Recent changes in the waterfowl situation in the lakes Mývatn and Vikingavatn, Iceland

JON FJELDSÅ

(Med dansk resumé: Nye ændringer i andefuglebestandene i søerne Mývatn og Vikingavatn, Island)

INTRODUCTION

The waterfowl populations in many Icelandic breeding areas decline alarmingly. In contrast to the situation on lower geographical latitudes, the populations have only to a minor extent been object to severe destruction of breeding habitats. Draining of lakes and marshes for agricultural purposes is taking place on a minor scale only, and pollution and local shooting pressure is insignificant. The breeding habitats remain on the whole intact, but the duck stocks nevertheless dwindle away.

Bengtson (1973) has given a demography of the most important breeding duck population, at Lake Mývatn, for the period 1961 - 70. This study served, together with previous field work by the present author in 1966, 1969 and 1970, as a suitable reference background for the present study. A census made in 1974 indicated that the decline of the population has now entered a still more grave phase. The rate of decrease appears to be accelerating, the species composition has shifted considerably, and there has also been a shift in habitats selected for nesting. This paper will give a 1974 status of the waterfowl situation in Mývatn and one other important bird lake, Vikingavatn, and an attempt will be made to evaluate the possible factors involved in the population changes.

THE STUDY AREAS

Lake Mývatn is situated in N.E. Iceland, at 277 m.alt., on the outskirts of the vast central lava deserts, in a previously very active volcanic area. The lake is 38 km square large, with an irregular shoreline, and several small and larger islands. It is very shallow; the northern basin, Ytriflói, mostly 1-1.5 m deep; the main basin, Sydriflói, mostly 3 m deep. Most shores are tephra-beaches, lava-coasts or firm, peaty edges, while swampy, sedge-fringed bays occur only locally. Most of the surrounding terrain is dry lava and sand, more or less overgrown with short grasses or heath vegetation, although with richer herb meadows on part of the nearest terrain, and there are three large, marshy areas with wide sedge meadows, dwarf shrub bogs and coppice, and several hundred sedge fringed ponds and smaller lakes.

Mývatn is a 'hydrostatic window', fed from numerous under-water springs with both cold and temperate water very rich in minerals and nutrients (Steffánsson 1971). The peculiar limnological conditions form the basis for an extraordinary production of periphytic diatoms, bluegreen algae (*Anabaena*), filamentuous green algae (*Cladophora aegagrophila*) and submergent macro-vegetation (e.g., *Potamogeton filiformis, Myriophyllum spicatum, Ranunculus confervoides*). The invertebrate fauna is quantitatively completely dominated by cladocerans and chironomid midges, the latter with a standing crop in the off-shore parts of the lake of average (for the whole year) 101 000 larvae per metre square bottom (instars 2, 3, 4) (Lindegaard & Jónasson in press). The incredible abundance of food has, together with suited physical conditions for feeding, nesting and loafing, made Mývatn the probably best nesting locality for ducks in Europe.

The other locality, Lake Vikingavatn, is situated at the coast right north of Mývatn, at only 4 m alt. It is a smaller lake, only 2.6 km square large, but resembling Mývatn in having an irregular shore-line, numerous islets, and very shallow water, which only in few places exceeds one metre in depth. Unlike Mývatn, most bays are fringed with dense sedges. The environs are dominated by grass-land, coastal dunes, and extensive, partly flooded sedge meadows. The biological productivity is a far cry from that of Mývatn,

Dansk orn. Foren. Tidsskr. (1975) 69: 89-102

although still rich as compared to average subarctic non-glacial lakes.

METHODS

The author's previous experience with the Mývatn area dates from a population study of horned grebes, *Podiceps auritus* (Fjeldså 1973). The main scope of the one month's stay in Iceland in 1974 was to study egg-laying in waterfowl, and variations in egg size in relation to clutch size, laying sequence and condition of the female. This is part of a more comprehensive study planned to evaluate theories on the adaptive significance of clutch size in waterfowl. Although irrelevant for the main scope of the study, all nest sites were described, and as the nest searching routes were laid through most parts of the area, the data are supposed to give a roughly unbiased sample of the present nest site selection. Previous nest site selection is well documented by 6674 nest records analysed by Bengtson (1971), and 973 nest records described in the previous notes of the present author. The 1974 data comprised 702 nest records (574 at Mývatn).

