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Changes in aquatic macrophytes since 1933 in an urban lake, Iidesjärvi, SW Finland

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Encroaching urbanisation changed Iidesjärvi from being a lake largely in a rural area surrounded by cultivated fields, pastures and meadows at the beginning of the 20th century to its present-day urban land setting. The lake has been damaged by pollution, road construction, dumping of toxic waste, introduced species and building of new settlements. To assess the impact of these temporal changes in the aquatic plant biodiversity of Iidesjärvi this study analysed macrophyte survey data collected during the course of the 20th century. The study indicated that despite of the environmental changes the total number of aquatic macrophytes remained relatively stable, but the species composition has changed considerably reflecting the changes in land use, water quality and the invasion of alien species. Some previously dominant species have disappeared with eutrophication affecting particularly elodeids and ceratophyllids. Some species have returned to the lake after a long absence. Similar lakes in the region form a dynamic system where the exchange of species from one to another may be possible. The semi-isolated lagoons may also help to re-establish aquatic macrophyte species in the main basin of Iidesjärvi, if the water quality improves in the future.

Key words: environmental monitoring, aquatic botany, macrophytes, urban ecology

Introduction

A frequently raised question is how ecology as a science can help solve environmental problems (Peters 1991, Shrader-Frechette & McCoy 1993). The increasing willingness to incorporate ecology into planning and decision making has led to a new situation where ecologists should be able to answer questions raised by, for example, urban planners.

Until very recently, ecological arguments have mostly been ignored in urban planning. Now, with the appearance of a new planning culture, cities face new challenges, such as what to do with environmentally valuable areas after decades or even centuries of non-ecologically orientated planning and land-use. Among possible strategies is environmental rehabilitation to at least partly recover the lost ecological values, creation of new habitats or leaving the area to develop naturally (Breuste 2004).

In an urban context the techniques of experimental ecology (like randomization, replication and control observations) are often not feasible.

Instead, the method of case studies may be applicable (Shrader-Frechette & McCoy 1993). The method of case studies has been described as holistic: it investigates a contemporary phenomenon within its real-life context (Yin 1994).

The aim of this study is to analyse the temporal change of plant biodiversity of Iidesjärvi within the City of Tampere, SW Finland, during the 20th century in the context of urbanisation and land use planning in the surrounding areas. Many factors have affected the lake and changed it in different directions. In this study, these factors will be identified and their consequences analysed.

Comparative studies on aquatic macrophytes have been made in Finland and in other countries (Rintanen 1996, Sand-Jensen *et al*. 2000, Barkman 2003, Preston *et al*. 2003). In Finland, the 20th century was the first century when relatively reliable biological information was available for the whole period. Also the methods used in earlier studies are often sufficiently similar to present ones to permit comparison of results. Other documentation is also available more or less from the beginning of the century like detailed maps, photographs (including aerial photographs) and basic environmental measurements (mostly hydrological data).

Study area

Iidesjärvi is a lake of 65 ha about 2 km southeast of the centre of the city of Tampere (population around 200 000). Iidesjärvi is a shallow lake: the mean depth is 1.2 m and the deepest point about 3 m. The length of the shoreline is about 6 km. The catchment area of the lake is 34 km^2, including two other water bodies, Kaukajärvi-Pitkäjärvi and Alasenjärvi. The catchment area consists mostly of residential housing areas, industrial areas, parks, grass- or shrublands (former fields) and small coniferous forests. A short brook, the Viinikanoja, runs from Iidesjärvi to Pyhäjärvi, a much larger lake. The total water volume of Iidesjärvi is 800 000 m^3 and theoretical retention time is about 40 days. The bedrock around Iidesjärvi consists mostly of gneiss. The soils are of clay and loam.

Until the 1970s, a marshy wetland (ca. 50 ha) occurred at the eastern side of the lake abutted Aakkulanharju, a high glacifluvial esker. The area was mostly a flooded meadow with some permanent ponds. Every spring the flood rose to the meadow. The meadow was dominated by various sedges (*Carex* spp.), reedy helophytes and partially by willows (*Salix* spp.). The high esker of Kalevanharju rises from the northern shore of Iidesjärvi and shelters the lake from winds from north. This creates favourable microclimatic conditions.

Review of Iidesjärvi data and background information

Data sources

As an urban, species-rich lake, Iidesjärvi has been the object of some biological observations and research during much of the 20th century. Data from this research is widely scattered and only partly published. Initially, plants and insects were collected irregularly for private and public collections. During the latter part of the century, local scientific societies (botany, entomology and ornithology) collected a lot of information about Iidesjärvi (e.g. Salokannel 2002, Paasivirta & Salmela 2002, Salmela 2002). The results of these works have mostly been published in the local journals and leaflets of these societies. Regular environmental monitoring by municipal and other authorities started in the middle of the century. The main objective for this monitoring was the water quality, although heavy metal concentrations in fish were also investigated.

Relevant information has also been found in many non-biological sources, like the archives of local museums, collections of historical photographs, local newspapers and magazines. These sources have been used for the evaluating the anthropogenic pressure on the lake.

Macrophyte surveys

Systematic botanical research on Iidesjärvi started with a flora inventory in the 1930s (Lehtonen 1933). Later the focus of botanical studies was on the flora and typology of the lake or influence of different environmental variables (like pH and nutrients) (Perttula 1954 (inventory made in 1947), Järnefelt 1956, Toivonen and Ranta 1976 (inventory made in 1975). In 1991 the open water area and most reed beds were studied by Heikki Toivonen and Kimmo Syrjänen. Aquatic and terrestrial flora of the lake was studied in 1994 by Lahtonen (Lahtonen 1994). Results form the 1991 and 1994 inventories are combined here. In 2000, the present authors repeated the inventory of water plants. A follow-up inventory was made in 2003 by Pertti Ranta. These data, (only slightly different from the data of 2000), has been used later in the analysis of the results.

