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# The occurrence of waterfowl in the biotest basin at the Forsmark nuclear power plant, Sweden, 1981 - 1984

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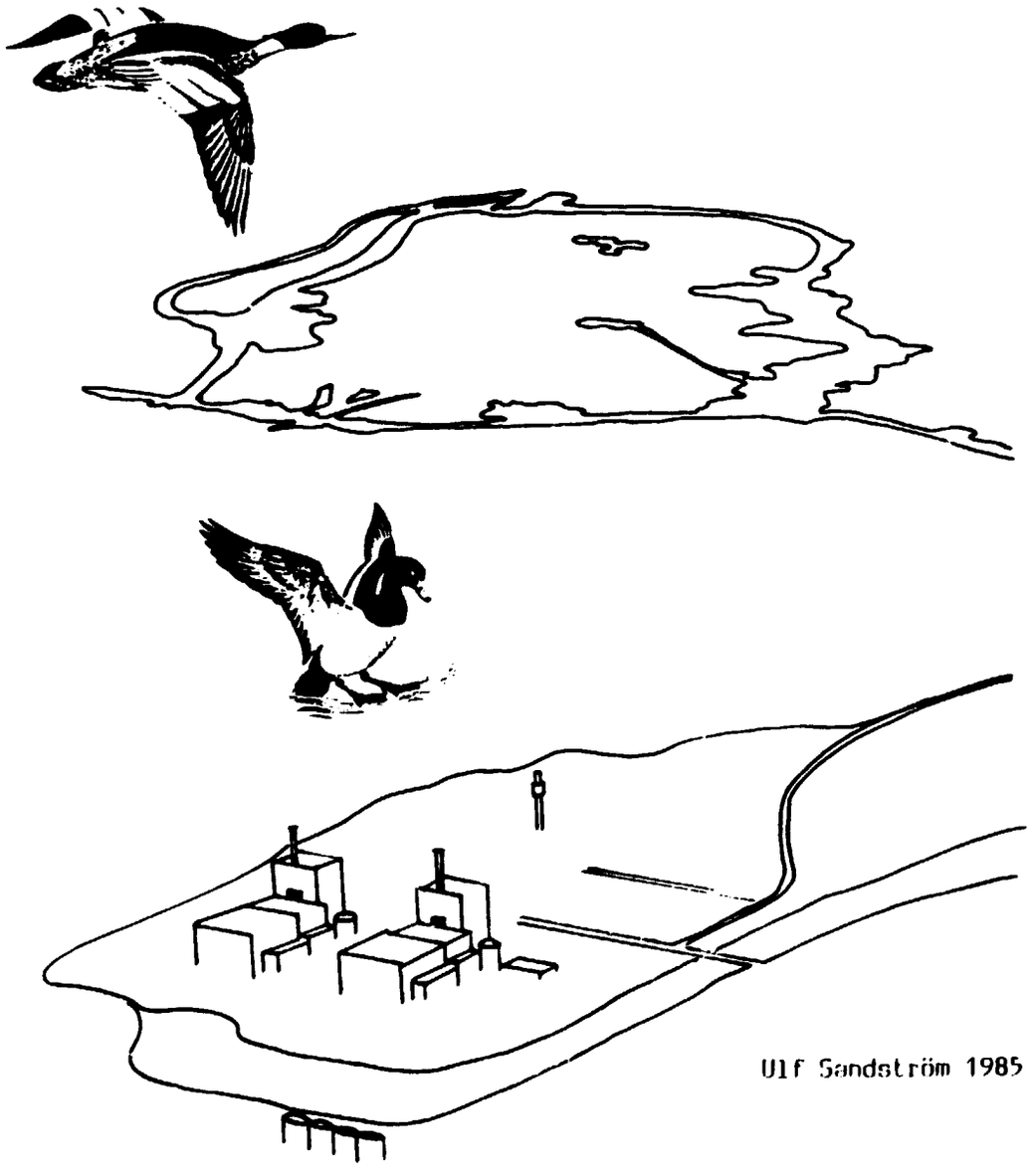
# THE OCCURRENCE OF WATERFOWL IN THE BIOTEST BASIN AT THE FORSMARK NUCLEAR POWER PLANT, SWEDEN, 1981 - 1984



Ulf Sandström 1985

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ABSTRACT

During the period September 1981 to August 1984 a monthly census was taken of waterfowl in the Biotest basin and its surroundings at Forsmark, as well as in a reference area in the region. During the same period the staff of the Biotest basin made weekly censuses of the basin.

The aim of the censuses was to establish if there was any increase in the number of waterfowl in the Biotest basin and its surroundings caused by the discharge of cooling water from the two nuclear power reactors that are in operation in Forsmark.

Seventeen waterfowl species were observed in the area during the period studied. Of these seventeen species five were regularly observed viz.: the Mute Swan *Cygnus olor* (J. F. Gmelin), the Mallard *Anas platyrhynchos* L., the Tufted Duck *Aythya fuligula* (L.), the Goldeneye *Bucephala clangula* (L.) and the Goosander *Mergus merganser* L. The first four species were generally found in low numbers in the Biotest basin and its surroundings, as well as in the reference area. This implies that the Biotest basin and its surroundings has not become an area of importance during the winter for waterfowl, with one exception: the Goosander.

The Goosander showed an increasing population growth in the Biotest basin and its surroundings during the studied period with a maximum average in the basin during the last winter. As a result, the size of the Goosander population may affect the number of small fish in the Biotest basin.

Keywords: the Biotest basin, cooling water, the Goosander, the Forsmark nuclear power station, waterfowl

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## INTRODUCTION

As nuclear power plants consume large amounts of cooling water, they are, in Sweden, sited with direct access to the sea. This means that a heated area is created by the discharge of cooling water. In northern areas, the effect is most noticeable in winter when the heat prevents the formation of ice.

The Forsmark nuclear power plant is situated on the eastern seaboard of Sweden in the SW part of the Bothnian Sea. The plant consists of three reactors and the cooling water from units No. 1 and No. 2 is released into an artificial enclosure; the Biotest basin. The basin is fairly well protected from exposure to wind and waves, as well as ice. The effects of 8-10$^{o}$C temperature increases on a coastal ecosystem are continuously monitored in this basin.

Waterfowl on migration willingly rest in calm areas that provide protection against adverse weather conditions. If food is available in sufficient amounts, they may stay for prolonged periods.

The resulting effect of the rather well-protected basin and its ice-free surroundings, could be that waterfowl which usually spend their winter further south will remain longer in this area in the autumn than they normally do. They may, in fact stay for the entire winter.

The Biotest basin was built in 1977 and the first of the three reactors in the Forsmark plant was started in the summer of 1980.

This report deals with the occurrence of waterfowl in the Biotest basin and its surroundings during the period September 1981 to August 1984.

Similar studies were made during the winter of 1980/81 (Sandström, 1981), and this paper presents results from a continuation of these studies. The primary objective was to establish if there had been any increase in the number of waterfowl in the Biotest

basin and its surroundings caused by the discharge of cooling water.

To ascertain the results, the Forsmark area was compared to an uninfluenced reference area, Kallrigafjärden.

## STUDY AREA

The study area consists of three areas (Fig. 3):

the Biotest basin which is permanently influenced by cooling water from the Forsmark nuclear power plant (Fig. 4);

the surroundings of the Biotest basin, viz. the outlet of the Biotest basin but also an area W and NW of the basin. The latter area was included because occasionally the cooling water is also released through the emergency outlet (Fig. 4);

the reference area. Kallrigafjärden is regarded as an uninfluenced area (Fig. 5).

### The Biotest basin

The Biotest basin is situated in the Forsmark archipelago, SW Bothnian Sea (Lat. $60^{o}26'$, Long. $18^{o}12'$) (Fig. 4). The basin is an area surrounded by islands linked by massive embankments, and covers about 0.9 $km^2$. The water is brackish, with a salinity of ~ 0.5 $^{o}/_{oo}$. It has an average depth of approximately 2.5 m with a maximum of 5-6 m. The entire body of cooling water (~ 86 $m^3/s$) discharged from units No. 1 and No. 2 at the power plant is led through a tunnel into the enclosed basin and then out into the open sea. This raises the temperature of the water in the enclosed basin to a level 8-$10^{o}C$ above that of the surrounding water. Consequently, the area never becomes covered with ice.

The water exchange takes about 100 h when a maximum of cooling water flows through, corresponding to a water velocity of ~ 0.3 m/s in the basin. The bottom substrate consists of stone blocks and sand.

Emergent vegetation covers less than 1 % of the water area. *Phragmites communis* Trin., *Scirpus tabernaemontani* C.C. Gmel. and *S. maritimus* L. are the dominating species (Svensson et al., 1982). The emergent vegetation expanded strongly during the period 1980 to 1982 (~ 3200 to ~ 6200 $m^2$) with the main part formed by *P. communis* (Svensson et al., 1983).

*Chara spp* and *Potamogeton spp* formerly dominated the floating and submerged vegetation, but have decreased in importance during the studied period. *P. pectinatus* L. and *Cladophora glomerata* (L.) Kütz. now make up the largest amount of biomass of such vegetation in the basin (Renström et al., 1984).

The biomass of the benthic fauna was low before 1978 when the Biotest basin was completed (Mo, 1984). *Chironomidae* and *Macoma baltica* (L.) were most abundant, followed by *Corophium volutator* Pallas, *Cardium spp*, *Gammarus spp*, *Lymnea peregra* Müller, *Oligochaeta* and *Paludestrina jenkinsi* Smith in decreasing order of importance. As an effect of the enclosure the abundance of *Chironomidae* and *Gammarus spp* increased dramatically until the summer of 1980.

When the release of cooling water started (1980/81), the benthic communities drastically changed and *Corophium volutator* became the most abundant species. Population growth of *Paludestrina jenkinsi* and *Oligochaeta* was also favoured by the water conditions.

