VI.4i. The insects

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In contrast to the situation generally occurring in tropical lakes, even at high altitudes, aquatic insects only represent a secondary component in the benthic fauna of Lake Titicaca and only certain groups are represented. Of course, it has to be acknowledged that although it is possible to be certain of the presence of an organism in a water body by finding it, its absence from samples is not an absolute proof that it is absent from this biotope, especially if this is as huge as Lake Titicaca. It is however remarkable that out of about 200 samples taken from most of the Huiñaimarca and the Bolivian part of the Lago Grande, we have not collected a single Plecoptera, whereas they are generally common in other lakes of the Cordillera (genus *Claudioperla*), nor any Ephemeroptera.

In samples covering several years and almost all seasons, we have collected and identified more than 84,000 benthic macro-invertebrates. Among these the proportion of insects, represented by the following groups, does not reach 20%:

Diptera Chironomidae	16.9%
Other Diptera	0.06%
Coleoptera	1.16%
Trichoptera	0.16%
Odonata	0.005%

Only chironomid Diptera can therefore be considered as being well represented, the other insects being more or less occasional and usually only occurring in very limited and localised biotopes.

The Odonata

Only two species were recorded by Roback *et al.* (1980), which we have also collected on rare occasions.

C. Dejoux and A. Iltis (eds.), Lake Titicaca, 365–382.

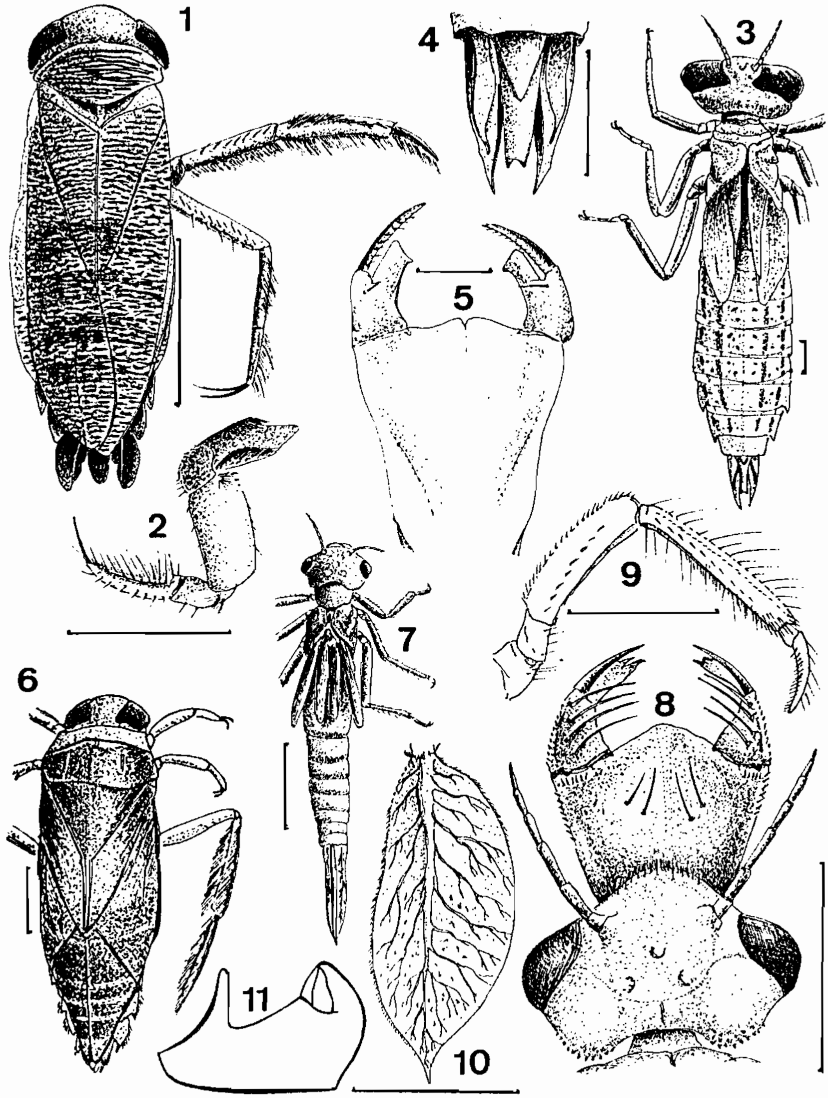

Plate 1. Fig. 1: *Ectemnostegella quechua*; 2: foreleg of male; 3: *Aeschna* (*Herperaeschna*) *peralta*; 4: extremity of the abdomen; 5: mask; 6: *Notonecta virescens*; 11: male paramere; 7: *Protallagma titicacae*; 8: mask and head; 9: foreleg; 10: anal gill lamella.

Protallagma titicacae Calvert, 1909 (Plate 1, Figs 7 to 10)

This a zygopteran belonging to the Coenagrionidae, that has been found at various localities in the Andes at between 3000 and 4300 metres altitude, but never in large numbers. The last nymphal stage, described by Balla (1972) measures about 1.5 cm long, excluding the gill lamellae; the body is elongate and uniform light brown in colour. The abdomen is covered with short spines and ends in elongated gill lamellae about 4 mm long, with spiny borders and a complex tracheal pattern.

It was recorded from the lake for the first time by Calvert in 1909 (Puno and Chililaya). Fraser (1972) refound it near Copacabana and Roback *et al.* (*op. cit.*) recorded it from near the town of Puno. This species is in fact more of an inhabitant of small streams and slow-flowing water courses of the Altiplano, where it lives under stones or among aquatic vegetation. It is most frequent in still water, living among macrophytes which are its preferred habitat.

Despite the fact that Lake Titicaca is very rich in submerged vegetation, it only occurs sporadically in the lake.

Aeschna (Hesperaeschna) peralta Ris, 1918 (Plate 1, Figs 3 to 5)

This species has a very wide distribution in Latin America, from low altitudes up to more than 4000 metres. It is not a large member of the Aeschnidae since the nymph hardly exceeds 3 cm in length. More or less light brown coloured body bears two darker medio-lateral longitudinal lines, formed of a series of spots in the form of exclamation marks, on each segment. In addition, a series of four symmetrical dots occurs along the median line, from the 5th to the 8th abdominal segment. The mask is typical of the family.