In all surveys (except that in 1991) the entire shoreline was studied by walking. The water area was studied from a rowboat, using the water-plant rake and also a viewing tube in later surveys. The frequency and abundance of macrophyte species was estimated using a seven-degree scale in all surveys (1933, 1947, 1975, 1991 and 2003) except the abundance of species in 1947. In surveys 1975, 1991 and 2003 scaling of frequency and abundance values was made based on the percentage values as follows:

- very rare, very sparse < 1.5%
- rare, sparse = 1.5%–3%
- fairly rare, fairly sparse = 3%–6%
- occasional, scattered = 6%–12%
- fairly frequent, fairly abundant = 13%–25%
- frequent, abundant = 26%–50%
- very frequent, very abundant = 51%–100%

The frequency values are based on the ratio of the summed length of occurrences of each species to the whole shoreline length. The abundance values give the average percentage (perpendicular projection) in representative stands of the species. The seven-degree scales used earlier for frequency in 1933 and 1947, and for abundance in 1933, are more subjective but may be roughly corresponding to the later inventories. The abundance for macrophytes in 1947 was given as the size of the largest stand of each species, using a five-degree scale as follows: 1 < 10 m^2, 2 = 10–100 m^2, 3 = 100–1000 m^2, 4 = 1000 m^2–1 ha, 5 > 1 ha.

Species included in this study were vascular aquatic macrophytes as defined in Finnish botanical studies since Linkola (1933). Aquatic macrophytes were classified according to growth forms as defined by Toivonen and Huttunen (1995). The growth forms used are helophytes (incl. tall sedges), nymphaeids, rhizophytic hydrophytes (elodeids and isoetids) and pleustophytes (ceratophyllids *s. lato* and lemnids *s. lato*).

A comprehensive inventory of the terrestrial plants on the shores was also made in 1975 by the present author Pertti Ranta. The study was repeated in 1999–2000 using the same methods. A study of the terrestrial plants was also published by Lahtonen (1994).

Anthropogenic pressures

Historical records, including old photographs and maps, give a clear picture of the changing land use and human impact on Iidesjärvi (Keskitalo-Tanskanen 1998). The total population of Tampere increased from 44 000 (1900) to 106 000 (1950) and 195 000 (2000) (City of Tampere 2005). At the beginning of the 20th century, the shores were mostly cultivated fields, pastures and hayfields (City of Tampere 1917). Grazing during the first half of the century kept the shores as treeless meadows, which favoured many species of vascular plants (Fig. 1).

On the slopes of the esker Kalevanharju a new suburban area was built at the turn of the 19th and 20th centuries. The lake was commonly used for household fishing and different recreational activities like boating and picnicking. During the first years of the 20th century, the water from Iidesjärvi was used directly as drinking water supply in wintertime.

A landfill site started to operate on the southern shore of the lake in 1929. Waste was partly dumped directly into the water. The landfill site functioned until 1959. Many complaints from local residents were recorded because of the smell and fumes from the burning of waste (Keskitalo-Tanskanen 1998). Now, over 40 years later, the site is still listed as a potentially dangerous contaminated land area. According to historical records, the quality of the fish started to deteriorate in the 1940s. The city started to expand in the surroundings of the lake in the late 1940s and early 1950s. New sewers were

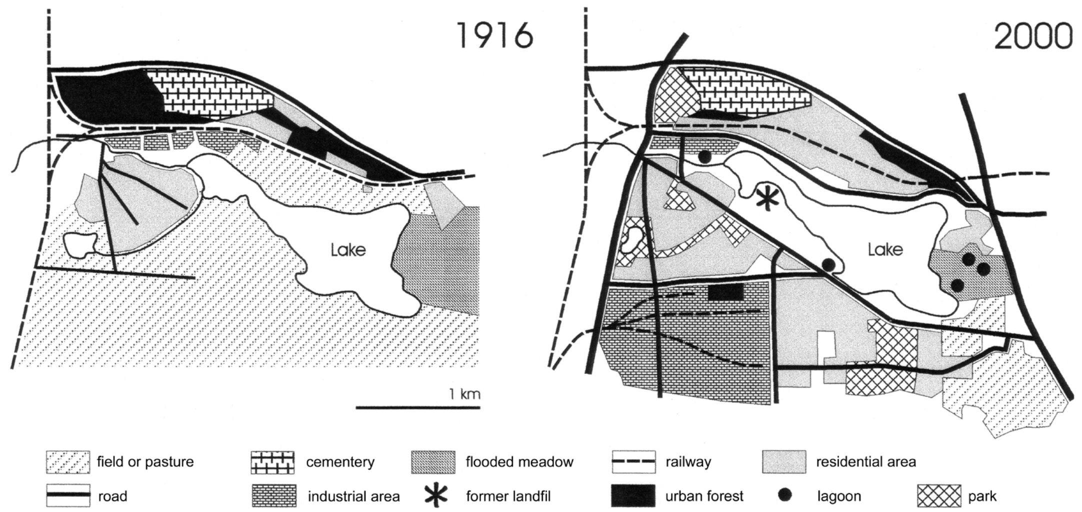

Fig. 1. Land use around Iidesjärvi 1916 and 2000.

constructed in the expansion areas. Untreated sewage entered Iidesjärvi. This led to the beginning of the nutrient-loaded sediments in the lake. Algal blooms were recorded in the lake 1948 (Perttula 1954), a period which coincided with a decline in the quality of the fish. In 1984, both pike (*Esox lucius*) and bream (*Abramis brama*) were assessed as being unsuitable for human consumption because of taste and smell problems. Lack of oxygen in the lake led to massive fish deaths in winter, which led to the mechanical pumping of air starting in 1981. This has continued every winter since then.

