

Further Observations on the Ecology, Rate of Growth and Food

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The major part of the work was done at the Pacific Biological Station, Nanaimo, B.C. and the remainder at the University of California. The writer

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Station 31 is located on Penelakut Spit at the northeast point of Kuper Island. The beach is steep and drops off rather rapidly to eel grass. It is constituted largely of shell and gravel and is exposed to fairly strong current and to northeast storms.

Station 32 is situated on the north shore of Departure Bay, directly below the Biological Station. The beach is gently sloping, running off gradually to eel grass. It consists of gravel mixed with larger stones and shell and is exposed to some current but is protected from heavy storms.

Station 33 is located near the "red buoy" south of False Narrows on the west side of Gabriola Island. The extent of the beach is about one mile in length along the shore line and of which about two hundred yards extends into the channel of the Narrows. It is a gently sloping beach inclined to be steep, dropping off to eel grass. The composition of the beach is of gravel, larger stones, sand and considerable shell. A very strong and rapid current courses through the channel in this region and the beach is exposed to storms.

In this area a great number of clams are present and the supply seems to be a constant one in spite of the fact that the animals are dug in large quantities.

#### Methods.

For the plankton distribution, series of samples were taken at each of the three stations. Two samples, one surface and one at the bottom were taken every hour at a given point over the clam beds during a complete run of the tide; that is, from high tide to high tide, at the spring tides in July and, at Departure Bay, one series was taken at the neap tide. The samples were

obtained by pouring twenty-five litres of water, pumped in by a small hand pump, through a silk net of number twenty-four mesh. In this way the conditions were kept as uniform as possible.

The two samples were preserved immediately in formalin for future qualitative and quantitative study and when time permitted, the living plankton was also examined. The samples were later centrifuged and graphs plotted of the amount of material in the twenty-five litres of water. The graphs will be referred to later.

Temperature readings of the water were taken three times during the day in each case.

When the beds were uncovered clams were dug, their bodies removed and placed at once in preservative and the shells retained for determination of the rate of growth. An effort was made to get the animals as soon as the beds were exposed in order to reduce the time for digestion of the food taken in before the ebb of the tide. The digestive tracts were examined for food content and the condition of the gonads was recorded.

Young animals, especially in their first year of growth, were sought for at each station.

#### Age and Distribution.

As in the previous study, the "annual ring" method was used for age determination, the measurements taken with calipers and the readings taken in millimetres. Stations 31 and 32, as before, showed good growth in clams and Station 33 held a similar position. At Station 33 however, some of the shells were very badly checked and scarred making age determination difficult in some cases.

As already indicated, Paphia and Saxidomus were both numerous at this

station, the largest numbers occurring just below half tide. All ages, from one to eight years in Paphia and from one to thirteen years in Saxidomus, were represented, five and six year olds being the most abundant in the case of the former and six and seven year olds in the case of the latter.

The number of individuals of Paphia in their first year of growth was greater at Station 33 than at any other station in the whole series. Over eighty specimens were obtained, ranging from 2.4 to 12.6 mm. and averaging about 5.0 mm. in length. Very few small Saxidomus were found at this locality.

Practically all these young animals occurred at the lowest level of the tide, at a -0.2 tide, and few if any were present higher up on the beach. Along with the small individuals at the low tide line there were several very large animals, both Paphia and Saxidomus, but practically none of intermediate size or age.

The difficulty experienced by the young clams in settling may account for the occurrence of the majority of very young individuals at so low a tide level. It is possible that these small forms are unable to survive on the part of the beach more frequently exposed and as a result, only those at the deeper levels remain. If this is the case, it would appear that there is some sort of migration up the beach. With the increased development of the body the byssus threads, by which the young clams are for a time attached to the particles of sand and gravel, disappear. It is possible that at this time the animals are washed by tides and currents to a higher region of the shore where they settle down and work their way into the surrounding gravel.

The number of clams in their first year obtained at Stations 31 and 32 was small although a careful and systematic search was made at both localities. Only about twenty specimens in all were found. In the investigations of the

two previous years very few young animals were found, only thirty Paphia and thirty-two Saxidomus having been taken from the thirty-two different beaches. Of the thirty-two specimens of Saxidomus twenty-two were found at Station 22 on the north side of Piers Island where the constitution of the beach is somewhat similar to that of False Narrows Station.