As only little egglaying had started by the arrival to Mývatn on the 20th of May, the first week was largely devoted to duck counting. Exact and repeated counts were made on some smaller areas, to study local movements taking place through the day and through the course of the egglaying period. The great number of ducks feeding on the vast offshore parts of the lake was counted from craters on the islands, and from similar elevated posts along the coasts, as far as possible by calm weather in the late evening, when many birds were feeding on water. The comparatively lower numbers of ducks which by this time occurred dispersed over less surveyable pothole areas were estimated by extrapolation from transect counts. Most of the district was covered before onset of intensive egglaying about 25th of May. The main shortcomings of these counts were probably corrected by further counting during the subsequent three weeks. Only some smaller, less important areas were not covered.

For most far offshore areas and some coastal areas all species were lumped when counting. The relative abundance of each species was calculated from ratios obtained from counts on smaller sample areas. Late May samples comprised 4721 identified ducks. Due to interspecific differences in habitat selection, the grand total had to be calculated by adding sub-totals calculated for each natural part of the district.

The ducks in Vikingavatn were counted on the 8th of June both from the shore and by boat, every island being visited, and on the following days from a route which followed the entire shore-line. All ducks were identified.

RESULTS

A. Waterfowl numbers in Mývatn

From the very day of arrival to Mývatn in 1974, it was felt obvious that the waterfowl populations were very low. Also the local farmers ment they were lower than ever. This was astonishing insofar as the weather in 1973 was very fortunate. The estimated grand total was only 15 500 individual waterfowl, or, taking the natural surplus of drakes into consideration, about 7500 pairs. Due to an exceptionally warm spring, the whole breeding population had probably arrived by the end of May. The total is far below that given by Bengtson (1973) for the period 1960 - 70. He found 30 - 50 000 ducks, (although lowest in the latter part of the period). This may be a slight overestimate. However, a rough estimate of 16 000 pairs in 1966, and 12 000 pairs in 1969, by the present author, is close to Bengtson's 15 990 and 13 180 pairs, respectively. This indicates that our methods are comparable.

The total 1974 numbers for each species, together with data on their local distribution, is given in Table 1. Fig. 1 shows population estimates for the ten most numerous species since 1961.

It appears that the 1974 population was dominated (43.5%) by the tufted duck, *Aythya fuligula,* the scaup, *Aythya marila,* coming next (20.9%), followed by Barrow's goldeneye, *Bucephala islandica,* (9.2%), red-breasted merganser, *Mergus serrator,* (6.2%), wigeon, *Anas penelope,* (5.6%) and mallard, *Anas platyrhynchos* (4.0%).

The most striking change since Bengtson's study, besides the low total, was the marked decline of the scaup relative to the tufted duck. The estimated 3245 *individuals,* is a far cry from the 4000 - 10 000 *pairs* registrated by Bengtson (1973). The tufted duck increased steadily in Iceland since the immigration by the end of the nineteenth century, but its relative abundance in Mývatn did not equal that of the scaup until by the end of the sixties. Then, over a three year period,