The fields and pastures around the lake were gradually converted into housing areas, but on the southern shore grazing continued until the 1970s. Towards the end of the century, the urban pressure started to change the surroundings of Iidesjärvi more fundamentally. In 1975, the new access road to the satellite city of Hervanta cut the eastern flooded meadow in half. At the same time, new settlements were constructed very close to the shoreline. The pressure to improve recreational possibilities around the lake increased. For example, a bird observation tower was constructed on the southeastern shore in 1993 — when most of the ornithological value of the lake had already been lost. However, the local residents still complained about smell, algal blooms and the lack of swimming and fishing possibilities.

The fundamental challenge of Iidesjärvi for municipal planning is densification at the main urban green structure near the centre of the city. "The city had to choose between growth and green. The original Green Area Network (1994) defined Iidesjärvi as a fundamental element in the green network for the whole Tampere region. However, the new Municipal Plan (1988–1998) allocated the area for infill building" (GREENSCOM 2002).

At the beginning of the 1980s it became obvious that the lake was in a very bad condition. Restoration plans were made to recover at least some of the ecological and recreational values of the lake (Tampereen kunnallistekninen virasto 1981, Veisterä 1992). The western part of the lake was dredged in 1983–1986. About 10 ha were dredged and the nymphaeid belt (mostly *Nuphar lutea*) removed. However, the dredged material was deposited onto shores of the lake resulting in some of the nutrients flowing back into the lake. This restoration created on open water area that still existed in 2003, but it had very little effect on solving the fundamental problems of the lake.

Two alien vertebrates were introduced to Iidesjärvi in the 20th century. The muskrat (*Ondatra zibethica*) was very common by the 1970s (Toivonen & Meriläinen 1980). The size of muskrat populations are known to vary considerably. During recent years their population has

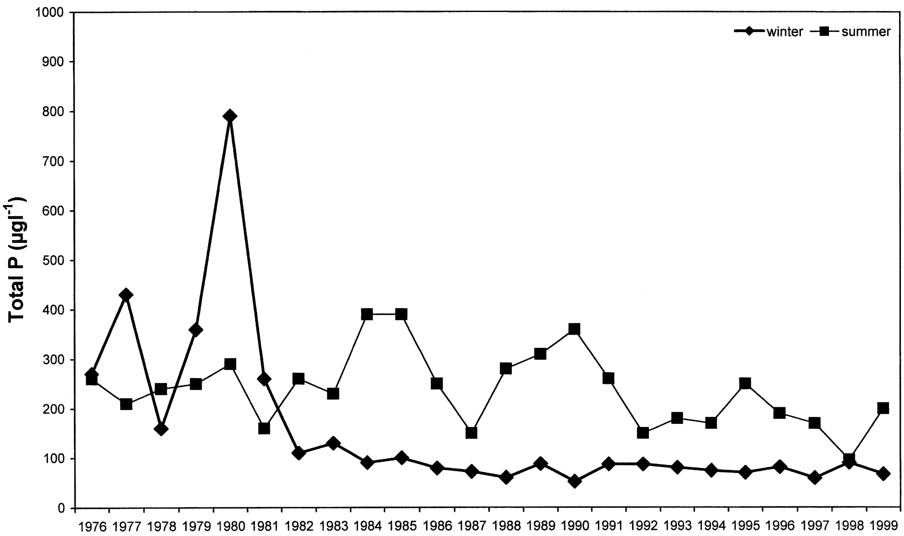

Fig. 2. Total phosphorus concentration near the bottom at the deepest part of Iidesjärvi.

again been abundant. The muskrats have caused considerable decline in the littoral vegetation of the lake. Another introduced animal is the carp (*Cyprinus caprio*). In 1989–1997 period about 2500 carps were released into the lake (Kosonen 1998). The carp has thrived in the lake.

The history of Iidesjärvi and sediment analysis

The history of Iidesjärvi and its surroundings has been recorded in the sediments at the bottom of the lake. The sedimentological analyses reflect the effect of urbanisation and industrialisation (Alhonen 1981, 1986, Vuorinen, Uusinoka & Alhonen 1983, Hakala 1998).

The isolation of Iidesjärvi from the Ancylus Lake took place about 7000–8500 years ago. Since then the productivity of the lake has remained high. During last centuries nutrients from the clay minerals in the soil and run-off from agriculture have further enhanced the high productivity of the lake. The results of diatom stratigraphy show that the dominant diatoms have almost always been *Melosira granulata*, *M. ambigua* and *M. italica*. Species like *M. granulata*, *Surirella robusta* and *Gyrosigma acuminatum* reflect the recent pollution of Iidesjärvi (Alhonen 1981).

