Auswerten von Zeigerwerten : das Programm "Aus"

Objekttyp: **Chapter**

Zeitschrift: **Berichte des Geobotanischen Institutes der Eidg. Techn. Hochschule, Stiftung Rübel**

Band (Jahr): **60 (1994)**

PDF erstellt am: **23.06.2024**

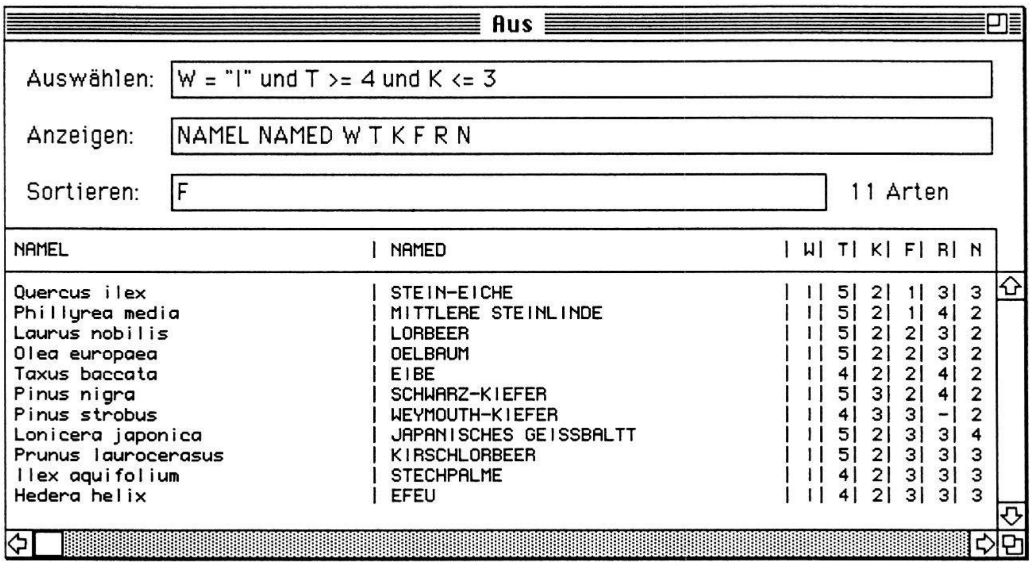
3. AUSWERTEN VON ZEIGERWERTEN: DAS PROGRAMM "AUS"

3.1 DIE ARTENLISTE DER UNI BERN ALS GRUNDLAGE

Diese Artenliste mit den Zeigerwerten nach LANDOLT (1977) wurde von der Universität Bern (W. DÄHLER) erstellt. Das Programm AUS selber kann Arten nur abrufen, aber nicht ergänzen.

3.2 MENGENLEHRE MIT ZEIGERWERTEN

Die Artenliste wird nach den Regeln der Mengenlehre zusammengestellt. UND bedeutet in Fig. 5. die Schnittmenge, resp. alle Arten die der Bedingung W="I" und gleichzeitig der Bedingung T>=4 entsprechen. Mit den Operatoren UND, ODER, ABER NICHT und der Klammer () können auch komplexe Fragestellungen beantwortet werden.



NAMEL	NAMED	W	T	K	F	R	N
Quercus ilex	STEIN-EICHE	I	5	2	1	3	3
Phillyrea media	MITTLERE STEINLINDE	I	5	2	1	4	2
Laurus nobilis	LORBEER	I	5	2	2	3	2
Olea europaea	OELBAUM	I	5	2	2	3	2
Taxus baccata	EIBE	I	4	2	2	4	2
Pinus nigra	SCHWARZ-KIEFER	I	5	3	2	4	2
Pinus strobus	WEYMOUTH-KIEFER	I	4	3	3	-	2
Lonicera japonica	JAPANISCHES GEISSBALTT	I	5	2	3	3	4
Prunus laurocerasus	KIRSCHLORBEER	I	5	2	3	3	3
Ilex aquifolium	STECHPALME	I	4	2	3	3	3
Hedera helix	EFEU	I	4	2	3	3	3

Fig. 5. Gesucht sind in einem einfachen Beispiel immergrüne Gehölze (W="I") in warmen Lagen (T>=4) und im subozeanischen Klima wie z. B. Tessin (K<=3) vorkommend. Das Programm AUS findet elf Arten.

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Auswählen: (NUMMER>=160 und NUMMER<=560 und f>=4 und R>=4) aber nicht f1>="i"
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Fig. 6. *Poaceae* und *Cyperaceae* basenreicher Flachmoore, aber nicht an dauernd überfluteten Stellen.

Vegetationstabellen sind auch Artenlisten und können als Auswahlkriterien miteinbezogen werden.

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Auswählen: f>=4 und DATEI "riet.veg"
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Fig. 7. Alle Feuchtezeiger (F>=4) in der Tabelle ***riet.veg.***

3.3 DIE ZWISCHENABLAGE VERBINDET PROGRAMME

Die Artenliste kann ausgedruckt, oder zur Weiterverarbeitung über die Zwischenablage in eine Tabelle oder einen Text kopiert werden. Die so kopierten Daten sind tabulatorgetrennt. Die Tabellenkalkulation Excel z. B. reserviert für jeden Zeigerwert eine Spalte, so dass diese für weitere Berechnungen verwendbar sind. Excel eignet sich aber auch bestens für die graphische Überarbeitung der Zeigerliste.

3.4 GEMITTELTE ZEIGERWERTE

Mittelwerte

Aufnahme/ Gesellschaft		F	R	N
42		3.4	3.0	3.2
56		3.3	3.0	3.3
30		3.5	3.0	3.3
28		3.5	2.6	3.0
.1	=>	3.4	2.9	3.2

Fig. 8. Die gemittelten Zeigerwerte der Aufnahmen und Gesellschaften.

Mittelwerte

Differentialartengruppe	F	R	N
. A	2.3	3.5	2.4
. B	2.7	3.3	1.7
. C	2.7	3.0	1.9
. D	3.2	3.0	3.0
. E	3.9	3.2	2.0
. F	4.7	3.0	2.3
. G	5.0	3.0	2.5
. H	3.0	3.0	3.8
. I	4.0	2.5	2.8

Fig. 9. Die gemittelten Zeigerwerte der Differentialartengruppen.

4. BEZUGSQUELLE DER PROGRAMME

Die Programme VEG, AUS und MULVA-4 können beim Ingenieurbüro Märki bezogen werden. Es wird ein Unkostenbeitrag von Fr. 100.-- berechnet. Das Progamm selbst ist public domain. Eine Gewähr für das korrekte Funktionieren kann nicht übernommen werden.

LITERATUR

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Ecological Field Investigations of Duckweed (*Lemnaceae*) in Argentina

Elias LANDOLT and Kazimierz ZARZYCKI

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1. INTRODUCTION, AIM OF THE INVESTIGATIONS

Lemnaceae are excellent subjects for physiological and ecological investigations. The results of many studies have been synthesized an published in detailed papers and were revised in LANDOLT (1986) and in LANDOLT and KANDELER (1987). The distribution and habitats of duckweed in North America were elaborated by LANDOLT and collaborators (LANDOLT 1957, LANDOLT and WILDI 1977, LANDOLT 1981, LANDOLT not publ.). LANDOLT and WILDI (1977) analized water samples, with and without *Lemnaceae* species, originating from the southwestern States of the U.S. The results lead to the main conclusion that, beside the climate, the nitrogene and the magnesium content of the water appear to be relevant in explaining the different distribution patterns of various *Lemnaceae* species. Other studies relating water quality and occurrence of *Lemnaceae* species have been carried out in northern Australia (LANDOLT 1992). Some of theses field results were confirmed under laboratory conditions (ZIMMERMANN 1981, LÜÖND 1983). However, the requirements and tolerances for different nutrient concentrations are not sufficiently known in order to understand the distribution of the species in nature. Though the aquatic system with a *Lemnaceae* cover is not as complex as a terrestrial one, it still contains so many factors difficult to measure and mutual relationships that it is by no means comprehensible. Therefore it seemed appropriate to investigate more examples to detect correlations between water quality and duckweed occurrence. The aim was not only to observe the ecological properties of the *Lemnaceae* species, closer and in more detail, but also to learn more about the ecological differentiation within a family of related genera and species.

After the 17th International Phytogeographic Excursion (IPE) 1983 through northern Argentina the authors had the opportunity to collect water samples and to note the water plants growing at each sample site. The investigations concentrated on the following questions:

1) What is the floristic composition of pleustonic plant communities in northern Argentina ?
2) What is the geographical distribution of the various *Lemnaceae* species in Argentina ?
3) Are there any water and climatic factors influencing the distribution of the *Lemnaceae*; is the distribution pattern similar to the pattern in other parts of the world?

Acknowledgements

Special thanks are due to Dr. U. Eskuche and his wife L. Zulema Ahumada de Eskuche, Corrientes, Argentina. They guided the 17th International Phytogeographic excursion in a scientifically competent manner. They proved to be superb organizers and lectured to us on the vegetation and environmental conditions of Argentina. Dr. U. Eskuche accompanied us on several field trips in the surroundings of Corrientes and let us take part in his rich experience with aquatic vegetation communities. In Buenos Aires we got very valuable information on aquatic habitats from Prof. Dr. R. Leon. We are also grateful for the friendly help of the INAL (Dir. Prof. Clarice Pignalberi, Ing. H. M. Cabral), especially for the boat trip within the inundation areas of Rio Paraná. Prof. Dr. L. Romero Fonseca, Corrientes, kindly filtered our water samples. The analysis of these samples was performed in Zürich by E. Schäffer of our Institute in collaboration with Dr. E. Szabo of the EAWAG. The detailed evaluation of the data was performed by Dr. M. Gasser and Dr. H.R. Binz. I. Gödickemeier and R. Venzin fed the data into the computer. April Siegwolf corrected the English language. We warmly thank all contributors for their very valuable support.

2. INVESTIGATION AREA, MATERIAL AND METHODS

2.1. INVESTIGATION AREA

The area in which the investigations were held extends in Argentina from 24° SL to 41° SL and from 55° WL to 71° WL. The sampling sites (1 to 180) are shown in Fig. 1. Most sampling was done in a transsect from Southern Buenos Aires (36° SL) to northeastern Formosa (24° SL) within 57° and 61° WL. The climate data of this transsect are presented in Fig. 2. The mean annual temperature decreases from North to South from 23° to 14° C and the annual amount of precipitation from 1400 to 600 mm. Days without frost vary from 350 days in the North to 150 days in the South. The absolute minima are relatively high: -8° C in the South and -4° C in the North. Roughly the transsect can be divided into three parts:

1) The southernmost part (*Bonareense*) includes the visited parts of the provinces of Buenos Aires and Cordoba, the vegetation consists of prairies (Pampa).
2) The central part (*Mesopotamica*) comprises the province Entre Rios and the southern part of the province, Santa Fé (northwards to Depto. San Justo); the vegetation is prairie with forest islands and open forest called Savanna (mainly *Prosopis alba* and *P. nigra* shrub with *Stipa* meadows); galery forest grows along the rivers.
3) The third part (*Correntino-Paraguaya*) covers the north of the province Santa Fé (from Depto. Vera northwards), the east of the provinces Chaco and Formosa and the north of Corrientes; the vegetation is similar to the one in the Mesopotamica, but the rain- green forests are often closer (mainly *Schinopsis balansae-Astronium balansae* forest).

There is no physical border between these regions. Consequently the climate and the vegetation transitions are flowing.

Table 1. Coordinates of the sample localities. Reference point: 24° SL / 54° EL, map of Argentina 1:500'000.

