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The Effects of Increased Water Level on Aquatic Macrophytes

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ABSTRACT

Lake Tämnaren, 60° N and 17° E, a shallow lake with a surface area of 35 km^2, was aerial photographed in 1973 at which time aquatic vegetation covered 80% of the lake area. In 1977 the water level of this lake was increased by 0.5 m and the propagation area of vegetation diminished. In 1983 the lake was aerial photographed again. The vegetation area was estimated and it had decreased to 14%. The differences in vegetation distribution between 1973 and 1983 are discussed as are the different methods used to interprete the infrared photographs.

Key words: Shallow lake, infrared, aerial photographs, digital image, *Phragmites australis, Nuphar lutea, Elodea canadensis.*

INTRODUCTION

The distribution of aquatic macrophytes has increased in many lakes, often due to the high input of nutrients (Wium-Andersen 1974, Lachavanne 1980). Another factor may be a lowered threshold in the outflow, which is followed by a decreased water level in the lake. Thus, increasing the shallow areas causes the propagation of aquatic vegetation.

Until about 1950, it was common in flatland areas of Sweden to reduce lake levels to minimize flooding of farm areas and to obtain more farmland. Most lakes in flatland areas are shallow and today one finds many lakes overgrown with aquatic plants. The catchment area of these lakes consists of a rather high percentage of farmland. This nutrien-rich environment influences the water quality of the lake and very often results in great aquatic macrophyte growth.

Description and mapping of aquatic macrophytes have been completed for several lakes. Some of these investigations deal with the propagation of the vegetation or of the different species found (Burgermeister and Lachavanne 1980, Kuflikowski 1986, Wallsten 1981). Some papers describe the changes in composition of the aquatic vascular plant species (Niemeier and Hubert 1986, Wium-Andersen 1974). The technique to use aerial color infrared photography is a great advantage when comparing changes of distribution of aquatic macrophytes (Martyn et al. 1986).

This paper deals with the aquatic macrophytes in Lake Tämnaren, 120 km northwest of Stockholm, and how their distribution changed after a dam was built in the lake which increased the water level. The vegetation in the lake was investigated in 1973 and 1976 (Wallsten 1974, 1981). A chemical investigation of the lake was conducted from 1974 to 1977 (Wallsten 1977, 1981). After the lake water level was increased in 1977, the vegetation was studied anually through 1983. However, a more concrete determination of the changed distribution of the aquatic vegetation before and after the increased water level was not possible before the lake was aerial photographed in 1983.

METHODS

Lake Tämnaren was aerially photographed at the end of July 1973 and 1983. The film and the method used in 1973 to interpret the infrared photographs are presented in Wallsten (1974). In 1983 the photographs were taken on Kodak Aerochrome 2443 negative infrared aerial colour film. The flight was made at an altitude of 1500 m. The photographs resulted in a 60% forward overlap in each frame and provided standard stereo coverage. The size of the infrared aerial photos was 25 x 25 cm at a scale of 1:10 000.

To accurately identify the species of aquatic macrophytes between the different red colours on the photos, fieldwork was performed by observing aquatic vegetation along 20 transects around the lake. Profiles were drawn from the shore through the vegetation zone to the open water. All observed species were listed and the zones of the dominant species along the transect were determined.

The vegetation along 2 km of the shoreline was interpreted from the infrared photos by stereoscope. The shoreline was drawn on transparent paper (polyesterfilm) based on a map published in 1978. The map and the aerial photos had a scale of 1:10 000. The distribution of dominant species—common reed (*Phragmites australis* (Cav.) Trin. ex Steudel), club rush (*Schirpus lacustris* L.), and yellow waterlilies (*Nuphar lutea* (L.) Sibth. & Sm.)—were mapped with different colours on the transparent paper, using one paper for each species.

This field identification of species was necessary when using the newly developed method of computerized image analysis introduced by Forsgren and Wallsten (1987).

