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CONVENTION ADDRESSES
GIVEN AT THE MEETING
OF THE
NATIONAL SHELLFISHERIES
ASSOCIATION
NEW YORK CITY
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Richard Messer, President

Edwin Warfield, Jr., Vice-President

Dr. Victor L. Loosanoff, Secretary

J. Richards Nelson, Treasurer

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Thurlow C. Nelson,
Rutgers University
and
New Jersey Oyster Research Laboratory

It is a basic biological law that each animal and plant reproduces "after its kind". Within certain definite limits of variation each species produces generation after generation of offspring which we readily recognize because of their close approximation to parental types. During the twentieth century, together with the rediscovery of Mendel's principles of heredity and a vast amount of brilliant research, we have made greater progress in the improvement of agricultural crops and in farm animals in four decades than was made in all historic time prior to 1900.

The dominant position of America in the world's food picture of today is no accident. We stand where we do primarily for two reasons: hard work and the application of the results of scientific research. Oysters are a farm crop raised under water, and like the land farmer the oyster farmer is thoroughly familiar with hard work. He knows long hours, hard back breaking labor, most of it performed in freezing and subfreezing weather. But in the application of science to his industry the oyster grower is a good half century behind his brother on the land. Aside from the improved sanitary conditions in our shucking houses which have grown out of our knowledge of bacteriology, oyster growers today are making use of but one scientific finding; the prediction of time and probably intensity of setting based upon: (1) the microscopic examination of water for oyster larvae; and (2) the condition of spawning of adult oysters. The pioneer work in this field was done by my father, the late Dr. Julius Nelson, between 1900 and 1915 in New Jersey and at Prince Edward Island, Canada. The work was developed practically by us at the New Jersey Oyster Research Laboratory, and by Churchill and Gutsell, and by Prytherch of the Fish and Wildlife Service, between 1917 and 1931. Application of these methods, together with much more accurate observations of the onset of spawning carried on chiefly at Milford, Connecticut, by scientists of the Fish and Wildlife Service, have been the most important factors in the recovery of the Long Island and New England oyster industry since the mid nineteen twenties. Restoration of the inshore spawning beds of Connecticut under the able direction of Dr. Prytherch, followed by the accurate setting predictions of Dr. Loosanoff and J. B. Engle, and by Dr. Loosanoff alone, have yielded financial returns to the oyster growers many times greater than the cost of all the research which made these results possible.

ON THE NEED FOR DEVELOPING NEW STRAINS OF OYSTERS THROUGH SELECTIVE BREEDING OR GENETIC STUDY, CLOSE SUPERVISION WITH OTHER STOCKS AND THE INTRODUCTION OF SPECIES FROM OTHER AREAS

Thurlow C. Nelson,
Rutgers University
and
New Jersey Oyster Research Laboratory

It is a basic biological law that each animal and plant reproduces "after its kind". Within certain definite limits of variation each species produces generation after generation of offspring which we readily recognize because of their close approximation to parental types. During the twentieth century, together with the rediscovery of Mendel's principles of heredity and a vast amount of artificial research, we have made greater progress in the improvement of agricultural crops and in farm animals in four decades than was made in all historic time prior to 1900.

The dominant position of America in the world's food pictures of today is no accident. We stand where we do primarily for two reasons: hard work and the application of the results of scientific research. Oysters are a farm crop raised under water, and like the land farmer the oyster farmer is thoroughly familiar with hard work. He knows long hours, hard breaking labor, most of it performed in freezing and confounding weather. But in the application of science to his industry the oyster grower is a good half century behind his brother on the land. Aside from the improved sanitary conditions in our shucking houses which have grown out of our knowledge of bacteriology, oyster growers today are making use of but one scientific finding: the predictions of time and probability intensity of spatting based upon (1) the microscopic examination of water for oyster larvae; and (2) the observation of spawning of adult oysters. The pioneer work in this field was done by my father, the late Dr. Julius Nelson, between 1900 and 1915 in New Jersey and at Prince Edward Island, Canada. The work was developed practically by us at the New Jersey Oyster Research Laboratory, and by Churchill and Chatwell, and by Prytherch at the Fish and Wildlife Service, between 1917 and 1921. Application of these methods, together with much more accurate observations of the coast of spawning carried on chiefly at Milford, Connecticut, by scientists of the Fish and Wildlife Service, have been the most important factors in the recovery of the Long Island and New England oyster industry since the mid nineteen twenties. Restoration of the Damage spawning beds of Connecticut under the able direction of Dr. Prytherch, followed by the separate setting predictions of Dr. Loosanoff and J. B. Engle, and by Dr. Loosanoff alone, have yielded financial returns to the oyster growers many times greater than the cost of all the research which made these results possible.

But why stop here? The land farmer many years ago abandoned the scrub chickens, the scrawny cattle and other nondescript stock of their grandfathers, and developed flocks and herds of vastly improved animals. Through the results of research in genetics the farmer learned that a high milk producing heifer can transmit that quality only through her son to her granddaughters, she cannot pass this directly on to her daughters. Likewise we honor the hen whose son will never set, yet we know that the 300-egg-a-year bird can pass on this character only through this never-setting son to appear then in her granddaughters, not in her daughters.

What do we know about inheritance in oysters? The answer is - virtually nothing. We do know that throughout the world over fifty different species are recognized and that these species breed true. To date I know of no clearly proven case of hybrids among these shellfish. Within each species exist fairly clear cut regional varieties. Thus, for example, any experienced oyster grower will quickly pick a southern oyster from among a group of Long Island oysters. Conversely when eastern or Long Island oysters were being transplanted in large numbers to Delaware Bay during the early nineteen thirties, even a relatively inexperienced observer could separate the newcomers from the native stock. It is important to note, however, that although these eastern oysters spawned extensively they have left no observable permanent effect on the oysters of Delaware Bay. We cannot pick out a spat here and there and state definitely that its parents were from Long Island. We know in some instances that these eastern oysters spawned at least two weeks prior to the first spawning of natives. Early sets were obtained but in their later growth these oysters have taken on at least the shell characteristics of the Delaware Bay oyster, not those of their Long Island parents.

Oyster growers in New Jersey, at least within my memory, have always stressed the value of introducing oysters from other areas. They insist that crossing must occur since the intensity of setting and the vigor of the stock seem to rise after such importations. Scientific proof does not exist either of crossing nor of increased vigor following the importation of oysters from outside. But, as a scientist who has been in life long contact with oyster growers, I would be among the first to pay tribute to their keen powers of observation. It costs money to bring in oysters from a distant point, hence I doubt if such importations would be continued unless there were pretty clear evidence of its beneficial results.

The improvements which follow crossing in other lines of plants and animals are well known. Outstanding are the results with hybrid corn and the superior strength and endurance of the mule. This the biologist attributes to so-called hybrid vigor or heterosis which has now been demonstrated among so many animals and plants that it may be considered a biological law. America's position in the world today is chiefly because of this very hybrid vigor: we humans are mostly hybrids and to this largely we owe the energy which so astonishes the rest of the world.

Rate of growth and ultimate size are hereditary factors which in other animals and plants have been shown to be handed on according to definite patterns of inheritance. Through selection of superior animals and by individual matings Mr. Charles O. Hayford of the New Jersey trout hatchery at Hackettstown was able by the third generation to double the rate of

But why stop here? The land corner many years ago abandoned the novel antelope, the scrawny cattle and other mediocre livestock of their grandfathers, and developed Angus and Herefords of yearly improved quality. Through the results of research in genetics the farmer learned that a high milk producing antler dan therefore that quality only through our son to her grandchildren, the farmer now gets directly on to her daughters. Likewise we honor the Dan whose dog will hunt her, yet we know that the 300-egg-a-year hen has been on the chicken only through this never-ending son to superior them in her grandaughters, not in her daughters.

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Lists of growth and ultimate size are horrifying factors which in other animals can clearly have been shown to be linked on genetically to certain patterns of inheritance. Through selection of superior animals and by individual matings Dr. Dustin O. Hayford of the New Jersey State Hatchery at Bridgeton was able by the third generation to double the size of

growth in trout. By November of their second year he had some fish up to fourteen inches in length as against a maximum of seven for the unselected general stocks. Dr. Carriker, later to appear on this program, together with co-workers in Wisconsin, developed a race of the common fresh-water snail, Lymnea, which was approximately one-fourth larger at maturity than the wild type from which the original parents came. G. W. Martin working in our own laboratories showed twenty years ago that of oyster spat which attach at the same time on glass plates where they are able to grow without obstruction from other spat, some may grow as much as three times more rapidly than others nearby.

Confirming this are these two oysters of the same age from Nyatt Point, Naragansett Bay, Rhode Island, which I am now showing you. These oysters were on the same bed, subject to the same conditions. The smaller one represents a good average for the oysters as a whole which were remarkably uniform as to size and shape. The most probable explanation for the much greater size of the larger oyster is that it was due to internal factors of inheritance. Looking closely at these oysters we see that in two of the years growth was greater than in the others. In these better years, however, the larger oyster made relatively a larger growth than did its neighbors. In other words it made better use of the more favorable growing conditions than did the other oysters nearby.

What do we know about the factors of size and rate of growth in the oyster? In the European oyster, Ostrea edulis, Professor J. H. Orton of Liverpool, showed in 1925 that in the Fal Estuary in England 42% of the oysters on the beds were of a type recognized as "dumpy". In these the growth rings are much closer together, the shell is rough, frequently misshapen and the thickness is appreciably greater due to greater thickness of the shells, not to a larger meat. He states that in general such oysters are from two to three years older than normal oysters of the same size. Because of the prohibition against removing oysters of less than two and one half inches from the beds Orton found a higher percentage of dumpy oysters among the small oysters under two and one half inches than among those above this size. I have recently suggested that one contributing cause to the decline in oyster production in the Chesapeake Bay has been the "three inch law" in accord with which all small oysters must be returned. Where dwarfed oysters are present it follows that their number will steadily increase since their slower growth will keep them below three inches longer than required for normal oysters. In many cases the dumpy oysters may never exceed three inches in length. Owing to the slower growth of the "dumps" a larger proportion of these was being thrown back on the beds than of normal oysters, resulting in almost one half of the oysters being "dumps" at the time of his investigation. Remembering that the European oyster carries its larvae upon the gills, let me quote from a paper by Professor Orton in 1926.

"Although the dumps are now seen to be not so good as the others for spawning purposes, yet they are only slightly inferior. There can remain no doubt, therefore, that dumps are valuable for breeding inasmuch as a high proportion yield larvae like normal individuals. We have no means at present of ascertaining the survival value of the larvae of the two types

of oysters, and on the other hand no substantial reason to doubt that the larvae of both types are healthy and will produce spat equally well under favorable conditions." May I emphasize that Dr. Orton judged the spawning ability of the dumps solely upon the numbers of larvae on gills which were only slightly less than in normal oysters. His conclusion that we have "no substantial reason to doubt" that the larvae of the dumps are as healthy and will produce spat equally with normal oysters is contrary to everything we know in other animals.

In the European oyster we have the great advantage in that prior to being shed into the water the larvae can all be traced back to at least one parent, the mother, on whose gills they lie. The fathers are unknown since oysters are not self impregnating, but the eggs on the gills are fertilized by sperm carried in with the incurrent stream of water. In Orton's observations there was an equal chance therefore of sperm from normal and of dumpy males fertilizing the eggs of the dumpy mothers. Assuming that Orton is correct in his assumption that dumps produce as vigorous larvae as normal oysters, it is probable that at least one quarter of the larvae on these beds came from parents both of which were dumpy while one half of them had either a dumpy father or a dumpy mother.

It is most unfortunate that Orton did not examine these oyster larvae microscopically. In Barnegat Bay, where most of my own larval oyster studies were carried on, a thriving industry practically disappeared in fifteen years. During this period the proportion of slow growing dwarfed oysters, which I class with the English dumps, steadily and rapidly increased. Coincidentally I began to find many swimming larvae in my collections in which the shell showed numerous wrinkles and was greyish rather than transparent. Unfortunately I did not photograph any of these larvae since at that time I did not suspect their possible significance. I have no proof that such larvae came from dumpy parents; I can only report their presence correlated with a rapid increase in the percentage of dumpy parents on the beds. The larval broods which contained large numbers of these wrinkled shelled larvae decreased very rapidly in numbers with but a small proportion of them reaching setting size.

In other animals as well as in plants tallness and dwarfness are inherited as definite characters as are also vigor and rapidity of growth. We are justified therefore, in assuming similar inheritance of these factors in oysters until definite scientific proof is obtained.

The rate of growth and the size attained by the Japanese oyster in the Pacific northwest is known to all of you. The shells on exhibit show oysters eighteen months after their importation as spat to Olympia, Washington. The meats of these same oysters, some of which I shucked immediately upon arrival from the west coast, ran eight to the pint, sixteen to the quart, or at the rate of sixty-four to the gallon. Dr. Prytherch has called my attention to a note by Dr. Bashford Dean in 1903 that he found in Japan, oysters weighing with shell four to five pounds not infrequently. Although inferior to the best of our own virginica when eaten raw, I am informed that in at least two respects they are superior. If canned when in their prime in May they

are reported to be free from the oily rancid taste which often develops in our eastern canned oyster. When rolled in dry bread crumbs, sprayed with olive oil and baked for five minutes in an oven of 450°F. they emerge brown as chestnuts and cooked to a delicious turn in their own steam. For such baking, I am informed, the home economics department of the University of British Columbia prefers the large Japanese oyster. If it were possible to obtain in our eastern oyster the rapid growth of the Japanese oyster it would revolutionize our industry. The cattleman takes three years to grow a fifteen hundred pound steer for market. The oysterman requires six years, or just twice as long, to grow a one ounce oyster. It just doesn't make sense, and the time has come when oyster growers and scientists should combine to remedy the situation. We know from our studies in Delaware Bay that the survivors from the intense sets on the Cape May shore rapidly outgrow oysters from elsewhere in Maurice River Cove. Samples on exhibit clearly support this. During studies of water pumping it was found that two-year-old Cape Shore oysters could outpump eight and ten year old Barnegat Bay oysters by two or three to one, thus giving evidence of their much greater vigor.

