Study of the Variance, Temporal Emergence Patterns, and Degree of Vertical Migration of Demersal Zooplankton In Two Different Benthic Habitats.

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Emily Gocke
419 Knott Hall
Dr. Richard Carlton
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behavior.

Although the methods in this experiment were not without error, a great deal was discovered about demersal zooplankton. Much more research is needed in this area which has been poorly neglected in the past.

INTRODUCTION

Acting as both predators and prey, zooplankton are found in virtually all regions of lakes, making them vital members of the limnetic community. Among the many different species of zooplankton that abound in fresh water, there are several that exhibit diel vertical migration patterns. Diel cycles are twenty-four hour cycles that can often exert considerable influence on community metabolism and structure (Reid, 1976). Migrating toward the surface at night and sinking toward the bottom during the day are the characteristic patterns of diel migratory species.

Demersal zooplankton are a special group of zooplankton which reside within substratum during the day, enter the water column at night and return to the benthos sometime before dawn (Porter and Porter, 1974). They inhabit both marine and freshwater systems, and there has been significantly more research concerning the activity of marine zooplankton. Demersal zooplankton can be found at any depth within the lake. However, the taxa residing in different zones of the lake will vary. This study examines the unique behavior of demersal zooplankton in fresh water, focusing on taxa that inhabit the littoral zone.

Littoral communities are found at the edge of lakes where there is ample sunlight often producing a flora carpeting on the bottom surface. Photosynthetic primary producers strive in these areas as well as the carnivorous organisms that depend on them (Cole, 1994). This region is typically rich in oxygen during the day as a result of photosynthetic plankton and algae. Demersal zooplankton in this region would have sufficient nutrients as well as oxygen as they spend their daytime hours in the sediments. Water movement is a major factor influencing the sediment type as well as the organisms that inhabit it (Reid, 1976).

The zooplankton of inland waters usually consist members from the Protozoa, the Rotatoria, the cladocerans, and the Copepoda. Other less common members may be ostracod crustaceans, water mites, larval molluscs, or insect larva (Cole, 1994). At UNDERC, many of the taxa of zooplankton feed on algae, ranging in size. The smaller algae are consumed by *Keratella cochlearis* while cladocerans and copepods consume the larger zooplankton. Larval fish consume algae with a wide range of sizes. Some of the zooplankton at UNDERC are carnivorous, such as the copepod *Mesocyclops* and the *Chaoborus* larva (UNDERC guide, 1996).

Although biologists have been interested in vertical migration of planktonic animals in both marine and fresh waters for at least two hundred and fifty years, it is one least understood phenomenon in aquatic biology (Swift, 1976). Scientists have studied vertically migrating zooplankton with many different trap designs and with experimental manipulation employed in the laboratory. There are several theories to why the planktonic animals exhibit this unique behavior. However, no single explanation has been found to be correct.

Of the scientists that have been interested in the vertical migration of zooplankton, few have focused on the behavior of demersal zooplankton. Most scientists who have studied on this phenomena have conducted their experiments in a marine environment. A.L. Alldredge and J.M. King led the way in designing traps for the emergence and reentry of demersal reef species. They conducted several studies concerning the distribution, abundance, and substrate preferences of demersal zooplankton, the distance they migrate above the benthos, and the effects of moonlight on the migration pattern of zooplankton (Alldredge and King, 1977, 1980, 1985). Many have followed their example in striving to contrive suitable traps for capture of demersal marine zooplankton.

Although there has been little research concerning demersal zooplankton in fresh water systems, this does not mean that this area is insignificant. It has been proven that demersal zooplankton play an important role in the flux of particulate material through benthic communities (Porter and Porter 1977) as well as important prey for fish and other consumers (Alldredge and King 1977, 1980). If the diel cycle of demersal zooplankton is interrupted or destroyed, it can have disastrous effects on the limnetic community. A study on the seasonal hypoxia in the Chesapeake Bay in 1992 revealed that hypoxic conditions cause some infaunal organisms to move closer to the surface of the sediment, increasing their availability to predators. Consequently, food resources may be diminished if the hypoxic conditions persist for a significant period of time (Llanso, 1992). Thus, although demersal zooplankton seem to "disappear" during the day, their role in the limnetic community does not act accordingly.

The fact that most of the research on demersal zooplankton has been conducted in marine environments elicits a challenge for any scientist desiring to study the same phenomena in a fresh water situation. Because this project falls into that category, there are several ways in which I have adapted marine methods to freshwater lakes. The problems that scientists faced in marine situations, such as faulty trap design or function, were analyzed before samples were taken. The emergence traps described in previous studies were tested in a swimming pool prior to using them at UNDERC. Although this study will took advantage of the previous research that has been conducted, it offered a new set of challenges resulting from the change in study sites.

The first question this project addresses is what kinds of demersal zooplankton are present in freshwater systems. Since little research has been done in this area, it was unknown which species will emerge from the sediments. Research done in marine systems, however, has revealed a difference in emergence from varying benthic areas. Keith Walters conducted a study comparing the migration of sediment-associated meiofauna in subtropical sand and seagrass habitats, and discovered differences in the numbers migrating between sand and seagrass habitats which were thought to be related to differences in sediment-associated meiofaunal densities (Walters, 1988). On a similar note, A.L. Alldredge and J.M. King studied the densities of zooplankton emerging at night from six substrate types and discovered that mush of the zooplankton over coral reefs actually lives on the reef itself (Alldredge and King, 1977). In both cases, the kinds of demersal zooplankton found in varying environments differed. This project determined if these characteristics hold true for fresh water systems as well as marine systems.

The second question the study considers is when the zooplankton move and to what extent they rise in the water column. A study conducted by A.L. Alldredge and J.M. King revealed that in marine ecosystems, small demersal zooplankton remained nearest the sediments, while the larger ones rose higher into the water column (Alldredge and King, 1985). In a study conducted by Sharon Lee Ohlhorst concerning the diel migration patterns of demersal reef zooplankton, it was ascertained that there was no single pulse of migratory activity. Instead, the zooplankton rise at variable rates throughout the night, with a peak activity usually during the second hour after sunset (Ohlhorst, 1982). As with the first part of the experiment, the second part determined if these conditions exist in a fresh water system as well as a marine system.

The third question proposed in this project deals with why the zooplankton emerge from the benthos. This question has proved to be quite controversial in studies past, as scientists struggle to discern why these organisms exhibit their unique behavioral patterns. There are three possible sub-questions under this topic. The first deals with the possibility that they migrate because they are escaping something. They could be escaping predation in the sediments by bottom feeding fish or carnivorous larvae such as the dragon fly larvae. The second deals with the possibility that they could be hungry. The herbivorous zooplankton could be seeking the phytoplankton while the predatory zooplankton could be seeking the herbivorous zooplankton. The third deals with the possibility that they could be suffocating as a result of the halt of photosynthesis and oxygen production when the sun goes down.

Various studies of diel migratory zooplankton have been conducted that shed light to this question regarding demersal zooplankton. In a study concerning diel vertical migration, James F. Haney revealed that in the absence of stratification of either food or temperature, *Daphnia* move upward when food is abundant (Haney, 1993). Regarding the oxygen availability to zooplankton, Edward LaRow studied the effect of oxygen tension on the vertical migration of the *Chaoborus* larvae. Although *Chaoborus* larvae are demersal species, this experiment was done in such a fashion that it only tested the effect of oxygen once the species was in the water column. From the experiment, LaRow discovered that low oxygen tension was a major regulatory factor for the vertical migration in the *Chaoborus* larvae (LaRow, 1970). The third part attempted to determining whether oxygen has a similar effect of stimulating emergence from the sediment.

MATERIALS AND METHODS

For this project, two different lakes on the UNDERC property were selected, Roach Lake and Crampton Lake. They were chosen because they are both relatively clear and have different sediment characteristics. The sites at Crampton lake were relatively flat, with a few logs and sticks in the area. The sediment was fine and there was a small amount of grass like vegetation. The sites at Roach Lake were slightly hillier than at Crampton Lake. The sediment in Roach Lake consists of a high sand content. It has low organic matter, but is heavily colonized with *Isoetes braunii.*

Another vascular macrophyte, *Myriophyllum tenellum*, as well as the moss *Drepanocladus exannulatus* is also found on the bottom (Jaynes and Carpenter, 1986).

Each site was chosen by snorkeling and was marked with three flags stuck into the sediment. The flags were placed 0.5 meters apart in the shape of a triangle. (see Figure 2). The sites were marked with a flotation marker made of styrofoam and fishing weights holding it in place.

Attempts were made to have the sites with equal depths. In Roach Lake, this was not difficult because it is a shallower lake than Crampton and has less of a depth gradient. All sites were very close to 2.9 meters. At Crampton, however, the lake gets deep much faster so there is more of a slope. Therefore, the depths of the sites varied slightly. Site one was 3.2 meters, sites two and three were 2.95 meters, site four was 2.6 meters and site five was 3.0 meters.

Trap Design

Funnel-shaped traps designed by Dr. Richard Carlton were used to collect the demersal zooplankton as they emerge from the sediment. (See Figures 1 and 2). The funnels are 25 cm high and have a diameter of 26 cm. They have three holes cut in the sides which allow a minimum of 200 square centimeters of surface area for water to pass through. These holes are needed for circulation of oxygen. Without them, the water under the trap would become anoxic very quickly and the project would be jeopardized. The holes are covered by 160 micrometer plankton mesh. The mesh should be small enough to maximize the catch and to restrict the infiltration of the small zooplankton (Youngbluth, 1982).

Weights were added along the bottom of the traps to keep them upright and to keep them close to the sediment. It was heavy enough so it didn't sink into the sediment more than one centimeter. Plastic mason jars were used as collecting jars.

Regular mason jar lids which fit the plastic mason jars were cemented to the top of the funnel.

A Schindler trap was also used to sample the water at different depths (Lind, 1979). Figure 3 shows what the Schindler trap looks like. It is a box-like structure constructed out of plexiglass. The top and bottom are 20 cm by 20 cm, and the trap is 30 cm high.

The third method of zooplankton collection was the vertical net tow. The purpose of this collection was to check the accuracy of the Schindler collections. The zooplankton net had a diameter of 30 centimeters and extended approximately one meter. The net tapered and the same jar which was connected to the Schindler trap was fastened at the end of the net. Collections were made at the surface, at 1.5 meters and at 2.5 meters.

To test the first hypothesis, samples were taken in Roach and Crampton Lake at night. The first sampling period was June 1-2 and the traps went in between 7 pm and 8 pm and were collected between 7 am and 8 am. When samples were collected, they were brought back to the lab and immediately preserved. They were poured through a zooplankton sieve and preserved with 70% ethanol. Volume of sample and the amount of ethanol used were recorded. Taxa were identified and counted on a 1 ml slide with a compound microscope. The total magnification was 450X.

The second sampling period was on June 10-11. Both Roach and Crampton Lakes were used in the third sampling period and the same procedure was used.

The third sampling period was the twenty-four hour sampling. In addition to using the funnel traps, the Schindler trap was used at every sampling period at the surface, 1.5 meters, and 2.5 meters. This sampling period began on June 17 and samples were taken at 1 pm, 7 pm, 1 am, and 7 am. Effort was made to use as little artificial light as possible. The only light that was used was when the snorkeler went down to collect the trap and to set the trap on the sediment. As soon as the snorkeler returned to the surface, the light was immediately turned off. This sampling period was designed to reveal the zooplanktons' emergence pattern over twenty four hours as well as how high they rise in the water column.

The next sampling period was a forty eight hour sampling. Samples were taken every twelve hours instead of every six. Instead of placing the traps in the center of the three flags, the snorkeler placed the funnels at different spots around the flags every time a new sample was taken. This was to correct for sediment disturbance which could jeopardize the project. The Schindler trap was used exactly as before, and the vertical net tow was used twice to check the accuracy of the Schindler trap.

The fourth and fifth hypotheses were not tested because of the limited time and money involved with this project. In an attempt to test the sixth hypothesis, core samples were taken from Crampton Lake and Roach Lake with a clear plastic cylinder corer with a diameter of 5.8 cm and length of 14.5 cm. Two samples were taken at each lake and were left to sit in darkness for several hours. After three hours, they were checked with a flashlight to see if anything had come out of the sediment.

In another attempt to test the sixth hypothesis, the same corers were used and four samples were taken from Crampton Lake. A dark room was set up and two of the samples were bubbled with oxygen and two were left as controls. They were left to sit and checked every hour. Since neither experiment helped answer the sixth hypothesis, it was concluded that the surface area that was sampled with the corer was insufficient to test the hypothesis.

Through out the course of the experiment careful attention was paid to weather and temperature, two variables that could play an important role in the project. Air and water temperature were recorded every time a sample was collected. Current weather was noted as well as the weather for the past three days.

RESULTS

Table 1 lists the light and weather conditions for each of the sampling periods. Table 2 shows the air and water temperatures for each of the sampling periods. Table 3 is a key for the graphs. It shows the four letter symbols at the bottom of the graph and lists the taxa which they represent. Because of the difficulty in identifying the Copepod species, the discussion will regroup them into families and compare the families.

There were many differences as well as similarities between the types of zooplankton in both lakes. The first testing period (see Figure 4) was done overnight from 2000 on June 1 until 0800 on June 2. Roach Lake had a greater abundance for almost all taxa. Odonata pupae and water mites were caught in both lakes. Roach and Crampton both had *Asplanchia*, *Bosmina*, Chironomids, *Keratella*, Centropagidae, Cyclopidae, *Nauplius*, and *Polyarthra*. Roach Lake had several taxa which were not found in Crampton such as *Trichocera* and *Lecane*. Roach Lake also had a significantly greater number of *Polyarthra*. Crampton had a great abundance of *Kelicottia* which was absent from Roach Lake.

The second sampling period (see Figure 5) was done overnight from 1830 on June 10 until 0730 on June 11. Roach Lake again had a greater abundance of most taxa. Chironomids, Odonata pupae, and water mites were found in both lakes. As in the first sampling period, Roach had a much greater number of *Keratella cochlearis.* Crampton also had a significant abundance of *Kelicottia.* Roach lake had *Asplanchia*, *Bosmina*, and *Holopedium gibberum*, which Crampton lacked. Both lakes had Cyclopidae, *Euchlanis*, *Lecane*, Centropagidae, *Nauplius*, and *Polyarthra.*

The third sampling period involved four collections during a twenty four hour time period. The first collection (see Figures 6 and 7), was done from 0730 until 1330 on June 17. For this sampling period, Roach Lake had more water mites while

Crampton had more Odonata Pupae. Roach Lake had *Asplanchia*, *Euchlanis*, and *Holopedium gibberum*. Crampton had *Kelicottia* and *Polyphemus pediculus*. Both lakes had *Bosmina*, *Keratella*, Centropagidae, Cyclopidae, *Nauplius*, *Polyarthra*, and *Trichocera*. Roach Lake again had a greater abundance than Crampton Lake.

Sampling was also done with the Schindler trap for these sampling periods. The first sample was taken on June 17 at 1330 when the trap was collected (see Figures 13 and 14). The sample taken from Roach Lake at 1.5 meters had the smallest abundance for most taxa. *Alona* were only found in the 2.5 meter sample and *Euchlanis* and *Lecane* were only found in the surface sample. The sample taken from Crampton Lake a relatively even distribution in abundance. *Bosmina* and *Kelicottia* were absent from the 1.5 meter sample. *Holopedium gibberum*, Centropagidae, and *Polyarthra* were missing from the surface sample.

The next sampling period was done on the same day from 1330 until 1930 (see Figures 6 and 7). The results for Roach Lake were almost the same as the sample taken in the morning. However, the results for Crampton varied. It was the period of greatest abundance for most taxa in Roach Lake during the twenty-four hour period. As in all previous sampling periods, Roach Lake had a greater abundance for most taxa. Crampton Lake had *Kelicottia*, *Polyphemus pediculus*, and a greater abundance of *Nauplius*. Roach lake had *Alona*, Chironomids, *Euchlanis*, and *Lecane*. Both of the lakes had *Asplanchia*, *Bosmina*, *Holopedium gibberum*, *Keratella cochlearis*, Centropagidae, Cyclopidae, *Nauplius*, and *Polyarthra*.

The next Schindler trap sample was taken at 1930 (see Figures 15 and 16). In Roach Lake, the abundance increased with depth for most taxa. Chironomids were only found in the 2.5 meter sample. *Holopedium gibberum* was absent from the 1.5 meter sample. Centropagidae were only found in the 1.5 meter sample. In Crampton Lake, abundance was greatest in the 1.5 meter sample for most taxa. *Bosmina* and

Holopedium gibberum were absent from the 2.5 meter sample.

The next sampling period had the greatest abundance for Roach Lake for most of the taxa. It was done from 1930 on June 17 to 0130 on June 18 (see Figures 8 and 9). Two larger taxa were caught in the traps, *Chaoborus* and Chironomids. *Chaoborus* were found in Roach Lake while Chironomids were found in Crampton lake. *Alona*, *Asplanchia*, and *Euchlanis* were found only in Roach Lake and Kelicottia and *Polyphemus pediculus* were only found in Crampton Lake. Both lakes had Cyclopidae, Centropagidae, *Bosmina*, *Keratella*, *Nauplius*, and *Polyarthra*. As before, Roach Lake had a much greater abundance of most taxa than Crampton Lake.

The Schindler trap was used to take a sample on June 18 at 0130 (see Figures 17 and 18). The graphs for Roach Lake show an increase in abundance with depth. *Euchlanis* was absent from the sample taken at the surface. The graphs from Crampton Lake, abundance was relatively constant at all three depths. Chironomids and *Polyphemus pediculus* were only found in the 2.5 meter sample. *Polyarthra* was absent from the surface sample.

The last sampling period of the twenty four hour sampling was done from 0130 until 0800 (see Figures 8 and 9). A large number of *Keratella* was found in Crampton in relation to the other taxa. *Asplanchia*, *Euchlanis*, and Chironomids were found in Roach Lake and *Daphnia*, *Kelicottia* and *Polyphemus pediculus* were found only in Crampton Lake. Both lakes had Cyclopidae, *Bosmina*, *Keratella*, Centropagidae, *Nauplius*, and *Polyarthra*. There was a decrease in abundance for most taxa in both lakes when compared with the previous sampling period.

