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DONALD J. KLEMM -- STUDIES ON THE FEEDING RELATIONSHIPS OF LEECHES (ANNELIDA:HIRUDINEA) AS NATURAL ASSOCIATES OF MOLLUSKS 1
(Concluded from Sterkiana No. 58)

SUSAN FRAKER CARNES -- MOLLUSKS FROM SOUTHERN NICHUPTÉ LAGOON, QUINTANA ROO, MEXICO 21

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Part III, Variations in Leech-Snail infestations

A summary of the results (Figures 1-25) clearly illustrated that leech-snail infestation was seasonal among all of the habitat types with the woodland pool habitat (Figs. 1-5) exhibiting a biannual cycle. In some of these habitats, except the woodland pool, snails were not collected during winter. This omission was not that they were not there but rather because they were difficult to find under the ice. The woodland pool leech fauna also was more restricted in that only one species, *M. lucida*, was found infesting five species of snails, especially *S. exilis* and *H. trivolvis*.

During 1972 and 1973 *M. lucida* first appeared in the snails in early spring reaching peak infestation in June, July, and August and with a definite decline thereafter. No free-living *M. lucida* was found. The young leeches grew in size each month suggesting a definite developmental period within the snails. During this same spring and summer period the snails, *S. exilis* and *H. trivolvis*, were available in abundance. In contrast very few *P. exacuous*, *P. armigera*, and *A. hypnorum* were scarce in this woodland pool. Many woodland pools are temporary and present variable ecological conditions; it is possible also that the snails could not withstand predation or parasite burden produced by the leeches.

By late summer of 1972 the woodland pool dried up and the only surviving snail, *S. exilis*, was alive and estivating while attached to various substrates by means of its secreted epiphragm. Its pattern of estivating was first reported by Sterki (1912) and again by van der Schalie (1940) in relating it to estivation of a few other pulmonates. This important behavior probably enabled *S. exilis* to survive temporary drought conditions. Klemm (1973) collected some of the estivating *S. exilis* during a dry period. These snails were infested with leeches and some also harbored trematode larvae. As a test, 40 specimens of *S. exilis* were left in a plastic bucket and as the water evaporated, they estivated on the sides of the container. These snails were not disturbed for four months. All of those that remained attached at the time they were dissected were alive and many were infested with leeches; several were infected with trematode larvae.

In 1973 that same woodland pool did not dry up but the snails and leeches nevertheless disappeared in late August just as they did during the dry season the previous year. Vlasblom (1971) stated that *A. hypnorum*, an associated woodland pool snail, occurred on soil types of low salinity in the Netherlands but largely in situations similar to our woodland pools. He reported that *Aplexa hypnorum* was adapted to withstanding dry periods on these soil types by the ability of eggs (?) and juveniles of the new generation to survive the drought and winter to emerge in the spring following hibernation. The snail species, *Aplexa hypnorum*, was found to produce only one generation a year. He further stated that due to the dry periods hatching may close temporarily so that an overall pool population may contain two different size/age classes in the autumn, winter and early spring.

In contrast, the data on *S. exilis* indicate that there was only one dry period which occurred in late summer of one year but not the next. Hence, no size/age classes were observed. This suggested that in the local woodland pools *S. exilis* has a one generation cycle with young occurring only in the early spring, reaching adulthood quickly and the adults then die in late summer. The development of *M. lucida* in *S. exilis* was closely synchronized with such a spring-summer cycle.

The data from lakes, ponds, a roadside ditch, and a creek (Figs. 6-25) show that leech infestations occur seasonally. Peak periods were observed in the spring, early summer, and in the fall with some variability occurring only with the species of snail and within the different habitats. Snails found in abundance indicated that peak leech infestations developed twice a year and occurred in all habitats during the winter. This trend demonstrated the possibility that there were two different size/age classes or generations of leeches with some varying degree of development within the various snails. As measured in percentage, the leech infestations in most habitats declined in June and July, increased in the fall to be maintained over the winter with peak periods in spring, early summer, and in the fall again.

In the various habitats the snails were infested with several species of leeches, mainly of the genus *Helobdella*, and then usually only one species and never multiple species infestations. Specimens of leeches collected early in spring and fall, as sampled each month, appeared to grow and develop within their molluscan host. Several specimens collected in early spring and late winter apparently reached maturity within the snail host since their gonads were clearly seen within their bodies.

Gruffydd (1965a), in contrast to this report, stated that *G. heteroclita*, an apparent annual and a different genus than *Helobdella*, never infested snails during the months of June to September. He found that infestation began in October and was at maximum in midwinter. Infestation then declined gradually to disappear in May, presumably when the leeches became free-living. He thought the increased infestation during late autumn into winter was probably a temporary shift of the *G. heteroclita* population into snails at the time for their free-living state or perhaps a gradual build-up on the host when the new generation of leeches succeeded in locating their snail hosts. There wws also a possibility that a continuous interchanging of individuals took place between their parasitic stage and the free-living forms in the leech population even during maximum infestation.

Wilkialis (1964) also found *G. heteroclita* f. *hyalina*, a species closely related to *G. heteroclita*, abundant in late autumn when these leeches were searching for a suitable shelter during deteriorating weather conditions and they tended to attack snails during the summer when they needed food. Hatto (1968), who also studied *G. heteroclita,* concluded, when he found an absence of food in the leeches' gut, that few leeches fed during the winter but resumed feeding in spring and summer. Many of the leeches collected from snails in winter during this study had food in their guts. While this might indicate that they had fed recently, leeches are known to store food in their guts for long periods and they are also able to go without food for long periods of time.

As among other helobdellids, brooding *H. stagnalis* were found by Sawyer (1972) in Michigan from early April to August, suggesting a pattern similar to the *Helobdellas* observed in this study. Under certain circumstances a population of *H. stagnalis* may produce two generations a year (Mann 1957b). In England some of the young leeches hatched in April and May and bred in July and August; others reproduced in a single season (Bennike 1943). Thut (1969) found *H. stagnalis* took one year to complete its life cycle in Lake Washington. Egg-laying started early in January but occurred predominantly in early May; the breeding season lasted until late in September with adults dying at the end of the breeding season. In Alberta, the breeding season reported by J.E. Moore (1964) was from May to early September with evidence suggesting that two generations were produced in a year. Further studies of the poorly known species in the genus *Helobdella* will be required.

Part IV. Leeches from mollusks under natural conditions

In contrast to the experimental approach taken by Chernin *et al.* (1956) on predator-prey, or the host-parasite studies by Wilkialis (1964), Gryffydd (1965a), Hatto (1968), Sarah (1971), and Klemm (1973), this study provides seasonal information on identification of all the leeches and mollusks collected. The precise organ of parasitizing leeches with the organs of mollusks in nature are tabulated (Tables 13-23). Moreover, information on the species of leeches attacking the several mollusk species makes possible interpretations of some of the predator-prey and host-parasite relationships.

Live snails were dissected in order to discover the anatomical sites or organs parasitized by the leeches. Six, mostly juvenile, leeches *(H. fusca, H. lineata, H. papillata, G. complanata, G. heteroclita,* and *M. lucida)* were found either on or inside the 14 species of pulmonates *(S. exilis, S. elodes, H. trivolvis, H. anceps, H. campanulatum, A. hypnorum, P. exacuous, P. armigera, G. parvus, P. gyrina, P. integra, P. parkeri, L. stagnalis, L. megasoma);* one sphaeriid clam, *S. simile,* served as leech host. Of all of these mollusks, *H. trivolvis* was the most widespread and occurred in most of the habitats studied (eurytopic).

The snail-leech, *G. complanata* (Pennak 1953, Mann, 1957a, 1953, Klemm 1972a, and Sawyer 1972), was never inside any of the mollusks studied even though adult specimens were abundant and free-living. Sarah (1971) found two juvenile *G. complanata* parasitizing *H. trivolvis* and *H. anceps.* In this study it was found only on the shells of the clam, *S. simile.* The immunological data given on the gut contents (Fig. 26) positively demonstrated that this species fed either as a temporary parasite or predator on mollusks in the various habitats.

Young glossiphoniids were reported by Mann (1962) to live for long periods in the mantle cavity of some of the larger freshwater snails. Chernin *et al.* (1956) demonstrated experimentally that small leeches were capable of invading the shell of a live snail once they were brought into contact with it by the parent leech. After carefully dissecting a specimen he found one leech attached under the dorsal margin of the mantle collar; a second was free in the mantle cavity and a third was firmly attached beneath the base of the columellar muscle.

In the various mollusks studied, leeches were found in five specific locations. They were: the mantle cavity; under the mantle (between the digestive gland and aorta); in the intermedium of the mantle (between the shell and mantle); in the kidney; and on the outer shell. Wesenberg-Lund (1937) found *G. heteroclita* in a dissection of *B. tentaculata* but he did not report its location. Gruffydd (1965a), in England, found *G. heteroclita* inhabiting the mantle cavity of *L. pereger.* Hatto (1968), in Wales, also reported this leech inside the shell and in the mantle cavity of *L. stagnalis.* Wilkialis (1964), in Poland, found mass occurrences of *G. heteroclita* f. *hyalina* in the mantle and mantle cavity of *L. stagnalis, L. ovata, S. palustris,* and *P. corneus.* In this study only one specimen of *G. heteroclita* was found parasitizing *P. gyrina;* it was above the mantle between the shell and aorta. A reason for not finding more *G. heteroclita* is that it is considered a rare species (Klemm 1972a and Sawyer 1972). Aside from this report of its occurrence on *P. gyrina,* it has never before been associated with a specific snail in North America.

In his survey Sarah (1971) found no leeches in the mantle cavity proper of either *H. trivolvis* or *H. anceps.* However, he discovered *H. papillata* beneath the mantle in 42% of specimens of *H. anceps,* whereas *H. lineata* was never found below the snail's mantle. He also stated that a probable reason for this site selection was that the small size of *H. papillata* encouraged a sub-mantle location restriction in the small *H. anceps,* whereas the larger size of *H. lineata* made sub-mantle infestations impossible and generally restricted them to parasitizing the larger *H. trivolvis.*

In a woodland pool Klem (1973) found that 89% of *M. lucida* in *S. exilis* were above the mantle, between the shell and the mantle in the vicinity of the albumen and digestive glands, 7% were in the mantle cavity, and 4% inside the kidney.

This investigation (Tables 13-23) showed that of the 1,004 *H. fusca,* 6.1% were in the mantle cavity, 34.8% under the mantle, 43.8% above the mantle, 14.8% in the kidney, and 0.09% outside and attached to the shell. Of the 390 *H. lineata* collected, 8.2% were in the mantle cavity, 36.7% under the mantle, 44.6% above the mantle, and 10% in the kidney. Of the 965 *H. papillata* collected, 8.5% were found in the mantle cavity, 70.4% under the mantle, 19.5% above the mantle, 0.82% in the kidney and 0.31% outside on the shell. Of 410 *M. lucida* collected, 2.7% were in the mantle cavity, 71.5% under the mantle, 11.5% above the mantle, and 14.4% in the kidney. These accumulated data also disclosed significant location differences, or preferences, similar to results obtained by Sarah (1971) between snails and leeches occurring in the same or different habitats.

In Table 13 for a woodland pool, 83.5% of *M. lucida* were found under the mantle of *S. exilis*, 13.1% above the mantle, and 1.9% in the kidney. But in *H. trivolvis*, 3.3% of *M. lucida* were found under the mantle, 6.7% above it, and 88.3% in the kidney.

When considered in terms of habitats, the following associations were discovered: from George Pond (Table 15), *H. trivolvis* was parasitized by *H. fusca* and *H. lineata*. The leeches were distributed, as follows: 34.8% of *H. fusca* were found under the mantle, 56.1% above the mantle, and 3.8% in the kidney; however, *H. lineata*'s locations were 34% under the mantle, 32% above it, and 30% in the kidney.

Bert Pond (Table 16) yielded *H. trivolvis* infested with *H. fusca* and *H. lineata*. Some significant differences in the sites established by these leeches were also observed: 13.7% of the *Helobdella fusca* were under the mantle, 31.5% above the mantle, and 29.8% in the kidney; for *H. lineata*, 6.9% were under the mantle, 75.7% above the mantle, and 13.9% in the kidney.

In Crane Pond (Table 17) *H. trivolvis* contained two species of leeches, *H. fusca* and *H. papillata*. Among the *H. fusca*, 5.4% were in the mantle cavity, 61.9% under the mantle, 25% above it, and 7.6% in the kidney. For *H. papillata*, 25% were in the mantle cavity, and 75% above it; none was under the mantle or in the kidney. Also in Crane Pond *H. papillata* was found on *H. anceps*, 6.5% in the mantle cavity, 77.6% under the mantle, 13.1% above the mantle, and 2.8% in the kidney. *Helisoma campanulatum* in Crane Pond was also found parasitized with *H. fusca* and *H. papillata* but with significant location differences: in *H. fusca* 86.5% were under the mantle, 6.7% above it, and 2.9% in the kidney; in *H. papillata* none was under the mantle, but 66.7% were above it, and 26.7% in the kidney.

Helisoma trivolvis collected from a lake (Table 18) was parasitized with *H. fusca*, *H. papillata*, and *H. lineata*. Significant differences were noticed among the three leeches: 25.2% *H. fusca* were under the mantle and 60.6% above it. Two *H. lineata* were above the mantle and three *H. papillata* in the mantle cavity and one under the mantle.

In Four-Mile Lake (Table 19) differences in location occurred between *H. fusca* and *H. papillata* infesting *H. trivolvis* and *P. gyrina*. *Helobdella fusca* collected from *H. trivolvis* had 16.5% in the mantle cavity, 22.9% below the mantle, 34.9% above it, and 7% in the kidney. *Physa* was infested with *H. papillata* with 7.6% in the mantle cavity, 79.4% below the mantle, 12.8% above mantle and none in the kidney.

From Murray Lake (Table 20) *H. campanulatum* was infested with *H. fusca* with 90% under the mantle and 30% in the kidney. The snails, *P. armigera*, *H. trivolvis* and *P. gyrina* were infested only under the mantle.

Snails from the Fleming Creek area (Table 21) had similar sites for *H. lineata* and *H. papillata* but there were species preferences as to host snails. *Helisoma trivolvis* was parasitized by *H. lineata* with 13.2% in mantle cavity, 60.8% below mantle, 23.8% above it and 2.1% in the kidney. *Physa gyrina* had *H. papillata* with 8% in mantle cavity, 56% below mantle and 36% above it.

From a roadside ditch (Table 22) *H. trivolvis*, *S. elodes*, *P. gyrina* were infested mainly with *H. lineata* and *H. papillata*. *Helisoma trivolvis* was parasitized mainly with *H. papillata* with 8.3% in mantle cavity, 77.7% below mantle, and 13.8% above the mantle. In *S. elodes* the *H. papillata* were distributed with 7.5% in mantle cavity, 75% below mantle, 12.5% above it, and 5% in kidney. *Physa gyrina* had two leeches: *Helobdella fusca* were distributed with 14.3% in mantle cavity, 71.4% below mantle, 14.3% above the mantle. However, *H. papillata* had 5.9% in mantle cavity, 71.3% below mantle, and 22.8% above it.

The leeches collected from the mollusks of the several incidental sites revealed similar location preferences and they were distributed mainly below the mantle and between it and the shell.

Sarah (1971) suggested that there was perhaps an anatomical or physiological difference between leeches as well as in the snails that would allow or necessitate that they find a haven in one location more than another. While none was given, an additional suggestion for location differences might be the nutrient preferences of the various leeches.

The results (Tables 13-23) also suggest a specificity of association between the various snails and leeches. These differences in frequencies of leeches on the snails examined were probably a function of differences in selectivity towards available snails as a source of food. Klemm (1972a) and Bennike (1943) stated that no other single factor is more important in restricting the distribution of leeches than the availability of food organisms. Contingency tables were developed to check the statistical significance of the data, using Chi-square, which are given in Siegel 1956, Snedecor 1961, Bishop 1967, or Langley 1970, as a test of snail and leech association. The null hypothesis was that there was an equal chance that leeches could parasitize the various snails of a particular habitat.

A chi-square value of 53.28 for one degree of freedom was found for *H. trivolvis* with *H. fusca* and *H. lineata*. A value of this magnitude for one degree of freedom indicated that the probability of these associations occurring by chance is highly insignificant. This evaluation suggested that in George Pond *H. fusca* was highly selective for *H. trivolvis*.

A chi-square value of 42.44 for one degree of freedom was determined for *H. trivolvis* with *H. fusca* and *H. lineata* in Bert Pond. Again this value indicated with one degree of freedom that *H. fusca* was highly selective for *H. trivolvis*.

In Crane Pond a chi-square value of 148.92 was obtained for two degrees of freedom for *H. trivolvis*, *H. anceps*, and *H. campanulatum* with *H. fusca* and *H. papillata;* this value also indicates that the probability of these associations occurring by chance was highly insignificant. In this area, *H. fusca* was highly selective for *H. trivolvis* and *H. campanulatum*, whereas *H. papillata* was highly selective for *H. anceps*.

The chi-square value of 288.62 for two degrees of freedom was determined for *H. trivolvis*, *H. anceps*, and *P. gyrina* with *H. lineata* and *H. papillata*. Such a high value with two degrees of freedom showed that the probability that these associations occurred by chance was also insignificant. Therefore, for the Fleming Creek area, *H. lineata* is highly selective for *H. trivolvis*, whereas *H. papillata* is selective for *H. anceps* and *P. gyrina*. Sarah (1971) also indicated that a similar association in the same area for *H. papillata* with *H. anceps* and for *H. lineata* with *H. trivolvis*.

From a roadside ditch (T1S, R3E, S1ASE), *H. trivolvis*, *S. elodes* and *P. gyrina* had a chi-square of 18.12 for two degrees of freedom with *H. fusca* and *H. papillata*. The probability of these associations occurring by chance is highly insignificant; the data show that *H. papillata* is highly selective for *H. trivolvis*, *S. elodes* and *P. gyrina*.

A chi-square value of 79.04 for one degree of freedom was found for *H. trivolvis* with *H. fusca* and *H. papillata*. The probability of these associations occurring by chance is negligible. It was also revealed that for the Four-Mile Lake area *H. fusca* is selective for *H. trivolvis*. In Four-Mile Lake *P. gyrina* had a chi-square value of 41 for one degree of freedom with *H. fusca* and *H. papillata*. This relationship as a matter of chance is quite insignificant and this value illustrates that *H. papillata* is highly selective for *P. gyrina*.

A chi-square value of 78.02 for one degree of freedom was calculated for *H. trivolvis* with *H. fusca* and *H. lineata*. This high value suggests that for that lake (T2S, R3E, S1NE) the probability that *H. fusca* occurred with *H. trivolvis* by chance is insignificant; again the association was highly selective.

Also for another lake (T2S, R3E, S1NE) the chi-square value of 11 with one degree of freedom was obtained for *H. campanulatum* with *H. fusca* and *Helobdella* spp. This high value with one degree of freedom showed that in this area *H. fusca* is selective for *H. campanulatum*.

The causes for these definite associations in terms of selections by certain leeches for specific snail hosts may involve several basic relationships, such as: anatomical, physiological, behavioral, nutritional, and perhaps others. These relationships require further investigations.

Part V. Mollusks Parasitized with Leeches; Cercarial Types; Leeches infected with Tetracotyles

In Michigan basic helminthological studies have as yet not been made on leeches. Sarah (1971) suggested that certain leeches inhabiting Fleming Creek, Michigan, seemed to avoid *Stagnicola* and *Physa* snails when they were carrying intense trematode infections. A study by Klemm (1973) provided data from a woodland pool that also indicated that the leech *M. lucida* tended to avoid *S. exilis* snails infected with trematode larvae. However, the following six pulmonates, *H. trivolvis*, *H. anceps*, *H. campanulatum*, *P. gyrina*, *S. exilis*, and *A. hypnorum*, were infected with trematodes and also infested with leeches. Four leeches, *H. fusca*, *H. lineata*, *H. papillata*, and *M. lucida*, and six cercarial types (xiphidiocercariae, echinostome cercariae, furcocercariae, amphistome cercariae, macrocercariae, and strigeid cercariae) were associated with these snails.

These results (Tables 24-29) suggest that the probability of leeches occurring with snails infected with trematode larvae is rare. These data also suggest that leeches under natural conditions prefer healthy mollusks and especially juveniles. It is possible that the mollusks infected with trematodes and also infested with leeches died sooner because of such a heavy parasite burden. Consequently, they were relatively rare. Chernin *et al.* (1971) in studies of host finding by miracidia reported that there were disruptions, in some ill-defined way occasioned by certain aquatic leeches (Chernin, unpublished data). Such interactions in natural waters may reduce the population of miracidia and thereby reduce the frequency of certain trematode infections in mollusks. Also, very few leeches infesting snails were observed with trematode larvae in their gut contents. Studies are, therefore, needed under natural conditions, to determine the relationships of the initial snail-miracidial-leech contact; the invasion process; and the establishment of the trematodes within the snail host when it was already infested with leeches or vice versa.

Another parasitic relationship exists in which both leeches and mollusks act as secondary intermediate hosts in the life cycle of helminthes; certain leeches may also act as intermediate hosts in the life cycle of certain cestodes. Mann (1962) and others cited several references in which leeches were infected with metacercariae of trematodes or with cysticercoids of cestodes.

Of the 2,790 specimens of leeches infesting mollusks in this study only eight leeches were infected with tetracotyles; five leeches with tetracotyles infesting snails and three infected with tetracotyles infesting snails infected with trematode larvae. Other leeches not found on mollusks may well play a more major role as secondary intermediate hosts in the life cycle of some trematodes.

Mann (1962) reported other cysts as occurring in *Erpobdella*. This cyst clearly shows a ring of hooks characteristic of cestodes. One such cyst has been shown to be the cysticercoid of *Hymenolepis parvula*, a small cestode found in the intestine of ducks. None of the leeches examined during this study had this type of cyst. It is possible that the Glossiphoniidae are not an ideal intermediate host as are leeches in the Erpobdellidae and Hirudinae.

Part VI. Distribution of Leeches found on Mollusks under Natural Conditions

The data (Tables 30-38) showing distribution of leeches found on snails under natural conditions do not contradict the findings of Sarah (1971) and Klemm (1973). This information, however, wws gathered seasonally, and from a variety of habitats, and many additional species of snails were examined for leeches. Sarah (1971) reported multiple infestations of snails with *H. papillata* (50%) at one time, while multiple infestations with *H. lineata* were less (37%). Klemm (1973) found multiple infestations of *S. exilis* occurring with *M. lucida* (9%), but single infestations occurred more often (70%). These additional data, as here reported, reveal that multiple infestations occurred in snails from all habitats sampled. The data from the ten selected habitats show that multiple infestations occurred seasonally but more often during spring, summer, and fall than in winter. It was quite apparent that the larger species of pulmonates in the different habitats had more multiple infestations. Again, among all specimens found with leeches, single infestations occurred more often than multiple ones. The same pattern was evident among the stations sampled only once.

Sarah (1971) stated that the difference in multiple infestations was one of overcrowding within the snail or the snail's inability to withstand predation. There are several possible explanations for the differences in multiple infestations: (1) the survival rate in snails with single infestations is probably higher and this would account for the higher number of them found. (2) The size of the snail must be considered since larger snails could withstand infestation by more leeches. (3) It is also possible that not all the leeches fed at the same time. Not all of the leeches studied were approximately the same size soasonally, but as the snails were sampled each month the sizes of the leeches increased proportionately. (4) Also, not all leeches were found in the same locations. When multiple infestations occurred in snails, the leeches were found between the shell, under the mantle, and in the kidney more often than in the mantle cavity. (5) All multiple infestations were by the same leech species. (6) Fewer multiple infestations were found in combination with both leech and cercarial types. It was reasoned that more leeches were not found because the snails probably would not withstand the parasite burden in this condition. (7) However, many multiple infestations did occur with both leeches and chaetogasters, but in that case both were using the snail's resources differently.

Part VII. Leech inside Snail under Natural Conditions

Leeches in the family Glossiphoniidae have a pore-like mouth through which a muscular proboscis is extended. This proboscis is inserted into the tissues of the host to consume the blood and soft tissues of the host. Thus, the glossiphoniids are equipped for sucking blood and they may suck all of the body fluids from small snails to the extent that they may remove all the animal tissues. This process clearly is predation, yet young specimens if the same species may live for long periods in the snail, only occasionally taking meals of blood --a mode of life which may reasonably be called parasitism.

Parasites which depend upon their association with other organisms for a food supply, must have a means of finding their hosts. Evans (1968), studying host recognition, stated that several leeches which fed on warm blooded vertebrates recognized their hosts by scent. This reaction can be seen from their behavior toward glass rods coated with host substance. They are not attracted by clean glass rods but attach themselves to rods that have been in contact with their hosts, and they attempt to suck from them. For example, *Hirudo* will attach itself to a rod held beneath a man's armpit; another, the duck leech, *Theromyzon*, reacts in this way to a rod which has been in contact with the preen of a duck. Evans also disclosed that another important identification stimulus is temperature. Experimental evidence demonstrated that both *Hirudo* and *Theromyzon* attached themselves to objects at about host body temperature but ignored objects at other temperatures. Jung (1955) in his experiments concluded that feeding habits of some leeches were more dependent on particle size.

Very little research has been undertaken to determine the attraction of leeches to molluscan hosts. Hatto (1968) indicated in laboratory experiments that *G. heteroclita* was attracted to crushed snails but not intact ones, and that the leeches did not accept undamaged snails. My study indicated that after putting an intact snail into a tank with hungry *Helobdella fusca* or *H. papillata*, these leeches appeared to detect the presence of the snail for they immediately became more active and were observed searching until they found it. It may be that the leeches detected the presence of the snail by its mucus secretion as it moved about in the tank or possibly from its waste materials.

In this study the feeding techniques of leeches were not investigated, but several investigators have described the general technique in some detail. Chernin *et al.* (1956) under laboratory conditions described the feeding techniques of adult and young *H. fusca.* Hatto (1968) described the feeding behavior of both young and adult *G. heteroclita.* In my study the same general feeding technique was observed, with *M. lucida, H. fusca, H. lineata, H. papillata,* and *G. complanata.* Frieswijk (1957), Wrede (1927), Degner (1921), and Chernin *et al.* (1956) also studied the responses of the host to the leech. Their results on the feeding techniques of leeches and responses of snails to leeches are verified by my observations.

Hatto (1968) found that adult leeches more rapidly secured a feeding hold on the soft tissues of small rather than on large snails, although given enough time, even the latter were caught and killed. Frieswijk (1957) discovered that on contact with a leech the snail made vigorous shaking movements with its shell and at the same time detached its foot from the substratum so that it might hurriedly move away from the predator. Their reaction occurred only on contact and not when the snail was some little distance away from the leech. Small amounts of mucus from one of these leeches can also produce the reaction. Wrede (1927) studied the reaction of *Physa fontinalis* (L.) as well as *P. acuta* Drap. and she found that there was no difference between the two *Physa* species in respect to their reaction to *G. complanata.* Degner (1921) described this reaction by *P. fontinalis* when its mantle border or its fringes were touched by a leech of the genus *Glossiphonia (G. complanata, G. heteroclita,* and *G. papillosa).*

Frieswijk (1957) found that both snails *P. fontinalis* and *P. acuta* showed some difference in sensitivity of different parts of the body when in contact with *G. complanata.* The mantle fringes were found to give the highest percentage of leech-avoidance reaction and this area was highly sensitive to mechanical stimulation. Chernin *et al.* (1956) while maintaining leeches in aquaria, observed that leeches would attach themselves with their posterior suckers to the shell. The leech would then occasionally probe some exposed part of the snail which sometimes caused it to withdraw. The leech would then probe deep into the aperture, attempting to insert its proboscis and, if successful, would proceed to feed upon the snail until the shell was empty. In aquaria (Chernin *et al.* 1956, Herter 1936 and in my experience) it was not uncommon to see three or more leeches feeding simultaneously on the same snail.

The adult leeches, in addition, carried their brood of young on their ventral surface where they were attached by their posterior suckers. When the parent leech secured or killed a snail and began to feed, the young leeches also started feeding, undulating actively from their point of attachment. Herter (1936) also observed that snails attacked often became week, would not move much, and both adult leeches and young all fed on the snail. If the snail was relatively small all that remained was the shell. These small leeches are actually capable of invading the shell of the live snail once they are brought into contact with it by the parent. No leeches were found invading the snail under natural conditions. This pattern was verified by Chernin *et al.* (1956) and in my study, where leeches were found invading various parts of the snails. Hatto (1968) demonstrated that young *G. heteroclita* returned to their parent after they had taken their first meal. The age at which the young leeches left the parent was not precisely defined. Hatto also discovered that young *G. heteroclita* leeches died if they were separated from their parents less than five days after hatching. The young leeches seemed dependent on the presence of the parent to enable them to take advantage of certain types of food. This did not seem to be the case under natural conditions for among many snails examined there were often young leeches, but the parents were never found.

Part VIII. Symbionts

Chaetogasters have long been associated with aquatic snails (von Baer 1827). The results given in Tables 2 through 12 show that small oligochaetes, *Chaetogaster limnaei,* were found abundantly inhabiting 15 species of aquatic pulmonates, one species of operculate, and two species of sphaeriacean clams. Several references indicated that the relationships between snails and chaetogasters have not been fully defined (Baily 1895, Volz and Fromming 1936, Krasnodebski 1936, and Michelson 1957). Wagin (1931), Boycott (1936), and other investigators found *C. limnaei* living on the shells of snails where they fed on microorganisms. Pennak (1953) reported *Chaetogaster* as being one of the few carnivorous forms of aquatic oligochaetes which feeds primarily on Entomostraca, insect larvae, and other oligochaetes. Their association with snails, therefore, was considered commensal.

Gruffydd (1965b), however, has given strong evidence for the existence of two distinct forms *(C. limnaei* and *C. limnaei vaghini),* based on morphology, anatomy, and behavior. His experimental evidence demonstrated that the new subspecies, *C. limnaei vaghini,* was found to be very specific in its habitat as it only colonized the kidney of freshwater snails, is considered an endoparasite, and feeds only on kidney cells. Michelson (1964) reported that snails could be free of external worms while harboring numerous worms in their kidney. *C. limnaei* was shown to live on the external surface of mollusks and feed on planktonic organisms. To my knowledge, *C. limnaei vaghini* has not been reported in North America. The relationships with the molluscan hosts are now believed by some authors to be commensalism in *C. limnaei* and parasitism in *C. limnaei vaghini.*

Several authors (Willcox 1901, Wagin 1931, Krasnodebski 1936, Chen 1940, Bayer 1955) have reported the presence of *C. limnaei* in the mantle cavity and on the outer surface of freshwater snails, but there are only a few reports (Lankester 1869, Vaghin 1946) of them being found also in the kidney. Eggleton (1953) found *C. limnaei* in the mantle cavity of the operculate snail, *Amnicola limosa,* in Douglas Lake, Michigan, but it was not found by me in the *A. limosa* in southeastern Michigan. Kenk (1949) observed *C. limnaei* in *Physa gyrina* from ponds in Michigan; my observations indicated that *C. limnaei* was living on the shell, mantle cavity, between shell and mantle, and the kidney. Coker *et al.* (1921) reported that freshwater mussels harbored *C. limnaei;* Gale (1973) reported them in the mantle cavity of two species of sphaeriids, *S. transversum* and *S. striatinum.* In my study chaetogasters were also found in the mantle cavity of *S.* (*=Musculium) lacustre* and *S.* (*=M.*) *fabale.* Gale (1973) also stated that the role of *Chaetogaster* in bivalves was uncertain because it was noted that several contained 'juvenile mussels' in their gut contents. Several reports have indicated that chaetogasters may benefit mollusks by devouring certain parasites. Some (Mrazek 1917, Wagin 1931, Backlund 1949, Ruiz 1951, and Khalil 1961, and others) believe that the presence of *C. limnaei* on snails may be an important factor in controlling trematode infections since they may feed on trematode miracidia and cercariae. Krasnodebski (1936), Bayer (1955) and others, were rather doubtful as to whether the worms would be present in sufficient numbers on snails, to play any major part in controlling parasites. Under laboratory conditions Michelson (1964) showed experimentally that infestations with *C. limnaei* afforded a degree of protection to the snail *Australorbis glabratus* when the snail was exposed to *Schistosoma mansoni* miracidia. Backlund (1949) observed that cercariae of *Fasciola hepatica* were ingested by chaetogasters; Ruiz (1951) also showed similar observations with respect to *S. mansoni.* Coelho (1957) noted that chaetogasters frequently ingested *S. mansoni* miracidia but believed that those worms did not protect snails from infection. Michelson (1964), under laboratory conditions, found that *A. glabratus* infested with *C. limnaei* are afforded a degree of protection against infections by *S. mansoni* miracidia and to a lesser extent protection against a cercaria of an echinostome. The exact role of *C. limnaei* appears to be commensal in nature but the types of trematode larvae in which they feed is not known. The association between *C. limnaei* and aquatic snails under natural conditions requires further investigation.