Frequently the survivors each represent the one oyster out of 630 spat per square inch which reached the end of the first year. The others were crowded out and smothered by their fellows. As yet no one has bred exclusively from such fast growers and proved that they will pass on this capacity for rapid growth to their offspring. May I suggest, however, that the improvement of New Jersey stock over the years following the introduction of southern oysters may be due to this very vigor. The imported stock which I have seen is mostly bunched with many long "cat tongue" oysters among them. As such they are of little value as market oysters, but being the survivors of heavy sets they may have passed along to their offspring the vigor which they themselves were prevented by crowding from exhibiting.

My only first hand experience with the Japanese oyster was in the early nineteen thirties when a bushel of them were tried out in Barnegat Bay in the hope of reviving the dying industry there. During the first two weeks in the bay they grew nearly three quarters of an inch. Then they stopped growing and gradually died over the next two years without showing any further signs of growth. It must be noted that salinities here ranged from approximately twelve to twenty as against salinities of over thirty or oceanic saltness on the beds of Japan where Dr. Dean studied them. In addition to these low salinities these gigas oysters in Barnegat Bay had to contend with the very factors of stagnation and low oxygen which were hastening the destruction of the native virginicas. It was, therefore, by no means a fair test of their ability to survive in Atlantic waters.

Another oyster in which I am deeply interested is the Australian oyster, Gryphaea cucullata. My good friend, Mr. T. C. Roughley, undertook to fly some to us in New Jersey last October but his plane was delayed in warm weather at Hawaii, so the oysters having been out of water for nine days without refrigeration were eaten and enjoyed by newspaper men and others in California. Mr. Roughley tells me that all Americans with whom he has talked in Australia claim the superiority of cucullata over our own virginica in flavor.

What the industry needs at this time is a thorough and unbiased study of the more promising foreign oysters together with efforts to hybridize them with each other and with our own eastern oyster. A hybrid with its increased vigor should grow to full market size in two years thus enabling the oyster planter to turn his money over three times where now he turns it over once. All such work must be conducted with the greatest care in enclosed basins in a laboratory whence no enemies nor inferior hybrid oyster, if produced, might escape to an oyster bearing region. All waste water from tanks holding any foreign oysters must be run into a sand pit whence it will enter the natural waters only through the sand, or the waste water must be treated to kill any life therein. Our industry is far too valuable to take any chances or to trust to luck. The virtual wiping out of the superior European oyster, Ostrea edulis, in France by the accidental introduction of the inferior portuguese oyster into the Gironde River about 1870 furnishes a vivid lesson to all of us.

The gigas oyster has already proved its value in the Pacific Northwest. Dr. Prytherch points out that Fisheries Statistics of the Fish and Wildlife Service for 1941 shows that from Washington, Oregon and California over twelve million pounds of these oysters were harvested in that year with a value of seventy-five cents per pound as compared with sixty-three cents for the small native lurida and forty-one cents for virginica raised out there. Such figures do not support the claim of inferiority. There are undoubtedly areas of high salinity along our Atlantic seaboard where the gigas oyster would do well but where the lack of fresh-water retards the growth and fattening of eastern oysters. We are taking a short sighted view of the potential development of our coastal waters if we do not at least consider the possibility of introducing into such areas an oyster which will thrive there.

A Suggested Program

1. In all areas dependent upon seed oysters produced under the care of the state it is urged that spawning sanctuaries be established in proximity to the areas to be shelled. To these sanctuaries should go the largest and most vigorous oysters available. I am recommending in New Jersey that the funds available for spawners be spent to buy back from the tongers and dredgers the largest and the best of the oysters as taken. A simple gage such as that illustrated at the side table should suffice for obtaining these. As these sanctuaries are developed their value will be demonstrated and year by year the population of superior breeders will be built up.

2. Where all seed oysters are obtained from private seed beds it is urged that when these are at some distance from the planted grounds small sanctuaries be established experimentally in close proximity to the shells. To these sanctuaries should go the largest and most thrifty of the oysters produced.

3. I concur fully with the recommendations which Dr. Prytherch has already made with respect to the Pacific or gigas oyster.

(a) That we cease calling them Jap oysters and thus get away from our present natural aversion to everything "made in Japan". The term Pacific oyster is a good one since the little native of our west coast is called the Olympia oyster. This would give us in the Pacific oyster the natural counterpart of the Atlantic oyster for the species virginica.

(b) That seed and adult Pacific oysters be promptly shipped to our Atlantic and Gulf shellfish laboratories for scientific studies of their suitability and adaptability for commercial use on these coasts.

(c) That test plantings be made on a small commercial scale under natural conditions where control or elimination of the imported species can be exercised if necessary.

(d) That a conference be arranged with the leaders in the oyster industry and state conservation officials, for a critical discussion of this issue with a view to permitting importation of Pacific oysters under control.

To the above conference I would ask that there be invited Dr. Radcliffe, Mr. Wayne Heydecker of the Atlantic Coast Fisheries Commission and those scientists who are in a position to throw light upon the discussion. I should like to include also Dr. C. Roy Elsey of British Columbia who combines technical scientific knowledge with extensive experience in handling the Pacific oyster. I ask also that consideration be given to other foreign species especially the European oyster, Ostrea edulis, and the Australian oyster, Gryphaea cucullata. With its spawning temperature 5°C. below that of the Atlantic oyster, edulis might well be the answer to our need of an oyster for the northern coastline.

To those who rightly fear uncontrolled importation of foreign shellfish I commend our New Jersey law which for thirteen years has given us complete protection but which gives the widest possible latitude for importation of foreign shellfish for scientific study under license of the Division of Shellfisheries of the State Department of Conservation.

In conclusion, oysters are a delicious, nutritious, health-giving food but their cost interferes with their becoming a common article of diet. Every year that can be cut off from the time required to raise them will materially reduce that cost. Science has given the oyster grower a dependable source of seed. The next two most important problems - fattening and more rapid growth await scientific study and solution. I have faith that both will yield to attack by research and that newer, better and fatter oysters await us in the not-too-far-distant future. Whatever the outgrowth of our deliberations here today the crying need of the world today for food leaves no room for less than the maximum development of our coastal waters for the production of seafood. To that task we dedicate ourselves.

OBSERVATIONS OF JAPANESE OYSTER CULTURE IN THE STATE OF WASHINGTON

A. E. Hopkins, Aquatic Biologist
U. S. Fish and Wildlife Service

For about seven years I was rather closely associated with the oyster industry in Puget Sound, Grays Harbor, and Willapa Bay, and had an opportunity to observe the rapidly developing Japanese oyster industry on the Pacific Coast. It has been about ten years since I left that region, but I was able to see this new species in its relatively early stage of importance as a commercial fishery venture.

A group of Japanese first introduced Japanese seed oysters into Samish Bay, a portion of Puget Sound, in about 1905. At that time there was no control over importation, or inspection of the seeds, which had been caught on either shells or brush. This company operated for a number of years on bottoms which had formerly been used for the production of Olympia oysters and for the bedding and fattening of eastern seeds brought in from Long Island Sound and adjacent areas.

In the early 1920's the Japanese company was taken over by an American company, and for several years small annual importations of seeds were made. I do not believe that, on the market, any distinction was made between the oysters grown from Japanese seeds and eastern oysters fresh shipped from the East Coast, or those grown from the seeds brought from the East.

However, it was well demonstrated that the Japanese species thrived, and certain business men in Japan recognized the possibility of raising seeds for export to the United States. In about 1928 various American companies in association with Japanese seed oyster producers started a rather tremendous seed planting program, particularly in Puget Sound, Willapa Bay, and Grays Harbor. It may be imagined that various promoters sold, at fabulous prices, large areas of previously non-productive bottom to the public. Such ventures, although they may have been designed to make profits from investors rather than from oysters, resulted in importations of seeds from Japan amounting to about 75,000 boxes of seeds per year during the early 1930's.

During the time of which I speak, the seed oysters were shipped in boxes containing about two cubic feet of shells on which the young oysters were growing. The spat ranged from about one-eighth to one-half inch in diameter, and I believe the Japanese producers were conservative when they guaranteed a minimum of 10,000 seeds per box. The price at that time ranged from $2.50 to $3.00 per box.

The Japanese method of stringing shells on wires and suspending them from racks to catch the seeds is probably well known to you. It is claimed by the seed producers that this method prevents the inclusion of predators, although one may be sure that there is no certain method of eliminating completely the possibility of importing a few such organisms.

It was very surprising to me to see how well those small spat lived through two or three weeks of travel, on the deck of freight ships across the Pacific, and also how rapidly the young oysters grew after being planted on virgin ground. They were planted on all types of bottom, from extremely soft mud to hard sand, but in almost all cases, they thrived to such an extent as to make increased importations at this low price economically feasible.

It must be borne in mind that our Pacific Coast previously had not produced oysters in any significant quantity with respect to the total oyster production of the Atlantic and Gulf Coasts. Our East Coast oyster had been tried for many years in various places and had not propagated on a commercial scale, except in one or two very small places, such as the mouth of the Naselle River, which empties into Willapa Bay. For that reason the fishery industry on the Pacific Coast had little to lose by importing a foreign species. In fact, it had much to gain as shown by the fact that in 1942 the pack of steam-canned oysters on the Pacific Coast amounted to approximately one-fourth the total steam-canned pack of the United States.

At first, with limited planting of seeds, the Japanese oysters grew at a tremendous rate so that within one year after the seeds were planted the oysters would produce meats at the rate of about one gallon to the bushel. During the second winter those same oysters would measure from six to fifteen inches in length, having a very deeply cupped shell holding a large-sized meat. In almost all cases the Japanese oyster is rather thin-shelled and deeply cupped. However, on hard bottom, it was often noted that the shells were much thicker and harder.

It was consistently noted by oyster growers that with increased quantities of seeds planted, growth and fattening became much slower. I might cite the case of a company operating in Padilla Bay, a portion of Puget Sound, which planted about 400 boxes of seeds on virgin bottoms in 1930. Within two years these seeds had grown to a very large size and the meats were rich and fat. Then the company started an intensive promotion by selling ground to the public to be planted by the company and harvested as a unit. During the next three years approximately 100,000 boxes of seeds were planted and arrangements made with a canner to handle the product. So far as I know, this company was never able to put any canned oyster products on the market except oyster soup, because the oysters not only grew very slowly but they failed to fatten like the original samples. This would suggest that there is a limitation on the number of oysters which any piece of ground or body of water may nourish and support.

The above instance may not be significant, for it was claimed that a pulp mill in the vicinity may have been responsible for the poor oysters due to discharge of waste materials. However, the same has been found to be true in the Willapa Bay area where it has been definitely noted by everyone that oysters more recently planted, since the bay has become well populated, do not grow at the rate of the original sample plantings. This may not be considered a disadvantage in every respect, since the early experience of many of the growers was that if they could not harvest the oysters when they reached the right size, the oysters would be too large for market during the following season.

Culture of the Japanese oyster on the Pacific Coast is in a transition stage, for it is attempting to become independent of the necessity for importing seeds from Japan. This species has apparently become adapted to environmental conditions in this country and, in at least a few places, has been propagating for several years on a commercial scale, particularly in certain portions of Puget Sound and Willapa Bay. In 1935 and 1936 the shores of parts of Puget Sound, such as Quilcene Bay, were completely covered with young Japanese oysters. In that region the shore line consists of pebbles which are exposed at low tide. Japanese oysters are very resistent to climatic conditions and are able to withstand exposure for long periods, both to drying in the sunshine and to freezing in the winter. That there has been a considerable amount of propagation is demonstrated by the fact that the war and the cessation of seed importation only slowed oyster production on the Pacific Coast.

In one portion of Willapa Bay there is still a small population of Eastern oysters which are the off-spring of stock originally imported from this coast. Frequently oyster growers have shown me oysters which they considered to be hybrids of the Japanese and American species. However, I was never able to be sure that such was the case, although I well recognize this possibility. In view of Dr. Galtsoff's findings that the two species will cross-fertilize, I should not be surprised if a hybrid would eventually be produced. According to available biological information, in the laboratory experiments the Japanese oyster required a higher temperature than the Eastern oyster in order to spawn. I found that at some times Japanese female oysters will spawn at temperatures as low as about eight degrees centigrade, or about fifty degrees F. With this in mind, I think we should be well aware of the probability that, if the two species are reasonably close together, cross-fertilization may take place, and that we do not know what the resulting oyster might be.

Two varieties of the Japanese oyster, although presumably the same species, have been used on the Pacific Coast. The variety of which I have been speaking grows in Northern Japan and the seeds are caught in the Matsushima region where the water is relatively cold. The seeds are caught during the summer, and by the following spring when they are shipped to this country, they are not more than one-half inch in diameter. The other variety is grown in the region near Hiroshima in Southern Japan, in warm water, so that the seeds caught during the summer are already an inch-and-a-half or more in diameter by the following spring when they are shipped.

