PROCEEDINGS OF THE NATIONAL SHELLFISHERIES ASSOCIATION

1949

ADDRESSES DELIVERED

AT THE CONVENTION OF THE

NATIONAL SHELLFISHERIES ASSOCIATION

Old Point Comfort, Virginia

June 7-8-9, 1949.

****

Dr. Victor L. Loosanoff,
President

Dr. J.Nelson Gowanloch,
Vice President.

James B. Engle,
Secretary

David H. Wallace,
Treasurer.

TABLE OF CONTENTS

1949 Addresses

"WHAT CAN SCIENCE OFFER THE OYSTER GROWER"

Thurlow C. Nelson, Ph.D.,D.Sc.

Professor of Zoology, Rutgers University,
Biologist, New Jersey State
Division of Shellfisheries.
In Charge, New Jersey
Oyster Research Laboratory.

INTRODUCTION

As we gather here today on the shores of historic Chesapeake Bay to discuss the problems of the great shellfish industry I am deeply conscious of the debt we owe to this area. It was here in Chesapeake Bay that the great biologist, the late Dr. William Keith Brooks of the Johns Hopkins University, undertook the first studies of the oyster in America. In 1878 he organized the Chesapeake Zoological Laboratory and during the following twenty-eight years during warm weather he was always at the seashore accompanied by a party of students. In keeping with the early traditions of the Johns Hopkins, the available money was mostly put into brains, not into buildings and boats. Starting with a vacant warehouse at Fort Wool* and three rowboats furnished by the Secretary of War, the group moved the next year into three barges of the Maryland Fish Commission at Crisfield, Maryland. In 1883 the laboratory was located in a building leased from the Normal School in Hampton, Virginia, but a few moments drive from where we are now gathered.

Thus we meet today in the very heart and home of oyster research in America. May we pause for a moment to pay tribute to this great scientist. As Chairman of the Maryland Oyster Commission Dr. Brooks submitted to the General Assembly of Maryland in 1884 a comprehensive report on "The Development and Protection of the Oyster in Maryland." If his recommendations had been followed there would be only one oyster problem for Chesapeake Bay today; where to find markets for the vast numbers of oysters produced on the prolific reefs of this area.

Of greater value to the country as a whole, however, has been the legacy Dr. Brooks left us in his students; Dr. James L. Kellogg long of Williams College Massachusetts whose work on molluscs has yet to be surpassed and whose student, David Belding, made such substantial contributions to the oyster, quahaug and scallop fisheries of Massachusetts. Dr. Caswell Grave for some years biologist of the Maryland Oyster Commission whose student, Dr. E. P. Churchill initiated the program of research on oyster larvae of the Fish and Wildlife Service. Lastly the even greater work and influence of my father, the late Dr. Julius Nelson at Rutgers, who lives on not only in your speaker but in William H. Dumont and in Jim Engle of the Fish and Wildlife Service, in Dr. C. A. Perry of the Maryland State Department of Health and Dr. C. Roy Elsey

of British Columbia, in Dr. L. A. Stauber, Dr. H. H. Haskin, and Dr. M. R. Carriker now at Rutgers, and Dr. A. F. Chestnut of the University of North Carolina's new Institute of Fisheries Research at Morehead City. Here also I must include my brother, Mr. J. Richards Nelson, who while still a student at Rutgers fell under the influence of the Brooks tradition and switched his loyalties from poultry husbandry to oyster farming. Through these men may this great scientific tradition carry on in ever widening circles.

The needs of the industry and the accomplishments of Science

The primary and basic needs of the oyster industry are:

1. A dependable supply of seed
2. Protection from enemies
3. Good growing and fattening grounds
4. Protection from industrial and domestic pollution.

What has science actually contributed thus far to the welfare of the industry and what prospects are there for the future?

1. Obtaining seed oysters

During the first decade of the present century Dr. Stafford in Canada and my father, the late Dr. Julius Nelson of Rutgers College in New Jersey, studied and described the free swimming stages of the oyster larvae and the conditions under which they are able to attach. The slide shows the first photograph ever taken of an oyster larva. It was made by my father in 1908 and published in his annual report in 1909. It represents a larva 9-10 days old. To these two scientists must be given credit for first demonstrating the importance of clean shells as cultch. They showed that spawning of the American oyster begins at a temperature close to 70 degrees Fahrenheit and that it is possible through microscopic ex amination of the water to determine the probable time and intensity of the expected oyster set.

Following the death of Dr. Julius Nelson in 1916 his work was expanded in that year at the New Jersey Station to include the world's first survey of an oyster bearing area to determine the abundance and age of oyster larvae at different points. This survey of Little Egg Harbor, published in 1917, demonstrated: first, that the oyster larvae work up-stream away from the sea, and second, that through determining the age of the larvae the time of expected set could be predicted ten days in advance.

The advent of the first World War interrupted all oyster research, but the decade beginning in 1920 saw greater progress in oyster research and wider application of its findings than in any comparable period in our history. Lack of time prevents me from more than mentioning some of the more important discoveries. Churchill and Gutsell of the U. S. Bureau of Fisheries, working in Great South Bay, Long Island, confirmed our findings in Little Egg Harbor and Barnegat Bay, paving the way for the outstanding work of Prytherch and Engle and their associates at Milford, Connecticut. Meanwhile Joe Glancy and Wm. Firth Wells working quietly for the New York Conservation Department were the first to raise oysters from the egg to setting size. Dr. Galtsoff, newly arrived in this country from the marine station at Sebastopol on the Black Sea, joined the Bureau of Fisheries and plunged into a study of the oceanography of Long Island Sound especially as related to the oyster industry.

The story is an exciting one, typical of what we like to think as being truly American. Great industrial expansion incident to the First World War let loose a flood of industrial wastes that threatened by 1924 to wipe out the great oyster setting grounds of Bridgeport and New Haven harbors.

The personnel and financial resources of the U. S. Bureau of Fisheries were thrown into the struggle, in which they were joined by two men of outstanding ability and vision. To them we scientists and oyster growers of America owe eternal gratitude. The vision and the industry of Mr. Howard Beach gave us the Oyster Institute. His confidence in Dr. Radcliffe as its Director has been abundantly justified in the years that have followed. The Institute, and the Milford Laboratory are monuments to these two men.

Supported by the valiant work of our late lamented Captain "Shang" Wheeler in Connecticut, and of Dr. Connelly in Rhode Island, pollution was greatly abated, inshore spawning areas were restored and the great Long Island .yster industry was saved. How typically American is this story, science and industry working together hand and hand to solve our common problems. The very valuable bulletins issued by Dr. Loosanoff at Milford are the latest evidence that through the aid of science oyster sets of abundance can be obtained in nature.

Of vital interest in the possible role of spawning sanctuaries in increasing seed production is the important question of how far may oyster larvae travel during their two weeks of free-swimming existence.

The only unquestioned proof of distance traveled by an oyster larva of which I know is that of Dr. Roy Elsey of British Columbia who found a spat of the Japanese oyster attached to a boulder estimated at approximately five tons and situated some five miles from a bed of Japanese oysters introduced the preceding summer. There were no other Japanese oysters in the area and that boulder

certainly wasn't dropped off an oyster boat!

In Delaware Bay we have indirect evidence that in some seasons vast numbers of oyster larvae may be carried upstream as much as fifteen miles from the planting grounds to set on the natural beds above.

Where spawning sanctuaries have been set up we have repeatedly found much heavier sets up and downstream from the parent oysters. This would seem to support Prytherch's findings at Milford that larvae remain close to their parents throughout the entire two weeks larval period. Another explanation, however, is possible. In 1921 I described and pictured 62 mature oyster larvae ready to set from the stomach of an adult oyster. Such larvae do not remain long in the digestive tract of the adult oyster, but are quickly carried out of the intestine. On emerging from their accidental prison they have frequently been seen to push out foot and velum and to swim away. Two years ago a group of large oysters were brought to Surf City, Barnegat Bay, from a distance of some eight miles. Less than two weeks later a heavy set approximately two weeks old was found on the oysters themselves and upon nearby gravel. There were no parent oysters in the area save a couple of bushels of small oysters in trays. The heavy set, confined to the shells of the large oysters and the gravel all within a few feet strongly suggests that there were larvae in the guts of the big oysters when brought here and that on planting, the large oysters liberated their load of captured young which promptly set in the immediate neighborhood. With hundreds of thousands of oysters each pumping twenty, thirty or more quarts of water an hour vast numbers of oyster larvae must be captured and subsequently liberated. Absence of such capture by the adults may well be an important factor in the failure of a depleted oyster bed to rehabilitate itself. It deserves much further study. Here is a field where radioactive tracer elements can be used to great advantage.

After twenty years experience on the Cape May shore of Delaware Bay we can give you the following as definite facts. During eighteen of these twenty years intensely heavy sets of oysters have occurred upon the flats within a few feet of our laboratory. Setting has taken place continuously night and day for from four to as much as ten weeks as determined from shells placed and removed each 24 hours. As high as 600 spat per concave surface of a quahaug shell have struck within a single 24-hour period, with over 100 per shell each 24 hour period for more than two weeks. Since the flats run bare each low tide to a distance of 2500 feet, the larvae must be carried at least that distance with each flood tide. The only oysters seaward from our laboratory are on a small depleted natural bed -- the Drum Beds in the public quahaug area. We are forced to conclude therefore, that the bulk of these larvae are produced on the

planted beds above us and are carried seaward during early development. By successively sinking on the ebb and rising on the flood they return to our New Jersey shore. Due to the effects of the rotation of the earth they are carried toward the Delaware shore during ebb tide while being borne toward the New Jersey side as the tide swings to the right with the flood.

Outside the bar, situated some 3000 feet from the high water mark, and in 14 to 20 feet of water are hundreds of acres of oyster bottom which have been heavily shelled year after year. In the main these shells have caught fewer spat in an entire summer than attach to similar shells in one tide close to the shore. It is evident therefore that with each flood tide these larvae by countless billions pass by these shells to attach to shells in shoal water on the flats. We have had excellent success moving such heavily set shells offshore into deeper water when the oldest are but 10 days of age.

It is my opinion that no more important problem faces the Chesapeake Bay area than to determine the role of parent oysters in capturing their young and finding out how far the larvae are carried. Here is a field in which radioactive tracer elements or even staining as used by Dr. Loosanoff could be employed to great advantage. It is understood that Dr. Chipman has recently completed the training required in handling radioactive elements. May I urgently recommend the tracing of oyster larvae for his early consideration.

2. Oyster enemies

Much has been learned about the enemies of the oyster but so far science has yet to give us methods for the control of oyster enemies comparable to those developed for the eradication of insect pests, for example. Since boring snails are also molluscs, breathing through gills, they are so close to the oyster that it is very doubtful if any method of poisoning them can be found which will not harm the oysters or render them unfit for human food. The plan to kill oyster drills through corrosive sublimate, or bichloride of mercury, as recently proposed appears highly dangerous through the habit of the oyster loading up with heavy metals such as zinc, bismuth, lead, mercury or copper whenever these occur in appreciable quantities in the surrounding waters.

The six year study of the oyster drill, Urosalpinx, carried on by Dr. L. A. Stauber at our laboratory with the aid of W. P. A. and P.W.A.

funds showed conclusively that three methods of control are effective and that their use will pay dividends. Where much new shell growth is present on the oysters the drill trap should be used. This is a chicken wire bag filled with oysters younger than those which it is desired to protect. Oysters growers have long known that drills will attack the youngest oysters available while, Dr. H. H. Haskin in our laboratory proved that drills can distinguish between the excurrent water coming from oysters of different year classes up to four years of age. Bags of young oysters strung on trot lines will confer much protection to oysters on the bed. If placed around a bed comparatively free from drills such bags if frequently shaken to remove the drills will largely prevent invasion from adjoining beds. For use in transplanting we strongly recommend either the deck screen or deck plate of steel with holes closely bored to let the drills through. For cleaning a ground before planting we recommend the drill dredge.

Starfish are destroyed by quick lime but this cannot yet be considered a substitute for mopping. Much of the difficulty comes from vast populations of starfish on barren bottoms from which the free swimming larvae may be carried long distances in a few days. Discovery of an economic use for starfish would stimulate a fishery for them thus keeping down their num bers on the barren bottoms. A few years ago I was greatly interested as well as amused to overhear a well known zoologist who spends his summer at the Woods Hole Laboratory on Buzzards Bay, Massachusetts, express the fear that inroads on the starfish of that area to supply biological laboratories would soon so reduce the number of these animals that it would be difficult to find enough for his own research work. You men from the Long Island Sound area will smile at this, but does it not hold a lesson for us; that steady pressure on any species over an extended period will reduce the population to small proportions?

Great hope for oyster pest control in the future lies in the work of Dr. Sewell H. Hopkins and of his numerous associates of the Texas A and M Research Foundation working in the Gulf. I look forward also with anticipation to what Dr. Prytherch will tell us shortly of his control of oyster enemies in North Carolina. Of this much we can be certain. When oysters are planted on new bottom relatively free from enemies the returns are often very large. With each succeeding year, however, the oysters' enemies increase and unless these are brought under control may ultimately put the oyster grower out of business. The boom years of 1920 to 1930 in Maurice River Cove are a good illustration. New bottoms were being taken up where oysters had not previously been planted and hence were comparatively free from drills. Aided by the wettest year in New Jersey's history more than five million dollars worth of oysters were shipped from the Cove in 1928, putting New Jersey in third

place among the states with a production of one seventh of the total oyster crop of the United States.

With the onset of the depression new grounds were not taken up, three of the driest years of record plus a hurricane took their heavy toll, with drills and the mud worm, Polydora, reducing the oyster crop by approximately one half. New Jersey slipped back into fifth place among the states. Return to our former position can only be accomplished through vigorous control of oyster pests; especially the drill.

3. Favorable growing and fattening grounds

Here science has been of little help; the oyster grower has had to depend almost wholly upon his own experience and that of others. We do not yet know why oysters grow well on some grounds, poorly on adjoining grounds. Even on the same ground, as every oyster grower well knows, growth and fattening may be good one year, poor the next. Much scientific work has been done in this field but as yet there is little that science can tell you of practical value. From our experience in New Jersey we know that when the diatom Skeletonema is abundant we have had fat oysters of excellent flavor. We have seen oysters increase in yield almost a pint per bushel in one week following a heavy invasion of this diatom. When associated with objectionable forms such as the "gremlin" Bicoeca in Great South Bay in 1943 oysters may remain thin and poor even in the presence of abundant Skeletonema.

Our experience in New Jersey does not support the conclusion of Dr. Loosanoff and his coworkers that oysters in nature will not feed in the presence of thick suspensions of food organisms. We have found oysters to feed actively throughout dense swarming of the dinoflagellate Amphidinium fusiforme, when the water had turned red and was a veritable soup of these algae and of their zoospores. Since Dr. Loosanoff's observations were made under laboratory conditions while ours were made in the open waters of Delaware Bay it is probable that poisonous substances produced by the algae at Milford were either not present in Delaware Bay or were quickly destroyed in our open waters. I have to be shown before I will believe that oysters will starve and die in nature in the midst of abundant food.

4. Protection from industrial and domestic pollution

Although in the past some oyster growers have looked upon bacteriologists as their worst enemies, we must all agree that in the main sanitary standards have aided and protected the industry. It is encouraging to find the United States Public Health Service now engaged in active research looking toward new techniques for identifying objectionable bacteria and to sounder more reliable methods of determing the sanitary quality of shellfish.

Federal and state attack on aquatic pollution is being actively pushed in many quarters, industry is cooperating as never before, ready to spend money liberally for research on waste disposal. Noteworthy is the two million dollar project of the U. S. Public Health Service which will be launched July 1st for the control of stream pollution.

Concrete evidence of improvement of the waters of New York Harbor is seen in a group of oysters on exhibit in this room. The late Captain Will Elsworth told me in 1923 that he had caught his last oysters in the lower Hudson River in 1917 close to the Statue of Liberty. Exhibited here today is a group of excellent oysters dredged last December on Robbin's Reef within the very shadow of the Statue of Liberty. One is tempted to become sentimental, and to suggest that even the lowly oyster is enjoying the protection of our Goddess of Liberty.

Finally we shall learn during this convention of the excellent progress made by Dr. Loosanoff and his associates in raising oyster and quahaug larvae to setting size at the Milford Laboratory. Armed with such technique there is every reason to hope that through selective breeding we can obtain oysters and quahaugs capable of attaining market size in half the time now required. From the growth studies of Martin and ourselves in New Jersey and of Dr. Loosanoff at Milford we know that certain oysters in any lot will outgrow others by as much as ten to one. In my own studies of water pumpage by oysters it has been found that two year old Cape May oysters selected through rigorous competition in the heavy sets of that area, can out-pump eight year old Barnegat Bay oysters, grown from non-selected seed, by at least two to one. Since the oyster must obtain the materials for growth and fattening from the water which it pumps, it follows that ability to pump water is probably the most important characteristic of a vigorous oyster. Unless the oyster is very different from most other animals such vigor is inherited in at least a portion of the offspring. Selection of the fastest growers in each succeeding generation should soon give us an oyster comparable to the large Pacific oyster imported from Japan which has in eighteen months reached a size where eight of them will make a pint. This may sound fantastic but science has produced equally miraculous results with other domestic and game animals such as trout; why not with oysters? To accomplish our goal research positions in the shellfisheries field must be made sufficiently attractive in salary and in tenure to interest young men of ability and with adequate training. Above all they must have complete independence of, and protection from, political interference. Looking back over half a century it is clearly evident that bad politics has been a

far worse enemy of the oyster than pollution, star-fish, drills and all other natural enemies combined. You in this industry have the political power to protect the scientists who are ready and eager to serve you; their fate is largely in your hands in a future that is bright with promise.

Varying Characteristics of Oyster Bottom

-by-

Allan A. Sollers, Commissioner
Maryland Department of Tidewater Fisheries
Annapolis, Md.

*****

An oyster, Mr. Chairman and friends, is the one thing in the world that I envy. The lazy rascal spends just about his entire life lying in bed. To complicate the matter further, this fastidious gentleman is a bit particular about the kind of bed he lies in. If it is too soft he settles in and dies. If the bed is too hard and shifting he likewise is covered up and departs for the oyster spirit world. Hence we are compelled to take due notice of these eccentricities of our exacting bivalved associate; our personal economic welfare is dependent on it.

The uniniated, though otherwise well informed, might quickly ask, "Why haven't physical and chemical analyses been made of the submerged lands, the several classes established, and these classes correlated with their capacity to grow oysters?" He would doubtless substantiate his question by pointing out the work done by the agricultural experiment stations ashore and refer to the glib way that farmers speak of loams, clays and sandy soils, marls and the host of other classifications in that book.

Such a classification might be useful; I have discussed the question with those qualified and have never discouraged such an attempt. I have by the same reasoning never strongly advocated such an effort for fear of oversimplification. There is more to the problem than would show in a simple physical analysis of the ground in question. I will discuss variations, complications and exceptions later.

If an attempt were made to classify the submerged lands, the Chesapeake Bay would be a good place to make it; surely we have every combination in the world there, and maybe one over for good measure.

Three general classifications would be immediately apparent.

The first to attract attention would be the sands along the shore lines. They feel relatively hard and firm to the bare feet of bathers but they lack any adhesive or cohesive qualities and shift about with the pounding of the surf. Their extent off shore is dependent on the degree to which the area in question is exposed to heavy seas.

Second, just beyond the shifting sands, we again find sand, but something has been added. Mixed with the coarse grains of sand, are smaller particles that possess definite adhesive qualities. I am not sure

what these smaller particles are, probably some type of clay. In any event they hold the grains of sand in a fixed position in much the same manner that the crystals in babbit bearings are held by the soft mental around them. The relative amounts of the component materials vary widely, but as long as both are present we have a firm, stable ground that remains amazingly constant. This is the combination of constituents of the natural oyster rocks of Maryland. Here we find the seventh heaven or the happy home of the oyster in our State.

Third, beyond these reefs or bars the percentage of sand sharply diminishes and we are on the mud. Generally the mud bottoms are definitely not the best places to grow oysters. I hasten to concede that there are great differences in the quality of mud bottoms, but do not feet that I should take the time at this point to discuss even the little that I know about these variations. I leave the point with the admonition that mud bottoms are bad places for uninitiated oyster planters who are long on ambition and capital and short on experience.

If the three classifications set forth above make the problem seem easy and simple, I hasten to dispel that illusion. For instance, there is another class. I set it forth as an exception because it appears pretty much without rhyme or reason in relation to the pattern set out above. The geologists call it Plum Point Marl. There are more local names for it in Maryland than there are sinners in Hades. Some of the local names are Fullers Earth, Blue Clay, Foolish Earth, etc.; you may take your choice. Generally it is excellent oyster ground. It will not shift under the most severe pounding of the seas. Again, generally, it appears in pure form; that is, not mixed with sand or mud. I know of a couple of exceptions. In Poplar Island Narrows in Maryland and off Port Mahan in the Delaware Bay is to be found an admixture of this blue clay and mud. The combination is somewhat softer than the pure clay and the blue color is lost. The mixture is black or nearly so and is called mud, locally. The combination makes an excellent oyster bottom in spite of the fact that those immediately concerned appear to be at a loss to explain why.

I said a moment ago a simple classification as indicated might be deceptive. Mr. Engle of the Fish and Wildlife Service has prepared a paper describing a splendid piece of research work he has done in Eastern Bay, a tributary of the Chesapeake. The paper will be worth your attention. A brief discussion of the kind of oyster ground found there might be worthwhile for it shows the influence of another environmental factor and definitely does not fit the pattern set forth. Eastern Bay is simply an oversized sand pit filled with water. In the state servic e I have had to deal with it, and I frankly say that the place kept me talking to myself

until I finally figured it out.

Here I found oysters growing on loose sand, the type of sand that sensible oysters would not be caught monkeying with. Contradictory or not, they do grow there. Here are the observations and the conclusions. Eastern Bay has a very irregular shore line and is dotted with several small islands. Long narrow peninsulas nearby bisect it. There are many oyster bars. It was noted that the bars began at varying distances from shore. In some instances the bars began in two or three feet of water, in others it was necessary to go off shore until a depth of fifteen or sixteen feet was reached before oysters and the inner edge of the bars were found. When this depth factor was correlated with the depth and extent of the open water to windward, the answer was apparent. The oysters grew on the loose sand as soon as the depth of the water became sufficient so that the impact of the seas would not shift the sand about.

This paper would be incomplete without some mention of the loess of the sea. In some arid regions of the earth, interior China for instance, this material drifts about the winds. In our element, the water, we call it quicksand. It is death to oysters and forms the building material for the siliceous tube worms, sand coral or coral sand according to where you live.

It would be fine if one could pick up a sample of some oyster bed, run to a laboratory and receive definite and final assurance on the survival of oysters on it. Your speaker, in the absence of more precise methods, has learned to determine the quality of oyster ground with the simple devices generally at hand. These include sounding poles, orange peel bottom samplers and tongs. He would be glad of a more precise system of determination, but is wondering how long it would take him to get use to the new method.

The situation reminds me of a story told years ago, in steamboat days, about a waterman in my section who had spent most of his time on old schooners and work boats. He married and decided to go to Baltimore by steamboat for a honeymoon trip. The transition from simple sail to the luxury of steam presented problems. The first to bedevil him was the purser. Recognizing him as the bridegroom, the purser asked, "Do you want the bridal suite?" Appreciating the fact that this trick would cost him money, our friend asked, "What is the difference between that and the others?" "Oh, the bridal suite has a private bath," was the pursers answer. After a moment's hesitation the waterman replied, "Just a minute, Mister, I'll go ask my wife, for my part if I get seasick or something I'll run to the rail like I been doing."

I have never insisted on the study indicated in this paper, for I might be too much like the waterman just referred to. Confronted with the problem of determining the quality of a piece of oyster ground, I am afraid I would grab a sounding pole, go over the area in question and make a final decision without further ado.

