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MICROHABITAT FIELD-STUDIES IN A NATURAL LAKE LITTORAL ZONE AND DIFFERENT MESOCOSM SYSTEMS FOR AN ECOTOXICOLOGICAL TEST WITH CYPERMETHRIN

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Abbreviations

BLfW	*Bayerisches Landesamt für Wasserwirtschaft*
CLASSIC	*community level aquatic system studies interpretation criteria*
DGL	*Deutsche Gesellschaft für Limnologie e.V.*
DOC	*dissolved organic carbon*
EC 50	*effective concentration (50 %)*
Fig.	*figure*
HARAP	*higher tier aquatic risk assessment for pesticides*
LC 50	*lethal concentration (50 %)*
OECD	*organization for economic cooperation and development*
PCA	*principal component analysis*
PRC	*principal response curves*
SETAC	*Society of Environmental Toxicology and Chemistry*
SRP	*soluble reactive phosphorus*
TP	*total phosphorus*
WWA	*Wasserwirtschaftsamt*

Punctuation marks and dates

The decimal numbers were expressed with the German punctuation mark (comma), this was due to the different cooperation partners involved in the thesis. The dates are also written in the German way (day/month/year).

1 Introduction

This thesis can be characterized as a combination of a descriptive and experimental approach. Its major aim is to help solve the ecotoxicological problem of transferability between artificial model systems and their natural equivalent. The descriptive part is realized in a natural lake littoral zone, and it is used to give an overall view of the natural benthic macroinvertebrate community. The experimental design is performed in an artificial mesocosm, which is treated with the pyrethroid cypermethrin.

The project combines the two scientific fields of limnology and aquatic ecotoxicology. Limnology describes the natural interactions between organisms and their freshwater environment. Ecotoxicology evaluates and judges disturbances in the aquatic ecosystem caused by different kinds of substances. It has a great demand for test system research, especially for tests at higher levels of organization (Cairns 1983, Giddings 1984). Different kinds of substances need to be examined, and their effects on natural ecosystems have to be calculated. Single species tests and multi-species tests both have their importance. Single species tests can never accurately predict species-competitive or predator-prey interactions and complex systems will never be able to predict a detailed, isolated component part. Size, shape and structure of the micro- or mesocosms are often discussed (Zieris 1986, Draxl 1990, Hill *et al.* 1994, Volm 1997).

Today various types of tests are in use. The different systems are always debated between regulators, scientists and industry (Campbell *et al.* 1999, OECD Guidelines 1996). The more realistic point of view makes the multi-species tests indisputable. Although at first it might seem easier to work under optimized conditions in the laboratory where parameters such as light and temperature can be adjusted, it is important to keep in mind that other environmental influences such as colonization from nearby ecosystems can never be simulated. It is important that the community within the created model mesocosm resembles one in nature (Giddings 1983). It is defined as a bounded and partially enclosed outdoor experimental unit that closely simulates the natural environment, particularly the aquatic environment (Odum 1984). This definition does not really set limits to complexity and there is no guideline for microcosm and mesocosm studies. Although research in this field has been going on for several years, the demand for a better transferability to natural waters is still of current concern. Especially system reproduction and accurate predictions to the environment need to be improved (Crane 1997).

Sometimes mesocosm experiments are performed in real “littoral enclosures” (Lozano *et al.* 1992). A large numbers of substances need to be tested. Using natural ecosystems for testing can never be considered on a larger scale because natural ecosystem conservation always has to be the most important aim. Germany today has designated 29 wetlands to the world list of "Wetlands of International Importance". The Federal Republic of Germany ratified the Ramsar Convention in 1976. The designation date of the study site Lake Ammersee was 26/02/1976. The site is especially important for wintering and staging water birds. The site includes the large natural freshwater lake as well as gravel beaches, rivers and swamp areas (Mitlacher 1997).

A possibility of simulating nature is to create a test system using the natural equivalent in several geographic regions. This is the only way to solve the problem of finding the most sensitive key figures in the individual ecosystems. The low species numbers and their very common distribution is a major aspect of criticism in the mesocosms. Although it is important to keep in mind that biodiversity is not always necessarily linked with the stability and function of an ecosystem (Schwartz 2000). Mesocosm systems can be quite stable through many years (Huber 1995, Huber *et al.* 1995).

Invertebrates make up about 95% of the worlds’ described species. Benthic macroinvertebrates are a common group and ideal indicators. The species have a broad range from sensitive to tolerant and occupy different trophic levels (Cummins 1974, Buikema *et al.* 1993). The aquatic insect communities, which are tested in the artificial ponds, need to be evaluated on a natural scale. This means a critical view has to be taken towards the tested community and whether or not it can also be found in a natural environment. Another very important point is the ecosystem functioning. The functional parameters such as primary production, nutrient cycling and decomposition of organic matter have to resemble those in natural ecosystems (Heger 2000).

The equivalent to the mesocosm ecosystem in nature is the lake littoral zone. This is the place where pollutants have the first contact with the aquatic ecosystem. In the 1970`s the nutrients found their way into the aquatic environment through sewage pipes and wastewater inlets. This same source is also likely for other pollutants and therefore the first effect can be observed in the littoral zone.

The littoral zone includes the depth up to the compensation level, where the light intensity is not enough to compensate the catabolism process. The borders between the regions are not fixed; in fact they can be very dynamic. Water levels and visibility have a broad range and cannot be generalized.

In order to create a viable artificial model, a typical representative of the lake littoral has to be first defined. The lakes littoral zone is very diverse and not easy to standardize. It is a complex interface zone between land and the water body. The size and structure of the littoral zone in relation to the pelagic area varies among lakes and incorporates a great variety of important functions. The dynamics are very complex and nearly impossible to accurately simulate in a model. Parameters such as general morphology, sediment structure, macrophyte community, influences from different inlets and general human influences, change along the shoreline. The easiest and most common way to get a general picture of a lake's quality is to examine the pelagic part of the lake (physical and chemical parameters, phytoplankton and zooplankton). These parameters are used most often to describe the lake's status. Compared to the littoral zone, the sampling of the pelagic zone has a traditional history and existing datasets go back a long time. The scientific understanding of the littoral zone is not as advanced. The littoral zone has a very divers character and the surroundings can have a great influence (Seele 2000). Further investigations of the littoral zone and its relationship to the pelagic zone of a lake are needed.

A good method to describe the littoral zone of a lake is to map the macrophytes. The different habitats for insects in the littoral zone are very much determined by the macrophytes. To estimate the trophic development along the shoreline, the so-called macrophyte index (Melzer 1988) is often used in Germany. Whether or not the fauna in lakes can be used as trophic indicators as in streams is often discussed controversially (Lalonde & Downing 1992, Kornijow *et al.* 1990). A dependency on the trophy could only be proven for a few species (BLfW 1992). The colonization of the lakeshore has been compared to that of rivers and streams (Schwoerbel 1999). In rivers, species assemblages can be used as descriptors of mesohabitats (Pardo & Armitage 1997). In lakes, it has been shown that microhabitats consisting of different macrophytes such as *Typha angustifolia, Scirpus acutus, Potamogeton spp.* and an open water site can be associated with different species composition (Olson 1995).

The structure of, and interaction between littoral communities is very complex. The relationship between macrophytes and macroinvertebrates is just one example. Macrophytes can be the source of food (Oertli 1995), a hiding place or a safe area in which to lay eggs. This is also true for the artificial pond mesocosms (Fiedl 1997). Invertebrates can sometimes control the growth of macrophytes (Brux 1989).

The colonization of the habitats is related to the biomass and the leaf morphology of the macrophytes (Cry & Downing 1988, Schramm & Jirka 1989, Rasmussen 1993). Different communities can be found in different heights and parts of the plant (Sloey & Schenck 1997).

One of the main factors of stress in the littoral zone is the fluctuating water level. (DGL 1999). In spring 1999 severe rainfall and the beginning thaw caused a century flood in the upper Bavarian region (WWA 2000). Up to 138,7 mm (l/m^2) rainfall was measured on the 21/05/1999 in Hohenpeißenberg. Lake Ammersee had an unusually high water level for several weeks. Being the most common disturbance for the lake macroinvertebrate community, the flood situation was an once-in-a-lifetime opportunity for investigation. The reed community can suffer greatly, especially when the shoots are below the surface for a longer period of time (Grosser 1997). The abundance, biomass and the relative proportions of functional feeding groups of macroinvertebrates can vary in relation to the water level (Neiff 1997).

The zooplankton community was examined at the same sites in cooperation to this thesis (Funk, unpublished).

This thesis will answer the following primary questions:

1. Does the macrophyte density influence the toxic effects of cypermethrin on macroinvertebrates?
2. At what level does the pyrethroid insecticide, cypermethrin, affect the macroinvertebrate community?

This thesis will also discuss the following issues:

1. Is it possible to establish an artificial pond for ecotoxicological testing with lake littoral fauna? To what extent can the microhabitats be transferred from a natural lake littoral?
2. How much do the physical and chemical parameters change in the littoral zone? How does the pelagic zone of the lake fit in with the values?
3. How does the macroinvertebrate community change with the trophic state of the littoral zone?
4. How does an extreme flood situation influence the lake’s littoral zone and its fauna?

2 Material and Methods

2.1 Lake Ammersee - Lake basin characteristics and morphology

The site is located 20 km Southwest of the city of München (Munich), in the Bundesland (Federal Land) Bayern, in Southern Germany. The lake's name, Ammer, originates from the Celtic expression for water. Lake Ammersee can be considered as a typical lake in the Northern pre- alpine region, so it serves as a good representative for the geographical region. It lies in a former glacial valley (Schneider 1995). Water is brought to the lake from the River Ammer to the South, and taken away by the River Amper to the North. The water level normally fluctuates by 150 cm during the year (rain, melting snow in the Alps). The Western and Eastern shores have narrow gravel beaches, surrounded by end-moraine-dams. Annual precipitation ranges between 750 to 1000 mm. The shoreline of the lake freezes regularly during the winter and in some years the lake is completely frozen. Average temperatures vary from 16 °C in July to nearly 2 °C in January. The government owns parts of the site and the surrounding are; the Conservation Society Ammersee-Süd and the National Trust own part for Bird Protection, and part has private ownership. The site is important for agriculture, commercial fishing and recreation (mainly sailing, surfing and swimming).

Table 1: Lake Ammersee characteristics

Coordinates: 48°01'N 011°08'E
Elevation: 533-545 m
Area: 6,517 ha
Precipitation: 750 to 1000 mm
Average temperatures: 2 to 16 °C
Max. Depth: 81m

Lake Ammersee has a total surface area of 46,6 km^2 and stretches 43 km from Stegen in the North to Aidenried in the South. It is only about 10 km wide and has a maximum depth of 81 m and a mean depth of 36,9 m. The surrounding area of Lake Ammersee consists predominantly of grassland and the total catchment area is 993 km^2. About 80% of the lake's runoff and its phosphorus influx originates from the River Ammer (Mangelsdorf 1972).

The smaller rivers and direct precipitation contribute about 10%. The water discharge rate of 2,7 years is relatively high (Lenhart 1993). The lake has been thoroughly investigated since 1975 (Lenhart 1987).

2.1.1 History of Lake Ammersees' trophy

In the last decade, eutrophication was one of the major topics for limnologists. In Southern Germany, many measures were taken in order to reduce the environmental phosphorus input. Sewage treatment plants in the surrounding catchment areas and along the shorelines of lakes were built to stop the most essential source of phosphorus loading originating from sewage waste. This was also true for the sub-alpine Lake Ammersee. The main sewer pipe around the lake was built in 1971. The lake was described as being in a eutrophic state in 1976/1977 (Steinberg 1978). Between 1982 and 1987, six sewage plants in the catchment area of the River Ammer were equipped with phosphorus elimination devices (Hohenpeißenberg, Weilheim, Peißenberg, Ettal, Oberammergau and Uffing). In 1981 and 1984, a law was passed to reduce the amount of phosphorus in detergents. In 1985/1986 the lake was reported to be in a more or less mesotrophic status (Lenhart 1987). Between 1991 and 1994 the other five sewage treatment plants in the area were modernized with phosphorus elimination devices. The eutrophication process was stopped successfully (Steinberg & Lenhart 1991). According to the water quality map of Bavaria (BLfW 1992), Lake Ammersee can be classified as mesotrophic.

2.1.2 Littoral site description Schondorf

The sample site Schondorf is located at the Northwestern part of the Lake Ammersee (Map 1, page 21, Picture 1). The shoreline can be characterized as rather narrow and steep. The littoral zone extends to a depth of about 1,5 m. The shoreline itself is fairly sheltered because West is the predominant wind direction. The degree of wave exposure is relatively low. The sediment shows a high total calcium carbonate content. Its exact characterization is described in Müller 1977.

Picture 1: Sampling site Schondorf

The physical and chemical characteristics of lakes are used to indicate their nutrient status. Aquatic macrophytes are known to give important additional information to describe the trophy of lakes. A method that uses the macrophytes as indicators of nutrient status and trophy is the “macrophyte-index” developed in Bavarian lakes (Melzer 1988). This index reveals the individual pollution situation along the shoreline of a lake. The last complete mapping of the macrophytes took place in 1987. In 1987 the site at Schondorf was classified as contaminated to a “low” degree by nutrients (2,47; BLfW 1996). In order to calculate the macrophyte indices at the sites, an area of about 250 m around the pebble basket sites was mapped on 01/09/1998.

At the sites in Schondorf (S1-S3) the shoreline is represented mainly by *Phragmites australis. Chara aspera* and *Chara contraria* were the predominating macrophytes up to the depth of 1 m. *Potamogeton filiformis* and *Potamogeton pusillus* were found scarcely in between. Below 1 m the following plants were mapped: *Schoenoplectus lacustris, Nuphar lutea, Chara fragilis,* and *Chara tomentosa, Nitellopsis obtusa, Najas intermedia, Potamogeton pectinatus, Potamogeton perfoliatus, Ranunculus circinatus and Utricularia australis.*

Chara fragilis plants were found up to the depth of 5,5 m. The macrophyte indices calculated for the area of Schondorf was 2,67, indicating a “moderate” nutrient pollution. This level is associated with the average total phosphorus content of 16 µg/l during circulation and the average secci transparency in summer of 4 m.

The pebble basket sites can be characterized as follows:

S1: Schondorf 1 – The reed plant *Phragmites australis*, along with *Chara aspera*; the average water depth is about 20 cm deep.

S2: Schondorf 2 – *Chara contraria* and some *Chara aspera*; the average water depth of 50 cm.

S3: Schondorf 3 – *Chara contraria* and *Chara fragilis*; the average water depth about 1 m.

2.1.3 Littoral site description Aidenried

Aidenried lies at the Southern end of the lake (Map 1, page 21, Picture 2) and the River Ammer and the Ammer-channel influences it to a great extent. The organic material content of the sediment is very high (Müller & Sigl 1977). The littoral zone is very broad and shallow. The whole delta is manifolded and covered with different kinds of patched macrophytes. The site is exposed to wind and waves. After a storm the shoreline is especially heavily wooded.

Picture 2: Aidenried (*Nuphar, Potamogeton*)

The sites in Aidenried were chosen in order to represent a different state of trophy. The contamination at the site in Aidenried was classified as “heavy” (3,86; BLfW 1996). The dominating reed plant is *Phragmites australis* along with a few spots of *Schoenoplectus lacustris*. The Yellow Water Lily *Nuphar lutea* grows 5 m off the shoreline. *Chara fragilis* grows within and between the Water Lily plants.

The diverse area has many different plant patches of *Ceratophyllum demersum, Elodea canadensis, Myriophyllum spicatum, Potamogeton pectinatus, Potamogeton perfoliatus, Potamogeton pusillus, Ranunculus circinatus, Zannichellia palustris* and *Fontinalis antipyretica. Fontinalis antipyretica* was found up to the depth of 3 m.

The calculated macrophyte index for the area Aidenried was 3,71. It indicates a littoral with a “heavy” contamination of nutrients. It is associated with the average total phosphorus content of 60 µg/l during circulation and the average secci transparency during summer of 2,4 m.

The pebble basket micro-habitats in Aidenried can be described as follows:

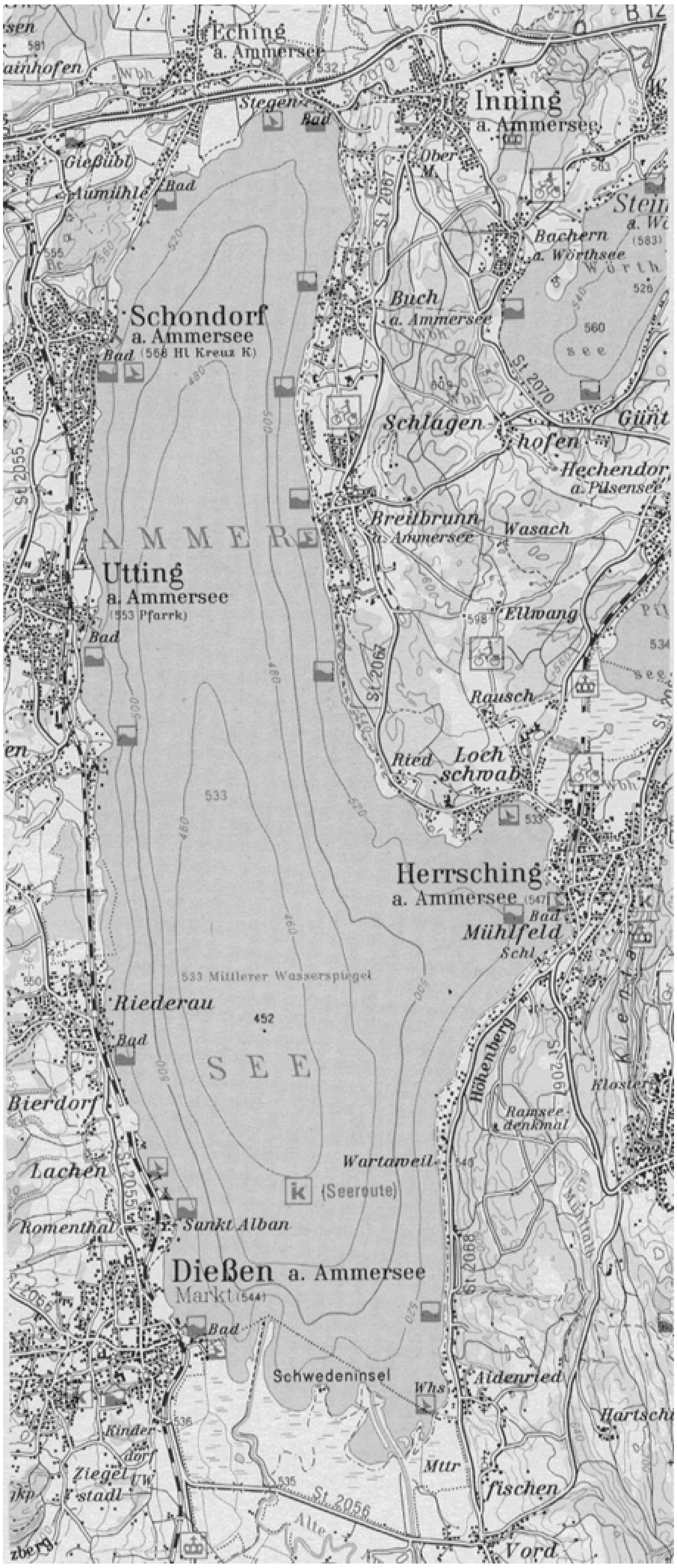
A1: Aidenried 1 – *Phragmites australis*; average water depth about 30 cm.

A2: Aidenried 2 - *Nuphar lutea, Schoenoplectus lacustris*; average water depth of about 50 cm.

A3: Aidenried 3 – *Potamogeton pusillus*, *Nuphar lutea*, *Myriophyllum spicatum* and *Chara fragilis*; average water depth of about 1 m.

2.1.4 Pelagic zone site

In the relatively large Lake Ammersee, the pelagic zone takes up the major surface of the lake. The site within the pelagic zone (Pelagial) is located in the mid-Southern part of the lake, near the shoreline level of the town of Riederau. It is close to the deepest point of the lake. The maximum depth of 81,1 m can only be measured in the middle of the lake; the average depth is around 38 m.



Map 1: Map from Lake Ammersee. (BLfW 1996)

2.2 Mesocosm site descriptions

The Pond M is located at the Grünschwaige Research Facility (Picture 3). It is about 15 km away from the main University campus. The surroundings are used for different agricultural purposes. The Technische Universität München, Weihenstephan owns all of the surrounding areas.

Picture 3: (Pond M with enclosures)

Pond S, the Split-Pond-System (Zieris 1986, Draxl *et al.* 1994) is located on the campus of the Technische Universität München, Weihenstephan (Picture 4).

Picture 4: Pond S

2.2.1 Pond M

The Pond M at the Grünschwaige Research Facility was established in March 1998. To compensate the irregular variation of the outside temperature, the mesocosm is situated 1 m below the ground. On 31/03/1998 the pond was stocked with two tons of Lake Ammersee sediment (calcium carbonate) and on 02/04/1998 it was filled with 25000 l of Lake Ammersee water. The pond itself is round and according to Hill *et al.* (1994), it can be considered a mesocosm. In 1998 the macroinvertebrates of the pond were monitored from March to November without enclosures. In 1999 the pond was separated in 18 identical compartments. The enclosures were set up in June and the macroinvertebrates were sampled until September.

Table 2: Technical data of Pond M.

Manufactured by	MTW Moderne Wassertechnik, Gilching, Germany
Framework material	0,8 mm stainless steel
Inner layer	1 mm polyethylene
Volume	23,5 – 27,5 m^3
Diameter	5 m
Height	1,2 - 1,5 m

Table 3: Technical data of the enclosures.

Manufactured by	Schorb Company, Moosburg, Germany
Material	Stainless steel
Volume	700 litres
Diameter	0,95 m
Height	1,5 m

2.2.2 Enclosure experiments in Lake Ammersee

Three enclosures were set up at each site at the lake. They were positioned within the reed area in Schondorf and Aidenried at about 60 cm depth. They were made of plastic with a frame of steel.

Picture 5: Lake enclosure in Schondorf

2.2.3 Pond S

The split pond experiment was run simultaneously with to the cypermethrin experiment in Pond M. The pond system was used for many successful studies (Ebke 1999, Grünwald unpublished, Rüschemeyer unpublished). The pond was established in April/May 1999. It was filled with 400 l of Lake Ammersee and rainwater and additional zooplankton and macroinvertebrates from Schondorf and Aidenried. Each basin was filled to a depth of 60 cm. Sediment from the Schondorf site at Lake Ammersee was added to a layer thickness of 10 cm. The compartments were separated on the 18/06/1999. The experimental design was the same as in pond M. The first cypermethrin application (100 ng/l a.i.) was on 27/07/1999 and the second (1000 ng/l a.i.) on 24/08/1999. The plants were harvested at the end of September 1999.

Table 4: Technical data of Pond S.

Manufactured by	Kraller, Waging am See, Germany
Material	Container: Polyester ; Sections: Polyvinylchloride
Volume	700 litres
Diameter	3,95 m x 1,00 m
Height	0,90 m
Date of establishment	07/04/1999
Sediment layer thickness	10 cm

2.3 Sampling techniques

The samples for all of the analyses were taken in 1000 ml SCHOTT glass bottles. The lake and the mesocosm sites were sampled in regular intervals. The exact schedule is attached in the appendix. The pelagic sample was integrated between 1 and 10 m depths. The littoral samples were taken directly at the site in 10, 50 and 100 cm depths. For the mesocosms a sample from top and bottom were taken seperately and then mixed.

2.3.1 Physical and chemical measurements

The physical and chemical measurements such as temperature, oxygen, conductivity and pH were conducted at the littoral and the pelagic sites every month.

Table 5: Technical data of the portable electrodes for temperature, oxygen, conductivity and pH

Oxygen and temperature: OX1 96 (Ser.No. 2907078) and OX1 320 (Ser.No. 71298025)
pH: pH 96 (Ser.No. 2902017)
Conductivity: LF 96 (Ser.No. 0907082)

Chlorophyll a, filtered total dissolved phosphorus and the unfiltered total phosphorus, the dissolved reactive phosphorus, ammonia, nitrate, nitrite content as well as the silica, chloride and dissolved organic carbon concentration were determined at the laboratories Wasserwirtschaftsamt Weilheim.

The absorption (chlorophyll a) was measured with the UV/VIS Spektrometer Lambda 12, Perkin Elmer Company according to the Bavarian method (BLfW 1992).

Both the filtered total dissolved phosphorus and the unfiltered total phosphorus was determined according to the Schmid-Ambuehl Method. The absorption was measured with the UV/VIS Spektrometer Lambda 12 as well.

The dissolved reactive phosphorus, ammonia, nitrate, nitrite content as well as the silica, chloride and dissolved organic carbon concentration were measured according to the Skalar CFA-Autoanalyser (Issue 011091/91054500; ammonia: ENISO 11732 – E23, paragraph 2; nitrate and nitrite: ENISO 13395 – D28).

2.3.2 Biological sampling

2.3.2.1 Macrophytes

The habitats at the lake littoral sites were chosen according to the results from the mapping of the lake in 1988. Two typical sites with similar habitats on one hand and a few differences on the other were chosen. On 01.09.1998 the macrophytes of the sites Schondorf and Aidenried were mapped by scuba diving. The macrophyte species from the lake sites were transferred to the mesocosms. The first planting within Pond M took place in May 1998. The macrophytes were put in pots and set up to cover approximately 20% of the pond's surface.

For the cypermethrin study, Pond M was equipped with additional plants along with the enclosures in June 1999. The enclosures were stocked with *Myriophyllum spicatum* and *Potamogeton natans* in order to make up three different plant densities with similar species.

At the end of the mesocosm study the plants were removed and weighed to determined the total macrophyte weight for each enclosure. The same procedure was done for the Pond S. The exact time schedule is attached in the appendix.

2.3.2.2 Macroinvertebrates

Kick sampling and hand collecting was done at the beginning of the project in 1998. Net sampling and emergence trap sampling was performed within the mesocosm studies along with the pebble baskets sampling every two weeks. At the lake sites the pebble baskets were sampled every three weeks.

Some destructive sampling methods such as kick sampling can only be used in a natural surrounding. At the lake sites, this method was used to give an overall view of the macroinvertebrate species. In order to compare the data from the natural sites and the mesocosms an artificial substratum was used. The pebble baskets serve as a good substrate to sample artificial ponds because they do not disturb the systems as much as any other method.

In addition to the artificial substratum, emergence traps and net samples were taken within the mesocosm (Smukalla 1988).

Table 6: Pebble basket, emergence traps and net sampling volume.

	Pebble basket	Emergence traps	Net sampling
Surface area (cm^2)	750	400	425
Height (cm)	50	100	86
Volume (cm^3)	37500	40000	36550
Volume in l	37,5	40	36,6
Comparison factor	3,8	4	3,7

2.3.2.2.1 Kick sampling and collecting

As described, the kick sampling method was only used at the lake sites. It is a method that was conducted according to ENISO 27828 - 7828. It covers approximately 7 cm of sediment. In addition to the kick sampling, rocks and pieces of wood were sampled by hand and the macroinvertebrates were collected and preserved in ethanol (99%) for identification.

2.3.2.2.2 Net sampling and emergence traps

Net sampling and emergence traps were used in addition to the pebble basket sampling within the enclosures of the mesocosm. The net sampling catches especially those macroinvertebrates attached to the macrophytes and within the water column itself. The plankton net (mesh size 250 µm) was pulled through the enclosures to a distance of 86 cm. The gathered macroinvertebrates were then rinsed into white plastic plates (40 × 30 × 5 cm) for counting. After identification, the macroinvertebrates were put back into the enclosures to prevent the enclosures from a greater loss of specimens.

The emergence trap was constructed in the manner established in stream ecology (Wetzel 1991, Schwoerbel 1994). The tent construction was covered with a gauze (mesh size 250 µm) and was supported by a stainless steel framework. The floating device was made of a wooden square with a polystyrene foam cover. The killing agent was ethanol (99%).

2.3.2.2.3 Pebble baskets

The artificial substrates consisted of three different pebble baskets and hardboard plates. The framework of the baskets was coated wire mesh. The two bottom baskets held different sized pebbles (upper: 1,5 – 2,5 cm, lower: 2,5 – 3,5 cm). The top basket was filled with *Phragmites australis* cut in 10 cm lengths.

The hardboard plates (10 × 10 cm) were used to hold the pebble baskets in place. They were soaked in tap water to prevent contamination with chemicals used for preserving the plates.

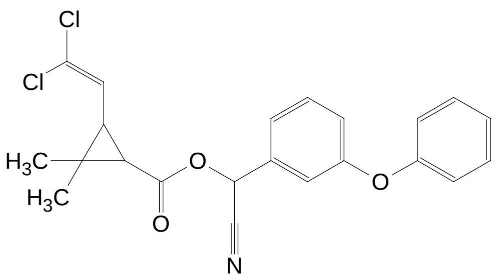
Picture 6: Pebble basket (length 13 cm, width 13 cm, height 3,5 cm)

2.3.2.2.4 Species identification

In order to preserve the mesocosm systems, the identification took place at the site. Sometimes it was necessary to preserve specimens for identification in the laboratory, using a stereoscopic microscope.

2.4 Cypermethrin and treatment in the mesocosms

Product description:	**pyrethroid insecticide**
Product name:	**Cymbush 25EC**
Source:	**ZENECA Agrochemicals, Fernhurst, Haslemere**



Picture 7: Chemical structure of cypermethrin (N = CN)

Table 7: Physical and chemical properties of cypermethrin.

Form	liquid
Color	Slightly hazy brown
Flash point	> 38 °C
Density	0,96 g/ml
Solubility	Miscible in/with water approximately 1-5 µg/l

The acute toxicity published for cypermethrin were 0,71 ml/kg oral median lethal dose for rats and > 4000 mg/kg dermal median lethal dose for rabbits. The ecotoxicity LC 50 (96 h) duration for rainbow trout is approximately 3,2 µg/l. The chemical has been in use for many years (Davies 1985).

2.4.1 Experimental design and Cypermethrin sampling

For both of the mesocosm tests the same experimental design was performed. A double treatment with the first application of cypermethrin (100 ng/l) and the second application (1000 ng/l) after four weeks was conducted. To apply the stock solution, the drop-application by pipette was used.

All together 18 enclosures were set up in Pond M and six split ponds with three basins each were used for the parallel Pond S experiment. Three replicates of three different plant densities (high, medium, low) were established. Nine enclosures with the different plant densities were treated with cypermethrin; the other nine, nearly identical enclosures, were not treated and served as controls. In this study the three replicates are not used in the classical sense. After the establishment phase they differed to a great extend, so they were judged not as replicates (Hurlbert 1984).

2.4.1.1 Abiotic

Physical and chemical measurements were taken once a week. Temperature, dissolved oxygen content, pH value, conductivity were measured at the site. The nutrients were measured at the laboratories of the Wasserwirtschaftsamt Weilheim.

For the cypermethrin analyses, an integrated water column from one replicate of each plant community was taken and then the samples were pooled. For the first treatment three different plant densities with one replicate on six occasions.

This makes 18 samples for the time intervals of one, three, twelve hours. For the second treatment the samples in three different depths: bottom, middle and surface were taken. Three plant densities and three depths with one replicate on six occasions totals 54 samples. The time spans were one hour (all three replicates); three hours (one replicate of each); and six, twelve and 24 hours.

The cypermethrin analyses were conducted by ZENECA.

2.4.1.2 Biotic

The artificial substrate was sampled every other week. The pebble baskets were taken with the help of a sampling device. It consisted of a steel frame with gauze sides and steel lid. The baskets were lifted into the sampling device, then the lid was closed and the whole device was pulled out of the water. The baskets were taken out of the sampler and the organisms were rinsed onto a plastic plate. The pebble baskets were rinsed equally from all sides with one litre of purified water. The specimens were identified within the plastic plate or prepared for further determination in the laboratory.

The emergence traps were sampled every week. The trapped organisms within the upper tent construction were collected and fixed with ethanol (99%). The trap itself was refilled with fresh ethanol and replaced on the water surface.

The macrophytes were mapped at the beginning of the experiment and harvested at the end. The macrophytes were either taken from the lake site or raised in the green house at the research facilities.

2.5 Statistical analysis

The computer programs “Origin” (Microcal), “Excel” (Microsoft), SPSS 9.0 for Windows and CANOCO 4.0 were used for statistical calculations.

The calculation of the average values and the standard deviation was done according to Kreyszig (1979).

For the species richness, the diversity and evenness the Shannon-Weaver Index was used (Ludwig & Reynolds 1988).

In order to characterize the habitat, movement, food and regional coordination the catalog from the Bayerisches Landesamt für Wasserwirtschaft (Schmedtje & Colling 1996) was used. For the cluster dendrograms between the sites, the rescaled distance cluster combine using average linkage between groups was chosen.

Due to the high variability of community level studies the statistical methods and their power to detect biological effects is an important tool (Kedwards *et al.* 1999). The principle component analyses (pca) and the principle response curves (prc) (Van den Brink & Ter Braak 1998, 1999) can be used as such a method in order to compare different communities. The logarithmic transformation of the data set and the elimination of the time and sample variance leaves only the variance of the wanted influence.

3 Results and Discussion

3.1 Studies in the natural Lake Ammersee

3.1.1 Water level

The water level was measured in Stegen at the outlet of the Lake Ammersee. Daily measurements were taken by the Bayerisches Landesamt für Wasserwirtschaft since 1968.

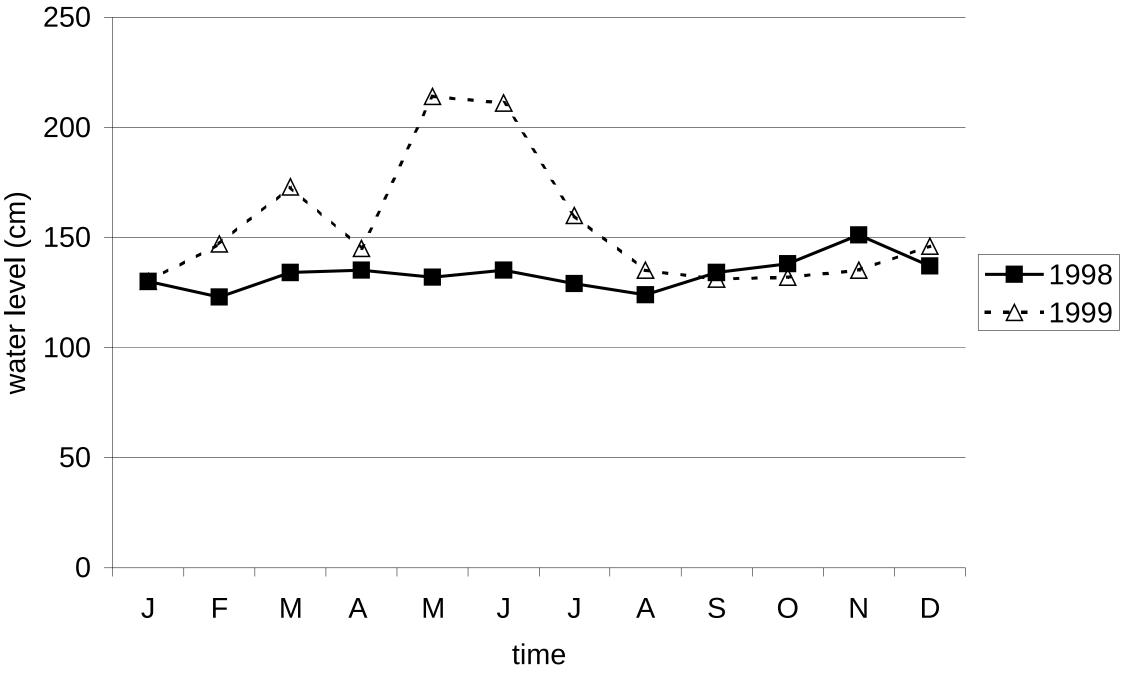


Fig. 1: Average monthly water level measured in Stegen 1998 and 1999.

The typical annual mean amplitude of the water level of Lake Ammersee varies between zero and 40 cm (Grosser *et al.* 1997). The average water level amplitude of 1998 was 28 cm; this can be classified as "typical". The average monthly maximum in the year 1999 measured 214 cm and the minimum 130 cm (Fig. 1). The annual mean amplitude of 84 cm was clearly above the "typical" value. The months of May, June and July of 1999 were clearly characterized by a flood situation. The heavy rainfalls in spring continued for several days and the water level reached a daily maximum of 337 cm (WWA 2000).

The development of reed plants can be heavily damaged by flood situations (Rücker *et al.* 1999). The water level affects the macroinvertebrate community density and composition along with physical parameters such as conductivity and dissolved oxygen (Neiff & Carignan 1997).

3.1.2 Physical and chemical parameters

The physical and chemical parameters of the examined habitats at the littoral sites and the pelagic zone are presented. In order to show similarities and differences between the three sites in Schondorf and Aidenried and the pelagial site the parameters are compared with the help of a cluster flow chart.

3.1.2.1 pH value

Fig. 2 depicts the pH values at the lake littoral sites in 1998 and 1999. The average pH value in Schondorf varied little (pH difference of 0,05) between the sites. The reed habitat (S1) had the lowest value of 8,38. The charophyte dominated site (S2) showed an average pH of 8,40. At this site (S3) an average pH value of 8,43 was measured.

The average pH value of 8,33 measured at the sites in Aidenried was only little below the average measures at the sites in Schondorf (8,40). The maximum pH of 9,77 and the minimum pH value of 7,49 were measured at the sites in Aidenried. The maximum values were due to the (three hours) later time of measure ment at that sampling date in March 1998. All three sites in Aidenried had their lowest average pH value of 7,71 shortly after the flood in June 1999 (arrow Fig. 2).

The all-time lowest average pH value showed the pelagic zone. It measured an average of 8,25 for 1998 and 1999 (Fig. 2).

The low mean amplitude of the pH value is due to the calcium carbonate rich sediment of Lake Ammersee. The variation was between 8,0 and 9,0. The photosynthetic activity is responsible for the oscillating pH value (Sigg & Stumm 1994). The maximum values in March 1998 at Aidenried were due to the photosynthetic activity of a diatom blossom and the later measurement time. The minimum values in July and August 1999 at Aidenried can be explained by the low transparency caused by the flood. This had an effect on the photosynthetic activity similar to the lack of daylight at night.

The two-year development of the pH value of the two charophyte dominated littoral habitats S2 and S3 showed the greatest resemblance. The pH values of the habitats A1 and A2 were also very similar. The reed sites S1 and A1 were not clustered according to their pH course. The annual course of the pH value of the pelagic zone showed the most resemblance to the sites in Schondorf.

As displayed in Fig. 3, geographical location plays a more important role in pH value than the macrophyte composition of the microhabitats.

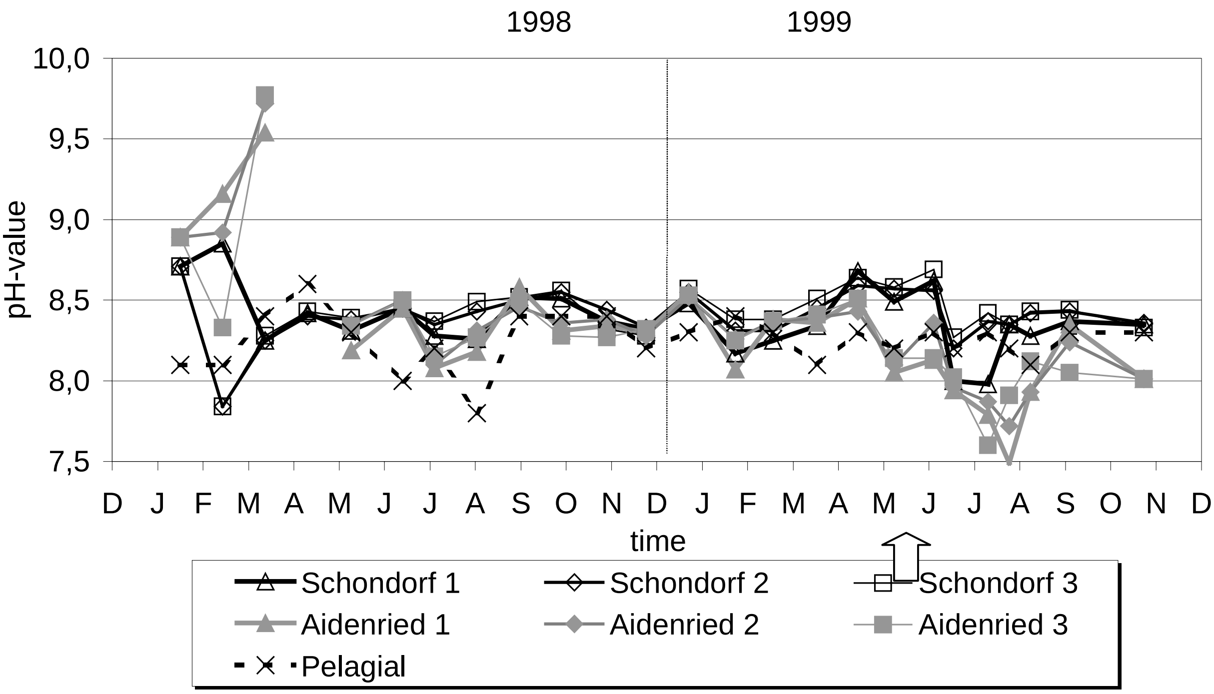


Fig. 2: **pH value at the lake littoral sites Schondorf, Aidenried and the pelagic zone of Lake Ammersee in 1998 and 1999. (The arrow marks the flood situation in 1999.)**

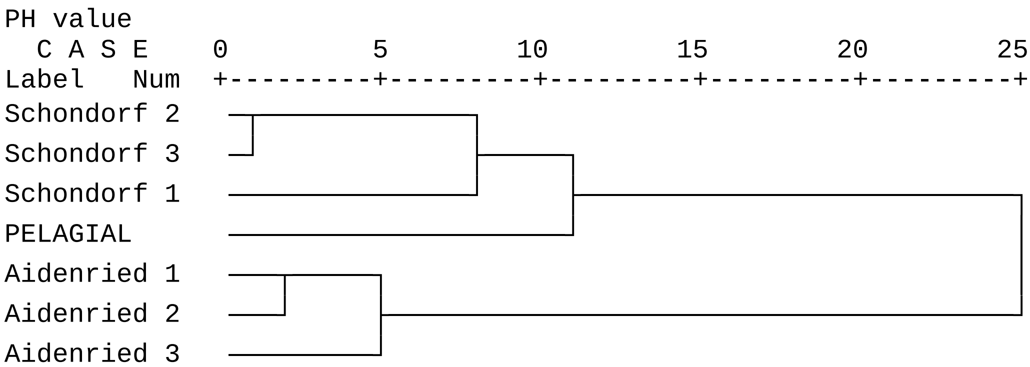


Fig. 3: **Rescaled distance cluster combine dendrogram using average linkage between groups of the pH values at all lake sites**

3.1.2.2 Conductivity

The general annual conductivity courses of all sites were closely correlated with the seasons. The highest conductivity values were measured in spring due to the melting snow and heavy rain in February 1999. The lowest conductivity was measured during the summer period (Fig. 4).

The three sites at Aidenried all show relatively high conductivity averaging between 401 and 394 µS/cm. This is mainly due to the direct influence of the River Ammer that has a high ionic concentration (Mangelsdorf 1972).

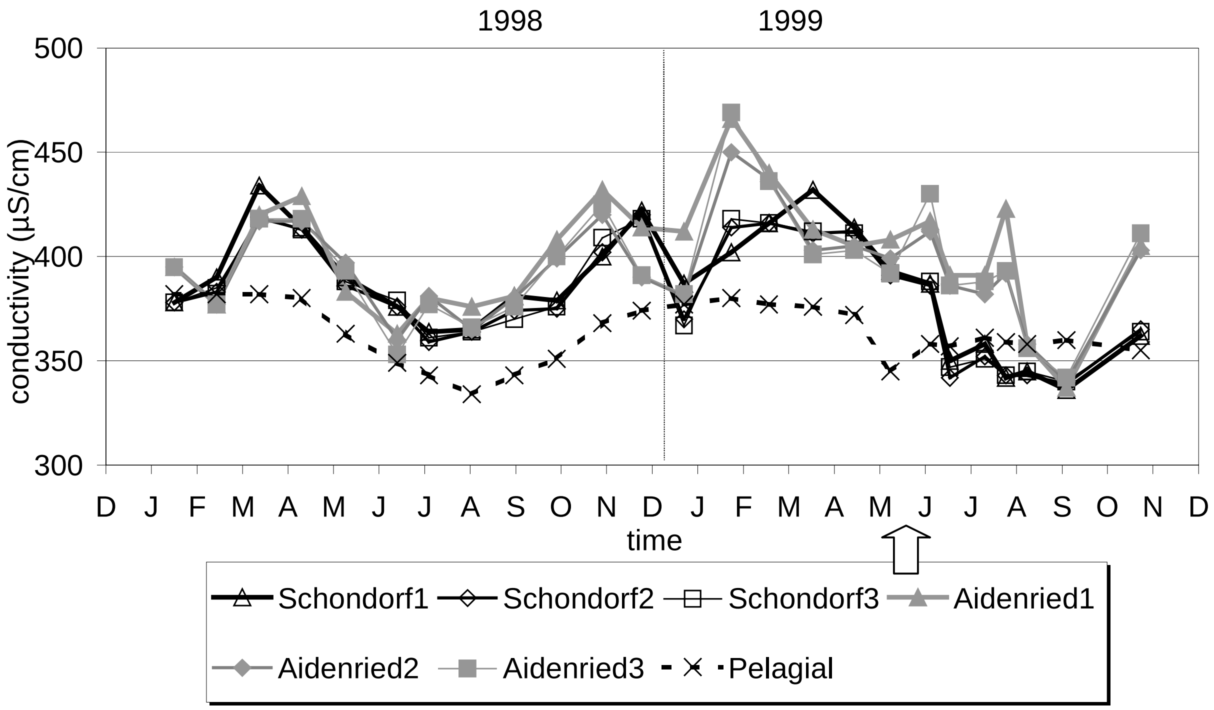


Fig. 4: **Conductivity values (µS/cm) at the lake littoral sites Schondorf, Aidenried and the pelagic zone of Lake Ammersee in 1998 and 1999. (The arrow marks the flood situation in 1999.)**

The conductivity measurements at the sites in Schondorf was lower than the values measured at Aidenried (the average conductivity 383 µS/cm).

The pelagic zone had the lowest average conductivity of 363 µS/cm. The values measured from February 1998 to June 1999 were below the ones measured at the littoral sites. The high water level in June 1999 changed the relationship between pelagic and littoral sites for the rest of the year.

The specific conductance reflects the exact geographical location of the sites. The seasonal course of the ionic concentration of the water at the sites in Schondorf was very similar. The same results were shown for the sites in Aidenried. As seen in Fig. 5, the site within the pelagic zone shows no resemblance with the littoral sites at all.

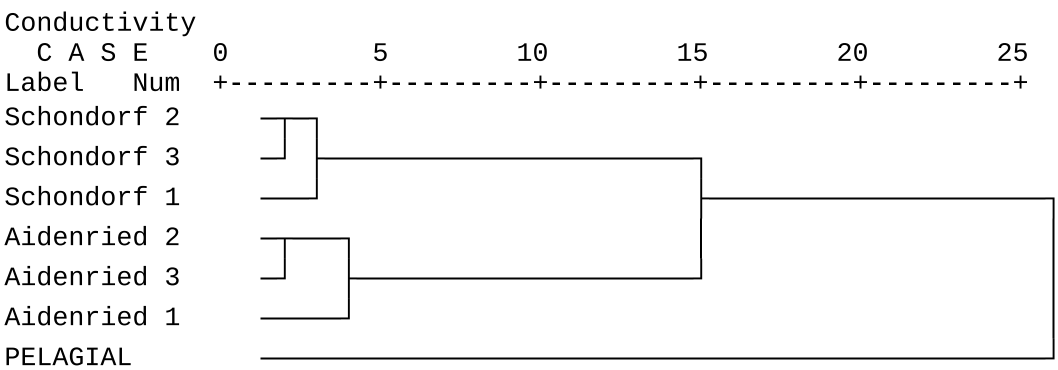


Fig. 5: **Rescaled distance cluster combine dendrogram using average linkage between groups of the conductivity values at all lake sites**

3.1.2.3 Dissolved oxygen content

The oxygen balance of lakes is determined through the supply of dissolved oxygen from the atmosphere and from photosynthetic activity inputs on one side, and the uptake by consumptive metabolisms on the other (Wetzel 1983).

There was no stratification measured because the dissolved oxygen content in the littoral is strongly influenced by wind and waves, and the littoral sites have an average water depth below 1 m.

The average oxygen saturation of 106% at the sites in Schondorf was a little above the average of 99% measured in Aidenried. The 100% oxygen saturation would be between 12 to 13 mg O_2/l at 4 °C near sea level (Wetzel 1983). The oxygen contents for all habitats varied between an average of 9,9 and 10,6 mg O_2/l.

The variation between the oxygen measurements was the greatest in Aidenried (79%). The maximum oxygen content measured was 146% (in September 1999). The minimum value of 67% was measured in July 1999.

At the sites in Schondorf the maximum oxygen saturation of 144% was measured in the beginning of July 1999. The minimum content of 80% was measured only four weeks later.

The course of the oxygen saturation at the pelagic site was mainly in between the two littoral sites. The fluctuation of only 49% was relatively low at the pelagic site (Fig. 6).

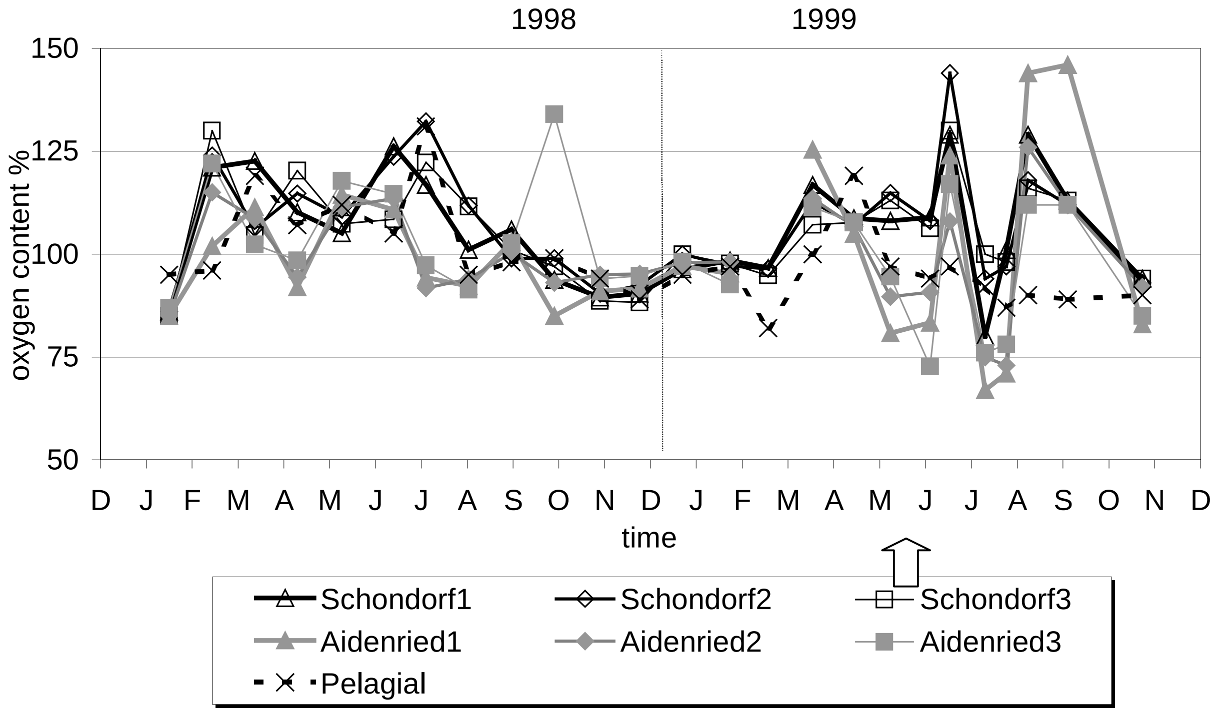


Fig. 6: Dissolved oxygen content (% saturation) measured at the lake littoral sites Schondorf, Aidenried and the pelagic zone of Lake Ammersee in 1998 and 1999. The arrow marks the flood situation in 1999.

The dissolved oxygen contents at the sites in Aidenried were clearly influenced by the higher water level in 1999. The fluctuation increased after the flood situation at the end of May 1999 (Fig. 6). The oxygen content was lowered due to the high load of organic substances contributed by the river Ammer (Schwoerbel 1999). In July, the photosynthetic activity of a major diatom blossom caused the oxygen content to rise at all sites. A month later it sank again to minimum values. The extreme values at Aidenried were also due to the later measurements (up to 3 hours later the same day).

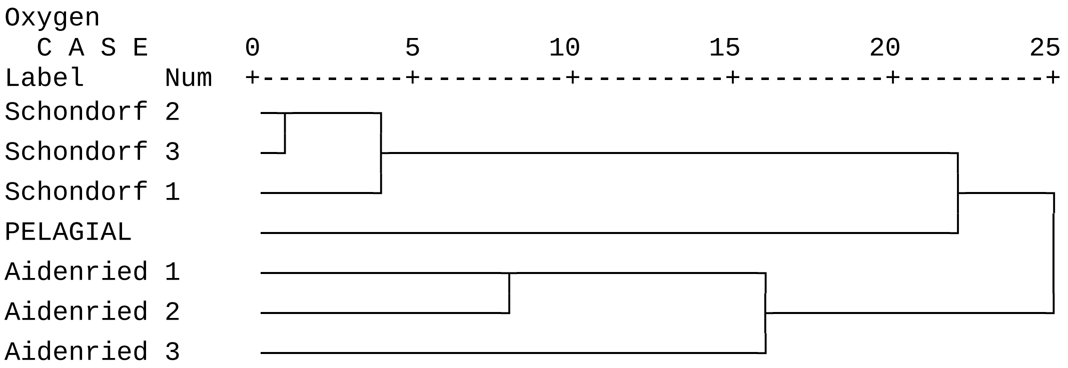


Fig. 7: Rescaled distance cluster combine dendrogram using average linkage between groups of the oxygen saturation at all lake sites

The two charophyte habitats in Schondorf (S2, S3) showed the greatest similarity (Fig. 7). The reed site S1 was also clustered within the same group.

The oxygen saturation development throughout the years at the two sites in Aidenried (A1, A2) showed only little differences, whereas the *Nuphar* habitat A3 showed less similarity.

The oxygen course of the pelagic site showed some resemblance to the Schondorf sites.

3.1.2.4 Temperature

The temperature courses of the years measured at the littoral habitats in Schondorf and Aidenried were about 2 °C higher than at the pelagic site. The low tempered water originating from the flood in 1999 caused the temperature to drop an average of 2 °C at the littoral sites. In both years, the highest temperatures between 23 and 27 °C were reached in July. The lowest temperatures (3 °C in average) were measured in February (Fig. 8).

The temperature development of the three sites at both littoral locations during the two years showed great resemblance. The temperature flow chart grouped the sites at Schondorf and at Aidenried. Further it clustered all littoral sites in a group.

The temperature course of the site within the pelagic zone showed no similarities with the littoral habitats (Fig. 9).

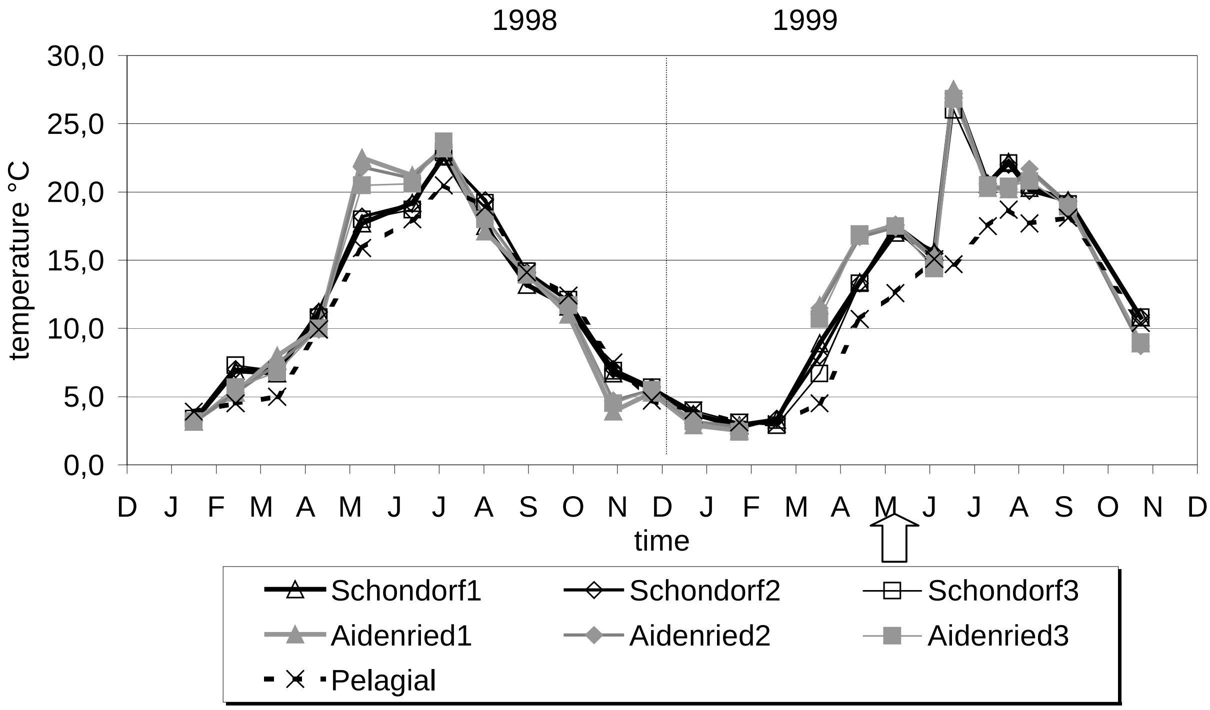


Fig. 8: **Water temperature (°C) measured at the lake littoral sites Schondorf, Aidenried and the pelagic zone of Lake Ammersee in 1998 and 1999. (The arrow marks the flood situation in 1999.)**

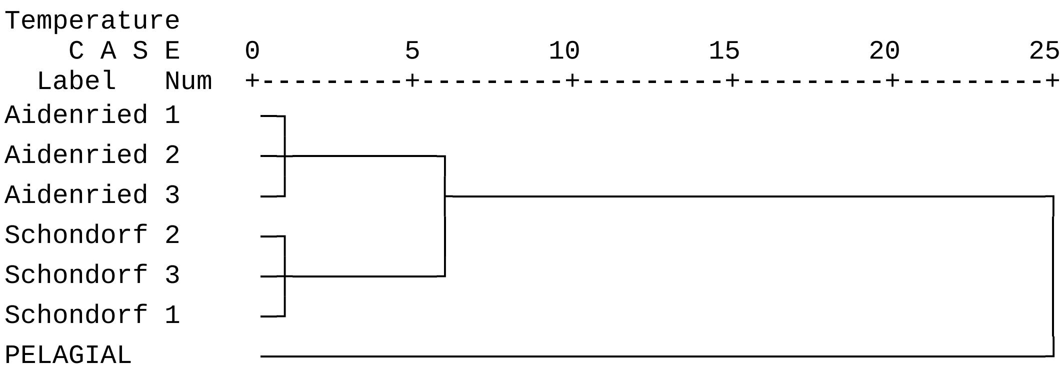


Fig. 9: **Rescaled distance cluster combine dendrogram using average linkage between groups of the temperature at all lake sites**

3.1.2.5 Phosphorus

The phosphorus compounds are the limiting nutrients for primary production (Schwoerbel 1999) and therefore an important parameter to judge the productivity of lakes. The littoral zone plays a major part within the phosphorus cycle. Not only do the littoral flora take part in the phosphorus flux, but also, the benthic invertebrates can incorporate organic material, transporting phosphorus to other compartments of the system when they emerge (Wetzel 1983).

Fig. 10, Fig. 11 and Fig. 12 depict phosphorus measurements at the lake littoral sites. Three different phosphorus parameters were measured: the total phosphorus concentration (TP), the soluble phosphorus concentration (SP) and the soluble reactive phosphorus concentration (SRP).

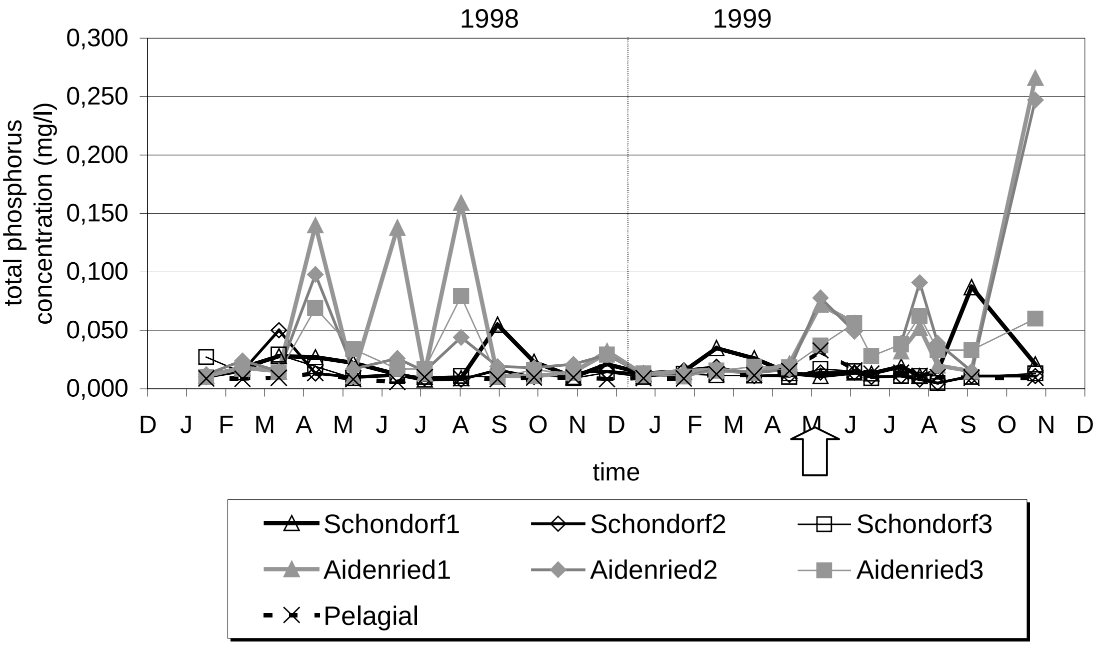


Fig. 10: **Total phosphorus concentration measured at the lake littoral sites Schondorf, Aidenried and the pelagic zone of Lake Ammersee in 1998 and 1999. (The arrow marks the flood situation in 1999.)**

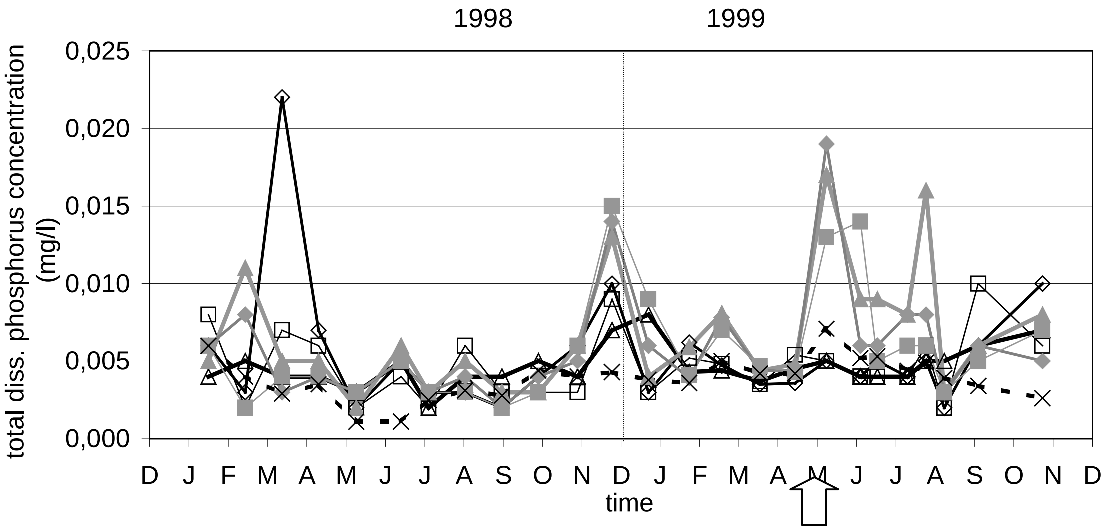


Fig. 11: **Total dissolved phosphorus concentration measured at the lake littoral sites Schondorf, Aidenried and the pelagic zone of Lake Ammersee in 1998 and 1999. (The arrow marks the flood situation in 1999.)**

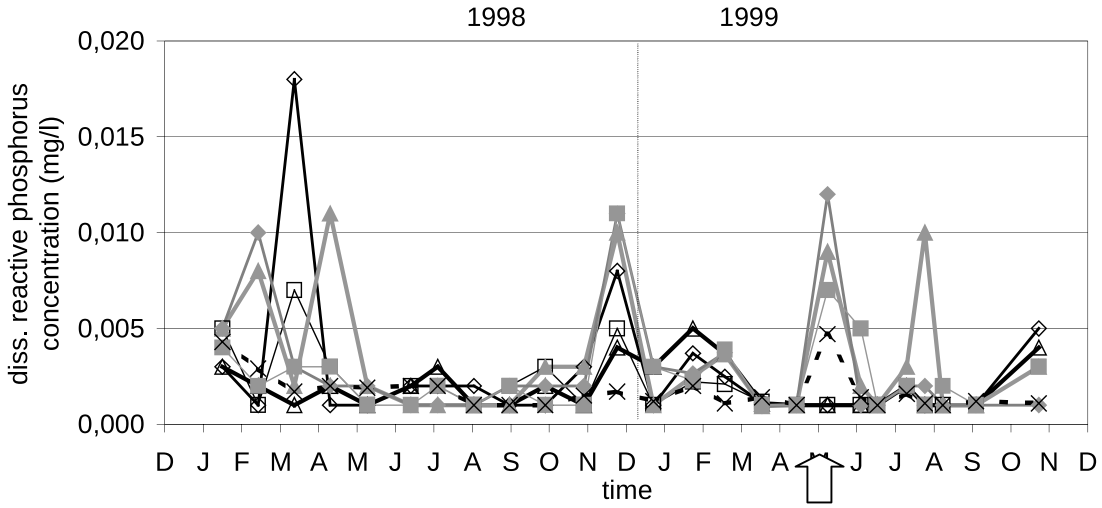


Fig. 12: Dissolved reactive phosphorus concentration measured at the lake littoral sites Schondorf, Aidenried and the pelagic zone of Lake Ammersee in 1998 and 1999. (The arrow marks the flood situation in 1999.)

The highest total phosphorus concentrations were observed at the littoral sites in Aidenried. The sites measured the average of 0,039 mg/l TP. The highest average TP-concentration was measured at the reed site A1. In May, July and September of 1998 and in November of 1999, the highest peaks were measured.

The TP concentration at the Schondorf sites ranged between 0,021 and 0,013 mg/l. The lowest average of 0,011 mg/l was measured at the pelagic site (Fig. 10).

The total phosphorus concentration includes particulate material as well as organic fractions. An unequal spread of particles within the samples is a possible reason for such high measurement fluctuations.

The average value of the dissolved phosphorus concentration was the highest at the Aidenried sites. An average of 0,006 mg/l was measured at the three sites.

The mean concentration of 0,005 mg/l was measured at the Schondorf sites. The maximum value measured in April 1998 at S2 was due to sample contamination.

The dissolved phosphorus concentration at the pelagic site shows the lowest measured average concentration (0,004 mg/l). The maximum concentration of 0,07 mg/l was measured shortly after the flood (Fig. 11) in 1999.

The SRP concentration stayed within the range of 0,002 – 0,003 mg/l at all sites. Sample contamination was responsible for the extreme value measured at the site S2 in April 1998. High concentrations were measured at the sites in Aidenried in February 1998, April 1998, December 1998, June 1999 and August 1999.

Peaks at the sites in Schondorf were measured in April and December of 1998 and February and November of 1999.

The highest value measured at the pelagic site was 0,009 mg/l in June 1999 shortly after the flood (arrow in Fig. 12).

The two charophyte habitats (S2, S3) and the pelagic site have the greatest similarity. The sites S1 and A3 are also clustered in one group. The sites located at Aidenried A1 and A2 are clustered separately (Fig. 13).

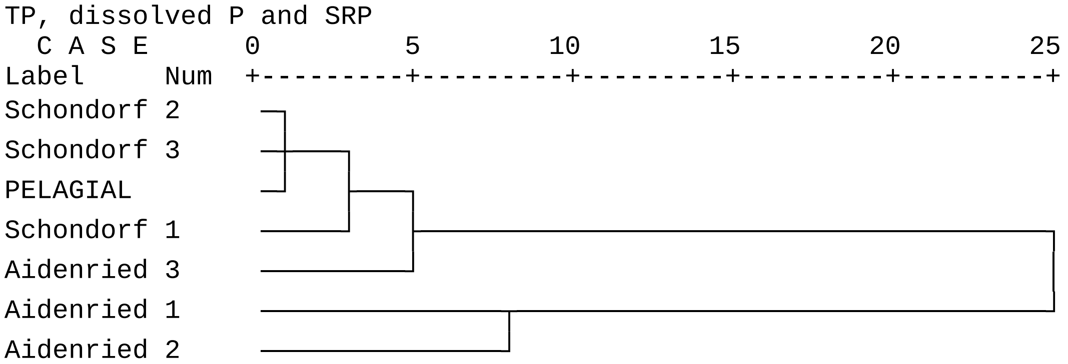


Fig. 13: Rescaled distance cluster combine dendrogram using average linkage between groups of all phosphorous parameters at all lake sites.