Collected in the lake near the town of Puno by Roback *et al.* (*op. cit.*), we have only found a single specimen among aquatic vegetation from Achacachi Bay. Given that it occurs fairly regularly on the Altiplano in small pools containing macrophytes, we think that its occurrence in the lake is, like that of *Protallagma titicacae*, only accidental.

The Hemiptera

The only Hemiptera recorded from Lake Titicaca are small Corixidae of the genus *Ectemnostegella*, a genus restricted to the mountainous regions of South America, and a Notonectidae, also known as an inhabitant of the Andes. Their occurrence in the lake is very sporadic, or even rare, whereas the genus *Ectemnostegella* for example occurs abundantly in all the stagnant water pools on the Altiplano and among the vegetation of numerous high altitude lakes. This genus is particularly abundant in the peat bogs of the Cordillera, where the waters are slightly acid. The slight salinity of the waters of Lake Titicaca is perhaps a factor limiting its development in this habitat.

Ectemnostegella quechua Bachmann, 1961 (Plate 1, Figs 1 and 2)

This species, originally described from the Andes in northern Argentina, was rediscovered by the Catherwood expedition among aquatic vegetation from Puno Bay, and in similar biotopes in Copacabana Bay (Roback *et al.*, *op. cit.*). We ourselves have collected it on two occasions in Achacachi Bay, close to the shore.

This small-sized Corixidae (4 to 5 mm at the adult stage) is distinguished from other species in the genus by the last segments of the foreleg of the male being elongated and narrow and by the form of the terminal part of the paramere, which is subparallel (Fig. 11) (Bachmann, 1962).

Ectemnostegella tumidacephala Hungerford, 1948

Also collected from Puno Bay by the Catherwood Expedition, Roback *et al.* (*op. cit.*) were not absolutely certain of the identification of this species that we ourselves have never found in our samples. Its occurrence in the lake needs confirmation.

Notonecta virescens Blanchard, 1852 (Plate 1, Fig. 6)

Uncommon in stagnant water, but also present in the Andes in Argentina, Chile, Bolivia and Peru, a single record exists for Lake Titicaca (Roback *et al.*, *op. cit.*).

The Coleoptera

These are hardly more diverse than the preceding groups and with the exception of the Elmidae, they are a rare component of the margins of the Lake Titicaca.

Elmidae

This family is no better represented than the following families, but its single representative in the lake *Austrelmis consors* Hinton, 1940, is relatively abundant in certain biotopes. The larvae and adults of this species (Plate 2, Figs 1–16) are found among submerged aquatic vegetation, mainly among *Elodea* and *Chara*. It is more frequent along the shorelines, inhabiting the undersides of stones. Hinton (1940) recorded it at down to 11 metres depth and we have found it down to 17 metres, but its preferred habitat is between 0.5 and 2 metres depth.

Hydrophilidae

Only three genera are recorded from the Lake Titicaca region: *Berosus*, *Enochrus* and *Tropisternus* (Roback *et al.*, *op. cit.*). The first two are possibly represented in the lake by only one species and the third by two species. This uncertainty is due to the fact that the publications records them from " Puno at Lake Titicaca ", without giving further details of the collection locality. It is therefore possible that these species came from lentic habitats situated at or near Puno, but not in the lake itself, the same being the case for the species they recorded from Huatajata, a small village on the shores of the Huiñaimarca. This is important, since it is possible that, as in the case of other insects, the lake's water is unsuitable for the development of these species, whereas they can find favourable conditions in nearby habitats.

The species recorded are *Berosus chalcocephalus andinus* Mouchamps 1963, *Enochrus* (*Hugoscottia*) *peruvianus* d'Orchymont 1941, *Tropisternus setiger* Germar 1824 and *T. lateralis limbatus* Brulle 1837. We ourselves have only ever collected two identical larvae of Hydrophilidae, among aquatic vegetation in the Huiñaimarca, which we are incapable of attributing to one or other of these species (Plate 3, Fig. 1).

Dytiscidae

Only one small species of Hydroporinae, *Liodessus andinus* Guignot 1937, has been recorded from the lake (Puno and Copacabana bays) by Roback *et al.*, 1980. We ourselves have collected two larvae among aquatic vegetation from the bottom of Achacachi Bay, but which we again cannot attribute to this species with certainty (Plate 3, Fig. 2). These rare collections of adults and larvae from Lake Titicaca, contrasting with the more abundant records from neighbouring lentic habitats, again prove that insects do not find the lake a very propitious environment for their development.

The Diptera

No Diptera other than Chironomidae were collected in Lake Titicaca by the Catherwood Expedition. In contrast, our own collections have produced 48