The absence of the information and the classifications indicated in this paper are no fault of the scientific organizations. They are biologists and chemists not mind readers. It is up to the industry to make its wants known. If you fellows think that such a study would be useful, let's ask that it be made. It might prove useful beyond our wildest expectations.

VARIATIONS IN INTENSITY OF SETTING OF OYSTERS IN LONG ISLAND SOUND

-by-

Victor L. Loosanoff, Director
U. S. Fish and Wildlife Service,
Milford, Connecticut

******

A good set of oysters in northern waters, including those of Connecticut, is not a rule but an exception. For example, of the past twelve seasons only four gave commercially important sets. Lightness and irregularity of setting are the chief handicaps of the oyster cultivators of Long Island Sound because the latter can never be assured that a new generation of oysters will be available to repopulate the beds.

At present the causes responsible for variations in the intensity of oyster setting in Long Island Sound are not fully determined and understood. Nevertheless, during the last twelve years, 1937-1948, enough new data have been collected which may help clarify some aspects of this important and interesting question. It is the purpose of this article to discuss some of the causes that may influence the intensity of setting.

We know that any species, in order to reproduce, should have a sufficient number of individuals to act as parents. Were our oyster beds depleted to such an extent that not enough spawners were present, lack of set could be ascribed to that cause. However, this probably has never occurred in our waters because there are always several million bushels of adult oysters in and near the area of the setting beds guaranteeing enough spawners. We cannot, therefore, consider the lack of spawners a cause responsible for the lack of set.

In some areas the failure of oysters to spawn could be advanced as a reason for the failure of setting. As a matter of fact, in some earlier articles discussing spawning of oysters opinions were expressed that in the deeper water of Long Island Sound oysters spawned only once in ten years (Nelson, 1928). Our observations showed, however, that this is not so. We found that oysters develop gonads and spawn every year. While the thickness of the gonads may vary from year to year, nevertheless, each year enough spawn is accumulated at the beginning of the spawning season.

There is no reason why the oysters in Long Island Sound should not spawn annually. Our records show that the summer temperature of the Sound is always high enough for the development of gonads and for inducing spawning. In depths up to about 40 feet a temperature of 20.0°C. or higher is maintained from about July 20 to September 15 or 20, i.e., approximately 55-60 days, a period long enough to permit the oysters to discharge their gonads completely. Even at the depth of 100 feet the temperature reaches 20.1 or 22.0°C. The majority of the oysters complete their spawning by about the first of September, approximately 15 or 20 days before the temperature begins to decrease below 20.0°C. (Loosanoff and Engle, 1942). Thus, failure of setting in our waters cannot be attributed to the failure of oysters to develop gonads and to spawn.

The failure of some aquatic species to propogate has been explained by the reason that a large number of the eggs discharged remained unfertilized and later perished (Thorson, 1946). This explanation cannot be applied to our oysters because, in their case, usually a large number of individuals spawn simultaneously, and this mass spawning insures fertilization of the majority of the eggs. On several occasions we observed spawning of oysters on the shallow bed of Milford Harbor. During the spawning the water over the bed was rendered milky with the discharged eggs and spermatozoa. Examination of the eggs showed that all were fertilized, thus indicating that there was no appreciable waste of eggs. A similar situation probably exists in the deep water beds. It is doubtful, therefore, that failure of fertilization is a cause responsible for the production of the small number of larvae.

On the basis of the presented considerations we may conclude that in Long Island Sound a sufficient number of oyster larvae is produced each year. These larvae are planktotrophic with a long free-swimming or pelagic life which, in our waters, is about 18 days. Larvae of this type, as Thorson (1946) points out, are "Cheap" because the eggs from which they develop are small, containing little yolk and, therefore, they can be produced in extremely large numbers. However, the initial advantage possessed by the oysters in producing a large number of eggs and larvae is counterbalanced by several disadvantages the first of which is, perhaps, the long larval period. During this period the larvae are exposed to the attacks of their enemies and are entirely dependent in their development upon the presence in the water of certain plankton forms which serve them as food. Furthermore, during this period the larvae are also exposed to continuous changes in their environment some of which may cause heavy mortality or the complete disappearance of broods of larvae.

Before proceeding to discuss the conditions that may, or may not, be responsible for the mass disappearance of larvae we should, perhaps, become familiar with the major events of the propagation of oysters in Long Island Sound. In the past a rather complex formula was offered for prediction of the time of the beginning of spawning and setting (Prytherch,1929). We find, however, that the situation is less complex than it appeared to earlier investigators. Our observations showed that spawning in Long Island Sound always begins either during the last few days of June or during the first days of July. The earliest date of spawning recorded was in 1945, or June 26, and the latest, in 1937, on July 3. Thus, in twelve years the beginning of spawning was confined to a calendar period of only eight days. We may be justified, therefore, to conclude that in Long Island Sound the beginning of the oyster spawning season should be expected on June 30 ± 4 days.

The beginning of spawning occurred at every lunar phase ranging from new moon to the last quarter. It was not related to definite tidal changes and, therefore, to the changes in hydrostatic pressure.

The earliest beginning of setting was recorded in 1941, on July 15, and the latest, in 1943, on July 23. Thus, in twelve summers the beginning of setting was confined to only about nine calendar days. Although it most often took place on July 17 we may, nevertheless, suggest that, for all practical purposes, in Long Island Sound the beginning of oyster setting should be expected on July 19 plus 4 days. The beginning of setting also happened at every moon phase and was not confined or even closely related to a definite tidal condition.

The formulae offered are based upon our observations which, I believe, are extensive enough to justify suggesting them. They should be found correct in the majority of instances but, nevertheless, we do not maintain that they should remain forever infallible. Some extremely abnormal conditions, not encountered thus far in our experience, may either hasten or retard spawning, or shorten or prolong the larval period to such an extent that the beginning of spawning or beginning of setting would take place outside the limits given in our formulae.

The setting season in Long Island Sound is of comparatively long duration. It usually extends from the third week of July to the end of September, and sometimes even to the first days of October. However, the intensity of setting

in time does not follow a rigid pattern from year to year but shows several variations. For example, in 1940 the first wave of setting was extremely heavy while the second wave was relatively light. In 1942, however, heavy setting came late in the season as part of the second wave. In 1944 setting continued almost uninterrupted during the summer but again the first wave was much heavier than the second. Finally, as in 1948, there may be two waves of setting of almost equal importance. In the latter case two distinct waves with pronounced peaks or maxima were especially well demonstrated.

The date of the peaks of setting showed no relation to the date of the beginning of spawning. In twelve years of observations the periods elapsing between the beginning of spawning and the day of maximum setting of the first wave varied from 16 to 40 days and averaged 30 days, and the beginning of the second wave varied from 47 to 66 days and averaged 56 days after the beginning of spawning. In time the date of maximum setting of the first wave varied from July 19 to August 10 and the second wave, from August 25 to September 12. These variations show that it is difficult to predict with any degree of accuracy the dates of maximum sets.

In search of signs of periodicity in the occurrence of the peaks of setting the number of days elapsing between the dates of maximum settings of the two waves of each year were determined (Table 1). The number of days for the year of 1938 is not shown in the table because the late setting in that year was a complete failure. The longest period between the two peaks was recorded in 1937, when 53 days elapsed between these two events. The shortest period of 23 days was noted in 1944. In the remaining years the period between the two peaks ranged between 28 and 38 days. Thus, as can be seen, setting of oysters not only varies in intensity from year to year but the peaks of the setting also do not show a definite time pattern.

What are the conditions responsible for the survival of larvae and, therefore, for variations in intensity and in the time of setting? Because our voluminous data are still not completely analyzed we can offer at this time only a general discussion of some factors without a complete evaluation of their importance. We hope, nevertheless, that later on, upon completion of a thorough statistical analysis of the material already available, we shall definitely establish the presence or absence of correlations between some of the ecological factors and intensity of setting.

Temperature is the first factor that always comes to mind when considering oyster propagation.

TABLE - 1

Number of days elapsing between the dates of maximum setting of first and second waves, Long Island Sound, 1937-1948

YEAR	DAYS	YEAR	DAYS
1937	53	1943	---
1938	30	1944	23
1939	36	1945	28
1940	31	1946	34
1941	38	1947	35
1942	38	1948	37

It cannot be denied that low temperature prolongs the larval period, thus exposing the larvae for several more days to their enemies and other unfavorable conditions. However, we do not think that fluctuations in temperature in Long Island Sound during any particular summer or, as recorded during different summers, may kill the larvae. The old conception that a sudden decrease in temperature of 2 or 3^{o} would kill the larvae has been disproven by our field observations (Loosanoff and Engle, 1940). Recent observations at Milford Laboratory by my colleague, Harry C. Davis, showed that if larvae kept at a steady temperature of about 22.0^{o}C. were placed directly in cold water of about 8.0^{o}C., and after being kept there for 30 minutes were again transferred back to 22.0^{o}C., they would survive this treatment, even if it was repeated several times at two-day intervals. The work of Sparck (1927) also showed that the larvae of O. edulis withstood quick cooling from approximately 20.0 to 0.0^{o}C., and were even able to survive at the latter temperature for at least 24 hours. Obviously, small fluctuations in temperature, as observed in the summer time in Long Island Sound, should not result in mass mortality of larvae.

Although temperature may affect the larvae by prolonging their swimming period or by affecting the quantity or quality of their food supply, no clear-cut relation was found between the departure of temperature from the mean during the periods between July 1 and September 30 and intensity of setting. It is interesting that the heaviest set of twelve years, which occurred in 1940, was during the year when the temperature departure was considerably below average. It is emphasized, however, that a further and more detailed analysis of our data may indicate that although no correlation between temperature and setting was noticed when long periods were considered, certain correlations may be found when the data are examined on a monthly, semi-monthly or weekly basis.

The changes in salinity in Lons Island Sound are so small that they certainly cannot be regarded as responsible for the mortality of the oysters. Roughly, our salinity range is between 25.0 and 28.0 parts per thousand. Usually the changes in salinity of the water for the

same period of the year seldom exceed 2.0 parts per thousand, and not in a single case did we find that the salinity for the corresponding week in twelve years exceeded 3.0 p.p.t. However, although these changes are not great enough to cause mass mortality of larvae they may, nevertheless, reflect on the production of the food on which larvae exist. This phase has not been thoroughly investigated as yet.

The percent of sunshine during the breeding period of oysters should also be considered as one of the factors which may have an important influence on the survival of larvae. This, of course, does not mean that intensity of light itself may kill or stimulate the growth of larvae. Its effect is largely confined to the growth of plankton forms which may serve as food for oyster larvae. Again, preliminary analysis of the data showed that in Long Island Sound the intensity of setting for the entire season was not correlated with the percent of sunshine during the period from July 1 to September 30. Nevertheless, it is possible that later on, upon a more detailed analysis, some correlation may become apparent.

Since, at present, none of the above discussed causes appears to be dominant in causing mass mortality of larvae, one, naturally, turns to look in another direction for an explanation why larvae disappear in our waters. We shall discuss two of the possible reasons, the first being extermination of larvae by their enemies and the second, death of larvae because of lack of food.

There is no doubt that a high percentage of larvae is eaten by their enemies, and that, in some cases, the presence of a large number of enemies may be the primary cause of failure of oysters to set. It is doubtful, however, that the failure of set in Long Island Sound is primarily due to that cause. Were we to assume that oyster larvae disappear because they are eaten, we would naturally expect to notice a similar disappearance of the larvae of closely related species of mollusks, such as clams, mussels, teredos, etc., which live in the same environment with oysters and have the same enemies. Our observations show that this is not the case. During several summers, including that of 1948, while oyster larvae were relatively few in number, the larvae of all ages of the clam, Mya arenaria, and of some other lamellibranchs were numerous. Furthermore, while the oysters failed to set in extremely small numbers, heavy setting of Mya and mussels continued throughout the summer. Thus, since, regardless of the presence of common enemies, the larvae of many lamellibranchs survive in large numbers to the setting stage, we should expect a similar rate of survival among oyster larvae. This, however, was not borne out by our observations.

We all know that in the southern states the fouling of shells with various organisms presents a definite problem because these organisms deprive the larvae of setting space. Most of these organisms are also larvae eaters. Furthermore, in addition to the bottom forms there are large numbers of jellyfish and other pelagic larvae-eating organisms. Yet, regardless of such a large variety and the large number of larval enemies heavy oyster sets occur rather regularly.

In Long Island Sound, on the other hand, the bottom fouling forms are fewer in species and numbers than, for example, in Chesapeake Bay or in the Carolinas. Although a few of our shells, planted in early July, may be found silted by the end of the season, very few of them would be encrusted with barnacles, ascidians, etc., as is almost always the case in southern waters. Obviously, the larvae enemies in our waters are not as numerous as in some other areas where good sets are, nevertheless, produced regularly. Thus, even if the larval period in our waters is longer than in the South, it still is improbable that the failure of our sets would be due almost exclusively to the activities of the larval enemies.

I can cite another example of the same type. In Connecticut waters the best and most consistant sets occur in the small, rather well-protected area of the Thimble Islands. The slopes of the shore of these islands are extremely heavily populated with different organisms which are plankton feeders. Large sections of the bottom are also heavily populated with larvae-eating invertebrates. Yet, regardless of such a predominance of enemies the oyster larvae there survive and set in large numbers, while the Sound proper experiences one failure after another. Obviously, if larvae enemies were the chief causes of failure of setting, the Thimble Islands area should not be a good place for the propagation of oysters.

We may conclude after the above discussion that while the importance of larval enemies is understood, and while it is recognized that the damage they do to the population of oyster larvae is rather extensive, it still seems improbable that in our waters, where the larval enemies are not as numerous as in other oyster-producing areas, failure of sets should be ascribed mainly to the activities of these enemies.

The final cause which we wish to consider in this article is that of lack of proper food for the oyster larvae. At first the suggestion that under natural conditions oyster larvae may perish from starvation in large numbers sounds highly improbable. Several years ago I would not even have considered such a suggestion because I know that, as a rule, the waters of Long Island Sound are comparatively rich in plankton. Yet, during the last few years, especially since the work on cultivation and physiology of oyster larvae was begun at our laboratory, more and more evidence is accumulating that oyster

larvae cannot utilize most of the forms of ultraplankton regardless of their small size. A more detailed discussion of this subject will be given to you by my colleague, Harry C. Davis, who did work on oyster larvae, while I shall limit myself to only a few remarks.

It has been found that the addition of mixture of laboratory cultures of ultraplankton forms measuring from 2 to 5 microns in size, thus small enough to be swallowed by the larvae, will not make oyster larvae grow. Apparently the mixture of plankton given to the larvae did not contain forms which could be assimilated by them. Yet, the same food given at the same time to cultures of larvae of other lamellibranchs was readily utilized by them. Thus, while, regardless of the presence of numerous ultraplankton organisms, oyster larvae refused to grow, the larvae of other species of lamellibranchs thrived on the same forms. This, of course, indicated the inability of oyster larvae to assimilate the ultra plankton forms which were present in the food cultures.

I think this phenomenon is extremely well illustrated by the experiment which I devised and which I asked my colleague, Mr. Davis, to perform for me. Last winter oysters and clams, Venus mercenaria, were made to spawn on the same day but in separate containers. A day or so later, after the larvae of both species had reached the straight hinge stage, we placed the larvae of the clams and oysters in the same container and began to feed them with a mixed culture of laboratory-grown food culture containing a large number of ultraplankton. Three days later the clam larvae had grown in size to 105μ while the oyster larvae were still 75μ. Five days after fertilization some of the clam larvae were already measuring 125μ, while the majority of the oyster larvae were practically at the same stage as at the beginning of the experiment. After eight days the clam larvae were over 140 while the oyster larvae were still between 75 and 80μ the majority showing no growth whatsoever. At the end of the ninth day the clams were growing very vigorously showing almost no mortality and measuring about 160μ while the oysters were dying in large numbers and those living were still measuring only between 75 and 80μ. After 12 days the clam larvae were finishing their free-swimming period and were setting in large numbers while all the oyster larvae were dead or dying. None of the oyster larvae were longer than 80μ.

Several variations of this experiment were run to be sure that the oyster larvae were not deprived of their food by the larger and more vigorous clam larvae. To achieve this some cultures were composed of a large number of oyster larvae and relatively few clam larvae. Regardless of the

ratios between the clam and oyster larvae and the ratios in number of larvae per given volume of water the results were always the same, namely, that the clam larvae grew very rapidly on the food they were given while the oyster larvae showed no growth.

Similar experiments were repeated by Mr. William Miller and me but instead of using hard shell clam larvae, the larvae of the surf clam, Mactra solidissima, were used. The results were the same - while the clam larvae grew, the oyster larvae remained approximately the same size they had reached upon entering the straight hinge stage. These experiments clearly demonstrated that oyster larvae cannot grow and survive on forms of ultraplankton which can be utilized by the larvae of other related species.

It is interesting that our observations on the food of oyster larvae are indirectly supported by a pioneer in larval culture, W. F. Wells. Wells established a hatchery at Cold Spring Harbor for the cultivation of oyster larvae but was unable to obtain any sets until the hatchery was moved to another location where the character of the water was different. Although at that time Wells did not realize the reason for his initial failure it is probable that the water of Cold Spring Harbor contained no micro-organisms which could be utilized by the oyster larvae. The new location, however, was probably rich in such forms.

Our field observations support our contention that there may be a difference in the ability of various mollusk larvae to utilize the food found in the water. For example, to any investigator familiar with the conditions in Long Island Sound it always appears peculiar that while clam larvae of all stages are almost found during the summer, oyster larvae seem to disappear within a few days after they hatch from the eggs. Is it not possible that this disappearance is due to the fact that during those periods our waters lack the food which can be assimilated by oyster larvae? Since it has been clearly demonstrated by our laboratory experiments that oyster larvae are unable to utilize many forms of ultraplankton, we are led to believe that the absence of proper food may be the cause of the failure of oyster larvae of Long Island Sound to live to the setting stage. This conclusion coincides with the opinion of Thorson (1946) who also thinks that lack of food is probably the chief reason responsible for the fluctuations of the larvae population in the sea.

Of course we still are very far from offering the final answer to this interesting and important problem. We know that in the first place it still is undetermined what forms in the plankton of Long Island Sound are utilized by oyster larvae. Secondly, the appearance or disappearance of such food forms would be very closely related to the environmental factors, such as probably

temperature, solar radiation, presence of certain nutritive substances, such as phosphates, nitrates, etc. These relations remain to be determined, and all the data should be more fully analyzed and studied. Nevertheless, I think we are now approaching the solution of the problem why the intensity of oyster sets in northern waters varies so greatly from year to year.

BIBLOGRAPHY

LOOSANOFF, V. L. and JAMES B. ENGLE, 1940. Spawning and setting of oysters in Long Island Sound in 1937, and discussion of the method for predicting the intensity and time of oyster setting. U. S. Bur. Fish., Bull. 33, Vol. 49, pp. 217-225.

LOOSANOFF, V. L., and JAMES B. ENGLE, 1942. Accumulation and discharge of spawn by oysters living at different depths. Biol. Bull., Vol. 82, No. 3, pp. 413-422.

NELSON, THURLOW C., 1928. Relation of spawning of the oyster to temperature. Ecology, Vol. IX, No. 2, pp. 145-154.

PRYTHERCH, H. F., 1929. Investigation of the Physical conditions controlling spawning of oysters and the occurrence, distribution, and setting of oyster larvae in Milford Harbor, Connecticut, U. S. Bur. Fish. Bull., Vol. 44, Doc. No. 1054, pp. 429-503.

SPARCK, R., 1927. Studies on the biology of the oyster II. The feeding and growth of the pelagic larvae of the common oyster (*Ostrea edulis*).

Rep. Danish Biol. Stat., Vol. 33, pp. 46-56.

THORSON, GUNNAR, 1946. Reproduction and larval development of Danish marine bottom invertebrates. Meddelelser Fra Kommissionen For Danmarks Fiskeri - Og Havundersøgelser, Serie: Plankton, Vol. 4, pp. 1-523.

PLANS AND PROGRESS OF OYSTER INVESTIGATIONS IN FLORIDA

-by-

Robert M. Ingle, Assistant
Director - Oyster Division,
Apalachicola, Florida.

****

The great decline in oyster production of the State in latter years prompted the 1947 legislature to appropriate $100,000.00 to begin the rehabilitation of the oyster bottoms of the State and to encourage greater harvests.

Dr. F. G. Walton Smith, Director of the Marine Laboratory of the University of Miami was made director of the newly created Division of Oyster Culture to serve without pay. Mr. Robert Ingle, shellfish researcher of the Marine Laboratory, was appointed as Assistant-Director on a full time basis. Both men were given broad powers to make rules, regulate closed seasons.

Although the money was appropriated in 1947, actual setting up of the new activity did not begin until February of this year (1949) when the above appointments were made by the newly nominated Superintendent of the State Board of Conservation, Mr. George Vathis.

Progress thus far has been mostly in setting up a research program designed to establish some of the basic facts concerning the Florida Oyster. This survey will try to throw light on such subjects as these:

(1) How long do oysters spawn within Florida waters? When do they start, quit?

(2) If there are peaks in the spawning, can they be predicted, or do they follow any regularity?

(3) What is the growth rate during each year of life?

(4) What is the length of larval life?

(5) How do the spawning seasons of competitors for setting space compare with oysters?

(6) What are the optimum eclogical conditions. What extremes of salinity, temperature, etc., can be tolerated by larvae and adults?

In order to answer these questions a broad research program has been started with the center of activity located in Apalachicola Bay. A field laboratory has been set up and equipped in one of the local seafood houses. Nine stations have been established at which fall of spat, salinity temperature, turbidity and other hydrographic data are obtained each week. In addition, growth rate of young spa is being studied and at two of the stations

the growth rate of larger size oysters is being carefully watched.

A weather station is located in Apalachicola which enables us to correlate facts obtained from the nine stations with meteorological finds such as air temperature, wind direction and intensity, precipitation.

Meteorological data for a period of thirty-five years is available to us in judging the normaley of the weather during the investigation and, hence, whether or not the findings of the investigations can be deemed typical.

In addition the U. S. Weather Bureau, maintains a river station at Blounstown, fifty miles up the Apalachicola River from the site of the investigation. Accurate data is obtainable from this station on flood stages, rate of fresh water discharge.

Thus we can surround our studies of oyster biology, especially spawning, by quantitative data on a great number of physical and chemical environmental factors, even to the amount of sunshine received by Apalachicola Bay.

This information, as it is received, is translated into constructive measures for the rehabilitation of the oyster bottoms. For instance, the discovery that spawning occurred much earlier than was anticipated has enabled us to beging the planting of cultch at an early date with the assurance that it would attract a substantial number of oyster spat.

Also, since spawning occurs in a greater density in different parts of the bay at separate time we are able to adapt our cultch planting operations to the areas which enjoy an intensified spawning during any particular week or month.

Coorelative studies are being carried out on a smaller scale in Cedar Key, Florida, a location at some distance from Apalachicola on the west coast of the State of a latitude of about 60 miles more southerly. It is expected that there might be slight differences in spawning habits of the oysters of this region due to greater temperatures on an overall, year around basis, although this contention remains to be proven. Several experimental plots of seed oysters have been planted in the waters south of the Suwanee River to ascertain which of these areas hold the greatest potentialities for oyster culture.

It will be interesting from an academic standpoint to compare the findings of this investigation with the knowledge already available on the same animal in other parts of the United States and Canada.

But more important will be the help these facts will provide in actual cultivation. In February 1949 there were only 1738 acres of oyster bottoms leased to private concerns. By consultation with interested planters and by encouragement it is hoped that this acreage can be doubled within the next year.

Closed seasons, management, (including the planting of cultch) and close observation are expected to increase the yield from natural bars.