Gruffydd (1965c) revealed that cercariae are taken in fair numbers by *C. limnaei,* living externally on snails. If *C. limnaei* fed abundantly on miracidia and cercariae in mollusks found in this study, they were not completely effective judging by the heavy cercarial infestations observed. Gale (1973) also found this to be true in *S. transversum.* Several *C. limnaei* were observed with cercariae among their gut contents. In addition the snails infested with leeches were also observed with chaetogasters and trematode larvae in the gut contents of leeches but not in abundance. When a leech feeds it takes in blood, tissues, and whatever else is present.

Gruffydd (1965c) reported that the mean number of *C. limnaei* per snail in *Lymnaea pereger* in North Wales increased sharply between March and May; in June the worms almost disappeared. Gale (1973) found a decrease in the worm population mostly in July and August, with infestations in *S. transversum* to a moderate degree during winter and early spring. Eggleton (1952) found *A. limosa* with 1 to 5 *C. limnaei* in July. Gruffydd (1965c) also stated that the size of the worm population was largely governed by the life cycle of the host. Gale (1973) reported that the mean numbers of *C. limnaei* per *S. transversum* increased with clam size. My observations indicate that larger mollusks had a higher intensity of chaetogaster infestations and that they were found in southern Michigan with various degrees of intensity during every month of the year during both 1972 and 1973.

Other macroorganisms found on snails in this study were three dipteran midges (*Chironomus* sp., *Glyptotendipes* sp., and *Polypedilum* sp.). Their presence was noted since only six specimens were discovered individually in the mantle cavity of three specimens of *H. trivolvis,* two specimens of *P. gyrina* and one *H. campanulatum.* References in the literature did not contradict my field-determined results since Hoffmann (1931) also examined a mixed series of 5,466 snails composed of *Physa ancillaria* Say, *P. heterostropha* Say, and *Lymnaea humilis* Say, but he only found five snails with chironomid larvae.

No evidence of the midge large relationship with snails was suggested by my field results, whether commensal or parasitic. Michelson (1957) cited several references which gave conflicting accounts of the association between midge larvae and certain aquatic mollusks.

Barnard (1911) discovered the larvae of *Chironomus* sp. in the mantle cavity of *Lymnaea peregra.* Mathias and Boulle (1933) disclosed that *Lymnaea limosa* was parasitized by similar larvae. Several additional observations were made by Edwards (1929) and Wesenberg-Lund (1943). Jutting (1938) called attention to the larvae of the midge *Tendipes (Parachironomus) varus* Gtgh. which she found in the mantle cavity of *Physa fontinalis;* it was her opinion that the larvae were commensal.

Bequaert (1925) classified the dipteran-molluscan relationship into three ethological types: (1) scavenger, (2) ectoparasites and (3) parasitodes. Michelson (1957) believes the best example of the above three would be parasitode for the midge-snail association as well as any other dipteran associated with mollusks.

Part IX. Biological Control

Several published manuals indicated that snail populations might be biologically controlled by using various predators or parasites, such as leeches. In some respects snail populations could be held in check better by using a biological control than by the use of molluscicides. Any such method would prove a boon in reducing both human and nonhuman trematode diseases in nature.

Ample evidence is available to indicate that several leech species are most active and efficient as parasites and predators on freshwater snails both in nature and in aquaria. Most leeches belonging in the genera *Helobdella, Glossiphonia,* and *Marvinmeyeria* are recognized as especially malacophagous and some definitely show a preference for snails as food. Investigators using aquaria, such as Chernin *et al.* 1956, McAnnally and D. V. Moore, 1966, did demonstrate with *H. fusca* and *H. punctatolineata* successful predation by leeches on snails. Consequently, leeches were shown to be effective in controlling snail populations under laboratory conditions only.

Wilkialis (1964), in contrast, also under laboratory conditions, found that the mortality of snails subjected to mass attacks by leeches, and those snails sporadically 'attacked' by leeches, showed leeches were not effective controllers in terms of snail mortality. Individual snails containing small numbers of the leeches, *G. heteroclita* f. *hyalina,* died over a 50 or more day period in contrast to those subjected to mass attack. However, snails entirely free of leeches also died during that time. While Harry and Aldrich (1958) also stated that *Helobdella punctatolineata* decimated laboratory colonies of snails, this leech did not seem an effective control agent in nature.

The foregoing data indicate that many snails in nature were found free of both leeches and trematodes and those that had leech and trematode infestations seemed to tolerate their parasitized conditions reasonably well, at least the ones found. This would indicate that leeches, under field conditions, are not very effective agents for controlling snail populations.

SUMMARY

This is a study of leeches in natural associations with mollusks at 10 intensively analyzed stations and 25 supplemental sites in Michigan.

1. Species in the family Glossiphoniidae infest mollusks in several habitat types, such as lakes, ponds, woodland pools, roadside ditches, and creeks.

2. As determined both by literature review and direct observation, mollusks represent the diets of most leeches in the genera *Helobdella, Glossiphonia,* and *Marvinmeyeria.* These leeches live as parasites on various snails and clams. As predators many leeches restrict their diets to certain groups of animals. Unfortunately the diets of many leeches remain uncertain.

3. A relatively wide variety of mollusks harbored an abundance of leeches, as well as trematode larvae and symbionts. Leeches were especially abundant in: *Helisoma anceps, H. trivolvis, H. campanulatum, Stagnicola exilis,* and *Physa gyrina.* They were least common in: *Promenetus exacuous, Gyraulus parvus, Physa integra, P. parkeri, Aplexa hypnorum, Stagnicola elodes, Planorbula armigera, Lymnaea megasoma, L. stagnalis,* and *Sphaerium simile.* None were found on the following: *Lymnaea columella, L. emarginata, L. catascopium, L. humilis, Physa sayii, Gyraulus deflectus, G. hirsutus;* **none** appeared in the operculates: *Valvata tricarinata, Campeloma decisum, Viviparus malleatus, Amnicola limosa, Pleurocera acutum, Goniobasis livescens,* and *Bythinia tentaculata;* nor in these sphaeriid clams: *Sphaerium (Musculium) lacustre* and *S. (M.) fabale.*

4. The five leeches that parasitized various mollusks under selective association with snails in some of the habitats were: *Helobdella fusca, H. lineata, H. papillata, Glossiphonia heteroclita* and *Marvinmeyeria lucida. M. lucida* was found on *Stagnicola exilis, Helisoma trivolvis, Aplexa hypnorum, Promenetus exacuous, Gyraulus parvus* and *Planorbula armigera* but predominantly in *S. exilis. H. fusca* occurred in *Helisoma trivolvis, H. anceps, H. campanulatum, Planorbula armigera, Promenetus exacuous, Gyraulus parvus, Physa integra, P. gyrina* and *Lymnaea stagnalis,* but predominantly in *H. trivolvis* and *H. campanulatum. Helobdella lineata* was found in *Helisoma trivolvis, H. campanulatum, H. anceps,* and *Physa gyrina* but predominantly in *H. trivolvis. Helobdella papillata* was found in *Helisoma trivolvis, H. anceps, H. campanulatum, Physa gyrina, P. parkeri, Stagnicola elodes, Lymnaea megasoma* but predominantly in *H. anceps, P. gyrina* and *Stagnicola elodes. Glossiphonia heteroclita* was only found in one specimen of *Physa gyrina.* This is the first report of a specific snail infested by this leech in North America. *Glossiphonia complanata* was found on the shells of *Sphaerium simile.*

5. A selective association was recognized between certain snails and their leech parasites in the various habitats. In habitats containing *Helobdella fusca* and *H. lineata, H. fusca* generally selected *Helisoma trivolvis* as host. The habitats that harbored *Helobdella fusca* and *H. papillata, H. fusca* were partial to *Helisoma trivolvis* and *H. campanulatum;* and where *Helobdella papillata* was found, it preferred *Helisoma anceps.* In habitats with *Helobdella lineata* and *H. papillata, H. lineata* also had *Helisoma trivolvis* as a preferred host, whereas *Helobdella papillata* went to *Helisoma anceps* and *Physa gyrina.* In those habitats that yielded *Helobdella fusca* and *H. papillata, H. fusca* was usually in *Helisoma trivolvis,* whereas *Helobdella papillata* selected *Physa gyrina.*

6. The various cercarial types. amphistomes and distomes (cystocercous, gymnocephalous, echinostome cercariae, xiphidiocercariae) as found with leeches in mollusks varied not only as to their infections in mollusk species but also among habitats. None of the mollusks examined had multiple infections of cercarial types; none harbored multiple-species leech infestations even though infested sites contained many leeches.

7. Among the mollusks examined, only *Helisoma trivolvis, H. anceps, H. campanulatum, Stagnicola elodes, S. exilis, Aplexa hypnorum,* and *Physa gyrina* had leech-snail-cercarial associations. Of these, *H. trivolvis* and *S. exilis* had the highest number of such associations.

8. The following leeches: *Helobdella fusca, H. lineata, H. papillata* and *Marvinmeyeria lucida* were associated in combination with cercarial types, such as echinostome cercariae, xiphidiocercariae, strigea cercariae, furcocercous cercariae, macro-

cercous cercariae and amphistomes. The total number of leech-snail associations indicated that the leech-snail-cercarial relationship rarely occurred. Five specimens of *Helobdella lineata* carried infections of tetracotyles of trematodes infecting *Helisoma trivolvis*, one *Helobdella lineata* infesting *Helisoma trivolvis* that was infectedwith echinostomes had tetracotyles; and two *Helobdella fusca* were found with tetracotyles infesting *Helisoma campanulatum* which was infected with xiphidiocercariae.

9. Multiple leech infestations appeared in *Stagnicola exilis*, *Helisoma trivolvis*, *H. anceps*, *H. campanulatum*, *Aplexa hypnorum*, *Physa gyrina*, and *Planorbula armigera;* they were predominantly in *Helisoma trivolvis*, *H. anceps*, *Stagnicola exilis* and *Physa gyrina*, but infestations were variable from habitat to habitat.

10. Leech-snail infestations were seasonal in all habitats studied, with a woodland pool exhibiting a biannual cycle. One leech, *Marvinmeyeria lucida*, infested snails in woodland pools; whereas several other leech species, *Helobdella fusca*, *H. lineata* and *H. papillata* were usually associated with various snails in the other habitats. *M. lucida* and cercarial types, amphistomes and echinostomes, were discovered in estivating *Stagnicola exilis* during a drought period. Peak periods of infestations were spring, early summer, and fall but they varied among the snail species studied. Infestations (percentage-wise) declined in June and July in most habitats; presumably the leeches then became free living. Leeches in spring, early summer and fall infestations seemed to represent two size/age classes or generations of young with a degree of development of the leeches occurring within the various snails.

11. Within the snail hosts five specific locations were discovered harboring leeches and these sites varied among the several species of leeches and the various mollusk hosts. The sites were: the mantle cavity; under the mantle, between the digestive gland and aorta; above the mantle but between the shell and mantle; in the kidney; and on the outer shell. Most leeches were found either above or below the mantle.

12. Two symbionts were found on the mollusks: chaetogasters and chironomid larvae. *Chaetogaster limnaei* were abundant on all except *Lymnaea columella*, *L. emarginata*, *Amnicola limosa*, *Goniobasis livescens*, *Viviparus malleatus*, *Physa parkeri*, *Gyraulus deflectus*, *Pleurocera acutum*, *Bythinia tentaculata* and *Sphaerium simile*. Three species of midges *(Chironomus* sp., *Glyptotendipes* sp., and *Polypedilum* sp.) were found in the mantle cavity: two specimens of *Chironomus* sp. and one specimen of *Glyptotendipes* sp. in *Helisoma trivolvis*, one specimen of *Chironomus* sp. and *Polypedilum* sp. in *Physa gyrina*, and one specimen of *Glyptotendipes* sp. in *Helisoma campanulatum*.

13. *Glossiphonia complanata* was not found in any mollusks but with an immunological method its gut contents gave positive proof that it fed on various mollusks in the different habitats. *Helobdella stagnalis* was also not found in any mollusks, but with the same immunological method its gut contents were negative which is, therefore, proof that this species was not feeding on molluscan tissue.

14. Evidence, as obtained in this study, indicates that the leeches infesting snails in Michigan would not serve as a biological control against snails, even though they may to some extent reduce or interfere with the numbers of trematode infections borne by such intermediate hosts.

LITERATURE CITED

ANNANDALE, N., PRASHAD, B., & AMIN-UD-DIN (1921) The aquatic amphibious molluscs of Manipur. -- Records Indian Mus. 22 Part 4 (28): 553

AUTRUN, H. (1936) Hirudineen. IN: H. G. Bronns, Klassen u. Ordnungen des Tierreichs. v. 4, sec. 3, Bd. 4, Pt. 1: 1-9.

BACKLUND, H.O. (1949) En kommensal som ater sitt varddjurs parasiter. -- Fauna Flora, Upps. 44: 38-41.

v. BAER, K. (1827) Beiträge zur Kenntnis der niedern Thiere.-- III. Nova Acta Phys. Med. Acad. Leop. Carol. Nat. Cur. Bonn. 13: 523-762, 881-882.

BAILEY, G. (1895) A mess-mate of *Limnaea stagnalis*. -- J. Malacol. 4: 8-10.

BAKER, F.C. (1928) The freshwater Mollusca of Wisconsin, Part I. Gastropoda. -- Wis. Geol. Nat. Hist. Survey, Bull. 70.

BANGHAM, R. V. (1933) Parasites of the spotted bass, *Micropterus pseudalplites* Hubbs and summary of parasites of smallmouth and largemouth black bass from Ohio streams. -- Amer. Fisheries Soc. Trans. 63: 220-228.

---- & HUNTER, G.W. (1939) Studies on fish parasites on Lake Erie. Distribution studies. -- Zoologica (New York) 24: 385-448.

BARNARD, K.H. (1911) Chironomid larvae and water snails. -- Ent. Mon. Mag. 47: 76-78.

BARROW, J. H. (1953) The biology of *Trypanosoma diemyctli* (Tobey) I. *Trypanosoma diemyctli* in the leech *Batracobdella picta* (Verrill). -- Trans. Am. Microsc. Soc. 72(3): 197-227.

---- (1958) The biology of *Trypanosoma diemyctyli* (Tobey) II. Factors influencing the cycle of *Trypanosoma diemyctyli* in the vertebrate host *Triturus v. viridescens*. -- J. Protozool. 5: 161-170.

BAYER, F.A.H. (1955) Notes on a carnivorous oligochaete commensal on certain fresh-water snails in South Africa. -- Proc. Zool. Soc. London 125: 407-409.

BECKER, C.D. (1964) The parasite vector-host relationship of the hemoflagellate *Cryptobia salmositica* Katz, the leech *Piscicola salmositica* Meyer, and certain freshwater teleosts. -- Ph. D. Thesis, University of Washington.

BECKER, C. D. & KATZ, D (1965) Transmission of the hemoflagellate, *Cryptobia salmositica* Katz, 1951, by a rhynchobdellid vector. -- J. Parasitol. 51: 85-99.

BENNIKE, S.A. (1943) Contributions to the ecology and biology of Danish freshwater leeches (Hirudinea). -- Folia Limnol. Scand. 2: 1-109.

BEQUAERT, J. (1925) The arthropod enemies of mollusks, with description of a new dipterous parasite from Brazil. -- J. Parasit. 11: 210-212.

BERE, R. (1929) Reports of the Jasper Park Lakes investigations, 1925-26, III. The Leeches. -- Contrib. Canad. Biol. Fish. (Toronto), n.s. 4(14): 177-

---- **(1931)** Leeches from the lakes of northeastern Wisconsin. -- Wis. Acad. Sci. Trans. 26: 437-440.

BERRY, E. G. (1943) The Amnicolidae of Michigan: Distribution, Ecology, and Taxonomy. --Misc. Publ. Mus Zool. Univ. Mich. No. 57: 1-68.

BHATIA, M.A. (1939) Fauna of the Dal Lake, Kashmir. -- Bull. Zool. Panjab Univ. 2(1): 1-17.

BISHOP, O. W. (1967) Statistics for Biology. -- Houghton-Mifflin Co., Boston, Mass.

BLANCHARD, R, (1894) Courtes notices sur les Hirudinées. XXII. Hirudinées de l'île Borkum. -- Bull. Soc. Zool. France 21: 137-138.

BOYCOTT, A.E. (1936) The habitats of fresh-water Mollusca of Britain. -- J. Anim. Ecol. 5: 116-186.

BOTZLER, R. G., WETZLER, T. F., & COWAN, A. B. (1973) *Listeria* in aquatic animals. -- J. Wildl. Dis. 9(2): 163-170.

BRINKHURST, R.O. & JAMIESON, B.G.M. (1971) Aquatic Oligochaeta of the World. -- Oliver & Boyd: Edinburgh.

BROCKLEMAN, W. Y. (1968) Natural regulation of density in tadpoles of *Bufo americanus*. -- Ph. D. Thesis, University of Michigan.

---- **(1969)** An analysis of density effects and predation in *Bufo americanus* tadpoles. -- Ecol. 50 (4): 632-644.

BRUMPT, E. (1941) Observations biologiques diverses concernant *Planorbis (Australorbis) glabratus* hôte intermédiaire de *Schistosoma mansoni*. -- Ann. Parasit. Hum. Comp. 18: 9-45.

BRUUN, A. Fr. (1938) Freshwater Hirudinea. -- Zool. Iceland 2(22): 1-4.

BURCH, J.B. (1972) Freshwater sphaeriacean clams (Mollusca: Pelecypoda) of North America. -- Biota of freshwater ecosystems identification Manual no. 3. Washington, D.C.

---- **& LINDSAY, G.K. (1970)** An immuno-cytological study of *Bulinus s.s.* (Basommatophora: Planorbidae). -- Malacol. Rev. 3: 1-18.

CAMPBELL, R.A. (1973a) Studies on the biology of the life cycle of *Cotylurus flabelliformis* (Trematoda: Strigeidae). -- Trans. Am. Micros. Soc. 92 (4): 629-640.

---- **(1973b)** Influence of temperature, host, and host size on metacercarial development of *Cotylurus flabelliformis* (Trematoda: Strigeidae). -- Trans. Am. Micros. Soc. 92(4): 662-665.

CASTLE, W.E. (1900) Some North American freshwater Rhynchobdellida and their parasites. -- Bull. Mus. Comp. Zool. Harvard Univ., 36: 17-64.

CHEMBERLIN, D. R. (1968) Ecological studies of the leech *Haemopis grandis*. --M.S. Thesis, Mankato State College, Mankato, Minn., 76 p.

CHEN, Y. (1940) Taxonomy and faunal relations of the limnitic Oligochaeta of China. -- Contr. Biol. Lab. Sci. Soc. China 14: 1-32.

CHERNIN, E., MICHELSON, E.H., & AUGUSTINE, D. L. (1956) Studies on the biological control of *Australorbis glabratus* populations by the leech, *Helobdella fusca*, under laboratory conditions. -- Am. J. Trop. Med. Hyg. 5: 308-314.

CHERNIN, E. & PERLSTEIN, J. M. (1971) Protection of snails against miracidia of *Schistosoma mansoni* by various aquatic invertebrates. -- J. Parasitol. 57(2): 217-219.

COELHO, M.V. (1957) Aspectos do des envolvimento das formas larvais de *'Schistosoma mansoni'* em *'Australorbis nigricans,'* -- Rev. Brasil. Biol. 17: 325-337.

COKER, R. E., SHIRA, A., CLARK, H. & HOWARD, A. (1921) Natural history and propagation of freshwater mussels. -- U.S. Bur. Fisheries Bull. 37: 77-181.

CREWE, W. & COWPER, S.G. (1973) A leech parasitic on *Bulinus*. TRSTA/RRANS R. Soc. Trop. Med. Hyg. -- 67(1): 65.

CROLL, N.A. (1968) Ecology of parasites. -- Harvard Univ. Press: Cambridge, Mass., p. 8, 11, 61, 71.

DAVIES, R. W. (1969) The production of antisera for detecting specific triclad antigens in the gut contents of predators. -- Oikos 20: 248-260.

---- **(1973)** The geographic distribution of freshwater Hirudinoidea in Canada. -- Canad. J. Zool. 51(5): 531-545.

DAWES, B. (1968) The Trematoda. -- Cambridge University Press: London, p. 419-469.

DEGNER, E. (1921) Über einen Abwehrreflex bei *Physa fontinalis*. -- Arch. Molluskenk. 53: 117-120.

DOBROWOLSKI, K.A. (1958) Pasozyty pijawek jeziora Druzno (Parazytofauna biocenozy jesiora Druzno. Cz. V). -- Acta Parasit. Pol. 6: 179-194.

DORIER, A. (1951) Présence de *Glossiphonia heteroclita* sub. sp. *hyalina* dans la cavité palléale de *Limnaea stagnalis*. Trav. Lab. Hydrobiol. Grenoble, p. 46-47.

EDWARDS, F. W. (1929) British non-biting midges (Diptera: Chironomidae). -- Trans. Ent. Soc. Lond. 77: 279-430.

EGGLETON, F.E. (1952) Dynamics of interdepression benthic communities. -- Trans. Am. Micros. Soc. 71: 189-228.

ELLIOTT, W.T. (1917) *Glossiphonia* (leech) destroying *Limnaea peregra*. -- Proc. Malac. Soc. London, 12: 307.

ERCOLANI, G. (1881) Dell'adattamento della specie all'ambiente. Nuove ricerche sulla storia genetica dei trematodi. -- Mem. Accad. Sci. Ist. Bologna 2: 239-334.

EVANS, S.M. (1968) Studies in invertebrate behavior. -- Heinemann Educational Books, Ltd.: London 12: 307.

FORBES, S. A. (1890a) An American terrestrial leech. -- Ill. State Lab. Nat. Hist. Bull. 3: 119-122.

---- **(1890b)** An American terrestrial leech. -- Amer. Natur. 24: 646-649.

---- **(1893)** A preliminary report on the aquatic invertebrate fauna of the Yellowstone National Park, Wyoming, and of the Flat-Head region of Montana. -- U.S. Fisheries Comm. Bull. 1891: 207-258. Hirudinea p. 218-220.

FRIESWIJK, J.J. (1957) A leech-avoidance reaction of *Physa fontinalis* (L.) and *Physa acuta* Drap. -- Basteria 21(3): 38-45.

GALE, W. F. (1973) Predation and parasitism as factors affecting *Sphaerium transversum* (Say) populations in Pool 19, Mississippi River. — Res. Popul. Ecol. 14: 169-187.

GEE, W. (1913) The behavior of leeches with especial reference to its modifiability. -- Univ. Calif. Publ. Zool. 11(1): 197-305.

GOODRICH, C. (1932) The Mollusca of Michigan. — Mich. Handbook Ser., Univ. Mich. Press, p. 1-120.

GRAF, A. (1899) Hirudineenstudien. -- Deutsch. Akad. Naturf. (Halle) Nova Acta Abhandlung der Kaiserlich Leop.-Carol. 72(2): 215-404.

GRASSE, P. (1959) Traité de zoologie, anatomie, systématique, biologie. Classe des Annelidés achètes ou Hirudinées ou Sangsues. -- 5(1): 471-593, Paris.

GRUFFYDD, L. D. (1965a) Notes on a population of the leech *Glossiphonia heteroclita* infesting *Lymnaea pereger*. Ann. Mag. Nat. 13(9): 151-154.

---- (1965b) Evidence for the existence of a new subspecies of *Chaetogaster limnaei* (Oligochaeta), in Britain. -- J. Zool. 146: 175-196.

----- (1965c) The population biology of *Chaetogaster limnaei limnaei* and *Chaetogaster limnaei vaghini* (Oligochaeta). -- J. Anim. Ecol. 34: 667-690.

GUIBE, J. (1936) *Glossiphonia heteroclita* (L.) hirudinée prédatrice de mollusques gastéropodes. -- Soc. Linnéenne Normandie, Bull. 8(8): 73-79.

HARDING, W.A. (1910) A revision of British leeches. — Parasitol. 3(2): 130-201.

---- & MOORE, J. P. (1927) The fauna of British India: Hirudinea. London.

HARMS, C. E. (1959) Checklist of parasites from catfishes of northeastern Kansas. — Trans. Kans. Acad. Sci. 62(4): 262.

---- (1960) Some parasites of catfishes from Kansas. -- J. Parasitol. 46: 695-701.

HARRY, H.W. & ALDRICH, D.V. (1958) The ecology of *Australorbis glabratus* in Puerto Rico. -- Bull. Wld. Hlth. Org. 18(3): 819-832.

HATTO, J. (1968) Observations on the biology of *Glossiphonia heteroclita* (L.). -- Hydrobiol. 31: 363-384.

HENSON, P.P. (1922) Rugby Mollusca. -- Rep. Rugby Sch. Nat. Hist. Soc. 56: 23.

HERRINGTON, H.B. (1962) A revision of the Sphaeriidae of North America (Mollusca: Pelecypoda). -- Misc. Publ. Mus. Zool. Univ. Mich. No. 118: 1-74.

HERRMANN, S. J. (1970) Systematics, distribution and ecology of Colorado Hirudinea. — Amer. Midl. Nat. 83(1): 1-37.

HERTER, K. (1929) Vergleichende bewegungsphysiologische Studien an deutschen Egeln. -- Z. vergl. Physiol. 9: 145-177.

---- (1932) Hirudineen, Egel. IN: P. Schalae, Biologie der Tiere Deutschlands. 12b (35): 1-158.

---- (1936) Die Physiologie der Hirudineen. IN: H. G. Bronns, Klassen u. Ordnungen des Tierreichs, v. 4, sec. 3, Bd. 4, Leipzig, p. 123-319.

HEYWOOD, V.H. (1971) Scanning electron microscopy. Academic Press: New York, p. 1-331.

HILSENHOFF, W. L. (1963) Predation by the leech *Helobdella stagnalis* on *Tendipes plumosus* (Diptera: Tendipedidae) larvae. -- Ann. Entomol. Soc. Amer. 56: 252.

---- (1964) Predation by the leech *Helobdella nepheloidea* on larvae of *Tendipes plumosus* (Diptera: Tendipedidae). — Ann. Entomol. Soc. 57: 139.

HOFFMAN, G.L. (1967) IN: Parasites of North American freshwater fishes. Berkeley and Los Angeles: Univ. Calif. Press. Hirudinea, p. 288-298.

---- (1970) Control methods for snail-borne zoonoses. -- J. Wildlife Diseases 6: 262-265.

HOFFMANN, C.H. (1931) Chironomid larvae associated with water-snails. -- Bull. Brooklyn Ent. Soc. 26: 71-74.

HYNES, H.B.N. (1960) The biology of polluted waters. -- Liverpool Univ. Press: Liverpool. 202 p.

---- (1970) The ecology of running waters. -- Univ. Toronto Press, Canada.

JACQUET, E. (1885) Sur quelques parasites des Lymnées. — L. Exchange 1: 2.

JANISZEWSKA, J. & ZMIJEWSKA, M. (1968) *Chaetogaster limnaei* K. Baker i *Glossiphonia heteroclita* (L.) pasozyty slimakow wodnych z okolik Wroclawia. -- Przegl. Zool. 12: 49-50.

JUGA, G.V. (1931) Les pigments de la *Glossiphonia paludosa*. -- Arch. Zool. Exp. Gén. 71: 1-97.

JUNG, T. (1955) Zur Kenntnis der Erhahrungsbiologie der in dem Raum zwischen Harz und Heide vorkommenden Hirudineen. -- Zool. J. (Allg. Zool.) 66: 79-128.

JUTTING, T. V. B. (1938) A freshwater pulmonate (*Physa fontinalis* (L.)) inhabited by the larva of a non-biting midge (*Tendipes (Parachironomus) varus* Gtgh.). -- Arch. Hydrobiol. Plankt. 32: 693-699.

KALBE, J. (1966) Zur Ökologie und Saprobiewertung der Hirudineen im Havelgebiet. -- Int. Revue Ges. Hydrobiol. 51: 243-277.

KARASSOWSKA, K. & MIKULSKI, J. S. (1960) Studia nad zbiorowiskami zwierzecymi roslinnosci zanurzonej i plywajacej jeziora Druzno. -- Ekol. Pol. A (8): 335-353.

KEITH, M.M. (1959) A simplified key to the leeches of Minnesota. -- Minn. Acad. Sci. Proc. 27: 190-199.

KENK, R. (1949) The animal life of temporary and permanent ponds in southern Michigan. -- Misc. Publ. Mus. Zool. Univ. Mich. 71: 5-66.

KHALIL, L. F. (1961) On the capture and destruction of miracidia by *Chaetogaster limnaei* (Oligochaeta). — J. Helminth. 35: 269-274.

KLEMM, D. J. (1970) Ecology and taxonomy of the leeches (Hirudinea) of Washtenaw County, with the distribution and an illustrated key to the leeches of Michigan. — M.S. Thesis, Eastern Michigan University, 208 p.

---- (1972a) The leeches (Annelida: Hirudinea) of Michigan. — Mich. Academician 4(4): 405-444.

---- (1972b) Biota of freshwater ecosystems, Identification Manual No. 8, freshwater leeches (Annelida: Hirudinea) of North America. — U.S. Govt. Printing Office, Washington, D.C., 54 p.

---- (1973) Incidence of a parasitic leech *Marvinmeyeria (=Oculobdella) lucida* Moore and two cercarial types in estivating *Stagnicola exilis* (Lea). -- Malacol. Rev. 6(1): 66-67.

KLIMEK, L. (1960) Studia nad Fauna denna jeziora Druzno Zesz. nauk. UMK, Biol. 5(7): 29-69.

KOPENSKI, M. (1969) Selected studies of Michigan leeches. -- Ph.D. Thesis, Michigan State University, 157 p.

KRASNODEBSKI, F. (1936) Untersuchungen über die Nahrung des Oligochaeten *Chaetogaster limnaei* K.E. v. Baer. -- Zoologica Polonica 1: 286-303.

KRULL, W.H. (1931) Importance of laboratory raised snails in helminthology with life history notes on *Gyraulus parvus*. --Occ. Papers Mus. Zool. Univ. Michigan No. 226, 10 p.

LANGLEY, R. (1970) Practical statistics simply explained. --- Dover Publ., Inc.: New York.

LANKESTER, E. R. (1869) A contribution to the knowledge of the lower annelids. -- Trans. Linn. Soc. London (Zool.) 26: 631-646.

LUKIN, E. I. (1929) Biologiczieskije zamietki o pijawkach bassiejna rieki Donca. -- Trav. Soc. Natur. 52, Charkiv.

---- **(1962)** Hirudinea. -- IN: Fauna of the Ukraine, Kiev, 30: 196.