These Hiroshima oysters look very different from the others. They are round and very deeply cupped so that many seemed to be almost spherical, like a walnut, for example. The mortality during shipment has been found to be much greater than that of the smaller Matsushima seeds. It has also been noted that growth is very much slower and that they never achieve the large size of the other variety. I mention this Hiroshima oyster because I believe if experiments are to be made on the importation of the Japanese oyster to the East Coast, special attention should be paid to this variety.

During my experience on the Pacific Coast I noticed only one enemy which had been imported with the seeds. This is the Japanese oyster drill, Tritonalia japonica. This drill is definitely very violent and dangerous, for, particularly in Samish Bay, I found a tremendous mortality due definitely to drilling by this snail. I have also found this same snail in southern Puget Sound on Olympia oyster grounds where some Japanese seeds had been planted. At the time I left the State of Washington, very few were to be found in Willapa Bay, and it may be that salinity in that bay is low enough to prevent them thriving.

If experiments are to be carried out on the possibilities and potentialities of the Japanese oyster on our Atlantic and Gulf Coast, I should recommend that the work be done in such a manner that the overflow water in which they are kept be sterilized, or filtered, before entering any of our natural waters. If fertilized eggs, or developing larvae, should escape and attach and grow in such a manner as to endanger the great eastern oyster industry, which we have had for many years, it would be about as impossible to control them as it is now to control the ship worm, starfish, drill, and other similar pests. By importing those foreign species, the Pacific Coast had little to lose and everything to gain. By contrast, the East Coast may gain, but it could lose one of the greatest fishery industries in the world.

Small plantings of Japanese seeds on the Gulf Coast have not resulted successfully enough to warrant optimism, although it may well be possible that in the colder waters of the North Atlantic Coast the results might be different. The Japanese oyster is biologically similar to the American oyster, and hybrids might presumably be obtained. One may be an optimist and assume that the hybrid oysters would combine the better qualities of the two species, but should this hybrid merely blend the unfavorable qualities of the two species, a very severe damage to the oyster industry would be produced. Several years ago Dr. Galtsoff very definitely warned the industry to avoid importing this species, and my experiences lead me to state that I think his warning was very opportune and very correct.

GROWTH OF OYSTERS OF DIFFERENT AGES IN MILFORD HARBOR

Victor L. Loosanoff, Director
Fish and Wildlife Service Biological Laboratory
Milford, Connecticut

The success of oyster farming, so widely practiced in the waters of New England and New York, depends chiefly upon growing small "seed" oysters to marketable size. This size is usually reached four or five years after the oyster larvae attach themselves to the cultch and metamorphose into juvenile oysters which the oystermen call "set".

So far little has been done to ascertain the increase in size and volume of oysters during each year of their existence from the time of setting until the age of 5 years or more is reached. In reviewing the literature on this subject one is impressed with the fact that the majority of the attempts to study the growth of oysters was of very short duration, usually of a few months, and of a rather limited scope. The longest period devoted to such observations was approximately one year. As a rule, the studies were confined to groups of the same age, and no distinction between the rate of growth of different age-classes was attempted.

Thus, although the field offers a very large number of unanswered problems the solution of which may be of considerable practical interest, very limited progress has been made in studying the growth of oysters. Therefore, to obtain necessary knowledge on growth, certain phases of which would provide a sound basis for estimation of the increase in size and volume from year to year, extensive studies have been carried on at Milford Laboratory since 1940. Because of limited time only certain aspects of the studies are discussed in this article. A more comprehensive description will be published later in a scientific journal.

I am taking this opportunity to express my thanks to Mr. James B. Engle, who until his transfer to another assignment assisted in the early stages of this investigation, and to Mr. Charles Nomejko, who for the last few years has been extremely helpful in conducting a number of growth experiments and in tabulating the data obtained during the entire course of this work.

The experiments were conducted in Milford Harbor, Connecticut. Five groups of oysters of different ages were collected from the beds of Long Island Sound and brought in for initial examination and measurement in early April 1940 (Table 1). Each group consisted of at least 125 individuals. The youngest group was composed of small oysters which set during the summer of 1939, therefore having grown only one season before having been used in the experiments. The oysters of the 1938, 1937 and 1936 year-classes had lived through two, three and four growing periods respectively. The group which was designated as the 1935+ year-class consisted of oysters which had

TABLE 1

MEAN LENGTH, WIDTH AND DEPTH OF OYSTERS OF FIVE DIFFERENT YEAR-CLASSES AT THE END OF GROWING PERIODS OF 1940, 1941 and 1942, MILFORD HARBOR
(measurements in mm.)

YEAR-CLASS	INITIAL SPRING, 1940				AUTUMN, 1940				AUTUMN, 1941				AUTUMN, 1942			
	Age	L.	W.	D.	Age	L.	W.	D.	Age	L.	W.	D.	Age	L.	W.	D.
1939	1	19	14	3	2	58	45	20	3	84	62	26	4	92	66	30
1938	2	59	45	21	3	81	60	28	4	94	68	32	5	102	72	35
1937	3	78	58	27	4	92	66	30	5	103	72	34	6	113	76	37
1936	4	90	64	33	5	98	69	35	6	105	71	38	7	113	77	40
1935+	5+	113	71	39	6+	121	77	40	7+	124	78	42	8+	130	81	44

The year-class of 1935+ consisted of oysters the age of which at the beginning of the observations ranged from 5 to 10 years.

lived at least through 5 growing periods. Their age varied from 5 to 10 years. The majority of these individuals was 6 years or older. Such a heterogeneous age-group was formed to study the growth of a mixed population of old oysters, which are usually used for stocking spawning beds.

In these studies the age of the oysters is based upon the number of growing periods completed. In Connecticut waters the period extends from the latter part of April to early November. Since in Milford Harbor and Long Island Sound a new generation of oysters usually appears in the middle of summer, its first growing period, confined between the date of setting and the beginning of hibernation, is shorter than subsequent ones, when growth continues from spring until autumn. Nevertheless, the first growing season, even if it is of short duration, will be regarded here as a complete one. Therefore, the oysters which have completed their first growing season will be considered here as one year old; those that have completed two growing seasons, two years old, etc. This method of age classification may be different from that employed by some oyster growers who consider the oysters which have completed their first growing period as "set", those which have completed their first and second growing periods as only one year old, etc. In such instances the age estimates of the oystermen will be one year behind ours. This discrepancy can be simply adjusted for the convenience of the oystermen by subtracting one year from our age figures.

In preparing the oysters for the experiments their shells were cleaned of all foreign growth and then the greatest length, width and depth of each individual were measured with the aid of calipers. Measurements were expressed in millimeters. Later, the volume was ascertained by using the displacement chamber method.

After the oysters had been measured they were placed in large wire baskets, which were suspended from a float anchored in the harbor. Each year-class was kept in a separate basket. Annual determinations of the increase in size were made each autumn when the growing period was over and the oysters were entering the hibernation stage.

The initial measurements made at the beginning of the experiment, in April 1940, showed that the most significant difference in sizes existed between the youngest year-class (1939) and the class composed of animals one year older (Table 1). The difference diminished when the older groups were compared.

In the two youngest groups the difference was especially pronounced in the case of depth, or thickness. The mean depth of the 1939 class was only approximately 3 millimeters, as compared with 20 millimeters shown by the group only one year older. Thus, the mean depth of the older (1938) age-class was almost seven times greater, while the mean length and width of the same year-class were only about three times as great as those of the younger group. Obviously, during the first growing period the increase in length and width progressed at a much more rapid rate than the increase in

depth. During the second period, however, the increase in depth proceeded at a comparatively greater rate than that of the length or width (Tables 1 and 2).

TABLE 2

PERCENT INCREASE IN MEAN LENGTH, WIDTH AND DEPTH OF OYSTERS OF FIVE DIFFERENT YEAR-CLASSES DURING GROWING PERIODS OF 1940, 1941 and 1942 MILFORD HARBOR

YEAR-CLASS	AGE APRIL 1940	INCREASE DURING 1940				INCREASE DURING 1941				INCREASE DURING 1942			
		Age	L.	W.	D.	Age	L.	W.	D.	Age	L.	W.	D.
1939	1 year	2	205	221	567	3	45	38	30	4	10	6	15
1938	2 years	3	37	33	33	4	16	13	14	5	9	6	9
1937	3 years	4	18	14	11	5	12	9	13	6	10	6	9
1936	4 years	5	9	8	6	6	7	3	9	7	8	8	5
1935+	5+years	6+	7	8	3	7+	2	1	5	8+	5	4	5

During the first season of observation the greatest percentage increase in size was shown by the youngest (1939) year-class which was then completing the second growing period of its life. This increase was 205, 221 and 567 percent for the length, width and depth respectively (Table 2). It was several times greater than the percentage of increase recorded for the 1938 class. In the latter case the increase in length, width and depth was only 37, 33 and 33 percent respectively. In comparing these two groups it is interesting to note once more that the increase in depth of the younger year-class proceeded more rapidly than that of the length or width.

The three older year-classes, including the 1935+ group, also showed an increase in all three dimensions. However, the percentage of increase became progressively smaller as the age of the oysters increased.

At the end of the second year of observation, 1941, the most outstanding fact noticed was a pronounced decrease in the rate of growth of the 1939 year-class which had just finished the third growing season. While during the preceding season the increase in length of this group was 205 percent, it was now only 45 percent (Table 2). A similar decrease was also noted in the case of the width, while in the case of the depth it was even

more sharply defined. Obviously, during the second year the rate of growth was much more rapid than in the third growing season.

The oysters of the classes older than the 1939 group also showed a continued growth during the second season of observation. However, in all cases their relative rate of growth was slower than that of the younger animals. As observed during the preceding year, the percent increase in size decreased with the advancing age of the oysters (Table 2).

During the third and last period of observation, which included the spring, summer and autumn of 1942, all the year-classes showed a further increase in size (Tables 1 and 2). However, in the case of the two youngest groups the relative rate of growth was much slower than in the preceding years.

At the end of the experiment the age of the oysters constituting the oldest age-class ranged from 8 to 13 years. Examination of the largest individuals of this group showed that they, too, had formed a new shell growth during the last summer of observation. Evidently, even those old oysters, which were completing the 13th year of life, still continued to grow.

In reviewing the experimental data attention may be called to a similarity of the mean dimensions reached by the different groups of oysters upon attaining the same age. For example, during this study four different groups were at some time four years of age (Table 1). The mean length of all these groups at the age of four was very close to 90 mm.; the mean width varied between 64 and 68 mm., whereas the mean depth was from 30 to 33 mm. In the case of the groups reaching the age of 2, 3, 5 or 6 years similar conclusions could be formed. It was also noted that the oysters of the 1936 year-class, upon reaching the age of seven closely resembled in their dimensions the measurements of the 1935+ class made at the beginning of the experiments, when the average age of the latter group was also approximately 7 years.

Perhaps the most significant part of our studies was that devoted to observations on the increase in the volume of the oysters from year to year. Both Milford Harbor and Long Island Sound oysters were used. The Sound oysters were supplied through the courtesy of Mr. Charles Wheeler, Manager of the Connecticut Oyster Farms, from the beds where oysters of known ages were kept. In comparing the mean volumes of Milford oysters with those of others of the same age a very close similarity was noted.

By volume determinations it was ascertained that the youngest year-class showed a relatively greater increase in volume than any other group (Table 3). The average volume of the animals representative of that class increased from 0.4 cc. to 19.5 cc. during the second growing period of their existence. This represented an increase of 4775 percent, indicating that during the second year of their lives the oysters may increase in volume almost 48 times. Thus, if they were grown under such hypothetical conditions where no mortality among them would occur, a bushel of culled single oysters planted at the end

of their first growing period would yield more than 47 bushels one year later. By the end of the fourth growing period their volume according to our estimates would show an increase of 16,500 percent.

As shown in Table 3 a comparatively large relative increase in volume was also shown during the third year of life. This increase averaged approximately 130 percent over the initial one recorded at the age of 2 years. An increase in volume was also noted in the case of all the other year-classes, but the proportional or percentage gain became smaller as the age of the oysters increased (Table 3).

TABLE 3

AVERAGE PERCENT INCREASE IN VOLUME OF OYSTERS OF DIFFERENT AGE-GROUPS
IN ONE AND IN THREE GROWING SEASONS
AVERAGES BASED ON DATA FOR MILFORD HARBOR OYSTERS

GROWING SEASONS (Age in Years)	PERCENT INCREASE IN ONE SEASON	GROWING SEASONS (Age in Years)	PERCENT INCREASE IN THREE SEASONS
Between 1 and 2	4775	2, 3, 4	16150
" 2 " 3	130	3, 4, 5	300
" 3 " 4	44	4, 5, 6	185
" 4 " 5	39	5, 6, 7	108
" 5 " 6	25	--	--
" 6 " 7	21	--	--

The figures given in Table 3 are based upon the data obtained during certain phases of the growth studies of Milford Harbor oysters. These figures, of course, should not be considered as fully applicable to every locality where the oysters are grown. It also should be remembered that during some years the rate of growth may be somewhat slower or faster than during others. Finally, it may be pointed out that the percent of increase in volume between the ends of the first and fourth growing seasons will be greatly influenced by the time of the year the oysters first set. If the setting occurred early in the summer and the set grew well, the percent of increase in volume between the end of the first growing period and the end of the fourth may be substantially smaller than shown in our table. On

the other hand, if the oysters of the late September set are taken as a group to begin with, their increase in volume during the next three growing seasons may even be greater than shown in Figure 3 for the youngest age-group. Nevertheless, regardless of possible wide variations the fact remains that the increase in volume during the second year of existence is proportionally far greater than during the following years of life.

