6-1954

Oyster Mortality Studies in Virginia. I. Mortalities of Oysters in Trays at Gloucester Point, York River

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OYSTER MORTALITY STUDIES IN VIRGINIA. I. MORTALITIES OF OYSTERS IN TRAYS AT GLOUCESTER POINT, YORK RIVER[1]

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INTRODUCTION

Despite an extensive literature, mortalities of oysters have seldom been explained satisfactorily. This is particularly true of sudden and widespread losses of an epizootic character. One of the chief difficulties has been the tardy discovery of losses, followed by ineffective postmortems over empty shells. Even more important is the lack of knowledge of the time and extent of mortalities during normal seasons. Without such information, it is difficult to understand and assess epizootics and other unusual losses. Over a period of three and a half years, detailed records have been kept on oysters in trays at the pier of the Virginia Fisheries Laboratory. The purpose has been to detect the annual and seasonal rates and fluctuations of mortalities. Such knowledge is essential to any study of the causes of mortalities.

In Chesapeake Bay, certain causes of mortalities are widely recognized. The oyster drills (*Urosalpinx* and *Eupleura*) are serious and widespread predators in waters exceeding 12-15 parts per thousand of salinity. At the heads of the various tributaries and of the Bay, fresh water takes a toll, particularly in wet years (Beaven, 1946; Engle, 1946).

Other reputed causes of high mortalities are not so well established. Sale and Skinner (1917) attributed the heavy losses of 1912 in several tributaries of Chesapeake Bay to deficiencies of oxygen. Prytherch (1931) assigned the same cause to the reported winter losses of 1929-30 in Mobjack Bay and York River. In a later report (1938), Prytherch associated the sporozoan parasite, *Nematopsis,* with the winter mortality and with other alleged heavy mortalities along the northern Gulf of Mexico. Galtsoff *et al.* (1947) found no evidence that *Nematopsis* was responsible for the poor quality of York River oysters and reported no mortality even among heavily infected oysters. While oxygen deficiencies and *Nematopsis* may have been contributing causes, these mortalities remain among those unsatisfactorily explained. Galtsoff *et al.* attributed the poor condition of oysters in the upper York River to the toxic effects of pulp-mill effluent. Shell pests, such as *Polydora* and *Cliona*, are also suspected of being contributing factors in Chesapeake Bay mortalities, but their significance has not been determined.

Oyster farming methods in Chesapeake Bay make the assessment of mortalities difficult. Oysters are usually handled only twice, to plant and to harvest. The more careful planters make counts of samples of each load of seed oysters. At the time of harvesting, samples of the catch are sorted

[1] Contributions from the Virginia Fisheries Laboratory, No. 49.

into piles of live oysters and shells to determine the quantity of live oysters in the load. During the two to three years allowed for growth, only casual and infrequent examinations are made of the oysters on the beds. Under these conditions, only vague estimates of total or annual mortality can be obtained.

Most published mortality records are generalizations based upon highly questionable methods. A common but unsatisfactory method of estimating mortalities is to count boxes, that is, empty shells which remain hinged. The persistence of boxes probably depends upon many factors, including size, location, amount of handling, and the activity of fouling or boring organisms. On natural grounds, it is almost impossible to relate the occurrence of boxes to a period of time. Hence, a count of boxes gives a minimum estimate of mortality over an indefinite period of time. Hopkins and Menzel (1952) have also emphasized the inaccuracies of this procedure.

The culture of oysters in trays was first attempted on a commercial scale in this country by the Chesapeake Corporation of Virginia, some 15 years ago (Evans, 1943). This method offers certain advantages in studying mortalities and their causes. Using trays, known numbers of the same oysters can be observed over definite periods of time. Accurate records of the occurrence and rate of mortalities can be obtained in this manner. By examining trays at frequent intervals, gaping oysters still retaining meats can be found in sufficient numbers to permit detailed studies of the causes of death. The protection afforded by the trays eliminates certain causes of mortality such as predation, smothering, and other factors related to the type of bottom. Therefore, relatively unknown causes such as disease, parasitism, and adverse water conditions may be suspected when oysters die in trays. The records of tray mortalities may be useful in analyzing certain widespread losses which are not caused by bottom conditions.

Some of the disadvantages of tray culture are the great amount of care necessary, the relatively small numbers of oysters which can be observed, and the inability to duplicate bottom conditions.

Description and Handling of Trays. Sea-Rac trays purchased from the Chesapeake Corporation were used for the studies at Gloucester Point. The tray consists of an asphalt-coated wire meshwork 40 inches long, 18 inches wide, and 4 inches deep, with one-inch openings (Fig. 1), and a capacity of about 150 three-inch marketable oysters. The tops of the trays were covered with one-inch galvanized chicken wire. The trays containing oysters were suspended from the Laboratory pier, about one foot off the bottom. Oysters were stacked in the trays with bills up and wooden stops were used to retain them in this position. Trays were cleaned or changed when fouling tended to inhibit water circulation. It was necessary to remove sea squirts and sponges from the oysters occasionally. During warm weather, when mortalities were high, trays were examined daily; in cool weather, at intervals of ten days to two weeks. Oysters were handled individually a number of times each year for cleaning, weighing, measuring and restacking. Boxes and gapers (dead oysters with the meats intact) were removed when found, and frequent counts made of the remaining live oysters to insure that oysters were not being lost accidentally. In short, extremely detailed records were kept on a few trays of oysters at one place.