3.1.2.6 Nitrogen

Ammonia, nitrate and nitrite concentrations were measured in order to describe the nitrogen situation at the sites. Large numbers of N_2 –fixing bacteria occur as epiphyte on submersed macrophytes and in the sediments of lakes. Along with precipitation, this is an important part for the nitrogen income of lakes (Wetzel 1983). Depending on the oxygen availability, the nitrogenous compounds can be converted into one another. Due to nitrification processes the compounds are reduced to a more oxidized state. This can also be reversed through denitrification and nitrate assimilation. Many different bacteria are responsible for these processes. *Nitrosomonas europaea*, for example, transforms ammonia to nitrite. *Nitrobacter winogradskyi* can complete the transformation from nitrite to nitrate. These processes are only possible in an oxygen environment. Facultative anaerobic bacteria like *Pseudomonas* can reverse the process by converting nitrate to ammonia and nitrate to nitrogen. N_2 –fixing bacteria like *Azotobacter* return nitrogen into the bio-available nitrogen cycle (Wetzel 1983).

The plants also take part in the nitrogen cycle. The leaves of the submerse macrophytes take up ammonia and nitrate (sometimes only one of the two) and release ammonia nitrogen at night (Schwoerbel 1999).

Ammonia, nitrate and nitrite concentration measurements are displayed in Fig. 14 through Fig.17. The measured average ammonia concentration throughout both years at the Aidenried sites was 0,041 mg/l. The highest concentration was measured at the reed habitat. The maximum peak concentration of 0,105 mg/l was measured in August 1998. In 1999 the maximum peaks were measured in August and November.

The ammonia concentrations measured at the Schondorf sites were clearly below the concentrations in Aidenried. The measured mean was 0,017 mg/l. The fluctuations at all three habitats were very low (Fig. 14). The positive oxygen conditions in Schondorf favored the nitrification processes.

The pelagic site had the lowest ammonia concentration of 0,010 mg/l in average. The measured values from the pelagic site represent only the epilimnia of the lake since the samples were taken from the first 10 m. The maximum concentration of 0,030 mg/l was measured shortly after the flood in 1999.

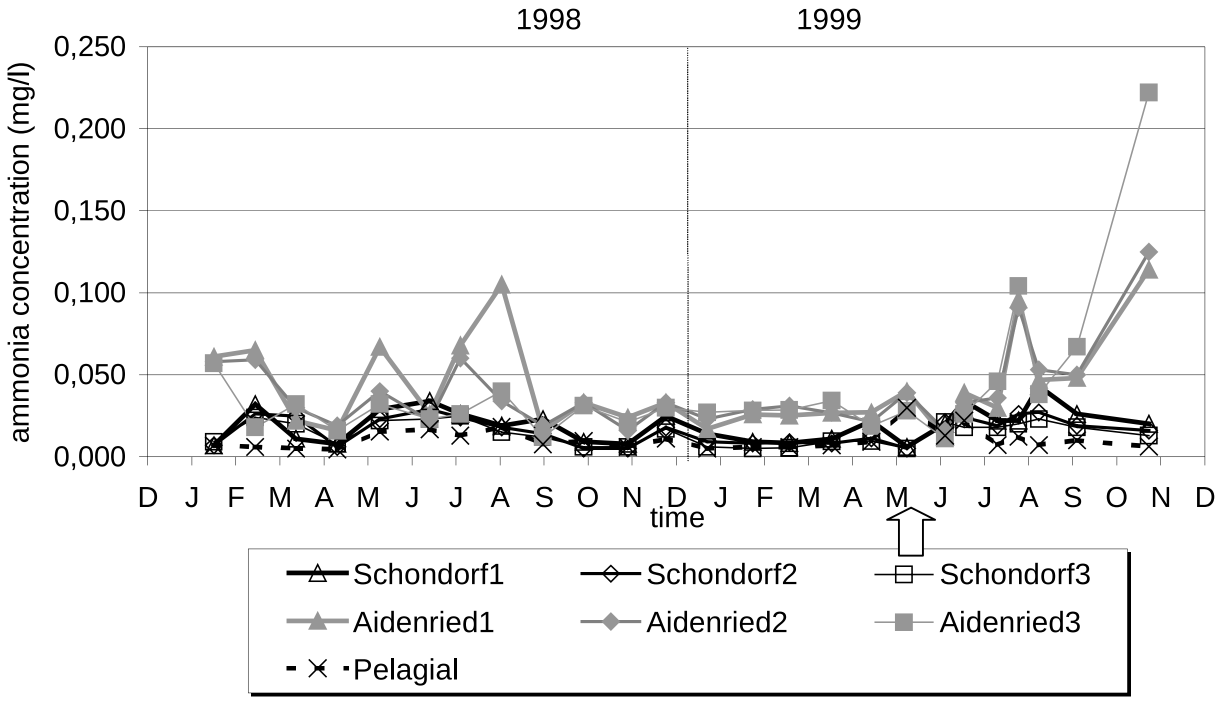


Fig. 14: **Ammonia (NH_4-N) concentration at the lake littoral sites Schondorf, Aidenried and the pelagic zone of Lake Ammersee in 1998 and 1999. (The arrow marks the flood situation in 1999.)**

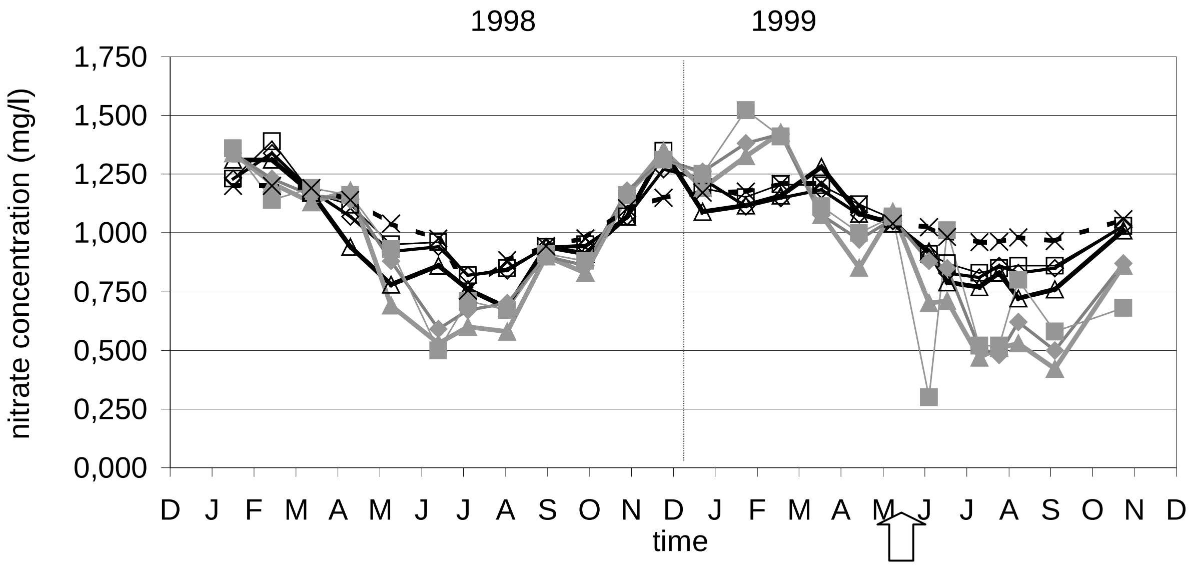


Fig. 15: **Nitrate (NO_3-N) concentration at the lake littoral sites Schondorf, Aidenried and the pelagic zone of Lake Ammersee in 1998 and 1999. (The arrow marks the flood situation in 1999.)**

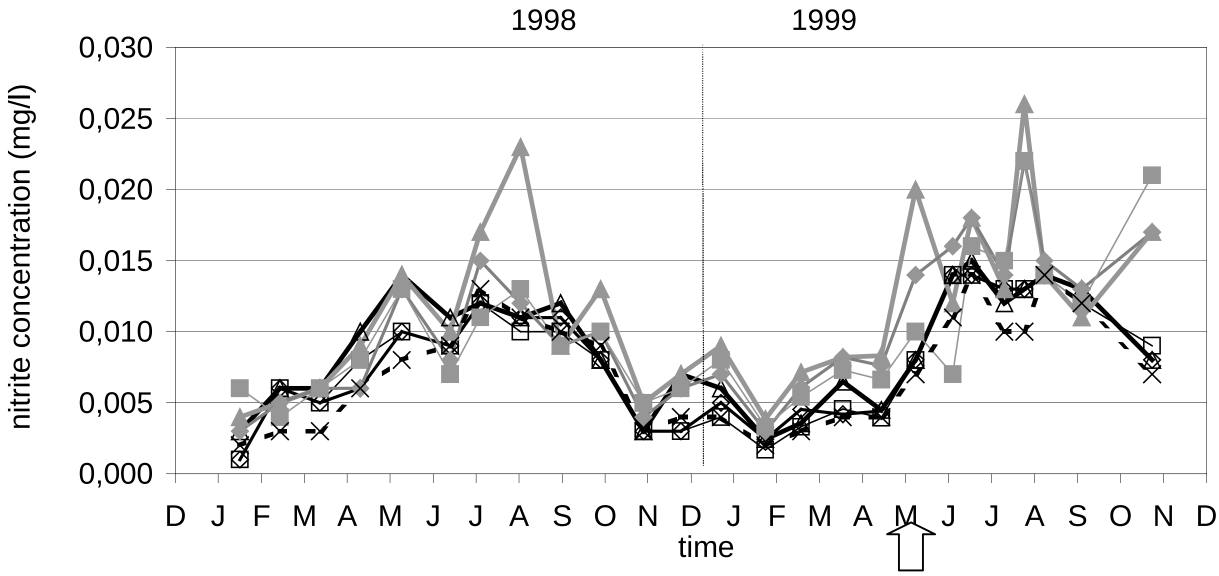


Fig. 16: **Nitrite (NO_2-N)concentration at the lake littoral sites Schondorf, Aidenried and the pelagic zone of Lake Ammersee in 1998 and 1999. (The arrow marks the flood situation in 1999.)**

The highest nitrate concentrations were measured in the winter months November, December, January, February and March. The lower nitrate concentrations measured during the warmer months (June, July, August and September) were due to the nitrate uptake of algae and macrophytes.

The nitrate concentrations reflect the inverse course of the ammonia concentrations. At the sites in Aidenried, the nitrate concentrations varied between 0,091 and 0,094 mg/l.

The nitrate concentrations of the reed habitats (S1, A1) were below the concentrations at the other littoral habitats. The nitrate concentrations at the Schondorf sites ranged between 0,99 and 1,04 mg/l. The pelagic zone had the highest mean nitrate contents of 1,06 mg/l (Fig. 15).

The nitrite contents (Fig. 16) had an inverse seasonal development as the nitrate courses (Fig. 15). The winter months measured the lowest concentrations and in summer the concentrations were relatively high.

The highest nitrite concentrations were measured at the Aidenried littoral habitats. The average at the sites ranged between 0,010 and 0,012 mg/l. At the Schondorf sites they varied between 0,008 and 0,009 mg/l. The lowest average concentration of 0,007 mg/l was measured at the pelagic zone site (Fig. 16).

The littoral sites of Schondorf and Aidenried showed a great similarity concerning NH_4–N, NO_3 -N and NO_2 –N contents. The pelagic site most resembled the sites in Schondorf. The sites in Aidenried were clustered in a separate group (Fig. 17).

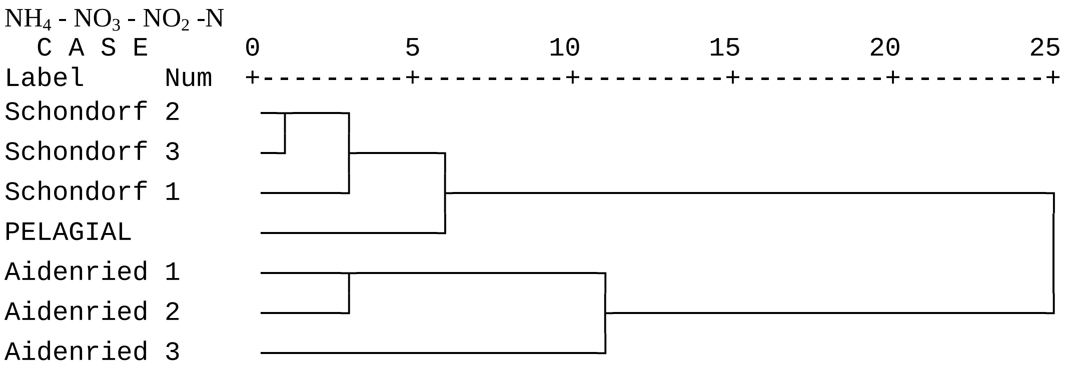


Fig. 17: Rescaled distance cluster combine dendrogram using average linkage between groups of all nitrogen parameters at all lake sites.

3.1.2.7 Silica

Silica concentrations in lakes are marked by seasonal variations. This is mainly due to the intensive assimilation of silica by diatoms (Wetzel 1983).

This typical seasonal variation of the silica content was clearly documented for all habitats. The diatom blossom in spring 1998 reduced the silica concentration to 30-40%. The diatom blossom shortly after the flood in 1999 left the littoral habitats with only 20% silica content. The pelagic site resulted in a cut down silica concentration of 60% (Fig. 18).

In the reed habitats the lowest silica concentrations were measured. The average silica content of 2,00 mg/l was measured at the habitat A1. The site S1 had an average of 2,03 mg/l silica content. The *Nuphar lutea* habitats (A2, A3) at Aidenried had silica concentrations between 2,03 and 2,06 mg/l.

At the charophyte sites (S2, S3) silica concentration ranged between 2,09 and 2,11 mg/l. The highest average silica content of 2,26 mg/l was measured in the pelagic zone of the lake (Fig. 18).

The silica contents of the charophyte habitats showed the greatest similarity. The same was observed for the two *Nuphar* habitats in Aidenried. The pelagic zone was clustered with the two sites S2 and S3 in Schondorf. The reed site in Schondorf showed no resemblance with the other habitats (Fig. 19).

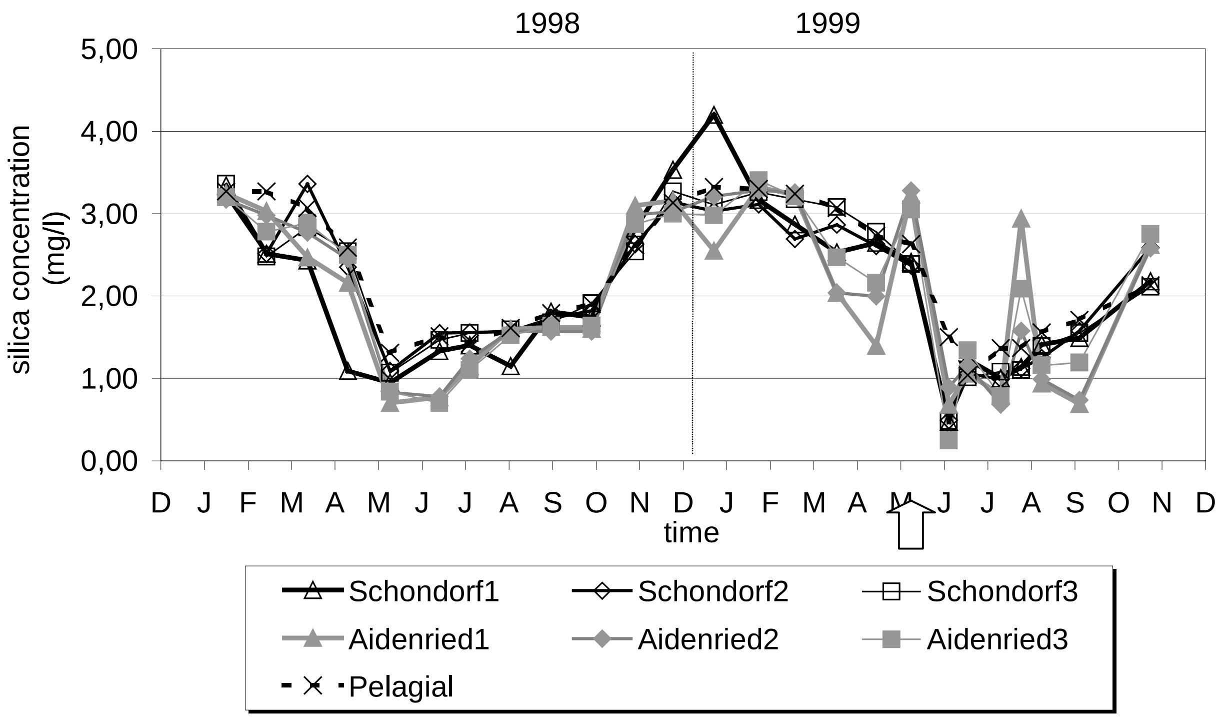


Fig. 18: Silica concentration at the lake littoral sites Schondorf, Aidenried and the pelagic zone of Lake Ammersee in 1998 and 1999. (The arrow marks the flood situation in 1999.)

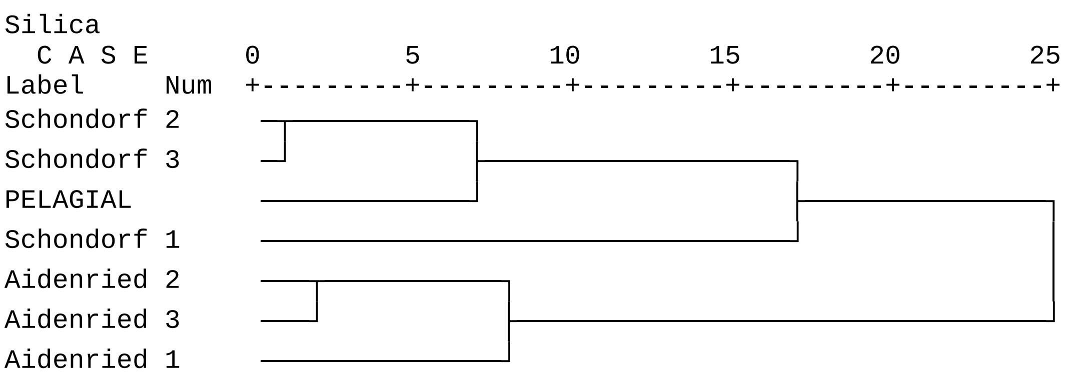


Fig. 19: Rescaled distance cluster combine dendrogram using average linkage between groups of the silica content at all lake sites.

3.1.2.8 Chlorophyll a

Chlorophyll a is the primary photosynthetic pigment of all oxygen-evolving photosynthetic organisms (Wetzel 1983). This parameter was used to give an overall view of the biomass development of the phytoplankton communities.

No obvious phytoplankton growth periodicities could be observed at the sites. As seen in the Fig. 20, the habitats at Aidenried showed the highest chlorophyll a concentrations. They ranged from 8,07 µg/l (A3) to 13,86 µg/l (A1) in average. The maximum values in 1998 were measured in May and July. Reduced phytoplankton growth was measured during the periods of March and September. In 1999, the numbers increased after the flood in June and July and remained relatively high compared to 1998. In November, the chlorophyll a concentration reached the maximum values.

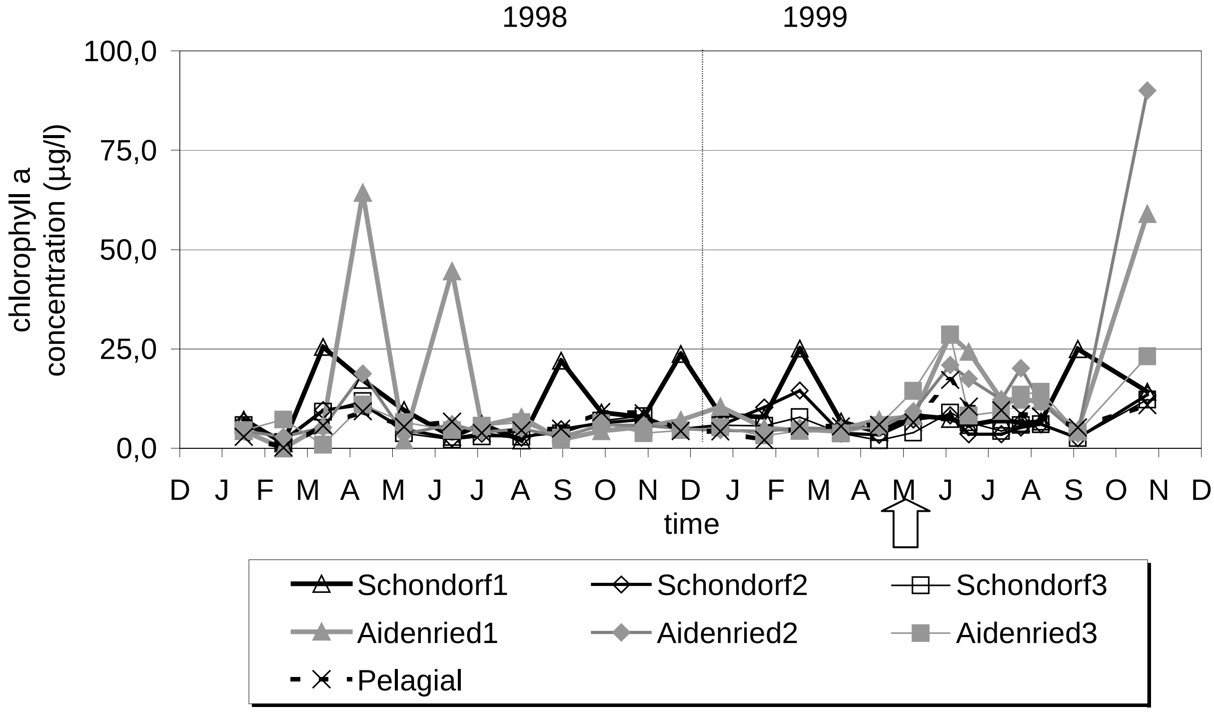


Fig. 20: **Chlorophyll a concentration at the lake littoral sites Schondorf, Aidenried and the pelagic zone of Lake Ammersee in 1998 and 1999. (The arrow marks the flood situation in 1999.)**

At Schondorf the concentrations between the two charophyte habitats varied between 5,57 µg/l (S3) and 6,14 µg/l (S2). Just like in Aidenried, the reed habitat in Schondorf (S1) showed a higher mean chlorophyll a content (10,69 µg/l) than the other two Schondorf sites. A spring maximum was built up in 1998 at the reed site (S1). Further peaks were measured in September and December 1998 and March and September 1999.

In the pelagic zone, an average chlorophyll a content of 6,62 µg/l was observed. The maximum values were measured in May and October 1998 and after the flood in June 1999. The values remained at a high level until September. In November, the chlorophyll a concentration rose to a value of 19,9 µg/l again (Fig. 20).

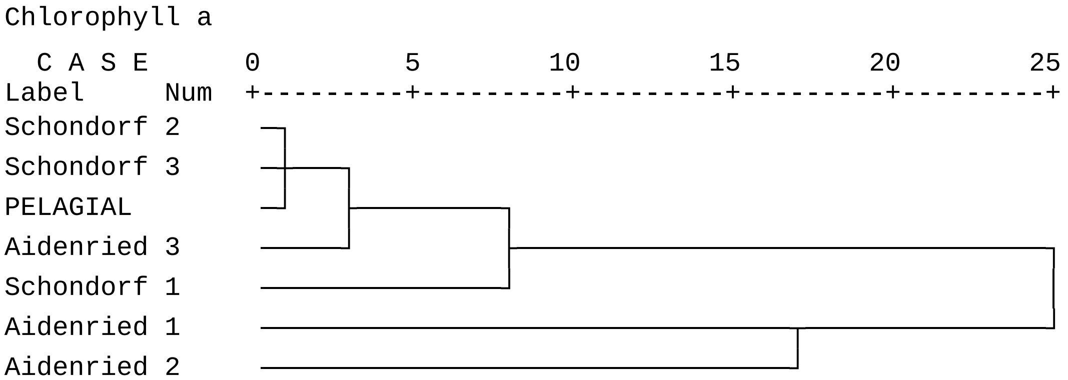


Fig. 21: Rescaled distance cluster combine dendrogram using average linkage between groups of the chlorophyll a concentration at all lake sites.

The two charophyte-habitats at Schondorf and the pelagic zone show the highest similarity. The site at *Nuphar* site in Aidenried (A3) was also grouped with the first cluster. These sites have the greatest distance from the shoreline in common. The two reed habitats S1 and A1 and the *Nuphar* site A2 showed no resemblance (Fig. 21).

3.1.2.9 Chloride

In lakes, chloride is often used as a parameter to measure pollutional effects (Wetzel 1983). Therefore extreme high values have to be considered critically.

The average chloride content of all habitats showed little variance. The concentration ranged between 6,3 mg/l at the pelagic site and 7,8 mg/l at the reed habitat (A1) in Aidenried.

The highest chloride concentration was measured at the reed site in Schondorf (S1) in April 1998. High values were also measured at the reed site in Aidenried (A1) in February and August 1999. At the *Nuphar* site A3, a high value of > 10 mg/l was observed in November 1998 and July 1999 (Fig. 22).

The two charophyte habitats (S2 and S3), the pelagic zone and the *Nuphar* habitat (A2) showed a similar chloride concentration course throughout the years. The two reed habitats (S1 and A1) and the *Nuphar* habitat (A3) showed no resemblance in the flow chart. This is due to the maximum values measured at these sites (Fig. 23).

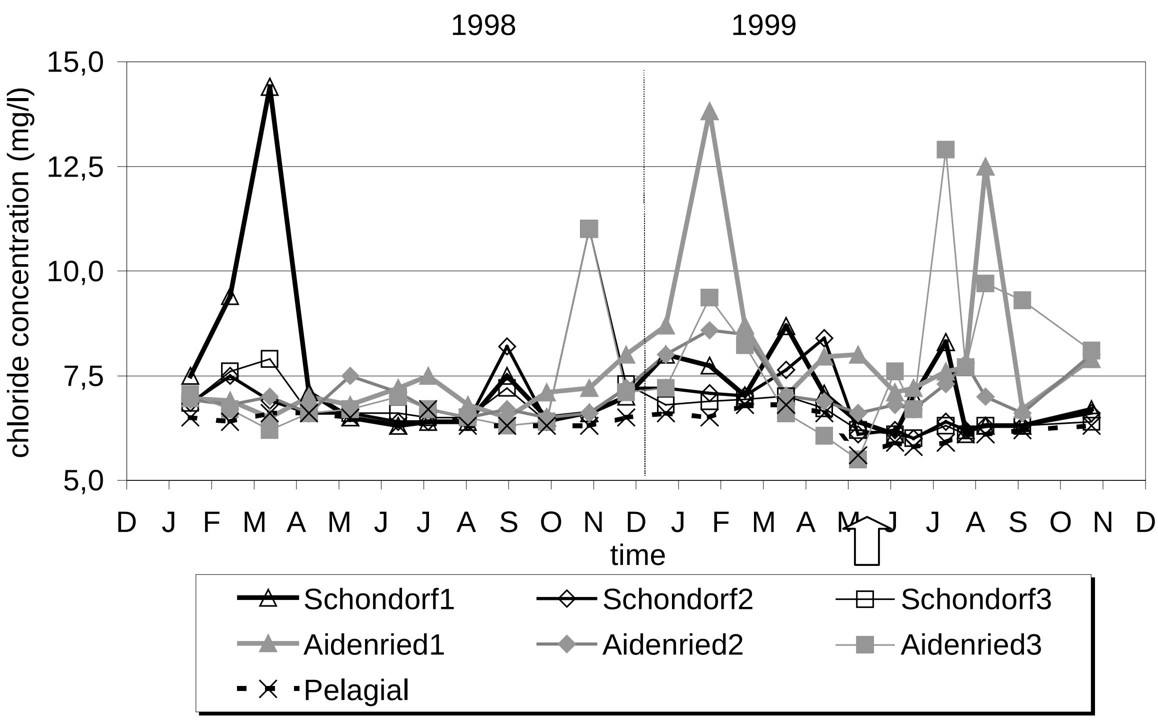


Fig. 22: **Chloride concentration at the lake littoral sites Schondorf, Aidenried and the pelagic zone of Lake Ammersee in 1998 and 1999. (The arrow marks the flood situation in 1999.)**

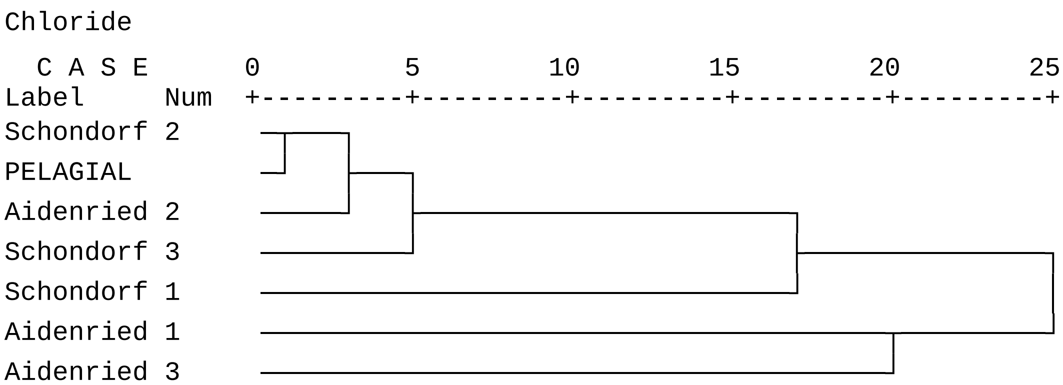


Fig. 23: **Rescaled distance cluster combine dendrogram using average linkage between groups of the chlorophyll a concentration at all lake sites.**

3.1.2.10 DOC

The average dissolved organic carbon concentrations of all habitats was measured with 3,4 mg/l ±0,07 mg/l standard deviation. The values measured at all sites in Aidenried (3,6 mg/l average) and S1, the reed site in Schondorf (3,5 mg/l), were slightly above those measured at the *Nuphar* sites in Schondorf (S2, S3) and at the pelagic site (average 3,3 mg/l).

A maximum value of 5,5 mg/l was measured in December 1998 at site A2. At the Aidenried sites, the dissolved organic carbon concentration was relatively high in the period from June to August, after the flood in 1999 (Fig. 24).

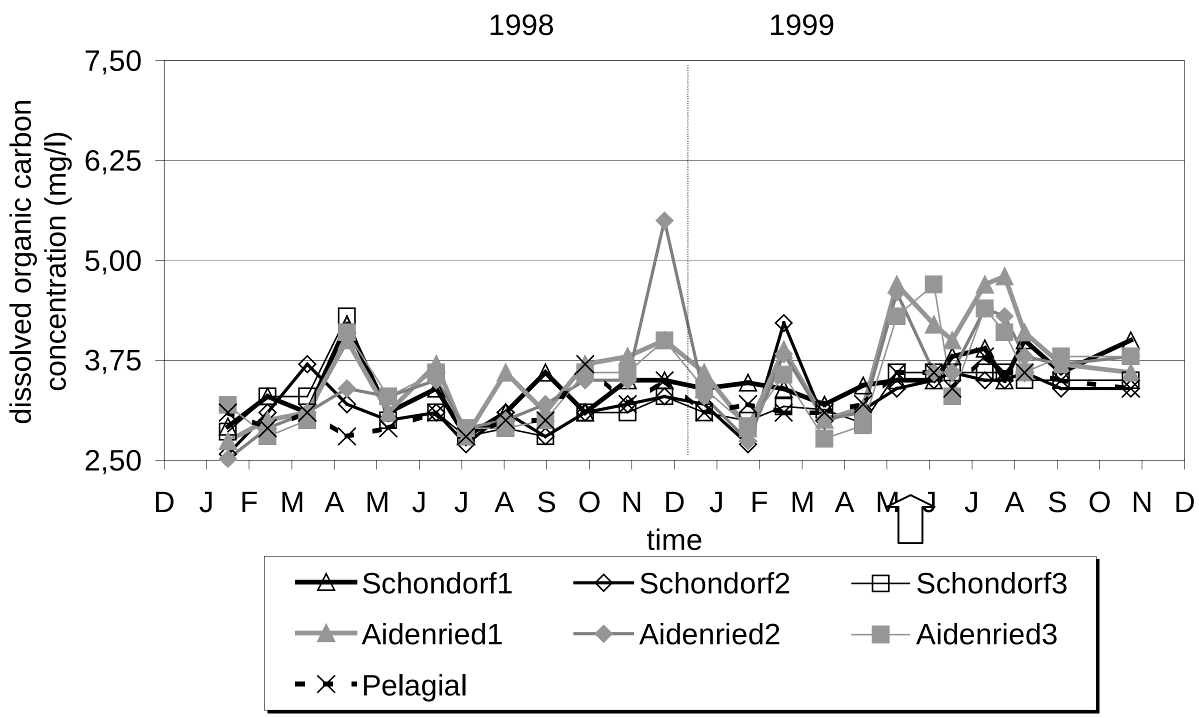


Fig. 24: **DOC concentration at the lake littoral sites Schondorf, Aidenried and the pelagic zone of Lake Ammersee in 1998 and 1999. (The arrow marks the flood situation in 1999.)**

The three habitats in Schondorf were clustered with the pelagic site. The three sites in Aidenried also showed great resemblance because they were all strongly influenced by the river Ammer, whereas the other sites were not. The courses of the DOC content reflected this influence (Fig. 25).

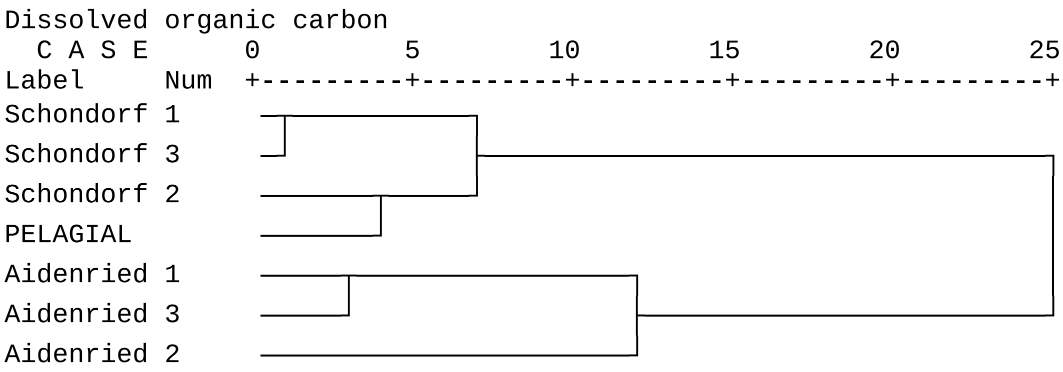


Fig. 25: **Rescaled distance cluster combine dendrogram using average linkage between groups of the DOC concentration at all lake sites.**

3.1.2.11 Sulfate

The sulfate concentrations were only measured during 1999. The average of all measured habitats was 15,3 mg/l ±0,15 mg/l standard deviation (Fig. 26).

The habitats at the two geographical locations, Schondorf and Aidenried, were clearly grouped in a cluster. The course of the sulfate concentration of the pelagic zone showed the greatest difference (Fig. 27).

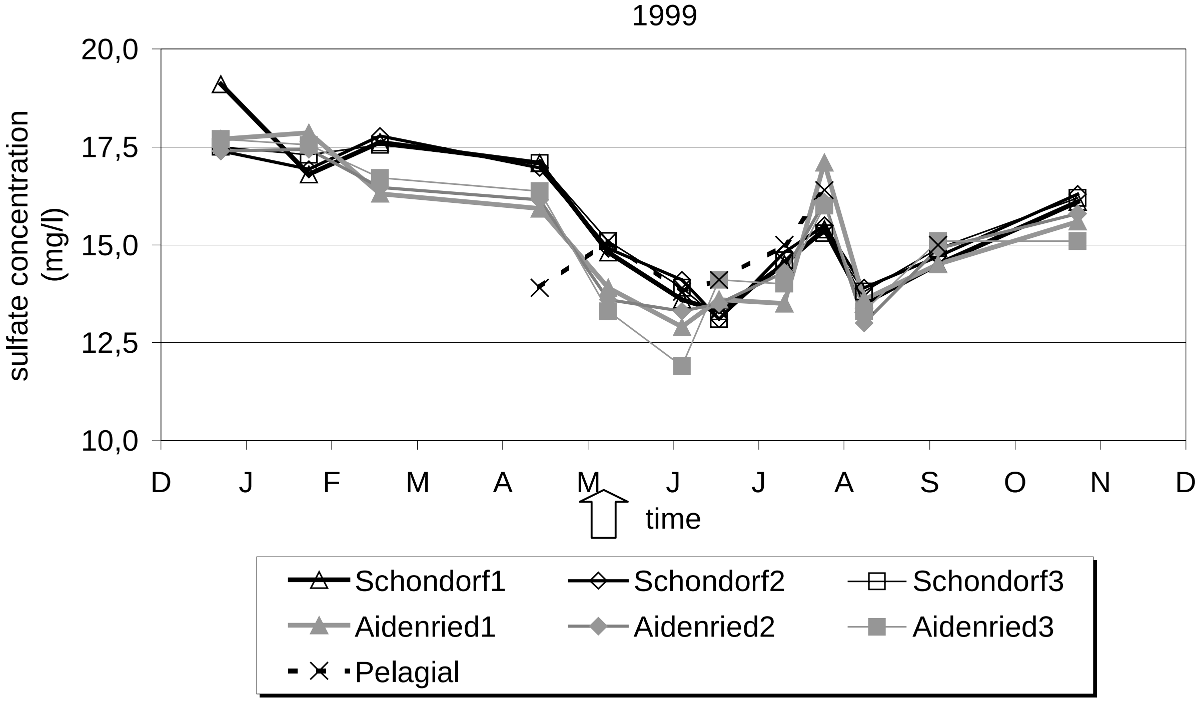


Fig. 26: Sulfate concentration at the lake littoral sites Schondorf, Aidenried and the pelagic zone of Lake Ammersee in 1999. (The arrow marks the flood situation in 1999.)

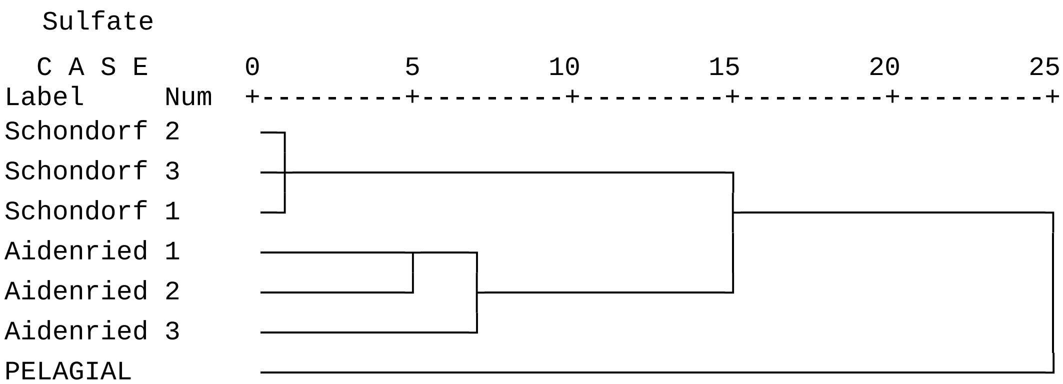


Fig. 27: Rescaled distance cluster combine dendrogram using average linkage between groups of the sulfate concentration at all lake sites.

3.1.3 Comparison of the lake sites

The physical and chemical parameters of the seven sites showed different relationships to each, other depending on the parameter regarded. They were grouped differently with each parameter measured. The three sites with the same geographical location were grouped more often as the microhabitats at the same depths. The water chemistry of the pelagic zone was strongly influenced by the flood situation in 1999. Parameters such as ammonia and nitrate showed a clear effect to the high water level at all sites. The flood had more influence on the physical and chemical parameters at the sites at Aidenried than in Schondorf.

The concentrations of the parameters measured at the pelagic site were grouped separately at 30% of the eleven documented parameters. It was grouped to the sites in Schondorf (S2 and S3) at 70% and was never grouped with the one of the sites in Aidenried.

3.1.4 Macroinvertebrates of the lake sites

Within charophyte habitats a positive correlation between mollusk and charophyte-biomass has already been proven (Van den Berg *et al.* 1997). Other studies examined macroinvertebrate interactions with macrophytes, such as *Phragmites australis, Sparganium erectum, Typha angustifolia, Polygonum amphibium, Ceratophyllum demersum, Elodea sp., Myriophyllum spicatum, Nitella mucronata, Chara globularis* (Dvorak & Best 1982, Kornijow & Gulati 1992). No significant correlations between macrophytes and macroinvertebrates were found. Different functional feeding groups have been defined for reed plants such as *Typha*, *Phragmites* and *Nuphar* (Dvorak 1996).

Since the plants differ in their leaf morphology and life cycle, it is important to make a representative selection (Van den Berg 1997). Plants with dissected leaves provide more substrate for the growth of periphytic algae (Dvorak 1982) and provide different habitat conditions for the invertebrates. Different invertebrates prefer different species of macrophytes (Cry 1988). The biomass from *Potamogeton pectinatus* and the associated macroinvertebrates can differ according to their location (Bergey 1992). So it is also important to consider the variety of the geographical locations.

A well-established qualitative (semi-quantitative) sampler to examine lake littoral is the basket type artificial substrate sampler (Merrit & Cummins 1984). Pebble baskets have been used successfully for many different kinds of studies (Brock *et al.* 1992). The seasonal change plays an important part for the development of the different macroinvertebrate species within the habitats (Kornijow 1989). Some authors question the method.

Experiments have shown that the colonization potential in natural habitats can be higher than in artificial substrates (Casey & Kendall 1996). When using an artificial substrate as quantitative method, the question of the „Island effect” for certain species arises (Rosenberg & Resh 1982). Substrates such as PVC-Labyrinth acc. Lubini-Ferlin 1986 (BLfW 1993) and pebble baskets in different sizes (Rosenberg & Resh 1982) have been used to obtain comparable quantitative results in littoral studies.

3.1.4.1 Turbellaria

The sampled turbellaria species all belong to the order of the Tricladia. *Dendrocoelum lacteum, Dugesia spp.* and *Polycelis spp.* all prefer habitats with a lot of water movement. The lakes shoreline offers this environment.

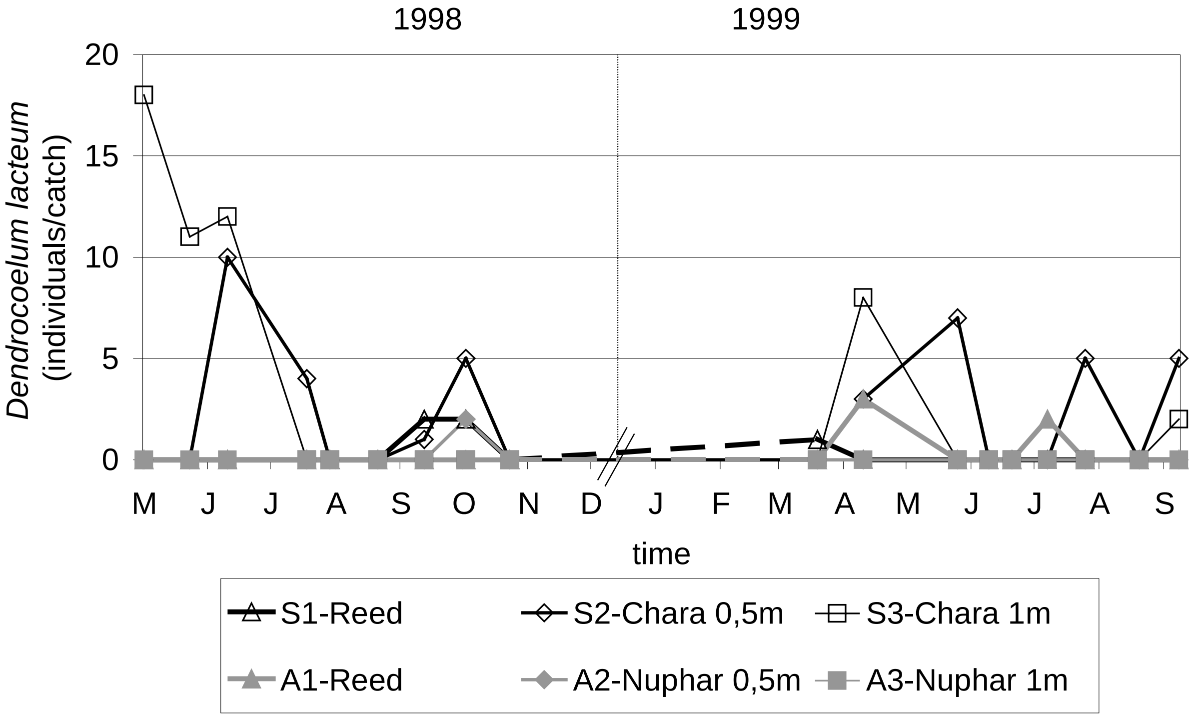


Fig. 28: ***Dendrocoelum lacteum* collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

The fairly common species are usually found in productive lakes where the calcium concentration is at least 10 mg/l (Reynoldson 1978). *Dendrocoelum lacteum* showed its highest counts of 18 individuals/catch in spring 1998. After the flood situation in 1999 maximum numbers reached only 7 – 8 individuals/catch. The reproduction rate of *Dendrocoelum lacteum* is usually negatively correlated with temperature because the species requires colder temperatures for reproduction (Wesenberg-Lund 1939).

The maximum reproduction was probably reached during the sampling pause in winter. The triclad breeds at temperatures of 3,5 to 15 °C (Reynoldson 1978). The charophyte habitats S2 and S3 were clearly preferred (Fig. 28). The numbers varied between 1 and 12 individuals/catch. The charophytes offered a habitat with the necessary light reduction and the right food resources. The fast moving predator feeds on small organisms and on carrion. Its distribution is often closely linked with that of *Asellus aquaticus* (Reynoldson 1978).

The species of the genus *Dugesia* breed within the range of 10 – 13 °C. They feed mainly on gastropods (Reynoldson 1978). *Dugesia spp.* was found in all three habitats in Schondorf as well as in Aidenried. There was no habitat preferred. The abundance was higher in 1998 than in 1999. In 1998, the individuals/catch ranged between 1 and 20. In 1999 an average of 5 individuals /catch and less was counted (Fig. 29).

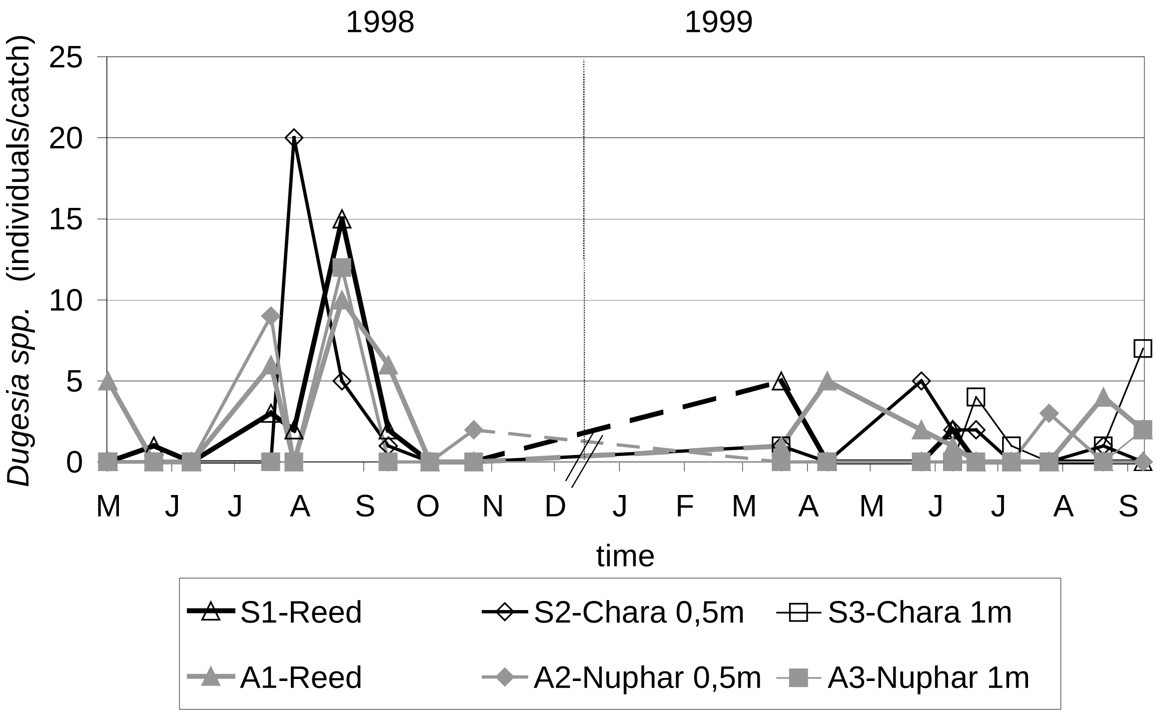


Fig. 29: ***Dugesia spp.*** **collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

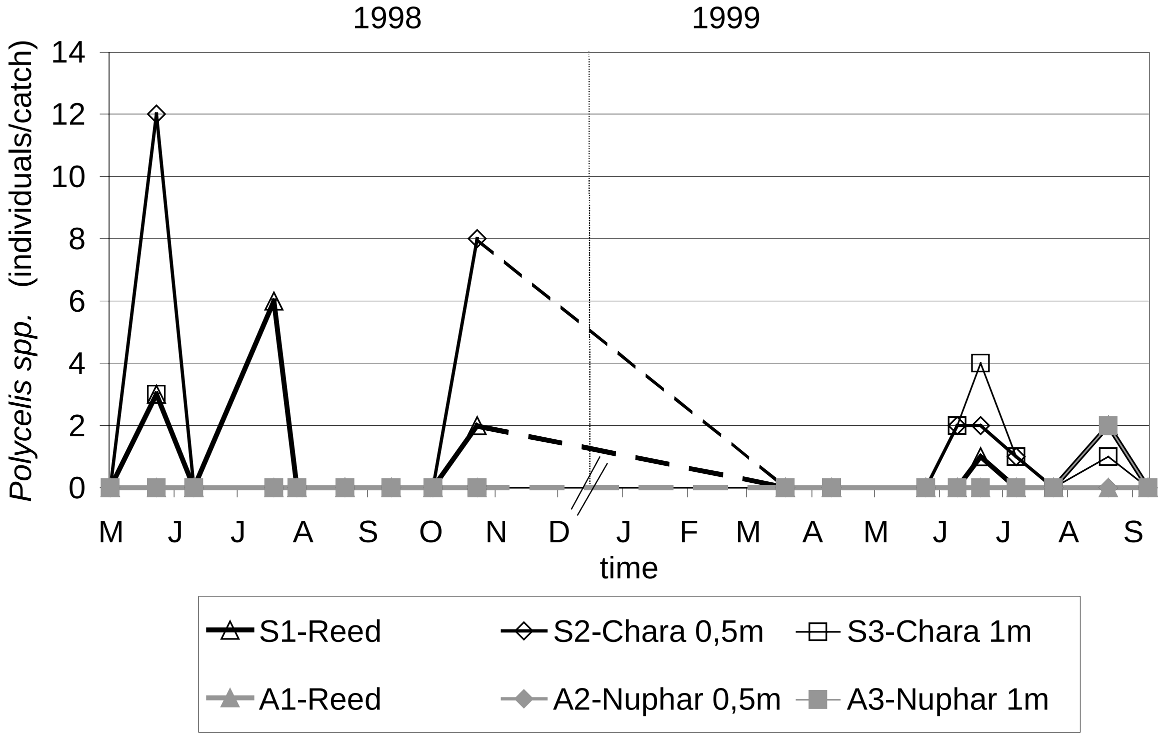


Fig. 30: ***Polycelis spp*** **collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

The species of the genus *Polycelis* are able to breed at the temperatures between 3,5 – 20 °C. They usually feed on oligochaetes, insect nymphs and larvae. The species are also known to feed on damaged specimens of *Asellus aquaticus* (Reynoldson 1978). Except on one sampling date in September 1999, the triclad *Polycelis spp.* was only found within the habitats in Schondorf. The highest numbers were reached in June 1998 with a total of 12 individuals/catch in habitat S2. In 1999 there were less than half as many specimens caught than in the year before (Fig. 30).

The populations of all three triclads were negatively influenced by the flood situation in 1999. 50% less specimens were caught in 1999 than in 1998.

3.1.4.2 Mollusca

Earlier investigations defined an influence but no significant correlation between the aquatic mollusks of Lake Ammersee and the surrounding macrophytes (Klingshirn 1985).

The first two discussed snail species *Bithynia tentaculata* and *Potamopyrgus jenkinsi* both belong to the family of the Rissoacea (Brohmer 1988).

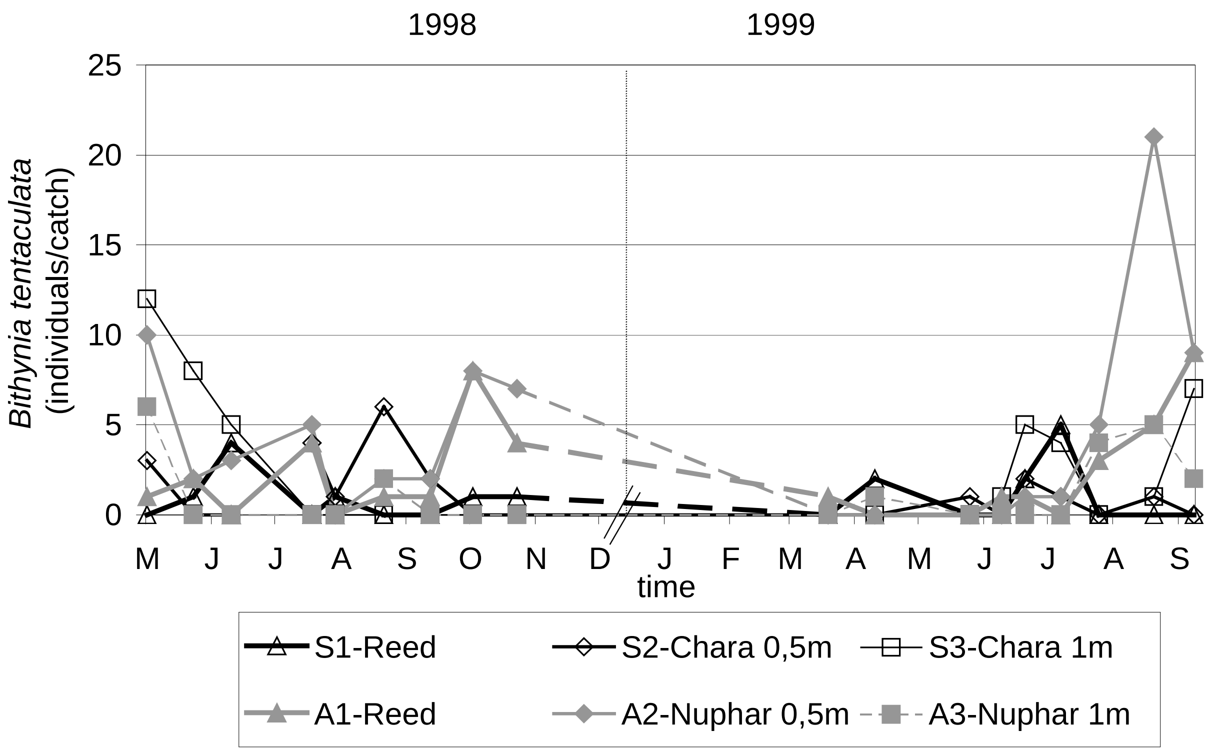


Fig. 31: ***Bithynia tentaculata*** **collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

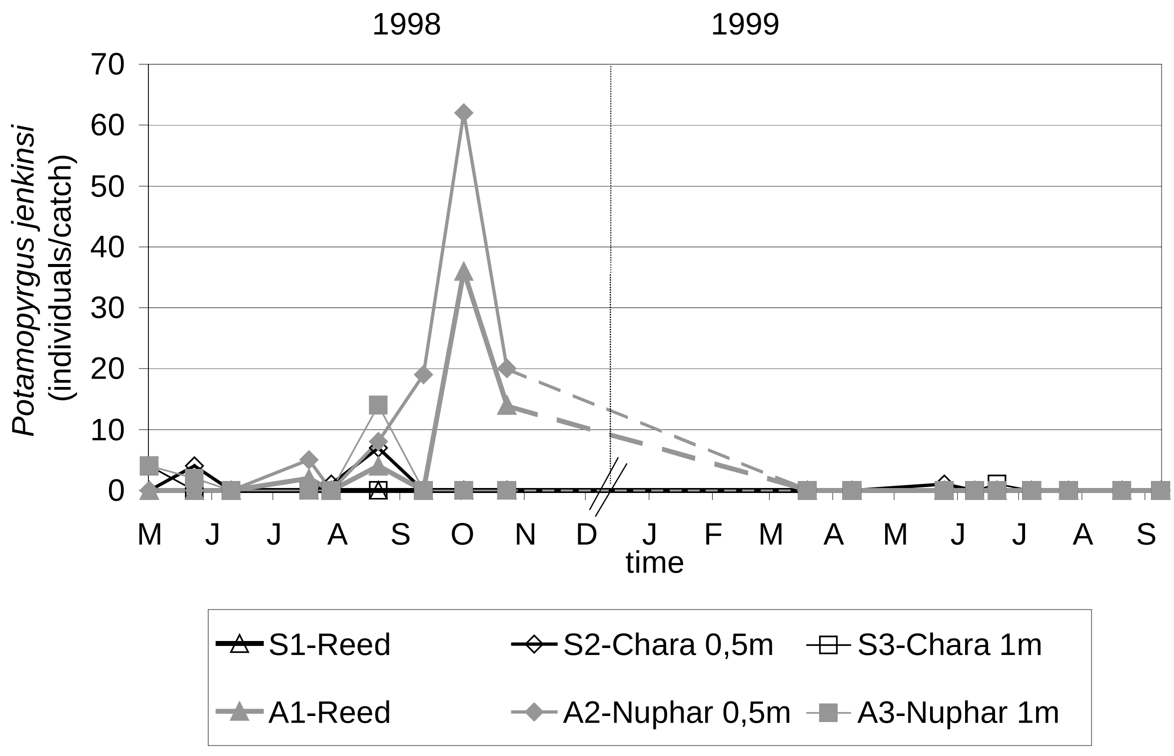


Fig. 32: ***Potamopyrgus jenkinsi*** **collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

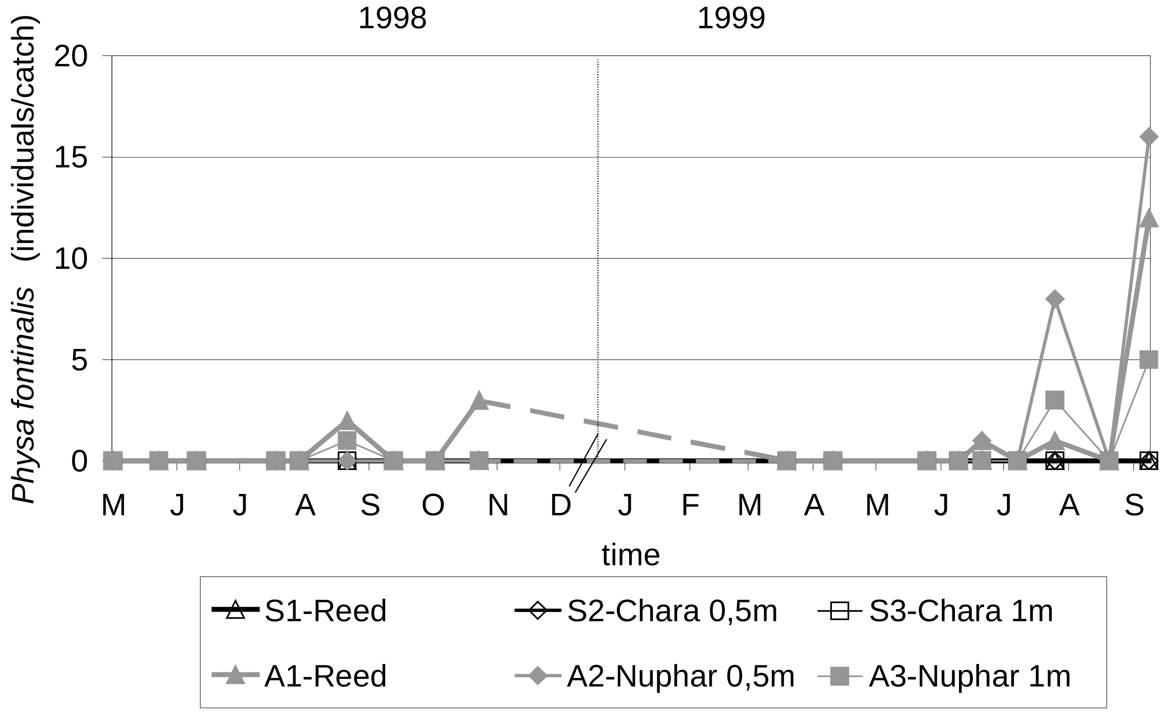


Fig. 33: ***Physa fontinals*** **collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

Bithynia tentaculata was found at all six habitats with an average between 1 and 4 individuals/catch. The *Nuphar* habitats at Aidenried were preferred. A maximum of 21 individuals/catch was collected in September 1999 at site A2 (Fig. 31).

The mollusk *Potamopyrgus jenkinsi* clearly preferred the habitats in Aidenried. In October 1998, a maximum of 62 individuals/catch were found within the habitat A2. The reed habitat (A1) counted a total of 35 individuals/catch on the same date. The Nuphar habitat A3 measured a maximum of 25 individuals/catch in September 1998. A total of only two specimens were caught in 1999 (Fig. 32). Investigations from 1985 calculated populations in one to three meter depths of about 1000 to 2000 snails per square meters (Klingshirn 1985). The southern parts of the lake were colonized to a greater extent.

Physa fontinals belongs to the pulmonate snails. They have a sac-like "lung" formed from a portion of the mantle. They breathe air at the water surface or through the body surface.

Physa fontinals was only found at the habitats in Aidenried. A total of only eight snails were caught in 1998. In 1999 a total of 45 specimens were caught at the sites in Aidenried. In July 1999, there was an increase in population at all three habitats A1, A2 and A3 (Fig. 33).

The two gastropods *Bithynia tentaculata* and *Potamopyrgus jenkinsi* showed an increase in numbers in 1999. *Physa fontinals* favored the flood situation in 1999 as well.

Galba truncata, Lymnaea stagnalis, Radix spp., Radix ovata and *Planorbis spp.* showed very low numbers, between one and nine specimens. Only one specimen of *Galba truncata* was found at the charophyte-dominated habitat S2. *Lymnaea stagnalis* was only found at the reed habitat A1 (three animals) and at the *Nuphar* habitat A2 (one specimen). Small *Lymnaidae* were found within the reed habitat in Schondorf with two individuals/catch. The small *Radix spp.* was found at the habitat S3 and at all three habitats in Aidenried. *Radix ovata* was collected at the two charophyte habitats S2 and S3 in Schondorf. Small *Planorbidae* were found at the reed habitats S1 and A1 and at the two *Nuphar* habitats A2 and A3. *Planorbis spp.* was also found at the two reed habitats and additionally at habitat A2.

The bivalve *Pisidium spp.* was only found five times. There were between one and two specimens caught in each habitat except the reed habitat in Schondorf (S1) (Fig. 34 – Fig. 39).

Dreissena polymorpha preferred the habitats in Schondorf. The charophyte habitat (S3) showed the highest counts with an average of 18 individuals/catch. The shell, *Dreissena polymorpha,* has planktonic larvae with the ability to swim. This way they can colonize habitats very quickly. They adopted the pebble baskets as an ideal substrate. The reed and the charophyte habitats at Schondorf counted the average of twelve individuals/catch. In Aidenried, the reed habitat was the most popular with an average of eight individuals/catch. The two *Nuphar* habitats counted an average between one and five individuals/catch (Fig. 40).

The two mollusks *Potamopyrgus jenkinsi* and *Dreissena polymorpha* were not recorded in earlier investigations (Salzmann 1956). It has been suggested that the explosion of the Zebra Mussel *Dreissena polymorpha* is one reason for the decline of the bigger Unionidae within lakes.

