

**FISHERIES RESEARCH BOARD
OF CANADA**

MANUSCRIPT REPORTS OF THE BIOLOGICAL STATIONS

No. 471

Title

Factors Limiting the Distribution and
Abundance of the Qushaug, Venus mercenaria L.

Author

C. J. Kerwill

1952

ABSTRACT

Quahaugs are limited in Canada to sheltered shallow-water areas with relatively high salinity where spawning temperature (23°C. or over) is reached in summer. They survived prolonged exposure to reduced salinity and high temperature in laboratory experiments. They can regain the surface if buried at unusual depths in summer. Since there is no extensive wandering by adults, the settlement of spat determines the distribution. Maximum settlement was generally found near half-tide level. Eel grass favours the settlement and survival of spat, especially on very soft bottom. The gastropod, Polynices heros, destroys most of the set in some localities. A disease has been responsible for deaths in numerous districts. Growth is slow, about five to eight years being required in favourable locations to reach a length of 50 mm. As a result, overfishing rapidly causes depletion. The obstacle of slow growth might be overcome by quahaug culture. At present there is no dependable source of seed stock and prospects for developing quahaug farming in Canada are poor.

FACTORS LIMITING THE DISTRIBUTION AND ABUNDANCE
OF THE QUahaug, VENUS MERCENARIA L.

by

C. J. Kerswill.

FACTORS LIMITING THE DISTRIBUTION AND ABUNDANCE OF THE

QUAHAUG, VENUS MERCENARIA L.

by

C. J. Kerswill.

An investigation of factors limiting the distribution and abundance of the quahaug (Venus mercenaria) in eastern Canada was conducted from 1938 to 1940 with the aim of assessing the possibilities of developing a successful quahaug fishery.

Quahaugs are distributed in sheltered bays and inlets around Prince Edward Island and along the Northumberland Strait shores of New Brunswick and Nova Scotia from Buctouche to Merigomish. In the past, extensive quahaug fishing has occurred sporadically, generally resulting in local depletion after a few years. At the present time there is a limited demand for quahaugs by canners, with good prospects of increased demand if a dependable source of supply could be developed.

Although scarce now, quahaugs were once very abundant in the Malpeque bay area of Prince Edward Island which from 1907-1913 supported the greatest quahaug industry that has ever existed in Canada. Thus the Prince Edward Island Biological Station on Bideford river, an arm of Malpeque bay, was chosen as the centre of the work. Investigations were carried on also in the Tatamagouche bay area of Nova Scotia, under different environmental conditions related to a range of tide of about eight feet as compared to three feet on the north shore of Prince Edward Island. These are about the upper and lower limits of tidal amplitude in any place occupied by quahaugs in Canada.

An attempt has been made to discuss the various factors in order of their prominence in limiting the distribution of the quahaug.

SALINITY

Quahaugs, like oysters, are found only where relatively high salinity prevails. The minimum requirement for oysters is about 20 per mille and there are no records of quahaugs occurring in constantly fresher water. Moreover, the absence of quahaugs but the abundance of oysters in the Bras d'Or Lakes where salinity is low throughout the year, suggests that somewhat higher salinities are required by quahaugs.

Laboratory experiments and exploration have shown that short periods of low salinity caused by spring freshets or heavy rains have no significant effect on the survival of quahaugs where other environmental conditions are favourable.

Laboratory experiments

These were designed to determine the period of survival of quahaugs of various sizes in different salinities at several temperatures. Specimens of three size-groups were used: small, averaging 8 mm. in length; medium, averaging 35 mm. in length; large, averaging 60 mm. in length. Salinities, ranging from that of normal sea water at about 30 per mille to fresh water, were obtained by diluting sea water with well water. Salinities higher than normal were prepared by the addition to sea water of salt from evaporated sea water.

A. In the first experiment, sets of specimens consisting of one from each size-class were taken from sea water at 21 to 22°C. and placed in fingerbowls containing 210 cc. sea water, 2/3 sea water, 1/3 sea water and fresh water, in thermostats at 20, 30 and 40°C. An additional set was exposed to the air in each thermostat. Observations on the condition of the specimens were made at intervals; the criterion for death was opening of the shell valves and failure to remain closed when pressed together. Where specimens continued to live, the water in the fingerbowls was changed at intervals of four or five days. The survival times are given in Table I.

Table I.

		20°C.	30°C.	40°C.
Sea water	L.	90+ days	12 days	Less than 80 minutes
	M.	"	13 "	"
	S.	"	13 "	3 to 6 hours
2/3 sea water	L.	"	10 "	Less than 80 minutes
	M.	"	28 "	"
	S.	"	Alive after 54 days	1½ to 3 hours
1/3 sea water	L.	39 days	10 days	Less than 80 minutes
	M.	20 "	10 "	"
	S.	10 "	9 "	1½ to 3 hours
Fresh water	L.	30 "	8 "	Less than 80 minutes
	M.	39 "	10 "	"
	S.	7 "	3 "	1½ to 3 hours
Air	L.	15 "	12 "	6 to 16 hours
	M.	24 "	13 "	"
	S.	60+ "	20 "	26+ hours

In sea water at 20°C. all sizes were alive after 90 days, at 30°C. all survived for 12 to 13 days, at 40°C. all the large and medium specimens were dead in less than 80 minutes

while the small specimens lived from 3 to 6 hours. In fresh water large and medium quahaugs lived for upwards of 30 days at 20°C., for at least 8 days at 30°C., but for less than 80 minutes at 40°C., while the small specimens generally died in less than half the time, but could survive for three days at 30°C. At intermediate salinities the survival time was in general proportional to the degree of salinity.