Early in 1953, expansion of the tray experiments was facilitated by building three catwalks extending from the main pier (Fig. 2). Trays of

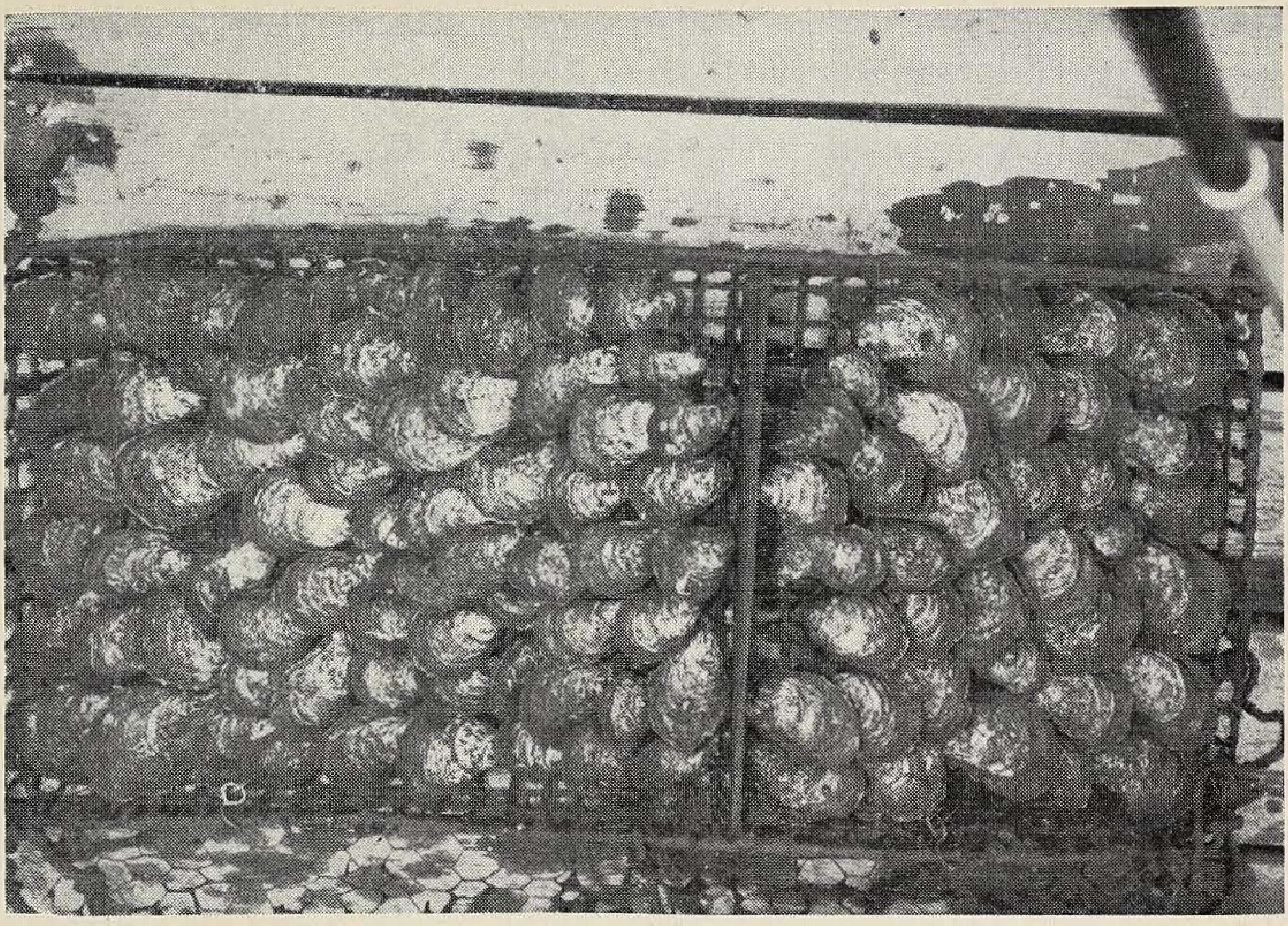


Fig. 1 Sea-Rac Tray Used in Mortality Observations.