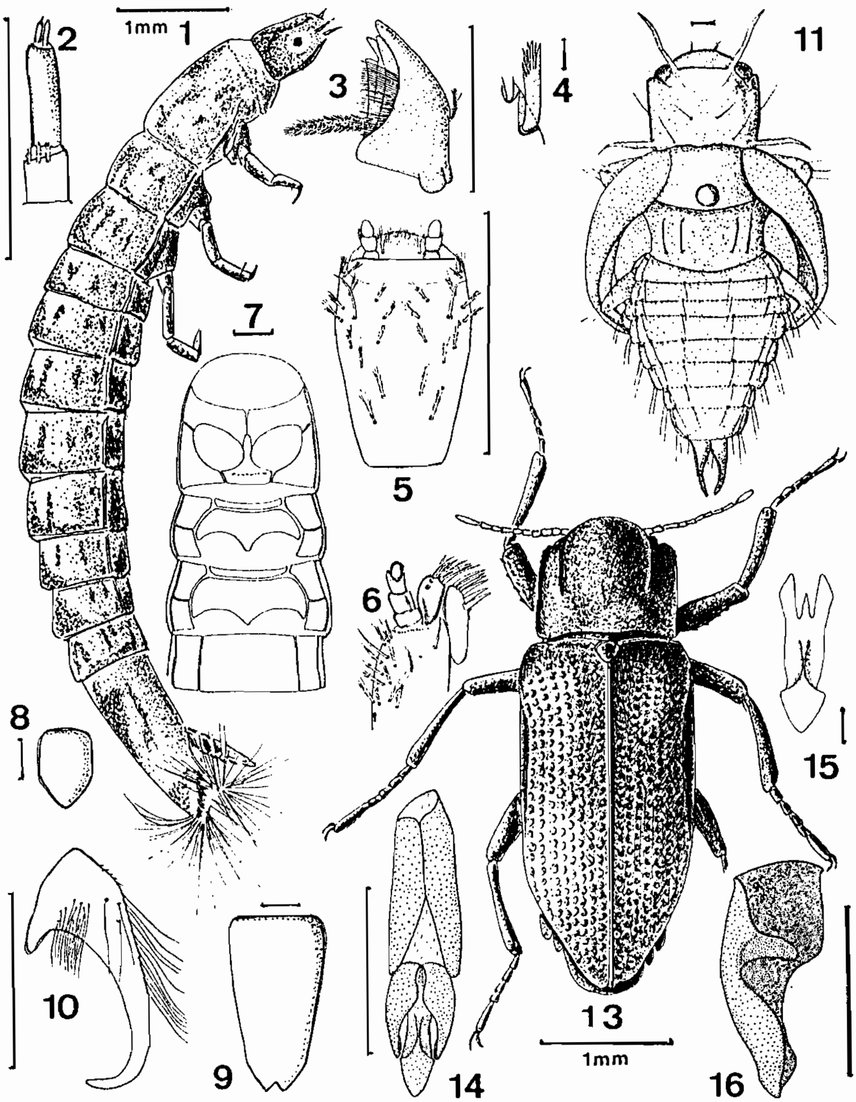

Plate 2. Austrelmis consors. Fig. 1: larva; 2: antenna of larva; 3: mandible; 4: bristle of anterior border of labrum; 5: ventral view of labium; 6: ventral view of right maxilla; 7: ventral view of thorax; 8: ventral view of the operculum; 9: dorsal view of 9th abdominal segment; 10: left opercular claw; 11: pupa; 13: adult; 14: male genitalia; 15: dorsal view of the median lobe; 16: ventral view of paramere. (from Hinton, 1940, except for Figs 1 and 13).

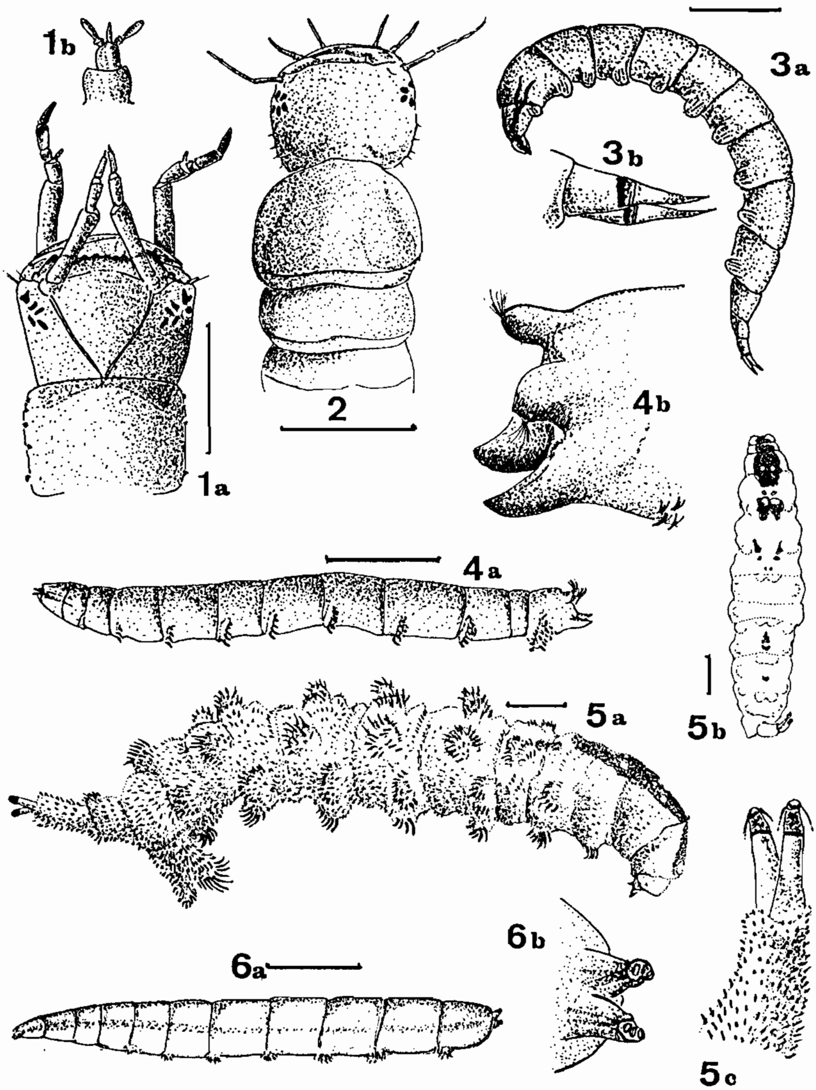

Plate 3. Fig. 1a: Hydrophilidae larva; 1b: ligula; 2: Dytiscidae larva; 3a: Dolichopodidae larva; 3b: extremity of abdomen; 4a: Dolichopodidae larva; 4b: extremity of abdomen; 5a: Ephydridae larva; 5b: ornamentation of the dorsal surface; 5c: extremity of abdomen; 6a: Dolichopodidae larva; 6b: extremity of abdomen.

individuals representing a little less than 0.06% of all the invertebrates examined from the lake. They are therefore rare and, with the exception of the Ephydridae, which were collected from sediments from the shorelines (Plate 3, Fig. 5), all the others come from among aquatic vegetation, either from the Huiñaimarca or from Achacachi bay.

Three species of Dolichopodidae, that we have not been able to identify any further, have been found; drawings of these are given in Plate 3, Figs 3, 4 and 6.

Chironomidae

This is by far the best represented group of insects in Lake Titicaca.

The first records of chironomids from this habitat appeared in the works of Brundin (1956) and only concerned Puno Bay. He did however compare the specimens collected from this locality with other samples made in neighbouring high latitude lakes and found the Bay to be relatively rich. He recognised 9 species for which he only gave the genera: 2 species of *Chironomus*, 1 *Polypedilum*, 1 species from a genus close to *Polypedilum*, 1 *Paratanytarsus*, 2 *Syncricotopus*, 1 species from the *Pseudosmittia* group and finally 1 *Corynoneura*. No description of the species collected was given, so that it is difficult to find the correspondence that may exist between these species and certain of the 15 taxa recorded nearly thirty years later by Roback and Coffman (1983) in their study of material brought back from the Bolivian and Peruvian Altiplano by the Catherwood Expedition. These latter in any case only identified the specimens collected incompletely and described them only to the generic level, with the exception of one species of *Polypedilum*. The material at their disposal was not representative of the entire lake since it came essentially from three regions: Puno Bay and its immediate neighbourhood (Capachica Peninsula) and the areas around Copacabana, together with a few samples made at Huatajata. In addition to *Polypedilum (Tripodura) titicacae*, they recognised two species of *Cricotopus sensu stricto*, three species of *Cricotopus*, probably belonging to the subgenus *Isocladius*, one species attributed without certainty to the genus *Paracladius*, a *Pseudosmittia*, a *Corynoneura*, two species of the genus *Chironomus* and finally three Tanytarsini belonging to the genera *Tanytarsus*, *Paratanytarsus* and *Rheotanytarsus*.