B. In other experiments sets of small and medium-sized specimens which had been held on the sea bottom at temperatures of 18 - 20°C. were placed in a thermostat in fingerbowls containing the same range of salinities as before. The temperature was increased at the rate of 1 to 1½°C. per hour until 40°C. was reached, and samples were removed at intervals, transferred to sea water at their temperature, and allowed to cool. The survival of those samples was observed.

In the first experiment using this technique with 5 small and 1 medium-sized specimens, as the temperature approached 40°C. the siphons of the quahaugs were in an extended limp condition and the valves would not remain closed when pressed together. 39.6°C. was the maximum survival by 2 small specimens, while the rest died after reaching this temperature.

In a repetition of this experiment using 25 small and 5 medium specimens in each fingerbowl, the same symptoms were observed when a temperature of 39.6°C. was reached. There was complete recovery, however, of all the specimens which had reached this temperature.

In another experiment, the same technique was employed, except that similar sets of 8 small and 3 medium quahaugs in the various salinities were heated from 18°C. to 35°C. This temperature was then maintained and observations were made at intervals on the condition of the specimens. The results are summarized in Table II, where the effect of reduced salinity on survival, at high temperatures is clearly shown by the proportions dead after 28 hours. It is remarkable that some small specimens could survive even 1/3 sea water for over a day at 35°C., while all survived in sea water.

Table II.

Time	Sea water	2/3 sea w.	1/3 sea w.	Fresh water
0 hrs.	Siphons out	Closed	Closed	Closed
8 hrs.	All alive	All alive	All alive	All alive
16 hrs.			1 sma.dead	2 med.dead
20 hrs.		1 sma.weak		1 med.weak
				8 sma.dead
25 hrs.			3 med.dead	3 med.weak
				6 sma.dead
				2 sma.weak
28 hrs.	1 med.dead	1 med.dead	2 med.dead	3 med.dead
	0 sma.dead	1 sma.dead	3 sma.dead	8 sma.dead

C. An experiment was performed to compare the ability of quahaugs to survive high temperature in water of salinity greater and less than the ordinary salinity of Bideford river.

Ten small and 2 medium quahaugs were placed in fingerbowls containing respectively 210 cc. of 5/3 sea water, 4/3 sea water, sea water and fresh water at 14.5°C. The temperature was raised at the rate of 4°C. per hour until 40°C. was reached, and held there for several hours.

After 2 hours at 40°C., one medium and one small quahaug had died in the fresh water. After 5 hours all the specimens were allowed to cool, and the only additional specimens which failed to recover were all the small quahaugs in fresh water. During the increase in temperature to 40°C., all the specimens except those in sea water remained closed until 38°C. was reached, then they began to open in all salinities.

Therefore, at a high temperature, quahaugs in unusually high salinities can survive as well as quahaugs in normal salinity, while in fresh water they cannot survive as long an exposure to high temperature.

Quahaugs are doubtless enabled to withstand salinity variations for considerable periods by the tight closure of their valves for the duration of the exposure. In the laboratory experiments, specimens opened only in ordinary sea water except when the temperature approached 40°C. Dugal (1939) has shown that quahaugs use calcium carbonate in their shells to buffer the products of anaerobic metabolism, and are thus able to remain closed for long periods.

Field observations

Quahaugs were raked thoroughly in each of the three heads of Paugh's creek, a tributary of Bideford river, where regular hydrographic observations have been made for several years. Here the salinity commonly fluctuates from 26 to 30 per mille during the summer, but it often falls to 17 per mille and sometimes to lower levels for a short time in the spring following the melting of snow, or after heavy rains. The raking revealed quahaugs up to 12 years of age in each arm of the creek to within several hundred yards of the head of tide where the width of the inlets was not over 100 yards. Thus there was practically no limit placed upon the distribution of quahaugs by lowered salinity, when the changes were of relatively short duration.

TEMPERATURE

(a) Spawning temperatures

Through its relationship to spawning activity, temperature limits the general distribution in our northern region of warm water molluscs like quahaugs and oysters. Nelson (1928) pointed out that Venus mercenaria is found only in relatively sheltered

areas where subtropical spawning temperatures of 25°C. are attained, while *Mytilus edulis*, with a low spawning temperature between 10 and 12°C. is the most widely distributed marine lamellib branch in the northern hemisphere.

Observations on the time of appearance of quahaug larvae in Bideford river by examination of plankton tows for three summers, have shown that the onset of spawning occurs only after the water temperature over the beds has reached at least 23°C. For example, in 1938 no larvae were found in plankton tows until June 24th, following a rise in temperature to 23.6°C. on the previous day, although temperatures between 20°C. and 22°C. had been reached almost daily in the two preceding weeks. In 1939 a maximum bottom temperature of 27.0°C. occurred on June 29th before any quantity of umbo-stage larvae appeared on July 7th, shown by their size to have spawned about a week earlier. In 1940 umbo-stage larvae were found first on July 16th, preceded by a maximum bottom temperature of 26.0°C. on July 10th. In 1939 and 1940 the last dates on which any quahaug larvae occurred in the tows were September 11th and August 29th respectively, when the water temperature had fallen to about 15°C.