LUTZ, A. (1921) Zur Kenntnis des Entwicklungszyklus der Holostomiden. Vorlaufige Mitteilung. -- Zbl. Bakteriol. Parasitenk. Abt. I, Orig. 86 124-129.

MACAN. T.T. (1950) Ecology of freshwater Mollusca in the Lake District. --J. Anim. Ecol. 19 124-146.

MALEK, E. A. (1958) Factors conditioning the habitat of Bilharziasis intermediate hosts of the family Planorbidae. -- Bull. 2&9 18 785-818.

---- **(1961)** The biology of mammalian and bird schistosomes. -- Bull. Tulane Univ. Med. Faculty 20(3): 181-207.

MANN, K. H. (1953a) A revision of the British leeches of the family Glossiphoniidae, with a description of *Batracobdella paludosa* (Carena, 1824), a leech new to the British fauna. -- Zool. Soc London, Proc. 123: 377-381.

---- **(1953b)** Some factors influencing the distribution of freshwater leeches in Britain. -- Int. Assn. Theo. Appl. Limnol. Pro. 12: 582-587.

---- **(1955)** The ecology of the British freshwater leeches. -- J. Anim. Ecol. 24(1): 99-119.

---- **(1957a)** A study of a population of the leech *Glossiphonia complanata*. --J. Anim. Ecol. 26(1): 99-111.

---- **(1957b)** The breeding, growth, and age structure of a population of the leech, *Helobdella stagnalis* (L.). -- J. Anim. Ecol. 26: 171-177.

---- **(1962)** Leeches (Hirudinea), their structure, physiology, ecology, and embryology. --Pergamon Press: New York, 201 p.

MASON, W. T., Jr. (1973) An introduction to the identification of chironomid larvae. -- U.S. Environ. Poll. Agency, AQCL NERC, Cincinnati, Ohio, 90 p.

MATHERS, C. K. (1948) The leeches of the Okoboji Region. -- Iowa Acad. Sci. 55: 397-425.

---- **(1954)** *Haemopis kingi*, new species (Annelida, Hirudinea). -- Am. Midl. Nat. 52(2): 460-468.

---- **(1963)** *Haemopis lateromaculatum*, new species (Annelida, Hirudinea). -- Am. Midl. Nat. 70 (1): 168-174.

MATHIAS, P. (1925) Recherches expérimentales sur le cycle évolutif de quelques trématodes. -- Bull. Biol. Soc. France et Belgique 59: 1-124.

---- **& BOULLE, L. (1933)** Sur une larve de Chironomide (Diptera) parasite d'un mollusque. -- C. R. Acad. Sci., Paris 196: 1744-1746.

McANNALLY, R.D. & MOORE, D.V. (1965) Relatiohship of *Helobdella* sp. to laboratory-reared *Australorbis glabratus*. -- J. Parasitol. 51(2), sec. 2: 32.

---- **(1966)** Predation by the leech *Helobdella punctatolineata* upon *Australorbis glabratus* under laboratory conditions. --J. Parasitol. 52(1): 196-197.

McDONALD, M. E. (1969) Catalogue of helminths of waterfowl (Anatidae). -- Bur. Sprt Fish. & Wildl., Special Sci. Rept. Wildlife, No. 126, Washington, D.C. Hirudinea p. 689-692.

McDONALD, S. L. C. (1969) The biology of *Lymnaea stagnalis* L. (Gastropoda: Pulmonata). -- Sterkiana 36: 1-17.

MEYER, M.C. & MOORE, J. P. (1954) Notes on Canadian leeches (Hirudinea), with the description of a new species. -- Wasmann J. Biol. 12(1): 63-96.

MICHELSON, E.H. (1957) Studies of the biological control of schistosome bearing snails. - Parasitol. 47 413-426.

---- **(1964)** The protective action of *Chaetogaster limnaei* on snails exposed to *Schistosoma mansoni*. -- J. Parasitol. 50: 441-444.

MILLER, J.A. (1929) The leeches of Ohio. -- Contrib Franz Theodore Stone Lab. 2: 1-38.

---- **(1937)** A study of the leeches of Michigan with a key to orders, suborder, and species. -- Ohio J. Sci. 37(2):85-90.

MOORE, J.E. (1964) Notes on the leeches (Hirudinea) of Alberta. -- Natl. Mus. Canada, Nat. Hist. Papers No. 27: 1-15.

---- **(1966)** Further notes on Alberta leeches (Hirudinea). -- Natl. Mus. Canada, Nat. Hist. Papers No. 32: 1-11.

MOORE, J. P. (1901) The Hirudinea of Illinois. -- Bull. Ill. State Lab. Nat. Hist. 5: 479-547.

---- **(1908)** The leeches of Lake Amatilan. - Publ. Field Mus. Nat. Hist., Chicago, Zool. Ser., 7: 199-201.

---- **(1920)** The leeches of Lake Maxinkuckee. -- A physical and biol. survey, Dept. Conservation, Indiana, v. 2: 87-95.

---- **(1923)** The control of blood-sucking leeches, with an account of the leeches of Palisades Interstate Park. --N.Y. State Coll. Forestry. Roosevelt Wildlife Bull. 2(1): 1-53.

---- **(1924a)** The leeches (Hirudinea) of Lake Nipigon. --Univ. Toronto Studies in Biol. 23 17-30. Duplicated article: Univ. Penn. Zool. Lab. Contr., 1924-25, 24 (21).

---- **(1924b)** Notes on some Asiatic leeches (Hirudinea) principally from China, Kashmir, and British India. -- Acad. Nat. Sci. Philadelphia 76: 343-388.

---- **(1929-30)** The leeches (Hirudinea) of China. -- Bull. Dept. Biol. Yenching Univ. 1(2): 39-43.

---- **(1939)** *Helobdella punctatolineata*, a new leech from Puerto Rico. -- F. Public Health Trop. Med. 14: 422-428.

---- **(1959)** Freshwater Biology, Chapter 23 'Hirudinea.' p. 542-557. Wiley: New York.

---- **& MEYER, M. C. (1951)** Leeches (Hirudinea) from Alaska and adjacent waters. -- Wasmann J. Biol. 9: 11-77.

MOQUIN-TANDON, A. (1846) Monographie de la famille des Hirudinées. -- Paris, Ed. 2, 448 p., atlas of 14 plates.

MRAZEK, A. (1917) The feeding habits of *Chaetogaster limnaei*. -- Sb. Zool. 1: 23-24.

NACHTRIEB, H. F., HEMINGWAY, E.E., & MOORE, J.P. (1912) The leeches of Minnesota. --Geol. Nat. Hist. Survey Minn., Zool. Ser. 5: 1-150.

OKLAND, J. (1964) The eutrophic Lake Borrevann (Norway). An ecological study of shore and bottom fauna with special reference to gastropods, including a hydrographic survey. -- Folia Limnol. Scand. 13: 1-337.

OUCHTERLONY, O. (1949) Antigen-antibody reactions in gels. -- Arch. Kem. Mineral. Geol. B (26): 1-9.

PALOUMPIS, A. A. & STARRETT, W.C. (1960) An ecological study of benthic organisms in three Illinois River flood plain lakes. -- Am. Midl. Nat. 64: 406-435.

PAWLOWSKI, L. K. (1936) Zur Ökologie der Hirudineen-fauna der Wigryseen. — Arch. Hydrobiol. Rybact. 10: 1-47.

---- **(1955)** Observations biologiques sur les sangsues. -- Bull. Soc. Sci. Lettr. Lodz (III) 6: 1-21.

PEARSE, A.S. (1924) The parasites of lake fishes. -- Wis. Acad. Sci. Arts, Letters, Trans. 21: 161-194.

PENNAK, R. W. (1953) Freshwater invertebrates of the United States. -- Ronald Press Co.: New York, 769 p.

---- **(1971)** Toward a classification of lotic habitats. -- Hydrobiologia 38(2): 321-334.

POE, T.P. (1972) Leeches (Hirudinea) parasitizing Illinois fishes. -- M.S. Thesis, Northern Illinois Univ., DeKalb. 99 p.

RICHARDSON, L. R. (1947) A review of New Zealand leeches. -- N.Z. Sci. Congr., p. 201-202.

---- **(1949)** The occurrence of the leech *Batrachobdella picta* (Verrill) in the dorsal subcutaneous lymph spaces of *Rana catesbiana.* — Canad. Field-Nat. 63(2): 85-86.

---- **& HUNT, P.J. (1968)** Trypanosomes in the crop of an Haemadipsid leech. -- Australian J. Sci. 30 (9): 374-375.

RICHARDSON, R.E. (1921) The small bottom and shore fauna of the middle and lower Illinois River and its connecting lakes, Chillicothe to Grafton: its valuation; its sources of food supply; and its relation to the fishery. -- Bull. Ill. Nat. Hist. Survey 13(15): 363-522.

RICHMOND, S.L. (1972) The leeches (Hirudinea) of northern Illinois, exclusive of the family Piscicolidae. -- M. S. Thesis, Northern Ill. Univ., De Kalb, Ill. 116 p.

ROBERTSON, M. (1909) Studies on Ceylon Haematozoa. -- Quart. J. Micros. Soc. n.s. 53: 665-695.

ROELOFS, E. W. (1944) Water soils in relation to lake productivity. -- Tech. Bull. 190, Mich. State Agric. Exper. Sta.

RUIZ, J. M. (1951) Nota sobre a cercariofagia de um Oligochaeta do genero *Chaetogaster* v. Baer, 1827. -- Anais Fac. Farm. e Odont., Univ. S. Paulo 9: 51-56.

RUPP, R. S. & MEYER, M.C. (1954) Mortality among brook trout, *Salvelinus fontinalis* resulting from attacks of freshwater leeches. -- Copeia 1954 (4): 294-295.

RYERSON. C.G.S. (1915) Notes on the Hirudinea of Georgian Bay. -- Canad. Biol. Bd. Contr. to Canad. Biol. 1911-1924, Fasc. 2: 165-176.

SANDNER, H. (1951) Badania nad fauna Pijawek. -- Acta Zool. Oecol. Univ. Lodz 4: 1-50.

---- **& WILKIALIS, J. (1972)** Leech communities (Hirudinea) in the Mazurian and Bialystov regions and the Pomeranian Lake district. --Ekologia Polska 20 (27): 345-365.

SAPKAREV, J.A. (1968) The taxonomy and ecology of leeches (Hirudinea) of Lake Mendota, Wisconsin. -- Trans. Wis. Acad. Sci. 56: 225-253.

SARAH, H. H. (1971) Leeches (Hirudinea) found on two species of *Helisoma* from Fleming's Creek. -- Ohio J. Sci. 71(1): 15-20.

SAWYER, R.T. (1967) The leeches of Louisiana, with notes on some North American species (Hirudinea, Annelida). -- Proc. La. Acad. Sci. 30: 32-38.

---- **(1968)** Notes on the natural history of the leeches (Hirudinea) on the George Reserve, Michigan. -- Ohio J. Sci. 68(4): 226-228.

---- **(1970)** Observations on the natural history and behavior of *Erpobdella punctata* (Annelida: Hirudinea). -- Am. Midl. Nat. 83(1): 65-80.

---- **(1972)** North American freshwater leeches, exclusive of Piscicolidae, with a key to all species. -- Ill. Biol. Monogr. 46: 154 p.

---- **(1973)** The rediscovery of *Glossiphonia swampina* (Bosc, 1802) in the coastal plain of South Carolina (Annelida: Hirudinea). -- J. Elisha Mitchell Scient. Soc. 89(1, 2): 4-5.

SCHELL, S. C. (1970) How to know the trematodes. -- W. M. Brown Co.: Dubuque, Iowa.

SERAFINSKA, J. (1958) Materialy do fauny pijawek (Hirudinea) Polski. --Fragm. faun. Mus. zool. Pol. 8: 17-64.

SHEVTSOV, A.A. (1958) Cyanthocotylosis in domestic ducks. -- Veterinarija 5: 82 (In Russian).

SIEGEL, S. (1956) Nonparametric statistics. -- McGraw-Hill Book Co.: New York.

SIKOROWA, A. (1965) Fauna denna jeziora Kortowskiego w latach 1952-1954. --Zesz nauk. WSR Olsztyn 19: 81-112.

SNEDECOR, G.W. (1961) Statistical methods. -- Iowa State Univ. Press: Ames, Iowa.

SOLTYS, M.A. & WOO, P.T.K. (1968) Leeches as possible vectors for mammalian Trypanosomes. --Trans. Roy. Soc. Med. Hyg. 62(1): 154-156.

SOÓS, A. (1964) A revision of the Hungarian fauna of Rhynchobdellid leeches (Hirudinea). --Opusc. Zool. Budapest 5(1): 107-112.

---- **(1966)** On the genus *Glossiphonia* Johnson, 1816, with a key and catalogue to the species (Hirudinoidea: Glossiphoniidae). -- Ann. Hist. Nat. Mus. Nat. Hung. 58: 271-279.

---- **(1967a)** On the leech fauna of the Hungarian reach of the Danube. — Opusc. Zool. Budapest 7: 241-257.

---- **(1967b)** On the genus *Hemiclepsis* Vejdovsky, 1884, with a key and catalogue of the species (Hirudinoidew: Glossiphoniidae). -- Opusc. Zool. Budapest 7: 233-240.

---- **(1967c)** On the genus *Batracobdella* Viguier, 1879, with a key and catalogue to the species. -- Ann. Hist. Nat. Mus. Nat. Hung. 59: 243-257.

---- **(1969)** Identification to the leech (Hirudinoidea) genera of the world, with a catalogue of the species. VI. Family Glossiphoniidae. -- Acta Zool. Hung. 15: 397-454.

---- **(1970)** A zoogeographical sketch of the freshwater and terrestrial leeches (Hirudinoidea). -- Opusc. Zool. Budapest 10(2): 313-324.

SOOTER, C. (1937) Leeches infecting young waterfowl in northwest Iowa. -- J. Parasitol. 23: 108.

STERKI, V. (1912) Fresh-water Mollusca living out of the water. -- Nautilus 26: 64-65.

SUDARIKOV, V.E. (1959) The order Strigeidida (La Rue, 1926) Sudarikov, 1959. Part 1. Trematody zhivotnykh i cheloveka 16: 219-629. (In Russian)

----, **KARMANOVA, E.M. & BAKHEMETEVA, T.L. (1962)** To the problem of the species composition of metacercariae from flukes of the order Strigeidida from leeches of the Volga-delta). — Tr. Astrakh. zapovednika 6: 197-202. (In Russian)

SZIDAT, L. (1930) Beitrage zur Entwicklungsgeschichte der Holostomiden. III. Über zwei Tetracotylen aus Hirudineen und ihre weiterentwicklung in Euten zu *Cotylurus cornutus* Rud. und *Apatemon gracilis* Rud. -- Zool. Anz. 86: 133-149.

TAUBE, C. M. (1966) Leeches. — Mich. Dept. Conservation, Res. & Dev., Rept. no. 55, Inst. Fish. Res. Rept. no. 1713, p. 1-14.

TAYLOR, D. W. & SOHL, N. F. (1962) An outline of gastropod classification. --Malacologia 1(1):7-32.

TE, G.A. (1972) Possible family distribution patterns in pulmonate gastropods. -- Malacol. Rev. 5: 18-20.

THOMPSON, F. G. (1973) Personal communication. -- Florida State Museum, University of Florida, Gainesville, Fla.

THUT, R.N. (1969) A study of the profundal bottom fauna of Lake Washington. -- Ecol. Monogr. 39: 79-100.

TIMON-DAVID, J. (1943) Sur la présence en Camargue et le développement expérimental de *Cotylurus cornutus* (Rud.) (Trématode, Strigeidé). — Bull. Mus. Hist. nat. Marseille 3: 17-21.

VAGHIN, V.L. (1946) On the biological species of *Chaetogaster limnaei*, K. Baer. — C.R. Acad. Sci. U.R.S.S. 51: 481-484.

van der **SCHALIE, H. (1940)** Aestivation of *Lymnaea lanceata*. -- Nautilus 53(4): 134-135.

---- **(1960)** Egypt's new high dam - asset or liability. -- Biologist 42(3-4): 63-70.

VERRILL, A. E. (1874) Synopsis of the North American freshwater leeches. -- U.S. Rep. Comm. Fish-(1872-73) 74: 666-689.

VLASBLOM, A.G. (1971) Further investigations into the life cycle and soil dependence of the water snail *Aplexa hypnorum*.

VOJTEK, J., OPRAVILOVA, V. & VOJTKOVA, L. (1967) The importance of leeches in the life cycle of the order Strigeidida. -- Folia Parasitologica (Praha) 14 (2): 107-119.

VOLZ, E. & FROMMING, E. (1936) Parasiten in *Acroloxus lacustris*. — Arch. Molluskenk. 68: 211-213.

WAFFLE, E. L. (1963) An ecological study of the Iowa Glossiphoniidae (Annelida: Hirudinea) with emphasis on feeding and reproductive habits. -- M.S Thesis, Univ. Iowa, p. 1-54.

WAGIN, W. L. (1931) *Chaetogaster limnaei* K. Baer als Cercarienvertilger. -- Zool. Anz. 95: 55-59.

WALTER, H.J. & BURCH, J.B. (1957) Key to the genera of freshwater gwstropods (snails and limpets) occurring in Michigan. -- Mus. Zool. Univ. Mich. Circ. no. 3: 1-8.

WARD, H.B. (1902) Notes on the leeches of Nebraska. -- IN: Nebraska State Board of Agric., Annual Rept., Lincoln, Nebr., 1901: 267-280.

WESENBERG-LUND, C. (1934) Contributions to the development of the Trematoda Digenea Part II. 9. Raekke, v. 3.

---- **(1937)** Ferskvandsfaunaen biologisk belyst. Invertebrata. Kobenhavn.

---- **(1943)** Biologie der Süsswasserinsekten. Copenhagen. 682 p.

WHITHEAD, H. (1935) The ecological study of invertebrate fauna of a chalk stream. -- J. Anim. Ecol. 4: 58.

WILKIALIS, J. (1964) On the ecology and biology of the leech *Glossiphonia heteroclita* f. *hyalina* (O. F. Müll.). -- Ekol. Pol. Ser. A. 12: 315-324.

---- **(1970a)** Some regularities in the occurrence of leeches (Hirudinea) in the waters of the Bioalystok region. -- Ekol. Pol. Ser. A. 18: 647-680.

---- **(1970b)** Investigations on the biology of leeches of the Glossiphoniidae family. -- Zool. Poloniae 20 (1): 29-54.

---- **(1971)** Influence of regulation of the Laczanka River on the occurrence of Hirudinea. -- Pol-Arch. Hydrobiol. 18(4): 359-365.

WILLCOX, M.A. (1901) Parasitic or commensal oligochaete in New England. -- Amer. Nat. 35: 905-909.

WISNIEWSKI, W. L. (1958) Characterizwtion of the parasitofauna of an eutrophic lake (Parasitofauna of the biocoenosis of Druzno Lake - Part II). -- Acta Parasitol. Polon. 6: 1-64.

WISNIEWSKI, L. W. (1935) *Cercaria dubia* sp.n. und deren weitere Entwicklung in *Herpobdella atomaria*. -- Bull. intern. Ac. Polon. Serie B. Scient. Nat. II.

WOO, P. T. K. (1969a) Trypanosomes in amphibians and reptiles in southern Ontario. --Canad. J. Zool. 47(5): 981-988.

---- **(1969b)** The life cycle of *Trypanosoma chrysemydis*. -- Canad. J. Zool. 47(6): 1139-1151.

---- **(1969c)** The development of *Trypanosoma canadensis* of *Rana pipiens* in *Placobdella* sp. -Canad. J. Zool. 47 (6): 1257-1259.

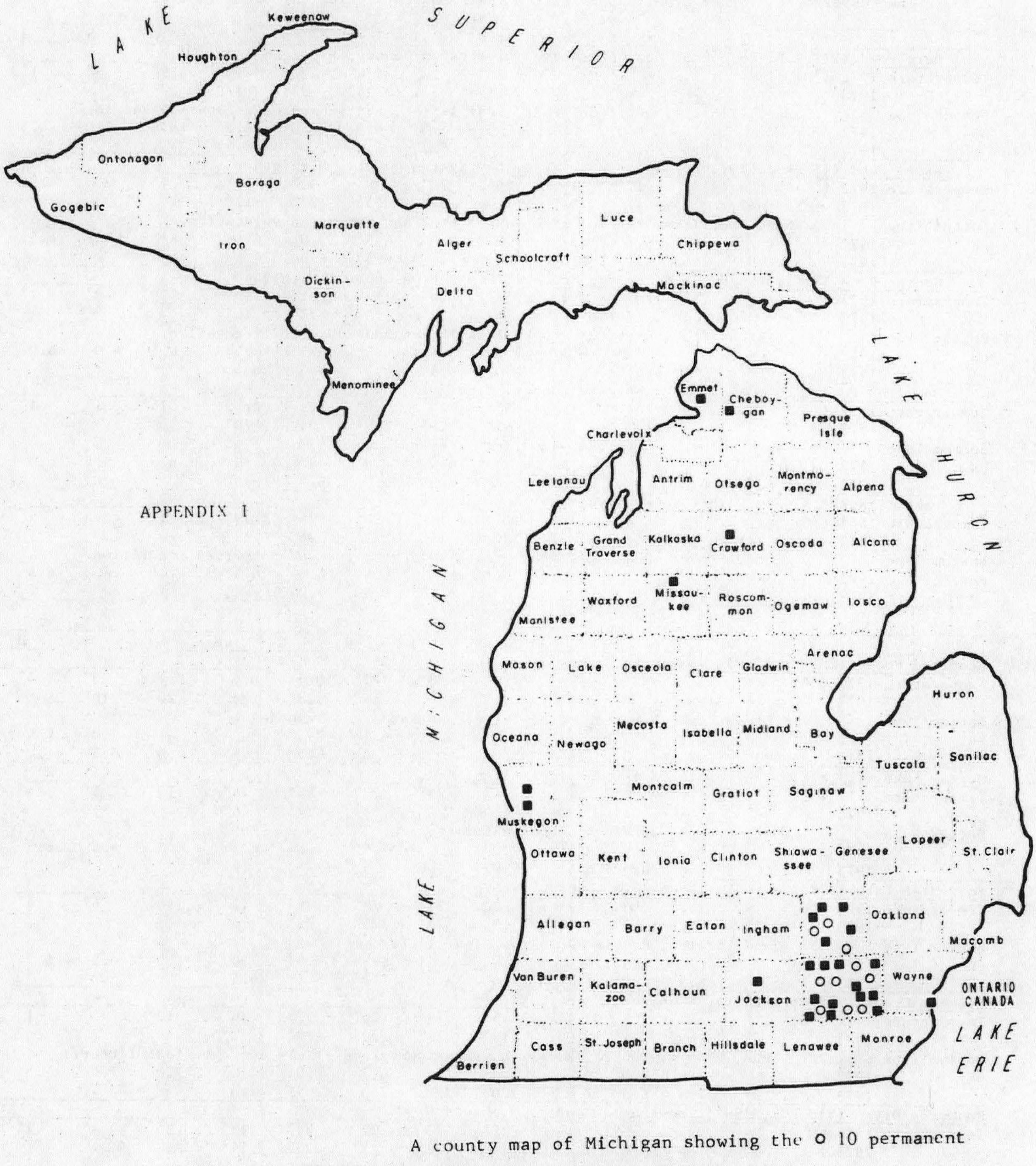
WREDE, W. (1927) Über die Abwehrreaktion von *Physa*. --Biologische Mitteilungen I. Zool. Jb. Physiol. 44: 315-322.

ZAJICEK, D. & VALENTA, Z. (1964) Prispevek k vyskytu furkocerkarii na nekterych lokalitach v Cechach. -- Cs. Parasit. 11: 273-294.

ZDARSKA, Z. K. (1964) Problemu vyvoje nekterych motolic. -- Cs. Parasit. 11: 295-308.

APPENDIX I

APPENDIX I



A county map of Michigan showing the ○ 10 permanent and ■ 25 incidental collecting sites

APPENDIX II

The Temperature, Bottom Type, and pH of the Ten Permanent Collecting Sites in 1972-1973

		J	F	M	A	M	J	J	A	S	O	N	D
Bert Pond (TIS,R3E,S19), E.S. George Reserve, Livingston County, Michigan													
Temperature	1972 (°C)			9°	10°	23°	20°	28°	32°	15°	9°	3°	1°
	1973	4°	6°	11°	9°	11°	27°	24°	23°	17°			
Bottom Type		Muck, Fibrous, Detritus, Peat, leaf litter, and submerged vegetation and logs.											
pH	1972			6.5	6.5	7.0	6.5	6.5	6.0	6.5	6.5	7.0	6.5
	1973	6.5	6.5	6.5	6.5	6.5	6.5	7.0	6.5	6.5			
Crane Pond (TIS,R3E,S19), E.S. George Reserve, Livingston County, Michigan													
Temperature	1972 (°C)			12°	10°	25°	20°	29°	32°	15°	9°	3°	1°
	1973	4°	7°	11°	10°	11°	27°	25°	22°	17°			
Bottom Type		Sand, Detritus, rubble, some leaf litter and submerged vegetation.											
pH	1972			6.5	7.0	7.0	6.5	6.5	7.0	6.5	6.5	6.5	6.5
	1973	6.0	6.5	6.5	7.0	7.0	7.0	6.5	6.5	6.5			
George Pond (Tls,R3E,S19), E.S. George Reserve, Livingston County, Michigan													
Temperature	1972 (°C)			10°	9°	22°	20°	26°	31°	15°	9°	3°	1°
	1973	2°	4°	11°	7°	11°	21°	25°	23°	18°			
Bottom Type		Fibrous Peat, Detritus, Muck, leaf litter and submerged vegetation.											
pH	1972			6.5	6.5	7.0	6.5	6.5	6.5	6.5	6.5	6.0	6.0
	1973	6.0	6.5	6.5	7.0	7.0	6.5	6.5	6.5	6.5			
Woodland Pool (T2S,R5E,S28E), Washtenaw County, Michigan													
Temperature	1972 (°C)			6°	11°	15°	24°	24°	Dry	Dry	14°	1°	1°
	1973	4°	3°	8°	11°	16°	20°	19°	23°	20°			
Bottom Type		Sand, Gravel, Detritus, some leaf litter.											
pH	1972			6.0	6.0	6.5	6.5	7.0	-	-	6.5	6.5	6.5
	1973	6.5	6.0	6.5	6.0	6.5	6.5	6.5	6.5	6.5			
Lake (T2S,R3E,S1NE), Washtenaw County, Michigan													
Temperature	1972 (°C)				12°	11°	14°	26°	26°	19°	12°	6°	1°
	1973	1°	4°	6°	7°	10°	25°	25°	26°	17°			
Bottom Type		Sand, Gravel, Pulpy & Fibrous Peat, some Detritus and submerged vegetation.											
pH	1972				6.5	7.0	6.5	6.5	6.5	6.5	7.0	6.5	6.5
	1973	6.5	6.5	6.5	7.0	7.0	6.5	6.5	7.0				
Woodland Pool (T2S,R3E,S9SW), Washtenaw County,Michigan													
Temperature	1972 (°C)					9°	20°	22°	Dry	Dry	Dry	3°	4°
	1973	4°	2°	8°	11°	10°	20°	19°	23°	23°	20°	10°	
Bottom Type		Fibrous Peat, Detritus, leaf litter and submerged branches.											
pH	1972					7.0	6.5	6.5	-	-	-	7.0	6.5
	1973	6.5	6.5	7.0	7.5	7.0	6.5	6.0	6.5	6.5	7.0	6.5	
Murray Lake (T2S,R7E,S10NW), Washtenaw County, Michigan													
Temperature	1972 (°C)			6°	11°	24°	25°	23°	25°	14°	15°	5°	4°
	1973	3°	4°	7°	9°	12°	24°	25°	24°	16°			
Bottom Type		Sand, Gravel, Detritus, some leaf litter											
pH	1972			6.5	6.5	7.0	7.0	7.5	7.0	6.5	6.5	6.5	6.5
	1973	6.0	6.0	6.5	6.5	7.0	7.0	7.5					
Four-Mile Lake (T2S,R3E,S4SE), Washtenaw County, Michigan													
Temperature	1972 (°C)			6°	12°	20°	25°	26°	25°	15°	15°	6°	4°
	1973	3°	4°	7°	7°	10°	25°	25°	25°	16°			
Bottom Type		Sand, Gravel, Rubble, Detritus, leaf litter.											
pH	1972			6.5	6.5	7.0	7.5	6.5	6.5	7.0	6.5	6.5	6.5
	1973	6.0	6.5	7.0	7.5	6.0	7.0	7.0	6.5	6.5			
Fleming Creek (T2S,R6E,S25SE), Washtenaw County, Michigan													
Temperature	1972 (°C)			6°	11°	15°	19°	20°	22°	18°	12°	5°	1°
	1973	3°	4°	4°	10°	19°	22°	20°	23°	23°			
Bottom Type		Sand, Gravel, Rubble, Rocks, numerous submerged sticks and some leaf litter.											
pH	1972			7.0	7.5	7.0	7.5	6.5	7.0	7.0	7.0	7.0	7.5
	1973	7.0	7.5	6.5	7.0	7.0	7.0	7.5	7.5	7.5			
Roadside Ditch (T1S,R3E,S19SE), Washtenaw County, Michigan													
Temperature	1972 (0°C)			5°	11°	12°	20°	22°	22°	18°	10°	4°	1°
	1973	1°	4°	6°	11°	12°	22°	21°	23°	14°			
Bottom Type		Clay, Sand, Detritus, submerged sticks, fibrous peat.											
pH	1972			6.0	6.0	6.0	6.5	6.5	6.5	6.5	6.5	6.5	6.0
	1973	5.5	6.0	6.5	6.5	6.5	6.5	6.5	6.0	6.5			

APPENDIX III

Leech Faunal Inhabitants Of The Waters Studied In Ten Permanent Sites

Bert Pond: (TIS,R3E,S19), E.S. George Reserve, Livingston County, Michigan

Batracobdella picta (Verrill, 1972)
Erpobdella punctata (Leidy, 1870)
Macrobdella decora (Say, 1824)
Helobdella fusca (Castle, 1900)
Helobdella lineata (Verrill, 1874)
Helobdella stagnalis (Linnaeus, 1758)
Glossiphonia complanata (Linnaeus, 1758)
Placobdella hollensis (Whitman, 1892)
Placobdella ornata (Verrill, 1872)
Placobdella parasitica (Say, 1824)
Theromyzon maculosum (Rathke, 1862)

George Pond:(TIS,R3E,S19), E.S. George Reserve, Livingston County, Michigan

Erpobdella punctata (Leidy, 1870)
Helobdella fusca (Castle, 1900)
Helobdella lineata (Verrill, 1874)
Macrobdella decora (Say, 1824)
Batracobdella picta (Verrill, 1872)
Placobdella hollensis (Whitman, 1892)
Placobdella parasitica (Say, 1824)

Crane Pond:(TIS,R3E,S19), E.S. George Reserve, Livingston County, Michigan

Batracobdella picta (Verrill, 1872)
Erpobdella punctata (Leidy, 1870)
Helobdella fusca (Castle, 1900)
Helobdella lineata (Verrill, 1874)
Helobdella papillata (Moore, 1952)
Helobdella stagnalis (Linnaeus, 1758)
Marvinmeyeria lucida (Moore, 1954)
Macrobdella decora (Say, 1824)
Placobdella hollensis (Whitman, 1892)
Placobdella parasitica (Say, 1824)
Placobdella ornata (Verrill, 1872)
Glossiphonia complanata (Linnaeus, 1758)