It is obvious that under natural conditions it would be impossible to achieve such high yields as have been indicated in our experiments, where it was shown theoretically that the volume of oysters, planted after the end of their first season of growth and gathered at the end of the fourth, may increase 16,150 percent. Nevertheless, we must admit that the present yields are extremely low. The experience of the oyster growers shows that only under very favorable conditions may one expect to gather 4 bushels of 4-year-olds for each bushel of 1-year-olds. It is more common, however, that the yield is only 2 or even 1 bushel of marketable oysters per each bushel of seed planted. Thus, instead of the theoretically possible 161 bushels or more the oyster farmers get only from 1 to 4 bushels.

The above given figures indicate very emphatically that the cultivation of oysters as it is now practiced is far from reaching its ultimate goal, and that considerable improvements in the methods of cultivation are desirable. Obviously, the industry which produces only a small fraction of what it may produce should attempt to ascertain and, if possible, eliminate various factors which so effectively keep the yield at a very low level.

The question that naturally arises is what are those factors. The answer can be given only after systematic prolonged studies are made by combining the efforts of the biologists and the oyster growers. At this time we are well aware of the fact that in some areas starfish and drills kill a large percentage of oysters. However, in many other instances the heavy mortality rate cannot be attributed to these two enemies. Yet, because of the lack of direct observations and studies, we may only speculate as to the enemies or conditions which so profoundly affect the survival of the oysters. Obviously future studies are necessary to clarify many aspects of this interesting and extremely important problem. However, because of the complexity of the problem it cannot be solved if we give it only casual attention by examining a few samples on infrequent occasions. The study should begin as soon as the oysters set and steadily continue through a period of four or five years until the oysters are ready to be marketed. Detrimental effects of and mortality caused by dredging, mopping and shifting are to be determined, while ecological conditions should be studied in as much detail as possible. A program of this type will require the efforts of several investigators and the full cooperation of oyster growers, but it will undoubtedly provide very valuable information which should result in a significant increase in the production of oysters.

Cases of unusually high yields, nevertheless, are known in the history of oyster cultivation. For example, one incident of this nature was described in a letter to the author by the manager of one of the New England companies. It was stated that in 1906 an oyster company located at Wickford, R. I. planted 200 bushels of three-month-old oysters gathered from lot 607 near Milford, Connecticut in Long Island Sound. Four years later when the planted oysters were dredged their volume amounted to 2,200 bushels. Thus the yield of 11 bushels for each bushel of set planted appears to be possible if conditions are favorable.

In the course of these studies it was determined, by ascertaining the actual volume of the oysters filling a bushel, that only approximately from 48 to 54 percent of the space in the container was taken up by the oysters, whereas the other part consisted of voids formed between them. Groups of oysters aged from 1 to 5 years were used in these determinations but no correlation between the age-groups and the percent of actual space occupied could be found. Therefore, if the capacity of a bushel is equal to 35,238 cubic centimeters, only approximately one half of its volume, or 17,619 cc., would actually contain oysters. Using the figures for the average volume of oysters of different ages, as determined by the studies in Milford Harbor, it was possible to calculate the approximate numbers of oysters of a given age per bushel. These numbers appear to be 44,047; 801; 383; 271 and 198 for oysters of the 1, 2, 3, 4 and 5 year-classes respectively. In the case of deep water oysters, where the rate of growth is slower, larger numbers of individuals of corresponding ages would be needed to fill a bushel.

In connection with the discussion it should be remembered that all references to bushels or any other units of volume are made here on the basis that only single culled oysters were used in these determinations. The presence of shells and other foreign material would, of course, decrease the number of oysters per bushel.

Returning again to the growth studies of oysters we may discuss the possibilities of applying some of the results to practical use. Of considerable importance is the observation that during their second year of life the oysters increase in volume proportionally much more rapidly than during later years (Table 3). Obviously it is of more advantage to oyster growers to purchase and plant this age-class in preference to any older group, even if the mortality is relatively higher.

The planting of oysters that are two years old also appears practical because during the next growing season they may more than double their volume, and at the age of five years yield approximately 3 bushels per each bushel planted provided, of course, that the mortality rate is kept at a low level. In practice, however, it may not be often achieved.

Oysters 3 years and older also continue to increase in volume, but such an increase proceeds at a comparatively slow rate. Therefore, the growers, who intend to plant older oysters should carefully evaluate whether the

increase in volume would compensate for the losses due to natural mortality, and the mortality which is caused by injuries sustained during the dredging and planting operations.

Finally our figures may serve as a criterion for comparing the yields from different beds with theoretically possible maximum production. This will enable the oyster growers to appraise critically the relative efficiency of their methods of cultivation.

Another aspect of our studies that may be of interest to the oystermen engaged in the shucking of oysters is that devoted to the determination of the average total weight, weight of shells and weight of meats of the oysters of different groups the age of which ranged from 3 to 8+ years.

The results of the study showed that the average total weight of the oysters at the end of the third growing period was only 73 grams, whereas at the age of seven it was about 216 grams. The average total weight of the oysters constituting the age-class designated as 8+ years and including specimens between 8 and 13 years of age, was slightly over 280 grams. The average weight of shells for 3 and 7-year-olds was 50 and 167 grams respectively.

The average weight of meats varied from 10.1 grams for the 3-year-old animals to 22.1 grams for the 7-year-old group. It should be remembered that since the oysters were examined in November, the time of the year when large quantities of glycogen were already accumulated and stored in their bodies, the meats were larger and heavier than at some other period of the annual cycle, for example, soon after the completion of spawning when the meats are usually very poor.

With the increase in age, the weight of meats became proportionally smaller, whereas the weight of shells gradually increased. In the youngest year-class especially kept for this study and which at the time of examination had completed their third growing season, the meats constituted 13.7 percent and the shells 67.6 percent of the total weight. In the case of the year-class composed of oysters from 8 to 13 years old, the weight of meats constituted only 10.1 percent of the total weight, while the weight of shells rose to 80.3 percent. Examination of the data for the intermediate year-classes showed a general trend toward a decrease in the percentage weight of meats and increase in the percentage weight of shells with advancing age.

The data offered here represent the results of observations on the growth of oysters (O. virginica) of different ages in Milford Harbor and to some extent in Long Island Sound. Since our observations were confined to a limited locality only, the conclusions formed cannot be considered as applicable to the oyster populations of all other areas where those animals exist. It is thought nevertheless, that the results of our experiments may be used as a criterion for the growth of oysters of a rather large geographical district, including the shore waters of the State of New York and of

New England. Although it is quite probable that the absolute growth in the different sections of this district may show certain variations, the relative growth, representing proportional or percentage gains at each age, would probably closely resemble that observed in our experiments.

SOME OBSERVATIONS ON THE FEEDING OF OYSTERS WITH ESPECIAL REFERENCE TO THE TIDE

A. F. Chestnut
New Jersey Oyster Research Laboratory
Rutgers University

Growth and fattening of oysters can be said to depend primarily upon many factors in the environment, all of which have a part in regulating the feeding mechanism (Nelson, Martin, Galtsoff, Hopkins, Berkely and others). The quantity and quality of the food in the surrounding waters produce the desired results after active feeding commences. Feeding has been shown by Nelson to be closely correlated with tidal cycles, with active feeding taking place on the flood and ceasing during the ebb tide. Loosanoff and Nomejko, however, concluded recently that under favorable conditions in Long Island Sound, tidal changes do not affect the rate of feeding. Their results, then, do not lend support to the theory that oysters are relatively inactive during the ebb tide.

Random examinations of oysters in Delaware Bay showed some discrepancies when attempts were made to correlate feeding activities of the oyster with tidal cycles. Such variations were found as oysters with full stomach contents during the ebb tide and oysters with empty stomach contents during the flood. The contents of the stomachs were withdrawn with a pipette as described by Nelson then examined with the aid of a microscope. Comparisons of numbers of stomach contents examined by this method showed a decided difference between the oysters dredged during the late flood and those dredged during the late ebb, although to the naked eye some of these samples appeared the same rich brown color.

The typical stomach contents of an oyster dredged during the late flood tide consist of a fairly large amount of dark, opaque matter such as sand grains, plant cells and detritus. The diatoms usually contain chloroplasts and from all appearances are undigested. The typical stomach contents of an oyster dredged during the early ebb tide contain fewer sand grains and evidence that a sorting of material has taken place in a few hours time. The diatoms are nearly all digested and the cell contents have probably gone into solution thus giving the stomach contents their brown color.

In studying the problem from a different approach it was found that oysters when kept out of water from two to six days in a cool place upon examination, instead of finding the animals starved as was anticipated, the stomach contents were dark in color. One such oyster was found with its digestive crypts full of oil globules, presumably of diatom origin, which stained readily with Sudan IV. Occasionally an oyster was opened which when cut through the stomach, the contents gushed out freely as some oysters do when opened immediately after dredging. Many of the diatoms in these stomach contents were unchanged and had not been digested. The contents of oysters

kept out of water for as long as nine days at air temperatures of from 50° to 60° F. differed only in becoming very viscid. It would not be wise to draw any definite conclusions since these studies are still in their preliminary stage but at present it appears that when an oyster which is actively feeding and with full stomach contents, is removed from the water, digestion ceases upon the dissolution of the style. The data from such oysters kept out of water and from actively feeding oysters dredged at all stages of the tide indicate that digestion continues at a fairly rapid rate in oysters which are passing water through their gills.

Some of the stations in Delaware Bay and its tributaries used in the routine collections of samples were selected as locations for further studies of feeding activities. At hourly intervals, approximately fifty oysters were dredged and examined through portions of the tidal cycle, with emphasis on the ebb tide. The oysters when opened were separated into one of six groups, based on the color and condition of the style or its absence and a rough estimation of the quantity of stomach contents. Since Nelson has shown that the style is built up when the animal begins active feeding, and Martin stated "that the style is of very considerable value as an indication of feeding, not only on the basis of its presence or absence, but also on.. its varying color and consistency" the presence of the style as a criterion of feeding is justified.

The results from three different areas are presented in the following tables (#11, #6AD, #13). The three columns on the left indicate the hydrographical conditions. In the right hand column, the dark brown firm style and full stomach contents indicate active feeding. The pale brown firm style and presence of food are interpreted as the beginning of feeding during the flood or the first signs of cessation of feeding at the first of the ebb. The pale brown soft style is a further indication of cessation of feeding on the ebb and probably the first sign of active feeding during the flood, (see table #11, 4 hours flood). Some overlapping may occur between the pale brown styles for some cases are not clear cut. The white style and the absence of styles are interpreted as complete cessation of feeding an hour or more previous.

Station #11 is at the mouth of Maurice River, an area where oysters rarely grow to market size because of the prevailing low salinities. The oysters are typical low salinity oysters characterized by their thin, white shells and stunted growth. These oysters are tonged and sold for seed. The results at this station show that active feeding ceases at low water, with the greatest percentage of oysters with no styles and no food occuring soon after low water. Salinity is, no doubt, the factor influencing feeding in this area.

Station #6AD is located in the third reach of Dennis Creek, an area reserved for the tonging of market oysters. Large, well-shaped oysters are found here usually in a good condition and sold by the tongers to the

shucking houses. In this area we also find that as low water is approached there is a uniform response to the decrease in salinity with the complete cessation of feeding activities.

Station #13 is in the privately leased area of Delaware Bay, located offshore in one of the best growing and fattening regions. In this table the discrepancies mentioned at the beginning become evident when large numbers of oysters are opened in a series rather than random samplings. Here the salinity and temperature have changed very little yet a decided difference is noted between the percentage of oysters feeding at high water and those feeding during the ebb tide.

In view of the light that Nelson's work was carried on in a tidal creek where the salinities approach the minimum for oysters, the results in the first two tables (#11 and #6AD) are in accord and support his findings as well as his conclusions, that in New Jersey oysters are relatively inactive during the ebb tide. Studies have not been made in the higher salinity ranges but on the basis of the findings at station #13 more diverse results would be expected. It is possible, therefore, that the difference between the findings of Nelson in New Jersey and those of Loosanoff and Nomejko in Long Island may be due to the difference in salinity of the two areas. Nelson's observations were in waters of optimum salinity and below, whereas in Long Island the salinity is at the optimum and above.