Larger fish prevented from entering and exiting the Biotest basin by a fish barrier of vertical gratings with a 20 mm spacing between the horizontal bars in each unit.

The predominant fish species are Perch *Perca fluviatilis* L. and Roach *Leuciscus rutilus* L. There has been a trend towards an increase in the number of small individuals in the fish community (Karås et al., 1984). Generally, cold water species and pelagic species have disappeared from the Biotest basin, as well as the formerly very common Sand goby *Pomatoschistus minutus* (Pallas) and the Three-spined stickleback *Gasterosteus aculeatus* L.

## The surroundings of the Biotest basin

An area of approximately 2 $km^2$ outside the Biotest basin does not become covered with ice during the winter (Fig. 4).

Occasionally the cooling water is also released through the emergency outlet (Fig. 4), thereby heating the area W and NW of the basin. Therefore an area between the Biotest basin and the mainland can also be heated by the cooling water as well as the area beyond the basin. In both regions, waterfowl were commonly observed.

There has been no investigation of the vegetation and the benthic fauna in this area, but it may be assumed that submerged vegetation common to the Biotest basin and benthic fauna common to the reference area could be found there. Both are of importance to birds.

It is likely that many small fish leave the Biotest basin through the outlet gates and are eaten by birds in the discharge area. Fishes from the surrounding sea may also make their way into this area (Neuman, E., 1979, Grimås, U., pers. comm.).

## The reference area

The reference area, Kallrigafjärden (Fig. 5), is situated approximately 9 km south of the Biotest basin. The bay covers about 6 $km^2$ and is rather shallow (1-3 m, maximum 5 m). It is covered with ice from mid-December until mid-April.

The benthic fauna is dominated by *Macoma baltica* and *Pontoporeia affinis* Lindstr. Other common benthic animals are *Prostoma obscurum* Schultze, *Oligochaetae*, *Chironomidae*, *Polychaeta*, *Mesidothea entomon* L. and *Corophium volutator* (Eriksson and Hedman, 1971).

Kallrigafjärden is rather similar to the Biotest basin as regards the existence of in- and outflow of water: the small rivers

Forsmarksån and Olandsån empty into the bay. The bay is delimited from the open sea by two peninsulas from each shore, leaving an opening of about 450 m.

Observations of waterfowl in the whole area can be made easily from two points at the shore, Kallerö and Sandören.

## WEATHER CHARACTERSTICS

Most monthly mean temperatures for 1982-1984 coincide rather well with the means for the period 1950-1965 (Fig. 1), the exceptions being the following:

January 1982 was much colder than average: -6.7°C. Ice was formed already on December 12, 22 days earlier than the average date for this region (Fig. 2A).

The winter 1982/83 was much milder than usual and ice did not form in the area until February 2 (Fig. 2B).

The winter 1983/84 did not differ much from the norm except that February was 2.1°C warmer than the average (Fig. 2C).

## METHODS

### Bird censuses in the Biotest basin and its surroundings

A mid-month census of the birds in the Biotest basin and its surroundings was carried out by the author every month, on the Sunday closest to the middle of the month, according to the IWRB waterfowl counts (BIN).

Observations were made from fixed points at different parts of the shore using a telescope (x 25 or x 40 magnification), thereby covering the entire basin and parts of the surroundings. All resting and swimming fledged waterfowl and half grown or older young were identified according to their species, and counted.

Once a week the staff of the Biotest basin made censuses of the number of birds of different species occupying the Biotest basin. These censuses were made by boat during the trips to check the fishing-nets in the basin, without using any optical aids.

Censuses in the reference area

In the reference area, observations were carried out monthly from fixed points (Sandören and Kallerö) using a x 25 or x 40 telescope.

Presentation of the results

Waterfowl utilization of the three localities are given in average number of birds (Fig. 6-10) and in bird-days (number of birds x number of days, Tables 3-7).

The mid-month and the weekly censuses cannot be compared with each other due to the differences in the methods used in counting the waterfowl.

The results of the censuses during the studied period are given separately for each season. Table 1 shows the length of the seasons in the Forsmark area. This will simplify the evaluation of the seasonal establishment of waterfowl in the area.

RESULTS

Seventeen waterfowl species were observed in the Biotest basin and its surroundings during the study period. Five species were regularly observed viz.; the Mute Swan (*Cygnus olor* (J.F. Gmelin)), the Mallard (*Anas platyrhynchos* L.), the Tufted Duck (*Aythya fuligula* (L.)), the Goldeneye (*Bucephala clangula* (L.)) and the Goosander (*Mergus merganser* L.) (Table 2).

Relatively few individuals of the regularly observed species were residing in the investigation areas (Table 3-7, Figures 6-10). The reference area was completely covered with ice in the winter and no waterfowl could be found then.

## The Mute Swan

The Mute Swan was found in low numbers in the Biotest basin and its surroundings during all seasons. In spring there are peaks presumedly formed by returning birds (Table 3, Fig. 6). In the reference area there was a similar pattern, but the peaks extended into the summer.

## The Mallard

The Mallard was generally found in low numbers especially in the spring, and with an irregular pattern (Table 4, Fig. 7).

In the Biotest basin small peaks of returning Mallards occur in the winters, with the highest average number of individuals in the last winter (36.5), the first two peaks included the autumns as well. This was not found in the reference area where only one noticeable peak was observed, in the last summer (1984).

## The Tufted Duck

The Tufted Duck was found in considerably high numbers on only two occasions (Table 5, Fig. 8); the Biotest basin during autumn 1981 (130 individuals) and in the reference area in spring 1983 (110). Otherwise, the Tufted Duck was only observed occasionally, especially in the Biotest basin and its surroundings.

The Goldeneye

The Goldeneye was normally observed in low numbers in all studied areas (Table 6, Fig. 9). There was only one noticeable peak; in the surroundings of the Biotest basin in the autumn of 1982 with ~ 120 individuals.

The Goosander

The Goosander showed an increasing population growth in the Biotest basin and its surroundings during the period studied, with a maximum average of 132 individuals in the Biotest basin in the winter of 1984 (Table 7, Fig. 10). In the reference area there was no corresponding population growth.

## DISCUSSION

The seventeen species of waterfowl observed in the Biotest basin and its surroundings are species that would be expected in this part of Sweden (SOF 1978) (Table 2). The abundance of the five species regularly observed in the study areas during the different seasons is generally low in this region. The deviations from the normal are the observations during the winters (Alf Sevastik, pers. comm., SOF 1978).

The number of waterfowl in the reference area may be underestimated due to its lower accesibility and higher frequency of disturbance during weekends. There may also be an underestimation of the waterfowl in the Biotest basin when censused from a boat due to the fact that most diving ducks feed during the day and may not be visible at all times. Secondly, dabbling ducks often spend parts of the day resting on the shore, or in the vegetation (BIN, Åke Andersson, pers. comm.). Accurate population numbers are, therefore, difficult to obtain.

Waterfowl strongly depend on the ice situation in their overwintering areas because the main part of them feed in more shallow water near the shore (Nilsson, 1984).

During the winter the whole of the Gulf of Bothnia, including its southern part, is usually covered with ice (Fig. 2) and consequently no waterfowl reside in the area (Alf Sevastik, pers. comm.). The closest areas to Forsmark with open water are in the northern parts of the Baltic Sea. From many years of midwinter counts Nilsson (1977) states that only five species of waterfowl are to be found north of Kapellskär (~ 90 km S Forsmark) during the winter and then in very small numbers. Among them are the Mute Swan (with around 100 individuals), the Goldeneye (~ 230) and the Goosander (~ 300).

## The Mute Swan

Of the Mute Swan only 1-3 individuals were found to spend the winter in the Biotest basin (Fig. 6). The basin is one of the very few ice-free areas in the winter in this part of Sweden, therefore higher numbers of this species could be expected (Nilsson, 1977). The Biotest basin is also rather shallow, a factor that would suit the Mute Swan rather well.

## The Mallard

The Mallard was found to spend the winters in the Biotest basin (Table 4, Fig. 7). On average, 24 Mallards overwintered in the Biotest basin and its surroundings. This is a rather low figure compared to the number of individuals of this species spending the winter in small areas of open water in the cities in this part of Sweden.

## The Tufted Duck

The Tufted Duck was not observed in winter in the Biotest basin and its surroundings (Table 5, Fig. 8). There were noticeable numbers only on two occasions. The recorded peak in autumn 1981 consisted of individuals resting in the Biotest basin and its surroundings, on their way to wintering areas in southern Sweden (Nilsson, 1979, 1984).

The Tufted Duck is not an efficient diver and feeds mostly in shallow waters; 0.3-5 m depths (Madsen, 1954, Olney, 1966, Nilsson, 1970, 1984). Such suitable depths are found in the Biotest basin and its surroundings as well as in the reference area. In the latter there was a peak in spring 1983, probably resulting from individuals resting and foraging before the breeding season. The Tufted Duck nests later than other ducks (Havlín, 1966, Rosenberg, 1984).

Thus the recorded sighting of the Tufted Duck cannot be regarded as significant.

## The Goldeneye

On average, 32 Goldeneyes overwintered in the Biotest basin and its surroundings (Fig. 9). This figure, compared to Nilsson's (1977) observations of wintering Goldeneyes north of Kapellskär (~ 230), indicates that roughly one-tenth of that number are found in the Forsmark area. This suggests that the area has not yet become important during the winter for the Goldeneye.

During the period studied only one noticeable peak was recorded: in the autumn 1982 there were fairly large numbers of Goldeneyes in the surroundings of the Biotest basin (Table 6, Fig. 9). The flocks seen consisted almost exclusively of subadult and adult males. Outside the area counted large flocks of the Goldeneye were often seen during this time of the year. These flocks were most

likely mixed, with the main part consisting of subadult and adult males.

These observations of the Goldeneye congregations coincide very well with the time for the moult of this species. In Denmark the moult for juvenile and adult males culminates between mid-July and the first half of August (Jepsen, 1973). On the Swedish west coast the Goldeneye occupy special moulting sites from mid-July to mid-September and juveniles, beginning their second year, made up the majority of the birds moulting in the first part of the moulting period (Persson, 1976).