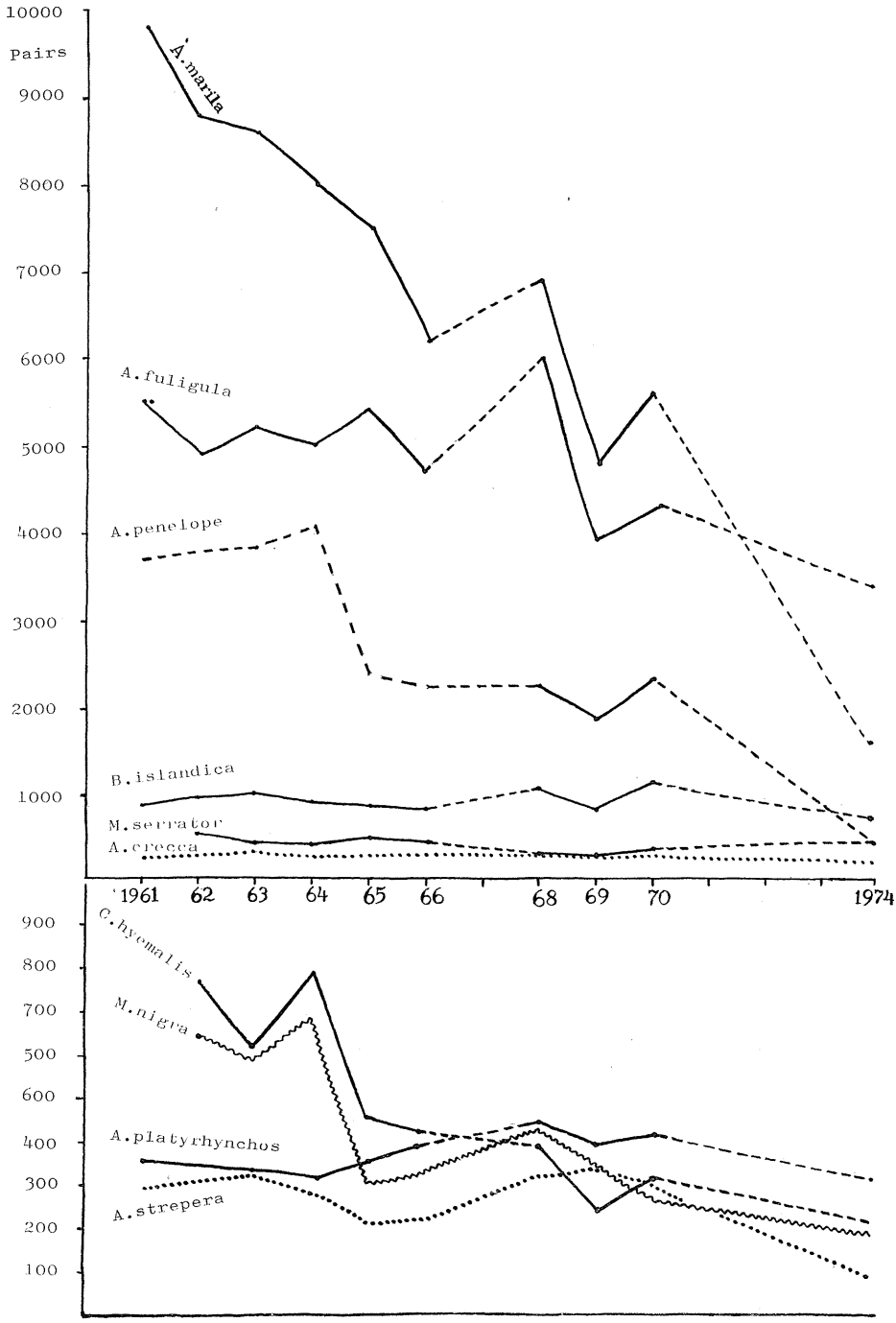

Fig. 1: Changes in the estimated breeding populations of ten species of ducks in Mývatn from 1961 to 1974.
Ændringer i antal af ynglepar af 10 andearter i Mývatn fra 1961 til 1974.

Table 1: The composition of the waterfowl population of Lake Mývatn in late May 1974. The percentual composition is given separately for seven main habitat types.
Sammensætningen af Mývatns andefuglebestand sent i maj 1974. Den procentvise sammensætning opgives for 7 hovedsagelige terrætntyper (de vandrette kolonner) fra oven: Dybere dele af Mývatn med faste, meget eksponerede kyster; dybere dele af Mývatn med mindre eksponerede kyster og øer; dybere dele af Mývatn nær op mod sumpområder; lavvandede dele af Mývatn med faste bredder; lavvandede dele af Mývatn med sumpede bredder; sumpområder med jævnt næringsrige småsøer; sumpområder med krat og næringsfattige småsøer.