Using this method, the photos were scanned with different colour filters. The covered area was digitized into 512x512 points. This gives a linear resolution of 0.11 mm in the photographs with one pixel equivalent to 1.18 m^2 on the ground. The computer analyzes the different coloured pixels and identified the plant species as well as computes their surface areas.

Comparisons were done between the two methods used to interpret the mapped vegetation areas: the manual method and the computerized method. The former was

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used when the vegetation area was studied in 1973 (Wallsten 1974).

To calculate the vegetation surface areas with the old method of using coloured areas on transparent paper, an additional step was taken. The paper with coloured areas was overlaid with another transparent paper. On this paper, the coloured area was outlined and filled in with black drawing ink. One species was represented on each paper. The blackened areas were measured in a photoelectric drumscanner. The same areas were used when calculated by both the computerized and manual method. In the latter case, both the blackened areas and the photos were used to calculate the vegetation area.

The submerged vegetation was not observed in the aerial photographs. Field work was conducted to map this vegetation.

RESULTS AND DISCUSSION

Lake Tämnaren is situated 60° 10′ N and 17° 22′ E in a flatland area. The lake is shallow with a mean depth of 1.5 m and a maximum depth of 2 m. It has a surface area of 35 km^2, with a maximum width of slightly over 5 km and length of 9.5 km. The water volume is 35 x 10^6 m^3 and the retention time is approximately 90 days.

Lake Tämnaren is an eutrophic lake (Wallsten 1977, 1981) with a watershed area of 719 km^2 of which 68% is composed of woodland and marsh, 25% farming land and grassland, and 7% lake. There are a few occupied residences close to the lake.

The water level of the lake has been lowered by man twice. The first time was in 1870-71 by 1 m, and the second time in 1950-54 by another 0.5 m. After the last drawdown, the aquatic macrophytes propagated in great numbers. The southern, shallower part of Lake Tämnaren, called Lake Sörsjön, occupies 3 km^2 and was in five years more or less overgrown. When the vegetation was mapped in 1973 (Fig. 1a), the dominant species in the lake were common reed, yellow waterlilies, pondweed (*Potamogeton natans* L.) and (*Elodea canadensis* Michx).

Lake Tämnaren is famous as a habitat for waterfowl. In spring and fall many species flock in great numbers at the lake. In summer, for example, about 500 mute swans (*Cygnus olor*) are seen there (Wallsten 1974). However, after 1977 when the submerged vegetation vanished, the swans, as well as many other birds, discontinued visiting the lake.

The increased water level in Lake Tämnaren in the spring of 1977 obviously influenced the distribution of vegetation. In the same summer, studies of the vegetation showed that all vegetation in the central part of the lake had disappeared, as well as a great part of the emergent vegetation. However, there are no data of vegetational distribution for that year. In 1978, some transects through the area of vegetation were investigated. Figure 2 shows one of the transects in Lake Tämnaren investigated in 1973 and 1978. The most striking alteration is the disappearance of submerged vegetation. However, in 1983 the lake was aerial photographed again and it was possible to measure the area of the emergent and floating leaved vegetation and make comparisons with the results from 1973 (Figure 1b).

Table 1 gives the values of the surface areas covered by common reed, club rush, yellow waterlilies and other vegetation. The values are given from 1973 and 1983. In 1973, 80% of Lake Tämnaren was covered by vegetation and in 1983 the value had decreased to 14%.

Field observations of the vegetation showed that common reeds grew in sparse numbers at the shoreline, becoming denser where they bordered the open water. Dead stems of the plant were seen on the lake bottom, evidence of a recent reduction of numbers. The dense vegetation occupied a 2 to 5 m wide zone.

Cattails (*Typha angustifolia* L.) grew in very narrow strips and generally on the edge of the reed zone. These areas were observed in the field but were difficult to see on the photographs. Therefore, when calculating the vegetation areas, the cattails were combined with the reeds.