INTENSITY AND DISTRIBUTION OF OYSTER SET IN CHESAPEAKE BAY AND TRIBUTARIES

Fred W. Sieling,
Oyster Biologist,
Maryland Department of Research & Education.

*****

The intensity and distribution of the commercial oyster set in the Chesapeake Bay and its tributaries has been studied for some years now by biologists of the Department of Research and Education at Solomons, the Fish and Wildlife Service and recently by the Virginia Fisheries Laboratory. Setting of previous years has been reported at these meetings thus only the 1947 and 1948 oyster set will be described. Obviously it is important to know what number of spat has set, so that future production plans may be formulated both for seed and marketable oysters. For the purpose of this report, the Maryland part of the Chesapeake Bay is divided into three distinct areas, each having its own particular characteristics. These areas may be defined as follows: The Upper Bay is that portion lying above Sandy Point on the Western Shore and Love Point on the Eastern Shore. The lower part of the Chesapeake Bay is divided by the ship channel into the western and eastern half. These two are quite different in their physical characteristics. The Main tributaries of the bay react as individual units and will be treated as such. The seed areas are sharply defined and have certain distinct characteristics which will be described later.

Very detailed observations are being taken on each oyster bar visited and a standard form filled in by the biologists of the several agencies working in the field. These forms have been developed jointly and all the groups working in the Chesapeake area are making uniform observations, so that information obtained in different areas can be compared accurately. In this way, there is being built up records of actual populations and the physical characteristics of the oyster bars.

Many areas are visited but once a year, so that it is important to have as complete a picture as can be made at that time. Other areas, notably seed areas, are under intensive observation and detailed information obtained at frequent intervals is available. These will be discussed in some detail later in this report.

The counts of oyster spat used in this report were made on one half bushel random samples from the oyster bar. Usually several samples were taken on each bar and the counts averaged.

Most of the Chesapeake Bay bars show a remarkably poor setting record for both 1947 and 1948. However, if the record is broken down according to areas, it will be seen that one area, the eastern shore of the Bay from Love Point to Tangier Sound had a rather consistent setting record. Several areas along this shore show setting characteristics comparable to seed areas. One such area in 1948 had a set of 743 spat per bushel on natural cultch.

The figure used in the following averages were derived by averaging only bars which were visited both in 1947 and 1948.

The average set on the eastern shore side of the Bay for 1947 was 61.2 spat per bushel and for 1948 was 15.5 spat per bushel. This figure does not include the two high setting areas visited in 1948. These counts are too low to make good self-sustaining bars. The western shore of the Bay has an even lower setting record. The average set on bars visited in both years showed a setting average of only 2.2 spat per bushel in 1947 and 3.4 spat per bushel in 1948.

The upper part of the Bay in which ten bars were visited both years showed in 1947 an average set of 5.5 spat per bushel. In 1948 this figure dropped to 0.3 spat per bushel. These figures show that the future populations of the upper and western parts of the Chesapeake Bay, barring an unusually heavy set, will be of practically no commercial value. This low setting rate combined with the low population level presents a very poor outlook for the near future of public oystering in the Bay proper. The bars mentioned are all Bay dredging bars.

In general, the 1948 setting record was even lower than the 1947 set, possibly reflecting the general lowering of the population level.

The picture in the tributaries is not good, but it is materially better in most cases than in the Bay proper. One of the large producing tributaries is the Choptank River. This area has in the past been largely self-sustaining but the population level is being gradually lowered. In 1947, the average number of spat per bushel was 28. In 1948 this figure fell to 9 spat per bushel. This set will not add materially to the production of the river. The tributaries of the Choptank are, however, rather heavy setting areas and can be expected to continue to produce.

Tangier Sound, one of the important producing areas, still has a good population of market oysters. These oysters are predominantly of the 1945 set which was excellent. This area in 1947, excluding the seed area of Holland Straits, has an average surviving set of 45 spat per bushel. In 1948, the set was slightly higher averaging 55 spat per bushel. Tangier Sound has many very excellent tributaries which are heavy oyster producing

areas and which may contribute materially to the set in the Sound. These tributaries receive good oyster sets each year and are good self-sustaining areas.

Pocomoke Sound, a fine self-sustaining area, showed a great drop in spat per bushel setting in 1948. In 1947, the record was 308 spat per bushel on natural cultch and in 1948 it was 197 spat per bushel. There is, however, an excellent population of oysters on the small area of natural rocks.

The Potomac River, excluding the tributaries, presents a rather discouraging picture as the population level is low on nearly all the major bars and it has received a very poor set during the last two years. In 1947, the average set was 10.8 spat per bushel and in 1948 the average set was only 7 per bushel. The tributaries of the Potomac River, however, present an entirely different situation. Excluding the St. Mary's seed area, the average set in the tributaries was 178 spat per bushel in 1947 and 86 spat per bushel in 1948. These records, again, cover producing bars and not shell plantings. However, there was a drop in 1948 almost proportional to the drop in setting in the Potomac River.

The Patuxent River, typically a poor setting area, continued its record of low setting with an average in 1947 of 15 spat per bushel. In 1948, the set was even lower, being 7 spat per bushel. Unlike some of the rivers, the Patuxent lacks oyster producing tributaries. The Patuxent must depend on plantings of seed oysters from the State's seed areas to maintain its bars in production. There is a low level of marketable oyster present in the population now, so the outlook is not bright for next year.

The three main seed areas of Maryland bear a rather striking resemblance in many of their physical characteristics. They are all nearly land-locked, have heavy populations of adult oysters and typically are not deep. There are many smaller potential seed areas which have not been developed and utilized but which are now excellent self-sustaining areas.

Eastern Bay is perhaps the largest potential seed area in the state. At this time only a fraction of its acreage is being used for seed purposes. It has a consistent record of heavy setting. Close study of this area is being made by the Fish and Wildlife Service. Examination of the shells planted there disclosed that the surviving set was 2002 spat per bushel in the fall of 1947. In 1948, the catch was lower, being 776 spat to the bushel on planted shells. Slag which has been planted as cultch in the Eastern Bay seed area for several years was found in 1947 to have a surviving set of 2280 spat per bushel. The 1948 planting of slag had a set of 944 spat per bushel. These counts are higher than those

on planted shells in the same area. There is however, a higher mortality in moving the spat on slag than there is in moving the spat on shells, due to the rolling of the particles of slag in the dredge which crushes the small spat. The natural oysters bars in the Eastern Bay area annually receive a good catch of spat. This area probably will be used more in the future by the State as a seed area.

Holland Straits is a large area which is not fully developed at present. It has had a somewhat more spotty setting record than Eastern Bay, but it is a good seed area. The last two years were below average in spat per bushel. In 1947, the surviving set was 153 spat per bushel and in 1948 the set was 408 spat per bushel. There is a possibility that too much brood stock is being removed and that an area should be established in which the oysters would be left to mature and breed. Such a sanctuary might, it appears, increase the average set materially. This area will be studied more closely during the coming setting season.

The area which has been studied most intensively by the Chesapeake Biological Laboratory is the St. Mary's River, a tributary of the Potomac River. This river has a consistently good setting record, but there is not a very large area available for development. The area here is much less than that available either in Holland Straits or Eastern Bay. There is an abundance of adult oysters on it which do not grow to a large size becuase, presumably, of overcrowding. The average surviving set in the St. Mary's River seed area on planted shells in 1947 was 1807 spat per bushel. This figure in 1948 feel to 788 spat per bushel. The natural bars in the river also receive a good catch of spat. Many types of experimental cultch have been tried here, including slag of three different sizes, tin scrap, broken plaster molds and porcelain insulators. Also, intensive observations of oyster setting and of fouling organisms have been carried on from June until September and weekly records of salinity and temperature have been taken.

This concludes an area by area analysis of the distribution and intensity of setting in Maryland waters of the Chesapeake Bay for 1947-1948. The year 1948 was below average for setting in most cases and in almost all cases

was below 1947 in average set of spat. As can be seen from the foregoing report, the need in Maryland is to develop the seed areas to a point where we can begin to build up the population on the now barren natural oyster bottom. The population level in the Bay proper and in many of the western shore tributaries, has reached a point where it now appears unlikely that they will return to a commercial level of production under natural conditions in this generation.

ON THE CULTURE OF OYSTER LARVAE IN THE LABORATORY

-by-
Harry C. Davis, Aquatic Biologist
Fish and Wildlife Service,
Milford, Connecticut.

****

In a study of the effects of the various conditions which the oyster larvae may encounter in nature, it is desirable to be able to maintain cultures of the larvae in the laboratory during as many months of the years as possible. Observations on these cultures will undoubtedly reveal many of the conditions responsible for the death of larvae in nature and may finally explain why the oyster set is a complete failure in certain localities in some years.

Using methods developed at Milford Laboratory for inducing gonad development out of season, it is now possible to obtain larvae almost throughout the year. During the last year larvae have been reared to the setting stage not only in summer but also in winter getting sets as high as several hundred spat per 16 liter (approximately 4.2 gallon) culture jar at either season.

The standard method for rearing oyster larvae has previously been described in detail. Briefly, it consists of changing the sea water in the culture jars, every second day, through stainless steel screens that retain the larvae. The cultures are constantly aerated and supplementary food is added daily. Our experience indicates that this offers the larvae the best conditions attainable, at the present time, in the laboratory. When more frequent changes have been made, except in rare instances, no improvement has been noted either in rate of growth or in survival of the larvae. They do not do as well if changed less frequently however, probably an accumulation of waste products causes the slower rate of growth and poorer survival of larvae noted in these cases.

In using the methods for inducing gonad development out of season and rearing larvae in the laboratory abnormal larvae were occasionally encountered. Some of these abnormal larvae were apparently due to immature eggs, obtained by induced abortive spawnings of females that were not fully ripe. In some cases such spawnings appeared to be quite normal and large quantities of eggs were released, more frequently, however, comparatively few eggs were released. If, for example, oysters were spawned after relatively short conditioning periods at temperatures only slightly above 20.0°C., the eggs sometimes developed only to the late gastrula or early trochophore stages. At these stages they became so "sticky" that they adhered to each other and to the walls of the culture jar, particularly at the water line where they normally congregate in large numbers. After 24 hours in such a culture, a gummy ring was found at the water line and all the larvae were dead. With somewhat more advanced but still immature eggs, the larvae developed

shells more or less normally but were quite small measuring only 60 to 70 μ at the 48-hour straight hinge stage.

A situation, which may have a similar explanation, was encountered with oysters from the natural beds in Milford Harbor and Long Island Sound in the summer of 1948. During the period of July 5-15 five groups of oysters from these beds were spawned with none of the five batches of spawn collected giving more than few very small straight hinge larvae, even though on July 1st and 2nd similar groups of oysters had been brought into the laboratory and spawned and the resulting larvae developed normally. Also on July 19 some of the oysters of the July 15 group spawned again and these larvae developed normally. Probably most of the oysters involved had spawned on the natural beds just prior to being brought in and possibly at the time of their first spawning in the laboratory had not again accumulated fully mature eggs.

Overcrowding the larvae in the culture jars may also result in abnormal larvae. In most cultures that contained 500 or more eggs per cubic centimeter, if the larvae developed to the shelled stages at all, the shells formed were abnormal and the larvae soon died. In some cases, however, using daily changes of water and the addition of large quantities of supplemental food, such cultures have been carried for 15 days and more, and the larvae have shown some growth.

Another possible cause of abnormal larvae is the use of sea water in which adult oysters have been kept. Eggs collected from the conditioning tanks and trays after a mass spawning usually gave a poor percentage of shelled larvae many of which were abnormal in shape. Fewer abnormal larvae are obtained when large numbers of eggs are spawned in a small vessel so that the sea water containing the eggs can be greatly diluted with fresh sea water in preparing the cultures. Parallel cultures, one of which was diluted with fresh sea water, while the other was diluted with water from an aquarium in which adult oysters were being conditioned, showed that the sea water in which adult oysters had been kept gave a much lower percentage of shelled larvae and many of them were abnormal in shape.

Regardless of the cause of the abnormality, such larvae rarely grow satisfactorily, even though the conditions causing it are later corrected and the larvae may live for several days.

Healthy larvae, however, appear to be quite hardy and capable of withstanding many of the temporary changes in the physical conditions they are

Healthy larvae, however, appear to be quite hardy and capable of withstanding many of the temporary changes in the physical conditions they are likely to encounter in natural waters. While our laboratory cultures that show the best growth are those constantly kept at temperatures of 21.0° to 23.0°C., nevertheless, oyster larvae have lived for periods up to 33 days and grown, even when subjected every 48 hours to a sharp drop from 20.0°C., to temperatures of 8.0 or 10.0° C., for periods of 15 to 30 minutes followed by an equally abrupt rise in temperature back to 20.0°C. In fact some of these larvae lived and later set after being returned to constant temperature conditions at 21.0° to 23.0° C. It would seem unlikely, therefore, that the ordinary fluctuations in temperature occurring in natural waters could directly account for any appreciable mortality of larvae. Loosanoff and Engle (1940) in their study of spawning and setting in Long Island Sound observed that larvae lived and set at temperatures ranging from 16.6° to 28.0° C., and likewise concluded that oyster larvae can withstand rather drastic changes in temperature.

Larvae are also apparently able to tolerate very low dissolved oxygen values, at least for short periods. For example, on one occasion a number of healthy larvae was accidentally left overnight in a small pipette of sea water, yet these larvae were found to be alive and healthy next morning although the oxygen content of the water must have been almost completely exhausted.

In another case a large oyster larva of setting size failed to get washed from a screen during a change of sea water only to be found alive and healthy after a six-hour exposure to air.

There is considerable evidence, however, that larvae of our Eastern oyster, Ostrea virginica, do not utilize as wide a variety of foods as do larvae of the hard clam, Venus mercenaria, or the Olympia oyster, Ostrea lurida, and that food is the limiting factor in the growth of our oyster larvae, at least in laboratory cultures.

Although an occasional culture of our Eastern oyster larvae has been grown to the setting stage without supplemental food, in no case have we been able to get larvae of the hard clam to grow under similar conditions. Nevertheless, any of several mixed plankton cultures serves quite well as supplemental food for clam larvae, while with oyster larvae, on the other hand, only occasionally have we been able to get a mixture that the early larvae can utilize. It is interesting that none of the pure cultures of green flagellates, colorless flagellates, or algae tried to date has given as good a rate of growth with either oyster or clam larvae, as do the mixed cultures.

That clam larvae do utilize foods that the oyster larvae cannot has been demonstrated by mixed cultures of clam and oyster larvae in which their living conditions must be the same. Supplemental foods were used that permitted the clam larvae to grow normally and set in the regular 12 to 14-day period. The oyster larvae, however, grew very little or not at all, and eventually died. These results were not due to the clam larvae, which are larger, robbing the oyster larvae of food since the results were the same even when only a half dozen or so clam larvae were present in the mixture. Similar results were also obtained using parallel cultures of clam and oyster larvae that received the same food.

The fact that cultures of clam larvae can regularly be reared to the setting stage, while many of our cultures of Eastern oyster larvae cannot appear to be due solely to the ability of the clam larvae to utilize a much wider variety of supplemental foods.

Likewise, larvae of our Eastern oyster cannot utilize foods that larvae of the Olympia oyster can use. Cultures of the Olympia larvae have been reared to the setting stage, while parallel cultures of our Long Island Sound larvae receiving the same food grew very slowly, with one culture all dead in 10 days, the second culture almost all dead at 15 days and the remaining culture showing a very wide range of sizes, from 75μ straight hinge larvae to medium umbo stages, by the time the Olympia larvae set.

In laboratory cultures, at least, food seems to be the limiting factor in the growth of oyster larvae. While occasional cultures have been reared to the setting stage merely by changing the sea water every 48 hours, throughout most of the year supplemental feeding is ncessary.

Evidence that it is lack of food that limits the growth in our cultures of oyster larvae was obtained from parallel cultures one of which received supplemental food while the other did not. Most of the cultures in which the larvae reached the setting stage were those that received supplemental food, and in most cases larvae in the parallel unfed cultures grew very little and eventually all died. In many cases, of course, both cultures grew very little and died in about 10 days, apparently becuase the supplemental foods used in those cases were not utilizable by the oyster larvae.

Another indication that it is lack of proper food that prevents many of our cultures of oyster larvae from growing is that it is possible to duplicate, with clam larvae, the slow rate of growth, wide variations in size and high mortality, so characteristic of many

of the cultures of oyster larvae, merely by supplying insufficient quantities or the wrong type of food to the clam larvae.

Finally, it is difficult to conceive any other factor than lack of proper food that would so prolong the free-swimming period of our Eastern oyster larvae while by using the same techniques hard clam larvae and Olympia oyster larvae are regularly reared to the setting stage in relatively normal time. Although in one experiment our Eastern oyster larvae were reared to the setting stage in 23 days, in most cases it required 36 to 40 days for the larvae to reach the setting stage, and in a culture from eggs spawned January 6 it required 50 days for the first larva to reach the setting stage, the most profuse setting was between the 52nd and 54th days and some setting continued until the 60th day.

Two conclusions, therefore, seem warranted - first, that our Eastern oyster larvae are not able to utilize as wide a variety of foods as can the larvae of the hard clam or the Olympia oyster, and second, that it is food, at least in laboratory cultures, that is the limiting factor in growth of oyster larvae.

Preliminary experiments are in progress to explore the possibilities of interspecific hybridization. On several occasions active Olympia sperm have been added to unfertilized eggs of our Long Island Sound oysters but fertilization did not occur. Such eggs held for as long as eight hours showed no evidence of fertilization. In some instances active sperm from our Eastern oysters were added two or more hours after the addition of the Olympia sperm and in such cases fertilization by the Eastern oyster sperm and the subsequent development of the eggs was equally as good as for unfertilized control eggs held for similar periods before the addition of Eastern sperm. The Olympia sperm, therefore, probably does not even enter the egg of our Long Island Sound oyster since it does not cause the formation of a fertilization membrane nor does it interfere in any way with the fertilization by Eastern oyster sperm.

Although crosses have been made between the Eastern oyster and the Japanese oyster, Ostrea gigas, and between the Eastern oyster and the Kumamoto oyster (probably a variety of O. gigas) and reciprocal fertilization is obtained, no conclusions can be drawn as to the viability of the resulting larvae. The adult Japanese and Kumamoto oysters were shipped to us from the State of Washington in the fall and apparently had not spawned in the Washington waters last summer since all were found to contain large quantities of spawn. Although some of these oysters were induced to spawn and their eggs and sperm used in the crosses, we are in some doubt that such spawn was normal. Hence, in

those cases where the larvae did not live, it remained undetermined whether it was an incompatibility of sexual products or simply the poor condition of the held-over spawn that caused the mortality. Even at the present time many of these oysters have not yet resorbed the old spawn and so cannot be induced to develop new gonads.

S U M M A R Y

It is now possible to obtain oyster larvae, in the laboratory, throughout most of the year and to rear the larvae to the setting stage both in winter and in summer.

In general, healthy larvae are quite hardy and can withstand at least temporary exposure to such conditions as low temperatures, low oxygen content of the sea water, and even exposure to short periods of drying.

It appears, however, that food is the limiting factor in the laboratory culture of oyster larvae and that supplementary feeding is required during most of the year. The ability to supply the proper food determines the success of rearing them in the laboratory. That larvae of the Eastern oyster, *Ostrea virginica*, are unable to utilize foods that some other larvae can use has been shown by comparative feeding experiments.

Preliminary studies to explore the possibilities of interspecific hybridization show that the Olympia oyster, *Ostrea lurida*, will not cross with the Eastern oyster but that the Japanese and Kumamoto oysters (varieties of *Ostrea gigas*) are capable of reciprocal fertilization with the Eastern oyster. Tests of the viability of the larvae from these latter crosses have not been concluded.

THE OYSTER INDUSTRY OF NORTH CAROLINA AND SOME OF ITS PROBLEMS.

A. F. Chestnut,
Institute of Fisheries Research,
Morehead City, N. C.

*****

According to the available statistics, North Carolina has maintained a rather modest position in oyster production over the past fifty years. In 1940, for example, it was third or fourth from the bottom of the list of oyster-producing states along the Atlantic and Gulf coasts. Since 1930 production has only twice exceeded 500,000 bushels in a single season. At least four surveys have been made of North Carolina waters concerning the possibilities of oyster culture (Winslow, 1886; Grave, 1904; Coker, 1907; Galtsoff and Seiwell, 1928). Each survey appears to express the opinion that potentialities exist for a great industry. However, the industry has been slow to develop, and the oyster continues to represent one of the great undeveloped natural resources of the state.

The oyster-producing areas are located in the numerous sounds of the state, bound on the ocean side by the so-called "banks", making these sounds almost landlocked bodies of water. Albemarle and Currituck Sounds are considered too fresh for oysters. Oysters are found growing from Roanoke Island to the South Carolina border. Pamlico Sound produces the bulk of the oysters marketed in the state. This is not surprising when we consider that this body of water with approximately 1, 100,000 acres is seven times greater than Roanoke, Croatan, Bogue and Core Sounds combined. Pamlico Sound, some seventy miles long by thirty miles wide at its greatest length and breadth, is a relatively shallow body of water averaging 18 feet in depth, with the greatest depth at 25 feet. Several shoals extend from the mainland into the sound. Brant Island Shoal with a depth of 2 to 8 feet extends in a northwest-southeast direction about half way across the sound. Bluff Shoal extends in a north-south direction from the northern shore of Pamlico Sound with a depth of 7 to 11 feet overlying the shoal. It merges into Royal Shoal which extends to Ocracoke Inlet. The bottom of Pamlico Sound varies from mud to hard sand with the mud bottom confined chiefly to the channels of the various tributaries. The salinity in the immediate vicinity of the inlets averages about 30 parts per thousand, progressively diminishing toward the mouths of the Pamlico and Neuse Rivers on the western side of the sound. The currents are determined largely by the winds, and the tidal fluctuations are found in the vicinity of the inlets.

Winslow (1886) estimated 10,000 acres of natural beds for the state with 7,700 acres located in Pamlico Sound. Ten years after Winslow's survey, extensive beds were discovered in Pamlico Sound about two miles off shore in deeper water. Grave (1904) states that some beds surveyed by Winslow in Hyde County had increased in area due to extensive dredging and estimated the natural beds in this county from 18,000 to 36,000 acres in 1900. No recent surveys have been made, but many of the areas surveyed by Winslow were found this past year to be productive. Occasional reports are received from shrimp trawlers that beds are located in the lower south-east Pamlico Sound Area. A survey is planned of this area in the near future.

The oyster industry of North Carolina became of importance in 1889 when decreased oyster production in the Chesapeake region led to the establishment of branch houses in the coastal areas. It is of interest that the oysters processed at the time were shipped to Baltimore and sold as Chesapeake oysters. This still exists at the present day. Many oysters are shucked, packed and reshipped by Chesapeake dealers.

Within the past few decades some changes have occurred in the area. The hurricane of 1933 opened twenty-eight inlets between Beaufort and Ocracoke Inlets and completely ruined the oyster beds at Harbor Island. Most of the new inlets have closed except Drum Inlet. The salinity in the vicinity of Drum Inlet has increased to over 30 parts per thousand as compared to an average of 23 parts per thousand reported by Galtsoff and Seiwell (1928). Clams are now abundant in an area where oysters were produced in marketable quantities.

More oysters are being shipped out from shucking houses instead of in the shell. Since 1946 at least 35 new shucking houses have been constructed. These are modest but clean, efficient plants, a marked contrast to the sheds of past years. According to Mr. Caldwell, chief sanitarian, the trend has been toward smaller plants located as near as possible to the oyster-producing areas, instead of larger houses near a railroad center. This past season there were 63 shucking houses in the state, with 28 certified for inter-state shipping. Twenty-five shucking houses are located in the Pamlico Sound area. Two steam canneries operated last season, utilizing the "coon" oysters from the Baufort Inlet area.