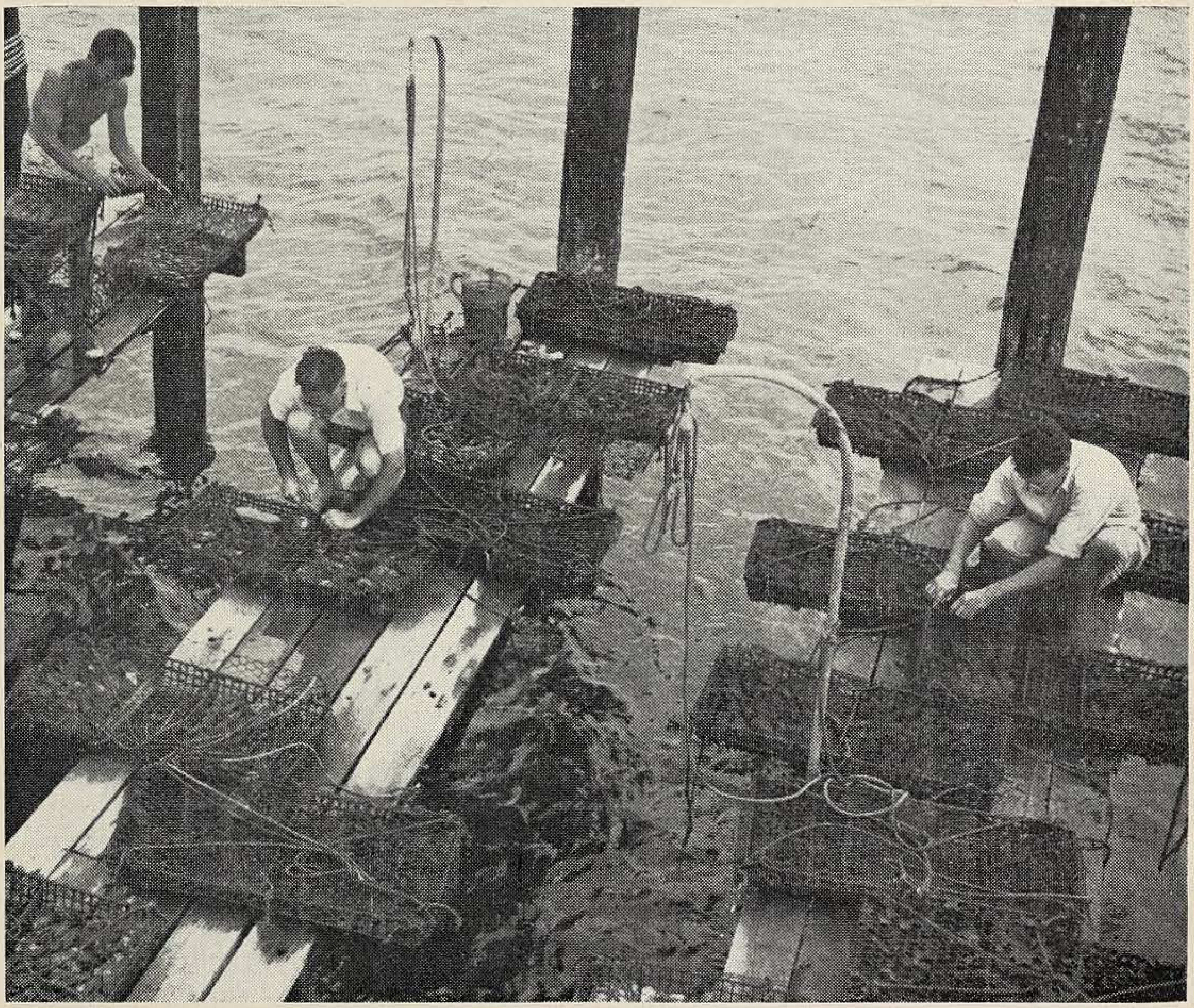


Fig. 2. Examining Trays of Oysters at the Virginia Fisheries Laboratory.

oysters are suspended from both sides of the platforms. Trays are lifted to the platforms by a davit with a pulley and a hook which catches in the crotch of four ropes attached to the corners of the trays. The depth of water at mean low tide is about four feet.

HYDROGRAPHIC CONDITIONS

Salinity. Since 1940, the salinity of the York River in the Yorktown-Gloucester Point area has ranged from 9 to 25 parts per thousand, although deviations from a range of 13 to 23 parts per thousand are rare. Low salinities tend to occur in winter and spring, and high salinities in late summer and fall, but high and low extremes have occurred at almost every season of the year. These figures indicate that salinities are suitable for oyster culture throughout the year and that fresh water kills are not to be expected. Surface salinities at the end of the Virginia Fisheries Laboratory pier for 1951 and 1952 are given in Figure 3.

Temperature. During the past 12 years, surface water temperatures at Yorktown and Gloucester Point have varied from 0° to 32° C. The usual range of minimal winter temperatures is 3° to 6° C, and summer temperatures nearly always exceed 28° C. Since the trays are suspended in water only three feet below the surface at mean low water, temperatures at the Laboratory pier show slightly greater fluctuation and extremes than would be expected on most natural oyster beds in deeper waters. This is not believed to be a significant factor in the tray mortalities.

Figure 4 shows that temperatures reach 20° C late in May and fall back below this reading about the middle of October. Spawning of oysters begins during the last half of June when temperatures have reached about 25° C (Andrews, 1951).

At Gloucester Point, Virginia, the tidal range is about 30 inches and currents are moderate. Further data on hydrographic conditions in the York River are given by Galtsoff *et al.* (1947) and for Chesapeake Bay by Pritchard (1952).

RESULTS AND DISCUSSION

Seasonal Distribution and Rate of Mortality. The average daily mortality rates, calculated for periods of 7 to 10 days, are shown in Figure 5. Deaths began increasing in June, reaching a peak in August and September, and declined to the winter level again about the first of November. The peak rate of death, as found in trays 1 to 3 and 6 to 10 combined, was about 0.30 per cent or six oysters per two thousand per day. From November to May the daily mortality rate seldom exceeded 0.05 per cent or one oyster per two thousand. In each tray this pattern was repeated, provided the oysters were at least two years old and had been acclimated about six months in the Gloucester Point area. Individual trays, containing as few as 100 oysters, showed the same pattern of high summer and low winter mortality as the combined groups of trays. Intensity as well as time distribution of losses was similar in each of the trays. The data for trays 1 to 3, 6 to 9, and 10 have been grouped and combined because of similarity in size and age of oysters and because the numbers in individual trays were small.

Table I further illustrates the seasonal character of mortalities and the effects of age of oysters and time of transplanting. Mortality for the "warm" months is the fraction of those present on June 1 which died by the end