Jepsen (1973) found that the moult migration of adult males appears to be directed towards quite specific localities, while the young males can moult in many places.

The previously mentioned observations of Goldeneye congregations in the area indicate that the area between the Biotest basin and the mainland cannot be disregarded as an area used as a moulting site of the Goldeneye in the future. A factor of importance that also suggests this is that the area gives very good protection against adverse weather conditions. This factor is of importance during the moult but of greater importance for the habitat selection of diving ducks during the winter season (Hildén, 1965).

The failure of the area to become an attractive wintering site is probably due to two reasons: traditional behaviour and scarcity of food.

As regards the former, Nilsson (1970) found that diving ducks year after year chose the same resting and feeding sites in an area that provided many other places of apparently equal quality; secondly, during the winter the waterfowl are obliged to resort to the Biotest basin and the ice-free area immediately beyond it. The Tufted Duck and the Goldeneye were found to spend more time foraging in the Biotest basin than in an uninfluenced area, probably as a result of the scarcity of food in the basin (Sandström,

1981). The figures for the five species of waterfowl regularly observed during the three winters studied (Tables 3-7, Fig. 6-10) indicate that during 1981-84 there was no increase in the available food. There is one exception: the Goosander.

## The Goosander

On average, 64 Goosanders were recorded in the Biotest basin and its surroundings during the winters studied. There was also an increasing trend in the number of individuals recorded for this season in the basin during the study period (Table 7, Fig. 10). Especially in the 1983/84 winter the number abruptly rose, although the temperature that winter did not differ much from average (Fig. 2C).

The migration during the winter for this species is strongly governed by the occurrence of open water (Kjell Sjöberg, pers. comm.). Nilsson (1970) found that the Goosander appears in numbers at the coasts only when the lakes and inland streams are frozen. During their stay in coastal waters they remain close to the shore (Nilsson, 1984) and prefer shallow waters up to a depth of 4 m (Cramp et al., 1977). The Biotest basin has an average depth of approximately 2.5 m, while the area immediately beyond the basin has a depth of 3-10 m.

The Goosanders spending the winter in the Biotest basin and its surroundings were found to concentrate predominantly in the outflow but also in the inflow areas, where they rested and fished from the edge of the ice or the shore. This is in agreement with the results obtained by Nilsson (1970) that the local distribution of the Goosander seems to be governed by the availability of suitable resting places with clear visibility in all directions and wellstocked fishing grounds nearby.

The observed occurrence of the Goosander in the Biotest basin and its surroundings in winter does not seem to be correlated with

the mean temperature for the winter.

## Fish predation by birds

The main emphasis of the monitoring programme at Forsmark is on fish ecology. Therefore, it is of interest to discuss whether predation by birds in the Biotest basin may have significant effects on fish stocks.

The most important fish-eating birds in Sweden are presented in Table 8. Of these species, only the Goosander was found in noticeable numbers in the Biotest basin and its surroundings.

Fish farm stocks in ponds in the south and middle of Sweden may be heavily exploited by the Goosander, the Common Tern *Sterna hirundo* L. and to a lesser degree by the Grey Heron *Ardea cinerea* L. (Bohlin, 1977).

In Lake Möckeln, a large lake (44 $km^2$) in southern Sweden, the Goosander was found to devour 62 per cent of the fish consumed by fish-eating birds during a year (Nilsson & Nilsson, 1976).

The prey of the Goosander is usually less than 10 cm in length. The upper limit of the fish which they will consume is determined by girth rather than length. Among other fish species, the Goosander feeds on Perch and Roach (Cramp et al., 1977). According to Nilsson (1974), the Goosander feeds on the fish species which are the most common in its fishing grounds, with an average length of approximately 9 cm.

In the Biotest basin the amount of small Perch (<17.5 cm) has increased enormously since 1980 (Krog, 1984). This means that the Biotest basin can provide well-stocked fishing grounds for the Goosander. Due to an outward drift of fry from the basin (Peter Karås, pers. comm.) the outlet area may also be used by Goosanders.

The estimated consumption of fish by the Goosander in the Biotest basin and its surroundings during the study period is shown in Figure 11. The average amount of food consumed per day and individual has been estimated to be 20 per cent of the body weight (Nilsson & Nilsson, 1976, Kjell Sjöberg, pers. comm.). This means that approximately 2800 kg of food were consumed by the Goosander in the area during the period from the winter of 1983/84 until summer 1984. Although the number of Goosanders were most abundant in the Biotest basin during the winters it is assumed that the food consisted to 95 percent of fish (Nilsson & Nilsson, 1976). As no censuses were made in autumn 1984 an addition of roughly 100 kg of fish should be made to calculate the total yearly consumption for 1983/84. The total amount of fish consumed by the Goosander in the Biotest basin and its surroundings during the period winter 1983/84 - summer 1984 would then be approximately 2800 kg.

If it is assumed that half of this amount has its origin in the Biotest basin, the fish consumption of the Goosander will be equivalent to a production of 1.6 g $m^{-2}$ $yr^{-1}$ in the basin.

The Biotest basin must be regarded as having rather high production figures due to the rise of the water temperature and the water exchange (see above) (Eriksson, 1985, Mo, 1984, Peter Karås, pers comm.). Gerking (1978) mentions that standing waters in temperate areas have produced up to 15 g fish $m^{-2}$ $yr^{-1}$ and cold water streams up to about 18.1 g fish $m^{-2}$ $yr^{-1}$. If these figures are transformed to the Biotest basin the result will be that about 10 per cent of the fish produced in the basin is consumed by the Goosander.

If it is assumed that all the amount of fish consumed by the Goosander 1983/84, viz. 2800 kg, has its origin in the Biotest basin the figure would be doubled. Thus, roughly between 10 and 20 per cent of the fish produced in the Biotest basin is consumed by the Goosander. This predation may have effects on the population of small fish in the Biotest basin but not to a noticeable degree compared to other losses, e.g. natural mortality and the outward drift of fry from the basin.

## Conclusion

Three years is a relatively short time to determine any trends or changes in the utilization of waterfowl of a recently created waterbody like the Biotest basin. Some general remarks can, however, be made:

1. the Biotest basin and its surroundings have not become an area of importance during the winter for waterfowl; the exception being the Goosander.

2. an increasing number of overwintering Goosanders in this area indicates that the area meets the winter needs of this species very well.

3. the fish predation by birds, notably the Goosander, in the Biotest basin may have effects on the population of small fish in the basin but not to a noticeable degree compared to other losses.

As tradition is an important factor for the habitat selection of ducks, it will probably take at least another five years to establish whether the Biotest basin and its surroundings will attract waterfowl to a noticeable degree. The start of the third reactor at Forsmark in 1985 may affect the development, as the ice-free discharge area will be larger in future winters.

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| season | length of season | # days | # weeks |
|---|---|---|---|
| autumn | 22/9 - 21/11 | 60 | 8.6 |
| winter | 21/11 - 29/3 | 128 | 18.2 |
| spring | 29/3 - 27/5 | 59 | 8.4 |
| summer | 27/5 - 22/9 | 118 | 16.8 |

Table 1: The approximate length of the seasons in eastern Uppland were Forsmark is situated. (Svenska Turistföreningen 1958).

Key to tables 3 - 7 and figures 6 - 10:

—— x —— : the Biotest basin censused by the author once a month.

- - o - - : the surroundings of the Biotest basin censused by the author once a month.

— — + — : the Biotest basin censused by the staff once a week.

——▲—— : the reference area censused by the author once a month.

| Species \ Season | autumn 1981 | winter 81/82 | spring 82 | summer 82 | aut 82 | win 82/83 | spr 83 | sum 83 | aut 83 | win 83/84 | spr 84 | sum 84 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Great Crested Grebe Podiceps cristatus L. | | | | x | | | | x | 1) | x | x | x |
| Cormorant Phalacrocorax carbo (L.) | | x | | | | | | | | | | |
| Mute Swan Cygnus olor (J.F.Gmelin) | x | x | x | x | x | x | x | x | | x | x | x |
| Greylag Goose Anser anser (L.) | | | | | | | x | x | | | x | x |
| Brent Goose Branta bernicla (L.) | | | | | x | | | | | | | |
| Wigeon Anas penelope L. | | | | | | | | | | x | | |
| Teal A. crecca L. | | | | | | | x | | | | | |
| Mallard A. platyrhynchos L. | x | x | x | x | x | x | x | x | | x | x | x |
| Pochard Aythya ferina (L.) | | | | x | | | | | | | | |
| Tufted Duck A. fuligula (L.) | x | | x | x | | x | x | x | | x | x | x |
| Eider Somateria mollissima (L.) | | x | x | x | x | | x | x | | x | x | x |
| Long-tailed Duck Clangula hyemalis (L.) | | | x | | | | | | | | | |
| Goldeneye Bucephala clangula (L.) | x | x | x | x | x | x | x | x | | x | x | x |
| Red-breasted Merganser Mergus serrator L. | | x | x | | | | | x | | | x | |
| Goosander M. merganser L. | x | x | x | x | x | x | x | x | | x | x | x |
| Coot Fulica atra L. | | | | | | | | | | | x | |
| Black Guillemot Cepphus grylle (L.) | | | x | | | | x | | | | | |

Table 2: Species of waterfowl observed by the author in the Biotest basin and its surroundings during the period from autumn 1981 to summer 1984.
1) No censuses were made during autumn 1983.