Such high temperatures are reached in few localities on the Atlantic coast. Geographic features which enable such a warming to occur in Malpeque bay are discussed by Needler (1931). They are (1) the closure of the mouth of the bay by sandbars except for narrow, shallow channels; (2) numerous shoals and islands further hindering exchange with the outside; (3) the presence of many well-protected inlets opening on the bay; (4) the small depths and the presence of considerable flats exposed at low tide, favouring warming. All or most of these features are characteristic of other areas in Canada where quahaugs reproduce successfully.

(b) Temperature and Intertidal Exposure

High Temperature. The local distribution of quahaugs in places where general conditions are favourable for their occurrence might be limited by exposure to high temperatures in summer or low temperatures in winter. To determine the effect of such exposure, field observations were made on specimens planted or occurring naturally at different levels of the intertidal zone, and laboratory experiments were performed.

In a series of plots in Bideford river running from above half-tide level to beyond low-water level, no deaths occurred as a result of high temperature in the three years. Maximum temperatures often above 25°C. and occasionally reaching 30°C. were recorded on Six's type of thermometers buried in the intertidal zone. The highest temperature recorded was 35°C. at the half-tide position during low water on the afternoon of August 14, 1939. In 1939 and 1940 when extensive screening of the bottom was carried out on the shore of Tatamagouche bay, there was no evidence of death as a result of high temperature in any small quahaugs in their second year of growth, which were distributed over the extensive intertidal zone.

In the laboratory experiments already described, small quahaugs under 10 mm. in length survived high temperatures in sea water for longer periods and had somewhat higher lethal temperatures than medium and large specimens. A maximum sub-lethal temperature of 39.6°C. was found when this temperature was reached at the rate of 1 to 1½°C. per hour, as might occur on shore. In the experiments where quahaugs were raised to temperatures around 40°C. in sea water of high salinity such as might result from evaporation in tidal pools, survival was as good as in ordinary sea water.

At the higher levels of the intertidal zone during the prolonged periods of low tide, quahaugs which live near the surface may be exposed to air at high temperatures. The results of the laboratory experiment shown in Table I indicate that there is little possibility of death occurring from high temperature when so exposed. Large and medium quahaugs lived from two to three weeks at 20°C.; 12 to 13 days at 30°C.; and for at least 6 hours at 40°C. Small quahaugs survived longer at all temperatures, even for 26 hours at 40°C.

While temperatures as high as 35°C. have been recorded rarely in the intertidal zone, they are of too short duration likely to have an effect. This exceptional survival of small quahaugs would have practical significance if it were ever desirable to transplant them at lower levels after one or two season's growth, near the half-tide level.

Determination of the growth of medium to large specimens planted in beds at various levels on the shore of Bideford river has shown that although survival is complete at the half-tide level, the growth rate is slow. Thus exposure at the higher levels of the intertidal zone is a matter of little consequence. Specimens planted just below high-water level died after two weeks, as in the laboratory experiments where quahaugs were held in air at 20°C. The cause of death was evidently desiccation rather than high temperature.

Low Temperature. Quahaugs in the intertidal zone have died during the winter on several occasions and there has been evidence of bottom disturbance in the immediate vicinity, caused by severe storms or by ice movements. The primary cause of death was likely prevailing low temperature which caused the quahaugs to be inactive and unable to bury themselves after being exposed.

Evidence of winter killing of quahaugs in the intertidal zone of Bideford river was obtained in 1940. After the planting of a large bed of quahaugs near the biological station in 1939, a settlement of spat occurred in the vicinity from low-water level to just above the half-tide level with a frequency of about 2 per square foot. In the spring of 1940, screening the bottom showed good survival near the low-water level where the bottom shelved steeply, but at higher levels nearly all had died. Several beds of medium to large quahaugs were planted from low-water level to above half-tide level and left over the 1939-1940

winter. The following spring 75% of the specimens near the half-tide level were dead, and there was evidence of the bottom having been disturbed. A few specimens occurring near large stones had survived. These mortalities were probably the result of ice, which breaks up into cakes on the shore, scrapes the bottom and often picks up and encloses shellfish.

On November 26, 1938 a very severe gale caused much disturbance of the bottom in the Malpeque bay area. The following spring large numbers of dead quahaugs, mostly of large size, were exposed on the bottom over the intertidal zone in Bideford river near Port Hill wharf. The deaths were probably a result of the low water temperature in the fall, when the quahaugs were inactive and unable to regain their normal level when exposed on the surface or buried under shifting sand.

The ability of quahaugs to regain the surface during summer when buried under a few inches of bottom material, and to bury themselves if exposed on the surface has been demonstrated.