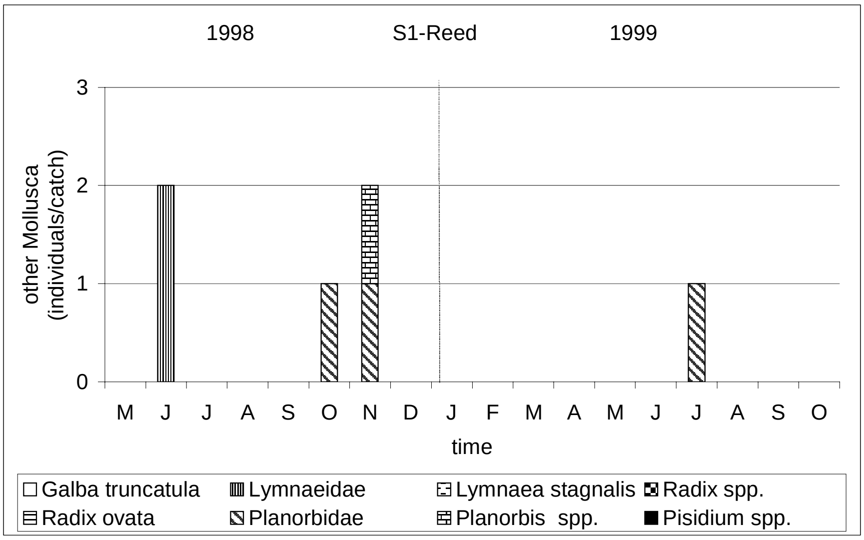


Fig. 34: **Other Mollusca species at habitat S1 in Schondorf**

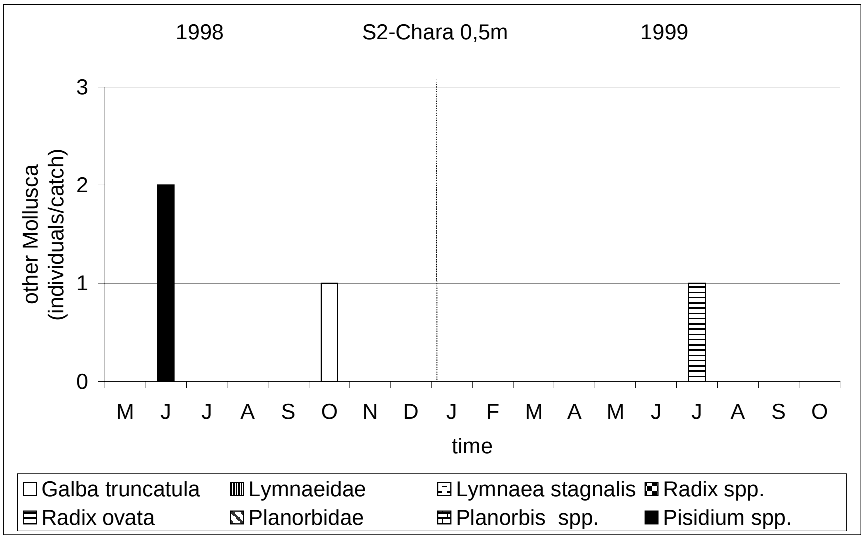


Fig. 35: **Other Mollusca species at habitat S2 in Schondorf**

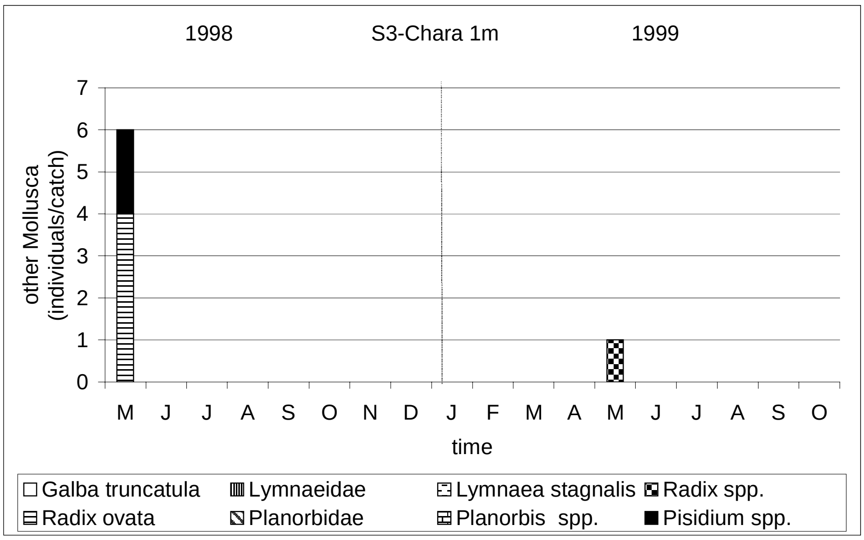


Fig. 36: **Other Mollusca species at habitat S3 in Schondorf**

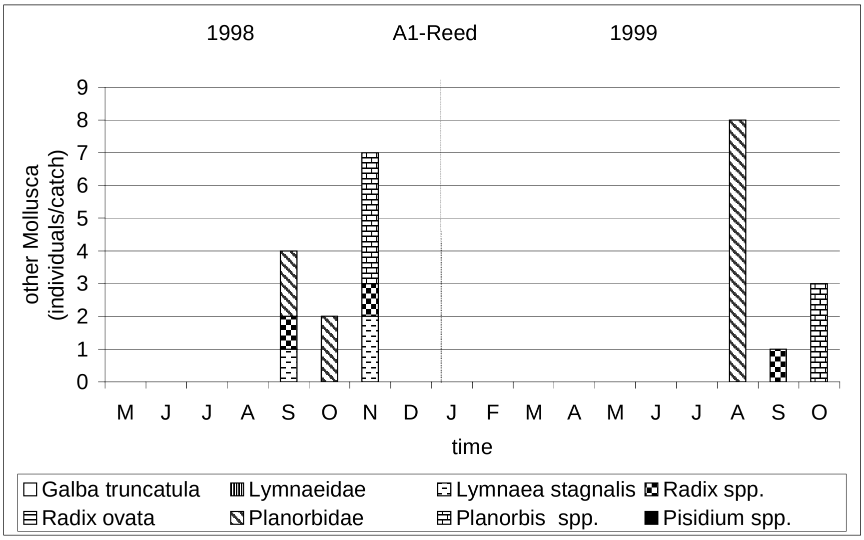


Fig. 37: **Other Mollusca species at habitat A1 in Aidenried**

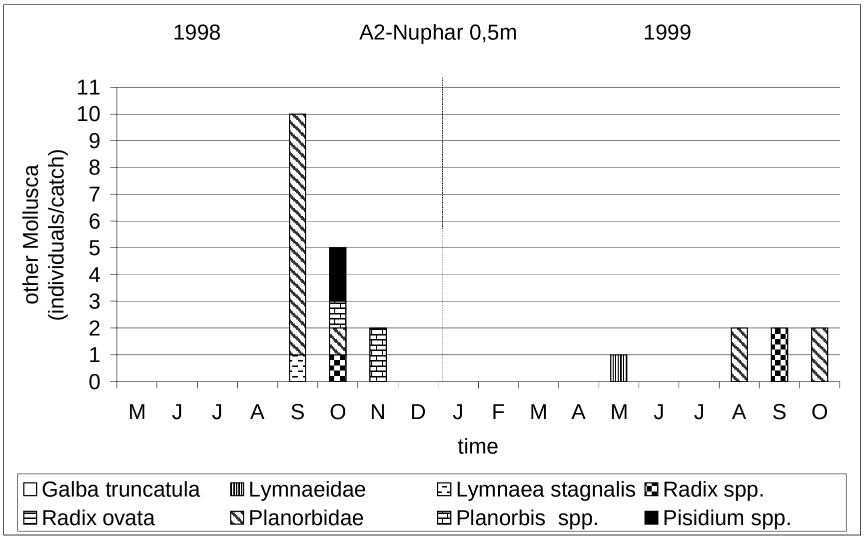


Fig. 38: **Other Mollusca species at habitat A2 in Aidenried**

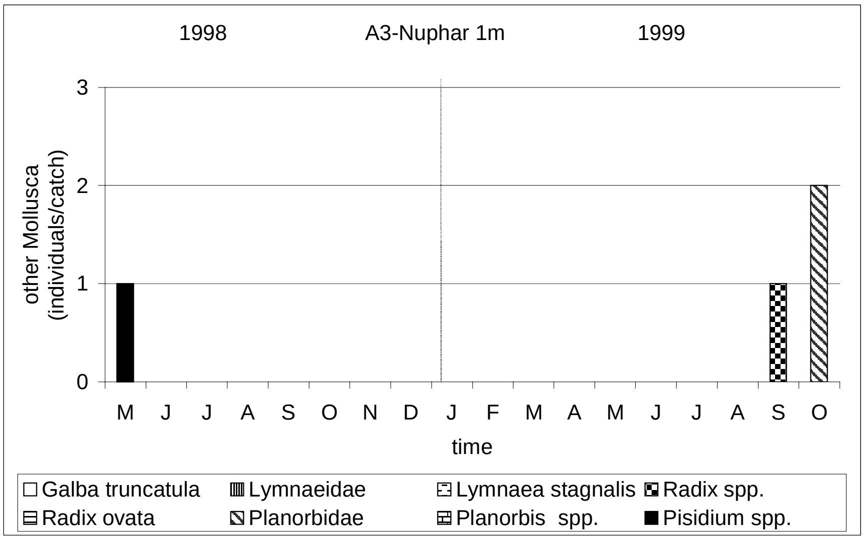


Fig. 39: **Other Mollusca species at habitat A3 in Aidenried**

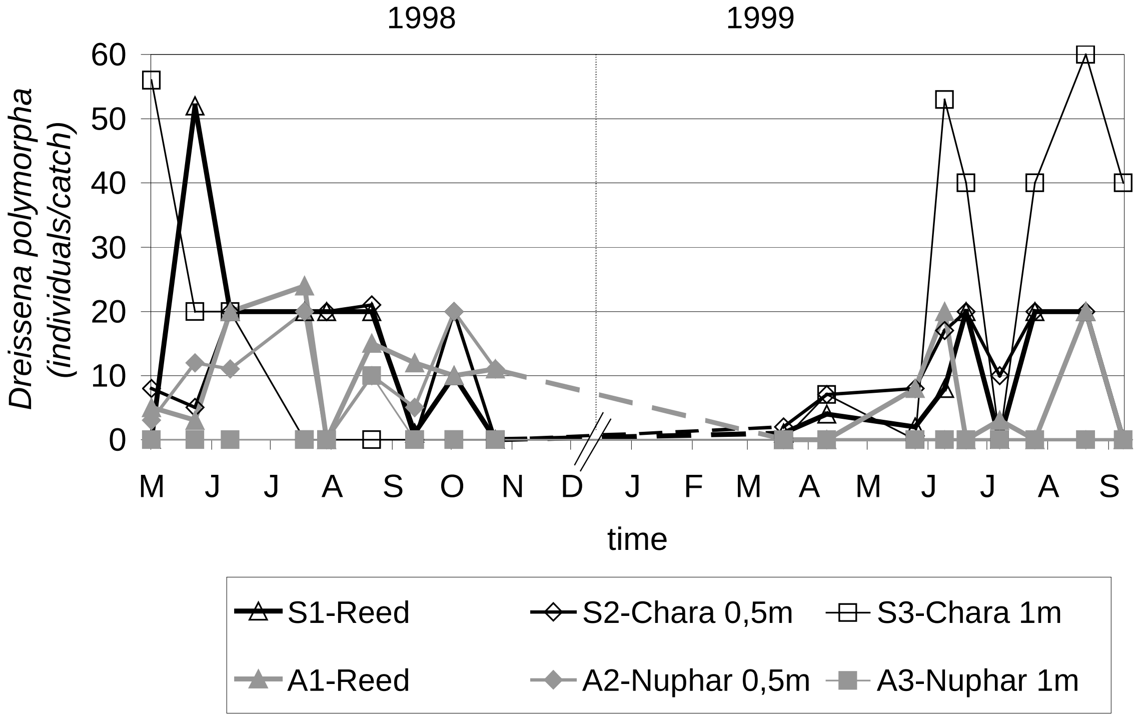


Fig. 40: ***Dreissena polymorpha*** **collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

3.1.4.3 Annelida

The earthworms are animals belonging to several major groups sharing a generally similar shape. Especially small specimens were impossible to identify. Small Oligochaeta were found in Schondorf at all habitats, in Aidenried only at the habitats A1 and A2. As reflected in Fig. 41, in September and October of 1998 and in April and September 1999, the most small worms were counted.

The members of family of the Naididae are not limited to the sediment like the rest of the Oligochaeta. Their mobility allows them to inhabit the vegetation in higher levels as well.

At the reed habitat in Schondorf, the Naididae showed a maximum of 20 individuals/catch in June 1998. For the rest of the year, no more peaks were measured.

In 1999, the reed habitat in Schondorf counted the highest number of specimens. In May, the maximum of 125 animals were caught. The charophyte habitat counted 60 individuals at the same date. In the other habitats, specimen numbers ranged between three and 19 individuals/catch. A major diatom blossom followed the flood in 1999 (Lenhart 2000). The worms are known to feed on diatoms (Wesenberg-Lund 1943).

The Naididae population increased after the flood and declined again through the year. In July, an average number of 40 animals were registered at the sites S1, A1 and A2.

For the rest of the year the specimen caught in these habitats ranged between two and 40 individuals/catch. The other habitats A3, S2 and S3 varied between zero and 20 individuals/catch (Fig. 42).

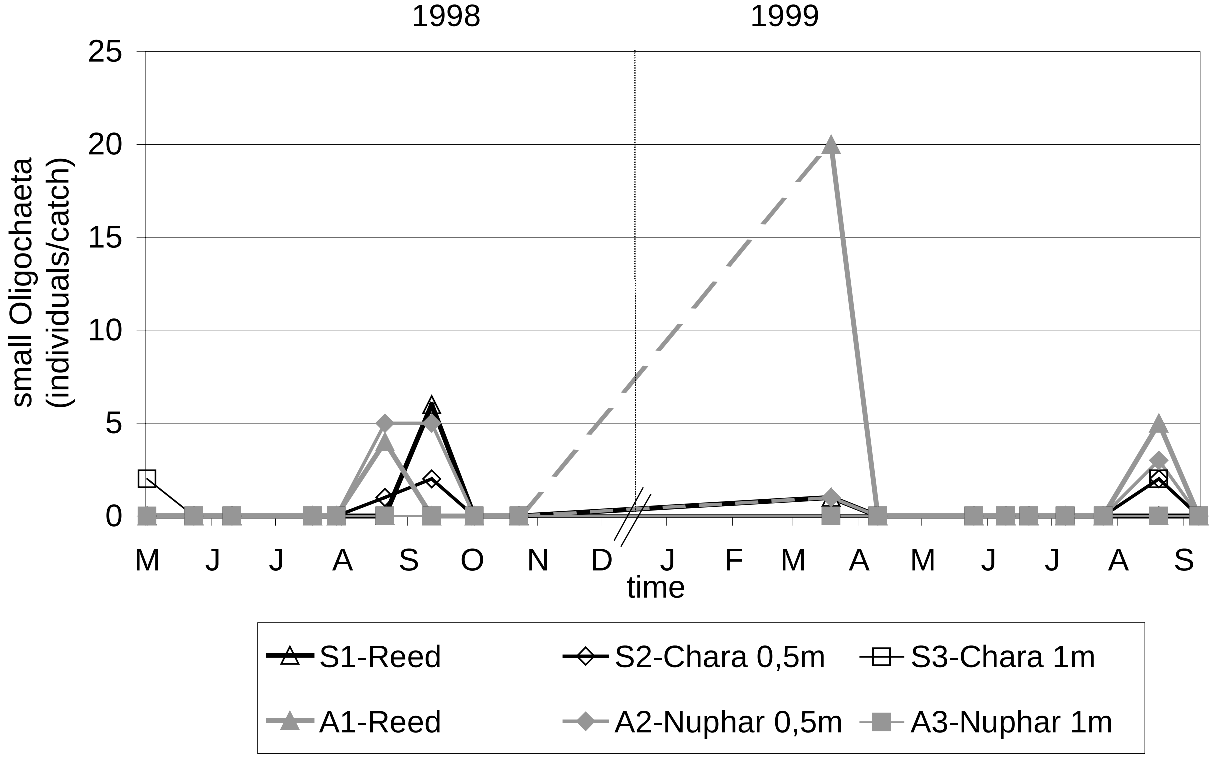


Fig. 41: **Small Oligochaeta collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

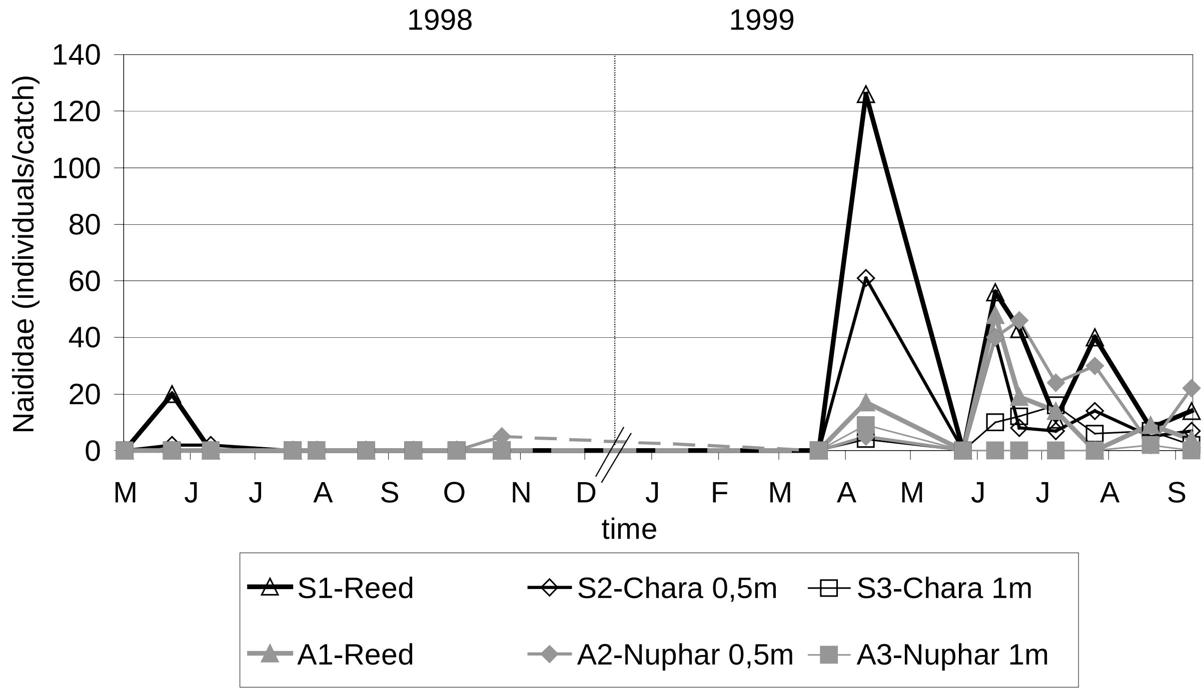


Fig. 42: **Naididae collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

The family of the Tubificidae is commonly known as aquarium food for fish and amphibians. They live in a bottom-dwelling tube, which they build out of mud. The head is usually buried in the mud and the tail waves in order to transport oxygen.

The reed habitats displayed the highest numbers of Tubificidae specimens. In June 1998, the reed habitat in Schondorf registered 50 individuals/catch. Another peak was measured in September 1998.

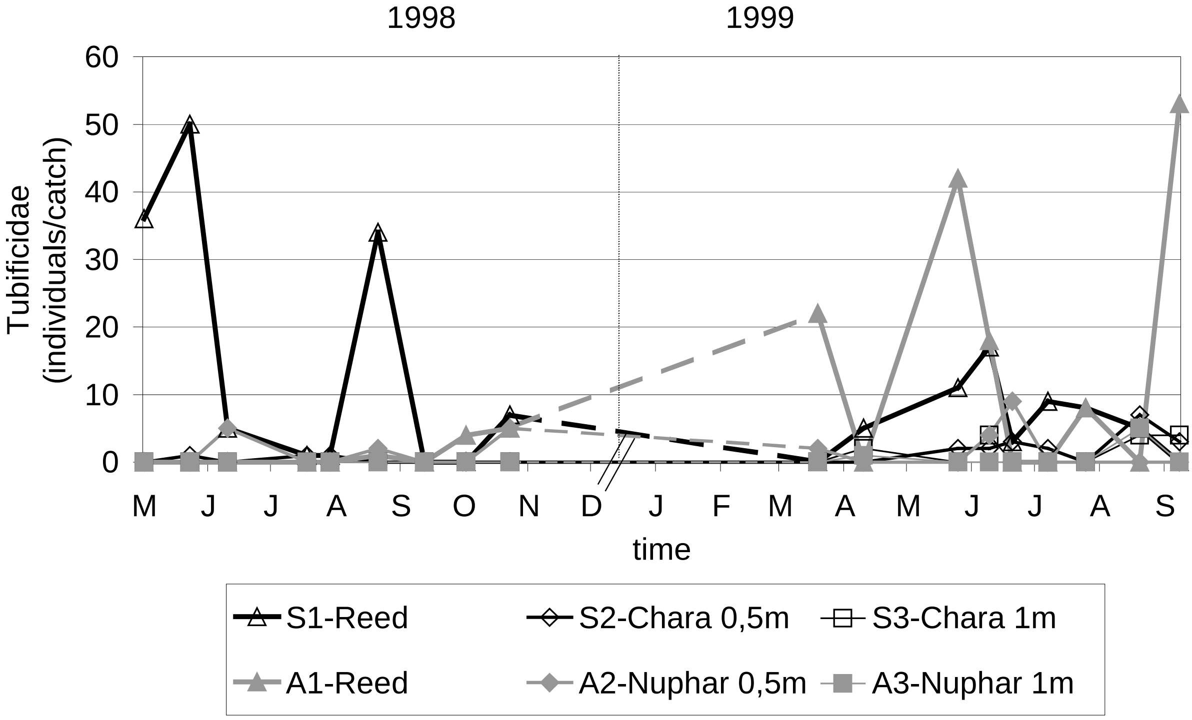


Fig. 43: Tubificidae collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.

In 1999, the reed habitat in Aidenried counted between 22 individuals/catch in April and 53 individuals/catch in October. The specimens within the other habitats varied between 0 and 18 individuals/catch (Fig. 43).

The small worms of the family Lumbriculidae are more or less transparent. The reed habitat in Schondorf showed the highest number of specimens. The maximum number of 26 animals was counted in May 1998. In June and July 1998 the numbers ranged between ten and twelve individuals/catch. Later in the year the numbers dropped below 10 individuals/catch. The other habitats varied between 0 and 6 individuals/catch at all times (Fig. 44).

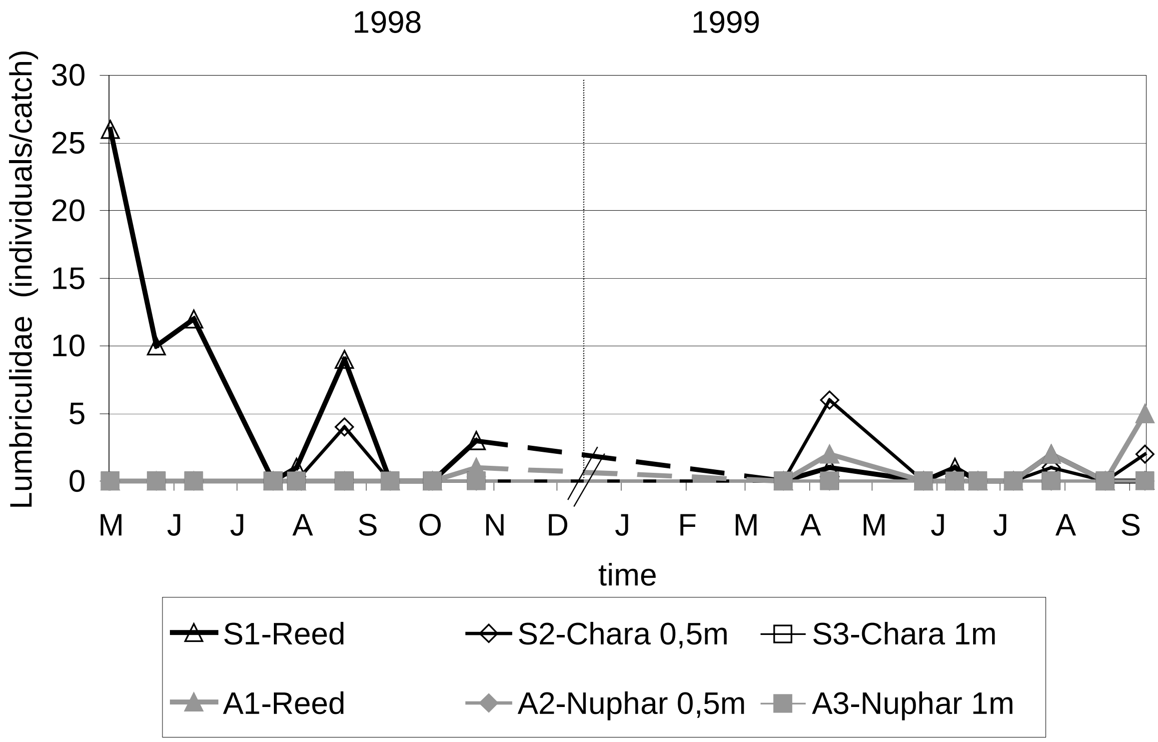


Fig. 44: Lumbriculidae collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.

The leech *Erpobdella octoculata* is a typical littoral inhabitant (Nesemann 1996). As a predator it feeds on many different types of invertebrates (Schmedtje *et al.* 1996).

At the reed site (S1) in Schondorf, maximum numbers of eleven and twelve leeches were caught in August and September 1998. The other two sites at Schondorf counted less than five animals throughout both years. An exception of eight individuals/catch was measured in June 1999 at the charophyte site (S2) at Schondorf.

The three sites at Aidenried reached clearly higher numbers, especially in 1999. The maximum, between 30 and 36 individuals/catch, was counted at the end of May in 1999 (Fig. 45).

The worm *Eiseniella tetraedra* is the aquatic representative of the principally terrestrial family of the Lumbricidae (Brinkhurst 1971). It was found within the two reed habitats in Schondorf and Aidenried and within the charophyte habitat S2. At the two habitats in Schondorf, an average one to two individuals/catch was found on two sampling dates in 1998. At the reed habitat in Aidenried, a total of 18 animals were found in May 1999 (Fig. 46-51).

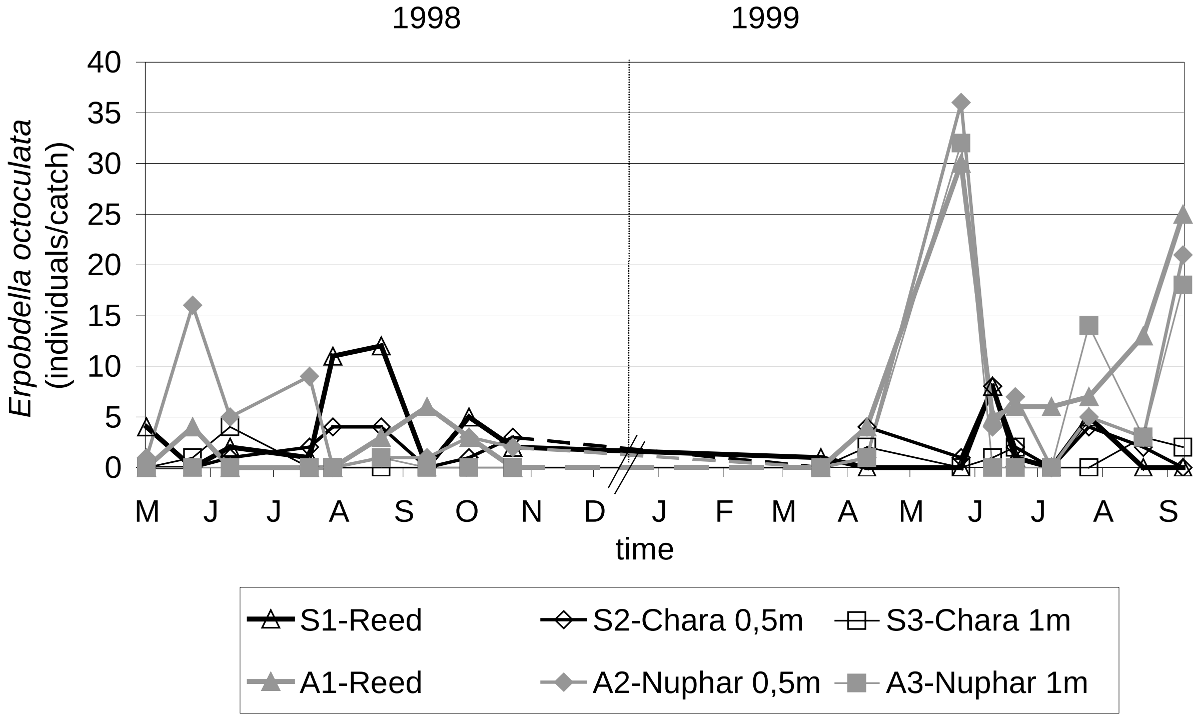


Fig. 45: ***Erpobdella octoculata* collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

The leeches *Glossiphonia complanata, Helobdella stagnalis and Piscicola geometra* were also only found in small numbers.

An average between one and three specimens of *Glossiphonia complanata* were found at the reed habitats at Schondorf and Aidenried, at the charophyte habitat S2 in Schondorf and at the *Nuphar* habitat A2 in Aidenried. A total of ten animals were found at the *Nuphar* habitat A3 at Aidenried in June 1998 (Fig. 46 - Fig. 51). The leech inhabits lentic and lotic water. It feeds on small mollusks such as *Bithynia tentaculata* (Nesemann 1996).

The leech *Helobdella stagnalis* was only found in 1998. The reed habitat at Schondorf (S1) counted an average of 4 individuals/catch in the months of August, September and October. The habitats S2, A1, A2 and A3 counted numbers < 3 individuals/catch. At the charophyte habitat S3, not a single animal was found (Fig. 46 - Fig. 51). The leech is often found in lakes (Nesemann 1996).

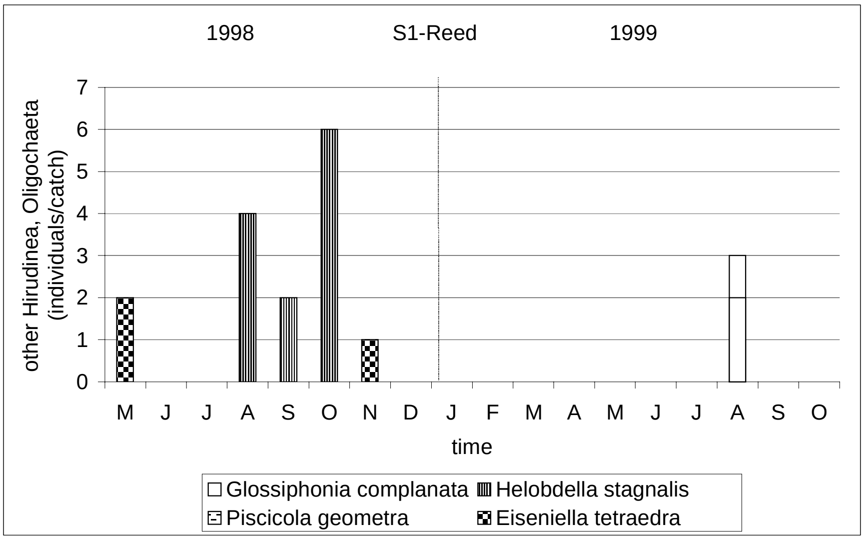


Fig. 46: **Other Annelida collected in the reed habitat in Schondorf**

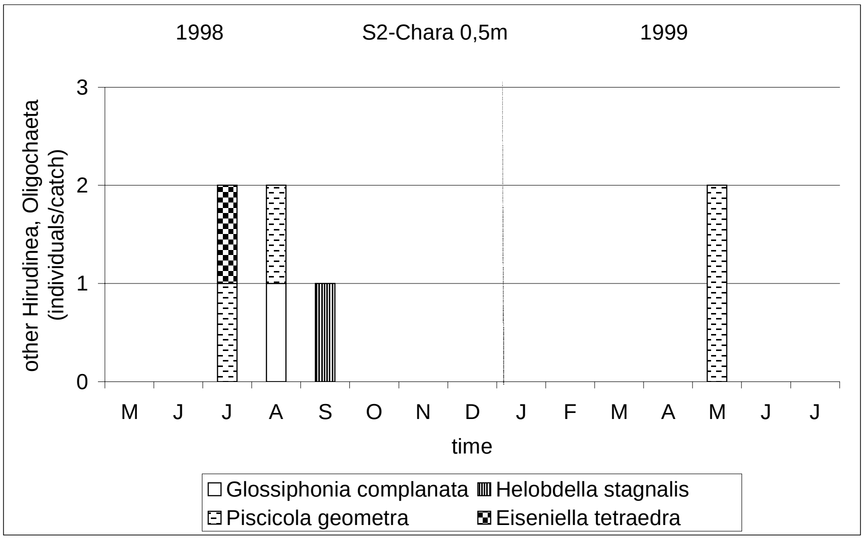


Fig. 47: **Other Annelida collected in the *Chara* habitat in Schondorf S2**

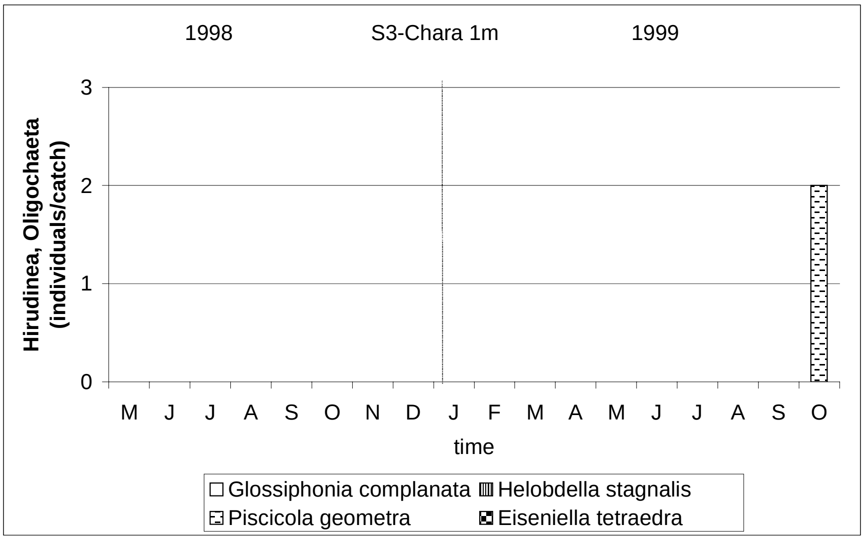


Fig. 48: **Other Annelida collected in the *Chara* habitat in Schondorf S3**

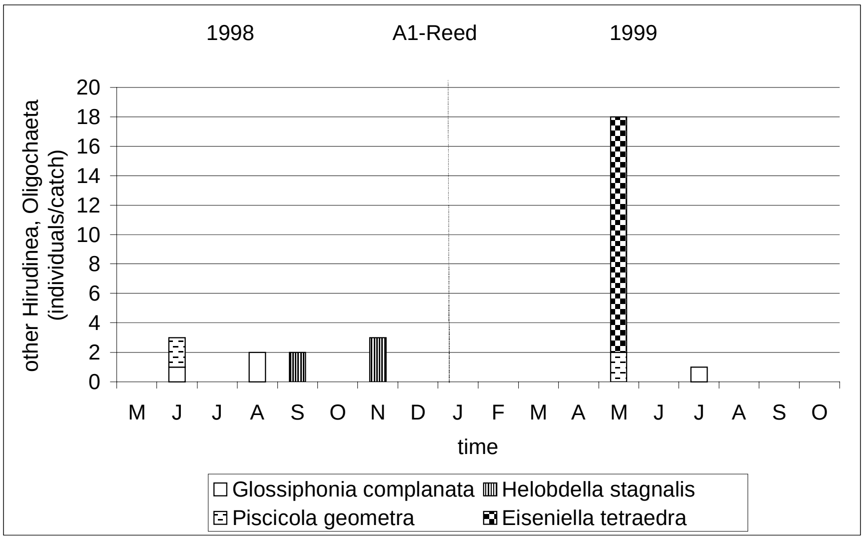


Fig. 49: Other Annelida collected in the reed habitat in Aidenried

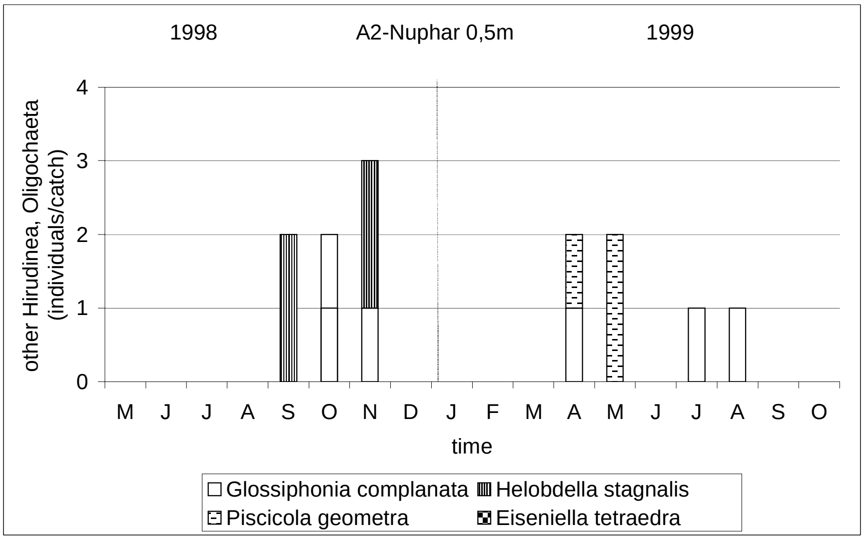


Fig. 50: Other Annelida collected in the *Nuphar* habitat in Aidenried A2

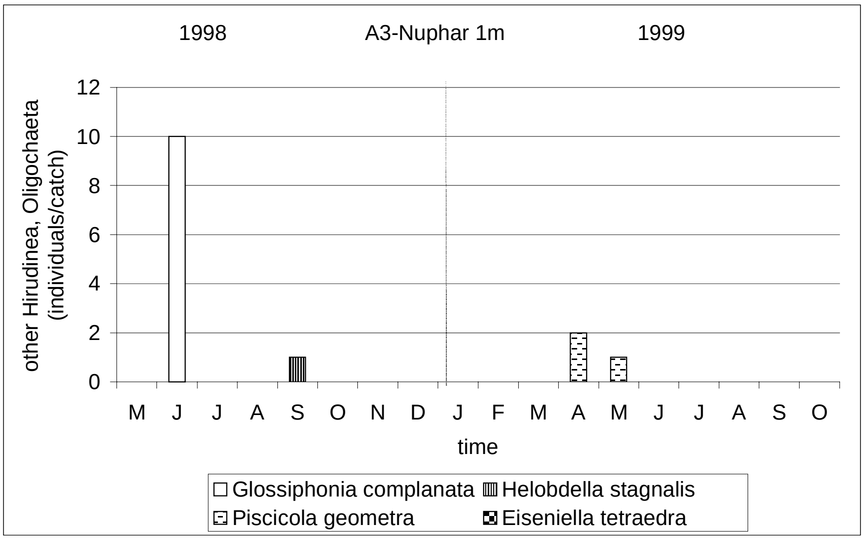


Fig. 51: Other Annelida collected in the *Nuphar* habitat in Aidenried A3

The fish parasite *Piscicola geometra* was found in low numbers at all habitats except the reed habitat at Schondorf (S1). It was never found on more than three sampling dates with an average of two individuals/catch (Fig. 46-51). The low numbers are possibly due to the mobility of the leech. The species is often found in lakes (Nesemann 1996).

3.1.4.4 Isopods

The isopod *Asellus aquaticus* is categorized mainly as shredder. It feeds on larger vascular plant tissue. Habitats consisting of plants or wood are usually preferred (Schmedtje *et al.* 1996). They can reproduce all year, but usually have one summer and one winter generation. The individuals found in spring are larger in size (Merritt & Cummins 1984).

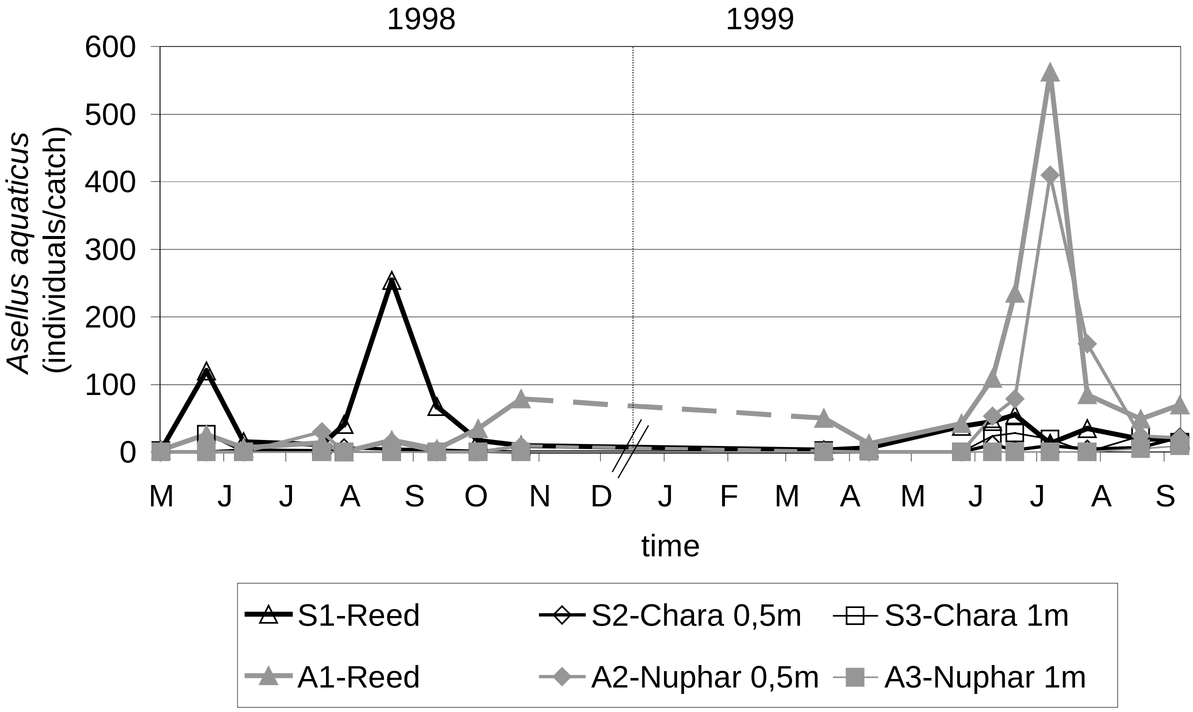


Fig. 52: ***Asellus aquaticus* collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

In Schondorf, the isopod showed a maximum count of 250 individuals/catch in August 1998 at the reed habitat. In July 1999, a maximum of 560 individuals/catch was counted at the reed habitat in Aidenried. The *Nuphar* habitat A2 counted 405 individuals/catch at the same sampling date. The other habitats counted *Asellus aquaticus* numbers below 100 individuals/catch (Fig. 52).

The high water level in 1999 was accompanied with great amounts of wood and other organic material. The sites at Aidenried were affected most by this event. This favored the development of the isopod, since they prefer this substrate.

3.1.4.5 Amphipods

The scud *Grammars roeseli* preferred the reed habitat at Aidenried. A maximum of 330 individuals/catch was counted in June 1998. In July and August 1999, the numbers ranged between 750 and 880 individuals/catch. The other two *Nuphar* habitats in Aidenried counted numbers up to 190 individuals/catch in 1998. In 1999 they were slightly higher, up to 580 individuals/catch.

The reed habitat at Schondorf contained a maximum of 120 individuals/catch in June 1998. The other sampling dates showed numbers below 100 individuals/catch. The scud was not found at the other sites in Schondorf (Fig. 53).

Gammarus roeseli prefers similar environmental conditions as *Asellus aquaticus*. The shredder also feeds mainly on decomposing plant tissue (Schmedtje *et al.* 1996). The scuds main reproduction takes place in autumn (Merritt & Cummins 1984).

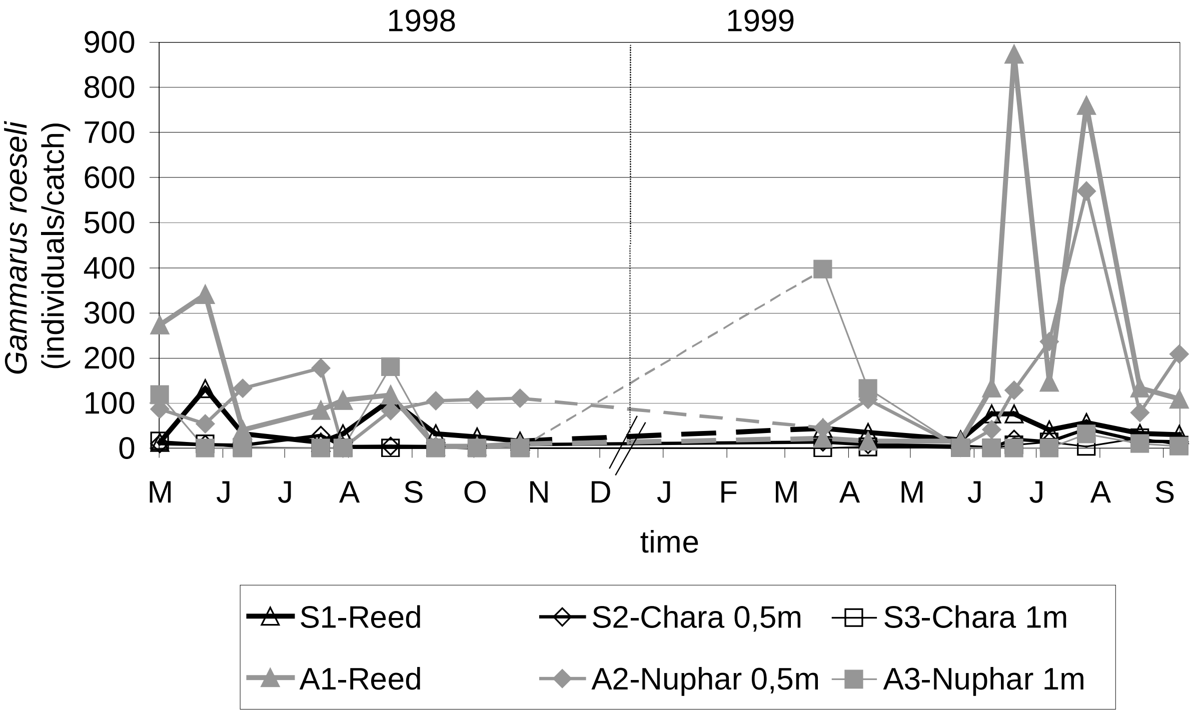


Fig. 53: ***Gammarus roeseli*** **(all sizes) collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

The population of *Gammarus roeseli* was examined through size composition. Size one represents scuds smaller than 0,3 cm length. Scuds between 0,3 and 0,7 cm were classified as size two. Size three were scuds with the length between 0,7 and 1,5 cm. Scuds bigger than 1,5 cm were grouped as size four.

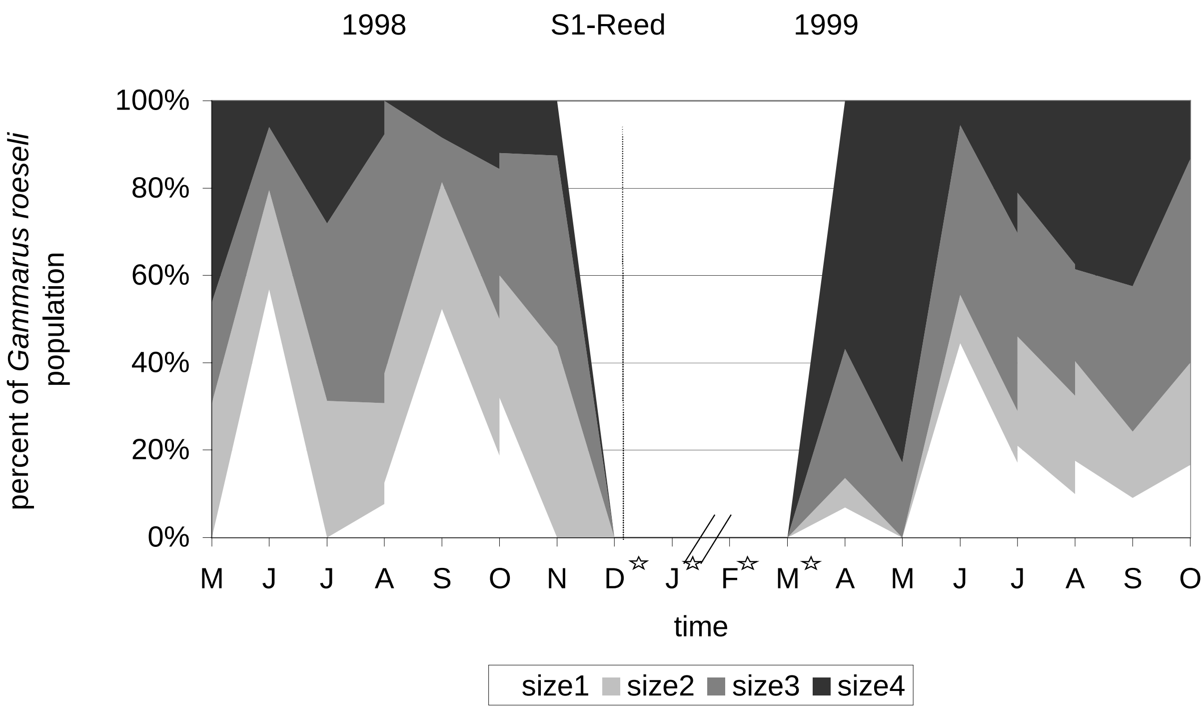


Fig. 54: Size composition of *Gammarus roeseli* at the reed habitat in Schondorf. No samples were taken in the months marked with asterisks.

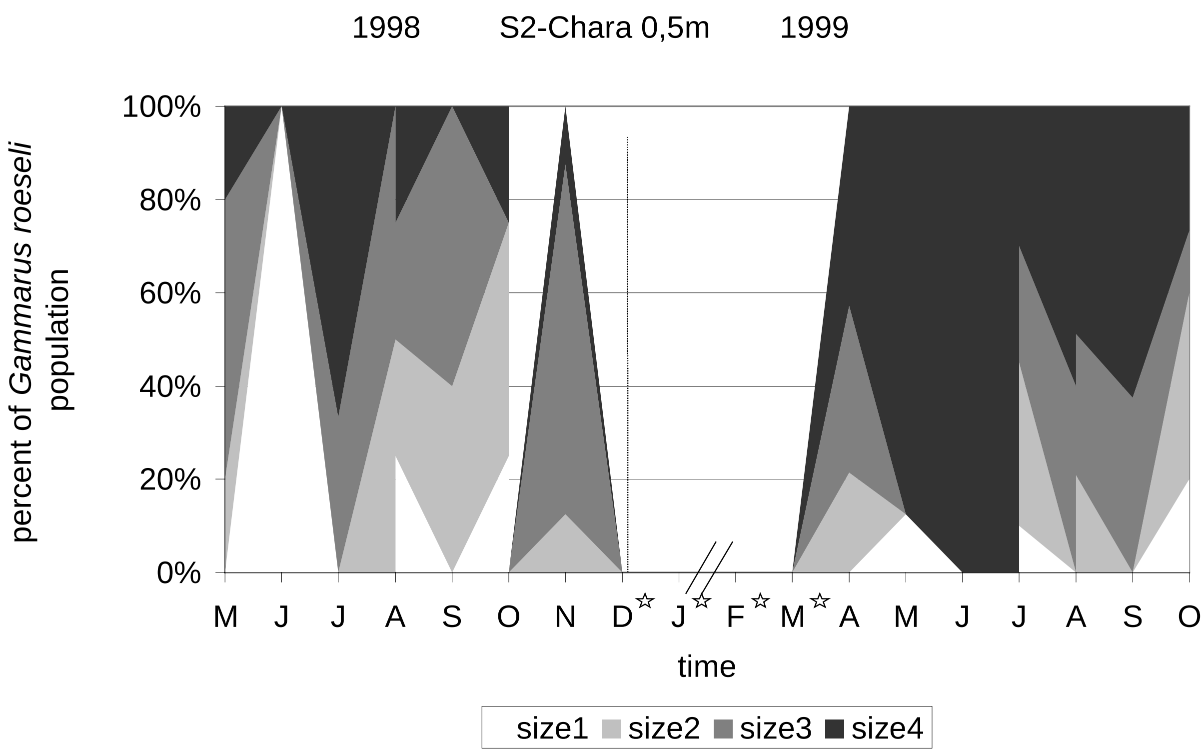


Fig. 55: Size composition of *Gammarus roeseli* at the *Chara* habitat in Schondorf. No samples were taken in the months marked with asterisks.

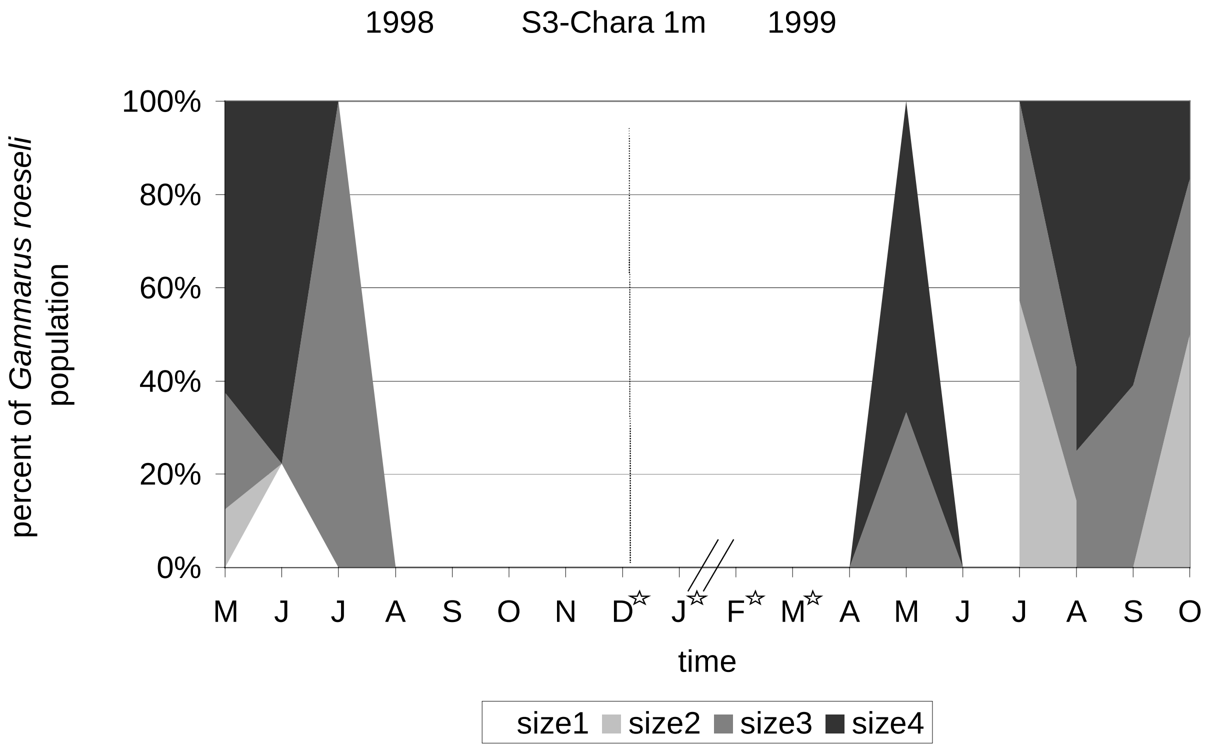


Fig. 56: **Size composition of *Gammarus roeseli* at the *Chara* habitat in Schondorf. No samples were taken in the months marked with asterisks.**

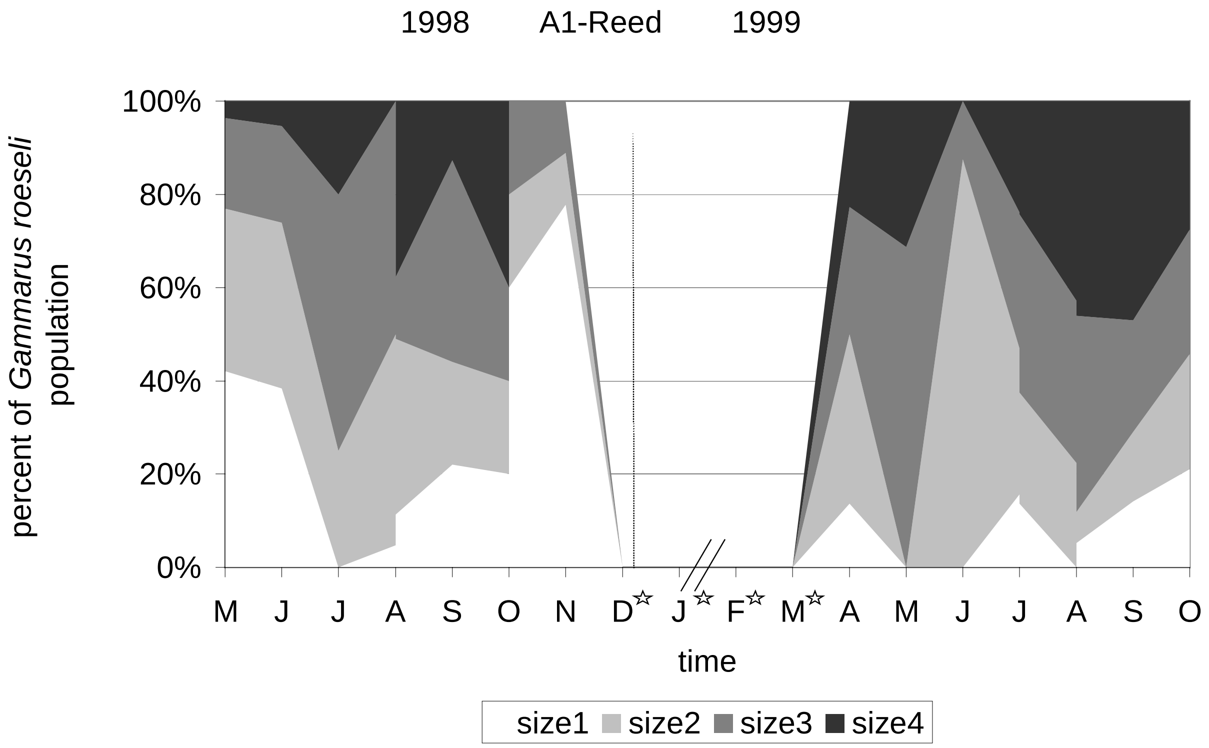


Fig. 57: **Size composition of *Gammarus roeseli* at the reed habitat in Aidenried. No samples were taken in the months marked with asterisks.**

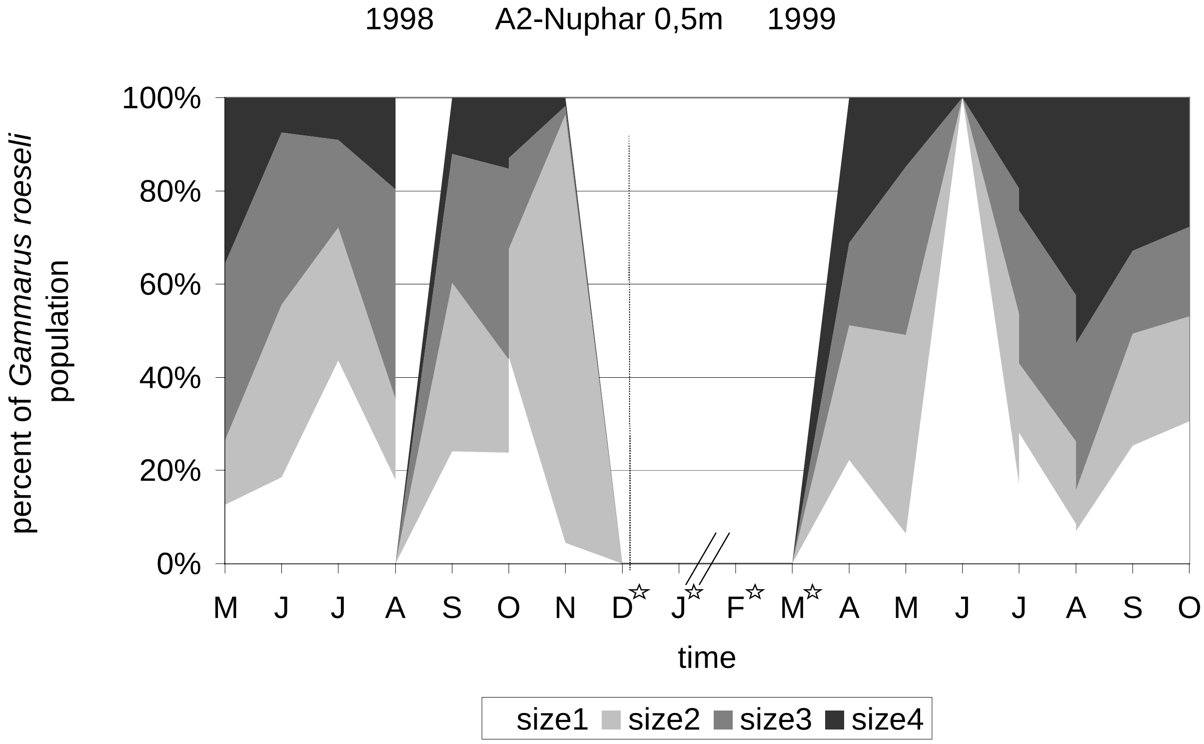


Fig. 58: **Size composition of *Gammarus roeseli* at the *Nuphar* habitat in Aidenried. No samples were taken in the months marked with asterisks.**

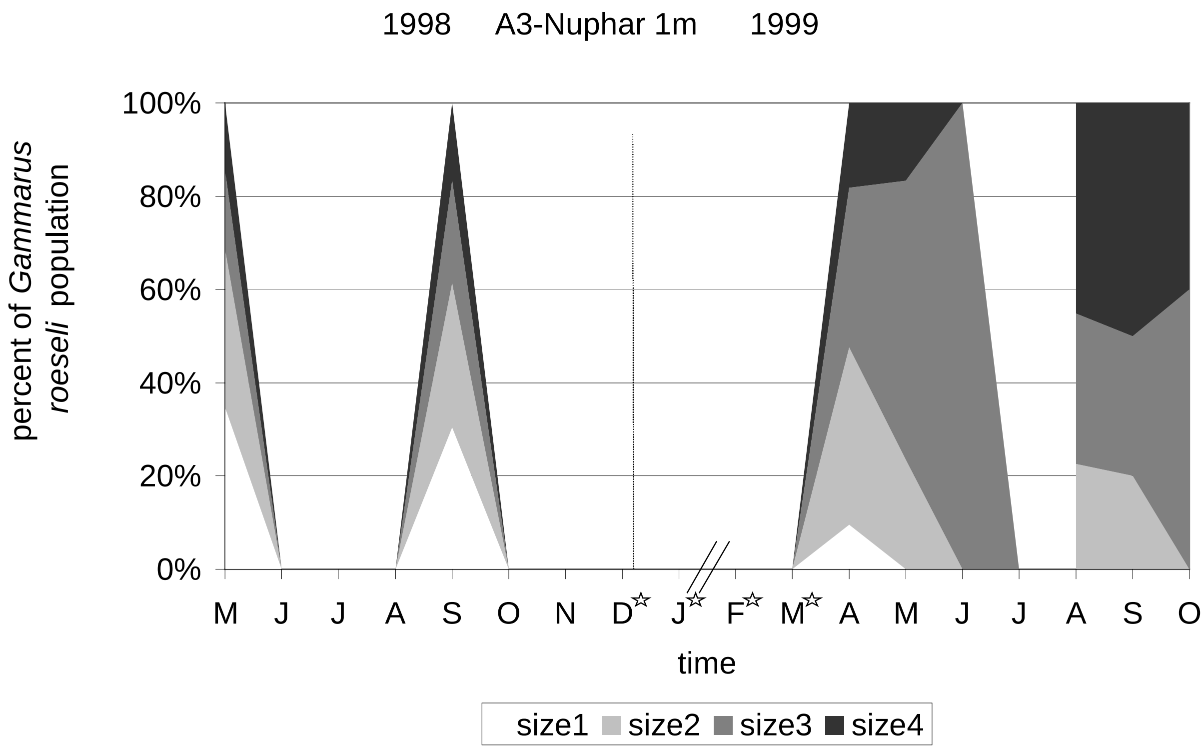


Fig. 59: **Size composition of *Gammarus roeseli* at the *Nuphar* habitat in Aidenried. No samples were taken in the months marked with asterisks.**

The two reed habitats have the largest percentage of small scuds. The reed habitat at Schondorf showed a reproduction maximum in June and September of 1998 and in June of 1999 (Fig. 54).

The charophyte habitat in Schondorf measured a reproduction maximum in June 1998. In 1999, the size four scuds represented the largest percentage part of the population (Fig. 55).

The charophyte habitat at Schondorf showed clear decrease in the scud population. The reproduction maximum was in June 1998. In 1999, no scuds with size one were found (Fig. 56). At the Schondorf sites, the flood in 1999 made the scuds wander to greater depths. In a depth of 0,5 m, the most scuds classified as size four were counted.

The reed habitat in Aidenried showed similar size composition as the reed habitat in Schondorf. A reproduction maximum was counted in May and November 1998. In April, July and October 1999, reproduction peaks were measured (Fig. 57).

The *Nuphar* habitat at 0,5 m depth in Aidenried showed reproduction maximums of *Gammarus roeseli* in July and October 1998 and in April, June and October 1999 (Fig. 58).

The *Nuphar* habitat at one-meter depths counted the most size one scuds in May and September, 1998 and in April, 1999. After the flood, no size one scud was found (Fig. 59).

3.1.4.6 Hydrachnellae

The different species of water mites are grouped together under the name of Hydrachnellae. These predators colonize the vegetated littoral zone of lakes (Schmedtje *et al.* 1996).

The mites clearly preferred the sites at Schondorf. The highest numbers were counted in the spring of both years. The two charophyte habitats measured an average of 50 individuals/catch in both years. The reed habitat at Schondorf stayed below 40 individuals/catch on average.

The reed habitat in Aidenried measured numbers up to 120 individuals/catch. The other two *Nuphar* habitats in Aidenried counted 75 individuals/catch on one sampling date. On all the other dates the numbers were below 25 individuals/catch.

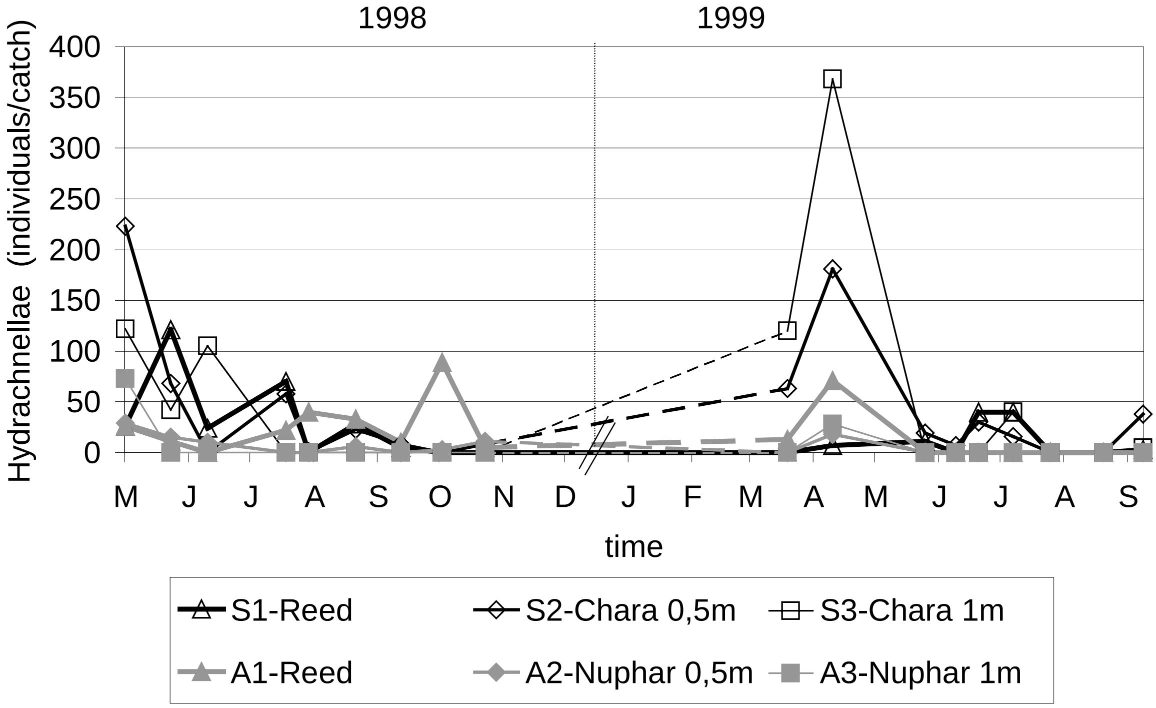


Fig. 60: Hydrachnellae collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.

3.1.4.7 Ephemeroptera and Plecoptera

The Baetidae is a relatively large and common family of the mayflies. The aquatic nymphs swim actively and scrape algae and the micro flora off the living and non-living substrates. They also collect sediment deposits (Schmedtje *et al.* 1996). They usually have one or two generations per year (Sauter 1992).

The small specimens of *Cloeon dipterum* and *Centroptilum luteolum* were grouped as small Baetidae. The count was a maximum of 70 individuals/catch in September 1998 at the reed habitat in Aidenried. In 1999, there were only half as many specimens counted. At the reed habitat in Schondorf, the small mayflies were only found in 1999.

The *Nuphar* habitat A2 at Aidenried showed an average of 10 individuals/catch in each year. The charophyte habitat S2 in Schondorf measured three peaks with an average of 40 individuals/catch in August, October and November 1998. In August 1999, a maximum of 80 individuals/catch was registered.

No specimens were found at the *Nuphar* habitat A3 in Aidenried. The charophyte habitat S3 in Schondorf measured an average of 25 individuals/catch on two sampling dates in 1999.

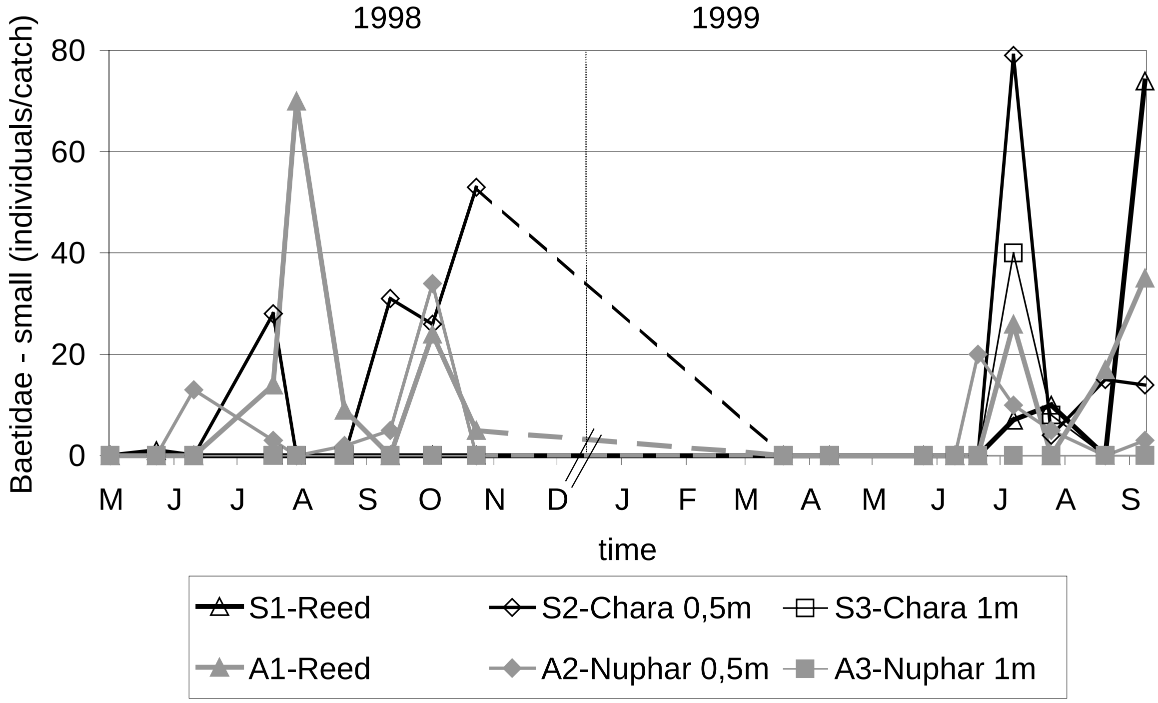


Fig. 61: **Baetidae collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

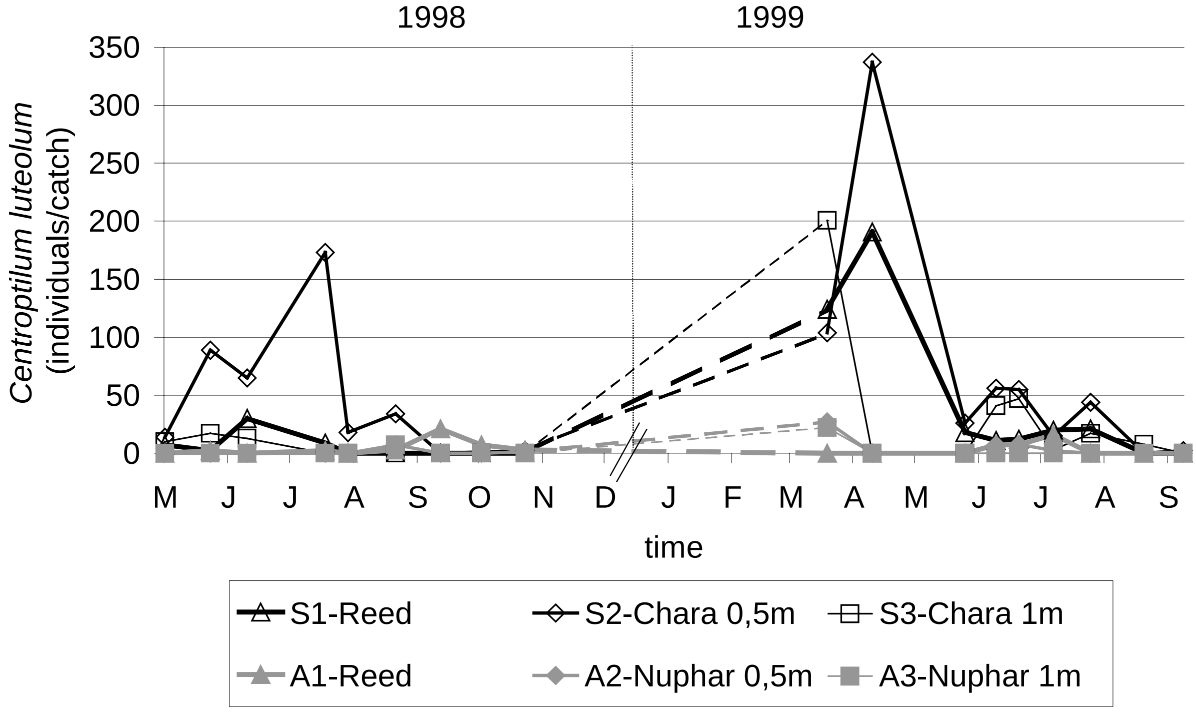


Fig. 62: ***Centroptilum luteolum*** **collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

The mayfly *Centroptilum luteolum* is a typical inhabitant of the littoral zone of lakes (Schmedtje *et al.* 1996). The scraper usually has a bivoltine reproduction rhythm (Sauter 1992).