At present, Iidesjärvi is a hypertrophic lake, where the excess of nitrogen and phosphorus maintain very high primary production. Oxygen deficiencies have been frequent in winters, which were recorded in the sediments as sulphide bands on the surface of clay-gyttja layers (Alhonen 1986). The strong eutrophication of the lake is clearly reflected in the limnological data from the 1970s: conductivity values in winter were occasionally over 30 mS m^{-1}, total phosphorus was over 1000 μg l^{-1} and the summer pH sometimes was as high as 10. Since then total phosphorus concentrations show a slight declining trend (Fig. 2): the latest values were 150 μg l^{-1} (summer 2006) and 58 μg l^{-1} (winter 2007) (Data provided by the Water Protection Association of the Kokemäenjoki). Although nutrients are no longer derived from inputs of sewage, the high internal loading from nutrient-rich deposits in the bottom of the lake are largely responsible for maintaining the high productivity. The total phosphorus concentration was 1.4–2.2 g kg^{-1} in the younger sediment layers (Oravainen 1990). The annual variation of the Secchi disc transparency shows a variation typical of a hypertrophic lake. In early summer, as well as in autumn, it is about 0.8–1 m. During periods of blue green algae blooms in late July and August, the transparency is often only 0.1–0.3 m.

The sediments have relatively high amounts of heavy metals, especially cadmium, lead, copper and zinc (Alhonen 1986). Zinc and copper showed the highest total amounts, which is typical for a heavily industrial city such as Tampere. In other lakes in the Tampere area the concentrations of heavy metals in sediments started to diminish as a result of reduced emissions, however, the concentrations in Iidesjärvi have remained stable (Hakala 1998). The lake functions as a sink for heavy metals.

In 1988, the sedimentary anthropogenic enrichment factors (SAEF) were 0.9–1.2 (Al), 0.8–1.1 (Fe), 1.3–3.5 (Mn), 2.8–3.9 (Cu), 2.3–3.0 (Zn), 4.3–10 (Cd) and 3.6–8.3 (Pb). In 1986, the SAEF value for mercury was 11.3. The concentration curves of copper, zinc, cadmium and lead show a clear turning point, where the concentrations start to grow in relation to the background. The turning point is situated at the same depth for all elements: about 3–6 cm from the top of the sediment layers. The age of these sediments coincides with the industrialisation of Tampere about 150 years ago (Alhonen 1986, Hakala 1998).

Analysis of changes in the macrophyte flora in Iidesjärvi since 1933

Aquatic plants

A total of 48 aquatic macrophyte species have been found in Iidesjärvi since 1933. This represents a high number of aquatic macrophytes for a small Finnish or NW European water body in general (Rørslett 1991). Twenty three helophytes, ten elodeids, four ceratophyllids, and five lemnids have been recorded. The number of nymphaeids (five species) is typical of Finnish eutrophic lakes, but the isoetids are represented only by one species (Table 1).

The species pool of macrophytes is dominated by species which thrive in eutrophic lakes and by species tolerating a variety of trophic conditions (= indifferent). Species preferring oligotrophic and oligo-mesotrophic lakes are relatively few and low in their abundances (Table 2). True oligotraphents are missing in Iidesjärvi.

Of the 48 recorded species, 23 persisted over the whole study period (1933–2003), 14 became extinct since 1933/1947, 10 colonized the lake, and 1 species disappeared but re-colonized later. The frequencies and abundances of aquatic plants in Iidesjärvi 1933–2003 are listed in Table 3. The highest number of species was recorded in 1947–1948 (37 species). As a whole, the number of species has remained rather stable during the whole period.

Permanent species (found in all surveys) are mostly indifferent or meso-eutraphent species. Of the species that disappeared, many were submerged. New species are mostly eutraphents or meso-eutraphents, and some of them (*Typha latifolia*, *Glyceria maxima*, *Sparganium erectum* and *Potamogeton crispus*) show increasing trends in the Finnish waters during recent decades (Rintanen 1996, Barkman 2003).

Two indifferent species (*Phragmites australis* and *Nuphar lutea*) were dominant species (both in terms of frequency and abundance) in the lake during the whole period (Table 4). *Schoenoplectus lacutris* was dominant in earlier decades but disappeared later. Two submerged plants of nutrient-rich waters (*Potamogeton obtusifolius* and

Table 1. The growth forms of aquatic macrophytes and the observed number of species in various inventories.

	1933	1947	1975	2003	Total
Helophytes	16	20	20	17	23
Nymphaeids	5	4	4	4	5
Elodeids	7	5	4	7	10
Isoetids	0	1	0	0	1
Ceratophyllids	2	3	2	2	4
Lemnids	4	4	4	4	5
Total	34	37	34	34	48

Table 2. The number of species of aquatic macrophytes in different trophic states in various inventories. o-m = oligotraphent-mesotraphent, m = mesotraphent, i = indifferent (wide ecological amplitude), m-e = meso-eutraphent, e = eutraphent (classification by Toivonen & Huttunen 1995).

	1933	1947	1975	2003	Total
o-m, m	5	8	4	4	11
i	11	10	10	9	11
m-e, e	18	19	20	21	26
Total	34	37	34	34	48

Table 3. Aquatic macrophytes in Iidesjärvi in 1933, 1947–1948, 1974–1975, 1991 and 2003. Frequency: 1 = very rare, 2 = rare, 3 = rather rare, 4 = occasional, 5 = fairly frequent, 6 = frequent, 7 = very frequent. Abundance: 1 = very scarce, 2 = scarce, 3 = rather scarce, 4 = scattered, 5 = fairly abundant, 6 = abundant, 7 = very abundant. GF = growth form. 1 = lemnid, 2 = ceratophyllid, 3 = elodeid, 4 = isoetid, 5 = nymphaeid, 6 = helophyte. TR = trophic state, *see* Table 2. 33F = frequency in 1933, 33A = abundance in 1933, etc. 47S = size of largest stand in 1947: 1 ≤ 10 m^2, 2 = 10–100 m^2, 3 = 100–1000 m^2, 4 = 1000–10 000 m^2, 5 ≥ 10 000 m^2. fen = occurs on fen margin, not in the open water area, lag. = occurs only in the lagoons.