Groups of specimens ranging in length from 20 to 80 mm. were buried to depths of 1, 3, 5 and 7 inches in sand bottom near low water level in Bideford river. After 24 hours all had regained their normal position just beneath the surface. Small quahaugs averaging 5 mm. in length were buried to depths of $1/8$, $1/2$ and $1\frac{1}{2}$ inches in fine sand in a laboratory jar. After $11\frac{1}{2}$ hours all had regained the surface, where they remained upside down for a short time then buried themselves to normal depth. Two 5 mm. specimens were placed at the bottom of each of two test tubes containing respectively 3 inches of soft mud and 3 inches of fine sand under running sea water. After 15 hours they had regained their normal level in each tube.

Observations on the rate of digging-in of quahaugs placed on the surface of the sea bottom have shown that during summer all sizes can bury themselves in all kinds of bottom ranging from fairly hard sand to soft mud, within about one-half hour. At low temperatures around 10°C. and below, quahaugs exhibit little activity and may not bury themselves for several days or until the temperature rises.

Therefore, the danger of exposure to extreme temperatures in the intertidal zone is more acute in winter than in summer. If quahaug farming were developed, an effort should be made to gather spat from the intertidal zone before winter, for replanting at lower levels.

LARVAL SETTLEMENT

Quahaugs planted in experimental plots have moved about very little. Medium and large specimens travelled no more than a foot and a half (1 foot = 30.5 cm.) in a season, the extent of movement varying inversely with the size. Small quahaugs under 10 mm. in length are quite active, but observations on their movements in sand-covered laboratory dishes and boxes buried in

the sea bottom show them to be aimless wanderings, and never extensive. Thus the distribution of quahaugs must depend upon the location of settlement of the larvae at the end of the free-swimming period.

In Bideford river the number of quahaugs annually settling on the bottom and surviving is very low at the present time. The greatest quantity was found in 1939 by screening the bottom near Port Hill wharf, where the tidal flats are about 150 yards wide. The maximum settlement of 1938 spat was found near the half-tide level, where it averaged one per square foot.

More spat were found on the shore of Tatamagouche bay, where tidal flats about 300 yards wide occur. On August 15 to 17, 1939, a series of bottom samples was screened at intervals of 50 feet from high-water to low-water level. 1938 spat were found first at a distance of 100 feet from high-water level. The number increased with distance from shore to a maximum of 5 per square foot at the 550-foot position, near the half-tide level. At lower levels fewer were found and beyond the 650-foot position no more were found in screening to the 950-foot position at the low-water level. Repetition of the sampling in 1940 gave similar results, with maximum occurrence of 1939 spat at the 600-foot position, but there were a few spat nearer high-water level, at the 50-foot position. The 1938 spat were almost entirely absent as a result of drilling by Polynices heros.

Thus the maximum settlement of spat evidently occurs in the vicinity of the half-tide level on the intertidal zone. Few, if any, become established as far out as the low-water level, where growth of older quahaugs has been found to be most rapid. Weymouth (1923) reported a similar distribution of young Pismo clams, Tivela stultorum, on the intertidal zone of beaches in California.

Such a distribution of spat suggests that they might be gathered in the intertidal zone several months after settlement, when about 5 to 10 mm. long, and transplanted to lower levels for development. There is at present no prospect of a sufficient quantity settling in any known locality to make such a procedure worthwhile.

EEL GRASS

Observations in Malagash basin have indicated that the presence of eel grass favours the survival of small quahaugs in soft muddy bottom.

Malagash basin is a small shallow bay one mile wide and one and one half miles long, communicating with Tatamagouche bay by a narrow channel. There is an intertidal zone about 200 yards wide with bottom grading from hard sand and gravel at the high-water level to very soft mud overlying harder sand and mud at the low-water level. Most of the basin has very soft muddy bottom, which is exposed at low spring tides.

In June, 1939, at low spring tide, a careful search of the soft bottom along the south shore showed an abundance of large quahaugs 6 cm. long and larger, but smaller sizes were entirely absent. Examination of shell rings showed that all the specimens were at least 8 years old, and the oldest was 17 years of age. Representatives of later age-classes from 2 years upwards were found on hard bottom at a higher level nearby, attached to mussels by the byssi of the latter. Thus the absence of small quahaugs in the soft bottom was not the result of spat failure in recent years.

Eel grass was very abundant in Malagash basin before 1931-1932, when it disappeared almost completely as a result of disease (Huntsman, 1932). It has not occurred to any extent since, but in the past several years small, thin, patches have developed and are spreading annually.

Small quahaugs upon settling to the bottom at the end of the free-swimming larval period, produce a single-thread byssus from a gland located in the foot. The largest quahaug found with a visible byssus was 8.8 mm. long. The byssus was between 10 and 15 mm. long, very elastic, and attached to small pebbles by several branches at the distal end. It was strong enough to cause the quahaug to regain its position if moved a few millimetres to one side.

When several small quahaugs were left in sand covering the bottom of fingerbowls filled with sea water, two were found later to be hanging by their byssi from the glass sides, several millimetres above bottom.

On August 19, 1940, quahaug larvae of settling-out size were picked from plankton tows and placed inside a larva-rearing jar designed to float on the water surface, with water circulation provided by wave action. Two days later a specimen 0.5 mm. long was observed clinging to the glass one inch above bottom, and to climb $\frac{1}{2}$ inch farther. It fell for $\frac{1}{4}$ inch, coming to an abrupt stop upon reaching the end of its byssus, which was too fine to be seen. Belding (1912) described the settlement of quahaug larvae upon surfaces above bottom, but no accounts of quahaugs climbing after settlement have been seen.