The last sample taken with a Schindler trap in the twenty four hour sampling was taken on June 18 at 0800 (see Figures 19 and 20). The data from Roach Lake shows an increase in abundance with depth. *Holopedium gibberum* was absent from the 2.5 meter sample. The data from Crampton Lake shows a decrease in abundance with depth for *Keratella cochlearis*, and an increase in abundance with depth for Centropagidae and *Nauplius*. In general, the 1.5 meter sample was the least abundant.

The sampling period for June 29-30 was done over twenty four hours and samples were taken twice (see Figures 10 and 21). The samples were only taken in Roach Lake. The traps which went in at 0730 and came out at 1955 was compared with the Schindler trap taken at this time. The Schindler trap showed an increase in abundance with depth for all taxa. The data from the regular traps shows the presence of water mites while the data from the Schindler trap does not.

The sample which went in at 1955 and was collected at 0745 was compared with the Schindler trap for this time. (see Figures 10 and 23). The most abundant area for the Schindler trap was at 1.5 meters. The taxa found in the regular trap at this time were consistent with what was found in the samples from the Schindler trap. The regular trap sample for this time had a much greater abundance than the regular trap from the previous time.

The next sampling period took place July 7-9. This sampling period lasted forty eight hours and samples were taken every twelve hours. It was done in Roach Lake only. The first sampling period was from 1945 on June 7 until 0745 on June 8 (see Figures 11 and 24). The data from the Schindler trap samples show a relatively consistent increase in abundance with depth. *Euchlanis* was absent from the surface sample but it was present in the regular trap sample. *Polyarthra* was absent from the 1.5 meter sample but present in the regular traps. *Chaoborus*, *Daphnia*, Hydryphantoidea, Eylaoidea, the unidentified water mites, Chydoridae and unidentified pupae were not found in any of the Schindler samples but showed up in the regular trap samples.

The next samples were from regular traps that went in at 1915 on June 8 and were collected at 0730 on June 9 (see Figures 11 and 26). The data from the Schindler trap shows an increase in abundance with depth. The data from the regular traps show a large abundance of *Bosmina* when compared with the Schindler trap as well as a greater abundance for *Holopedium gibberum* than *Keratella*.

The last sample was taken from traps that went in at 0730 on June 9 and were collected at 1930 (see Figures 12 and 27). The data from the Schindler traps shows the a relatively constant increase in abundance at the three depths with a slight increase in abundance for *Keratella* at 1.5 meters. *Trichocera* were only found in the surface layer of water as well as in the regular traps. Water mites were found only in the regular traps and did not show up in the data from the Schindler traps. The data from the regular traps also shoes a much higher abundance for *Holopedium gibberum* than *Keratella*. *Euchlanis* are absent from the 1.5 meter sample but appear everywhere else.

The Zooplankton Net was used twice to calculate the accuracy of the Schindler trap (see Figures 21 and 22). All samples were taken on June 29 at 1955. The data reveals a very low abundance in the Zooplankton Net Tow in comparison with the Schindler trap. At the surface, the data showed that three taxa, *Holopedium gibberum*, *Polyarthra*, and *Trichocera* failed to show up in the Schindler trap. At 1.5 meters, *Daphnia* failed to show up in the Zooplankton Net Tow and *Trichocera* failed to show up in the Schindler trap. At 2.5 meters, *Alona*, *Daphnia*, and *Polyarthra* failed to show up in the Schindler trap.

The Zooplankton Net was used again on July 8 at 0745 (see Figure 25). The data from this sampling period also revealed a very low abundance in the Zooplankton Net Tow in comparison with the Schindler trap. At the surface, *Euchlanis* and *Trichocera* failed to show up in the Schindler Trap. At 1.5 meters, *Trichocera* also failed to show up in the Schindler trap. At 2.5 meters, *Euchlanis*, *Polyarthra*, and

Trichocera all failed to show up in the Zooplankton Net tow.

DISCUSSION

Serving as both predators and prey, demersal zooplankton are significant members of the aquatic ecosystem. Since little research has been done on demersal zooplankton in fresh water, there is much to be learned from studying them. The first hypothesis in this study was that zooplankton taxa would not differ between lakes. From the data collected, it is evident that many of the taxa are the same in the two lakes. Some taxa, however, were only found in one of the lakes. Roach Lake consistently had a higher abundance of most taxa. This may be because Roach is a more productive lake. The environmental conditions that exist may be more conducive to the growth of zooplankton.

Odonata pupae were one of the larger taxa caught in the regular traps in both lakes. Water mites were caught in both lakes, however they appeared in the samples from Roach Lake more frequently. Since water mites are highly dependent on the substrate, it can be concluded that Roach Lake's benthic characteristics are more hospitable to water mites.

Keratella cochlearis were very abundant in both lakes. Roach Lake always seemed to have a higher abundance of them, which could be due to the large abundance of *Kelicottia* in Crampton Lake. Since *Kelicottia* were only found in Crampton Lake, they can be considered competitors against *Keratella cochlearis* in the environmental niche which was studied.

Asplanchia was found in both lakes, however there were several occasions in which they were only found in Roach Lake. This was also the case with *Bosmina*, *Holopedium gibberum*, *Trichocera*, *Lecane* and *Euchlanis*. All of these taxa were found in both lakes at one time or another throughout the sampling period. For some reason, they tended to show up in the samples from Roach Lake more frequently than the samples from Crampton Lake.

There could be several reasons for this phenomena. The variance could be due to an environmental change that led to higher abundance in one lake relative to the other. It could also be due to the fact that they would have different life cycles in the two lakes depending on such things as the temperature or weather. As the Table 3 shows, the temperatures in Roach Lake and Crampton Lake were close but not always the same. Another reason could be the abundance of predators. For example, maybe there is a certain kind of aquatic animal that loves to eat *Asplanchia*. If they were at a point in their lives where they needed more food for growth, this may have a significant effect on the population of this taxa of zooplankton. One last reason has to do with human error. The amount of sample counted (1 mL) may not have been large enough to accurately represent which taxa were present.

Some taxa were found in one lake and never in the other. This was the case with *Kelicottia*. This taxa consistently showed up in high abundance in the traps from Crampton Lake. *Polyphemus pediculus* also showed up only in Crampton Lake. The insect larvae *Chaoborus* was found primarily in Roach Lake. The reasons leading to this could be similar to any of the ones discussed previously. It may be one simple environmental factor such as pH or a certain nutrient content that could be excluding these taxa from a specified environment.

The second hypothesis considered in this study was that the emergence patterns of demersal zooplankton do not vary temporally. The results from the June 17-18 sampling period show that there were variances in the abundance at the different times. The most abundant time period was on June 17 from 1330 until 1930. The most probable explanation for this is that it had begun to get darker and the zooplankton that exhibit vertical migration had started to rise in the water column.

The sample from 1930 on June 17 to 0130 on June 18 had some larger taxa in them, *Chaoborus* and Chironomids. These two taxa may have emerged later because they are larger. The smaller vertically migrating zooplankton can migrate earlier because they are smaller and less likely to be consumed by predators. Since *Chaoborus* and Chironomids are larger, they wait until it is darker to emerge from the sediment.

The last sampling period was on June 18 from 0130 until 0800. The data from this sample revealed a decrease in abundance for most taxa in both lakes when compared with the previous sampling period. This makes sense because less taxa would be going out of the sediment or rising vertically in the water column because it starts to get light during this time period. Instead, they would be returning to the sediment.

The sampling period on June 29-30 from 0730 until 1955 had a much smaller abundance than the sample taken from 1955 on June 17 to 0745 on June 18. An explanation for this is that most of the zooplankton emerge at night and that is why a greater abundance was found in the sample that was taken over night. If more had risen during the daytime, they would have been in danger of falling victim to predators.

The final sampling period from July 7 - 9 also supports the theory that zooplankton emergence patterns vary temporally. The sample which was taken from 0745 to 1915 on July 8 was the least abundant. The sample which was taken from 1915 on July 8 to 0730 on July 9 was the most abundant. This agrees with the data from the other samples. The greatest emergence was overnight and least was during the daytime.

Finally, the sample taken from 0730 to 1930 on July 9 showed abundance values which were intermediate in value when compared with the other two sampling periods. At first glance this may not make sense because it seems like it should have as low an abundance as the first sample that was taken, since they were both taken during the day time. Weather may have played a key in this disparity. The light conditions for the first sampling period were much sunnier than the last sampling period. Thus, the lack of sunlight would have provided the incentive for vertical migratory taxa to rise into the water column, where they could feed on phytoplankton.

The final hypothesis was that zooplankton do not rise to different levels in the water column. The first sampling period in which the Schindler trap was used was June 17-18. For the Schindler trap taken on June 17 at 1330, *Euchlanis* and *Lecane* were only found in the surface sample which suggests that they are not vertical migrators. If they were, they would not have been that high in the water column in daylight hours. Since the 1.5 meter depth at Roach had the least abundance, it means that there were probably no taxa that were migrating at the time the sample was taken.

The next sample was taken on June 17 at 1930. The data showed an abundance of Chironomids in the 2.5 meter sample. It is difficult to speculate how high they rise in the water column because since this sample was taken at dusk, they could have just emerged and could be on their way up in the water column. In Crampton Lake, since the greatest abundance was in the 1.5 meter sample, this means that the taxa were migrating vertically at this time. This is a valid explanation in comparison with the previous sample, where the taxa abundance was relatively constant throughout the three depths. *Holopedium gibberum*, which had been absent from the previous surface sample, was now only found in the surface sample. This suggests that it is a vertically migrating taxa. The same is true with Centropagidae which were also missing from the previous surface sample. Since these taxa were both larger, they would benefit from the protection the dark would bring.

The next collection was made at 0130 on June 18. The results for this time period are a little different than what was predicted. A higher abundance in the water near the surface would be expected, as the vertical migrators would be feeding there.

In Roach, however, there was an increase in abundance with depth. In Crampton, the abundance was relatively constant. An explanation for this could be the fact that it was windy when the samples were being taken. The wind could have been disturbing the water and influencing the zooplankton to descend in the water column, where there would be less turbulence. Since Chironomids were only found in the 2.5 meter sample, it can be concluded that they don't migrate very high vertically in the water column.

The last sampling period for June 18 was done at 0800. Roach lake showed an increase in abundance for most taxa which is what is expected, as the vertical migrators move down in the water column. In Crampton Lake, *Keratella cochlearis* was more abundant in the water near the surface. This suggests that either they are not vertical migrators or they migrate later in the day. There was an increase in depth for Centropagidae and *Nauplius.* Since they are both larger taxa, this fits with what was predicted.

The next sampling period was June 29-30 and was taken only in Roach Lake. Data from the Schindler trap showed an increase in abundance with depth in the 1955 sample taken on June 29. At this point, it is assumed that most of the vertical migration has not occurred yet. Since water mites were found in the regular traps at this time and not the Schindler trap, they probably emerged before 1955. Another explanation is that they are highly associated with the bottom substrate and wouldn't usually be found in the water column. The data from the Schindler trap at 0745 on July 30 shows that 1.5 meters was the most abundant level of the water. This suggests that the most of the taxa were migrating at this moment.

The last sampling period was from July 7-9. The first sample was collected at 0745 on June 8. In the regular traps, *Chaoborus*, *Daphnia*, Hydryphantoidea, Eylaoidea, the unidentified water mites, Chydoridae, and unidentified pupae were found in the regular traps but not in any of the Schindler trap collections. This suggests that they did emerge at night but by the time the Schindler samples were taken, they had already returned to the sediments. The data from the Schindler samples shows an increase in abundance with depth which is what was expected.

The next samples for this period were collected at 0730 on June 9. Again, the data showed an increase in abundance with depth. In contrast with previous data, the abundance of *Bosmina* was high when compared with the Schindler trap. This means they were equally distributed through the water column or had returned to near the sediment. The abundance of *Holopedium gibberum* was unusually high when compared with the abundance of *Keratella cochlearis*. This supports the previous data that suggested that *Holopedium gibberum* was a vertical migratory species.

The final samples taken on July 9 at 0730 showed a constant increase in abundance with depth. Again, water mites were found in the regular traps but did not show up in the data from the Schindler traps. The abundance of *Holopedium gibberum* was higher than *Keratella cochlearis* once again which backs up the previous data. *Euchlanis* are found in the surface sample but are missing from the 1.5 meter sample. Since they are found either at the surface or the lowest sample almost every time, it can be concluded that if they are migrating vertically, they do so very quickly, and are rarely found in the 1.5 meter sample.

The data from the vertical net tow did not match the data from the Schindler trap exactly. The difference in abundance in the vertical net tow could have resulted from the uncertainty which existed as a result of the method. The depth of the vertical tow net depended heavily on the speed with which the person was rowing the boat. Another factor to consider is that the exact distance the net was towed was difficult to measure. Since several taxa show up in the vertical net tow and not in the Schindler trap, it is possible to conclude that some of the zooplankton exhibit patchy abundance.

In the 2.5 meter sample that was taken on July 8, the explanation for why it was lacking several taxa could be due to the fact that the net wasn't down completely in the water. The person rowing the boat could have been rowing at a faster rate than normal, thus causing the net to rise.

FUTURE RESEARCH

There are several aspects of this project that inspire future research. The first area is determining what triggers their emergence from the sediment. This study attempted to test if the absence of oxygen was the reason for the emergence of demersal zooplankton. Since the method was not successful, a different experimental design could be employed to test this hypothesis.

It would also be interesting to study the chemical parameters that exist in the two lakes studied. The different nutrient contents, pH, temperature, and visibility may be helpful in explaining why some taxa exist in one lake but not the other. The predators that exist in the lakes would be interesting to study, as well as an in depth examination of the sediment from which the demersal zooplankton emerge.

ACKNOWLEDGEMENTS

I would like to thank Molly McCracken, Laura Eidietes, and Noah Gray for all of their field assistance in my project. I also appreciated Jeff Runde's guidance, technical support, and patience. I would like to thank Dr. Richard Carlton for helping me design, plan, and carry out my project. I appreciate Dr. Hellenthal's commitment and dedication in making UNDERC such a worthwhile experience. Finally, I would like to thank the Bernard J. Hank family Endowment for providing me with the opportunity to participate in the UNDERC program.

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Table 1: Weather and Light Conditions

Figs.	Date	Time	Light Condition	Current Weather	Past Three Days Weather
4	6-1	1930	low light; dusk	cloudy; light rain	sunny; clear; warm
5	6-10	1900	low light; dusk	light cloud cover; still	sunny; clear
6 13 14	6-17	1330	cloudy	light rain; moderate wind	mostly cloudy; light rain
7 15 16	6-17	1930	cloudy	cloudy; cool; light wind	same
8 17 18	6-17	0200	none	strong wind; cool	same
9 19 20	6-18	0830	cloudy	cloudy; light wind cool	same
10 21 22 23	6-29	2000	sunny	clear; warm	warm; humid; thunderstorm 6-26
11 24 25	7-8	0745	sunny	cool; scattered clouds	sunny; warm; humid; rainy and cloudy 7-6
11 26	7-9	0730	cloudy	cool; slight wind	same
12 27	7-9	1930	cloudy	still; cool	same

Table 2: Air and Water Temperature

Figs.	Date	Time	Lake	Air Temperature	Water Temperature
4	6-1	1930	Crampton	16.5	14.1
4	6-1	1930	Roach	15	16.1
5	6-10	1900	Crampton	18.4	19
5	6-10	1900	Roach	18	18.5
6, 14	6-17	1330	Crampton	18	21.5
6, 13	6-17	1330	Roach	18	20
7, 16	6-17	1930	Crampton	18	19.5
7, 15	6-17	1930	Roach	18	20
8, 18	6-18	0130	Crampton	17	19.5
8, 17	6-18	0130	Roach	17	19.5
9, 20	6-18	0730	Crampton	17	19
9, 19	6-18	0730	Roach	17	18.5
21, 22	6-29	2000	Roach	24	23
10, 23	6-30	0800	Roach	19	22
11, 24 25	7-8	0800	Roach	18	23.5
11, 26	7-9	0730	Roach	16	23
12, 27	7-9	1930	Roach	15	22

Table 3: Key for Taxa Identification on Graphs

Symbol		Family	Genus species
NAUP	Class Copepoda		*Nauplis*
LIMN	Order Calanodia	Centropagidae	*Limnocalanus Macrurus*
KERA	Phylum Rotifera	Brachionidae	*Keratella cochlearis*
KELI	Phylum Rotifera	Brachionidae	*Kellicottia*
BOSM	Class Cladocera	Bosminidae	*Bosmina*
POLY	Phylum Rotifera	Synchaetidae	*Polyarthra*
MESO	Order Cyclopodia	Cyclopidae	*Mesocyclops*
CHIR	Order Diptera	Chironimidae	
TROP	Order Cyclopodia	Cyclopidae	*Tropocyclops*
ASPL	Phylum Rotifera	Asplanchnidae	*Asplancha*
CHAO	Order Diptera	Chaoboridae	*Chaoborus*
WMUN			Water Mites - Unidentified
EYLA	Class Arachnida	Eylaoidea	
HYDR	Class Arachnida	Hydryphantoidea	
EUCH	Phylum Rotifera	Euchlanidae	*Euchlanis*
TRIC	Phylum Rotifera	Trichocercidae	*Trichocera*
PUPA			Pupae - Unidentified
ACAN	Order Cyclopodia	Cyclopidae	*Acanthocyclops*
LECA	Phylum Rotifera	Lecanidae	*Lecane*
DIAP	Class Cladocera	Sididae	*Diaphanosoma*
ALON	Class Cladocera	Chydoridae	*Alona*
POPE	Class Cladocera	Polyphemidae	*Polyphemus pediculus*
HOLO	Class Cladocera	Holopediidae	*Holopedium gibberum*
EPHE	Order Ephemeroptera	Ephemerellidae	
POCE	Order Trichoptera	Polycentropus	
DAPH	Class Cladocera	Daphniidae	*Daphnia*
NAID	Phylum Annelidia	Naididae	
CHYD	Class Cladocera	Chydoridae	
FISH			fish larvae
PUSH			Pupae Shell - Unidentified

"Figure 1"

"Figure 1. Funnel-shaped emergence traps designed by Richard Carlton were used to trap demersal zooplankton as they emerged from the sediment. The traps were 25 cm high and had a diameter of 26 cm. One quart Nalgene mason jars were screwed on top. The three holes in the side allow a minimum of 200 square centimeters of surface area for water to pass through and allow for circulation of oxygen. The holes are covered with 160 micrometer plankton mesh."

