NOTES ON THE HABITAT AND HABITS OF *CLEVELANDIA IOS* (JORDAN AND GILBERT)

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Abstract

A short description of the habitat of *Clevelandia ios* is given.

It is observed that while some of the larger individuals go into the burrows of *Urechis*, *Callianassa* or *Upogebia*, during low tide, the smaller ones remain in the pools formed. No accessory respiratory adaptations are noticed in the fish even though they retire into the burrows of the hosts, where the oxygen content of the water is lowered after the mud flats are exposed. Experiments have shown the *Clevelandia* is eurythermic.

Details of food and feeding habits are given. Analyses of stomach contents of specimens of different sizes collected over a period of twelve months show that there are changes in the diet with age and with season although copepods form the mainstay of food at all ages and at all seasons. During, the periods when the copepods are low the fish seem to eat more of ova, nauplii, nematodes annelids, etc. The larger fish eat more of larger organisms and smaller items such as diatoms and tintinnids decrease with increasing size. There seems to be a gradual change from plankton to bottom feeding with advancing age.

Introduction

Clevelandia ios, commonly known as the "arrow goby", belongs to the family Gobiidae. Actually a specimen of *C. ios* was first described as the type specimen of a new species (*Gobiosoma ios*) by Jordan and Gilbert in 1882. The genus *Clevelandia* was first erected by Eigenmann and Eigenmann (1888) and they described a new species, *C. longipinnis*. Jordan and Starks (1895) referred *ios* to *Clevelandia*. Jordan (1896) described a supposed new species, *Clevelandia rosae*, from San Diego. Jordan and Evermann (1898) recognised and described two species of the genus *Clevelandia*, *C. ios* and *C. rosae*. The specific name *longipinnis* was considered to be preoccupied, but since they believed the two species *longipinnis* and *rosae* to be identical, they used the latter specific name. Jordan, Evermann and Clark (1930) recognised only one species of this genus, *C. ios* and all the other names have been reduced to synonyms.

In distribution this species ranges from Lower California to the Strait of Georgia in Southern British Columbia. In California they have been recorded as occurring in the following localities : Bodega Lagoon, Tomales Bay, Butano Creek, Carquinez Strait in Solano County, San Pablo Bay, San Francisco Bay, Mouth of Salinas River, Elkhorn Slough, Morrow Bay, fresh tide-water region of San Gabriel River and Morrow Creek in San Luis Obispo County, in the *esteros* at Carpenteria and Goleta in Santa Barbara County, Mugu Lagoon in Ventura County, Mission Bay, San Diego Bay and Tijuana Slough in San Diego County.

Material and Methods

The material for this study was collected from Elkhorn Slough, a tributary of Monterey Bay (36° 48′ 45″ N ; 121° 47′ 15″ W) from July 1946 to February 1948.

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In July and August 1946 a regular "minnow seine" was used for collection but from September onwards a small "bobinet" seine measuring 255 cm. in length and 94 cm. in depth was adopted. The meshes of this net are approximately round, measuring 2 mm. in diameter.

The fish were measured after they had been killed in a 5 per cent formaldehyde solution. A pair of needle-point dividers were set to the length to be determined and the reading made on ruler marked into half-millimeter units. The measurements were expressed to the nearest quarter of a millimeter by estimation.

Habits and Habitat

Clevelandia ios is a small active fish that lives both free and commensally in the borrows of *Urechis, Upogebia* and *Callianassa.* They prefer a bottom composed of a mixture of sand and mud in shallow waters where the wave action is slight. As a typical habitat mention may be made of Elkhorn Slough, a tributary of Monterey Bay, where they are most abundantly found[1], especially in the region of the clayey sand. The ecological conditions of the Slough have been described in detail by MacGinitie (1935). Since the publication of his work, the conditions of the Slough remained more or less the same, as described by MacGinitie, until September 1946 when an opening was made through the long sand spit in order to facilitate the fishing boats to enter the Slough. Fig. 1 shows the place where the opening was made (X). Further north a causeway was built across the Slough and at present the water on either side of the causeway communicates through a pipe 3 feet in diameter. The new opening to the sea and the partial shutting off of the old communication with the sea, by the construction of the causeway, have brought about changes in the nature of the Slough. Before the new opening was made, escape of water from the Slough during low tide was delayed or prevented by the formation of a sand bar at the mouth of the Slough. This resulted in a greater portion of the Slough being covered with water. The water that now comes in through the new opening during high tide flows out rapidly during low tide because of the deepening of the channel and the lack of formation of a bar. This leaves the major part of the Slough completely exposed except for a channel on the western side and a few shallow pools here and there.