Lake: (T2S,R3E,SINE), Washtenaw County, Michigan

Batracobdella phalera (Graf, 1899)
Batracobdella picta (Verrill, 1872)
Helobdella fusca (Castle, 1900)
Helobdella lineata (Verrill, 1874)
Erpobdella punctata (Leidy, 1870)
Mooreobdella fervida (Verrill, 1871)
Helobdella papillata (Moore, 1906)
Helobdella stagnalis (Linnaeus,1758)
Placobdella ornata (Verrill, 1872)
Placobdella parasitica (Say, 1824)
Macrobdella decora (Say, 1824)
Glossiphonia complanata (Linnaeus,1758)

Woods Pool: (T2S,R3E,S9SW), Washtenaw County, Michigan

Batracobdella picta (Verrill, 1872)
Helobdella stagnalis (Linnaeus, 1758)
Marvinmeyeria lucida (Moore, 1954)

Woods Pool: (T2S,R5E,S28SE), Washtenaw County, Michigan

Helobdella stagnalis (Linnaeus, 1758)
Marvinmeyeria lucida (Moore, 1954)

Four-Mile Lake: (T2S,R3E,S19SE), Washtenaw County, Michigan

Helobdella fusca (Castle, 1900)
Helobdella lineata (Verrill, 1874)
Erpobdella punctata (Leidy, 1870)
Macrobdella decora (Say, 1824)
Mooreobdella fervida (Verrill, 1871)
Glossiphonia complanata (Linnaeus, 1758)
Glossiphonia heteroclita (Linnaeus, 1761)
Helobdella elongata (Castle, 1900)
Helobdella stagnalis (Linnaeus, 1758)
Placobdella ornata (Verrill, 1872)
Placobdella parasitica (Say, 1824)
Helobdella papillata (Moore, 1906)

Fleming Creek: (T2S,R6E,S25SE), Washtenaw County, Michigan

Batracobdella picta (Verrill, 1872)
Batracobdella phalera (Graf, 1899)
Haemopis plumbea Moore, 1912
Dina lateralis (Verrill, 1871)
Dina parva Moore, 1912
Erpobdella p. annulata Moore (1922)
Erpobdella punctata (Leidy, 1870)
Helobdella lineata (Verrill, 1874)
Mooreobdella fervida (Verrill, 1871)
Mooreobdella bucera (Moore, 1949)
Glossiphonia complanata (Linnaeus, 1758)
Haemopis marmorata (Say, 1824) Moore, 1901
Placobdella papillifera (Verrill, 1872)
Helobdella papillata (Moore, 1906)
Helobdella stagnalis (Linnaeus, 1758)
Macrobdella decora (Say, 1824)
Haemopis grandis (Verrill, 1874)
Nephelopsis obscura Verrill, 1872
Haemopis terrestris (Forbes, 1890)
Placobdella ornata (Verrill, 1872)
Placobdella parasitica (Say, 1824)

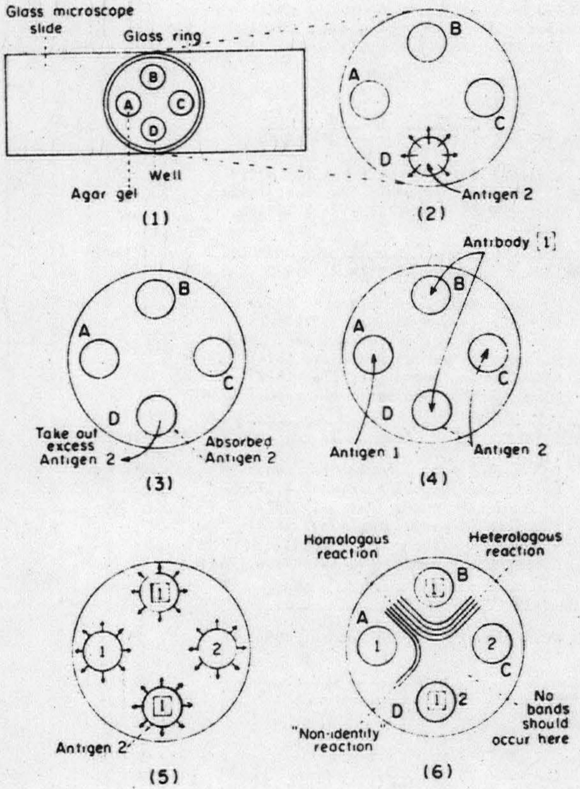
Roadside Ditch: (T1S,R3E,S19SE), Washtenaw County, Michigan

Helobdella fusca (Castle, 1900)
Helobdella papillata (Moore, 1906)
Glossiphonia heteroclita (Linnaeus, 1761)
Helobdella stagnalis (Linnaeus, 1758)
Marvinmeyeria lucida (Moore, 1954)

Murray Lake: (T2S,R7E,S10NW), Washtenaw County, Michigan

Helobdella fusca (Castle, 1900)
Helobdella stagnalis (Linnaeus, 1758)
Mooreobdella ferivda (Verrill, 1871)
Glossiphonia complanata (Linnaeus, 1758)
Glossiphonia heteroclita (Linnaeus, 1761)
Macrobdella decora (Say, 1824)
Placobdella parasitica (Say, 1824)

APPENDIX IV



Procedure for filling micro-Ouchterlony wells with antigen and antisera. 'Heterologous reactions' between wells B and C in (6) are the precipitation reactions of homologous proteins between the antibody and a heterologous antigen, i.e., from a different population. (From Burch and Lindsay, 1970, fig. 1).

ERRATA

Page 1, r.h. col., para. 2, line 1, for a read as

Page 3, r.h. col. para. 2, 10th line from bottom, for Sapkarev 1967, read Sapkarev 1968.

Page 4, r. h. col. para. 3, 5th line from bottom, for the are, read they are.

Page 5, Table 1, **B. paludosa,** under Leech Distribution. add (?) after N. America.

Page 6, l.h. col. 9th line from top, for Aqwatic, read Aquatic.

Page 7, r.h. col. para 2, 8th line, for investigaters, read investigators.

Page 8, l.h. col. para 2, l. 5, for Sawyer (1972), read Sawyer 1972).

Page 8, r. h. col. para. 5, 4th line from bottom, for decomated, read decimated.

Page 10, l. h. col., delete entire first line.

Page 10, l. h. col., 1st para., 4th and 3rd lines from bottom, for *Dina (=M.) bucera*, read *Macro-Macrobdella (=Dina) bucera*.

Page 10, r. h. col., 3rd. para., l. 5 from bottom, for contrstions, read concentrations.

Page 11, l. h. col., para. 2, l. 21, after *sanguisuga*, add a period.

Page 11, r.h. col., para. 1, l. 9. for *Planorbarius* read *Planorbis*.

Page 26, Figure 6, before 1972, add (--1971)

Page 48, l. h. col., para. 5, l. 4, for 196[illegible] read 1968.

Page 50, Addendum, l. 4. for 1967, read 1968.

STUDIES ON THE FEEDING RELATIONSHIPS OF LEECHES *(ANNELIDA: HIRUDINEA)* AS NATURAL ASSOCIATES OF MOLLUSKS

DONALD J. KLEMM

Adapted from a dissertation submitted in partial
fulfillment of the requirements for the degree
Doctor of Philosophy (Fisheries)
in the University of Michigan, 1974

STERKIANA **No. 58: 1-50, June, 1975 and No. 59: 1-20, September, 1975**

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Double pagination in Sterkiana 59 is omitted in this table of contents.

MOLLUSKS FROM SOUTHERN NICHUPTÉ LAGOON, QUINTANA ROO, MEXICO[1]

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ABSTRACT

Representatives of 182 species of mollusks are present in sediments of southern Nichupté Lagoon, Quintana Roo Territory, Mexico. It is possible to recognize several molluscan assemblages in surface sediments. An Open Lagoon assemblage is recognized in subsurface sediments that were deposited during a time when Nichupté Lagoon was less restricted.

INTRODUCTION

Nature and Purpose of Study

The purpose of this study is to describe the mollusks found in the surface and near-surface sediments from the southern part of Nichupté Lagoon in the Territory of Quintana Roo, Mexico (Fig. 1) and to report their distribution. Brady (1971) recently completed a detailed sedimentological study of several lagoons, including Nichupté Lagoon, on the northeastern coast of Yucatan. On the basis of various physical and chemical characteristics, Brady was able to recognize several distinct environments of deposition in and around each lagoon, for example, lagoonal, tidal delta, and back-lagoon marsh. Information obtained from the study of Recent sediments was then used by Brady to analyze subsurface sediments and to interpret the depositional history of each lagoon. Although Brady (1971: 17-26, 152) includes a general review of the biota of the lagoons in this area, a detailed investigation of the local fauna was beyond the scope of his study.

Brady's report provides excellent background for a comparison between molluscan species distributions and sedimentary environments. A primary goal of this study is to determine the extent to which local environmental differences influence molluscan species distribution in and around southern Nichupté Lagoon. A further goal is to determine whether the change in depositional environments through time (Brady, 1971: 187) is reflected by vertical faunal changes in soft-sediment cores.

PREVIOUS WORK

The earliest account of Mollusca from the Yucatan Peninsula is the description of two species (*Physa princeps* Phillips and *Glandina obtusa* Pfeiffer) by Phillips (1846: 66-67). In 1890 the Academy of Natural Sciences of Philadelphia sponsored an expedition to Yucatan and Baker (1891: 45-55), a member of this party, collected and identified specimens of 216 species of marine and brackish water mollusks. Eighty-three species of non-marine mollusks collected by this expedition were identified by Pilsbry (1891b: 310-334). Fischer and Crosse (1894) dealt with the non-marine Mollusca from Mexico and Guatemala. They reported that the terrestrial Gastropoda compare with those of South America but that the non-marine Pelecypoda are more similar to those of North America. At about the same time, data were being compiled for the monumental *'Biologia Centrali-Americana'* (1879-1915). Von Martens (1890-1901) wrote volume 9, dealing primarily with terrestrial and freshwater mollusks, but also including a section on 'Mollusca living on or near the seashore' (von Martens, 1890-1901: 555-596). Weisbord (1926: 81-87) listed 100 species of marine mollusks from the coast between Vera Cruz and Progreso. Bequaert and Clench (1933: 525-545; 1936: 61-75; 1938: 257-260) reported a total of 78 non-marine mollusk species (47 terrestrial, 18 freshwater and 13 brackish-water species) from Yucatan and provided an excellent summary of previous work in that area. Prior to 1946 published reports of molluscan faunas from the Yucatan Peninsula neglected the Territory of Quintana Roo, dealing mostly with the state of Yucatan and locations to the north and west. Jaume (1946: 95-110), the first to deal directly with faunas of Quintana Roo, reported 134 species of mollusks from Cabo Catoche, Isla Contoy, Isla Cancun, and Punta Nisuc. Rice and Kornicker (1962: 366-403; 1965a: 172; 1965b: 108-171) provided lists and illustrations of more than 200 species of marine mollusks from Alacran Reef and deeper waters of Campeche Bank, off north-

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[1] A complete table of contents for this paper will appear at the end of the complete paper in Sterkiana 60, planned for December 1975.

[2] Present address: Texaco Laboratories, Houston, TX

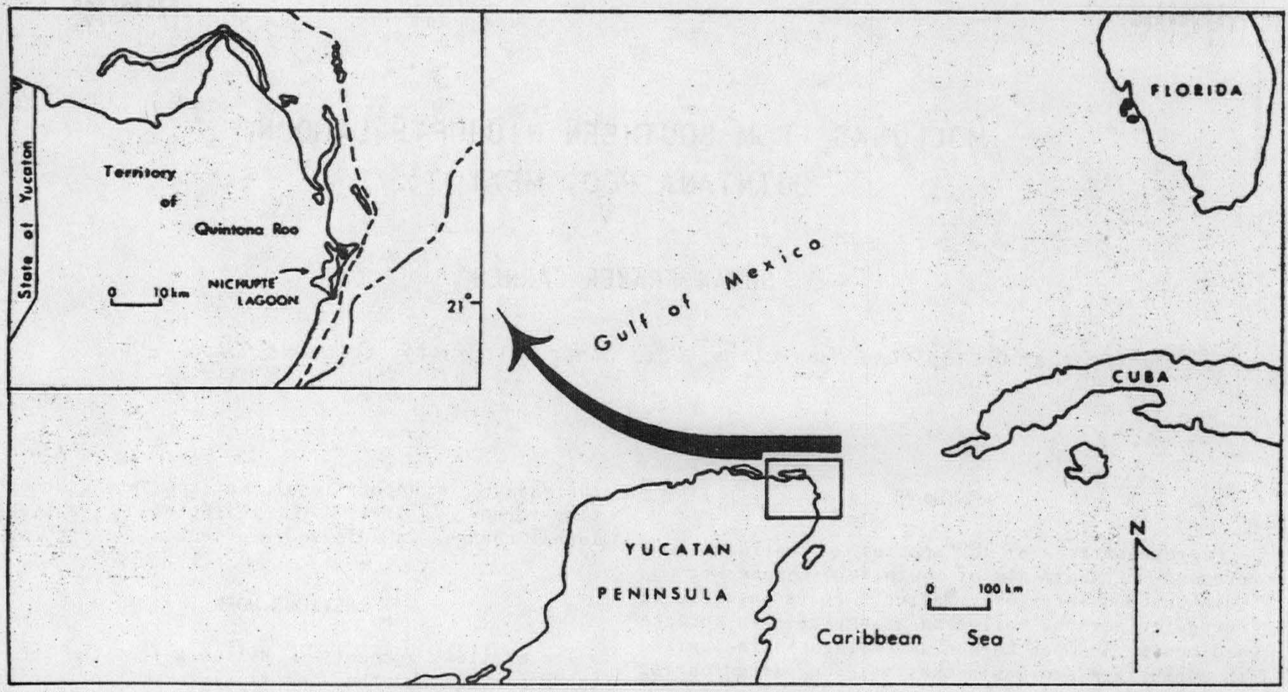

Figure 1. Map of the Caribbean Sea-Gulf of Mexico-Yucatan Peninsula area with the northeastern Yucatan Peninsula enlarged.

western Yucatan. Garcia-Cubas (1963: 1-55) described the distribution of 41 species of marine micromollusks from Terminos Lagoon, Campeche. Ekdale (1972; 1974: 638-668) conducted a faunal survey in the vicinity of Isla Cancun and Isla Contoy and reported 316 species of marine Mollusca. Moore (1973: 5-6) identified 25 species of marine micromollusks found in sediments from a landlocked lagoon at Cozumel Island.

SETTING OF NICHUPTÉ LAGOON

Nichupté Lagoon (Fig. 2) is a nearly landlocked body of water bounded on the west by the mainland of Quintana Roo and on the west by Isla Cancun. Isla Cancun, which is nearly 14 km long and rarely more than 0.5 km wide, consists of ridges of consolidated Pleistocene eolianites, on which Holocene eolianites, up to 15 m high, have been deposited (Ward, 1970). An oölitic sand beach is developed on the Caribbean side of the island, whereas the lagoonal side is characterized by sparse to dense vegetation (Brady, 1971: 30-31). Punta Nisuc (Fig. 2), the southern tip of Isla Cancun, marks the northernmost development of the most extensive barrier reef in the western hemisphere, a coralgal-molluscan complex that continues for nearly 600 km southward to Belize and Guatemala (Brady, 1971: 29-30). Tombolos, formed by eolian deposition and spit accretion of bioclastic and oölitic sands (Brady, 1971: 31), join the northern and southern portions of Isla Cancun to the mainland. Tidal channels through the tombolos provide passage into the lagoon for normal marine waters from the Caribbean. Tidal deltas are built up on both the Caribbean and lagoonal sides of these channels. Two transverse mudbanks, which are nearly awash at low tide, divide the main body of the lagoon into three ponds. Two smaller lagoons, Bojorquez and Inglés, are separated from Nichupté by encroaching mangrove banks, the positions of which are controlled by late Pleistocene duneand terrace topography (Brady, 1971: 29). Nichupté Lagoon and Inglés Lagoon are flanked on the west by a back-lagoon marsh which is generally one to three km wide. The marsh is replaced landward by dense hardwood jungle developed on late Pleistocene bedrock (Brady, 1971: 32).

DEPOSITIONAL ENVIRONMENTS

The depositional environments recognized by Brady (1971) in and around Nichupté Lagoon are summarized below. Only those data which are pertinent to the present discussion of molluscan faunas are reviewed. This information is taken exclusively from Brady (1971: 34-42, 98-104) to whom the reader is referred for more detailed information.

Back-Lagoon Marsh

The Back-Lagoon Marsh is characterized by extremely shallow water (0 to 0.4 m) and by short-term and seasonal variations in salinity (2 to 21 parts per thousand), caused by fluctuations in rainfall, run-off from the mainland, restricted circulation and evaporation. Mangrove, sawgrass and finely disseminated algal fragments make up more than 90 percent of the total volume of the sediment, whereas the remaining volume consists of calcitic mud

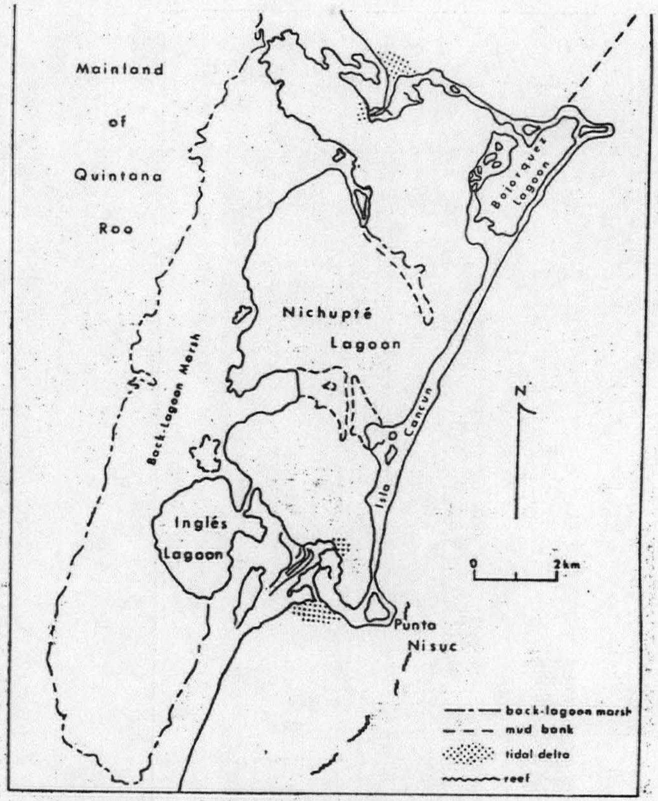

Figure 2. Map of the Nichupté Lagoon area

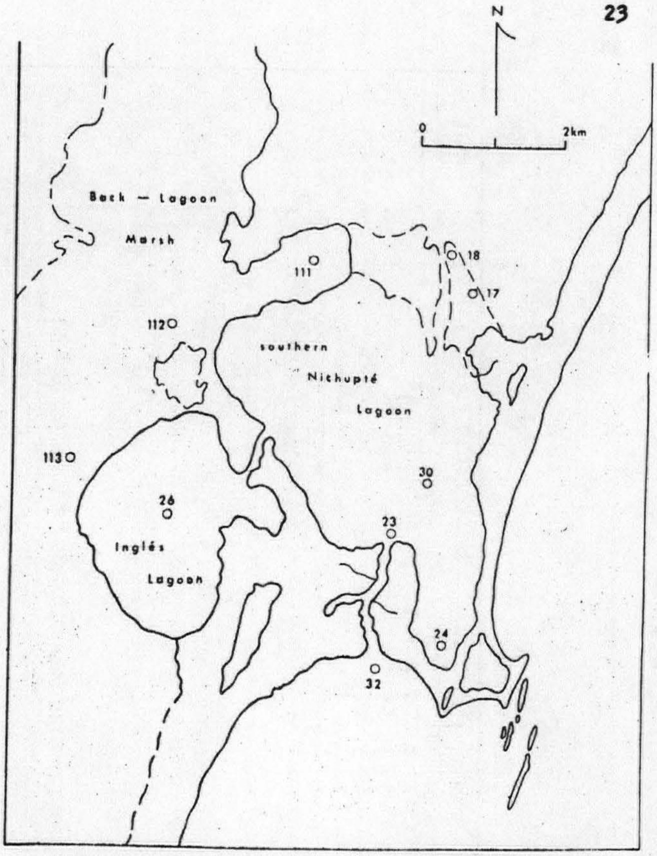

Figure 3. Map of southern Nichupté Lagoon with core localities.

and skeletal remains. Skeletal remains include brackish and freshwater mollusks (87 percent of total skeletal remains) and minor Foraminifera.

Nichupté Lagoon.

The Lagoonal depositional environment can be subdivided into three subenvironments: the main body of the lagoon (including ponds), transverse mudbanks, and lagoonal tidal deltas.

The main body of the lagoon has water depths of 1.5 to 3.0 m, with maximum depths of 3.5 to 4.0 m in the central portions of the three major ponds. Except in the immediate area of the tidal deltas, water circulation is sluggish and impeded by the transverse mudbanks. The mudbanks have water depths of 0.3 m and are nearly emerged at low tide. Channels (depth 0.5 to 3.0 m) through the mudbanks permit circulation between ponds. Water depth in the area of the tidal deltas is, in most cases,: less than 0.5 m and channels (maximum depth 5.0 m) through these deltas allow influx of more normal marine water into the lagoon.

Salinity in the lagoon varies from 24 parts per thousand in areas adjacent to the back-lagoon marsh to 32 parts per thousand in the vicinity of the tidal deltas. Short-term and seasonal variations in rainfall produce significant salinity changes only. in the shallow parts of the lagoon adjacent to the marine water into the lagoon.

The lagoonal sediment is a 'soupy, pelleted, organic-rich muck having a gelatinous character because of the binding effects of blue-green algae' (Brady, 1971: 38) and is completed disrupted by burrowing organisms and plant roots. Skeletal remains, which constitute 25 to 50 percent of the total volume of the sediment, include marine mollusks, Foraminifera, Ostracoda and *Halimeda*. Mollusks, Foraminifera and *Melobesia* (a coralline alga which encrusts lagoonal grasses and contributes mud-size sediments) are the most prominent constituents of lagoonal sediments. Sediments of the lagoonal tidal delta contain relatively less mud and organic material than sediments of the main body of the lagoon and mudbanks, due to improved water circulation.

Caribbean Tidal Delta

Water depth in the area of the Caribbean Delta is generally less than 0.5 meter. Salinity approaches normal marine but is influenced by tidal exchange with the lagoon. Sediment, only 10 to 60 percent mud, is a mixture of open marine (oöids, rounded fragments, lithoclasts, echinoderm spines, sponge spicules and coral) and lagoonal (fecal pellets, Foraminifera, and coralline algae) grain types.

Inglés Lagoon

Inglés Lagoon is a shallow body of water (maximum depth 1 m), nearly surrounded by freshwater marshes and is the least saline (13.5 to 16.5 parts per thousand) of the major bodies of water protected by Isla Cancun. The sediment is similar to the or-

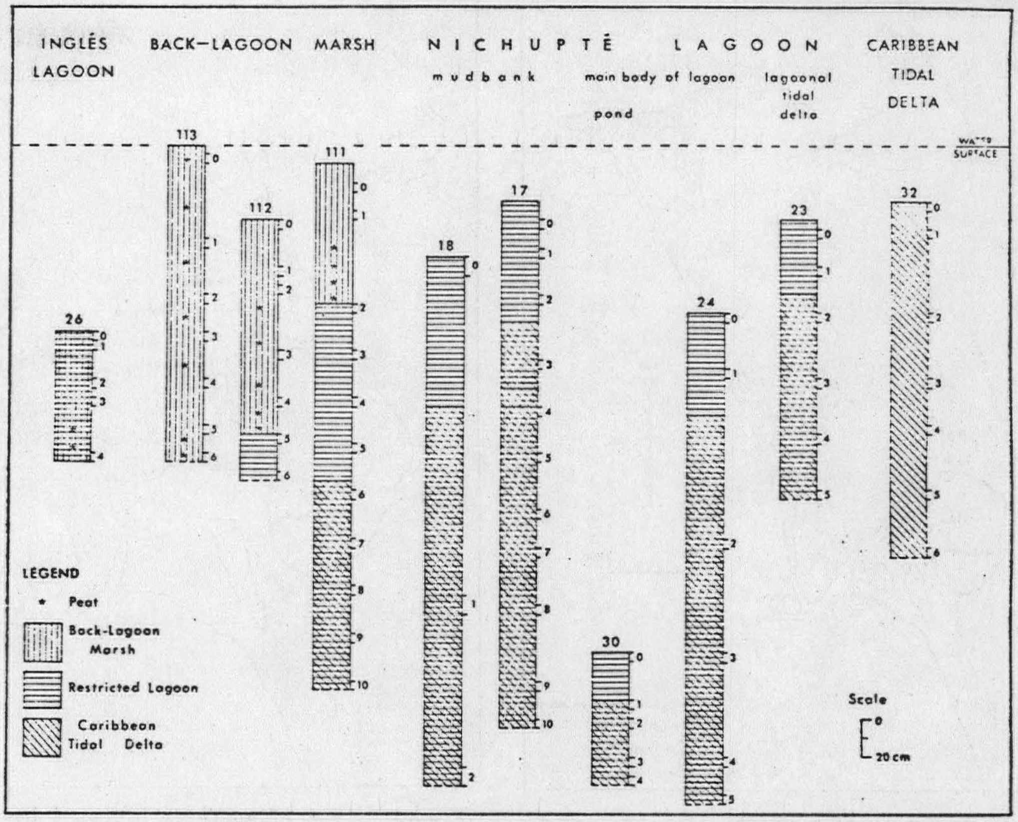

Figure 4. Core diagrams with sample numbers indicated.

ganic-rich muds found in the main part of Nichupté Lagoon. Skeletal remains consist mainly of peneroplid Foraminifera (80 per cent of the total skeletal grains) and Mollusca.

HISTORY OF NICHUPTÉ LAGOON

The thickness of unconsolidated sediment in Nichupté Lagoon varies from 2.5 to 4.5 m in the main part of the lagoon, and from 4.0 to 11.5 m in the vicinity of the mudbanks and tidal deltas (Brady, (1971: 38). However, only the upper 0.25 to 0.5m of the sedimentary succession (Brady 1971: 41) is typical of deposits in present-day Nichupté Lagoon which represents a restricted lagoon environment. In chemical composition, present-day lagoonal sediments consist mainly of high-magnesium calcite (57 to 67 percent) (Brady, 1971: 43, table 1), reflecting the abundance of peneroplid Foraminifera and *Melobesia*. Beneath this thin mantle of calcitic mud, the sediment is characterized by a high percentage (71 to 75 percent) of aragonite, which is typical of more open marine sediments. For example, the present-day Caribbean tidal delta deposits are 61 to 73 percent aragonite (Brady, 1971: 275 cores 32 and 37) whereas the average composition of open marine sediments of northeast Yucatan is 83 percent aragonite (Brady, 1971: 99). In addition to the types of grains found in present-day lagoonal sediments, the aragonitic sediments also contain abundant fragments of *Halimeda*, as well as fragments of echinoderms, the coral *Porites*, and sponges. Also present are rounded carbonate fragments, oöids and lithoclasts that are similar to those found in the present-day Caribbean tidal delta (Brady, 1971: 42).. In the western part of the central pond, the aragonitic sediments are underlain by a thin layer of peat and organic-rich mud which rests directly on bedrock. (Brady, 1971: 185, core 20).

On the basis of the above information, and on the basis of Carbon 14 dates taken from mollusk shells collected at the contact between aragonitic sediments and calcitic sediments, Brady (1971:186) interprets the history of the lagoon as follows: Thirty thousand years before present, sea level was lowered by late Pleistocene (Wisconsin) glaciation and the bedrock beneath present-day Nichupté Lagoon was exposed. Transgression began about 5,000 to 6,000 years before present and is marked by a basal layer of peat which represents a marginal marine marsh deposit. As transgression continued, marine lagoonal sediments accumulated over the peat. At this time, Isla Cancun acted as a barrier to the east, but the lagoon was open to normal marine waters to the north and south. Brady characterizes the lagoonal sediments that accumulated during this time as 'partially-restricted' marine deposits. In the present paper, the term 'open lagoon' is preferred.

When rising sea level reached about 1.0 to 1.5 m lower than present (1,000 to 1,500 years ago), a major change in environment occurred. Tombolos

TABLE 1

Core	Location	Core Length m	Sediment Thickness m	Water Depth m	Salinity ‰	Temperature °C	Chemical Composition (%)		
							Aragonite	Magnesium Calcite	Calcite
17	Mudbank	2.8	6.7	0.3	29.15	29.4	39	58	3
18	Mudbank	2.8	6.7	0.6	28.60	29.4	33	67	0
30	Center of Pond	0.7	5.2	2.7	29.70	29.4	55	43	2
24	Extreme S. E. Nichupté Lagoon	2.6	5.2^+	0.9	31.90	--	55	42	3
23	Lagoonal Tidal Delta	1.5	5.2^+	0.4	30.25	30.0	--	--	--
32	Caribbean Tidal Delta	1.9	3.1	0.3	36.30	30.0	73	25	2
111	Back-Lagoon Marsh	2.8	7.9	0.1	35.75	41.0	0	0	99
112	Back-Lagoon Marsh	1.4	3.1	0.4	--	--	--	--	--
113	Back-Lagoon Marsh	1.7	2.0	0.0	--	--	0	0	100
26	Inglés Lagoon	0.7	0.7	1.0	13.20	29.4	1	99	0

Table 1. Core Data compiled from Brady (1971, p. 270, 274-276).

connected the northern and southern ends of Isla Cancun to the mainland and the lagoon was further restricted. Communication between the lagoon and open marine waters was confined to the tidal channels cutting through the tombolos. Open lagoon conditions were replaced by restricted lagoon conditions which exist in the lagoon today.

For further data on the history of Nichupté Lagoon, see Brady (1971: 183-190).

AREA OF STUDY

The area of study for this report includes Inglés Lagoon, the southern part of Nichupté Lagoon (hereafter referred to as southern Nichupté Lagoon) and the marsh which borders these lagoons to the west. (Fig. 3).

METHODS OF INVESTIGATION

Brady (1971) collected more than 100 soft-sediment cores in five coastal lagoons of the northeast Yucatan Peninsula. The cores were frozen and then slit vertically. Brady used half of each core for various sedimentological analyses and placed the remaining half at the disposal of other workers. Ten cores from southern Nichupté Lagoon were selected for the present study (Fig. 3) in order to obtain, as nearly as possible, a representation of Recent and past sediments and molluscan faunas. These cores (Fig. 4 and Table 1) vary in length from 0.7 to 2.8 m and all the cores were taken in water shallow enough to permit use of an aluminum coring device (diameter 7.3 cm) except core 30 which was taken with a plastic core device (diameter 2 cm). Each core half was measured, described, and sampled at 5 cm intervals, except core 18. Bulk samples, each about a pint in volume, were taken from core 18. Samples of equal volume vary in weight due to differences in sediment composition. For example, surface samples from the back-lagoon marsh area (cores 111, 112, 113) were considerably lighter than samples of similar volume from the main lagoon because of large amounts of plant debris.

Various methods were used to disaggregate the dried sediment. Gentle washing with warm water was effective for breaking down many of the samples whereas others, apparently bound by organic material, disaggregated only after soaking for several minutes in 50 percent Clorox solution. The sediments were dried, then the residue of particles exceeding 0.4 mm in diameter was examined microscopically for Mollusca.

DESCRIPTION OF CORES INVESTIGATED

Back-Lagoon Marsh

Three cores (111, 112, 113) from the Back-Lagoon Marsh were examined. Marsh sediment is characterized by white, calcitic silt and clay with abundant plant debris, peat and wood fibers.