| season | # bird-days | | | |
|---|---|---|---|---|
| | — x — | - - o - - | — · — + — | —▲— |
| autumn 81 | 240 | 0 | 162 | - |
| winter 81/82 | 180 | 60 | 112 | 0 |
| spring 82 | 870 | 0 | 779 | 330 |
| summer 82 | 390 | 60 | 329 | 840 |
| autumn 82 | 90 | 0 | 66 | 360 |
| winter 82/83 | 180 | 60 | 128 | 0 |
| spring 83 | 60 | 60 | 404 | 870 |
| summer 83 | 570 | 1260 | 212 | 780 |
| autumn 83 | - | - | 192 | - |
| winter 83/84 | 180 | 450 | 192 | 0 |
| spring 84 | 1290 | 360 | 517 | 750 |
| summer 84 | 780 | 390 | 188 | 630 |

Table 3: The number of bird-days for the Mute Swan, Cygnus olor, in the study areas during the period from autumn 1981 to summer 1984.

| season | # bird-days | | | |
|---|---|---|---|---|
| | — x — | - - o - - | — · — + — | —▲— |
| autumn 81 | 480 | 0 | 156 | - |
| winter 81/82 | 2940 | 0 | 1628 | 0 |
| spring 82 | 120 | 0 | 118 | 60 |
| summer 82 | 900 | 240 | 153 | 240 |
| autumn 82 | 1380 | 0 | 180 | 0 |
| winter 82/83 | 1980 | 60 | 983 | 0 |
| spring 83 | 60 | 60 | 103 | 450 |
| summer 83 | 180 | 690 | 459 | 450 |
| autumn 83 | - | - | 287 | - |
| winter 83/84 | 2190 | 0 | 2017 | 0 |
| spring 84 | 30 | 180 | 118 | 0 |
| summer 84 | 540 | 60 | 84 | 2400 |

Table 4: The number of bird-days for the Mallard, Anas platyrhynchos, in the study areas during the period from autumn 1981 to summer 1984.

| season | # bird-days | | | |
|---|---|---|---|---|
| | — x — | - - o - - | —·— + — | —▲— |
| autumn 81 | 0 | 3900 | 44 | - |
| winter 81/82 | 0 | 0 | 351 | 0 |
| spring 82 | 2340 | 0 | 154 | 450 |
| summer 82 | 420 | 1800 | 988 | 1320 |
| autumn 82 | 0 | 0 | 0 | 2760 |
| winter 82/83 | 30 | 0 | 60 | 30 |
| spring 83 | 1050 | 0 | 294 | 6600 |
| summer 83 | 2490 | 0 | 75 | 3300 |
| autumn 83 | - | - | 0 | - |
| winter 83/84 | 0 | 60 | 0 | 0 |
| spring 84 | 1860 | 270 | 118 | 0 |
| summer 84 | 3570 | 180 | 0 | 660 |

Table 5: The number of bird-days for the Tufted Duck, Aythya fuligula, in the study areas during the period from autumn 1981 to summer 1984.

| season | # bird-days | | | |
|---|---|---|---|---|
| | — x — | - - o - - | —·— + — | —▲— |
| autumn 81 | 0 | 570 | 66 | - |
| winter 81/82 | 1440 | 1350 | 702 | 0 |
| spring 82 | 360 | 210 | 243 | 1200 |
| summer 82 | 90 | 1800 | 1989 | 1440 |
| autumn 82 | 360 | 7290 | 120 | 2640 |
| winter 82/83 | 1560 | 1800 | 1341 | 0 |
| spring 83 | 1410 | 2290 | 514 | 1170 |
| summer 83 | 90 | 510 | 882 | 3000 |
| autumn 83 | - | - | 180 | - |
| winter 83/84 | 2040 | 870 | 792 | 0 |
| spring 84 | 2190 | 1650 | 1258 | 1290 |
| summer 84 | 4560 | 30 | 977 | 900 |

Table 6: The number of bird-days for the Goldeneye, Bucephala clangula, in the study areas during the period from autumn 1981 to summer 1984.

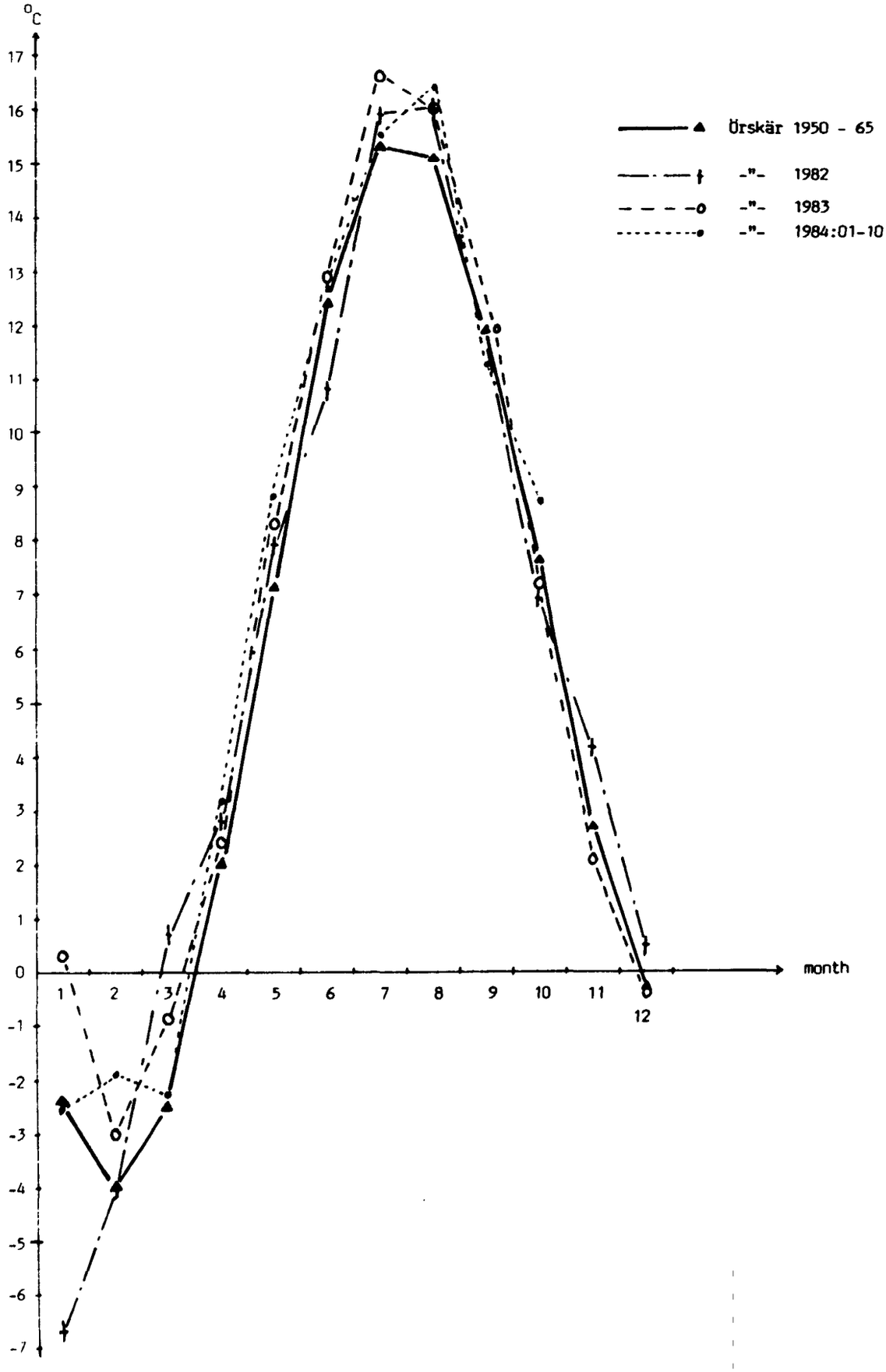
| season | # bird-days | | | |
|---|---|---|---|---|
| | —— x —— | - - o - - | — — + — | ——▲—— |
| autumn 81 | 30 | 360 | 0 | - |
| winter 81/82 | 1050 | 240 | 335 | 0 |
| spring 82 | 60 | 120 | 103 | 60 |
| summer 82 | 540 | 630 | 224 | 90 |
| autumn 82 | 30 | 450 | 0 | 0 |
| winter 82/83 | 1230 | 1380 | 511 | 0 |
| spring 83 | 270 | 180 | 184 | 570 |
| summer 83 | 240 | 360 | 412 | 930 |
| autumn 83 | - | - | 20 | - |
| winter 83/84 | 7920 | 1740 | 2860 | 0 |
| spring 84 | 630 | 510 | 506 | 390 |
| summer 84 | 420 | 30 | 35 | 0 |

Table 7: The number of bird-days for the Goosander, Mergus merganser, in the study areas during the period from autumn 1981 to summer 1984.

| Species | Percentage of fish in diet* |
|---|---|
| Black-throated Diver Gavia arctica (L.) | 90 |
| Great Crested Grebe Podiceps cristatus (L.) | 75 |
| Grey Heron Ardea cinerea L. | 80 |
| Red-breasted Merganser Mergus serrator L. | 75 |
| Goosander M. merganser L. | 85 (95) |
| Osprey Pandion haliaetus (L.) | 100 |
| Herring Gull Larus argentatus Pontoppidan | 50 |
| Great Black-backed Gull L. marinus L. | 80 |
| Common Tern Sterna hirundo L. | 90 |