The ground colour of *Clevelandia* in life is pale olivaceous to grey, spotted with black pigments. Closer examination shows that xanthophores are present associated with many of the melanophores. Irridescent white spots, varying in number, are found along the mid-lateral region and sometimes also on the opercula. The colour matches perfectly with the environment and it is difficult to locate the fish when it is at rest. The fish is also capable of changing its colour as are many other fishes (Mast, 1914). On a light background it turns pale whereas on a dark background it quickly changes to a darker shade.

Clevelandia, when disturbed, retreats into the burrows of *Urechis, Upogebia* or *Callianassa.* The burrow is used as a shelter rather than as a residence. When the tide goes out they do not generally migrate into deeper waters, but remain either in the pools or in the burrows of one of the hosts mentioned until the next high tide covers the area. On such occasions, when the beds of these hosts are exposed, the gobies can be collected by digging and as many as five gobies have been taken from a single burrow. Only the larger individuals go into the burrows. In this connection it is worth quoting the observations made by MacGinitie (1934) : "*Clevelandia ios,* a small goby fish, is a very interesting creature. It not only seeks shelter within the burrows of the above-mentioned hosts, but, as observed in the laboratory, it makes inspection trips throughout the length of the burrows,

[1] Dr. Bolin informs me (personal communication, January 1955) that they are not particularly common in this area any more.

being perfectly at home at any depth and wriggling past its host whenever it wishes, to the entire indifference of the latter."

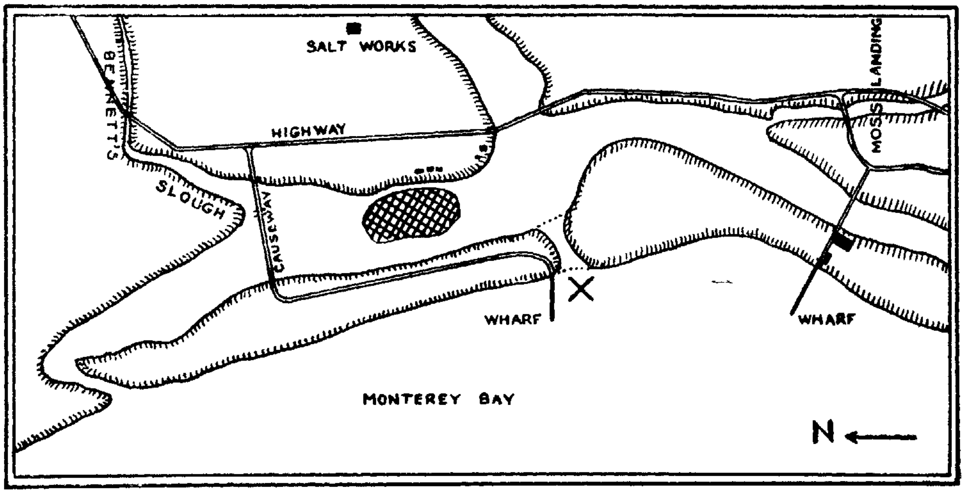

Fig. 1. Map of Elkhorn slough. The cross hatched region indicates the area where samples of *Clevelandia* were collected for this investigation. (After MacGinitie, 1935 with necessary modifications).