1	4.5/1.1	50	19.8/9.6	116-118	10.0/10.3
2-3	7.5/9.2	51-54	19.6/10.1	119	9.5/10.2
4	9.3/8.0	55	19.5/10.0	120	8.8/10.1
5	9.1/9.0	56-57	19.1/11.0	121	8.7/10.1
6	8.0/9.2	58	18.9/11.2	122-123	8.3/10.2
7	6.4/11.5	59-60	18.6/11.5	124-125	8.0/9.6
8	1.5/20.8	61-62	18.1/11.9	126	5.9/9.1
9	1.6/20.8	63	17.7/12.0	127-128	8.3/10.2
10	2.5/22.8	64	16.6/12.2	129	5.2/8.8
11	2.1/22.8	65	16.6/12.4	130-132	5.0/8.7
12	1.7/22.6	66-67	16.5/12.5	133	4.6/8.3
13	14.0/19.7	68-69	16.5/12.6	134	4.4/8.3
14-15	16.1/19.0	70	16.6/12.2	135-136	4.0/8.1
16	15.8/20.1	71-73	16.4/12.7	137-138	3.8/8.0
17	18.9/27.4	74-75	16.2/12.8	139	3.2/7.6
18-19	37.5/29.1	76-78	16.0/12.8	140-143	2.9/7.6
20	37.4/28.0	79-80	15.8/12.7	144	2.8/7.6
21-22	25.0/8.2	81-86	15.3/12.7	145-146	2.7/7.9
23	26.7/6.7	87/88	14.1/12.0	147-148	2.5/8.5
24-25	26.5/6.8	89	13.9/11.9	149-151	2.4/8.7
26	25.2/6.0	90	13.6/11.9	152-156	2.5/8.4
27-30	25.1/7.4	91-92	13.1/11.9	157-160	6.1/9.2
31-36	25.2/7.3	93	13.0/11.9	161-162	6.6/9.6
37-38	22.5/8.8	94-95	12.3/11.8	163-167	7.5/9.2
39	22.4/8.9	96-97	12.3/11.9	168-169	7.4/9.6
40	22.2/9.1	98-101	12.2/12.1	170-171	7.8/9.1
41-42	22.0/9.1	102	12.1/11.7	172	7.6/9.1
43-45	21.9/9.1	103-104	11.7/11.6	173	7.6/9.0
46	21.3/9.2	105-106	11.4/11.1	174	7.6/8.9
47	21.1/9.2	107-111	11.1/10.7	175-181	7.3/8.9
48	20.5/9.4	112-114	11.0/11.3	182	7.5/8.6
49	20.3/9.5	115	10.6/10.6		

2.2. FIELD MEASUREMENTS

At each water sample site, a plant sociological relevé of the pleustophytes was performed (method of Braun-Blanquet), and the water depth was measured. The sampling consisted of 2 x 250 cm^3 water and a herbarium sample. The pH was measured colorimetrically as well as with an electric pH meter. Fur thermore, conductivity and carbonate hardness data were registered. Most samples could be filtered through bacterial filters right in the field. A few samples, clouded by very fine clay particles, had to be filtered by pressure at the end of the trip in Corrientes.

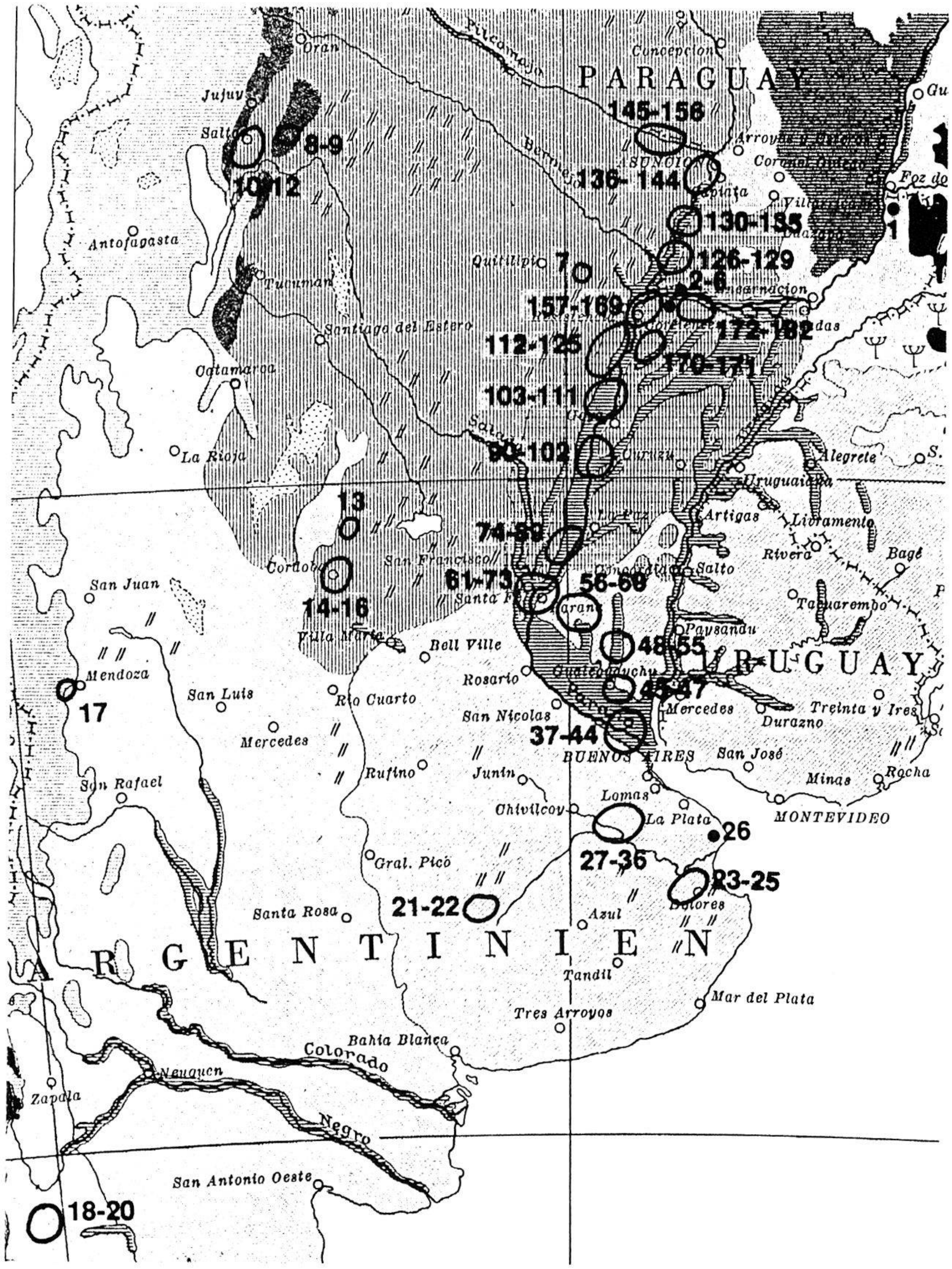


Fig. 1. Vegetation map of northern and central Argentina with location of the samples (map from TORUNSKI 1962). The exact coordinates of the locations are put together in Table 1.

Tropical and subtropical rain forest

Mountain rain forest

Araucaria forest (partly destroyed)

Chaco forest (quebracho and algarrobo)

Galery forest

Devastated and open forest (fields and pastures)

Shrub steppe, brier (caatinga, chaparal, espinal)

Prairies with forest islands

Prairies (llanos, pampa)

Patagonian steppe

Alpine steppe, region of the high mountains without trees (puna, paramo, rocks)

Semidesert

Sporadic occurrence of *Araucaria*

periodically inundated region

Salt pan

2.3 ANALYSIS OF THE WATERS

The water analyses were performed in the chemical laboratory of the Institute in Zürich. Conductivity and pH measurements were repeated and the following elements measured (Table 2).

Some of the water samples showed sedimentation on arrival at Zürich. The sediments were also analyzed and the ion balance checked. They contained mostly sulfate, Fe, Zn and Mn. Therefore, it must be concluded that these ions are under-represented in some of the samples. The values of Mn were so fragmentary that we did not evaluate the results.

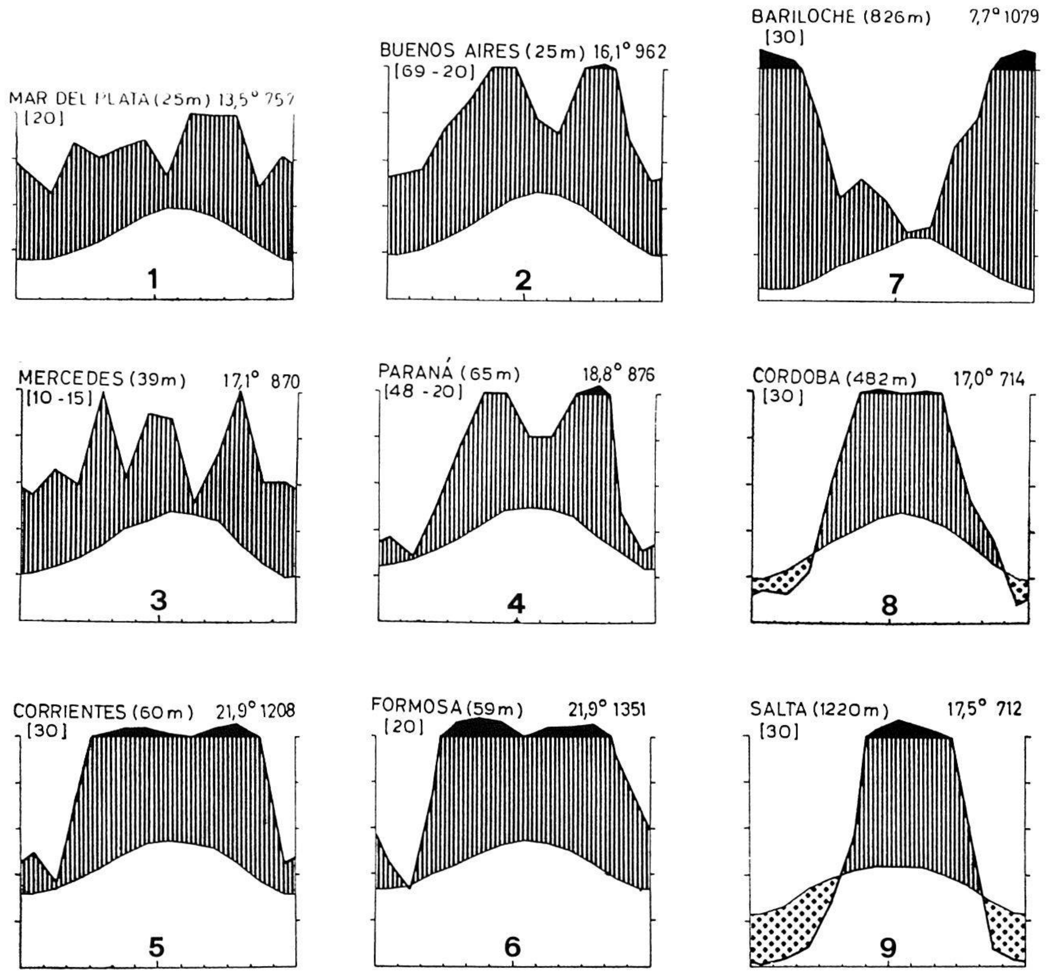


Fig. 2. Climate diagrams of the visited areas in the :
1 and 2: *Bonaerense* region (samples No. 21 to 44)
3 and 4: *Mesopotamica* region (samples No. 45 to 111)
5 and 6: *Correntino-Paraguaya* region (samples No. 1 to 11 and No. 112 to 182)
7: *Valdiviano-Neuquena* region (samples No. 18 to 20)
8: *Centrale* region (samples No. 13 to 17)
9: *Tucumano-Boliviana* region (sample No. 12)
The diagrams 7, 8 and 9 represent three regions with only scarce sampling. The region of Bariloche (Patagonica) (7) is relatively cool and rather dry in summer. *Lemna minuta* was the only lemnid found in that region. The regions of Cordoba (Centrale) (8) and Salta (Tucumano-Boliviana) (9) are climatically similar to the region of Mesopotamica but have much drier winters. The few relevés of this regions were incorporated into group Two (Mesopotamica).

Table 2. Factors and ions measured.

factors and ions	methods
NO_3-N	colorimetric with nitro salicylic acid
NH_4-N	colorimetric with indophenol
PO_4-P	colorimetric with molybdene blue
Cl^-	colorimetric with ferrothio-cyanate
SO_4^{--}	spectral photometric
Ca^{++}	photometric by flame
Mg^{++}	photometric by flame
Na^+	photometric by flame
K^+	photometric by flame
Mn^{++}	photometric by flame
Zn^{++}	photometric by flame
$Fe^{++,+++}$	photometric with bathophenanthrotin-disulfonic acid
carbonate hardness	titration with HCl

2.4. EVALUATION METHODS

2.4.1. Common occurrence of pleustonic species in the same waters

The evaluation of the common occurrence of different species was tested by means of a x^2 test in a contingency table. The zero hypothesis was checked; the difference between observed and expected frequency of common occurrence indicates a positive or a negative correlation.

2.4.2. Species versus data of environmental factors

The transformed values for the factors (see 2.4.3) were divided into 15 classes with the program GRAP. The number of relevés (N) in each class was determined. In the histogram the percentage of occurrence of each pleustonic species in every class is presented.
The occurrence of a species has not been weighted. The results present only the presence/absence data.

2.4.3. Distribution of the data

The data of the measured values of water parameters are distributed asymetrically for Na, K, Ca, Mg, N_{tot}, SO_4, Cl, P_{tot}, conductivity in the field and in the laboratory, total and carbonate hardness. A logarithmic (ln) transformation shows a more or less normal distribution of the values. The transformed values are ready to use for evaluation. The pH values from the field and laboratory did not have to be transformed. For the Zn values, which were only slightly asymetrically distributed, a root transformation was suitable. On the other hand, the values for NH_4 and less so for NO_3 were extremely asymetrically distributed and could not be reasonably transformed. The Fe values were often too low to be determined accurately. An evaluation, therefore, made no sense.