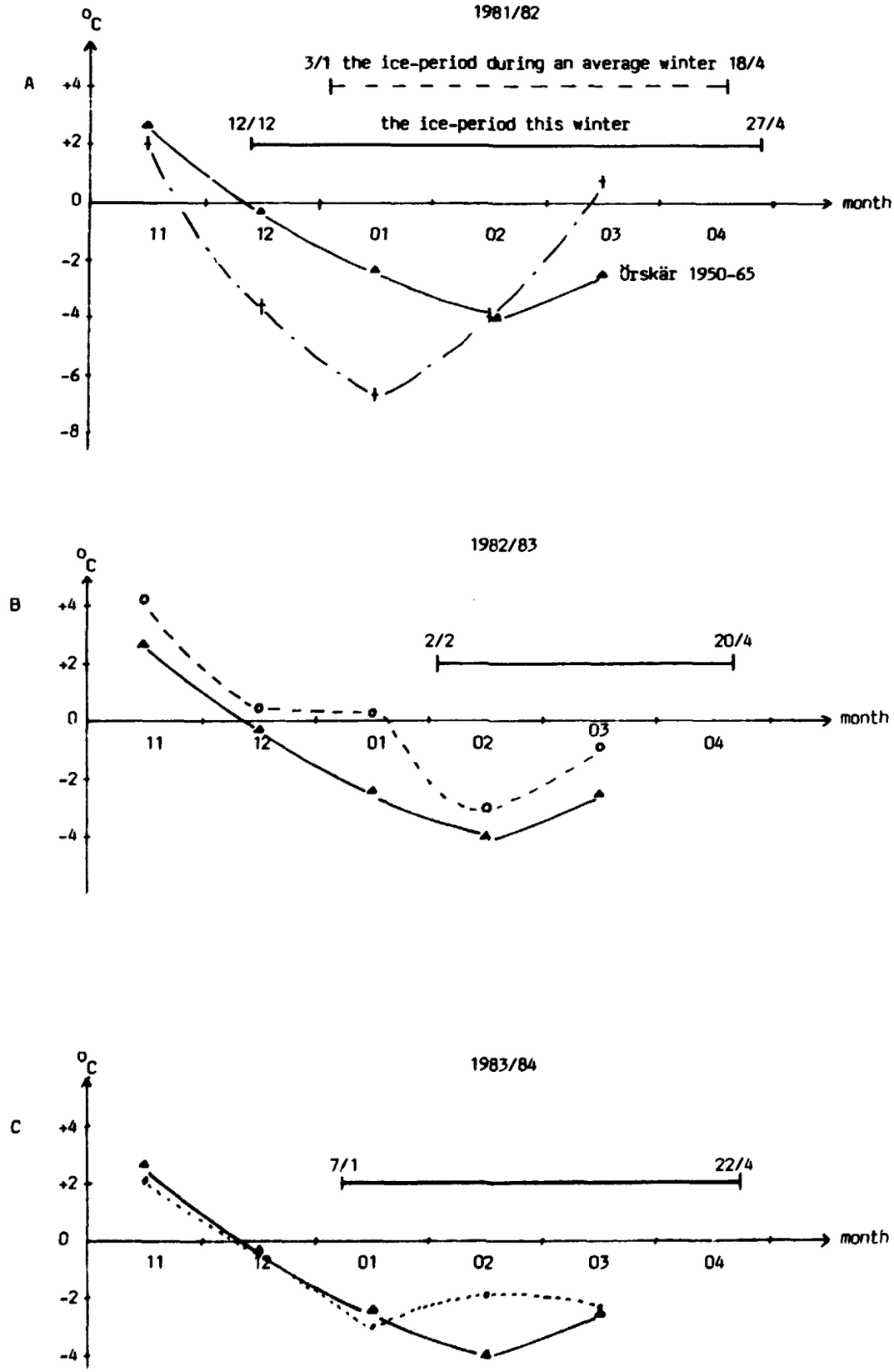
Table 8: The most important fish-eating birds in Sweden. (The percentage of fish in the diets is assumed to be the same during the winter, with the exception of the Goosander whose percentage is assumed to be 95). *(From Nilsson & Nilsson 1976).

Monthly mean temperatures for Örskär, off Forsmark. Figure 1
1982 - 84 compared to the period 1950 - 65 (SMHI).



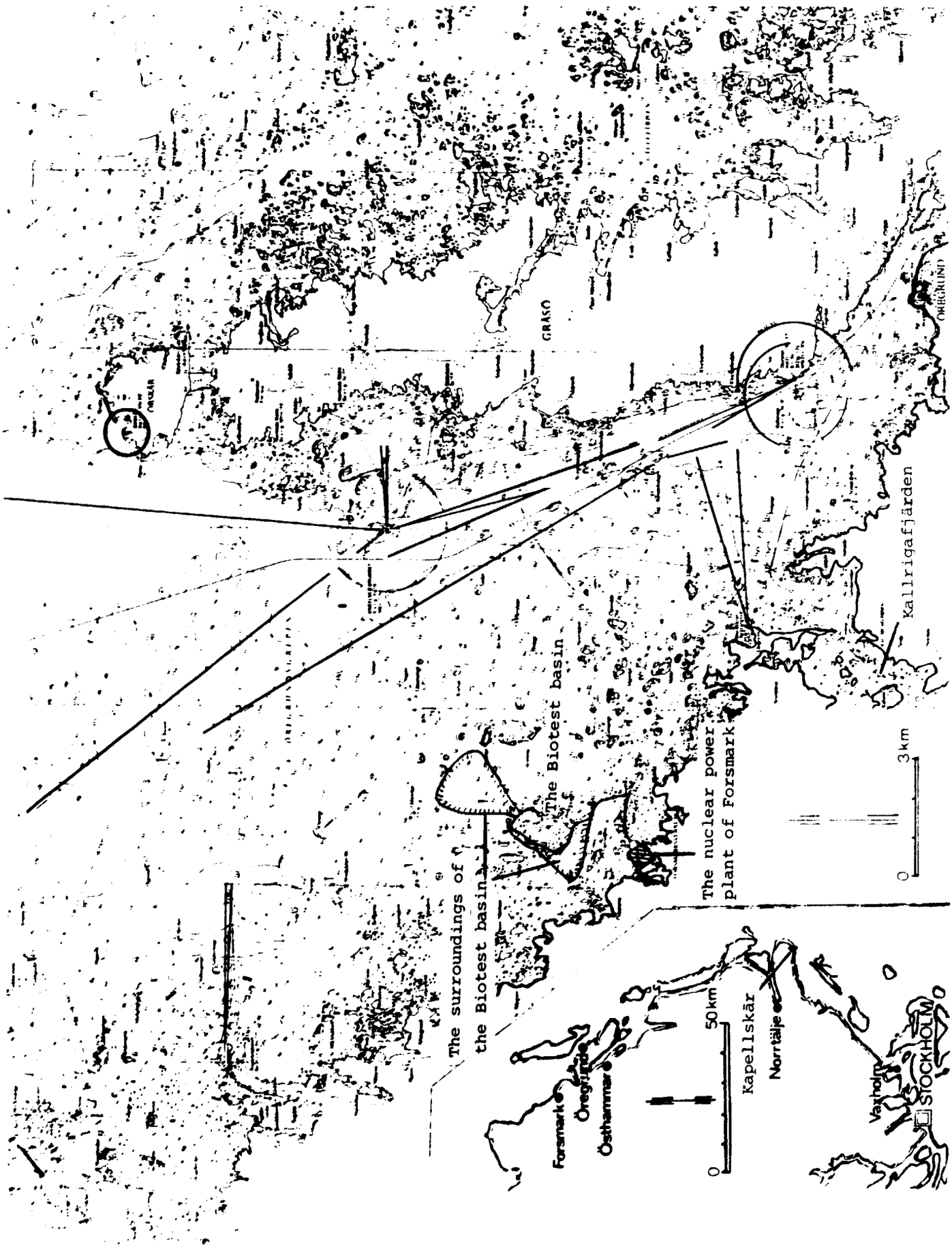
Mean temperatures of the month during the winters 81/82, 82/83 and 83/84. The freeze-up and the break-up of ice are also shown. (The winter = 21/11 - 29/3).

Figures 2 A-C



Key map to the investigation areas.

Figure 3



The Biotest basin and its surroundings.