The movements of *Clevelandia* are not different from those of other species of gobies and it is believed that the fish uses its ventral fin to support itself on any surface. Duncker (1929) remarks: "Die Bewegungen der meisten *Gobius*-Arten sind auffällig ruckartig; von dem Punkt, an dem sie gesessen haben, schiessen die Tiere geradling zu einem anderen, um dort sofort wieder still zu sitzen. Nicht nur an Steinen, Pfählen und dergleichen, sondern auch auf ebenem Sandgrund werden dabei die Bauchflossen der Unterlage angedrücket. Es ist nicht ganz leicht, sich von der Funktion der letzteren ein klares Bild zu machen. Beim ersten Angedrücktwerden flachen die *V* sich natürlich ab; um jedoch eine Haftwirkung auszuüben, müssen sie einen Hohlraum negativen Drucks umschliessen. Die einzige, schwierig wahrzunehmende Bewegung der *V* unmittelbar nach dem Andrücken besteht in einer Abduktion ihrer Stacheln, durch welche der bisweilen gefranste Hinterrand der Trichtermembran gestrafft wird. Ob sich dadurch, wie zu erwarten, die Trichtermembran von der Ventralfläche der Bauchflossen abhebt und auf diese Weise den erforderlichen Hohlraum bildet, konnte ich nicht mit Sicherheit festellen, ist mir jedoch nach Versuchen am Präparat wahrscheinlich. Die Haftfähigkeit besteht für alle Neigungswinkel der als Unterlage dienenden Flächen."

MacGinitie (1935) remarks: "By means of its pectoral fins it is able to cling to the side of the glass in an aquarium." To find out how *Clevelandia* clings to the glass in an aquarium, three simple experiments were conducted. In the first experiment the lower half of the pectoral fins was cut off so that the fins could not touch the surface but the ventral fin was left undisturbed. The clipping off of the pectoral fins does not seem to hamper the movements of the fish. The fish could still cling to the surface as usual and while it is clinging to the glass side of the aquarium the pectoral fins were not touching the surface.

Aquarium observations have shown that the fish first presses the ventral fin against the glass wall or the bottom and then gradually raises its body which at the same time slightly elevates the ventral fin, too. This gives one the impression that the fish is trying to create a vacuum, as is usually believed. To test this the transverse membrane at the base of the ventral fin was cut off to prevent the formation of a vacuum. The result, as was expected, was that the fish could not cling to the side wall of the aquarium. In another specimen the ventral fin was cut longitudinally into two halves which also prevented the formation of a vacuum. The same result was observed. From these it is concluded that *Clevelandia*, and probably all the other gobies with a united ventral fin, use the ventral fins and not the pectoral fins for clinging to a surface. This is brought about by the creation of a partial vacuum inside the sucker-like ventral fin.

Fighting amongst *Clevelandia* has been noticed only once. A very interesting combat was observed one day while feeding them. A few copepods were dropped into the aquarium. Two female gobies having simultaneously tried and failed to catch the same copepod, lay quiet for a second, then opened their mouths to the fullest extent and charged head on. Their jaws interlocked, one biting the upper jaw of the other and the other the lower jaw of its opponent. Holding this grip they raised about two-thirds of their body from the bottom. This was followed by violent shaking and wriggling movements of the body. Following this the combatants freed themselves, moved back and charged once again. The same procedure was repeated three times after which the fight stopped for a while and they moved about picking up the copepods. But when the same two individuals met again face to face, they picked up the fight once more. The final result was that one of them lost a part of its lower jaw.

The fight has nothing to do with parental care during which period gobies have been observed to attack other gobies or any intruder who might disturb the eggs.

The habit of *Clevelandia* retiring into the burrows of *Urechis* during low tide when the mud flats are exposed, brings up the interesting question of specialized respiratory organs. Redfield and Florkin (1931) have shown that the oxygen content of the water in the burrows decreases rapidly during the first hour after the flat is exposed and, by the fourth hour, to reach a minimal value of 0.06 c.c. per 100 c.c. of water. During the fifth hour there is a definite increase in the oxygen content of the water. Thus there is a possibility of integumental respiration being carried on by *Clevelandia* during this period of low oxygen concentration as found in such species of gobies as *Typhlogobius*, *Bathygobius* and *Gillichthys*.