Core 113 penetrated 1.7 m of the total sediment thickness of 2.0 m. The sediments are of marsh en-

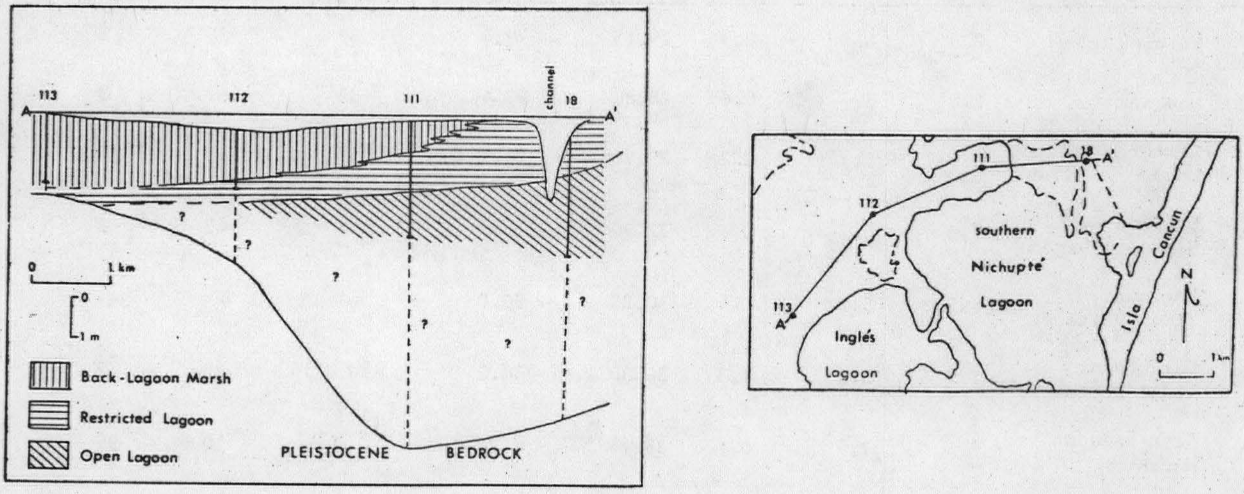

Figure 5. West to east cross-section from back-lagoon marsh to mudbank.

vironment character throughout. The upper 9 cm of sediment is silt and plant debris with few skeletal remains. A concentration of shells was encountered at 55 cm below the top of the core. From 85 to 100 cm the sediment is muddy with plant roots preserved.

Core 112 penetrated nearly half of the total sediment thickness (1.4 of 3.0 m). The upper 120 cm of sediment is of marsh environment character and this is underlain by lagoonal sediments. The interval from 45 to 50 cm below the top of the core is primarily peat with some silty mud. From 50 to 100 cm, peaty marsh sediments predominate. At 100 cm below the top of the core, a layer of peat, 20 cm thick and devoid of shells, is present. Below this peat layer is 20 cm of organic-rich lagoonal silty mud.

Core 111 penetrated 2.8 cm of the total sediment thickness of 7.9 m. Back-lagoon marsh sediments occupy the upper 80 cm of the core and are underlain by lagoonal sediments. The upper 5 cm of marsh sediment is a carbonate crust. From 5 to 40 cm below the top of the core, silty, grassy marsh sediments are observed. The upper 40 cm of sediment is underlain by a spongy peat layer which is also 40 cm thick. From 80 to 170 cm, restricted lagoonal sediments are observed and these are underlain by 110 cm of open lagoonal sediments. The restricted lagoon sediments are primarily muds with some organic fibers. At 170 cm depth the sediments become slightly coarser and the amount of *Halimeda* plates increases. Core 111 is positioned on what was, in the past, part of the transverse mudbank (Fig. 3). The encroachment of the mangroves onto the mudbank is recorded in the upper half of the core.

Nichupté Lagoon

Five cores from Nichupté Lagoon proper were examined. Two cores (17, 18) are from the transverse mudbank, two are from the main body of the lagoon (24) including the pond (30), and one is from the lagoonal tidal delta (23).

Cores 17 and 18 each penetrated the sediment to depths of 2.8 m. The change from open lagoon to restricted lagoonal sediments is observed in cores 17 and 18 at depths of 65 cm and 80 cm respectively. The restricted lagoonal sediments are tan to brown, silty, and contain abundant organic material. The downward increase in grain size, observed by Brady (1971: 39) is less evident in these mudbank cores, but the change in fauna (for example, the presence of sponge, coral, and echinoderm fragments and the increase in *Halimeda* fragments) can be observed.

Core 30 from the lagoonal pond, was taken in the deepest water (2.7 m) of all the cores studied. Core 30 penetrated only 0.7 m of a sediment thickness of 5.2 m. The upward change from open lagoon sediments to restricted lagoonal sediments occurs 30 cm below the top of the core.

Core 23, from the lagoonal tidal delta, penetrated 1.5 m of sediment. The upward change from open lagoon sediments to restricted lagoonal sediments occurs at a core depth of 40 cm. The open lagoon sediments are somewhat coarser in this core than in other lagoonal cores and skeletal remains are broken, worn, and abraded. The open lagoon sediments are comparable to those found in the present-day Caribbean tidal delta.

Caribbean Tidal Delta

Core 32 penetrated 0.9 m of carbonate sand which consists primarily of rounded, unidentifiable skeletal fragments.

Inglés Lagoon

Core 26 is of particular interest because it penetrated the entire sediment thickness (0.7 m) to bedrock. The upper 65 cm of sediment consists of peneroplid-rich lagoonal mud, whereas the lowermost part of the core is peat, representing the basal transgressive layer described by Brady (1971:185).

MOLLUSCAN DISTRIBUTION

The molluscan fauna of southern Nichupté Lagoon and the immediately surrounding area is dominated by gastropods and bivalves. Chitons and scaphopods are present but rare. The fauna is largely a tropical to subtropical shallow water marine and freshwater assemblage, like that found in many West Indian localities. A list of the mollusks identified from core samples within the study area is provided in Table 2. As shown in this table, a few species are restricted to sediments from one particular depositional environment. Also, some species which occur in deposits representing several different environments are consistently common in those from one particular environment, while rare or only sporadically abundant in those from other environments. Three basic molluscan assemblages may be recognized on the basis of species preferences for particular environments represented in surface sediments: Back-Lagoon Marsh, Lagoon, and Caribbean Tidal Delta. It is also possible on the basis of mixing of molluscan assemblages to distinguish between Restricted Lagoon faunas and Open Lagoon faunas in subsurface samples.

Back-Lagoon Marsh Assemblage

Restricted Species:
Acteocina canaliculata
Assiminea succinea
Biomphalaria havanensis
Blauneria heteroclita
Cerithidea costata
Detracia bullaoides
Ferrissia cf. *excentrica*
Gastrocopta pellucida
Lamellaxis micra
Marinula succinea
Melampus coffeus
Neritina virginea
Physa marmorata
Polygyra carpenteriana
Pyrgophorus coronatus
Thysanophora cf. *conspurcatella*
Truncatella spp.
Cyrenoida floridana
Polymesoda maritima

Consistently common species:
Anomalocardia auberiana
Parastarte triquetra

The Back-Lagoon Marsh Assemblage is characterized by a relatively small number of species (Table 3, 22 species). The brackish-water gastropods *Acteocina canaliculata, Assiminea succinea, Cerithidea costata* and *Pyrgophorus coronatus* and representatives of the brackish-water bivalves *Anomalocardia auberiana* (dwarfed) and *Polymesoda maritima* are abundant and considered characteristic of the environment. Representatives of the fresh to brackish-water bivalve *Cyrenoida floridana* are not present in large numbers, but are restricted to sediments from the marsh environment. Melampid gastropods*(Blauneria heteroclita, Detracia bullaoides, Marinula succinea, Melampus coffeus)*, freshwater gastropods *(Biomphalaria havanensis, Ferrissia* cf. *excentrica* and *Physa marmorata)* and terrestrial gastropods *(Gastrocopta pellucida, Lamellaxis micra, Polygyra carpenteriana, Succinea* spp., *Thysanophora* cf. *conspurcatella)* are sparsely represented in the study area but are also restricted to the back lagoon marsh sediments. *Truncatella* species are most common in marsh sediments, but fresh shells are also found in very small numbers in sediments of the lagoonal and tidal delta cores located very close to land, for example, Core 32, Caribbean Tidal Delta sediments yielded 2 specimens.

Abbott (1974: 534) reports that the bivalve *Parastarte triquetra* is restricted to coastal Florida and possibly Texas. He explains the occurrence of representatives of this species elsewhere as due to droppings of water fowl. Valves of this clam are encountered in only a few samples from the marsh in the study area, but when they are found, they are present in relatively large numbers. Most of the valves found are disarticulated, but several complete specimens were also collected.

The mollusks found in Inglés Lagoon sediments represent basically a Back-Lagoon Marsh brackish-water assemblage, lacking terrestrial forms and with an admixture of lagoonal species. Over 1,000 dwarfed specimens of *Anomalocardia auberiana*, which is typical of the Back-Lagoon Marsh assemblage, were recovered from the sediments of Inglés Lagoon. Also present in relatively large numbers and considered characteristic of the marsh assemblage are the gastropods *A. canaliculata* and *C. costata*. Representatives of 13 species, more commonly encountered in lagoonal sediments, are found in the sediments of Inglés Lagoon (gastropods: *Alvania auberiana, Bulla striata, Crepidula* sp. juveniles, *Diastoma varium, Finella dubia, Marginella apicina, Odostomia laevigata, Sayella* cf. *crosseana*; bivalves: *Anomia simplex* juvenile, *Brachidontes exustus, Cumingia tellinoides, Laevicardium mortoni, Tellina mera)*. Most of these basically lagoonal representatives are present in very small numbers, except the bivalves, *B. exustus, G. gemma*, and *L. mortoni*, which are present in relatively large numbers. Although Inglés Lagoon contains sediments similar to those of Nichupté Lagoon, the fauna reflects primarily a Back-Lagoon Marsh Assemblage due to low salinity of the waters.

Restricted Lagoon Assemblage

Restricted species:
Astraea americana
Barleea sp.
Cerithium muscarum
Rissoina catesbyana
Carditamera floridana
Cumingia tellinoides
Laevicardium mortoni
Modiolus squamosus

(Text continued p. 32)

TABLE 2 Summary of Species Distribution

	26	113	112		111			18		17		30		23		24		32	
GASTROPOD SPECIES	Inglés	BLM	BLM	RL	BLM	RL	OL	RL	OL	RL	OL	RL	OL	RL	OL	RL	OL	TD	Total
Acmaea pulcherrima	-	-	-	-	-	3	10	-	13	2	20	14	76	10	4	19	34	7	212
Acteocina canaliculata	71	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	95
Acteocina candei	-	-	-	48	-	1	1	2	9	3	10	34	18	12	29	1	7	42	217
Alaba incerta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	5	6
Alvania auberiana	2	-	-	-	-	-	1	3	2	6	4	23	16	2	15	4	6	8	92
Amphithalamus cf. vallei	-	-	-	-	-	4	41	9	28	46	114	4	42	16	3	14	6	2	329
Anachis sparsa	-	-	-	-	-	-	-	3	1	3	-	-	-	3	-	1	-	3	14
Anticlimax pilsbryi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	2	4
Anticlimax sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Assiminea succinea	9	59	73	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	144
Astraea americana	-	-	-	-	-	-	4	5	9	-	3	2	6	-	-	-	1	-	30
Astraea phoebia	-	-	-	-	-	-	-	-	1*	1*	-	-	-	-	-	-	-	-	2*
Atys cf. riiseana	-	-	-	-	-	-	1	-	3	-	10	-	1	1	1	1	4	2	24
Barleeia sp.	-	-	-	-	-	11	25	31	16	7	28	25	33	-	5	162	4	-	347
Biomphalaria havanensis	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Blauneria heteroclita	-	-	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24
Bulla striata	5	-	-	5	-	1	-	2	4	3	3	5	-	4	1	6	3	1	43
Bullacea spp. (juveniles)	17	-	-	54	-	8	-	3	9	4	11	30	8	32	10	10	-	5	201
Caecum floridanum	-	-	-	-	-	-	-	-	1	-	-	1	1	1	15	1	-	6	26
Caecum imbricatum	-	-	-	-	-	-	-	-	-	-	-	-	4	5	28	2	2	38	79
Caecum pulchellum	-	-	-	-	-	-	-	-	-	-	-	4	13	4	28	5	-	1	55
Cavolina longirostris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Cerithidea costata	104	321	25	1	92	-	-	-	-	-	-	-	-	-	-	-	-	-	543
Cerithiopsis greeni	-	-	-	-	-	-	2	1	-	5	1	-	-	1	1	-	-	-	11
Cerithiopsis sp. 1	-	-	-	-	-	2	-	2	-	14	7	-	1	1	-	-	3	-	30
Cerithiopsis sp. 2	-	-	-	-	-	-	1	2	2	4	-	2	1	-	-	5	2	-	19
Cerithiopsis sp. 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2
Cerithium algicola	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	2	1	5
Cerithium eburneum	-	-	-	1	-	11	7	5	7	25	9	24	21	34	12	13	14	3	186
Cerithium litteratum	-	-	-	-	-	6*	25	-	4	-	2	-	3	3	18	1	10	21	93
Cerithium lutosum	-	-	-	-	-	-	-	-	-	-	3	-	-	1	-	-	-	12	16
Cerithium muscarum	-	-	-	-	-	2	1	4	-	15	4	5	-	4	1	11	-	-	47
Cerithium spp. (juveniles)	-	-	-	8	-	14	10	3	13	39	6	48	-	153	6	17	30	25	372
Columbella mercatoria	-	-	-	-	-	-	-	4	1	1	1	-	2	2	2	-	3	2	18
Conus stearnsii	-	-	-	-	-	-	-	1	1	-	4	-	1	-	1	-	2	2	12
Cosmioconcha nitens	-	-	-	-	-	1	2	-	7	8	15	1	-	-	-	3	1	-	38
Crassispira cf. fuscescens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Crassispira leucocyma	-	-	-	-	-	-	2	2	1	-	-	-	-	-	-	7	2	1	15
Crepidula convexa	-	-	-	4	-	-	1	7	1	10	1	3	-	8	-	5	1	-	41
Crepidula plana	-	-	-	-	-	-	-	-	1	-	1	-	-	1	1	2	26	4	36
Crepidula spp. (juveniles)	5	-	-	41	-	22	2	11	2	40	13	4	2	8	8	41	5	8	212
Creseis sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2
Crucibulum cf. striatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2
Cylichna sp.	-	-	-	-	-	-	-	-	-	1	-	5	1	-	1	-	-	-	8
Detracia bullaoides	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Diastoma varium	8	-	-	-	-	1	-	151	10	86	18	63	5	203	12	90	-	15	662
Diastoma sp.	-	-	-	-	-	-	-	-	-	49	-	-	-	122	2	-	-	-	173

GASTROPOD SPECIES	26	113	112		111			18		17		30		23		24		32	
	Inglés	BLM	BLM	RL	BLM	RL	OL	RL	OL	RL	OL	RL	OL	RL	OL	RL	OL	TD	Total
Diodora cayenensis	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
Diodora dysoni	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	4	-	6
Emarginula pumila	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2
Epitonium echinaticostum	-	-	-	-	-	-	-	-	-	1	1	-	1	-	-	-	-	1	4
Ferrissia cf. excentrica	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Finelia dubia	1	-	-	-	-	-	-	-	-	1	-	1	3	-	-	-	-	3	9
Gastrocopta pellucida	-	1	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11
Granulina ovuliformis	-	-	-	-	-	1	-	1	2	3	2	4	5	3	-	9	1	-	31
Haminoea elegans	-	-	-	-	-	-	-	-	1	-	5	1	-	1*	3	-	1	-	12
Henrya goldmani	-	6	-	6	-	-	-	7	-	-	-	2	1	2	2	2	-	1	29
Hyalina albolineata	-	-	-	-	-	-	2	1	3	-	4	2	2	-	-	1	-	-	15
Hyalina avena	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	3
Hyalina pallida	-	-	-	-	-	-	1	-	1	-	3	-	2	-	-	-	2	-	9
Lamellaxis micra	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Litiopa melanostoma	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-	-	2	6
Mangelia bartletti	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	3	4	9
Mangelia biconica	-	-	-	-	-	1	2	-	-	1	-	-	-	-	-	-	2	-	6
Marginella apicina	1	-	-	-	-	3	2	3	1	8	1	3	-	1	-	7	-	-	30
Marginella eburneola	-	-	-	-	-	-	3	1	-	4	2	7	1	4	-	13	3	1	39
Marginella labiata	-	-	-	-	-	-	-	-	4	-	2	-	-	-	-	-	-	1	7
Marginella lavalleeana	-	-	-	2	-	15	9	5	3	12	4	2	2	4	10	4	12	19	103
Marginella roosevelti	-	-	-	-	-	-	1	1	1	-	1	-	-	-	-	1	1	-	6
Marginella spp. (juveniles)	3	-	-	10	-	19	3	7	1	11	4	2	3	21	-	9	1	1	95
Marginelliopsis serrei	-	-	-	-	-	12	1	2	7	3	7	3	12	3	5	7	39	16	117
Marinula succinea	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Meioceras cornucopiae	-	-	-	-	-	-	-	-	9	1	2	3	12	9	5	5	7	15	68
Meioceras nitidum	5	-	4	10	-	17	1	104	48	247	138	580	505	655	192	849	7	2	3364
Melampus coffeus	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Melanella sp.	-	-	-	-	-	-	1	-	4	1	2	-	2	1	3	-	2	-	16
Melongena bispinosa	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	2
Mitrella argus	-	-	-	-	-	-	3	-	1	-	2	-	-	-	-	-	2	-	8
Mitrella nycteis	-	-	-	-	-	-	2	-	-	-	5	-	-	-	1	-	-	-	8
Modulus modulus	-	-	-	8	-	36	10	46	22	80	24	38	20	49	12	80	17	11	453
Nassarius albus	-	-	-	-	-	3	2	-	3	-	1	-	-	-	-	1	3	2	15
Neodrillia cydia	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1
Neritina virginea	-	3	-	-	-	2#	-	-	-	-	-	-	-	-	-	-	-	-	5
Odostomia impressa	-	-	-	-	-	-	-	5	-	2	-	-	-	26	-	5	1	-	39
Odostomia laevigata	5	-	-	1	-	-	-	-	2	1	1	3	1	-	-	-	1	3	18
Odostomia sp.	-	-	-	-	-	-	-	1	-	11	1	-	-	-	2	-	-	-	15
Olivella dealbata	-	-	-	-	-	-	-	-	5	-	9	-	3	2	11	-	8	18	56
Olivella minuta	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	8	11
Pachystremiscus ornatus	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-	-	4
Pachystremiscus pulchellus	-	-	-	-	-	-	-	-	-	-	-	-	-	8	30	-	3	3	44
Parviturbo cf. rehderi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Persicula fluctuata	-	-	-	-	-	-	1	-	2	-	1	-	-	-	-	-	-	-	4
Physa marmorata	-	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12
Polygyra carpenteriana	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Pyramidella crenulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Pyramidella sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	2	-	-	5
Pyrgocythara sp.	-	-	-	-	-	1	-	-	1	1	-	2	1	-	-	5	-	-	11
Pyrgophorus coronatus	-	781	36	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	819

GASTROPOD SPECIES	26	113	112		111			18		17		30		23		24		32	Total
	Inglés	BLM	BLM	RL	BLM	RL	OL	RL	OL	RL	OL	RL	OL	RL	OL	RL	OL	TD	
Rissoella caribaea	-	-	-	-	-	-	-	-	-	-	1	-	4	2	1	-	2	-	10
Rissoina bryerea	-	-	-	-	-	-	1	2	-	-	1	3	4	1	-	-	-	1	13
Rissoina cancellata	-	-	-	-	-	-	2	-	-	-	-	1	1	1	1	-	9	3	18
Rissoina catesbyana	-	-	-	-	-	-	-	32	-	-	-	-	-	-	-	-	-	-	32
Rissoina multicostata	-	-	-	-	-	-	1	-	-	-	1	-	4	1	-	1	-	-	8
Rissoina striosa	-	-	-	-	-	-	1	6	-	-	1	1	1	-	-	-	1	-	11
Sayella cf. crosseana	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	2
Sayella cf. fusca	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
Smaragdia viridemaris	-	-	-	-	-	-	1	-	1	-	-	-	1	1	4	-	4	6	18
Solariorbis cf. terminalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	3	-	6
Succinea sp. 1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Succinea sp. 2	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Tegula fasciata	-	-	-	-	-	-	1	-	1	-	2	2	4	1	3	2	-	-	16
Teinostoma cf. clavium	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	-	2	-	7
Teinostoma cf. megastoma	-	-	-	-	-	-	-	1	1	-	-	-	2	1	1	2	-	-	8
Thala foveata	-	-	-	-	-	-	1	1	-	1	2	-	-	4	-	5	2	-	16
Thysanophora cf. conspurcatella	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Tricolia affinis	-	-	1	-	-	2	36	139	8	20	26	37	23	91	44	97	5	79	608
Tricolia bella	-	-	-	-	-	4	20	2	3	-	2	6	6	9	13	10	18	18	111
Triphora nigrocincta	-	-	-	-	-	-	-	1	-	3	-	-	-	-	-	-	2	-	6
Triphora turristhomae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2
Triphora sp.	-	-	-	3	-	-	1	5	-	-	-	-	1	1	1	10	2	-	24
Truncatella spp.	-	-	36	-	-	-	-	-	1	-	-	-	-	-	-	-	-	2	39
Turbonilla bermudensis	-	-	-	-	-	-	-	8	1	3	2	16	19	19	3	2	1	5	79
Turbonilla heilprini	-	-	-	-	-	-	-	-	3	1	1	2	3	-	3	-	3	1	17
Turbonilla cf. pyrrha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Turbonilla unilirata	-	-	-	-	-	-	-	-	-	1	-	-	-	-	2	1	-	-	4
Turbonilla sp.	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	2
Vermicularia spirata	-	-	-	-	-	-	-	-	-	-	1	-	-	3	1	-	4	1	10
Vexillum albocinctum	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	2	-	3
Vexillum hanleyi	-	-	-	-	-	-	-	-	1	-	1	1	-	1	-	-	-	-	4
Vitrinella floridana	-	-	-	-	-	-	-	1	-	-	-	-	-	4	-	2	-	-	7
Vitrinella helicoidea	-	-	-	-	-	-	-	-	-	1	-	-	-	1	4	-	-	-	6
Zebina browniana	-	-	-	-	-	3	26	35	10	22	33	-	5	6	6	3	34	22	205
SCAPHOPOD SPECIES																			
Cadulus carolinensis	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	2	1	4
Dentalium antillarum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	2
CHITON SPECIES																			
Acanthochitona cf. pygmaea	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	2
Craspedochiton cf. hemphilli	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	2
Ischnochiton cf. papillosus	-	-	-	-	-	-	-	24	-	1	-	16	1	31	-	8	-	-	81

BIVALVE SPECIES	26	113	112		111			18		17		30		23		24		32	
	Inglés	BLM	BLM	RL	BLM	RL	OL	RL	OL	RL	OL	RL	OL	RL	OL	RL	OL	TD	Total
Americardia guppyi	-	-	-	-	-	1	1	-	3	3	-	-	1	2	21	-	4	12	48
Anomalocardia auberiana	1076	66	5	51	2	-	-	2	1	1	-	2	-	5	-	-	-	-	1211
Anomia simplex	1#	-	-	-	-	-	-	-	1#	1#	-	1#	1#	1	2#	1#	-	-	9
Barbatia cancellaria	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	3	2	6
Barbatia cf. domingensis	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2	2	6
Brachidontes exustus	254	-	4	18	1	4	-	133	-	176	7	96	10	332	20	62	1	4	1122
Carditamera floridana	-	-	-	-	-	12	4	3	1	38	10	2	-	5	4	-	3	-	82
Carditopsis smithii	-	-	-	-	-	-	-	-	-	2	-	3	1	2	-	-	9	5	22
Chione cancellata	-	-	-	-	-	20	9	7	10	67	37	15	9	11	44	15	16	41	301
Chione sp.	-	-	-	-	-	-	2	-	-	-	-	-	-	3	5	-	28	20	58
Codakia orbiculata	-	-	-	-	-	-	5	2	-	1	-	4	11	4	1	1	9	9	47
Crassinella lunulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4
Crenella divaricata	-	-	-	-	-	-	-	-	-	-	-	1	2	4	24	-	9	54	94
Cumingia tellinoides	1	-	1	-	-	-	5	13	8	16	13	3	2	8	4	11	4	-	89
Cyrenoida floridana	-	14	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	17
Diplodonta nucleiformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	2
Divaricella quadrisulcata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	6
Ervilia concentrica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	15	16
Ervilia nitens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	3	16	20
Erycina cf. fernandina	-	-	-	-	-	-	-	-	-	-	-	-	1	-	3	-	-	4	8
Gemma gemma	134	52	-	744	-	36	12	3	-	-	1	-	2	3	5	25	1	23	1041
Laevicardium mortoni	100	-	-	6	-	-	-	6	-	10	-	15	2	7	7	6	1	-	160
Lima pellucida	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1
Limatula cf. hendersoni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	15
Linga pensylvanica	-	-	-	-	-	-	-	-	-	1	-	-	1	1	1	-	-	9	13
Lucina nassula	-	-	-	-	-	3	9	3	6	9	7	2	9	2	5	-	21	2	78
Lucina pectinata	-	2*	-	-	-	-	-	-	-	-	-	-	-	-	-	1*	-	-	3*
Lucina cf. radians	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	3	5
Lyropecten antillarum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Modiolus squamosus	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1
Musculus lateralis	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	1	-	3
Mysella sp. 1	-	-	-	-	-	-	-	-	1	4	3	11	4	-	5	3	2	1	34
Mysella sp. 2	-	-	-	-	-	2	-	15	-	2	-	2	-	4	-	-	-	2	27
Mysella sp. 3	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Nucula sp.	-	-	-	-	-	-	10	4	2	-	3	3	7	-	6	-	18	10	63
Parastarte triquetra	-	63	-	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-	79
Parvilucina blanda	-	-	-	-	-	-	-	-	-	-	-	-	-	2	8	-	2	19	31
Parvilucina multilineata	-	-	-	-	-	-	-	-	-	15	-	2	5	-	6	1	1	-	30
Pinctada imbricata	-	-	-	-	-	-	4	11	5	18	14	2	4	10	8	5	-	1	82
Pitar fulminata	-	-	-	-	-	-	-	-	3	-	1	-	2	2	5	1	2	6	22
Pleuromeris tridentata	-	-	-	-	-	-	-	-	-	-	-	1	-	1	14	-	10	77	103
Polymesoda maritima	4	110	-	-	90	-	-	-	-	-	-	-	-	-	-	-	-	-	204
Tagelus divisus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Tellina candeana	-	-	-	-	-	-	-	-	-	-	1	-	-	-	2	-	-	2	5
Tellina mera	15	5	-	4	-	11	5	7	17	11	32	9	8	7	11	12	4	1	159
Tellina similis	-	-	-	-	-	-	1	3	2	2	4	1	3	2	3	-	5	3	29
Transennella cubaniana	-	-	-	-	-	-	-	-	-	-	-	-	2	1	36	-	11	199	249

* = fragmental or abraded specimens.

= juvenile specimens.

Table 2. Summary of Species Distribution.

Consistently Common Species:
Alvania auberiana
Amphithalamus cf. *vallei*
Bulla striata
Cerithium eburneum
Cosmioconcha nitens
Crepidula spp.
Diastoma varium
Marginella apicina
Meioceras nitidum
Modulus modulus

Odostomia impressa
Turbonilla bermudensis
Brachidontes exustus
Pinctada imbricata
Tellina mera

Ischnochiton cf. *papillosus*

The distribution of most of the 71 species (Table 3) reflects little consistent environmental control. Many of these species are also present in Caribbean Tidal Delta sediments and have been reported from open marine waters. However, eight species are restricted to lagoonal sediments. Representatives of *Rissoina catesbyana* (all adult) were found only in the surface sediments of lagoonal mudbank core 18, otherwise, no consistent differences in mudbank and pond faunas are observed. Some species, for example the gastropods *Diastoma varium, Modulus modulus, Meioceras nitidum, Tricolia affinis,* and the bivalve *Brachidontes exustus,* are commonly found in relatively large numbers in surface lagoonal sediments.

Representatives of certain species usually found in the study area in more open marine conditions (Caribbean Tidal Delta) are found in sediments near the tidal channel (cores 23, 24 and, to some extent, 30), illustrating a mixing of lagoonal and more normal marine assemblages: *Caecum* spp., *Meioceras cornucopiae, Pachystremiscus* spp., and *Tricolia bella.*

Caribbean Tidal Delta Assemblage

Restricted species:
Alaba incerta
Cavolina longirostris
Hyalina avena
Litiopa melanostoma
Pyramidella crenulata
Triphora turristhomae

Cadulus carolinensis
Dentalium antillarum

Barbatia spp.
Crassinella lunulata
Divaricella quadrisulcata
Ervilia spp.
Erycina cf. *fernandina*
Limatula cf. *hendersoni*

Consistently Common Species:
Caecum spp.
Cerithium litteratum
Cerithium lutosum
Marginellopsis serrei
Meioceras cornucopiae
Olivella spp.
Pachystremiscus spp.
Tricolia bella

Americardia guppyi
Crenella divaricata
Linga pensylvanica
Nucula sp..
Parvilucina blanda
Pitar fulminata
Pleuromeris tridentata
Transennella cubaniana

The Caribbean Tidal Delta Assemblage has the largest number of species (Table 3, 91 species) of the three assemblages. The species restricted to this environment are usually present in relatively small numbers. Representatives of one bivalve, *Pleuromeris tridentata,* are found in moderate numbers, whereas representatives of another bivalve, *Transennella cubaniana,* are found in somewhat larger numbers (Table 2).

Several species appear to be common to both Lagoonal and Tidal Delta sediments, the gastropods *Acteocina candei, Marginella lavalleeana, Tricolia affinis, Zebina browniana* and the bivalves *Chione cancellata, Codakia orbiculata* and *Gemma gemma.*

Subsurface-Open-Lagoon Assemblage

The upward change from open-lagoon sediments to restricted-lagoon sediments is seen in all of the cores from Nichupté Lagoon proper and in one core from the Back-Lagoon Marsh (111). Figure 5 is a cross-section illustrating the horizontal distribution of Open-Lagoon sediments and Restricted-Lagoon sediments are interpreted from the vertical distribution of these sediment types in cores 18, 111, 112, and 113. This figure also illustrates the lagoonward encroachment of mangroves as indicated by the upward change from Restricted-Lagoon sediments to Back-Lagoon-Marsh sediments in Cores 111 and 112.

In the subsurface parts of the cores (depths in excess of 0.25 to 0.8 meters) interpreted as Open-Lagoonal, the molluscan assemblage is essentially a mixture of Restricted-Lagoon forms and forms characteristic of the Caribbean Tidal Delta Assemblage.

At the contact of Open-Lagoon sediments and restricted lagoon sediments, several downward trends are observed (Table 2 and Appendix B: Tables 6-8):

1. Representatives of some species that are characteristic of the Restricted-Lagoon environment decrease in number:
Brachidontes exustus
Carditamera floridana
Cumingia tellinoides
Laevicardium mortoni

2. Representatives of some species that are present in Restricted-Lagoon sediments but are more common in the Caribbean Tidal Delta sediments, increase in number downward:
Acmaea pulcherrima
Cerithium litteratum
Marginella lavalleeana
Marginellopsis serrei
Rissoina cancellata
Tegula fasciata

Tricolia bella
Zebina browniana

Codakia orbiculata
Lucina nassula
Nucula sp.
Transennella cubaniana

3. Several species appear that are characteristic of the Caribbean Tidal Delta Assemblage but are absent in Restricted Lagoonal sediments:
Caecum spp.
Olivella spp.
Smaragdia viridemaris

Cadulus carolinensis
Dentalium antillarum

Ervilia spp.
Erycina sp. cf. *E. fernandina*

The sudden downward decrease in faunal diversity (Table 3) and the change in relative abundance of several species strikingly illustrates the effect that the restriction of Nichupté Lagoon had on the molluscan faunas.