2.4.4. Main component analysis

The transformed data of Na, K, Ca, Mg, Zn, SO_4, Cl, N_{tot}, P_{tot}, total and carbonate hardness, conductivity in the field and in the laboratory were calculated by main component analysis with the aid of the program package of Wildi and Orlocci (1983). To estimate the similarities of the relevés, the covariance according to the Rese program was used. The detailed methods are described in Wildi and Orlocci (1983) and in Wildi (1986). The graphic presentation of the first two factors proved to be appropriate enough. Therefore the ordination was restricted to these first two dimensions.

2.4.5. Ordination of vegetation relevés

The ordination according to the package of Wildi did not reveal very convincing results, although some of the relevés with *Lemna gibba* and *Azolla filiculoides* could be separated. Therefore typical relevés of the southern part of the transsect and of the northern part (except relevés with *Lemna aequinoctialis*) as well as the relevés with *Lemna aequinoctialis* were separately grouped by hand in the sequence of the most frequent species within the group.

3. RESULTS

3.1 CLIMATE AND DISTRIBUTION

The distribution of the different *Lemnaceae* species occurring in Argentina was mapped world-wide by Landolt (1986). The localities found during the reported trip have already been taken into account. Much more collecting is required to facilitate more detailed maps of Argentina. Table 3 shows the occurrence frequency of the species within the shaded area. Apparently, *Lemnaceae* are unequally distributed throughout the visited transsect of Argentina. There is a gradient from South to North (BA to CP). *Lemna gibba* and *Azolla filiculoides* (very distinctly), *Spirodela intermedia, Wolffia brasiliensis* and *Lemna minuta* (only slightly) are become rarer to the North whereas *Azolla caroliniana, Lemna aequinoctialis, Pistia stratioides, Wolffiella lingulata, Lemna valdiviana and Utricularia gibba* are more frequent in the North.

In the coolest region, Bonaerense, the following species are represented by a higher frequency than expected: *Azolla filiculoides, Lemna gibba, Wolffia*

Table 3. The frequency of occurrence of *pleustophyte* species in the different parts of the field trip (only species which occur in more than 20 % of the localities of one region are mentioned). Two localities of Barriloche with a different climate and consisting of only *Lemna minuta* were not considered. The numbers in brackets show the percentage of occurrence for the single species in the region. The relative frequency in a region compared with the whole area is demonstrated by the number in italics.

- Localities with *Lemnaceae*: 166 (100%)
- Localities in Bonaerense (BA): 23 (14%)
- Localities in Mesopotamica (including 5 samples of the region Centrale and one sample of the region Tucumano-Boliviana (MP): 41(25%)
- Localities in Correntino-Paraguaya (CP): 102 (61%)

Species	whole area	BA		MP		CP	
Lemna minuta	115 (67%)	20 (87%)	*1.2*	34 (83%)	*1.2*	61 (60%)	*0.9*
Azolla caroliniana	93 (55%)	4 (17%)	*0.2*	23 (56%)	*1.0*	67 (66%)	*1.2*
Wolffiella lingulata	84 (51%)	1 (4%)	*0.1*	20 (48%)	*1.0*	63 (62%)	*1.2*
Pistia stratioides	81 (48%)	3 (13%)	*0.3*	18 (44%)	*0.9*	60 (59%)	*1.2*
Salvinia minima	77 (46%)	4 (17%)	*0.4*	23 (56%)	*1.2*	50 (49%)	*1.1*
Wolffiella oblonga	70 (42%)	9 (39%)	*0.9*	20 (48%)	*1.1*	41 (39%)	*1.0*
Limnobium laevigatum	65 (39%)	7 (30%)	*0.8*	17 (41%)	*1.0*	41 (40%)	*1.0*
Wolffia columbiana	61 (36%)	8 (35%)	*0.9*	19 (53%)	*1.2*	34 (33%)	*0.9*
Spirodela intermedia	58 (35%)	13 (57%)	*1.6*	16 (39%)	*1.1*	29 (28%)	*0.8*
Ricciocarpus natans	57 (34%)	15 (65%)	*1.9*	9 (23%)	*0.6*	33 (32%)	*0.9*
Azolla filiculoides	56 (34%)	21 (91%)	*2.7*	31 (76%)	*2.2*	4 (4%)	*0.1*
Lemna gibba	56 (34%)	18 (78%)	*2.3*	27 (66%)	*1.9*	11 (11%)	*0.3*
Lemna valdiviana	44 (26%)	2 (9%)	*0.3*	7 (17%)	*0.6*	35 (34%)	*1.3*
Salvinia herzogii	42 (25%)	2 (9%)	*0.3*	13 (32%)	*1.2*	27 (26%)	*1.0*
Wolffia brasiliensis	32 (19%)	10 (43%)	*2.3*	8 (20%)	*1.1*	14 (14%)	*0.7*
Utricularia gibba	22 (13%)	1 (4%)	*0.3*	1 (2%)	*0.2*	20 (20%)	*1.5*
Lemna aequinoctialis	21 (12%)	0 (0%)	*0.0*	1 (2%)	*0.2*	20 (20%)	*1.7*

brasiliensis, Ricciocarpus natans, Spirodela intermedia. Species with lower frequencies in this region are: *Lemna aequinoctialis, Wolffiella lingulata, Azolla caroliniana, Pistia stratioides, Lemna valdiviana, Salvinia herzogii, Utricularia gibba, Salvinia minima.*

Species with a higher frequency than expected in the Mesopotamica region are: *Azolla filiculoides, Lemna gibba.* Of lower frequency are: *Lemna aequinoctialis, Utricularia gibba, Lemna valdiviana, Ricciocarpus natans.*

In the region Correntino-Paraguaya, the following species grow with a relatively high frequency: *Lemna aequinoctialis, Utricularia gibba, Azolla caroliniana, Wolffiella lingulata, Pistia stratioides.* With low frequency occur: *Azolla filiuloides, Lemna gibba, Spirodela intermedia, Wolffia brasiliensis.*

From the reported results it can be shown that the distribution of some lemnid species (pleustophytes) is directly or indirectly dependent on the climate (for climatic data see chapters 2.1 and 4.1).

3.2. VEGETATION STUDIES

The various relevés contain between one and 12 lemnid species (fig. 3). In addition, *Scirpus cubensis,* a species rooting in the soil, was included in the relevés when it was growing on floating mats of organic detritus and/or pleustophytes within the water. It must be remembered that the selection of the investigated waters was not purely accidental. Waters with no lemnids were

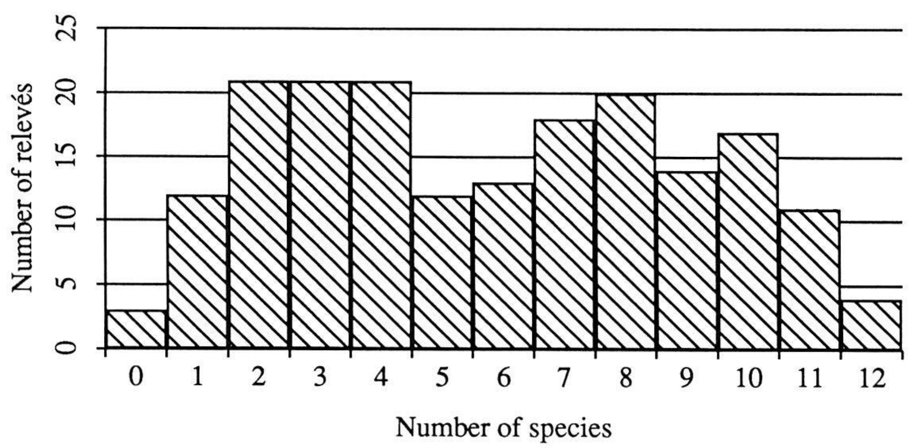


Fig. 3. Distribution of pleustophyte species numbers within the relevés.

sampled only very specifically. In regions with many lakes, ponds and pools, not all waters could be examined, waters with a closed cover (containing more than one or two species) were preferred. Therefore the classes with 1 (and 2) species in Fig. 3 are underrepresented. Two peaks are obvious, one from 2 to 4 species and one from 7 to 10 species. The diversity of up to 12 lemnid species per relevé is quite remarkable. In Europe relevés with more than 7 species are very rare.

Since the statistical evaluation did not reveal an ordination useful for sociological units, the ordination was made by hand after having divided the samples in three groups according to predominance of the following three *Lemna* species: *L. gibba, L. minuta, L. aequinoctialis.* In the tables 4 to 6, relevés with only one or two species are excluded.

The three distinct pleustonic communities can be characterized by the following combinations:

***Lemna gibba* - *Azolla filiculoides* community**: *Azolla filiculoides, Lemna gibba, Lemna minuta, Wolffiella oblonga*

***Lemna minuta* - *Salvinia minima* community**: *Salvinia minima, Lemna minuta, Wolffiella lingulata, Azolla caroliniana, Limnobium laevigatum, Pistia stratioides*

***Lemna aequinoctialis* - *Azolla caroliniana* community:** *Lemna aequinoctialis, Azolla caroliniana, Pistia stratioides.*

The three communities are connected by many transitions. The main factor for the development of these communities seems to be the climate since the first community is mainly distributed in the South (and West) i.e. in the cooler and drier regions. Whereas, the third community with *Lemna aequinoctialis* prefers the northern (and eastern) region which is warmer and receives more precipitation. Whether the three communities can be divided into subunits is difficult to decide. The qualitative feature of a body of water may determine the abundance of a species at a certain place. The abundance is also dependent on a few other factors like seasonal drying, possibility of colonizing the water, temperature conditions, birds, fish and other herbivores. Some plant sociologists may divide the community into many lower units. However, it would be difficult to clearly distinguish defined associations because the stands change their species composition throughout the year, and the presence of one species or another might well be incidental and temporary.

The first community belongs to the *Lemnion gibbae* R. Tx. et Schwabe 1974 and is not yet documented by many relevés. A typical relevé of this

Table 4. 35 relevés of the *Lemna gibba-Azolla filiculoides*-community. The number of the relevé can be localized on the map in fig. 1. (Fr = frequency)

relevé number	27	29	21	32	22	23	54	77	75	30	82	48	24	49	76	28	33	26	53	36	39	37	34	25	13	59	60	55	79	62	57	58	31	78	56	Fr
species number	10	10	8	8	8	8	7	7	10	7	6	11	9	10	6	5	4	4	4	3	3	3	3	3	3	4	4	4	3	4	3	3	4	7	4	
Azolla filiculoides	2	1	2	3	2	4	5	5	5	5	5	3	4	1	3	5	+	3	5	5	5	4	5	3	1	5	5	1	4	3	1	1	4			V
Lemna gibba	1	1	2	1	+	+	1	1	2	1	2	2	+	+	1	1	+	+	1	1	+	3	+	5	1	3	3	5	4	1	2	1		4	2	V
Lemna minuta	3	2	4	2	+	3	2	2	3	2	1	1	1	2	+	2	+	+	1	2	2	1	+	1	+									2	1	IV
Wolffiella oblonga	2	1	2	2	+	3	1	2	3	3	2	+	2	+	+																			4		III
Wolffia columbiana	2	1	+	+	2	+	2	1	2	+	3								3							2	1	1	2	2	1	2		2		III
Wolffia brasiliensis	1	1	2	+	2	3	+	1	+			1	2	+												2	1	2					+			III
Ricciocarpus natans	1	+	2	5	3	+				1	2	1	1			2	+	+															1			III
Spirodela intermedia	4	4	1	+								1	+	+		1																	+		+	II
Ceratophyllum dem.	5	3			3	+			3																											I
Limnobium laevig.	+	+										+	+	+																				2		I
Lemna valdiviana							+			1		2	+	1																						I
Azolla caroliniana												3		3	4															3					1	I
Wolffiella lingulata								1	+																									+		I
Salvinia minima												+		5																				2		I
Salvinia herzogii									2						3																					I
Pistia stratiotes									+																											I

Table 5. 62 relevés of the *Lemna minuta* - *Salvinia minima* community. The number of the relevé can be localized on the map in fig. 1. Fr = frequency.