In cases of well developed integumental respiration it is always observed that the blood vessels come as close to the surface of the integument as possible to facilitate easier and quicker diffusion of the gases. The diffusion of gases is, of course, inversely proportional to the thickness of the partition and hence the efficiency of diffusion is increased if the blood vessels come as close to the surface of the integument as possible. Many examples of integumental respiration have been given by Schoettle (1931). An examination, even with the naked eyes, of those species where there is definite integumental respiration will show a superficial network of blood vessels. *Typhlogobius californiensis* has a subepidermal network of blood vessels (Ritter, 1893). *Bathygobius soporator* has vascularized pectoral fins (Beebe, 1931), and the jaw membrane of *Gillichthys mirabilis* shows rich vascularization (Weisel, 1947). *Clevelandia ios* does not have any such rich subepidermal vascularization. This has been proved by the study of microtome sections of the operculum, pectoral fin, body wall and the tissue covering the head. It can be said with certainty that there is no specially developed integumental respiration in *C. ios*.

MacGinitie (1935) suggests: "They use their operculi but little, and it is probable that they respire mainly through the integument." On the other hand Wilby (1933) has observed: "The rate of breathing varies considerably." He studied the fish in aquaria. The fish buried themselves in the sand and soon made a water passage one on either side of the body, immediately behind the head, by a few slow expansions of the under side of the head followed by rapid contractions. He goes on to say: "After burial the first regular pulsations were about 40 per minute. As soon as a water passage had been made the rate increased to about 50 or 60 varying with the different individuals. At a temperature of about 25°C the fish were still alive but apparently in distress and the breathing rate increased to about 80 per minute."

The observations the author made on respiration of *Clevelandia* were at a temperature of 13.5°C. The number of breathing movements of the opercula were counted for six individuals at rest. It varied from 36 to 62 per minute.

One would normally expect *Clevelandia* to be eurythermic, placed as they are in an environment which is subject to wide fluctuations in temperature. Experiments were conducted in the laboratory to ascertain the tolerance of *Clevelandia* to changes in temperature. A number of individuals collected from Elkhorn Slough, were subjected to different temperatures for a maximum period of sixty hours and the mortality rate observed. The range of temperature varied from 4°C to 33.5°C. The results of the experiment are given in Table 1.

TABLE 1

Effect of temperature on Clevelandia ios.

Number of fish	Range of temperature	Time Hours	Observations at the end of the time indicated in the left hand column
13	4.0°C	4	Slightly inactive, but when disturbed swam around actively. 2 of the 13 specimens lay upside down, but when disturbed they turned around and swam about.
		16	Inactive, 50 per cent of them lay with their belly up, but none of them was dead.
		22	One dead and the others showed signs of slight distress and were sluggish.
		40	All alive but very sluggish.
		60	All alive but very sluggish.
4	17°–18°C	4	All alive and active.
		16	All alive and active.
		22	All alive and active.
		40	All alive and active.
		60	All alive and active.
13	22°–26°C	4	All alive and active.
		16	All alive and active.
		22	A few showed slight distress and swam about in circles.
		40	All alive and seemed apparently all right.
		60	All alive and active.
13	29°–33.5°C	4	One dead and the others showed slight distress.
		16	Ten dead and the others showed increasing distress and restlessness.
		22	Two more out of the remaining 3 died.
		40	All dead.

From these observations it is evident that the low temperature did not suit them well and the extreme sluggishness of the fish is evidence of this. They behaved normally and remained very active throughout in the 17° to 18°C range; whereas from 22° to 26°C even though all specimens survived to the end of the experiment, the fish began to show signs of distress, but they soon got over it and regained their normal activity. This is perhaps due to the fact that they became acclimated to the higher temperature. Wilby (1933) has stated that the fish survived at a temperature of about 25°C but apparently were in distress. As the temperature increases (29° to 33.5°C) the ability of the fish either to withstand it or to get acclimated to decreases and results in death.