"Figure 2"

"Figure 2 is a picture of the underwater sites and one of the traps used to catch the demersal zooplankton. The three flags were placed 0.5 meters apart in the shape of a triangle and the trap was placed between them by a snorkeler."

"Figure 3"

"Figure 3. Schindler trap used to capture zooplankton at varying depths in the water column. The upper and lower doors are shown partially open" (Lind, 1979)."

"Figure 4"

"Figure 4. Numbers of trapped organisms (mean of three traps) caught in demersal emergence traps in Crampton Lake (upper panel) and Roach Lake (lower panel). Traps in at 1930 on June 1, 1996 and out at 0745 on June 2, 1996."

"Figure 5"

"Figure 5. Numbers of trapped organisms (mean of three traps) caught in demersal emergence traps in Crampton Lake (upper panel) and Roach Lake (lower panel). Traps in at 1830 on June 10, 1996 and out at 0730 on June 11, 1996."

"Figure 6"

"Figure 6. Numbers of trapped organisms (mean of three traps) caught in demersal emergence traps in Crampton Lake. Traps (upper panel) in at 0730 on June 17, 1996 and out at 1330 on June 17, 1996. Traps (lower panel) in at 1330 on June 17, 1996 and out at 1930 on June 17, 1996."

"Figure 7"

"Figure 7. Numbers of trapped organisms (mean of three traps) caught in demersal emergence traps in Roach Lake. Traps (upper panel) in at 0730 on June 17, 1996 and out at 1330 on June 17, 1996. Traps (lower panel) in at 1330 on June 17, 1996 and out at 1930 on June 17, 1996."

"Figure 8"

"Figure 8. Numbers of trapped organisms (mean of three traps) caught in demersal emergence traps in Crampton Lake. Traps (upper panel) in at 1930 on June 17, 1996 and out at 0130 on June 18, 1996. Traps (lower panel) in at 0130 on June 18, 1996 and out at 1940 on June 18, 1996."

"Figure 9"

"Figure 9. Numbers of trapped organisms (mean of three traps) caught in demersal emergence traps in Roach Lake. Traps (upper panel) in at 1930 on June 17, 1996 and out at 0130 on June 18, 1996. Traps (lower panel) in at 0130 on June 18, 1996 and out at 1940 on June 18, 1996."

"Figure 10"

"Figure 10. Numbers of trapped organisms (mean of three traps) caught in demersal emergence traps in Roach Lake. Traps (upper panel) in at 0730 on June 29, 1996 and out at 1955 on June 29, 1996. Traps (lower panel) in at 1955 on June 29, 1996 and out at 0745 on June 30, 1996."

"Figure 11"

"Figure 11. Numbers of trapped organisms (mean of three traps) caught in demersal emergence traps in Roach Lake. Traps (upper panel) in at 1945 on July 7, 1996 and out at 0745 on July 8, 1996. Traps (lower panel) in at 1915 on July 8, 1996 and out at 0730 on July 9, 1996."

"Figure 12"

"Figure 12. Numbers of trapped organisms (mean of three traps) caught in demersal emergence traps in Roach Lake On July 9, 1996. Traps in at 0730 and out at 1930."

"Figure 13"

"Figure 13. Zooplankton densities sampled from three depths in water column of Roach Lake at 1315 on June 17, 1996."

"Figure 14"

"Figure 14. Zooplankton densities sampled from three depths in water column of Crampton Lake at 1350 on June 17, 1996."

"Figure 15"

"Figure 15. Zooplankton densities sampled from three depths in water column of Roach Lake at 1905 on June 18, 1996."

"Figure 16"

"Figure 16. Zooplankton densities sampled from three depths in water column of Crampton Lake at 1940 on June 18, 1996."

"Figure 17"

"Figure 17. Zooplankton densities sampled from three depths in water column of Roach Lake at 0116 on June 18, 1996."

"Figure 18"

"Figure 18. Zooplankton densities sampled from three depths in water column of Crampton Lake at 0203 on June 18, 1996."

"Figure 19"

"Figure 19. Zooplankton densities sampled from three depths in water column of Roach Lake at 0740 on June 18, 1996."

"Figure 20"

"Figure 20. Zooplankton densities sampled from three depths in water column of Crampton Lake at 0810 on June 18, 1996."

"Figure 21"

"Figure 21. Zooplankton densities sampled from three depths in water column of Roach Lake at 1955 on June 29, 1996."

"Figure 22"

"Figure 22. Zooplankton trapped in horizontal tow done in Roach Lake at 1955 on June 29, 1996."

"Figure 23"

"Figure 23. Zooplankton densities sampled from three depths in water column of Roach Lake at 0742 on June 30, 1996."

"Figure 24"

"Figure 24. Zooplankton densities sampled from three depths in water column of Roach Lake at 0745 on July 8, 1996."

"Figure 25"

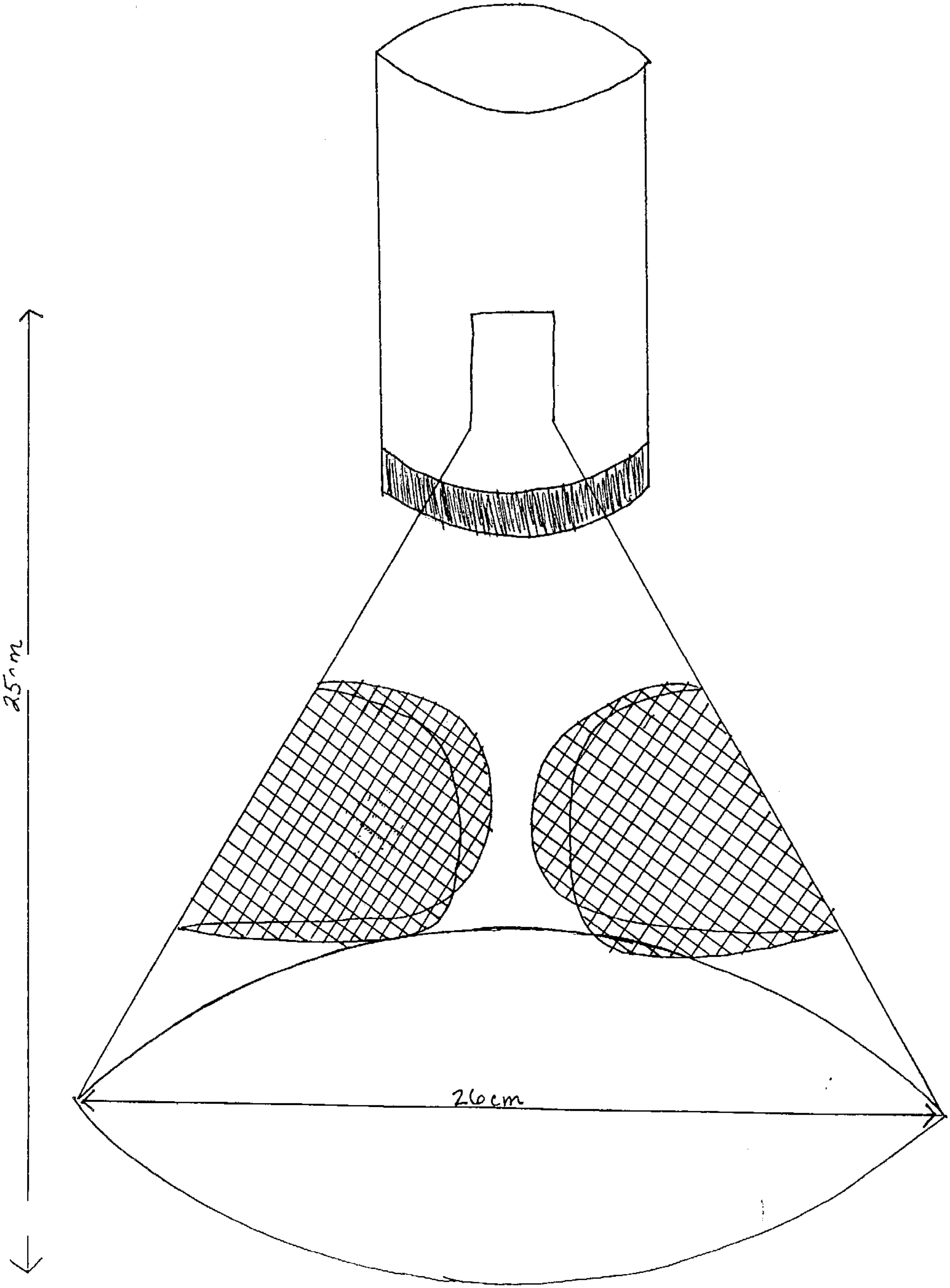
"Figure 25. Zooplankton trapped in horizontal tow done in Roach Lake at 0745 on July 8, 1996."

"Figure 26"

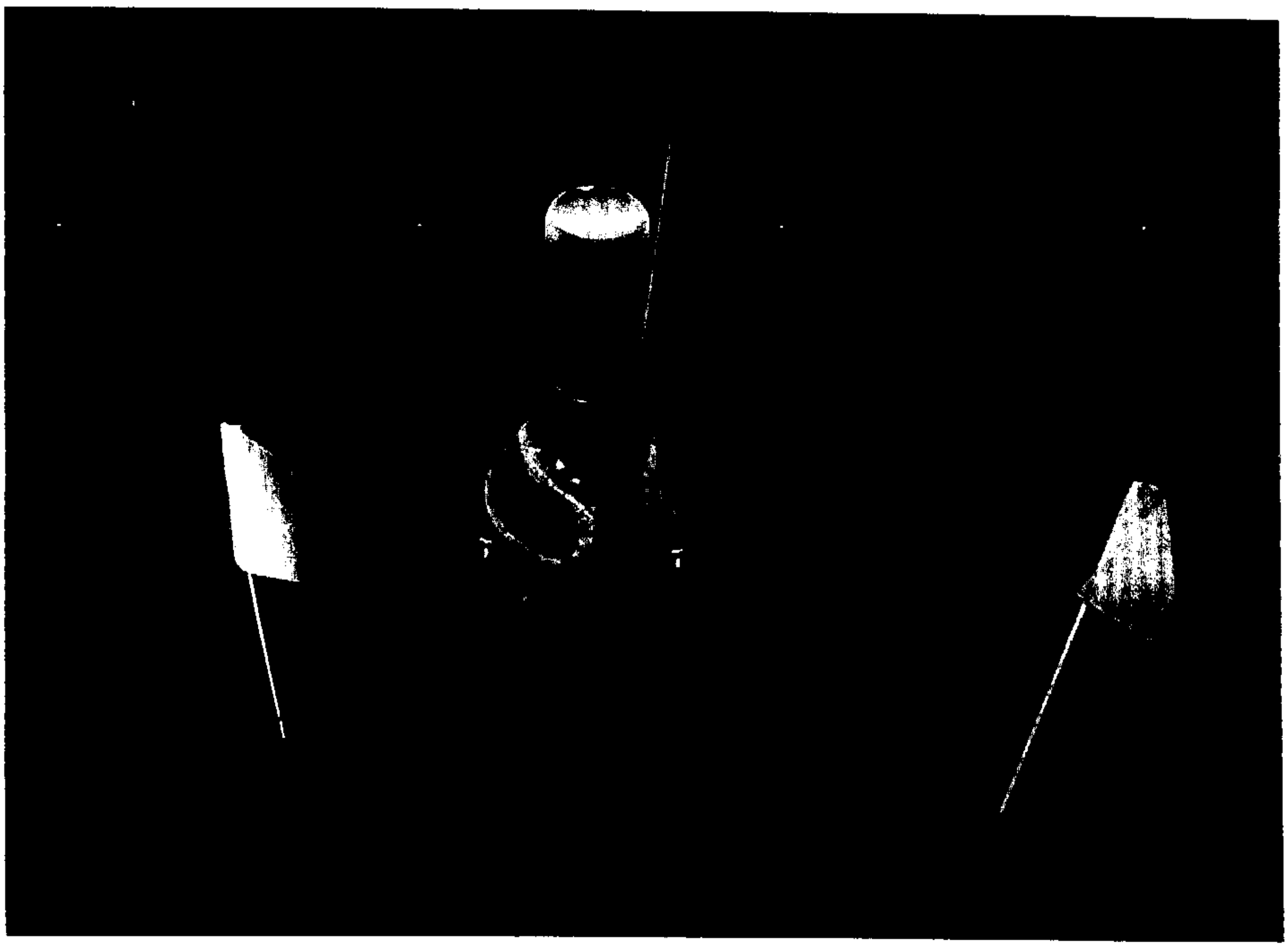
"Figure 26. Zooplankton densities sampled from three depths in water column of Roach Lake at 0730 on July 9, 1996."

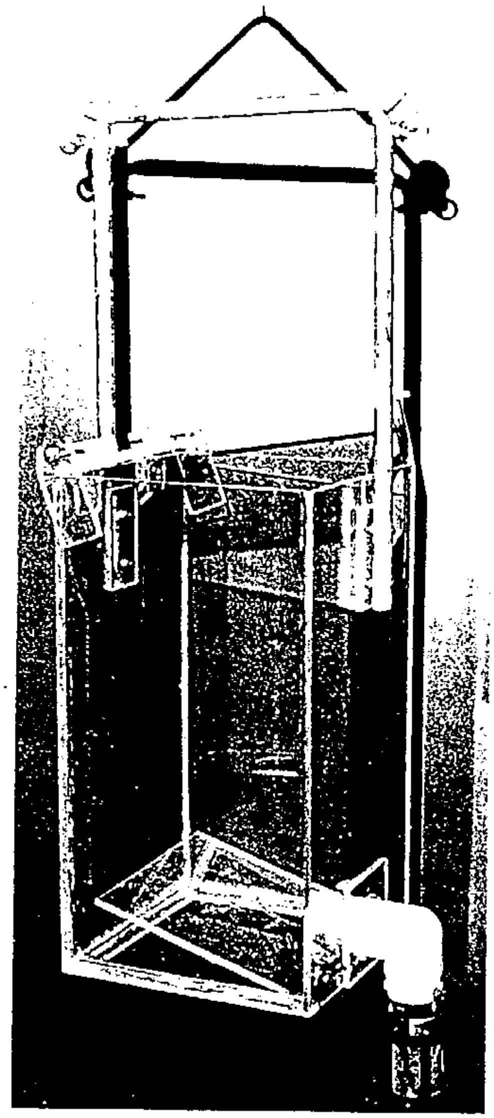
"Figure 27"

"Figure 27. Zooplankton densities sampled from three depths in water column of Roach Lake at 1930 on July 9, 1996."