Plates 4 to 7 represent the descriptions of the main species recorded by Roback and Coffman (*op. cit.*).

Our samples of the benthic fauna from the Bolivian part of the lake have provided us with numerous chironomid larvae and pupae as well as a few adults, captured along the shore or over the lake itself at emergence. These data have enabled us to define the status of these Diptera within this geographical area.

The proportions of the various species among the more than 14,000 chironomid larvae examined, are given in Table 1. It is immediately evident that during the period of study, 2 genera clearly dominated, one living mainly among aquatic vegetation (*Rheotanytarsus*) and the other in the sediments (*Chironomus*).

Although it is certain that the *Chironomus* species that we have collected is the same as the *Chironomus* sp. 1 recorded by Roback and Coffman, the

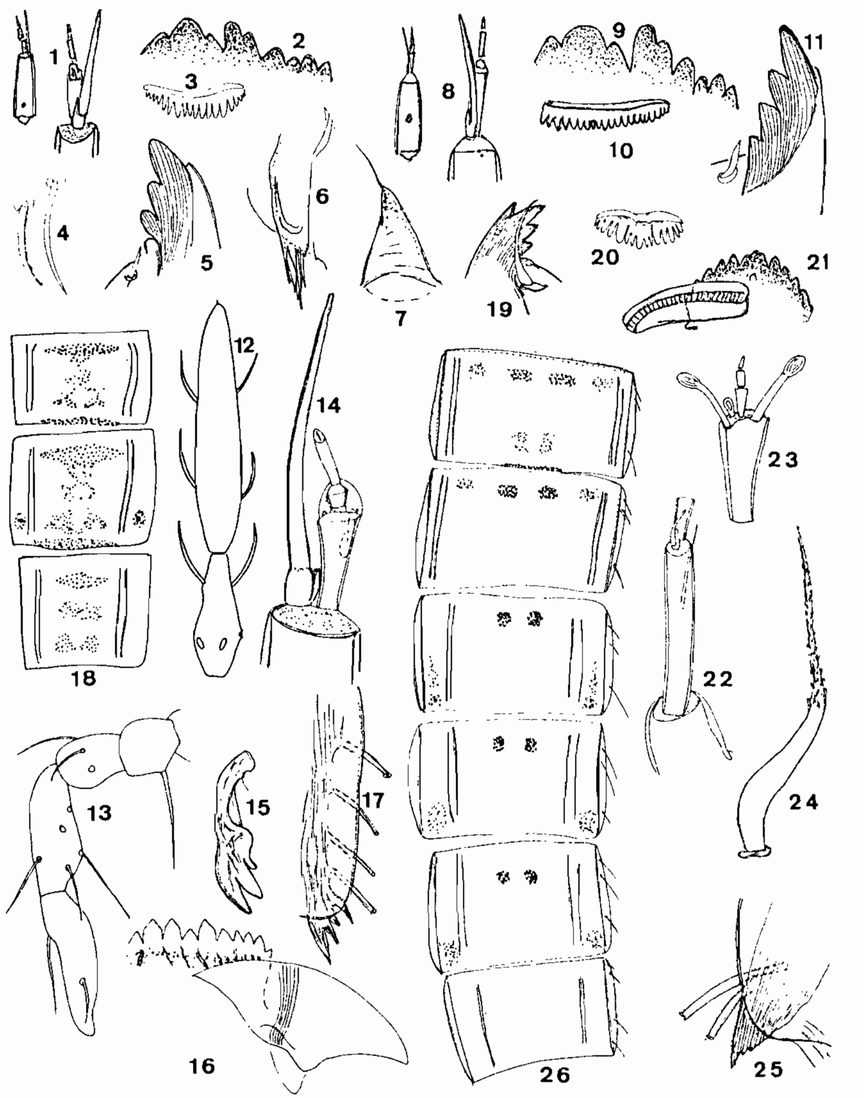

Plate 4. Chironomus sp. 1. Fig. 1: antenna of larva and detail of apical segments; 2: mentum teeth; 3: epipharyngeal comb; 4: anterior and posterior epipharyngeal setae; 5: apex of mandible; 6: lateral spur of last abdominal segment of the pupa; 7: cephalic tubercle. *Chironomus* sp. 2. 8: antenna of larva and detail of apical segments; 9: mentum teeth; 10: epipharyngeal comb; 11: apex of mandible. *Polypedilum* (*Tripodura*) *titicacae*. 12: last segments of antenna of female; 13: palp; 14: detail of last segments of antenna of larva; 15: premandible; 16: mentum and paralabial plate; 17: lateral spur of last abdominal segment of pupa; 18: ornamentation of tergites III to VI. *Paratanytarsus* sp. 19: apex of mandible; 20: epipharyngeal comb; 21: mentum and paralabial plate; 22: basal segments of the antenna; 23: apex of antenna; 24: respiratory organ of pupa; 25: lateral spur of the last abdominal segment; 26: abdominal tergites. (from Roback and Coffman, 1983).