Species	Cygnus cygnus	Anser anser	A. brachyrhyrchus	Anas platyrhyncus	A. acuta	A. crecca	A. strepera	A. penelope	A. clypeata	Aythya ferina	A. fuligula	A. marila	Clang. hyemalis	H. histrionicus	Mel. nigra	Buc. islandica	Merg. serrator	M. merganser
Estimated number	101	243	10	625	75	306	137	895	4	2	6743	3245	397	60	318	1426	922	30
Per cent	0.7	1.6	+	4.0	0.5	2.0	0.9	5.6	+	+	43.5	20.9	2.6	0.4	2.0	9.2	6.0	0.2
Percentual composition of duck numbers on various habitats																		
Deeper parts of Mývatn with very exposed, firm coasts	-	-	-	2.6	-	0.4	0.4	0.9	-	-	32.7	34.6	2.8	-	2.4	16.9	6.0	0.2
Deeper parts of Mývatn with less exposed, firm coasts and islands	0.2	0.4	-	4.7	0.2	2.0	1.3	5.5	-	-	30.4	26.0	1.5	+	1.5	18.5	7.4	0.4
Deeper parts of Mývatn adjacant to pothole areas	-	2.0	-	3.2	0.4	1.3	0.8	5.4	-	-	46.6	18.6	1.8	-	2.2	11.7	6.0	-
Shallow parts of Mývatn with firm coasts	+	2.0	-	4.2	0.2	2.6	2.5	8.7	+	-	47.3	13.2	0.6	-	0.8	2.7	14.6	0.6
Shallow parts of Mývatn with marshy coasts, close to pothole areas	10.4	0.3	-	6.7	2.0	3.5	0.6	8.6	0.2	0.2	43.5	12.5	4.8	-	3.5	1.3	1.8	-
Marshy areas with mesotrophic pools and small lakes	0.5	7.4	0.2	2.9	0.8	3.3	0.2	5.6	0.1	-	47.8	20.0	5.3	-	2.0	0.9	2.9	-
Marshy areas with coppice and oligotrophic pools and lakes	0.8	4.9	-	3.4	0.4	2.9	0.8	4.8	-	+	42.2	24.6	3.2	-	4.0	0.4	8.0	-

they have completely changed roles as the character duck of the area (Fig. 1). In the shallow portions of Mývatn, and on all places where sheets of open water alternated with flooded sedge meadows and wet shrub-meadows, more than half of all waterfowl were tufted ducks (Table 1). Scaups and tufted ducks were equally abundant only on areas with deeper water, along non-marshy, exposed coasts and islands with grassy slopes or lava to the south and southeast of Mývatn, and on some dystrophic and oligotrophic pools with almost bare bottom. It seems that the difference in habitat selection between the two species, prior to breeding, has accentuated. It is not known whether a competitive exclusion is involved.

Another catastrophically declining species is the wigeon. Bengtson estimated 4000 pairs up to 1964, then fully 2000 pairs up to 1970. Certainly it signed up for more than half of all dabbling ducks in the area, but the exact figures given seem yet to represent an overestimate. Since 1970 the species has declined to the present estimate of poor 895 individuals.

The gadwall, *Anas strepera,* had a down about 1965, but counted about 300 pairs both in the early and late sixties. Also this species has shown a drastic recent decline, to the present 137 individuals.

The long-tailed duck, *Clangula hyemalis,* and common scoter, *Melanitta nigra,* declined gradually from 600 - 800 pairs each in the early sixties, to 300 pairs each about 1970. The present 397 and 318 individuals, resp., do not indicate any accentuation of the previous rate of decline.

Also mallard, teal, *Anas crecca,* and Barrow's goldeneye showed a lower total than found at any time in the sixties, but these differences were so slight that they are likely due to differences in census method or efficiency. These populations appear, together with those of tufted duck, pintail, *Anas acuta,* harlequin duck, *Histrionicus histrionicus* (present

estimate only upper 2.5 km of Laxá river) and goosander, *Mergus merganser,* to be effectively stable. The redbreasted merganser appears, with its present 922 individuals, to have recovered after a down in 1969.

The shoveler, *Anas clypeata,* and pochard, *Aythya ferina,* have never amounted more than the present one or two pairs.