TABLE 11

PERCENTAGE OF OYSTERS WITH FOOD AND STYLES THROUGH A PORTION OF A TIDAL CYCLE
MOUTH OF MAURICE RIVER, MAY 8, 1946

Temp. °C.	Sal. ppm.	Tide	No Style No Food	No Style Food Present	White Soft Style Little or No Food	Pale Br. Sft. Style Little or No Food	Pale Br. Firm Style Food Present	Dark Firm Style Full Stomach
13.9	12.1	4½ ebb	7%	0	7%	17%	34%	35%
14.2	10.1	5½ ebb	5%	0	15%	25%	43%	12%
14.4	7.4	L.W.	20%	0	10%	50%	20%	0
14.0	6.5	1 fld	47%	0	7%	42%	5%	0
--	--	--	--	--	--	--	--	--
14.7	10.5	3 fld	12%	8%	0	0	54%	28%
14.5	12.2	4 fld	16%	0	0	10%	34%	40%

TABLE 6AD

PERCENTAGE OF OYSTERS WITH FOOD AND STYLES THROUGH THE EBB TIDE
THIRD REACH, DENNIS CREEK, MAY 13, 1946

Temp. °C.	Sal. ppm.	Tide	No Style No Food	No Style Food Present	White Soft Style Little or No Food	Pale Br. Sft. Style Little or No Food	Pale Br. Firm Style Food Present	Dark Firm Style Full Stomach
18.0	20.6	1½ ebb	4%	0	0	0	10%	86%
18.5	20.1	2½ ebb	2%	2%	2%	0	34%	60%
18.8	18.1	3½ ebb	2%	0	2%	16%	50%	30%
18.8	12.8	4½ ebb	2%	0	6%	44%	46%	2%
19.0	7.8	5½ ebb	4%	4%	12%	66%	14%	0
19.0	6.3	L.W.	24%	22%	18%	32%	4%	0
19.4	6.5	1 fld	38%	62%	0	0	0	0

TABLE 13

PERCENTAGE OF OYSTERS WITH FOOD AND STYLE THROUGH A PORTION OF A TIDAL CYCLE
EGG ISLAND BAR BUOY, MAY 16, 1946

Temp. °C.	Sal. ppm.	Tide	No Style No Food	No Style Food Present	White Soft Style Little or No Food	Pale Br. Sft. Style Little or No Food	Pale Br. Firm Style Food Present	Dark Firm Style Full Stomach
16.6	18.0	5 fld	14%	4%	2%	0	24%	56%
16.6	18.1	5½ fld	10%	4%	8%	4%	15%	58%
16.6	18.0	H.W.	13%	0	0	2%	18%	67%
16.6	18.0	½ ebb	17%	0	10%	2%	19%	52%
--	--	--	--	--	--	--	--	--
17.1	17.1	3½ ebb	8%	3%	8%	14%	33%	33%
17.3	16.9	4 ebb	4%	6%	8%	14%	32%	36%
17.8	16.8	4½ ebb	10%	0	16%	16%	32%	26%
--	--	--	--	--	--	--	--	--
18.0	17.0	5½ ebb	0	0	14%	16%	34%	36%

A BRIEF CRITICAL SURVEY OF THE EVIDENCE FOR THE HORIZONTAL MOVEMENTS OF OYSTER LARVAE

Melbourne R. Carriker
Department of Zoology
Rutgers University

Over the years evidence has accumulated indicating that the larvae of the eastern American oyster display certain horizontal movements, independent of, but aided by, the flow and ebb of the tides. This phenomenon was first mentioned by Dr. Julius Nelson in 1911 and in 1913. In recent years Dr. Thurlow Nelson has investigated this behavior in more detail, and describes their movements as follows: oyster larvae are herded horizontally into swarms of uneven distribution. These occur in definite lanes up and down stream from spawning oysters and are so distributed by the tidal currents. Heaviest sets occur in these lanes. Larvae do not seem to be distributed laterally to the current to any extent. They may move upstream during the later larval stages, further than can be accounted for by passive tidal conveyance, by remaining in the fastest currents on the flood and sinking on the ebb. Larvae are thought to be stimulated to rise on the flood by the saltier flood water and by the increased current velocity. They tend to remain in the strata of greatest salinity change (the halicline) if such be present. As the tide increases in velocity, the effect of current is added to that of salinity, giving the larvae a maximum stimulation to rise. At high slack water they tend to sink bottomward. During the ebb only the current stimulus is received. A decrease in salinity, caused by the inflow of fresh water, depresses larval activity, so that the total stimulation is thus probably less than on the flood.

In a recent criticism of the Nelsons' theory, Korringa, a Dutch oyster scientist, points out that the congregation of larvae in special strata of differing current velocities may result in horizontal distribution, but doubts that this influence is as efficacious as assumed by Nelson; for although the influence of salinity makes a movement upstream possible in principle, the combination of the influence of haliclines and different current velocities may well have a resultant in another or even in an opposite direction. Korringa, however, presents no evidence to support his objection. In the Oosterschelde where he has made his observations there are strong tidal currents and very little salinity stratification, so that probably he was not in a position to notice such effects. He states that the European oyster larvae are uniformly distributed in the Oosterschelde, are moved passively by the tides, and their distribution does not seem to be influenced by temperature, currents, salinity or light. Yet in a subsequent passage he writes that he has often met with peaks of greater or lesser larval concentration and with differences between the number of larvae at the surface and at the bottom. He thinks these differences are caused by the proximity of spawning oysters. He took only a surface and a bottom sample at each place, and thus did not receive a complete vertical picture. And finally the European oyster is a different species, so comparisons may not always agree.

A brief review of the larval period (taken from the researches of W. Brooks, J. Nelson and T. Nelson) will make clearer the evidence for the native movements of oyster larvae. It is thought that sexually mature oysters spawn during the late flood tide, the total annual production by one female being estimated at three hundred million eggs! Sperm and eggs are thrown into the lower strata of the water, where fertilization occurs. Early embryos do not develop swimming organs (cilia) for 4 or 5 hours, and settle to the bottom at the rate of about one inch in 7 minutes. However, in a current of 0.3 mile per hour or more, they may be carried some distance. After the cilia form, the embryos crowd to the surface, pursuing an active spiral progression through the water. About a day after fertilization, the embryos, now larvae with complete purse-shaped shells, are recognized as straight-hinged larvae; they measure approximately 0.06 mm., and sink to various depths swimming actively in all directions. In succession these free-swimming larvae go through the stages of "early umbo", "late umbo", "mature", and "eyed". Eyed larvae are relatively more powerful swimmers than younger larvae, and although they are unable to make much headway against a current, may rise in less than an hour from the bottom to the surface of shallow oyster bays. Eyed larvae measure about 0.3 mm. After careful selection of the proper attachment site, in or during relatively still water, they cement themselves to surfaces on the bottom, and are then called spat. In laboratory experiments, T. Nelson found that older larvae became more active when a higher salinity was introduced, and less active when less saline water was added. Currents passing over the larvae stimulated them to rise. In still water they came to rest umbo-downward on the bottom in one to 20 minutes at summer temperatures.

The Nelsons advance the following points in support of their theory on the movements of oyster larvae: (1) Most larvae were found on the flood tide in estuaries of strong tidal currents (Little Egg Harbor) and in about equal numbers on the flood and ebb in those of less currents (Barnegat Bay). They do not state whether this decrease in the number of larvae on the ebb in certain bays is not due in part to destruction of larvae by enemies. (2) Distinct variations in the number of larvae occurred at different depths on the ebb and on the flow respectively; the youngest larvae showed no marked differences in vertical distribution, but the older larvae stayed in the lower strata or on the bottom on the ebb, and in the upper strata on the flood. Stauber, in a singular instance, once pumped 700 eyed larvae per 100 liters of water from close to the bottom at low slack water in Delaware Bay. (3) In the horizontal plane they found the earlier larval stages farther downstream, and the older larvae most numerous upbay. (4) Setting occurs far upstream from spawners, farther than would be accounted for by passive transport on tidal currents alone. Also, larvae suddenly return to set on beds over which previously no younger larvae were found, as in Long Island Sound. T. Nelson, however, gives no actual figures to indicate how far larvae might be moved passively by the tides. (5) And finally, since in local estuaries the tide usually runs for a longer time on the ebb than on the flood, there is produced in combination with the current caused by fresh water coming down

from the streams above, a general tidal drift which tends to carry all freely moving objects oceanward. The fact that some larvae, even though carried into the ocean on the ebb, return to set in the bays, would indicate some independent movement exerted by them. The Nelsons do not indicate however, out of the billions of potential spat in larval swarms, the possibility that great numbers of larvae may be lost at sea during normal weather conditions, and still leave enough larvae for the usual sets occurring in oyster regions.

An analysis of such factors as salinity, current, temperature, light, turbidity and pH in larvae-bearing waters has been attempted by various investigators in order to determine the fundamental biological principles which govern larval behavior. T. Nelson in an extensive study of the effect of salinity, principally in Barnegat Bay, finds that relatively greater aggregations of larvae occur in the halicline. When no halicline is present the larvae are found in greatest numbers on or near the bottom. Korringa writes that according to Nelson's data the larvae in many instances remain uniformly distributed in the absence of a halicline. A review of Nelson's data does indicate this. Perkins, also working in Barnegat Bay, came to the conclusion that salinity is not as important in determining vertical distribution as T. Nelson believes; and Korringa, after a review of the work of both of these investigators, concludes that salinity plays a greater part than Perkins is inclined to admit. T. Nelson reports that the records of seven years show significant numbers of larvae only at the halicline in Barnegat Bay, and that if such stratification were permanent few if any larvae would set in the deeper parts of the bay, but would be swept on the flats where no significant salinity gradients are evident. This has been shown to occur. Salinity gradients may, in part, explain larval movements in bays of slight tidal currents such as those of Barnegat Bay, but would not seem to play as important a role in estuaries of strong tidal currents.

Perkins, after a study of the effect of current on the vertical distribution of oyster larvae in Barnegat Bay, concluded that in strong currents larvae are distributed vertically according to the water currents, that when current velocities are low and salinity gradients relatively great, larvae congregate above the halicline, and that if the current is negligible and there is no halicline, the larvae are found near the bottom. Korringa in an analysis of this work, showed conclusively, however, that in some of Perkins' data a relatively strong current has no effect in concentrating larvae in a stratum when a halicline is present and that in other instances a relatively weaker current, which according to Perkins should play a part in concentrating the larvae, even in the absence of a halicline does not do so. Korringa further believes that water currents are not great enough to bring about the effect observed by Perkins. In the strong tidal currents of the Oosterschelde Korringa says he noted no correlation between current velocity and larval distribution and yet his data show instances where more larvae occur in the surface samples than in the lower samples. And further, he collected his greatest number of larvae (2,000 per 50 l.) at half flood in a surface sample! A serious objection to Perkins' larval work, as well as to much of that of others,

is that consecutive vertical series of samplings have not been collected throughout the cycle of the tide.

As to the influence of light on larval distribution, Korringa, along with other European workers, found no correlation. T. Nelson finds that in the presence of light, eyed larvae continue to move until they come into shade. J. Nelson thought that larvae tend to stay near the bottom at night and to rise during the day.

The effect of temperature on larval movements also deserves greater study. Korringa, though noting no correlation between temperature and distribution in the field, thinks that vertical distribution of larvae is not the same at lower temperatures as at higher temperatures. J. Nelson believed that higher water temperatures caused larvae to rise to the surface. He counted more larvae on warmer than on colder days, and observed that in the laboratory embryos swim in schools in ascending and descending columns. European workers observing the same movements in the European oyster larvae, think they resemble convection stream movements.

Perkins found no obvious correlation between pH and larval distribution in his Barnegat studies. Such factors as the effect of food and of turbidities on larval distribution have received but scant attention, and merit further investigation.

In the summers of 1938, 1939 and 1940, I studied the vertical distribution of larvae in Barnegat and in Great Bay, N. J. Series of successive vertical samplings were taken through the cycle of the tides, with salinity, temperature and turbidity observations. Unfortunately, current velocities were not determined. Most obvious result in this study was the extreme variation in both the horizontal and in the vertical distribution of the larvae. Roughly speaking more larvae were found in the flood than in the ebb in both Barnegat and Great Bay. In general, a tendency was noted for the younger larvae to remain more uniformly distributed vertically than the older ones. Strata of maximum concentration of younger larvae jumped over the vertical picture somewhat, but tended to rise in the early flood, to sink around high water and to rise again during the middle of the ebb. Older larvae were never found in sufficient numbers to obtain a clear picture of their movements. Eyed larvae, however, showed definite tendencies: out of some 620,100 liter samplings made in the three summers (about half on the ebb and half on the flood) a total of 82 eyed larvae were found in 15 flood samplings, and only 16 larvae in 5 ebb samplings. In Barnegat Bay no eyed larvae were ever found in the water on the ebb (no samples were taken off the bottom). It is realized that these are small numbers of larvae, but then this stage is never as abundant as the earlier stages, mortality apparently proceeding at a high rate during the pelagic existence. No influence of temperature, light and turbidity on larval distribution was observed. In some instances in Barnegat haliclines appeared to influence distribution, at others not to. In summary, it is possible, at least, to agree with previous workers that the larvae, especially the older stages,

appear to rise on the flood and sink on the ebb tide. However, much more exhaustive work must be done both in the laboratory and in the field before this ecological problem is solved.

Hypothetically it may help in a study of this kind to consider that differences in larval behavior are being dealt with which have arisen through natural selection over the centuries in the response of oysters in their adjustment to the varying conditions in the different estuaries. For, it is doubtful that much, if any, intermixing has occurred in recent times between the larvae of the various geographically distinct estuaries. Thus, rather than an identical reaction of oyster larvae from different regions to the various combinations of the environmental influences there, it should be expected that a few fundamental biological responses underlie this behavior, and that the identity of these responses is confused in each instance by the interplay of the changing proportions of the local influences.