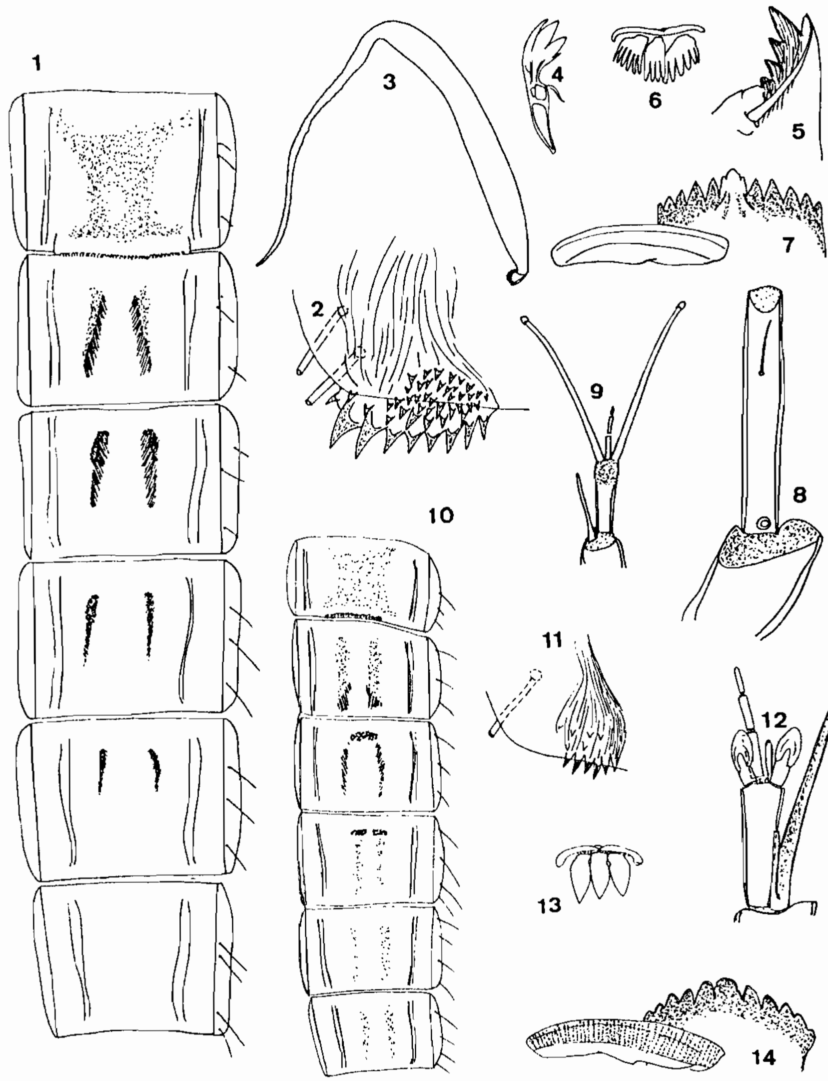

Plate 5. Tanytarsus sp. Fig. 1: abdominal tergites of pupa; 2: lateral spur of the last abdominal segment; 3: respiratory organ; 4: larval premandible; 5: mandible; 6: epipharyngeal comb; 7: mentum and paralabial plate; 8: segments at the base of the antenna; 9: terminal segments of antenna. *Paratanytarsus* sp.; 10: abdominal tergites of pupa; 11: lateral spur of the last abdominal segment; 12: terminal segments of antenna of larva; 13: epipharyngeal comb; 14: mentum and paralabial plate. (From Roback and Coffman, 1983).

species belonging to the genus *Rheotanytarsus* in contrast is not the same as that described by them. The difference in the larvae is slight although they do have Lauterborn organs on the antennae which are much shorter (about half the length of the last three segments combined). The paralabial plates

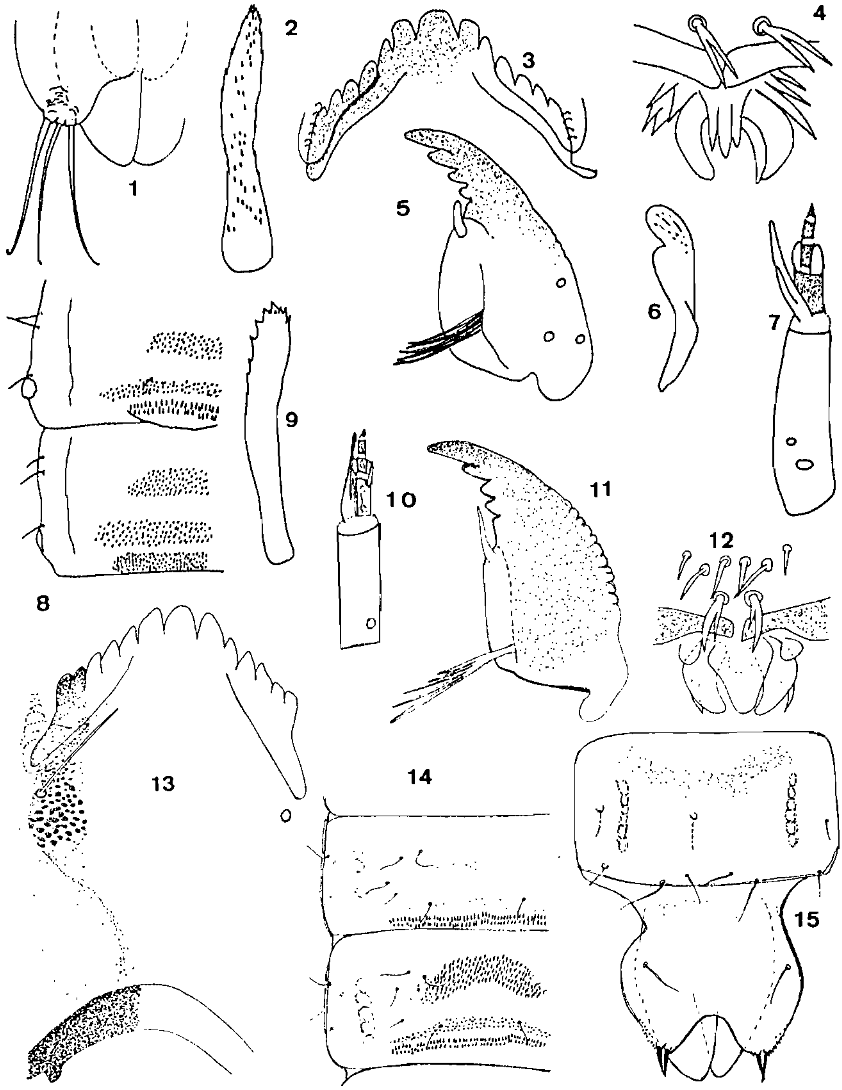

Plate 6. Cricotopus (*Cricotopus*) sp. 2. Figs 1 and 2: lateral setae of the last abdominal segment and respiratory organ of the pupa. *Cricotopus* (*Cricotopus*) sp. 3. 3 and 4: mentum and epipharyngeal comb of the larva; 5, 6 and 7: mandible, premandible and antenna; 8 and 9. abdominal tergites and respiratory organ of pupa. *Cricotopus* (*Isocladius*?) sp. 1. 10, 11, 12 and 13: antenna, mandible, epipharyngeal comb and mentum of larva; 14 and 15: abdominal tergites and last abdominal segments of pupa. (from Roback and Coffman, 1983)