In Elkhorn Slough the usual range of temperature is from 12° to 19°C. But it has been noticed that in the pools that are left when the tide recedes the temperature of the water rises, in the sunshine, to 23°C. However, at the same place where the temperature of the water was 23°C, the temperature in the underlying mud, at a depth of six inches, was only 15°C. The highest temperature recorded in such mud was only 19°C. These figures are taken from MacGinitie (1935). Thus the bottom living *Clevelandia* has to encounter in nature only a range of temperature from 12° to 19°C. The experiments at the same time show that they can withstand a wider range of temperature even though they are most active in the 17° to 18°C range.

Feeding Habits and Food

The feeding habits of adult *Clevelandia* have been observed in the aquarium. Different kinds of food, such as small Annelids, pieces of Phoronids, small shrimps, pieces of crab and mussel meat and copepods were readily taken. Algal filaments, which were provided, were seldom eaten. Even though they pick up any kind of material, the particles are not eaten always unless they are of the right type of food material. MacGinitie (1934) observed in the laboratory: "If a large piece of, for example, clam meat, too large for a goby to swallow, is put into the burrow which also contains crabs, the goby, after attempting to swallow or tear it apart, will carry the meat to a crab and stand by while the latter makes it smaller, the fish at intervals snatching it for another attempt at swallowing, to the disconcertion of the crab. The fish will do the same thing in an open aquarium with *Spirontocaris* present." It was observed that the fish prefer moving objects and generally pick up the animals from the bottom. Occasionally they come up and feed on the animals sticking to the sides of the aquarium but they have never been noticed to feed from the surface of the water. The food material is picked up from the bottom by a quick lateral movement combined with a slight forward jerk or a straight front attack using their pectoral fins for the forward movement. Feeding seems to be confined to day time as they have not been seen feeding at night.

The stomach contents of thirty specimens, including the smallest and the largest in the catch, were examined each month soon after the fish had been killed and preserved in a 5 per cent formaldehyde solution. The alimentary canal of each specimen was dissected out and the contents, spread out on a slide, were examined. No attempt was made at a thorough quantitative analysis and even in the qualitative analysis the usual procedure was to record only the genera of the organisms present. In a few cases the species also were determined when the condition of the organism permitted it. The organisms were recorded as 'present but few', 'present in fair numbers' and 'numerous'. Later relative numerical values (arbitrary) were assigned to these and graphed (Figs. 2 and 3).

DIATOMS: Out of the samples examined the percentage of individuals found feeding on diatoms varied from 0 to 57 per cent. From November to May they are fairly well represented in the food and the utmost utilization by the maximum number of individuals was observed in May. A larger proportion of diatoms form the food of the smaller fish. The following genera of diatoms were included in the food: *Coscinodiscus*, *Grammatophora*, *Gyrosigma*, *Melosira*, *Navicula*, *Nitzschia* and *Thalassiothrix*.

FILAMENTOUS ALGAE : Filaments of *Enteromorpha intestinalis* were occasionally seen as part of the food. Only fourteen out of 360 had them in the alimentary canal.

TINTINNIDS : The percentage of fish found feeding on Tintinnids varied from 3.3 to 47 per cent in the different monthly samples. The peak falls in August and September. They form only a minor item of the food but are present all the year round, at least in one specimen. They all belong to the genus *Favella*.

OVA : Small eggs ranging from 55 to 60 micra in diameter formed a fair proportion of the food of both the young ones as well as the adults. Except in September and January, eggs were present in varying proportions as part of the food in all months. An analysis of the samples shows that from 26.6 to 87.7 per cent of the individuals were feeding on these ova. Identification of these ova proved impossible. Lebour (1919) mentions ova as forming a large proportion of the food of young fish. The diameter of the eggs, she observed, was about 1.6 mm. and since the size approximates that of the eggs of *Calanus finmarchicus*, which has free eggs, she believes that the eggs are of this species of copepod.

NEMATODES : Nematodes belonging to the genus *Metoncholaimus*, resembling *M. pristiurus*, form a large proportion of the diet all the year round. Mostly the larger specimens feed on them. In the samples examined the percentage of individuals feeding on Nematodes varied from 3.3 to 66.7 per cent. Large number of this free living Nematode are found in Elkhorn Slough and they are doubtless food organisms and not parasites.

