Nematopsis ostrearum.

This work was done at the Virginia Institute of Marine Science, Gloucester Point, Virginia, and was supported by the National Science Foundation Undergraduate Research Participation Program (Grant No. G12293 to the Institute).

Vida Carmen Kenk
Museum of Comparative
Zoology
Harvard University
Cambridge, Massachusetts

ASSOCIATION AFFAIRS
ANNUAL CONVENTION

The 1964 convention was held jointly with the Oyster Institute of North America and the Oyster Growers and Dealers Association at the Fontainbleau Motor Hotel, New Orleans, La.

The 1963-1964 officers were re-elected for 1964-1965, as follows:

President . . . . . JOHN B. GLUDE
Bureau of Commercial Fisheries
Seattle, Wash.
Vice-President . . . . . JAY D. ANDREWS
Virginia Institute of Marine Science
Gloucester Point, Va.
Secretary-Treasurer. . JOHN GILMAN MACKIN
Texas A&M University
College Station, Tex.
Members-at-Large. . . . . ALBERT K. SPARKS
University of Washington
Seattle, Wash.
and DANA E. WALLACE
Maine Dept. of Sea and Shore Fisheries
Augusta, Me.

The Editorial Committee consisting of Sewell H. Hopkins (chairman), Lawrence Pomeroy, and Daniel B. Quayle was reappointed and it was voted not to change the mode of publication.

It was voted that no member be allowed to present a paper at future meetings without previously filing an abstract.

SPECIAL NOTICE

Starting with the 1965 volume, Mr. Arthur S. Merrill, Biological Laboratory, Oxford, Maryland, is now the Chairman of the Editorial Committee. Mr. Merrill is also the custodian for editorial records, back numbers of the Proceedings (for sale at $4.00 each), and micro-card reproductions of back issues covering a 30-year period (for sale at $8.00 per set).

Applications for membership and dues ($6.00 per year) should be sent to Secretary-Treasurer Joseph H. Manning, Department of Chesapeake Bay Affairs, Annapolis, Maryland.

MBL WHOI LIBRARY
WH 1ABD +