The byssus evidently enables the small clam not only to maintain its position after settlement, but also to climb to more favourable surroundings. Eel grass which once occurred in Malagash basin probably offered support for small quahaugs in the soft muddy bottom and enabled them to keep above the mud and silt until they reached sufficient size for the feet to be effective in maintaining their position.

Even on clean, firm sand there is evidence that eel grass favours the survival of small quahaugs. Observations on the occurrence of the 1939 set were made on July 5, 1940, in Bideford river near Port Hill wharf, by screening the bottom between half-tide level and low-water level. The river bottom here

consists of fine sand with a little mud, and there are scattered patches of eel grass, 5 to 10 feet in diameter. Equal areas of bottom were shovelled to a depth of 2 inches on clean and on grassy bottom. In each of five ten-shovelful samples taken on both types of bottom, more quahaugs occurred in the grassy areas. The total number obtained in an area of 28 square feet was 32 in grassy bottom as compared to 12 on clean bottom. Further screening along the beach gave similar results.

PREDATORS

The gastropod, Polynices heros, appears to be the only serious predator, having been the chief cause of the failure of quahaug sets to survive recently in the Tatamagouche bay area. It was the cause of death of 80% of all dead quahaugs collected there. In the Malpeque bay area P. heros is not generally as abundant as in the Malagash district, and only occasional drilled quahaugs have been found.

Polynices commonly attacks quahaugs beneath the surface of the sea bottom, but quahaugs exposed among mussels or oysters on the shore or on bars are also attacked successfully. The size of the prey suitable for any Polynices appears to be limited by the size of the latter, because of the method of attachment to the quahaug during drilling. The edges of the large foot of the gastropod are curled around the valves of the quahaug, usually placing the radula near the umbo. Quahaugs that have been killed by Polynices are recognizable by a round hole with a bevelled edge, up to several millimetres in diameter, on one valve. In the Malagash area the largest Polynices found was 63 mm. in height, and it had just completed drilling a quahaug of length 54 mm. When 10 Polynices ranging in height from 37 to 56 mm. were caged with 15 quahaugs, after two weeks only the five smallest quahaugs (28 to 37 mm. long) had been drilled and the 10 larger specimens (50 to 75 mm. long) were still alive.

Screening the bottom on the west shore of Tatamagouche bay on August 15 to 17, 1939, showed the 1938 set of quahaugs to occur with a frequency of 5 per square foot near the half-tide level. Similar collections on September 21 showed what many had been drilled, and on May 22, 1940, there was a complete absence of living 1938 stock at this level. Large numbers of recently drilled shells of this size class were found there and also washed up along the high water mark. Screening on September 6th showed a similar predation on the 1939 set in the vicinity of the half-tide level where maximum settlement had again occurred. There were more spat than in the previous year at higher levels where the bottom consisted of hard sand and gravel. None of the small quahaugs were drilled here, possibly because Polynices was unable to contact them in the hard bottom.

Quahaugs are readily attacked and devoured by starfish (Asterias vulgaris) when the two species are held in laboratory tanks. It is, however, doubtful whether quahaugs which are buried normally can be seriously damaged by starfish. No dead quahaugs

have been found, in experimental plots or elsewhere, where death could be attributed to this cause.

Shore birds and flatfish are possible predators on quahaugs exposed on the surface by digging operations.

DISEASE

There are, from time to time, reports of quahaugs dying from an unknown disease in almost all localities. These reports usually follow the fishing of quantities of quahaugs with rotting meats, or the death of specimens after they have been out of water for a few hours.

Several fishermen claim that large numbers of dead and dying quahaugs were fished in Malpeque bay about 1916, and describe dark pustules in the meats. More recently quahaugs have been reported to be dying of disease in other parts of Prince Edward Island, for example the Charlottetown area, Brae harbour, and Enmore river. In 1914 large numbers of quahaugs supposed to be suffering from disease died in shipment from Buctouche, N. E., to Chicago, and Cox (1916) could find no trace of disease due to pathological causes in the fluid and organs of any specimens. Disease in the Amet sound area of Nova Scotia has been reported by a local canner. In 1940, a large quantity held for several hours on the beach at Brule harbour after being fished, died before they could be canned, and in 1941 a considerable number of dead quahaugs were fished with rotting meats still present.

To determine the effect on apparently normal quahaugs of exposure to sun and air such as might occur when quahaugs are piled on the beach, an experiment was performed in 1940 at the P. E. I. Biological Station. An insulated box was provided with a glass cover and placed to receive the direct rays of the sun. On September 20, 100 quahaugs obtained in Bideford river were piled about 10 deep in the box and a Six's type maximum and minimum thermometer was placed in the upper layer. Temperatures ranging from 106 to 118°F. were reached on four out of five clear days while on an intervening dull day the maximum temperature was 66°F. None of the specimens died, but a few at the surface lost some shell liquor when their valves opened slightly during the high temperature periods. It would appear that the quahaugs which died at Brule harbour after only short exposure to sun and air, and doubtless to lower temperatures, were in some unusual condition.