ANNELIDS : Annelids, either larval or otherwise, do not form an important item of the food. Out of 360 specimens examined only nine contained Polychaetes. They belonged mostly to the species *Capitella capitata*, and a few post-larval Polychaetes were also found. It is interesting to note here that out of 360 specimens examined for the year, fourteen of them were found to feed on the little known annelid belonging to the genus *Dinophilus*.

CRUSTACEANS : The most important item of the food is the crustaceans. Copepods of different species were found to be the most predominant among these and such larval forms as nauplii and zoea, especially the zoea stage of *Callianassa*, were also found occasionally. Only four out of 360 specimens contained no copepods. Copepods formed the staple food of the young as well as the adults throughout the year. Other crustaceans such as amphipods, isopods and *Nebalia* sp. were also included in the diet. The chief copepods forming the food were in two genera of Harpacticoids : *Canthocamptus* and *Pseudobradya*.

In a few instances the stomach contents were so far digested that identification was impossible. In three of such cases it is believed that the partly digested material was *Urechis* larvae. MacGinitie (1935) remarks that *C. ios* undoubtedly eats great numbers of the larvae of *Callianassa*, *Urechis*, annelid worms, etc.

The analysis of the food of *Clevelandia* on the basis of size (Fig. 2) reveals the following interesting facts. Copepods constitute the main item of food practically at all sizes. The other crustaceans such as amphipods, isopods, etc., become important only to the larger fish. So also the nauplii, zoeae and ova seem to become more important with age. The data given in Fig. 2 also suggest that the peak for the smaller nauplii occurs in the smaller fish. The complete absence of nauplii and zoeae in the 40-45 mm. group is surprising but it should be pointed out here that only nine specimens were available in this size range. It is difficult to explain why the ova become more promient in the larger size group, but it is likely that these being not actively moving may require a considerable period of learning on the part of the fish before they are taken and hence become prominent in the larger size groups. Diatoms and tintinnids seem to be most important at a size range of 15-30 mm. and the decline in the importance of these in the larger fish is probably due to the size factor. The nematodes and annelids, which are comparatively larger organisms, become more prominent in the older groups and it is possible that