The highest numbers were counted at the charophyte site S2 in Schondorf. In 1998, they ranged between zero and 175 individuals/catch. In May 1999, a maximum of 340 individuals/catch were counted.

In 1998, the other habitats were below 30 individuals/catch. In the following year, the three habitats at Schondorf measured more than 50 individuals/catch. The sites in Aidenried were below 30 individuals/catch (Fig. 62).

In 1998, the summer generation emerged in late July. In 1999 the summer generation emerged towards the end of May. The flood seemed to have caused the mayflies to emerge earlier. Baetidae are known to emerge in reaction to stress situations (Resh & Rosenberg 1984).

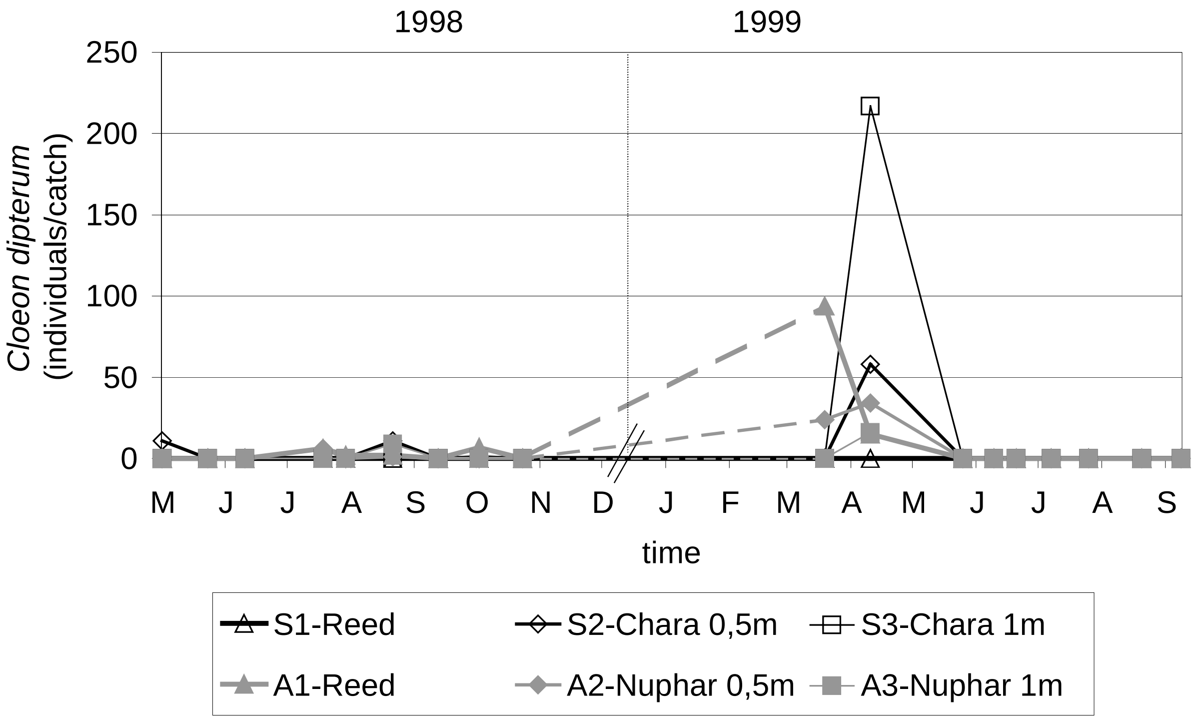


Fig. 63: ***Cloeon dipterum* collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

The mayfly *Cloeon dipterum* has similar requirements from the environment as *Centroptilum luteolum.* They can survive with less space and are classified as scrapers and collectors (Schmedtje *et al.* 1996).

In 1998, none of the habitats counted more than 20 individuals/catch. In 1999, the three sites in Aidenried counted up to 90 individuals/catch. The findings were restricted to the months April and May.

A maximum of 215 individuals/catch was measured at the charophyte habitat S3 in Schondorf in May 1999. The charophyte habitat S2 measured 60 individuals/catch at the same date.

Similar to *Centroptilum luteolum* there were fewer specimen found shortly after the flood.

The mayflies of the *Caenis horaria* group and the *Caenis macrura* group are included in *Caenis spp*., due to the low numbers. Both groups of mayflies are known to colonize the littoral zone of bigger lakes (Malzacher 1986). All *Caenis* species feed on collected sediment deposits (Schmedtje *et al.* 1996).

The reed habitat at Schondorf measured two peaks in 1998 and three peaks in 1999. The first peak of 175 individuals/catch was counted in May 1998. The second was measured in September 1998. In 1999, the first peak was counted in May, the second in July and the third in September. At the other Schondorf sites, the count was less than 50 individuals/catch on all sampling dates, except in September 1999, where the charophyte habitat S2 reached a total of 125 individuals/catch (Fig. 64).

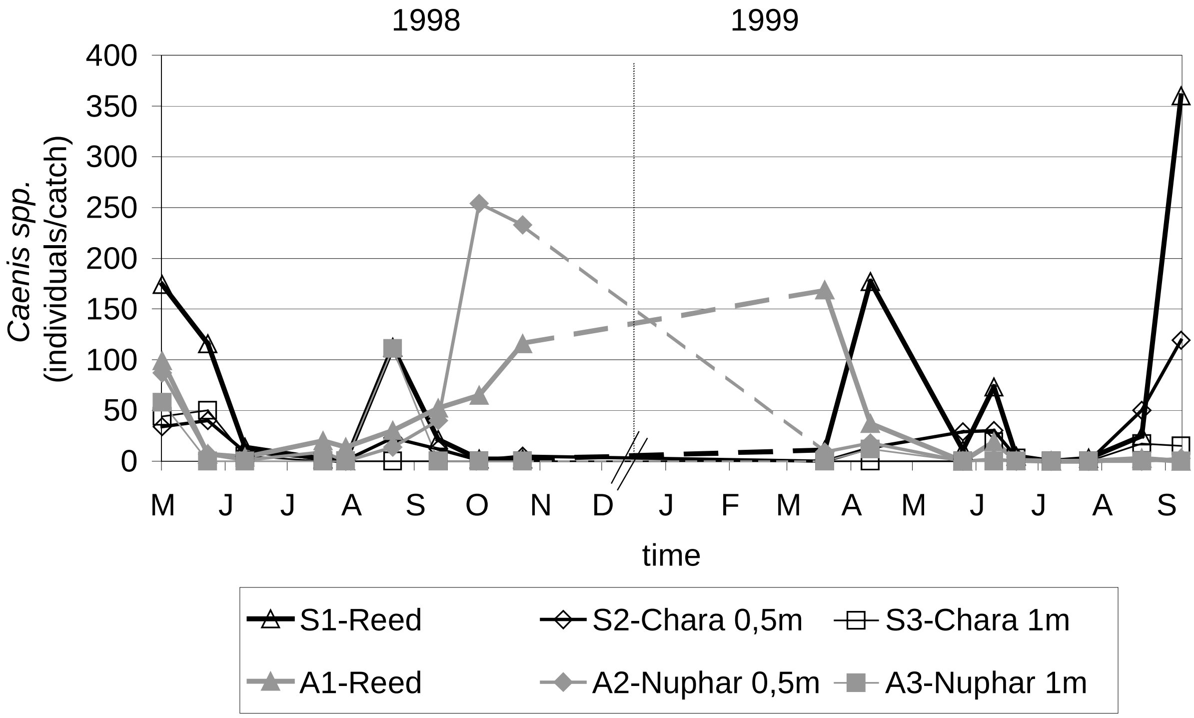


Fig. 64: ***Caenis spp.*** **collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

The reed habitat at Aidenried showed two maximum count of 100 individuals/catch in May and November 1998. In 1999, a maximum of 160 individuals/catch was registered.

In 1998, the *Nuphar* habitat A2 reached the maximum of 250 individuals/catch in October. The *Nuphar* habitat A3 counted the maximum of 110 individuals/catch in September. The two *Nuphar* habitats showed no more than ten individuals/catch during 1999 (Fig. 64).

The three mayfly species *Ephemera danica, Heptagenia spp.* and *Siphlonurus lacustris* were found in low numbers. *Ephemera danica* usually has a semivoltine reproduction cycle (Sauter 1992). Each generation takes two years to develop. They dig through sandy substrate and feed on the sediment deposits, which they collect (Schmedtje *et al.* 1996). One specimen was found at the reed habitat in Schondorf in May 1998 and one at the reed habitat in Aidenried in April 1999 (Fig. 65; 68). The *Nuphar* habitat A3 registered one animal in May 1999 (Fig. 70).

All mayfly species of the genus *Heptagenia* have a univoltine reproduction cycle and spend the winter as larvae (Sauter 1992). They are scrapers and collectors and usually prefer running water (Schmedtje *et al.* 1996). At Schondorf, one animal was found in October 1998 at the reed habitat and one animal was found in July 1998 at the *Chara* habitat S3 (Fig. 65, 66).

The reed habitat in Aidenried registered two individuals/catch in November 1998 and in June 1999 (Fig. 68). The *Nuphar* habitat A2 measured one individual in June 1999 (Fig. 69).

Siphlonurus lacustris has a univoltine reproduction cycle where part of the generation spends the winter in the egg stage and part as larvae (Sauter 1992). This mayfly specie collects sediment deposits and is known to inhabit the vegetation of the lake littoral (Schmedtje *et al.* 1996). Only one specimen of *Siphlonurus lacustris* was found in April 1999 at the *Nuphar* habitat A3 in Aidenried (Fig. 70).

The Plecoptera usually colonize running waters with stronger currents. The stoneflies belonging to the genus *Isoperla* are no exception (Aubert 1959). The species are predators (Schmedtje *et al.* 1996). The findings of so few specimens may be due to the closeness of the river Ammer.

The stoneflies were thinly represented at the sites A1 and A2 in Aidenried with three individuals of *Isoperla spp.* The reed habitat measured only one specimen in June 1998 (Fig. 68). One individual was found in April and two animals were found in May 1999 at the habitat A2 (Fig. 69).

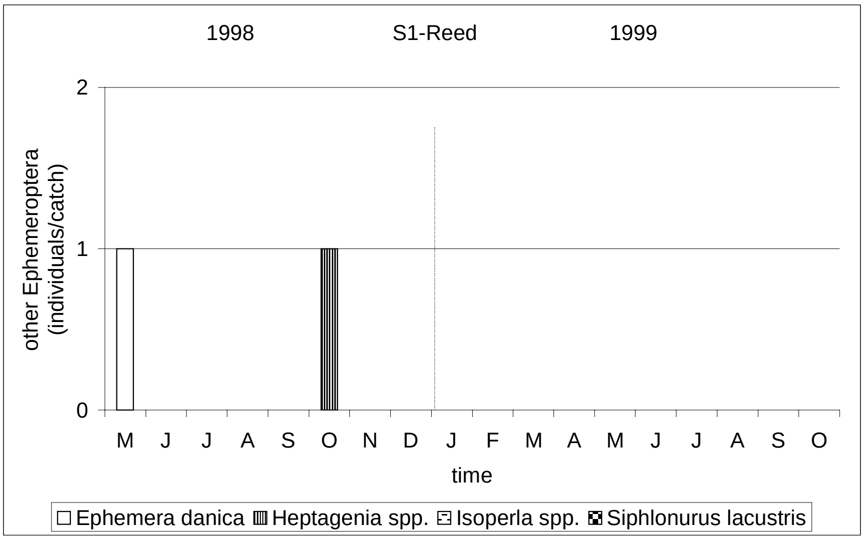


Fig. 65: Other Ephemeroptera and Plecoptera collected in the reed habitat in Schondorf

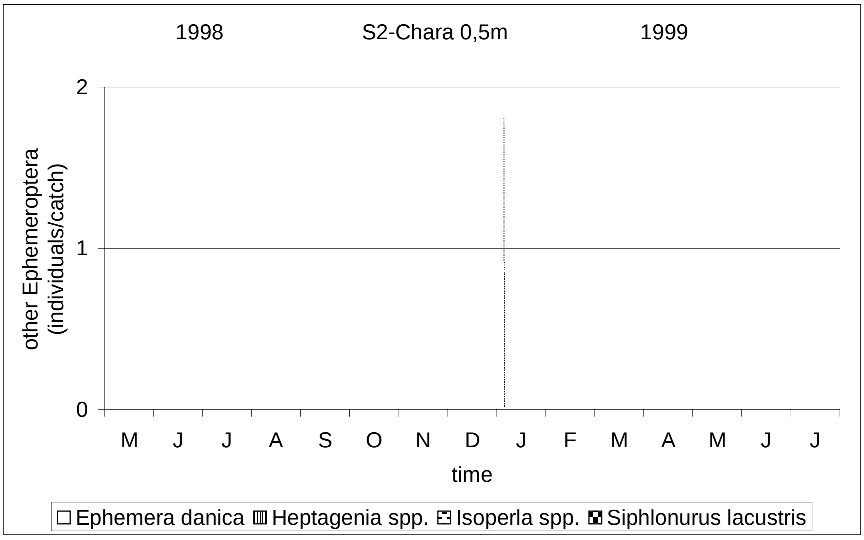


Fig. 66: Other Ephemeroptera and Plecoptera collected in the *Chara* habitat in Schondorf

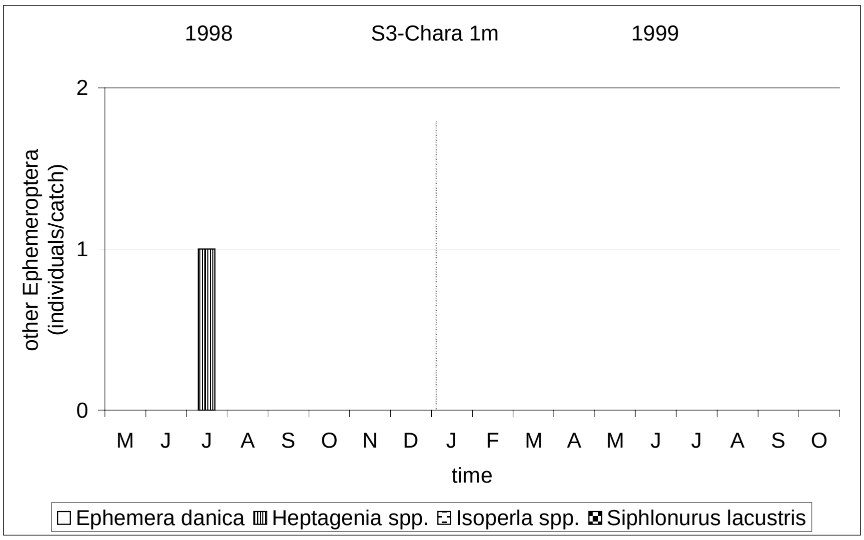


Fig. 67: Other Ephemeroptera and Plecoptera collected in the *Chara* habitat in Schondorf

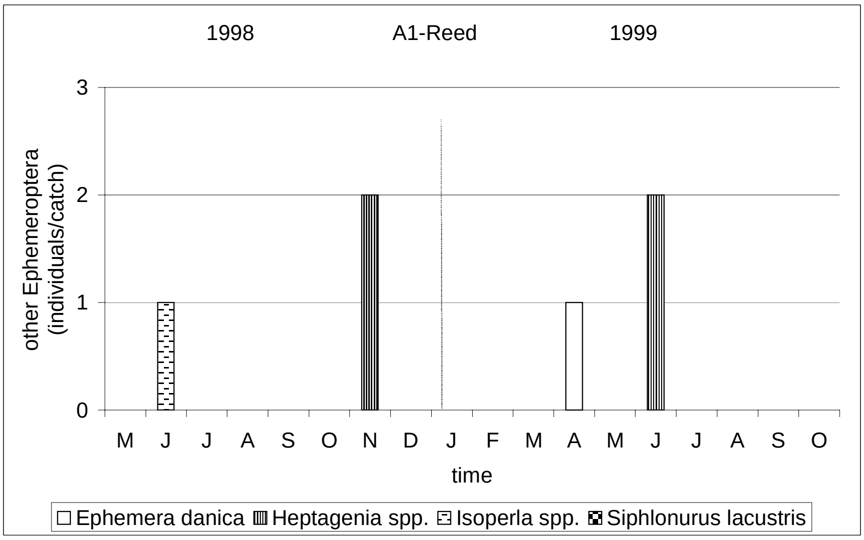


Fig. 68: Other Ephemeroptera and Plecoptera collected in the reed habitat in Aidenried

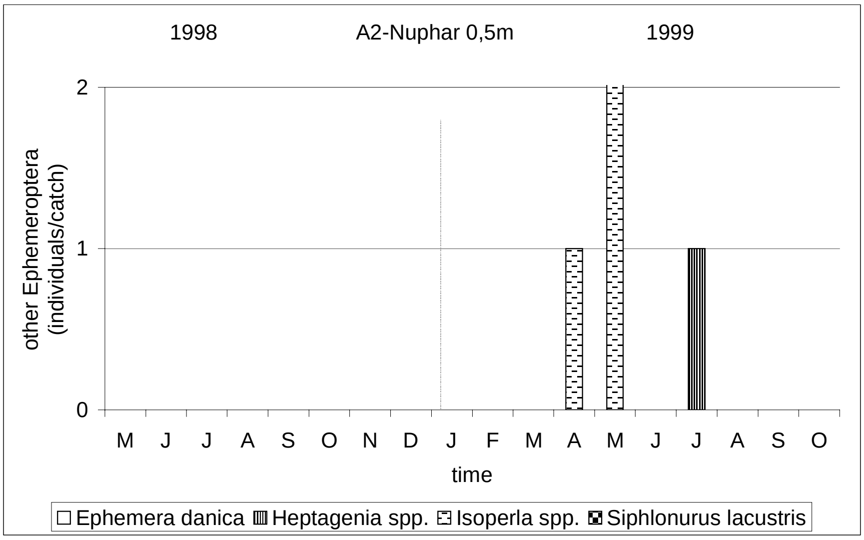


Fig. 69: Other Ephemeroptera and Plecoptera collected in the *Nuphar* habitat in Aidenried

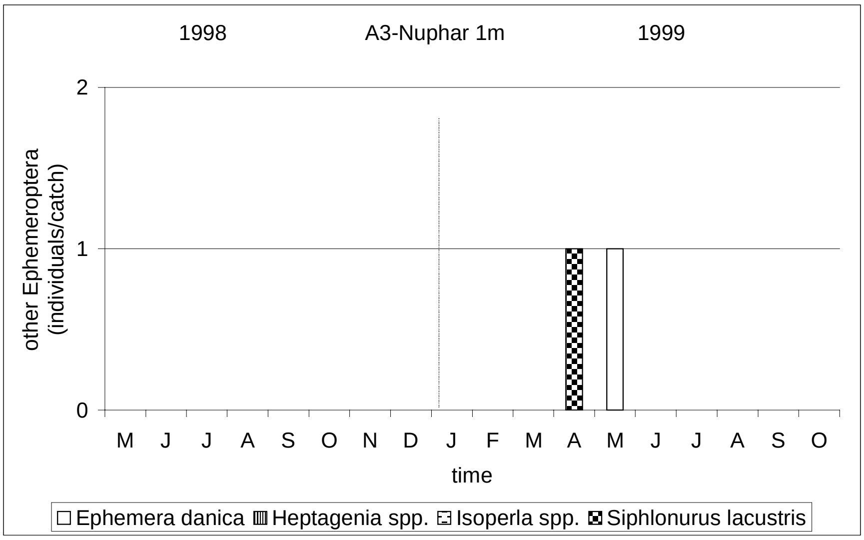


Fig. 70: Other Ephemeroptera and Plecoptera collected in the *Nuphar* habitat in Aidenried

3.1.4.8 Odonata

The dragonflies of the species *Coenagrion puella/pulchellum* were grouped together as Coenagrionidae. These predators are often associated with floating leaf communities (Schmedtje *et al.* 1996).

Except in one case, all of the dragonflies were found at the sites in Aidenried. The reed site measured numbers up to eight individuals/catch in 1998 and numbers up to 4 individuals/catch in 1999. The *Nuphar* habitats A2 and A3 counted numbers up to 6 individuals/catch. In 1999, only half as many specimens were found as in 1998 (Fig. 71).

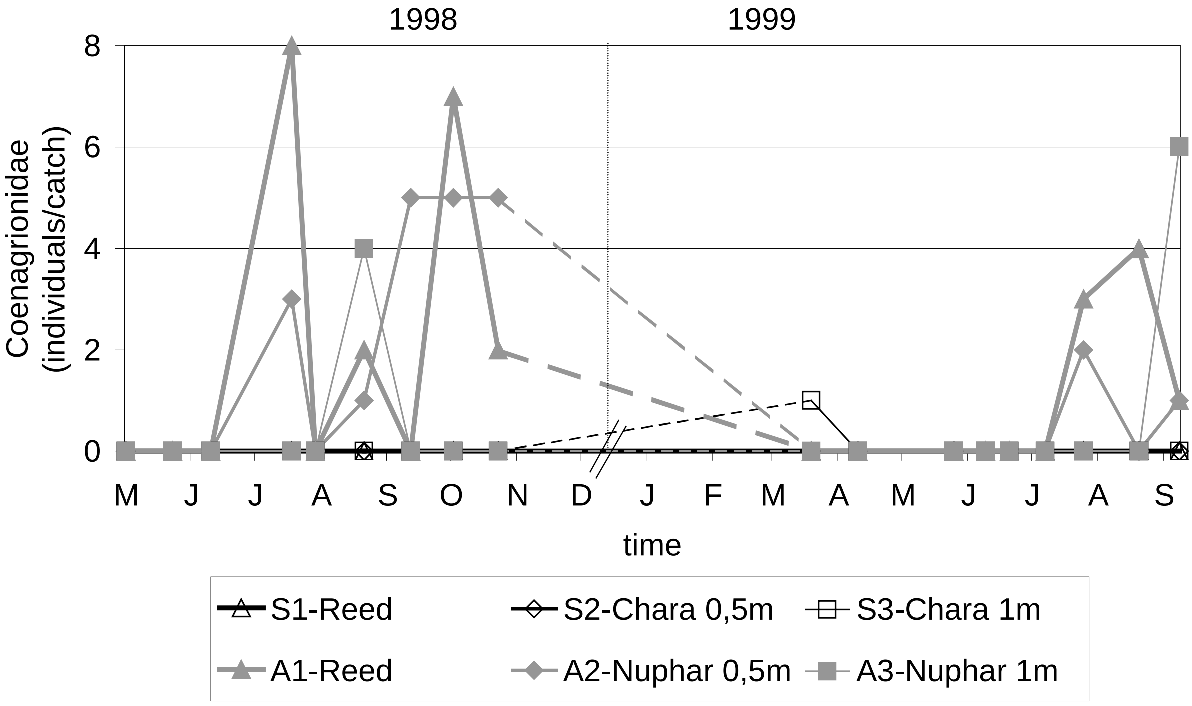


Fig. 71: Coenagrionidae collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.

The Anisoptera were grouped together, because of the low number of the species. The following species were found: *Aeshna cyanea, Aeshna grandis* and *Sympetrum vulgatum*. All of the species are very common and were recorded for the close geographical region of the Osterseen (Burmeister 1984).

The dragonflies were restricted to the reed and the 0,5 m *Nuphar* habitat A2 at Aidenried. In 1998, a total of 15 individuals/catch was counted. In 1999, only 4 individuals/catch were found (Fig. 72).

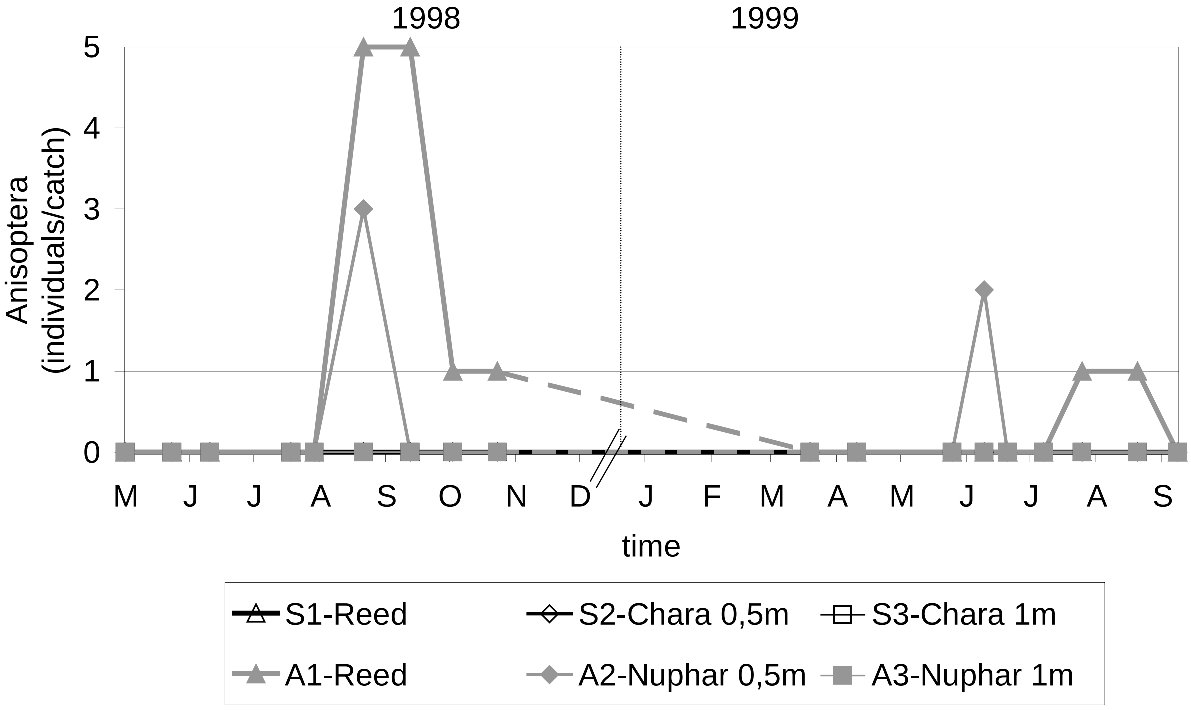


Fig. 72: **Anisoptera collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

3.1.4.9 Heteroptera and Megaloptera

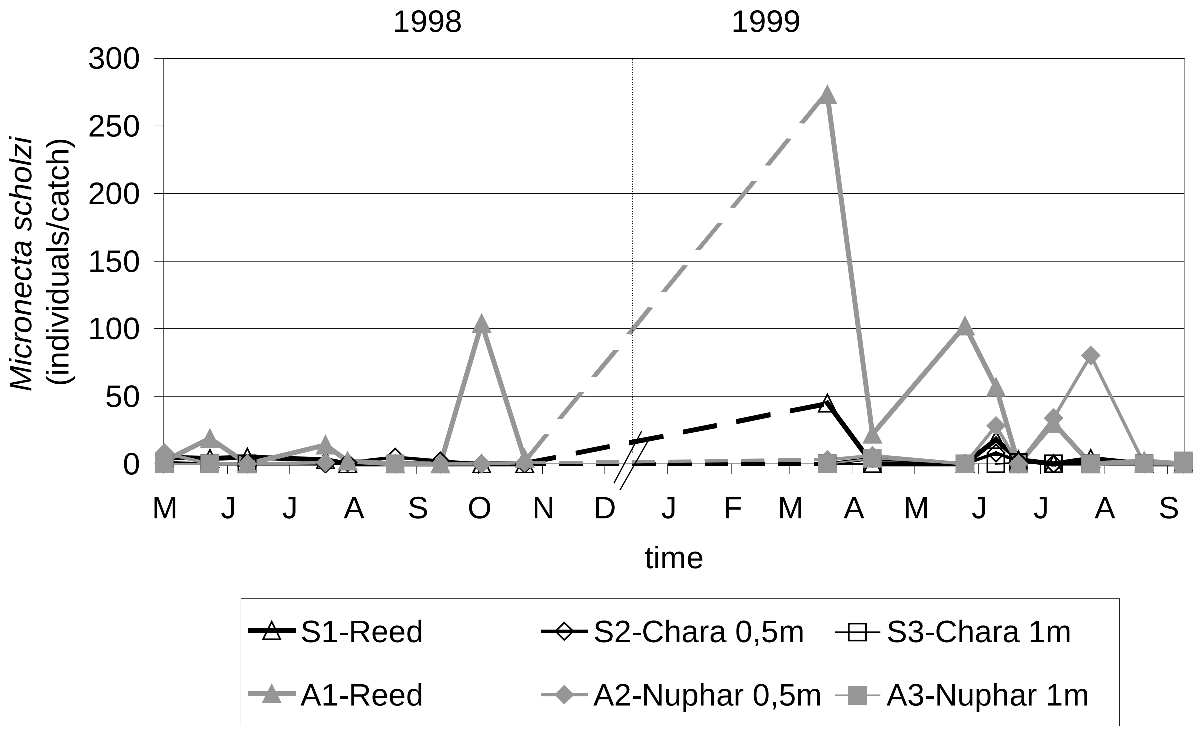


Fig. 73: ***Micronecta scholzi* collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

Micronecta scholzi is known to inhabit the lakes with sandy or stony bottoms and is abundant on the exposed shores of lakes (Macan 1976).

The small, true water bug, *Micronecta scholzi* was predominately found at the sites in Aidenried. The reed habitat in Aidenried registered the highest number of water bugs. In 1998 the maximum of 100 individuals/catch were counted in October. In April 1999 a maximum of 270 individuals/catch were found. The *Nuphar* habitat A2 reached a maximum of 80 individuals/catch in July 1999. At the *Nuphar* habitat A3 not a single water bug was found.

At the sites in Schondorf the numbers of registered *Micronecta scholzi* was much lower. The maximum of 45 individuals/catch was reached at the reed habitat in April 1999.

The only other Heteroptera *Sigara spp.* was found in all habitats, except the charophyte habitat S3, with up to eight individuals/catch.

The two Megaloptera *Sialis lutaria* and *Sialis fuligionsa* were collected only at the sites in Aidenried (Fig. 74 - Fig. 79).

The larvae of both *Sialis lutaria* and *Sialis fuligionsa* are widespread and live in lakes and sluggish parts of streams and rivers where there is an abundance of silt. The life cycle usually takes about two years from egg to adult. The larvae occur in the littoral, sub-littoral and, sometimes, the profundal zones of lakes and have been recorded at depths to seven meters. They are carnivores and their predominant food organisms are chironomid larvae and oligochaetes in the larger larvae, benthic crustaceans in the smaller larvae and micro-organisms and detritus in the first instar larvae (Elliott 1977).

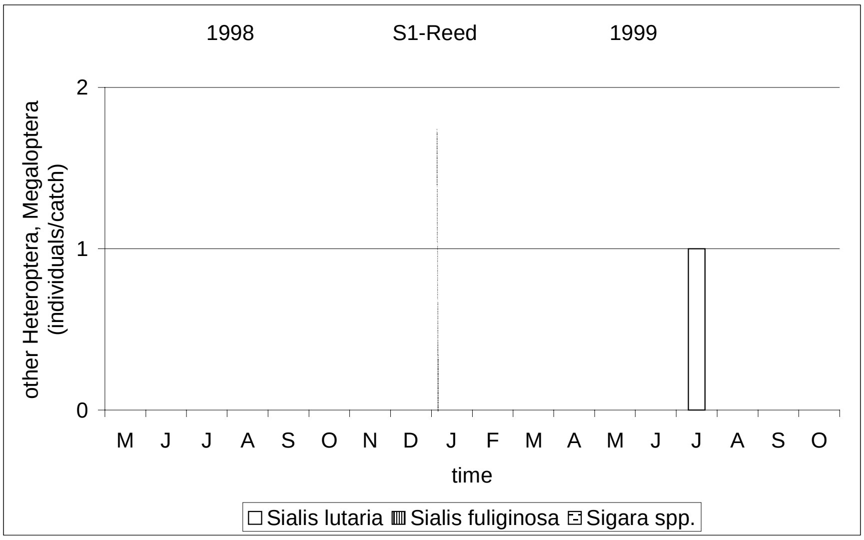


Fig. 74: Megaloptera and other Heteroptera collected at the reed habitat in Schondorf

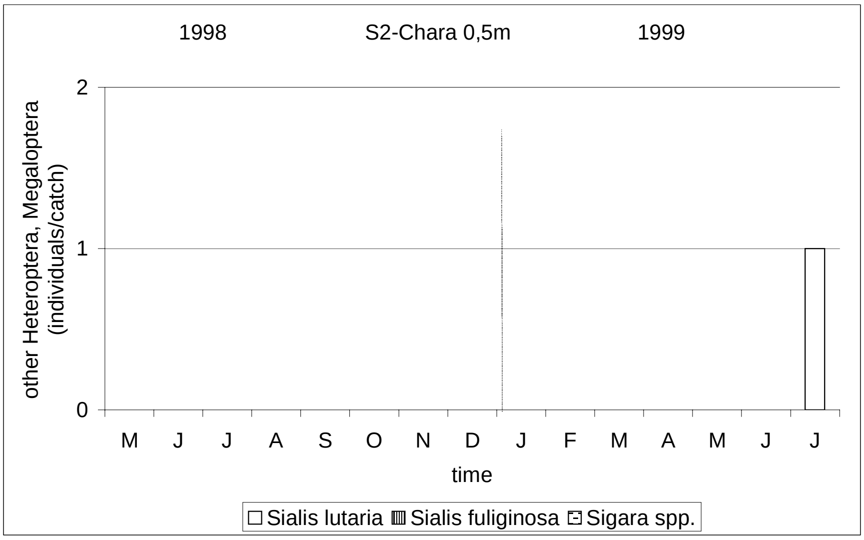


Fig. 75: Megaloptera and other Heteroptera collected at the *Chara* habitat in Schondorf

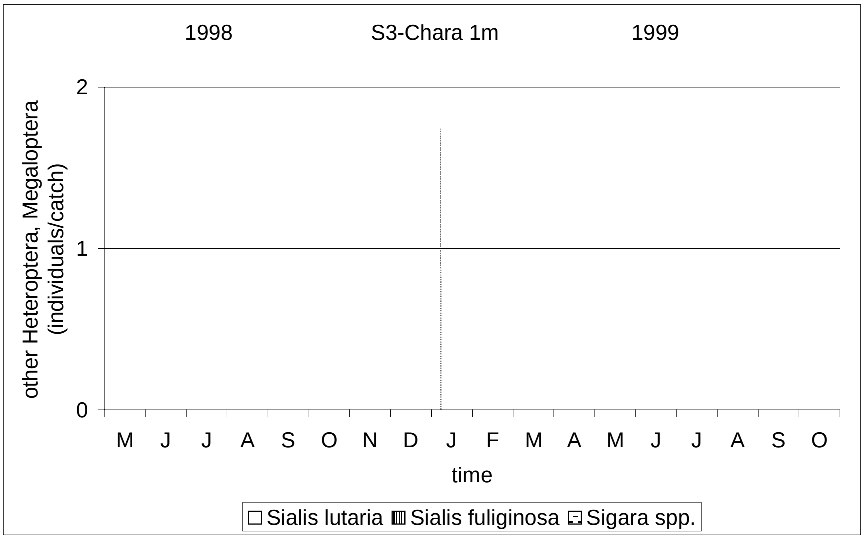


Fig. 76: Megaloptera and other Heteroptera collected at the *Chara* habitat in Schondorf

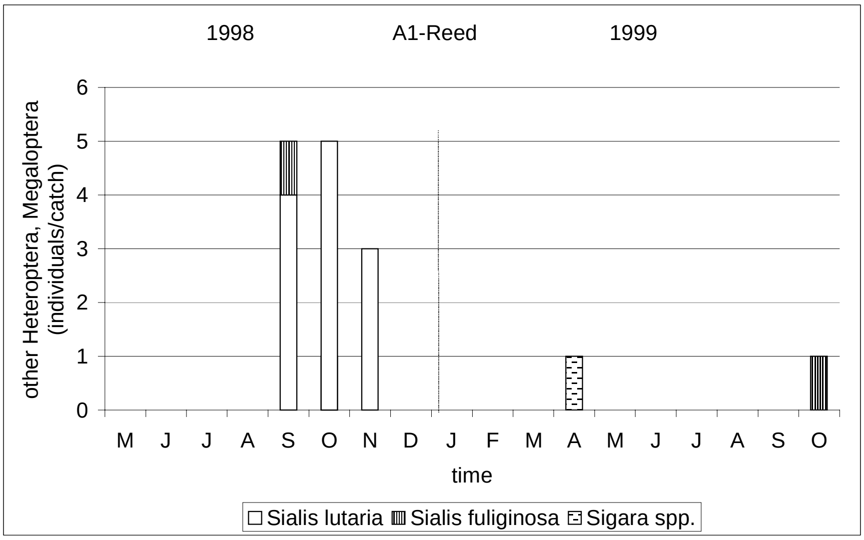


Fig. 77: **Megaloptera and other Heteroptera collected at the reed habitat in Aidenried**

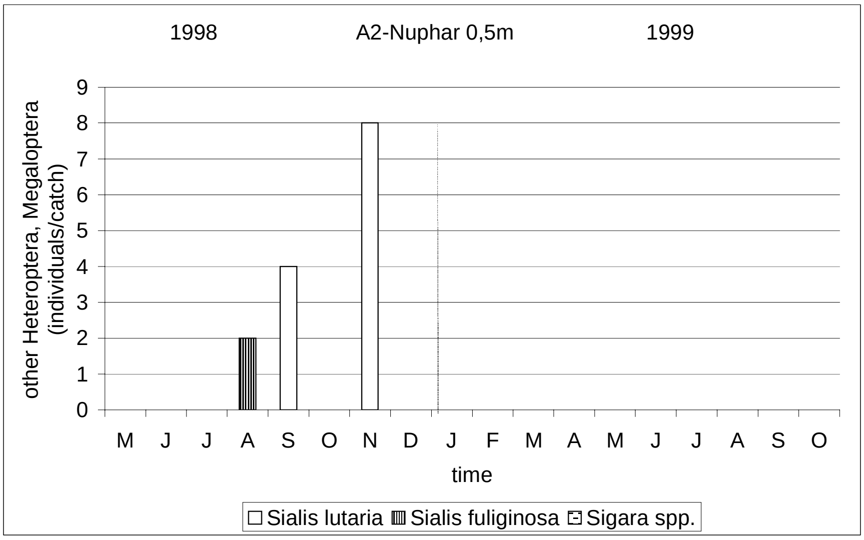


Fig. 78: **Megaloptera and other Heteroptera collected at the *Nuphar* habitat in Aidenried**

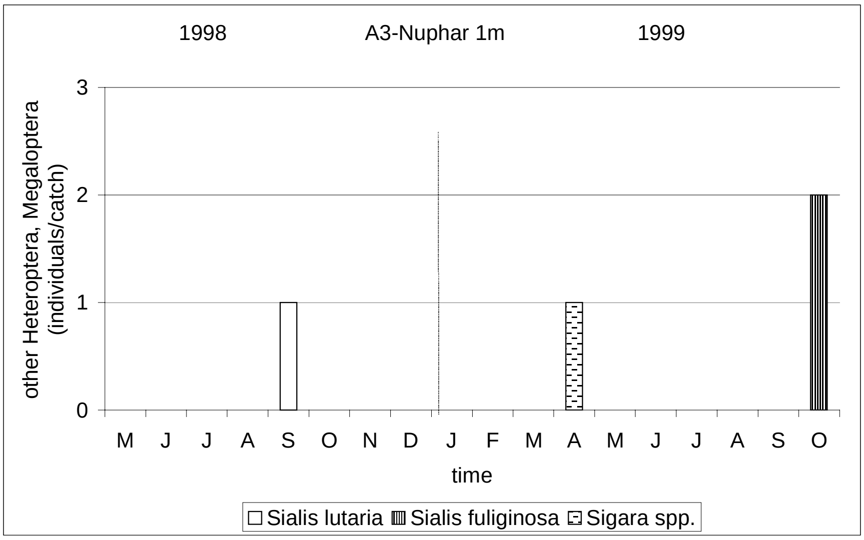


Fig. 79: **Megaloptera and other Heteroptera collected at the *Nuphar* habitat in Aidenried**

3.1.4.10 Coleoptera

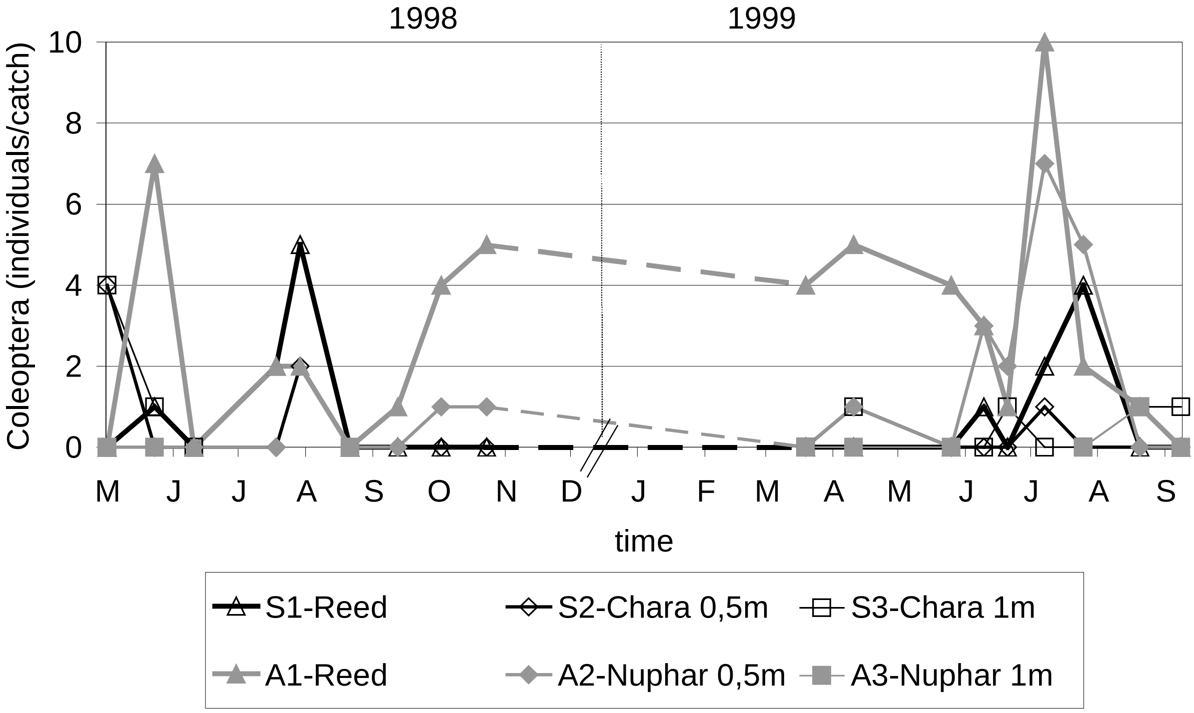


Fig. 80: Coleoptera collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.

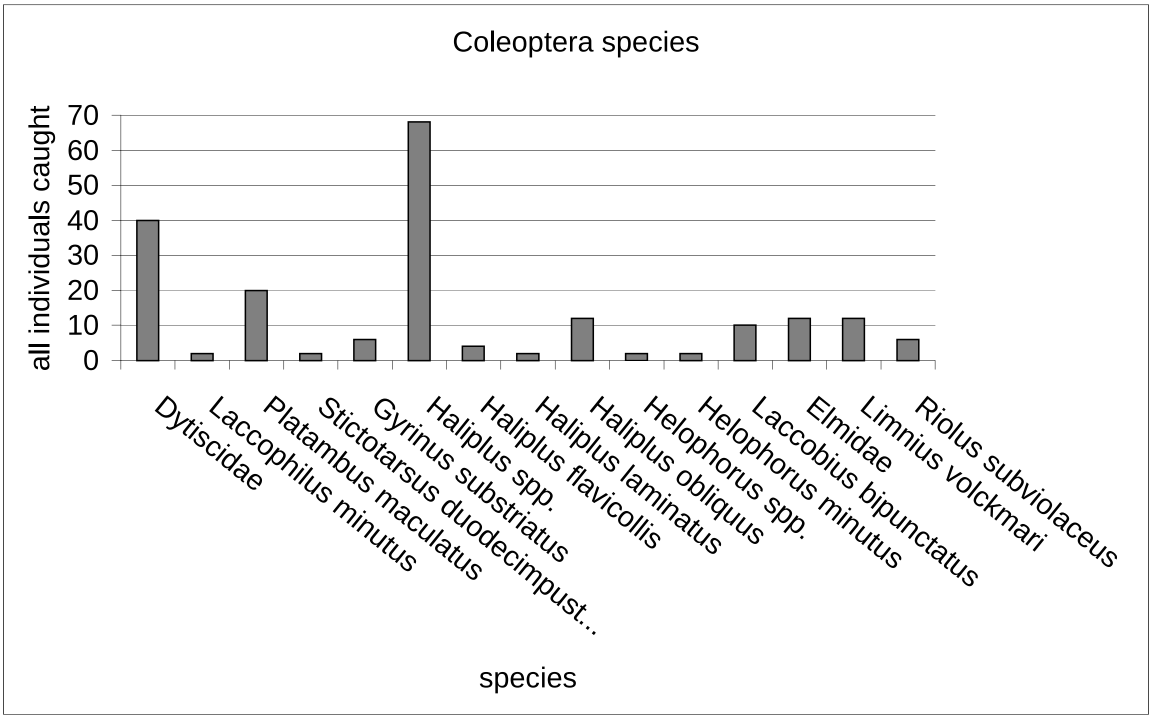


Fig. 81: Coleoptera species collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999 (Dytiscidae=all adults and larvae Dytiscidae found).

All Coleoptera species were grouped together because of the low concentration of the species. The water beetles showed their highest frequency at the reed habitat in Aidenried. The *Nuphar* habitat A2 showed a little lower abundance. The numbers of specimens found in 1998 were a little below those measured in 1999.

The reed habitat at Schondorf numbered five individuals/catch in August 1998 and four individuals/catch in July 1999. The two charophyte habitats measured up to four individuals/catch (Fig. 80).

The following species counted ten animals and less: *Laccophilus minutus, Stictotarsus duodecimpustulatus, Gyrinus substriatus, Helophorus minutes and Laccobius bipunctatus.* A total of two *Helophorus spp.* larvae were also found.

The family of the Elmidae was represented by the species *Limnius volckmari* and *Riolus subviolaceus*. Their numbers ranged between eight and eleven animals. Eleven Elmidae larvae were also found.

The count of the larvae of the family of the Dytiscidae revealed 40 specimens. The most common specie was *Platambus maculates* with a total of 20 animals.

The family of the Halipildae was represented with three species: *Haliplus flavicollis, Haliplus laminatus* and *Haliplus obliquus*. A total number of 68 *Haliplus spp.* larvae were also collected. *Haliplus obliquus* was most common Haliplidae (Fig. 81).

3.1.4.11 Trichoptera

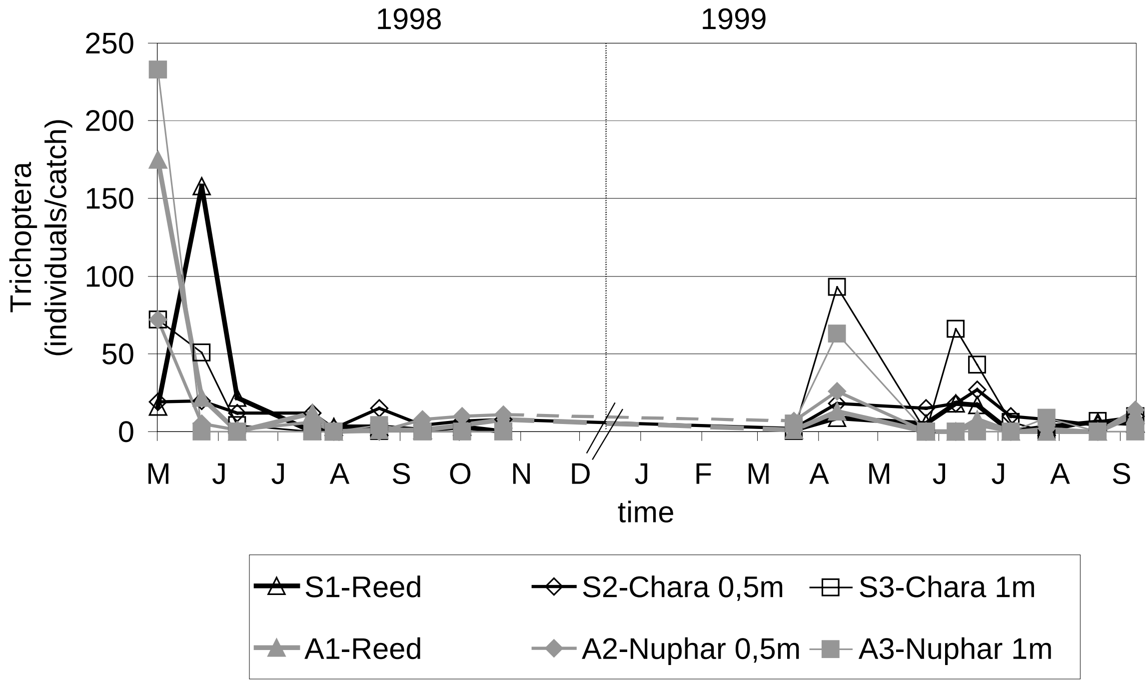


Fig. 82: Total number of Trichoptera collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.

The *Nuphar* site A3 at Aidenried counted a maximum of 230 individuals/catch in May 1998. In 1999 a total number of 60 Trichoptera larvae were caught. The reed habitat A1 at Aidenried measured a maximum of 175 individuals/catch in May 1998. The *Nuphar* habitat A2 registered 70 individuals/catch at the same sampling date.

The reed habitat at Schondorf counted 155 individuals/catch in June 1998. The charophyte habitat S2 measured never above 25 individuals/catch in both years. The charophyte habitat A3 reached up to 100 individuals/catch in 1998 and 1999 (Fig. 82).

The family of the Limnephilidae was represented by the two species *Limnephilus lunatus* and *Potamophylax cingulatus.* The peak of 41 individuals/catch was measured at the charophyte habitat S3 in June 1999 (Fig. 83).

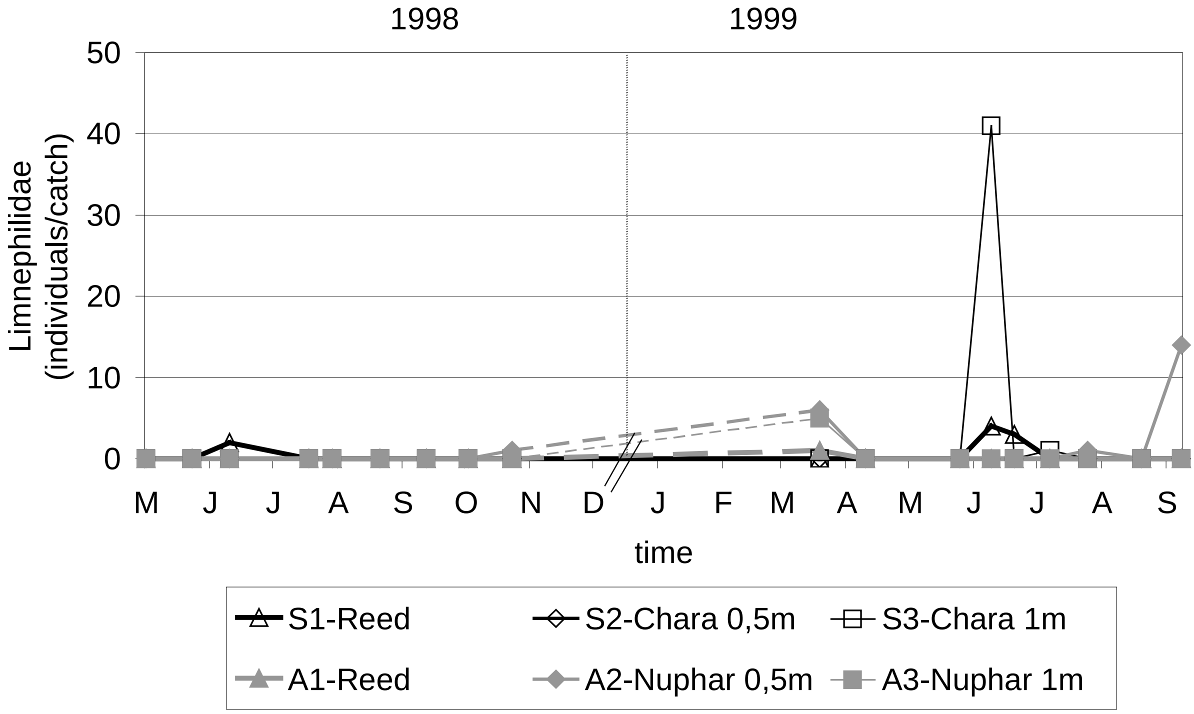


Fig. 83: Limnephilidae collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.

The larvae of the family of the Hydroptilidae were more often seen in 1998 than in 1999. The greater abundance was measured in May and June at the habitats S1, S3, A1 A2 and A3. The numbers ranged between 30 and 225 individuals/catch (Fig. 83).

The Trichoptera *Molanna angustata* was only observed once and is not discussed further.

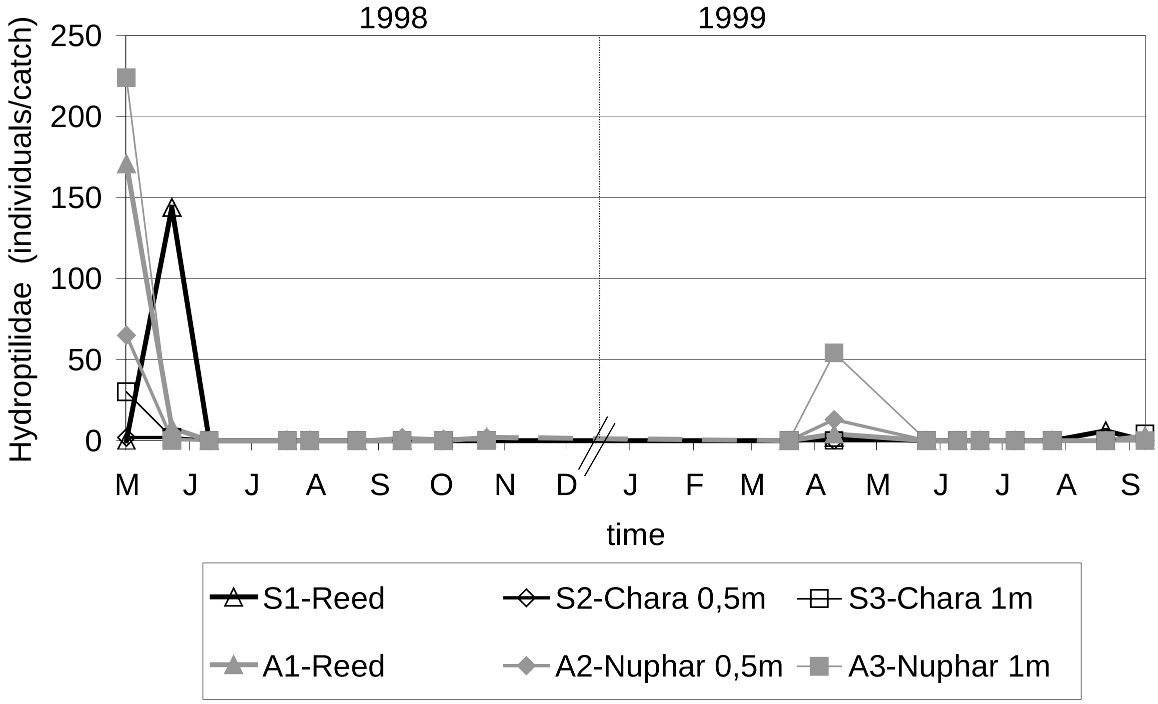


Fig. 84: **Hydroptilidae collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

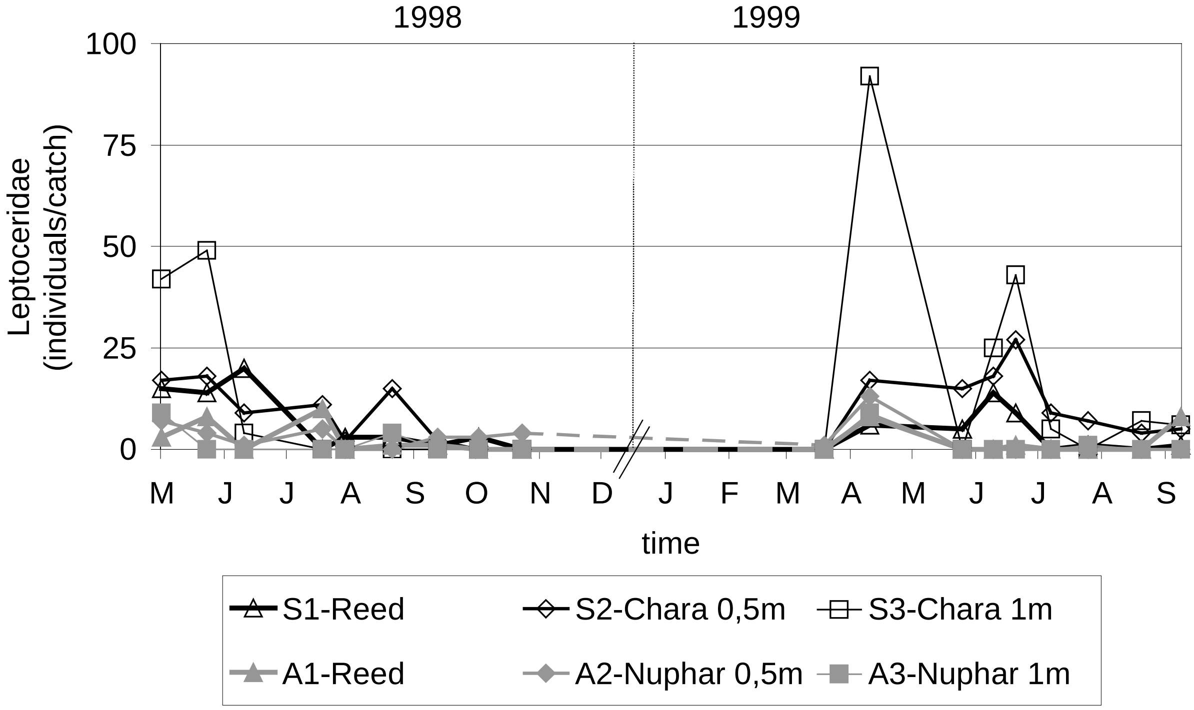


Fig. 85: **Leptoceridae collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

The family of the Leptoceridae was measured at a peak of 92 individuals/catch at the charophyte habitat at Schondorf in April 1999. The habitat was also clearly preferred in May, June 1998 and June, July 1999. The other two habitats at Schondorf ranged up to 28 individuals/catch. All sites at Aidenried measured lower numbers of larvae than at Schondorf (Fig. 85).

The composition of the Leptoceridae was made up of small Leptoceridae, *Athripsodes spp., Athripsodes albifrons, Athripsodes bilineatus, Athripsodes cinereus, Mystacides spp., Mystacides azurea, Mystacides longicornis* and *Oecetris ochraceae*. The small Leptoceridae, with 337 specimens, was the largest number. Small specimen of *Athripsodes spp.* and *Athripsodes bilineatus* were also abundant (Fig. 86).

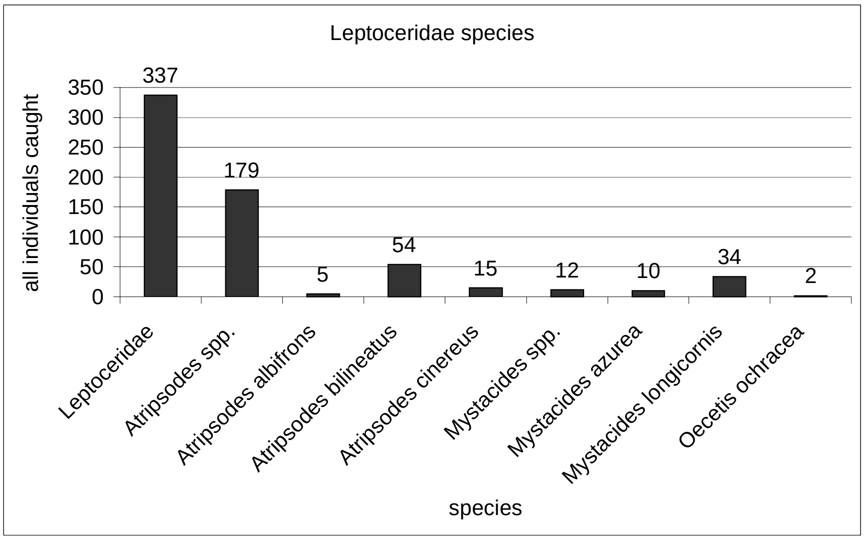


Fig. 86: Leptoceridae collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999(Leptoceridae = all Leptoceridae found).

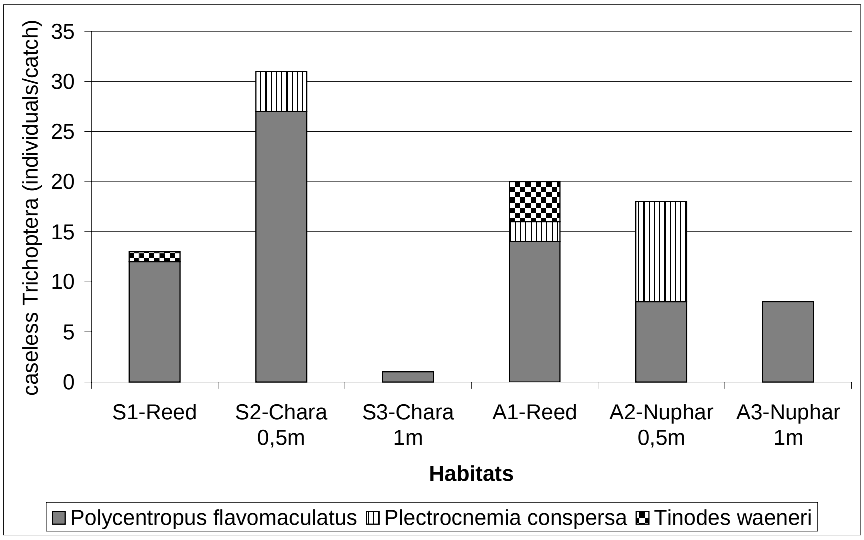


Fig. 87: Caseless Trichoptera collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.

The caseless Trichoptera; *Polycentropus flavomaculatus, Plectrocnemia conspresa* and *Tinodes waeneri;* grouped together at each habitat. *Polycentropus flavomaculatus* was the most abundant species. The charophyte habitat S2 at Schondorf showed the highest number of specimens. At the charophyte habitat S3 only one specimen of *Polycentropus flavomaculatus* was found. The other habitats ranged between eight and 20 individuals/catch (Fig. 87).

3.1.4.12 Diptera and other organisms found

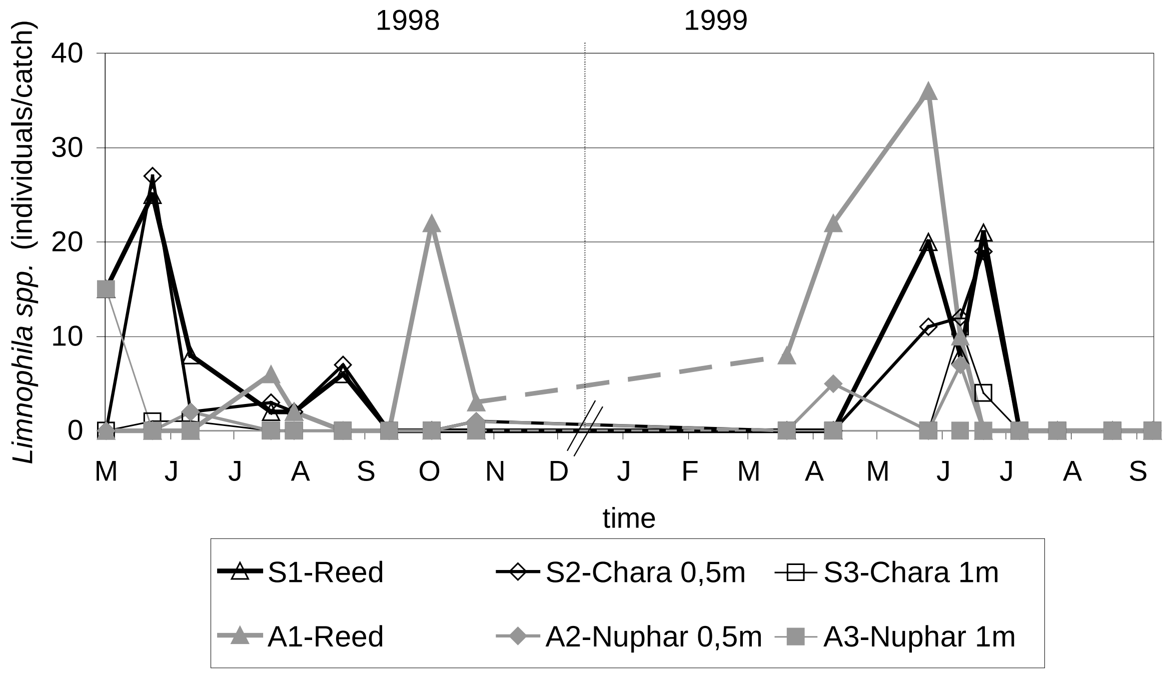


Fig. 88: ***Limnophila spp.*** **collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

The Diptera, *Limnophila spp.* was most abundant at the reed habitat at Aidenried. The numbers ranged up to 36 individuals/catch. The reed habitat at Schondorf measured a peak of 25 individuals/catch in June 1998 and two peaks of 20 individuals/catch in May and June 1999. The charophyte habitat S2 measured numbers between eleven and 27 individuals/catch at the same sampling dates. At the other habitats the numbers of counted larvae were below 15 individuals/catch (Fig. 88).

The larvae of the Chironomidae measured two peaks in August 1999, 140 individuals/catch at the reed habitat and 200 individuals/catch at the *Nuphar* habitat S2 at Aidenried. The reed habitat at Schondorf measured a maximum of 80 individuals/catch in June 1998 and of 70 individuals/catch in August 1999. The two charophyte habitats counted numbers between up to 80 individuals/catch. The lowest numbers were registered at the *Nuphar* habitat A3 in Aidenried (Fig. 89).

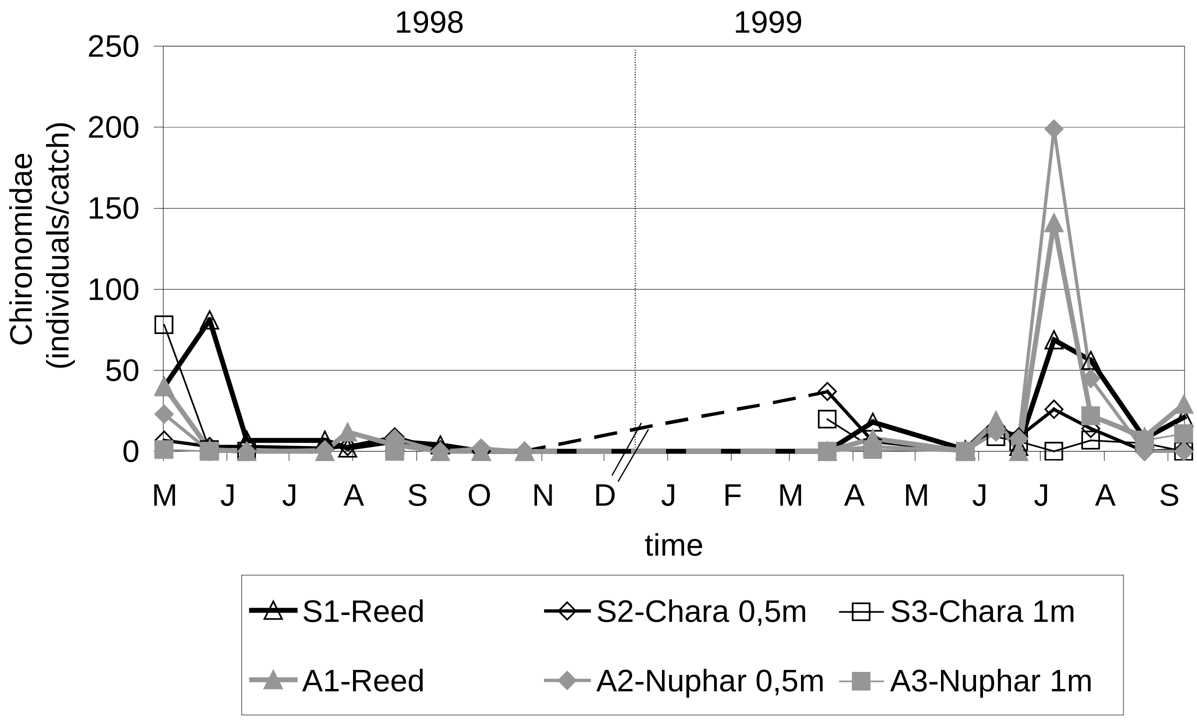


Fig. 89: **Chironomidae collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

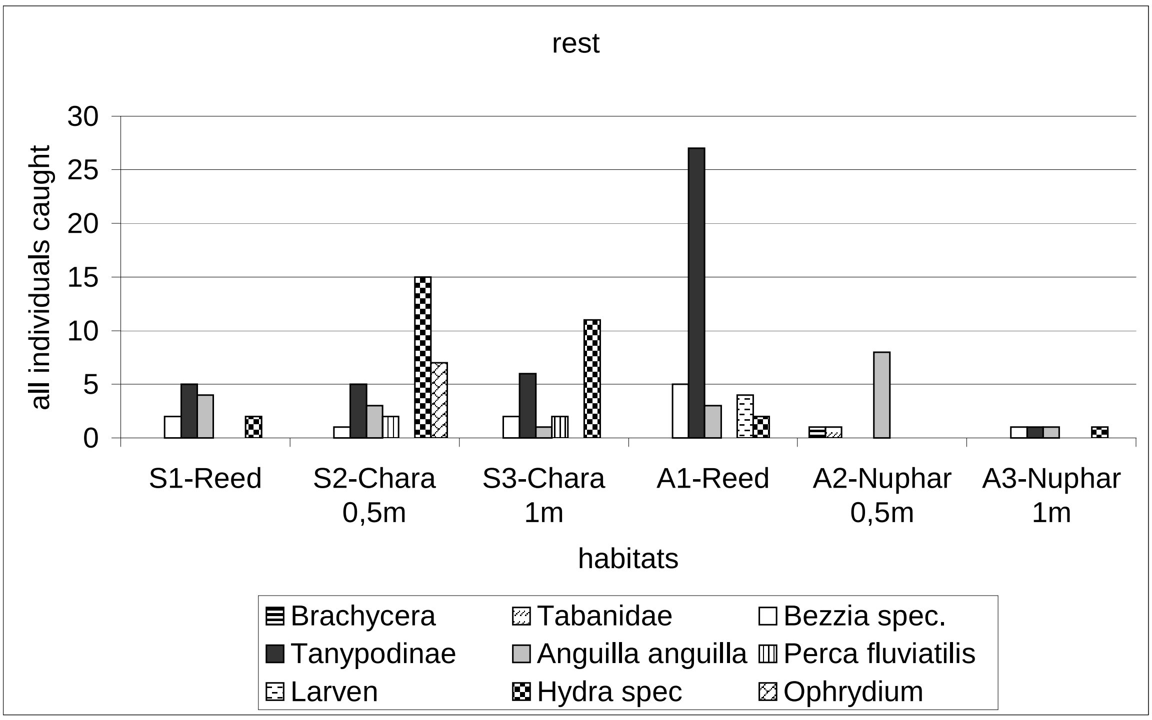


Fig. 90: **Other organisms collected at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

The other organisms found were grouped together to provide an overview. The Diptera families of the Brachycerca and Tabanidae were just found once at the *Nuphar* habitat A2. Larvae of *Bezzia spp.* and the family of the Tanypodinae were found in all habitats except the *Nuphar* habitat A2. The two fish species caught were *Anguilla anguilla* and *Perca fluvialilis*. The eel was found at all sites except the *Nuphar* habitat A3 in Aidenried. The perch was found at the two charophyte habitats in Schondorf. *Hydra spp.* was observed at all habitats except the *Nuphar* habitat A2. *Ophrydium spp.* was only found at the charophyte habitat S2 in Schondorf (Fig. 90).