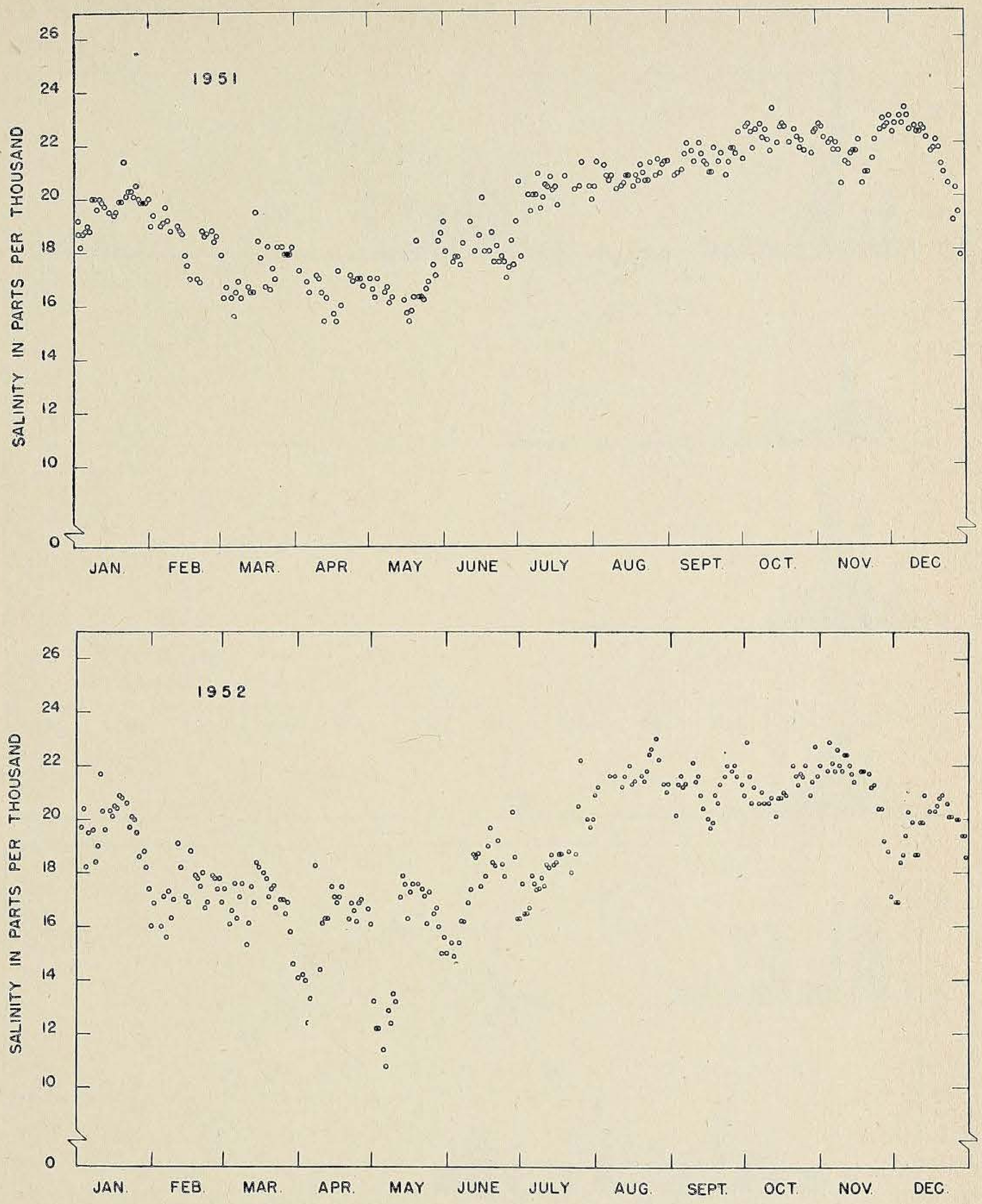
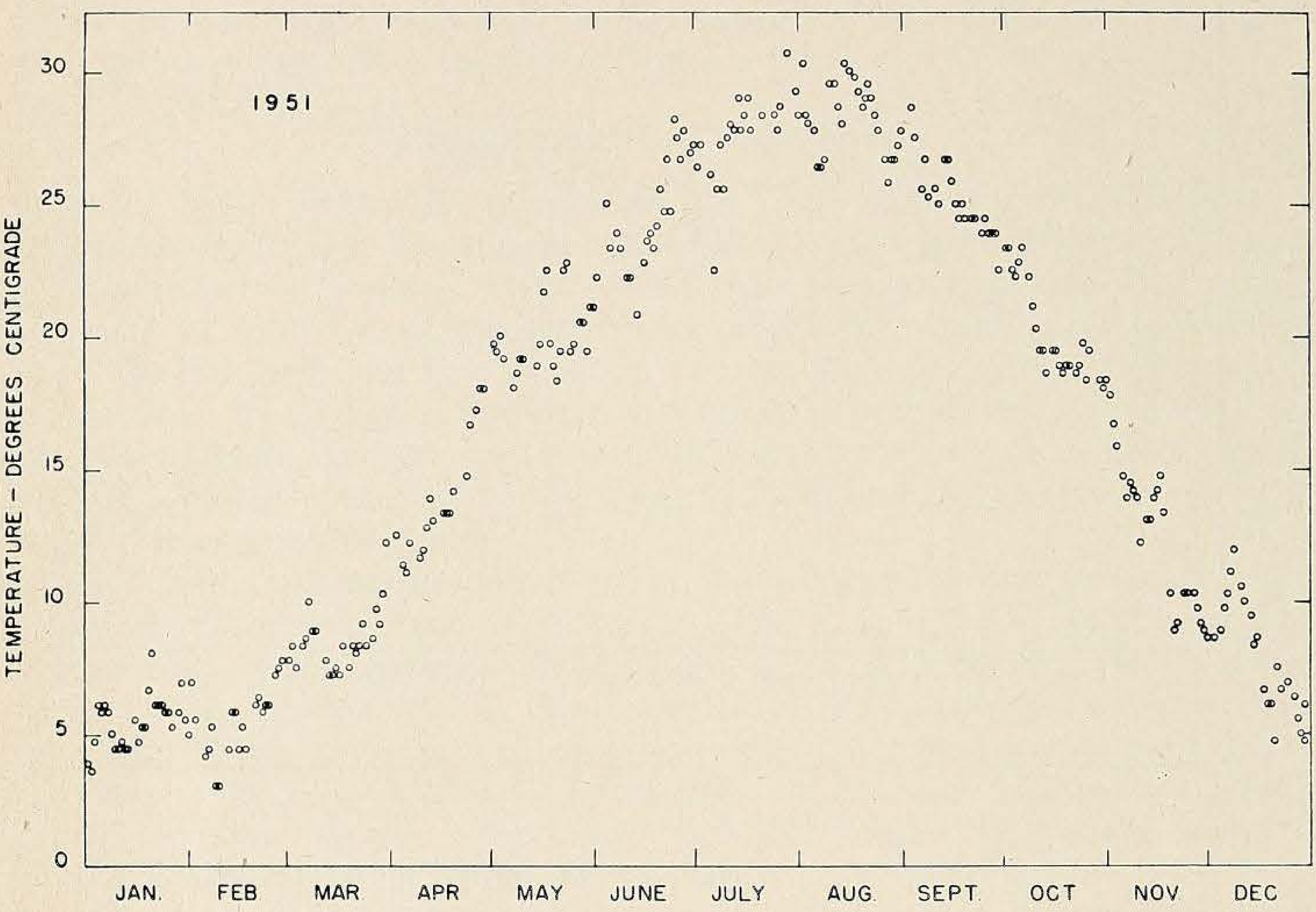