Club rush typically grows in radial formations (Lohammar 1938). In Lake Tämnaren, club rush grew more densely in the outer 2 to 3 m of these circles, with sparse numbers towards the center. Compared with 1973, the number of club rush stands had substantially decreased.

Yellow waterlilies propagated abundantly, covering a substantial surface area. They created dense one-species beds in areas where common reeds had grown earlier, which as mentioned above, remained as a dead field of stubble on the bottom. The waterlilies also grew intermingled with reed and club rush, especially in areas where there was sparse vegetation.

Sparse stands of milfoil (*Myriophyllum spicatum*) were observed in the northern part of the lake. However, most plants did not reach the surface water level and were not observed on the infrared photographs.

The water was rather turbid with a mean Secchi depth of 0.6 m. Earlier, the transparency of the lake was the same as the water depth, about 1.5 m in the central part of the lake (Wallsten 1977). At that time, a large part of the lake was covered with dense floating leaves and submerged vegetation which prevented wave action. The large surface area of Lake Tämnaren is interrupted only by a few small islands, resulting in rather high waves in the shallow water. In windy weather, the waves in the shallow lake stir up the unconsolidated bottom sediment, creating turbid water.

The most remarkable difference between the maps is the change in floating leaves (Fig. 1). In 1973, the area with scattered floating leaves-stands occupied 1,910 ha. These stands had totally disappeared in 1983. However, the area with yellow waterlilies increased from 275 ha to 322 ha. The surface area value given from 1973 is only from dense vegetation propagation. Common reed and club rush decreased from a total of 442 ha to 71 ha and 215 ha to 79 ha, respectively.

Table 2 provides the results from the different methods used to calculate the vegetation areas using a control area of 185 ha. The manual technique of distinguishing between areas of different species using dark ink on the transparent paper before estimating the propagation