LOUISIANA'S OYSTER MANAGEMENT PROGRAM

James N. McConnell
Director, Oyster Division

Mr. Chairman, Ladies and Gentlemen of the 1946 annual joint oyster convention:

Since the oyster interests of Louisiana have only recently become associated with your efficient and most important organization, we felt that it might be appropriate at this time to endeavor to acquaint you with our program of oyster management in Louisiana. By legislative act, the State of Louisiana has declared, and I quote from the act:

> "That all beds and bottoms of rivers, streams, bayous, lagoons, lakes, bays, sounds, and inlets bordering on or connecting with the Gulf of Mexico, within the territorial jurisdiction of the State of Louisiana, including all oysters and other shell fish and parts thereof, grown thereon, either naturally or cultivated, and all oysters in the shells after the same shall have been caught or taken therefrom shall be, continue and remain the property of the State of Louisiana, until the title thereto shall be divested in the manner and form herein authorized; and shall be under the exclusive control of the Department of Wildlife and Fisheries of the State of Louisiana until the right of private ownership shall vest therein, as herein provided."

On numerous occasions during the twenty years that I have personally directed our Oyster Division, attempts have been made by unscrupulous individuals to exploit improperly the vast oyster production possibilities of our State. This type of promotion has never been allowed in Louisiana. We welcome, however, and will assist in every way possible, any legitimate oyster interests that might care to avail themselves of opportunities for oyster cultivation and production which our State affords. We in Louisiana firmly believe that at present less than ten per cent of our oyster producing area is being utilized. This opinion is concurred in by several oyster experts from other sections of the country, after surveys made of oyster producing territory in this area.

It has always been felt that it is necessary to lease State-owned water bottoms to private individuals in order that the State may give proper protection and encourage individual cultivation of oyster areas.

The State of Mississippi, by contrast, does not allow private leasing of water bottoms for oyster cultivation, and I believe that our other sister state, Texas, has only in recent years allowed the leasing of its water bottoms for oyster purposes and this only under limiting conditions.

Because of the several hundreds of thousands of acres of natural oyster reefs now producing large quantities of natural growth oysters, Louisiana allows the leasing of these natural reef bottoms, only limiting the amount available to each individual or packer. Any individual or company desiring to obtain leased bottoms from us would proceed as follows:

Locate the area desired, make an application for same to be surveyed and amount of acreage determined. Upon completion of this survey, and map of location having been made, a rental notice in the amount of one dollar per acre per year is mailed to the applicant. Upon receipt of this money, a map and lease is given the applicant. The lease is for a period of fifteen years with the privilege of renewal for an additional ten years, providing that the annual rental be paid in advance each year.

The lessee may then take oysters from his leased grounds at any time of the year and by any method that he finds advantageous. He must, however, obtain an annual license for his boats handling oysters, at the rate of fifty cents per ton carrying capacity.

A privilege tax of two and a half cents per barrel is levied on all oysters removed from leased grounds and three cents per barrel on all oysters taken from the natural reefs of the State. A fifty-dollar annual license per boat is required for all dredge boats operating on public reefs.

Louisiana has at present approximately twenty thousand acres under lease in small tracts of from one to twenty acres. However, a few larger tracts from fifty to five hundred acres are recorded.

It has been the policy of our Department for many years to require all packers and canners operating upon the natural reefs of the State to return as "cultch" ten per cent of the oyster shells taken from the reefs. In other words, anyone removing ten thousand bushels of oysters is required to return one thousand bushels of shells. The entire operation is done at the expense of the person removing the shells, and the shells must be rebedded under the direction of the Department of Wildlife and Fisheries at the time and place and in the manner prescribed by said Department.

Shells planted under this program alone have been annually ranging from a top of two hundred and fifty thousand bushels to a minimum of seventy thousand bushels, dependent upon the annual production from natural reefs.

The legislature in 1944 passed an act appropriating "any and all funds collected by the Department of Wildlife and Fisheries for the sales or grants of the right or privilege to take shell or shell deposits from the shell deposits of the State to be dedicated to the establishment of 'oyster seed grounds,' and to the planting, propagation, cultivation, policing, preservation and distribution of oysters on and from said grounds."

We have just completed, from money obtained from this source alone, the planting of three hundred and thirty thousand bushels of clam shells as "cultch" in various selected spots.

Practically all of our shells are now being planted by the hydraulic method and it has been found to advantage to use two or more pumps to each barge when unloading.

We are also using some of this money in transplanting oysters from over-populated reefs to areas where new reefs can be made of better quality oysters.

We are endeavoring in certain areas, where oysters are growing too thickly and in clusters, to use dredges with the bags removed to drag the reefs and break up the clusters, which appears to be a step in the right direction.

A special seismic section of the Division of Oysters and Water Bottoms was organized in 1939 for the purpose of preventing loss of oysters, fish, shrimp and wildlife due to seismic exploration. Intergration of the intensive search for oil, based upon the use of explosives, and industries dependent upon oysters, fish, and other forms of life sensitive to shock waves was necessary for the economic operations of these industries. Regulations now in force are based upon findings obtained from a public hearing held between Department officials and counsel for the Department, together with representatives of the oil interests and their attorneys, and representatives of the fishing and wildlife interests of the State. It can now be stated that after more than six years of seismic operations in the State, both the oil companies and the seismic exploration companies have given their wholehearted support to the Department of Wildlife and Fisheries in its endeavor to protect other natural state resources. This is well illustrated by the fact that today we have fifty-five seismic exploration parties operating in the State. A conservation agent is assigned to each of these parties who renders daily reports of their activities to our Department. The salaries and expenses of these agents are borne by the various oil companies and all agents are hired and fired by the Department of Wildlife and Fisheries and are responsible to said Department.

I have with me, for any of you that might be interested, a number of sets of our seismic regulations together with handbooks which are given to each agent for his instruction and guidance.

The Oyster Division uses for its patrol work a sixty-three-foot twin-engined Diesel-operated boat with a crew consisting of captain, cook and engineer. A fast speed boat tender is part of the equipment. The crew of the boat spends its entire time patrolling the oyster beds of the State and enforcing the oyster laws, noting the condition of oysters in various areas and when any exceptional mortality occurs in any area the main office is contacted so that biological examinations may be made.

Two speed boats are continually in use to protect the newly created seed grounds. A departmental airplane is used considerably for patrol work and also for biological observations and obtaining biological samples.

In addition to this, a boat is engaged in gathering data necessary for future biological observations.

Several years ago a biological laboratory was built and equipped at our Port of Entry located in the Louisiana marsh area adjacent to Mississippi Sound, and about seven miles south of Louisiana-Mississippi line which passes through the Sound.

It is unfortunate that ever since the outbreak of the war when we lost our technician to defense industries, we have been unable to secure another biologist to take charge of this laboratory.

We now have the authority to employ a first class biologist under the provisions of Civil Service.

As stated before, a boat with crew is ready and waiting to carry out a special oyster biological program as soon as someone can be obtained to carry on this most important work.

Dr. Hopkins of the Federal Fish and Wildlife Service laboratory in Pensacola has rendered most valued assistance to our Department in many ways and we have often taken advantage of the splendid facilities made available by the Fish and Wildlife Service in his laboratory at Pensacola. The existence of this laboratory under Dr. Hopkins' direction is of fundamental importance to the oyster and other fisheries interests of the whole Gulf Coast.

Dr. Galtsoff who is associated with the same Service has in many ways assisted both Dr. Gowanloch, our Chief Biologist, and me in determining the cause of a number of biological problems pertaining to oysters which have arisen during the past twelve years in Louisiana.

We sincerely hope that when we are able to obtain the proper personnel and with the able assistance of the Federal Fish and Wildlife Service together with our own Dr. Gowanloch, we may through scientific research obtain much information of great importance to the oyster industry of Louisiana and indeed that of the entire gulf area.

It seems important to me in completing this talk to you to mention the cordial relations now existing in the oyster industry between Louisiana and our sister state, Mississippi.

There are more than twenty-five oyster canning factories located along the Mississippi Gulf coast that obtain from seventy-five to one hundred per cent of their steam stock oyster from the natural oyster reefs of Louisiana.

We have an agent with office located in the city of Biloxi. Every oyster boat leaving Mississippi must obtain a permit from our agent and before leaving the State of Louisiana with oysters must pass through our Port of Entry located near the Mississippi line. Here, another agent inspects this cargo and writes on the permit the estimated amount of same. Before this boat may come into Louisiana waters again, it must obtain another permit and present this signed permit together with the share slip obtained from the cannery, giving the exact number of barrels for which the fisherman has been paid. Our auditors annually check these share slips against the factory books and we feel sure that by this method Louisiana obtains all of the taxes due for oysters removed from our State and packed in Mississippi.

Let me now thank you all for the courtesy extended to me in my endeavor to acquaint you with some of our present oyster operations in Louisiana and some of our future plans. It will please me greatly at this time to answer any questions which you may see fit to ask relative to our present operations or future plans in Louisiana.

EFFECT OF SUSQUEHANNA RIVER STREAM FLOW ON CHESAPEAKE BAY SALINITIES AND HISTORY OF PAST OYSTER MORTALITIES ON UPPER BAY BARS

G. Francis Beaven, Biologist I
Chesapeake Biological Laboratory
Solomons, Maryland

It has long been recognized that an area of extensive oyster rocks in Upper Chesapeake Bay, north of Kent Island, is characterized by erratic production, slow growth and occasional heavy oyster mortality. These Upper Bay bars once supplied large quantities of small stock for the steam houses in Baltimore when Cove Oysters were canned. Quantities of the small round single oysters, which at times are abundant, have been utilized by both private industry and the State as seed oysters for planting further down the Bay. At rare intervals, the upper Bay oysters make good growth and produce a quantity of acceptable market oysters for the shucking houses.

The subject of proper management of these bars presents different problems from those encountered in the rest of the State and has evoked considerable discussion and debate. Although the effect of fresh water in adversely affecting the oysters in this area is generally recognized, the fact that an extensive mortality in 1943 occurred at a time when local precipitation was known to be deficient, as was true also in other instances, gave rise to other theories concerning the cause of the oyster losses. A "blight", pollution from Baltimore, and the opening of the bars to commercial dredging in certain years have each had vociferous adherents as the explanation for oyster losses occurring on the bars.

Far too little factual data is available concerning past oyster mortalities. Even as late as 1943 no observations on these bars were made until several months after a severe mortality had occurred. Since that year, the bars have been kept under continuous observation and the extensive studies made during the past two years by the Fish and Wildlife Service form the subject of the next paper on this program.

The possibility of a "blight" or oyster disease being a causative agent in an extensive mortality extending some distance down below Kent Island during 1916 was investigated by the Bureau of Fisheries. At that time no conclusions as to the exact agency responsible for the oyster deaths were reached. Examination of oysters then and in other more recent instances failed to disclose any recognized parasite in unusual abundance. Observations on the dispersal of industrial pollutants from Baltimore and the fact that the intensity of the mortalities observed has been greater on bars above and to the eastward than on those nearest to the approaches to Baltimore offer no support to the theory that pollution from Baltimore has caused the extensive losses observed. Continuous examination for the presence of both parasites and pollutants must, nevertheless, be continued since they constitute a potential danger which may vary from year to year.

The proximity of the upper Bay bars to the entrance of the Susquehanna River and the frequent references in past conservation reports to destructive floods from that River have prompted a study of available records for the purpose of organizing the data and determining what relationship exists between Susquehanna stream flow, Chesapeake salinities and past oyster mortalities.

The Chesapeake Bay is a drowned valley and comprises the largest inland waterway on the Atlantic Coast. It has been formed by the flooding of the lower stream system of the Susquehanna River as a result of coastal subsidence. Its salinity varies from slightly below that of the open ocean at the Virginia Capes to fresh water on the Susquehanna flats. An average outward flow of about three tenths of a knot was calculated by Wells, Bailey and Henderson in their 1929 publication. The outward flow of the fresher and lighter water at the surface is accompanied by a slow movement of denser salt water up the Bay in the deeper channels. Deflection of currents towards their right by the earth's rotation together with greater stream flow from the western shore of the Bay have resulted in slightly higher salinities on the eastern side than on the western. The normal heavier run-off from the land during the spring months causes an annual salinity fluctuation with lowest salinities occurring in the spring and highest in the fall. Seasonal variations in evaporation, precipitation, and wind direction and velocity all influence the salinity pattern of the Bay.

The drainage area of the Bay system is about 64,900 square miles with the Susquehanna River comprising approximately 43% of the total. Stream flow from the Susquehanna represents over 85% of all contributions north of the Potomac and over 95% of that above the Patapsco. Variations in the flow of the Susquehanna River would thus be expected to have a major influence on salinities in the upper part of Chesapeake Bay, with its effects being marked as far down as the entrance of the Potomac.

No continuous daily record of salinities in the upper Bay proper is available. At Solomons, some 65 miles below the affected bars, daily surface salinity is a little less than 14 p.p.t. or approximately double the normal salinity on the upper Bay oyster bars. It ranges from a normal of 10.3 about May 1 to 17.3 in early November. A comparison of intermittent salinity records from the upper Bay with those at Solomons shows that both follow the same general trend with abrupt fluctuations more smoothed at Solomons than up the Bay. Extensive surface and bottom samples on oyster bars have further shown that surface salinity fluctuations correlate closely with those occurring in the slightly higher salinities of the bottom water.

Salinities at Solomons have been plotted and compared with graphs of the precipitation recorded for the Maryland-Delaware section by the U. S. Weather Bureau. Monthly average salinities at Solomons and monthly average precipitation during the past five years are shown by the accompanying graph. There is some general relationship shown between recorded salinities and precipitation but no well defined correlation exists. The marked low salinity which occurred in 1943 is not accompanied by above normal precipitation

for the same period. This lack of correlation might be expected from the relatively small portion of fresh water which is contributed to the upper Bay by local run off.