Fig. 3. Daily Surface Salinities for 1951 and 1952 at Gloucester Point, York River, Virginia.

of October, and the "cold" period mortality is the fraction of oysters present on November 1 which died by May 31 of the following year. Annual mortality is based on a period beginning June 1 of one year and ending on May 31 of the succeeding year. The trays of oysters have been arranged in groups according to age and the period of acclimatization. The first group includes oysters that were over two years old and had been acclimated six months or more at Gloucester Point, prior to the warm season indicated in the table. In this group an average of 26.6 per cent of the oysters died



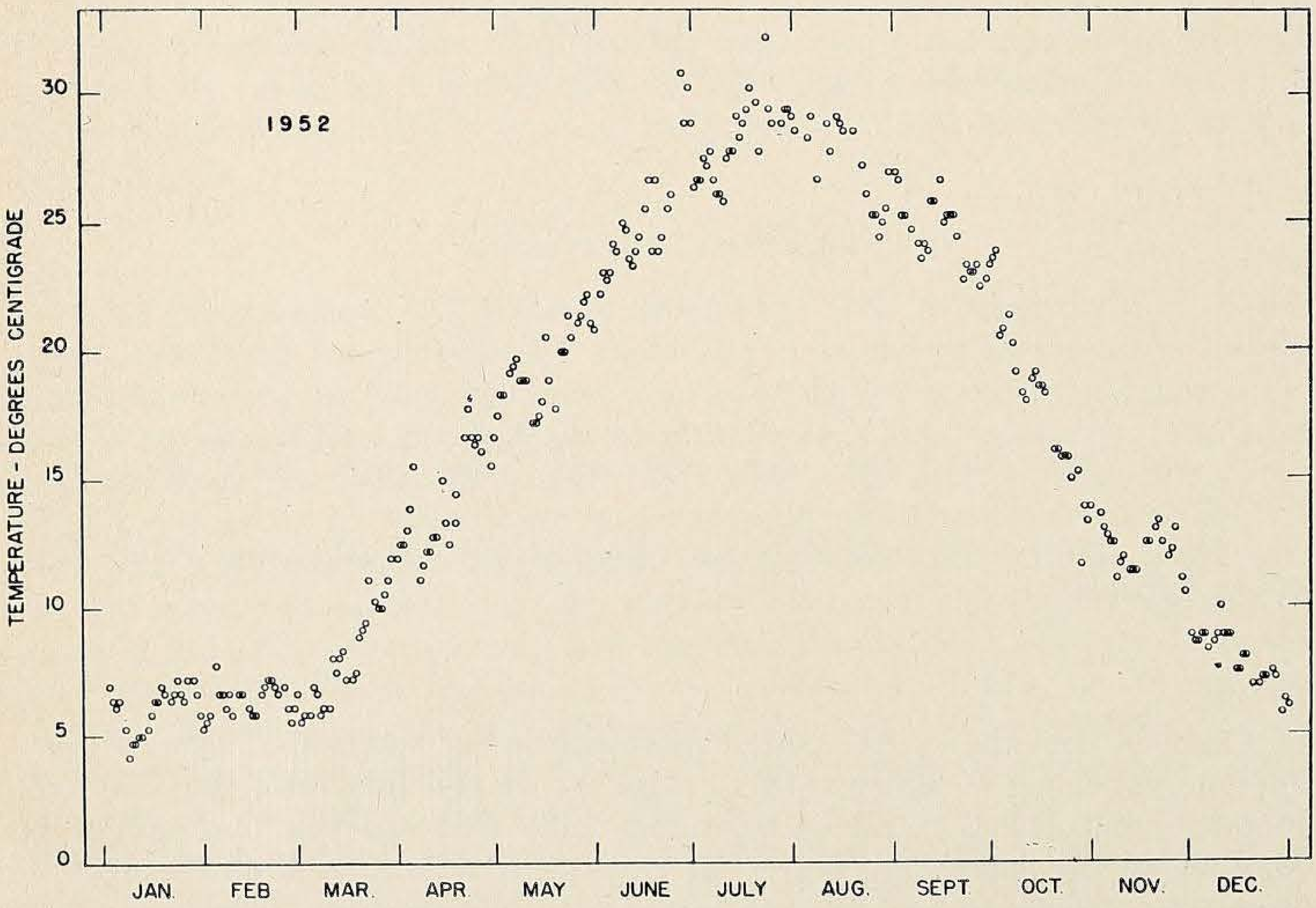


Fig. 4. Daily Surface Temperatures for 1951 and 1952 at Gloucester Point, York River, Virginia..