3.1.5 Community analysis

The reed habitat at Aidenried offered a suitable environment for species of the family of the Coenagrionidae and Aeshnidae. Especially after the heavy rains in 1999 the reed represented an optimal refuge for *Asellus aquaticus* and *Gammarus roeseli*. *Micronecta scholzi* was one of the species exclusively found at the reed habitat in Aidenried. The greatest number of Coleoptera was also counted at this site. The reed habitat at Aidenried counted an average of 73 species, which was the highest average number of species (Fig. 91). The calculated diversity for the habitat was an average of 2,3 (Fig. 92).

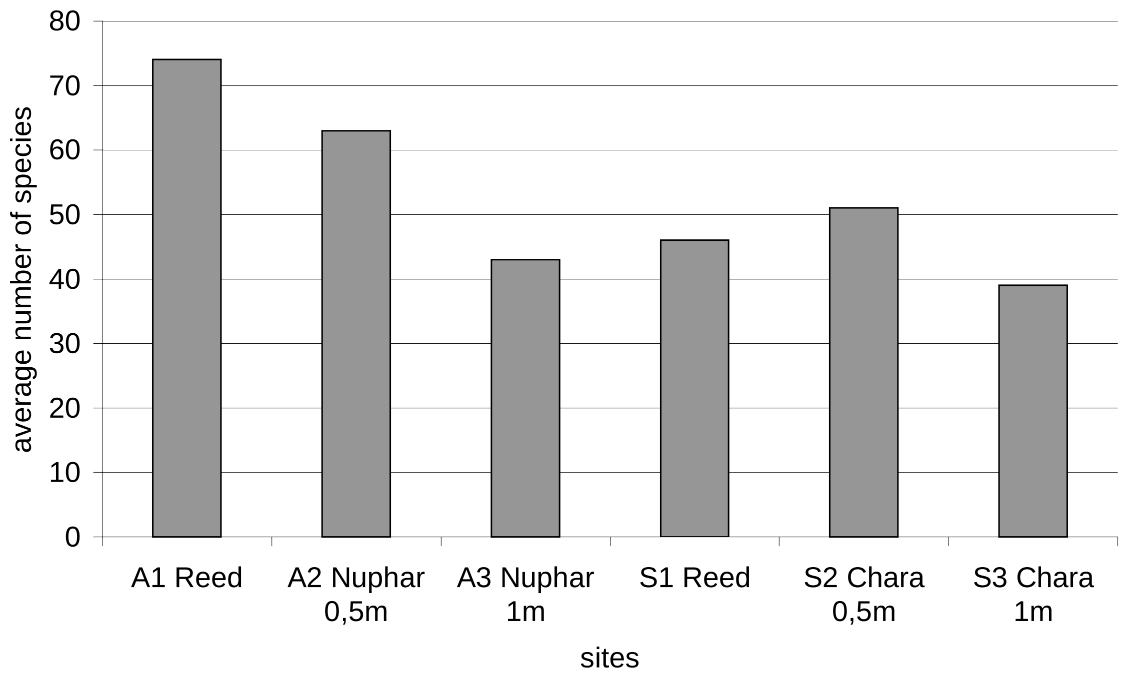


Fig. 91: Average number of species at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.

Earlier investigations showed great similarities in the invertebrate community between *Phragmites australis* and floating leaved plants (Dvorak 1982). The *Nuphar* habitat at 0,5 m depth in Aidenried was the ideal habitat for the snails *Bithynia tentaculata, Potamopyrgus jenkinsi* and *Physa fontinalis*. *Erpobdella octoculata* and *Gammarus roeseli* was also abundant at the habitat. *Gammarus roeseli* was the only specie found in the reed and the *Nuphar* habitat in great numbers. The *Nuphar* habitat A2 had an average of 62 species (Fig. 91). The calculated diversity was 2,3, the same as at the reed habitat (Fig. 92).

The *Nuphar* habitat A3 situated at 1m depths favored species such as *Erpobdella octoculata* and the members of the family of the Hydroptilidae. The average number of species was 42; the lowest of all habitats (Fig. 91). The diversity of 2,1 was also relatively low (Fig. 92).

At the reed habitat in Schondorf, the Oligochaeta such as Naididae, Tubificidae and Lumbriculidae were abundant. *Asellus aquaticus* and *Caenis spp*. also preferred this habitat.
Reed plants such as *Typha spp*. are known to have great species richness (Olson 1995). The reed habitat at Schondorf measured an average of 47 species (Fig. 91). The average diversity of 2,7 was the highest measured at all habitats (Fig. 92).

The charophyte habitat S2 had the highest numbers of the Emphemeroptera *Centroptilum luteolum* and the caseless Trichoptera, *Polycentropus flavomaculatus*. Earlier studies proved relative high specie diversity for Charophytes (Kornijow 1992). The habitat had the highest species richness of the three sites in Schondorf. The average number of species was 51 and the diversity was calculated with 2,6 (Fig. 91, Fig. 92).

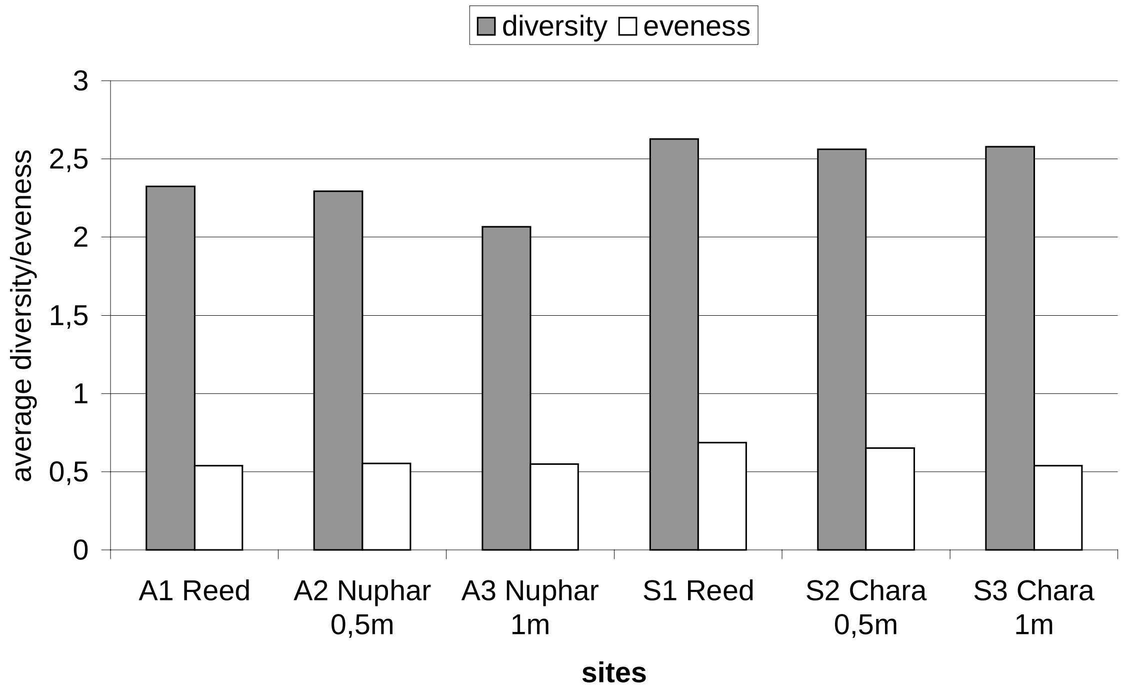


Fig. 92: **Average diversity and evenness at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

The charophyte S3 habitat situated at one meter depth in Schondorf, showed the most specimen of *Dendrocoelum lacteum*, *Dreissena polymorpha* and members of the family of the Hydrachnellae and the Leptoceridae. The counted average number of species of 39 was the lowest noted at all habitats (Fig. 91). The calculated diversity was the same as the other charophyte habitat (Fig. 92).

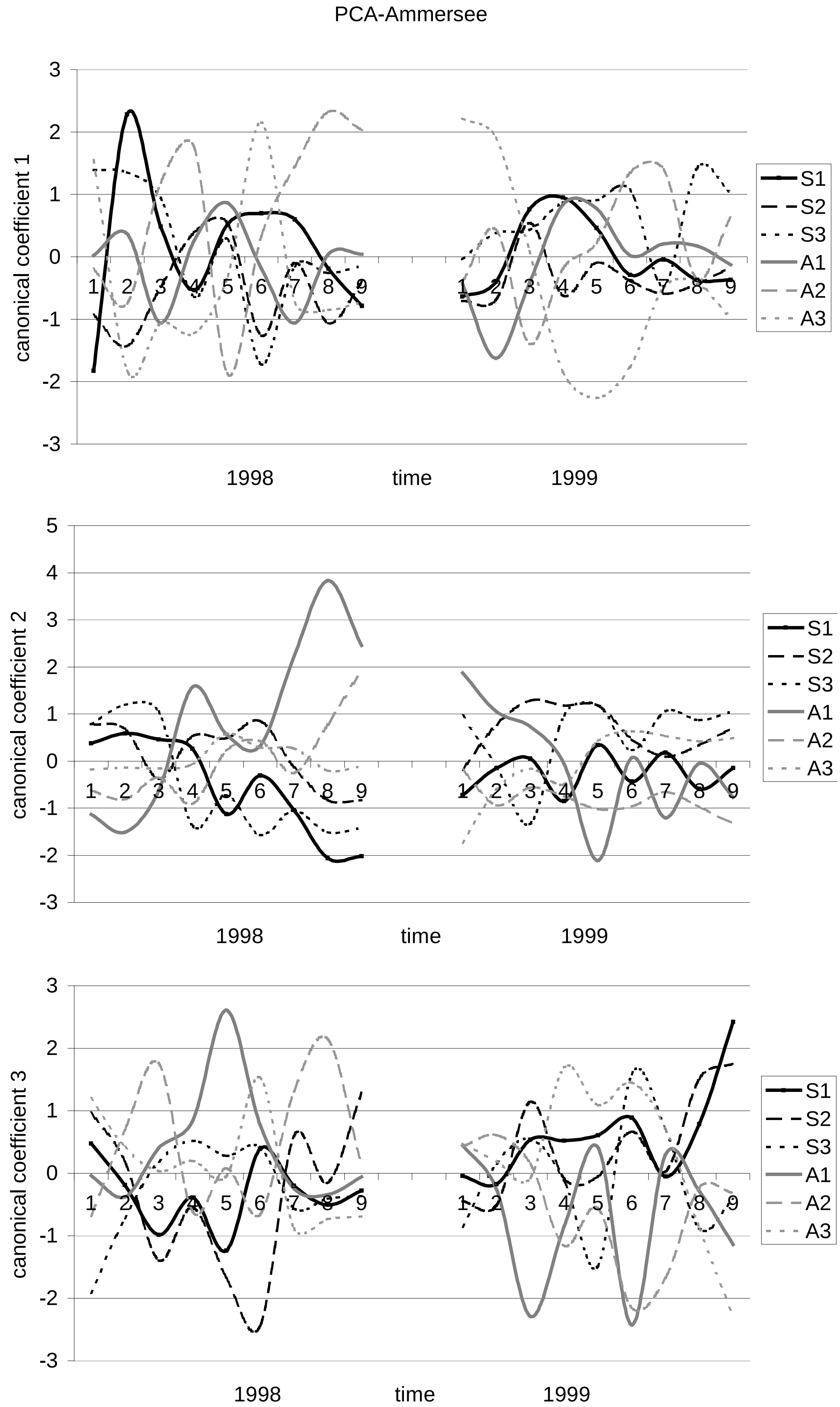


Fig. 93: **Principal component analysis (canonical coefficients 1, 2 and 3) at the littoral habitats Schondorf and Aidenried of Lake Ammersee in 1998 and 1999.**

To make the similarity between the three sites in Schondorf and in Aidenried for all species at the different points of time visible a pca analysis was calculated. The principal component analysis of the six habitats (Fig. 93) was used to describe the major macroinvertebrate community at the sites through the investigation period.

The first coefficient explains 15,8% variance and describes mainly the general absolute numbers of the specimens at the sites. The species with the highest loadings were *Gammarus roeseli, Bithynia tentaculata, Mystacides, Potamopyrgus jenkinsi, Dreissena polymorpha, Zygoptera, Asellus aquaticus* and *Caenis spp.* (Table 8). For the other species, scores with less weight, between -0,3 and 0,3 were calculated. Most of the species (*Gammarus roeseli, Bithynia tentaculata, Potamopyrgus jenkinsi, Zygoptera, Asellus aquaticus*) clearly preferred the habitats in Aidenried. The curves from the habitats A2 and A3 had the highest scores alternating from positive to negative. The community at the site A3 was clearly influenced by the flood in 1999 (date 4 in 1999). The curve from S1 showed a high score at date two in 1998. By this time the *Gammarus roeseli* (highest loading) developed a population maximum at the reed site. The pca curves of the other habitats, with the same depth at the different sites S2 and S3 as well as A1, showed only little changes. The curves of the two habitats at the same sites, but in different depths (S2 and S3) ran parallel at certain periods of time (date 5, 6 and 7 in 1998). The curves of the two habitats in Aidenried (A2 and A3) had similar amplitudes but not in the same time period. Each of the four curves developed unique in 1998 and again in 1999. The different sediments at the two sites, Schondorf and Aidenried, were one of the possible reasons for the different species composition and therefore reaction (Schramm 1989). Another was the macrophyte composition (Kornijow 1990). The different depths of the macrophytes also result in different colonization possibilities for the macroinvertebrates (Sloey 1997). The six examined habitats showed no clear uniformity in seasonal changes. The seasonal changes in the qualitative composition of the fauna were small (Kornijow 1989).

The second coefficient of the pca explains 28,8% variance. The species with the highest loadings were: *Gammarus roeseli, Cloeon dipterum, Zygoptera, Centroptilum luteolum, Potamopyrgus jenkinsi, Dreissena polymorpha, Limnephilus lunatus, Sialis lutaria,* Hydrachnellae, *Caenis spp.* and the Elmidae. The species scores of all other species varied between -0,3 and 0,3 (Table 8). The coefficient describes relative numbers at the habitats. At the sampling date eight in 1998 and sapling date 5 in 1999 showed high scores for the two reed habitats in Schondorf and Aidenried. The loading of the canonical coefficient was in the opposite direction (Fig. 93).

The third coefficient explains 36,1% variance and the following species showed high loadings: *Asellus aquaticus, Mirconecta scholzi,* Chironomidae and *Caenis spp*. The species scores of all other species ranged between -0,3 and 0,3 (Table 8). Extreme values were calculated for the two reed habitats and the habitats at half a meter depths (S2 and A2) at different sampling dates (Fig. 93).

Table 8: The highest species loadings of coefficient 1,2 and 3 calculated for the pca at the littoral habitats

coefficient 1		coefficient 2		coefficient 3	
variance 15,8%		variance 28,8%		variance 36,1%	
species	scores	**species**	scores	**species**	scores
Eiseniella tetraedra	-0,2286	***Gammarus roeseli***	**-0,3224**	***Asellus aquaticus***	**-0,3601**
Hirudinea	-0,2037	*Lymnea stagnalis*	0,2164	***Mirconecta scholzi***	**-0,3274**
Chironomidae	-0,2005	*Dugesia spp.*	0,2261	**Chironomidae**	**-0,3152**
Lymnea stagnalis	0,2098	*Mirconecta scholzi*	0,2311	*Haliplus spp.*	-0,2824
Limnephilidae	0,2284	*Tinodes spp*	0,2330	Haliplidae	-0,2686
Plectrocnemia conspersa	0,2675	*Bithynia tentaculata*	0,2366	Planorbidae	-0,2590
Hydroptilidae	0,2869	*Gyrinus spp.*	0,2372	Ophrydium	-0,2364
Caenis spp.	**0,3089**	*Limnius spp.*	0,2372	*Laccobius biguttatus*	-0,2258
Asellus aquaticus	**0,3110**	Anisoptera	0,2682	Heptagenia spp.	-0,2145
Zygoptera	**0,3150**	*Riolus spp.*	0,2872	*Centroptilum luteolum*	-0,2061
Dreissena polymorpha	**0,3161**	***Cloeon dipterum***	**0,3005**	Dydiscidae	-0,2040
Potamopyrgus jenkinsi	**0,3186**	***Zygoptera***	**0,3193**	Baetidae	0,2772
Mystacides spp.	**0,3390**	***Centroptilum luteolum***	**0,3324**	**Caenis spp.**	**0,3449**
Bithynia tentaculata	**0,4272**	***Potamopyrgus jenkinsi***	**0,4023**		
Gammarus roeseli	**0,5497**	***Dreissena polymorpha***	**0,4109**		
		Limnephilus lunatus	**0,4126**		
		Sialis lutaria	**0,4270**		
		Hydrachnellae	**0,4276**		
		Caenis spp.	**0,4319**		
		Elmidae	**0,5150**		

The communities can be described with the major species *Gammarus roeseli, Bithynia tentaculata, Elmidae, Caenis spp.,* Hydrachnellae, *Sialis lutaria, Limnephilus lunatus, Potamopyrgus jenkinsi, Dreissena polymorpha* and *Asellus aquaticus*. The alternating cycle of the species driven by the annual reproduction and emergence on one side and the recolonisation of niches (and deeper habitats) on the other determines the community structure.

The structure stage of the community at the habitats did not undergo the seasonal changes at the same points of time. The time span varied between 3 and 6 weeks. The six habitats did not show any significant resemblance.

The Community structure of the two years 1998 and 1999 showed no significant resemblance. The community reacted to the flood in 1999 with a delayed time rhythm at the sites. The sites at Aidenried were influenced to a greater extent than the ones at Schondorf. The species reacted differently according to their possibilities to the flood. The large sized stages from *Gammarus roeseli* at the reed in Schondorf for instance migrated to deeper depths. The species *Bithynia tentaculata, Dreissena polymorpha* and *Limnephilus lunatus* wandered to deeper regions as well. Species such as *Potamopyrgus jenkinsi* disappeared totally and were probably drifted away. Species such as *Asellus aquaticus* and *Gammarus roeseli* favoured the environmental condition and the food sources brought by the flood.

3.2 Mesocosm studies

3.2.1 Comparison between the littoral and the mesocosm (Pond M without enclosures) habitats

3.2.1.1 Physical and chemical parameters

The pH values at the littoral habitats and the mesocosm had a similar development in the two years. The deviation between the two was usually below 5%. Only on two sampling dates, in April and July 1998, was the standard deviation 10% (Fig. 94).

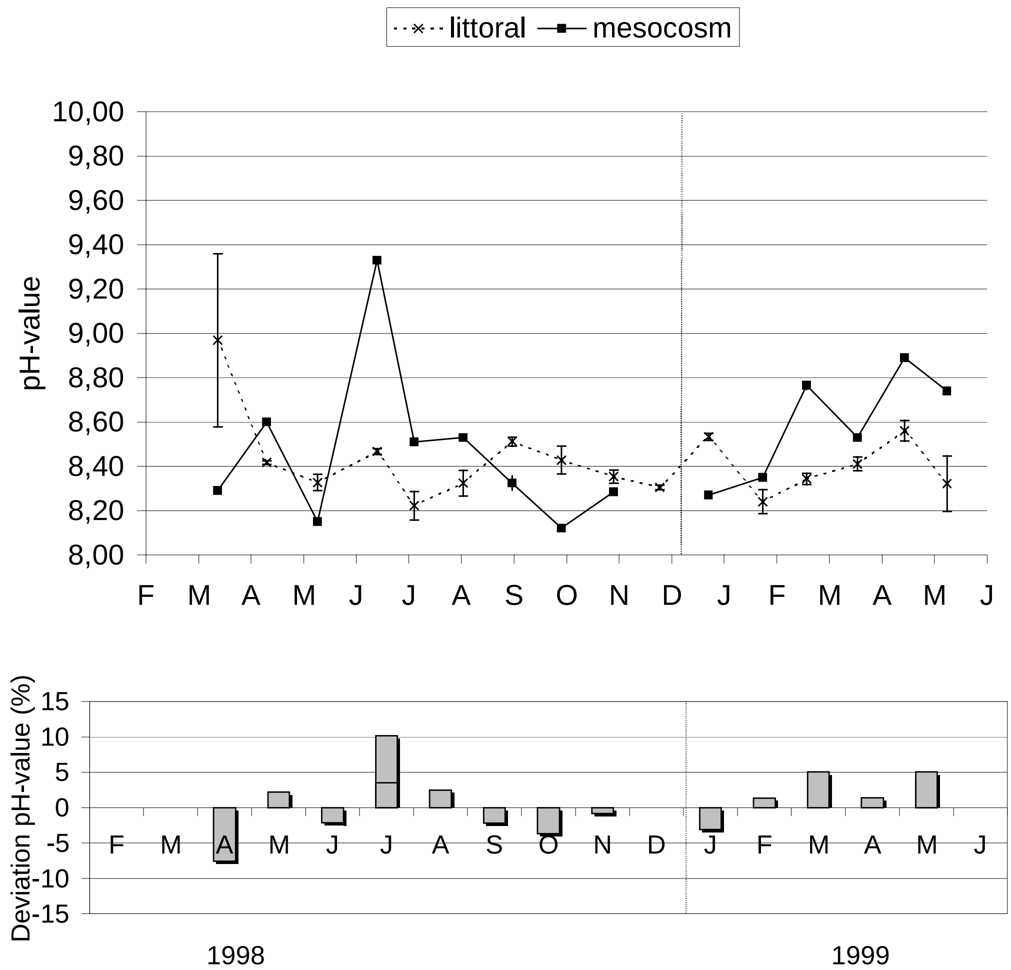


Fig. 94: pH value of the littoral habitats at lake Ammersee and the mesocosm in 1998 and 1999.

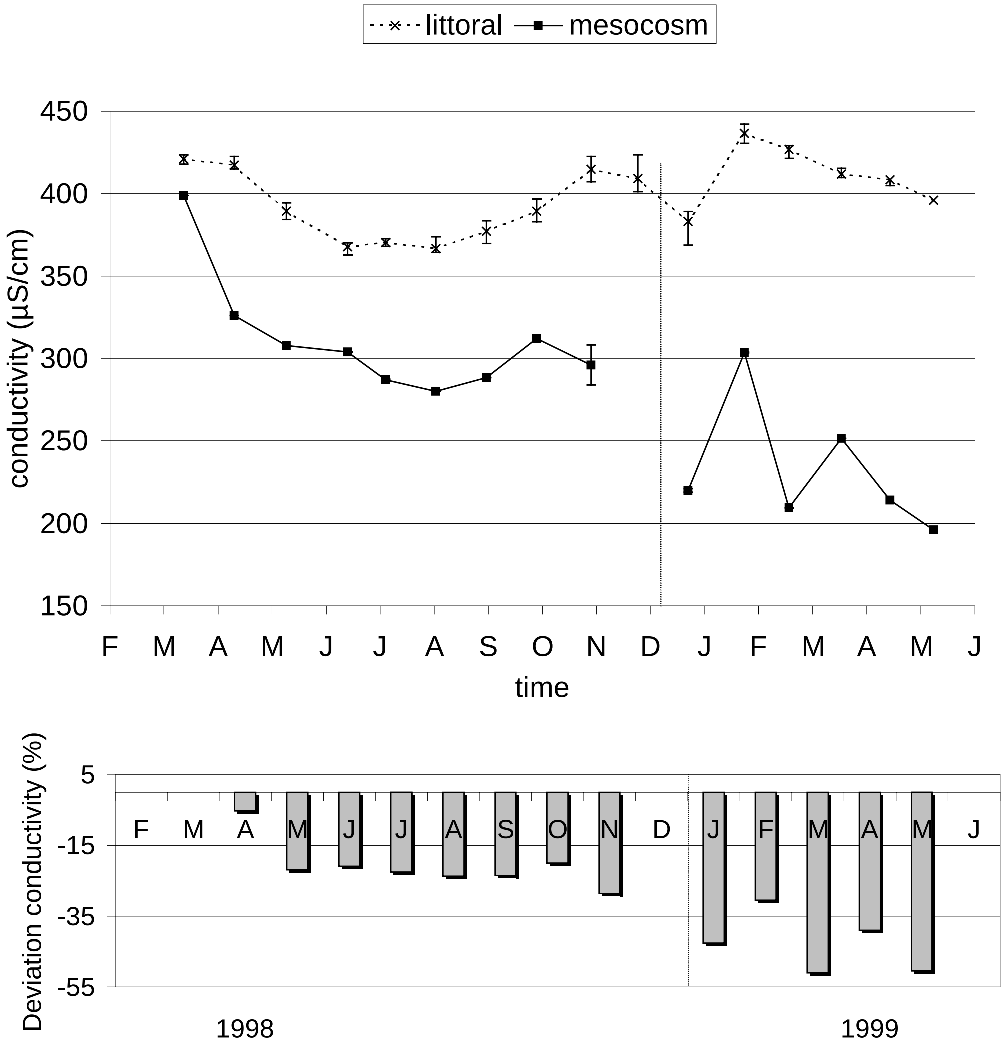


Fig. 95: Conductivity of the littoral habitats at lake Ammersee and the mesocosm in 1998 and 1999.

The conductivity of the mesocosm system was clearly below that of the littoral habitats. The difference increased through time. In 1998, the deviation in April was 5% in November it went up to 30%. In 1999, the deviation varied between 30 and 50% (Fig. 95). The enclosed mesocosm system was not enriched with ions from the environment, as much as the natural littoral.

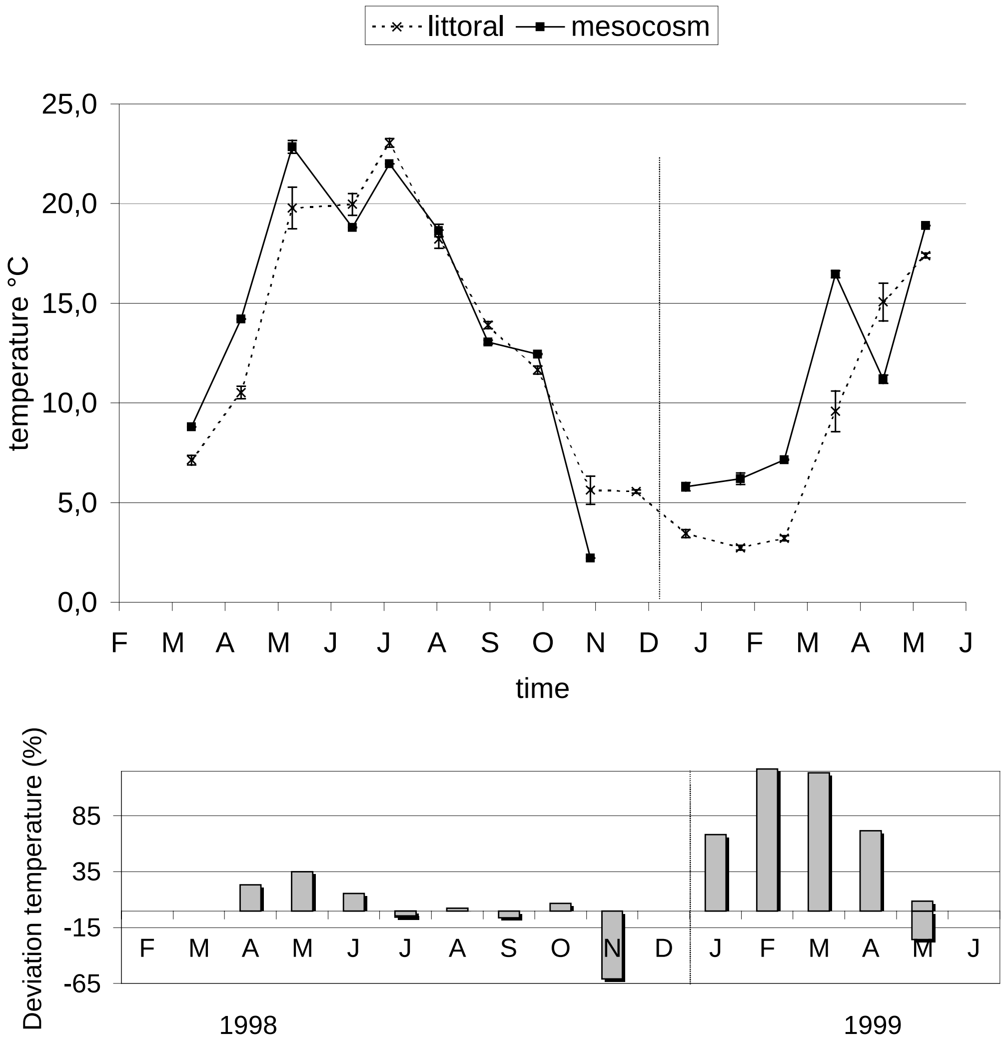


Fig. 96: Temperature of the littoral habitats at lake Ammersee and the mesocosm in 1998 and 1999.

The seasonal variation of the temperature was similar at the littoral habitats and the mesocosm system. The deviation between the two systems was higher in 1999 than the year before. The warm and sunny spring in 1999 caused the mesocosm to warm up much faster than the lake habitats (Fig. 96).

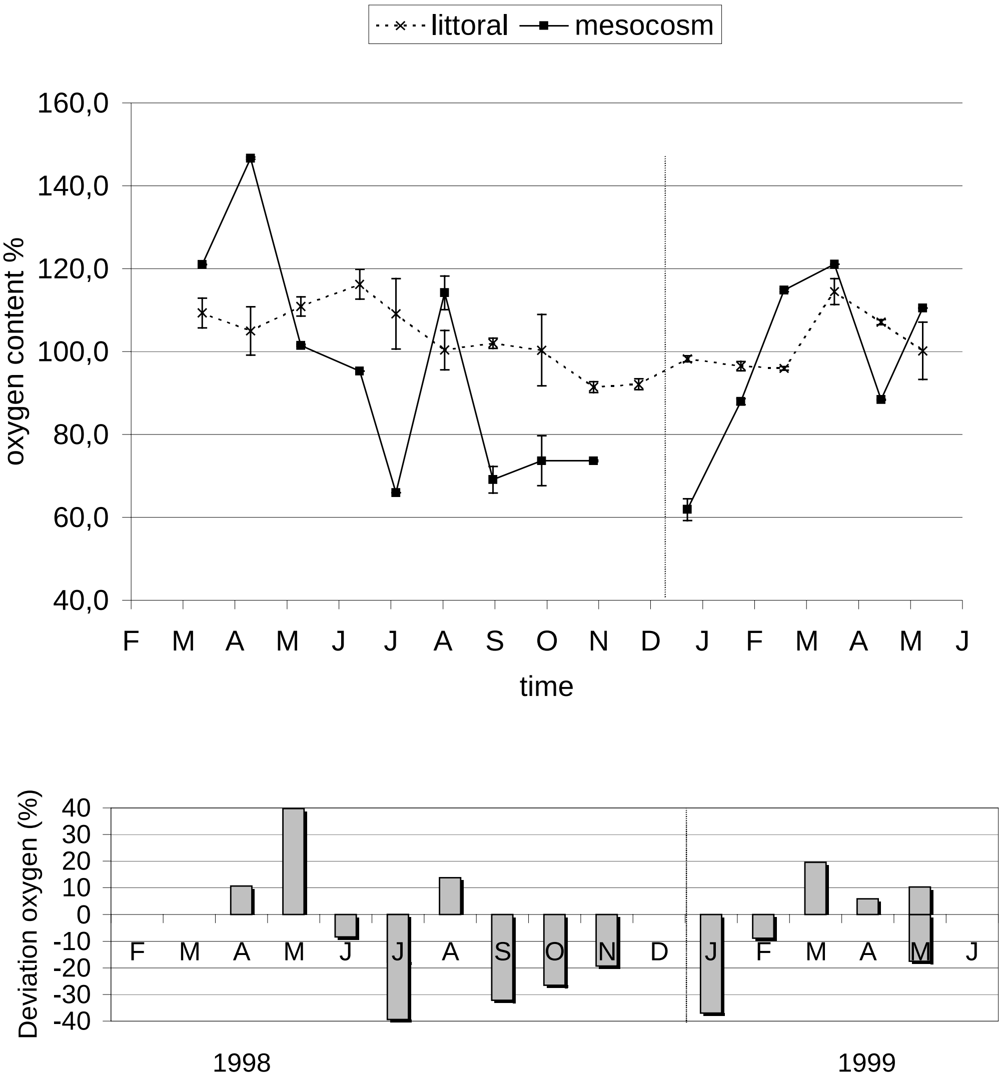


Fig. 97: Oxygen contents of the littoral habitats at lake Ammersee and the mesocosm in 1998 and 1999.

The variation of the oxygen content at the littoral habitats was much lower than in the mesocosm system. The average oxygen content at the lake habitats ranged between 90% and 120% saturation. The amplitude at the mesocosm was between 60% and 150% saturation. The deviation between the two varied from 5% to 40% (Fig. 97). The measurements taken at the littoral sites in Aidenried were later in the day (up to three hours) so the values were difficult to compare.

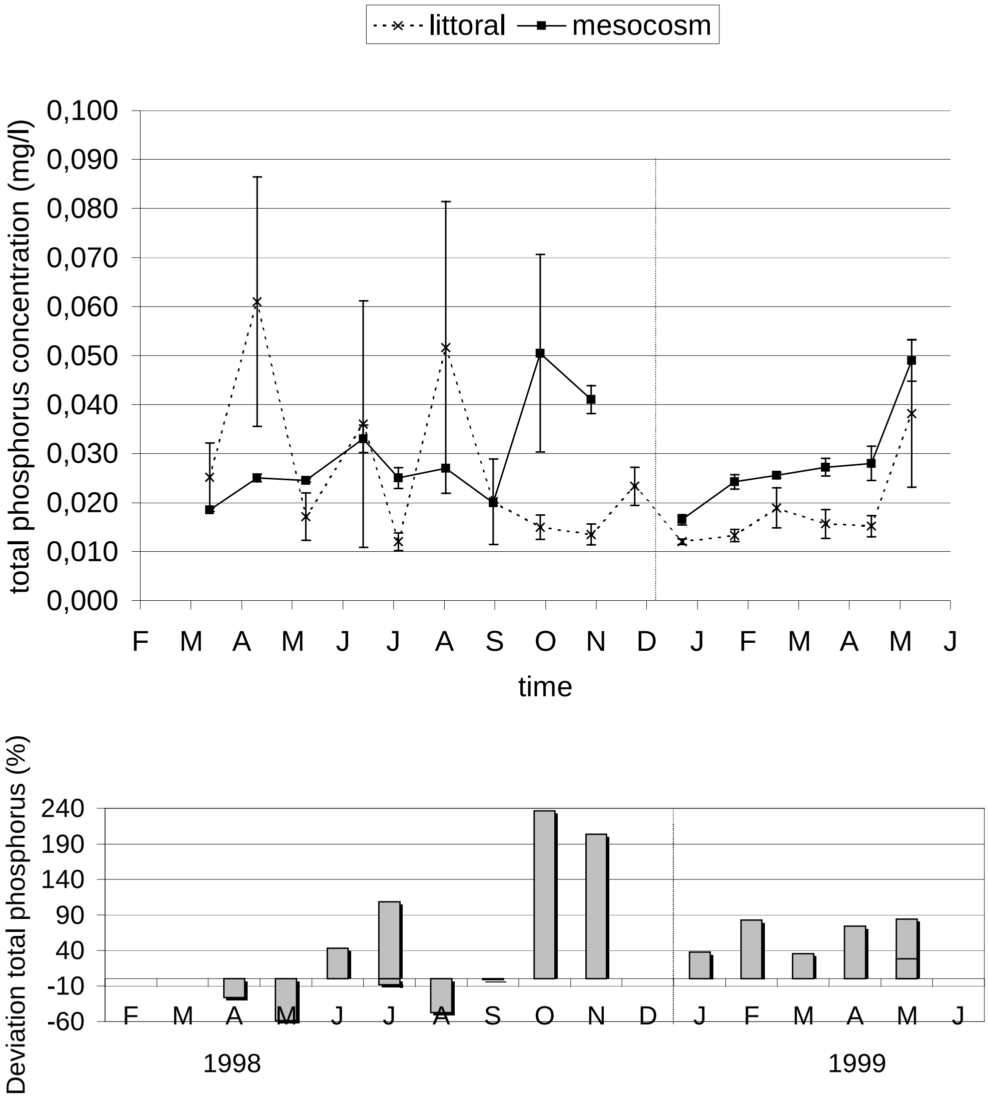


Fig. 98: **Total phosphorus contents of the littoral habitats at lake Ammersee and the mesocosm in 1998 and 1999.**

The total phosphorus concentration measured at the mesocosm was higher at most sampling dates. In 1998, the deviation between the littoral habitats and the mesocosm system ranged between 5% and 240%. The standard deviation of the littoral habitats was too high for comparison. In 1999, the mesocosm measured phosphorus concentrations from 40 to 90 % higher at all sampling dates (Fig. 98).

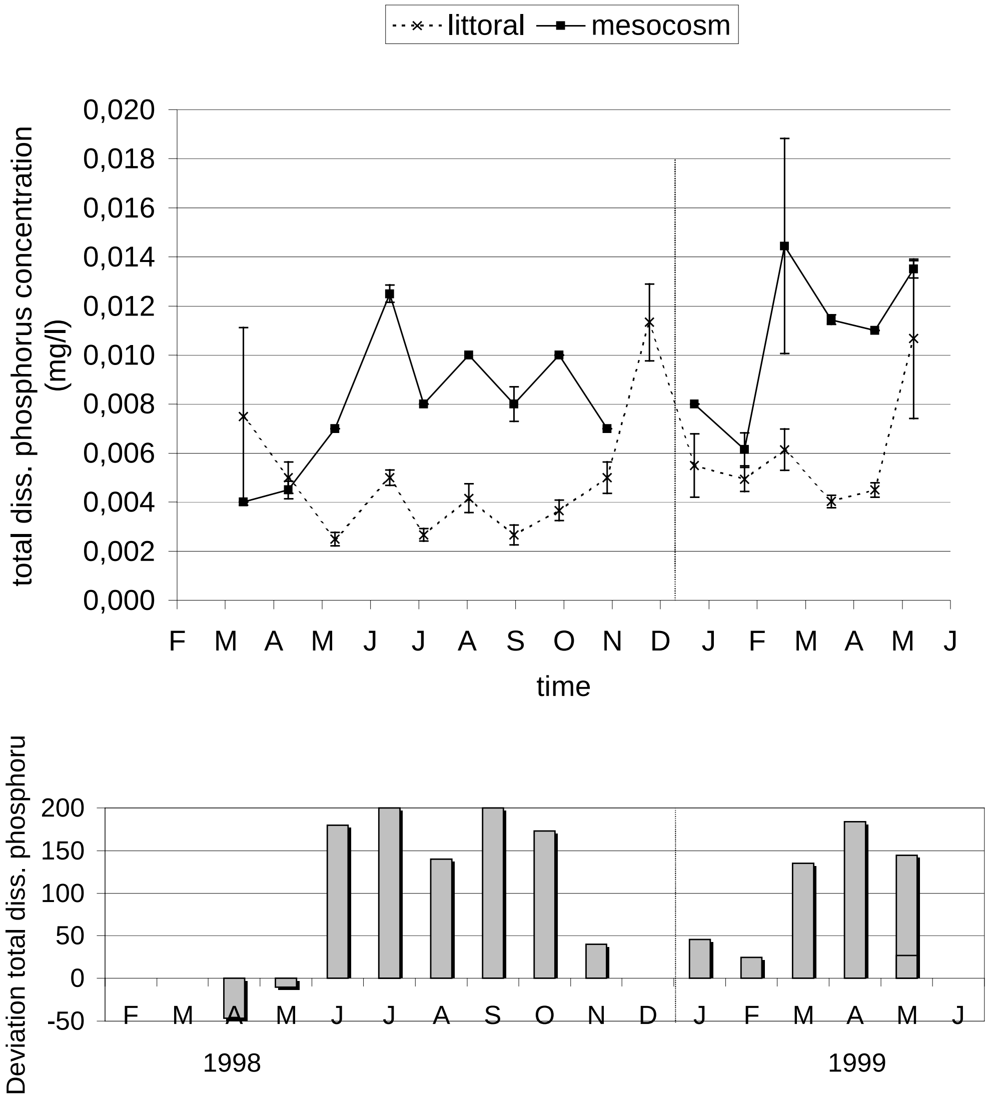


Fig. 99: **Total diss. phosphorus contents of the littoral habitats at lake Ammersee and the mesocosm in 1998 and 1999.**

The soluble phosphorus concentration measured at the mesocosm was also higher within the mesocosm system. The deviation varied between 10% and 200% (Fig. 99).

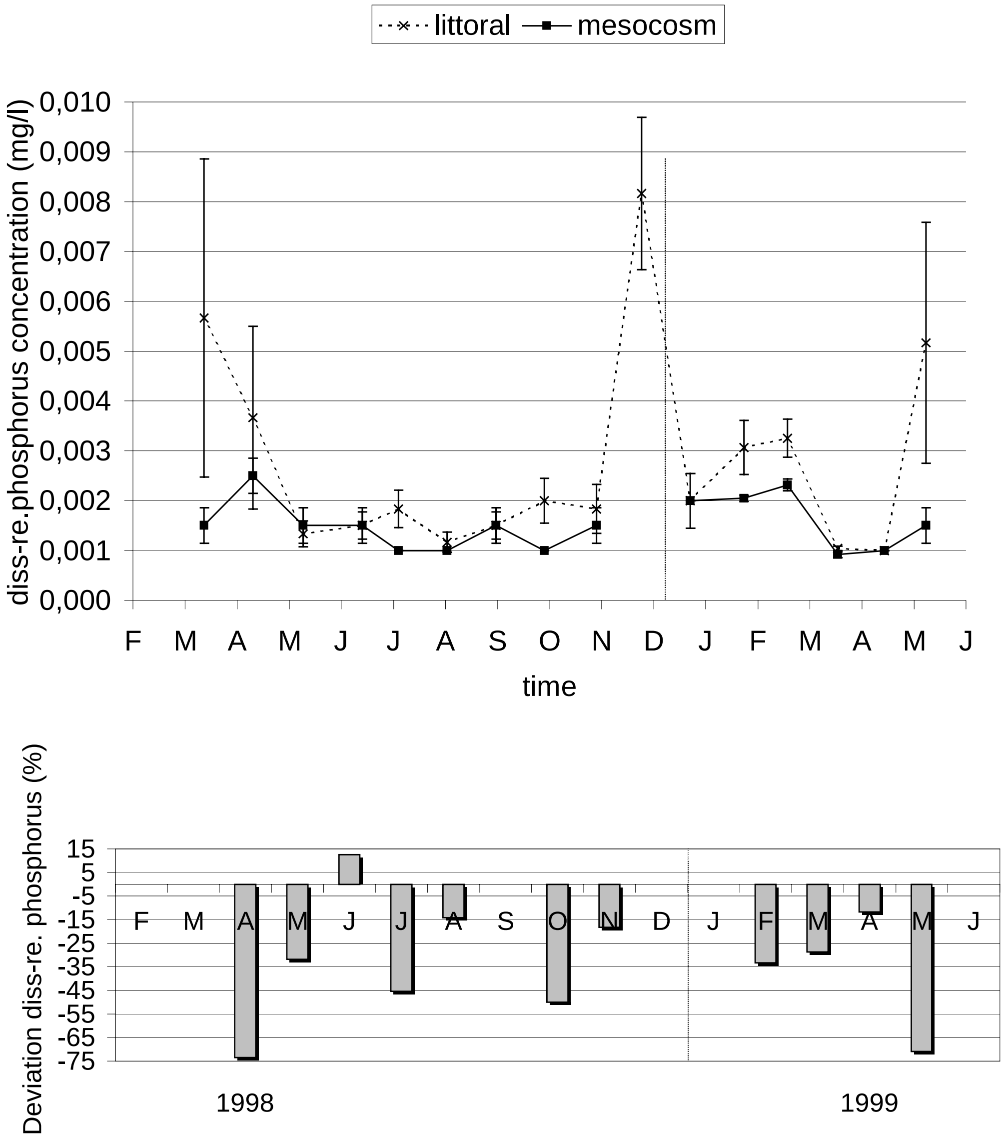


Fig. 100: **Dissolved reactive phosphorus contents of the littoral habitats at lake Ammersee and the mesocosm in 1998 and 1999.**

The soluble reactive phosphorus concentration at the littoral sites and the mesocosm did not differ much. Only at the sampling dates in March and April 1998 and March 1999 did the littoral sites measure a clearly higher concentration. At these dates the values showed a very high standard deviation (Fig. 100).

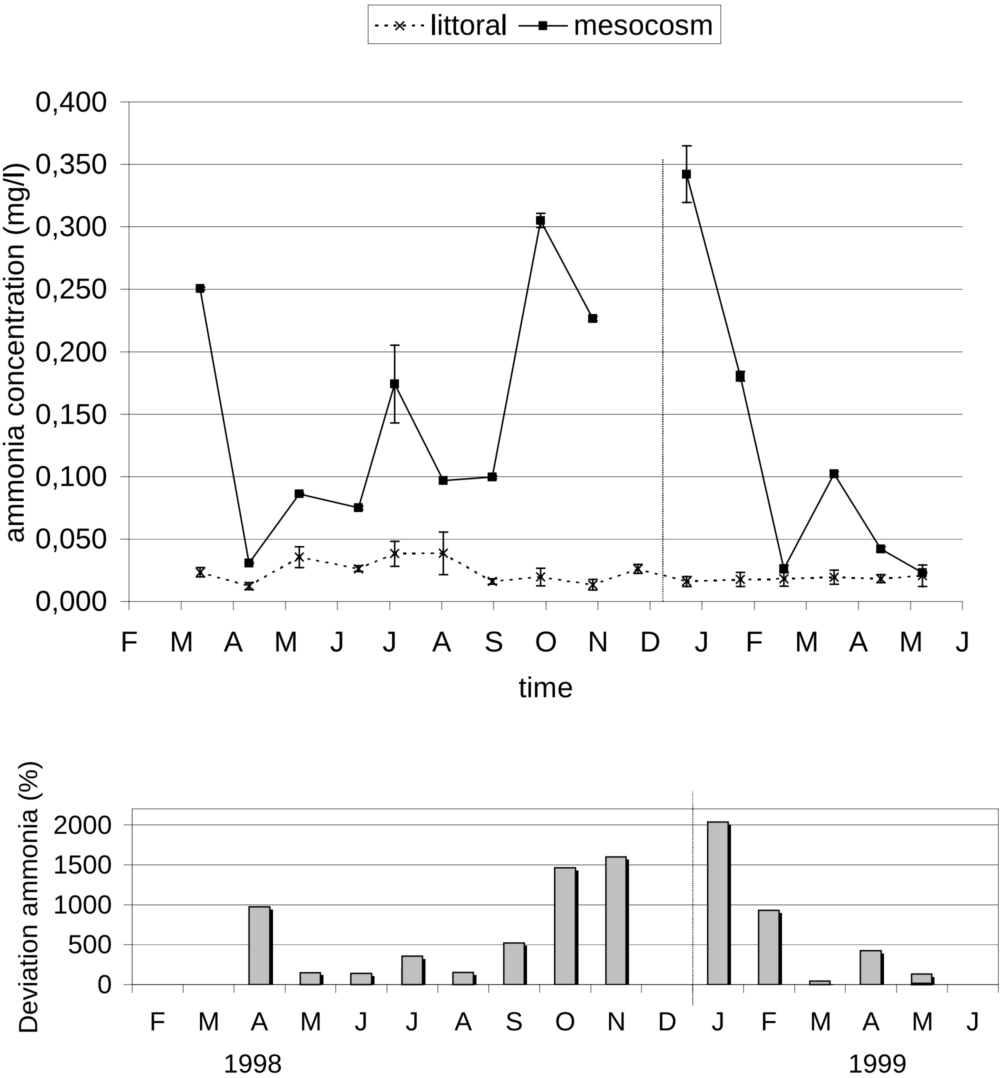


Fig. 101: Ammonia contents of the littoral habitats at lake Ammersee and the mesocosm in 1998 and 1999.

The ammonia concentration measured at the mesocosm was clearly above that measured at the littoral sites. The deviation of the ammonia content varied between 755% and 2000% (Fig. 101).

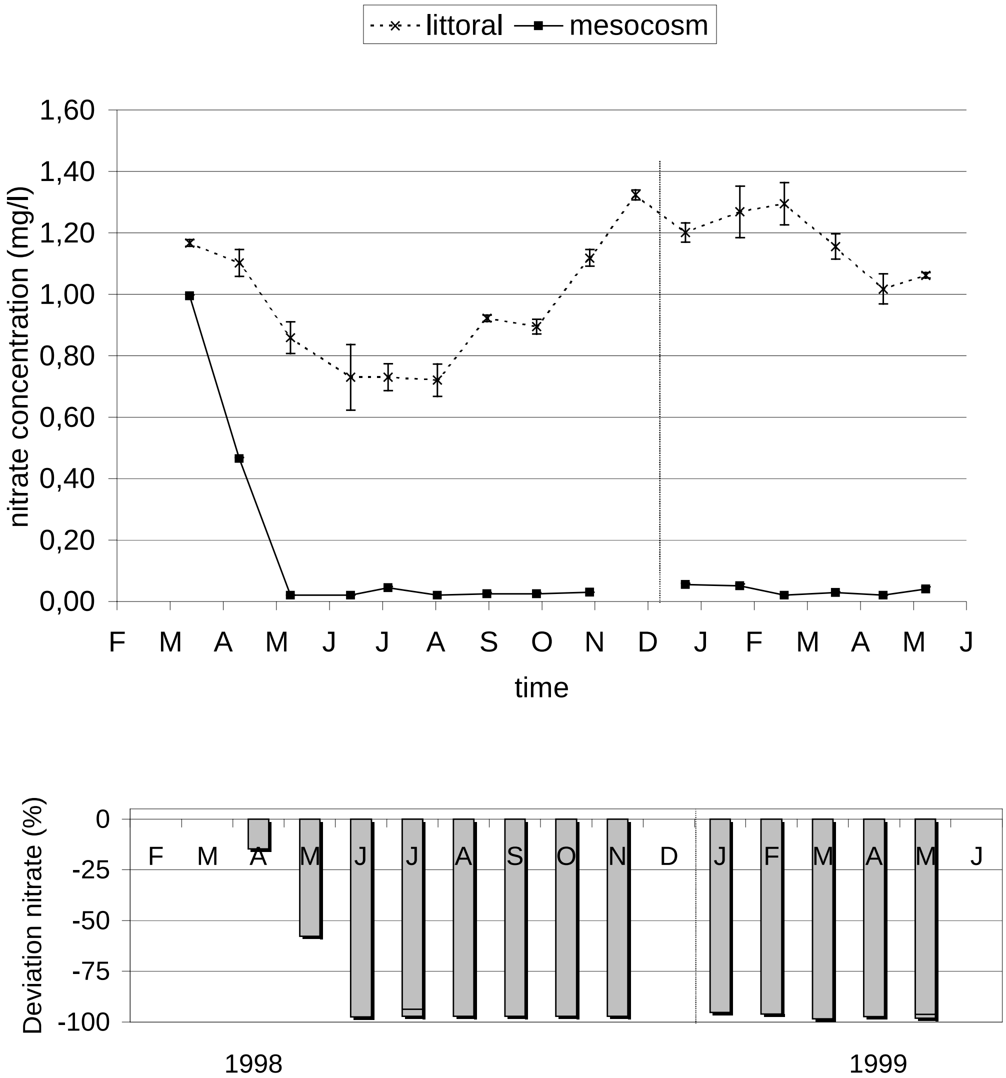


Fig. 102: **Nitrate contents of the littoral habitats at lake Ammersee and the mesocosm in 1998 and 1999.**

The nitrate concentration dropped close to zero after April 1998 and stayed at that low level for the rest of the sampling period. At the first two sampling dates the nitrate content deviation was below 60%. Then the deviation of the mesocosm was around 100% (Fig. 102).

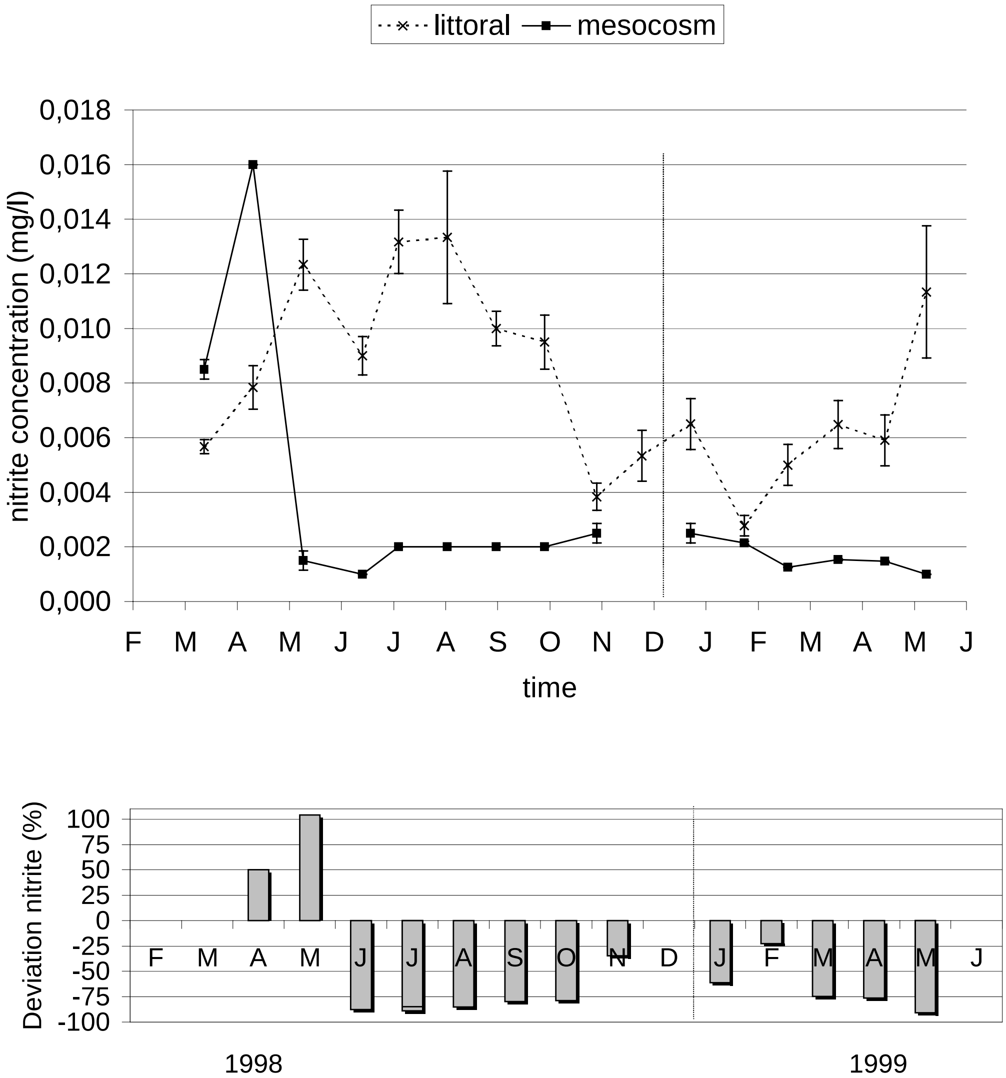


Fig. 103: Nitrite contents of the littoral habitats at lake Ammersee and the mesocosm in 1998 and 1999.

The nitrite concentration of the mesocosm in March and April 1998 was 50% and 100% above those of the littoral sites. During the rest of the investigation period the concentration was clearly below the one measured at the littoral sites (Fig. 103).

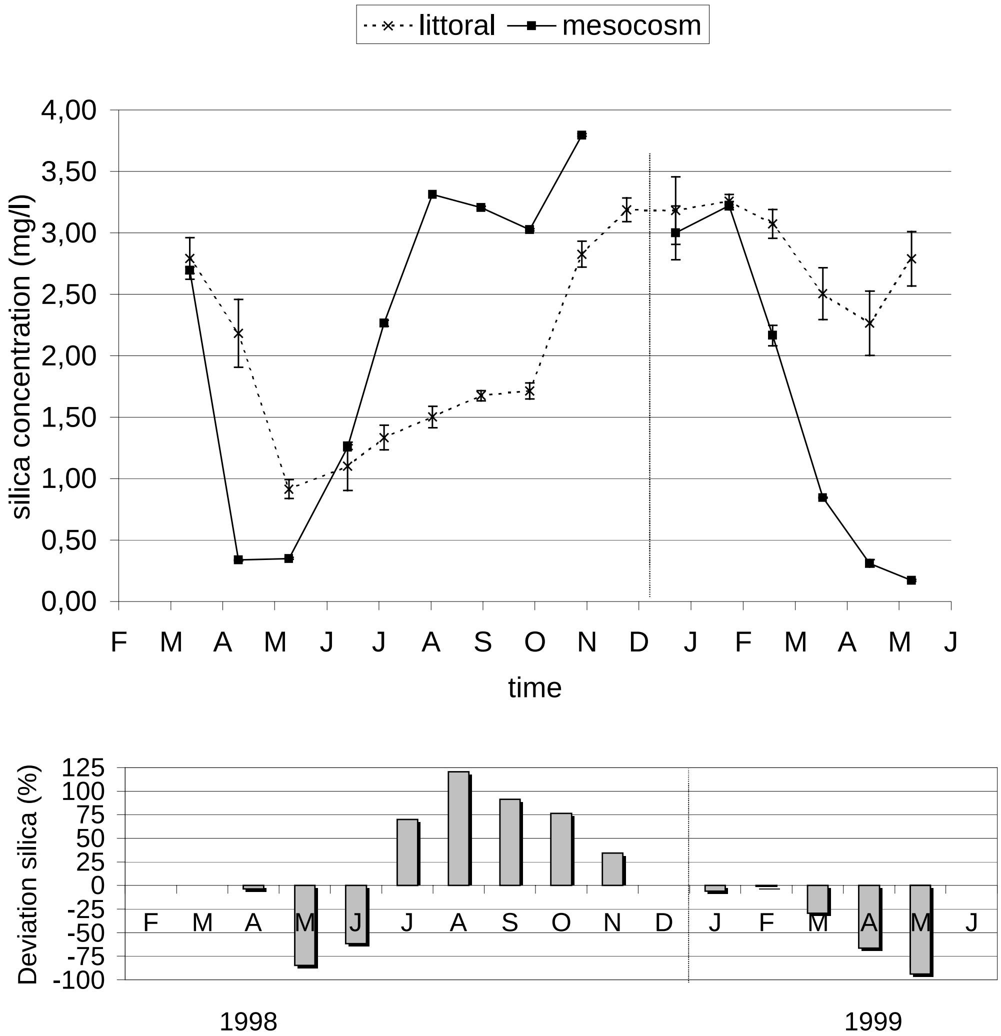


Fig. 104: Silica contents of the littoral habitats at lake Ammersee and the mesocosm in 1998 and 1999.

The silica concentration showed a similar development at the littoral sites and at the mesocosm system. The silica content in Spring, 1998, and 1999 decreased much faster at the mesocosm. The same was observed with the silica increase during the summer months of 1998. The values at the littoral sites changed at a slower rate. The deviation between the two was the greatest in March, 1998 and 1999 and August, 1998 (Fig. 104).

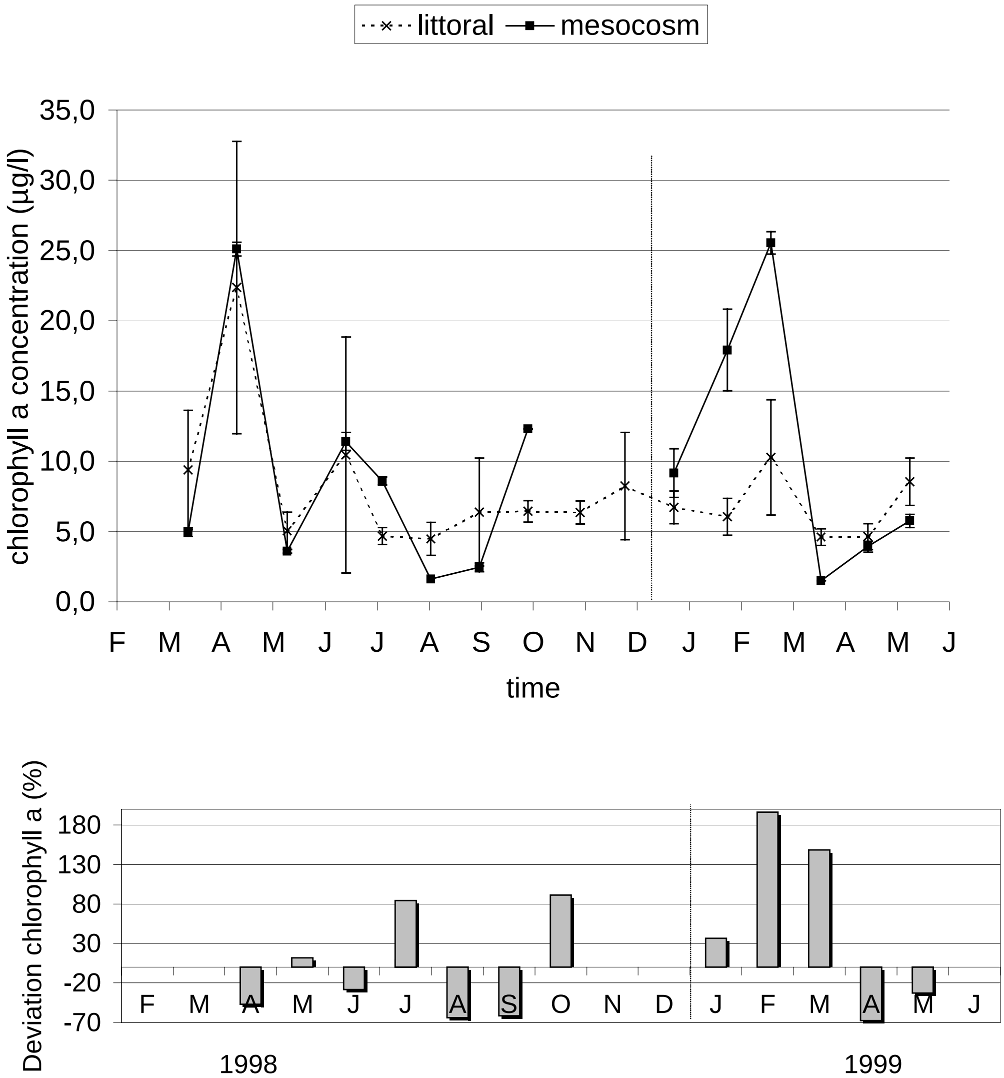


Fig. 105: Chlorophyll a concentration of the littoral habitats at lake Ammersee and the mesocosm in 1998 and 1999.

The general development of the chlorophyll a concentration of the littoral sites and the mesocosm was similar. The range of variation was more rapid at the mesocosm systems. The deviation between the two was the greatest in January and February, 1999 (Fig. 105).

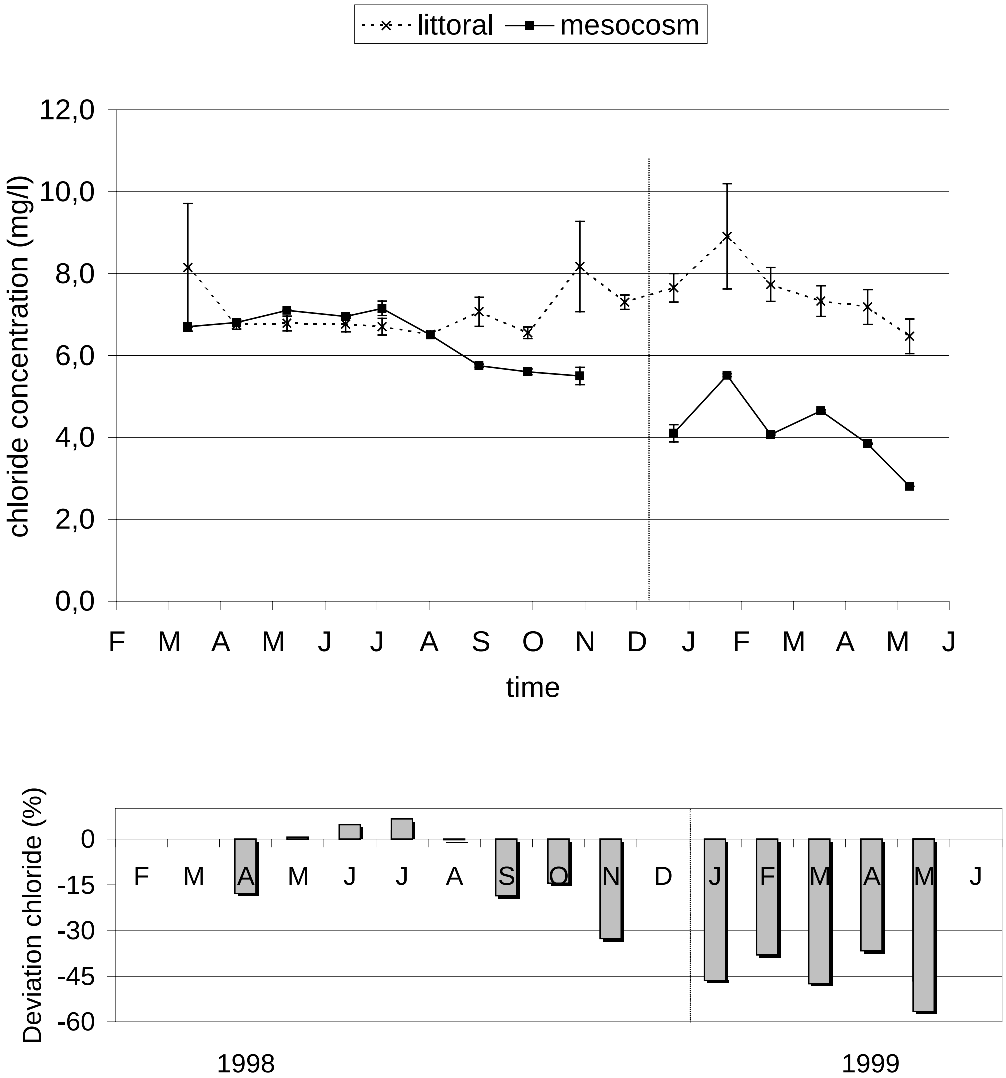


Fig. 106: Chloride concentration of the littoral habitats at lake Ammersee and the mesocosm in 1998 and 1999.

Until August 1998, the chloride concentration of the littoral sites and the mesocosm maintained similar values. After September 1998, the chloride content at the mesocosm dropped to a deviation of 60% (Fig. 106).