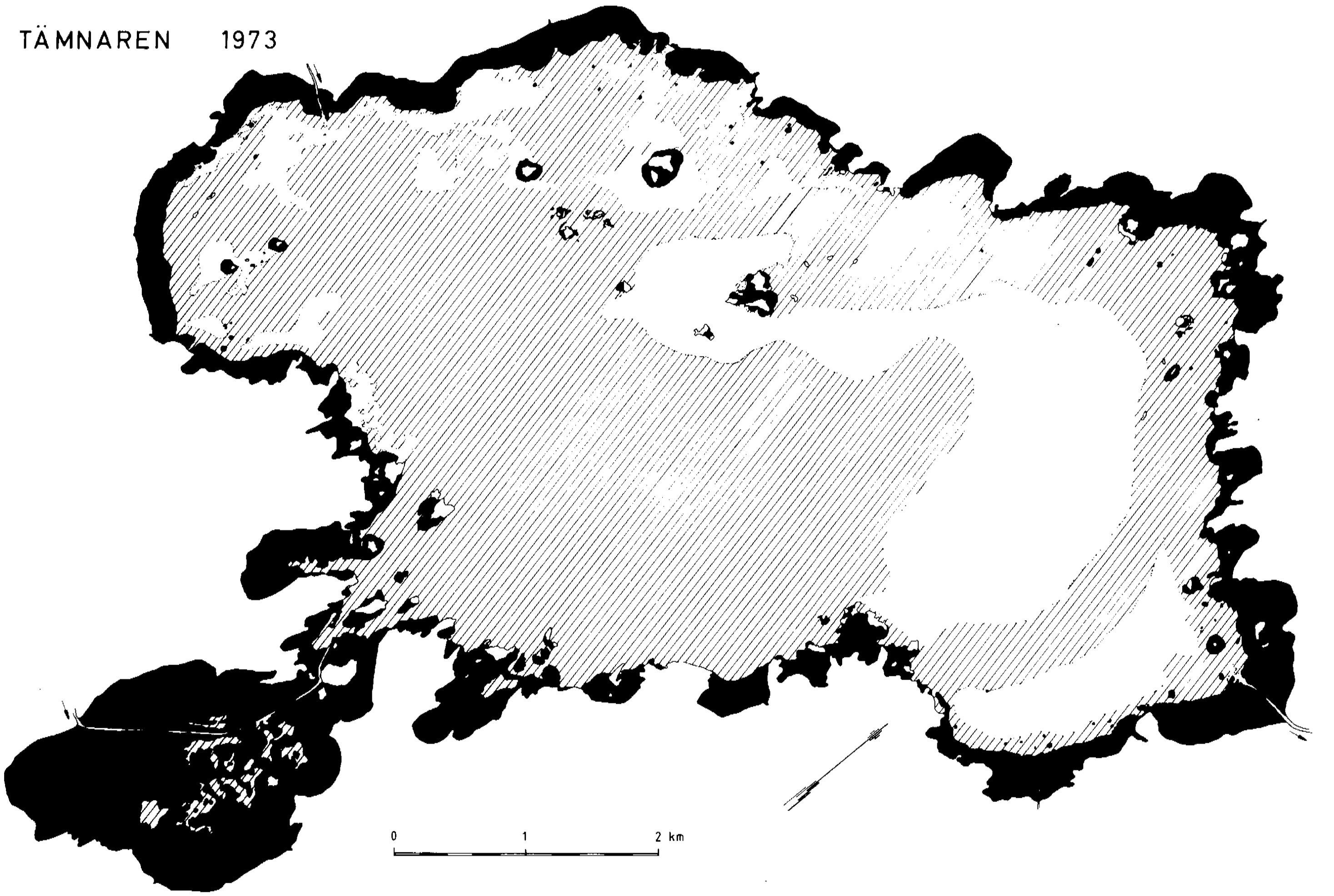

Figure 1a (above) and 1b (on opposite page). Vegetation maps of Lake Tämnaren in 1973 and 1983. The shaded areas represent floating leaved aquatic plants and the black areas represent the distribution of emergent vegetation.

area gives a higher value than the number received from digital image analysis. The waterlilies covered great areas and when quantifying them there was little variation between the different methods used. Club rush and reed have mostly small linear, circular or semi-circular formations. When these narrow areas are covered by ink on a transparent paper, the dark areas are easily enlarged. This results in a greater value of the areas in black compared with the estimated digital image analysis.

Lake Tämnaren was aerially photographed at about the same time of the year, at the end of July in 1973 and 1983. The stage of vegetation growth was almost identical in the two years. The increased water level in 1977 totally changed the distribution of vegetation. The wave activity in lakes significantly influence the sediment, even at considerable water depths (Håkanson and Jansson 1983, p. 192). The water depth in Tämnaren does not go over 2 m, and in the areas with vegetation it is usually about 0.5 m. The increased water depth of 0.3-0.5 m may have resulted in more powerful waves in the shallow lake which prevented the vegetation from growing. Another reason for the decreased propagation of vegetation may be from increased turbidity in the water which restricts the light penetration. The light intensities at the bottom varied between 1 and 6% of the light at the surface water level (Figure 3).

After 1977, the quantity of suspended material in the water increased greatly. The chlorophyll a content in Tämnaren varied between 9 and 50 μg/l with a maximum value of 70 μg/l in July 1983. Plankton production increased, probably as a consequence of nutrients released from the stirred-up sediment. The water movements in shallow eutrophic lakes, like L. Tämnaren, result in efficient mineralization of organic matter and influences the recycling of phosphous in the lake water (Boström 1980).