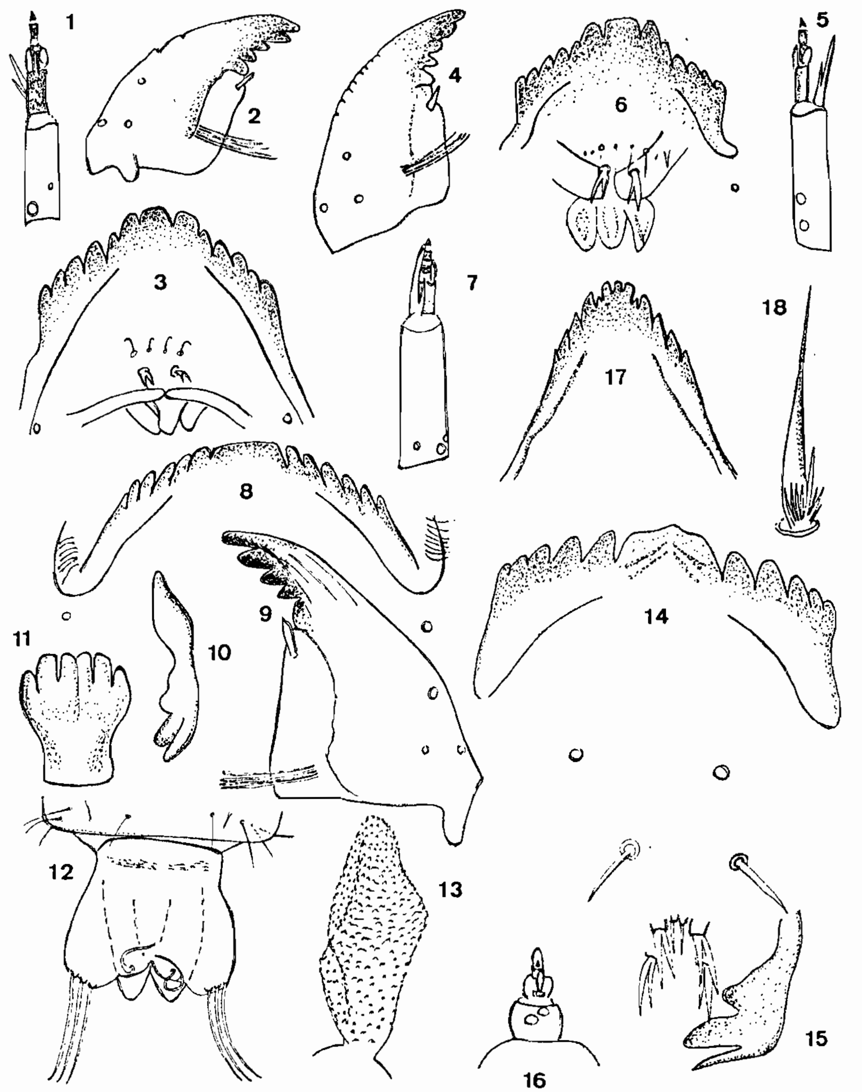

Plate 7. Cricotopus (*Isocladius*?) sp. 2. Figs 1, 2 and 3: antenna, mandible and mentum of larva, with epipharyngeal comb. *Cricotopus* (*Isocladius*?) sp. 3; 4, 5 and 6: mandible, antenna, mentum and epipharyngeal comb of larva. *Paracladius*? sp. 1; 7, 8, 9, 10 and 11: antenna, mentum, mandible, premandible and structure similar to a ligula, of the larva; 12 and 13: last abdominal segment and respiratory organ of pupa. *Pseudosmittia* sp. 2; 14, 15 and 16: mentum, premandible with epipharyngeal setae and antenna of larva. *Corynoneura* sp. 3; 17 and 18: mentum and basal setae of the parapod of the larva. (from Roback and Coffman, 1983).

Table 1. Main species of Chironomidae collected in the Bolivian part of the lake between 1985 and 1989. Identification refers to the work of Roback and Coffman (1983), or to the collection codes of the author (e.g. sp. CHBF).

Sampled species	Percentages (total number of organisms : 14.282)
Rheotanytarsus sp.	44,5
Polypedilum (Tripodura) titicacae	1,4
Cricotopus (Isocladius) sp. 1, R & C	3,9
Cricotopus (Isocladius) sp. 4, R & C	0,01
Chironomus sp. 1 R & C	42,8
Cricotopus sp. (CHBF)	5,4
Cricotopus sp. (CHBG)	0,6
Corynoneura sp. 3, 4 & C	0,8
Pentaneurini, cf. *Pentaneura* sp. (CHBI)	0,01
Orthocladiinae sp. (CHBJ)	0,9
Orthocladiinae sp. (CHBK)	0,02

are also long and narrow and the mentum has four teeth on each side of a central monocuspid tooth. The difference is more pronounced in the pupa, which for example has six pairs of chitinous plates on the abdominal tergites of segments III to IV.

Roback and Coffman (*op. cit.*) recorded the occurrence of *Chironomus* sp. 1 down to 120 metres depth in the Lago Grande. In 1986–89 this species was not very frequent in this basin (only present in Achacachi Bay down to about fifteen metres), but it was very abundant in the deep water area of the Huiñaimarca (between 5 and 40 metres), where densities in excess of 2000 individuals per square metre were recorded.

Rheotanytarsus sp. was equally abundant in the Huiñaimarca and in the Lago Grande, inhabiting submerged macrophytes, the larva living in a small tube of irregular shape, generally formed of an agglomeration of mucus and organic debris. Densities reached 700 to 800 larvae per 10 grams dry weight of plant substrate.

The two members of the Orthocladiinae in the genus *Cricotopus* were the third and fourth most abundant species in the Bolivian part of the lake during our study, accounting for 4 and 6% of the individuals collected, respectively. They lived mainly among the aquatic vegetation and on rocky substrates along the shores. *Polypedilum* (*Tripodura*) *titicacae*, inhabiting both among macrophytes and in the sediment, seems to be a widespread species in the Andes that we have encountered in other lakes on the Altiplano and in the Cordillera and which occurred regularly in the samples. In contrast, the other species only occurred sporadically in our study.