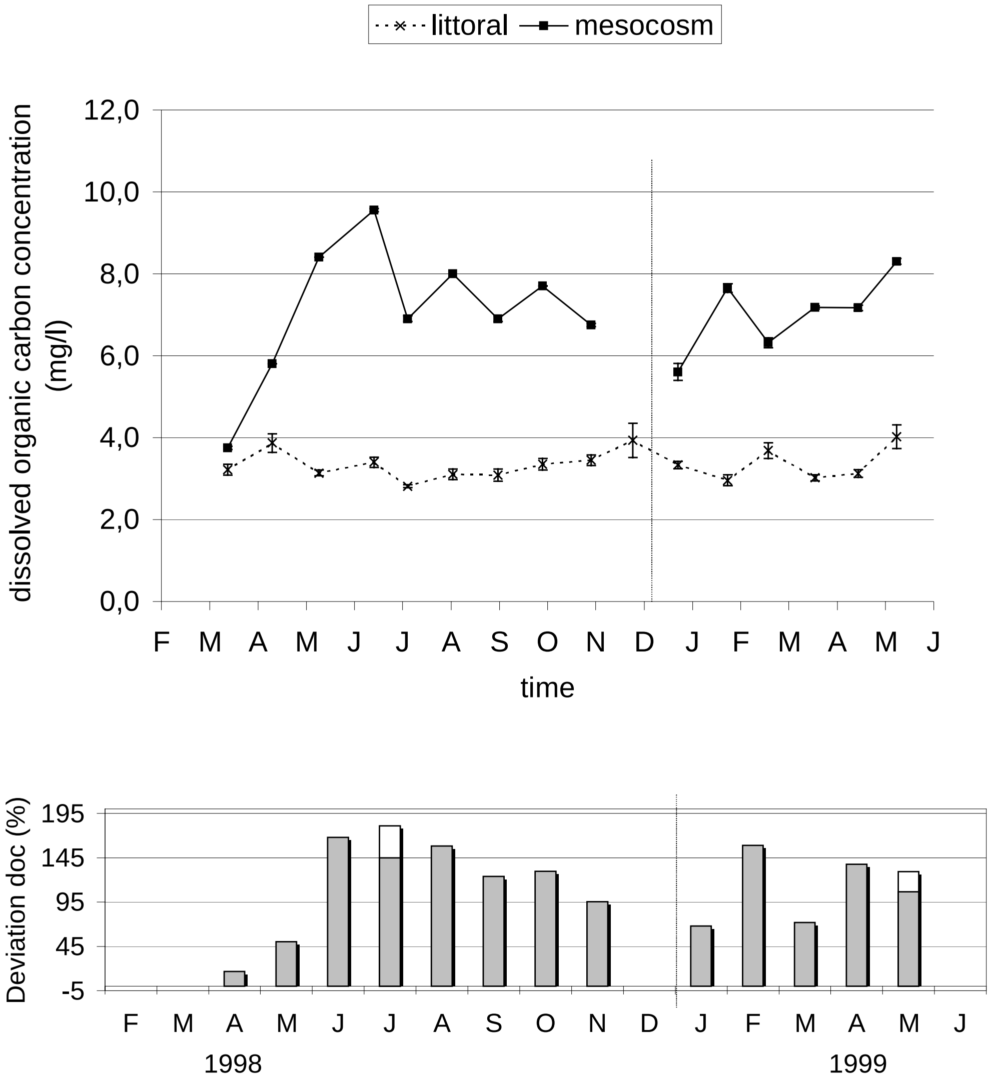
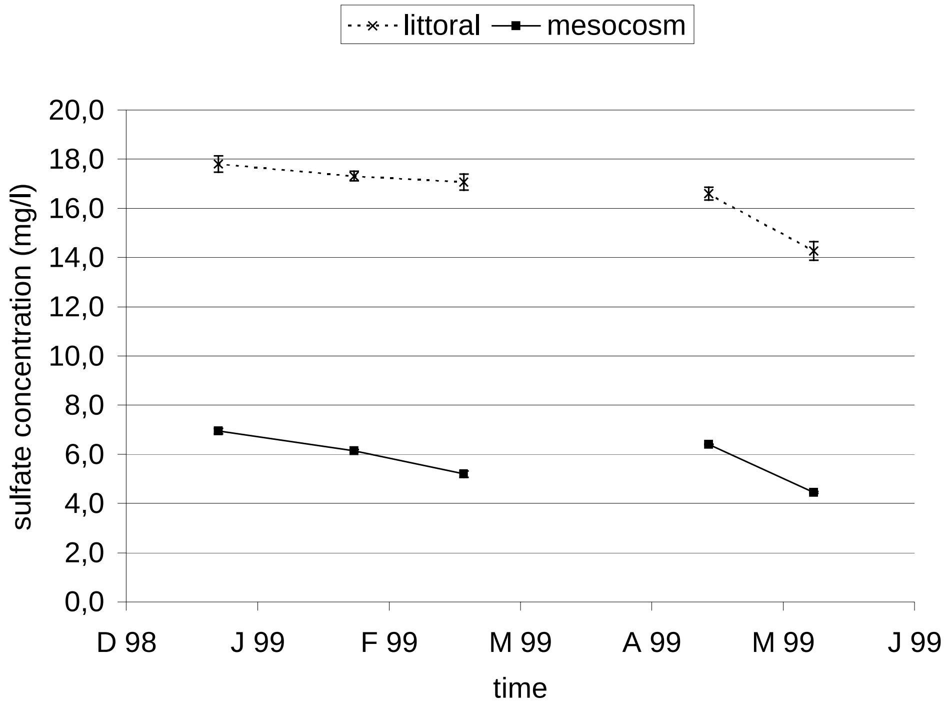


Fig. 107: Dissolved organic carbon concentration of the littoral habitats at lake Ammersee and the mesocosm in 1998 and 1999.

The DOC content of the mesocosm was clearly above the one measured at the littoral sites. The deviation was between 10% and 180% (Fig. 107).

The sulfate concentration at the mesocosm was below the one measured at the littoral sites. The deviation was between 60% and 70% (Fig. 108).

It was difficult to determine a general relationship, between the physical and chemical parameters of the littoral sites and the mesocosm. Each parameter behaved differently. The only generalization that could be made was that parameters such as conductivity and nutrients (SRP, nitrate, sulfate) measured lower values within the mesocosm (Table 9).



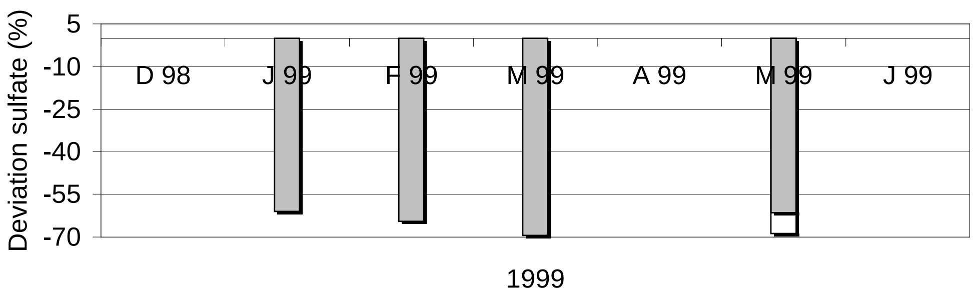


Fig. 108: Sulfate concentration of the littoral habitats at lake Ammersee and the mesocosm in 1998 and 1999.

Table 9: Average values of the littoral sites and the mesocosm.

Average values	Schondorf	Aidenried	Mesocosm
pH	8,40	8,32	8,51
conductivity (µg/cm)	383	396	280
temperature °C	13,1	13,8	13,2
oxygen mg/l	10,6	9,9	9,7
oxygen %	106,3	99,6	96,4
P(unfiltered) (mg/l)	0,0159	0,0395	0,0291
P(filtered) (mg/l)	0,0049	0,0062	0,0090
diss. reactive P (mg/l)	0,0022	0,0030	0,0015
NH_4 (mg/l)	0,0167	0,0416	0,1387
NO_3 (mg/l)	1,0143	0,9340	0,1276
NO_2 (mg/l)	0,0083	0,0107	0,0032
SiO_2 mg/l	2,08	2,10	1,95
Chlorophyll a (µg/l)	7,47	11,06	9,85
Chloride (mg/l)	6,99	7,49	5,50
DOC (mg/l)	3,32	3,56	7,03
SO_4 (mg/l)	15,53	15,19	5,83

3.2.1.2 Macroinvertebrate community

An average number of 53 species were found at the littoral sites. Within the mesocosm system (Pond M without enclosures) 36% fewer species were found. The total number of specimens varied at the littoral sites between 1900 and 8100 animals. At the mesocosm a total of 9000 specimens were caught in the same period. This difference was mostly due to *Chaoborus crystallinus*. The Diptera developed very high numbers. The lake microhabitats with the highest species - potentials are the reed and floating leaf macrophytes communities. *Phragmites australis* inhabits the largest number of species. The combination of the floating and the big submerse leaves of *Nuphar lutea* offer many niches for macroinvertebrates.

Table 10: Average number of species, diversity and evenness

average 98/99	littoral	standard deviation	mesocosm	standard deviation	deviation
number of species	53	13	34	8	**-36%**
diversity	2,41	0,22	2,01	0,14	**-16,7%**
evenness	0,59	0,06	0,57	0,02	**-2,4%**

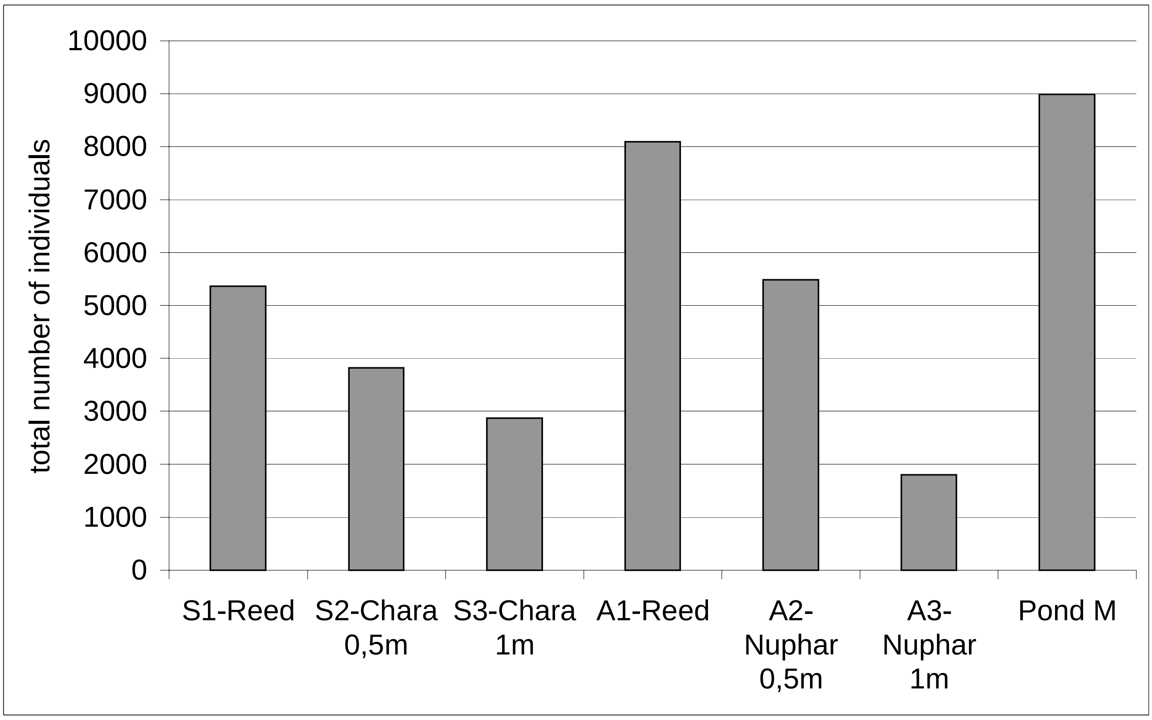


Fig. 109: Total number of individuals found at the littoral habitats at lake Ammersee and the mesocosm in 1998 and 1999.

In order to compare the macroinvertebrate community at the sites, the species preference towards habitat, movement, food, current and region was compared. The fractions of the habitat coordination of the species were similar at the sites. The “phytal” describes a vegetated area. Algae, aquatic macrophytes as well as living plant parts from the shoreline make up this habitat. 40% of the species from Pond M preferred this kind of habitat. The “phytal” species at the lake sites varied between 20% and 40%. Another major fraction at the mesocosm is the “pelal” type. This habitat is associated with soft sediments with a grain size < 0,063 mm. This habitat was preferred by 23% of the species at Pond M. At the other sites this habitat fraction made up to 18%. In the mesocosm, 12% of the species preferred organic material such as dead tree parts and detritus. The species preferring organic material at the other sites varied between eight percent and 20 %. The “lithal” is characterized with pebbles and rocks with the grain size bigger than two centimeters. Species favoring this habitat were represented by eight percent of the mesocosm. At the lake habitats this percentage was much larger, it ranged between 20% and 30%. The “psammal” is characterized by sand with the grain size from 0,063 to 2 mm. At pond M, six percent of the species can be classified as preferring such a habitat. At the other habitat it ranged between two percent and eight percent. The “akal” represents pebbles with the grain size from 0,2 to 2 cm. Only three percent of the species caught in the mesocosm were classified as favoring the “akal” substrate. At the other habitats up to six percent of the species preferred such a substrate. Species not classified in the mentioned groups, such as parasites, were only represented at the mesocosm with one percent. At the lake habitats, two percent to 20% of the species preferred substrates, other than those discussed (Fig. 110).

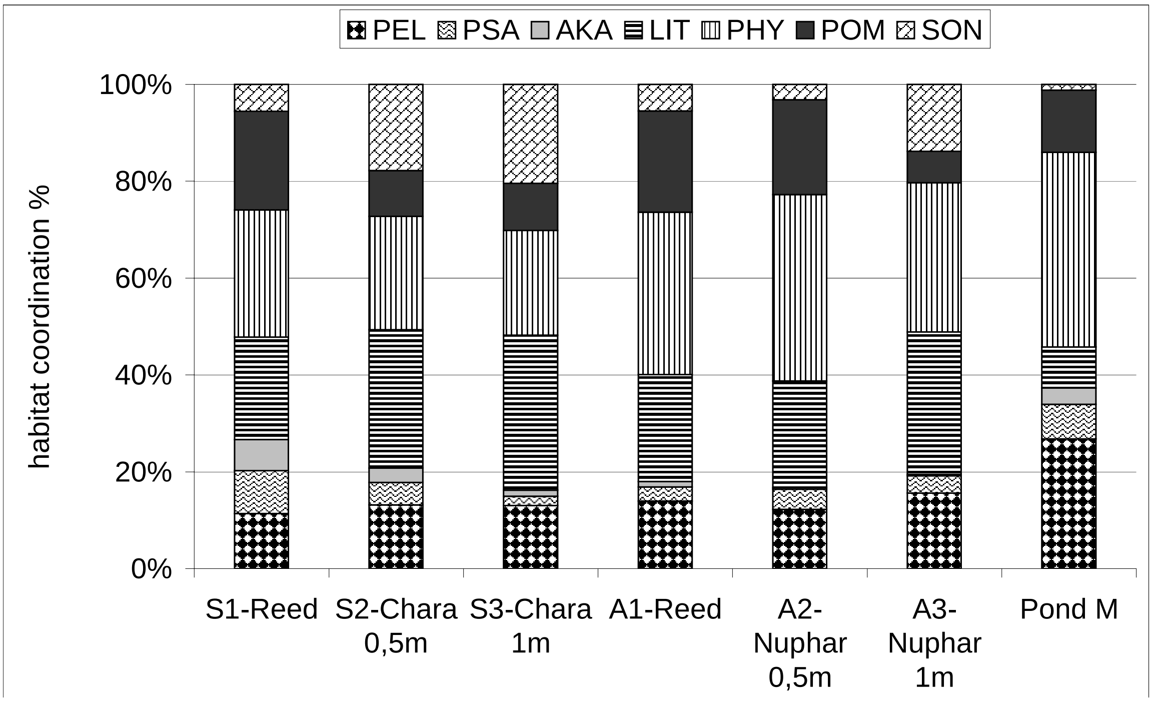


Fig. 110: Habitat coordination at the littoral habitats at lake Ammersee and the mesocosm in 1998 and 1999. (Abiotic=PEL-Pelal, PSA-Psammal, AKA-Akal, LIT-Lithal, Biotic=PHY-Phytal, POM-particles organic material, SON-others)

The habitats were also classified according to the species movement. At the mesocosm, all species were classified either as crawling or swimming. At the habitats in Aidenried, these were also the major percentages. In addition the attached living organisms were represented at the habitats in Aidenried between two percent and three percent. At the habitats in Schondorf it varied between twelve percent and 20%. The floating species were only found at the three habitats in Schondorf at rates of one percent and two percent. Species with another moving mechanism were only found to be one percent at the sites in Aidenried and two percent to five percent in Schondorf. Digging species were only found to be one percent in all the habitats (Fig. 111).

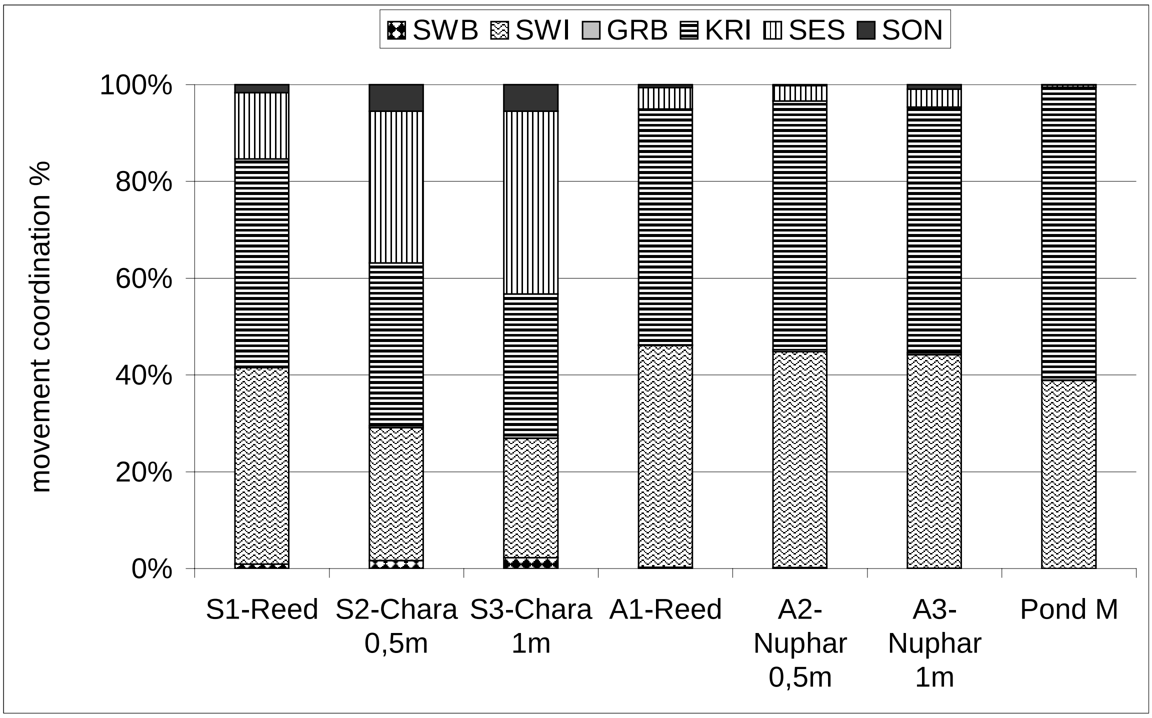


Fig. 111: Movement coordination at the littoral habitats at lake Ammersee and the mesocosm in 1998 and 1999. (SWB-floating, SWI-swimming, GRB-digging, KRI-crawling, SES-attached, SON-others)

In order to characterize the community, the food coordination is an important functional parameter. The species found at the mesocosm were divided into two main fractions: the shredders (40%), and the deposit collectors (30%). The shredders depend on decaying macrophytes, whereas the collectors need soft sediments. At the habitats in Aidenried, the same two feeding types showed a high contribution. The group of shredders ranged between 40% and 48% and the deposit collectors varied at around 25%. At the reed habitat in Schondorf S1, the relationship between shredders and deposit collectors was similar. At the two other habitats S2 and S3 the numbers of these species were much lower. The group of predators made up 40% at these habitats, whereas, at the other habitats, the contribution was mostly below 20%. Another important group found at the charophyte sites S2 and S3 were the parasites. They made up 15%, whereas at the other habitats, the parasites had only a minor part (below 3%).

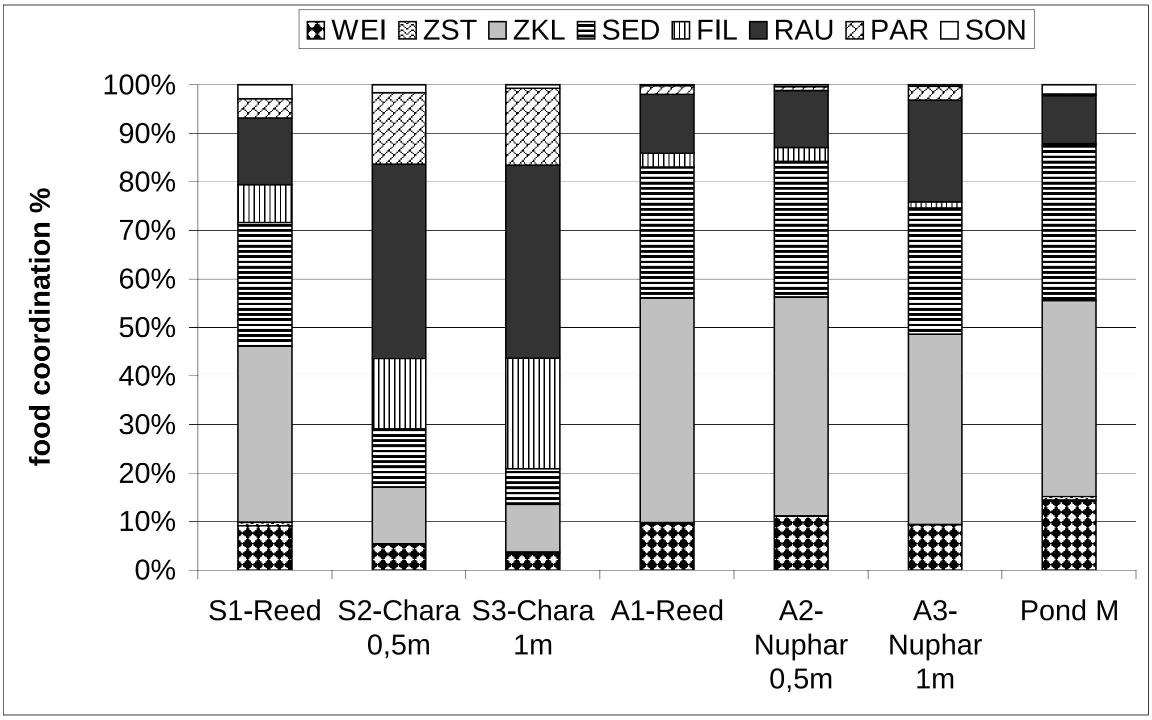


Fig. 112: **Food coordination at the littoral habitats at lake Ammersee and the mesocosm in 1998 and 1999 (WEI-scrapers, ZST-piercers, ZKL-shredders, SED-deposit collectors, FIL-filter feeders, RAU-predators, PAR-parasites, SON-others).**

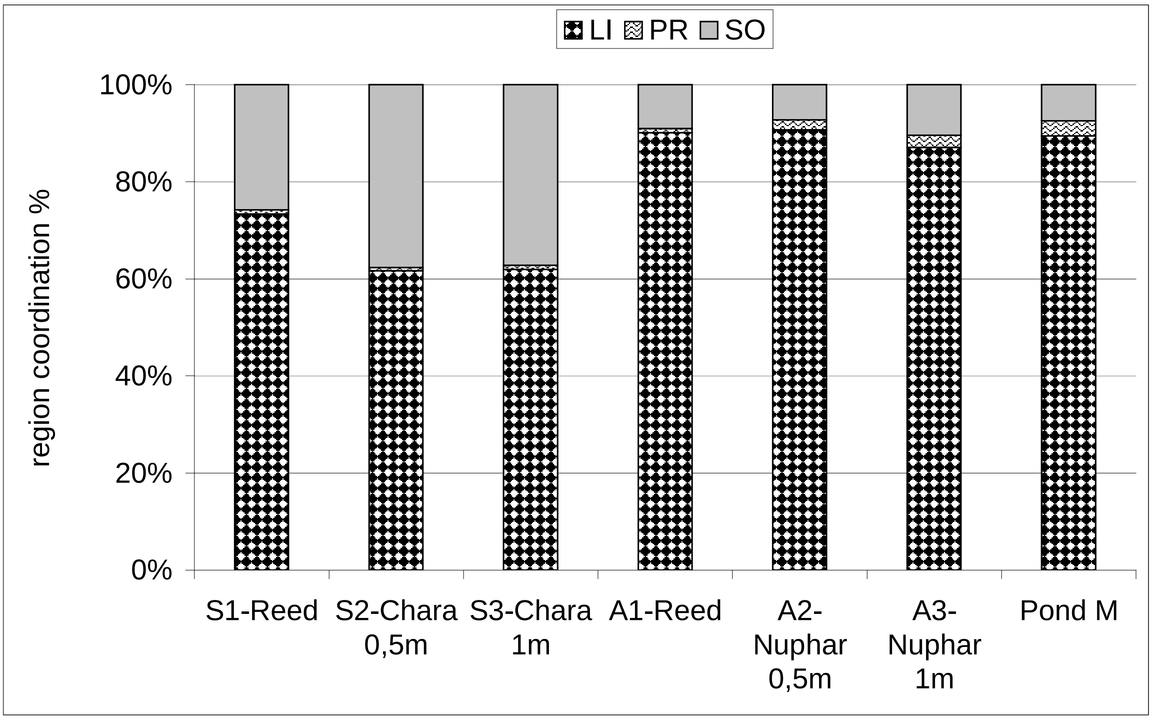


Fig. 113: **Regional coordination at the littoral habitats at lake Ammersee and the mesocosm in 1998 and 1999 (LI-littoral, PR-profundal, SO-others).**

The scrapers had a distribution of 13% at the mesocosm. At all the other habitats, the scraping organisms made up 10% and below. The filter feeders showed the maximum of eight percent at the reed habitat at Schondorf. At the other habitats the distribution was below two percent. Another organism group only found in small numbers were the piercers. They represented less than one percent at all habitats (Fig. 112).

Littoral species made up the major part of all habitats. The distribution at the mesocosm and at the sites in Aidenried made up nearly 90%. At the sites in Schondorf the contribution varied between 61% and 72%. Three percent of the species found at the mesocosm were profundal species. This group represented less than two percent of all the other habitats. Species not grouped in either lake zone, made up between 25% and 40% at the sites in Schondorf. The mesocosm site and the sites in Aidenried counted only about ten percent of these species (Fig. 113).

3.2.2 Enclosure effect

An average of 53 species were found at the lake sites (Fig. 114). Within the lake enclosures, the number of species was reduced to 37%. In the artificial mesocosm, 62% of the littoral fauna was established. The lowest species numbers were found in the enclosures within the mesocosm (only 22% of the lake littoral fauna). The diversity value (Shannon) at the lake site was significantly higher than in the enclosed systems. The evenness values did not change significantly at any of the sample sites (Fig. 115).

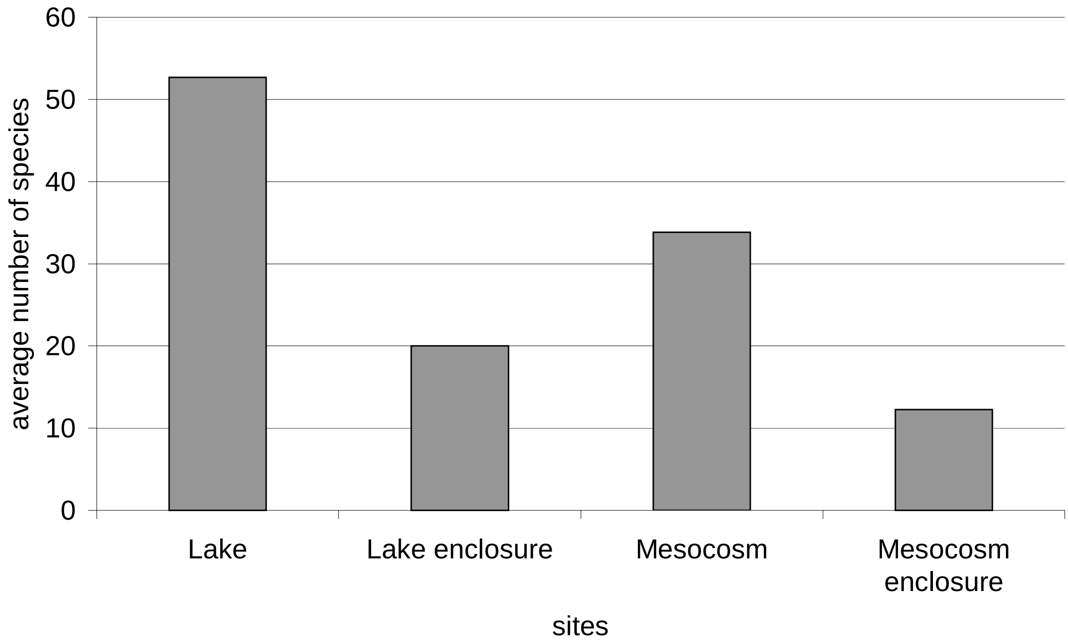


Fig. 114: Average number of species in the Lake habitats, lake enclosure, mesocosm and mesocosm enclosures.

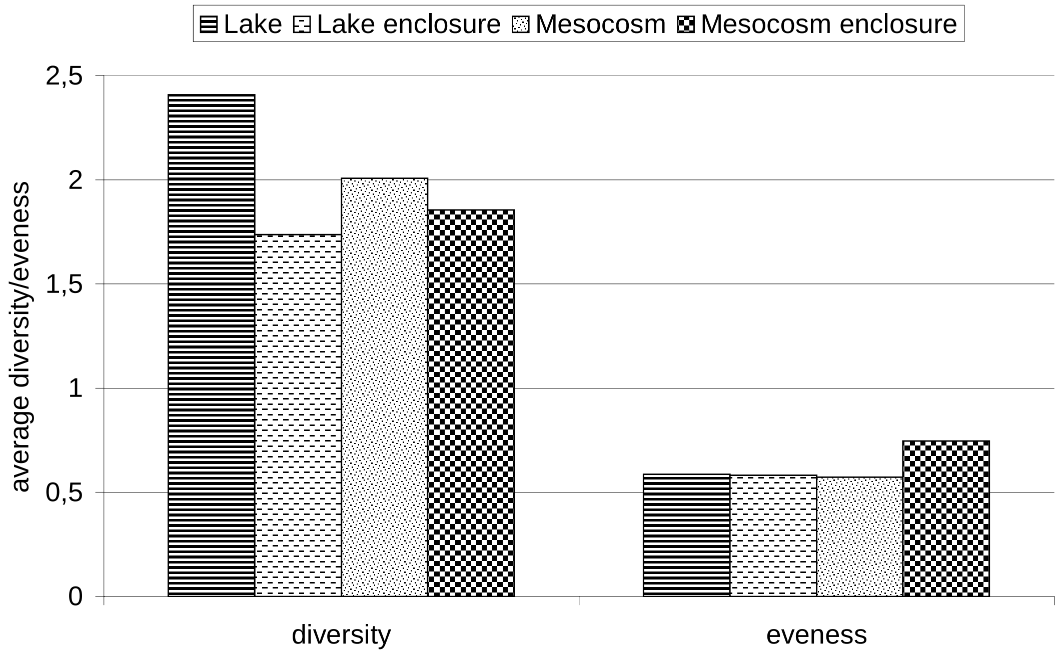


Fig. 115: Average number diversity and evenness in the lake habitats, lake enclosure, mesocosm and mesocosm enclosures.

The enclosure effect had a clear influence on the macroinvertebrate community. This is important to keep in mind in judging mesocosm studies of similar sizes. The treatment effect of the tested substance might be mingled with the enclosure effect. The communities of such small sized systems will never have the same potentials as a natural ecosystem. The volume is an important parameter for the establishment of a community.

3.2.3 Test systems Pond M and Pond S and the cypermethrin study

After documenting the development of the mesocosm Pond M in 1998 and the beginning of 1999 it was separated into 18 enclosures. A double treatment with cypermethrin (100 ng/l and 1000 ng/l) was carried out simultaneously with an experiment in Pond S.

3.2.3.1 Macrophytes

The enclosures of the mesocosm Pond M contained macrophytes ranging from 16292 cm^2 to 45585 cm^2 total plant surface. The macrophytes play a important part in field tests (Blake 1994, Brock *et al.* 1992). The plant composition was similar in the enclosures. The main species were *Potamogeton natans* and *Myriophyllum spicatum*. Together they made up at least 90% of the total plant surface in each enclosure.

Other species such as *Potamogeton pusillus*, *Potamogeton perfoliatus*, *Chara intermedia*, *Chara fragilis*, *Elodea canadensis* and *Nuphar lutea* took less than 25% of the total plant surface (Fig. 116, Fig. 117).

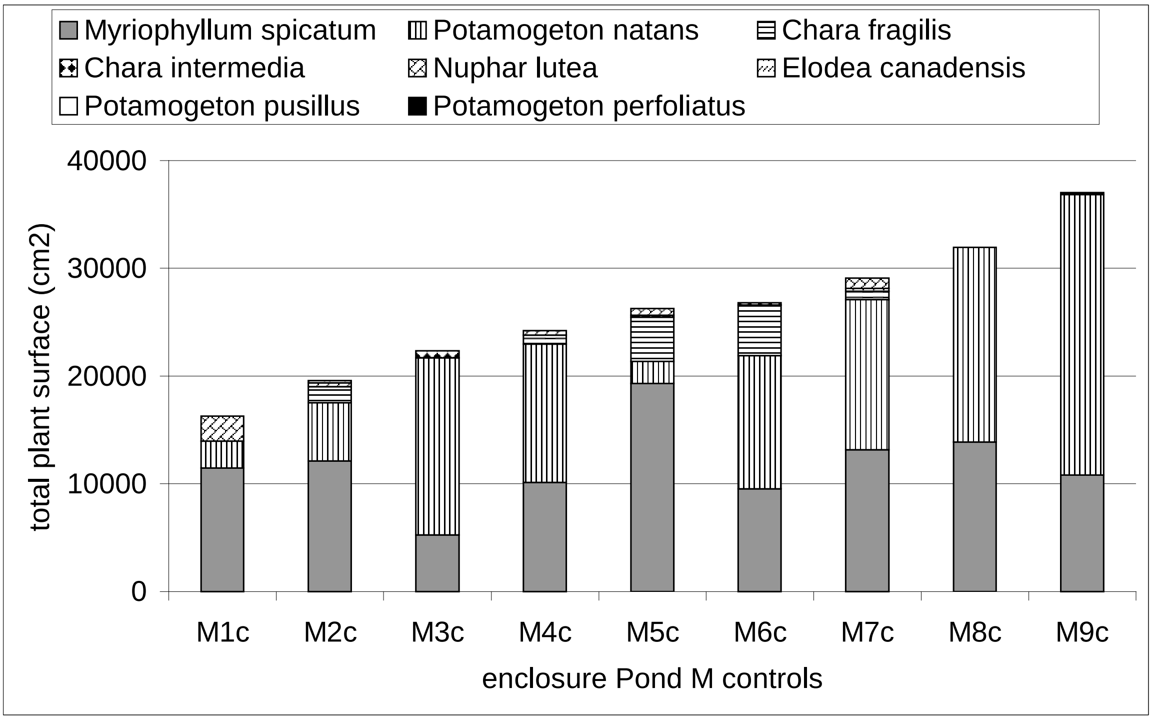


Fig. 116: Total plant surface of the untreated enclosures in Pond M.

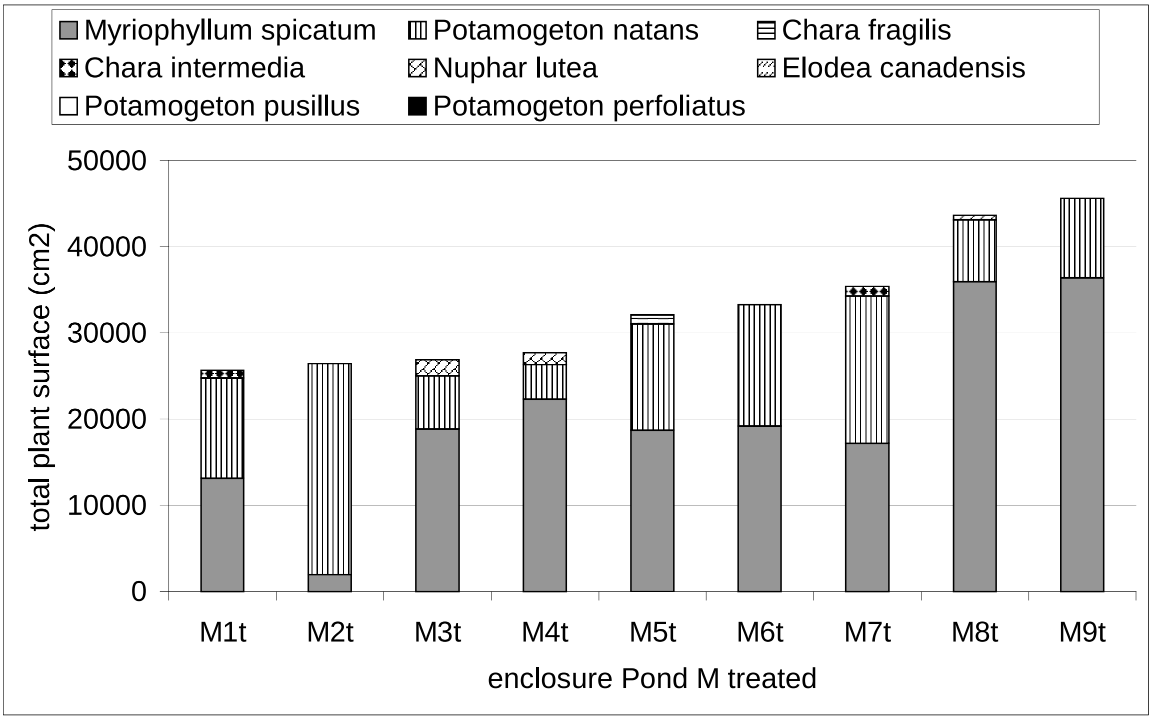


Fig. 117: Total plant surface of the treated enclosures in Pond M.

The plant surface of the macrophytes at the mesocosm Pond S ranged between 3381 cm^2 and 40554 cm^2. The two plant species *Potamogeton natans* and *Myriophyllum spicatum* made up 75% of the total plant surface within the enclosures. The only exception was enclosure S3c where *Chara aspera* exploded and took up 60% the total plant surface. The following species were also found in the enclosures: *Potamogeton perfoliatus*, *Potamogeton pectinatus*, *Potamogeton lucens*, *Chara intermedia*, *Chara fragilis* and *Elodea canadensis* (Fig. 118, Fig. 119).

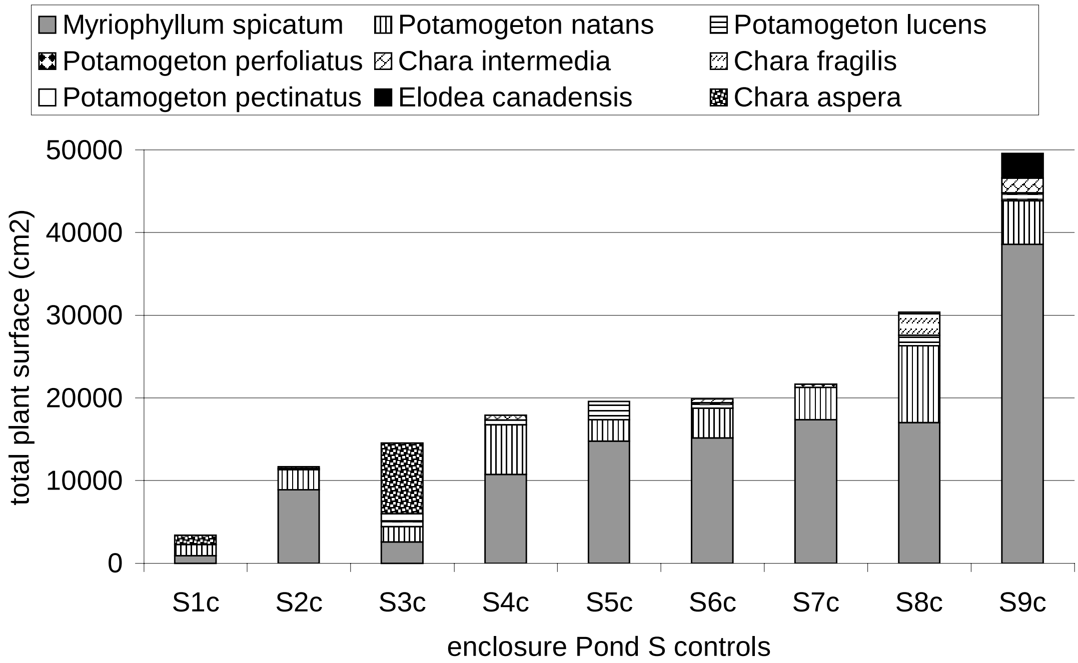


Fig. 118: Total plant surface of the untreated enclosures in Pond S.

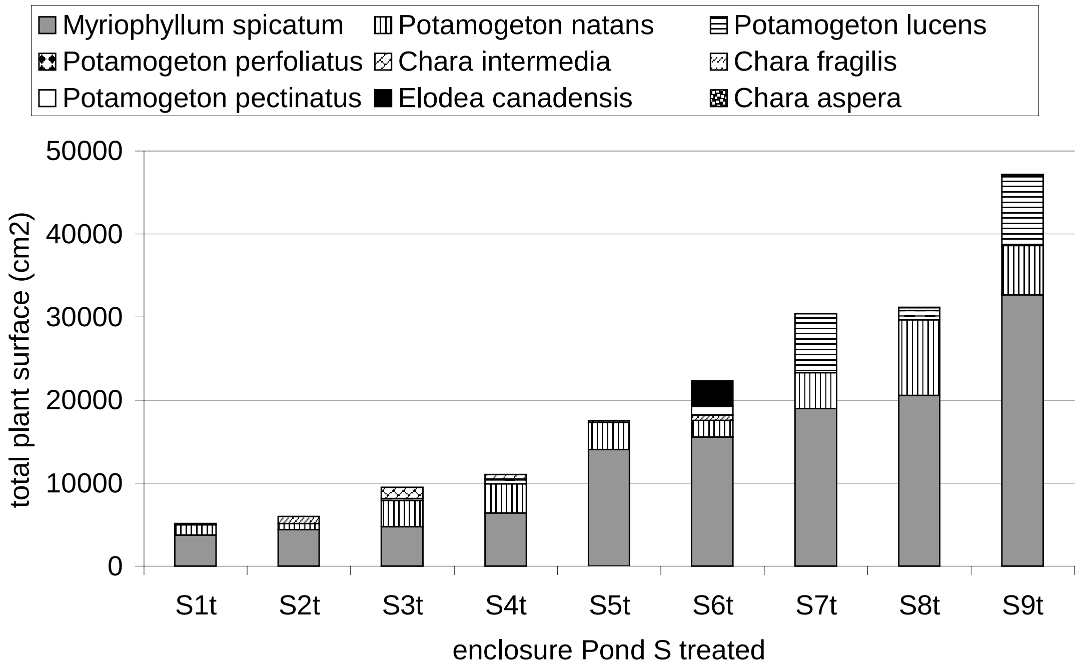


Fig. 119: Total plant surface of the treated enclosures in Pond S.

The total wet weight of the plants of the untreated enclosures of Pond M ranged between 700 g and 1480 g. The dry weight of the plant material within the controls varied between 85 g and 175 g (Fig. 120).

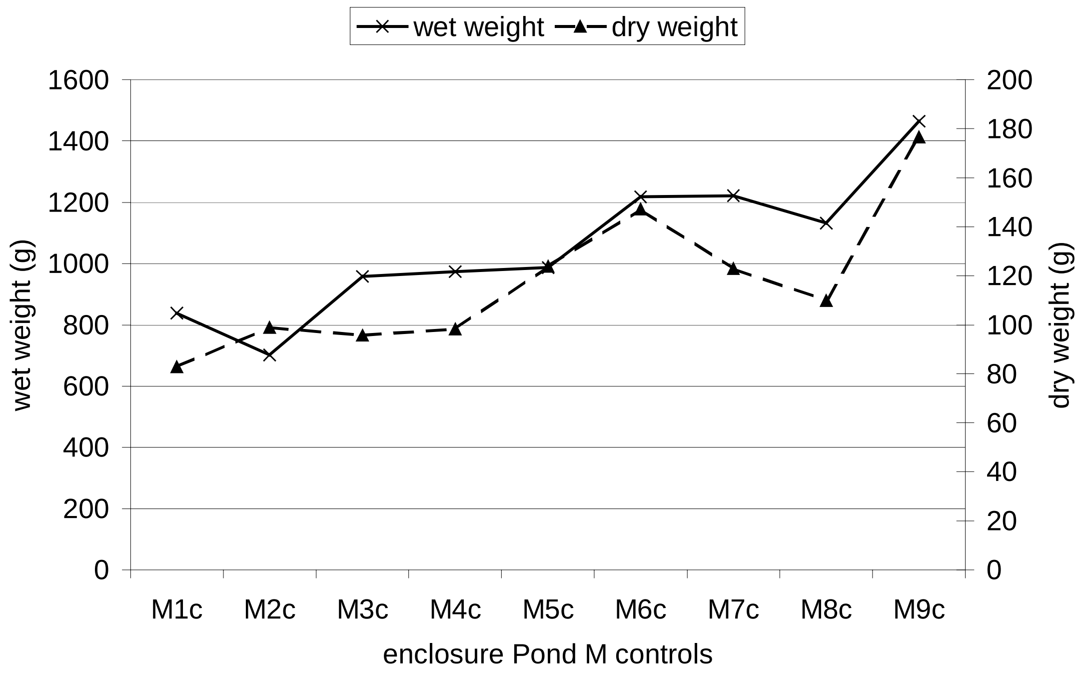


Fig. 120: Wet and dry weight of the untreated enclosures in Pond M.

The macrophytes of the treated enclosures of Pond M measured a total wet weight between 900 g and 1160 g and a dry weight between 95 g and 115 g (Fig. 121).

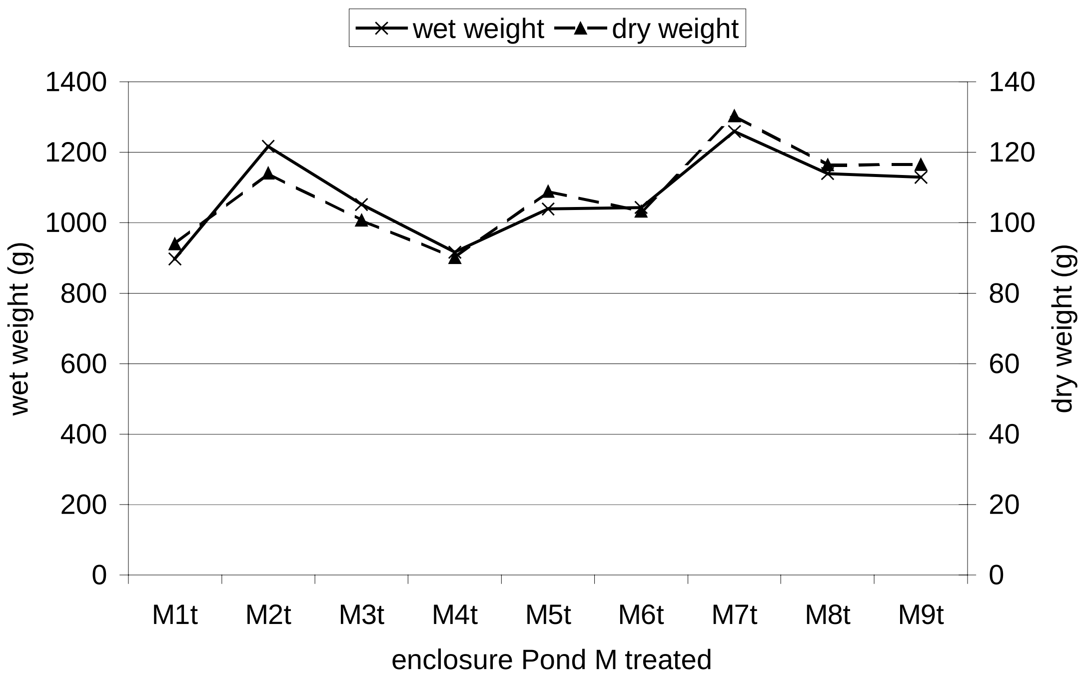


Fig. 121: Wet and dry weight of the treated enclosures in Pond M.

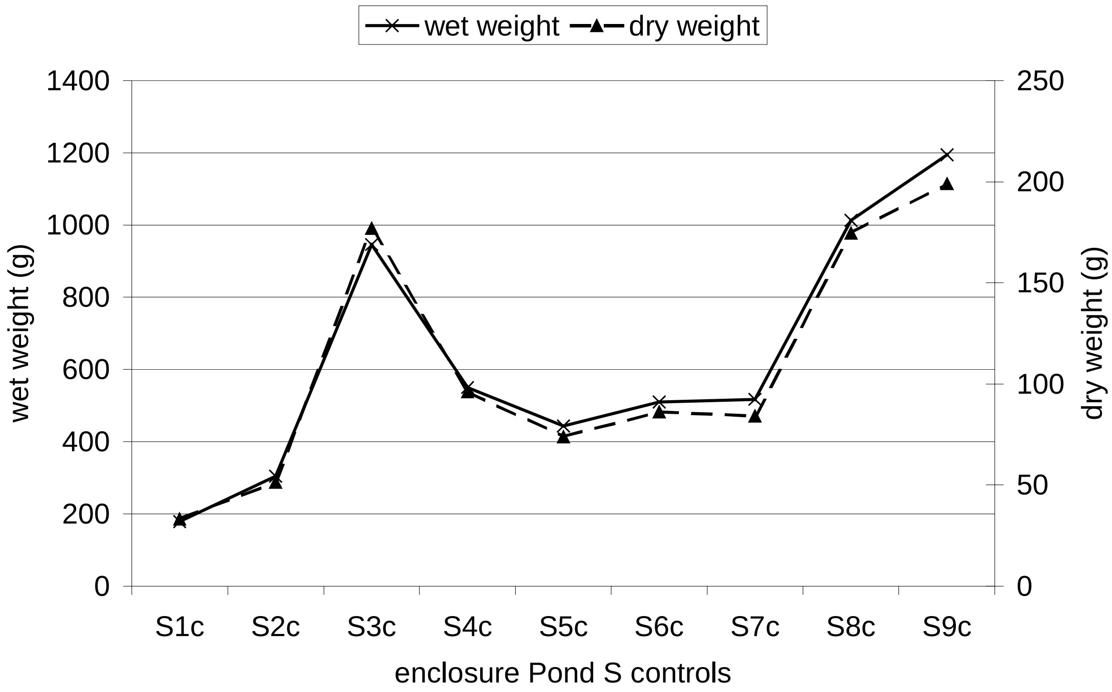


Fig. 122: Wet and dry weight of the untreated enclosures in Pond S.

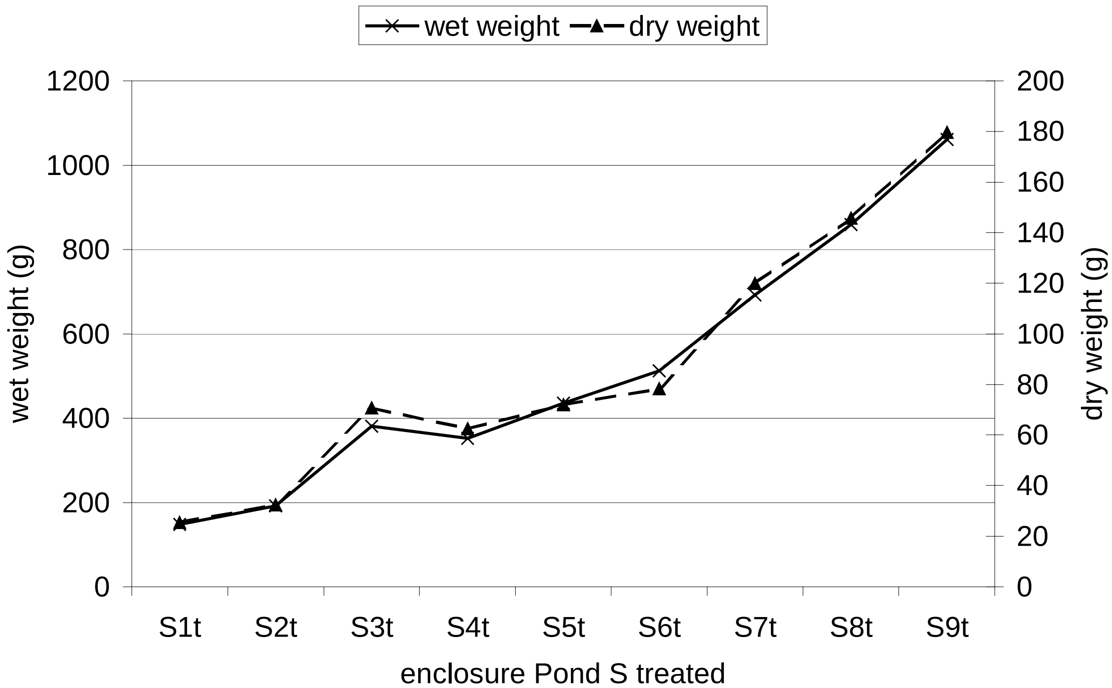


Fig. 123: Wet and dry weight of the treated enclosures in Pond S.

The weight of the wet plant material of the controls of Pond S ranged from 190g to 1200 g. The dry weight varied between 30g and 200 g (Fig. 122).

The plants of the treated enclosures of Pond S measured a wet weight from 150g to 1080 g and a dry weight between 25 g and 180 g (Fig. 123).

3.2.3.2 Physical and chemical parameters

The average pH value of the control enclosures at Pond M varied between 7,7 and 8,6 (Fig. 124). The pH value of the treated enclosures ranged between 7,5 and 8,8 (Fig. 125). These limits were similar before the treatments and after. The measurement after the second treatment was the often the lowest of both the control enclosures and the treated enclosures. Neither the cypermethrin dose nor the different plant densities showed a clear effect on the pH value.

At Pond S, the pH value of both the controls and the treated enclosures varied between 7,7 and 8,5 (Fig. 126, 127). The lowest value measured at all enclosures was usually found after the first treatment. As in Pond M, no effects of the cypermethrin and different plant densities, considering the pH value, were observed.

The average conductivity at the controls and the treated enclosures of Pond M varied between 180 µS/cm and 280 µS/cm (Fig. 128, 129). No clear conductivity difference was observed as caused either by the insecticide treatment or the plant densities. At Pond S the conductivity in the controls and the treated enclosures varied between 150 µS/cm and 275 µS/cm (Fig. 130, 131). The conductivity of the enclosures did not show an effect of the cypermethrin and was not influenced by the different plant densities.

The average temperature before the treatments of both Pond M and S measured 22 °C. After the first treatment it sank to 21 °C in all enclosures. After the second treatment it sank again to 17,5 °C (Fig. 132-135). This effect is due to the seasonal temperature change.

At all enclosures in Pond M, the average oxygen saturation ranged between 40% and 100% (Fig. 136, 137). There was no clear difference between the treated and the untreated enclosures. In addition, no effect of the different plant densities was notable. The average oxygen saturation at the enclosures in Pond S varied between 60% and 110% (Fig. 138, 139). The oxygen content showed a similar development in all enclosures.

In Pond M, the average chlorophyll a concentration in the enclosures before treatment was 0,5 µg/l. After the first treatment the average chlorophyll a concentration ranged between 0,5 and 12 µg/l. After the second treatment, the concentration varied between 0,7 and 24 µg/l (Fig. 140, 141). The measured differences between the chlorophyll a contents in the controls and in the treated enclosures were not associated with the macrophyte densities. The concentration peaks were measured after the second treatment in all the enclosures.

In Pond S the chlorophyll a concentration in the controls ranged between 0,7 to 5,2 µg/l (Fig. 142). The chlorophyll a concentration of the treated enclosures before and after the first treatment varied between 0,7 and 2,3 µg/l. After the second treatment the concentration varied between 1 µg/l and 9,6 µg/l (Fig. 143).

All enclosures in Pond S, with the lower plant surface had slightly higher chlorophyll a content than the enclosures with the higher plant surface. The enclosures S1t to S7t showed a higher chlorophyll a concentration after the second treatment. The 1000 ng/l cypermethrin treatment did not show such an effect in the enclosures (S8t and S9t) with the highest plant densities.

The other chemical parameters such as total and soluble reactive phosphorus, ammonia, nitrate, silica, hardness and alkalinity did not measure a notable difference in the enclosures in either pond (Table 11).

Table 11: Mean and standard deviation of TP, SRP, ammonia, nitrate, silica, hardness and alkalinity (treated and untreated).

Pond M	mean	standard deviation	Pond S	mean	standard deviation
TP [mg/l]	0,036	0,013	**TP [mg/l]**	0,021	0,003
SRP [mg/l]	0,002		**SRP [mg/l]**	0,002	
NH^{4+} -N [mg/l]	0,023	0,008	**NH^{4+} [mg/l]**	0,084	0,064
NO^{3-} -N [mg/l]	0,028	0,027	**NO^{3-} [mg/l]**	0,024	0,013
silica [mg/l]	1,055	0,485	**silica [mg/l]**	1,106	0,581
hardness [°DH]	7,188	0,472	**hardness [°DH]**	6,076	0,797
alkalinity	103,89	7,68	**alkalinity**	99,57	8,22

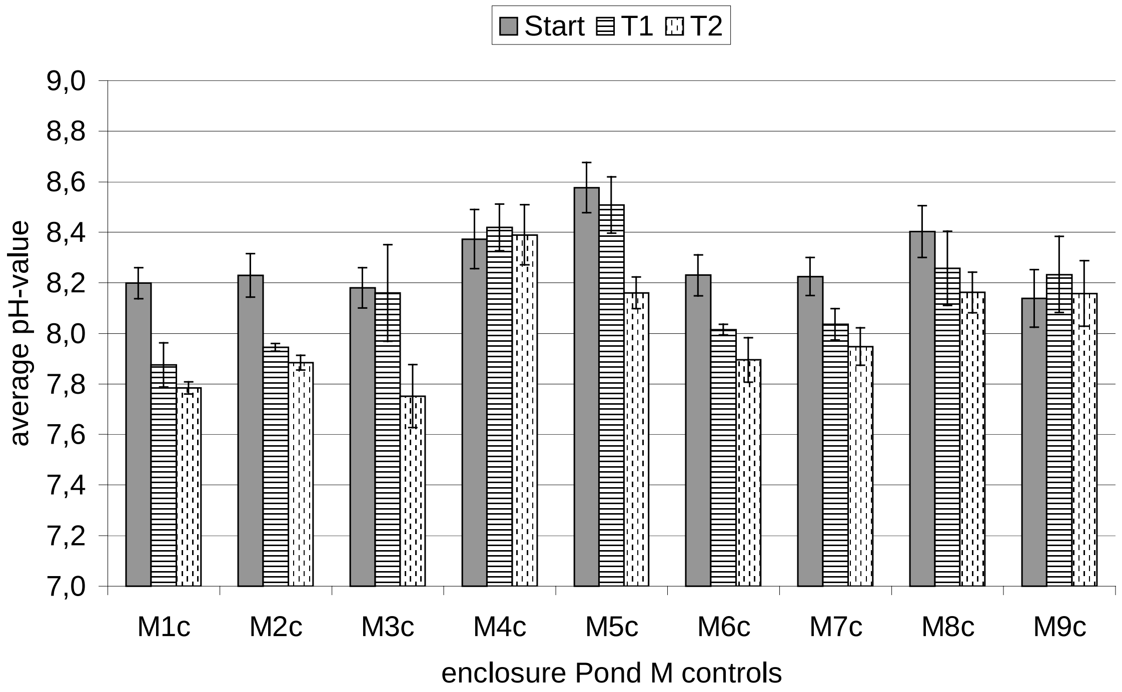


Fig. 124: Average pH value before treatment, after the first treatment and after the second treatment of the control enclosures in Pond M.

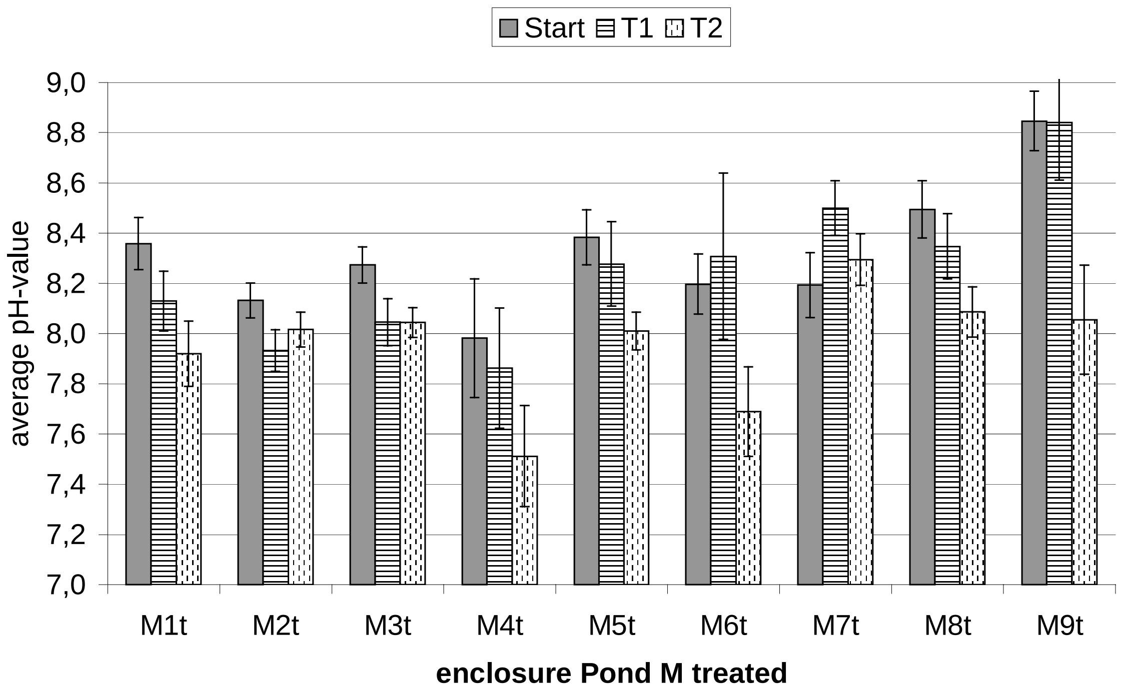


Fig. 125: Average pH value before treatment, after the first treatment and after the second treatment of the treated enclosures in Pond M.

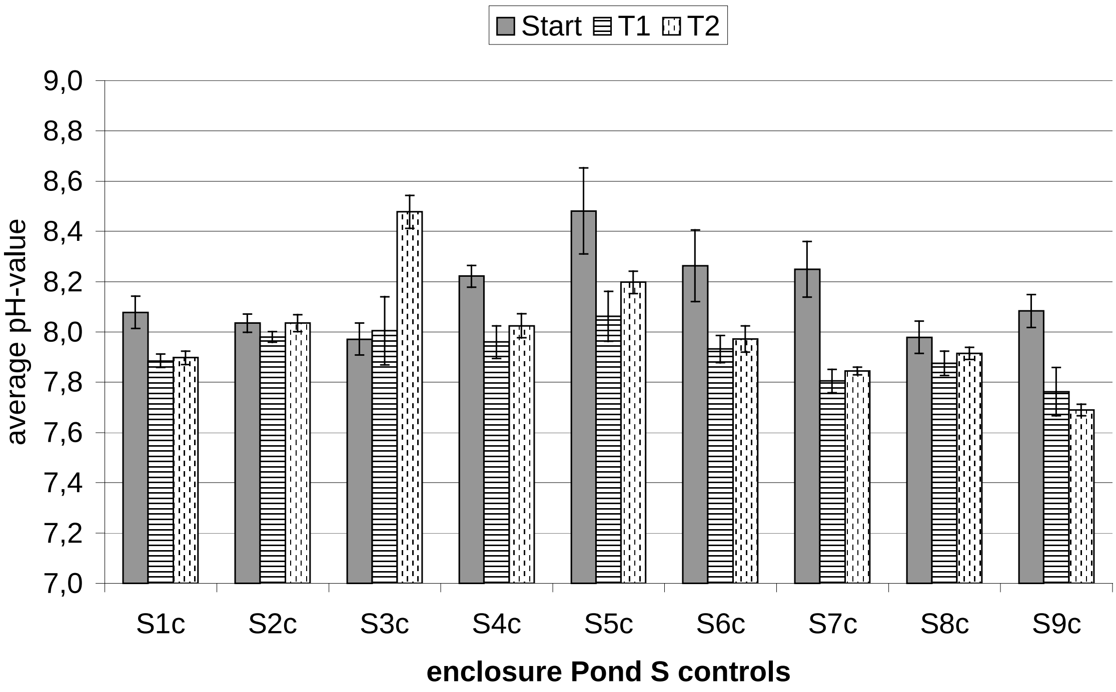


Fig. 126: **Average pH value before treatment, after the first treatment and after the second treatment of the control enclosures in Pond S.**

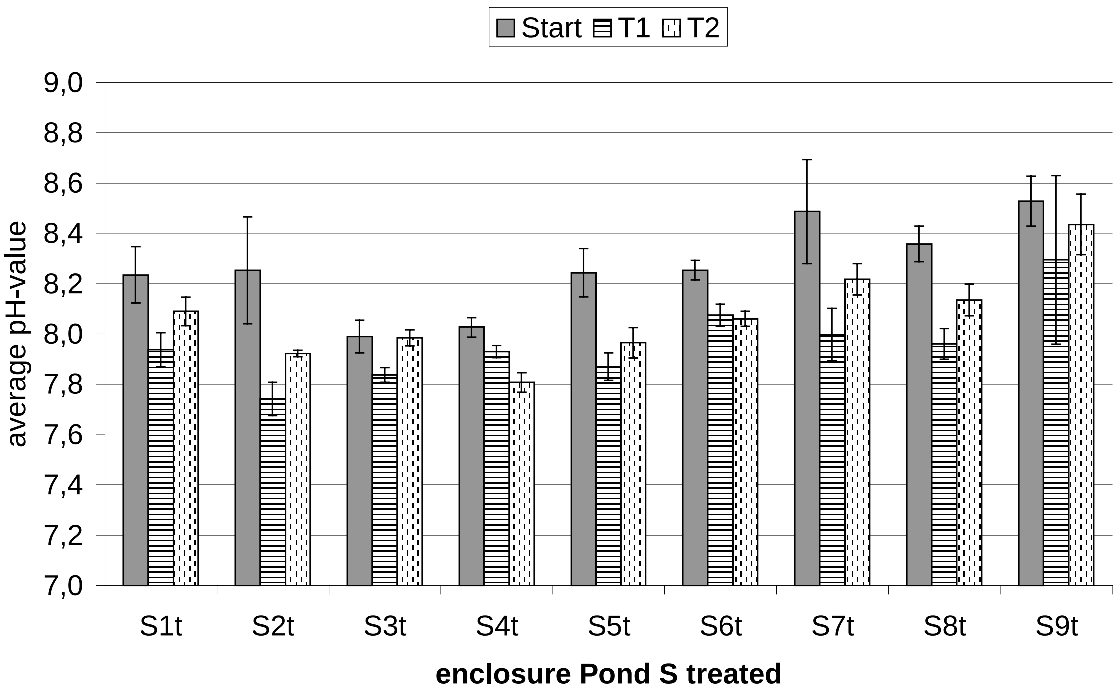


Fig. 127: **Average pH value before treatment, after the first treatment and after the second treatment of the treated enclosures in Pond S.**

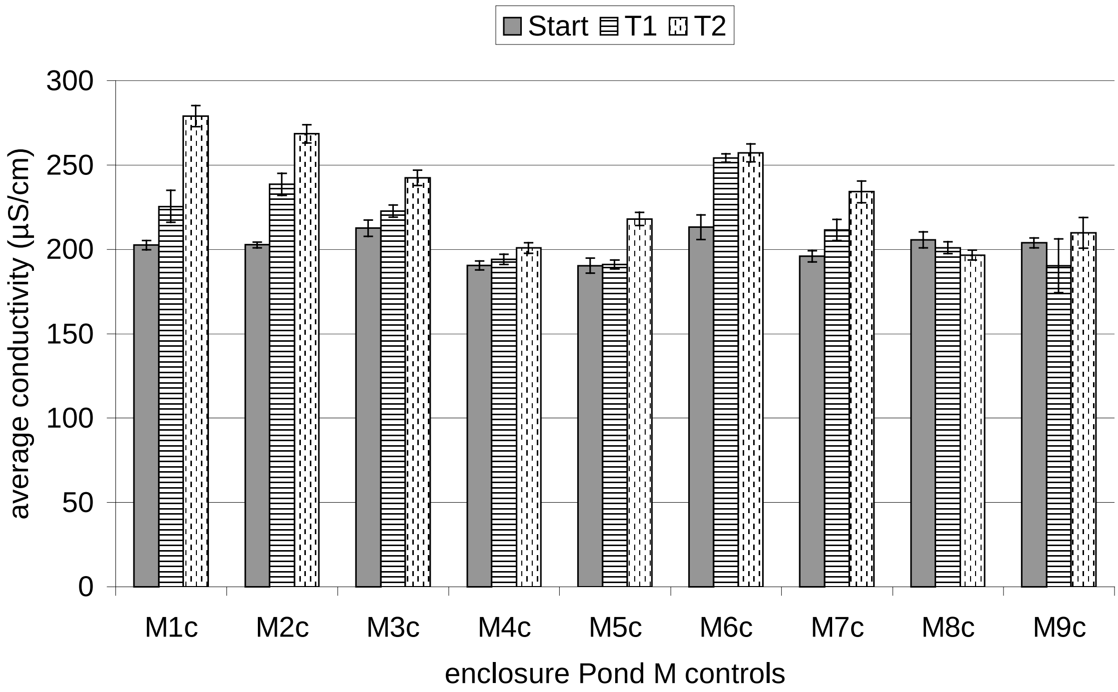


Fig. 128: Average conductivity before treatment, after the first treatment and after the second treatment of the control enclosures in Pond M.