Species	GF	TR	33F	33A	47F	47S	75F	75A		91F	91A		03F	03A	
Permanent species															
Equisetum fluviatile	6	i	6	5	4	4	3	6		3	2	fen	2	1	fen
Phragmites australis	6	i	6	5	7	5	7	6		7	6		7	6	
Sagittaria sagittifolia	6	m-e	5	5	4	2	1	3		0	0		1	2	
Scolochloa festucacea	6	m-e	4	4	4	2	1	5		3	2		5	4	
Lysimachia thyrsiflora	6	i	4	4	5	1	4	2		3	2		4	2	
Sparganium emersum	6	i	4	4	3	2	1	5		1	2		5	5	
Alopecurus aequalis	6	m	4	4	4	1	3	2		2	1		1	1	
Alisma plantago-aquatica	6	m-e	4	3	3	1	2	2		2	1		4	3	
Eleocharis palustris	6	i	4	2	2	1	1	1		1	1		2	2	
Iris pseudacorus	6	m-e	4	2	1	1	1	1		3	3		2	3	
Typha angustifolia	6	e	1	1	2	3	1	1		0	0		1	1	
Rorippa amphibia	6	e	1	1	4	1	3	4		4	2		6	4	
Nuphar lutea	5	i	7	7	7	5	7	6		7	7		6	7	
Nymphaea alba	5	i	6	5	7	3	3	3		0	0		4	2	
Potamogeton natans	5	i	3	4	5	3	3	4		2	4	lag.	2	5	lag.
Persicaria amphibia	5	m-e	2	3	1	2	2	2	fen	1	1		2	1	
Potamogeton obtusifolius	3	m-e	7	5	5	2	6	6		2	2	lag.	3	4	lag.
Potamogeton praelongus	3	m-e	6	5	4	2	2	4		2	2		3	2	
Callitriche spp.	3	m	4	2	4	1	3	2		3	3	lag.	3	5	lag.
Utricularia vulgaris	2	i	3	2	5	3	2	4		2	4	lag.	2	4	lag.
Lemna minor	1	m-e	6	6	7	3	5	3		5	3		6	4	
Spirodela polyrhiza	1	e	5	4	7	3	2	2		4	2		4	3	
Riccia fluitans	1	m-e	1	1	3	1	1	1		3	2	lag.	1	2	lag.
Number of species			23		23		23			20			23		
Disappeared species															
Nuphar pumila	5	o-m	4	4	0	0	0	0		0	0		0	0	
Potamogeton alpinus	3	i	2	1	0	0	0	0		0	0		0	0	
Potamogeton perfoliatus	3	m	5	4	2	1	0	0		0	0		0	0	
Ranunculus lingua	6	m-e	1	1	1	1	0	0		0	0		0	0	
Butomus umbellatus	6	e	5	5	4	2	2	1		0	0		0	0	
Ceratophyllum demersum	2	e	7	7	7	3	4	3		0	0		0	0	
Potamogeton gramineus	3	m	2	1	1	1	1	1		0	0		0	0	
Schoenoplectus lacustris	6	i	7	7	7	4	3	4		1	1		0	0	
Glyceria fluitans	6	m-e	2	1	3	1	1	1		1	1		0	0	
Hydrocharis morsus-ranae	1	e	2	1	4	2	1	1		1	1		0	0	
Number of species			10		8		6			3			0		
In 1947 survey, disappeared later															
Sparganium natans	6	o-m	0	0	2	1	1	3		2	2		0	0	
Hippuris vulgaris	6	m	0	0	2	1	0	0		0	0		0	0	
Ranunculus reptans	4	o-m	0	0	4	1	0	0		0	0		0	0	
Utricularia intermedia	2	o-m	0	0	1	1	0	0		0	0		0	0	
Number of species			0		4		1			1			0		
Newcomer after extinction															
Potamogeton compressus	3	e	6	4	0	0	0	0		0	0		1	3	lag.
New species															
Typha latifolia	6	m-e	0	0	4	2	4	5		4	5		5	5	
Acorus calamus	6	e	0	0	1	1	1	1		0	0		1	1	
Glyceria maxima	6	e	0	0	0	0	2	1		2	3		2	3	

continued

Table 3. Continued

Species	GF	TR	33F	33A	47F	47S	75F	75A	91F	91A		03F	03A	
Sparganium erectum	6	e	0	0	0	0	1	1	2	3		1	1	
Potamogeton berchtoldii	3	m-e	0	0	0	0	0	0	2	5	lag.	2	3	lag.
Thelypteris palustris	6	e	0	0	0	0	0	0	2	5		2	6	
Callitriche hamulata	3	o-m	0	0	0	0	0	0	0	0		1	5	lag.
Potamogeton crispus	3	e	0	0	0	0	0	0	0	0		2	4	
Utricularis minor	2	o-m	0	0	0	0	0	0	0	0		1	1	lag.
Ricciocarpus natans	1	m-e	0	0	0	0	0	0	0	0		1	2	lag.
Number of species			0		2		4		5			10		
Total number of species			34		37		34		29			34		
% from the species pool (n = 48)			71		77		71		60			71		

Ceratophyllum demersum) were earlier abundant or even dominant but declined during the last decades. *Ceratophyllum* disappeared before the survey 1991. *Typha latifolia* (m-e) has increased markedly in last decades (Table 4).