Accurate records of Susquehanna River stream flow have been kept near its mouth at Conowingo Dam since 1933 by the Susquehanna Electric Company. These have been studied and plotted in several ways for the entire period. Relationships of stream flow, precipitation and salinity at Solomons are shown graphically for the year 1945, a year of marked precipitation and stream flow peaks. No noticeable effect of local rainfall on salinity can be found except a slight dip following record breaking rains in mid-July. This same period also showed a moderate rise in stream flow from the Susquehanna. The graph of daily stream flow at Conowingo, however, shows a definite relationship to daily salinity. Each marked peak of flow is followed by a low peak of salinity. The interval of time ranges from five to about fourteen days and is usually slightly less than one week. However, the effect of periods of high stream flow is cumulative so that when salinity is depressed it does not recover fully for a period of weeks or months.

Exposure to a brief period of low salinity seems to have little permanent effect upon oysters, but long or frequently repeated exposure may result in serious damage. Thus, salinities averaged over a monthly period are more significant than the daily extremes. At the bottom of the graph, the monthly average salinity at Solomons is plotted with low figures at the top and high ones at the bottom so that peaks of low salinity will parallel peaks of high stream flow. In order to smooth out and show the cumulative effect of stream flow, the monthly average, three month progressive average and six month progressive average daily flow are plotted. The six month progressive average curve appears to correspond more closely with that of monthly salinity than do the others. Several years were plotted in similar manner and the same general relationships were found to hold. Other periods of progressive average flow were tried, but the six month period seemed to follow general salinity trends best as illustrated by the five-year graph shown.

Salinity records at Solomons do not extend back enough years to cover earlier periods of recorded oyster mortalities at the Head-of-the-Bay nor do the stream flow records at Conowingo. Daily salinity records at Fort McHenry in Baltimore Harbor have been kept by the Coast and Geodetic Survey since 1914. Solomons records were considered best for preliminary analysis since they are at the mouth of a long and broad tidal estuary and are little affected by local stream flow while those at Baltimore are likely to be more influenced by local Patapsco River conditions. When both, however, are plotted together a high degree of correlation is shown generally.

Records of Susquehanna stream flow extending back to 1890 have been kept at Harrisburg by the Coast and Geodetic Survey. When daily flows at Harrisburg and Conowingo are plotted in parallel a very high correlation is found. Records of peak floods showed that the average time interval for a peak to travel from Harrisburg to Conowingo is eight hours. The narrow gorge of the

Susquehanna and the maintenance of a continuous high head of water back of the dams gives them little if any flood control effect. Stream flow records at Harrisburg thus furnish a reliable index of the water discharged into the upper Bay by the Susquehanna River.

Publications of various agencies in Maryland dealing with oysters have been searched for records of general mortalities occurring at the Head-of-the-Bay. It is found that such losses when occurring in spring or summer were sometimes unreported until the rocks were visited after Christmas so that records of such loss may be given in the following year. There is also evidence that oysters weakened by spring floods may succumb the following winter when environmental conditions are unfavorable. The following major mortalities and no others were found to have occurred during the period for which records are available: 1908-1909, estimated at 55% on the Tea Tables and 62% on Man O' War Shoals; 1916, only an occasional living oyster could be found above Swan Point and the Patapsco River; 1928, an 80% mortality of up-Bay oysters; 1936, a heavy mortality from freshets down to Swan Point and Sandy Point; 1943, 97% loss on Tea Tables ranging to little loss at Swan Point and Sandy Point; 1945-46, to be reported in detail by Mr. Engle.

The six-month progressive average daily flow of the Susquehanna River at Harrisburg for the period of recorded mortalities has been plotted together with the existing monthly average salinity records from Baltimore. Mortality years are marked on the graph by an "M". These six mortality periods correspond with the six highest sustained periods of cumulative run-off from the Susquehanna. The five mortality periods reported since Baltimore salinities were available correspond with five of the seven recorded periods when salinities remained below five for three months or longer. These records thus afford excellent evidence that the oyster mortalities at the Head-of-the-Bay have all been associated with and probably are the direct result of low salinities caused by periods of high run-off from the Susquehanna River.

COMMERCIAL ASPECTS OF THE UPPER CHESAPEAKE BAY OYSTER BARS IN LIGHT OF THE RECENT OYSTER MORTALITIES

James B. Engle, Aquatic Biologist
U. S. Fish and Wildlife Service

The conditions existing on the upper Chesapeake Bay oyster bars during the last two oyster seasons present an exciting and deeply challenging situation to the biologist, but a sad and depressing picture to the industry depending on the supply of oysters. I appreciate both viewpoints and take this opportunity to discuss the significance of our observations from both sides.

The Fish and Wildlife Service in cooperation with Maryland Conservation agencies has been studying the biology and factors relating to the cultivation of oysters in Chesapeake Bay since 1944, and the value of the biological observations has already benefitted the oyster industry to a certain extent through advice based on information gathered in the course of these investigations. A major portion of the study was centered on the area known as the "Head of the Bay" located north of a line from the Chester River and Sandy Point. The reason for this critical interest is founded on the fact that wide fluctuations of salinity occur in this area from year to year and within the year. The cause of these salinity changes is in the amount of the fresh water run-off of the Susquehanna River. The drainage area of this River is located largely outside the State of Maryland in Pennsylvania and New York, but in Maryland, however, the greater part of this drainage is impounded by a large dam at Conowingo situated above Havre de Grace. During years when rainfall, snowfall and spring thaws are responsible for high river stages, large quantities of the fresh water escape over the dam or are released through flood gates and flow into the head of Chesapeake Bay. The salinity depression caused by the influx of the overflow varies in its extent and amount from year to year. Fortunately, coincidence during the last two years has permitted us to observe the effect on salinity of a reasonably dry season with a light flood from the Susquehanna River, and a year of heavy spring run-off following a quick and heavy thaw augmented further by excessive rainfall in the drainage basin, and in the immediate vicinity of the Bay. The contrast of these two years represents the difference between the existence and the destruction of oysters found on some of these bars of the "Head of the Bay". A more detailed discussion of our observations during each of these years will disclose the effect of the changes on oysters.

In 1944, the year the investigation was started, the salinity picture was as follows: From February to May 10 there was a drop from 10 parts of salt per thousand parts of water to fresh water. The fresh water lasted about two weeks, and then a steady increase in the salts occurred throughout the rest of the year reaching 15 parts per thousand in October. Oysters during this year were not materially harmed by the short period of fresh water with the exception of a slight retarding of the gonad development and

the absence of setting. Spawning did occur later in the season, and oysters grew normally and "fattened". In fact, the growth was better than usual and brought a large number of undersized oysters into the legal class for marketing. On the basis of the large number of market size oysters in good "fat" condition present on the "Head of the Bay" bars, the Maryland Department of Tidewater Fisheries on the advice of the oyster biologists of the Fish and Wildlife Service opened about 600 acres of oyster bottom to harvesting. Between 75,000 and 100,000 bushels of oysters were marketed and netted a substantial profit to the industry. This move also provided an additional supply of food at a critical period during the meat shortage. The whole operation was under the control of the State and Federal agencies, and the harvesting was stopped before any serious reduction was made in the population on the bars. In view of what happened before the 1945 year was over, it might have been well if all the oysters had been removed either to the market or transplanted to other bars. We are not gifted with the ability to foresee what the weatherman had in store for the area, so the bars were left with an adequate number of oysters to furnish brood stock for rebuilding the population for the future. We followed an acceptable conservation procedure in both cases, namely in harvesting some of these oysters and in leaving a portion of the population on the bars.

Now let us follow the sequence of events during 1945. From the salinity of 15 which was maintained through the fall and winter of 1944-5, it suddenly dropped to fresh water during the latter part of March. The fresh water remained over the bars for about three weeks. The heavy run-off was caused by an unusually early thaw in the whole Susquehanna River drainage basin that melted the heavy snows in New York and Pennsylvania and created flood stages on the river. When the floods had subsided, the salinity rose in the upper Chesapeake Bay to about 7 during the latter part of April. This rise was false assurance, for the spring rains came early in May and again dropped the salinity to zero. This condition was maintained until the end of May when once more the salinity started upward. The rise, however, was stopped by the rains of a very wet summer. Salinity hovered between 3 and 6 parts per thousand until the end of August; rose to about 9 during September; and dropped to 5-7 for the rest of the year. Studies by oyster scientists have shown that oysters are not able to grow, "fatten" and reproduce under these salinity conditions. Oysters in this part of Chesapeake Bay demonstrated this fact during 1945. Sex products in the majority of oysters did not ripen until August, spawning was meager, and no setting occurred. Meats were puffed up and transparent with water at the time when oysters normally accumulate large amounts of glycogen, which usually accounts for their creamy "fatness" and desirable firmness. These oysters, when shucked, began losing the absorbed water immediately and soon became shrivelled and dark and contained only one-fifth of the solid matter usually expected in a good market grade oyster. By November they began to die and before the winter was over the mortality had reached from 50 to 92 percent of the population. Those animals that had not died were in such poor condition that their survival was doubtful. For the moment it is sufficient to say that none of these oysters were fit to be marketed and the loss to the industry was great.

The extent of the affected area went beyond the "Head of the Bay" bars, and included many of the oysters in the Chester River, most of the bars on the Bay side of Kent Island, and a major portion of the bars in Anne Arundel County on the western shore of the Bay. The mortalities were not as severe below the "Head of the Bay" bars, but the condition of the oysters was so poor that they could not be marketed. The parts of the Bay and the tributaries below the above mentioned sections did produce many oysters, and made it possible for the State of Maryland to maintain production figures approximately equal to the 1944-5 season.

The sad part of this season's losses is more profound than appears at the first glance. Among the areas affected were bars being developed as part of a program by the Maryland Department of Tidewater Fisheries for rebuilding the grounds of low yield and the partially depleted areas. Most of these planted and cultivated areas are in the Bay proper, but several others are located in the Chester River. During 1943 a set of oysters caught on shells planted at Love Point, Kent Shore and the bars in Anne Arundel County. This set was supplemented by seed of the same year setting transplanted from prepared seed areas. Many of these oysters had reached marketable size and were part of the projected crop expected for the 1945-6 production. When the past season opened in September 1945, the condition of the meats was below the quality required for marketing on the basis of appearance and yield in pints per bushel, so the areas were not opened for harvesting. It was at first expected that the oysters would improve as the season progressed and the animals had more time to "fatten" after spawning had ceased. They could then be harvested later in the fall. This did not happen, and instead, many died. The survivors became progressively poorer as the season advanced, and entirely unfit for marketing. The fact that these oysters did not reach the market is no reflection on the State program, for the conditions occurring on these bars are unusual and they happen infrequently.

On the basis of unmarketability and loss through the heavy mortality, the State of Maryland oyster production for the season of 1945-6 was deprived of over one million bushels. Approximately 40 percent of these oysters would have come from the reserved areas cultivated by the State of Maryland Oyster Management Plan. In the following table the detail upon which these figures are based is given. The losses from the "Head of the Bay" bars are not included because that area cannot be rightly classed as a dependable source of oysters for the Maryland market. The losses on these latter bars, however, were heavy and represent considerably more than half of the population left there after the mortalities following the freshet of 1943 and the marketing during the fall of 1944.

I believe I am justified in expressing a word of encouragement to close this otherwise depressing discussion. Some of the loss during the present season was due to unmarketability, and this may be recovered when the water conditions improve, and the subsequent improvement of the poor oysters.

Table 1. Mortalities and production losses from the bars in the upper part of Chesapeake Bay, 1945-6, and marketable residue.

Name of Bar	Bushels			
	Expected crop 1945-6	Mortality loss	Marketable residue	
Love Point	100,000	92,000	8,000	1/
Broad Creek	200,000	100,000	100,000	1/
Gum Thicket	60,000	15,000	45,000	1/
Bloody Point	50,000	10,000	40,000	1/
Chester River	25,000	10,000	15,000	1/
Anne Arundel	15,000	5,000	10,000	1/
Totals	450,000	232,000	218,000	
Swan Point	500,000	300,000	200,000	2/
Anne Arundel	500,000	150,000	350,000	2/
Totals	1,000,000	450,000	550,000	
Combined Totals	1,450,000	682,000	768,000	

1/ Bars cultivated State of Maryland Oyster Management Plan

2/ Natural bars with oysters too poor to harvest

The loss through the heavy mortality on some of the bars is irreparable of course, but the cultch bought at this high price may be a small but useful element on the credit side in the rehabilitation. At the present time, hydrographical conditions are favorable for a drier season which should improve the salinity. The blame for the losses during the 1945-6 season may be put directly on the low salinity maintained throughout the whole of 1945 and early 1946. In the effort to explore all possible causes for the poor condition and high mortalities, an independent study of the distribution of the sporozoan parasite, Nematopsis, in the oysters from most of the bars in upper Chesapeake Bay was made by Miss Helen Landau, Biologist in the Fish and Wildlife Service. No correlation could be found between the distribution and the intensity of infestation of the parasite in the oysters with the poor condition and mortality.