relevé number	96	109	111	3	129	165	164	163	70	64	66	120	133	110	168	141	167	104	112	102	134	114	140	118	170	176	139	72	6a	119	124	156
species number	11	12	11	10	10	11	10	9	11	10	10	12	11	10	9	9	10	7	8	10	6	8	8	8	11	8	6	7	5	6	9	8
Lemna minuta	3	2	2	2	1	2	2	1	1	2	2	2	2	2	1	+	1	+	2	3	+	1	+	+	+	2	2	2	1	3	+	+
Wolffiella lingulata	+	1	1	+	1	+	1	+	1	+	+	+	1	2	2	+	2	1	1	+	1	1	+	2	1	2	1	2	1	2	2	3
Azolla caroliniana	+	+	+	2	+	2	1	3	3	1	3	2	+	+	+	1	1	3	4	+	+	4	1	4	+	1	+	3	1	+	5	+
Salvinia minima	+	2	4	4	5	4	4	5	2	4	4	1	1	5	2	3	2	1	+	2	2	2	2	3	+	5	4					
Pistia stratioides	5	2	+	+	3	2	1	+	+	1	3	5	3	2	4	3	5	4	+	5	5	2	4					5	4	1	+	2
Limnobium laevigatum	2	1	+	1	+	+	+	+	3	3	3	+	+	2	+	1	1	1	3					2	4					3		
Spirodela intermedia	+	1	4	+	2	1	1	1	2	2	1	2	+	2	2					2						2				2		
Ricciocarpus natans	1	1	2	2	1	1	+	2	2	1	2								2	+		2			2	1		+	+	2		
Wolffia columbiana	1	3	3	1	3	2	1	1				2		1	1	+			+				+				+	2			2	3
Wolffiella oblonga	3								1	1	+	2	+				1	+	1	2	1	1		1	2			1			+	
Lemna valdiviana		1	+									2	+	2			+					+		2	1							3
Salvinia herzogii		4		1		2			4		3	2	4		2	4	2			2			+		3	3					+	
Wolffia brasiliensis																									1							
Salvinia auriculata		2				3	1		2				2	1		+							+				4					
Utricularia gibba													2				+								3						+	
Lemna aequinoctialis					2																					+						+
Lemna gibba	+		2																													+
Ceratophyllum dem.																								2								
Azolla filiculoides										2																						
(*Scirpus cubensis*)						1	+								2		2								2	2	5					

Table 5. (contin.) 62 relevés of the *Lemna minuta* - *Salvinia minima* community. The number of the relevé can be localized on the map in fig. 1. (Fr = frequency)

relevé number	166	108	169	137a	137b	7	46	65	181	180	178	175	182	174	103	171	173	101	159	150	107	67	94	179	152	68	6	177	151	155	Fr
species number	7	10	7	7	7	5	12	5	7	10	11	9	7	6	6	4	6	5	7	6	4	8	8	10	7	8	4	9	4	6	
Lemna minuta	2	1	1	2	4	3	3	+					+	+	4	+	+	1	+	+	4	2	3	1	2	1	1				V
Wolffiella lingulata	1	3	2	1	+	+			1	1	2	1	1	2	2	+	2	2	+	2								1	3		V
Azolla caroliniana	4						+	5	+	2	2	1	+	5	2	3					+	2	+	1	+		1			+	V
Salvinia minima		4	3	3	3	5	+	+	2	3	2	2					2				3	2				3		3		3	IV
Pistia stratioides	+	+	4	3	4	1	3	2	4									5	2	5			5	2	5	2				5	IV
Limnobium laevigatum	+	+	+				2	3		3	4	3	4	2					3			2	+	2		+		4		3	IV
Spirodela intermedia		2	+	3	3		4			2								+	4			2	+			1					III
Ricciocarpus natans	+	+					2		1	2	2	2	3	3		2			+					1		+		2			III
Wolffia columbiana	1	1	+	3	3		1								1					2	1		1					1	2		III
Wolffiella oblonga						+	+			+	1	2						2		1		+	3	1	1	+	5	2		2	III
Lemna valdiviana		+					+		2	1	+								2	2				1	4				2	3	II
Salvinia herzogii		3																				4		5						3	II
Wolffia brasiliensis							2			1	1	2	4	3	2		2							1	1		3	2			II
Salvinia auriculata									3		2		3				4											3			II
Utricularia gibba									1	+	2	2					+											3			I
Lemna aequinoctialis											1				+							+		+							I
Lemna gibba																							+		+						I
Ceratophyllum dem.				3	4																										I
Azolla filiculoides							2																								I
(*Scirpus cubensis*)	+											2												2							I

community is No. 21. OBERDORFER (1960) describes a fragment of this community from Chile under the name of *Lemno-Azolletum chilense.* Further relevés can be found in SCHWAAR (1986; there *L. gibba* is named *L. parodiana;* only fragments), in RAMIREZ and BECK (1981) (from the region of La Paz, Bolivia with only fragments reduced to stands of *L. gibba* and *Azolla filiculoides*) and in LIBERMANN CRUZ et al. (1988,1991) (from Lake Titicaca and Lake Uru-Uru, Bolivia). These authors classify the relevés as an association *Lemno minutae (minusculae)-Lemnetum gibbae.* However, these relevés have only up to 4 species. *L. gibba* and *Azolla filiculoides* are frequent, *L. minuta* relatively rare. In addition, *L. valdiviana* occurs in several relevés. The fragmentary formation of all these *Lemna gibba* communities demonstrates that the climatic conditions (above all the cold tempartures) are more extreme in those places.

ESKUCHE and ROMERO-FONSECA (1982) and ESKUCHE (1986) published relevés of associations with *Lemnaceae* from the region of Corrientes, part of which can well be compared with the relevés of **the second community**. Differing from ESKUCHE et al., but in agreement with SCHWABE-BRAUN and TÜXEN (1981), only pleustophytes (plants swimming on the surface of the water or floating in the water, but not rooting in the ground) were taken into account by the present authors. Furthermore, plants which protrude more than 10 cm above the water surface (e.g. *Eichhornia, Hydrocotyle*) were left out, even if the plants had no connection with the bottom of the water. If this is taken into account, many of their relevés can be integrated in table 5. A typical relevé of the second community is No. 165. The community belongs to its own alliance which is characterized by *L. minuta, Limnobium laevigatum* and *Salvinia minima* (and *S. herzogii*).

The third community is poorly represented in the investigated area. The stands are mostly fragments. A typical relevé is No. 129b. Additional relevés are needed. This community belongs to a different order (*Lemnetalia aequinoctialis* Schwabe-Braun and R.Tx. 1981) which is mainly wide-spread in tropical regions throughout the whole world.

If vegetation of the *Lemnetea* are to be seriously studied, it must be kept in mind that:

1) occurence and frequency of the species change often during the year
2) propagules of the species are transported by birds from one water to the other
3) the ecosystem may perform a succession over years or decades, from an original pioneer stage with only one or very few species to a well developed final stage of many organisms.

Table 6. 10 relevés of the *Lemna aequinoctialis - Azolla caroliniana* community. The number of the relevé can be localized on the map in fig. 1. (Fr = frequency)

relevé number	129a	129b	99	132	123	27	149	131	4	25	Fr
species number	10	10	9	3	4	3	5	4	3	5	
Lemna aequinoctialis	2	3	+	4	2	5	4	5	5	+	V
Azolla caroliniana	1	+	3	4	4	1	1				IV
Pistia stratioides	3	2	+	2	3			1	2		IV
Ricciocarpus natans	1	2	+			2				+	III
Limnobium laevigatum	+	+	1					2			III
Spirodela intermedia	2	2						1	+		III
Wolffiella lingulata	1	1								+	II
Wolffia columbiana	3	3					3				II
Lemna minuta	1	1								+	II
Salvinia minima	5		4								II
Utricularia gibba			1		2					2	II
Ceratopteris pteridoides		+									I
Lemna gibba			+								I
Wolffiella oblonga			1								I
Lemna valdiviana							3				I

Table 7. Frequency of the *Lemnetea* species in the three communities.
V >80%; IV 60-79%; III 40-59%; II 20-39%; I 1-19 %.

species	communities 1	2	3
Azolla filiculoides	V	I	-
Lemna gibba	V	I	I
Wolffia brasiliensis	III	II	-
Wolffiella oblonga	III	III	I
Lemna minuta	IV	V	II
Wolffiella lingulata	I	V	II
Salvinia minima	I	IV	II
Limnobium laevigatum	I	IV	III
Azolla caroliniana	I	V	IV
Pistia stratiotes	I	IV	IV
Lemna aequinoctialis	-	I	V
Spirodela intermedia	II	III	III
Ricciocarpus natans	III	III	III
Wolffia columbiana	III	III	II
Lemna valdiviana	I	II	I
Salvinia herzogii	I	II	-
Ceratophyllum demersum	I	I	-
Salvinia auriculata	-	II	-
Utricularia gibba	-	I	II

Whereas pioneer stages often differ distinctly from each other in their nutrient and other mineral content characteristics, the final stages are more similar in mineral composition of the water, most of the minerals being fixed in the biomass. Therefore pioneer stages can begin with various species whereas the final stages differ only slightly in species composition. Sometimes it is difficult to decide if a community of one or two species corresponds to a pioneer stage or if it is a very reduced variant of the final stage caused by some extreme factors like temperature, competition of other organisms, presence of herbivores etc. For a classification of the *Lemnetea* communities, it is best not to regard these stands as independent associations but to try to understand them either as pioneer stages or fragments of well developed end stages.

In the southeastern and western part of the investigated area (i.e. in the provinces of Buenos Aires, Rio Negro, Cordoba and Salta) the succession begins with either *L. gibba* on waters rich in minerals (especially magnesium and nitrogen) or with *Azolla filiculoides* (or sometimes *Lemna minuta*) on waters poor in nitrogen and phosphorus. The succession proceeds to a two-storied cover of *Lemnaceae* consisting of a surface cover of *Lemna minuta, L. gibba, Azolla filiculoides, Wolffia brasiliensis* and *W. columbiana,* and in the lower story of submerged floating *Wolffiella oblonga.* The ecosystem does not develop further under the regular climatic conditions. In the drier and cooler regions of the South, *Wolffiella oblonga* cannot exist.

In the more northern regions of Argentina (Entre Rios, Santa Fé, Corrientes, Formosa) the succession begins with a layer of one or very few of the following species: *Lemna minuta, Spirodela intermedia, Wolffia brasiliensis, Azolla caroliniana, Pistia stratiotes, Salvinia minima.* It is not quite sure which species occurs first under which conditions. However, *Pistia, Salvinia* and *Azolla* are able to colonize waters which are too poor in nutrients (especially phosphorus and nitrogen) for the growth of *Lemnaceae.* The stands of *Azolla caroliniana* from Uruguay described by SCHWAAR (1983) also belong to these pioneer stages. In the course of succession the nutrient cycle of the ecosystem increases, eventually giving growth possibilities for *Lemnaceae.* The further succession leads to a many-layered cover of pleustophytes and finally to a carpet of floating vegetation which enables amphibious plants like *Scirpus cubensis* to root. The mentioned succession was described by SCHULZ (1961), JUNK (1970), TUR (1972), NEIFF (1982), ESKUCHE (1986), WOLF (1990) and is demonstrated in Fig. 4.

The final stage of the tropic-subtropic pleustonic vegetation in northern Argentina, beginning with *Lemna aequinoctialis* or *Azolla caroliniana*

Pioneer vegetation	transition vegetation of	compact floating vegetation cover of
Salvinia minima	→	*Salvinia-Scirpus cubensis*
Azolla caroliniana	→	*Azolla-Scirpus cubensis*
Lemna minuta	→ *Lemna minuta-Salvinia* →	*Salvinia-Lemna-Azolla-Scirpus cubensis*
Pistia stratiotes	→	*Pistia-Scirpus cubensis*

Fig. 4. Successions of pleustonic vegetation in Northern Argentina.

seems to be similar as in Fig. 4. Since the typical vegetation with *L. aequinoctialis* is very rare in Argentina, the succession has to be studied in northern South America where there additional species exist (e.g. *Wolffiella neotropica, Wolffiella welwitschii, Wolffiella caudata*).

3.3. COMMON OCCURRENCE OF VARIOUS SPECIES IN THE SAME WATER

Table 8 shows the results of the test of independent appearance of the *Lemnaceae* species collected on the trip and table 9 summarizes the situation within the whole southern part of South America. For this purpose, herbarium specimens from Argentina, Chile, Uruguay, Paraguay and the extratropical parts of Brazil, Bolivia and Peru were considered in addition to the notes of the field trip.This should give rise to higher statistical significance.

All together, 700 localities (duplicates carefully excluded)have been considered. Consulted herbariums include BA, BAA, BAB, BAF, CORD, CTES, LIL, LP, MCNS, MERL, SI, SP, VALD, Herb. G. Beck, La Paz and most of the larger herbaria of North America and Europe (see LANDOLT 1986). Unfortunately, lemnids other than *Lemnaceae* were not always determined and therefore not included in the present study. Between 7 % and 48 % of the samples of the various species consist of pure stands. The typical pioneer species like *L. gibba, L. aequinoctialis* and to a lesser extent *L. minuta* and *S. intermedia* are frequently found without other species of *Lemnaceae,* whereas species indicating stable situations usually grow along with other species (*Wolffiella lingulata, W. oblonga, W. columbiana*).