TABLE 3

DEPOSITIONAL ENVIRONMENT	GASTROPODA	SCAPHOPODA	AMPHINEURA	BIVALVIA	TOTAL
Inglés Lagoon	16	--	--	8	24
Back-Lagoon Marsh	15	--	--	7	22
Nichupté Lagoon					
mudbank	49	--	1	20	70
main body (pond)	52	--	1	19	72
tidal delta	44	--	1	24	69
Caribbean Tidal Delta	58	2	--	31	91
Subsurface: Open Lagoon					
mudbank	63	1	3	13	80
main body (pond)	65	1	1	28	95
tidal delta	55	1	2	27	85

Table 3. Number of Species Found in each Depositional Environment.

COMPARISON WITH FLORIDA BAY MOLLUSCAN DISTRIBUTION

Turney and Perkins (1972) recently presented a detailed analysis of molluscan distribution in Florida Bay illustrating the extent to which mollusks are controlled by the physical environment. Turney and Perkins recognized four 'subenvironments' of deposition (Northern, Interior, Atlantic, and Gulf based on physical parameters (for example: salinity, water circulation and currents) (Turney and Perkins 1972: 1, Table 1). Their study was of a broader scope and concerned with a much larger area, but it serves as a useful model for comparison with physical conditions and molluscan distribution in southern Nichupté Lagoon. The 'Northern Subenvironment' of Florida Bay, like the Back-Lagoon Marsh of Nichupté Lagoon, is characterized by short-term and seasonal variations in salinity, caused by freshwater runoff from the mainland and restricted circulation (Turney and Perkins 1972: 5). The 'Interior Subenvironment' of Florida Bay, like the Lagoonal Environment of Nichupté Lagoon, is characterized by restricted circulation, but is not subjected to large short-term or seasonal variations in salinity (Turney and Perkins, 1972: 5, Table 1). The 'Atlantic Subenvironment' of Florida Bay, like the Caribbean Tidal Delta depositional environment in the Nichupté Lagoon area, approaches normal marine conditions and has little temperature and salinity fluctuation (Turney and Perkins, 1972: 8, Table 1). The 'Gulf Subenvironment' of Florida Bay is hydrographically and sedimentologically similar to the 'Atlantic Subenvironment' primarily on the basis of molluscan faunas (Turney and Perkins, 1972: 13, fig. 6). Although three species from the 'Gulf Subenvironment' are found in Nichupté Lagoon *(Carditamera floridana, Phacoides nassula* and *Tellina similis)*, it is not possible to distinguish a counterpart of the 'Gulf Subenvironment' in southern Nichupté Lagoon.

Table 4 is a chart designed to show the species in common for the corresponding environments in Florida Bay and southern Nichupté Lagoon.

SUMMARY AND CONCLUSIONS

Representatives of 182 species of mollusks, representing 123 genera have been identified from surface and subsurface sediments of southern Nichupté Lagoon. The distribution of a large number of these species is greatly influenced by parameters in the depositional environments and it is possible to recognize Back-Lagoon Marsh, Restricted Lagoon and Caribbean Tidal Delta mollusk assemblages in surface sediments. The Back-Lagoon Marsh assemblage is characterized by a few non-marine and brackish-water species, some of which are represented in large numbers. The Restricted Lagoon assemblage is characterized by a change in character (marine) when compared with the Back-Lagoon Marsh assemblage, and a substantial increase in diversity, but still, a small number of species is dominant. The Caribbean Tidal Delta assemblage is characterized by increased diversity over the Restricted Lagoon assemblage. Representatives of only two species are present in numbers in excess of 10 in most samples.

Molluscan distribution is also seen to be environmentally controlled in the subsurface. In the subsurface Open Lagoon environment, characteristic of a time when southern Nichupté Lagoon was less restricted, the mollusk assemblage is marked by a greater diversity and by occurrence of more normal marine forms when compared with the present-day Restricted Lagoon assemblage.

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TABLE 4

FLORIDA BAY		NICHUPTÉ LAGOON	
Northern Subenvironment	Characteristic species:		Back-Lagoon Marsh
	Anomalocardia cuneimeris	+	
	Species more common here than elsewhere:		
	Ostrea sp.	-	
	Parastarte triquetra	+	
	Lyonsia floridana	-	
	Rissoina browniana	++	
	Melongena corona	+	
	Retusa canaliculata	+	
Nearshore and on keys	Melampus coffeus	+	
	Truncatella spp.	+	
	Batillaria minima	-	
	Cerithidea scalariformis	a	
	Pseudocyrena maritima	+	
Interior Subenvironment	Characteristic species:		Lagoon
	Brachidontes exustus	+	
	Pinctada radiata	+	
	Cerithium muscarum	+	
	Bittium varium	+	
	Species more common here than elsewhere:		
	Lucina multilineata	++	
	Rissoina bryerea	+	
	Modulus modulus	+	
	Olivella sp.	++	
Atlantic Subenvironment	Characteristic species:		Caribbean Tidal Delta and Open Lagoon
	Codakia orbicularis	-	
	Tegula fasciata	+	
	Astraea longispina	+	
	Astraea americana	+	
	Cerithium litteratum	+	
	Species more common here than elsewhere:		
	Barbatia cancellaria	+	
	Glycymeris pectinata	-	
	Lucina pensylvanica	+	
	Codakia orbiculata	+	
	Trigoniocardia medium	-	
	Laevicardium laevigatum	-	
	Chione pygmaea	-	
	Acmaea sp.	+	
	Tricolia sp.	+	
	Smaragdia viridis	+	
	Vermicularia sp.	+	
	Cerithium eburneum	+	
	Melanella	+	
	Natica carena	-	
	Columbella mercatoria	+	
	Terebra sp.	-	

+	= present	a	= similar species C. costata present.
++	= present but more common elsewhere	b	= synonym is A. phoebia.
-	= absent		

Table 4. Comparison of Molluscan Distribution in Florida Bay (from Turney and Perkins, 1972, p. 9-13, figs. 6, 11) with that of Nichupté Lagoon.

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SYSTEMATICS

Specimens of most of the species found in Nichupté Lagoon are well illustrated in other, easily located references. The only forms illustrated here are either the most unusual or those that have not been well illustrated previously (Plate I).

The following abbreviations have been used in the *Occurrence* paragraphs in the Systematics part of this paper and in Tables 2 and 6-8:

BLM - Back-Lagoon Marsh
OL - Open Lagoon
RL - Restricted Lagoon
TD - Caribbean Tidal Delta

In tabulation of bivalve specimens, disarticulated left and right valves were counted separately and the larger of the resulting number, plus the number of whole specimens collected, was recorded as the number of specimens collected (Tables 2 and 6-8; Occurrence information).

CLASS GASTROPODA Cuvier, 1797
Subclass PROSOBRANCHIA Milne-Edwards, 1848
Order ARCHAEOGASTROPODA Thiele, 1925
Superfamily FISSURELLACEA Fleming, 1822
Family FISSURELLIDAE Fleming, 1822
Subfamily EMARGINULINAE Gray, 1834

Genus EMARGINULA Lamarck, 1801

Emarginula pumila (A. Adams, 1851)
References: Farfante, 1947: 107-108, pl. 47; Kornicker, 1965: 116, pl. 1: 2; Morris, 1973: 112, pl. pl. 36: 10; Abbott, 1974: 20, no. 41.
Description: The small shell (diam. 5 mm, ht 1.5 mm) is yellow-green, moderately arched and bears a slit, 1 mm long at the anterior margin.
Occurrence: Two specimens were recovered from OL sediments of Core 24 (depth 240-260 cm).
Total number collected: 2.
Distribution: Southeastern Florida, Bermuda, the West Indies, south to Brazil.
Remarks: Identification of specimens was verified by Dr. D. R. Moore (personal communication, 1974).

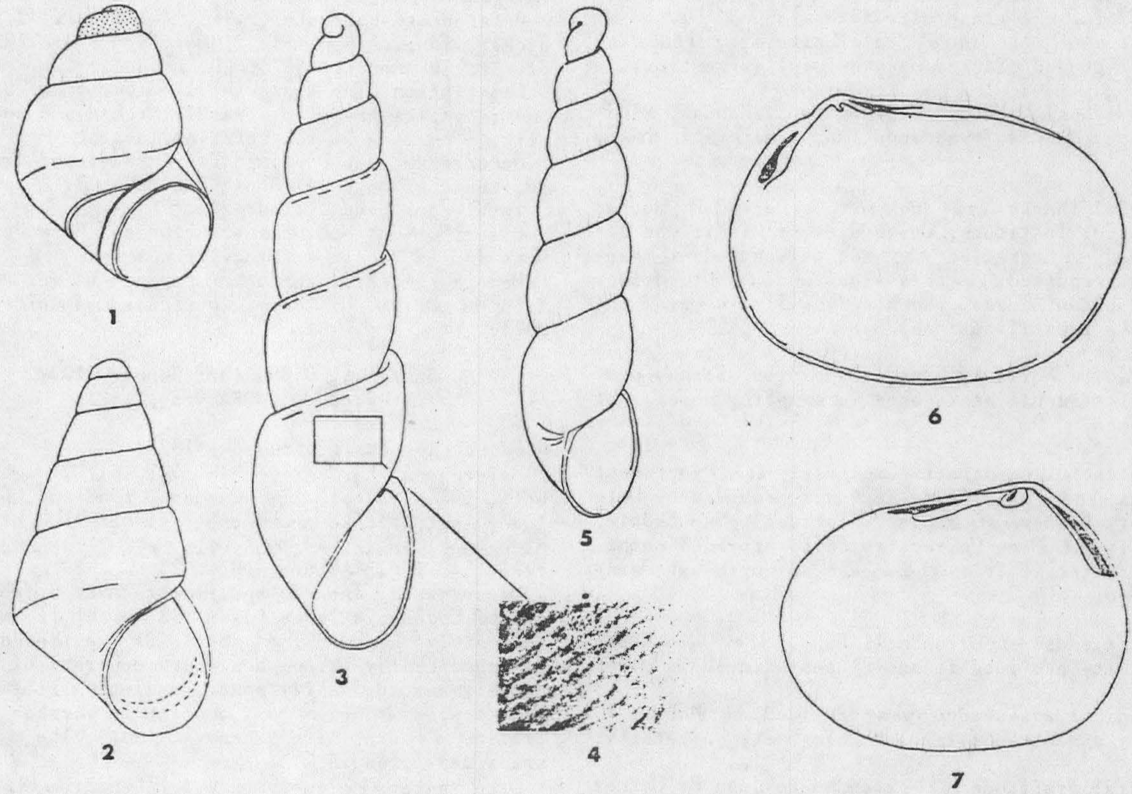
Subfamily DIODORINAE Odhner, 1932
Genus DIODORA Gray, 1821

Diodora cayenensis (Lamarck, 1822)
References: Farfante, 1943: 5-7, pl. 2: 1-6; Abbott, 1954: 96, pl. 17m; Coomans, 1958: 53, pl. 2: lower left; Warmke and Abbott, 1962: 37, pl. 5k; Rice and Kornicker, 1965: 116, pl. 1: 3; Andrews, 1971: 54, fig.; Abbott, 1974: 23, no. 88.
Description: The only specimen recovered from Nichupté Lagoon is large (diam. 32 mm, ht 11 mm) and moderately heavy. The shell is weathered and bleached chalky-white. Sculpture consists of fine, closely spaced, nearly equal, radiating ribs which are crossed by numerous concentric threads. The orifice is oval with a heavy callus. The margins are finely crenulate.
Occurrence: One specimen was taken from OL sediments of Core 17 (depth 115 cm).
Total number collected: 1.
Distribution: Maryland south to Brazil.

Diodora dysoni (Reeve, 1850)
References: Farfante, 1943: 7-8, pl. 2: 11, top; Coomans, 1958:53, pl. 3: center; Warmke and Abbott, 1962, p. 37-38, pl. 5:e; Morris 1973: 110, pl. 36: 2; Abbott, 1974: 24, no. 91.
Description: The largest specimen (diam. 4.5 mm, ht 1.6 mm) found is juvenile, moderately arched, white and ornamented with 18 major radiating ribs, crossed by concentric ridges. Nodules are formed at the points of intersection. Eight solid, charcoal-gray rays radiate from the orifice which is bounded anteriorly and laterally by a black line.
Occurrence: Two specimens were recovered from RL sediments of Core 18 (depth 10 cm) and four specimens from OL sediments of Core 24 (depth 125-185 cm).
Total number collected: 6.
Distribution: Bermuda, Florida, the West Indies, south to Brazil.

Family ACMAEIDAE Carpenter, 1857
Genus ACMAEA Rathke, in Eschscholtz, 1830
Subgenus COLLISELLA Dall, 1871

Acmaea pustulata (Helbling, 1779) form *pulcherrima* ('Guilding' Petit, 1856)
References: Abbott, 1954:106; Warmke and Abbott, 1962:41, pl. 6c; Morris, 1973: 114, pl. 37: 1; Abbott, 1974: 33, no. 168.



EXPLANATION OF PLATE I

Fig. 1. *Amphithalamus* sp. cf. *A. vallei* Aguayo and Jaume, 1947 (height 1.06 mm, diam. 0.76 mm).

Fig. 2. *Barleeia* sp. (height 2.9 mm, diam. 1.5 mm).

Fig. 3. *Turbonilla bermudensis* Dall and Bartsch, 1911 (height 2.36 mm, diam. 0.60 mm).

Fig. 4. Enlargement of part of Fig. 3 (X 190).

Fig. 5. *Turbonilla* sp. (height 1.9, diam. 0.44 mm).

Fig. 6, 7. *Erycina* sp. cf. *E. fernandina* Dall, 1899.. 6, left valve (length 3.10 mm, height 2.26 mm); 7, right valve (length 2.74 mm, height 2.14 mm).

Description: Specimens found vary in size (diam. 1 to 8 mm) and in ratio of diameter to height (3/1 to 4/1). The exterior of the thin shell is white with flecks of orange-red, arranged in 12 radiating rays. The interior is semitransparent, polished white with a yellowish callus.

Occurrence: Representatives of this species are found in relatively small numbers in most RL, OL and TD sediments.

Total number collected: 212.

Distribution: Bermuda, southeastern Florida, and the West Indies.

Remarks: Identification of specimens was verified by Dr. D. R. Moore (personal communication, 1974).

Superfamily TROCHACEA, Rafinesque, 1815
Family TROCHIDAE, Rafinesque, 1815
Subfamily MONODONTINAE Cossman, 1916
Genus TEGULA Lesson, 1835

Tegula fasciata (Born, 1778)

References: Abbott, 1954: 118, pl. 17 p; Warmke and Abbott, 1962: 44, pl. 7d; Andrews 1971: 56, fig.; Morris, 1973: 121, pl. 38:2; Abbott, 1974: 50, no. 378.

Description: The largest specimen found (ht 6 mm, diam. 8.5 mm) has 4 postnuclear whorls (most adults have 12 postnuclear whorls and measure 12 to 18 mm in diameter; Andrews, 1971: 56L. All of the shells are reddish brown with white and black mottlings. Under low magnification, spiral rows of alternating red and white dashes are seen.

Occurrence: Representatives of this species are found in relatively small numbers in some RL and OL sediments.

Total number collected: 16.

Distribution: Southern Florida, the West Indies, south to Brazil.

Remarks: Identification of specimens was verified by Dr. D.R. Moore (personal communication, 1974).

Family CYCLOSTREMATIDAE Fischer, 1885
Subfamily SKENEIDAE Thiele, 1929
Genus PARVITURBO Pilsbry and McGinty, 1945

Parviturbo sp., cf. *P. rehderi* Pilsbry and McGinty, 1945

References: Pilsbry and McGinty, 1945b, p. 54-55, pl. 6: i; Abbott, 1974: 57, no. 460.

Description: The largest specimen recovered from Nichupté Lagoon sediments is minute (ht 0.94 mm, diameter 0.94 mm) and juvenile. The nuclear whorl is white and smooth whereas the 2 postnuclear whorls are marked with spiral colds, the interspaces of which are marked with fine and closely spaced axial striae. The first postnuclear whorl has 4 spiral cords. The umbilicus is narrow and bounded by a spiral cord.

Occurrence: One specimen was recovered from TD sediment of Core 32 (depth 5 cm).

Total number collected: 1.

Distribution: Southern Florida, south to Panama.

Family TURBINIDAE Rafinesque, 1815
Subfamily ASTRAEINAE Davies, 1933
Genus ASTRAEA Röding, 1798

Astraea americana (Gmelin, 1791)

References: Dall and Simpson, 1901: 442; Abbott, 1954: 124, pl. 3 i; Rice and Kornicker, 1962: 368, pl. 2: 14; Morris, 1973: 124, pl. 38; Abbott, 1974: 59, pl. 2: 481.

Description: The adult shell is large (ht 25 mm, diam. 21 mm), solid, stony, chalky light brown and white. The juvenile shell is light brown with numerous cream-colored axial ribs; however, in general appearance the juvenile differs markedly from the adult. In the juvenile shell, the axial ribs terminate as bifurcated spines at the periphery. Close examination of earlier whorls in the adult shell reveals this pattern; however, most of the spines are worn and only the axial ribs remain. The mean spire angle also differs (juvenile 70°, adult 57°) but measurement of the angle formed by early whorls in the adult agrees with the angle of the juvenile spire. These and other measurements are shown below:

number post-nuclear whorls	H height (mm)	W width (mm)	H/W ratio	number basal ridges	spire angle
2.0	2.2	3.5	1/1.60	1	74°
3.5	4.0	5.5	1/1.38	3	74°
5.0	8.5	11.0	1/1.30	4	70°
7.0	24.5	21.5	1/0.88	6	54°

During ontogeny, spines are replaced by ribs, the shell becomes more elongate and the spire becomes acute.

Occurrence: Representatives of this species are found in RL sediments of Cores 18 and 30 and the OL sediments of Cores 111, 17, 18, 30 and 24.

Total number collected: 30.

Distribution: Southeastern Florida.

Remarks: The same ontogenetic changes are observed among representatives of this distinctive species in reference samples, collected by the author, from John PenneKamp Coral Reef preserve in southern Florida.

Astraea phoebia Röding, 1798

References: Abbott, 1958: 30-31, map 6; Warmke and Abbott, 1962: 47-48, pl. 8g; Abbott, 1974: 58-59, pl. 2: 479.

Description: Fragments of this low-spired, cream-colored, triangular-spined shell are found in Nichupté Lagoon sediments. The largest fragment is less than half complete (reconstructed shell height 9 mm), but distinct.

Occurrence: Fragmental specimens were found in surface RL sediments of Core 17 and OL sediments of Core 18 (depth 190 cm).

Total number collected: 2 fragments.

Distribution: Bermuda, northwest Florida to southeast Florida and the West Indies. Brazil.

Remarks: Whole shells, collected in the Florida Keys, were useful for comparison with fragmental remains from Nichupté Lagoon.

Family PHASIANELLIDAE Swainson, 1840
Genus TRICOLIA Risso, 1826

Four distinct forms of *Tricolia* have been found in sediments from Nichupté Lagoon. Two of the forms present in the lagoon are assigned to the species *Tricolia affinis*. Robertson (1958: 262-268) describes four subspecies of *T. affinis*, but the wide variety of color patterns among representatives of this species from Nichupté Lagoon makes subspecific identification difficult without comparative material. A third form, designated below as *Tricolia* sp. cf. *T. affinis*, is described but no subspecies name is applied at this time. A fourth distinct form is *T. bella*.

Tricolia affinis (C. B. Adams, 1850)

References: Clench and Turner, 1950: 250, pl. 36: 6; Abbott, 1954: 126-127; Robertson, 1958: 262-268, pl. 143-145; Warmke and Abbott, 1962: 48, pl. 8: a; Andrews, 1971: 56; Abbott, 1974: 61-62.

Description: The first form of *Tricolia affinis* is cream-colored with alternating brick-red dots and white dashes. Generally, the shell is thin, has 3½ whorls and measures 4 mm (ht) by 3 mm (diam.). The nuclear whorls are finely striated and the later whorls are smooth and well-rounded. The spire is produced at an angle of 63° to 65°. The aperture is oval and the umbilicus is deep and narrow.

The second form of *T. affinis* is like the first except that seven pairs of irregular, wavy axial streaks are superimposed on the dot-dash pattern. The streaks are alternating flames of brown and white, red and white or orange and white. The shell is relatively heavier and the nuclear whorls are smooth. The umbilicus is a little wider than that of the first form.

Occurrence: Representatives of this species are found in most RL sediments and to a lesser extent in OL and TD sediments. *Tricolia affinis* is the most abundant species of the genus *Tricolia* represented in Nichupté Lagoon sediments. Only three individuals of the first form were found (core 23, depth 10 cm), but the second form is well represented in most lagoonal sediments.

Distribution: Florida, Gulf of Mexico, West Indies, south to Brazil.

Remarks: Dr. D. R. Moore verified the identification of the first form of *T. affinis* (personal communication, 1974).

Tricolia sp. cf. *T. affinis* (C. B. Adams, 1850)

Description: In general shell morphology, these specimens are much like the second form of *T. affinis*. The primary difference is a lack of spots and greater regularity of color flames. There are two rows of flames (alternating dark brown and white) on each whorl. The white flame-marks are triangular in outline (especially in the upper row), whereas the brown color fills in the remaining area. Whether these seemingly surficial differences are important enough to keep the specimens taxonomically separate from *T. affinis* is questionable; however, this decision cannot be made without access to identified comparable material.

Total number collected: 608.

Tricolia bella (M. Smith, 1937)

References: Smith, 1937: 81, pl. 31: 30; Clench and Turner, 1950: 331, pl. 40: 9, *Turbo* (?) *pulchellus* Adams, 1845; Abbott, 1954: 127, pl. 17 r; Robertson, 1958: 274-276, pl. 139: 5, 142: 4, 5, 143: 5, 147: 1, 2; Warmke and Abbott, 1962: 49, pl. 8 f; Abbott, 1974: 62, no. 512.

Description: The small shell (ht 4.2 mm, diam. 2.1 mm) is moderately striated and the whorls are shouldered. The color pattern is alternating brown and white dashes on a cream-colored background. The aperture is nearly round and the umbilicus is a small slit.

Occurrence: Representatives of this species are found in OL and TD sediments and to a lesser extent in RL sediments.

Total number collected: 111.

Distribution: Florida, the West Indies, south to Brazil.

Family NERITIDAE Rafinesque, 1815
Genus NERITINA Lamarck, 1816

Neritina virginea (Linnaeus, 1758)

References: Russell, 1941: 374-377, pl. 2: 7, 8; Abbott, 1954: 129, pl. 4 i; Coomans, 1958: 61, pl. 7, right; Warmke and Abbott, 1962: 50, pl. 9, f; Andrews, 1971: 58, fig.; Morris, 1973: 128, pl. 39: 9; Abbott, 1974: 64, pl. 3: 527.

Description: The largest shell (ht 14 mm, diam. 11 mm) has 4 whorls. The body whorl makes up most of the shell (ht. 10 mm). The color of the shell is white with dark purple lines and white mottling.

Occurrence: Three adult specimens were recovered from BLM sediments of Core 113 (depth 55 cm) and two juvenile specimens were recovered from RL sediments of Core 111 (depth 80-130 cm).

Total number collected: 5.

Distribution: Bermuda, Florida, the Gulf of Mexico, the West Indies, south to Brazil.

Subfamily SMARAGDIINAE Baker, 1923
Genus SMARAGDIA Issel, 1869

Smaragdia viridis viridemaris (Maury, 1917)

References: Maury, 1917: 316-317, pl. 24: 11, *Nerita viridemaris*, Lower Miocene; Abbott, 1954: 130, pl. 4 h; Rice and Kornicker, 1962: 369, pl. 4: 13; Warmke and Abbott, 1962: 52, pl. 9e; Andrews, 1971: 58-59, frontisp. and fig.; Robertson, 1971, pl. 1: 1-4, SEM photos of larval *S. viridis*; Morris, 1973, pl. 39: 13.

Description: The largest shell (ht 7.5 mm, diam. 5 mm) found in the sediment is small and glossy. Most of the shells are smaller (ht 3 mm, diam. 2 mm) but are recognized by their bright yellow-green color with white streaks near the apex.

Occurrence: Representatives of this species are found in relatively small numbers in some OL and TD sediments and to a lesser extent in RL sediments.

Total number collected: 18.

Distribution: Bermuda, Florida, the Gulf of Mexico and the West Indies.

Order MESOGASTROPODA Thiele, 1925
Superfamily RISSOACEA Gray, 1847
Family HYDROBIIDAE Stimpson, 1865
Genus PYRGOPHORUS Ancey, 1888

Thompson (1968: 37-38) reviews the complex nomenclatorial history of *Potamopyrgus coronatus* (Pfeiffer, 1840), concluding that the proper generic designation is *Pyrgophorus* Ancey.

Pyrgophorus coronatus (Pfeiffer, 1840)

References: von Martens, 1890-1891: 432-434; Pilsbry, 1891b: 328; van der Schalie, 1948: 107-108, pl. 9: 11; Thompson, 1968: 37.

Description: The small, opaque white shell (ht 4 mm, diam. 2.3 mm) is elongate with 4 rounded postnuclear whorls. The shell is marked with very fine spiral striae which are sometimes obsolete. The angle of spire divergence is variable (35° to 43°). The sutures are impressed. Two forms of this species are represented in the sediments of the Back Lagoon Marsh in southern Nichupté Lagoon, one form ecarinate and the other carinate. The sculptural carinae are poorly developed at best and absent in most shells. Triangular spines are present on the uppermost spiral thread of the third and fourth postnuclear whorl in the carinate form.

Occurrence: Representatives of this species are found in relatively large numbers in most BLM sediments.

Total number collected: 819.

Distribution: Southern Florida, Texas, West Indies (exclusive of the Bahama Islands), south to Panama, Colombia and Venezuela.

Remarks: van der Schalie (1948: 107-108) summarized the thoughts of previous workers concerning the formation of carinae in *P. coronatus* and related gastropods. According to him, some workers related increased shell sculpture to increased alkaline conditions, whereas others (Pilsbry, 1896-99: 570) found no evidence to support this theory. Warwick (1944: 799) reported that spinosity is not caused by water chemistry but instead by algal diet during early growth.

Family TRUNCATELLIDAE Gray, 1840
Genus TRUNCATELLA Risso, 1826

Specimens of the genus *Truncatella* are well represented in the upper meter of sediment from core 112. Keys for the classification of *Truncatella* species are numerous (*e. g.*, Pilsbry, 1948: 1068; Clench and Turner, 1948: 152; de la Torre, 1960: 87–88) and the most recent, that of de la Torre will be followed here because it summarizes and modifies the earlier ones. Species are determined by shell characters, including size, shape, number of ribs on the body whorl and the presence or absence of apertural varices. All known species in the genus *Truncatella* are mechanically truncated (Clench and Turner, 1948: 150).

Truncatella barbadensis Pfeiffer, 1856
References: de la Torre, 1960: 87; Abbott, 1974: 80, no. 724.
Description: The shell is decollate with 3½ remaining whorls and small (ht 5 mm, diam. 1.8 mm). The fine costae are well developed on all of the whorls and there are 38 transverse costae on the body whorl. The outer lip of the aperture is markedly duplex.
Occurrence: Representatives of this species are found only in the BLM sediments of Core 112 (depth 0–30 cm).
Total number collected: 7.
Distribution: The Lesser Antilles.

Truncatella caribaeensis 'Sowerby' Reeve, 1842
References: Binney, 1865: 98, fig. 198; Pilsbry, 1948: 1071–1072, fig. 572: a,b; Clench and Turner, 1950: 347, pl. 40: 11, *T. succinea* C. B. Adams, 1845; de la Torre, 1960: IR; Warmke and Abbott, 1962: 55, pl. 10 e; Abbott, 1974: 80, no. 719.
Description: Representatives of this species occur in the sediment of the Back Lagoon Marsh in two forms: one smooth, the other costate. The shell is decollate with 3 remaining whorls and small (ht.6 mm, diam. 2.5 mm). The 36 fine transverse costae are either well developed or obsolete. The outer lip of the aperture is simple.
Occurrence: Representatives of this species are found only in the BLM sediments of Core 112 (depth 0–40 cm).
Total number collected: 5.
Distribution: Bermuda, southern Florida, west to Texas, and the West Indies.

Truncatella scalaris clathrus Lowe, 1832
References: Pilsbry, 1948: 1069, fig. 571 c; de la Torre, 1960: 86; Warmke and Abbott, 1962: 56, pl. 10 d; Abbott, 1974: 80, no. 722 form.
Description: The shell is decollate with 4 remaining whorls and small (ht. 5 mm, diam. 2.1 mm). There are 12 transverse costae on the body whorl. The outer lip is duplex and slightly detached.
Occurrence: Representatives of this species are restricted to the BLM sediments of Core 112 (depth 0–75 cm).
Total number collected: 12.
Distribution: Bermuda, Florida and the West Indies.

Truncatella pulchella Pfeiffer, 1839
References: Pilsbry, 1948: 1070–1071, fig. 572: c, no. 3; de la Torre, 1960: 83; Warmke and Abbott, 1962: 55, pl. 10 b; Andrews, 1971: 63, fig.; Abbott, 1974: 80, no. 718.
Description: The shell is decollate with 4 remaining whorls and small (ht 5 mm, diam. 2.1 mm). There are 24 indistinct rib markings at the suture. The outer lip of the aperture is not markedly duplex, but thickened.
Occurrence: Representatives of this species are found only in the BLM sediments of Core 112 (depth 0–30 cm).
Total number collected: 3.
Distribution: Florida, the West Indies, south to Panama.

Truncatella pulchella form *bilabiata* Pfeiffer, 1840
References: Binney, 1865: 99, fig. 199; Pilsbry, 1948: 1069–1070, fig. 571: b, no. 2; Warmke and Abbott, 1962: 55, pl. 10: a; Abbott, 1974: 80, no. 718, form.
Description: This shell is the costate form of *T. pulchella*, is decollate with 4 remaining whorls and small (ht 5 mm, diam 2 mm). The body whorl bears 22 transverse costae. The outer lip is markedly duplex. Juvenile specimens are also present and may be recognized by the presence of 2 smooth nuclear whorls and a simple outer lip. Most juvenile shells found are small (ht 3 mm, diam. 1.5 mm) and have 5 whorls.
Occurrence: Representatives of this species are found in the BLM sediments of Core 112 (depth 0–30 cm) and a few specimens were recovered from OL and TD sediments of Cores 18 and 32, respectively.
Total number collected: 12.
Distribution: Bermuda, Florida and the West Indies.

Family ASSIMINEIDAE H. & A. Adams, 1856
Genus ASSIMINEA Leach, in Fleming, 1828

Bartsch (1920: 159) placed the genus *Assiminea* in synonymy with *Syncera* Gray, 1821 and changed the family name from Assimineidae Synceratidae. Dall (1922: 36) agreed with the validity of the generic name *Syncera*, but most workers since 1922 (*e.g.* Keen, 1958: 287; Palmer, 1958: 167–168; Taylor and Sohl, 1962: 9; Abbott, 1958a: 213–278) except Johnson (1934: 97) do not regard *Syncera* as a valid generic name. Palmer (1958: 167) quotes Gray's original description of '*Nerita Syncera Hepatica*, N. S.' and states that the name *Syncera* cannot be regarded as validly proposed and thus would not have priority over *Assiminea*.