Figure 4

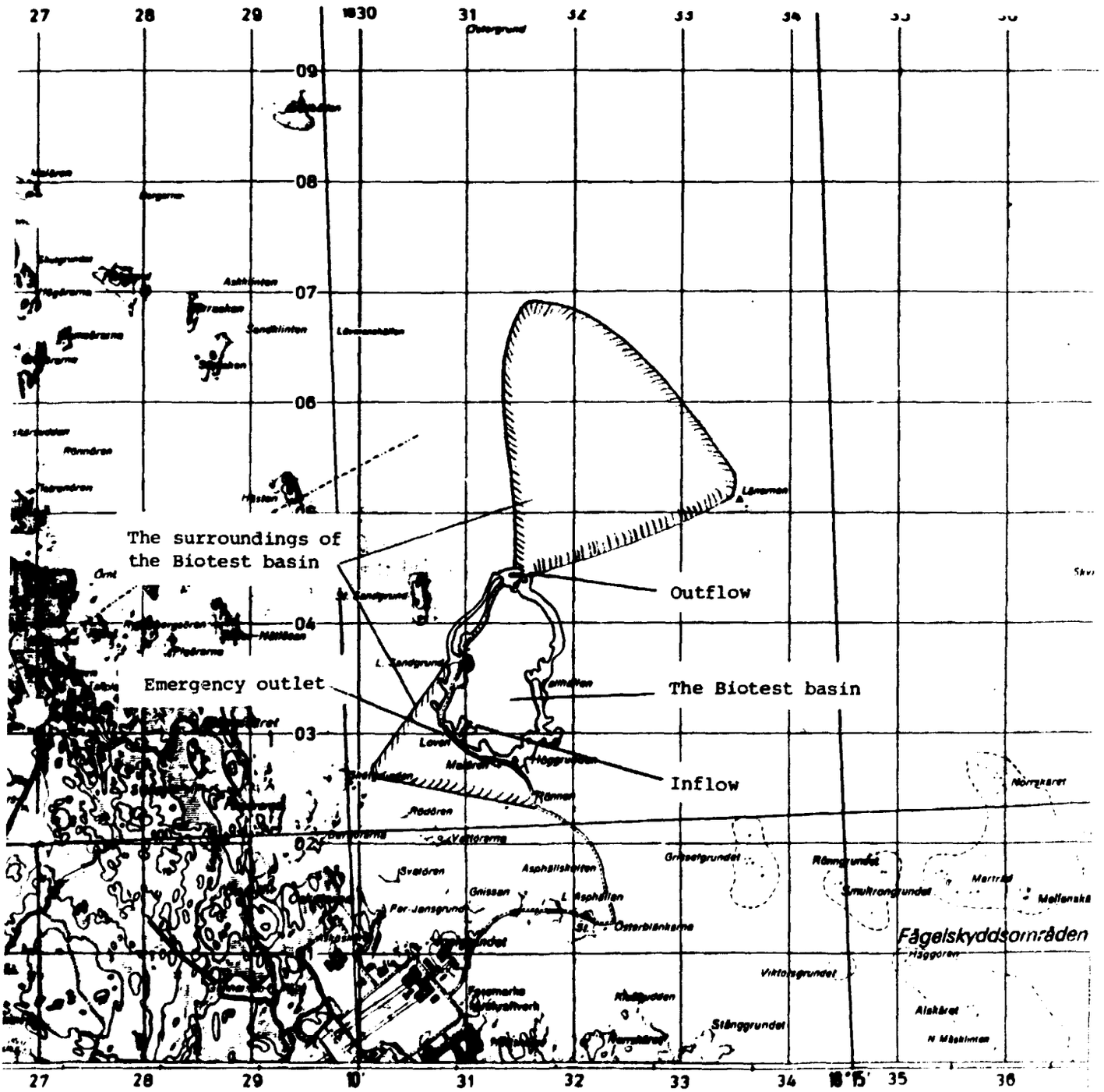
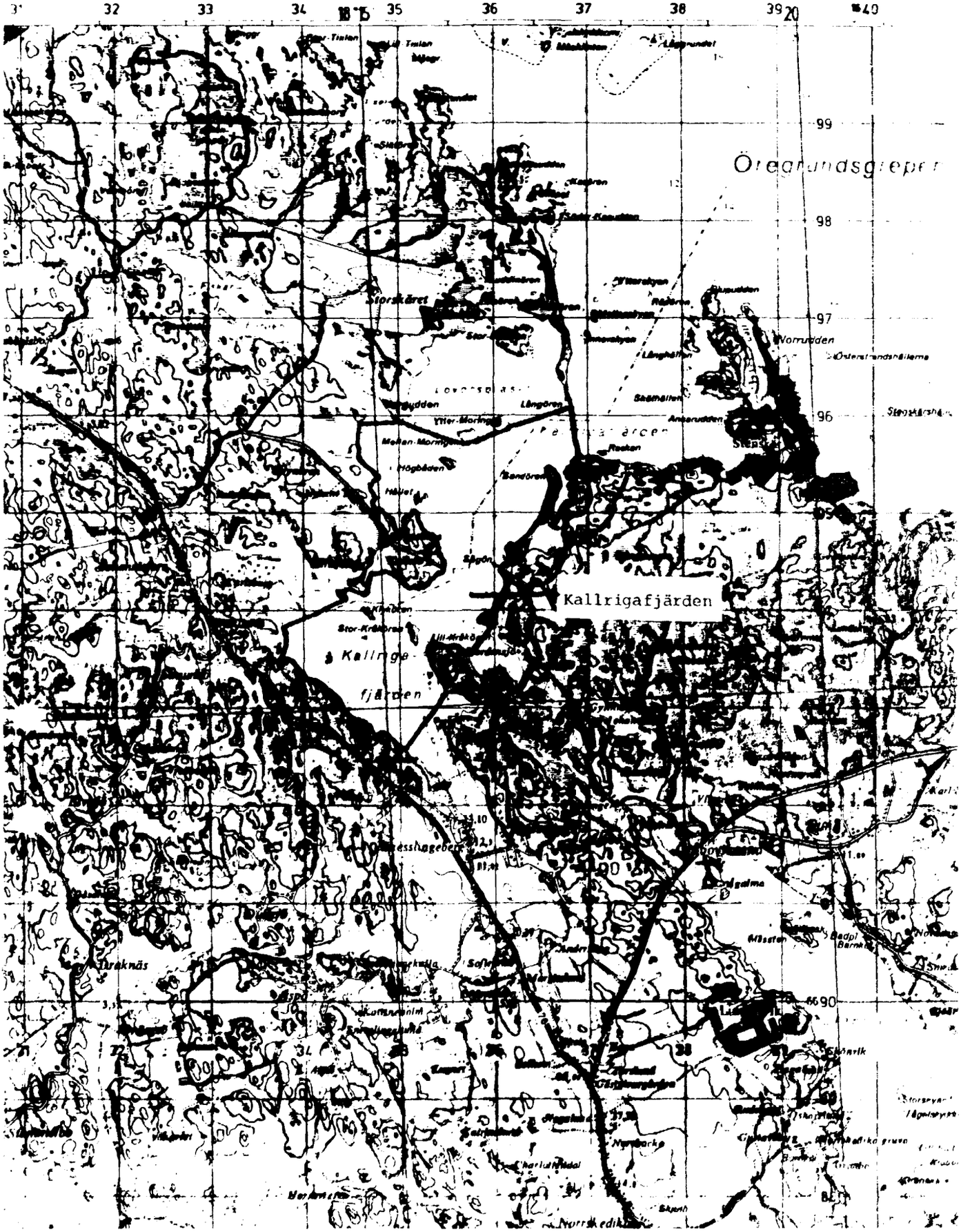
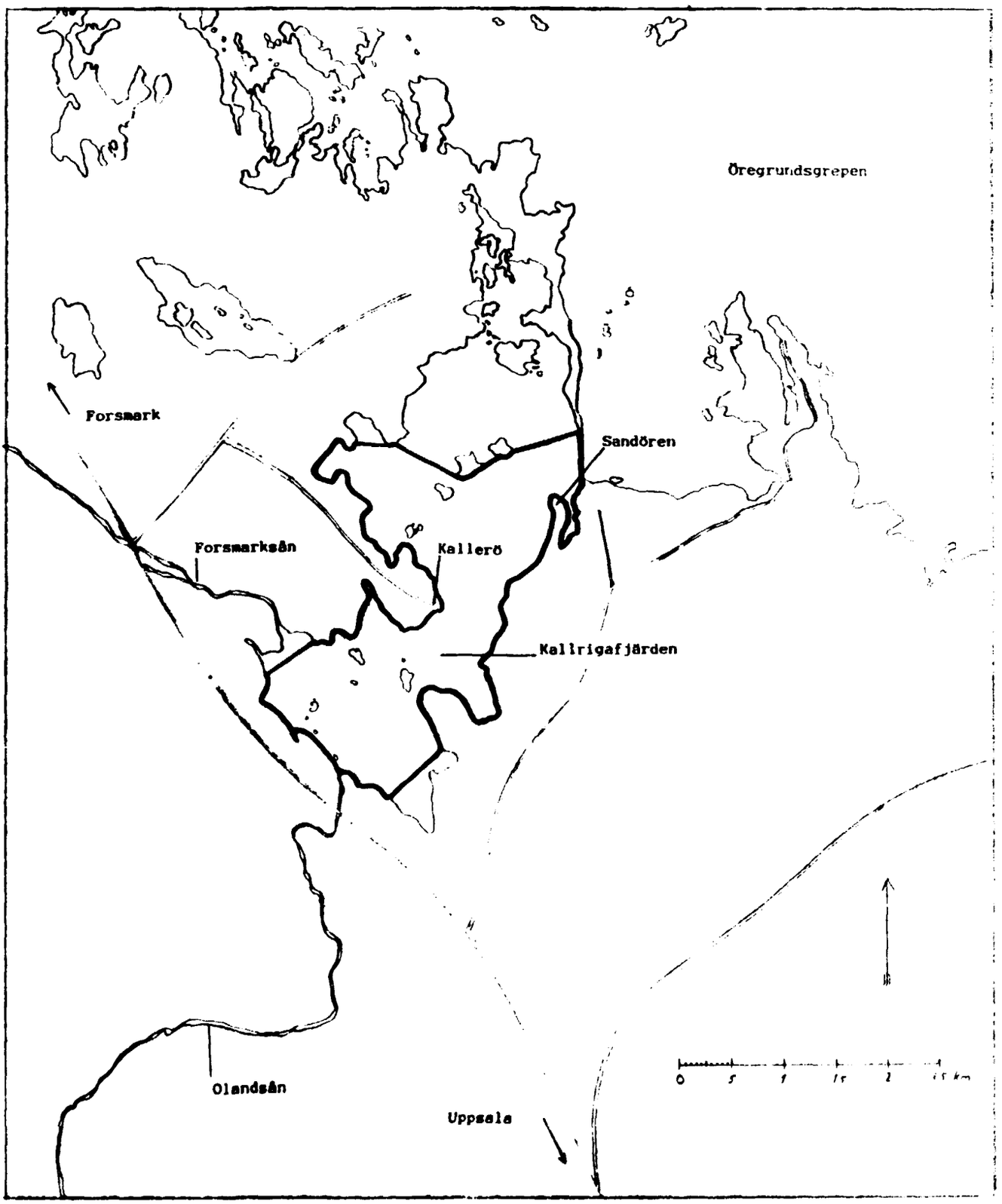


Figure 5: The reference area - Kallrigafjärden.
The censused area is enclosed with a
line of demarcation.



The reference area - Kallrigafjärden.
The censused area is marked with a bold line.

Figure 5



Average number of individuals of the Mute Swan, Cygnus olor, censused during each season in the Biotest basin and its surroundings and the reference area. (For explanation see key to Tables 3-7 and Figures 6-10).