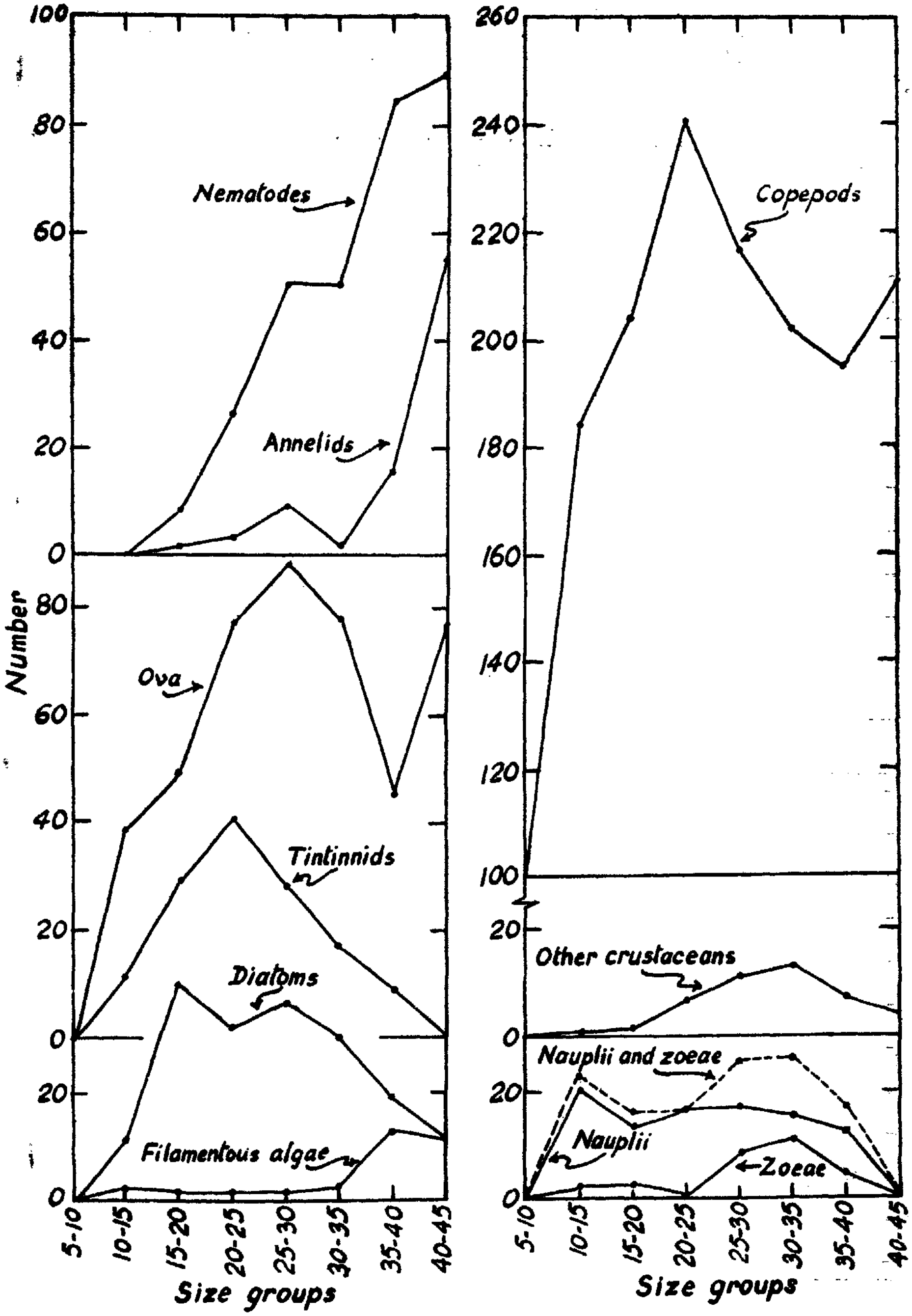

Fig. 2. Showing the food of *Clevelandia* at various size groups.

this may also mean a change from plankton to more of bottom feeding in the larger fish. Filamentous algae, which are negligible up to about 35 mm., show an increase in the larger fish. The presence of these may be incidental to catching the nematodes and annelids and seem to support the inference that the larger fish tend to feed more and more at the bottom. The observations in the laboratory also indicate that the adult fish feed more at the bottom.

Fig. 3 shows the seasonal variation in the food. Here again the copepods are the mainstay at all times and the other crustaceans show a small peak in September when the copepoods show a decrease. From February to August there is a prominent peak of ova. It is likely that these are copepod eggs and the peak.