The whooper swans, *Cygnus cygnus,* are chiefly non-breeders. This species desisted from breeding in the area for a long period after the recent increase of human activity, but has now begun to nest again. Three breeding-pairs were found. The greylag goose, *Anser anser,* is evidently increasing and spreading to new nesting habitats.

In conclusion, the decline of the total waterfowl population seems to be accelerating, and this is chiefly due to a great reduction in numbers of scaup, wigeon and gadwall.

(The running average for the estimated total duck numbers will, if extrapolated, approach zero by 1980, although certainly the curve must be expected to smoothen out before that.)

B. Waterfowl numbers in Vikingavatn

311 ducks were counted on the lake on the 8th of June, almost the same number, 305, on the following day (these figures do not include females flushed from the nest). The approximate number for each species was: Whooper swan 2 pairs; greylag goose 45 - 50 (probably 18 breeding pairs); mallard 16 (11 drakes); pintail one female; teal 8 (4 drakes); wigeon 19 (12 drakes); shoveler 4 (3 drakes); tufted duck 179 (132 drakes); scaup 51 (34 drakes); long-tailed duck 9 (3 drakes); common scoter 16 (8 drakes); red-breasted merganser 5 (4 drakes). Supposing the number of drakes to be correct, and a slight male surplus, this indicated a total of 360 ducks.

The duck numbers are certainly minor as compared with that only few years ago. The local farmers collected, 15 years ago, nearly 2000 duck-eggs on the islands in the lake, and they judged that 100 eggs were laid daily on these places, during late May- early June. They had stopped egg-picking completely now, and we found only one mallard nest on the islands (but several goosenests). The total population then must have been several times the present estimate. Dr. A. Gardarsson (in litt.) suggested that the low present estimate was due to a too late date of census. As the nearby brackish water lagoons (Lón and Arnarneslón) were not censused, it cannot be ex-

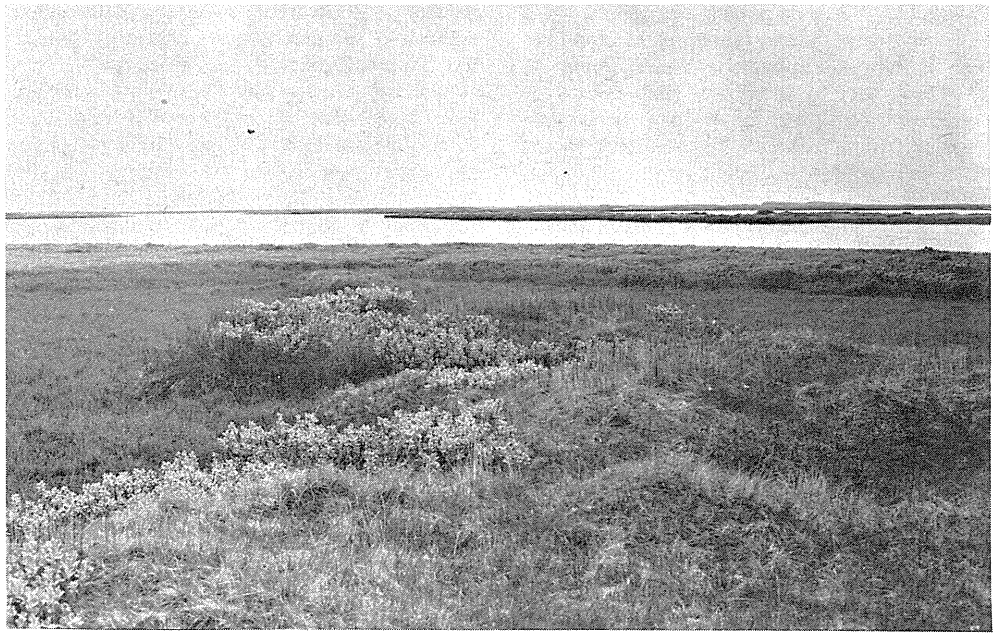

Fig. 2: Former nesting habitat for ducks on the islands of lake Vikingavatn.
Tidligere yngleterræn for ænder på øerne i Vikingavatn.

cluded that larger numbers of drakes had moved to these places. Anyway, the number of breeding females at Vikingavatn must have been very low, and the former nesting areas, clearly pointed out by the local people, were all deserted.