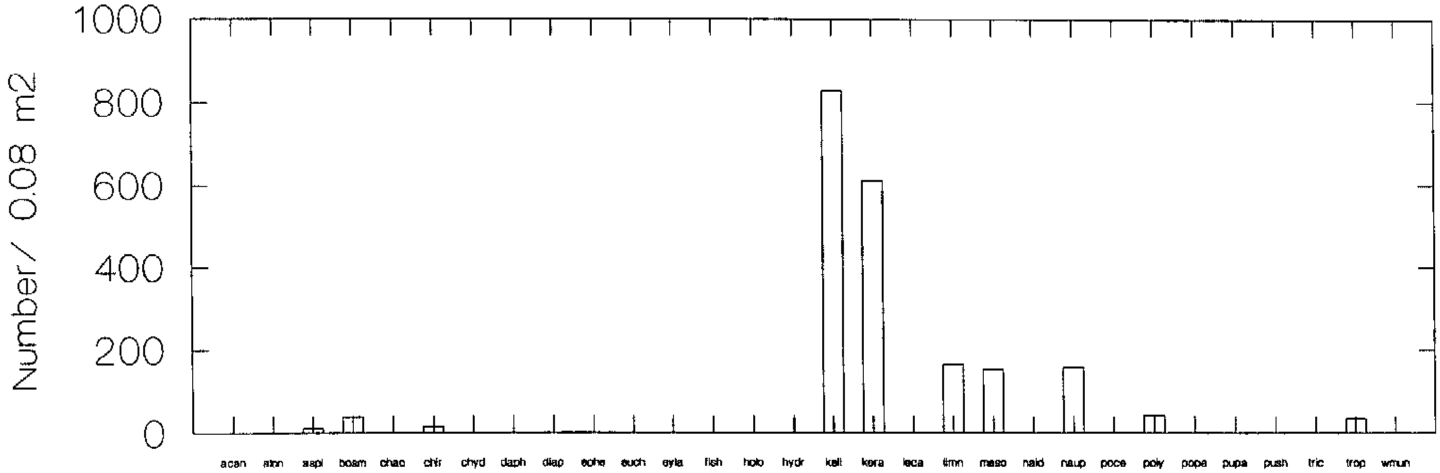


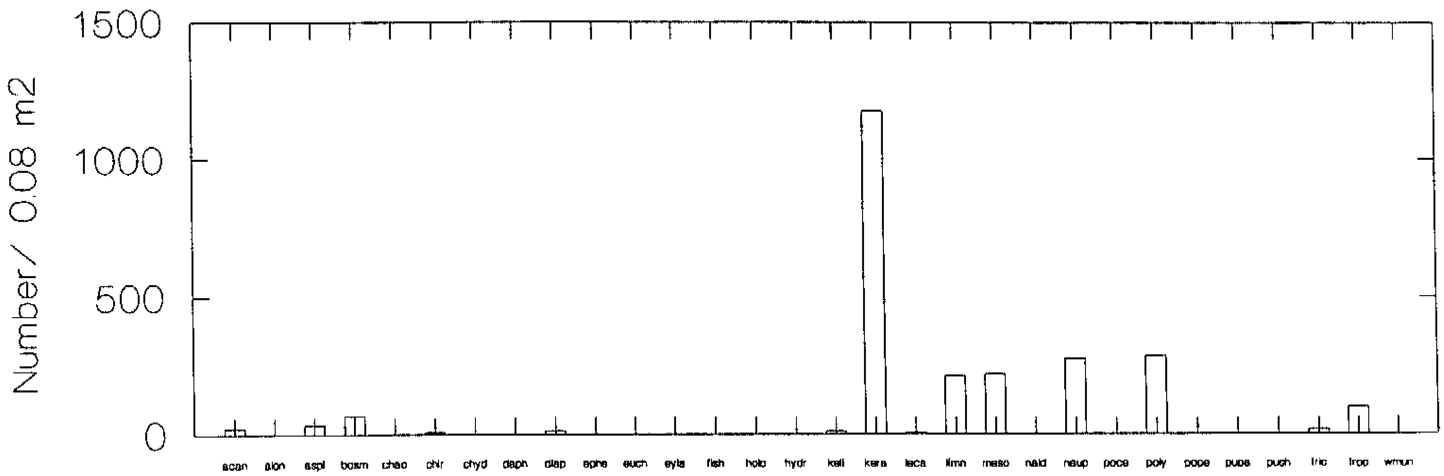
25cm
26cm



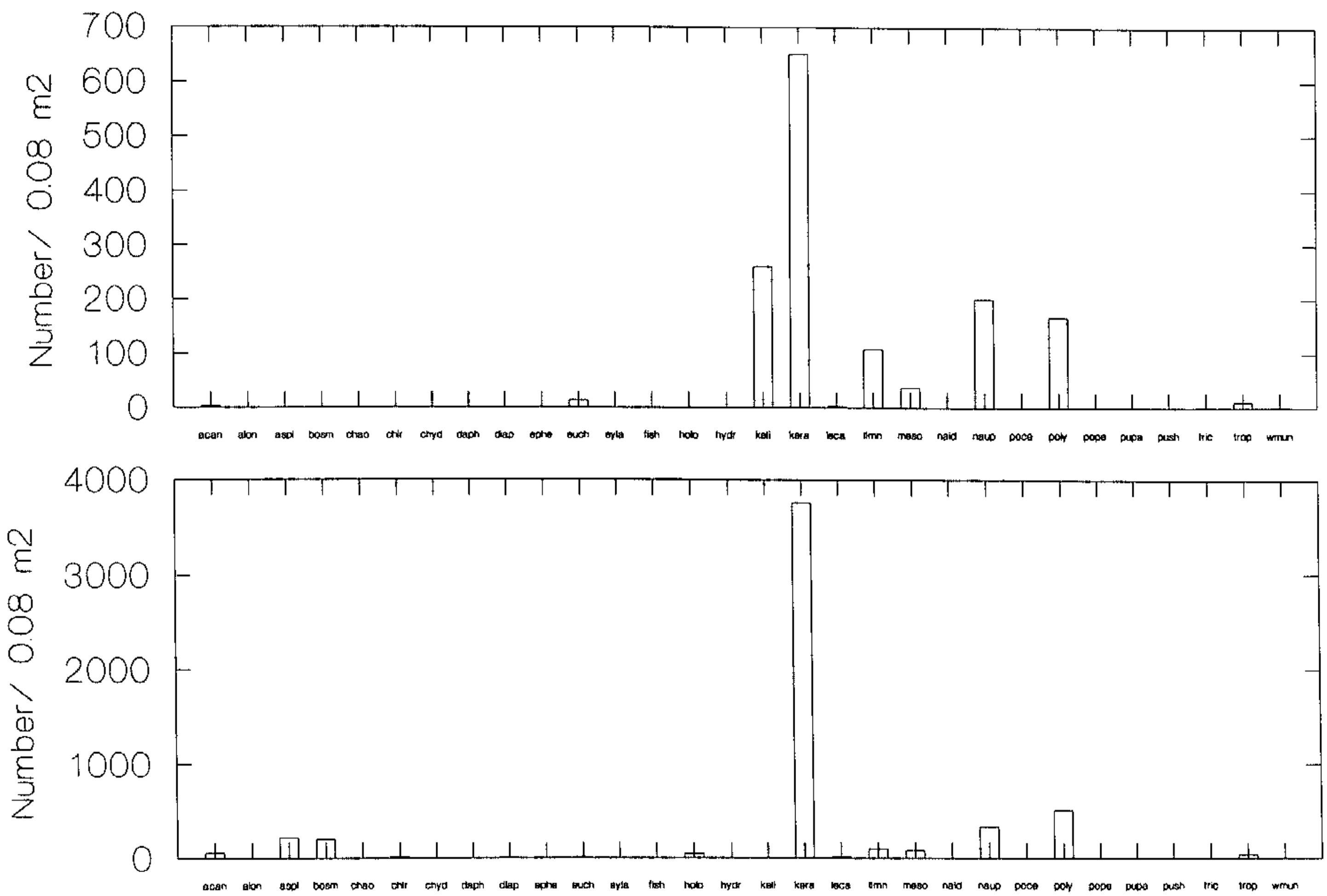


Traps Crampton and Roach June 1

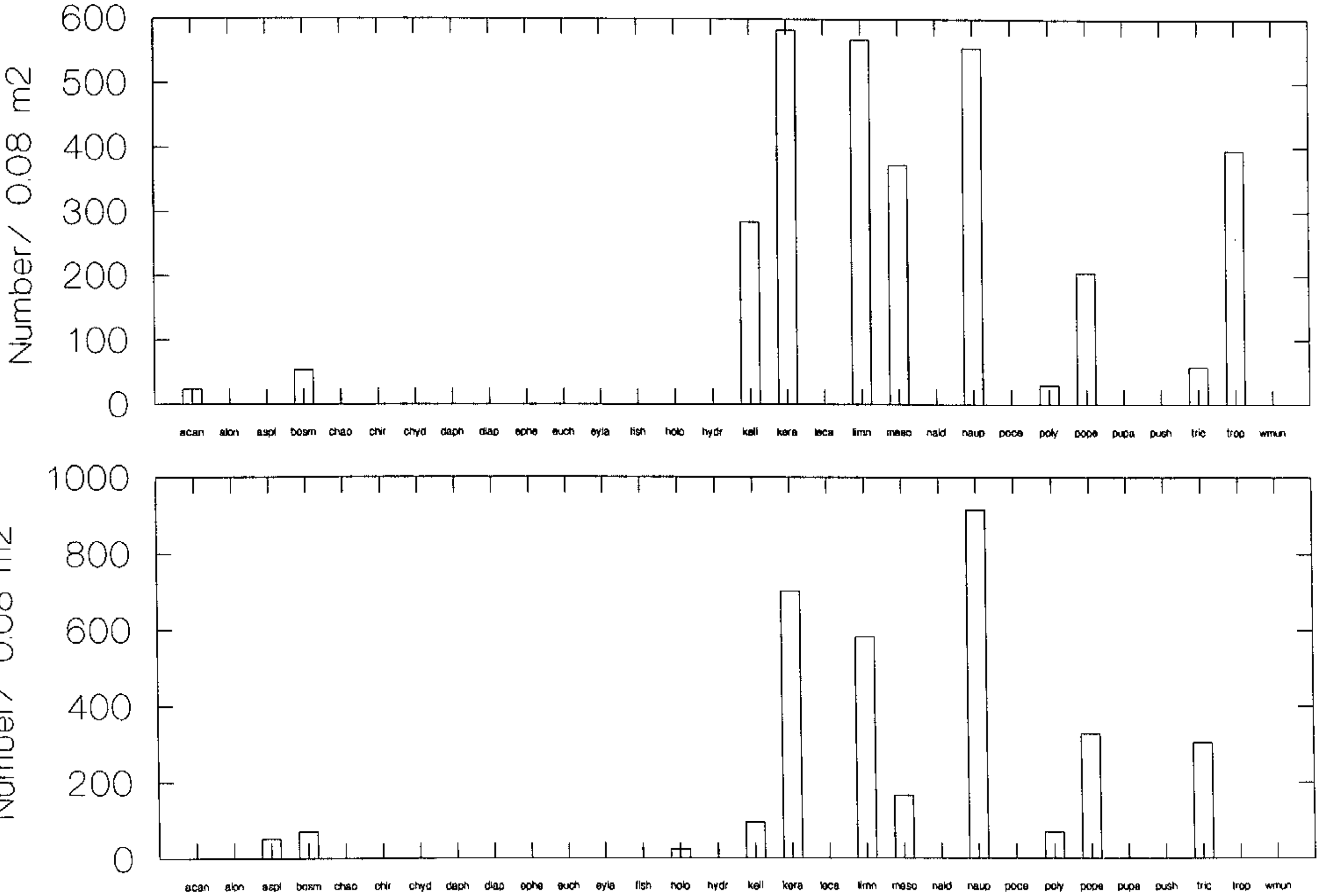




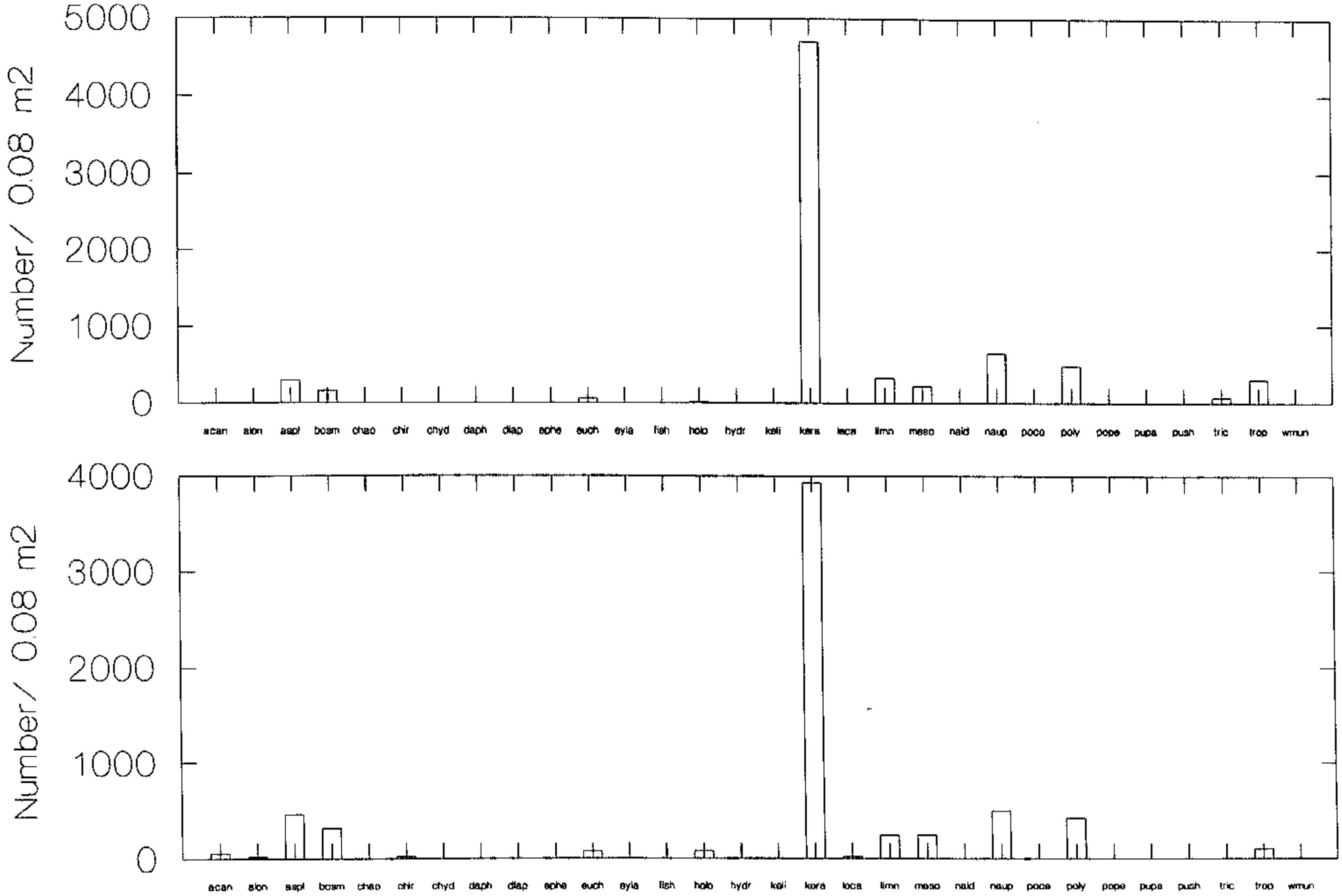
Traps Crampton and Roach June 10



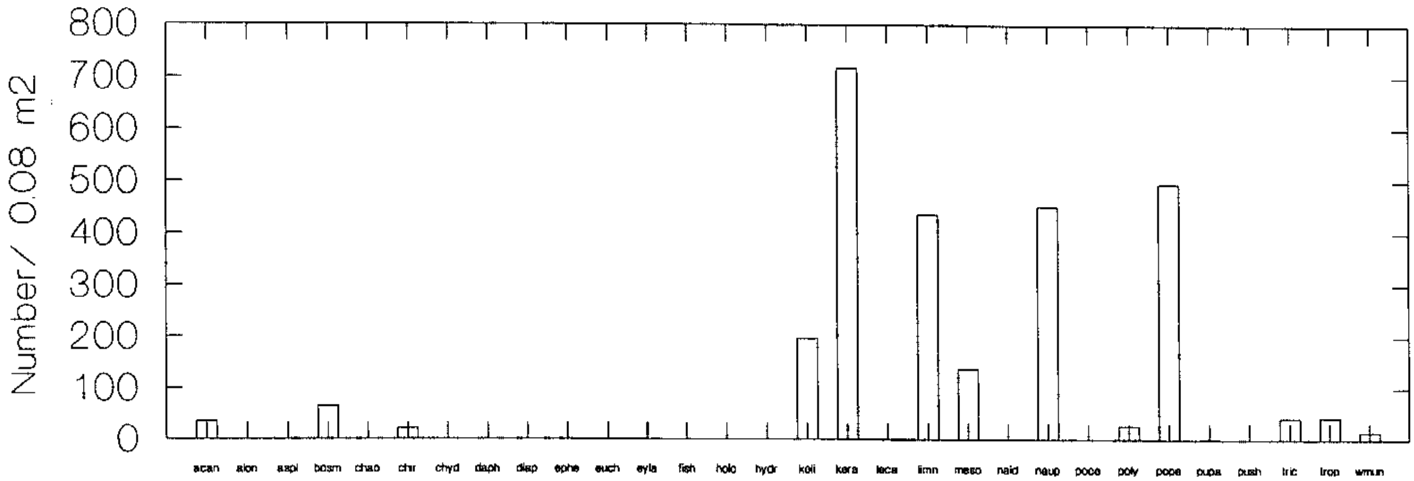
Traps Crampton, June 17

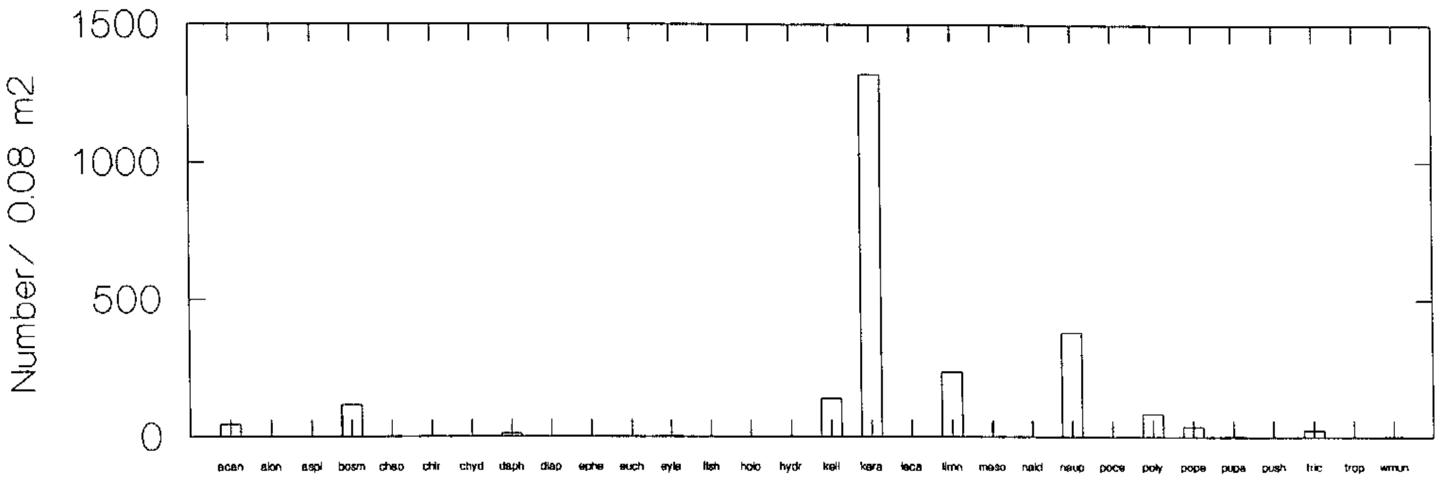


Traps Roach, June 17