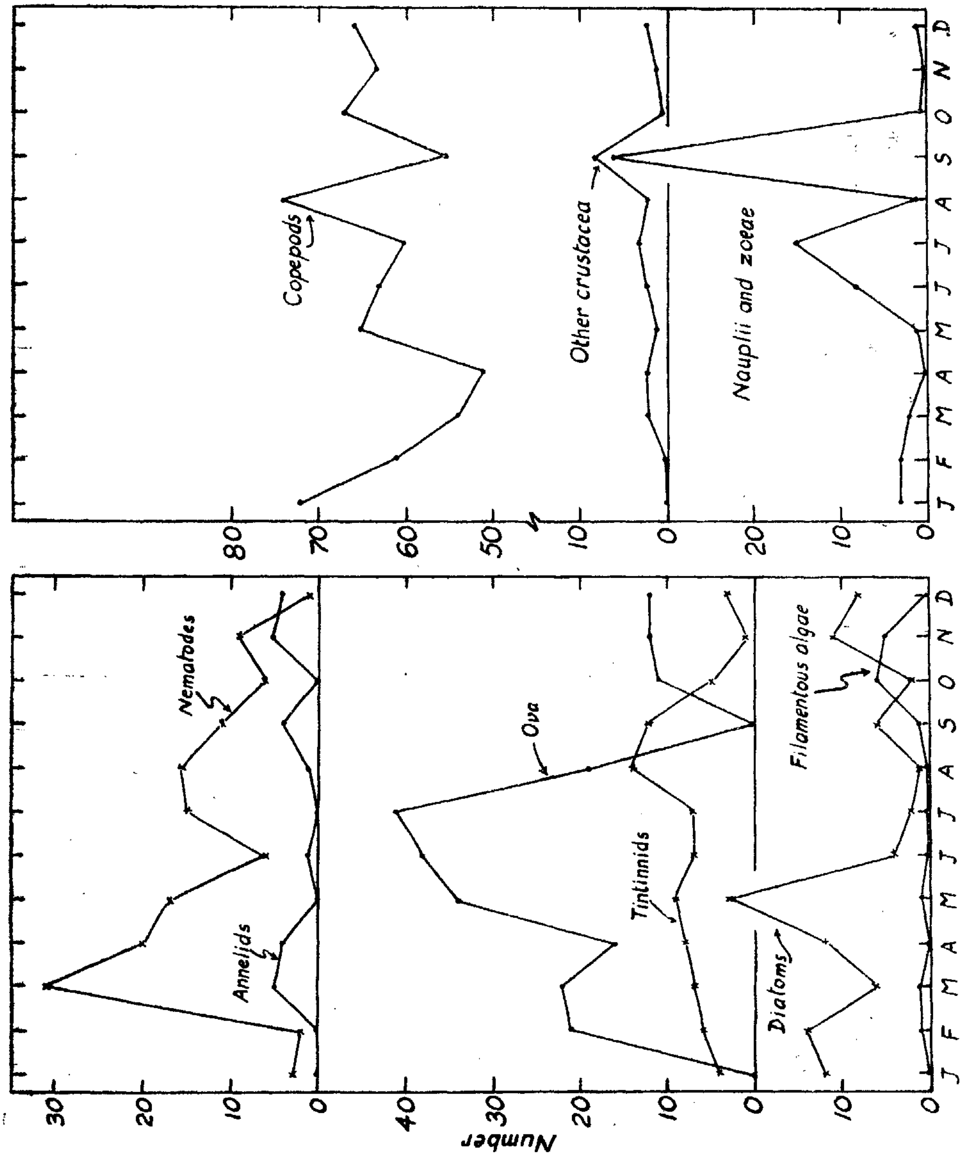

Fig. 3. Showing the food of *Clevelandia* in different months.

probably is a reflection of the spawning of copepods. The nauplii and zoeae are found in fair numbers in June-July and in large numbers in September. If they are considered separately the peak of nauplii shows a tendency to occur in July and September which follows the peak of copepod eggs. The zoea peak on the other hand, occurs in September. These zoeae are, as mentioned earlier, of *Callianassa* and the peak coincides with their spawning. The nematodes show a prominent peak in March and are relatively abundant from March to September (with the exception of June when the value was low but this may be due to sampling error) and low values are obtained for the other months. It appears from this that the nematodes are more common during the warmer months when the fish feed on them actively. The annelid curve shows weak peaks in March-April and again towards the end of the year. The tintinnids, which form a minor item of food, show a distinct peak and it is interesting to note that the tintinnid curve is somewhat opposite to the diatom curve. This possibly suggests that when the diatoms are low the tintinnids are exploited as a substitute food. The diatoms show a distinct peak in summer and are fairly high during November-February and low during June to October which coincides fairly well with the period when the low nutrient oceanic water dominates the area. The filamentous algae, which are probably incidental to feeding at the bottom, show a very faint peak in October-November.

In summing up, it may be said that there are changes in the diet of *Clevelandia* with age and with season. The larger fish eat more of larger organisms and such smaller items as diatoms and tintinnids decrease with age. The increase in the number of nematodes and annelids, supported by the presence of more filamentous algae in the larger fish, suggests a gradual change from plankton to bottom feeding. The copepods form the mainstay of food at all times and at all seasons, but it was observed that during periods when the copepods are low, the fish eat more of nematodes, annelids, ova, nauplii, zoeae and other crustaceans like amphipods, isopods and *Nebalia*.

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