The potential sequence of events which led to the vegetational status of the lake as observed in 1983 may have been as follows: The dense mat of submrged vegetation and floating leaves which earlier covered great areas in the lake absorbed nutrients supplied by external inputs to the lake. The vegetation itself also acted as an internal nutrient source to the lake. When the vegetation in the lake disappeared, the nutrients leached out into the water column and were taken up by plankton, resulting in a higher plankton production and more turbid water. This in turn affected the light conditions in the lake, as discussed above. The light intensity may have been too low for submerged

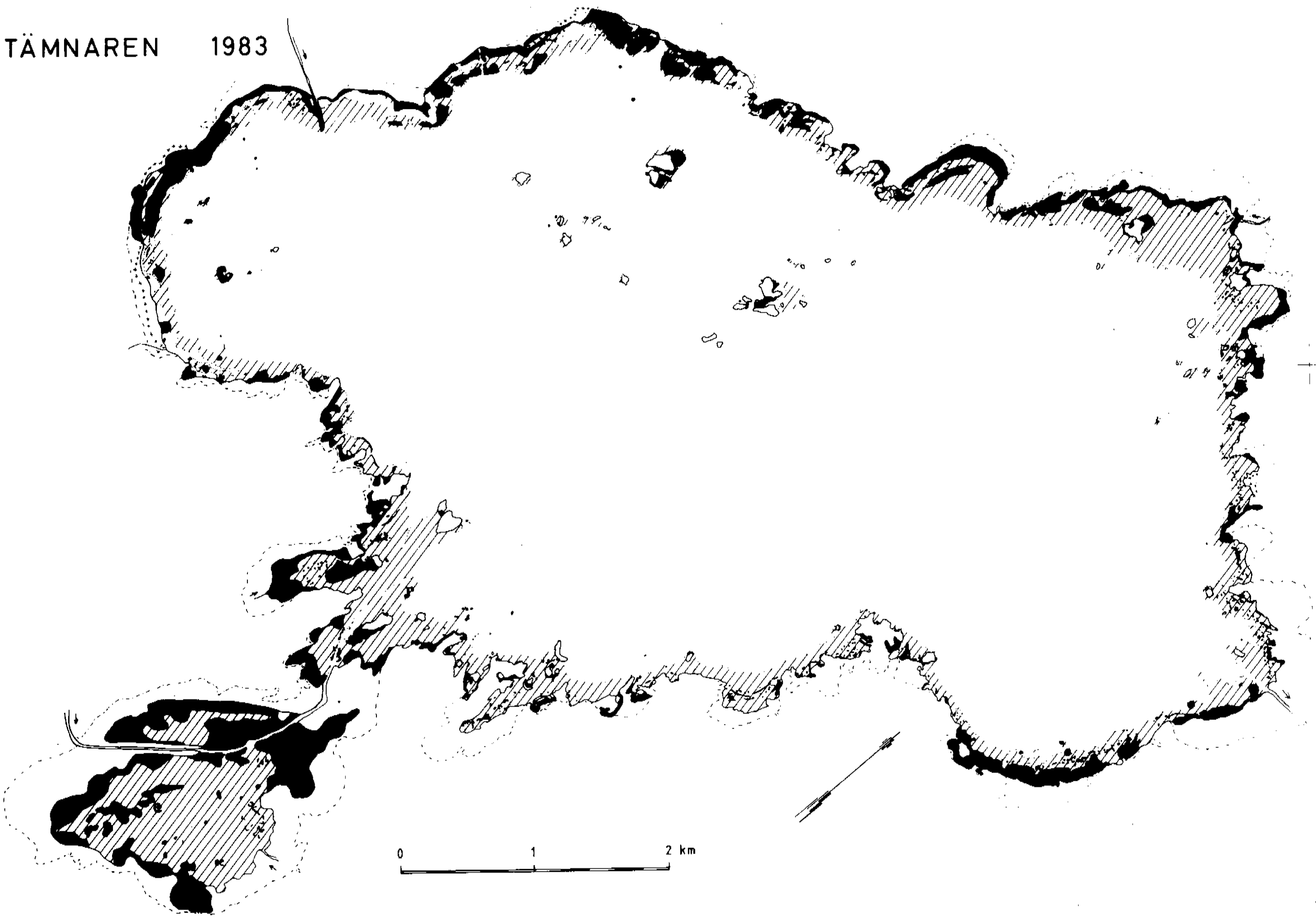

Figure 1b.

aquatic plants to survive, resulting in diminished production (Wetzel 1985). The underwater light governed the existence of submerged plants (Chambers and Kalff 1985, Duarte et al. 1986).