From our own samples and from previous records, it would appear that about twenty species can be found in the various biotopes in the lake, but among these only 5 or 6 are really abundant. A special study on this group would be needed to produce a full description of the taxa present, allowing their identification to the species level.

The Trichoptera

This is also one of the groups of insects rarely collected in the lake, although they can be abundant, but never very diverse in other lacustrine habitats in the Cordillera. We have however found seven species during our study, whereas Roback *et al.* (1980) only recorded one.

Limnophilidae

Anomalocosmoecus blancasi Schmidt, 1957. (Plate 9, Figs 1–3)

This species was recorded for the first time as an adult by Schmidt (1957), from two localities in the Lago Grande (Pomata and Vilquechico); the larvae of this limnephilid belonging to the subfamily Dicosmoecinae were also collected by the Catherwood Expedition in Copacabana Bay in depths of 2 to 5 metres (Roback *et al. op. cit.*; Flint, 1982). Based on what Schmidt *op. cit.* wrote about the genus to which it belongs and in the absence of records from elsewhere, it is likely that this species is endemic to Lake Titicaca. "The genus *Anomalocosmoecus* is very interesting. It is no doubt derived from *Magellomyia* and has acquired the status of a genus to itself by its very marked specialisation. It would appear to be adapted to living on the margins of Lake Titicaca . . .".

Anomalocosmoecus, nr. *argentinicus* Flint, 1982. (Plate 9, Fig. 4)

A single individual of this species has been collected from a site off Escoma. Its presence in the lake may be viewed as accidental.

Magellomyia illiesi Marlier. (Plate 8, Figs 8–10)

This species has only been collected three or four times in small numbers in the immediate neighbourhood of the mouths of inflowing rivers (Río Suchez, small seasonal streams near Huatajata and in the Ancoraimes region). As it is very abundant in most of the water courses of the Cordillera, it is almost certain that it entered the lake by the phenomenon of biological drift, and that it continued to grow near the mouths of these water courses in the lake, but did not penetrate any further. As it can complete its life cycle in the

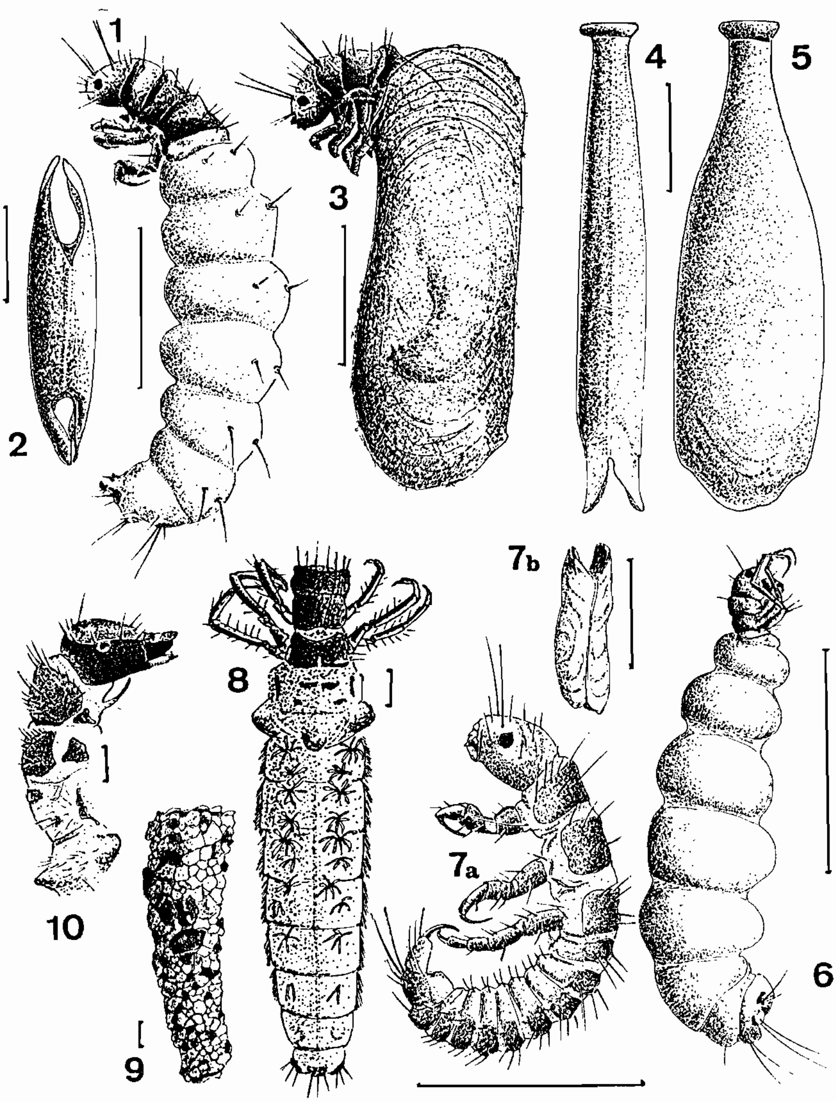

Plate 8. Ochrotrichia (Metrichia) sp. Figs 1, 2 and 3: larva; case and larva in its case. *Oxyethira* sp.; 4, 5 and 6: lateral and front view of case; larva. *Leucotrichia* sp.; 7a: larva; 7b: case. *Magellomyia illiesi*; 8, 9 and 10: general aspect of larva; case, lateral view of front end.

littoral areas of other high altitude lake in the valleys draining into the Altiplano (Dejoux and Wasson, in press), it seems likely that a limiting factor exists in Lake Titicaca preventing its full development away from the areas directly influenced by inflow rivers.