Regulations requiring dredging with sail power and limitations on sizes of vessels were repealed in 1948. Heretofore, vessels over 32 feet in length were required to dredge with sails.

The legislature of 1947, upon the recommendation of a committee appointed by Governor Cherry, passed a law imposing a tax of 50¢ on every bushel of oysters going out of the state in the shell. Attempts to repeal this measure were defeated during the 1949 session. Opponents of the tax believe that North Carolina could be developed into an important seed-producing area and believe that such a tax is hindering this program. There are areas where an abundance of seed could be procured in Bogue, Core and Pamlico Sounds. A question arises whether the available seed be used within the state to maintain and encourage the industry or be allowed to leave the state. There may be sufficient for both purposes. The legislature of 1947 also passed a regulation specifying the return of 50 percent of the shells accumulating at the shucking houses, thus inaugurating a definite shell-planting program. A tax on oysters harvested from the natural beds was increased from 4 to 8¢ per bushel. The increased revenue is to aid in meeting the expenses of shell plantings. In 1947, 63,258 bushels of shells were planted. In 1948, this amount was increased to 95,919 bushels. In 1949, 119,517 bushels of shells were planted as the state's quota with an additional 34,000 bushels of shell purchased. Ten thousand bushels of seed oysters were transplanted as an experimental procedure in three counties.

The private leasing of grounds for oyster culture has been emphasized since the time of Winslow's survey in 1886. This supposed solution to the problem of increased oyster production and development of the industry has not been too popular. Leasing of bottom is permitted within the state with limits of 50 acres in the tributaries and 200 acres in Pamlico Sound. However, the counties of Hyde and Pamlico prohibit leasing of bottom. There are at present but 3,232 acres under lease. The majority of these grounds average ten acres and are used to raise oysters for family use or to supply oyster roasts. These leased areas are found chiefly in the tributaries of Core and Bogue Sounds.

Many factors appear to favor North Carolina as an oyster-producing area. There is an abundance of seed in some areas. Potentialities exist in Core and Bogue Sounds for greater utilization and development of oyster seed. The quality of oysters is, in general, good and can compare favorably with oysters from other areas. The fact that North Carolina oysters have since 1890 been sold as Chesapeake oysters cannot be overlooked. North Carolina is situated about in the geographical center of the extreme ranges of the eastern oyster. Weather conditions favor rapid growth, making it possible, in some localities, to produce a marketable oyster in two years. The numbers of enemies are not as great as in other oyster-producing areas; Pamlico Sound is

virtually free of predatory enemies. The boring sponge, Cliona, does not cause damage to oysters in North and New Rivers. In the upper regions of Middle Bay and Caffee Bay the shells of all oysters examined, over two years old, were heavily riddled with sponge. Polydora is prevalent in widely separated localities with heavy infestations in the oysters growing on the shoals at Ocracoke Inlet. Mussels (*Mytilus recurvus*)cover oyster to form large masses in the head of Jones Bay, Swanquarter Bay and other localities. Industrial and domestic pollution are of minor consequent in Pamlico Sound. Over 27,000 acres of shellfish-producing area were restricted in North Carolina because of pollution during the 1948-49 season. However, there were no areas closed in Pamlico Sound during the same season due to pollution.

The Institute of Fisheries Research is acting in an advisory capacity to the North Carolina Department of Conservation and Development in the rehabilitation and development of the industry.

GROWTH OBSERVATIONS OF OYSTERS HELD ON TRAYS AT SOLOMONS ISLAND, MARYLAND

G. Francis Beaven

Oyster Biologist
Maryland Department of Research and Education

It is a common observation that oysters growing on different bars may differ widely in rate of growth. Deepness of the cupped shell, ratio of length to width, and general appearance also may differ markedly. The reasons for slow rates of growth are not always apparent. On some of Maryland's seed areas, few oysters reach legal size even when six or more years old. This condition might be attributed to crowding. However, the most rapid growth observed in Maryland's portion of the Chesapeake area occurred in upper Pocomoke Sound where a very heavy set on shell plants produced many individuals around 3 inches in length by late fall of the year when they set, and numerous 6 inch oysters by the second fall. Crowding caused these oysters to be rather elongated but they had good meats with shells so thin they often broke in two at the muscle when shucking. The slow growth characteristic of oysters on the Head of the Bay bars probably results largely from frequent periods of low salinity when little if any feeding activity occurs. It is difficult, however, to correlate a higher rate of growth with increased salinity. In Chincoteague Bay, where salinities normally are just under 30°/00, growth was extremely poor in 1945 and exceptionally fast during 1948-49.

Numerous measurements of State transplanted seed were made from 1943 to 1946 using random samples of about 400 individuals. Seed from St. Mary's River transplanted to the upper Patuxent increased from a length of 28 mm. in April, 1944 to 83 mm. in October 1945 when the bar was opened, a gain in length of 196%. Holland Straits seed planted in three different bars in Tangier Sound all grew rather uniformly with an increase from 36 mm. in April 1944, to about 69 mm. in September 1945, a gain in length of only 92%. Yearling seed oysters grew 151% faster in length in the Upper Patuxent River than in Chincoteague Bay during 1944-45, but grew 26% faster in Chincoteague Bay than on a mid-Patuxent River bar during 1946. Similar wide variations have been observed among other State planted bars where growth of the seed was followed. Obviously varying environmental conditions play a very important part in the growth and condition of oysters. Among the factors which may influence growth are variations in salinity, temperature, turbidity, species of food organisms, abundance of food organisms, current flow, bottom texture, toxic organisms such as those producing the red tide, organisms competing for food, or-

ganisms competing for food, organisms competing for space, pollution, natural decomposition products and others.

Oyster planters often report that seed from one area will grow faster than that from another and that survival also may vary. Dr. Nelson has postulated that enforcement of a three inch cull law may tend to produce a slower growing race of oysters by returning the runts or "dumpy" oysters to the bars where they form an increasingly higher proportion of the brood stock. Dr. Korringa has stated that the Dutch have produced a faster growing oyster in Holland than the same species grown along the coast of France by putting back the faster growing individuals as brood stock. In areas of intensive setting such as along the Gulf, portions of the South Atlantic Coast, and certain seed areas further north, the older oysters are quickly covered over and smothered out by the younger set with only the fastest growing individuals able to survive. Such conditions would seem favorable to a natural selection of a quick growing race of oysters.

Observations of growth on various plantings such as the ones previously quoted are so influenced by environmental factors that it is difficult if not impossible to evaluate the effect of any inherent tendency towards a rapid or slow rate of growth. Measurement by random sampling of a planting may have considerable error and possesses the further disadvantage that a given group or year class tends to lose its identity after the second year. By following the growth of the same individuals held on a tray, or identified in some other manner, a much more accurate record of growth and mortality may be obtained. This method has been followed by a number of observers. Dr. Loosanoff measured the length, width, depth and volume of marked groups of oysters and determined the decreasing rate of growth with age under conditions prevailing in Long Island Sound at the time of the experiments. (Southern Fisherman, January, 1947). He later compared the survival and growth of Maryland Eastern Bay seed with the native Long Island Stock and reported that the Maryland set grew somewhat slower but survived better than the natives, (Oyster Institute Bulletin, February 7, 1949).

In an attempt to throw additional light on the question of whether or not oysters from certain areas may possess inherent characteristics favoring their growth and survival under given conditions, batches of oysters from various areas were planted at Solomons under as nearly the same environmental conditions as practicable. During early observations, difference in survival and growth can be expected to occur as a result of the extent to which the oysters must become adjusted to a different environment. Data accumulated over a number of years, however, should afford an indication as to the presence and extent of inherent characteristics. Practical

value of the results of such observations lies in the designation of those seed sources from which oysters do best when transplanted to typical Maryland conditions. If seed from certain areas should show superior growth and survival characteristics then effort can be made to establish them as brook stock in the state seed producing areas.

All oysters in these experiments have been grown on trays of the Sea Rac type placed on the bottom under the Laboratory pier in the Patuxent River. Depth of water over the trays is about four feet, the trays being placed side by side in a line extending at right angles to the shore and with a comparatively weak tidal current flowing across them. All oysters were placed by hand at a slight angle leaning on the left valve with the bills up. This position insures a uniform exposure but seems to have produced a somewhat more elongate oyster than those grown flat down on the left valve. Tidal amplitude averages 1.2 feet and salinity approximately $14^{0}/00$ varying from a normal of about 11 in late spring to 16.5 in the fall. Considerable variations from normal may occur from year to year.

The initial plantings consisted of groups of 500 oysters divided between two trays. Later plantings have employed somewhat smaller numbers. Each tray had 2 x 4 timbers wired to its bottom to prevent settling. These timbers were abandoned after the first year since it was found that they were destroyed by shipworms in one season and no apparent difference resulted from resting the trays directly on the bottom. Measurements of the length and width of each oyster were made, usually at bi-monthly intervals. Depth was not measured because the difficulty encountered with fouling organisms and erosion of the shell made it impractical to attain sufficient accuracy where so many animals are measured. Boxes were measured and a correction for their size was applied to the preceding measurement since it was observed that typically those which died had made little or no recent growth. Occasionally a few individuals disappeared from the trays and could not be accounted for. The series under observation was added to in 1948 and again in 1949. Similar plantings have been started in a prong of the Maryland portion of Chincoteague Bay.

Growth and mortality curves for the various groups have been plotted. The patterns of growth at Solomons during 1947, 1948 and the spring of 1949 have been somewhat different. Growth during the spring of 1947 was good but levelled off with little or no growth occurring during July and August. Rapid fall growth followed. The interval between late fall and early spring measurements was too great to show any cessation of growth during the winter months. Growth during the spring of 1948 was again rapid and of an

open frilly nature with the thin growing edges somewhat reflexed. This growth period was followed by an upturn in mortality particularly among one group of local seed. During the summer months much of this growth eroded away so that the oysters generally dropped back in both length and width. Very good fall growth then followed and continued through December. During January and February of 1949, a moderate recession in growth again occurred. This spring the new growing edge or bill remained back within a fold of the old growth so that the overall measurements up to early May had failed to increase and in some cases dropped back slightly. The oysters, however, were in good condition and the new growing edge was about even with the margin of the older growth.

Ratio of length to width of tray grown oysters has tended to approach 1.5 with young round shaped oysters showing an increasing, and long coon-type oysters a decreasing ratio. In comparing the groups, the product of the length in millimeters times the width in millimeters was selected as the most satisfactory index of growth from the available data. For the purposes of this paper detailed growth during the year will not be shown.

Table 1 gives the late spring, early fall and winter length measurements of selected groups of seed. It compares two groups of similar size composition which show the more marked differences in growth. These also illustrate the greater fall growth as compared with spring growth, the very poor summer growth of 1948 and the lack of growth this spring. Average length by age groups is quite similar to that given by Loosanoff for Long Island Sound.

To illustrate that environmental and seasonal differences may affect growth to a much greater extent than is apparent between the different groups growing together at Solomons, the lengths of oysters in a tray planting in Chincoteague Bay and in an older seed planting in the Patuxent River are given.

TABLE 1

LENGTH IN MM. OF TRAY GROWN SEED

Source	Dominant year class	May '47	Sept. '47	Winter	May '48	Sept. '48	Winter	May '49
(Holland Straits	1945-46	46	55	70	73	75	84	85)
(Maurice River	1945	48	53	65	68	68	73	72)
(Gull Rock	1944-45	67	71	84	86	86	92	92)
(Mullica River	1944-45	67	67	77	79	79	83	83)
Fishing Bay	1945 planted in Chincoteague Bay				73	102	112	118

LENGTH IN MM. OF RANDOM SAMPLES
OF PATUXENT PLANTING

Seed from shell plants in	Year class	April '44	July '44	Dec. '44	July '45	Oct. '45
St. Mary's River	1943	27	43	71	74	83

(marketed in 3rd year)

Tables 2 and 3 show the growth of all groups started on trays in 1947 and 1948 as indicated by the product of length and width for one year periods. The cumulative per cent of mortality observed is also given. It will be noted that the mortality of established oysters during the second year is less than during the initial year. Higher mortality generally occurred among oysters transplanted from waters of greater salinity and among those of the smaller sizes. The best survival at Solomons, 5% mortality, has been among Gull Rock, N. C., seed, which were of comparatively large size and from water subject to periods of fairly low salinity. The greatest mortality, 58.4% was among the Long Island Sound Oysters from waters of a comparatively high and stable salinity. The seed transplanted from Chesapeake salinities of around 12 to a portion of Chincoteague Bay, where salinities range from 20to 30 have shown better survival and growth than any of those planted at Solomons.

TABLE 2

GROWTH AND MORTALITY OF SEED OYSTERS
PLANTED AT SOLOMONS IN MAY, 1947;
SIZE EXPRESSED AS MM. LENGTH X MM. WIDTH

Source of Seed	Initial Size	Size in 1 year	% Mort. 1 year	Size in 2 years	% Mort. 2 years
Gull Rock, N. C.	2993	5047	2.8	5450	5.0
Mullica River, N. J.	2846	4289	7.0	4442	12.6
Milford, Conn.	2745	4599	40.8	4701	58.4
St. Mary's River, Md.	2623	4327	22.8	5236	26.2
James River, Va.	2594	4230	9.8	4410	13.4
Delaware River, N.J.	2094	3625	14.0	3982	23.2
Maurice River, N. J.	1649	3261	16.4	3484	20.4
Holland Straits, Md.	1584	3793	6.2	4901	15.0
Eastern Bay, Md.	1348	3410	15.4	4339	17.4

TABLE 3

GROWTH AND MORTALITY OF SEED OYSTERS
PLANTED AT SOLOMONS IN APRIL-MAY, 1948

Source of Seed	Initial Size	Size in 1 year	% Mortality 1 year
New Haven, Conn.	3673	4095	27.6
Edisto River, S. C.	2954	3566	14.9
Green Point, L. I.	2834	3575	37.0
New River, N. C.	2047	2860	25.7
Beaufort, N. C.	1906	2322	22.0
Delaware River, N. J.	1213	1667	41.6
Eastern Bay, Md.	431	1678	48.6
Seed planted in Chincoteague Bay			
Harris Creek, Md.	4054	8503	5.0
Fishing Bay, Md.	3885	8646	2.8

Duration of the experiment has been too brief to furnish conclusive evidence as to whether or not significant differences in growth exist among the groups of surviving oysters after adjustment has been made to the environmental conditions prevailing at Solomons. That initial differences in growth and mortality are evident has been pointed out. Seed from the local state seed areas and that from Gull Rock, have thus far proven superior for planting under local conditions. However, differences in growth among individuals within a group have been observed to be much greater than those among the group averages. A greater or less number of runts which have made little noticeable growth during the period of measurements has been present in all groups.

The two plantings in Chincoteague Bay shown in Table 3 present an interesting feature in that the Harris Creek seed are native to water which is typically clear and seldom roiled by wave action while the Fishing Bay seed are from a shallow water area frequently roiled by wave action rendering the water rather turbid and silt laden. The latter condition of the water is very pronounced over the soft textured shoals of Chincoteague Bay. Although both groups have made very rapid growth, the ones native to turbid water have done somewhat better in both growth and survival.

These observations in general offer some indication that oysters which have grown for many generations in a given environment may thrive somewhat better in that or a similar environment than will stock transplanted from areas where different conditions prevail. This does not preclude the

assumption that sparsely populated bars where reproduction is slow may have a larger proportion of adult runts or dumpy oysters due to the lack of their elimination through competition. Also, it may be found that certain areas have developed a population which will thrive better when transplanted to a similar habitat than do the oysters native to it. Plantings made this spring have included seed from areas of the Gulf Coast. Future plantings of oysters that have demonstrated rapid growth in their native habitats are plannted.

FISH AND WILDLIFE SERVICE

CLAM INVESTIGATIONS

John B. Glud

Fishery Research Biologist
U. S. Fish and Wildlife Service

The Clam Investigation was authorized by Public Law 556 of the 1948 Congress which was sponsored by the Atlantic States Marine Fisheries Commission and which reads as follows:

("Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,) THAT, the Fish and Wildlife Service of the Department of the Interior is hereby authorized and directed to undertake, in cooperation with appropriate State and interstate agencies, comprehensive studies of the soft-shell clam, *Mya arenaria*, and the hard-shell clam, *Venus mercenaria*, with particular respect to the biology, propagation, and methods of cultivation of such clams. Such Service shall from time to time recommend appropriate measures for (1)arresting depletion in existing productive beds; (2) restoring to production beds formerly productive but now barren or unusable; (3) developing new areas which may be found suitable; (4) improving methods and techniques of digging, transplanting, and handling; and (5) otherwise increasing production and improving the quality of such clams for the benefit of both producers and consumers."

The first step in planning this five year investigation was a survey of the problems in each area along the entire Atlantic Coast. Conferences were held with representatives of the industry, state conservation departments, universities. Particular thanks are due the clam specialists committee of the Atlantic States Marine Fisheries Commission for their valuable guidance in establishing this Program. The results of this survey were used to establish a research program which would attack the most urgent problems in each area to provide the greatest benefit to the industry and to the agencies charged with the responsibility of conservation of this natural resource.

For practical purposes the Investigation has been divided into two parts: (1) Soft-shell Clam Investigation north of Cape Cod; and (2) Hard-Shell Clam Investigation south of Cape Cod. Apologies are hereby made to the Rhode Islanders who like to call their hard-shell clams quahaugs and to the Southerners who like to call their soft-shell clams "long necks" or "mannanoses."

SOFT CLAM INVESTIGATION:

The State of Maine has great quantities of soft-shell clams and an intense commercial fishery. The principal problem of the State of Maine Sea and Shore Fisheries Commission is the management of this fishery so that it shall not become depleted. In places the digging can be greatly increased, in other places it must be curtailed if the industry is to continue.

FISH AND WILDLIFE SERVICE RESEARCH PROGRAM IN MAINE:

Boothbay Harbor has been selected as headquarters for the Clam Investigation as laboratory facilities are available there and also as it is about the center of the soft clam producing area. Three biologists are stationed there at the present time and two bays have been chosen for study to develop methods for management of the clam fishery. These two bays, Sagadahoe Bay and Robinhood Cove, are located at the south and north side, respectively, of Georgetown Island. Sagadahoe Bay is a wide, flat, sandy bay, facing the open ocean. Low tides expose an area of flats three-quarters of a mile long and half a mile wide. From six to twelve diggers work in this area during the Winter and twenty to twenty-five during the Summer. Robinhood Cove which opens at the north side of Georgetown Island is a long, narrow, deep bay with rather steep muddy banks. A relatively small area is exposed at low tide but the shore line is about seven miles long and clams are quite abundant. The same men dig in both Robinhood Cove and Sagadahoe Bay are sell their catch to one or two clam buyers. These buyers have kept daily records of the number of bushels each man has dug for the last three years. They will give us these records and will continue to keep them for us in the future which will enable us to determine catch per unit of effort, or bushels per man tide in both areas.

Each bay will be handled as a separate management problem to determine the amount of clams which can be removed each year without depleting the stock. To determine this we must first learn how fast the clams grow and how many clams are now present in the bay. We must determine how many young clams are added each year by setting and how many die of natural causes, such as predators, silting, freezing, disease, or old age. We have to know how many small clams are killed by the commercial digging and how many eggs are produced by clams of different ages and sizes.

Balancing all of these factors will tell us the amount of clams which can be removed safely each year. This figure

will be compared with the actual production from records kept by the clam buyers. The clam population census will be taken twice each year to check the accuracy of our predictions. We may find, for example, that the diggers are removing fifteen thousand bushels per year when our estimate of sustained yield is ten thousand bushels per year. A decline in the abundance of clams over a period of several years would confirm our predictions that too many clams were being removed.

These studies will also enable us to determine the extent of natural fluctuations in abundance which can then be compared with the changes in abundance caused by digging. These investigations are being conducted jointly by the State of Maine Sea and Shore Fisheries Commission and the Fish and Wildlife Service as pilot plant studies of the management problem. When methods have been perfected the State of Maine will be able to apply these techniques to all of her coast line.

In addition to the management studies at Sagadahoc Bay and Robinhood Cove other problems of mutual interest to the industry, the State, and the Service will be investigated, such as methods of clam farming, cause of "water belly", effect of thinning stunted clams, methods of catching seed clams, best time and methods of transplanting seed, etc.

NEW HAMPSHIRE AND MASSACHUSETTS:

The story of the disappearance of the soft clam in New Hampshire and Massachusetts has received much publicity and is responsible in a large measure for the present investigation. Flats which formerly supported three hundred fifty to four hundred diggers now support thirty-five. Areas which were once productive are now barren. Sewage pollution has closed many of the best areas. The problems in Massachusetts are varied because of the different environmental conditions. Management of the fishery by closed areas and seasons and catch limits seems ineffectual where depletion has become so serious. Farming of soft clams, using methods similar to those developed in Japan, may be a partial answer. Town planting programs may provide enough clams for tourist digging. Perhaps eventually a combination of private farming, town planting for tourist digging, and a managed commercial fishery will solve the problem.

FISH AND WILDLIFE SERVICE MASSACHUSETTS PROJECT:

The Parker River Wildlife Refuge near Newburyport has been chosen for the location of clam research in Massachusetts. Plum Island Sound, resulting from the estuaries of

the Ipswich, Parker and Plum Island Rivers, was once a center of clam production and still has great potentialities. Most of this area is free from pollution and lies within the Refuge where experimental plots are easily protected.

An office has been established at Newburyport and three biologists are stationed there. Arrangements have also been made for cooperative studies with Harvard University in this area.

The Newburyport Unit will establish experimental clam farms and determine their commercial practicability, Spawning and setting of the larvae will be followed to develop methods of obtaining seed clams. Growth rates and mortality of the young clams will be determined. The effects of predators and means for their control will be studied.

In addition, investigations will be made to establish the reasons for the decline in abundance of clams. Past catch records from the town shellfish wardens and the diggers themselves will be obtained to determine if overdigging can account for the decrease or if it could be a periodic fluctuation as some believe. Observations of areas closed because of sewage pollution should yield some valuable information concerning changes in abundance where there is no commercial fishery. The Joppa Flats, at the mouth of the Merrimack River, are full of large clams but have no small ones. This may indicate that no setting has occurred during the last three years or that some unfavorable condition has killed the smaller clams. Spawning and setting will be studied here during this Summer to determine if reproduction is normal.

All of this work will be in close cooperation with the Woods Hole Oceanographic Institution project at Barnstable and the Shellfish Program of the Marine Fisheries Division of the Massachusetts Department of Conservation.

HARD CLAM INVESTIGATIONS:

The great range of *Venus mercenaria* from New England to Florida and the variety of conditions under which it exists makes the selection of sites for research very difficult. Eleven states are involved and each would like to have a project located within its borders. The limited appropriation makes it necessary to concentrate the work in a few representative areas where the most valuable results can be obtained. Cooperative studies with State Conservation Departments and universities are planned to utilize existing research facilities as much as possible.

NEW JERSEY:

The extensive hard clam fishery of New Jersey, plus the research project of Dr. Thurlow Nelson and his group at Rutgers University, present many opportunities for joint studies. A cooperative agreement has been established between Rutgers University and the Fish and Wildlife Service to facilitate research on quahaugs in this State. During the Summer of 1949 two graduate students will be assigned to work with Dr. Nelson's group on certain phases of the problem. (1) One man will try to develop methods of obtaining seed clams from natural reproduction. We know that clean shells placed in the water at the proper time will catch oyster spat, but how can we catch clam spat? Until methods of obtaining seed clams are developed commercial clam farming can never be feasible. In Japan loosely woven palm fiber matting is hung in the water and the ark-shell clams attach as heavily as fifteen hundred per square foot. Maybe similar methods will be successful here with the hard shell clam. Perhaps changing the character of the bottom in certain places like the Woods Hole Oceanographic Institution is doing at Barnstable will induce setting of quahaugs also. It may be possible to locate areas where natural setting is very heavy and where seed clams can be strained from the sand. These are the possibilities that one of the biologists at Rutgers will explore this Summer.