Table 8. Common occurrence of lemnid species in Argentina (field trip results)

Significance levels: ***, --- p<.001; **, -- p<.01; *, - p<.05; *: positive correlation, -: negative correlation

	Spirodela intermedia	*Lemna gibba*	*Lemna aequinoctialis*	*Lemna valdividiana*	*Lemna minuta*	*Wolffiella lingulata*	*Wolffiella oblonga*	*Wolffia brasiliensis*	*Wolffia columbiana*	*Azolla caroliniana*	*Azolla filiculoides*	*Salvinia minima*	*Salvinia auriculata*	*Salvinia herzogii*	*Ricciocarpus natans*	*Limnobium laevigatum*	*Utricularia gibba*	*Pistia stratiotes*	*Eichhornia crassipes*	*C. demersum*	*Scirpus cubensis*
Spirodela intermedia					***					*		***		**	***	***		***	*		
Lemna gibba			-			---		*	**	---	***	---	-	--		--	--	---	---	**	
Lemna aequinoctialis					-						--										
Lemna valdividiana						**	***				-	***		*	*	***	***				
Lemna minuta						**	**		**			**		**	***	***		*			
Wolffiella lingulata							***		*	**	---	***	***	**	*	***		***			*
Wolffiella oblonga								***				***		**	**	***	**	*		**	
Wolffia brasiliensis									*		*				***			--			
Wolffia columbiana																	--	*		**	
Azolla caroliniana											---	***		***	*	***		**	*		
Azolla filiculoides												---	-	--		--		---	--	*	
Salvinia minima													*	***	**	***		***	***		
Salvinia auriculata																**					
Salvinia herzogii																***		**	***		*
Ricciocarpus natans																***					
Limnobium laevigatum																	***	***	***		
Utricularia gibba																					
Pistia stratiotes																			*		
Eichhornia crassipes																					
Ceratophyllum demersum																					
Scirpus cubensis																					
number of samples	54	56	18	43	107	72	70	29	59	90	51	72	13	49	54	58	25	75	22	13	10

The following species have positive connections (statistically significant) (Table 8):

- ***Spirodela intermedia*** with *Lemna minuta, Salvinia minima, S. herzogii, Ricciocarpus natans, Limnobium laevigatum, Pistia stratiotes, Azolla caroliniana* and *Eichhornia crassipes*
- ***Lemna gibba*** with *Azolla filiculoides, Ceratophyllum demersum, Wolffia columbiana, Wolffia brasiliensis*
- ***Lemna valdiviana*** with *Wolffiella oblonga, Salvinia minima, Limnobium laevigatum, Utricularia gibba, Wolffiella lingulata, Salvinia herzogii, Riccocarpus natans*
- ***Lemna minuta*** with *Spirodela intermedia, Ricciocarpus natans, Limnobium laevigatum, Salvinia minima, S. herzogii, Wolffiella lingulata, W. oblonga, Wolffia columbiana, Pistia stratiotes*
- ***Wolffiella lingulata*** with *Wolffiella oblonga, Salvinia minima, S. auriculata, Limnobium laevigatum, Pistia stratiotes, Azolla caroliniana, Salvinia hercogii, Lemna valdiviana, L. minuta, Wolffia columbiana, Ricciocarpus natans, Scirpus cubensis*
- ***Wolffiella oblonga*** with *Lemna valdiviana, Wolffiella lingulata, Wolffia brasiliensis, Salvinia minima, Limnobium laevigatum, Lemna minuta, Salvinia herzogii, Ricciocarpus natans, Utricularia gibba, Ceratophyllum demersum, Pistia stratiotes*
- ***Wolffia brasiliensis*** with *Wolffiella oblonga, Ricciocarpus natans, Lemna gibba, Wolffia columbiana*
- ***Wolffia columbiana*** with *Lemna gibba, Lemna minuta, Ceratophyllum demersum, Wolffiella lingulata, Wolffia brasiliensis, Pistia stratiotes*

Especially remarkable is the close connection between *L. gibba* and *W. oblonga* which also reflects the phytosociological distinctivness of stands with these three species. *Azolla filiculoides,* which belongs to the same vegetation communities, was only considered for the samples collected on the field trip (without samples from the herbaria) and demonstrates the same close connection to *L. gibba.*

On the other hand, the following species grow much more seldom together than expected (statistically significant) (Table 8):

- ***Spirodela intermedia*** with *Lemna gibba, Azolla filiculoides, Utricularia gibba*
- ***Lemna gibba*** with *Wolffiella lingulata, Azolla caroliniana, Salvia minima, Pistia stratiotes, Eichhornia crassipes, Salvinia herzogii, Limnobium*

laevigatum, Utricularia gibba, Lemna aequinoctialis, Salvinia auriculata

- ***Lemna aequinoctialis*** with *Azolla filiculoides, Lemna gibba, L. minuta*
- ***Lemna valdiviana*** with *Azolla filiculoides*
- ***Wolffiella lingulata*** with *Lemna gibba, Azolla filiculoides*
- ***Wolffia brasiliensis*** with *Pistia stratiotes*
- ***Wolffia columbiana*** with *Utricularia gibba*

Azolla filiculoides and *A. caroliniana* avoid each other to a high degree. The rare common occurrence of *Lemna aequinoctialis* with *L. gibba, L. minuta, Wolffiella oblonga* and *Azolla filiculoides* reflects the different climatic requirements of the species (see chapter 4.1). *L. aequinoctialis* has stronger connections to tropical species which are not considered here. Under tropical conditions, *L. aequinoctialis* is by far the most frequent species of *Lemnaceae*. In the Rio de Janeiro (Brazil) region, *L. aequinoctialis* was found in two out of three waters with pleustonic plant species. The connection between *L. gibba* and *L. minuta* is negative though *L. minuta* is strongly connected to the *Lemna gibba - Azolla filiculoides* community. However. *L. minuta* is also distributed in warmer climates where *L. gibba* does not occur.

Table 9. Common occurrence of lemnid species in extratropical South America (652 herbarium samples).
Significance levels: ***, --- p< .001; **, -- p< .01; *, - p< .05
* : positive correlation, - : negative correlation

	Spirodela intermedia	*Lemna aequinoctialis*	*Lemna gibba*	*Lemna minuta*	*Lemna valdiviana*	*Wolffiella lingulata*	*Wolffiella oblonga*	*Wolffia brasiliensis*	*Wolffia columbiana*
Spirodela intermedia			---						
Lemna aequinoctialis			---	---			---		
Lemna gibba				---	---	---	***	-	--
Lemna minuta					---				
Lemna valdiviana						***	***		
Wolffiella lingulata							*		*
Wolffiella oblonga								*	
Wolffia brasiliensis									***
Wolffia columbiana									
number of samples	144	61	248	318	93	91	174	53	97

Table 10. Flowering *Lemnaceae* species in the field.

species	flowering samples	total samples	percent of flowering in Argentina	percent of flowering world-wide
Lemna gibba	16	56	29	14
Lemna aequinoctialis	4	21	19	19
Lemna minuta	9	115	0.8	5
Wolffia columbiana	4	61	0.7	1.5
Wolffia brasiliensis	2	32	0.6	2
Wolffiella oblonga	3	70	0.4	4
Spirodela intermedia	2	58	0.3	3
Lemna valdiviana	0	44	<0.2	3
Wolffiella lingulata	0	84	<0.1	13

3.4. FLOWERING

In some of the collected samples flowering was observed (Table 10). The world-wide flowering percentage is taken from LANDOLT (1986). In this publication, some 10´000 *Lemnaceae* samples have been tested for flowering. Some of the species show the same flowering percentage in Argentina as world-wide (*L. aequinoctialis, W. oblonga* and *S. intermedia*). This probably means that the environmental conditions in October and November 1983 represented the average flowering conditions for the species. However, the conditions for flowering of *L. gibba, L. minuta, W. columbiana* and *W. brasiliensis* apparently were more favourable than the avarage conditions throughout the collecting season. *L. valdiviana* and *Wolffiella lingulata* were not found flowering at all.

3.5. WATER QUALITY AND SPECIES OCCURRENCE

3.5.1. Ecological characterization of the sites

The water analysis values are distributed asymetrically for Na, K, Ca, Mg, N_{tot}, SO_4 , Cl, P_{tot}, conductivity in field and in laboratory, total and carbonate hardness. A logarithmic (ln) transformation leads to a more or less normal distribution of the values. In this way the transformed values can be used for evaluation. The transformed values are shown in Fig. 5. The following data did not have to be transformed: pH in the field and in the laboratory. For Zn with values distributed only slightly asymetrically, a root transformation was suitable. The distribution of the values for NH_4 and NO_3 were too highly asymetrical to be usefully transformed. The Fe values were sometimes so low that an evaluation did not make much sense.

The relationship between various measured factors is shown in Table 11. The following facts can be observed:

1) There is a strong correlation between Na, SO_4, Cl, carbonate hardness and conductivity (in the field and in the laboratory). Fig. 6a shows the scattergram of the conductivity in the field and in the laboratory. This result was to be expected since the ion content of the water should not change much during the translocations of the water samples. The correlation between Na content and conductivity in the field is demonstrated in Fig. 6b. Especially in higher concentrations of Na the connection is very strong.
2) Ca , Mg, total hardness and conductivity are higly interdependent as well.
3) Zn is independent from or negatively correlated with all other values.
4) N tot is slightly positively correlated to or independent from all other values.

Table 11. Correlation coefficients between different water factors.
significance level: $r > 0.15$ for $p = 5\%$; $r > 0.27$ for $p = 0.1\ \%$

	Na [mg/l]	K [mg/l]	Ca [mg/l]	Mg [mg/l]	Zn [mg/l]	SO4 [mg/l]	Cl [mg/l]	NH4 [mg/l]	NO3 [mg/l]	NT [mg/l]	Fe [µg/l]	Ptot [µg/l]	total hardness	carb. hardness	conduct. (lab.)	conduct. (field)	pH laboratory	pH field
Na [mg/l]	1	0.50	0.56	0.74	-0.24	0.82	0.85	0.05	0.22	0.21	-0.06	0.35	0.69	0.83	0.92	0.92	0.70	0.52
K [mg/l]		1	0.51	0.59	-0.05	0.55	0.49	0.21	0.41	0.44	-0.02	0.44	0.55	0.62	0.59	0.59	0.51	0.28
Ca [mg/l]			1	0.91	-0.35	0.59	0.52	0.10	0.13	0.16	-0.57	0.11	0.89	0.71	0.73	0.74	0.65	0.39
Mg [mg/l]				1	-0.33	0.73	0.70	0.09	0.18	0.20	-0.45	0.20	0.95	0.78	0.86	0.87	0.66	0.43
Zn [mg/l]					1	-0.20	-0.21	0.28	-0.08	0.06	0.21	-0.15	-0.34	-0.26	-0.28	-0.30	-0.20	-0.19
SO4 [mg/l]						1	0.76	0.06	0.17	0.18	-0.02	0.44	0.67	0.69	0.83	0.84	0.56	0.42
Cl [mg/l]							1	0.04	0.12	0.12	-0.08	0.25	0.63	0.61	0.84	0.83	0.46	0.38
NH4 [mg/l]								1	0.05	0.51	-0.05	-0.07	0.11	0.02	0.09	0.07	0.12	0.07
NO3 [mg/l]									1	0.88	0.07	0.34	0.18	0.28	0.24	0.21	0.29	0.09
NT [mg/l]										1	0.03	0.26	0.20	0.24	0.25	0.21	0.30	0.11
Fe [µg/l]											1	0.45	-0.42	-0.20	-0.18	-0.25	-0.30	-0.32
Ptot [µg/l]												1	0.20	0.35	0.35	0.33	0.24	-0.04
tot. hardness													1	0.74	0.81	0.82	0.64	0.40
carb. hardness														1	0.84	0.85	0.85	0.52
conduct. (lab.)															1	0.95	0.71	0.47
conduc. (field)																1	0.73	0.52
pH laboratory																	1	0.55
pH field																		1