The period just past, usually the time when the upper part of Chesapeake Bay is under the bad influence of the spring freshets from the Susquehanna River show by the records that it is the driest experienced since the Conowingo dam has been in operation. The overflow has been cut off except for power manufacture, and even this has been curtailed in order to maintain sufficient head to run the turbines. The salinity at the head of the bay has reflected this meager discharge of water from the dam and is now 10 parts per thousand higher than it was in 1945, and approximately 5 parts higher than it was in 1944. We still may get precipitation heavy enough to cause heavy run-off which would depress the salinity, but some ground has been gained by having a dry early spring. A short term depression will not seriously harm the oysters provided a reasonably dry summer and fall permits the steady rise in salinity. I offer hope to Maryland in particular and to the oyster industry on the whole, for a substantial increase in oyster production from this area during the coming season. With higher salinities one may also expect a better possibility of normal gonad development and a subsequent set to replace some of the losses just suffered by the oyster population in the upper Chesapeake Bay.

On the evidence of our observations of the "Head of the Bay" conditions it seems appropriate to mention here that it would be more profitable to expand oyster cultivation in a southerly direction in the Maryland portion of the Chesapeake Bay and avoid trying to answer the question "is the head of the Bay a nursery or a death trap for oysters?" There is no doubt that a potential value exists in the head of the Bay and oysters will occur from time to time. When they do occur it would profit the State to remove them to safer areas to grow. A better oyster is produced where salinity remains higher and with less fluctuation than is found in the above area.

HOW CAN WE PROFIT BY THE U. S. FOOD AND DRUG ADMINISTRATION HEARINGS

Curtis L. Newcombe, Director
Virginia Fisheries Laboratory
Yorktown

The extent to which oyster packers may profit from the recent hearings of the U. S. Food and Drug Administration depends firstly on what added significance they have been led to attach to handling and packing procedures. I think that many have come to realize more than ever before the bad effects on oysters and oyster markets of excessive contact with fresh water or too great variability in counts or excessive amounts of shell fragments. The need for a standard of some kind is probably evident now to many that before the hearing considered standards unnecessary. Hence, it is likely that the Hearings have resulted in giving added significance to Standards in this industry.

The extent to which the Hearings have been profitable depends, secondly, on new information that has been provided by the various Federal, State, and private agencies. After listening to carefully prepared testimony offered by the Food and Drug Administration and by the several other agencies, I became impressed with the need for Standards of some kind, the need of the oyster industry for the backing of the established Federal agency for promulgating standards - namely the U.S.F.D.A.- and especially the need for more facts to serve as a basis for Standards. The oystermen of the different states do not yet have the needed records to define the type of standards that best suit the country as a whole (if indeed such can be found) or that are applicable to even one general section. It is true that the various state agencies in cooperation with the U. S. Fish and Wildlife Service did a great deal in a short time but the job is too big to be completed in a few months. Likewise, the testimony of the U. S. Food and Drug Administration impressed me as lacking technical facts on essential aspects of the regulations, and, too, the evidence seemed to reveal a lack of appreciation of the practical problems which every oysterman encounters.

I may cite an example of variations in oysters from two different parts of Virginia which clearly show that there is no royal road to generalizations as far as behavior of oysters is concerned. The two localities where our observations were made were near the mouth of Chesapeake Bay - salinity about 20 parts per thousand - and on the seaside of the Eastern Shore - salinity about 30 parts per thousand. Gallon samples were used. Bayside oysters shucked in a dry container had a drainage loss immediately after shucking of 25.2 percent as compared with 8.2 percent of Seaside oysters. These same oysters were drained and weighed six more times in succession to see how much liquid they continued to lose on continued draining. As a result of being drained and weighed seven times in succession, Bayside oysters had a total drainage loss of 44.4 percent whereas Seaside oysters showed a corresponding loss of only 18.1 percent.

These findings were supported by other experiments in which oysters were shucked into containers containing 25 percent of fresh water and 75 percent of fresh water by volume. The data show clearly the difficulties that are likely to arise in an effort to establish Standards that will apply equally well in both regions.

In any attempt to promulgate uniform handling procedures for different areas, such differences as those given above cannot be ignored. Pertinent data on how oysters respond to different handling procedures, and, too, on what constitutes the best practical procedures for the different sections should be made known to the oyster packers and to the regulating authorities. Both groups stand to benefit from strict adherence to such regulations. The oyster growers can benefit from the Food and Drug Administration Hearings by taking steps to get a factual basis for needed regulatory measures.

The subject of uniform count has been discussed at some length. Our observations have not been comprehensive enough to permit generalizations. It seems clear, however, that the counts are more uniform in some houses than in others and that concerted effort by the industry will result in significant improvements.

Preliminary observations were made on the number and weight of shell fragments in individual gallon samples of "Select" and "Standard" oysters. Standards, as expected, were found to contain far more bits of shell than Selects. In one instance a gallon sample of Standards contained 139 shell fragments which weighed 24 grams, the largest fragment being one and one-half inches in length. The remaining samples were lower, one gallon of selects containing only 1 fragment which weighed 0.5 gram. These extremes are cited to indicate that there is a large variation between different plants and between different days in the same plant depending on the experience of the workers and the oyster stock.

As in the case of the problem of getting reasonably uniform packs, the oyster packer could, seemingly, accomplish much through constant effort to reduce the amount of shell fragments. Doubtless, the Hearings have resulted in improvements in more than one plant by making the operators increasingly aware of the effect on the quality of the oyster pack of excessive contact with fresh water, excessive blowing, and excessive quantities of shell fragments.

It would appear that such a step should help improve the demand for oysters. Furthermore, without effective regulations the progressive packer is likely to be penalized by the careless packer who is relatively indifferent to the quality of his product.

The importance of quality and not just size as a basis for grading has been stressed and deserves still more emphasis.

I suggest that the Oyster Grower's Institute keep this whole subject of Standards alive by designating a committee to work on the project. A function of the Committee might be to stimulate and coordinate the investigations needed to provide the necessary facts and to cooperate with the government agencies in assuring adherence to the desired standards of handling and packing oysters. By keeping the packers more conscious of the ill effects of long contact with fresh water, of excessive blowing and of large numbers of shell fragments, a better oyster pack can be assured.

BACTERIOLOGICAL OBSERVATIONS ON OYSTER GROUNDS OF THE HAMPTON ROADS AREA

P. Arne Hansen, Bacteriologist,
U. S. Fish and Wildlife Service

Every oysterman is confronted with a great many problems in securing the best possible product for his market. One of the many obstacles which he is facing is the difficulty in finding adequate planting grounds in a locality where the oysters will fatten quickly and where sea water is sufficiently clean to meet the requirements of the U. S. Public Health Service. It may be added that the oyster grounds should be, of course, at a convenient distance from both shucking house and seed beds. The massive increase in population in the Hampton Roads area, especially during the war years, has been responsible for adding more acres to the already extensive restricted shellfish producing area with the result that the oyster growers have been practically forced out of the lower Bay between Willoughby Spit and Little Creek, an area of 3,847 acres. The monetary loss in production of market oysters is difficult to estimate exactly, but for the entire Hampton Roads area, it may well exceed 2 million dollars. Besides the actual decrease in the production of marketable oysters, there is an additional loss in the value of oyster bottoms which have been carefully improved for years by shell planting and which represent a considerable investment.

The loss of oyster producing bottoms has caused deep concern to the oystering industry of Virginia. The Fish and Wildlife Service during the last 18 months has carried out studies on the trend of the pollution in the lower Chesapeake Bay with the object of finding areas free from objectionable contamination.

Foods consumed in a raw condition, especially such which are of nitrogenous, non-acid nature, are of particular concern to public health officials. Since shellfish belong in that category, much has been done to safeguard the public and to dissociate the shellfish trade from the slightest suspicion by excluding from the market any shellfish which might possibly harbor potential danger. State officials, in cooperation with the U. S. Public Health Service, are continuously surveying shellfish waters to ascertain their suitability from the Public Health point of view.

The degree of safety of shellfish waters is evaluated in terms of "Most Probable Numbers" of coliform bacteria, abbreviated M.P.N. This group of organisms in itself is not dangerous to human health, but it is universally associated with the excreta of humans and warm blooded animals which may carry organisms that are dangerous. Coliform bacteria are not present, at least not in significant numbers, in localities which have not been exposed to recent pollution. By planting definite amounts of sea water in suitable culture media, the number of coliform organisms can be fairly closely estimated. This quantitative method has become very widely used because it affords a fairly direct way to determine pollution. The most direct approach; namely,

the counting of dangerous pathogenic bacteria, is not practical. Instead of testing for these, we have chosen to discriminate simply against all intestinal bacteria.

According to the standard established by the Public Health Service, an M.P.N. of coliform bacteria in excess of 70 per 100 ml. should place a water as a moderately polluted, and such water areas should be considered as polluted and restricted for shellfish production. If the value of M.P.N. would remain more or less constant at the same sampling station, the work involved in testing would be of relatively simple nature. The task of the investigator, unfortunately, is made quite complicated by the fact that numerous factors, such as temperature of water, state of tide, recency and amount of precipitation, wind direction, presence of nutrients or inhibitors in the water, and still other influences, govern to a very considerable degree the number of bacteria present. Due regard must be given to occasional occurrences of very high numbers, hence it is prescribed that the median (the middle value) of a large set of data be used for expressing the just figure. The variations from one sampling trip to another are particularly pronounced in the Lower Chesapeake Bay where sound judgement can be arrived at only after prolonged and all-year-round sampling. The field laboratory at Hampton has been studying the progress of retreat of the sewage front in the lower Bay, expressed in terms of M.P.N.

The restricted area studied, between Fort Wool, Willoughby Spit, and Ocean View, slopes very gradually from the northwest boundary where the depth is 12-15 feet to 22-27 feet at the eastern border, the main part having a depth of about 20-24 feet. North of this region, at a distance of about 2000 yards, is a deep water channel, an important shipping lane, varying in depth, but mostly around 40-50 feet. Naturally enough, the pollution from the Hampton Roads area follows in some measures, as experiments have shown, this deep water channel being washed back and forth by the tidal wave. A certain amount reaches, as our data indicate, the oyster growing area, mostly from the west and northwest. Before the pollution reaches the extensive and almost uniform flat regions north of Willoughby Spit and Ocean View, it is almost uniformly mixed and somewhat diluted.

The pollution of this area decreases when one passes from Fort Wool eastward. During the war, when there was extensive activity near Little Creek, an increase of M.P.N. of coliform bacteria was noticed toward the eastern border of the area. The numbers rise, as a rule, in an off-shore direction approaching the deep water channel, except in the most western part near Fort Wool and Willoughby Spit where discharges from Norfolk leave the deeper water and pass over the Willoughby Bank. The shallowness in this part is favorable for higher numbers, because of lesser dilution.

As a whole, M.P.N. are higher on ebb than on flood tide. Excepted, however, are certain off-shore points approaching the deep water channel where the flow of sewage may be pushed out sideways with the incoming tidal water.

The influence of season has been found to be extremely important. After relatively low values during parts of the winter, and into March 1945, the number of coliforms increased to high values late in April. Very high numbers were reached during July and September 1945. Not before February 1946 did the pollution subside in most of the field studied. In the region most closely situated to Fort Wool the figure remains relatively high.

The pollution seems to bear a certain relationship to rainfall. Some climatological extremes occurred in 1945. It is worth noting that July 1945 was the wettest July of record for Virginia. Tidewater Virginia averaged in this month 13.46 inches of rainfall, or 8.40 above normal. September was next to the wettest September of record and Tidewater Virginia averaged 5.6 inches of rainfall, 2.22 above normal. This rainfall may have had some relationship to the high M.P.N. of the two months. Not only did a number of stations show considerable pollution, but it was also observed over an extended area. Whether the seasonal variation will be repeated in 1946 is impossible to answer, but the first part of the year has shown some slight hope for improvement. It may be related to the cold spring, to the decrease in wartime population, or, possibly, to a change of sewage.

The future of the oyster grounds in the Lower Chesapeake Bay will depend very closely on the progress of the plans for the treatment of sewage effluents scheduled by the Hampton Roads Sanitation District Commission. Since 1927 an increasing effort to provide for improved sanitation of the Hampton Roads area found its expression in the formation of various important commissions, culminating in the creation of the Hampton Roads Sanitation District and the Acts of 1940, which were approved in November 1940. The District includes territories on both sides of Hampton Roads and considerable advance has been made in the extensive engineering projects for suitable sewage disposal. So far, the main accomplishments are the following. All main sewers on the Hampton side have been completed. Sewage west of Sunset Creek since April 1st, 1946, has been discharged into the outfall near the Small Boat Harbor at Newport News. The south side of the Hampton Roads area is now almost completely being served by lateral sewers, and the outfall at the Army Base has been in operation since early in 1945. The Portsmouth sewers are completed and the plant at Pinners Point is under construction. At the present moment, no sewage treatment plant in the Hampton Roads Sanitation District is in operation but several are under construction. The Small Boat Harbor plant is expected to start operating in November 1947 and the Army Base Outfall late in the summer or fall of 1947. The entire plan is expected to be completed at sometime in 1948.

The Fish and Wildlife Service is looking forward to following these changes closely insofar as they will reflect themselves in the bacteriological findings in the oyster producing waters of the region. It is hoped that the "clearing up" of a region and the consequent lifting of restrictions on shellfish production will be reached in the not too distant future. The importance attached to the pollution problem in the Lower Chesapeake Bay should not in any way be so construed as to be reflecting any stigma on oyster production

business in the Hampton Roads region. On the other hand, the extremely rigid restrictions on shellfish production areas, with which the market has been protected, has placed the quality of the oysters beyond reproach.