(2) The other graduate student working with Dr. Nelson's group will investigate the basic problem of identifying the organisms used as food by hard clams in New Jersey waters. This information is necessary for a complete understanding of the growth rates in different areas.

VIRGINIA:

A preliminary survey of the clam fisheries of Virginia has been made and conferences have been held with the biologists of the State Fisheries Laboratory. Cooperative

studies are planned for the future and it is expected that the results of clam farming experiments can be adapted for use along the Eastern Shore.

NORTH CAROLINA:

A preliminary survey of the clam fisheries of North Carolina was made during February. Plans have been made to base Southern Clam Research at the Beaufort Laboratory of the Fish and Wildlife Service. A fairly good clam industry is located in the vicinity of Beaufort and a great variety of environment conditions are to be found.

Fundamental studies of the rate of growth, age at maturity, and salinity tolerance, as well as development of practical methods for increasing and managing the fishery will be conducted here. It may be possible to develop methods of commercial clam farming near Beaufort which will be applicable to the southern part of the Atlantic Coast.

SOUTH CAROLINA:

The problem of developing the fishery is important in South Carolina as in North Carolina. Clams are present in some abundance along most of the coastline, but the fishery is limited by economic factors.

The development of hard clam farming may offer an opportunity for increasing production at some future date, but the demand must increase before farming can become profitable.

FLORIDA:

A survey of the clam fisheries of Florida was made during February with interviews of representatives of the industry and research agencies. The present fishery is very limited although great quantities of clams were once taken by dredge in the Ten Thousand Islands. The cannery at Naples is now closed and the dredge has sunk. The beds among the islands still contain many clams and it is important to know the true extent of this resource for proper management and development of the fishery.

CONNECTICUT:

The quahaug fishery of Connecticut is small but might be expanded by farming in connection with the oyster industry in Long Island Sound.

No field work is anticipated here at present but funds have been allocated to Dr. Loosanoff at the Fish and Wildlife Service Shellfish Laboratory at Milford to develop methods of artificial propagation. This work will explore the possibility of producing seed clams in hatcheries while the field units in Rhode Island and New Jersey investigate seed production from natural spawning and setting.

RHODE ISLAND:

An intensive quahaug fishery by tonging, raking and power dredging methods is located in Rhode Island. Tonging is conducted the year around in every clean part of Narragansett Bay by about thirteen hundred diggers. Power dredging is permitted only in part of the Sakonnet River from December 1st to March 31st and supports less than thirty-five boats. A serious controversy has developed over the relative merits of these two methods and the Fish and Wildlife Service has been asked by the industry and the State Conservation Department to settle it. Tongers claim that power dredges tear up the bottom killing the seed and breaking many of the marketable sized clams. Dredgers claim their operations cultivate the bottom preventing silting and increasing setting. Dredgers want additional beds which are too deep for hand tongers opened for the use of power dredges.

Two biologists are now stationed at Wickford, R. I., and have just completed a survey of the hard clam population throughout the Bay in cooperation with the Narragansett Marine Laboratory of the Rhode Island State College. This information will be used to select a representative area for experiments to test the effect of hand vs. power methods on adult clams, juvenile clams, setting, and related bottom forms such as fish and scallops.

Part of the test area will be hand tonged or raked and another part will be dredged. Equal amounts of hard clams will be removed from each plot. Periodic examinations will show the effect of each method.

The results of this experiment will find application all along the coast wherever controversies exist between hand and power methods of clam fishing.

Seed production from natural spawning will be investigated this Summer by the Rhode Island unit as a beginning of quahaug farming studies. Although clam farming is not permitted in Rhode Island at present, the methods developed here should apply in other places.

A management study area is also planned for Narragansett Bay. One part of the bay which supports a small fishery will be observed and records will be kept of actual catch. Methods similar to those described for the soft clam studies in Sagadahoc Bay and Robinhood Cove in Maine will be used to arrive at an estimate of the sustained yield. This estimate will then be compared with actual production and correlated with quahaug population trends in the bay.

Management methods developed here can be applied wherever a State Conservation agency has the responsibility of regulating the fishery.

I would like to close with this thought. The program of the Clam Investigations is flexible and can be shaped to fit the needs of each area. We would welcome suggestions of the industry to help us establish studies which will provide the most benefit to all concerned.

THE SPAWNING OF QUAHAUGS IN WINTER AND CULTURE OF THEIR LARVAE IN THE LABORATORY

-by-
V. L. Loosanoff and H. C. Davis
U. S. Fish and Wildlife Service
Milford, Connecticut

The success of any shellfishery, including that of the hard shell clam, *Venus mercenaria*, depends to a large degree upon the availability of a supply of young individuals, commonly called set or seed, which can later be grown to marketable size. In some areas sets of young clams are heavy enough to take care of local needs; in others, which unfortunately are more common, the sets are usually irregular and light. Realizing the importance of having a good supply of seed Belding (1912) tried to raise young hard shell clams by artifical means under laboratory conditions. Unfortunately, Belding was not successful, because most of the larvae in his cultures died either before they reached the straight hinge veliger stage or soon afterwards. Belding concluded that there was no practical method for raising hard shell clams to the setting stage because of the small size and delicate nature of the eggs. Nevertheless, several years later Wells (1927) showed that by using a certain technique clams could be propagated artificially from the egg to the setting stage. Wells, however, was mostly interested in oysters and did not continue the clam work.

Our entrance into the field of raising clam larvae was motivated by several considerations. First, we still believe that by developing proper and efficient methods artificial production of clam seed may be economically feasible. Secondly, if we could succeed in keeping clam larvae of different ages in the laboratory, a wide field would be opened for studies of the physiological requirements of larvae, and also for studies of the effects of different factors of environment on larval growth and survival. Such information should be extremely important for understanding why some areas produce heavy clam sets while others fail. Finally, the methods developed for raising larvae to the setting stage will offer us the opportunity to enter the field of selective breeding by crossing the individuals with certain desirable characters, such as unusually rapid growth, etc. The latter may appear somewhat far-fetched at this time but we believe, nevertheless, that selective breeding of commercial mollusks will become a reality within a few decades.

Working with the hard shell clam is not new to Milford Laboratory because one of us has been studying intermittently various aspects of the

clam's biology for the last 16 years. Our first extensive experiments on raising clam larvae were, however, undertaken some time last summer. Clams were stimulated to spawn under laboratory conditions and several cultures of larvae were grown to the setting stage.

Obtaining spawn in the summer time is relatively a simple procedure. During the summers of 1933, 1934 and 1935 many clams were induced to spawn simply by raising the water temperature a few degrees (Loosanoff, 1937). However, because the spawning season of clams in our waters is confined to a period of approximately 2 or 3 months, experimenting with their eggs and larvae were necessarily also confined to the same period of time. Fortunately, since a method has been recently devised to induce oysters to develop spawn in the winter time (Loosanoff, 1945), we decided to apply this method to clams also, hoping in this way to extend considerably the period during which ripe eggs and sperm could become available for laboratory work. The method was successful, and by using it we are now able to make clams spawn, thus obtaining their eggs and spermatozoa, throughout the winter and spring. The method was successfully tried by other groups of investigators to whom we described it.

It should be remembered that under natural conditions there is a marked difference in the condition of the gonads of oysters and clams during the winter time. As has been shown (Loosanoff, 1942), the oysters of our waters resorb remnants of their gonads after spawning, pass through a stage when the follicles are free of all but the indifferent cells, and then, just prior to hibernation, enter a brief period of gametogenic activities during which ovogonia and young ovocytes are formed in females, while in males a few spermatocytes may be found in some follicles. In general, however, the gonad remains undeveloped consisting of a few follicles scattered in the form of small islands throughout the connective tissue which lies in the area between the body wall and the digestive gland. In this stage the oysters enter into a long period of hibernation, which in our waters lasts approximately from the end of November until April.

In hard clams, on the other hand, an active and very rapid gametogenesis begins soon after the completion of spawning, and by the end of October active spermatozoa can be found in virtually all the follicles of the males (Loosanoff, 1937a). Thus, excluding a brief post-spawning

period the gonads of adult males of *Venus mercenaria* contain spermatozoa that appear to be morphologically mature at all seasons of the year.

In the females the proliferation of follicles and growth of young ovocytes is also very rapid during the latter part of October. Towards the end of November and in December the ovaries already contain mostly large ovocytes of mature appearance. Thus, the gonads of female clams collected late in the fall or in the early winter appear morphologically ripe. Therefore, if we compare the gonads of clams and oysters in the late fall or in the winter, we shall find a striking difference between them because while in oysters they are in typical winter condition, containing only a few immature sex cells, clams already have either fully developed sperm or large ova. It is possible that this difference explains somewhat the better viability of eggs and larvae of winter-conditioned clams, as compared with those obtained from oysters conditioned in the same way.

Our method for conditioning clams to spawn in the winter time can be briefly described as follows: Clams brought from their natural beds in Long Island Sound, where the temperature of the water in the winter time is near 0.0°C., are placed in trays of running sea water having a temperature of approximately 5.0 to 7.0°C. Then, at intervals of 3 to 5 days the temperature in the trays is increased by several degrees. Eventually the temperature is raised to about 22.0°C., and the clams soon become ready for spawning. The entire conditioning period usually takes about 3 weeks, but can be made even shorter if the intervals between the increases in temperature are shortened to about one day, or if the clams are placed directly into water of a temperature of about 20.0°C. Under the latter condition we were able to make clams spawn on the eighth day of the conditioning period.

Conditioned clams are induced to spawn by raising the temperature of water to about 32.0 or 34.0°C. If the temperature is raised above 34.0°C., most of the clams usually withdraw the siphons and close the shells. It was often noticed that spawning begins during a decrease in temperature, i.e., if the temperature is first raised to about 35.0°C., and then gradually decreased to 32.0 or sometimes even to 28.0°C.

In several instances cases of spontaneous and apparently unprovoked spawning were observed at temperatures several degrees lower than 24.0°C., which had been considered the minimum at which

clams could spawn. For example, on February 7 and March 4, 1949 clams were seen spawning at 22.0°C., and on March 28 and April 5 large groups spawned in the trays having a temperature of only 21.0 and 20.6°C., respectively. In all cases both males and females were spawning, many of them quite profusely. The eggs from these spawnings were collected and cultured, the larvae reaching the setting stage. In the first two cases the clams had been used earlier in the day in spawning experiments during which they were subjected to a temperature of about 34.0°C.; however, after that they had been moved back to the tray of running water at 21.0 to 22.0°C., and remained there for about six hours before beginning to spawn. The third group, however, had not been exposed to a temperature higher than 22.0°C. for at least 11 days prior to the spontaneous spawning, and the last group, which spawned on April 5 at 20.6°C., was just transferred there several hours before from the conditioning tray of 15.0°C. Regardless of the nature of the factors that caused the spawning it is important that it took place at such comparatively low temperatures, thus suggesting that in nature clams can also spawn under the same condition.

While conducting the spawning experiments it was established that spawning of an individual clam is not completed in one day but is spread throughout a long period. For example, in one of our groups a marked female was induced to spawn on six different occasions between February 2 and March 3. Many other animals of the same group spawned several times. In general, this group provided us with spawn for a period of approximately 5 or 6 weeks, before the majority of the clams became spent.

Contrary to observations on oysters, spawning of which can be induced by the addition of a suspension of sperm or eggs, clams do not react sharply to this type of stimulation. The majority of ripe clams could not be induced to spawn by the addition of a suspension of sex products. However, many would respond if the temperature was raised several degrees. Apparently temperature was a more important factor than chemical stimulation.

Not all the eggs discharged in our experiments by the spawning females possessed the same vitality. Probably some clams were compelled by the strong temperature stimulation to abort the eggs even if the eggs were not fully ripe. Such eggs usually developed into feeble larvae which soon died. The last batches

of eggs discharged by virtually spent females also gave feeble larvae that grew slowly and showed a high mortality. With a little experience, however, an investigator can learn to recognize various types of spawnings and select only those batches of eggs that are suitable for cultivation. We found it rather difficult to induce spawning of clams, which were about 4 inches or more in size. Smaller clams, measuring about 3 inches, usually responded better than the larger individuals.

The eggs used for cultivation of the larvae were fertilized as soon as they were discharged. To separate them from the debris accumulating in the spawning dishes the eggs were run through a stainless steel sieve, which allowed the eggs to pass through but retained the larger particles. After that the egg suspension was filtered once more through another sieve, which was fine enough to retain the eggs but let the water containing the sperm, blood cells, etc., pass through. The retained eggs, now free of all impurities, were placed in fresh sea water in the hatching jars, which were continuously aerated.

The eggs and later young larvae remained undisturbed until they developed into early veliger. Then the water in the jars was renewed about every second day. To accomplish this the content of the jars was strained through fine sieves, which retained the larvae but let the water pass through. The jars were then filled with new water and the larvae returned to them.

To feed the larvae small quantities of mixed plankton cultures, consisting primarily of forms of about 5μ in size, were added daily to each jar. When the larvae were reaching the setting stage old oyster shells were placed on the bottom of the jars to provide a place for attachment, or the larvae were transferred to special aquaria on the bottom of which a layer of sand was spread.

A description of the development of the egg and clam larvae has already been given by Belding (1921). Therefore, it is not necessary here to go into most of the details. Instead we shall offer a comparatively brief account of the development from fertilized eggs to the dissoconch stage, as observed in our laboratory on good batches of eggs kept at about 22.0°C.

The egg of the clam measures about 70μ in diameter (Figure 1,A). It differs from the eggs of many other lamellibranchs because it is surrounded by a thick gelatinous envelope the diameter of which varies from approximately 163 to 170μ. We noticed on many occasions that this membrane continues to surround the egg past the blastula stage and, sometimes, until trochophore larvae are formed. If at fertilization spermatozoa are numerous, many can be seen imbedded in the outer portion of this envelope.

The fertilized egg will reach the two-called stage in about 45 minutes (Figure 1,B), and the four-celled stage is reached in about an hour and a half (Figure 1,C). In about 6 hours the embryo becomes a well developed, rotating, ciliated blastula. The early gastrula stage is reached 9 hours, and finally the larva enters into the trochophore stage which is reached about 12 hours after fertilization (Figure 1,D). This form, roughly pear-shaped, moves through the water with a spiral motion, propelling itself by a circlet of cilia around the anterior end, aided by a velar tuft of longer cilia at the extreme anterior. In this respect it differs from the gastrula stage during which almost the entire body of the larva was covered with small cilia. Furthermore, the trochophore larva begins to form a primitive mouth and develops a shell gland. The larva at this time measures about 90 x 65μ.

As the development progresses, a small thin shell is secreted by the shell gland and is gradually extended to cover the entire animal. This usually occurs from 24 to 36 hours after fertilization and the larva is now in the early veliger or early straight hinge stage (Figure 1, E). Its size at this time is approximately 105 x 80μ. About 8 to 12 hours later a true veliger or straight hinge stage is attained. (Figure 1, F). At this stage the larva, which is approximately 110 x 90μ in size, becomes quite a proficient swimmer using for this purpose its highly developed velum.

If conditions are favorable, the veliger continues to grow reaching the size of about 122 x 98 by the end of the fourth day, but still remaining in a stright hinge stage (Figure 1, G). By the sixth day it is already in the early umbo stage and measures approximately 154 x 143 (Figure 1,H). In 8 days some rapidly growing larvae may reach the size of 205μ, while the average are in the medium umbo stage measuring 195 x 178μ (Figure 1,I). After about 10 days after fertilization many individuals in good cultures are in the late umbo stage, measuring about 214 x 192μ (Figure 1,J) and after 12 days some of the mature, ready-to-set larvae may be as large as 227 x 210μ (Figure 1,K).

Just prior to this stage clam larvae begin to undergo very prominent changes. The velum begins to disappear and some of its functions are taken over by a foot which is covered with numerous cilia. At first this ciliated foot aids in swimming, but gradually is used more in gliding over the bottom and in crawling. Eventually the velum entirely disappears, thus ending the free-swimming period.

In our cultures many larvae reached the setting stage in about 12 days attaining at that time the size of about 210μ. Young clams of this size were often seen attached by the byssus to the shells which were placed on the bottom of the aquaria. Thorson (1946) states that the veligers of Venus gallina also very often set when they are only about 210μ, although the length of the prodissoconch varies between 210 and 225μ. We found even greater variations in the size of the prodissoconch shell of Venus mercenaria grown in our cultures, some of them being as large as 240μ. However, none of the prodissoconch of our cultures ever approached the size of 320μ as reported by Sullivan (1948) for the Venus Larvae of Malpeque Bay. Nevertheless, as Jorgensen (1946) showed, the size of the larvae at the time of setting may vary considerably according to the conditions of the environment and, therefore, the measurements made at setting are only of relative importance.

After the attachment the young clam begins to form the adult or dissoconch shell. Successive stages of growth showing the increase in size and formation of adult shell are given in Figure 1, L, M, N, O and P. The sizes of these small clams were 240 x 223, 260 x 245, 313 x 308, 366 x 340 and 463 x 423μ respectively. The oldest individual shown was 28 days counting from the day of fertilization. In general, under laboratory conditions the growth of recently set clams was rather slow.

Significant variations in the sizes of the individual larvae of the same cultures were very often noticed. For example, while some of the largest larvae were approximately 210μ in size and were ready to metamorphose, the other larvae of the same culture were only 150 or 160μ long and were still far from the end of the free-swimming stage. Sometimes, because of overcrowding, a difference in temperature or other factors, the average size of the larvae of two parallel cultures carried in two different jars would also show significant differences.

Occasionally, almost all individuals of some cultures would appear to be abnormal. These abnormalities were usually caused by unfavorable conditions, such as low temperature, lack of food, etc. Sometimes, if these conditions were corrected

while the larvae were still in the early stages, some of them would survive and eventually develop into normal individuals which would reach the setting stage.

We found that the method for staining oyster larvae, which we described some time ago (Loosanoff and Davis, 1947) is also applicable to clam larvae. By using a weak solution of Neutral Red clam larvae were stained and thus became easily distinguishable from the normal indviduals. It is believed that this method will help, later on, to study the dispersal of larvae from the place of origin, their rate of growth under natural conditions, etc.

Our experiments showed that clam larvae are not too selective in their food and will survive and grow on different diets composed of different micro-organisms, instead of being confined to a few forms, as the larvae of *O. virginica* seem to be. The execption was when the clam larvae were fed almost a pure culture of Chlorella. The larvae so fed grew more slowly and showed a heavier mortality than these which were fed mixed plankton cultures containing different green algae, flagellates, bacteria, etc.

In conclusion it may be said that our experiments showed rather conclusively that cultivation of clam larvae to the setting stage is comparatively an easy matter. By following the few simple principles and rules given in this article mature sperm and eggs can now be obtained on almost a year-round basis, and the resulting larvae can be grown to the setting stage even in the middle of winter. In other words, as far as research work is concerned, we can now accomplish in one year as much as could previously be accomplished in three or four. With the method well developed and with the possibility of using it in summer and winter we are now looking forward to carrying on a number of experiments devised to study the ecological and physiological requirements of clam larvae, and to begin preliminary work on selective breeding of clams.

S U M M A R Y

The method is described by means of which hard shell clams (V. *mercenaria*) can be made to form ripe gonads and to spawn under laboratory conditions in winter. The method of raising clam larvae to the setting stage is also described in detail.

BIBLIOGRAPHY

BELDING, DAVID L., 1912. A report upon the quahaug and oyster fisheries of Massachusetts. *The Commonwealth of Massachusetts, Dept. of Conservation*, pp. 1-134.

JORGENSEN, C. B., 1946. Reproduction and larval development of Danish marine bottom invertebrates. 9. Lamellibranchia, *Meddelelser Fra Kommissionen For*

Danmarks Fiskeri-Og Havundersogelser, Serie: Plankton, Vol. 4, No. 1, pp. 277-311.

LOOSANOFF, V. L., 1937. Spawning of Venus mercenaria (L.). Ecology, Vol. 18, No. 4, pp. 506-515.

LOOSANOFF, V. L., 1937a. Seasonal gonadal changes of adult clams, Venus mercenaria (L.) Biological Bulletin, Vol. 72, No. 3, pp. 406-416.

LOOSANOFF, V. L., 1942. Seasonal gonadal changes in the adult oysters, Ostrea virginica, of Long Island Sound. Biological Bulletin, Vol. 82, No. 2, pp. 195-206.

LOOSANOFF, V. L., 1945. Precocious gonad development in oysters induced in midwinter by high temperature. Science, Vol. 102, No. 2640, pp. 124-125.

LOOSANOFF, V. L. and H. C. DAVIS, 1947. Staining of oyster larvae as a method for studies of their movements and distribution. Science, Vol. 106, No. 2763, pp. 597-598.

SULLIVAN, C. M., 1948. Bivalve larvae of Malpeque Bay, P. E. I. Fisheries Research Board of Canada, Bulletin No. 77, pp. 1-36.

THORSON, GUNNAR, 1946. Reproduction and larval development of Danish marine bottom invertebrates. Meddelelser Fra Kommissionen For Danmarks Fiskeri-Og Havundersogelser, Serie: Plankton, Vol. 4, No. 1, pp. 1-523.

WELLS, W. F. 1927. Report of experimental shellfish station. Report, Conservation Commission, State of New York, 1926, pp. 1-26.

Growth Studies on the Quahaug, Venus mercenaria

Harold H. Haskin, Rutgers University
The State Universiyt of New Jersey.

****

Two years ago commercial funds were made available to us through Rutgers University to examine the problem of hard clam farming. Specifically it was desired to know whether or not it would be practical to establish hard clam farms on the same stable basis of culture employed in the oyster industry. As you undoubtedly know, the hard clam industry at present is based on the exploitation of a wild crop and is consequently characterized by great fluctuations in yields, prices, etc.

Our thinking in attacking this problem was guided by the experience of Dr. Thurlow Nelson along the lines indicated by many of the papers on oyster problems discussed at these meetings. Obviously to establish hard clam culture, it is necessary to insure a supply of seed and secondly to be able to raise it to marketable size without excessive mortalities. I will not discuss our efforts to secure seed clams - we have had some success in artificial spawnings and some slight success in trapping natural spawn, but we are looking to the techniques of the Milford Laboratory, as described here by Dr. Loosanoff and Mr. Davis, to supply us with seed. I will consider briefly here some aspects of the second group of problems i.e., the raising of seed clams to marketable size. In simplest terms the problem is "How long does it take to raise a marketable clam?"

When one thinks of measuring a growth rate, the first question that arises is, "What dimensions are best used?" In our first year of work we made measurements of length, height, thickness, volume and weight of clams of all sizes available.

The <u>first slide</u> indicates the results of measurements of over 2000 clams with length, height, thickness and weight measurements averaged for groups of ten. It is seen here that when height, width or the cube root of the weight is plotted against length, a straight line is obtained. This shows that there is no change in proportions of these clams as they grow larger. These data plots are particularly useful in that if one average dimension for a group of clams is known the other dimensions may be obtained directly from the graph. For example one can weigh a group of 10 clams and immediately read off the average length, width and thickness of the group with an error of less than 5%. Because of the relative ease of obtaining weights as contrasted with caliper measurements, weights are now used in most of our growth studies.

One way of studying growth rates of clams is to make experimental plantings of all sizes available, measure the increase for each size for a single growing season and then add all these increases together to get a composite curve covering the growth of the clam from seed to chowder size. This is essentially what we have done.

The second slide shows the growth curves for five different sizes of clams for the 1947 growing season on the tide flats of Delaware Bay, Pierces Laboratory, Cape May County, New Jersey. The sizes planted here ranged from 10,000 per bushel to less than 200 per bushel. Note that the smallest clams showed the greatest percentage gain in weight - about 570% - while the largest clams gained only about 7% in the season.