Figure 6

The Mute Swan (Cygnus olor)

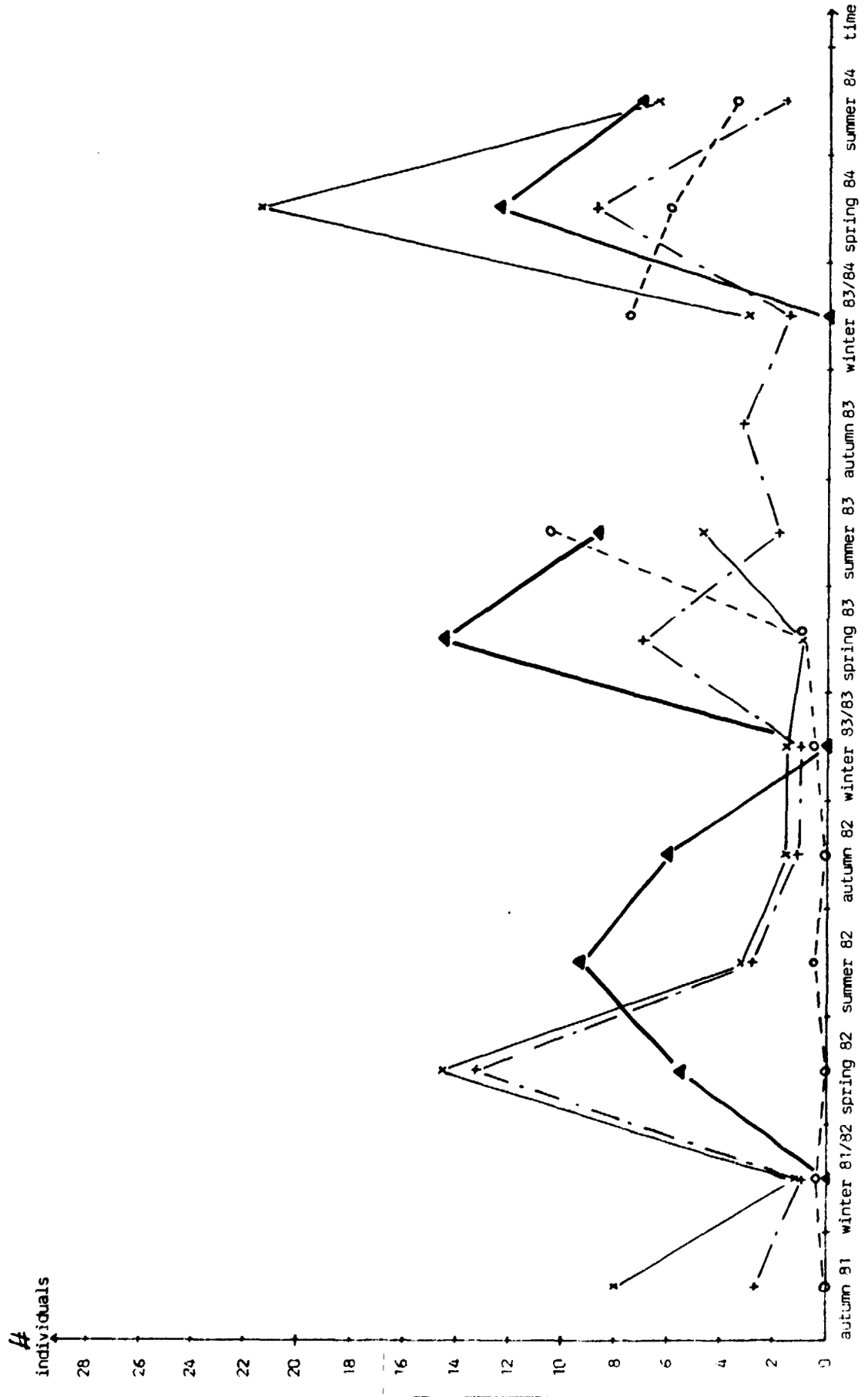
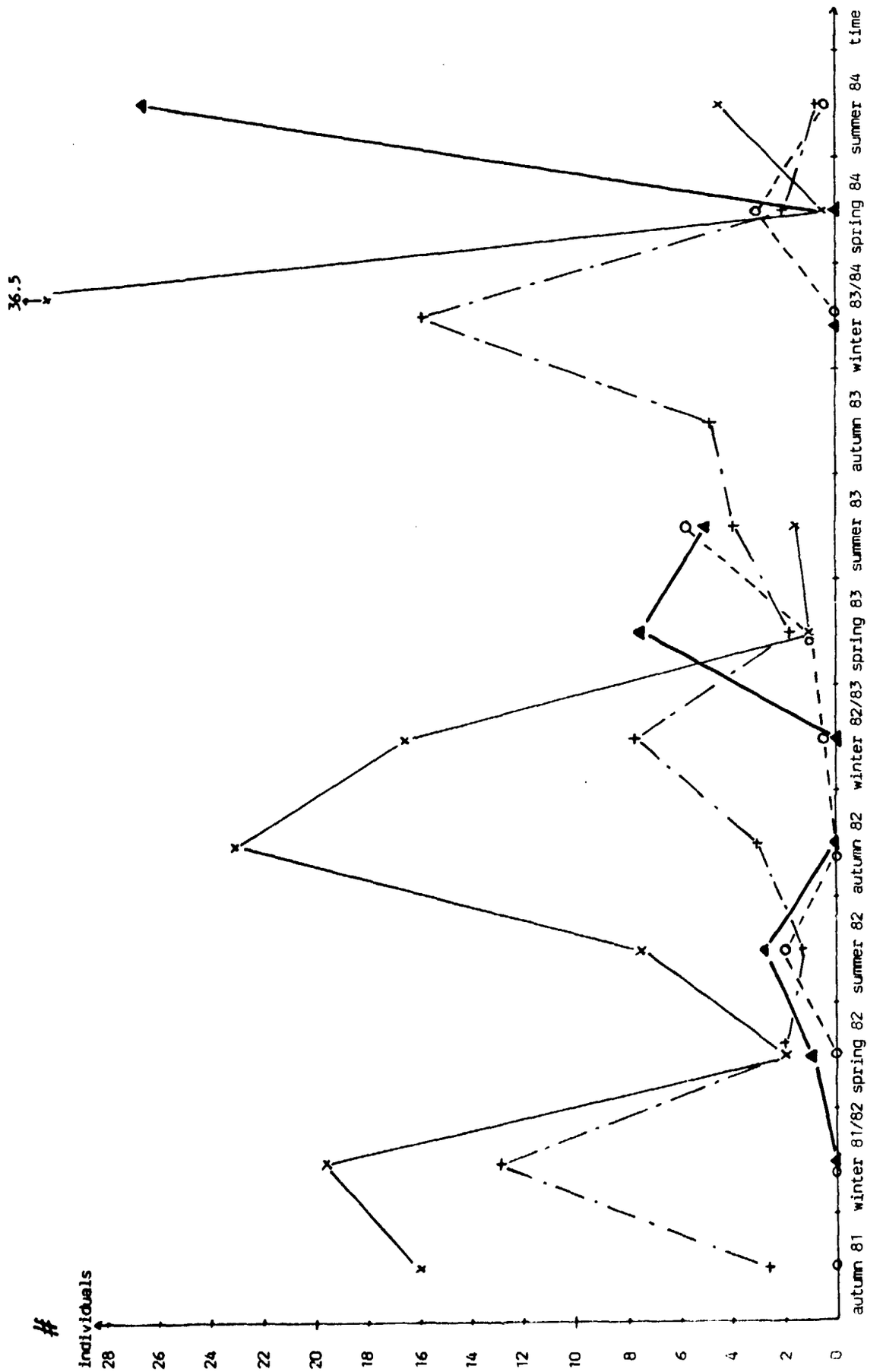


Figure 7

The Mallard
(Anas platyrhynchos)

Average number of individuals of the Mallard, Anas platyrhynchos, censused during each season in the Biotest basin and its surroundings and the reference area. (For explanation see key to Tables 3-7 and Figures 6-10).



Average number of individuals of the Tufted Duck, Aythya fuligula, censused during each season in the Biotest basin and its surroundings and the reference area. (For explanation see key to Tables 3-7 and Figures 6-10).

Figure 8

The Tufted Duck (Aythya fuligula)