No direct observations were made on supposedly diseased quahaugs until September, 1940, when the empty shells of small quahaugs, four and five years of age, were found at the surface of the bottom of Enmore river, P. E. I. A few living specimens were similarly situated at the surface and one specimen just dying was found, with the valves slightly agape and only slow closure possible. All the specimens exhibited very little growth in 1940 as compared to previous years, as shown by growth rings. In a collection of 200, including both dead and living quahaugs, the 1940 growth was from 0.5 to 3.0 mm. in height as compared to

an increase in height of 6.8 to 9.7 mm. in 1939 and previous years. Slow growth during the season preceding the death of oysters from disease has been observed by Dr. A. B. Needler, and and the death of the quahaugs may be the result of the same or a similar disease, the cause of which is still unknown.

The possibility of quahaugs dying at any time from disease must be considered in planning any quahaug culture programme. Care must be taken to prevent the possible spread of disease in the transfer of quahaugs or fishing gear.

RATE OF GROWTH

It has been proved in this investigation by a study of the growth of notched specimens in numerous beds, that growth rings are reliable indices of the age of quahaugs. Thus the growth rates of quahaugs of any age can be determined by measurement of the size to the edges of the annual bands of growth, as in Tivela stultorum, the Pismo clam, (Weymouth, 1923) or in Mya arenaria, the soft shell clam, (Newcombe, 1935).

To obtain growth curves for quahaugs in the Malpeque bay area, collections of 100 specimens were made in Bideford river at Port Hill wharf, which is about 5 miles from the head of tide, and near the head of tide in Paugh's creek, a tributary of the river. Measurements were taken with vernier calipers of the height of the valves to the ventral edge of each year's band of growth. The measurement of height was found to be more convenient than the length measurement which is generally taken in molluscs, because the annual rings are obscured at the ends of the valves by other ridges. These measurements were grouped into classes of 2 mm. height range, and height-frequency polygons were constructed to show the size distribution at the end of each year.

When the polygons are plotted along ordinates corresponding to the various years, joining the medians of each distribution gives the age-size relationship shown in figure 1. Plotting the data in this manner shows the variation in height at the end of each year and the range of time within which quahaugs may be expected to reach any size can be seen readily. To determine the time required to reach marketable size, a line has been drawn at the height corresponding to the minimum marketable length of $1\frac{1}{2}$ inches, which is enforced in Prince Edward Island and Nova Scotia. This shows that at Port Hill wharf quahaugs are marketable in from 4 to 7 years, averaging about $5\frac{1}{2}$ years, while in Paugh's creek, 6 to 9 years, averaging about $7\frac{1}{2}$ years, are required to reach the same size. This difference in growth rate is thought to be largely the result of better water circulation at the down-river location.

Examination of quahaugs from other parts of Prince Edward Island has shown that growth is no faster than at Port Hill wharf. Similarly, large collections from the Tatamagouche bay area, N. S., show that at least 6 to 7 years are usually required for marketable size to be reached. A collection from Shediac bay, N. B., showed a slightly faster growth rate since the minimum marketable length in New Brunswick of 2 inches was reached in an average period of 5 years.