The third slide shows these percent-gain data plotted to show a relative growth curve for the hard clam for the conditions obtaining at the Cape May location in 1947. This curve enables us to compute yields and sizes of clams obtainable from seed of any given size, assuming that a succession of similar growing seasons will occur. For example, 1 bushel of seed clams weighing about 1/3 of an ounce apiece, would yield 18 bushels of medium-sized clams in 5 such growing seasons. This checks almost exactly with growth rates obtained by Dr. Belding at Wellfleet, Massachusetts in 1906-1909.

This slide shows also the relative growth curves for this area in 1948 and for 4 other areas in 1948. Note that in none of these cases do the growth rates equal the first figures obtained in 1947.

The fourth slide shows these growth data plotted in the form of the more conventional cumulative growth curves. These show for example that 1 oz. seed clams planted under the conditions existing in the Cape May area in 1947 would grow to chowder size in an additional three to five years. Under the conditions existing here in 1948 about 7 years would be required. Growth curves are also shown for the Jarvis Sound, Edge Cove, Surf City and Raritan Bay areas.

The fifth slide represents an attempt to gain further information from these growth data. Here for each area the logarithm of the initial weight at the beginning of a growing season, is plotted against the logarithm of the ratio of the final weight to the initial weight. A series of parallel straight lines results, with each line representing a certain planting area. The approximate formula for

these lines is

$$F = I^{2/3} \times \text{Constant}$$

where F = final weight at end of growing season
I = initial weight at beginning of growing season.

The constant depends on the intercept of the line.

The exponent of I (approximately 2/3) depends on the slope of the lines.

Since a two-thirds power of a weight is an expression of surface area, this empirical relationship between initial weight and final weight at the end of the growing season suggests that some exchange between the clam and its environment, limited by the surface area of the clam, is controlling the season's growth. With increasing size of the clam the ratio between its surface area and volume becomes more unfavorable and this is accompanied by a slower growth rate.

The intercepts of these straight lines with the zero axis of log $\frac{F}{I}$ enable us to calculate a theoretical limiting size for each of the areas investigated. This limit indicates a size beyond which the clams would grow only in more favorable growing years. For the Cape May area in 1947 the limit is 250 grams, for the Surf City area in 1948 it is 150 grams and for the Raritan Bay area in 1948 it is 64 grams.

It is interesting to consider what will happen to clams transplanted into an area which has a limiting value less than the size of the transplanted clams. This was actually done in the Raritan Bay area in 1948. Five sizes of clams were planted in the area in the spring. All were of uniformly high meat quality (approximately 18% wet weight). The three smaller sizes, all below the theoretical limit of 64 grams for the area, held their high meat quality. The two larger sizes, clams "too big for their new environment," declined sharply in meat quality to about two-thirds the initial meat level.

This study of hard clam growth is being continued in various New Jersey waters. To date it has shown several things which promise to be of considerable value to the prospective "clam farmer".

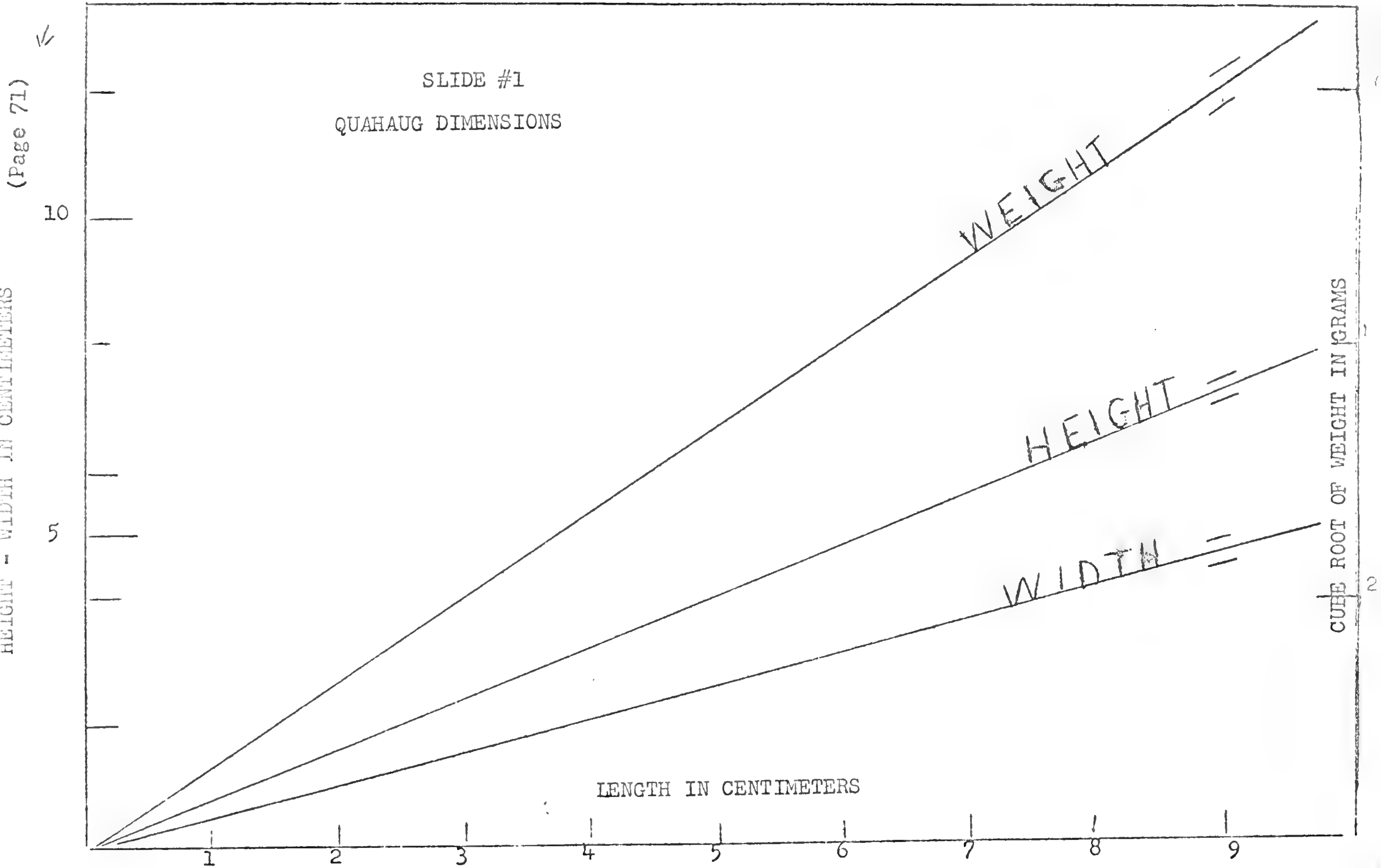
1. The approximate times required to raise seed clams to market sizes.

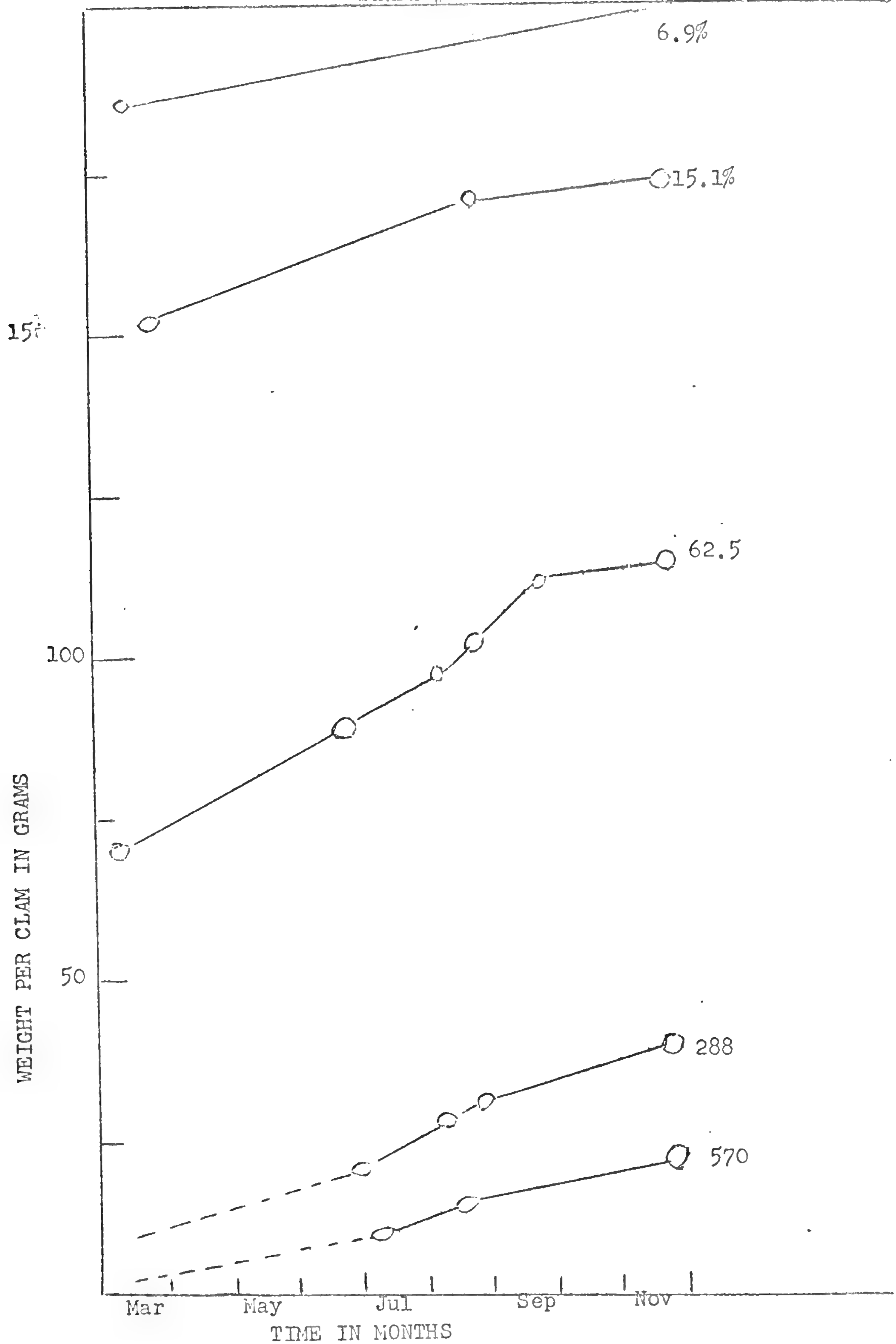
2. The great differences in growth rates for the same year in different locations and from year to year in the same location.

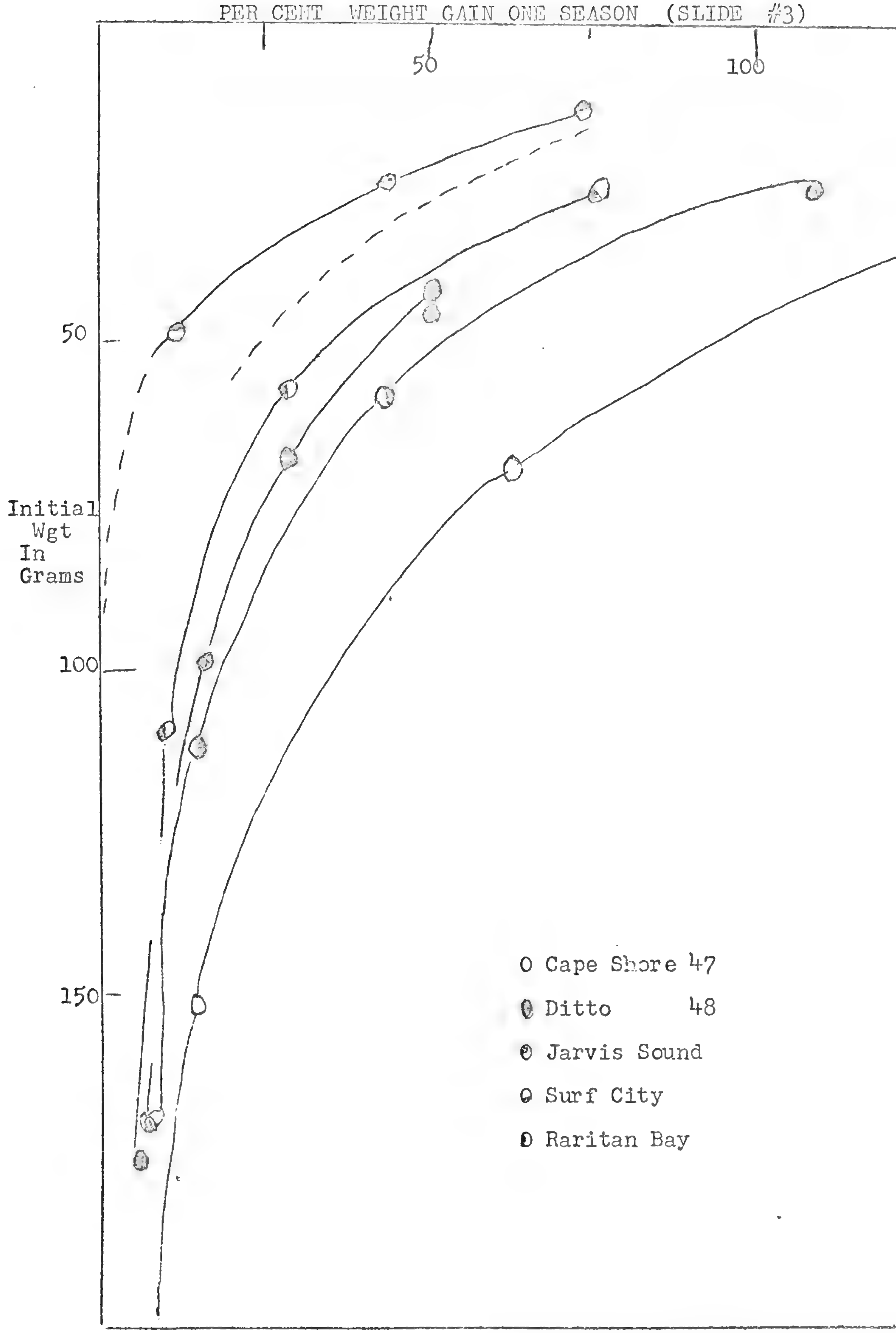
3. That the growth in any one season is limited by a surface area to weight relationship which indicates control of growth by environmental exchanges.

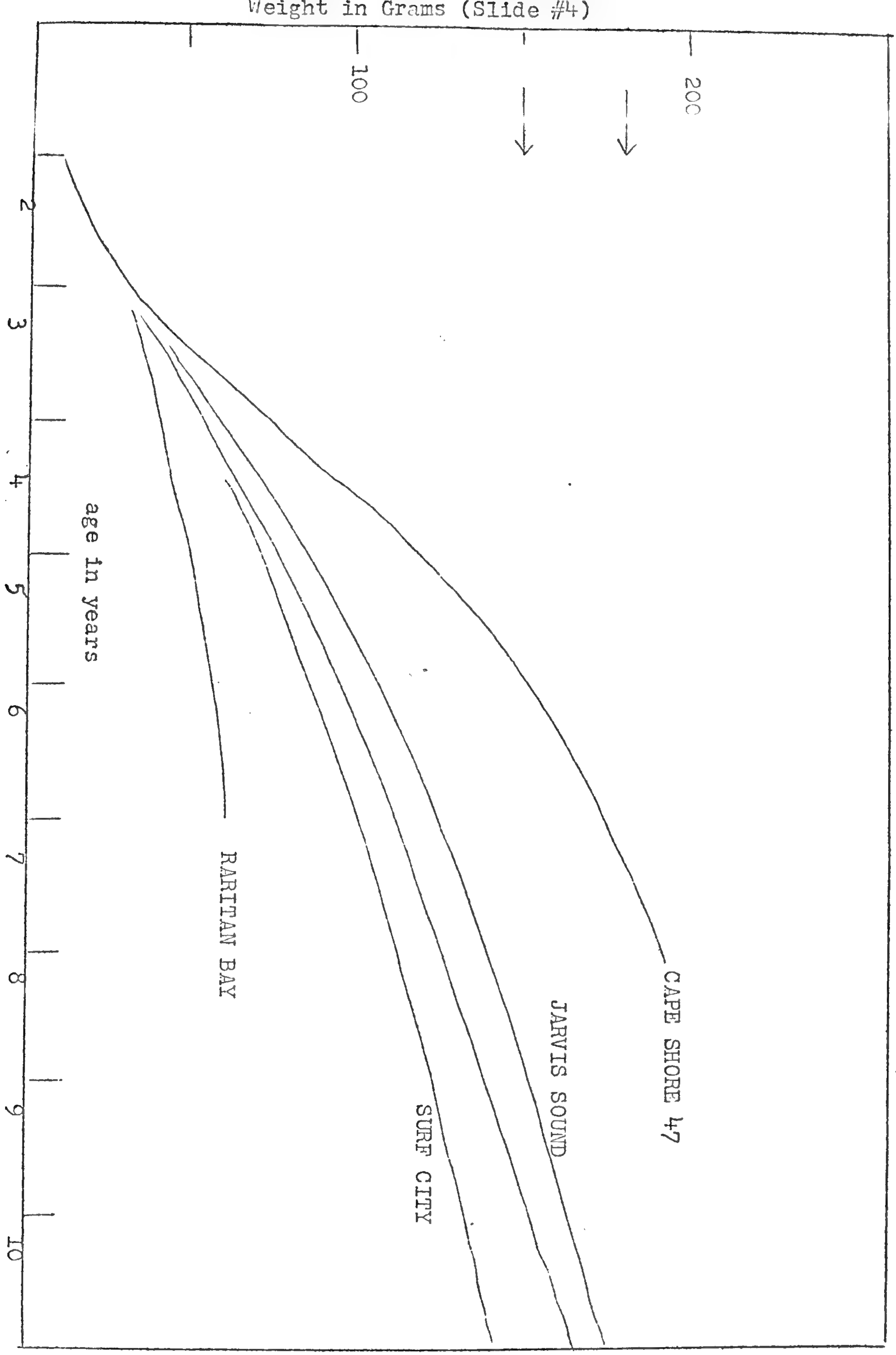
4. The size limit for a given area will indicate whether the clam-farmer should attempt to grow "cherry-stones", or "chowders" or neither in that area.

5. A low theoretical size limit for a given area indicates that it is unsuitable for "laying-out" larger clams for any considerable period of time.

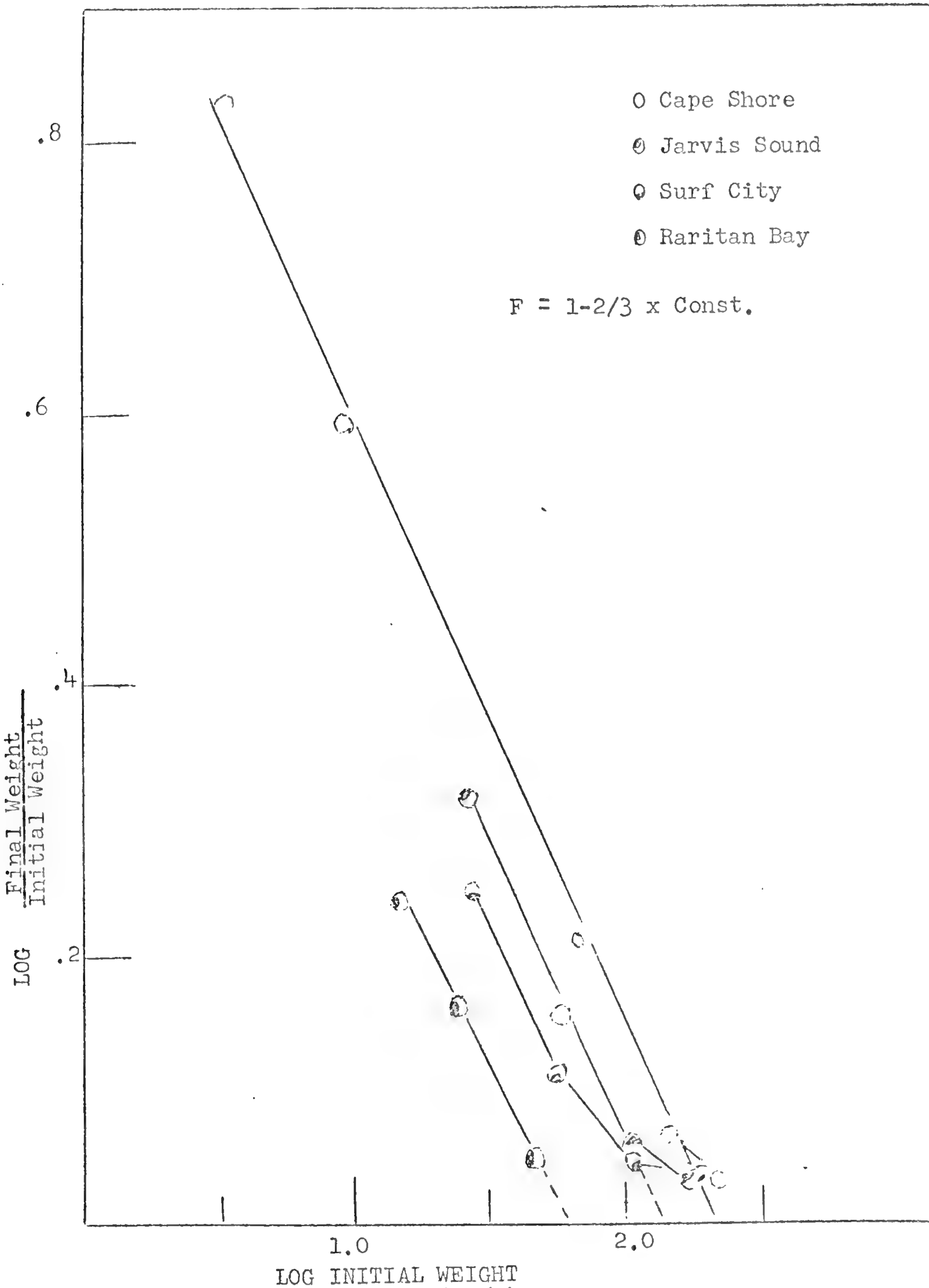

SLIDE #1
QUAHAUG DIMENSIONS
HEIGHT - WIDTH IN CENTIMETERS
10
5
WEIGHT
HEIGHT
WIDTH
CUBE ROOT OF WEIGHT IN GRAMS
2
LENGTH IN CENTIMETERS
1
2
3
4
5
6
7
8
9


6.9%
15.1%
62.5
288
570
150
100
50
WEIGHT PER CLAM IN GRAMS
Mar
May
Jul
Sep
Nov
TIME IN MONTHS


PER CENT WEIGHT GAIN ONE SEASON (SLIDE #3)
50
100
50
100
150
Initial Wgt In Grams
O Cape Shore 47
Ditto 48
Jarvis Sound
Surf City
Raritan Bay


Weight in Grams (Slide #4)
100
200
age in years
2
3
4
5
6
7
8
9
10
RARITAN BAY
SURF CITY
JARVIS SOUND
CAPE SHORE 47

SLIDE #5


O Cape Shore
Jarvis Sound
Surf City
Raritan Bay
F = 1-2/3 x Const.
.8
.6
.4
.2
LOG Final Weight / Initial Weight
1.0
2.0
LOG INITIAL WEIGHT

Practical Problems of the Propagation of the Soft Shell Clam, *Mya arenaria*

****

Harry J. Turner, Jr.,
Woods Hole Oceanographic Institution.
Woods Hole, Massachusetts.

**

The needs of the clam farmer are essentially the same as those of the oyster grower. He must have some sort of title to control a suitable plot of ground. He must also have some means of seeding or populating that ground with stocks of clams. Finally he must have some idea as to what to expect in the way of losses from predators, natural mortality, and destruction caused by other agencies.