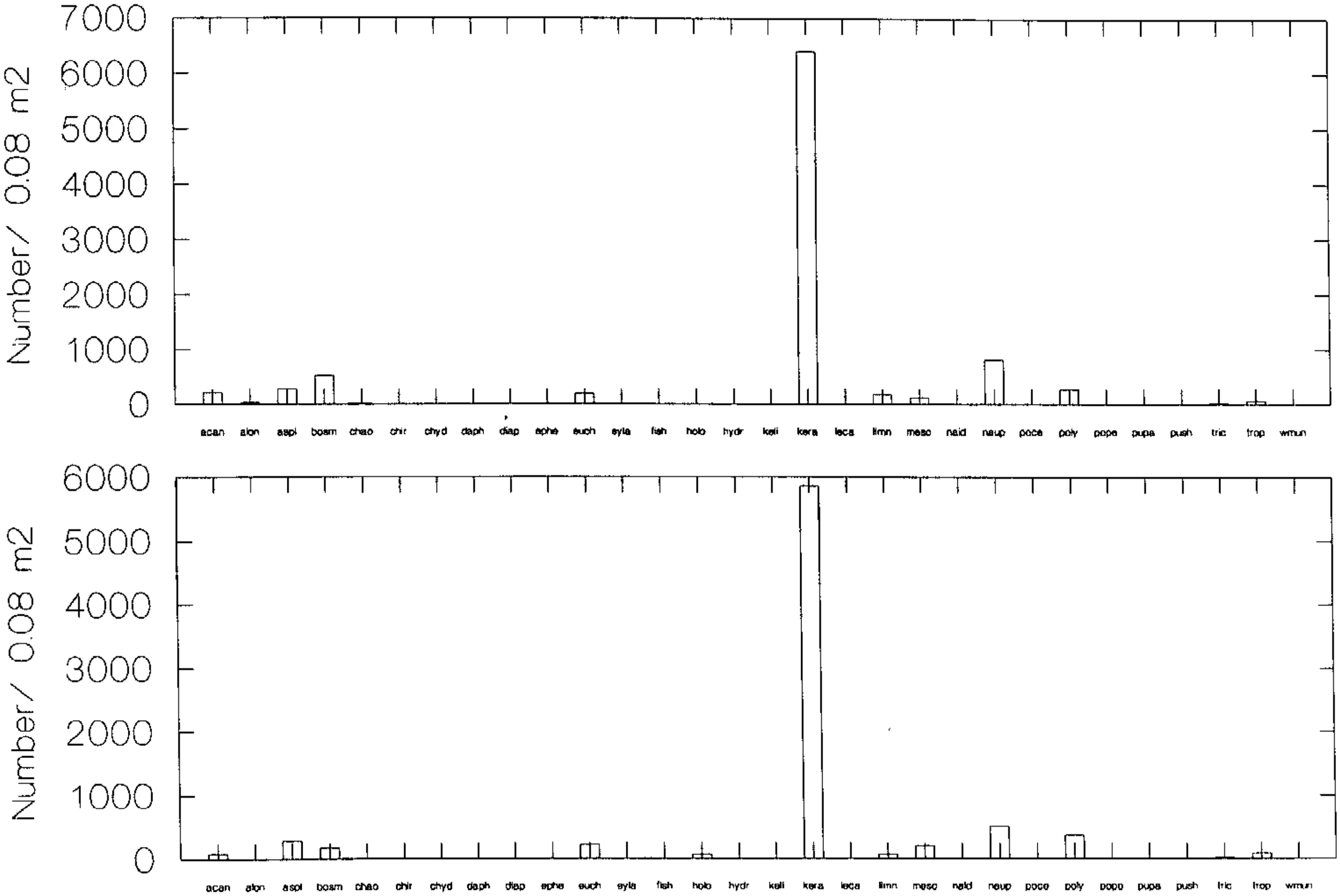


Traps Crampton, June 17-18

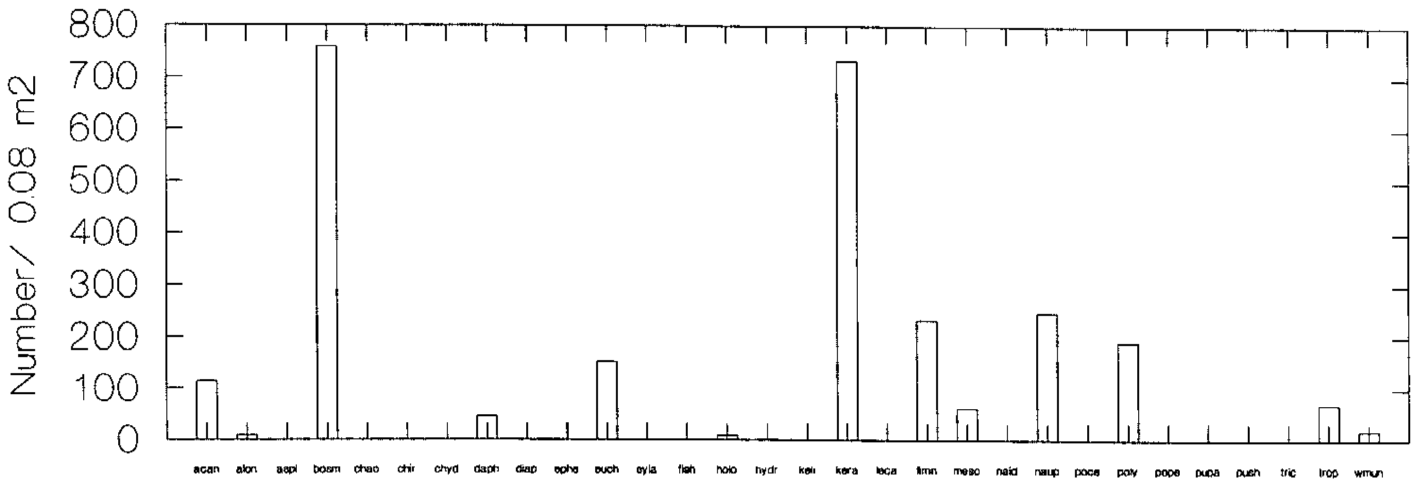


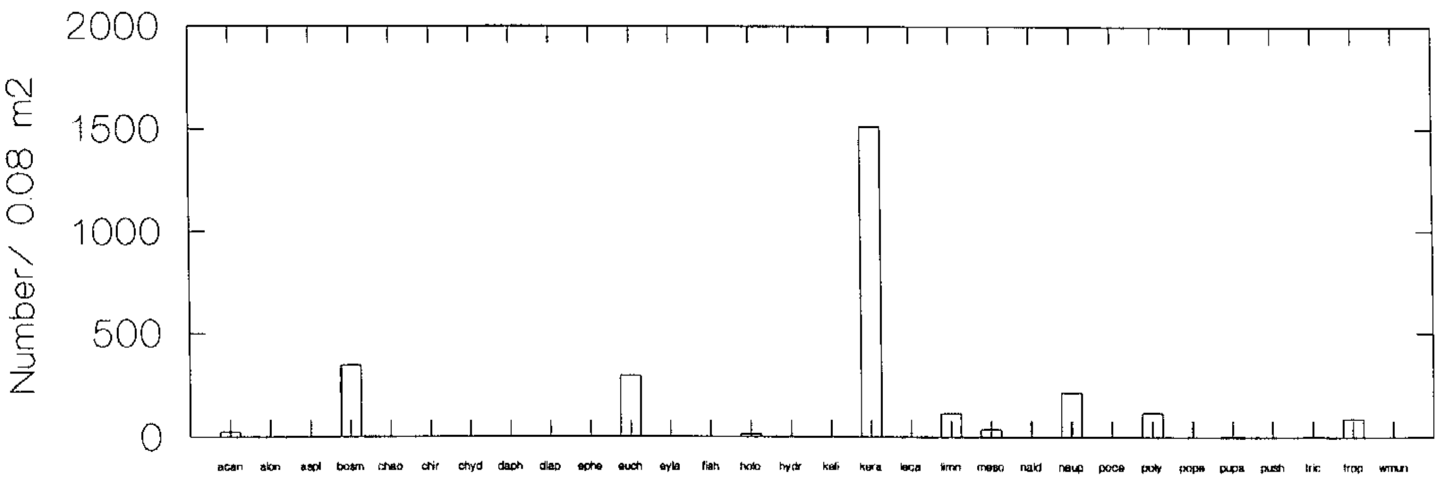


Traps Roach, June 17-18

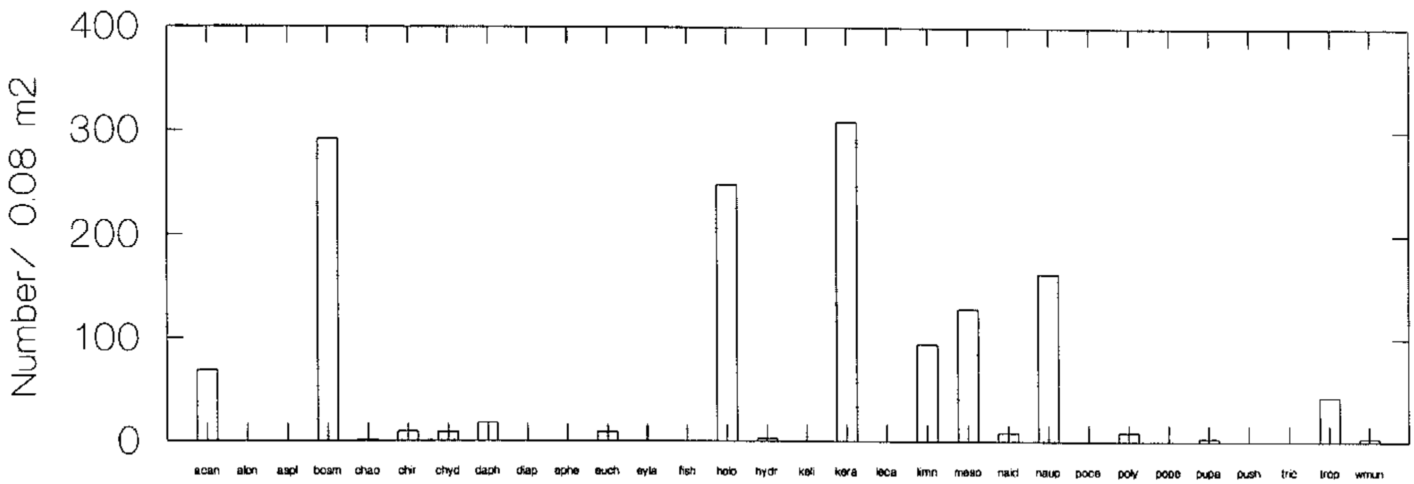


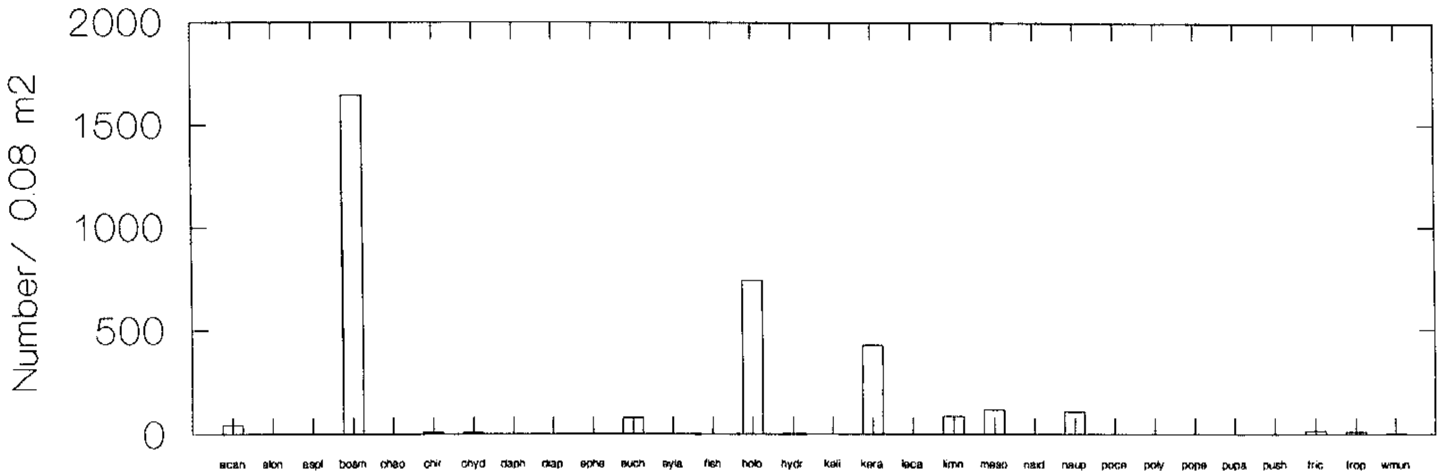
Traps Roach June 29



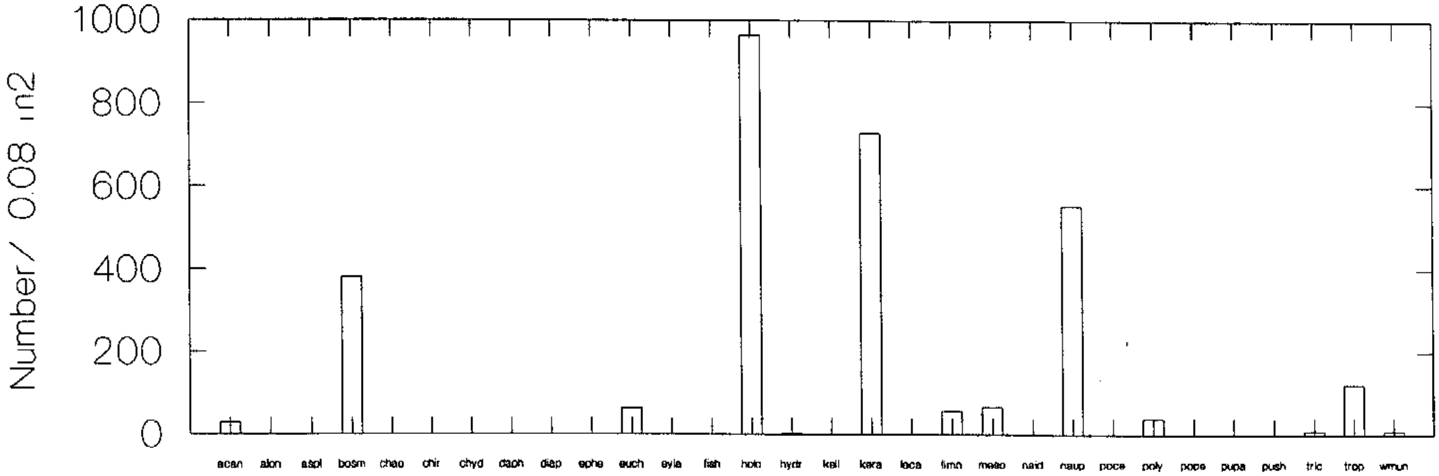


Traps Roach July 7-8

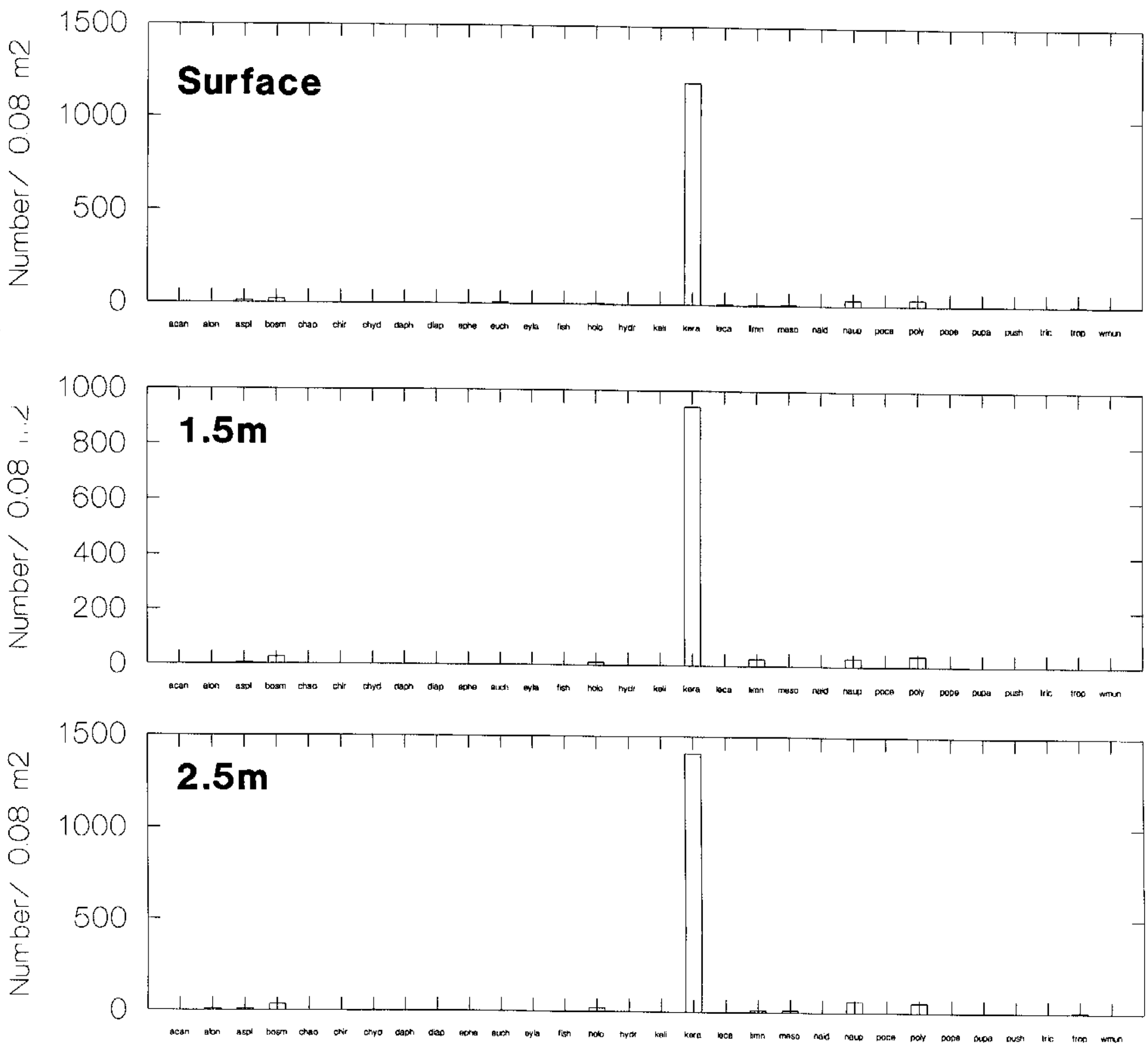




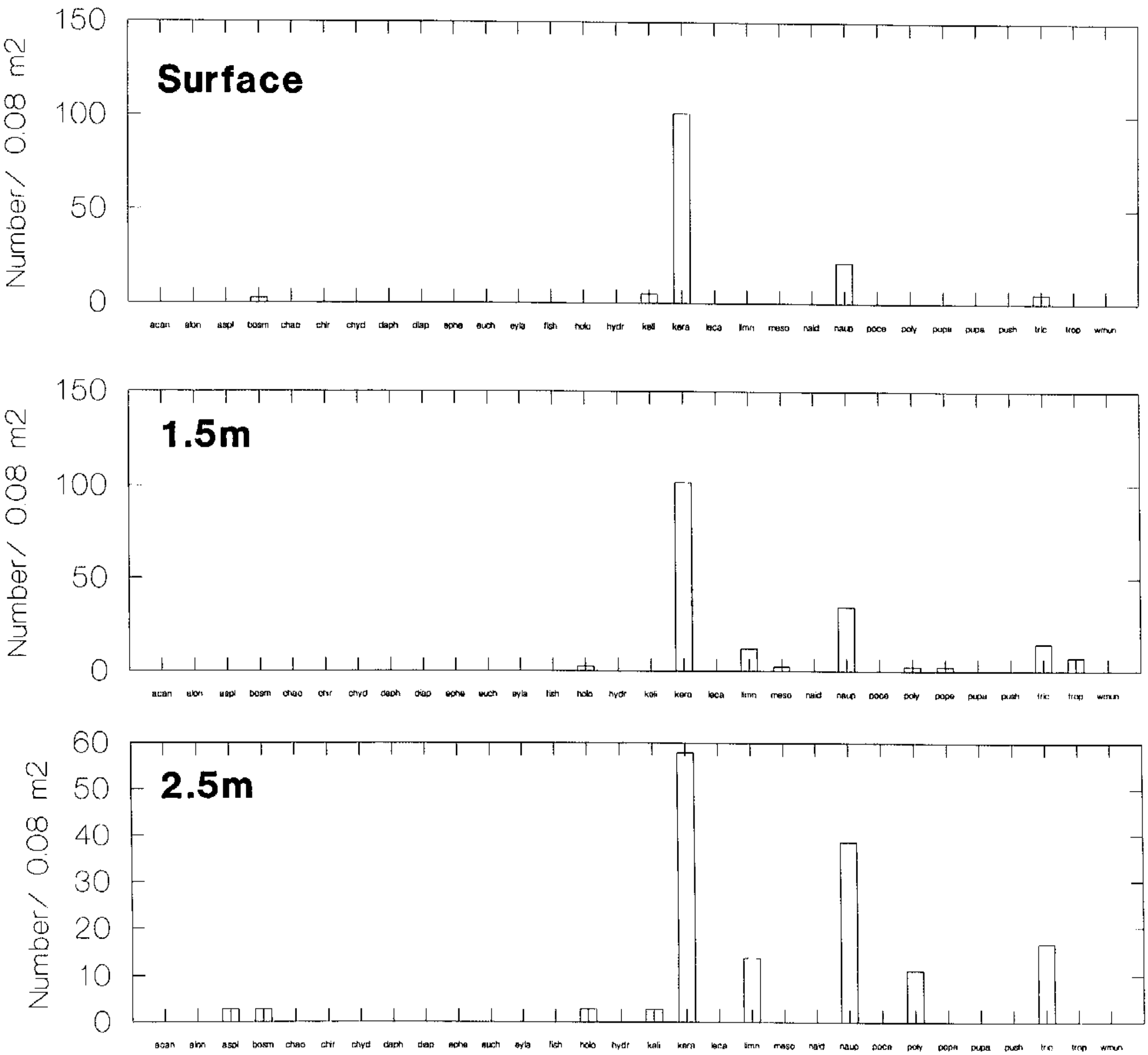