The diminished propagation of emergent plants, mainly reed and club rush, was not as dramatic as for submerged plants. The emergent stands in Lake Tämnaren are located in shallower water than the submerged stands; thus the reduced light in the lake had more a fan effect on the submerged plants. The scenescent vegetation was mainly in the deeper part of the lake. In the shallower areas, the vegetation grew in sparse stands, about 10 shoots per m^2, as compared to about 50 per m^2 in the deeper areas.

TABLE 1. VEGETATION AREAS (HA) IN LAKE TÄMNAREN 1973 AND 1983.

Vegetation	1973	1983
Phragmites australis	442	71
Scirpus lacustris	215	79
Nuphar lutea:		
dense stands	275	322
sparse stands	1910	—
Other vegetation	236	—
Total area	3078	472

Young yellow waterlilies emerged in the area, where the reeds grew earlier. It is possible that waterlily seeds had been stored in the sediment. When the reeds disappeard, the waterlilies had the opportunity to grow. Two years after the water level was raised, small waterlily plants covered the lake bottom where sparse reeds also grew or had formerly grown. Approximately three years later, the plants had reached the surface water level. By 1983, the waterlily leaves created a dense mat on top of the water.

In 1973, Eurasian milfoil was observed in the entire lake. It reached the surface water level and became, together with *Elodea canadensis*, a real nuisance for people who used the lake for recreation. By 1983, very few stands of milfoil were observed. The increased water level apparently had also affected the milfoil. It was found primarily outside bays in the north and southeast portions of the lake.

TABLE 2. VEGETATION AREAS WERE COUNTED BY A DIFFERENT METHOD IN A 185 HA SECTION OF LAKE TÄMNAREN.

	New method	Old method	Calibration factor
Phragmites australis	4.0	6.5	1.62
Scirpus lacustris	3.2	4.5	1.40
Nuphar lutea	28.6	31.6	1.10