In New England, clam farming has never been developed to the same extent as has oyster growing. It would appear that tradition and nature have conspired against the clam farmer to prevent him from attaining his primary needs. The traditional idea of free fishing in the intertidal zone has made it very difficult for private individuals to secure control of suitable ground. In addition, factors which control setting are unknown to that once ground is secured, the clam farmer has no way of getting his plot seeded. Finally, the effects of numerous enemies are difficult to evaluate since they operate below the surface of the sand.

In 1947, several residents of the town of Barnstable, Massachusetts obtained leases on a barren flat in Barnstable Harbor and requested the Woods Hole Oceanographic Institution to conduct a series of investigations on propagation and growing of soft shell clams. A seven-acre plot, adjacent to the leases, was set aside for experimental purposes.

Two methods of populating barren areas appeared promising. The first involved transplantation of contaminated stocks which could be obtained from polluted areas at a reduced price. It was found that transplantation could be satisfactorily effected by simply broadcasting the clams on untreated flats, and the majority of the clams would dig in and establish themselves quickly. It did not appear necessary to plow or otherwise treat the surface before transplanting.

The second method involved treatment of the surface to induce setting. There were a few records of intense sets which occurred on new flats created as a result of dredging operations. There was also a former clam grower who claimed to have induced setting by resurfacing his flat with sediments taken from a special thatch island. Several test plots

were resurfaced with a variety of materials and it was found that setting occurred on most of them. The most satisfactory soils were composed of very fine sediments which also contained roots and other fibrous material. Certain soils would induce setting but lacked physical properties to withstand winter storms and ice. It has not been determined as yet how these new sediments induce setting, but the matter is under investigation.

The problem of predators turned out to be much more serious than had been expected. It was know that certain crabs, crab-like organisms, and boring snails subsisted on soft clams but there was very little information as to how much damage these organisms actually did. During the spring of 1948, severe losses occurred in the stocks which had been experimentally transplanted and careful observations indicated that the common horseshoe crab was the responsible predator. Laboratory tests confirmed the field observations. It was finally determined that a large horseshoe crab could probably destroy as much as a square foot of well populated flat per day. Since horseshoe crabs were very numerous it became apparent that clam farming could not possibly be successful until methods of protecting beds could be devised. The problem of horseshoe crab control is now under investigation.

It would appear that the prospect of developing clam farming in New England is promising. Municipalities are becoming less resistant to leasing barren flats. There is a plentiful supply of seed stock in the extensive polluted areas which will rapidly purify itself after being transplanted in clean flats. Surface treatment to induce setting also shows promise. If methods of controlling predators can be devised, it is entirely possible that the clam farmer may be able to expect the same success as the oyster grower has enjoyed for many years.

A STUDY OF DUCK FARM POLLUTION OF A SHELLFISH AREA

****

M. H. Bidwell and C. B. Kelly

*

M. H. Bidwell, Shellfish Bacteriologist; C. B. Kelly, Sr., Sanitary Chemist, Sanitation Unit, New York State Conservation Department, Freeport, L.I., New York.

*****

Under the provisions of the Conservation Law of the State of New York, shellfish sanitation is a function of the Conservation Department. The chief problems of shellfish sanitation consist of: (1) the determination of safe production areas from which shellfish may be taken for food without danger to the public health, and (2) the inspection of plants opening or packing shellfish to assure the continued safety of the product being shipped.

This paper deals with the study which has been made of one small area of Long Island for the purpose of deciding its potential safety as a source of production. The area in question is known as the Peconic, Reeves, and Flanders Bays area. It consists of about 3,500 acres from which some oysters and large quantites of hard clams are produced annually.

The usual procedure of studying an area of this type for the purpose intended is to consider two main factors: (1) the sanitary survey of the watershed, and (2) the results of laboratory examination of samples of water for the presence of organisms indicating pollution.

The Sanitary Survey

The Peconic River is about 12 miles long with approximately 40 square miles of watershed. The average daily run-off of fresh water from this watershed is estimated at about 40 M. G. The watershed is sparsely settled and is mostly farm and woodlands. The river is a fresh water stream above the village of Riverhead. Sources of human or industrial pollution in this part of the river are insignificant. There are, however, a number of duck farms along the river and its tributaries contributing pollution. The pollution from these latter sources is greatly intensified during the Summer when duck production is at its peak.

In addition to the fresh water entering these bays, they are subjected twice a day to the influence of some 4,500 M.G. of clean salt water due to the rise and fall of about 4 feet of tide. The tidal waters enter this area from the east and the fresh water from the west.

The tidal areas are subject to some pollution of human origin in and around Riverhead. The village of Riverhead has a public sewerage system and

treatment plant and discharges effluent about halfway between the village and the mouth of the river. The treatment plant was placed in operation about 1938. It is an activated sludge plant of modern design and of adequate capacity. Samples collected at various times indicate that it is well operated. Typical results are as follows:

Results at Riverhead Sewerage Treatment Plant
September 27, 1948.

	Raw	Prim.Eff	% Removed	Final Eff	% Removed
Total Solids	894	417	54	304	66
Suspended Solids	616	106	83	24	96
B.O.D.(5 day-20°)	500	350	35	48	90

Coliform in Effluent - Maximum M.P.N. per 100 ml. 330
Total Bacteria in Eff. -- " per ml. 610

The river also receives the discharge from a laundry at Riverhead. Admittedly, the discharge of untreated laundry wastes may have some effect on the river and may be a violation of the Conservation Law. Serious damage to the river from this source, however, has not been demonstrable by laboratory tests.

The greatest source of pollution of this area is the numerous duck farms located at various points along the river and near its entrance to the bay. These ducks are of the White Pekin variety and grown in large numbers during the Spring, Summer, and early Fall. Only a relatively few ducks are kept on the farms for breeding purposes during the winter months. A survey of duck farms made by this Unit in 1937 indicated some 21 farms producing more than 1,000,000 ducks annually contributed pollution to this area.

The sources of pollution tributary to this area may, therefore, be summarized in order of their importance as follows:

1. The duck farms, especially in the Summer.
2. Miscellaneous sources of human pollution in and around Riverhead.
3. The Riverhead Laundry.
4. The effluent from the Riverhead Sewage Treatment Plant.

Laboratory Results

Samples of water have been collected from this area many times, and under various conditions, since 1937. Fourteen (14) separate surveys have been made during these studies. It is the usual procedure to collect four samples at each sampling station -- one at each quarter stage of the tide. These are examined for coliform organisms and total bacteria.

Results of these surveys show that in the Spring the pollution is restricted to those waters adjacent to the

duck farms. During the Summer, this pollution extends throughout the entire area and even into Peconic Bay. In the Fall, it recedes to the immediate duck farm locations.

Chart I shows a twelve-year summary of coliform results in this area. It is interesting to note, particularly, the vast extent of polluted waters in the summer months.

Based upon these studies, the Department has adopted a policy of closing the entire area during the Summer and allowing the use of most of the area, except around the months of the River and Meeting House and Sawmill Creeks, during the winter months.

The Sanitary Significance of the Findings

It has generally been accepted in the past that pollution of animal origin was not as potentially dangerous as pollution of human origin. Recent studies of the relationship of pathogens to coliform in duck polluted waters, however, would seem to require a revision in this thinking. It appears quite obvious from these studies that duck pollution may have considerably greater importance from a public health angle than was previously assumed. The balance of this paper will be devoted to the discussion of this particular aspect of the problem.

Discussion of Sanitary Significance of Pollution from Ducks.

Although there is no record of the presence of the typhoid organism ever having been isolated from waters tributary to duck farms or from duck "droppings" themselves, there is quite an extensive literature on the isolation of many members of the paratyphoid group now generally known as Salmonella. This group of organisms is capable of producing quite wide-spread and rapidly progressing outbreaks of intestinal disease which, in many respects, resemble typhoid fever -- the death rate from these outbreaks extending to something in the order of 6%. On the establishment of the presence of Salmonella in domestic ducks, Edwards[1] reports on 56 outbreaks of Salmonelosis in ducks, from which 13 types were isolated. All of these types are recorded by Seligman[2] and Edwards[3], of the National Salmonella Centers, as having at sometimes been associated with outbreaks in humans. The pathogenicity of Salmonella originating from ducks is further demonstrated by Mallam[4], Scott[5], and Snapper[6], who cite cases of human Salmonellosis resulting from the ingestion of ducks' eggs or products prepared from ducks' eggs.

Of particular significance from the standpoint of pollution is the method of infection of these eggs. Both Mallam and Scott agree that the eggs become infected either by introduction of contaminated material into the oviduct during copulation, or by direct contact of the egg with contaminated fecal material on the ground. Thus, the prime origin of Salmonella in eggs is fecal material. These observations are also confirmed by Solowey[7] who found that eggs with adhering fecal material were infected with Salmonella more often than clean eggs. The infection could not be attributed to contamination during the opening since pre-washing in heavily chlorinated water, or wet or dry scrubbing did not reduce the incidence of infected eggs. Although Hilbert[8] reports that Salmonellosis is not a major factor among flocks on Long Island, he does report occasional S. anatum infections. Further, there is no reason to believe that the situation is any different from that prevailing in other parts of this country and in Europe in which the ducks are rather heavily infested with Salmonella. Hansen[9] reports a 5% infection; Clarenberg[10] reports at least 1%. Further evidence available from the literature certainly indicates that ducks should not be excluded from the statement of Edwards[11] that "birds constitute the greatest reservoir of paratyphoid infection among domestic animals."

In order to place the responsibility for the pollution of these bays more directly on ducks, there remains only the necessity to demonstrate the possibility of transmission of these pathogens by water and the question of the degree of survival of the pathogenic organisms as compared to the index organisms, the coliform group.

Attempts have been made in this laboratory to isolate Salmonella from discharges of duck farms and to trace these Salmonella downstream through the heavily polluted areas into the moderately polluted and reasonably clean sections. Results of these investigations will be found in Tables I, II, and III. It will be noted that efforts were concentrated in Flanders Bay and, more particularly, in Meeting House Creek. This area was chosen primarily because of its proximity to shellfish grounds and to the rather heavy pollution emanating from the duck farms in the area, and also because there is little, if any, pollution of human origin associated with these discharges. It was not difficult to recover viable strains of Salmonella from either branch of Metting House Creek, and all types of Salmonella recovered are listed by Seligman[2] as having been associated with many outbreaks of human Salmonellosis. It was also possible to recover Salmonella from the water a quarter of a mile below these discharges, but of more significance is the recovery of Salmonella from a specimen of oysters taken from a private oyster bed which, during the winter, is considered of satisfactory sanitary quality.

Possible Solution of the Problem

It has been shown that duck farm pollution is menacing extensive areas of productive shellfish grounds. The New York State Conservation Department is not content with having found this condition to exist and closing the affected areas to shell fishing. It is believed that the source of this pollution can and must be corrected.

Analyses of the wastes from these farms and preliminary experimental work indicate that the simplest methods of treating sanitary sewage--namely, plain settling for, perhaps, one (1) hour and chlorination--will be effective in substantially correcting this condition and that it can be done at a cost well withing reasonable limits.

Therefore, for the immediate future, the Department will maintain seasonal closed areas as indicated by the surveys and try to interest one or more duck farmers in cooperating in the development of a waste treatment plant, the operation of which may be observed and thus find the ultimate solution to this problem -- i.e., the elimination of the pollution.

CONCLUSION

In conclusion, it appears from the studies made of duck farm pollution of shellfish areas that:

1. Pathogenic organisms are present in water discharged or flowing from duck farms.
2. Such organisms -- potentially dangerous to man -- have been recovered in shellfish taken from water polluted by duck farms.
3. Therefore, public health agencies in charge of shellfish sanitation must give as much consideration to the presence of excessive numbers of coliform organisms originating from duck farms as they would if such organisms were of human origin.
4. That elimination of this pollution by reasonable and economical means appears possible, and is certainly necessary in the public interest.

TABLE I

ISOLATION OF SALMONELLA FROM WATERS TRIBUTARY TO DUCK FARMS

Date	Station	Coliform M.P.N.	Salmonella Isolated	Volume of Sample
8/2/48	5.1, Flanders	4,600,000	S. bredeney, S. give	10 ml.
6/8/48	5.2, Flanders	2,400,000	S. bredeney	10 ml.
6/15/48	5.2, Flanders	930,000	S. bredeney	100 ml.
8/2/48	5.2, Flanders	4,600,000	S. bredeney	10 ml.
9/27/48	5.2, Flanders	2,400,000	S. bredeney	10 ml.
7/12/48	5.2A, Flanders	930,000	S. typhi-murium, S. bredeney	10 ml.
7/12/48	Oyster 4.1, Flanders	24,000	S. typhi-murium	10 ml.
9/27/48	Saw Mill Creek	11,000,000	S. Typhi-murium	10 ml.
9/27/48	Saw Mill Creek	460,000	S. typhi-murium	10 ml.
6/8/48	8.6 Peconic River	2,100	S. bredeney, S. anatum	10 ml.

TABLE II

ISOLATIONS OF SALMONELLA FROM WATER DISCHARGED FROM DUCK FARMS IN MORICHES BAY AREA

Samples Collected May 10, 1949.

Sample #	Farm	Coliform M. P. N.	Salmonella Isolated	Volume of Sample Tested
18135	A	9,300,000	S. anatum	10 ml.
			S. typhi-murium	10 ml.
18136	B	9,300,000	S. meleagridis	100 ml.
			S. bredeney (4 isolations)	10 ml.
18137	C	930,000	S. typhi-murium	10 ml.
18138	D	15,000,000	S. typhi-murium	10 ml.
18139	E	2,400,000	none isolated	100 & 10 ml.

TABLE III

INCIDENCE OF SALMONELLA TYPES ISOLATED IN INFECTIONS OF MAN AND DUCKS

******

Type	Man Edwards[1] No. Outbreaks	No. Cases	No. Fatalities
Total - All Types	1677	2949	56
S. typhi-murium	357	469	12
S. derby	49	126	1
S. bredeney	16	34	0
S. panama	73	124	4
S. give	36	75	0
S. anatum	64	165	1
S. meleagridis	16	43	0

Type	Man Seligman[2] No Outbreaks	No. cases	No. Fatalities	Ducks Edwards[3] No. Outbreaks
Total All types	941	1107	57	56
S. typhi-murium	307	356	22	32
S. derby	34	37	1	1
S. bredeney	4	4	0	2
S. panama	46	57	1	1
S. give	17	17	0	2
S. anatum	49	64	1	8
S. meleagridis	13	13	0	0

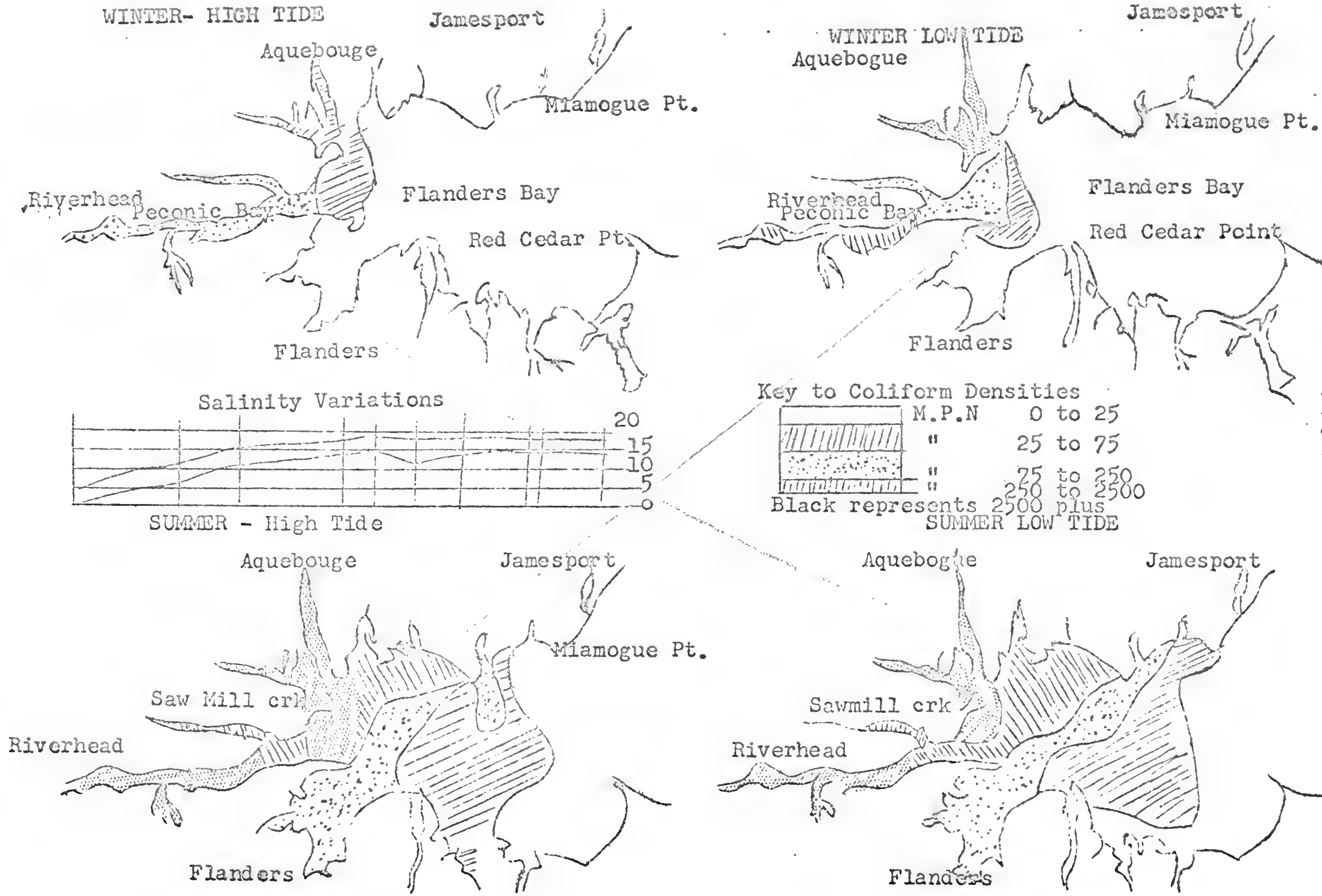
* * * * * * * * * * * * * * * *

REFERENCES

1. P. R. Edwards, D. W. Bruner, and A. B. Moran
Further Studies on the Occurrence and Distribution of Salmonella Types in the United States.
J. Infectious Diseases 83 220-231 (1948)

2. E. Seligman, I. Saphra, and M. Wasserman
Salmonella Infections in the United States.
J. Immunology 54 69 (1946)

3. P. R. Edwards, O. W. Bruner, and A. B. Moran
Salmonella Infections of Fowls
Cornell Veterinarian 38 247 (1948)


WINTER- HIGH TIDE
Jamesport
Aquebouge
Miamogue Pt.
Riverhead
Peconic Bay
Flanders Bay
Red Cedar Pt.
Flanders
WINTER LOW TIDE
Jamesport
Aquebogue
Miamogue Pt.
Flanders Bay
Riverhead
Peconic Bay
Red Cedar Point
Flanders
Salinity Variations
20
15
10
5
0
SUMMER - High Tide
Key to Coliform Densities
M.P.N 0 to 25
" 25 to 75
" 75 to 250
" 250 to 2500
Black represents 2500 plus
SUMMER LOW TIDE
Aquebouge
Jamesport
Miamogue Pt.
Saw Mill crk
Riverhead
Flanders
Aquebogue
Jamesport
Sawmill crk
Riverhead
Flanders

PRELIMINARY OBSERVATIONS OF THE PREDATION OF COMMERCIAL SHELLFISH BY CONCHS

******

Melbourne R. Carriker, Ph. D.
Zoology Department, Rutgers University and
New Jersey Oyster Research Laboratory.

INTRODUCTION

Baymen from many estuaries along the northeastern coast of the United States credit the conchs (*Busycon carica* and *B. canaliculatus*) with severe predation of oysters on native bay bottoms. Thus conchs captured by them in their tonging and dredging operations are thrown up on banks to perish or are destroyed in some other way. Colton (1908), an early investigator of bivalve predation by these conchs, from observations of these snails in marine aquaria, concluded that they may not be as serious a pest to the oystermen as previously reported. In view of this variance, it seemed desirable to make further investigations which will ultimately indicate the extent of such predation, particularly on commercial shellfish. The present report is concerned with a study of conchs in captivity; studies of the conch in its native habitat are anticipated for the coming summer.

METHODS

These studies were begun in the fall of 1947 and were carried out in the Rutgers University Vivarium in a number of 10 gallon marine aquaria. These tanks were connected in series with large siphons permitting the circulation of the sea water by means of a simple air lift pump placed at one end of the chain of aquaria. Further aeration was provided by the release of compressed air into each tank through thin cross sections of wooden dowel. Sand used in some of the aquaria was obtained at a local ocean beach. Clean bay water was collected in Shark River Basin, and in the Vivarium aquaria ranged in salinity in the course of the observations from 26.4 to 28.5^{o}/oo. Water temperatures ranged from 63 to 77^{o}F. Hydrogen ion concentration was found to drop after a time from approximately 8.0 to 6.0 as organic wastes accumulated in the water; sodium bicarbonate was added to return the pH to approximately 7.5. No filter was required in the circulating sea water system since the numerous shellfish used to feed the conchs provided excellent natural filtration. Six conchs, 4 knobbed (*B. carica*) and 2 channeled (*B. canaliculatus*) collected in Great Bay, N. J., and in Peconic Bay, Long Island, N.Y., were used in the study. The conchs ranged in length from 2.7 to 6.2 inches and during the course of the observations in the last year added a maximum of 0.5 inch of shell at the outer lip. Conditions in the aquaria were sufficiently favorable to permit oysters

and quahaugs to add as much as 0.2 inch of new shell. The shellfish used in feeding the conchs were obtained in Shark River, with the exception of the oysters which were collected in Delaware.

OBSERVATIONS

METHOD OF PENETRATION OF SHELLFISH BY THE CONCH. Copeland (1918) has shown that the conch responds very quickly to the blood of a fresh oyster. This marked response is observed again in the readiness with which a conch will locate an oyster or even a clam buried in the sand in an aquarium. The snails creep at a relatively fast rate, attracted by the water pumped from the excurrent siphon of the bivalves. Nor are shellfish such as quahaugs which normally occur buried shallowly in the bottom, safe, since conchs readily dig them out. It is not known whether they can dig up such deeply buried molluscs as adult clams.

Colton (1908) observed that these conchs will penetrate and consume such shellfish as quahaugs, mussels, oysters, razor clams and soft clams. Magalhaes (1948) found that in North Carolina these conchs consumed 8 additional kinds of shellfish. Colton's findings were confirmed in the course of the present observations. It was also noted that they consume such molluscs as the soft clam (Mya arenaria), in which portions of the soft parts are unprotected by the valves, merely by tearing out the flesh bit by bit until the valves are clean. Such thin-shelled bivalves as the edible mussel (Mytilus edulis) are enveloped by the foot of the conch to the extent permitted by the size of the conch foot and of the mussel, leaving the portion of the mussel valves farthest from the hinge exposed and oriented directly under the outer lip of the snail shell. The conch by contracting the columellar muscle (that muscle connecting the foot with the shell at a point within the shell spire) then very slowly and forcibly brings its outer lip to bear between the bills of the mussel. This pressure either forces apart or chips off a portion of the valves. The curvature of this part of the conch shell aids in spreading the mussel valves, and the concavity of the valves leaves a ready entrance for the conch proboscis. In one experiment 3 conchs were placed in an aquarium with an assorted collection of shellfish. Within 10 minutes each of the conchs had a mussel enclosed in its foot; 4 1/2 hours later the 3 conchs had opened and consumed 7 mussels (0.9-1.2 inches long), 1 clam (0.8 inch), 1 razor clam (2 inches) and 1 quahaug (1.6 inches). Throughout, the conchs showed a decided tendency to prey upon the thiner-shelled molluscs first.