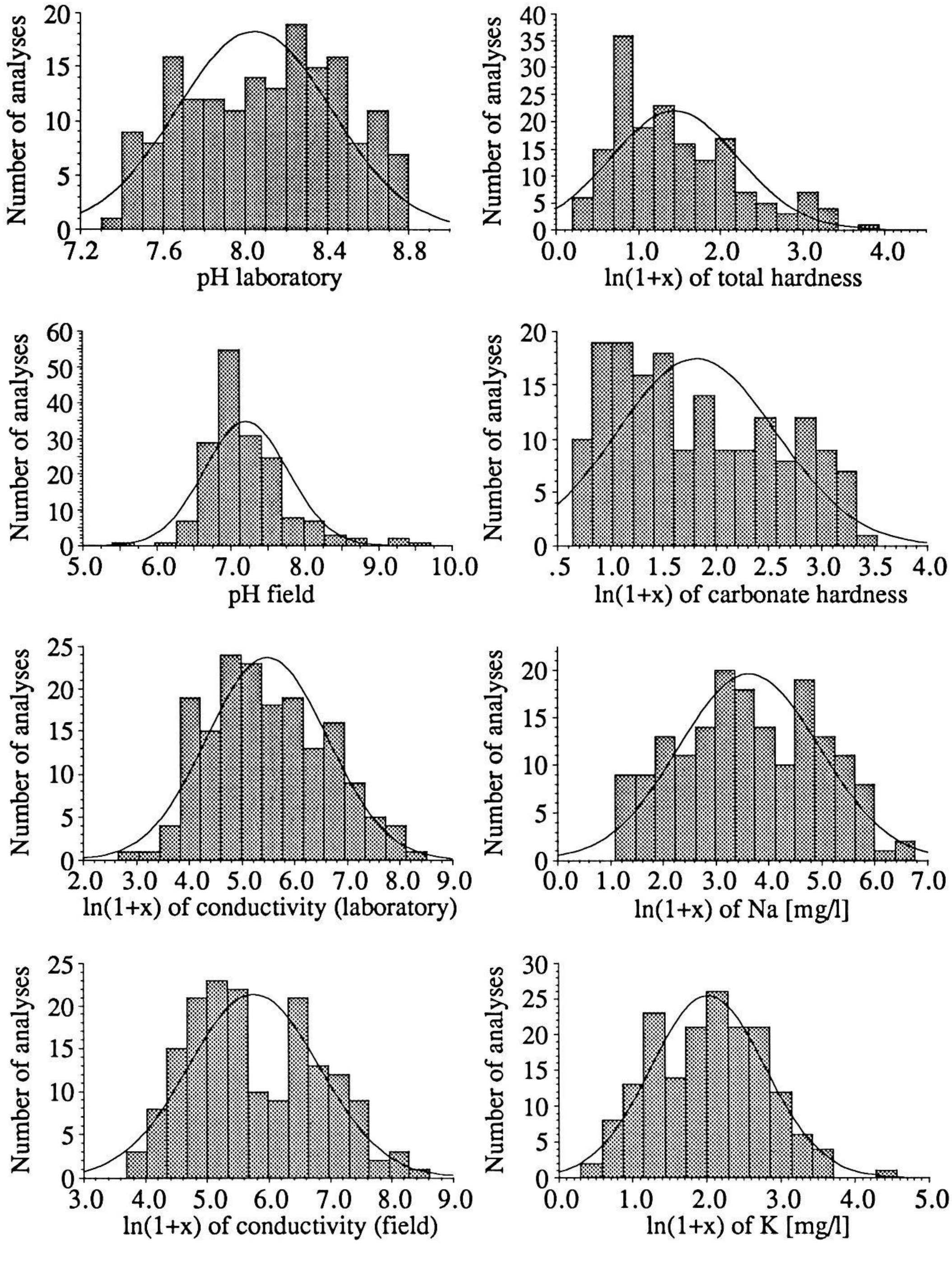


Fig. 5. Data of water analysis.

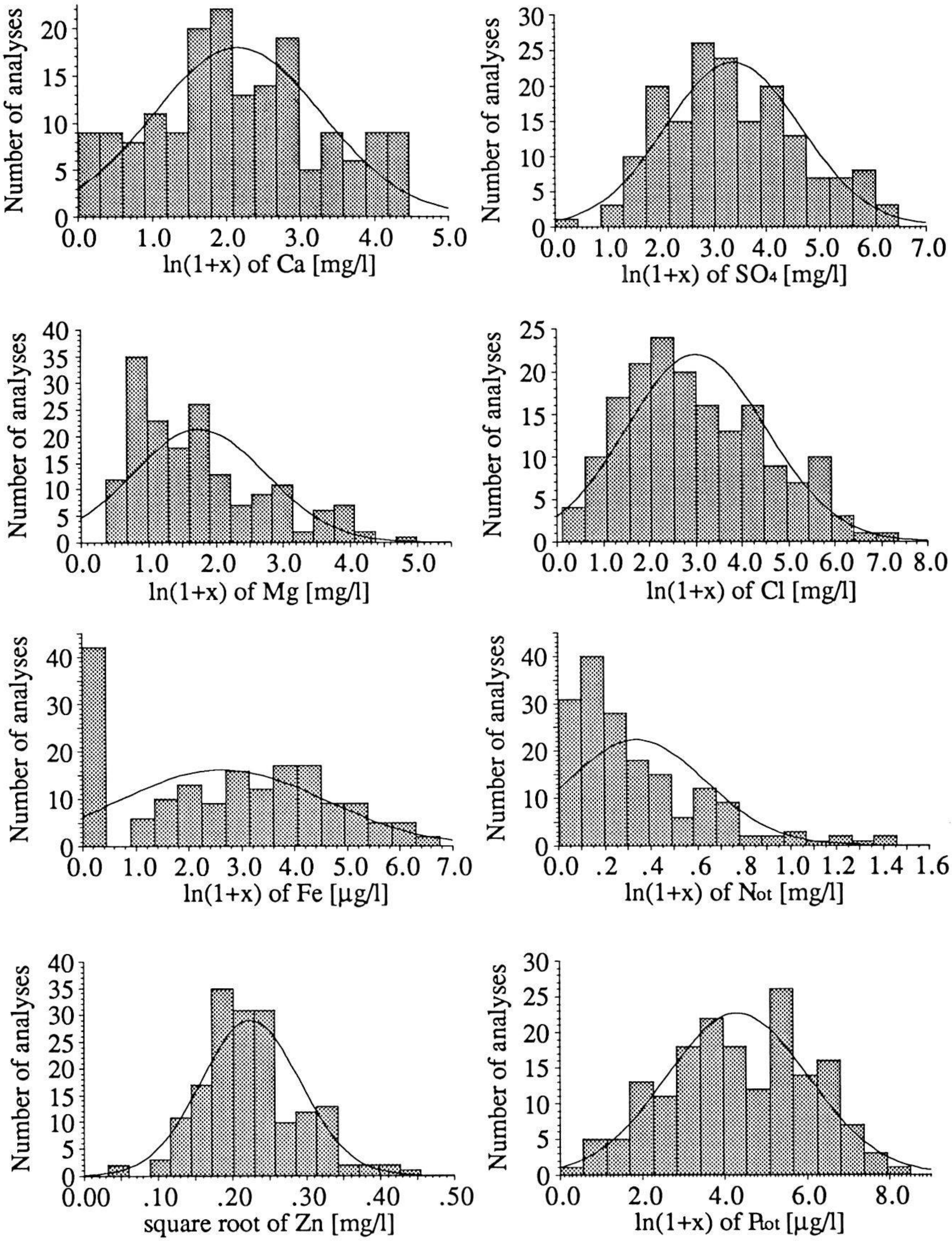


Fig. 5. (contin.) Data of water analysis.

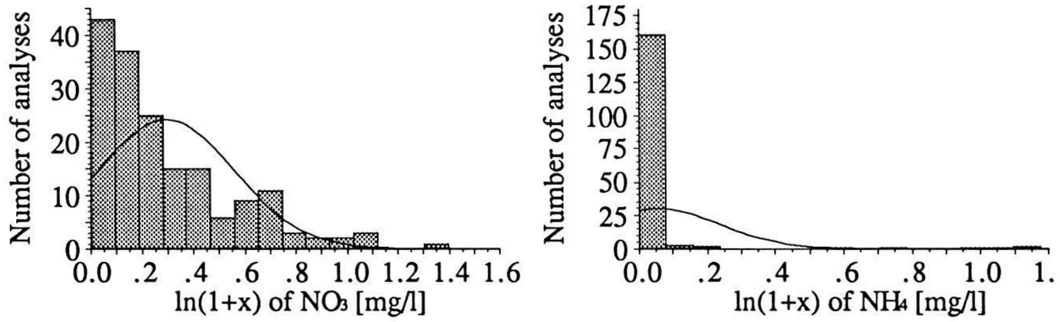


Fig. 5. (contin.) Data of water analysis.

5) pH is independent of all other factors. The pH in the field and in the laboratory is not correlated (see Fig. 6c). The pH range in the field was higher than in the laboratory (between 5.5 and 9.5 versus 7.3 and 8.8 in the laboratory), and the average pH was lower as well. Since the pH in the field is dependent not only on the base content of the water but also on the intensity of biological reactions going on. The measured pH reflects only a momentary stage and is subject to changes throughout the day and year.

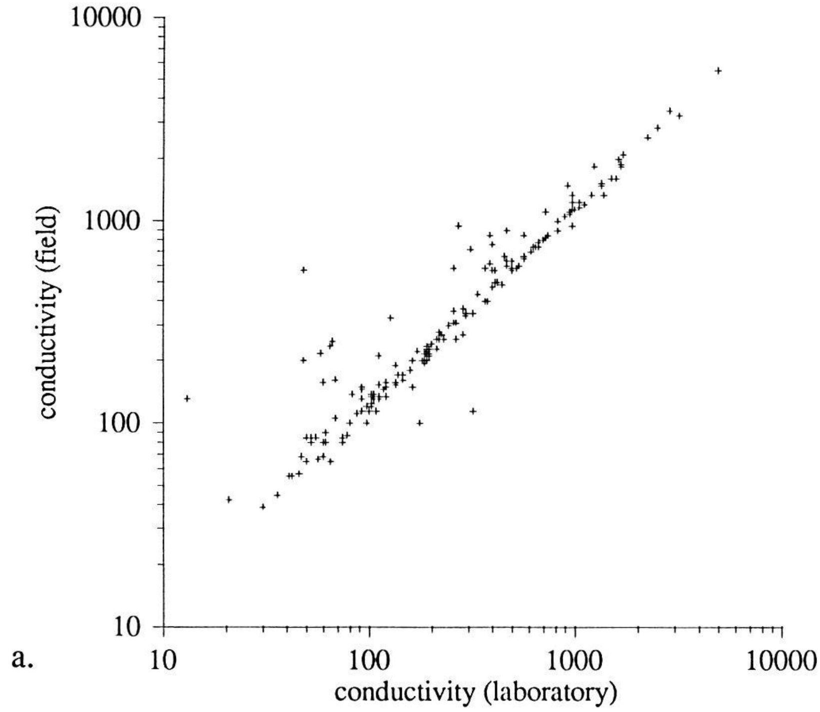
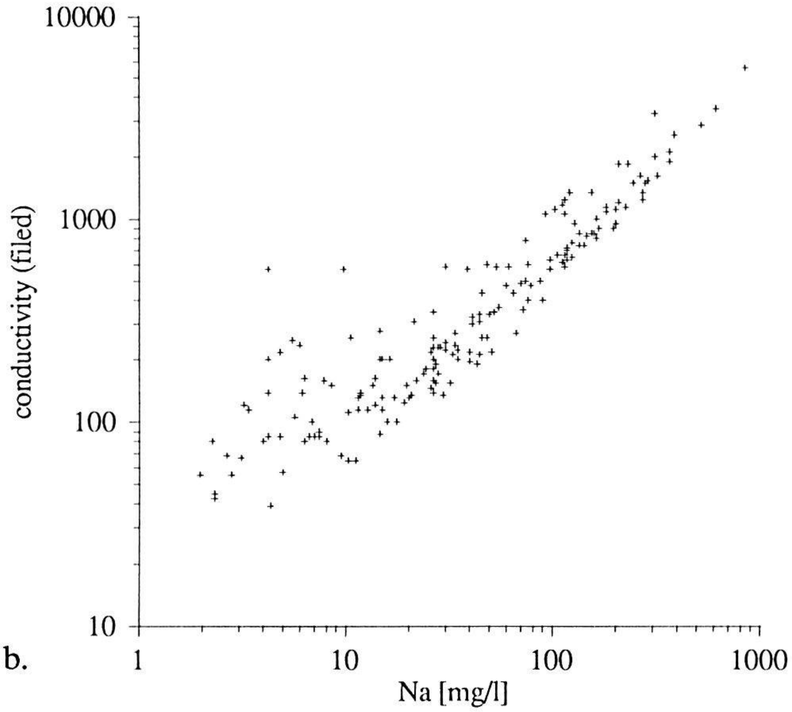
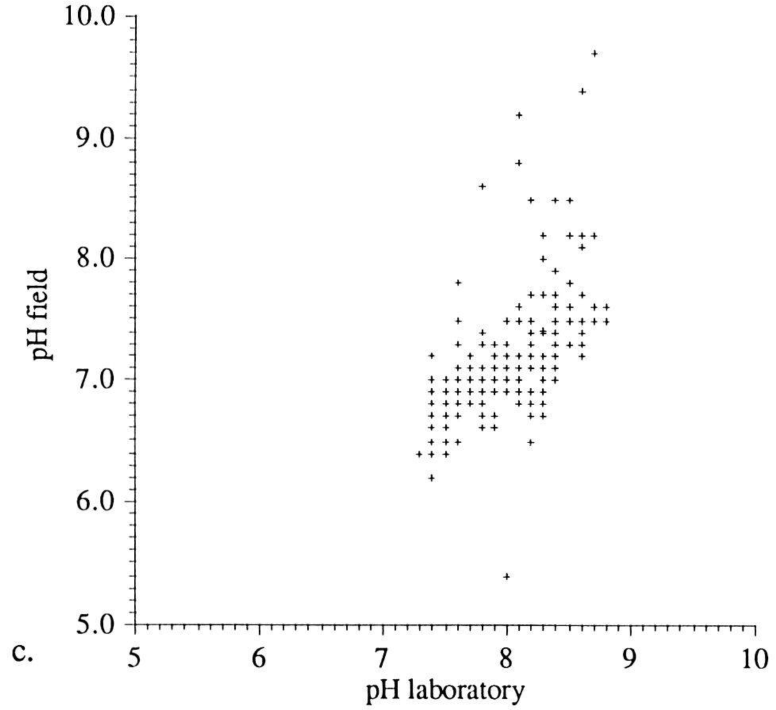


Fig. 6. Correlations between different water parameters.



b.



c.