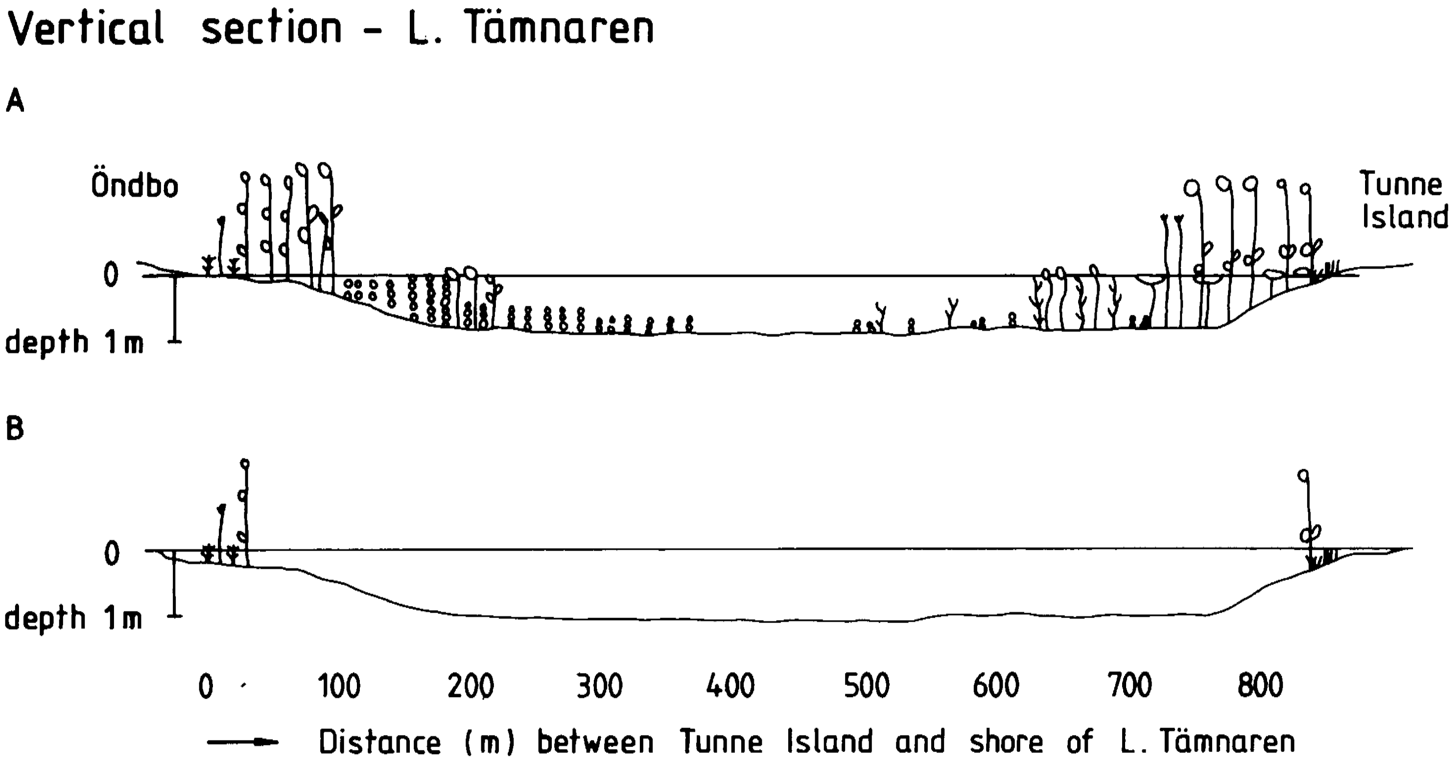

Figure 2. A typical verticle transect on Lake Tämnaren in 1973 (A) and in 1978 (B).