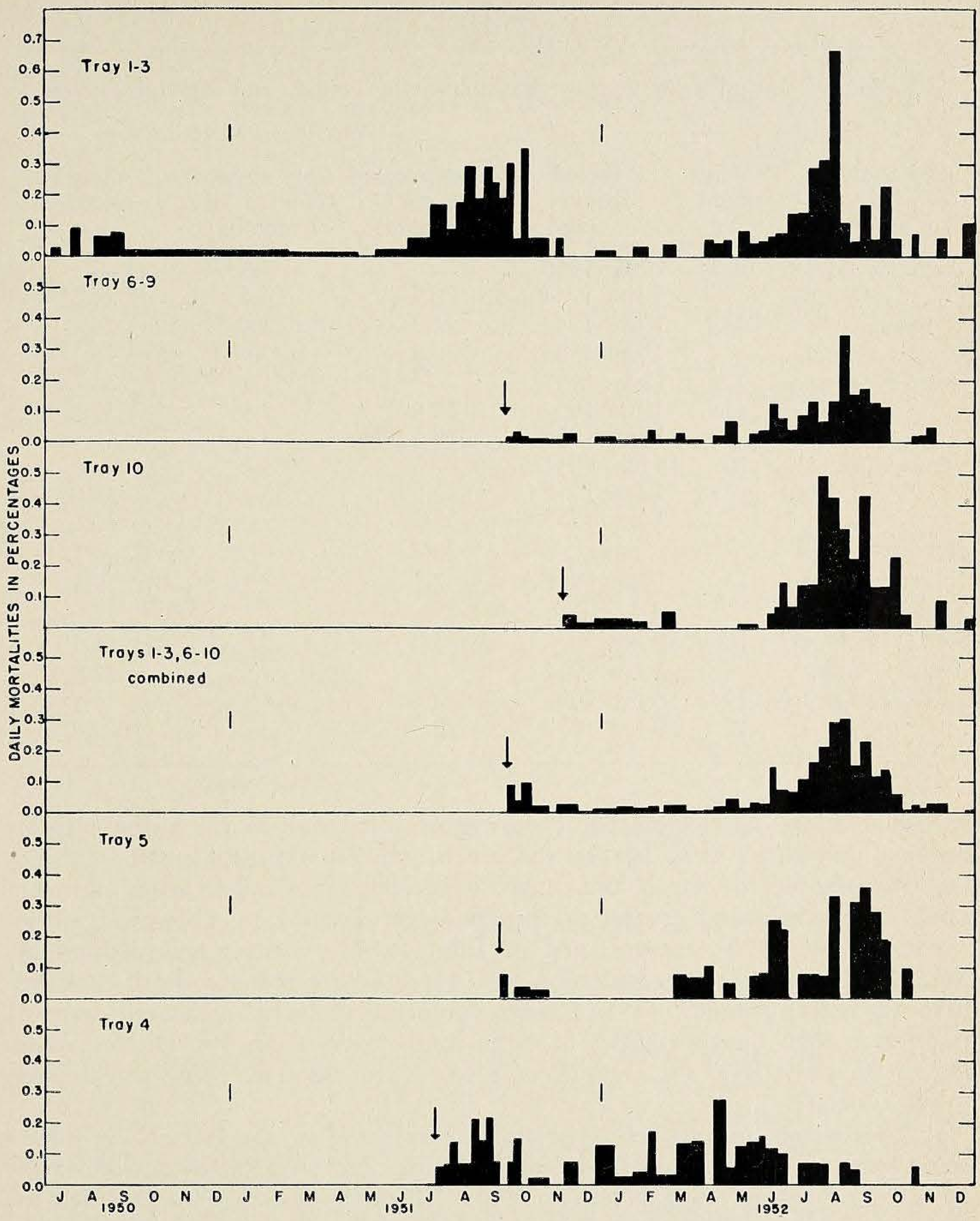


Fig. 5. Mortalities of Oysters in Trays at Gloucester Point, Virginia, in Per Cent Per Day.

during the five warm months, and only 3.5 per cent died during the remaining seven cold months. In the peak mortality months of August and September for the years 1952 and 1953, trays 1-3 and 6-10, combined, had an average monthly mortality of about 9 per cent. The rate for the low mortality months of February and March was 0.3 per cent.

Relation of Mortality to History and Age of Oysters. In Virginia most seed oysters are obtained from low salinity areas. When such oysters were

TABLE I

Relation of Mortality to Season, Acclimatization Period, and Age of Oysters

History of group	Tray number	Period beginning	Percentage Mortality: Warm months (June to Oct. 5 months)	Cold months (Nov. to May 7 months)	Annual mortality
Acclimatized	1-3	1 Nov 1950	—	3.5	—
		1 Jun 1951	20.7	4.6	24.3
oysters;	incl.	1 Jun 1952	22.0	3.5	24.8
		1 Jun 1953	36.2	—	—
over two	6-9	1 Nov 1951	—	3.2	—
	incl.	1 Jun 1952	15.0	2.3	17.2
		1 Jun 1953	29.3	—	—
years of age	10	15 Nov 1951	—	4.0	—
		1 Jun 1952	26.6	3.3	29.0
		1 Jun 1953	37.2	—	—
Averages			26.7	3.5	—
Recently transplanted; over	13	1 Jun 1952	7.1	2.2	9.1
two years of age	14	10 Jun 1952	3.8	0.6	4.4
Young; under	4	1 Jun 1952	7.1	6.3	12.8
two years of age	11	10 Jul 1952	3.5	3.7	7.1
	12	19 Jun 1952	2.2	0.4	2.6

transplanted to Gloucester Point during or just prior to the warm season, summer mortalities were delayed and much reduced. Trays 13 and 14 (Table I), transplanted in March and June respectively, had much lower summer losses than acclimated oysters of the same age. Trays 1 to 3 also had a low death rate in 1950 (transplanted in July, 1950). Oysters transplanted in the fall (trays 6 to 9 in September, 1951) showed a reduced death rate the first succeeding summer (1952) when compared to fully acclimated oysters. It appears that the mortalities of large seed oysters from low salinity areas remain at a low level for a period of 6 to 12 months after being transferred to salty waters.