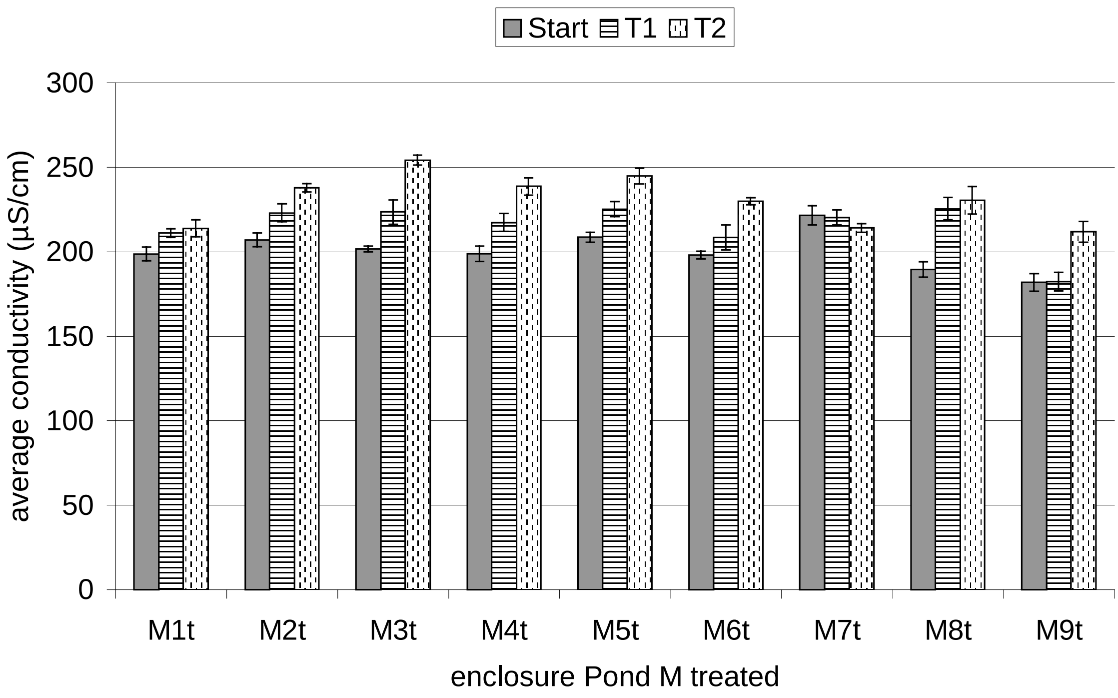


Fig. 129: Average conductivity before treatment, after the first treatment and after the second treatment of the treated enclosures in Pond M.

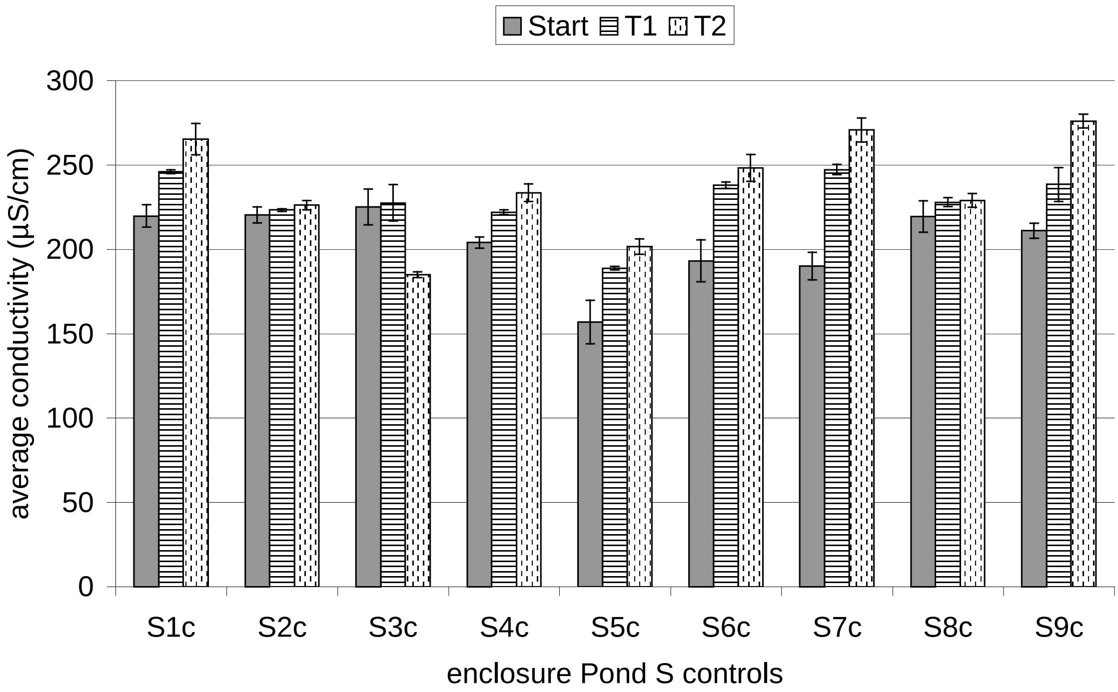


Fig. 130: **Average conductivity before treatment, after the first treatment and after the second treatment of the control enclosures in Pond S.**

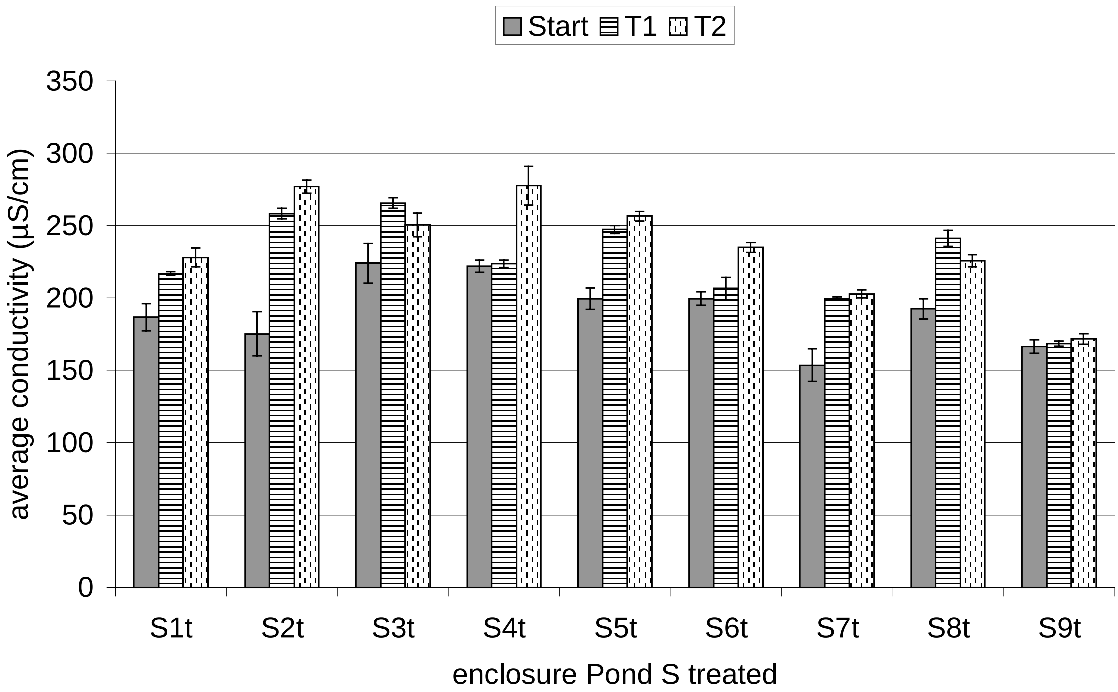


Fig. 131: **Average conductivity before treatment, after the first treatment and after the second treatment of the treated enclosures in Pond S.**

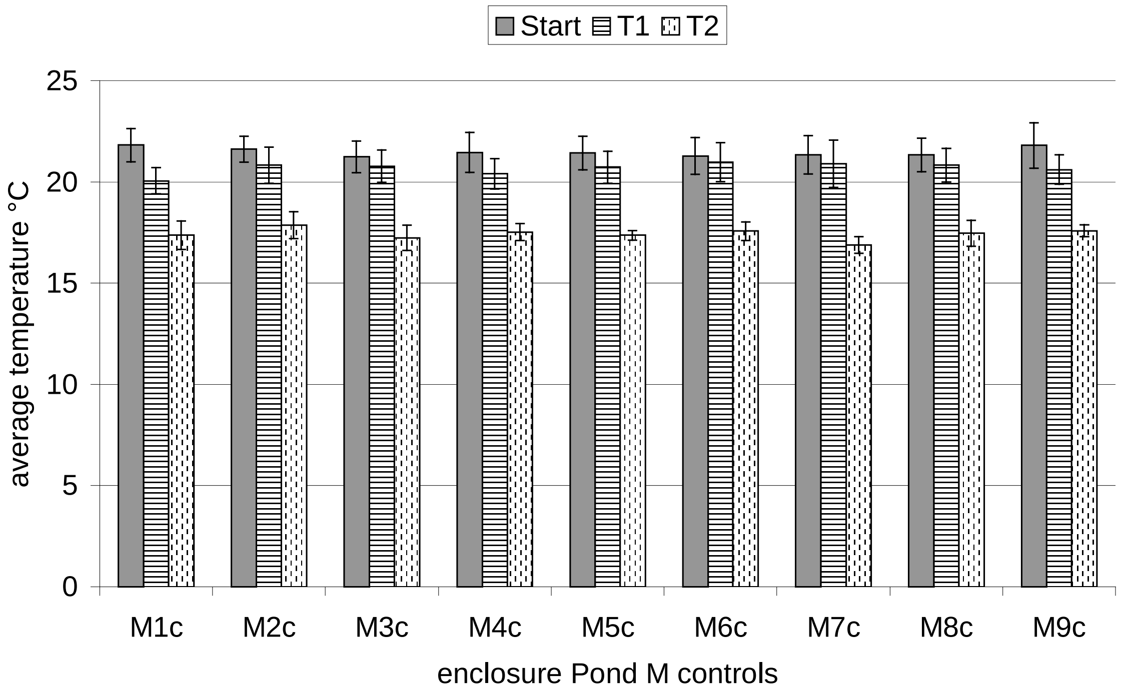


Fig. 132: **Average temperature before treatment, after the first treatment and after the second treatment of the control enclosures in Pond M.**

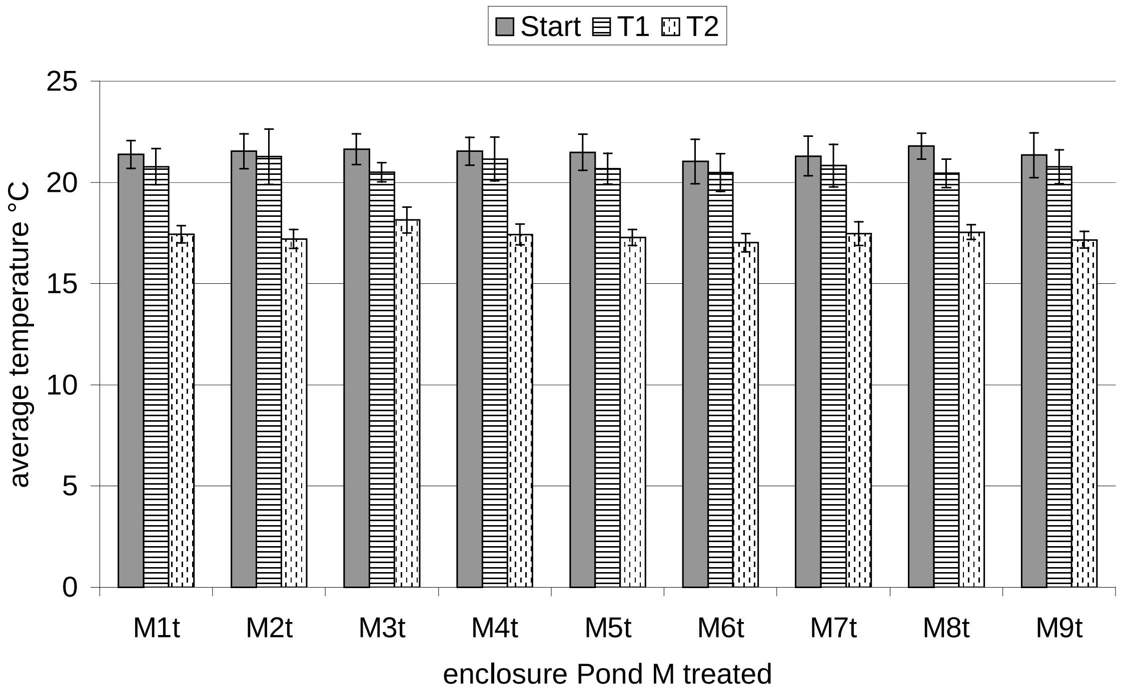


Fig. 133: **Average temperature before treatment, after the first treatment and after the second treatment of the treated enclosures in Pond M.**

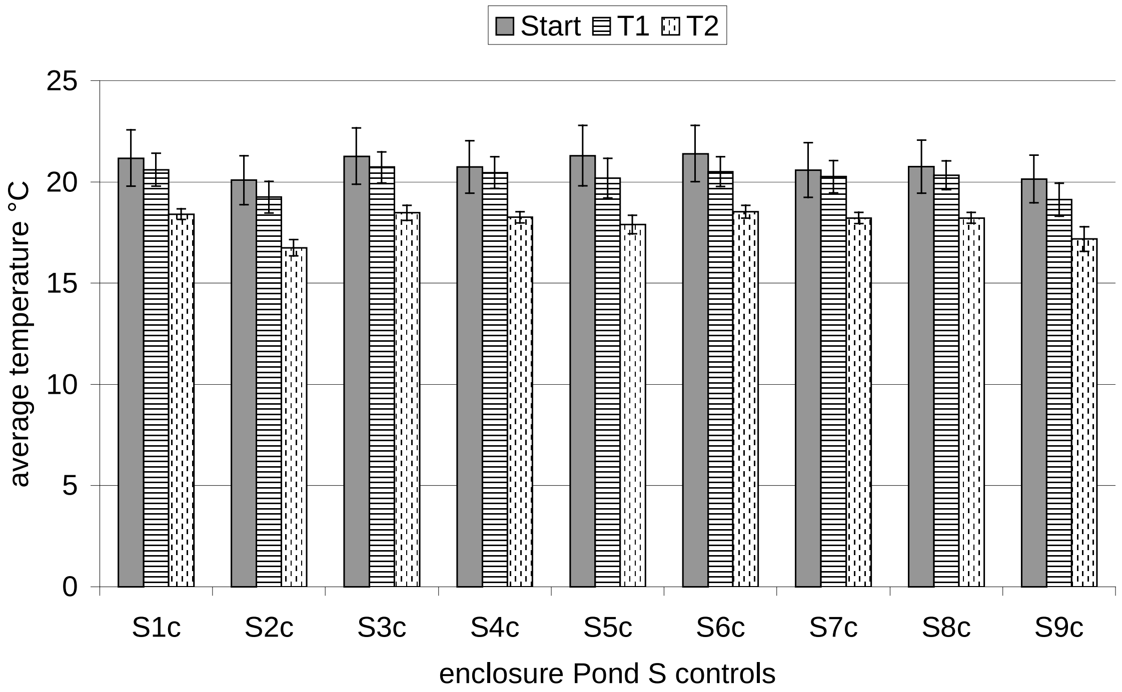


Fig. 134: **Average temperature before treatment, after the first treatment and after the second treatment of the control enclosures in Pond S.**

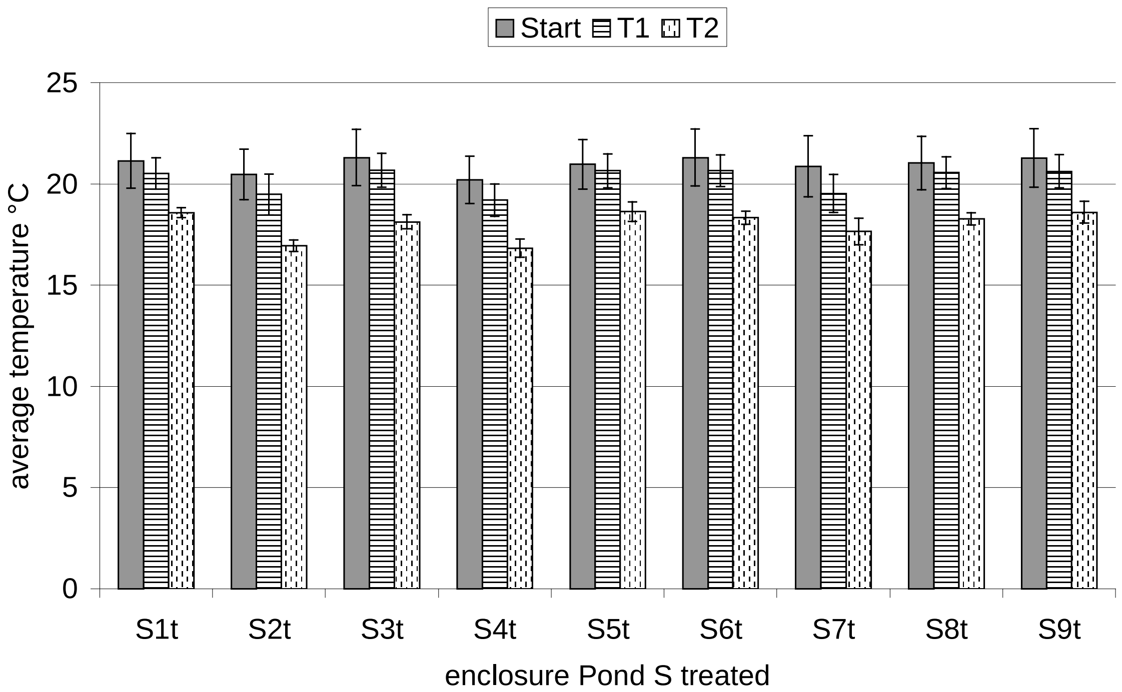


Fig. 135: **Average temperature before treatment, after the first treatment and after the second treatment of the treated enclosures in Pond S.**

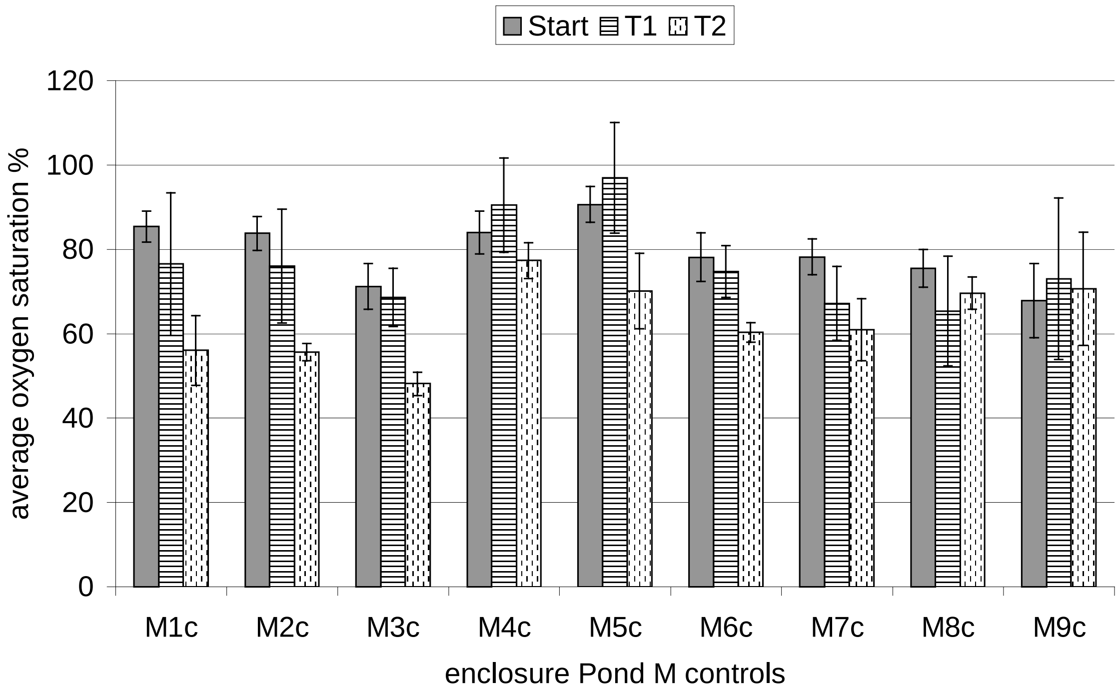


Fig. 136: **Average oxygen saturation before treatment, after the first treatment and after the second treatment of the control enclosures in Pond M.**

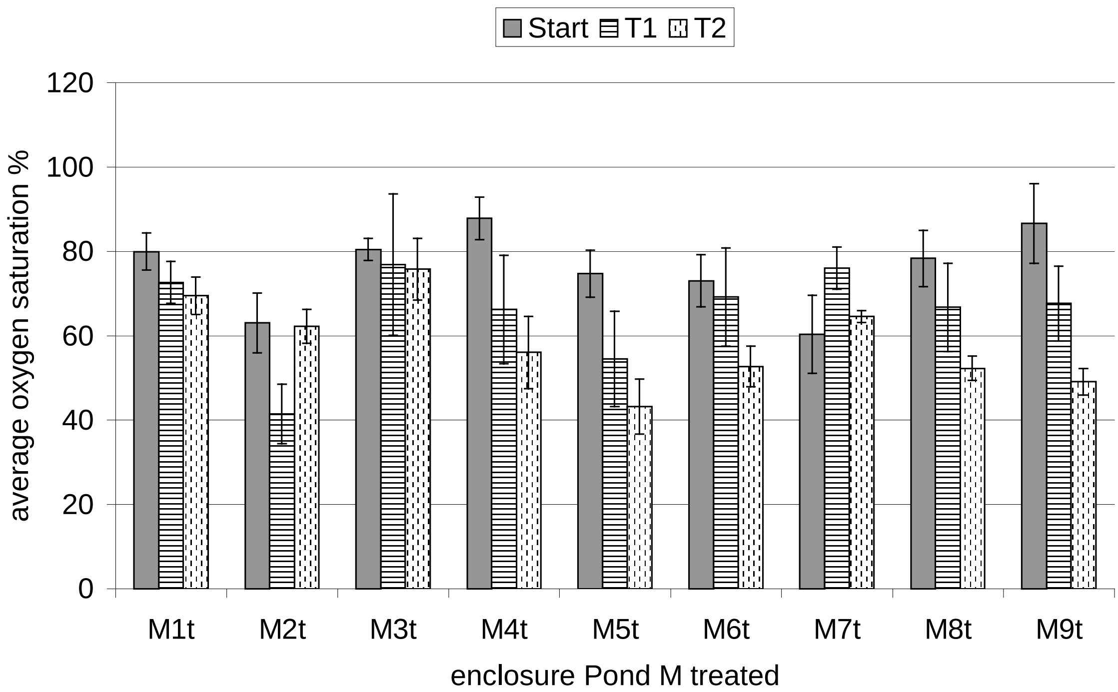


Fig. 137: **Average oxygen saturation before treatment, after the first treatment and after the second treatment of the treated enclosures in Pond M.**

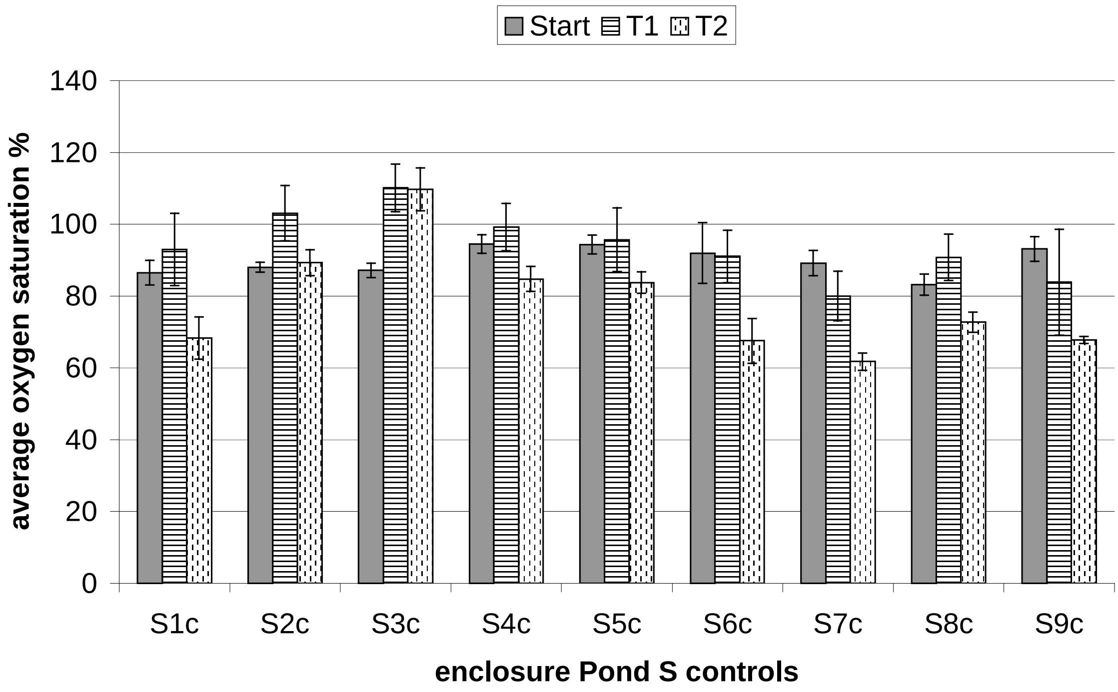


Fig. 138: **Average oxygen saturation before treatment, after the first treatment and after the second treatment of the control enclosures in Pond S.**

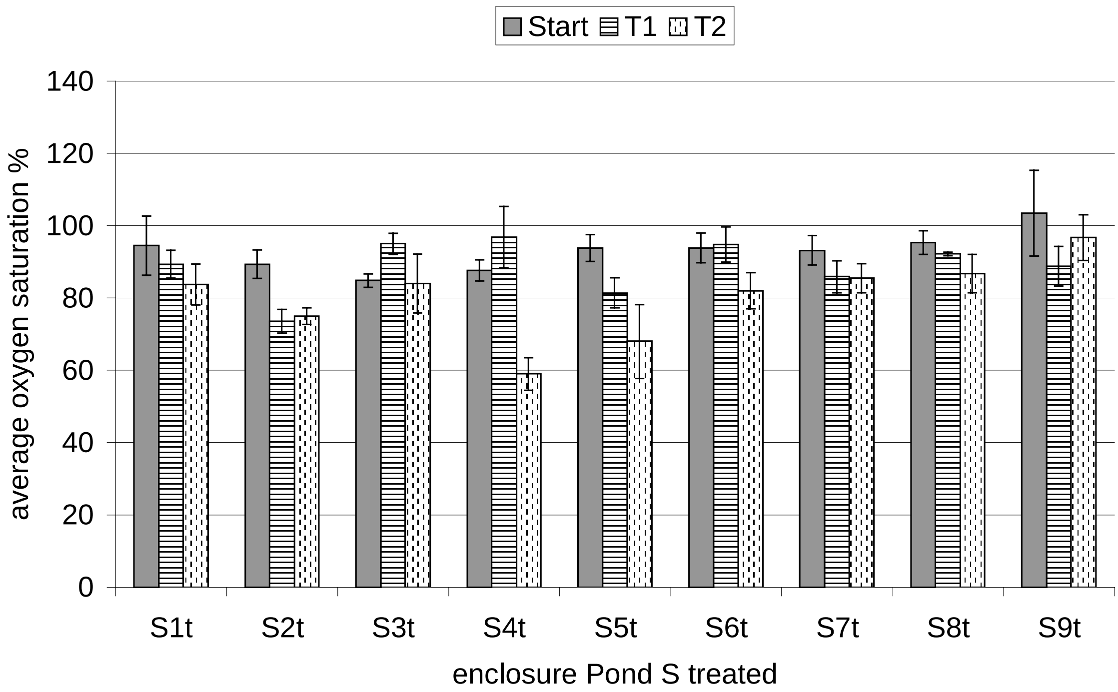


Fig. 139: **Average oxygen saturation before treatment, after the first treatment and after the second treatment of the treated enclosures in Pond S.**

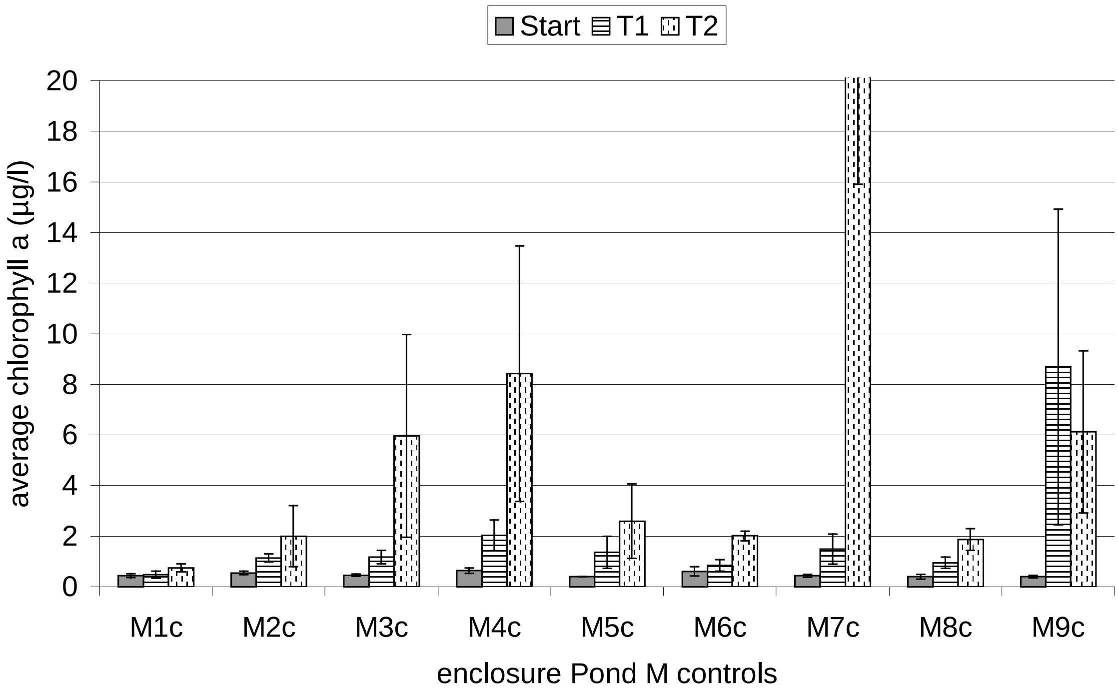


Fig. 140: Average chlorophyll a concentration before treatment, after the first treatment and after the second treatment of the control enclosures in Pond M.

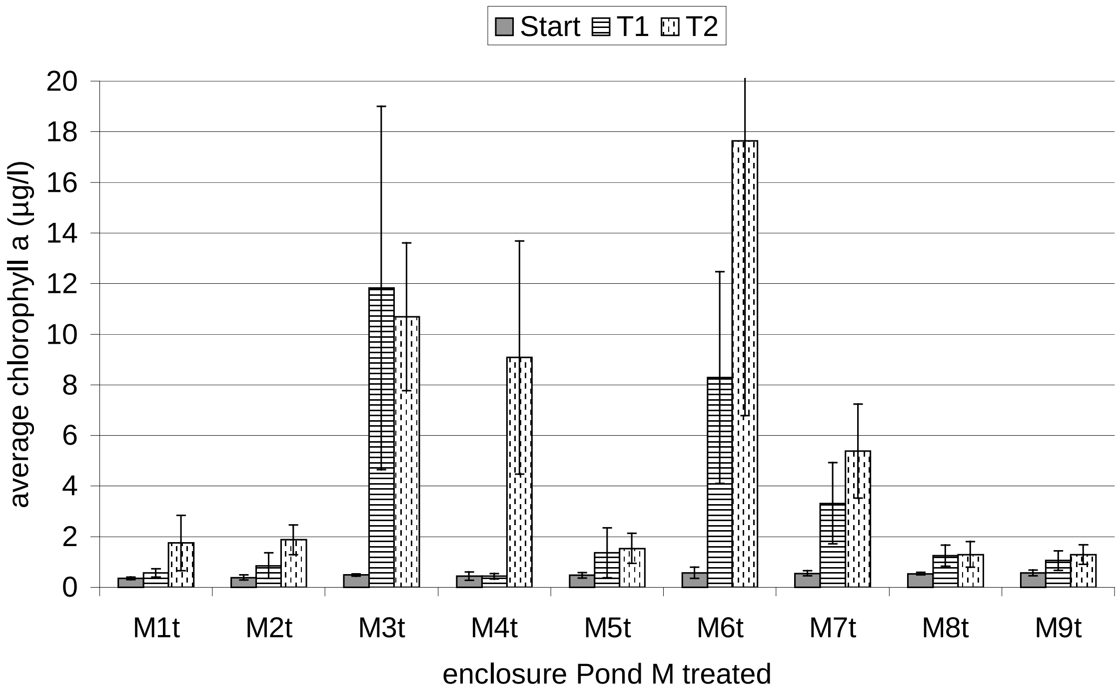


Fig. 141: Average chlorophyll a concentration before treatment, after the first treatment and after the second treatment of the treated enclosures in Pond M.

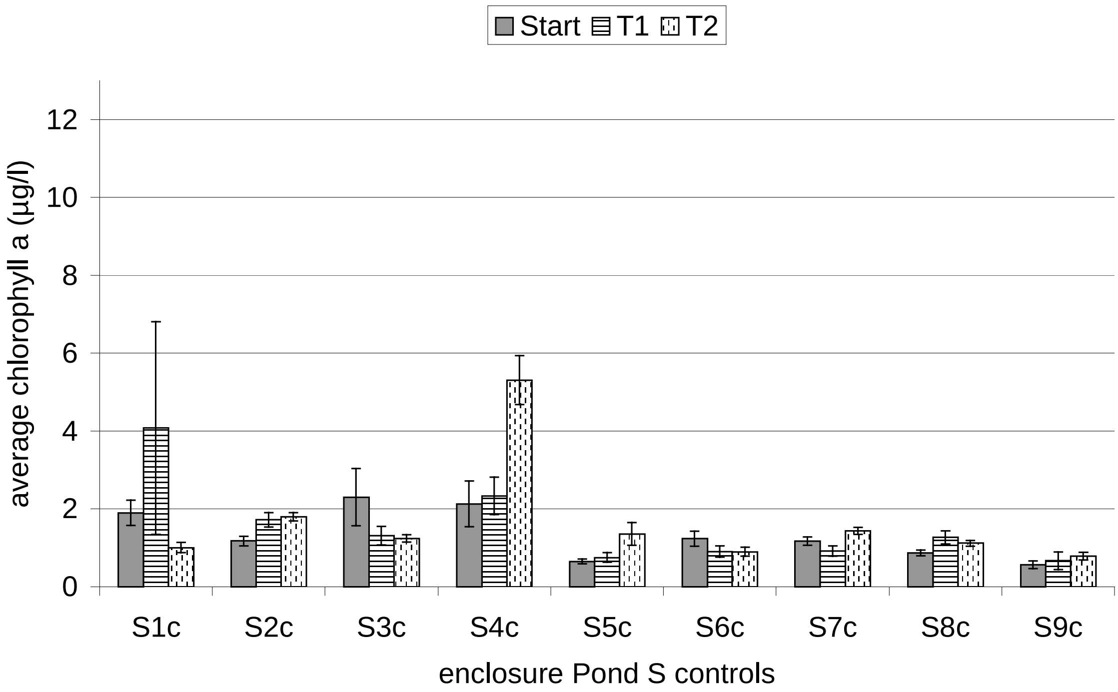


Fig. 142: **Average chlorophyll a concentration before treatment, after the first treatment and after the second treatment of the control enclosures in Pond S.**

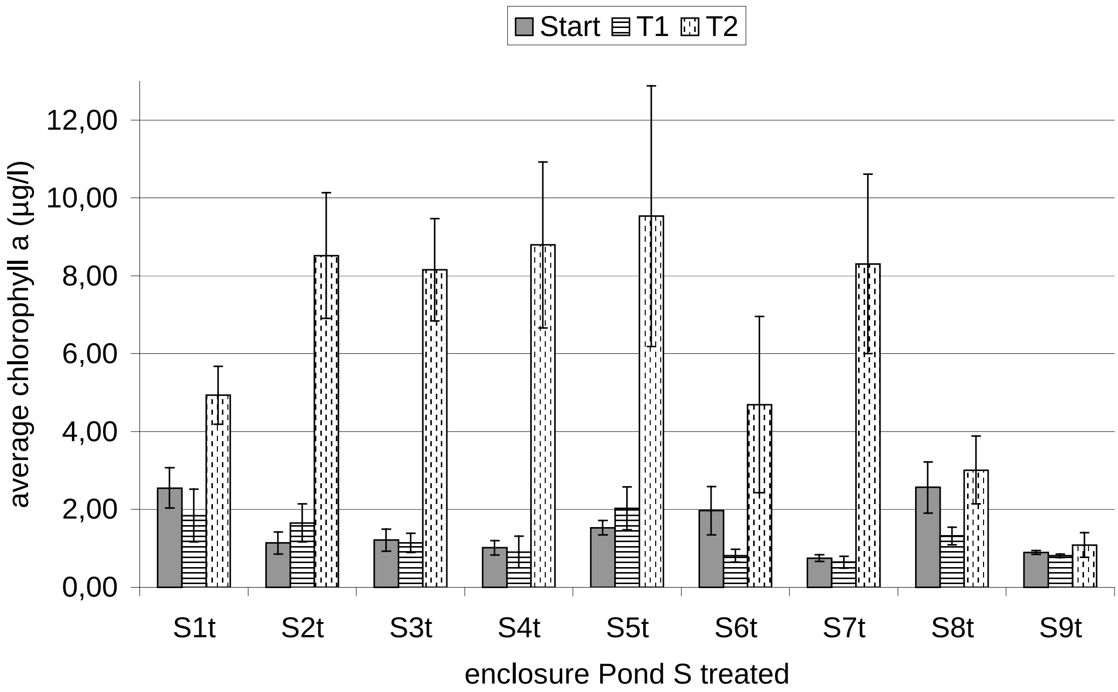


Fig. 143: **Average chlorophyll a concentration before treatment, after the first treatment and after the second treatment of the treated enclosures in Pond S.**

3.2.3.3 The macroinvertebrate species

In order to examine the effect of the cypermethrin, the species absolute numbers in the treated enclosures were substracted from the numbers found in the control enclosures. At Pond M, the dates T1-T7 were illustrated. In order to simplify the development of the species numbers an average of the three time periods was calculated for Pond S. T1 stands for the time before treatment, T2 stands for the 100 ng/l cypermethrin treatment and T3 stands for the 1000 ng/l treatment.

In Pond M the cypermethrin treatments (T3, T5) did not influence the numbers of *Dugesia spp*. in any of the tested plant densities (Fig. 144). In Pond S, less *Dugesia spp*. specimen were found within the treated enclosures with medium and high plant densities (S6, S8). It is to be noted, that all of the enclosures had similar numbers both before the treatments and afterward (Fig. 145). *Dugesia spp.* has EC 50 (48h) for cypermethrin > 100µg/l (Maund unpublished). The effective concentration was a effect up on the movement of 50 % of the tested animals.

Lymnaea stagnalis did not show an effect to either of the two treatments in either pond. All the enclosures with the different plant densities kept a certain population level all through the investigation period (Fig. 146, 147). *Lymnaea stagnalis* LC 50 (48h) has been tested for permethrin > 10 µg/l (Mian & Mulla 1992). The (movement) EC 50 (48h) for cypermethrin is > 100 µg/l (Maund unpublished).

In Pond M and S, the Naididae population did not show a direct effect to the cypermethrin treatments. Many of the control enclosures had many more specimens even before the first treatment (148, 149).

The Tubificidae showed no clear reaction to the cypermethrin treatments. The enclosures kept their individual levels throughout the whole study period. They did not seem to prefer any certain plant density at either of the two ponds (150, 151). The (movement) EC 50 (48h) for cypermethrin is > 100 µg/l (Maund unpublished).

The population of *Asellus aquaticus* showed an effect after the 100 ng/l cypermethrin treatment in Pond M. The enclosures with medium macrophyte densities (M5, M6) measured a clear decrease within the treated enclosures. After the second treatment the effect became more obvious. The enclosures with the low plant densities also showed an effect after the 1000 ng/l treatment (Fig. 152). In Pond S the first treatment was observed with a reduction in the *Asellus* population in all enclosures except S4 and S7. The second treatment showed an effect in all of the enclosures (Fig 153).

The LC 50 (24h) dose level for cypermethrin is 200 ng/l (Stephenson 1982) and for LC (96h) 9 ng/l (Maund unpublished) The toxicological lethal effect is controversely discussed. The (movement) EC 50 (48h) for cypermethrin is 4 ng/l (Maund unpublished).

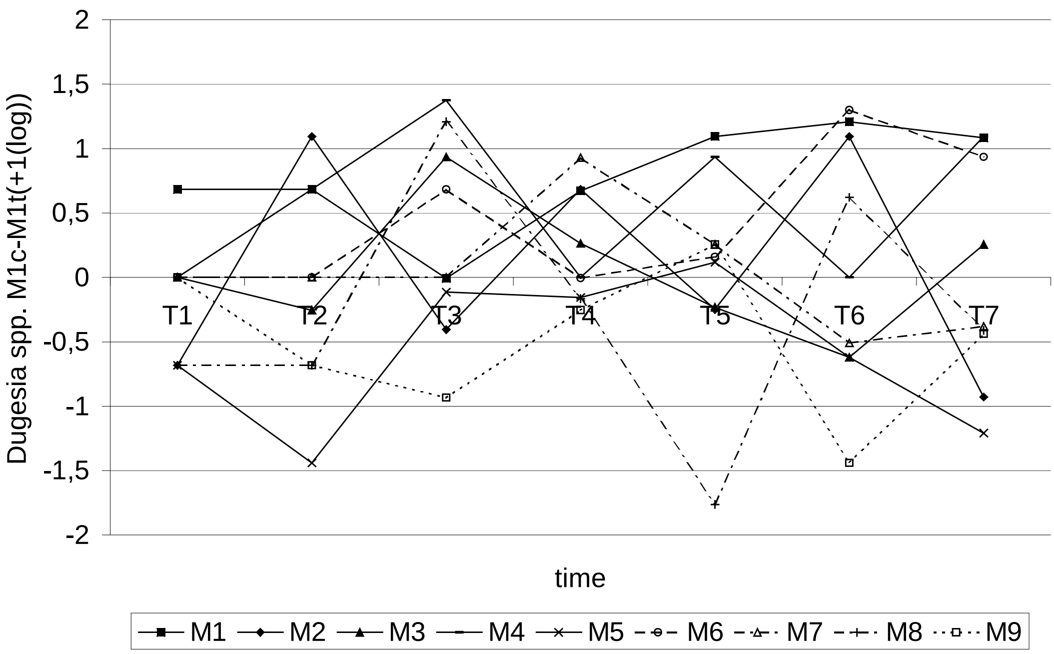


Fig. 144: The differences in numbers between the treated and control enclosures of *Dugesia spp*. in the enclosures in Pond M through time.

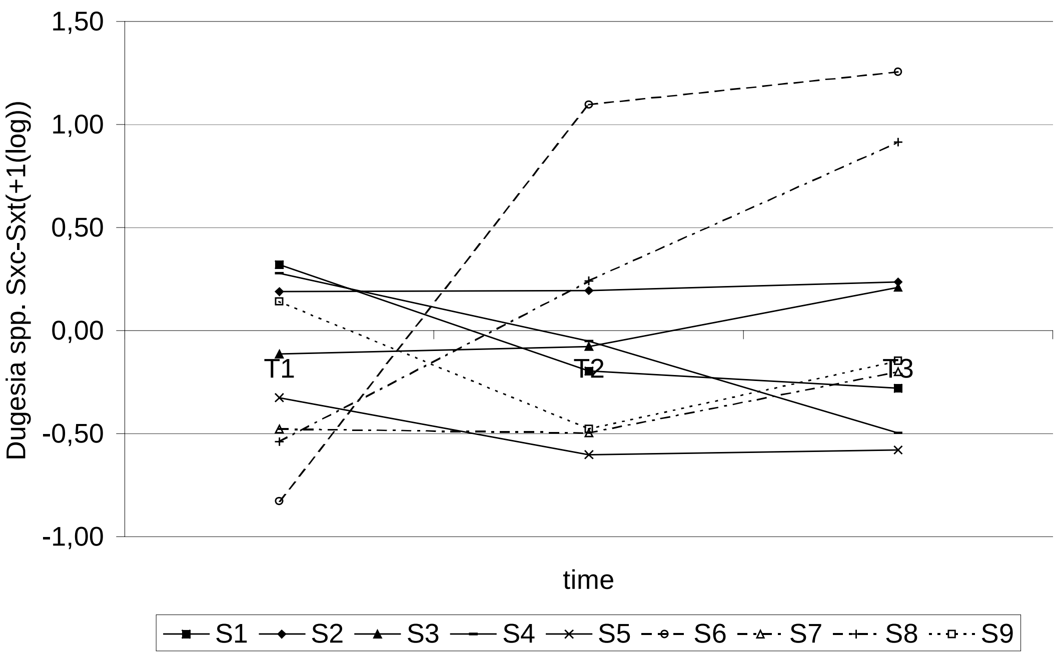


Fig. 145: The differences in numbers between the treated and control enclosures of *Dugesia spp*. in the enclosures in Pond S before the treatments, after the first and after the second treatment.

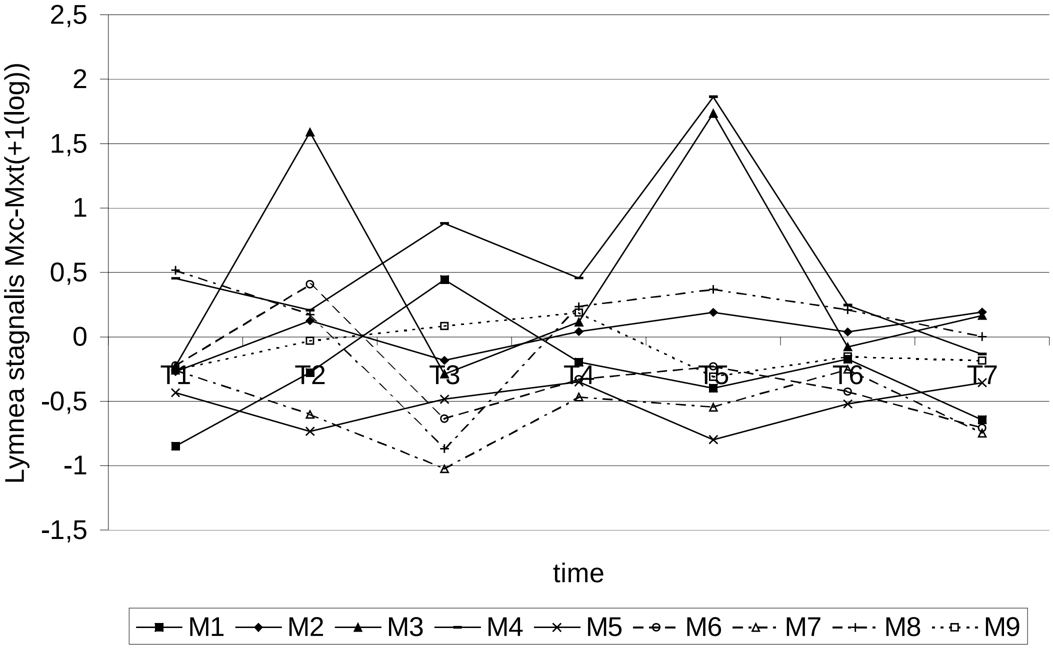


Fig. 146: The differences in numbers between the treated and control enclosures of *Lymnaea stagnalis* in the enclosures in Pond M through time.

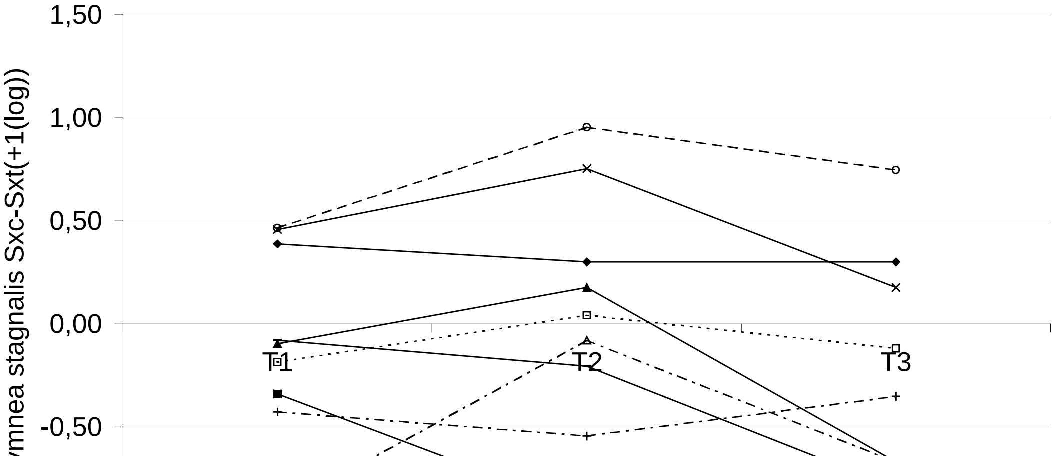


Fig. 147: The differences in numbers between the treated and control enclosures of *Lymnaea stagnalis* in the enclosures in Pond S before the treatments, after the first and after the second treatment.

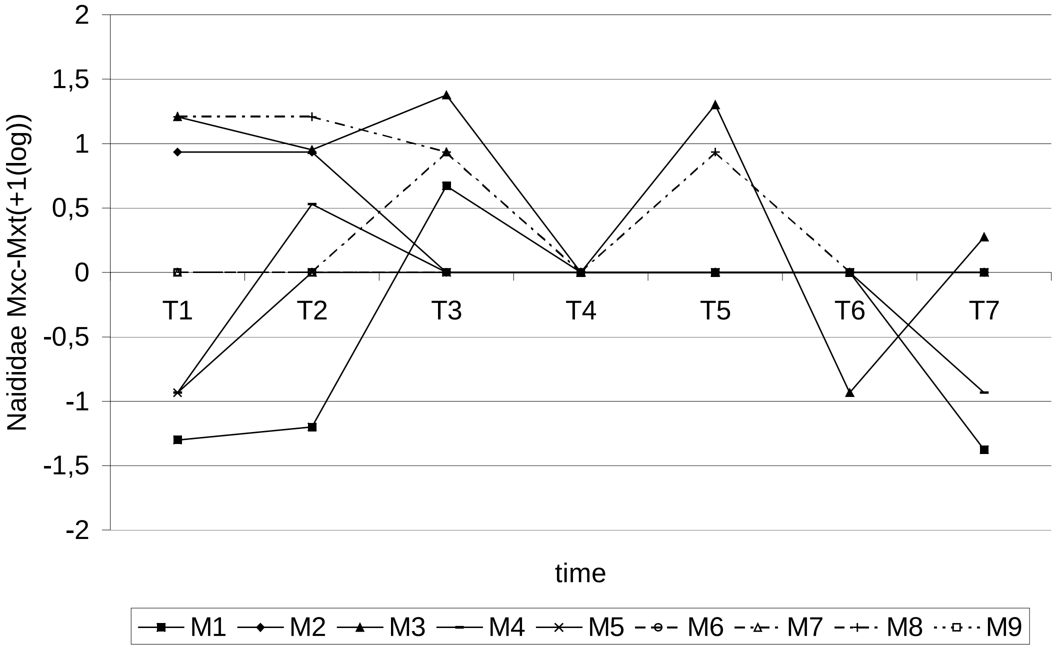


Fig. 148: **Differences in numbers between the treated and control enclosures of Naididae in the enclosures in Pond M through time.**

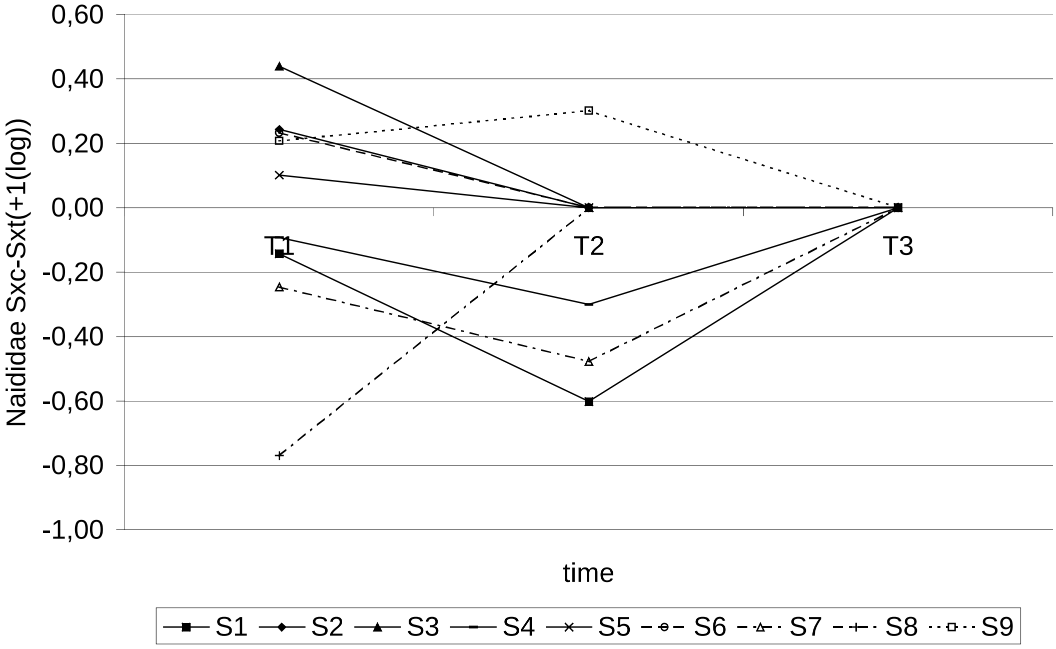


Fig. 149: **The differences in numbers between the treated and control enclosures of Naididae in the enclosures in Pond S before the treatments, after the first and after the second treatment.**

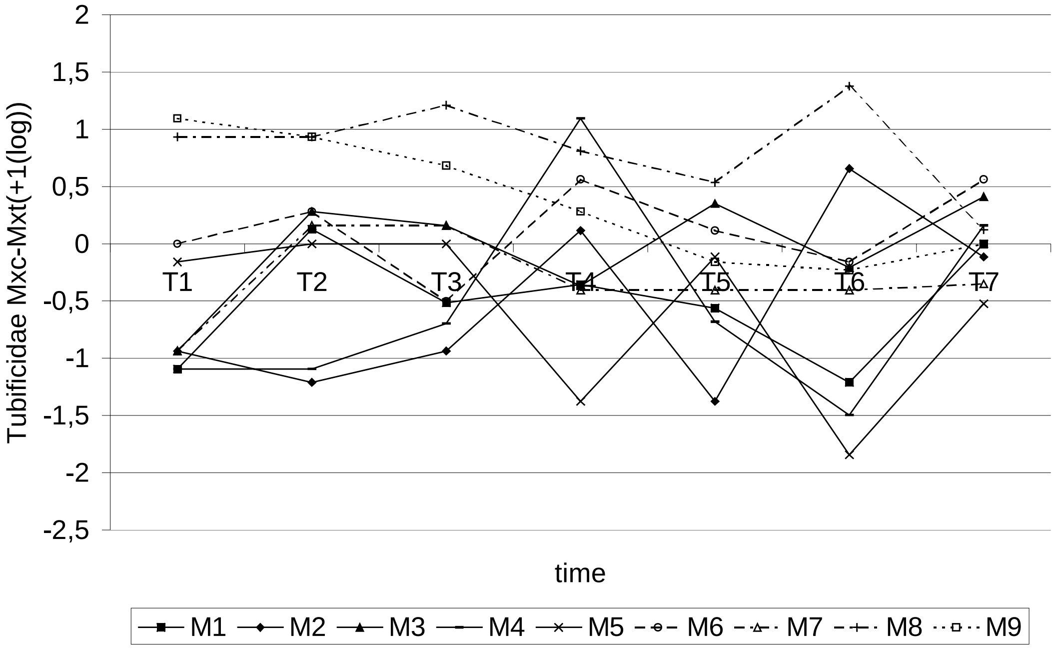


Fig. 150: The differences in numbers between the treated and control enclosures of Tubificidae in the enclosures in Pond M through time.

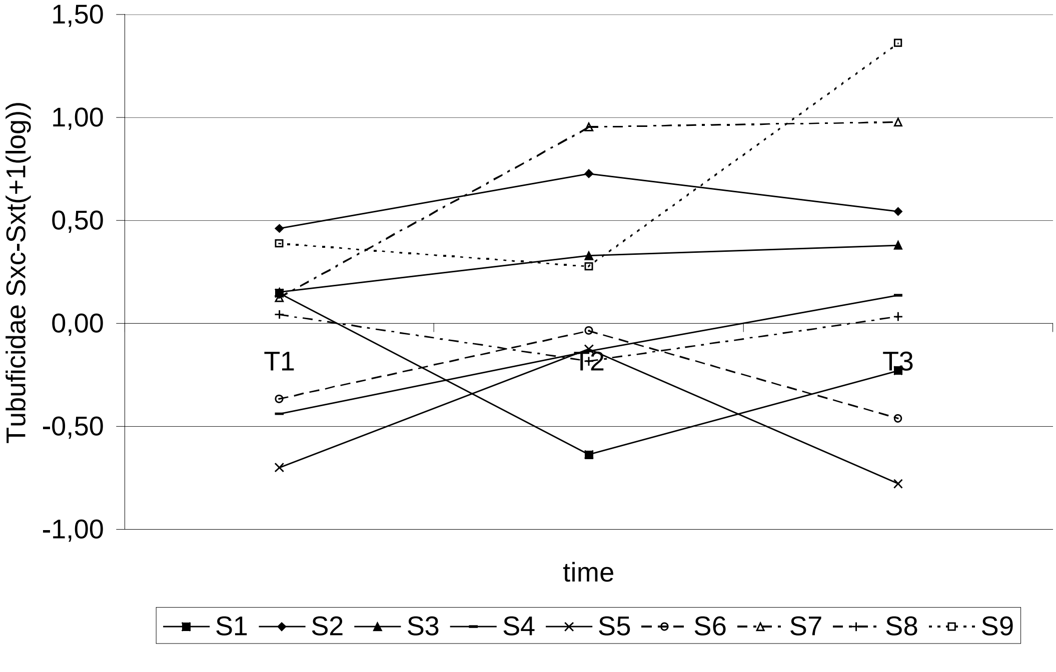


Fig. 151: The differences in numbers between the treated and control enclosures of Tubificidae in the enclosures in Pond S before the treatments, after the first and after the second treatment.

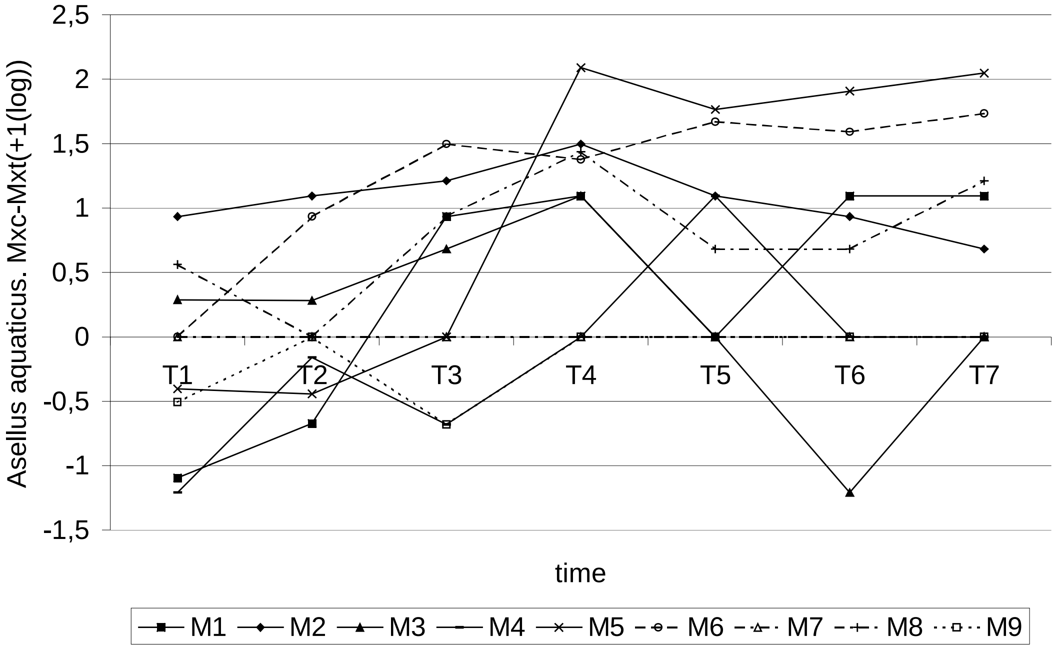


Fig. 152: The differences in numbers between the treated and control enclosures of *Asellus aquaticus* in the enclosures in Pond M through time.

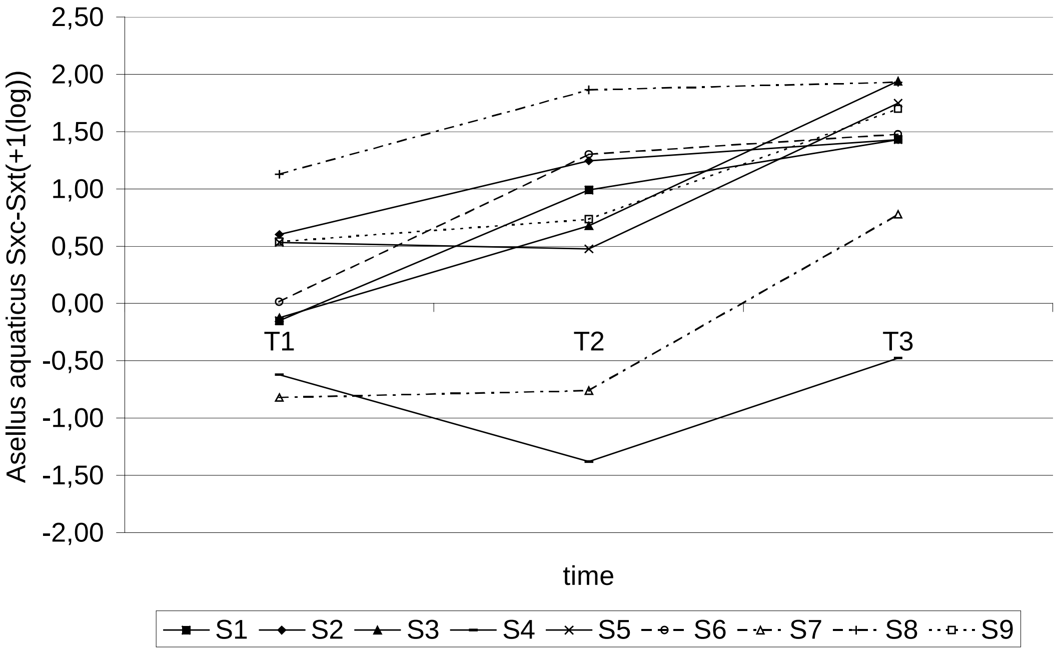


Fig. 153: The differences in numbers between the treated and control enclosures of *Asellus aquaticus* in the enclosures in Pond S before the treatments, after the first and after the second treatment.

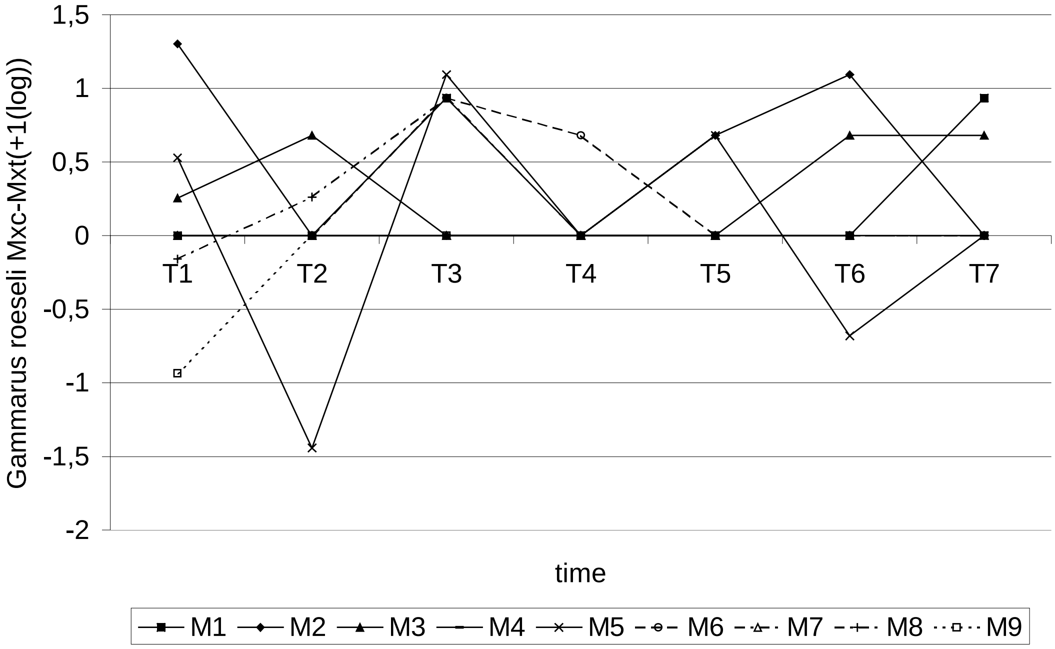


Fig. 154: The differences in numbers between the treated and control enclosures of *Gammarus roeseli* in the enclosures in Pond M through time.

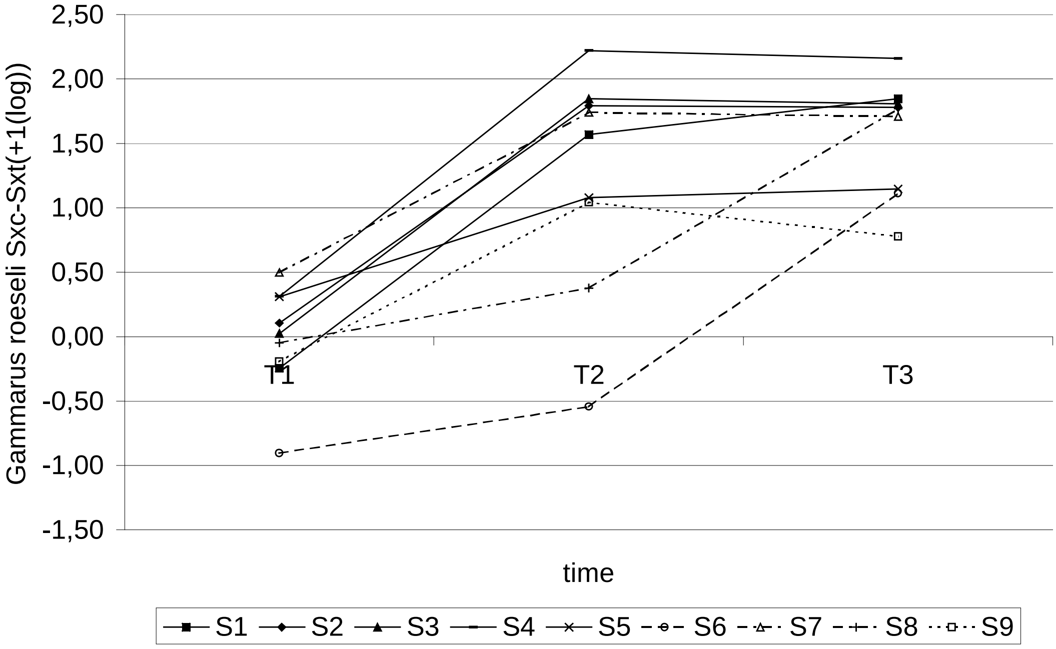


Fig. 155: The differences in numbers between the treated and control enclosures of *Gammarus roeseli* in the enclosures in Pond S before the treatments, after the first and after the second treatment.

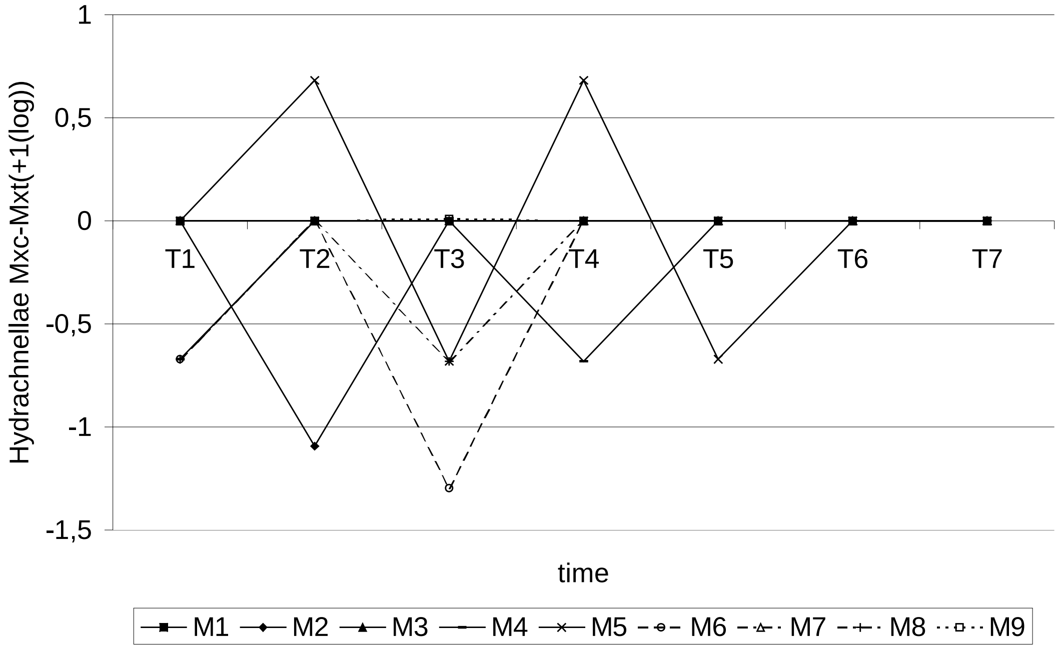


Fig. 156: The differences in numbers between the treated and control enclosures of Hydrachnellae in the enclosures in Pond M through time.