Traps, Roach, July 9



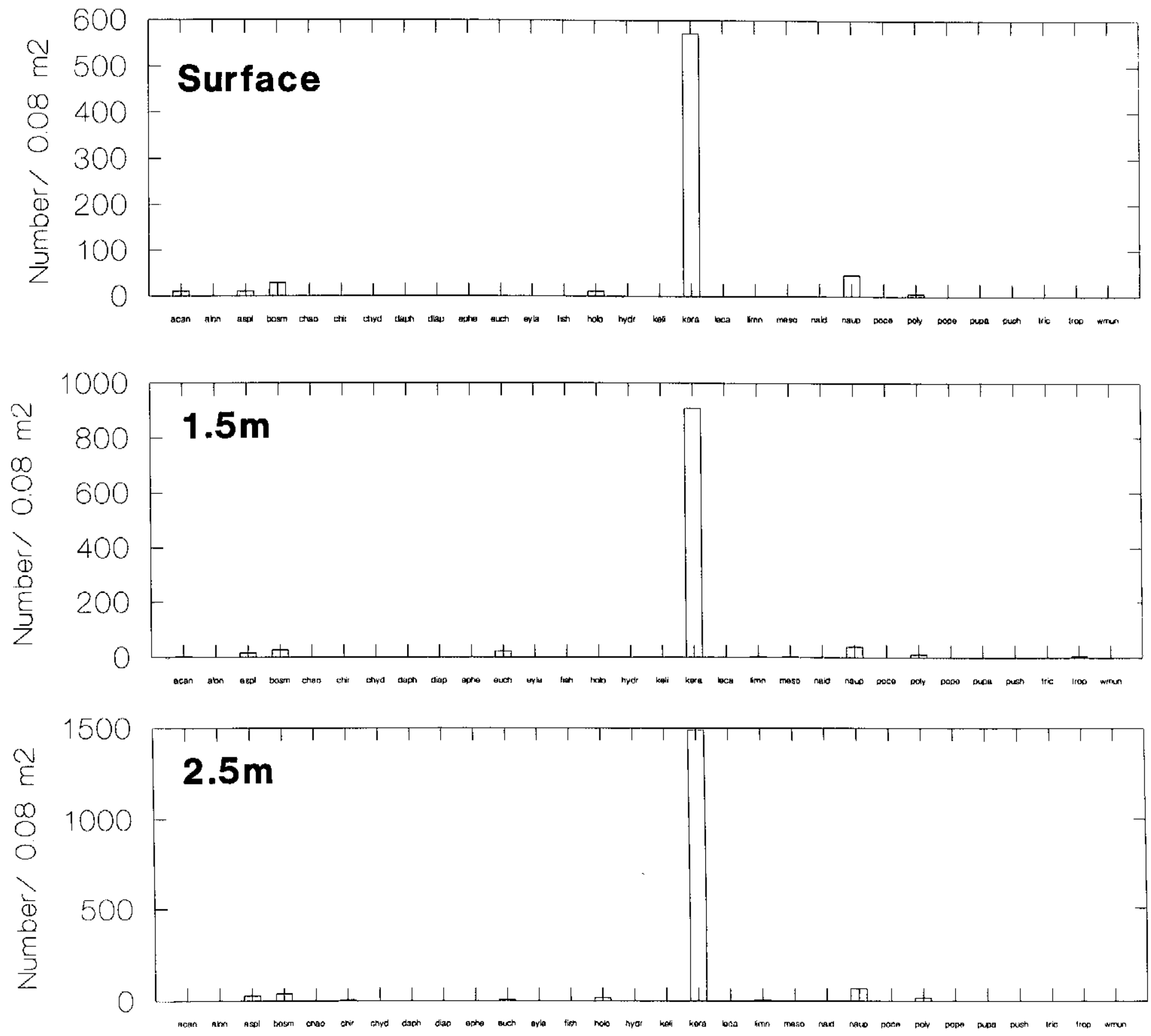
June 17. Schindler Trap, Roach



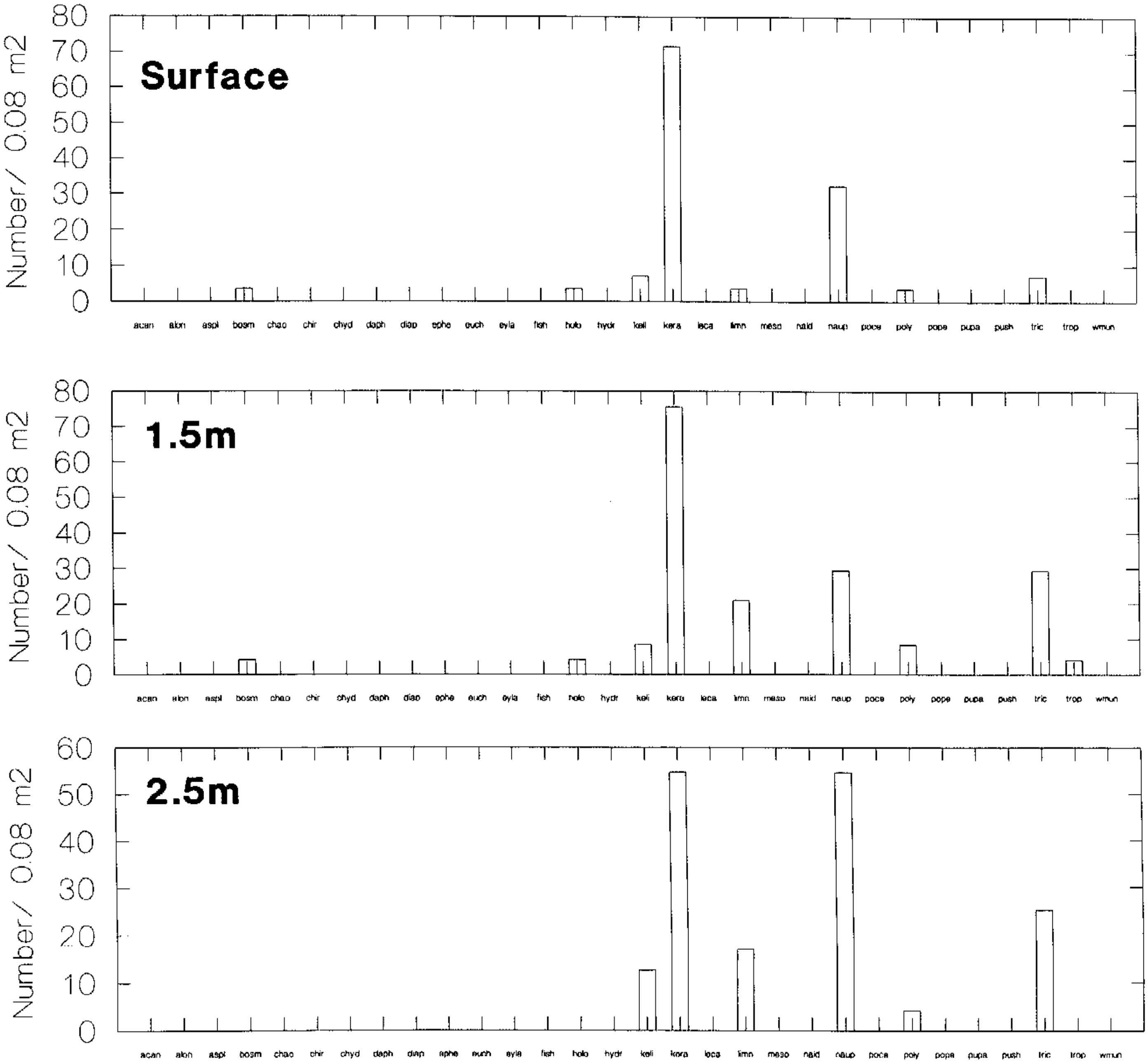
June 17, Schindler Trap, Crampton



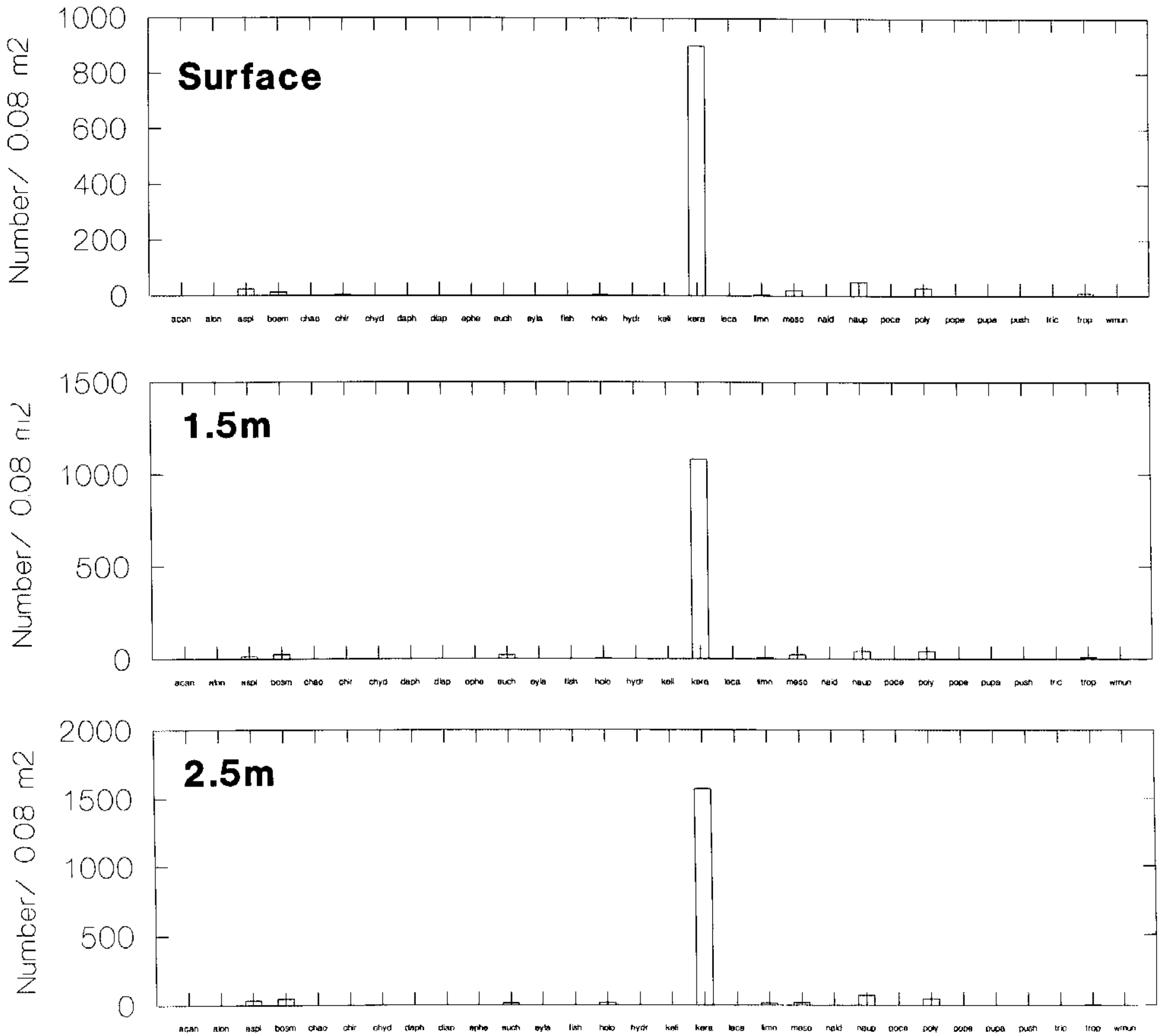
June 17, Schindler Trap, Roach



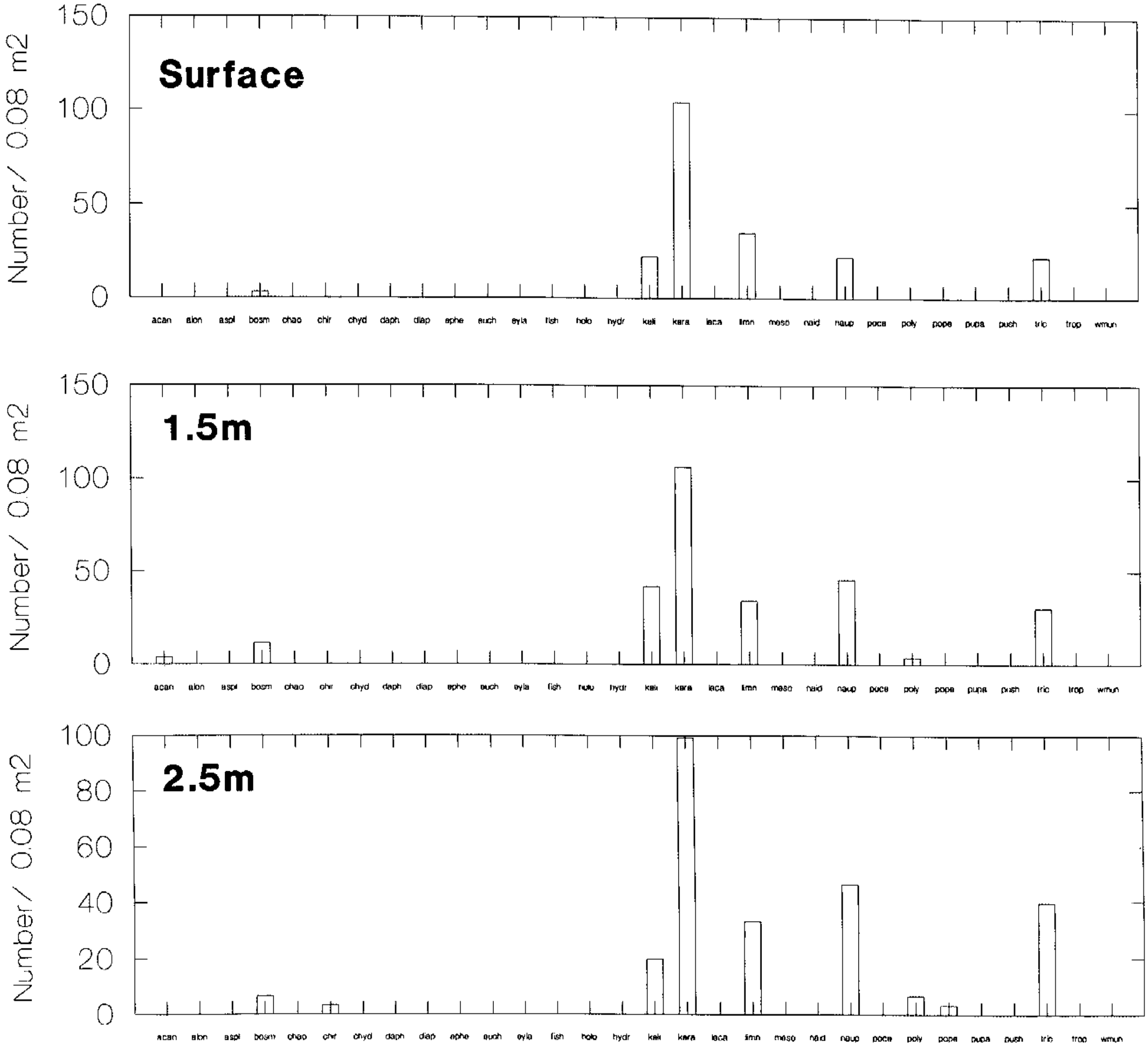
June 17, Schindler Trap, Crampton



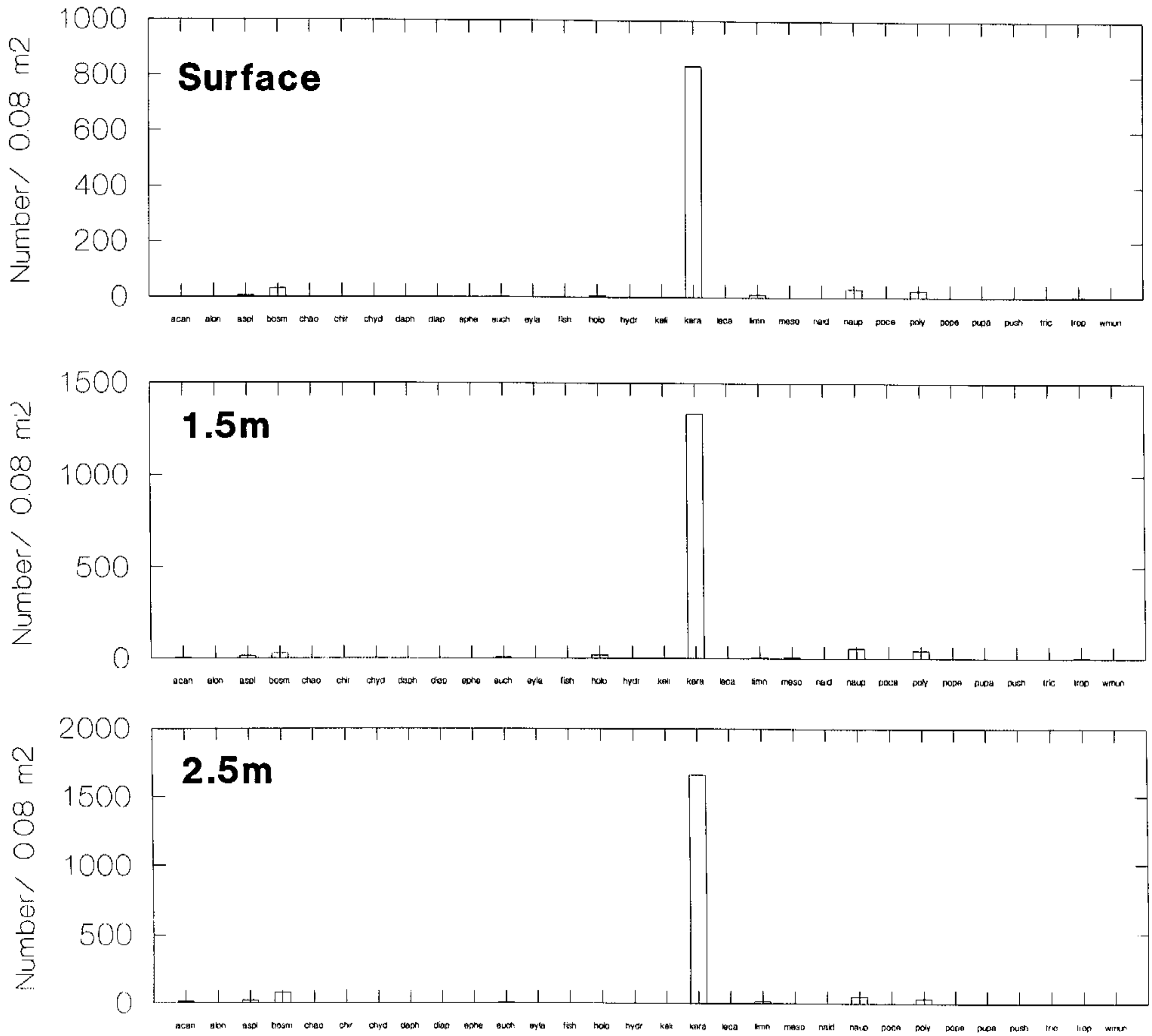
June 18, Schindler Trap, Roach