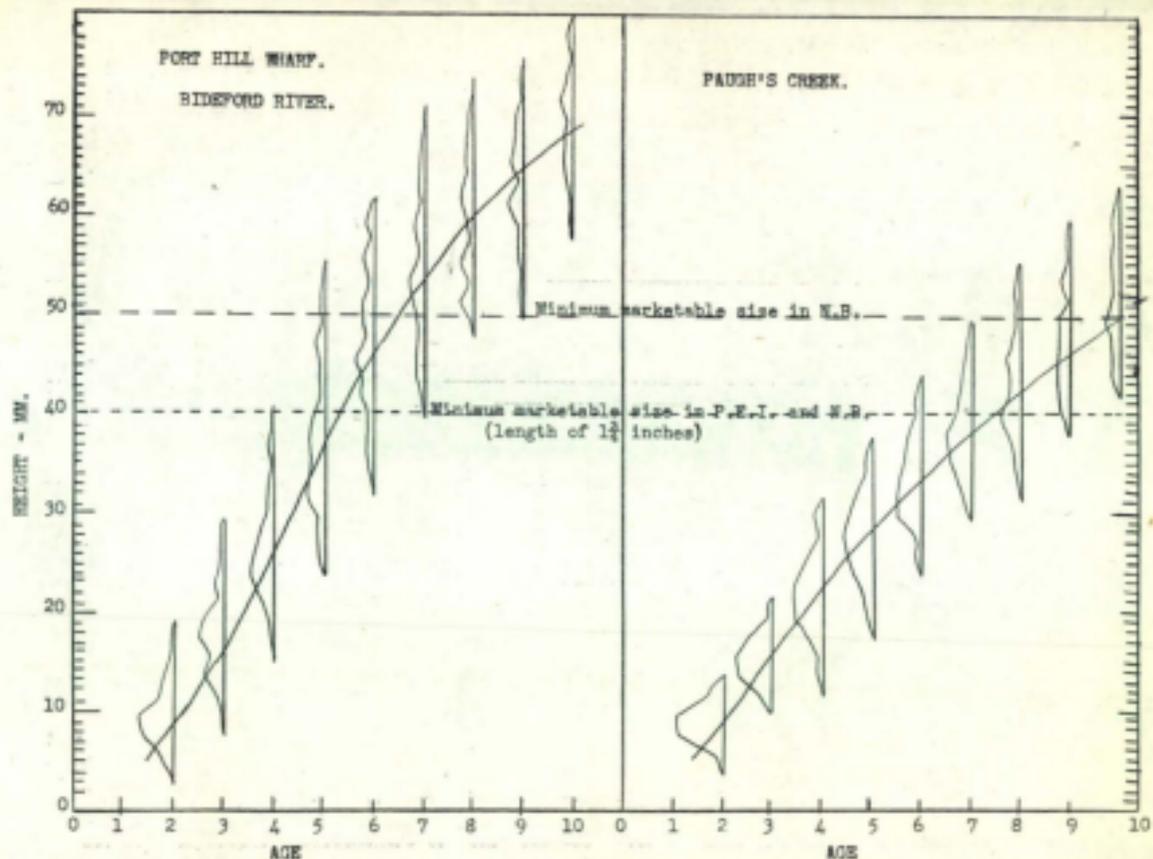


Fig. 1 - Age-height relationships of Port Hill and Paugh's Creek quahaugs, from growth-ring measurements

Fig. 1.

The growth rate of quahaugs is slow as compared to oysters, which generally reach the minimum marketable length of $3\frac{1}{2}$ inches in 3 to 5 years. This difference in the growth rates of quahaugs and oysters has not been appreciated by fishermen.

RATE OF REMOVAL

Information on the rates of removal of quahaugs by fishing and its effect upon the fishery has been obtained from the annual statistics and reports of fishery officers, published by the Canadian government.

Probably because the value of the soft shell clam and quahaug fisheries has been generally low, the catches of both species have been combined frequently in the statistical reports. Since 1935 separate listings have been given for both species in each province, but previously, except from 1911 to 1914, the catches were combined in Nova Scotia and New Brunswick. Fortunately more complete data are given for P. E. I., where quahaugs had a separate listing from 1905 to 1914. This interval covers the only period when quahaugs have been fished intensively there, the production approaching 50,000 barrels in 1907. At other times the combined figures for clams and quahaugs have fluctuated between 1000 and 4000 barrels per year.

In figure 2 are shown the recent catches in each province and the earlier total annual catches in Prince Edward Island and the catches in the Malpeque bay area alone. The increasing relative importance of the Malpeque fishery until it reached 92% of the total catch in the province may be seen.

The great increase in the catch in 1906 and 1907 was a result of a market opening in the United States. The marketed value of quahaugs from Prince Edward Island in these years was \$95,424.00 and \$96,572.00 respectively. In 1908 the inspectors' reports indicated that the industry was becoming exhausted, and by 1911 it was reported that quahaugs were so scarce that a fisherman could scarcely make fair wages fishing, and by 1915 the Malpeque bay area was practically fished out.

The length of time that the fishery survived in the Malpeque bay area was greater than in other areas where intensive fishing has developed after a long period of inactivity. This may be explained by its much more extensive area. More recently smaller areas, for example Brae harbour and Charlottetown, have been exploited, and the fishery lasted for only about two years.

Because of the slow growth rate of quahaugs in Canadian waters, an area can withstand intensive fishing for only a few years. Then a long period of inactivity is necessary for natural reproduction to bring about repopulation. This may be interfered with by disease, as in the Malpeque bay area where most of the stock remaining after the intensive fishery previous to 1915 apparently died off in 1916.