Considerable changes have taken place during the last 70 years, but the change has not been linear. The changes in the aquatic macrophyte community from 1933 to 1947 (14 years) and from 1947 to 1975 (28 years) were comparable but the change from 1975 to 2003 (28 years) appears to have been more dramatic (Table 5). During this latter period, submerged vegetation disappeared from the open water area and some new species became established in the adjacent lagoons. The survey 1991–1994, representing one of the worst periods of the lake, was unfortunately not detailed enough to be used for comparison in Table 5. Results from the survey, however, clearly demonstrate poor occurrence or lack of many aquatic macrophytes, particularly in the main basin.

With regard to the aquatic vegetation, Iidesjärvi belongs to the eutrophic *Typha-Alisma* type of Maristo (1941). Earlier studies (Pertula 1954, Järnefelt 1956) describe the clear zonation of aquatic vegetation (from shore to the open water): *Carex acuta–Equisetum fluviatile–Phragmites australis–Schoenoplectus lacustris–Nymphaea alba–Nuphar lutea–Potamogeton praelongus*. By 1991, *Equisetum* and *Schoenoplectus* had disappeared from the open water area. The decline of these species was already obvious in 1975. The disappearance of these two emergent species greatly changed the general appearance of the lake. The last stronghold of these species was the south-eastern bay of the lake (Fig. 3). On the other hand, *Scolochloa festucacea* has increased in frequency and grows now as small colonies all around the lake, but it has not replaced the disappeared tall reeds. *Phragmites australis* and *Typha latifolia* are now the dominant emergent species.

Among smaller helophytes, *Butomus umbel-*

Table 4. Dominant species (D) with their frequency (F) and abundance (A) in different inventories; *see* Table 2 for the frequency and abundance scales.

	1933		1947		1975		2003	
	F	A	F	A	F	A	F	A
Schoenoplectus lacustris (i)	7	7 (D)	7	4 (D)	3	4	0	0
Phragmites australis (i)	6	5	7	5 (D)	7	6 (D)	7	6 (D)
Nuphar lutea (i)	7	7 (D)	7	5 (D)	7	6 (D)	6	7 (D)
Ceratophyllum demersum (e)	7	7 (D)	7	3	4	3	0	0
Potamogeton obtusifolius (m-e)	7	5	5	2	6	6 (D)	3	4
Typha latifolia (m-e)	0	0	4	2	4	5	5	5 (D)

latus was relatively common in 1933. It has declined since that time and was no longer found in 2003. Also *Sagittaria sagittifolia* has been declining slowly. *Rorippa amphibia* shows the opposite trend and it is now one of the most common herbaceous helophyte of the lake.

The severe, annual blue-algae blooms almost prevent light reaching the deeper water layers in most of the basin. The situation is different in a few neighbouring lagoons which are separated most of the growing season from the open water area by dense reed beds. Only during the spring floods does the water mix well between the lagoons and the main lake basin. Water in these sand bottom lagoons is more transparent (often about 1–1.5 m) and is free from intensive algal blooms. In the southeastern lagoon which is influenced by running water from one of the inflow brooks of the lake, some rare elodeids were found in 2000, namely *Callitriche hamulata*, *Potamogeton crispus* and *P. compressus*. The first two species were first time recorded in Iidesjärvi. *Potamogeton compressus* was frequent in 1933, but was not found in 1947, 1975 and 1991 surveys. Other hydrophytes of the lagoons that are missing in the main basin are *Utricularia vulgaris*, *U. minor*, *Potamogeton berchtoldii*, *Riccia fluitans* and *Ricciocarpus natans*. Most of the recent occurrences of *Spirodela polyrrhiza* are also in the lagoons.

In the main basin the elodeids and ceratophyllids clearly showed decreasing trends until the late 1990s. *Potamogeton gramineus* and *Ceratophyllum demersum* have disappeared since 1975. *Potamogeton obtusifolius*, once very frequent, is now rare. *Potamogeton praelongus* has maintained the same frequency since 1975, although it was much more frequent in 1933. The ten last years the lake has some initiation to develop a shorter or longer clear-water state before the appearance of algal blooms. During this phase some elodeids (*Potamogeton crispus*) have been common or abundant.

Terrestrial plants

The vegetation on the shores of Iidesjärvi consists of *Carex*-dominated wet meadows, mesic meadows (partly former pastures) and small forest patches composed of broad-leaved deciduous trees (*Alnusincana–Salix caprea–Salix fragilis–Betula* spp.). A municipal tree nursery is also situated on the southern side of the lake.

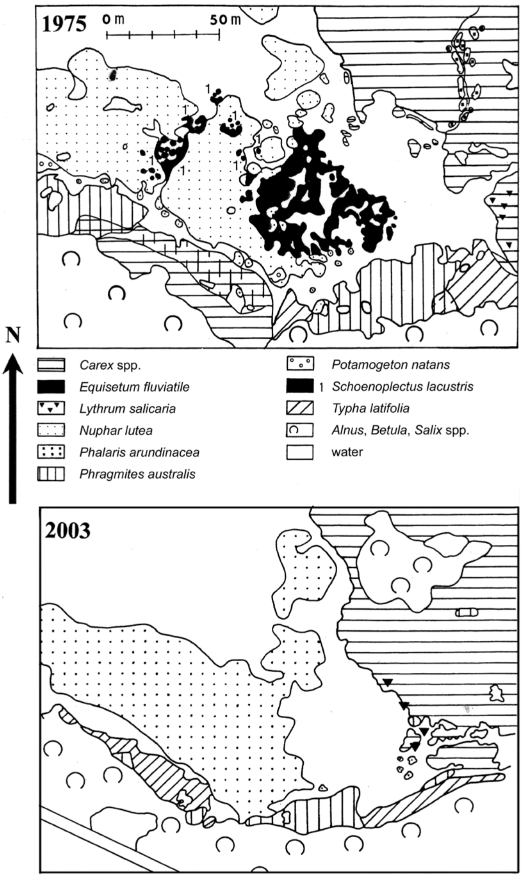

Fig. 3. Vegetation map of the southeastern bay of Iidesjärvi 1975 and 2003.