Fig. 6. (contin.) Correlations between different water parameters.

Table 12. Mean values of various nutrient factors in the water for each species of lemnids. n = number of samples.

	Na	K	Ca	Mg	Zn	SO_4	Cl	N_{tot}	P_{tot}	carb. hard.	pH	cond.	n
Spirodela intermedia	66	6.1	10.7	6.7	0.050	49	47	0.59	0.16	5.6	7.2	459	53
Lemna gibba	157	14.8	24.2	16.1	0.053	16	126	0.70	0.22	13.4	7.6	973	53
Lemna aequinoctialis	77	8.5	20.2	12.2	0.048	77	58	1.07	0.58	6.7	7.1	546	18
Lemna valdiviana	83	9.4	21.1	14.7	0.053	99	87	0.40	0.37	6.5	7.9	509	42
Lemna minuta	85	8.1	13.5	8.9	0.056	66	71	0.42	0.19	6.8	7.2	563	110
Wolffiella lingulata	74	7.2	14.9	9.6	0.054	71	70	0.36	0.24	5.1	7.1	530	69
Wolffiella oblonga	81	8.5	13.5	9.5	0.060	73	71	0.34	0.24	6.2	7.2	538	66
Wolffia brasiliensis	92	12.5	14.6	9.9	0.068	88	66	0.53	0.15	8.1	7.3	600	32
Wolffia columbiana	128	9.1	19.6	13.5	0.048	104	104	0.46	0.30	9.9	7.4	822	56
Salvinia auriculata	27	4.0	5.7	3.0	0.052	15	21	0.12	0.10	2.8	6.9	173	12
Salvinia herzogii	50	6.0	10.1	5.7	0.051	42	48	0.32	0.12	4.0	7.0	369	38
Salvinia minima	58	6.1	11.9	7.2	0.058	47	53	0.35	0.26	4.5	7.1	346	67
Azolla caroliniana	41	6.1	10.3	6.1	0.057	50	32	0.36	0.19	4.0	7.0	321	91
Azolla filiculoides	146	13.5	18.3	11.7	0.058	87	120	0.63	0.21	12.0	7.6	859	52
Ricciocarpus natans	68	7.8	9.3	7.5	0.064	46	67	0.35	0.11	5.2	7.1	444	55
Limnobium laevigatum	46	5.4	9.1	4.8	0.060	40	38	0.30	0.12	3.9	7.0	325	63
Pistia stratiotes	71	6.8	14.8	9.4	0.050	70	63	0.57	0.30	5.4	7.1	510	80
Ceratophyllum dem.	171	9.3	16.1	12.6	0.051	114	140	0.32	0.16	10.8	7.7	1070	13
Utricularia gibba	30	6.3	8.0	3.4	0.070	29	25	0.27	0.09	3.6	6.8	228	22

3.5.2. Distribution of species and water quality

The mean values of nutrient content of all waters in which the various species occur are shown in Table 12 and the variation is put together in Fig. 7. Species with distinct deviations from the mean are listed in Table 13. The NO_3 and the NH_4 contents were so varied that there is no sense in correlating these factors with the occurrence of different species. *Lemna gibba, Ceratophyllum demersum, Azolla filiculoides* and, to a lesser extent, *Wolffia columbiana* and *W. brasiliensis,* occur usually in water with more Na, K, Ca and Mg than the other species. On the other hand *Salvinia auriculata* and *Utricularia gibba* generally grow in waters with a below average content of these ions.

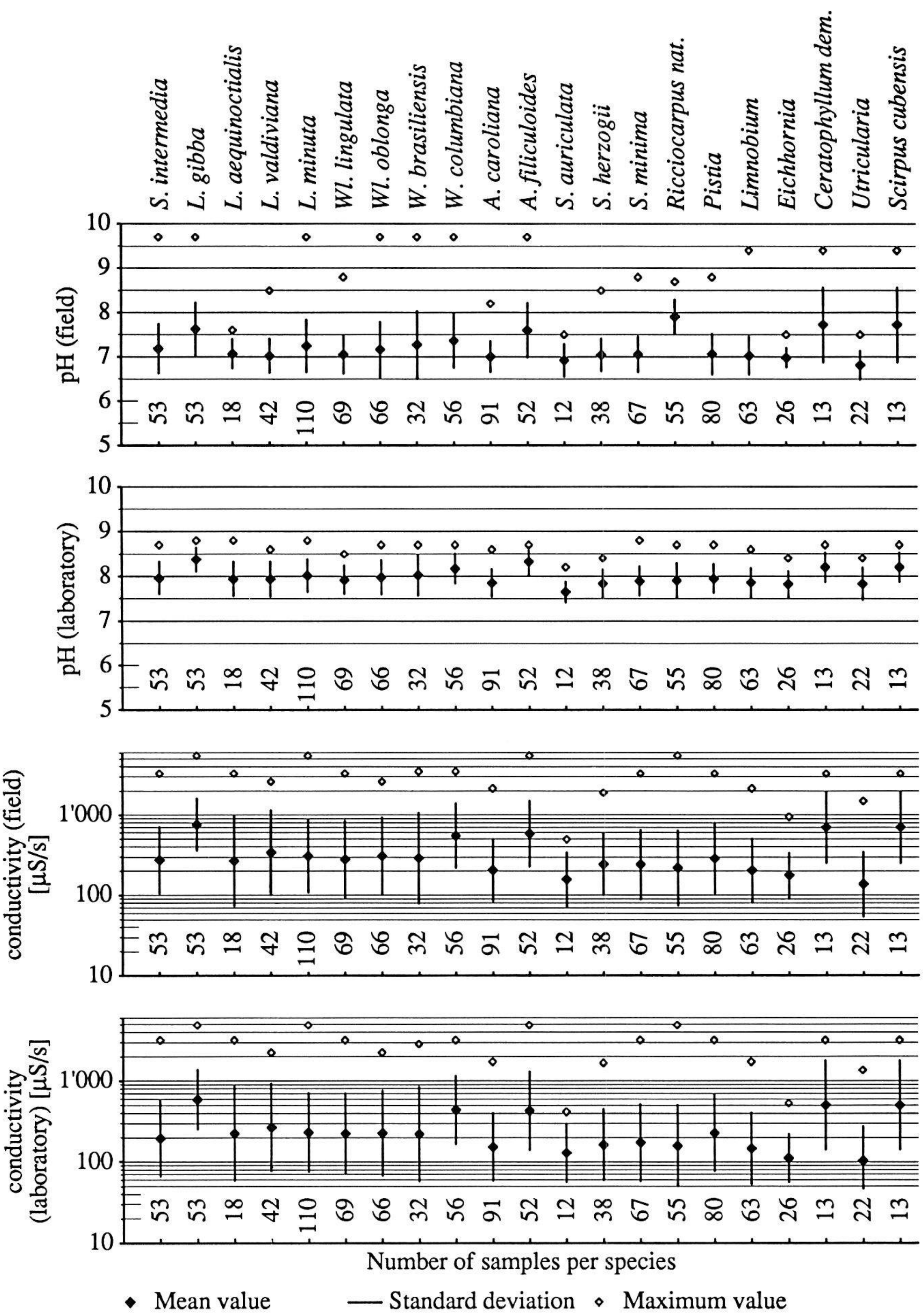


Fig. 7. Parameters of the water samples with the various species of lemnids.

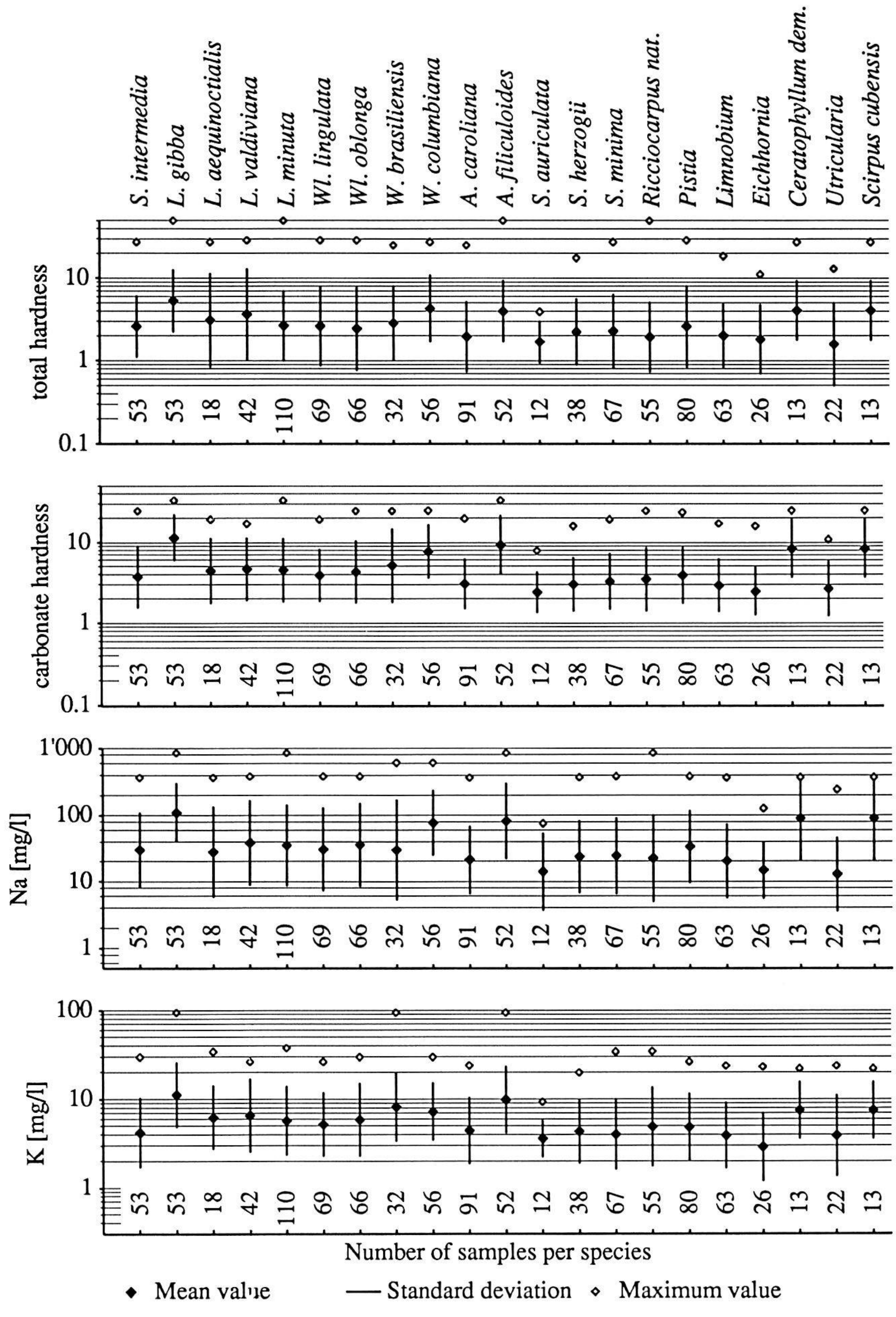


Fig. 7 (contin.) Parameters of the water samples with the various species of lemnids.