The inability to find any quantity of very young specimens at some of the stations may be due to their occurrence at a level too low to be exposed except at a very low tide. Consequently, in a collection made at an average low tide or higher, they might be missed entirely.

#### The Age of Maturity and the Time of Spawning.

The age of maturity at all three localities is apparently from two to three years in Paphia and from three to four years in Saxidomus. This condition is similar to that found in the stations previously dealt with.

The gonads of Paphia obtained from these three localities during the month of July, showed no indication of spawning although the eggs and sperm were becoming mature and in some individuals the sperm were already motile. In Saxidomus, on the other hand, the gonads were more mature and in a few instances there were signs of spawning. At False Narrows some individuals had the gonads still unspent, some were partly spent while others had the gonad completely spent. At Kuper Island, on both north and south faces of Penelakut Spit, there was no evidence of spawning and on the south side the gonads were still somewhat immature.

#### Food Content.

The contents of the digestive tracts of the clams were examined microscopically and the relative amount of food material estimated, although no definite volumetric determination was made. In spite of the fact that the bodies

were removed and preserved immediately after being collected, little material was found in the stomachs. It is evidently difficult to obtain clams with the food material still in the stomach. This may be because the clam, like the American oyster (Nelson, 1922), feeds most actively during the flow of the tide. If this be the case the food taken in during the flood tide would in all probability have passed into the intestine by the time the beds were uncovered sufficiently for the animals to be dug.

The intestine, especially that of Saxidomus, was well filled with plant and animal material. In both species the bulk of the intestinal contents consisted of plant forms, largely diatoms. The genera most commonly represented and in greatest abundance in the tracts of the two species were Navicula, Nitzschia, Coccinodiscus, Pleurosigma, Fragilaria, Skeletomema and Cocceinis. Less frequently appeared Biddulphia, Grammatophora, Synedra, Bacillaria and numerous other small unidentified forms. Although there was rarely much complete Chaetoceros material the presence of spine-like structures similar to those of Chaetoceros gave evidence that they were there. Besides the diatoms there occurred occasionally fragments of other algae and numerous types of spores.

The animal material was less abundant but presented considerable variation. The Protozoa constituted the greater portion of the animal forms. The shells and fragments of the flagellate, Dinophysis, were widely distributed and very numerous throughout. Distephanus speculum was likewise frequently present. The genus Peridinium was represented by several species, among them P. pellucidum and P. oceanum, but the number of individuals at any time was not great. The ciliates were somewhat rare. Only the shelled forms were found, possibly because the softer parts had already been digested. The tintinnids, Tintinnus subulatus in particular, were the most abundant. There was one new radiolarian

which has been tentatively identified as Echinus sphaericum, scattered at intervals throughout the material. Aside from the Protozoa there was little animal material, an occasional copepod, barnacle larva, cladocera or gastropod veliger being the only representatives in most cases.

The digestive tracts of the clams as a rule contained considerable detritus or dead organic matter. Some authors, Moore (1910), and Petersen (1908), believe this material to play an important role in the economy of the oyster and it is possible that the same is true of the bivalves here.

#### The Plankton.

As has already been stated, the plankton samples from each of the three localities were centrifuged and the amount in twenty-five litres determined and recorded by graphs. The results are shown in Graphs 1, 2, 3, 4, and 5.

In most cases the bottom and surface samples showed great similarity in the amount of material present. This might be expected, however, since the depth of the water was never more than fifteen feet at any of the stations. There was also a tendency for the samples to become more alike as the tide went out, on account of the decrease in the depth of the water and of the consequent decrease in distance between the samples; the reverse was true in the case of the returning tide.

From the graphs it may be seen that there was in general a gradual decrease in the amount of plankton with the ebb and a corresponding increase with the flow of the tide. It is apparent also that there was a slight rise in the amount of material in both deep and surface samples shortly before half tide during the ebb tide. This rise was possibly due in part to the stirring up of bottom material caused by the movement of the water. It might be due also, at

stations 32 and 33 at least, to the effect of the mixture with Fraser River water. Following this rise there was a sudden decrease in quantity of plankton in both samples until low tide, when the last sample available before the beds were uncovered showed a slight increase. Since the water was very shallow at the time these samples were taken, it is possible that there was present sand or sediment which would produce the apparent increase.