Assiminea succinea (Pfeiffer, 1840)
References: Pilsbry, 1930: 299, *Syncera concolor* (C. B. Adams, 1850); Clench and Turner, 1950: 267, pl. 36: 3, *Phasianella concolor* C. B. Adams, 1850; Robertson, 1959: 346; Robertson, 1960: 22; Odé, 1970a: 46; Odé, 1973a: 54. fig.; Abbott, 1974: 78–
Description: The small yellow-brown shell (ht 2.5 mm, diam. 1.6 mm) has 5 whorls and is ovate-conic

in shape. The angle of divergence of the spire varies in specimens from 40° to 50°. The aperture is ovate. The umbilical region is indented and bears a callus deposit.

There is variation in size (2 to 2.5 mm) and angle of spire divergence in specimens from Nichupté Lagoon. A faint sutural ridge is developed on some of the smaller, more obese shells. These specimens are comparable with an *Assiminea* species described by C. B. Adams (1850) as *Cingula* (?) *concinna* (Clench and Turner, 1950: 266, pl. 39: 4) which Johnson (1934: 97) places in synonymy with *Syncera (=Assiminea) affinis* d'Orbigny, 1842.

Occurrence: Representatives of this species are found primarily in the BLM sediments and sparingly in some RL and OL sediments.

Total number collected: 181.

Distribution: Massachusetts, south to Florida, Bermuda, Texas, south to Brazil.

Family RISSOELLIDAE Gray, 1850
Genus RISSOELLA Gray, 1847

Rissoella caribaea Rehder, 1943

References: Bartsch, 1920: 159-160, generic description; Rehder, 1934: 194, pl. 20: 7; Robertson, 1960: 22-23; 1961: 134-135, pl. 9: 2-7; Warmke and Almodóvar, 1963: 163-177; Abbott, 1974: 80, no. 725.

Description: The minute, white shell (ht 1.47 mm, diam. 0.9 mm) is smooth and has 4 rounded whorls. The suture is impressed and previous whorls are visible through the semi-transparent shell. The umbilicus is open, narrow and bordered by a narrow keel. The aperture is ovate. The inner lip is reflected over the umbilicus.

Occurrence: Representatives of this species are found in relatively small numbers in OL sediments and to a lesser extent in some RL sediments.

Total number collected: 10.

Distribution: Florida Keys to the Bahamas.

Remarks: Specimens from Nichupté Lagoon are slightly less obese than those shown by previous workers.

Family RISSOIDAE Gray, 1847
Genus ALVANIA Risso, 1826

Alvania auberiana (d'Orbigny, 1842)

References: Warmke and Abbott, 1962: 58, pl. 10k; Morris, 1973: 136, pl. 38: 14; Abbott, 1974: 71, no. 586.

Description: The small, white shell (ht 2.1 mm, diam. 1.3 mm) has 5 whorls. The first 2 whorls are smooth and the remaining whorls are sculptured with axial and spiral ribs of equal intensity, except at the base of the body whorl, where only spiral ribs are present, giving the shell a cancellate ornamentation.

Occurrence: Representatives of this species are found in relatively small numbers in most RL, OL and TD sediments.

Total number collected: 92.

Distribution: Bermuda, Florida, Texas and the West Indies.

Genus AMPHITHALAMUS Carpenter, 1865

Amphithalamus sp., cf. *A. vallei* Aguayo and Jaume, 1947

References: Aguayo and Jaume, 1947: 53-55, fig. 1; Keen and Coan, 1974: 40-41; Abbott, 1974: 75, no. 658.

Description: The minute shell (ht 1.06 mm, diam. 0.76 mm) has 3½ whorls and is turbinate in shape. Color varies from white to yellow-brown (horn color). The nuclear 1½ whorls are finely pitted. The inner lip of the aperture is separated from the open umbilicus by a shelf.

The description of *A. vallei* by Aguayo and Jaume (1947: 54-55) compares well with specimens from Nichupté Lagoon. The ratio of height to diameter reported in the text (1.14/0.78 mm, a ratio of 1/46: 1.0) also compares well with the specimens present in lagoonal sediments; however, the ratio of height to diameter of their figure of *A. vallei* (Aguayo and Jaume, 1947, fig. 1) is about 1.7/1.0. This discrepancy between their printed text and accompanying figure creates some question as to which ratio is valid. Thus the identification to species of specimens from Nichupté Lagoon is not feasible without verified, comparative material.

Occurrence: Representatives of this species are found in most 4), OL and TD sediments.

Distribution: Southern Florida, the West Indies, south to Cozumel.

Family RISSOINIDAE Stoliczka, 1868
Genus RISSOINA d'Orbigny, 1840
Subgenus PHOSINELLA Mörch, 1876

Rissoina cancellata Philippi, 1847

References: Desjardin, 1949: 204-205, pl. 9: 3; Clench and Turner, 1950: 332-333, pl. 33: 8. *Rissoa pulchra* C. B. Adams, 1850, synonym; Rice and Kornicker, 1962: 370, pl. 3: 13; Warmke and Abbott, 1962: 57, pl. 10: 1; Abbott, 1974:76

Description: The largest specimen (ht 8 mm, diam. 2.5 mm) has two smooth, glassy nuclear whorls and 8 strongly cancellate postnuclear whorls.

Occurrence: Representatives of this species are found in relatively small numbers in some OL and TD sediments, and to a lesser extent, in some RL sediments.

Total number collected: 18.

Distribution: Bermuda, Texas, Florida, the West Indies, south to Brazil.

Subgenus SCHWARTZIELLA Nevill, 1881

Rissoina bryerea (Montagu, 1803)

References: Desjardin, 1949: 194-195, pl. 9: 2; Warmke and Abbott, 1962: 56, pl. 10m; Morris, 1973: 135, pl. 39: 1; Abbott, 1974: 76, no. 673.

Description: The shell is small (ht 4.5 mm, diam. 2 mm) and has 2 smooth nuclear whorls and 5 postnuclear whorls which bear 18 to 20 strong, transverse ribs per whorl. Spiral striae are lacking except on the base of the body whorl. The suture is impressed.

Occurrence: Representatives of this species are found in relatively small numbers in some RL, OL and TD sediments.

Total number collected: 13.

Distribution: Bermuda, southern Florida, the West Indies, south to Brazil.

Rissoina catesbyana d'Orbigny, 1842

References: Desjardin, 1949: 198-199, pl. 9:7; Clench and Turner, 1950: 339, pl. 33:3, *Rissoa sca-*

larella C.B. Adams, 1845; Odé, 1969a:4-5; Andrews, 1971: 63-64, fig.; Abbott, 1974: 76, no. 674.

Description: The shell is small (ht 4.5 mm, diam. 2 mm) and has two smooth nuclear whorls and 6 postnuclear whorls which bear 14 strong transverse ribs. The ribs continue over the faintly impressed suture lines. There is a strong tooth on the inside of the outer lip.

Occurrence: Representatives of this species were found only in RL sediments of Core 18 (depth 0-10 cm).

Total number collected: 32.

Distribution: North Carolina, Bermuda, Texas, the West Indies, south to Brazil.

Subgenus ZEBINELLA Mörch, 1876

Rissoina multicostata (C. B. Adams, 1850)

References: Desjardin, 1949:194, pl. 9:1; Clench and Turner, 1950:312, pl. 33:4, *Rissoa multicostata* C. B. Adams; Rice and Kornicker, 1962: 370, pl. 3: 14; Warmke and Abbott, 1962: 56, pl. 10 h; Odé, 1973b: 31; Abbott, 1974: 76, no. 675.

Description: The shell is small (ht 4.5 mm, diam. 2 mm) and has two smooth nuclear whorls and 5 postnuclear whorls which bear 22 to 26 regular transverse ribs and numerous distinct spiral striae. The transverse ribs remain strong to the base, whereas the spiral striae become stronger toward the base. The suture is moderately impressed.

Occurrence: Representatives of this species are found in relatively small numbers in some OL sediments.

Total number collected: 8.

Distribution: Southeastern Florida, Texas, and the West Indies.

Subgenus MORCHIELLA Nevill, 1884

Rissoina striosa (C. B. Adams, 1850)

References: Desjardin, 1949: 203, pl. 10: 5; Clench and Turner, 1950: 344-345, pl. 34: 8; Warmke and Abbott, 1962: 57, pl. 10i; Abbott, 1974: 76, no. 677.

Description: The shell is small (ht 4.5 mm, diam. 2 mm) and has two clear nuclear whorls and four postnuclear whorls which bear 28 transverse ribs and numerous spiral striae. The transverse ribs become obsolete in the lower part of the middle whorls; the spiral striae are distinct but fine throughout. The suture is moderately impressed.

Occurrence: Representatives of this species are found in relatively small numbers in some RL and OL sediments.

Total number collected: 11.

Distribution: Southeastern Florida and the West Indies.

Genus ZEBINA H. and A. Adams, 1854

Zebina browniana (d'Orbigny, 1842)

References: Desjardin, 1949: 205-207, pl. 10: 4; Clench and Turner, 1950: 300-301, pl. 33: 7, *Rissoa laevissima* Adams, 1850; Warmke and Abbott, 1962: 58, pl. 10f; Andrews, 1971: 64, fig.; Abbott, 1974: 77, no. 687.

Description: The small shell (ht 4 mm, diam. 1.6 mm) has 8 smooth, nearly flat-sided whorls. The suture is well defined but not impressed. The aperture is oval and the outer lip thickened.

Occurrence: Representatives of this species are found in RL, OL and TD sediments.

Total number collected: 205.

Distribution: North Carolina, Texas, Bermuda, south to the West Indies.

Remarks: The identification of specimens was verified by Dr. D. R. Moore (personal communication, 1974).

Subfamily BARLEEIINAE Thiele, 1925
Genus BARLEEIA Clark, 1853

Barleeia sp. Plate I, fig. 2

References: Bartsch, 1920: 166-167; Keen and Coan, 1974: 45.

Description: The light yellow-brown to gray shell is small (ht 2.9 mm, diam. 1.5 mm) and has 4 smooth postnuclear whorls. The whorls are flat-sided and the outline of the body whorl is somewhat angulate. The aperture is sharp, but just posterior to the lip there is a thickened varix.

Occurrence: Representatives of this species are found in most RL sediments and to a lesser extent from OL sediments.

Total number collected: 347.

Distribution: The genus has not been officially recorded from the Atlantic coast of North America (Abbott, 1974: 78).

Remarks: The specimens were identified by Dr. D. R. Moore (personal communication, 1974).

Family VITRINELLIDAE Bush, 1897
Genus VITRINELLA C. B. Adams, 1850

Vitrinella floridana Pilsbry and McGinty, 1946

References: Pilsbry and McGinty, 1946b: 16-17, pl. 2: 4; Moore, 1964: 59-61, fig. 4; Andrews, 1971: 72-73, fig.; Abbott, 1974: 83.

Description: The minute, white shell (ht 0.8 mm, diam. 1.4 mm) is smooth and has three whorls. The shell is depressed and the spire is barely visible in apertural view. The suture is impressed and the whorls are rounded. The aperture is circular and oblique. The umbilicus is wide, deep and not carinate.

Occurrence: Representatives of this species are found in very small numbers in the RL sediments of Cores 18 (depth 0-10 cm), 23 (depth 0-30 cm) and 24 (depth 0-5 cm).

Total number collected: 7.

Distribution: Southern Florida and Texas, south to Campeche, Mexico.

Vitrinella helicoidea C. B. Adams, 1850

References: Fischer, 1857: 173; Bush, 1897: 105-107, pl. 23: 9; Pilsbry, 1946b: 2, fig. 1; Pilsbry and McGinty, 1946b: 13-14, pl. 2: 3; Clench and Turner, 1950: 290-291, pl. 35: 1; Moore, 1964; p. 56-59, fig. 3; Andrews, 1971: 73, fig., Abbott, 1974: 82.

Description: The minute, glassy-white shell (ht 0.5 mm, diam. 1.6 mm) is discoidal and has 2¾ smooth whorls. The glassy protoconch of 1¾ whorls is low but the spire is conspicuous and visible in apertural view. The margin of the body whorl is appressed at the suture so that a thin edge extends over the preceding whorl, forming a false sutural line. The umbilicus is open, narrow and deep. The columella is curved inward and extends forward near its dorsal insertion.

Occurrence: Representatives of this species are found in very small numbers in some RL and OL sediments.

Total number collected: 6.

Distribution: Bermuda, North Carolina, south to Florida, Texas, West Indies and Panama.

Genus TEINOSTOMA H. and A. Adams, 1853

Teinostoma sp., cf. *T. clavium* Pilsbry and McGinty, 1945

References: Pilsbry and McGinty, 1945a: 4, pl. 1: 1; Moore, 1964: 92-94, fig. 13; Abbott, 1974: 88.

Description: The small, white shell (ht 0.97 mm, diam. 1.6 mm) is depressed and solid. The surface of fresh specimens is marked with fine spiral grooves. The suture is located on the upper third of the dorsal surface of the rounded whorls. The smooth, umbilical callus is thick, concave and extensive. A slight ridge separates the columella from the umbilicus.

Occurrence: Representatives of this species are found in very small numbers in some RL and OL sediments of Cores 23 (depth 0-90 cm) and 24 (depth 125 cm).

Total number collected: 7.

Distribution: Southern Florida and the Bahamas.

Teinostoma sp., cf. *T. megastoma* (C.B. Adams, 1850)

References: Fischer, 1857: 173, distribution Antilles; Dall, 1885b: 331; Pilsbry, 1946b: 4-5, fig. 2; Clench and Turner, 1950: 306-307, pl. 35: 2; Abbott, 1974: 89, no. 847.

Description: The small, white shell (ht 0.9 mm, diam. 1.5 mm) is thin, smooth, depressed and has 3 whorls. The apex is obtuse (angle of divergence: 130-135°) and the spire is low but visible in the apertural view. The margin of the body whorl is appressed at the suture so that a thin edge extends over the preceding whorl, forming a false sutural line. The umbilicus is nearly filled with a small callus.

Occurrence: Representatives of this species are found in very small numbers in some RL and OL sediments of Cores 18, 30, 23 and 24.

Total number collected: 8

Distribution: West Indies.

Remarks: Specimens from Nichupté Lagoon compare well with figures and dimensions of *T. megasoma;* however, they also resemble *T. parvicallum* Pilsbry and McGinty, 1945 (1945a: 4-5, pl. 2: 2; Moore, 1964: 85-87, fig. 10; Andrews, 1971:72, fig.) which has been reported from southern Florida, Texas and Mexico. By comparison with figures, the angle of divergence of representatives of *T. parvicallum* is less (about 110-115°), making the spire less obtuse than *T. megastoma* or specimens from Nichupté Lagoon. Without verified comparative material, the identification cannot be made with certainty.

Specimens from Nichupté Lagoon are also comparable with *T. reclusa* (Dall, 1889b: 361, pl. 28: 7, 8; Abbott, 1974: 89, no. 844) which has been reported from North Carolina to the Yucatan Strait. Specimens from Nichupté Lagoon differ primarily by having a larger diameter-height ratio, but this characteristic cannot be used dependably when comparing a juvenile specimen with described adult specimens.

Genus SOLARIORBIS Conrad, 1865

Solariorbis sp., cf. *S. terminalis* (Pilsbry and and McGinty, 1946)

References: Pilsbry and McGinty, 1946b: 17, pl. 2: 5; Moore, 1964: 117-119, fig. 19.

Description: The largest specimen recovered from Nichupté Lagoon (ht 1.3 mm, diam. 1.7 mm) sediments has 3½ whorls and is immature. The minute white shell is slightly worn but some characters are observed. The 2¼ nuclear whorls are smooth and form a low spire. Sculpture on the postnuclear whorl consists of 7 spiral cords, the interspaces of which are marked with extremely fine and closely spaced axial striae. The base is marked with spiral ribs at its periphery and fine axial striae throughout, especially around the small umbilicus.

Occurrence: Representatives of this species are found in very small numbers in some RL and OL sediments of Cores 23 (depth 55 cm) and 24 (depth 35-240 cm).

Total number collected: 6.

Distribution: Northwestern Florida.

Remarks: Problems created by identification of juvenile specimens may become quite complex when compounded by lack of sufficient material. The juvenile shells from Nichupté Lagoon were at first mistaken for representatives of *Parviturboides interruptus* (C. B. Adams, 1850) (Pilsbry, 1937b: 53, pl. 8: 3; Pilsbry and McGinty, 1945b: 57-58, pl. 6: 2, 5, 9, *P. zacalles* Mazÿck, 1913, *P. sanibelense;* Pilsbry, 1946b: 5, fig. 4, 5, *P. interruptum;* Clench and Turner, 1950: 294-295, pl. 35: 4, 5; Pilsbry and McGinty, 1950: 86-87; Perry and Schwengel, 1955: 110, pl. 22: 141; Moore, 1964: 156-161, fig. 27; Andrews, 1971: 69, fig.) and are especially comparable with the figure of the subspecies *sanibelense*. Fresh adult specimens of *P. interruptus* from Naples, Florida beach drift were useful in comparison with the slightly worn juvenile shells from Nichupté Lagoon. The Nichupté Lagoon specimens have fewer and less regular ribs, lack ribs on the base, have much finer axial striae and specimens of comparable size have fewer whorls than the specimens of *P. interruptus* from Naples.

Genus ANTICLIMAX Pilsbry and McGinty, 1946

Anticlimax pilsbryi (McGinty, 1945)

References: McGinty, 1945: 142-143; Pilsbry and McGinty, 1945a: 3, pl. 1: 5; Pilsbry and Olsson, 1950: 10, *A. tholus*, p. 4, history of the genus; Moore, 1964: 165-168, fig. 28, with synonymy; Abbott, 1974: 86, no. 804; Odé, 1974b: 40, fig.

Description: The small, white, thin shell (ht 0.9 mm, diam. 1.5 mm) is depressed, has 2½ whorls, and is juvenile. The nuclear 1½ whorls are smooth and clear. The postnuclear whorls are axially undulate, have a keeled periphery decorated with numerous, closely-spaced, zig-zag spiral striae. The umbilicus, nearly covered with a heavy callus, is reduced to a chink.

Occurrence: Single specimens were recovered from the OL sediments of Core 23 (depth 90 cm) and 24 (depth 125 cm) and 2 specimens were taken from the TD sediments of Core 32.

Total number collected: 4.

Distribution: Southern Florida, Texas and Mexico.

Anticlimax sp.

Description: Only one weathered specimen was recovered from Nichupté Lagoon sediments. The small, chalky-white shell (height 1.3 mm, diam. 2 mm) is depressed trochiform. Only coarse surface sculpture can be described in view of the poor condition of the specimen. The body whorl is keeled. The base is marked with broad radial undulations. Spiral striae are not observed on this worn shell. The umbilicus is large but partly concealed by a callus.

Occurrence: One specimen was recovered from the OL sediments of Core 24 (depth 260 cm).

Total number collected: 1.

Remarks: Moore (1964: 163) lists the 3 known Recent species of *Anticlimax: A. schumoi* (Vanatta), *A. pilsbryi* (McGinty), and *A. proboscidae* (Aguayo). In general outline and coarse surface sculpture, the specimen from Nichupté Lagoon is comparable with *A. schumoi* (Vanatta, 1913, p. 24-25, pl. 2: 2, 7, *Discopsis schumoi)* but the worn condition of the shell does not permit confirmation of the identification. *A. schumoi* was described from British Honduras. Moore considers *A. athleenae* Pilsbry and McGinty, 1946 (1946a: 78, pl. 8: 3; Abbott, 1974: 86, no. 801) a fossil species of unknown age (Moore, 1964: 163).

Genus PACHYSTREMISCUS Olsson and McGinty, 1958

Pachystremiscus ornatus (Olsson and McGinty, 1958)

References: Olsson and McGinty, 1958: 33, pl. 4: 1; Moore, 1964: 197-200, fig. 34.

Description: The adult shell is minute (ht 0.38 mm, diam. 0.8 mm) white, planispirally coiled and delicately sculptured. There are 5 strong, sometimes nodulose, spiral ribs with finer spiral and axial striae. A row of nodules without associated rib is developed near the suture on both sides of the shell. The margin of the round aperture is thickened and complete.

Occurrence: Representatives of this species were recovered from RL and OL sediments of Core 23 (depth 0-150 cm).

Total number collected: 4.

Distribution: Southern Florida, the West Indies, south to Panama.

Remarks: Specimens were identified by Dr. D. R. Moore (personal communication, 1974).

Pachystremiscus pulchellus (Olsson and McGinty, 1958)

References: Olsson and McGinty, 1958: 32-33, pl. 4: 2; Moore, 1964: 195-197, fig. 33.

Description: Specimens are minute (ht 0.4 mm, diam. 0.9 mm) and differ from *P. ornatus* (above) by the following characters: Although the apex is depressed, the shell is not planispirally coiled. Sculpture is similar except that the spiral ribs are not nodulose and the fine axial and spiral striae are more evident. As in *P. ornatus*, there is a row of nodules along the dorsal suture and the shallow umbilicus. The aperture is similarly round, thickened and complete.

Occurrence: Representatives of this species are found in some RL, OL and TD sediments (Cores 23, 24, 32) near the mangrove channel, through which water of a more normal marine salinity enters the lagoon.

Total number collected: 44.

Distribution: Southern Florida, the West Indies, south to Panama.

Remarks: Specimens were identified by Dr. D. R. Moore (personal communication, 1973).

Family CAECIDAE Gray, 1850

Crosse (1877: 316-317, pl. 5: 1, 2) reviewed de Folin's 1875 Monograph of the Caecidae and reproduced figures of the protoconchs of *Caecum* and *Meioceras* from de Folin's work. Kisch (1959: 15-42) listed 131 species of Caecidae from the de Folin collection in Paris.

Prior to Moore's review of the systematic position of the Caecidae (1962: 695-701), most workers followed William Clark's (1849) suggestion that the Caecidae belonged to the superfamily Cerithiacea, near the Vermetidae (Moore, 1962: 695). Moore studied live caecids and discovered that although they superficially resemble the Vermetidae, they are more closely related to the Vitrinellidae and therefore belong in the superfamily Rissoacea (Moore, 1962: 696-700).

Genus CAECUM Fleming, 1813
Subgenus CAECUM Fleming, 1813

Caecum pulchellum Stimpson, 1851

References: Dall, 1889a: 142, pl. 50: 22; Abbott, 1954: 147, text fig. 37: d; Warmke and Abbott, 1962: 67, text fig. 15: a; Andrews, 1971: 77; Morris, 1973: 139; pl. 41: 7; Abbott, 1974: 91, no. 866.

Description: The largest specimen (ht 2.4 mm) is marked with 21 closely set annular rings.

Occurrence: Representatives of this species are found in some RL, OL and TD sediments (Cores 30, 23, 24 and 32) near the tidal channel, through which water of a more normal marine salinity enters the lagoon.

Total number collected: 55.

Distribution: Cape Cod, south to the West Indies.

Remarks: Identification of the specimens was verified by Moore (personal communication, 1973).

Subgenus ELEPHANTULUM Carpenter, 1857

Caecum floridanum Stimpson, 1851

References: Abbott, 1954: 146-147, text fig. 37: a; Moore, 1970: 372, fig. 2; Abbott, 1974: 92, no. 874.

Description: The largest specimen (ht 3.5 mm) from Nichupté Lagoon is marked with 25 strong annular rings which are crossed by very fine longitudinal threads. Three apertural rings are more widely separated than the others.

Occurrence: Representatives of this species are found in some OL and TD sediments and to a lesser extent, in RL sediments.

Total number collected: 26.

Distribution: North Carolina south to the West Indies.

Remarks: Identification of specimens was verified by Moore (personal communication, 1973).

Caecum imbricatum Carpenter, 1858

References: de Folin, 1867: 50-52, pl. 2: 5,*C. coronatum*, p. 52-53, pl. 2:4,*C. insigne*, synonyms; Moore, 1970: 371-372, fig. 1: c; Andrews, 1971: 76, fig.; Moore, 1972: 891-892, fig. 6; Abbott, 1974: 92, no. 875.

Description: The largest specimen (ht 3.8 mm) is moderately curved and sculptured with weak longitudinal and annular ridges.

Occurrence: Representatives of this species are found in some RL, OL and TD sediments (Cores 30, 23, 24 and 32) near the tidal channel, through which water of a more normal salinity enters the lagoon.

Total number collected: 79.

Distribution: Florida and the Bahamas.

Remarks: Identification of specimens was verified by Moore (personal communication, 1973).

Genus MEIOCERAS Carpenter, 1858

Meioceras cornucopiae Carpenter, 1858

References: Pilsbry and Aguayo, 1933: 122, pl. 6: 5, *M. constrictum;* Pilsbry and Aguayo, 1934: 112, *M. bermudezi;* Rehder, 1943: 190-191, pl. 20: 8, *Fartulum nebulosum;* Moore, 1972: 895, 896, fig. 10; Abbott, 1974: 94, no. 895a.

Description: The small shell (height 2.1 mm) is slender and tubular. Specimens of *M. cornucopiae* are more slender and have a less oblique aperture than representatives of *M. nitidum.*

Occurrence: Representatives of this species are found in the cleaner OL and TD sediments and to a lesser extent in the RL sediments.

Total number collected: 68.

Distribution: South Florida, southern Gulf of Mexico and the West Indies.

Remarks: Specimens were identified by Moore (personal communication, 1973).

Meioceras nitidum (Stimpson, 1851)

References: Abbott, 1954: 150, text fig. 37: e; Warmke and Abbott, 1962: 70, text fig. 15: c; Andrews, 1971: 77; Moore, 1972: 892-895, text fig. 10 (includes a complete synonymy list up to 1970); Abbott, 1974: 94, no. 895.

Description: The small adult shell (ht 2.4 mm) is smooth and tubular. The shell is blunt and narrow at the posterior end, wider in the middle and contracted near the aperture. Most specimens are white and others are cream-colored with diffuse white spots and smaller brown dashes. Juvenile specimens are also found in the sediments. The first stage of growth is a very small (ht 1 mm), tightly coiled shell. The second stage, often found with the first stage adhering, is an open spiral (resembles a cow horn). Juvenile shells are found in about equal numbers as the third stage, or adult shells, described above.

Occurrence: Representatives of this species are found in very large numbers in RL sediments and to a lesser extent in Inglés Lagoon, BLM, OL and TD sediments.

Total number collected: 3,364.

Distribution: Florida, Gulf of Mexico, West Indies, south to Brazil.

Remarks: Identification of specimens was verified by Moore (personal communication, 1973).

Superfamily CERITHIACEA Fleming, 1822
Family TURRITELLIDAE Clark, 1851
Genus VERMICULARIA Lamarck, 1799

Vermicularia spirata (Philippi, 1836)

References: Abbott, 1954: 144-145, pl. 21: c, text fig. 22: i; Gould, 1968: 9, fig. 1; Morris, 1973: 142, pl. 41: 17; Abbott, 1974: 96, no. 918.

Description: The largest specimen found is juvenile (ht 11 mm, diam. 4 mm) and has 10 whorls. The shell is slightly faded, opaque, light amber (fresh specimens are translucent dark amber). The shell is smooth except for one spiral cord in the middle of the postnuclear whorls. After the first 8 tightly coiled whorls (ht 6 mm), the evolute style of coiling is exhibited and two additional spiral cords (at the top and base of each whorl) are seen. Finely incised spiral lines are also present on later whorls. The aperture is subangulate and broken.

Occurrence: Representatives of this species are found in relatively small numbers in OL and TD sediments of Cores 23, 24 and 32. Three very small juvenile shells were taken from RL sediments of Core 23 (depth 5 cm).

Total number collected: 10.

Distribution: Southern Florida, Bermuda and the West Indies.

Family MODULIDAE Fischer, 1884
Genus MODULUS Gray, 1842

Modulus modulus (Linnaeus, 1758)

References: Abbott, 1944: 2-4, pl. 2: 1-4; Coomans, 1958: 67, pl. 7: center; Rice and Kornicker, 1962: 371, pl. 4: 16; Warmke and Abbott, 1962: 70-71, pl. 11: j; Andrews, 1971: 77-78, fig.; Abbott, 1974: 102, no. 976.

Description: The largest specimen found (ht 12 mm, diam. 11 mm) has 6 whorls and is grayish white flecked with red-brown dashes. The size of specimens varies (ht 1 to 12 mm) but most are 7 mm in height. Each postnuclear whorl has broadly sloping shoulders and is keeled. The upper portion of each whorl is marked with five low spiral threads and oblique transverse lines, whereas the base of the body whorl is marked with five strong spiral cords. The aperture is round. The thickened outer lip has seven low ridges within. The columella is short with a single tooth at the base.

Occurrence: Representatives of this species are found in most RL sediments and to a lesser extent, in OL and TD sediments.

Total number collected: 453.

Distribution: North Carolina, Bermuda, Florida, Gulf of Mexico, and the West Indies, south to Brazil.

Remarks: Identification of specimens was verified by Moore (personal communication, 1973).

Family POTAMIDIDAE H. and A. Adams, 1854
Genus CERITHIDEA Swainson, 1840

Cerithidea costata (da Costa, 1778)

References: von Martens, 1890-1901: 572-573, pl. 44: 11; Bequaert and Clench, 1933: 542; Bequaert, 1942a: 20-30; Bequaert, 1942b: 2-3, pl. 2: 1-7; Clench and Turner, 1950: 255, pl. 38: 7, *Cerithium* *ambiguum* Adams, 1845; Coomans, 1958: 68, pl. 7: center; Coomans, 1969: 81; Abbott, 1974: 102-103, no. 980.

Description: The largest shell found (ht 11.5 mm, diam. 4.5 mm) has 10 whorls. Specimens are slender, turreted and dark amber brown. The whorls are convex with numerous perpendicular axial ribs and possess well defined sutures.

Occurrence: Representatives of this species are found in relatively large numbers and are restricted to the brackish water sediments of the BLM and Inglés Lagoon.

Total number collected: 543.

Distribution: South Carolina to Florida and the West Indies, Caribbean shores of Mexico, Central and South America, east to Venezuela.

Family CERITHIIDAE Fleming, 1822
Subfamily CERITHIINAE Fleming, 1822
Genus CERITHIUM Bruguière, 1789

Cerithium algicola C. B. Adams, 1845

References: Clench and Turner, 1950: 255, pl. 37: 4; Warmke and Abbott, 1962: 73, pl. 13, p; Morris, 1973: 148, pl. 43: 21; Houbrick, 1974b: 62-65, pl. 31: 7, *C. lymani* Pilsbry, 1949; Abbott, 1974: 104, no. 996.

Description: The largest specimen found (ht 21 mm, diam. 8 mm) has 8 whorls and is bleached white with some light brown blotches. It differs from *C. eburneum* Bruguière by its more slender outline and lack of rounded beads and former varices on the whorls.

Occurrence: One specimen was taken from RL sediments of Core 30 (depth 5 cm), whereas the remaining specimens were confined to the OL and TD sediments of Cores 17, 24 and 32.

Total number collected: 5.

Distribution: Southern Florida and the West Indies.

Remarks: Houbrick (1974b: 65) reports that *C. algicola* is a form of *C. eburneum.* In this paper the two are listed separately because their shell characters are different and easily separated. The gradation between the two, reported by other workers, is not seen in Nichupté Lagoon sediments, perhaps due to the small size of this collection.

Cerithium eburneum Bruguière, 1792

References: Warmke and Abbott, 1962: 73, pl. 13: n; Rice and Kornicker, 1962: 371, pl. 4: 20; Coomans, 1969: 82; Turney and Perkins, 1972: 13; Houbrick, 1974a: 18, fig. 4: c; Houbrick, 1974b: 62-67, pls. 30-33; Abbott, 1974: 104, no. 995.

Description: The largest specimen found (ht 21 mm, diam. 9.8 mm) has 9 whorls. The shells are generally white with brown markings. Sculpture consists of 4 to 5 spiral rows of small beads separated by fine spiral striae. The beads are sometimes aligned to form vague, nodulose, vertical ribs. Former varices (larger than the vertical ribs) are present on some specimens. The aperture is ovate with well developed short siphonal and anal canals. The outer lip is thin, thickened behind (varix) and crenulate within.