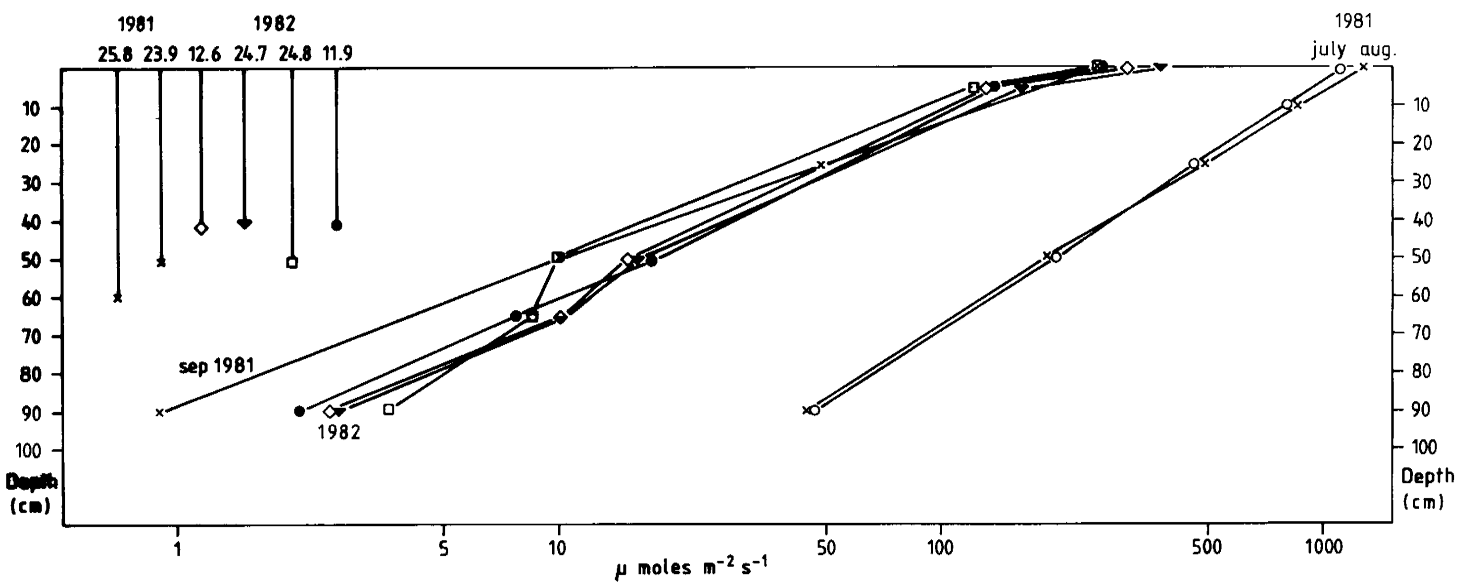

Figure 3. Light intensities at various depths and times in Lake Tämnaren.

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Problems and Control of Aquatic Weeds in the Irrigation Systems of Thailand

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ABSTRACT

The aquatic plants which cause problems in the extensive irrigation systems of Thailand are usually the exotic species which find conditions in the irrigation channels favorable for growth and proliferation. The most troublesome weeds, as well as some of the control methods used in Thailand, is discussed in this paper.

Key Words: Mimosa, Hydrilla, Potamogeton, Salvinia, Eichhornia, chemical control, biological control.

INTRODUCTION

Thailand is one of the Southeast Asian countries in the tropical part of the world, located between latitude 6 and 20 degrees north and longitude 98 and 106 degree east. The land area is 51.4 million hectares, of which 23.6 million hectares are farmed. Only 3.32 million hectares are irrigated. All the irrigation and drainage work in Thailand is under the direction and responsibility of the Royal Irrigation Department (RID) of the Ministry of Agriculture and Cooperative.

To provide a proper water control system to the irrigable area, many irrigation structures have been constructed. For example a diversion dam on the main river, Chao Phraya, at Chainat forms a distribution canal system to supply water to paddy fields and many other agricultural purposes. These constructions affected the aquatic ecosystem, often adversely by providing excellent habitat or by stimulating weed growth. The explosive growth of aquatic plants, especially introduced plants, create problems involved with practically all water uses in Thailand.

A recent survey by the aquatic group of the Weed Control and Research Branch, RID, showed that more than 10% of the water area maintained by the Royal Irrigation Department suffers from serious weed problems and requires regular weed control.

REGIONAL WEED PROBLEMS

Thailand is approximately 1800 and 800 km north to south and east to west, respectively. This large size and the existence of tropical lowlands, as well as mountainous regions, allows the division of the country into four physiographic regions (Figure 1). The aquatic plants which cause problems in each of these regions are described below.

Northern

The northern region is also the mountainous region of the country with elevations of up to 2600 meters above sea level. Irrigation and hydroelectric reservoirs as well as natural lakes are commonly found in this area. Four relatively flat basins are the origin of four major tributaries of the Chao Phraya, Thailand's major river system. These tributaries are the Ping, Wang, Yom and Nan rivers, all of which seasonally flood and thus have a flood plain particularly conducive to the growth of the exotic *Mimosa pigra* L. This species is the most serious weed problem in and along all types of waterways in this region[2]. It is estimated that not less than 10,000 ha of land, mostly adjacent to water bodies, are now infested with *Mimosa pigra. Eichhornia crassipes* (Mart.) Solms, *Hydrilla verticillata* (L.F.) Royle and

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