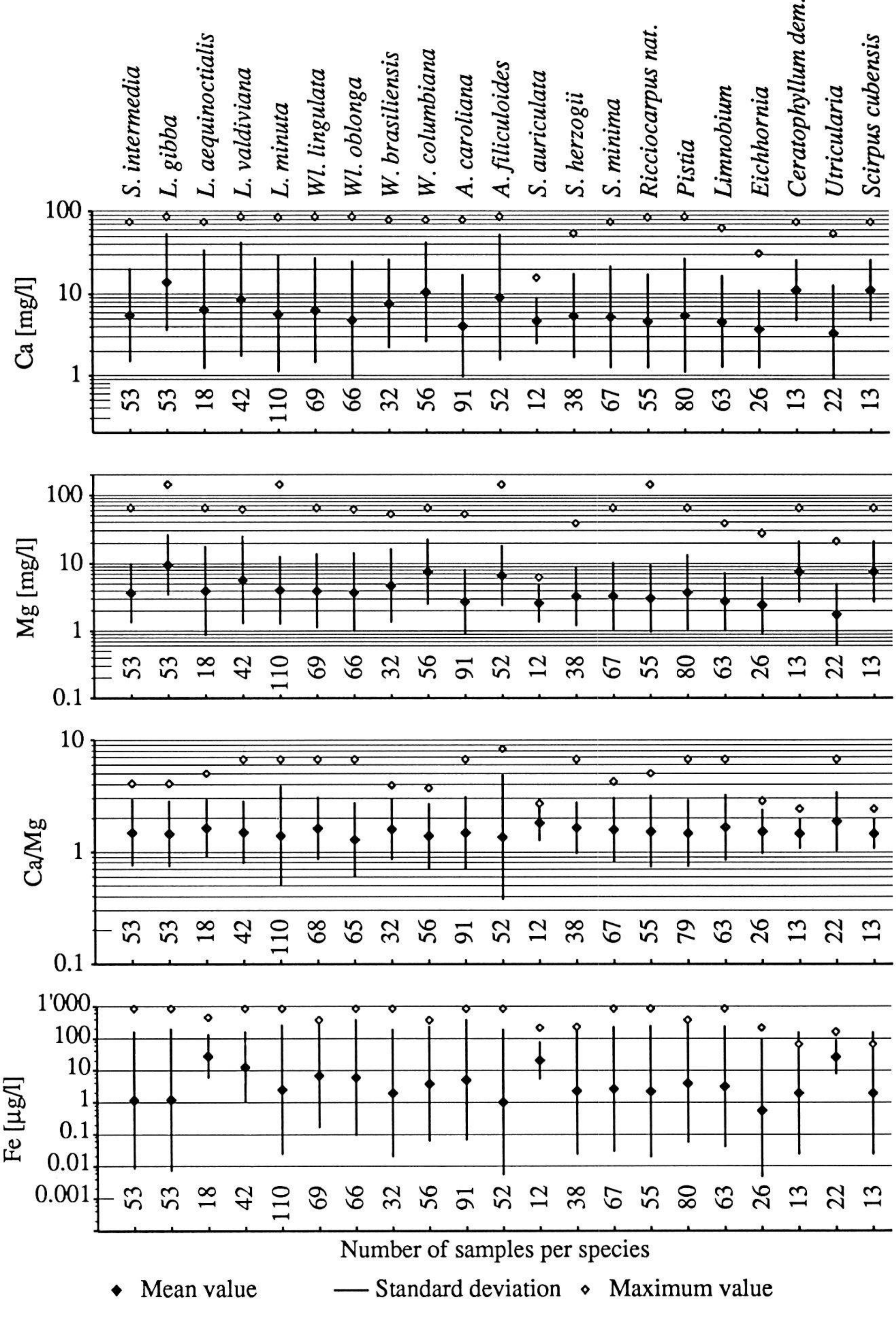


Fig.7. (contin.) Parameters of the water samples with the various species of lemnids.

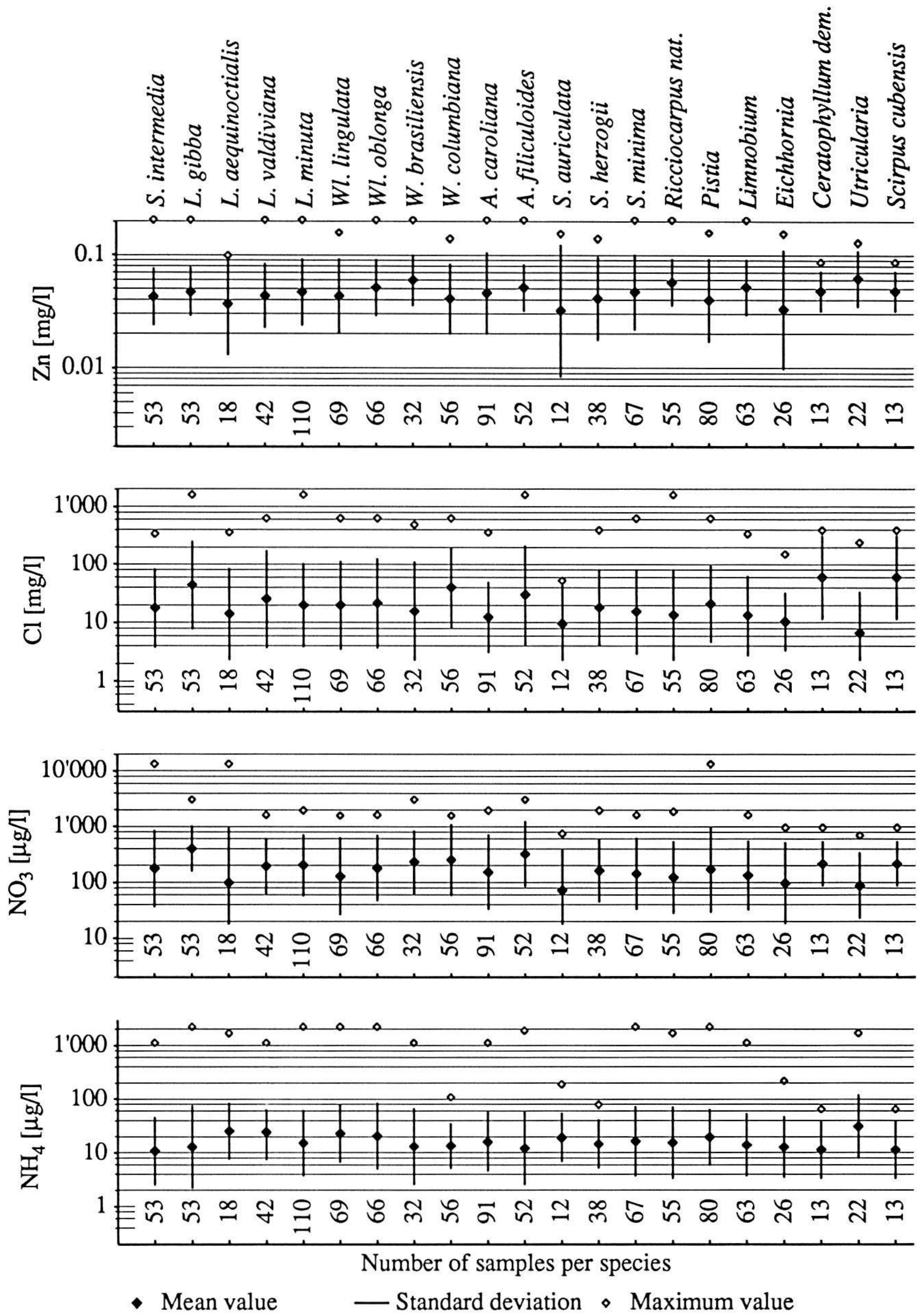


Fig.7. (contin.) Parameters of the water samples with the various species of lemnids.

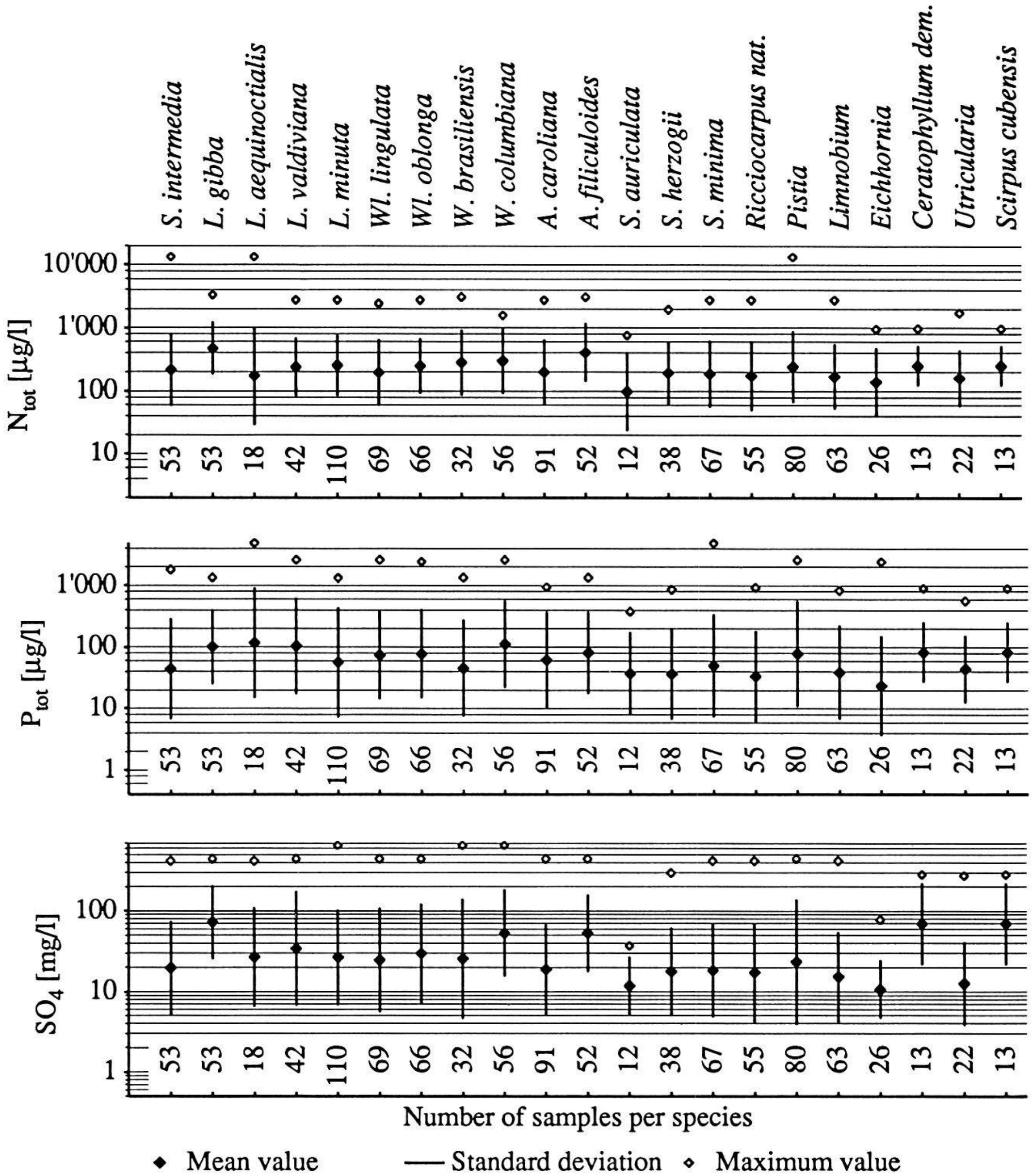


Fig.7. (contin.) Parameters of the water samples with the various species of lemnids.

Table 13. Deviation of the various species from the mean of various water characteristic values.

ions	higher than mean	lower than mean
Na	*Lemna gibba*	*Salvinia auriculata*
	Azolla filiculoides	*Utricularia gibba*
	Wolffia columbiana	*Eichhornia crassipes*
	Ceratophyllum demersum	
K	*Lemna gibba*	*Salvinia auriculata*
	Azolla filiculoides	*Eichhornia crassipes*
Ca	*Lemna gibba*	*Utricularia gibba*
Mg	*Lemna gibba*	*Utricularia gibba*
	Azolla filiculoides	*Eichhornia crassipes*
	Wolffia columbiana	
Fe	*Lemna aequinoctialis*	*Eichhornia crassipes*
	Salvinia auriculata	
	Utricularia gibba	
Zn	*Utricularia gibba*	
	Wolffia brasiliensis	
SO_4	*Lemna gibba*	*Salvinia auriculata*
	Ceratophyllum demersum	*Utricularia gibba*
	Wolffia columbiana	*Eichhornia crassipes*
Cl	*Lemna gibba*	*Utricularia gibba*
	Ceratophyllum demersum	
N_{total}	*Lemna gibba*	*Salvinia auriculata*
	Azolla filiculoides	
P_{total}	*Lemna aequinoctialis*	*Eichhornia crassipes*
	Lemna valdiviana	*Lemna gibba*
	Wolffia columbiana	
total hardness	*Lemna gibba*	*Salvinia auriculata*
	Wolffia columbiana	*Utricularia gibba*
	Azolla filiculoides	*Ceratophyllum demersum*
carbonate hardness	*Lemna gibba*	*Salvinia auriculata*
	Wolffia columbiana	*Utricularia gibba*
	Azolla filiculoides	*Eichhornia crassipes*
	Ceratophyllum demersum	
conductivity in the field	*Ceratophyllum demersum*	*Utricularia gibba*
	Lemna gibba	*Salvinia auriculata*
	Wolffia columbiana	*Eichhornia crassipes*
	Azolla filiculoides	*Azolla caroliniana*