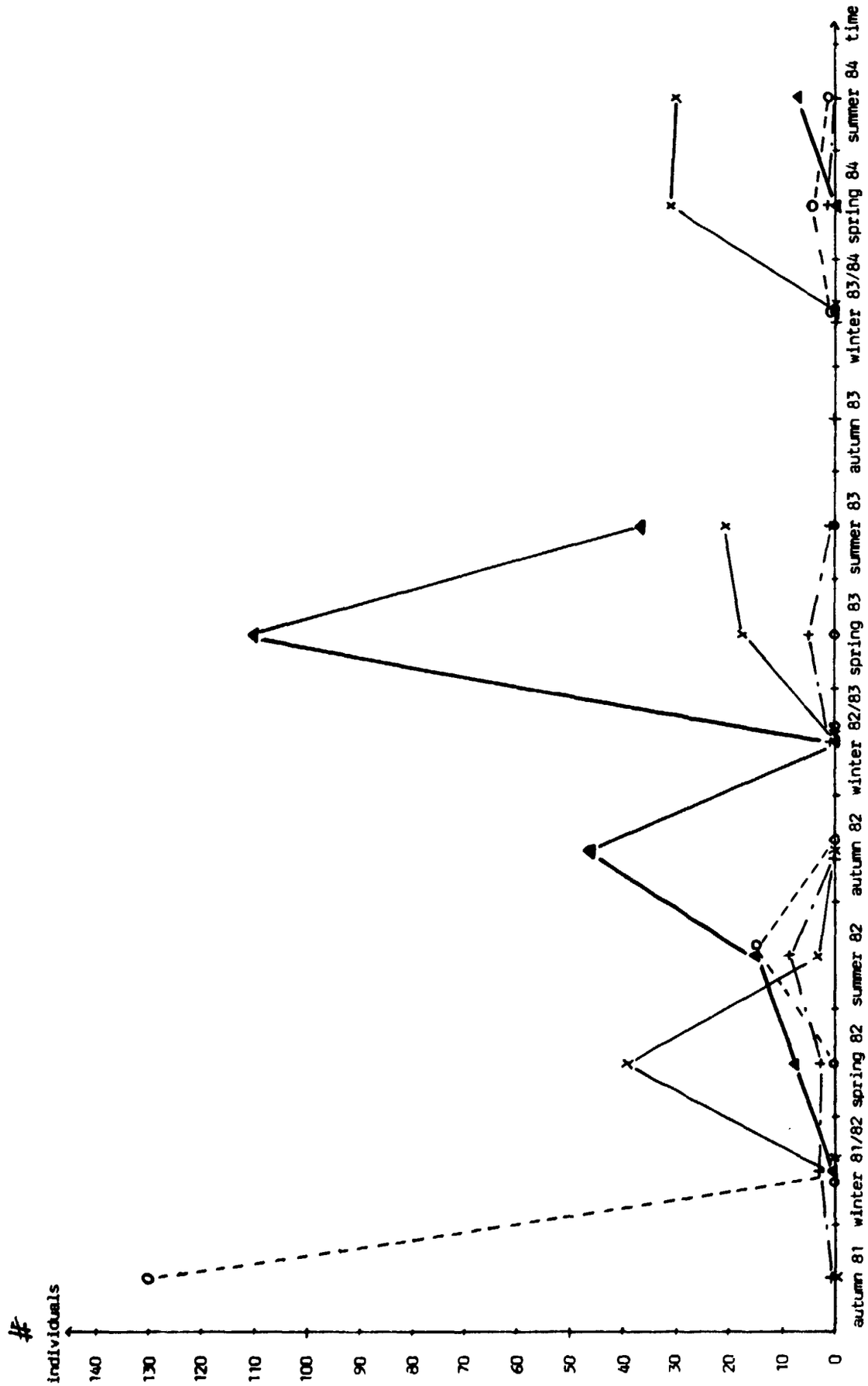
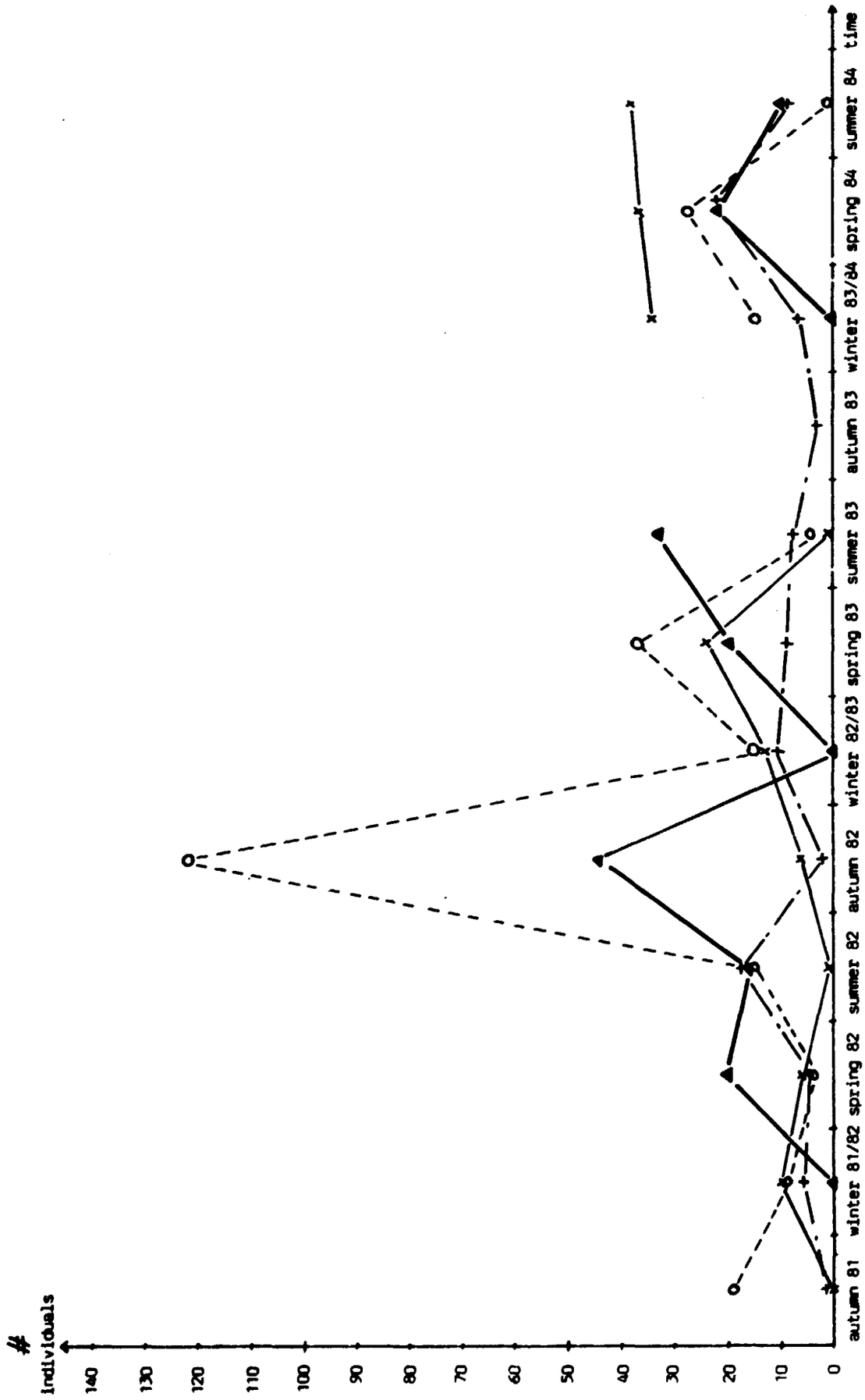


Figure 9

The Goldeneye (Bucephala clangula)

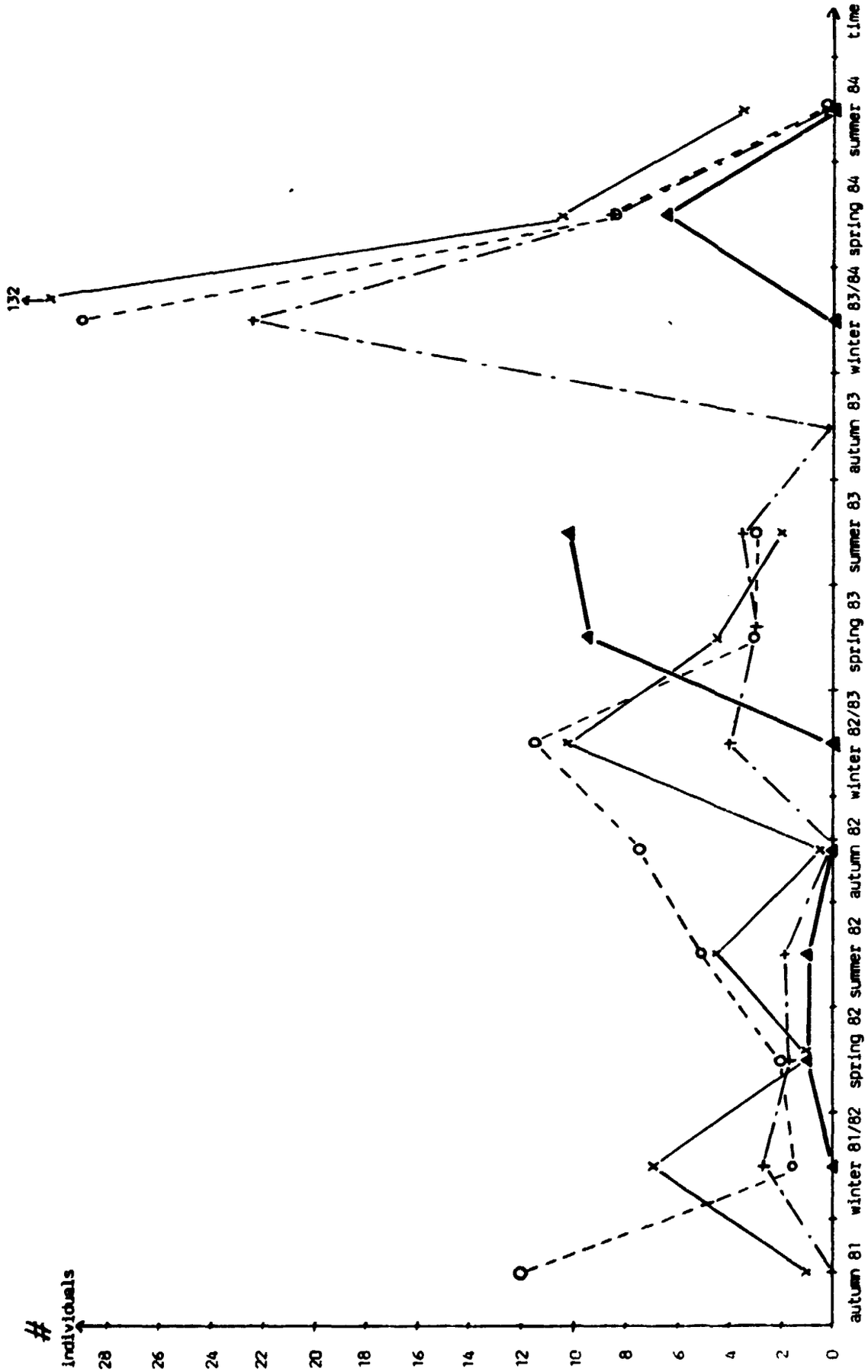
Average number of individuals of the Goldeneye, Bucephala clangula, censused during each season in the Biotest basin and its surroundings and the reference area. (For explanation see key to Tables 3-7 and Figures 6-10).



Average number of individuals of the Goosander, Mergus merganser, censused during each season in the Biotest basin and its surroundings and the reference area. (For explanation see key to Tables 3-7 and Figures 6-10).

Figure 10

The Goosander (Mergus merganser)



Consumption of fish by the Goosander, Mergus merganser, during the years autumn 81 - summer 82 to winter 83/84 - summer 84 in the Biotest basin and its surroundings. (Fig. 11 is based on Table 7). One fish = 10 g.

Figure 11