With the incoming tide the amount of material increased rapidly until after half tide when there was a slight drop for a short time, followed by a considerable increase. There are two possible explanations for this undulating rise. In the first place, the plankton may have been temporarily reduced by the intense feeding of numerous shore animals as the tide came in. In the second place, the mixing of the salt water with the fresh water from the Fraser River may have been accompanied by an increase in the amount of plankton present. The influence of the Fraser River will be referred to later.

In all three localities, 31, 32, 33, there occurred two plankton maxima similar to those recorded by Hutchinson (1927) for the deeper and more open waters of this region inside the series of islands which parallel Vancouver Island. In both cases the two plankton maxima have a similar explanation, namely by the effect of the Fraser River water. There are, according to Hutchinson, two sources by which this water can be brought to this area; "first, and more directly, through Gabriola, Porlier and Active Passes and in the second place, the river water previously swept northward is fed into these inner waters through Dodds' Narrows".

It is an interesting point that the station nearest the Fraser, i.e. Kuper Island, which is almost directly west of the river's mouth, had the greatest quantity of plankton throughout the entire series. This agrees with

Hutchinson's statement that the Fraser River water contains a beneficial factor on the life of marine organisms in this region.

At each of the three stations here considered the highest point in the amount of plankton was reached during the flood tide. This is also in accord with Hutchinson's findings that the stations to the north of the Fraser have the maximum amount on the flow of the tide.

The last sample taken in the evening, namely that taken at the peak of the flood tide, showed different results in the plankton measurements at the different stations. At Departure Bay there was in every case an increase in surface with a decrease in deep amounts. The reverse was true of the other two stations, that is, there was a decrease in surface with an increase in deep amounts. The reason for this is not clear.

It may be seen from graphs 1 and 2 that there is a marked tendency at Departure Bay for the surface changes to lag behind the deep. For example the surface maxima at this station came approximately an hour later than the deep, and the same is true, to a greater or less degree, in the case of the surface minima. This would seem to indicate that the deep water precedes the surface during the ebb and flow of the tide.

From these graphs it is also evident that the amount of plankton in any station varies from time to time. The two series shown here indicate that the quantity of plankton present on July 6th (chart 1) was much less than it was in the series ten days later from the same station. The increased amount on the latter date was apparently due to an increase in the number of Chaetoceros diatoms.

Chart 5 is a record of a series taken during the neap tides at Departure Bay. At this time the beds were never uncovered at any part of the day and the lowest points of the tide occurred in the morning and evening and not in the middle of the day, as during the spring tides. The amount of plankton rose with the flow and fell with the ebb of the tide and throughout the series the deep material was more abundant than the surface.

#### Qualitative Results.

The qualitative examinations were made, for both surface and deep samples, about five times during each series beginning at the morning high tide and running through at regular intervals until the evening tide.

There was considerable variation in the plankton material throughout but the types from the three stations did not differ greatly. When there was a higher reading at one station than another it was an indication, not of greater variety in species, but rather of larger numbers of the representatives of the species already there. When a very notable increase occurred such as that from the second series at Departure Bay (graph 2), it was usually due to a greater abundance of forms such as Chaetoceros.

There was on the whole little difference in variety of forms between the material from the deep and that from the surface samples. In some of the deep samples there was considerably more detritus than there was in those from the surface. Occasionally some form, such as the protozoan identified as Rohinus sphaericum, was found as in Departure Bay, from the deep material while it was not found in the surface samples. This does not indicate, however, that it was never present in the surface water.

In all cases the diatoms made up the greater portion of the plankton material. The most widely distributed and most abundant were the Chaetoceros forms of various species. At times these forms, together with another very common genus Ditylum, constituted practically the entire sample. Less common were Skeletonema, Navicula, Coscinodiscus, Nitzschia, Asterionella, Eucampia, Biddulphia, Synedra, Fragilaria and Thalassiosira. Besides these there were numerous smaller unidentified diatoms and various types of spores from diatoms and other plants. Filamentous algae and bits of seaweed were likewise frequently present.