The oysters in tray 10 were also transplanted in the fall of 1951 but came from an area of moderately high salinities and were stored out of water for 10 days before being placed in trays. All other oysters were returned to the water as promptly as possible after being taken from their native beds. A brief history of each tray is given in Table II.

Young oysters showed low summer losses even after a year of acclimatization. Trays 4, 11, and 12, all containing oysters one year old in the summer of 1952, had less than half the mortality of older oysters. Tray 4 contained spat transplanted from South Carolina in July, 1951, when only one month old. During the first summer (1951) and again in the following spring, mortality was rather high, which was not unexpected among spat because their small size increases the probability of injury, smothering, and predation. Oysters obviously killed by injuries and other accidental factors were not counted in the mortality records, but such injuries are more difficult to detect in spat. By March of 1952, these spat, still under one year of age, averaged two inches in length. It is improbable that unrecognized in-

TABLE II

Histories of Tray Oysters at Gloucester Point, Virginia

Tray number	Source	Salinity % at source	Year class	Date transplanted	Original count
1	James River Brown Shoals	6-22	1948	27 Jun 1950	105
2	James River Deep Water Shoal	0-12	1948	28 Jun 1950	114
3	Rappahannock River, Hoghouse Bar	10-17	1948	14 Jul 1950	124
4	We Creek, So. Car.		1951	11 Jul 1951	220
5	Seaside, Hog Island Bay	28-30	1950 1951	1 Sep 1951	174
6*	James River, Wreck Shoal	5-18	1950	28 Sep 1950	121
7	James River, Wreck Shoal	5-18	1949	28 Sep 1951	292
8	James River, Wreck Shoal	5-18	1949	28 Sep 1951	305
9	James River, Wreck Shoal	5-18	1948	28 Sep 1951	73
10	Rappahannock River, Hoghouse Area	10-17	1950	15 Nov 1951	305
11	James River, Wreck Shoal	5-18	1951	30 Nov 1951	247
12	Corrotoman River, Island Bar	5-16	1951	30 Oct 1951	238
13	York River, Va.	4-19	1948	19 Mar 1952	100
14	Rappahannock River, Ross Rock	0-11	1949	10 Jun 1952	160

* Trays 6-9 contained oysters of the following sizes respectively: 30-40; 40-50; 50-60; 60-75 mm.

juries and predation were responsible for many of the deaths the first winter and spring. During the second summer, the death rate of these South Carolina oysters declined to less than one per two thousand per day. These oysters were approximately 15 months old on the first of September, 1952, when the rate of mortality of older oysters was at a maximum. During the second winter the mortality rate remained low in tray 4 with 5.8 per cent dying from November, 1952 to June, 1953.

In the summer of 1953, at the age of two years, trays 11 and 12 had "warm" period mortalities of 24.5 and 17.0 per cent respectively, approaching the level of older acclimatized oysters. The oysters from South Carolina, with a "warm" period loss of 9.3 per cent in 1953, showed continued resistance to the summer mortality factors through the second year.

Size does not appear to be as important as age in relation to summer mortalities. Some oysters in tray 4 were over three inches long and well-shaped at an age of 12 months, yet the "warm" season mortality was low in this tray.

Comparison with Mortalities in the Gulf of Mexico. The delay in the appearance of summer mortalities in recently transplanted oysters, and the resistance of young oysters to summer deaths suggest that biological agents are involved in warm season mortalities. A disease caused by the fungus *Dermocystidium marinum* Mackin, Collier and Owen, which was first reported in the Gulf of Mexico (Mackin *et al.*, 1950), is now known to be widely distributed in Chesapeake Bay in waters of high salinity. There is evidence that the fungus is involved in the summer mortalities in this area. Therefore, a comparison of our data with similar warm-month mortalities reported by Mackin (1951a, 1951b) for Barataria Bay, Louisiana, is pertinent. Mackin's records also were obtained largely by tray culture.

In Barataria Bay, mortalities accelerated rapidly in May and June, reached a peak in mid-summer, followed by a decline to the end of the study in mid-September. Our data for Virginia waters show that the rapid increase does not begin until July, after which August and September are the peak months of mortality. There is no evidence in our data that the mortality rate declines until after temperatures begin to drop in the fall.

While Mackin's experiments ran 14 months, it is obvious that his oysters were essentially exposed to one period of high mortality, since deaths were few the first summer and fall following transplantation from an area of low salinity. Therefore, his mortality figures probably can be compared directly with ours. On this basis mortalities were approximately three times as frequent in Barataria Bay (about 75 per cent in 14 months) as at Gloucester Point.

The Mobjack Bay Mortality of 1929-30. Prytherch (1931) reported a severe winter mortality in Mobjack Bay in 1929-30, but presented no evidence to prove that the deaths actually occurred in winter. Since he did not begin his investigations until May, 1930, the validity of his conclusion is doubtful. Summer losses usually are not discovered until the oystering season begins in early fall. It is, therefore, possible that the alleged winter mortality occurred in the summer of 1929.

The present study offers a possible explanation of Prytherch's failure to detect serious summer mortalities in tray oyster experiments in 1930. He placed oysters from low salinity waters of the James River in trays in Mobjack Bay and the York River about the middle of May, 1930. These oysters were held for eight months without significant losses. Our experience with similar transplants indicates that serious losses would not be expected until the second summer.

Effect of Tray Culture on Mortality. The question arises, to what extent are tray mortalities representative of those on natural bottoms? Control oysters resting on natural bottom were not kept because of the difficulty of recovering the same oysters regularly.