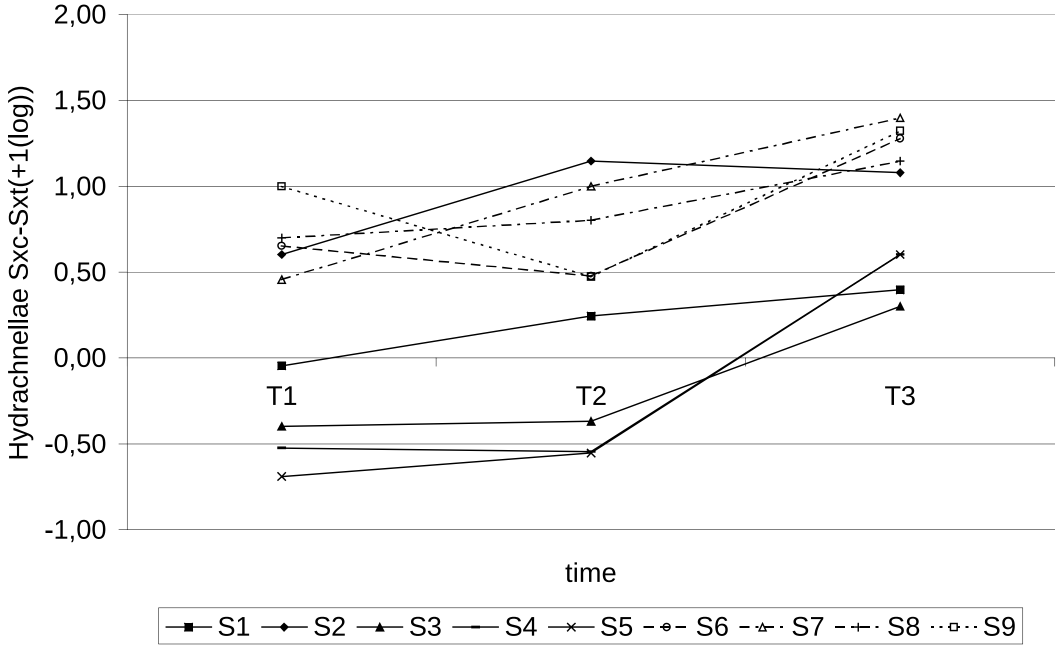


Fig. 157: The differences in numbers between the treated and control enclosures of Hydrachnellae in the enclosures in Pond S before the treatments, after the first and after the second treatment.

In Pond M, the population of *Gammarus* was so low that the effect of the cypermethrin was difficult to observe. Only in one enclosure (M5), at one date (T6), more scud specimens were found in the treated enclosure than in the untreated one. All other enclosures measured higher numbers in the control enclosures. No plant density was preferred (Fig. 154). After the 100 ng/l treatment, all treated enclosures in Pond S measured lower *Gammarus* numbers. After the second treatment, only the enclosures with the high plant densities (S8, S6) showed further reduction in population (Fig. 155). For a close related species (*Gammarus pulex*) the LC 50 (24h) dose level for cypermethrin was 40 ng/l (Mian & Mulla 1992).

In Pond M, there were not enough Hydrachnellae specimens present at the sampling dates, so that the counts cannot be associated with the treatments nor with the plant densities (Fig. 156). In Pond S, the treated enclosures S1, S2 and S7 showed a reduction in Hydrachnellae population after the 100 ng/l treatment. After the second treatment the enclosures S3-S9 showed a further effect (Fig. 157).

In Pond M, the numbers of all the Baetidae sank rapidly in all except one (M7) treated enclosure after the first treatment. At the sampling date T4 the control of enclosure M7 had reduced Baetidae numbers due to emergence. The difference between treated and untreated enclosures became negative. After the second treatment the effect was not as clear because the emergence influenced the larvae numbers in both the treated and untreated enclosures (Fig. 158).

The development of the population of the mayfly *Cloeon dipterum* in the enclosures of Pond M fluctuated to a great degree. This was due to the emergence process, taking place before and after the treatments in all enclosures. The numbers were reduced within the control enclosures due to emergence and additionally in the treated enclosures to the cypermethrin treatment. The effect of the first treatment on the *Cloeon* population was documented in the enclosures M1, M3, M5, M6 and M8. There was a clear, visible difference between the untreated and the treated enclosures between the sampling dates T3 and T4. An effect of the different plant densities could not be seen (Fig. 159). The number of the *Cloeon dipterum* larvae documented effects of the two cypermethrin treatments in all enclosures. The populations in the enclosures with the lower plant densities (S1 –S6) were influenced by the 100 ng/l treatment to an greater extent than the other enclosures. The second treatment of 1000 ng/l lead to a total breakdown of the mayfly population within all enclosures (Fig. 160). The LC 50 (24 h) dose level for cypermethrin is 600 ng/l (Stephenson 1982) and for LC 50 (96 h) 46 ng/l (Maund unpublished).

The larvae of Zygoptera showed no clear reaction to the cypermethrin treatments in both ponds. They did not prefer a certain plant density. Some treated enclosures counted more (M1, M8), some less (S1, S2) specimens than the untreated controls with the same macrophyte density (Fig. 161, 162). The (movement) EC 50 (48 h) dose level for cypermethrin by Coenagrion is > 5 µg/l (Maund unpublished).

In the treated enclosures in Pond M, the numbers of the Coleoptera *Eubrychius velutus* were reduced due to the 100 ng/l cypermethrin treatment. The difference between the control and the treated enclosure with the same plant density was changed through the second treatment (Fig 163). The *Haliplus spp.* specimens showed similar results (Fig. 164). The ability to fly and recolonize water bodies relatively quickly makes these organisms difficult to use in an open field experiment like the one used in this study. The same difficulties arose with the following water beetles species: *Hydroporus palustris*, *Guignotus pusillus*, *Ilybius ater* and *Helophorus minutus,* and the Heteroptera species, *Plea leachi* and *Notonecta glauca.* Additionally they were not all represented in sufficient numbers to detect an effect of cypermethrin and they did not seem to prefer a certain plant density.

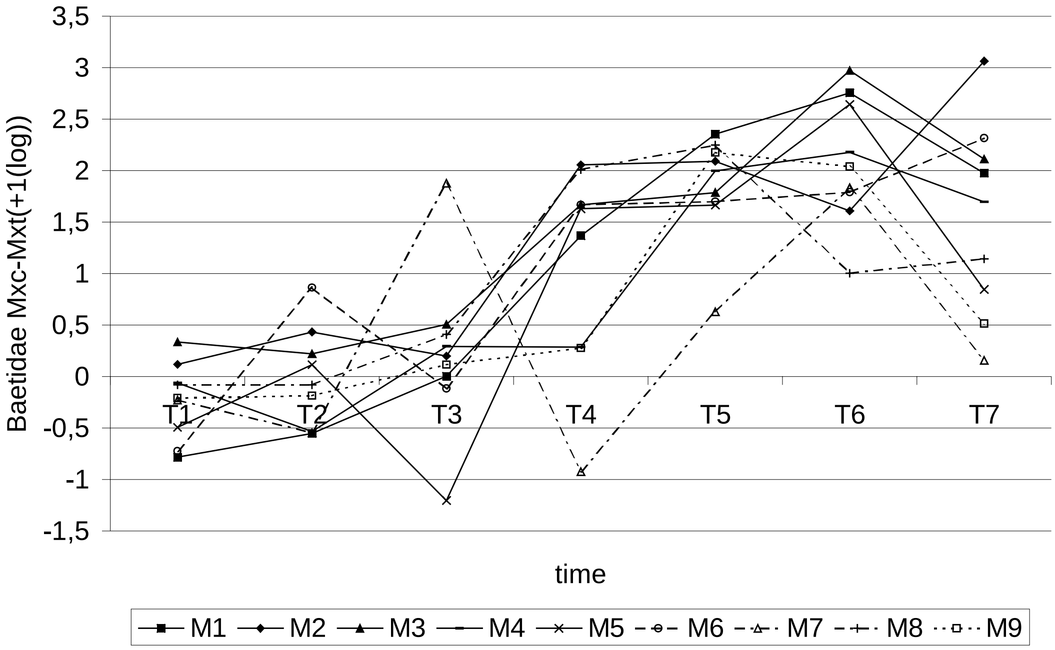


Fig. 158: The differences in numbers between the treated and control enclosures of Baetidae in the enclosures in Pond M through time.

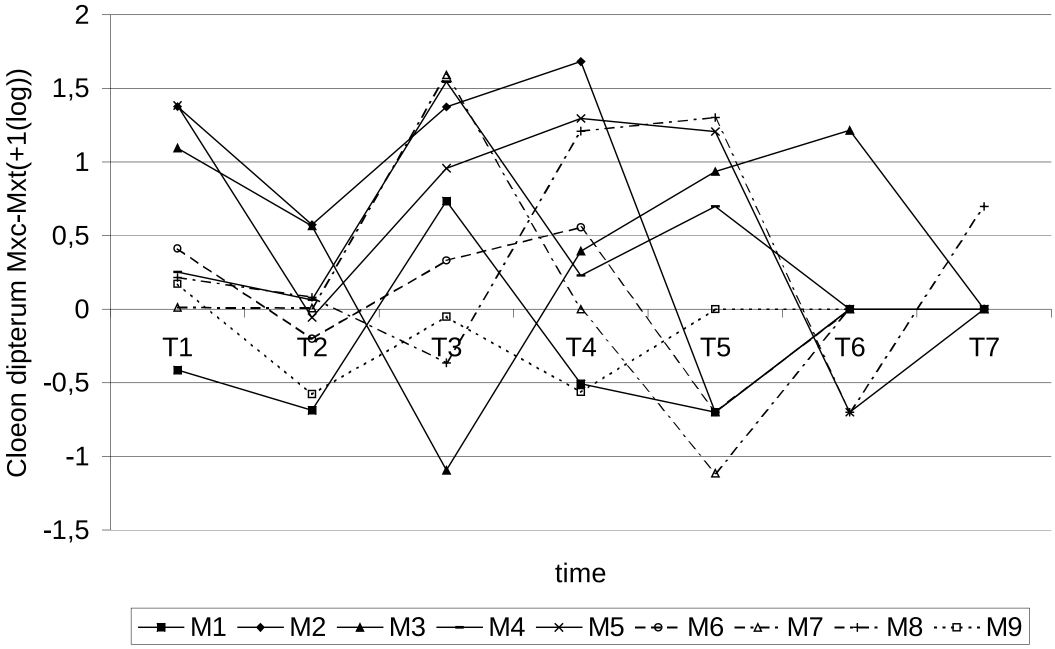


Fig. 159: The differences in numbers between the treated and control enclosures of *Cloeon dipterum* in the enclosures in Pond M through time.

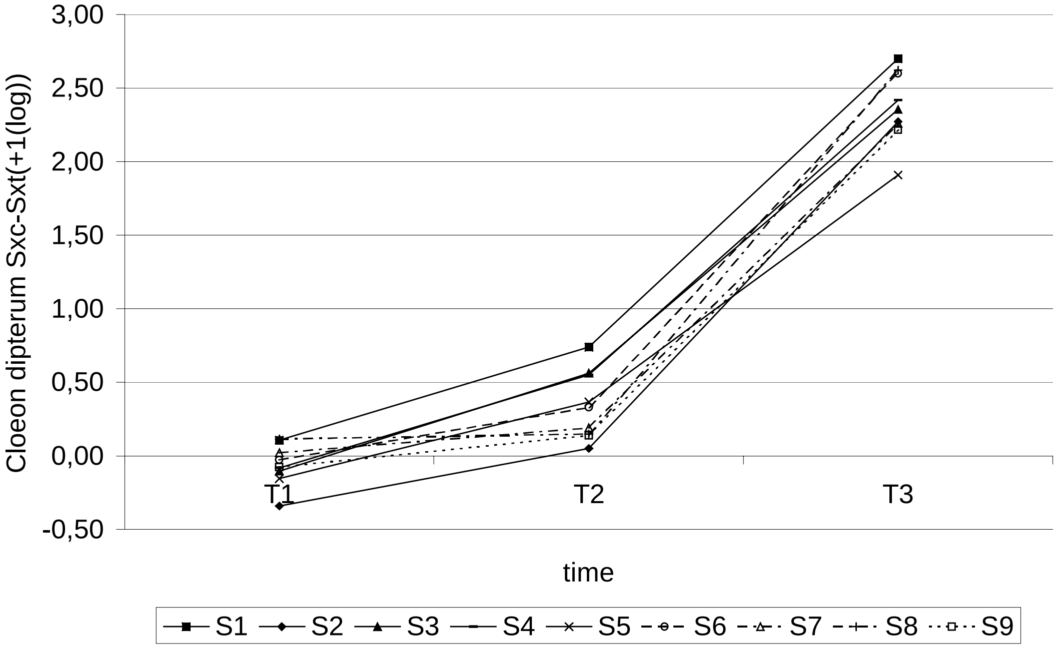


Fig. 160: The differences in numbers between the treated and control enclosures of *Cloeon dipterum* in the enclosures in Pond S before the treatments, after the first and after the second treatment.

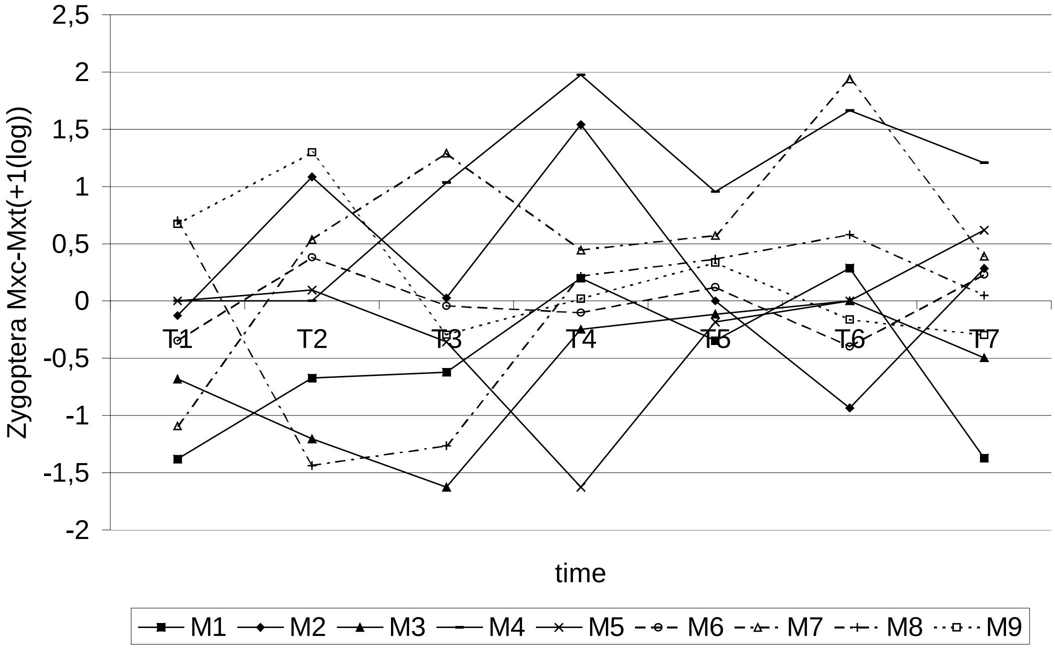


Fig. 161: The differences in numbers between the treated and control enclosures of Zygoptera in the enclosures in Pond M through time.

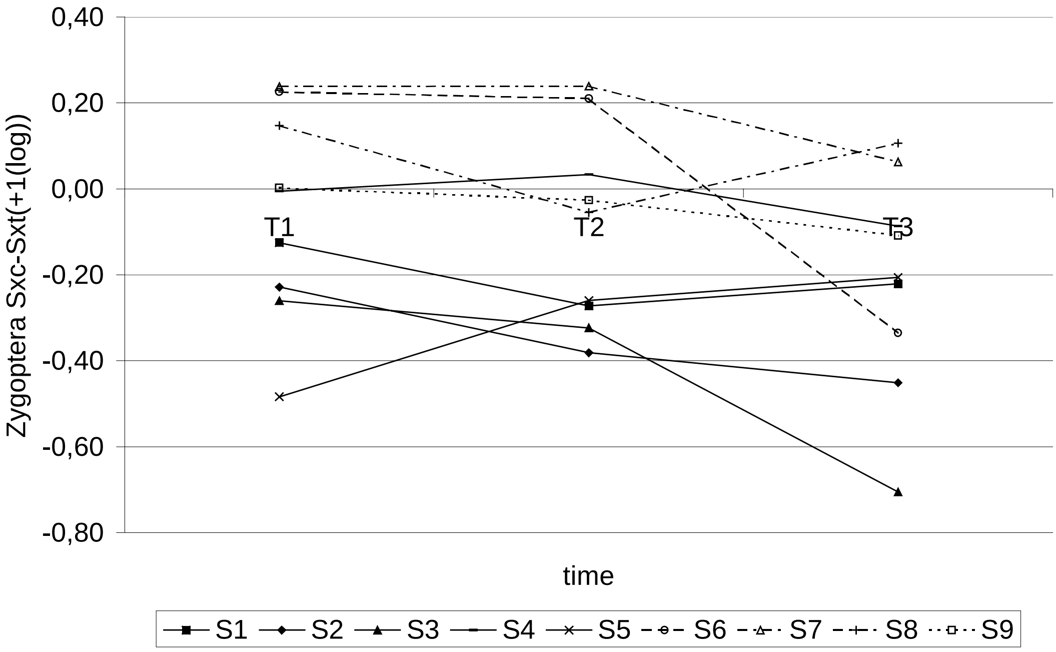


Fig. 162: The differences in numbers between the treated and control enclosures of Zygoptera in the enclosures in Pond S before the treatments, after the first and after the second treatment.

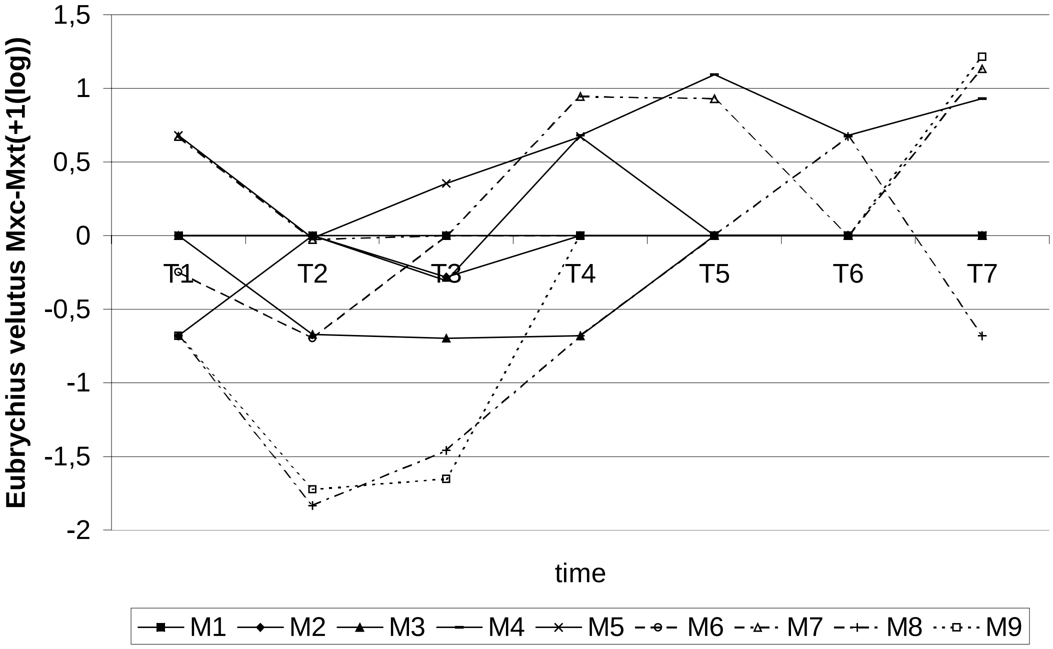


Fig. 163: The differences in numbers between the treated and control enclosures of *Eubrychius velutus* in the enclosures in Pond M through time.

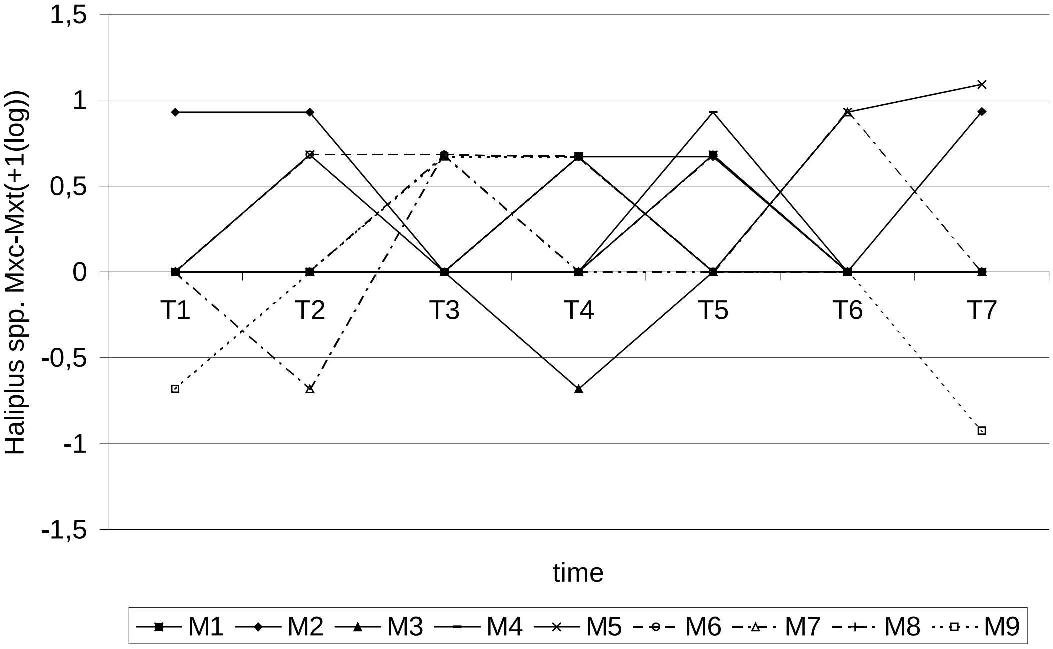


Fig. 164: The differences in numbers between the treated and control enclosures of *Haliplus spp.* in the enclosures in Pond M through time.

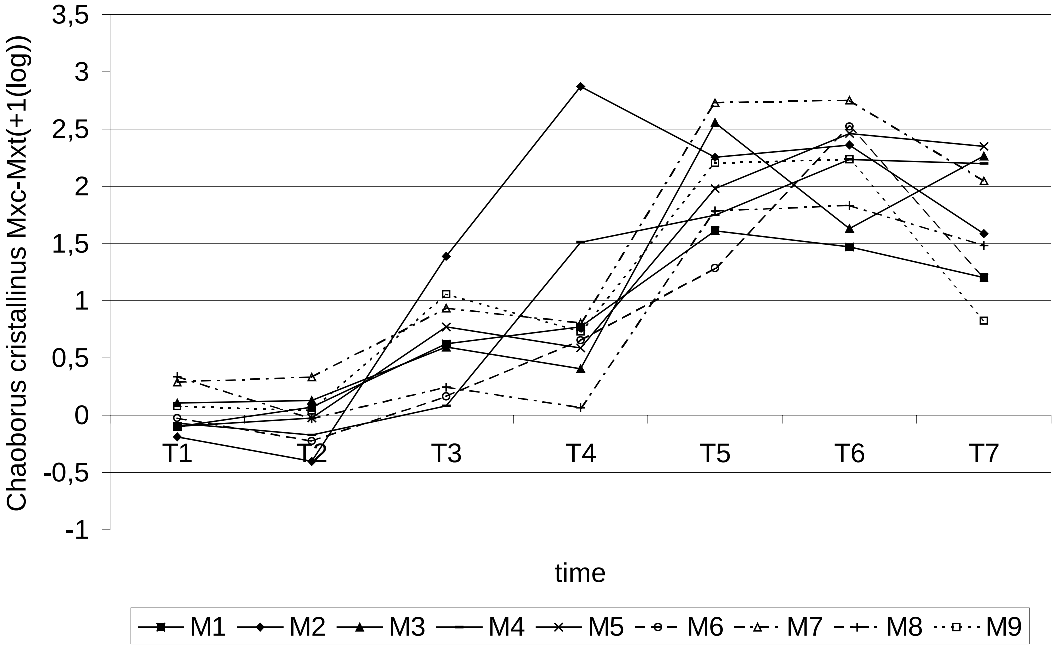


Fig. 165: The differences in numbers between the treated and control enclosures of *Chaoborus crystallinus* in the enclosures in Pond M through time.

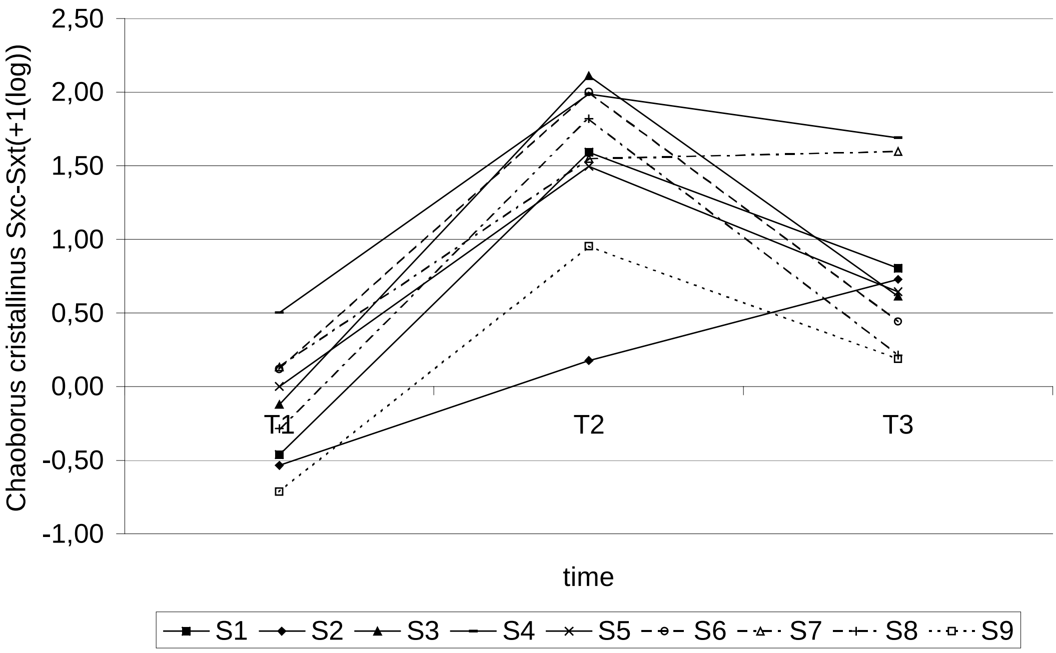


Fig. 166: The differences in numbers between the treated and control enclosures of *Chaoborus crystallinus* in the enclosures in Pond S before the treatments, after the first and after the second treatment.

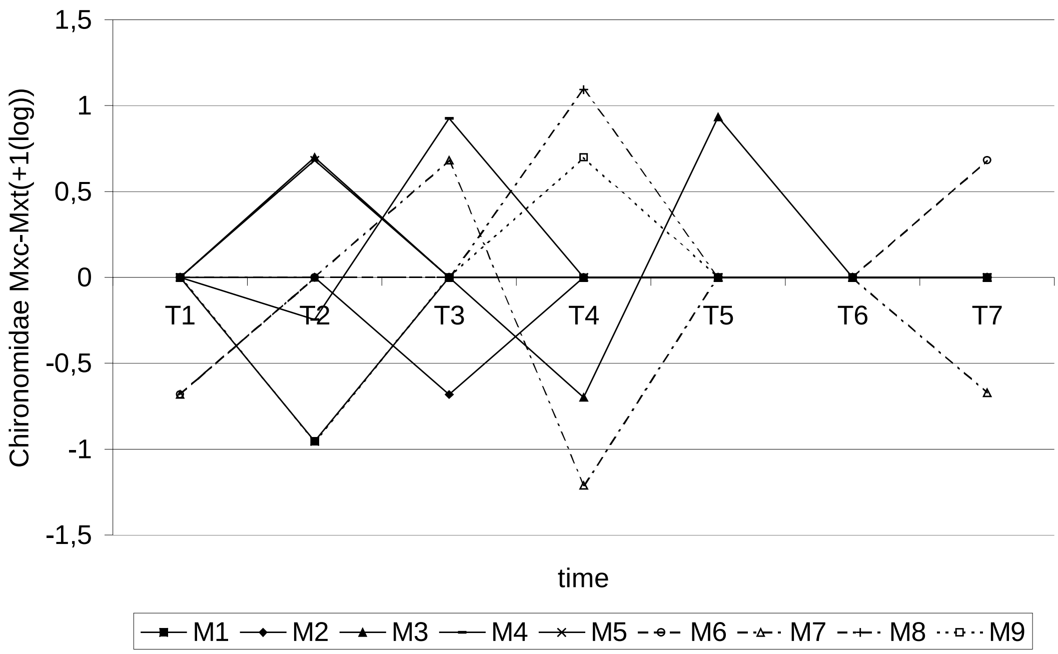


Fig. 167: The differences in numbers between the treated and control enclosures of Chironomidae in the enclosures in Pond M through time.

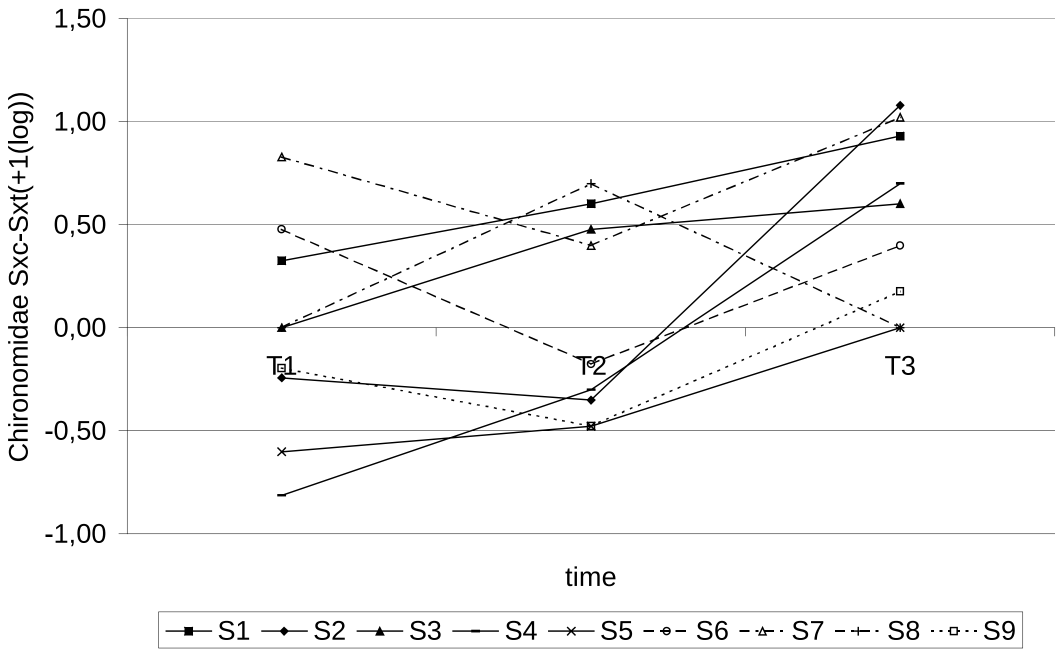


Fig. 168: The differences in numbers between the treated and control enclosures of Chironomidae in the enclosures in Pond S before the treatments, after the first and after the second treatment.

In all of the treated enclosures the larvae of *Chaoborus crystallinus* responded to the 100 ng/l treatment with a total population collapse. The hatching process within the controls on one side, and the recolonisation of all enclosures on the other, resulted in a decrease in difference between the number of larvae between the treated and the untreated enclosures. In Pond M, after the second treatment, the difference increased, because the recolonisation of the control enclosures continued. Later on, the midges emerged from the controls. The same happened in Pond S towards the time of the second treatment. The different plant densities did not influence the effect the cypermethrin had on the number of *Chaoborus* larvae. The midges disappeared on both application dates regardless of the plant density (Fig. 165, 166). The EC50 and LC50 concentrations for the phantom midge, *Chaoborus crystallinus,* range between 0,03µg/0,2µg (Hill 1985). The LC 50 (24h) dose level for cypermethrin has been determined with 200 ng/l (Stephenson 1982) and (movement) EC 50 (48h) with 3 ng/l (Maund unpublished).

The first treatment did not influence the larvae of the Chironomidae in the treated enclosures in Pond M. In Pond S, the treated enclosures with the lower plant densities (S1, S3, S4) showed a decrease in numbers of larvae. This effect was not visible in the treated enclosures with the higher macrophyte content. The reaction of the Chironomidae population to the second cypermethrin treatment was not documented because the larvae had already emerged from the controls. In Pond S, all enclosures except S8 reacted with a decrease in numbers within the treated enclosures (Fig. 167, 168). The LC 50 (24h) dose level for cypermethrin for a related species (*Chironomus thummi*) is > 5 µg/l (Hill 1985).

3.2.3.4 Community analysis (PRCs)

The first canonical coefficient of the principal response curves for all species in Pond M explains 20,3 % of the variance. This multivariate statistical method eliminates the variance of time and the system in order to concentrate on the effect of the treatment. The species with the highest species scores were the small Baetidae, *Chaoborus crystallinus* and *Asellus aquaticus.* A medium ranged species score was calculated for Zygoptera, *Haliplus spp, Eubrychius velutus, Cloeon dipterum, Dugesia spp., Gammarus roeseli* and the Tubificidae (Table 12). The species scores of the other species varied between 0,1520 and –0,1280.

The curves of all enclosures showed a clear effect from the first treatment of 100 ng/l (0,1 µg/l) cypermethrin (T3). The species *Chaoborus crystallinus, Asellus aquaticus,* Zygoptera, *Cloeon dipterum* and *Gammarus roeseli* showed an effect by this concentration according to Mian & Mulla (1992), Stephenson (1982), Hill (1985) and Maund (unpublished).

The animals are affected immediately (Clark *et al.* 1989, Coats *et al.* 1989). The curves can be explained with the specimen numbers of the species with the highest loadings, the small Baetidae and *Chaoborus crystallinus* (Fig. 158, 165). The enclosure showed M1t and M2t with the lower plant densities started out as being different as the other enclosures, even before the treatment. The different plant densities did not influence the reaction of the macroinvertebrate community towards the cypermethrin significantly.

The macroinvertebrate community did not reflect the 1000 ng/l application. The explanations were given by the specimen numbers of the small Baetidae and *Chaoborus crystallinus.* The specimens decreased in the controls due to the hatching process. The treated enclosures had no specimens as a result of the first treatment. That way the curves in the prc are reversed. All enclosures behaved in the same manner, regardless to their plant density.

Table 12: The species scores with the most weight in Pond M.

species	scores
Tubificidae	0,2958
Gammarus roeseli	-0,1671
Dugesia spp.	-0,2113
Cloeon dipterum	-0,2251
Eubrychius velutus	-0,2515
Haliplus spp.	-0,2749
Zygoptera	-0,3892
Asellus aquaticus	**-0,8693**
Baetidae small	**-2,0838**
Chaoborus crystallinus	**-2,1635**

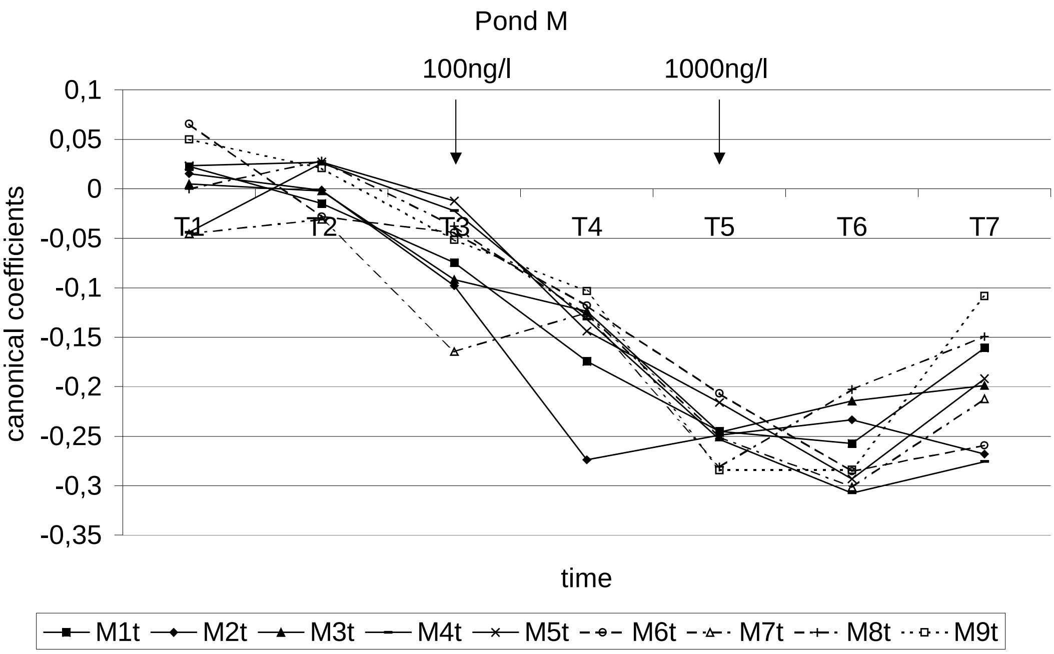


Fig. 169: Principal response curve analysis of the macroinvertebrate community of the enclosures in Pond M.

The principal response curve for Pond S, of all macroinvertebrate species, was calculated with the first canonical coefficient which explains 20,5 % of the variance. The highest species scores were calculated for *Cloeon dipterum*, *Chaoborus crystallinus*, *Gammarus roeseli* and *Asellus aquaticus*. A medium weight species scores had the Hydrachnellae and the Zygoptera. The species scores of the other species ranged between 0,1088 and –0,164 (Table 13).

Table 13: The species scores with the most weight in Pond S

species	scores
Zygoptera	0,1202
Hydrachnellae	-0,3166
Asellus aquaticus	**-0,5266**
Gammarus roeseli	**-0,5507**
Chaoborus crystallinus	**-0,5519**
Cloeon dipterum	**-0,7185**

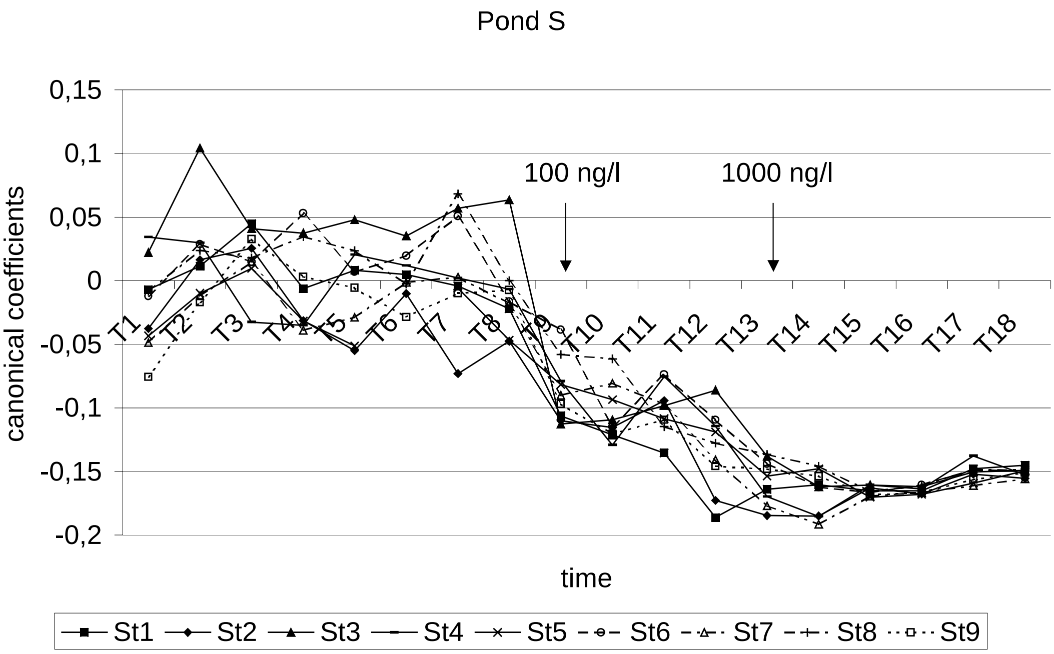


Fig. 170: Principal response curve analysis of the macroinvertebrate community of the enclosures in Pond S. (The sampling dates T1-8 are equivalent to the time interval T1, T9-12 represent T2 and T13-18 represent T3).

The principal response curves calculated for the macroinvertebrate community in Pond S reflected the first cypermethrin application clearly. At the sampling dates T9 and T10 the curves of all enclosures became negative (Fig. 170). The development was similar at all the enclosures. The macrophyte density did not influence the effect of the cypermethrin significantly. The second cypermethrin treatment only showed an effect in the all enclosures, except St1. The effect was not observed as severe as at the first application. This was due to the low specimen numbers present in the treated enclosures. A reverse trend of the curves was also documented. The effect of the chemical was not significantly different within the enclosures with the different plant densities.

3.2.3.5 Cypermethrin analysis

The cypermethrin analysis of the water column was conducted in three enclosures with different plant densities in each Pond (Table 14). After the first cypermethrin application samples were taken after 1, 3, 24 and 72 hours. The enclosures with the lowest plant density (M1t, S2t) showed a lower cypermethrin dissipation rate, after the first hour, than the enclosures with higher plant densities. After 3 hours the dissipation rate of all enclosures was similar. In Pond M the residue levels were higher than in Pond S. The level reached in all enclosures after 72 hours was beneath 10 ng/l in both Ponds (Fig. 171, 172).

Table 14: Total plant surface, wet and dry weight of the examined enclosures.

enclosure	total plant surface (cm2)	wet weight (g)	dry weight (g)
Pond M9t	45585,47	1129,50	116,47
Pond M4t	27702,11	916,50	90,01
Pond M1t	25645,00	897,00	94,01
Pond S9t	47162,65	1061,50	179,58
Pond S3t	9515,28	381,00	70,75
Pond S2t	5981,63	192,00	32,29

After the 1000 ng/l cypermethrin application samples were taken after 1, 3, 6, 12, 24 hours and after 7 and 14 days. In Pond S an additional sample was taken after 4 days. The enclosures with the medium plant density (M4t, S3t) revealed the highest cypermethrin residue levels after 1 hour in both ponds. In Pond M the medium enclosure measured higher levels up to the sampling after 7 days. The other 5 enclosures had a very similar dissipation rate after the 3 hours sampling (Fig. 173, 174).

A significantly different dissipation rate for the different plant densities was not found.

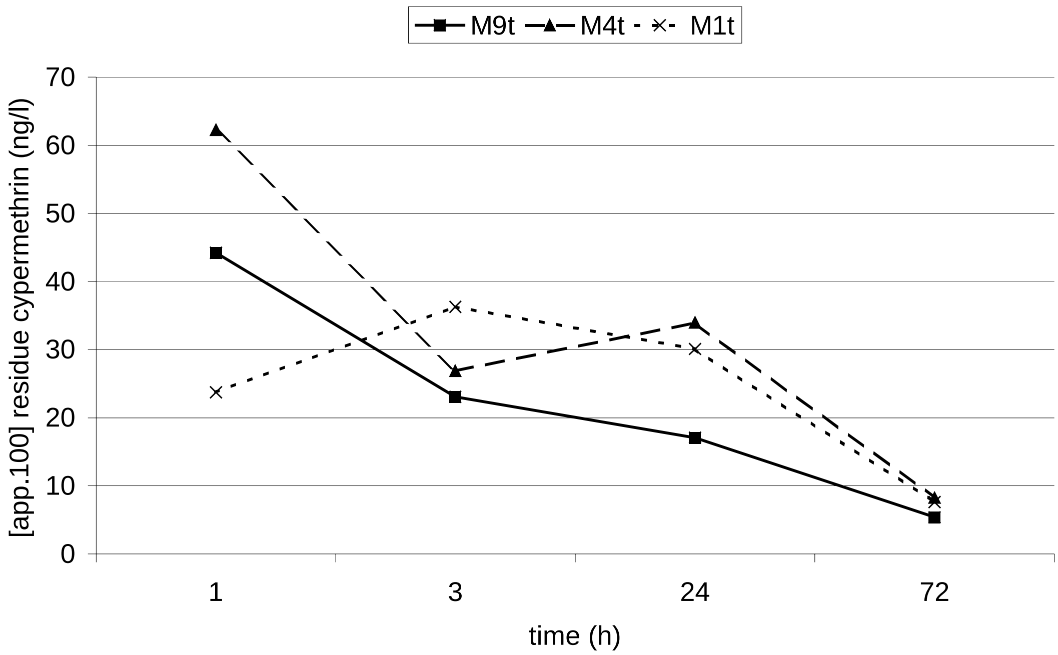


Fig. 171: Cypermethrin residue after the 100 ng/l application in Pond M.

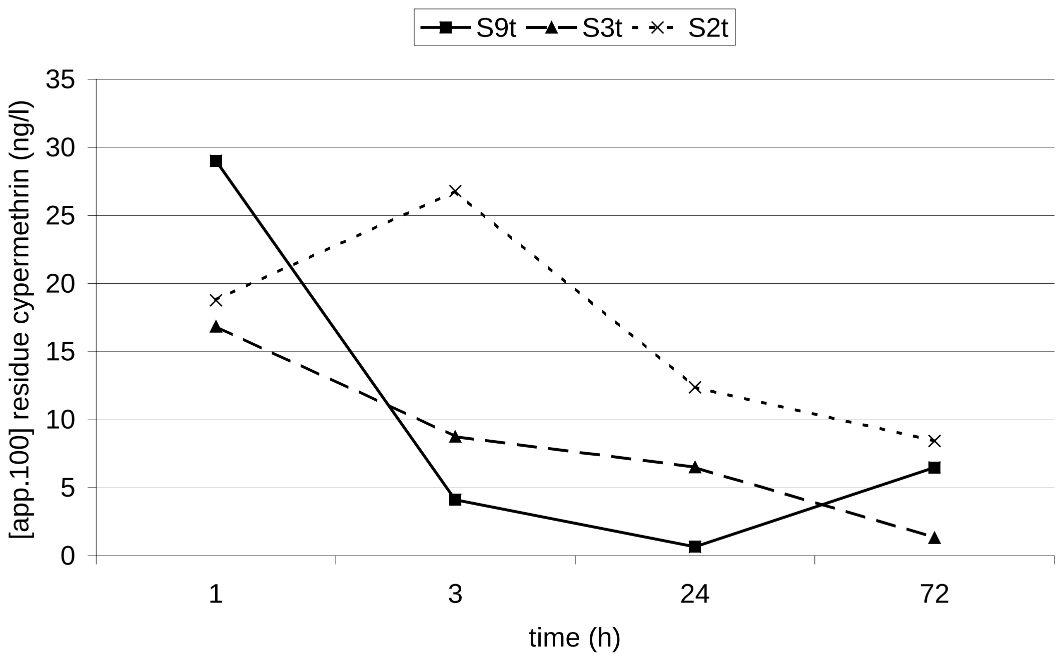


Fig. 172: Cypermethrin residue after the 100 ng/l application in Pond S.

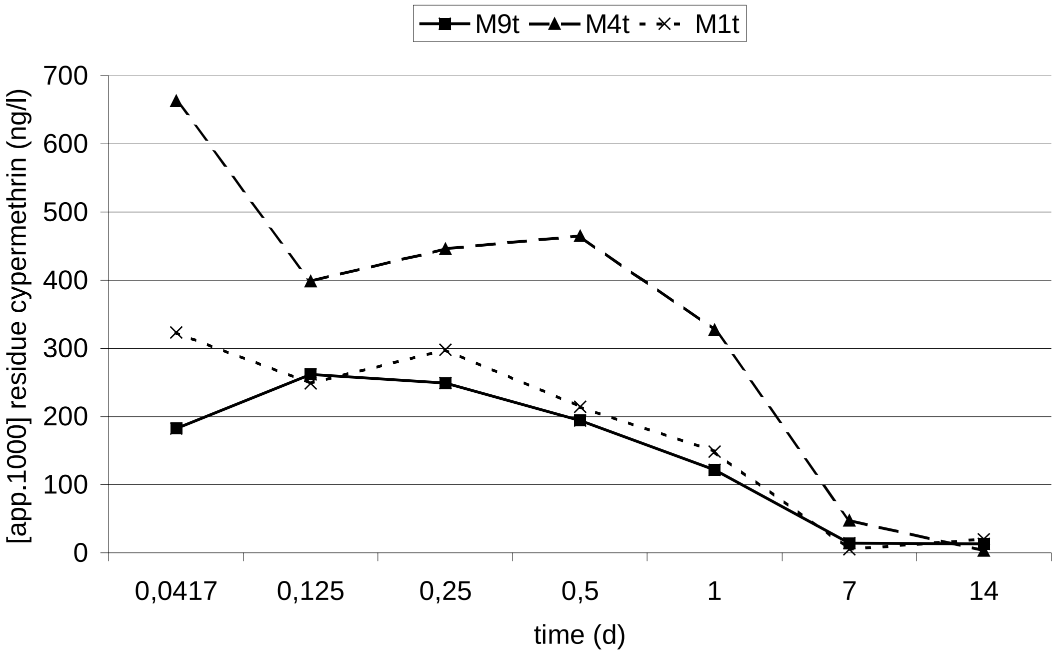


Fig. 173: Cypermethrin residue after the 1000 ng/l application in Pond M.

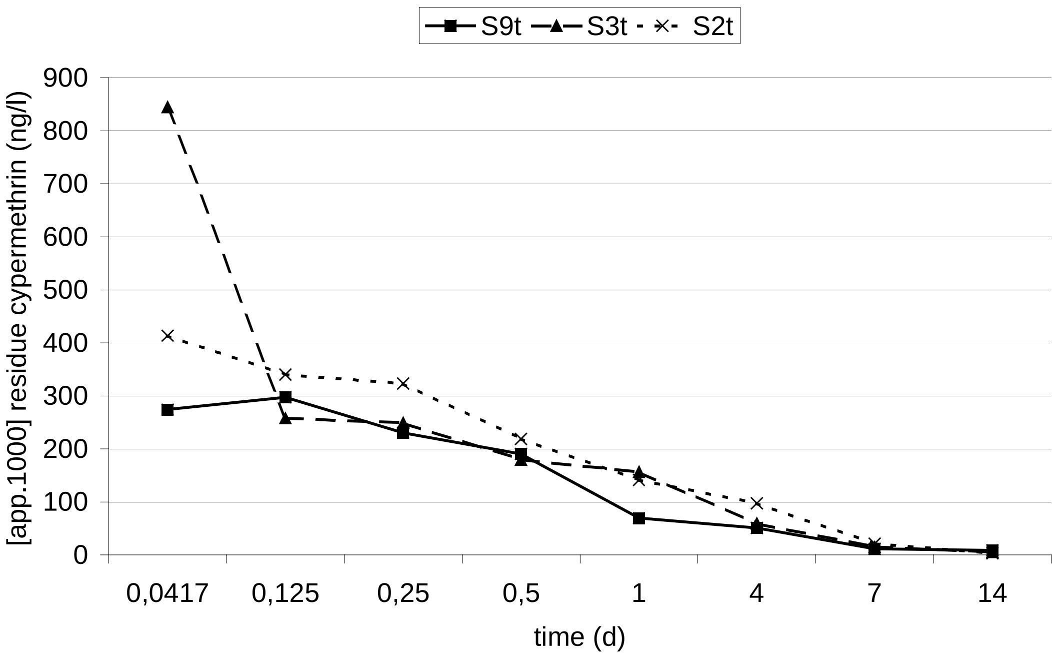


Fig. 174: Cypermethrin residue after the 1000 ng/l application in Pond S.

4 Final discussion and conclusions

4.1 Does the mesocosm system respresent a natural littoral zone?

In order to answer the question to what extent an artificial mesocosm systems represents a natural littoral zone, the environmental conditions have to be taken into account first. The relationship between ammonia and nitrate is predominantly dependent on the oxygen level in the system. In comparison to the examined littoral habitats, the mesocosm showed much more unstable oxygen conditions. One result was the higher ammonia level and the lower nitrate level in the systems. The light could not penetrate through the water column to the bottom of the artificial enclosures due to the steel frame. The decomposition processes could not be compensated through the photosynthetic activity (in the lower part of the enclosure). The conductivity was another parameter, which showed much lower values within the enclosure systems compared to the natural habitat. The missing ionic input through run off is an obvious deficiency at the isolated mesocosm. The volume of the tested pond or enclosure has a big influence on the limnological parameters (Severin *et al.* 1999). These deficits require manipulating regulations in order to be within the same range as the natural equivalent.

There are a great variety of natural sources of stress within the littoral zone of a lake. This forces the littoral zone community to adapt to the changing environmental conditions within short periods of time (DGL Arbeitskreis 1999). The flood in 1999 influenced most of the measured physical and chemical parameters (dissolved organic carbon, ammonia and nitrate). In rivers, floods can contribute to the variety of the macroinvertebrate community (Resh & Rosenberg 1984). At the examined littoral habitats, the macroinvertebrate community compensated the flood. The species community remained the same after the flood, although some species numbers fluctuated to a greater extent.

The established artificial mesocosm Pond M developed a littoral macroinvertebrate community, which differed from the one at the natural microhabitats. The species inhabiting the lake littoral were transferred to the mesocosm to 62%. Due to the enclosure effect, the number of species within the enclosures was reduced further to 22% of the lake macroinvertebrates. In order to improve the introduction of the complex macroinvertebrate community in an artificial pond further steps have to be taken. The less space did not offer enough habitat variability for the macroinvertebrates. Devices to enable the colonisation of shallow areas are needed.

The reed community at the lake sites was the one with the greatest species richness. The one-meter depths and the floating leaf macrophytes did not offer enough niches for the macroinvertebrate community.

In conclusion for the construction of artificial mesocosms the reflection of the natural environment is most important. The establishment phase of one year at Pond M was acceptable in order to maintain more stable physical and chemical parameters. The species composition introduced from the lake habitats survived only a few months and then disappeared. The experiment with Pond S showed, that its shorter lasting lifetime, gave very similar results. The community, which settled in the enclosed systems, was nearly identical.

4.2 Does the plant density of the mesocosm influence the toxicity of cypermethrin?

Pyrethroids, in combination with the group of the organophosphates, are the most commonly used insecticides that have a long history and are still up to date today (Elliot 1989, Mogensen & Stuer-Luaridsen 1996). In 1998, about 61 tons of pyrethroids were sold in Germany (BBA unpublished). The pesticides find their way into the freshwater system through run off and direct use against unwanted mosquito larvae (Hill 1985). Cypermethrin, which was tested in the study, serves as an example for many other used pyrethroids.

The two application levels (100 ng/l and 1000 ng/l cypermethrin) affected the macroinvertebrate community in both tested pond systems significantly. The double application caused the macroinvertebrate community to collapse (Fairchild *et al.* 1992, Farmer & Maund 1995). Species populations of *Asellus aquaticus, Gammarus roeseli, Chaoborus crystallinus* and *Cloeon dipterum* were completely destroyed. Although the major predator of the system, *Chaoborus crystallinus,* disappeared no secondary effect of the treatments (Cairns 1983, Fent 1998) such as an increase in other predators like Zygoptera, was observed. Sublethal effects could also not be examined. These effects are better determined under close up supervision in the laboratory.

The environmental conditions within a test system are mainly determined by the macrophytes (Blake 1994). Cypermethrin is known for its ability to adsorb on organic and inorganic surfaces (Kennedy 1994). The fate of pyrethroids (cypermethrin) is characterised by the sorption, hydrolysis, photolysis and microbial degradation (Agnihotri *et al.* 1986, Agnihotri *et al.* 1989, Crossland 1982).

The theory that more plant biomass and surface reduces the toxic effect has been suggested for the pyrethroid lambda-cyhalothrin (Hand *et al.* 2000). The study conducted was designed to determine, whether or not the tested plant densities showed an influence on the treatment effects. The observed difference between the macroinvertebrate community in the treated enclosures and the untreated controls with the different plant densities was not significant.

In order to examine the influences of the plant surface and the cypermethrin toxicology fate studies with labelled cypermethrin, need to be conducted. The question, of whether or not the pyrethroid stuck to the organic matter, the inorganic steel coat of the enclosures or if it was consumed by the organisms, can be answered in those kind of studies. This is the only way to gather the evidence on the cypermethrin whereabouts. The pathways of the pyrethroids have to be exploited on a small scale as well as in bigger outdoor systems.

5 Summary

5.1 English

Several macrophyte communities in the littoral zone of Lake Ammersee (Bavaria, Germany) and the inhabiting fauna were examined in the years 1998 and 1999. To represent a broad variability of the littoral, the sample sites differed in morphology, sediment and nutrient input. The defined macroinvertebrate community of the examined littoral habitats consisted of the following 16 major taxa: *Gammarus roeseli, Asellus aquaticus, Bithynia tentaculata, Potamopyrgus jenkinsi, Dreissena polymorpha,* Elimidae, *Caenis spp., Cloeon dipterum, Centroptilum luteolum,* Zygoptera, *Mystacides spp., Limnephilus lunatus, Sialis lutaria,* Hydrachnellae, *Micronecta sclolzi* and Chironomidae. The community did not change significantly at the sites with different indicated trophy. The physical and chemical parameters of the littoral habitats had more resemblance at the sites with the same geographical location (sediment) than the habitats with equal depths. The values from the pelagic zone were either similar to the closer Schondorf sites or were totally different from any measured at the littoral sites.

In addition, different enclosure systems were established at the research facility of the Technical University of Munich. The mesocosm systems were equipped with water, sediment and the macrophytes from Lake Ammersee. The different biotic structures and microhabitats were adapted from the lake sites. The two pond-systems were subdivided into 18 enclosures. Nine enclosures were treated with the insecticide cypermethrin, the other nine served as controls. The double application dose of the cypermethrin was 100 ng/l and 1000 ng/l. The enclosures differed in plant densities (between 0,3 and 2 g/l wet plant material). The results showed that the different plant densities did not influence the toxic effect of cypermethrin on the macroinvertebrate community. The treated enclosures all showed more or less the same toxic effect on the macroinvertebrate community regardless to their plant density.An average of 53 taxa was found at the lake sites. Within the lake enclosures, the number of species was reduced to 37% of the surrounding littoral area. In the artificial mesocosm 62% of the littoral fauna were established. The lowest species numbers were found in the enclosures within the mesocosm (only 22% of the lake littoral fauna). The diversity value (Shannon) at the lake site was significantly higher than in the enclosed systems.

5.2 German

Verschiedene Makrophyten und deren Makroinvertebratengesellschaften im Seenlitoral des Ammersees wurden in den Jahren 1998 und 1999 untersucht. Die Probestellen unterschieden sich hinsichtlich ihrer Morphologie, Trophie sowie der Beschaffenheit des Sediments. Folgende 16 Taxa wurden gefunden: *Gammarus roeseli, Asellus aquaticus, Bithynia tentaculata*, *Potamopyrgus jenkinsi*, *Dreissena polymorpha,* Elimidae*, Caenis spp., Cloeon dipterum, Centroptilum luteolum,* Zygoptera, *Mystacides spp., Limnephilus lunatus, Sialis lutaria,* Hydrachnellae, *Micronecta scholzi* and Chironomidae. Die Gesellschaft änderte sich nicht signifikant mit veränderter Trophie der Probestellen. Die physikalischen und chemischen Parameter der Litoralhabitate der gleichen geographischen Lage zeigten mehr Ähnlichkeit als die der selben Seetiefe.

Zusätzlich wurden zwei unterschiedliche künstliche Mesokosmensysteme auf dem Gelände der Technischen Universität München, Weihenstephan errichtet. Sie wurden mit Wasser, Sediment und Pflanzen aus dem Ammersee ausgestattet. Die Testteiche wurden in 18 Kompartimente unterteilt. Neun davon wurden mit dem Pyrethroid Cypermethrin belastet und neun dienten als Kontrollen. Eine Doppelapplikation von 100 ng/l und 1000 ng/l Cypermethrin wurde getestet. Die einzelnen Kompartimente unterschieden sich in ihrer Pflanzendichte (zwischen 0,3 and 2 g/l Pflanzennassgewicht). Die Ergebnisse zeigten, dass die einzelnen Pflanzendichten keinen signifikanten Einfluss auf die toxische Wirkung Cypermethrins bezüglich der Makroinvertebraten hatten. Die Artengesellschaften der belasteten Enclosures glichen sich unabhängig von ihrer Pflanzendichte.

An den Litoralprobestellen wurden durchschnittlich 53 Taxa gefunden. Innerhalb der Seen-kompartimente wurde die Artenzahl auf 37% reduziert. In den künstlichen Mesokosmen etablierten sich 62% der Makroinvertebratentaxa. Innerhalb der Kompartimente der Testsysteme konnten nur 22% angesiedelt werden. Der Diversitätsindex (Shannon) war in den Seehabitaten signifikant höher als in den nachempfundenen Testsystemen.

6 Appendix: Calendar and sampling schedule

12.01.1998: WATER CHEMISTRY *Ammersee* pelagic zone
09.02.1998: WATER CHEMISTRY *Ammersee* littoral sites; Pond M
10.02.1998: WATER CHEMISTRY *Ammersee* pelagic zone
09.03.1998: WATER CHEMISTRY *Ammersee* pelagic zone and littoral sites; Pond M
31.03.1998: Sediment Pond M established
02.04.1998: Pond M filled with water
06.04.1998: WATER CHEMISTRY *Ammersee* pelagic zone and littoral sites; Pond M
30.04.1998: Pebble Baskets were set up in Pond M
04.05.1998: WATER CHEMISTRY *Ammersee* littoral sites, Pond M, pebble baskets were set up at the Lake
05.05.1998: WATER CHEMISTRY *Ammersee* pelagic zone
20.05.1998: Sampling pebble basket Pond M
27.05.1998. Sampling pebble basket *Ammersee*
02.06.1998: WATER CHEMISTRY *Ammersee* littoral sites, Pond M
03.06.1998: WATER CHEMISTRY *Ammersee* pelagic zone
10.06.1998: Sampling pebble basket Pond M
18.06.1998: Sampling pebble basket *Ammersee*
01.07.1998: Sapling pebble basket Pond M
06.07.1998: WATER CHEMISTRY *Ammersee* pelagic zone, littoral sites, Pond M; pebble basket Ammersee
20.07.1998: Pebble basket Pond M; plants planted in pots in Pond M
27.07.1998: WATER CHEMISTRY *Ammersee* pelagic zone and littoral sites; Pond M
15.08.1998: Sampling pebble basket Pond M
13.08.1998: Sampling pebble basket *Ammersee*
19.08.1998: Sapling pebble basket *Ammersee*
24.08.1998. WATER CHEMISTRY *Ammersee* littoral sites, Pond M; sampling pebble basket *Ammersee*
25.08.1998: WATER CHEMISTRY *Ammersee* pelagic zone
01.09.1998: Mapping of the macrophytes at the lake sites
16.09.1998: Sampling pebble basket *Ammersee*
21.09.1998: WATER CHEMISTRY *Ammersee* littoral sites, Pond M
23.09.1998: WATER CHEMISTRY *Ammersee* pelagic zone; sampling pebble basket Pond M
08.10.1998: Sampling pebble basket *Ammersee*
19.10.1998: WATER CHEMISTRY *Ammersee* pelagic zone and littoral sites; Pond M
26.10.1998: Sampling pebble basket Pond M
28.10.1998: Sampling pebble basket *Ammersee*
17.11.1998: WATER CHEMISTRY *Ammersee* pelagic zone
18.11.1998: WATER CHEMISTRY *Ammersee* littoral sites, Pond Mand sampling pebble basket *Ammersee*
23.11.1998: Pond M froozen!
14.12.1998: WATER CHEMISTRY *Ammersee* pelagic zone and littoral sites; Pond M
11.01.1999: WATER CHEMISTRY *Ammersee* pelagic zone and littoral sites, Pond M
08.02.1999: WATER CHEMISTRY *Ammersee* pelagic zone
11.02.1999: WATER CHEMISTRY *Ammersee* littoral sites, Pond M

08.03.1999: WATER CHEMISTRY *Ammersee* pelagic zone and littoral sites, Pond M
22.03.1999: Pebble baskets set up at the Lake and at Pond M
06.04.1999: WATER CHEMISTRY *Ammersee* pelagic zone and littoral sites, Pond M
07.04.1999: Sediment and Water filled in Pond S
12.04.1999: Sampling, emergence, net, pebble basket Pond M
14.04.1999: Sampling pebble basket *Ammersee*
03.05.1999: WATER CHEMISTRY *Ammersee* pelagic zone and littoral sites, Pond M
05.05.1999: Sampling, emergence, net, pebble basket Pond M
06.05.1999: Sampling pebble basket *Ammersee*; Water filled in Pond S
11.05.1999: Plants set up in Pond S
23.05.1999: Heavy rainfalls! *Ammersee* FLOOD
26.05.1999: WATER CHEMISTRY *Ammersee* pelagic zone; Sampling, emergence, net, pebble basket Pond M
27.05.1999: WATER CHEMISTRY *Ammersee* littoral sites, Pond M; Ammersee water level back 30 cm!
07.06.1999: WATER CHEMISTRY *Ammersee* pelagic zone
08.06.1999: Sampling, emergence, net, pebble basket Pond M; Enclosures set up at Pond M; Plants stocked up at Pond M
17.06.1999: WATER CHEMISTRY Enclosures Pond M; sampling, emergence, net, pebble basket Pond M
18.06.1999: Enclosures set up in Pond S, Water filled in Pond S
20.06.1999: Sampling pebble basket *Ammersee*
21.06.1999: WATER CHEMISTRY Pond S; sampling, emergence, net, pebble basket Pond S
22.06.1999: WATER CHEMISTRY *Ammersee* pelagic zone and littoral sites
23.06.1999: WATER CHEMISTRY Enclosures, sampling, emergence, net, pebble basket Pond M
28.06.1999: WATER CHEMISTRY Pond S; sampling, emergence, net, pebble basket Pond S
30.06.1999. WATER CHEMISTRY Enclosures Pond M; sampling, emergence, net, pebble basket Pond M
05.07.1999: WATER CHEMISTRY *Ammersee* littoral sites and enclosures Pond M and Pond S, sampling pebble basket *Ammersee* and Pond M and Pond S(emergence, net)
06.07.1999: WATER CHEMISTRY *Ammersee* pelagic zone
07.07.1999: Sampling, emergence, net, pebble basket Pond M
12.07.1999: WATER CHEMISTRY Pond S; sampling, emergence, net, pebble basket Pond S
13.07.1999: 100ng/l application Pond M
14.07.1999: WATER CHEMISTRY enclosures Pond M; sampling, emergence, net, pebble basket Pond M
16.07.1999: Sampling pebble basket *Ammersee*
19.07.1999: WATER CHEMISTRY Pond S; sampling , emergence, net, ebble basket Pond S
21.07.1999: WATER CHEMISTRY enclosures Pond M; sampling, emergence, net, pebble basket Pond M
26.07.1999: WATER CHEMISTRY *Ammersee* pelagic zone and Pond S; sampling, emergence, net, pebble basket Pond S
27.07.1999: WATER CHEMISTRY enclosures Pond M; , emergence, net, pebble basket Pond M; 100 ng/l application Pond S
28.07.1999: WATER CHEMISTRY *Ammersee* littoral sites,
02.08.1999: Sampling pebble basket *Ammersee*
03.08.1999: WATER CHEMISTRY Pond S; sampling, emergence, net, pebble basket Pond S
04.08.1999: WATER CHEMISTRY Enclosures; sampling, emergence, net, pebble basket Pond M

09.08.1999: WATER CHEMISTRY *Ammersee* pelagic zone and Pond S; sampling, emergence, net, pebble basket Pond S
11.08.1999: WATER CHEMISTRY Enclosures Pond M and *Ammersee* littoral sites; sampling, emergence, net, pebble basket Pond M
16.08.1999: WATER CHEMISTRY Pond S; sampling, emergence, net, pebble basket Pond S
18.08.1999: WATER CHEMISTRY Enclosures Pond M; sampling, emergence, net, pebble basket Pond M
20.08.1999: 1000 ng/l application Pond M; Sampling pebble basket *Ammersee*
23.08.1999: WATER CHEMISTRY *Ammersee* pelagic zone and Pond S; sampling, emergence, net, pebble basket Pond S
24.08.1999: Sampling pebble basket Pond M; 1000 ng/l application Pond S
25.08.1999: WATER CHEMISTRY Enclosures Pond M and Ammersee littoral sites; sampling, emergence, net, pebble basket Pond M
30.08.1999: WATER CHEMISTRY Pond S; sampling, emergence, net, pebble basket Pond S
01.09.1999: WATER CHEMISTRY Enclosures Pond M; sampling, emergence, net, pebble basket Pond M
06.09.1999: WATER CHEMISTRY Enclosures Pond M and Pond S and sampling, emergence, net, pebble basket Pond M and Pond S
13.09.1999: WATER CHEMISTRY Pond S; sampling, emergence, net, pebble basket Pond S
15.09.1999: Sampling pebble basket *Ammersee*
16.09.1999: WATER CHEMISTRY Enclosures Pond M; sampling, emergence, net, pebble basket Pond M
20.09.1999: WATER CHEMISTRY *Ammersee* pelagic zone and littoral sites and enclosures Pond M and Pond S; sampling, emergence, net, pebble basket Pond M and Pond S
22.09.1999: WATER CHEMISTRY Enclosures Pond M; sampling, emergence, net, pebble basket Pond M
28.09.1999: Harvesting all plants out of Pond M, Pond S
04.10.1999: Sampling pebble basket *Ammersee*
08.11.1999: WATER CHEMISTRY *Ammersee* pelagic zone and littoral sites
26.05.2000: Pond M emergence, net, pebble basket monitoring
20.06.2000: Pond M emergence, net, pebble basket monitoring

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