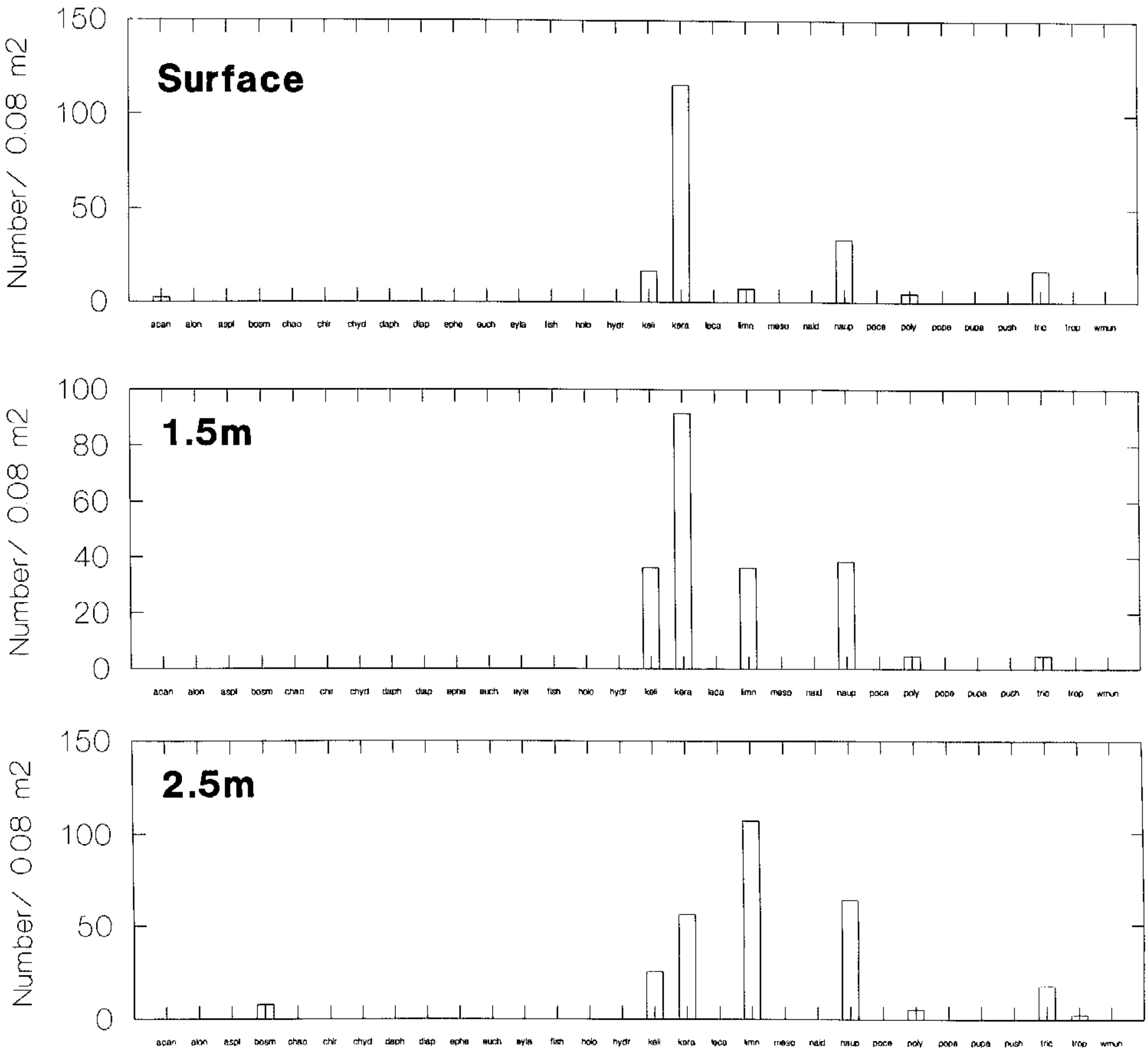
June 18. Schindler Trap, Crampton



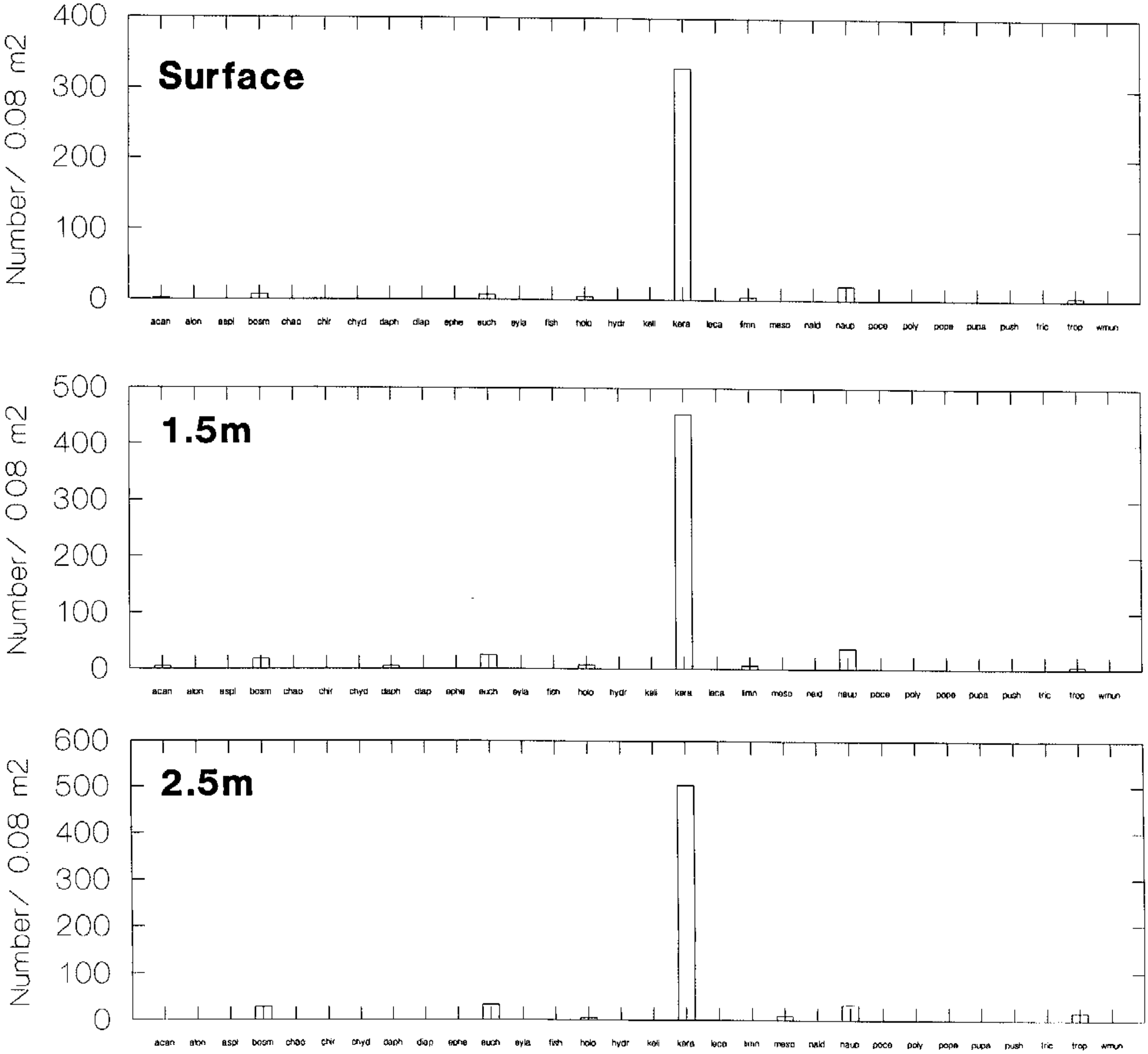
June 18, Schindler Trap, Roach



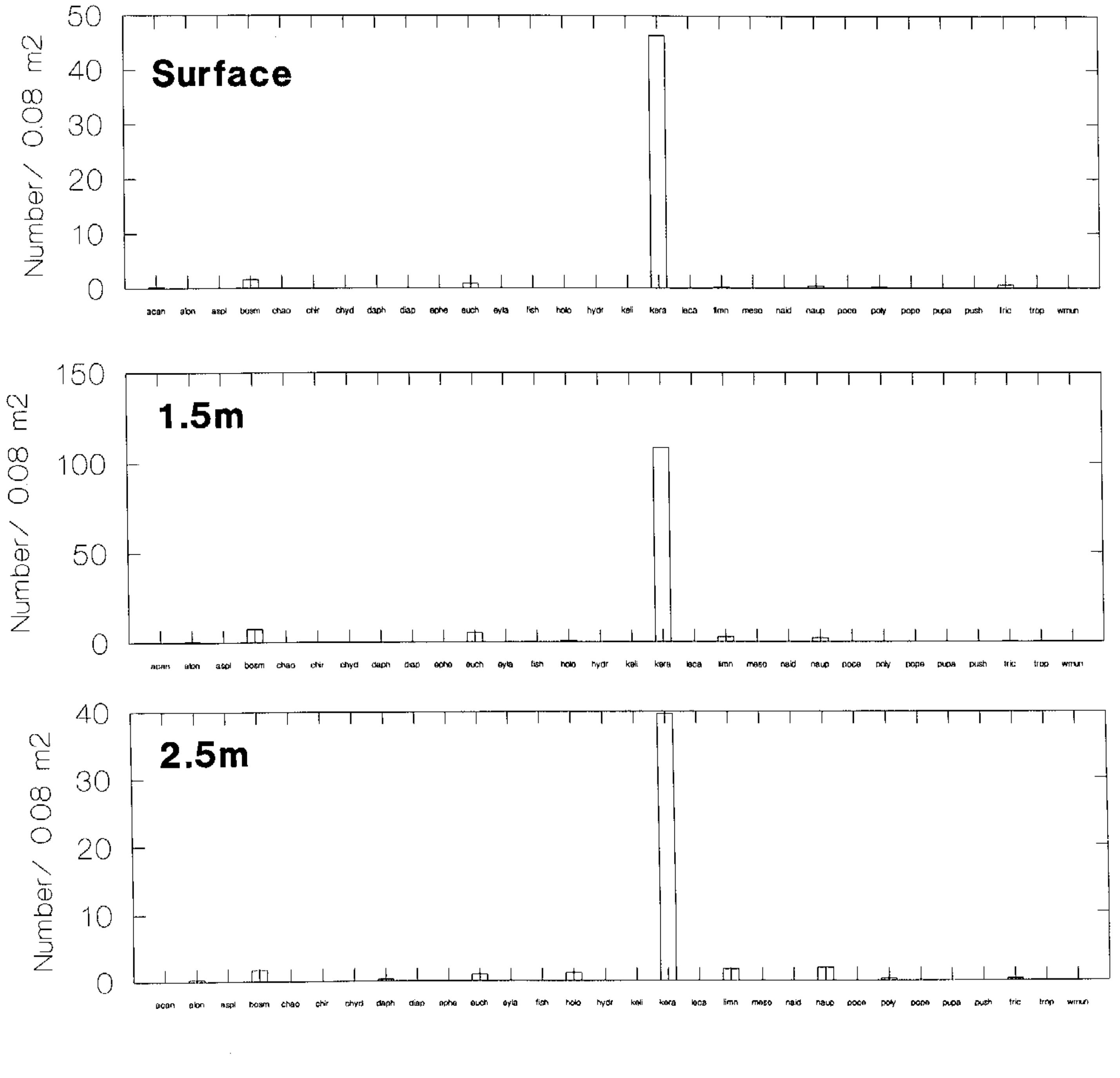
June 18, Schindler Trap, Crampton



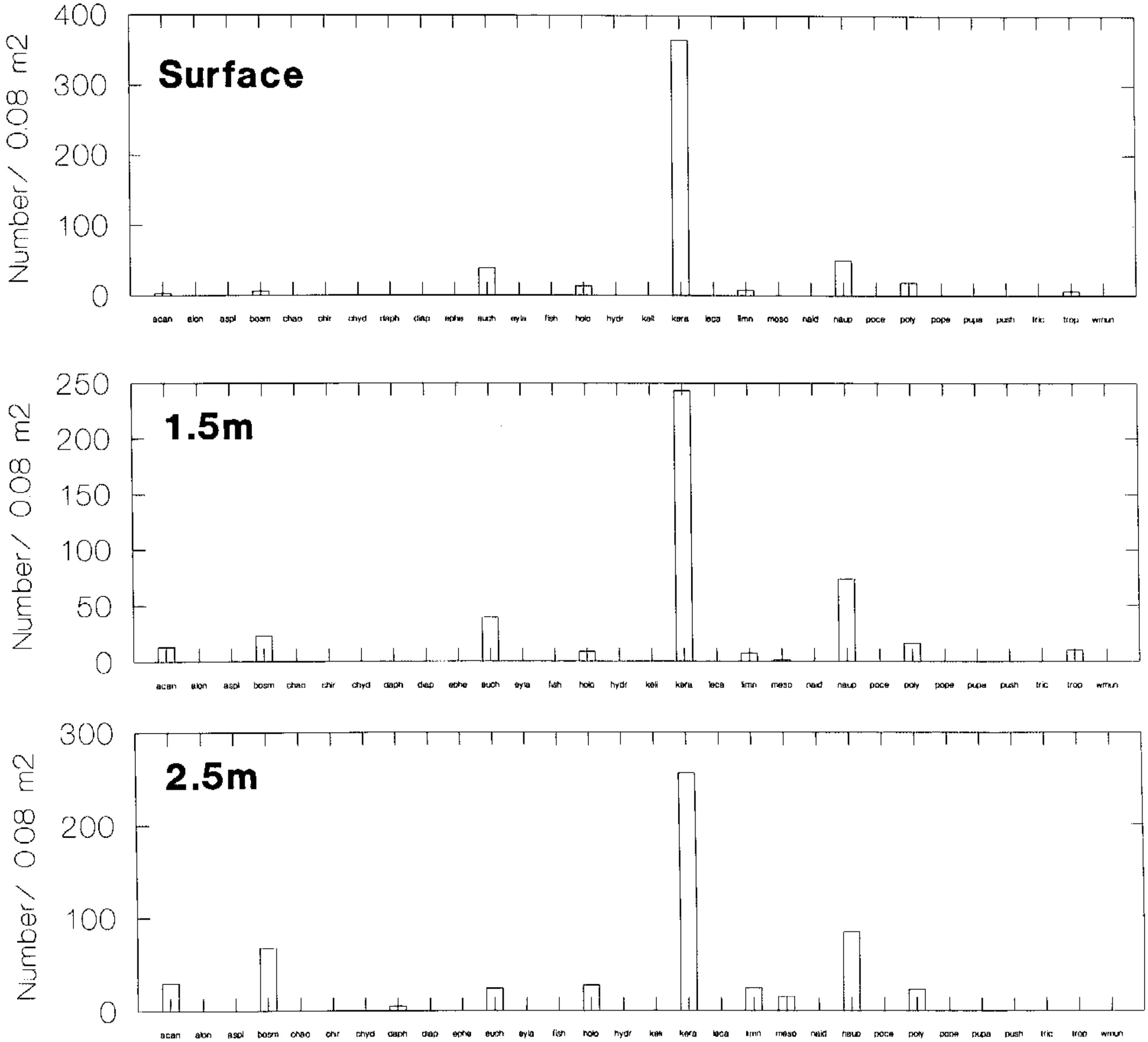
June 29, Schindler Trap, Roach



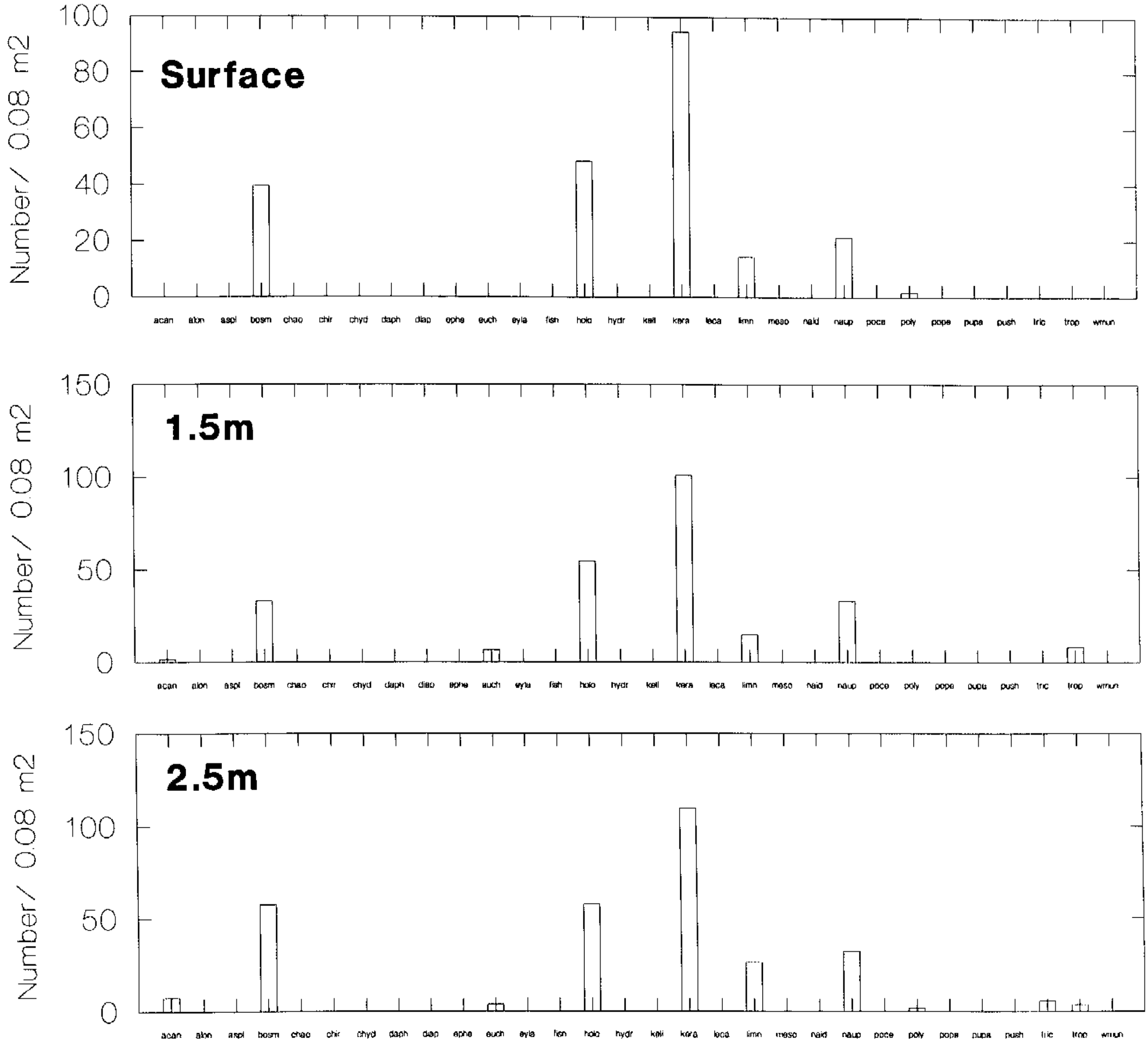
June 29, Zoop Tow, Roach



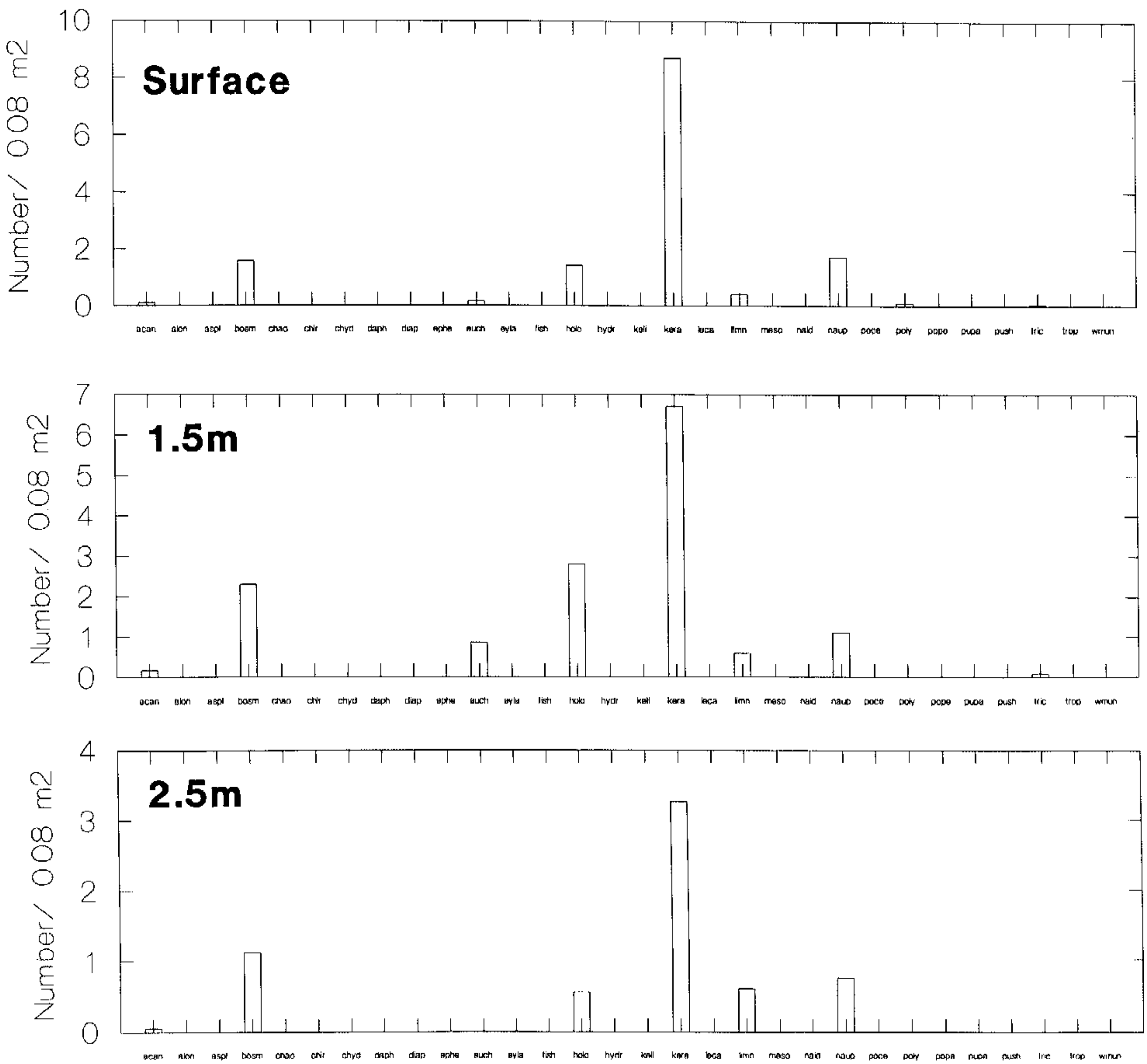