Certain factors tend to reduce mortality in trays as compared to natural bottoms. Suspending the trays off the bottom and covering them with wire mesh eliminates nearly all predation. This also prevents smothering by shifting sand and soft mud. Mechanical obstructions and injuries attending the operations of planting and harvesting are avoided. All of these are constituents of the complex of natural mortality.

On the other hand, several spurious sources of mortality may arise from tray culture of oysters. Trays at Gloucester Point were handled frequently, and during the summer were lifted out of the water once a day. Care was taken to prevent long exposures and sudden temperature changes. No sudden losses were experienced and there was no evidence suggesting adverse effects from handling and exposure.

The possibility of depletion of food supply by overcrowding is often discussed by oystermen. Prytherch (1931), evidently suspecting the effects of crowding, placed oysters in trays at concentrations of 1, ½, ¼, and ⅛ bushels per square yard but found no apparent influence on growth or mortality. When a new supply of water is available almost constantly, it seems unlikely that the number of oysters in a tray or several contiguous trays can deplete the food supply seriously. It is probable that local water currents and the total plankton feeding population in a body of water are of more importance in determining the food supply than the proximity of oysters or small groups of oysters. By local standards, growth is excellent in the tray oysters at Gloucester Point.

One effect of crowding, which may be important but has not been measured, is that pest or disease organisms may be spread by contact or contagion. Any disease transmitted by direct contact with the discharges or disintegration of infected oysters might cause increased mortality in oysters in trays.

Oysters in trays at Gloucester Point reach a marketable size much quicker than those on most natural bottoms. Possibly this indicates more efficient use of food because the oysters are raised out of the silt-laden bottom layer. It may also reflect increased filtration of water, again as a result of reduced work in sorting food. If there is an increase in the amount of water pumped, water-borne diseases (Mackin, 1951a) such as *Dermocystidium marinum* may be substantially augmented in trays.

Finally, when a factor is isolated for study under experimental conditions, there is danger of overestimating the real contribution of this source of mortality under natural conditions. On natural oyster beds all causes of mortality interact but in trays certain important sources of death are eliminated, allowing the remaining factors full play. Since tray culture helps to isolate individual factors for study, it is a desirable method of investigation, provided the effects of interaction with other causes of mortality are considered in interpreting the results.

There are reasons to believe that natural mortalities exceed those encountered in trays, even among old oysters where drill predation is not important. This belief is not based on a measurement of natural mortalities but on analysis of yields and the prevalence of certain diseases in oysters grown both in trays and on natural bottom.

Applications to Commercial Oyster Planting. The scarcity of dying oysters and the rapid disintegration of boxes lulls oystermen into believing that their annual losses are not very great. Not until oysters are harvested and low yields obtained do oystermen realize that unusual losses have occurred. Oysters grown in trays at Gloucester Point have an annual mortality of about 25 per cent. By using figures believed to be typical for lower Chesapeake Bay, it is possible to check this rate by an analysis of the yield from natural grounds. Assuming 900 seed oysters per bushel, a yield of one bushel of market oysters for each bushel of seed oysters planted, a three year interval between planting and harvesting, and 300 market oysters per bushel, then the total mortality for three years is 66.7 per cent. From Ricker's (1948) table, this corresponds to an instantaneous rate of 1.10 for the three year period, or annual instantaneous mortality rate of 0.366. This is equivalent to an annual mortality of 30 per cent on the natural grounds. The count of 900 seed oysters per bushel does not include current year spat, most of which are probably killed by drills in the lower Bay.

Owen (1953) uses another method for checking natural mortality on planted grounds based on the length of the oysters at planting and harvesting. According to his figures (Table IV, page 48), if the yield is one for one and 50 millimeter seed are held until a size of 85 millimeters is reached, 80.6 per cent of the oysters will have died. These lengths probably approximate the average for seed and harvest oysters in lower Chesapeake Bay. A mortality of 80.6 per cent in three years is equivalent to an average annual mortality of 42.3 per cent.

In areas where such death rates exist, fast growth and the earliest possible harvesting are essentials. Young oysters appear to be less susceptible to the high summer losses. The advantage which might be gained by the use of young oysters is offset by the fact that in order to obtain seed with relatively large, thick shells which will withstand predation by drills, oystermen in the lower Chesapeake Bay area are compelled to leave oysters on the seed grounds for two or three years. Unfortunately, growth is poor on the seed grounds.

If, in high salinity areas, the annual mortality on Virginia oyster grounds is 30 per cent or more, losses are greater than most oystermen think. Oysters which have been on the growing ground for as long as two or three years seldom show more than about 20 per cent boxes. If records of tray culture are reliable indices of mortalities on natural grounds, counts of boxes are extremely misleading.

SUMMARY

Oyster mortality studies have been conducted over a period of three and one-half years at the Virginia Fisheries Laboratory, York River, Virginia. Records have been obtained on approximately 2600 oysters, in groups of 100-300 of various ages from several sources, suspended in trays from the laboratory pier.

The annual mortality rate in 1952 ranged from 17 to 29 per cent for oysters which had been acclimated to the area for six months or more. The death rate was high during warm months and low during cold months. The mean monthly mortality for August and September was 9 per cent, but only 0.3 per cent per month during February and March. Average daily mortality rates are given for periods of 7-10 days.

Oysters under two years of age, and those which were transplanted from low salinity areas near the beginning of the summer period, did not show the pattern of high summer mortalities revealed in older acclimated oysters. The death rate of oysters transplanted from low salinity waters to Gloucester Point was found to be low for six to twelve months after they were moved. There appears to be a relation between the time of transplanting and the development of the mortality pattern of the locality to which the oysters are transferred.

There is evidence that the disease caused by the fungus *Dermocystidium marinum* is related to the high summer mortalities.

It is probable that mortalities on Virginia oyster grounds may be much higher than the estimates commonly made by commercial planters.

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