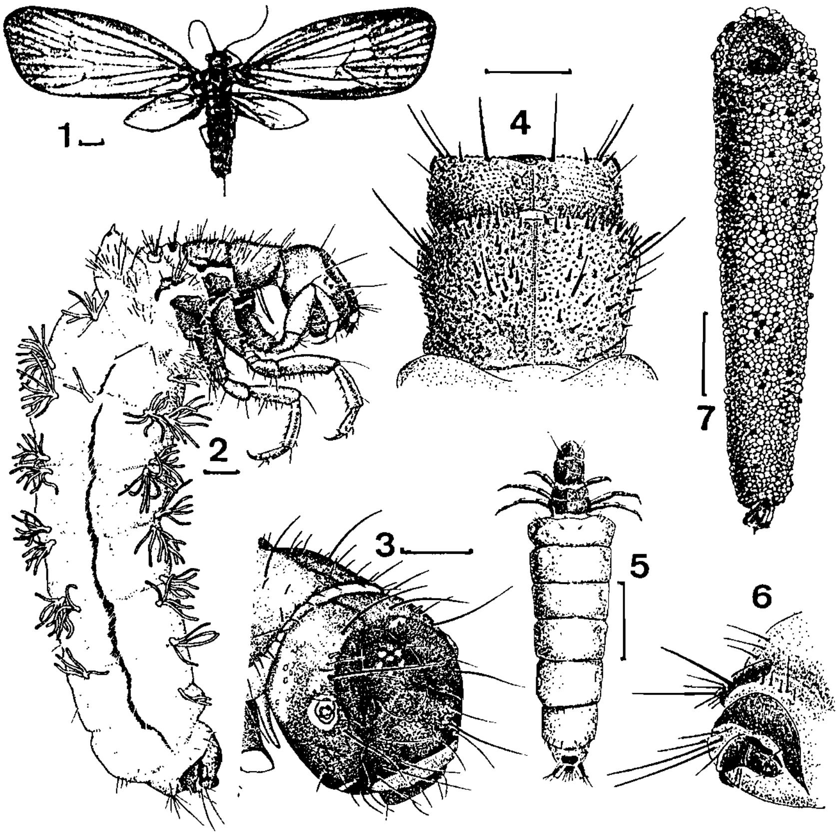

Plate 9. Anomalocosmoecus blancasi. Figs 1, 2 and 3: adult; general view of larva; head. (from Schmidt, 1957 and Flint, 1982). *Anomalocosmoecus* nr. *argentinicus*; 4: dorsal view of head. *Neotrichia* sp.; 5, 6 and 7: general view of the larva; abdominal laws; case.

Hydroptilidae

Four species have been collected sporadically, mainly living among the aquatic vegetation and some under stones along the margins. All these species are of small size.

Oxyethira sp., (Plate 8, Figs. 4–6)

The case in the form of a flattened bottle is characteristic of the genus, the larva itself having a typical morphology, with an abdomen with rounded swollen segments, the posterior pair of legs long and slender and the anterior pair short, broad and prehensile. The case with an average length of 2 mm, is closed at the two ends at pupation. It has a flexible leathery consistency.

We have found about fifty specimens of this species among submerged macrophytes in the Huiñaimarca and in the same biotopes in the Lago Grande (Achacachi Bay). It seems to be more frequent among plants situated near to the surface and was much more common among a small crucifer growing at the lake margins than on other species of macrophytes.

Ochrotrichia (*Metrichia*) sp., (Plate 8, Figs 1–3)

This species, in which the last instar larva measures about 2 millimetres, lives in the same biotopes, but is also sometimes found under stones on the shore, especially when these are covered by dense periphyton. The case is also of a leathery consistency and is in the form of a spectacle case; it is often fixed to vegetation by a small mucous ligament situated on the lower side. It is an uncommon species.

Leucotrichia sp., (Plate 8, Figs 7a and b)

We have only rarely encountered this species in its case. It is very small (1.4 mm), and the larva has only ever been found among *Chara* where it is infrequent, only six individuals having been collected. The case is shaped like a grain of wheat.

Neotrichia sp., (Plate 9, Figs 5–7)

A dozen individuals of this small species of Hydroptilidae, occasionally also found in other high altitude lakes, have been collected on two occasions in biotopes of the same type, consisting of angular stones lying on sandy sediments in shallow water. These biotopes, of which one is situated in a bay on the north west of Sun Island and another on the north west of the Taraco Peninsula, are beaten by waves, and therefore well oxygenated. The larva is enclosed in a curved case formed of small sand grains stuck together with mucus. A similar mucus secretion fixes the case to the underside of the stones.

Conclusions

With the exception of chironomid Diptera, the aquatic insects are a minor component of the benthic fauna of Lake Titicaca – a remarkable situation. It is difficult at the moment to know the exact reason; it is only possible to put forward a hypothesis of the existence in this environment of an overall factor unfavourable for insects, which is perhaps the excessive salinity (1000 to 1500 $\mu s\ cm^{-1}$ depending on locality). The fact that certain species have only been found in areas close to the mouths of permanent inflowing rivers or along the shorelines, which at certain times of year receive major inputs of freshwater by direct runoff after heavy rainfall, support this hypothesis. It is known that the rivers flowing into Lake Titicaca have a rather high salinity, especially when they flow over the sedimentary formations of the Altiplano (5 to 20 mmol l^{-1} according to Carmouze *et al.*, 1981). Despite this total dissolved salt concentration, the streams support a benthic insect fauna that can be considered as being rich and fairly diverse, when account is taken of the high altitude (Marin, 1989). The biological drift, which is a characteristic feature of every water course should, for those organisms that are not strictly rheophylic, therefore be a factor allowing colonisation of the lake areas near to the river mouths, provided they find suitable ecological conditions there. The fact that only rare individuals of species not found elsewhere in the lake, but present in the water courses, are found in these areas of Lake Titicaca, shows that the phenomenon of arrival in the drift occurs, but that it leads to virtually no colonisation of the lacustrine environment. It therefore seems likely that the salinity threshold allowing normal development of such organisms is quickly surpassed in the lake, or else that they are sensitive to the natural toxins produced by the very abundant charophytes in the lake.

It is remarkable that no Plecoptera have been recorded from the waters of Lake Titicaca, whereas they are very frequent in the other neighbouring lakes of the Cordillera. The same remark cannot be made for the Ephemeroptera since Gilson (1964), without referring to published data, recorded them as present. It is nevertheless strange that in four years of observations we have not encountered a single individual. The chironomid Diptera are in contrast a permanent component of the macro-invertebrate fauna of the lake, and taking into account the altitude, they can be considered as being very diverse. Their occurrence, sometimes in very large quantities in the macrophyte beds or in the sediments, means that they play a considerable role in the secondary production of the lake, comparable in some seasons and some sites to that of the molluscs and amphipods. In the absence of detailed studies of the stomach contents of the fish inhabiting the lake, the position they occupy in the diet of the fish fauna is poorly known. At the times of major emergences of the large *Chironomus*, it is on the other hand evident that they constitute a real bonanza for many birds, including both gulls and ducks (see Chapter VI.6c).

Acknowledgements

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