As Colton has pointed out and as confirmed in these observations, the conchs readily attack oysters. A conch creeps onto one valve of an oyster, again, in such a manner as to bring the outer lip of its shell directly over the bills of the oyster. The oyster at first closes its valves tightly, then opens them gradually, inadvertently permitting the conch to thrust its shell between the valves. The curvature of the conch shell when pressed between the oyster valves pries the valves apart; the conch then introduces its proboscis under the protection of its own shell and eats its fill. Inspection of oysters opened by conchs in many instances reveals very little if any detectable chipping of the bills. If a portion of the oyster valve is broken away, a conch will not attempt to pry the valves open but will introduce the proboscis directly. The ventral surface of the foot of the conch secretes a highly viscous mucus while attached to prey and this may play a part in the great effectiveness of the conch foot in retaining its hold. Magalhaes incorrectly suggests that this mucus is probably saliva. A conch once attached to a bivalve is not easily driven off. In these experiments bivalves to which conchs were adhering were moved about, and the conchs themselves were handled, with no effect on the conchs other than to cause them to bring their shells down more closely over the foot. From the point of food conservation, the method of feeding employed by conchs has much in its favor, since in small bivalves the snail foot almost entirely envelopes the bivalve so that none of the flesh is lost and potential poachers are kept away. In the case of larger bivalves, although the foot does not entirely envelope the animal, the conch's shell is wedged between the valves thus affording considerable protection against raids by other animals.

Of all shellfish, the quahaug-like bivalves offer the greatest resistance to the predation of conchs, and yet these are also readily opened and consumed. It is in the penetration of the quahaug that the conch displays best its highly specialized mechanical method of opening shellfish. The conch mounts the quahaug and holds it, as Colton expressed it, "in the hollow of its foot", so oriented that the bills of the quahaug lie directly under the outter lip of the conch shell. Then the conch, by very slowly and strongly contracting the columellar muscle, brings the margin of its own shell to bear on the slight depression present between the junction of the two quahaug valves, and presses against the edge of the quahaug valve farthest from it. Such pressure is sufficient to chip a portion of the quahaug valve away. The conch then slowly relaxes its columellar muscle and draws its shell margin back from the bills of the quahaug. This slow chipping away of the quahaug bills continues until an opening of sufficient size is made to permit the conch to wedge its shell margin

between the quahaug valves. Warren (1916) recorded a rate of chipping of 6 times per minute. During this chipping attack the conch occasionally ceases its slow hammering to check the extent of damage inflicted: the rim of the anterior portion of the foot, held just under the bill of the valve to which the conch is attached, is brought over the damaged area and numerous tiny lobe-like projections of this rim are passed back and forth over the erroded shell as if in examination. If the pressure from the conch is severe enough to crack off a large opening, as often happens, or if one or both of the quahaug valves crack from the pressure exerted by the quahaug in an attempt to keep its valves closed, as occasionally happens, the conch makes no attempt to wedge its shell between the valves. However, more commonly it takes repeated chipping to expose a small opening. The conch attempts to wedge its shell between the valves as soon as an opening sufficiently large to permit penetration is chipped. Some victims, for example, showed chipped holes only 0.197 inch in width. The bluntness of the conch shell margin also determines the size of hole necessary for penetration of the conch shell; and this bluntness varies from time to time as considerable wear of the conch shell takes place during attack. The conch apparently adds new shell during resting periods at which time it generally remains buried in the bottom. Such rest periods have extended as long as 16 days in aquaria. Thus the conspicuous indented nature of the lines of shell growth along the body whorl of the conch shell are explained on the basis of the periodic erosion which occurs during attacks. It happens in some instances that the chipping of the quahaug valves results not in the formation of an opening but in the smoothing off of the quahaug bill, particularly of the valve edge farthest from the conch, and/or in the formation of an opening which is too small to permit wedging. In such cases the conch eventually deserts the quahaug. In one such instance a conch worked alternately between two quahaugs for 7 days without penetrating either, and finally deserted them. Out of 37 quahaugs which were placed with one large conch in one experiment, 15 quahaugs were opened and 10 were attacked but could not be opened. In only 2 cases in these observations did a quahaug victim show two areas of attack, in which apparently the first attack failed, and then the conch returned on a subsequent day in a second attack which was successful.

In 31 quahaugs opened in one series of observations by conchs it was noted that 52% of the sites of attack were located posteriorly over the siphons, 27% over the midventral region, and 21% over the anterior portion of the quahaug opposite the siphon. It is suggested that the selection of the sites of attack may be influenced by the flow from the excurrent siphon of the quahaug.

It was reported to me by members of the crew of the "Quinnipiac" during a trip on Peconic Bay, Long Island, that in the course of examining the material pumped off the bay bottoms and passed down the conveyer they had observed two cases in which large conchs still affixed to quahaugs and with proboscides extended into the quahaugs also had the operculum wedged between the quahaug valves. The use of the operculum in this way has not been observed during these experiments; it may well be a further means of facilitating penetration.

It was interesting to note that although shellfish are helpless against conchs, small sea anemonies on these shellfish are not as ready victims: one oyster on which a conch was creeping held a small sea anemone. As the foot came close to the anemone that portion of the foot nearest the coelenterate was suddenly withdrawn. The conch approached several times, each time retracting. Eventually it passed over the anemone, carefully elevating that portion of the foot over the anemone. Apparently, the nematocysts shot out by the anemone were effective defense.

Colton in his brief description of how quahaugs are opened by conchs, wrote that there are three ways in which penetration is effected: "First, it may flatten out its proboscis so that it will go through the crack; secondly, it may pour in a secretion between the valves which kills the clam; and thirdly, it may wedge its shell between the valves." The first and third ways mentioned by Colton agree with the observations herein reported; however, there is no evidence (nor did Colton present any) substantiating his statement that the conch may pour a secretion into the prey to kill it, nor Magalhaes' suggestion that the conch may initiate digestion externally. On the contrary, there is evidence against such a statement: in some of the attacked but unopened quahaugs, holes as large as 0.4 x 0.47 inch were left and yet apparently no secretion had been poured into the quahaugs since they were vigorous healthy animals weeks later. Some observers believe that the valves of shellfish are pulled apart by suction of the foot. However, Magalhaes has shown that a pull of 4 to 6 pounds is sufficient to dislodge a conch firmly attached to a surface, whereas Reese (1942) has estimated that a force of 23 to 26 pounds is necessary to force open a quahaug.

Extent of Conch Predation on Shellfish in Captivity. In the first feeding experiment all 6 conchs were placed in an aquarium of slate bottom, 23 x 12 inches, covered with about 1/2 inch of sand, in the presence of numerous quahaugs and edible mussels, and a few salt oysters, razor clams and soft clams. The temperature of the water remained in the vicinity of 68°F. and the salinity,

$28^o/oo$. In the course of 23 days the following shellfish were opened and consumed:

Edible mussels (Mytilus edulis), 0.6-1.6 inches long	69
Quahaugs (Venus mercenaria), 0.8-2 " "	17
Clams (Mya arenaria), 1.4-2.4	3
Razor Clam (Ensis), 2 inches long	1
	90
Shellfish consumed per conch per week	4.5

Conspicuous here is the fact that between the quahaugs and the mussels which were present in large numbers, the conchs made greater inroads on the mussels.

In a second experiment the 5 smaller conchs were placed in the same aquarium with an excess of oysters of various sizes. In a period of 99 days from December 29th to April 7th these conchs opened and consumed the following Ostrea virginica:

Ostrea Size Range. - Longest Dimension	Number Consumed
0.4-0.7 inch	28
0.8-1.1 inch	9
1.2-3.1 inch	22
	59

Or one oyster consumed per conch every 8 days.

In a third experiment the same 5 smaller conchs were placed in the same aquarium with an excess of oysters of various sizes. In a period from April 8th to May 8th for the 5 smaller conchs, and April 25th to May 8th when the larger conch was added to the tank, or a total of 163 conch days, these conchs opened and consumed the following Ostrea virginica:

0.4-0.7 inch.	33
0.8-1.1 inch	18
1.2-2.6 inch	12
	63

Number of oysters consumed per conch per week 2.7

The threefold increase in consumption of oysters in the second period may be attributed to the increase in the temperature of the water. In the first oyster experiment above the temperature of the water remained between 64 and 68°F., whereas in the second experiment the temperature remained between 68 and 75°F., or higher.

In a fourth and final experiment it was hoped to check the extent of predation of quahaugs that were permitted to bury in sand, since in the previous experiments the shellfish were lying directly on the bottom, exposed to the conchs. The largest conch (Busycon carica) was placed alone in an aquarium with slate bottom 2 x 1 feet in area covered with approximately 2.5 inches of beach sand. Thirty-seven quahaugs

varying in length from 0.8 to 3.0 inches (nicks to chowders) were allowed to bury in the sand of the aquarium. In a period of 131 days, from December 15th to April 25th, the conch opened and consumed 15 quahaugs ranging in length from 1.3 to 2.2 inches or one quahaug consumed per conch every eight days. In this same period eleven detectable unsuccessful attacks were made on quahaugs. If this figure is added to the 15 quahaugs consumed, the consumption per conch becomes one quahaug every 5 days.

CONCLUSIONS AND SUMMARY

It can be agreed with Colton and Magalhaes then that these conchs do prey upon a variety of shellfish; and with minor exceptions it can be said that Colton's brief description of the method of penetration employed by the conchs fits the observations herein reported. The extent of predation on quahaugs, oysters and edible mussels, as studied under artificial conditions, is, however, of much greater potential consequence than Colton's report would indicate. Final conclusion will come from actual field studies.

REFERENCES CITED

Colton, H. S. 1908. How Fulgur and Sycotypus eat oysters, mussels and clams. Proc. Acad. Nat. Sci. Phila. 60: 3-10.

Copeland, M. 1918. The olfactory reactions and organs of the marine snails Alectrion obsoleta (Say) & Busycon canaliculatum (Linn.) Jr. Exp. Zool. 25: 177-227.

Magalhaes, H. 1948. An ecological study of snails of the genus Busycon at Beaufort, North Carolina. Ecol. Monog. 18: 377-409.

Reese, A. M. 1942. The old star-fish clam question. Science N. S.96: 513-515.

Warren, S. 1916. Feeding habits of Busycon. Nautilus 30: 66-68.

TOXIC EFFECTS OF OIL MIXED WITH CARBONIZED SAND ON AQUATIC ANIMALS.

-by-

Walter A. Chipman, Jr., and Paul S. Galtsoff
U. S. Fish and Wildlife Service.

******

(A paper presented at the Annual Meeting of the National Shellfisheries Association at Old Point Comfort, Virginia, on June 9, 1949.)

***

Oil pollution of inshore coastal waters is a problem of major importance for the conservation of our quatic resources. Aside from being destructive to aquatic animals and plants, oil and other organic liquids floating on the water are a great nuisance to such recreational activities as boating and bathing and create a serious fire hazard, especially around piers and other structures built of creosoted wood.

After a damaging fire at the Norfolk Naval Shipyard, resulting from the accidental ignition of oil floating on the water, the Chemical Laboratory of the shipyard undertook a comprehensive study of the existing methods of removal of oil slicks and began a search for better ones. The experimenters of the Navy found that a carbonized sand can be prepared simply and cheaply by roasting creosote and sand in a specially designed kiln and that this has remarkably good organophilic and hydrophobic qualities. The sand, with its carbon coating, is sprayed on the surface of an oil slick. Coming in contact with oil, the carbon coating forms a stable bond with the oil. The mixture may then be readily removed. If on the surface of the water, the combined sand and oil may be sunk by a stream of water under pressure or by some other method of agitation. The bonding of the oil and carbon surface of the sand is permanent and an oil slick thus treated remains anchored on the bottom.

A popular account and graphic story of this new way of removal of oil slicks appeared in "Life" (1947, Vol. 23, No. 19). The caption to one of the photographs accompanying this article stated that the submerged sludge "is lethal to most marine life". Since there was no corroborative evidence of thetoxicity of oil bound by carbonized sand, the United States Navy, through its Bureau of Ships, asked the cooperation of the Fish and Wildlife Service in a study of the problem. The present report summarizes the results of the experiments conducted in compliance with this request.

Oils discharged into coastal waters do not remain floating indefinitely. They are absorbed by particulate matter suspended in the water. Agitation of the water by currents and wave action helps the settling of the oil-saturated material on the bottom, but the oil slick is not securely fixed and may be carried to

distant places. This characteristic behavior and its importance in aquatic life has been emphasized by Nelson (1925) and Gowanloch (1925).

Injury caused to ducks and other water birds by oil floating on the water is well-known, since many instances have been recorded of the finding of oil-smeared birds unable to fly (Lincoln, 1936; Adam, 1936). Likewise sedentary animals living within the tidal zone and coming in direct contact with oil may be destroyed.

The toxicity of oil in sea water, due to water soluble substances extracted from oil has been demonstrated many times experimentally using fishes and marine invertebrates. (Seydel, 1913; Nelson, 1925; Roberts, 1926; Gardiner, 1927; Ministry of Transport and the Ministry of Argiculture and Fisheries, Joint Committee on Damages to Fisheries, 1930; Gowanloch, 1934; Galtsoff et al., 1935; Galtsoff, 1936; Veselow, 1948; and others).

Since there is convincing evidence of the leaching out of toxic substances from oils present in sea water, it is desirable to ascertain whether the combination of oil with carbonized sand would alter this action. The combination may either lessen the toxicity of the oil, or it may increase it by bringing the poisonous oil closer to the bottom-dwelling forms, permanently anchoring it there, and allowing a slow and continued extraction.

For our study we selected for experimental animals such forms that would normally live attached to submerged objects, or on the bottom in estuaries and harbors where this type of pollution is most apt to occur. We chose in particular animals of known economic importance, but also included others which aptly land themselves to the experimental procedures desired. We used the following organisms: the hydrosoan Tubularia crocea, which grows attached to pilings and docks; the barnacle a very common form growing abundantly on rocks and structures near low tide mark; the embryos of the toadfish Opsanus tau, one of the common bottom-dwelling fishes in harbors and bays which attaches its large eggs to wood, rocks, and other submerged objects; the hard shell clam Venus mercenaria, which inhabits the mud flats; and the oyster Ostrea virginica, found on rocks and on the bottom in all coastal waters.

The oils tested were supplied by the Navy. these included crude oil, Navy Grade Special Fuel Oil, lubricating oil (SAE 20), and Diesel oil.

Because of the necessity of making this paper short, only a brief summary of the many experiments performed can be presented. A more complete description of the experiments and the results obtained in each is soon to be published.

EXPERIMENTS WITH TUBULARIA CROCEA

Weakend or dying polyps of Tubularia lose their dark pink color and become slightly opaque. Their tentacles fail to respond to touch and, finall, the entire hydranth, with its whorl of filliform tentacles, separates and drops off, leaving dense tufts of tangled stems. This characteristic change makes it convenient to employ colonies of Tubularia as test animals. The death point of an individual hydranth may be takne as the time when it drops off the stem and the progress of mortality in the group can be easily expressed in the number of lost hydranths.

The tests made with Tubularia consisted in determining the survival of this organism in standing or in running sea water containing known quantities of mixtures of various oils and carbonized sand, and in its survival in water to which an extract of crude oil was added. Relatively dilute concentration of oil or oil mixed with carbonized sand were toxic to Tubularia in standing solutions, a strenght of 1:1000 killed about 33% within 24 hours. Apparently there is sufficient toxic material leached out in a short time to be deleterious to this organism. When this is made more dilute by a flow of sea water, the injuriousness is less pronounced. With a flow of 65 to 75 liters per hour a toxic effect becomes apparent after 48 hours if 5 ml. or more of oil mixed with sand are placed in the immediate vicinity of Tubularia in a 2-liter jar.

The results comparing different oils show that lubricating oil was least toxic, while crude oil appeared to be the most toxic. The toxicity of the crude oil apparently resulted from something leached from the oil by water, for extracts were found to be toxic to Tubularia.

EXPERIMENTS WITH BARNACLES, Balanus balanoides(Ag.)

Adult barnacles can be conveniently used in toxicological tests. The barnacles can be easily arranged in a desired position in the experimental set-up. The effect of a toxic substance can be studied by observing and timing the sweeping of their cirri. In running sea water or in containers in which the water is renewed daily, they remain active and apparently in good condition in the laboratory for many days and weeks.

The test performed clearly demonstrated the toxic effect of crude oil and sand mixtures placed in the immediate vicinity of barnacles. A slowing of the cirri

was observed within 6 hours in the weakest concentration tried, 1:50. Poisoning was progressive and complete death of 80 to 90% of the barnacles took place within 70 hours.

EXPERIMENTS WITH TOADFISH EMBRYOS, _Opsanus tau_ Linn.

Toadfish embryos present excellent material for bioassay; they are large, fairly transparent, and are attached by egg membranes to pieces of wood, stone, shells, and similar objects. Normally they are quite active in the laboratory jars and the beating of their hearts and the circulation of blood can be easily observed with adequate illumination and suitable optical equipment.

Crude oil mixed with carbonized sand was found to be quite toxic. Even the lowest concentration of 1:200 was sufficiently toxic to kill all the embryos in 11 days. The mortality of embryos in water with greater quantities of oil was more rapid. If the log of the survival time is plotted against the log of concentration, the toxicity curve approximate a straight line. The linear relationship obtained by such plotting can be approximately represented by a general equation of type $y = a x^c$ and the constants a and c may be computed from the empirical data.

The relative toxicity of the different oils mixed with carbonized sand was ascertained. Crude oil added in the ratio of 1:40 killed three out of five test embryos within 47½ hours. Toxicity of Diesel oil was noticeable within 52 hours in the concentration of 1:20, while lubricating oil was ineffective even in the concentration of 1:10 (50 hours).

EXPERIMENTS WITH HARD SHELL CLAMS, _Venus mercenaria_ Linn.

The hard shell clam, chosen for experiments because of its economic value, is frequently found in polluted bottoms of harbors and bays. Because of their ability to close themselves within their shell, clams, like oysters, are capable of slowing down their activities to a low minimum for rather protracted periods of time. In this way they may reduce the immediate effect of unfavorable conditions.

In the one experiment performed, the sea water supply to the clams flowed at the rate of 21 liters per hour through containers containing 20 ml. of an oil or an oil and sand mixture. None of the clams died during the 12½ days of the test in the sea water containing crude oil, fuel oil, Diesel oil, or lubricating oil or mixtures of these oils with carbonized sand. There was no evidence of their weakening.

EXPERIMENTS WITH OYSTERS, *Ostrea virginica* gm.

Because of its great economic importance, the oyster has been studied more than most marine invertebrates. Consequently its physiology, habits, and life history are better known than other lamellibranchs. Living attached to rocks or lying on the bottom it is frequently affected by oil wastes discharged into waters. Having no means of moving from unfavorable environments, the oyster protects itself by tightly closing its valves. If the inimical condition persists, the oyster is eventually damaged or killed.

Tests of the toxicity to oysters were made of standing water to which were added crude oil in a dilution of 1:500 and Diesel oil in strengths of 1:200, and similar strengths in which the oils were sunk to the bottom mixed with carbonized sand. In the test with Dissel oil the first death occurred on the third day with an oil layer on the surface, and on the fourth day in the aquarium with the oil and sand mixture. By the end of the test on the 13th day, the mortality was 67 per cent in the test with oil on the surface against 25 per cent with the oil treated with carbonized sand. There was no mortality among the control oysters. Experiments with crude oil added in the ratio of 1:500 gave similar results. In these first death was observed in the ninth day and the mortality was less pronounced, due probably to the small quantity of oil used.

In experiments with oysters kept in large tanks of running sea water and exposed to a mixture of crude oil and carbonized sand, no toxicity was observed in 35 days of the test. It was found that 500 ml. of oil introduced into a water system running at the rate of 180 liters per hour and anchored by carbonized sand were insufficient to cause mortality or to inhibit the growth of the shells of adult oysters.

The maintenance of a steady flow of water through the gills of an oyster is essential for its feeding and respiration. The measurement of the rate of filtration of water is a very sensitive means of studying the effect of changes in the environment of the oyster, for the organism rapidly reacts to the presence of toxic substances which may be introduced into natural waters. Methods are available at present for measuring the efficiency of the ciliated mechanism concerned with pumping alone or for obtaining the overall picture of the function of the entire pumping system involving also the mantle and shell. Experiments were performed with each method, the former known as the carmine-cone technique and the latter the apron method (see Galtsoff, et.al., 1947).

It is impossible in this short paper to describe in detail the numerous experiments performed and the results observed using the various oils, these oils

mixed with carbonized sand, and extracts of these oils in experiments in the physiology of oysters. We conclude from the various tests we performed that there was a realease of physiologically active substances which suppress the activity of the ciliated epithelium of the gills of the oyster and that the anchoring of oil by carbonized sand does not prevent this release.

S U M M A R Y

We found that crude oil, Diesel oil, and Navy Grade fuel oil added to sea water are toxic to the various animals normally inhabiting estuarine environments, the more sensitive forms being killed rather promptly when compared to the forms known to be more hardy. The toxicity of these oils is apparent whether they are present as oil slicks on the surface of the water or are held on the bottom bound to carbonized sand. This toxicity results from material leached out of the oil by water. The oyster responds to relatively weak concentrations of the toxic materials leached from oil by a marked reduction in the amount of water filtered for respiration and feeding and a decrease in the number of hours open.

There is definite advantage in the use of carbonized sand in treating oil slicks for its localizes the oil pollution, prevents the spread of oil over the surface of water, and submerges and permanently anchors the oil near the source of pollution. In view of the fact that bottoms of harbors and bays near inductrial ports are grossly polluted and non-productive, the sinking of oil in these localities will not increase the damages to the fisheries.

Dusting with carbonized sand is a highly efficient method of removal of oil from the surface of the water. It is useful around docks and piers to combat fire hazards and also has distinct advantage in preventing the movement of oil slicks to productive areas where great injury to sea food resources may occur. We hope that the method will be adapted in some way to have more general use in combatting oil pollution in coastal waters.

LITERATURE CITED

ADAM, N. K.,
1936. The pollution of the sea and shore by oil. 22 pp. London: Harrison and Sons, Ltd.

GALTSOFF, P.S.
1936. Proc. North American Wildlife Conferences, Feb. 3-7, 1936. pp. 550-555.

GALTSOFF, P. S.; PRITHERCH, H. F.: SMITH, R.O: and KOEHRING, V. 1935. Bull. U. S. Bur. Fish. 48:142:210.

GALTSOFF, P. S.: CHIPMAN, JR.: W.A.: ENGLE, J.B: and CALDERWOOD, H.N. 1947. Fish. Bul of the Fish and Wildlife Service 51:59:-186.

GARDINER, A. C.
1927. Fish. Invest.(Great Britain) Series I, Vol. III, No. 2, 14 pp-

CORANLOCH, J.
1934. 11th Biennial Rept. La. Dept. Conserv. pp. 67-127.

1935. Trans. Amer. Fish. Soc. 65:293-296.

LINCOLN, F. C.
1936. Proc. No. American Wildlife Conf. Feb. 3-7, 1936, pp 555-559.

MINISTRY OF TRANSPORT AND MINISTRY OF AGRICULTURE AND FISHERIES, 1930. Detailed Biological and Chemical Reports on Tars Used for Road Surfacing, 171 pp., London.

NELSON, T. C., quoted by LANE, F. W.: BAUER, A.D: FISHER, H.F.: AND HARDING, P.N.
1925. Rept. of U. S. Comm. of Fish. for 1925, Appendix V.

SEYDEL, E.
1913. Mitteilungen d. Fischerei - Vereins fur dic Provins. Bradenburg, 5, No. 3, pp. 26-28

VESELOV, E.A.
1948. Rybnoe Khoziaistvo 12:21-22