Occurrence: Representatives of this species are found in most RL, OL and TD sediments.

Total number collected: 186.

Distribution: Southeast Florida to the West Indies.

Cerithium litteratum (Born, 1778)

References: Abbott, 1954:154, pl. 19:1; Coomans, 1958: 69, pl. 11, left; Warmke and Abbott, 1962: 72, pl. 13: o; Turney and Perkins, 1972: 10, fig. 11; Morris 1973: 149, pl. 43: 27; Abbott, 1974: 104, no. 994; Houbrick, 1974b: 49-54, pl. 21.

Description: The largest specimen found (ht 25 mm, diam. 10 mm) has 9 whorls. Sculpture consists of many spiral threads which are often weakly nodulose. On the penultimate and the body whorl, directly below the suture, there is a distinct row of strong nodules, forming blunt spines, and a lesser developed nodulose row on the base of the whorl. Previous whorls and juvenile shells are straight-sided and generally lack the diagnostic strong nodules. The aperture is ovate with well developed siphonal and anal canals. The outer lip is thickened, flaring and crenulate within. The shell is cream-colored with red-brown coloration between the nodules.

Occurrence: Representatives of this species are found in most OL and TD sediments and in some RL sediments.

Total number collected: 93.

Distribution: Bermuda, southeastern Florida and the West Indies, south to Brazil.

Cerithium lutosum Menke, 1828

References: Clench and Turner, 1950: 354, pl. 37: 2, *C. variabile* C. B. Adams, 1845; Coomans, 1958: 70, pl. 11, center; Warmke and Abbott, 1962: 72-73, pl. 13: w; Houbrick, 1974a: 17-18, fig. 4: b; Houbrick, 1974b: 71-77, pls. 41: 3, 4, 42: 1, 2, 5; Abbott, 1974: 105, no. 998.

Description: The largest shell (ht 6 mm, diam. 3 mm) found has 6½ whorls. The first 3½ whorls are white and worn. The remaining whorls are usually red-brown and sculptured with 4 to 5 spiral rows of beads separated by fine spiral striae. Some shells are white with brown markings. Sutures are distinct. Former varices are present on some of the larger specimens. The aperture is ovate with short siphonal and anal canals. The outer lip is weakly denticulate within.

Occurrence: Representatives of this species are found in TD sediments and rarely in RL and OL sediments.

Total number collected: 16.

Distribution: South Carolina and Bermuda, south to South America.

Cerithium muscarum Say, 1832

References: Abbott, 1954: 154, pl. 19:m; Coomans, 1958: 69, pl. 11: center; Morris, 1973: 149, pl. 43: 25; Houbrick, 1974a: 15-17, fig. 4: d; Houbrick, 1974b: 77-81, pl. 47: 1-5; Abbott, 1974: 104, no. 993.

Description: The largest shell found (ht 17 mm, diam. 5.5 mm) has 9 whorls. The shell is elongate, slender and marked with spiral striae, crossed by stronger transverse axial ribs (13 per whorl), giving the shell a nodulose surface. The base of the shell has one strong and four weaker nodulose spiral cords. The shell is cream-colored with red-brown dashes on the spiral striae between the nodules. Sutures are impressed. The aperture is ovate with short anal and well developed long and curved siphonal canal.

Occurrence: Representatives of this species are found in most RL sediments and in some OL sediments.

Total number collected: 47.

Distribution: Southern Florida to the West Indies.

Subfamily DIASTOMINAE Cossman, 1850
Genus DIASTOMA Deshayes, 1850

Diastoma varium (Pfeiffer, 1840)

References: Warmke and Abbott, 1962: 73, pl. 13: h, *Bittium varium;* Andrews, 1971: 79, fig.; Morris, 1973: 150, pl. 43: 14; Abbott, 1974: 107, no. 1037.

Description: The largest specimen found (ht 5 mm, diam. 1.6 mm) has 8½ whorls. Shells vary in color from white to tan to dark brown. The first 1½ whorls are smooth, whereas the postnuclear whorls are sculptured. Each postnuclear whorl slopes downward and is ornamented with 14 nearly vertical, transverse ribs and about 4 less well developed spiral threads, which create a slightly nodulous appearance. The base of the body whorl is marked with 6 spiral threads. The aperture is round and thin with a poorly developed anterior siphonal canal. A varix is developed posterior to the aperture.

Occurrence: Representatives of this species are found in most RL sediments and to a lesser extent in OL, TD and Inglés Lagoon sediments.

Total number collected: 662.

Distribution: Maryland, south to Florida, the Gulf of Mexico, and south to Brazil.

Remarks: Identification of specimens was verified by Dr. D.R. Moore (personal communication, 1973).

Diastoma sp.

Description: Specimens generally conform to the description of *D. gibberulum* given in Clench and Turner (1950: 287, pl. 37: 3) but this identification is open to question because the name *D. gibberulum* is reported by some to be synonymous with *D. varium* (Coomans, 1963a: 68). These specimens are easily separated from specimens of *D. varium* from the sediments of Nichupté Lagoon by the differences outlined below:

1. The shell is larger and proportionately wider (ht 5.5 mm, diam. 2.5 mm, proportion ht/diam. is 1/0.45) than shells of *D. varium* (ht 5 mm, diam. 1.6 proportion ht/diam. is 1.0.32).
2. Whorls are not sloping as in *D. varium,* but instead are even.
3. The six postnuclear whorls are more markedly nodulose, that is, the five spiral threads and 16 vertical transverse ribs are evenly developed, but like *D. varium,* ornamentation becomes less apparent on the lower third of the body whorl.
4. The aperture is more angulate and both anterior and posterior siphonal canals are poorly developed.
5. Color is invariably dark brown with white nodules.

Occurrence: Representatives of this species are found in RL sediments of Cores 17 and 23. Two shells were taken from OL sediment of Core 23 (depth 55 cm).

Total number collected: 173.

Distribution: C. B. Adams (1845: 5) described *D. gibberulum* from Jamaica.

Genus FINELLA A. Adams, 1869

Finella dubia (d'Orbigny, 1842)

References: Dall, 1889b: 258, *Alaba cerithioides;* Olsson and Harbison, 1953: 292-293 pl. 48: 9; Warmke and Abbott, 1962: 73, pl. 13: b; Morris, 1973: 151, pl. 43: 12; Abbott, 1974: 108, no. 1039, *F. dubia.*

Description: The largest specimen found (ht 3 mm, diam. 1.2 mm) is white and has 8 whorls. The first 3 whorls are smooth, whereas the remaining whorls are marked with narrow, transverse axial ribs and fine spiral threads. The aperture is rounded anteriorly.

Occurrence: Representatives of this species are found in very small numbers in Inglés Lagoon, RL, OL and TD sediments.

Total number collected: 9.

Distribution: Bermuda, Florida and the West Indies.

Remarks: *Alabina cerithioides* (Dall, 1889) is a synonym.

Subfamily LITIOPINAE H. A. Adams, 1854
Genus LITIOPA Rang, 1829

Litiopa melanostoma Rang, 1829

References: Warmke and Abbott, 1962: 74, pl. 13: g; Andrews, 1971: 80, fig.; Robertson, 1971: pls. 2: 5, 7, 3: 9, 10, 4: 13-16, SEM photos of larval shells; Abbott, 1974: 108, no. 1047.

Description: The largest shell found (ht 4.2 mm, diam. 2 mm) has 8 whorls. The first two whorls are smooth and transparent, the next three are finely incised with regular vertical and spiral striae, and the final three are smooth with microscopic spiral striae. The aperture is rounded with a strong basal columellar ridge and a rim of brown coloration along the outside edge.

Occurrence: Representatives of this species are found in very small numbers in sediments throughout Core 23 and in TD sediments of Core 32.

Total number collected: 6.

Distribution: Pelagic on sargassum in the Atlantic Ocean. Southern United States, Bermuda, south to Brazil.

Subfamily CERITHIOPSINAE H. and A. Adams, 1854
Genus ALABA H. and A. Adams, 1853

Alaba incerta (d'Orbigny, 1842)

References: Clench and Turner, 1950: 350-351, pl. 34: 3, *Rissoa tervaricosa* C.B. Adams, 1845; Warmke and Abbott, 1962: 74, pl. 13: r; Andrews, 1971: 82-83, fig.; Robertson, 1971, pls. 2: 6, 8, 3: 11, 12, SEM photos of larval shells; Abbott, 1974: 110, no. 1121.

Description: The largest shell (ht 5 mm, diam. 2.2 mm) is white and has 8 whorls which are marked with fine, spiral striae and numerous rounded varices.

Occurrence: One specimen was recovered from OL sediment of Core 23 (depth 90 cm) and 5 specimens were taken from TD sediments of Core 32.

Total number collected: 6.

Distribution: Bermuda, southern Florida, the West Indies, Gulf of Mexico, south to Brazil.

Genus CERITHIOPSIS Forbes and Hanley, 1849

Cerithiopsis greeni (C. B. Adams, 1839)

References: Dall, 1889a: 138, pl. 52: 2; Clench and Turner, 1950: 289-290, pl. 37: 17, 18, *Cerithium greeni;* Abbott, 1954: 157, pl. 19: v; Perry and Schwengel, 1955: 140, pl. 27: 190; Rice and Kornicker, 1965: 119, pl. 2: 10; Andrews, 1971: 81, fig.; Morris, 1973: 151, pl. 43: 19; Abbott, 1974: 108-109, no. 1048.

Description: The small, brown shell (ht 4.35 mm, diam. 1.35 mm) is elongate-conic and has 12 whorls. The 4 nuclear whorls are smooth, whereas the postnuclear whorls are sculptured with beaded spiral ridges. The size of the beads increases anteriorly, both within each whorl and from whorl to whorl. The suture is channelled. In later whorls, there is a spiral ridge within the channel and this ridge is seen on the basal periphery of the body whorl. The aperture is oval. The outer lip is smooth and flaring. The anterior siphonal canal is short and notched. The inner lip is reflected and fused anteriorly to the callused parietal area.

Occurrence: Representatives of this species are found in relatively small numbers in RL and OL sediments.

Total number collected: 11.

Distribution: Massachusetts, south to Florida, Bermuda, south to Brazil.

Remarks: Smaller specimens are similar to *C. virginica* Henderson and Bartsch (1914: 421, pl. 14: 2) from Virginia.

Cerithiopsis sp. 1.

Description: The small shell (ht 3.5 mm, diam. 1.3 mm) is conical and has 8½ whorls. The tan nuclear 2½ whorls are smooth, whereas the brown postnuclear whorls are sculptured with spiral and axial threads, giving the surface a nodulose-reticulate pattern. There are 2 (on the first postnuclear whorl) to 3 strong spiral cords (the middle thread is the strongest), crossed by lesser, but prominent, axial threads (18 increasing to 24 axial threads) on each whorl. There is a fourth spiral cord on the periphery of the base. The angle of spire divergence is about 35°, decreasing to less than 30° for the total shell outline. The suture is impressed. The aperture is oval. The anterior siphonal canal is short, slightly curved and notched. The inner lip is reflected and complete posteriorly.

Occurrence: Representatives of this species are found in relatively small numbers in RL and OL sediments.

Total number collected: 30.

Remarks: Specimens from Nichupté Lagoon may be juvenile representatives of *C. gemmulosa* (C. B. Adams, 1847) (Clench and Turner, 1950: 287, pl. 38: 13) which is found from the West Indies, south to Brazil (Abbott, 1974: 109, no. 1086).

Cerithiopsis sp. 2.

Description: The small shell (ht 3.3 mm, diam. 1.1 mm) is conic-cylindrical, and has 10½ whorls. There are 3½ smooth, brown nuclear whorls and 7 brown postnuclear whorls. Specimens are comparatively more slender than specimens described above as *C.* sp. 1. Although surface sculpture is similar to that of *C.* sp. 1, the nodulose spiral cords have better developed beads which become increasingly square-shaped anteriorly. Also, the fourth spiral cord on the body whorl is nodulose and there are 2 spiral cords on the base of the body whorl. The anterior cord is also strong, but smooth. A weaker cord lies between the peripheral and anterior cords. The angle of divergence is acute (about 24°). The suture is impressed. The aperture is oval. The siphonal canal is short, curved slightly and notched. The notch in these specimens is smaller than that observed in specimens described as *C.* sp. 1. The inner lip is thin and complete posteriorly.

Occurrence: Representatives of this species are found in relatively small numbers in RL and OL sediments.

Total number collected: 19.

Remarks: Specimens from Nichupté Lagoon may be juvenile representatives of *C. vinca* Olsson and Harbison (1953: 297-298, pl. 48: 2) which was described from the Pliocene of Florida. The specimens described by Olsson and Harbison are apically decollate, but otherwise comparable. Also, specimens from Nichupté Lagoon may be compared with *C. iota* (C. B. Adams, 1845) (Clench and Turner, 1950: 295-296, pl. 37: 16) which is found from Florida and Texas, south to the West Indies. Nuclear whorls of *C. iota* are not described. Specimens resemble the photo given by Andrews (1971: 81-82); however, the description cites the shell height as 12 mm. Perhaps this is a typographical error. Clench and Turner give Adams' measure of height as 0.12 inches (about 3 mm).

Cerithiopsis sp. 3.

Description: The small white shell (ht 2.88 mm, diam. 1.06 mm) is conical, juvenile and quite different from the other specimens of *Cerithiopsis*. There are 7 transparent, glassy, smooth nuclear whorls (ht 0.56 mm), then 5 glassy, cancellate postnuclear whorls. The shell is straight-sided. The first postnuclear whorl is marked with 2 beaded spiral threads and 14 axial threads of similar width. The remaining whorls have 3 beaded spiral threads and 14, increasing to 20 axial threads on the body whorl. The beads formed at bead intersections are glassy, round and high. The posterior thread is very near the distinct, but not impressed, suture, whereas the other 2 threads divide each whorl into thirds. There is a fourth spiral thread on the basal periphery of the body whorl. The base is nearly flat. The aperture is oval with a straight outer margin. The anterior siphonal canal is short, straight and deeply notched.

Total number collected: 2.

Remarks: The protoconchs of specimens from Nichupté Lagoon are comparable with those of *C. maisana* Olsson and Harbison (1953: 299, pl. 43: 9) from the Pliocene of Florida, however the postnuclear whorls of specimens from Nichupté Lagoon are more straight-sided, sutures are not impressed and overall shape is more conical than specimens of *C. maisana*.

Family TRIPHORIDAE Gray, 1847

Genus TRIPHORA Blainville, 1828

Triphora nigrocincta(C. B. Adams, 1839)

References: Dall, 1889a: 138, pl. 52: 3; Clench and Turner, 1950: 315-316, pl. 38: 11, 14; Abbott, 1954: 159, pl. 19: y; Perry and Schwengel, 1955: 139, pl. 27: 189; Warmke and Abbott, 1962: 76, pl. 13: k; Andrews, 1971: 83, fig.; Morris, 1973: 153, pl. 43: 4: Abbott, 1974: 111, no. 1131.

Description: The sinistral shell is small(ht 3.5 mm, diam. 1.1 mm), elongate-conic, dark red-brown and has 8 postnuclear whorls. There is a black band anterior to the suture. The protoconch consists of 1½ globose, smooth, glassy, light brown whorls. The first postnuclear whorl has one slightly nodulose, spiral ridge. Postnuclear whorls 2 to 4 have two beaded spiral ridges. On the fifth postnuclear whorl there is a slightly nodulose spiral thread lying between the 2 beaded spiral ridges. The remaining postnuclear whorls have 3 spiral ridges bearing gray, glassy beads. The sutures are slightly excavated. The base is keeled with a nodulose spiral ridge. The aperture is oval. The outer lip is thin. The anterior siphonal canal is short and slightly curved.

Occurrence: Representatives of this species are found in relatively small numbers in RL sediments of Cores 17 (depth 0-55 cm) and 18 (depth 10 cm) and OL sediments of Core 24 (depth 240-260 cm).

Total number collected: 6.

Distribution: Massachusetts, south to Florida, Texas, the West Indies and Brazil.

Remarks: Actually, the small specimens from Nichupté Lagoon compare best with descriptions of *T. modesta* (C. B. Adams, 1850) (Clench and Turner, 1950:310, pl. 39:8) however, Dall (1890-1891: 264) considered *T. modesta* a southern race or subspecies of *T. nigrocincta*. Dall believed the 2 forms to be intergradational.

Triphora turristhomae (Holten, 1802)

References: Dall, 1889a:138, pl. 41: 6; Dall and Simpson, 1901: 423; Clench and Turner, 1950: 309, pl. 38: 1, *Cerithium mirabile* C. B. Adams, 1850, synonym; Warmke and Abbott, 1962: 76, pl. 13: j; Morris, 1973: 153-154, pl. 43: 3; Abbott, 1974, p. 111, no. 1132.

Description: The sinistral shell is small (ht 3.1 mm, diam. 1.5 mm, apical whorls are missing), fusiform and broken so that only the final 6 whorls remain. Each whorl is marked with 2 spiral rows of glassy, round beads. The anterior row is yellow brown and the posterior row is white. The most distinctive feature of this specimen is the small, nearly round, aperture. The siphonal canals are enclosed and tubular and placed nearly at right angles to the shell axis. The suture is not impressed.

Occurrence: Two specimens were taken from TD sediments of Core 32 (depth 0-65 cm).

Total number collected: 2.

Distribution: North Carolina and Bermuda, south to Brazil.

Triphora sp.

Description: The sinistral shell is small (ht 4.2 mm, diam. 1.8 mm) elongate-conic, light brown and has 10½ whorls. The protoconch consists of 2½ smooth, glossy, light brown whorls. The first 4 postnuclear whorls are marked with 2 beaded, spiral ridges. The remaining postnuclear whorls each have 3 beaded spiral ridges. There are approximately 22 beads per row. Also, anterior to the beaded ridges is a smooth spiral ridge. The base is marked with 3 smooth spiral ridges. The sutures are slightly excavated. The aperture is oval. The outer lip is thin and crenulate without, reflecting the external sculpture. The inner lip is thin, reflected and fused posteriorly to the callused parietal area. The anterior siphonal canal is short and curved.

Occurrence: Representatives of this species are found in RL sediments and to a lesser extent, in OL sediments.

Total number collected: 24.

Remarks: Specimens from Nichupté Lagoon compare well with the descriptions and figures of *T. pyrrha* Henderson and Bartsch (1914: 419, pl. 14: 1) from Virginia. However, specimens from Nichupté Lagoon are not white and are larger (with more whorls) than those described as *T. pyrrha*. Also, specimens from Nichupté Lagoon may be compared with *T. decorata* (C. B. Adams, 1850) (Clench and Turner, 1950: 272, pl. 38: 2; Abbott, 1974: 111, no. 1133) and may represent juveniles of this species. The specimens are not maculated with red brown but instead are completely brown. In addition, specimens from Nichupté Lagoon are smaller and have fewer whorls. The major difference is that the anterior canal is only slightly curved and not tubular. These characteristics may be developed with maturity. A synonym, *T. decorata* C. B. Adams, var. *olivacea* Dall, 1889 (1889b:244) also lacks this tubular anal notch and differs in color. *T. decorata* is found from southeastern Florida and Bermuda, the West Indies, south to Brazil.

Superfamily EPITONIACEA Berry, 1910
Family EPITONIIDAE Berry, 1910
Genus EPITONIUM Röding, 1798

Epitonium echinaticostum (d'Orbigny, 1842)

References: Clench and Turner, 1951: 250, 253-255, pl. 109: 1-3; Warmke and Abbott, 1962:79, pl. 14: q; Morris, 1973: 156-157, pl. 44: 9, 10; Abbott, 1974: 119-120, no. 1238.

Description: The largest specimen (ht 3.5 mm, diam. 2.2 mm) found has 8 whorls. The five nuclear whorls are transparent and marked with microscopic axial striae. The remaining whorls are produced at an angle to the spire, widely umbilicate, exhibit evolute coiling and are marked with thin, blade-like axial costae which are fluted at the edge. There are 14 blades on the body whorl.

Occurrence: Single specimens of this species are found in RL, OL and TD sediments of Cores 17, 30 and 32.

Total number collected: 4.

Distribution: Bermuda, southern Florida to the West Indies. Brazil.

Family MELANELLIDAE Bartsch, 1917
Genus MELANELLA Bowdich, 1822

Melanella sp.

Description: The minute shell (ht 2.3 mm, diam. 0.8 mm) is glossy white and probably juvenile. The elongate spire is generally straight, but in a few specimens, a very slightly tilted spire is observed. The 8 whorls increase in size gradually and the straight sides of the shell form an angle of divergence of about 22°. The sutures are distinct, but not impressed and slightly oblique. The aperture is small (ht 0.6 mm), oval and continuous. The shell is nonumbilicate. The columellar margin is thickened, whereas the outer margin is sharp, advancing in the middle and slightly flaring.

Occurrence: Representatives of this species are found in relatively small numbers in some RL and OL sediments.

Total number collected: 16.

Remarks: The specimens from Nichupté Lagoon compare well with descriptions and figures of *Eulima atypha* Verrill and Bush (1900: 528, pl. 64: 10) from Bermuda and *Melanella carolii* Dall, 1889, and its synonym *affinis* C. B. Adams, 1850 (Clench and Turner, 1950: 250) from Jamaica. A comparison of diagnostic characteristics may prove useful:

	Height	Diameter	No. of whorls	Angle of Divergence
affinis Adams	2.28 mm	0.86 mm	-	19°
atypha Verrill and Bush	2.20 mm	0.80 mm	7-8	23°
Melanella sp. Nichupté Lagoon	2.30 mm	0.80 mm	8	22°

Family ACLIDIDAE Sars, 1878
Genus HENRYA Bartsch, 1947

Henrya goldmani Bartsch, 1947

References: Bartsch, 1947: 14, pl. 3: 3; Odé, 1969d: 34-35, 1971a: 90, fig.; Abbott, 1974: 133.

Description: The translucent-white shell is minute (ht 1.64 mm diam. 0.62 mm) and has 5 whorls. The apex is blunt and the well rounded whorls gradually increase in diameter. The sutures are impressed. The aperture is oval. The outer lip is thin and the inner lip is thin and reflected.

Occurrence: Representatives of this species are found in some BLM and RL sediments and to a lesser extent, in some OL and TD sediments.

Total number collected: 27.

Distribution: The species was described from specimens collected in a saline lagoon near Progreso, Yucatan.

Remarks: This species is quite variable and the three species of *Henrya* described by Bartsch (1947: pl. 3: 1, *H. morrisoni*, pl. 3: 2, *H. henryi*, pl. 3: 3, *H. goldmani*) may represent variants of the same species whose distribution extends along the entire Gulf of Mexico coastline and the Bahamas (Odé, 1971: 90).

Superfamily CREPIDULACEA Fleming, 1822
Family CREPIDULIDAE Fleming, 1822
Subfamily CREPIDULINAE Fleming, 1822
Genus CREPIDULA Lamarck, 1799

Specimens of juvenile *Crepidula* are common in lagoonal sediments but confusing to identify. Juvenile shells of *Crepidula* are difficult to separate (Abbott, 1954: 171) and not to be attempted here without soft part information and comparative data. Below, larger shells found are described. Juvenile shells are termed *Crepidula* spp. and counted together for the Distribution Charts (Tables 2, 6-8).

Crepidula convexa Say, 1822

References: Say, 1822: 227-228; Dall, 1889a: 152, pl. 50: 25; Fluck, 1905: 56; Abbott, 1954: 171, pl. 21: n; Perry and Schwengel, 1955: 131, pl. 38: 331; Warmke and Abbott, 1962: 87, pl. 15: k; Andrews, 1971: 95, fig.; Morris, 1973: 164, pl. 45: 8; Abbott, 1974: 141, no. 1559.

Description: The largest specimens found (ht 7.5 mm, diam. 4.7 mm, width 2.5 mm) are highly arched. The apex is prominent and the exterior of the shell is wrinkled and dark brown to light brown, streaked with red brown. The platform is nearly straight.

Occurrence: Representatives of this species are found in most RL sediments and to a lesser extent in OL sediments.

Total number collected: 41.

Distribution: Massachusetts, south to Bermuda, Florida, Texas and the West Indies. Introduced to California.

Crepidula plana Say, 1822

References: Say, 1822: 226-227; Dall, 1889a: 152, pl. 48: 12, 50: 26; Fluck, 1905: 56; Abbott, 1954: 172; Perry and Schwengel, 1955: 131-132, pl. 25: 174; Warmke and Abbott, 1962: 87, pl. 15: j; Rice and Kornicker, 1965: 121, pl. 3: 13-14; Andrews, 1971: 95-96; Morris, 1973: 165, pl. 45: 12; Abbott, 1974: 142, no. 1570.

Description: The largest specimens found (ht 11 mm, diam. 7.5 mm, width 1.5 mm) are elongate-oval and flat. The apex is depressed and the exterior of the shell is smooth and white. The platform is less than half the length of the shell and notched on one side.

Occurrence: Representatives of this species are found in relatively small numbers in OL and TD sediments and to a lesser extent in RL sediments.

Total number collected: 36.

Distribution: Canada to Florida, Bermuda, the Gulf of Mexico and the West Indies, south to Brazil.

Subfamily CALYPTRAEINAE Blainville, 1824
Genus CRUCIBULUM Schumacher, 1817

Crucibulum sp., cf. *C. striatum* Say, 1824

References: Dall, 1889a: 152, pl. 50: 27, 28; Abbott, 1954: 170, pl. 21: r; Perry and Schwengel, 1955: 129-130, pl. 24: 172; Morris, 1973: 164, pl. 45: 5; Abbott, 1974: 140, no. 1548.

Description: The shell is small (ht 2.5 mm, diam. 7 mm) and cap-shaped. The surface is marked with fine growth lines. The blunt apex is at the anterior third of the shell. The interior cup is located beneath the apex. One-third of the shelly cup is attached anteriorly (beneath the apex) and the rest of the cup margin is free. The shell is bleached white. Identification is not confirmed because the specimens lack the radial striae characteristic of *C. striatum*. The specimen from Nichupté Lagoon may be immature.

Occurrence: Two specimens were recovered from the OL sediments of Core 24 (depth 185 cm).

Total number collected: 2.

Distribution: Nova Scotia to the Florida Keys.

Remarks: Specimens were compared with specimens of *C. striatum* from Florida. The juvenile shells from Nichupté Lagoon have a more rounded apex; however, internally the shells are quite similar.

ORDER NEOGASTROPODA Thiele, 1925
Superfamily BUCCINACEA Rafinesque, 1815
Family COLUMBELLIDAE Swainson, 1840
Genus COLUMBELLA Lamarck, 1799

Columbella mercatoria (Linnaeus, 1758)

References: Dall and Simpson, 1901: 403; Abbott, 1954: 220, pl. 25: bb; Coomans, 1958: 88, pl. 14: center; Marcus and Marcus, 1962: 344-346, pl. I: 5; Rice and Kornicker, 1962: 375, pl. 4: 5; Warmke and Abbott, 1962: 110, pl. 20: a; Coomans, 1967a: 77, fig. 4; Morris, 1973: 200-201, pl. 54: 1; Abbott, 1974: 195, no. 2044.

Description: The largest shell (ht 12 mm, diam. 7 mm) found has 7 whorls. The spire is low (ht 3 mm) and worn. The aperture is elongate (ht 7.5 mm) and narrow. The outer lip is thickened, incurved at the middle and strongly crenulate within (14 crenulations). The inner lip has 8 small teeth. There is a single fold at the base of the columella. The sutures are distinct. The shell is sculptured with numerous, distinct spiral ridges. The shell is cream-colored with broken brown spiral streaks.

Examination of younger specimens (6 whorls, ht 10 mm) reveals more information about the spire, which is generally worn in adult specimens. The nuclear whorls are smooth and the first 2 postnuclear whorls have weak axial ribs and strong spiral ridges.

Occurrence: Representatives of this species are found in relatively small numbers in 4), OL and TD sediments.

Total number collected: 18.

Distribution: Bermuda, northeast Florida and the West Indies, south to Brazil.

Remarks: Identification of specimens was verified by comparison with material at the Museum of Zoology, University of Michigan.

Genus ANACHIS H. and A. Adams, 1853
Subgenus COSTOANACHIS Sacco, 1890

Anachis sparsa (Reeve, 1859)

References: Marcus and Marcus, 1962: 338-339, pl. I: 2; Warmke and Abbott, 1962: 111, pl. 20: s; Morris, 1973: 202, pl. 54: 9; Abbott, 1974: 195, no. 2047.

Description: The largest shell found (ht 9 mm, diam. 4 mm) is fusiform and has 7½ whorls. The 2 smooth, nuclear whorls are brown and the postnuclear whorls are cream-colored with orange-brown markings. The postnuclear whorls are marked with strong axial ribs (14 on the body whorl) and 7 spiral striae which are present only on the base. The outer lip has 7 denticles within and the inner lip callus has 7 small teeth which correspond to the basal striae.

Occurrence: Representatives of this species are sometimes found in relatively small numbers in RL and TD sediments.

Total number collected: 14.

Distribution: Bermuda, southeastern Florida and the West Indies, south to Brazil.

Genus COSMIOCONCHA Dall, 1913

Cosmioconcha nitens (C. B. Adams, 1850)

References: Dall and Simpson, 1901: 405, pl. 57: 12, *Columbella perpicta*, n. sp., synonym; Clench and Turner, 1950: 316-317, pl. 39: 17, *Fusus nitens* C. B. Adams; Warmke and Abbott, 1962: 113, pl. 20: f, *Mitrella nitens;* Abbott, 1974: 197, no. 2074.

Description: The largest specimen (ht 10.5 mm, diam. 4.5 mm) is fusiform and has 7½ whorls. The smooth shell is light orange-brown with irregular white spots. The outer lip is thickened and has 10 denticles within. The inner lip is thin and reflected slightly. The lower columella is nodulose. There are numerous spiral striae on the base.

Occurrence: Representatives of this species are found in some RL and OL sediments.

Total number collected: 38.

Distribution: The West Indies and Central America.

Genus MITRELLA Risso, 1826

Mitrella argus d'Orbigny, 1842

References: Marcus and Marcus, 1962: 342-343, pl. I: 4; Warmke and Abbott, 1962: 112, pl. 20: k; Morris, 1973: 203, pl. 54, 16; Abbott, 1974: 199, no. 2112.

Description: the largest specimen found is juvenile (ht 5 mm, diam. 2 mm). The shell is elongate and slender. The 2 nuclear whorls are smooth and brown, the next 2 whorls are light brown with white dots, and the remaining 2 whorls are brown with irregular white markings. The shell is smooth except for the penultimate whorls which are marked by weak, axial ribs.

Occurrence: Representatives of this species are found in relatively small numbers in OL sediments and to a lesser extent in some 4) sediments.

Total number collected: 8.

Distribution: Southeastern Florida and the West Indies. Brazil.

Remarks: *Nitidella dichroa* (Sowerby, 1844) is a synonym (Abbott, 1974: 199).

Subgenus COLUMBELLOPSIS Bucquoy, Dautzenberg and Dollfuss, 1822

Mitrella nycteis (Duclos, 1846)

References: Clench and Turner, 1950: 280-281, pl. 41: 2, *Columbella fenestrata* C. B. Adams, 1850; Warmke and Abbott, 1962: 113, pl. 20: L; Abbott, 1974: 200, no. 2118.

Description: The largest shell found (ht 5.8 mm, diameter 2.3 mm) is elongate-fusiform and smooth. The glossy shell is cream-colored with light brown flame-line markings. The aperture is long (ht 2.2 mm) and narrow. The outer lip is thickened and bears small teeth within.

Occurrence: Representatives of this species are found in small numbers in OL sediments and to a lesser extent, in some RL sediments.

Total number collected: 8.

Distribution: Southern Florida and the West Indies.

Remarks: *Mitrella fenestrata* (C. B. Adams, 1850) is a synonym (Abbott, 1974: 200).