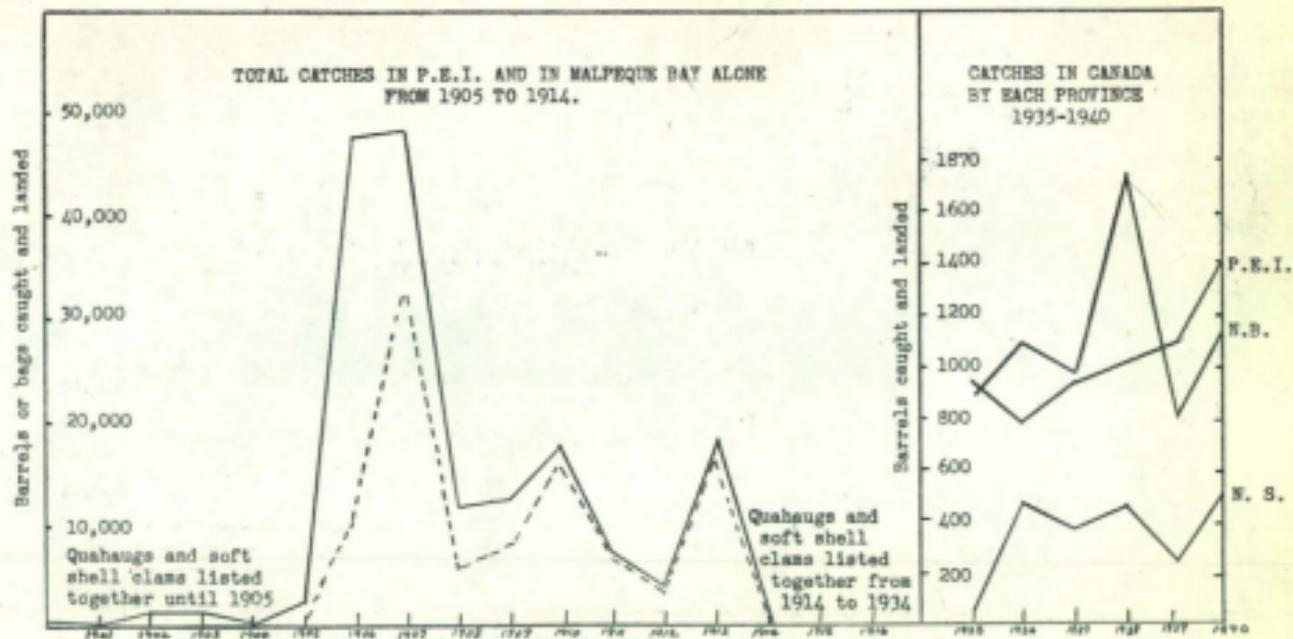


Figure 2 - Annual catches of quahaugs listed in the Fisheries Statistics

Fig. 2.

CULTURE

To ensure a steady supply of quahaugs, farming principles similar to those employed with the soft-shelled clam in Massachusetts might be employed. This would involve the restocking of fished areas with seed clams obtained in the intertidal zone, and the fishing of areas in rotation. Such a programme cannot be adopted at the present time because there is no large supply of seed quahaugs. This may be because of insufficient quantities of breeding stock, and in some areas it can be ascribed to predation by Polynices.

There are poor prospects of a dependable quahaug industry ever developing in Canada, chiefly because of the slow growth rate and the uncertainty of successful reproduction owing to the high critical spawning temperature.

SUMMARY

Quahaugs are limited to areas where relatively high salinity, averaging around 28 per mille, prevails. However, experiments and exploration have shown that wide variations in salinity can be survived for considerable periods. Thus quahaugs may occur well up towards the head of tide in inlets where there is very low salinity for short periods, as during spring freshets.

Temperature limits quahaug distribution chiefly in its relationship to spawning. The relatively high temperature of 23°C. is required before spawning occurs, and such a temperature is reached only in a few sheltered shallow-water areas.

Laboratory experiments have shown that quahaugs can survive unusually high temperatures in sea water of various salinities and in air, for longer periods than would be experienced on areas of the sea bottom, where satisfactory growth occurs. Therefore, high temperature is not a factor of importance in limiting their distribution on the intertidal zone.

Low temperature may be the primary cause of death of quahaugs in the intertidal zone during winter after the sea bottom has been disturbed, as by storms or ice movements. Quahaugs are then inactive and unable to regain their normal depth, whereas in summer they can readily bury themselves if exposed, or regain the surface if buried several inches lower than usual.

Adult quahaugs do not wander to any extent, therefore the location of spat settlement is of primary importance in determining the distribution. The maximum settlement has been found to occur generally in the intertidal zone near the half-tide level. Since growth of adults is most rapid at lower levels and survival over the winter is hazardous near the half-tide level, it should be profitable to transplant the small quahaugs if sufficiently heavy sets occurred. At present an average of only 5 spat per square foot was found in the best location.

There is evidence that the presence of eel grass favours the settlement and survival of quahaug spat especially on very soft bottom, but also on firm sandy bottom.

The gastropod, Polyneices heros, is responsible for the rapid loss of most of the annual settlement of quahaugs in some localities. Larger quahaugs are also attacked and over 80% of all dead quahaugs collected in the Tatamagouche bay area had been drilled by this predator.

A disease of unknown cause has been apparently responsible for the death of many quahaugs in numerous districts. Observations have been made on its occurrence recently.

The rate of growth of quahaugs in Canada is so slow that overfishing has frequently caused depletion. In the most favourable locations for growth in Prince Edward Island and Nova Scotia an average period of $5\frac{1}{2}$ years is required for the marketable length of $1\frac{1}{2}$ inches to be reached.

The history of the fishery in the Malpeque bay area shows that intensive fishing of quahaugs from 1906 to 1912 caused depletion from which recovery has been slow and very slight. Intensive fishing in other districts has had similar results, but depletion is usually serious after about two years because these areas are more limited in extent than Malpeque bay.

The obstacle of slow growth might be overcome by the development and operation of culture methods. However, a dependable supply of seed stock is essential for any attempt at quahaug farming, and there is no suitable source at the present time. Prospects of developing a quahaug industry are poor.

REFERENCES

- Cox, P. Contr. Canad. Biol., 6, 73-79, 1916.
- Belding, D. A report upon the quahaug and oyster fisheries of Massachusetts. The Commonwealth of Massachusetts, 1-112, 1912.
- Dugal, L. P. J. Cell and Comp. Physiol., 13, 235-251, 1939.
- Huntsman, A. G. Fish. Res. Bd. Can. Prog. Rep. Atl. 5, 11-14, 1932.
- Needler, A.W.H. Biol. Bd. of Canada, Bulletin 22, 1931.
- Nelson, T. C. Science, 67, 220-221, 1928.
- Newcombe, C. L. Can. Jour. Res. D., 13. 97-137, 1935.
- Weymouth, F.W. State of California Fish and Game Comm. Fish. Bull. 7, 1923. 1-120.