The animal life at all three stations was very much alike. The greatest variety occurred in the samples from station 33 (False Narrows) possibly because of the fact that, of the three, this region was exposed to the strongest currents during both the ebb and flow of the tide.

The Protozoa were among the most widely distributed and the most extensively represented. The flagellates and ciliates were the most numerous. The flagellate, Distephanus speculum, which was so very abundant in the waters to the south the previous year, was found only in a few samples. Of the dinoflagellate group, Noctiluca was perhaps the most frequently occurring form and at times it was very plentiful. There were several species of the genus Peridinium, among them P. pellucidum, P. claudicans, P. oceanum and P. triquetra(?). Ceratium, especially C. longipes, C. fusus and C. tripos, were very abundant at Departure Bay and False Narrows. Ceratium furca occurred but rarely. Gonyaulax spinifera, Girodinium spirale, Girodinium corallinum (?), Gymnodinium variable, Gymnodinium bicornis and Polykrikos kefoidea were scattered more or less abundantly throughout the samples.

The commonest and most numerous ciliates were the shelled forms, the Tintinnids. This is probably partially due to the fact that, for the most part, preserved material was examined and some of the more delicate naked forms had been destroyed by the formalin. The species of Tintinnids found at these three stations were very similar to those previously recorded from the waters to the south. As before, the most abundant one was Tintinnus subulatus. Tintinnus lususundae var. rectus was frequently present. The species of the genus Tintinnopsis were somewhat more diverse. Of these the commonest were Tintinnopsis tubulosa, T. beroidea and T. davidoffi var. cylindrica. Other less frequently occurring representatives were Tintinnopsis ventricosa, T. expansa, T. nucula and Cyttarocylis arcuata. The several varieties of the form Phytocylis urnula, which up to the present, have been included in the one species, may later prove to belong to separate groups.

The one Radiolarian found in some deep samples from Departure Bay has been tentatively identified as Echinus sphaericum.

Besides the Protozoa many of the other animal groups were represented. Pleurobrachia and annelid larvae were present at all three stations but were most numerous at Departure Bay and False Narrows, respectively. Rotifers were occasionally present but were not abundant in any of the samples. Barnacle larvae occurred in fairly large numbers but were most numerous at False Narrows. The copepods and their larvae were most plentiful of all the larger forms, especially Microcalanus, which was particularly abundant at Departure Bay and False Narrows. The large form, Acartia longiramus, was fairly well represented at Kuper Island. Gastropods and gastropod eggs occurred at each of the three stations and bivalves were likewise frequently present. There was one form of bivalve, very numerous at False Narrows, which closely resembled young Paphia.

There were numerous representatives of Ascidian larvae at all three stations.

Along with these more or less generally occurring groups there were a few that were quite rare. Obelia medusae were found in small numbers at Departure Bay and Kuper Island. Echinoderm and Cyphanautes larvae were present but relatively scarce at Departure Bay and False Narrows, respectively. One of the cladocera, Podon intermedius, was sparsely scattered in the samples from Departure Bay but was very plentiful in those from False Narrows.

#### Conclusions.

The clams from the three stations, Departure Bay, False Narrows and Kuper Island, showed similar conditions of growth, maturity and spawning to those from the stations to the south the previous year. More young individuals in their first year of growth were found at False Narrows than at any other station. These were located at an extremely low level of the tide.

The amount of plankton varied with the height of the tide, falling off with the ebb and rising with the flow. Two plankton maxima occurred in every series and the highest point was reached during the flood tide. Both of these results are in accord with Hutchinson's explanation of the influence of the Fraser River water.

The plankton content and the content of the digestive tract of the clam were very similar, indicating that the clam ingests everything that comes its way and that is sufficiently small to be readily available. Consequently, it is to be expected that the food material in the body of the clam will vary with the change in plankton content. For example, when diatoms are abundant in the plankton the digestive tract will be well filled with plant material while, on the other hand, when animal forms or detritus are numerous in the plankton they will abound in the intestine of the clam.

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