June 30, Schindler Trap, Roach



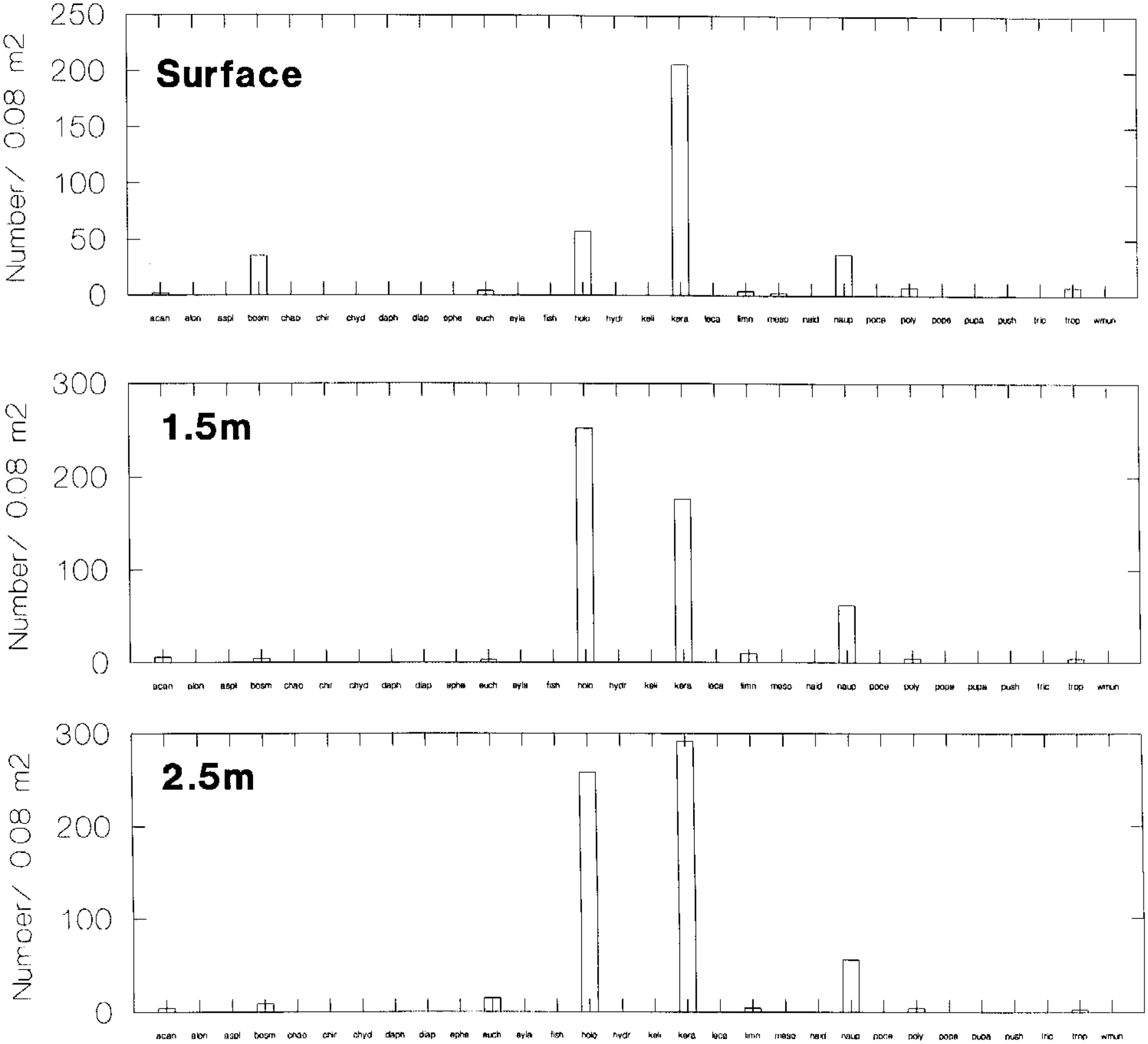
July 8. Schindler Trap. Roach

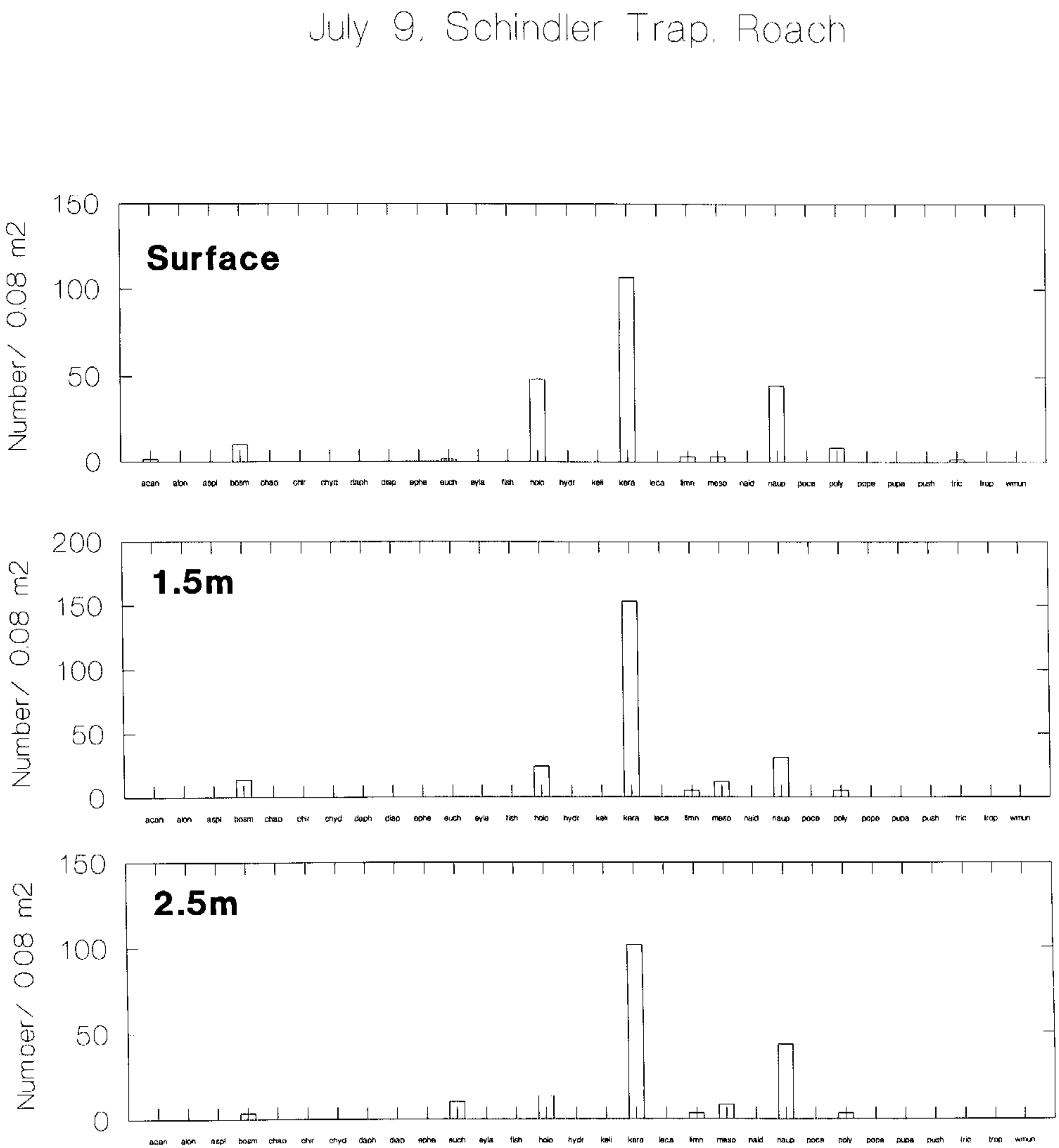


July 8, Zoop Tow, Roach



July 9. Schindler Trap, Roach





July 9, Schindler Trap, Roach
Surface
1.5m
2.5m
Number / 0.08 m2
0
50
100
150
200
acan
alon
aspl
bosm
chao
chir
chyd
daph
diap
ephe
euch
eyla
fish
holo
hydr
keli
kera
leca
limn
meso
naid
naup
poca
poly
pope
pupa
push
tric
trop
wmun