Table 5. Floristic change between various inventories. Dissimilarity index (DI) between surveys T1 and T2 = nT2 + dT2/tT1 + tT2; nT2 = new species in T2 survey, dT2 = disappeared species in T2 survey, tT1 = number of species in T1 survey, tT2 = number of species in T2 survey.

Inventories	DI (%)
1933–1947	12.7
1947–1975	9.9
1975–2003	20.6
1933–1975	14.7
1947–2003	29.5
1933–2003	29.4

The terrestrial flora, recorded in 1999–2003 consisted of 291 species (Lahtonen 1994). The influence of residential areas is indicated by the relatively high number of cultivation escapes (51). The total number of species on the shores has increased by 32 since 1975, 19 of which are new cultivation escapes. Some locally rare native species also grow in the area, for example *Salix rosmarinifolia*, *Humulus lupulus*, *Anemone ranunculoides*, *Carex cespitosa* and *Rumex aquaticus*.

Very few shore plants seems to have disappeared: only *Carex panicea* and *Vaccinium oxycoccos*. Other shore plants reported as having disappeared in 1994 (Lahtonen 1994) were found in 2003.

Discussion

The aquatic flora and vegetation changed considerably in Iidesjärvi during the study period (1933–2003). In Iidesjärvi only 60%, i.e. 24 of the 40 species found in inventories 1933 and 1947 persisted or re-colonized (23 and one species, respectively) during the study period. It is quite probable that some other extinctions and re-colonisations occurred during the surveys. At the same time 35% from species found in 1933–1947 disappeared later. On the other hand 10 new species have appeared since 1933.

The species turnover in Iidesjärvi is much higher than that in a group of small forest lakes (n = 25) in the Municipality Konnevesi, Central Finland (Virolainen *et al*. 1996). In the lakes of Konnevesi, 88% (28 of 32) of the original species persisted over 63 years (1933–1996). The changing anthropogenic pressure in Iidesjärvi forced some species out and favoured others that were able to colonize. Colonisation was possible because of the rich species pool of aquatic plants present in the Tampere area. All the colonizing species have several localities in other lakes at distances of 5–20 km from Iidesjärvi. The most probable vectors are water birds.

Some of the observed changes in the aquatic plant composition are common to many other lakes in the adjacent region. *Typha latifolia* is still spreading to smaller and more remote lakes in southern Finland (Toivonen 1980). It arrived in Tampere in 1912 and started to grow in Iidesjärvi between 1933 and 1947 (Toivonen & Ranta 1976). Another spreading reedy species is *Glyceria maxima*.

In the case of Iidesjärvi, some of the formerly most abundant species have disappeared totally or from the open water area and consequently changed the general appearance of the lake. Several historical photographs show clearly wide belts of *Schoenoplectus lacustris* around the lake in the beginning of the 20th century. *Schoenoplectus lacustris* was the dominant reedy helophyte during the first half of the century. In 1933, *Equisetum fluviatile* was as frequent and abundant as *Phragmites australis*. At the end of the century, *P. australis* and *T. latifolia* dominated the belts of helophytes. *Scolochloa festucacea* increased notably during the last 20 years. The dredging in 1983 of the main site of *Scolochloa* on the southern shore probably sent floating pieces of rhizome all around the lake. Also the activity of muskrats may have had similar effect. *Glyceria maxima* and *S. festucacea* are mentioned as increasing species also in Vesijärvi, a lake about 100 km from Iidesjärvi (Lammi & Lammi 1988).

Three main explanations can be found for the decline of the formerly dominant reedy helophytes. First, grazing on the shores of Iidesjärvi gradually decreased and finally stopped completely, which favoured *Phragmites*. Second, *Equisetum* does not tolerate excessive eutrophication (Kurimo 1970, Uotila 1971). Third, *Schoenoplectus* and *Equisetum* are among the favourite foods of muskrats (Artimo 1960). The decrease of these species coincides with the maximum density of muskrats in Iidesjärvi. *Typha latifolia* (and perhaps also *Scolochloa*) were able to expand after the decrease of the muskrat populations in the 1980s.

According to Smirnov and Tretyakov (1998) the importance of muskrats for the aquatic vegetation has been underestimated. In their study area on the Valaam (Valamo) islands of Lake Ladoga the invasion of muskrats caused a clear decline of biodiversity. The impact of muskrats has been observed also in some other lakes in the Tampere area (Perttula 1954, Toivonen & Meriläinen 1980). In Iidesjärvi, the stronghold of the muskrat population about 30 years ago was the eastern flooded meadow. After that meadow was mostly destroyed by road construction, the muskrat population started to decline.

The group of herbaceous helophytes shows contradictory trends in Iidesjärvi. The species that has increased most is *Rorippa amphibia*, a rare species in Finland. The dredging in the western part of the lake may have sent pieces of rhizomes or seeds floating around the lake. *Acorus calamus* occurring at the dredging site survived, but not *Butomus umbellatus*. *Ranunculus lingua* and *Hippuris vulgaris* have not been recorded in Iidesjärvi during the latter part of the century. *Sagittaria sagittifolia* shows a decreasing trend and may disappear from the lake in near future. *Thelypteris palustris* is a new species, which became well established on the reedbeds in the southern shore in the 1990s. It has increased in some other locations in the Tampere area.

In Iidesjärvi, *Nuphar lutea* maintained its position as the dominant nymphaeid for the whole century. *Nymphaea alba* decreased because of the muskrats and the dredging. *Persicaria amphibia* re-appeared as a floating-leaved plant in 2003. The decrease and temporal disappearance of *Glyceria fluitans* and *Alopecurus aequalis* can be explained by the discontinued grazing on the shores and the enhanced growth of reeds and other taller helophytes. Small open pools near the shore have mostly disappeared due to the expansion of *Phragmites australis*. As a group the nymphaeids usually tolerate eutrophication relatively well.

Losses in submerged plants were higher, out of total ten elodeids recorded in the lake, three were not found in 2003. Two of the four ceratophyllids were not found in 2003. *Ceratophyllum demersum* showed the greatest decline over the study period. It was clearly the dominant elodeid during the first half of the century and was still occasionally recorded in 1974–1975, but was missing by 1991 and 2003. The elodeids and ceratophyllids suffer particularly from hypertrophy and the consequent low transparency of the water (Sand-Jensen *et al*. 2000). Also *Potamogeton obtusifolius*, a meso-eutraphent species, declined from being very frequent to rather rare.

In Iidesjärvi, however, the situation is more complicated than elodeid and ceratophyllid species simply being lost, some species are being gained. *Potamogeton compressus* reappeared after an absence of almost 70 years. According to Lehtonen (1934) it grew besides Iidesjärvi also in Kaukajärvi (distance 5 km), and was found in the 1960s in the small Taivallampi (15 km east of Iidesjärvi). In the 1970s the species was not found in any of these lakes nor in other small lakes in the region (Toivonen & Huttunen 1995). It appeared in the 1980s in Kirkkojärvi (a lake 15 km east from Iidesjärvi (Bäck *et al*. 1988), and in early 1990s again in Kaukajärvi (H. Toivonen pers. obs.).

Potamogeton compressus was found in 2003 in a partly isolated lagoon under the influence of running water from the inflow brook on the eastern side of the lake with *Callitriche hamulata* and *Potamogeton crispus*. *Callitriche hamulata* was found for the first time in the lake. It was formerly found in the Tammerkoski rapids in the centre of Tampere (Ranta 1976) but has recently been found also in other lakes in Tampere. *Potamogeton crispus* formed dense stands in the main basin of Iidesjärvi in 2000 and later. In the Tampere region is was found for first time in 1947 in Kirkkojärvi, about 15 km east of Iidesjärvi (Perttula 1948). In recent years it has been found also in some other lakes in Tampere region. It has been recorded to be an expanding species in southern Finland (Lammi & Lammi 1989. All records of *Utricularia vulgaris* and *U. minor* (new species) were in the lagoons. The appearance of new rare elodeids in Iidesjärvi can be understood only by the existence of a suitable microhabitat where the conditions are essentially more favourable than in the main basin. As a whole, the five small lagoons have a great impact on the macrophyte diversity of the lake and function as refuges for several species or as recolonization sites.

As can be expected, given its natural productivity Iidesjärvi offers hardly any possibilities for isoetids. *Ranunculus reptans* was found only in 1947–1948. Of the four lemnids, only *Spirodela polyrhiza* has declined. The decline of this species may be connected with the end of grazing, cattle created shallow water microhabitats by trampling.

The actual state of the lake is an inheritance from the past. Particularly, the past actions explain the present-day high internal loading of nutrients in the lake. Some of the most damaging actions, such as discharge of untreated sewage to the lake or establishing a landfill and waste dumping site on the shore, are no more possible due to present-day laws and standards. Also road construction directly across an important wetland (and conversion of a part of it into a golf course) without any mitigation of environmental damage is against current planning principles of Finland and the European Union. However, construction of new housing units very near the shore still goes on.

In spite of the improvements in legislation, planning principles and regulations, the planning culture still has difficulty in seeing natural areas as functional entities. In the case of Iidesjärvi, the core area (the lake itself), the buffer zone (shore vegetation) and the catchment area have been badly damaged. Popular activities like fishing, boating and swimming, frequently mentioned in historical records, gradually declined as the quality of the lake deteriorated. However, the remaining biodiversity is still appreciated by thousands of people who visit the bird observation tower and nature trails around the lake every spring and summer. Iidesjärvi is still valuable as a landscape.

The example of Iidesjärvi shows the value of long term environmental monitoring. The various environmental factors such as changes of land use and water quality or invasion of alien species reflect in the floristic and faunistic history of the lake. Besides the land-use planning the future of the lake depends on the removal (or isolation) of the bottom sediments, which are causing severe blue-algae blooms due to the high internal loading. The vegetation has also shown good persistence in a changing environment. The species pool of emergent and submerged macrophytes is considerable, and the vegetation may have good possibilities to recover if the water quality of the main basin does improve in the future. In this regard the species of the semi-isolated lagoons will have a special role as "pockets of biodiversity". At the same time a buffer zone needs to be created for the protection of the remaining meadows, fields and small forests on the shores from the future urban development.

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