C. Egg-laying and nest site selection

The spring 1974 was exceptionally warm – the ice breaking up on Mývatn by the 18th April. Also feeding conditions were excellent, with extraordinary swarmings of midges in late May. Divers, horned grebes, geese and some few dabbling ducks laid eggs unusually early (first mallard ducklings 20th of May, according to Örn Fridriksson, first teal ducklings 30th of May, first wigeon ducklings 5th of June). However, intensive egg-laying did not start until in the very last days of May, i.e. by ordinary time. A very marked peak of egg-laying followed some days of calm, hot weather, while egg-laying diminished again towards mid-June.

A striking difference in nest distribution from earlier years soon became apparent. Previously, duck nests were dispersed over large parts of the district, including on areas with short, grassy vegetation, and colonies occurred on many herb meadows along the coasts and on the larger islands, and on smaller isles with lush herbage of *Angelica archangelica*. Bengtson (1970) found an average of 772 nests per km square (omitting nests of Barrow's and mergansers) along the non- marshy south-eastern coasts. Until the last check here by the 7th of June 1974 only nine nests (omitting 13 Barrow nests) had been recorded, suggesting, according to the methods used by Bengtson, roughly 40 nests per km square. Also on the larger islands the nest density had dropped markedly, from an average of 835 per km square in the sixties to approximately 80 nests per km square. Direct comparison of the figures is not fully justified, as the 1974 nest survey stopped before egg-laying was completed, but anyway the decline on these places must have been considerable. Scarcely any nests were found to the north and east of the northern basin of the lake, and very few also on other dry, grassy areas. This change seems to have taken place over several years. During the author's first stay here in 1966, several dense duck colonies were found on herb meadows or hummocky-grassy terrain east and south of the lake. They were gone in 1969. Also islandnesting had declined much already by that year.

The 1974 duck nests were concentrated in damp, often hummocky shrub meadows (*Betula nana, Vaccinium uliginosum, Salix* ssp.) with undergrowth of sedges, and particularly where areas with such vegetation was interrupted or surrounded by flooded shrub meadows. The densest concentrations were found on shrub-covered islets in sedge-filled water, and with colonies of black-headed gulls, *Larus ridibundus*. 32.5% of all duck nests found were in three main gulleries (Tengur in Lake Sandvatn, with 213 gull nests; an islet in Lake Nátthagatjörn, with 173 gull nests, and Fretvógur-Nidurnes, with about 90 pairs of gulls). The size, distribution and habitats of the gulleries are described by Fjeldså (1975). Nests in gulleries comprised 58% of all nests of tufted duck; 45% of all scaup nests; 4 out of 7 pintail nests; 11 out of 18 long-tailed duck nests; 4 out of 8 scoter nests. Dabbling ducks, especially teal, nested more independently of gulleries, and the Barrow and mergansers nested only outside gulleries.

Although the evidence is too inconclusive to calculate exact nest densities for each habitat, the impression is that duck nests were almost as abundant as previously in most marshy areas.

The change in vegetation selected as nest cover may be illustrated by Table 2. The amount of nest searching done on each type of habitat is indicated to justify direct comparison of the present data and those presented by Bengtson (1971, Table 4).

Mallards may possibly have shifted slightly from herb meadows and *Angelica* vegetation to shrub meadows. The gadwall possibly has decreased slightly on its previous habitat, small *Angelica*-covered islands, but its habitat selection does not appear to have changed markedly. The pintail still prefers wet mainland shrub meadows. Teal and wigeon prefer shrub meadows, shrub heaths and coppice without obvious changes stated, except probably that the wigeon decreases on meadows and *Angelica* vegetation. Tufted duck, scaup and long-tailed duck have declined much among *Angelica* vegetation on the islands and increased proportionally on damp shrub meadows, in particular on damp places with gulleries. No obvious changes can be stated among scoter, the Barrow or mergansers.

Regarding the distance of the nest from open water, gadwall, long-tailed duck and the Barrow previously often nested close to the water edge. This tendency may be less

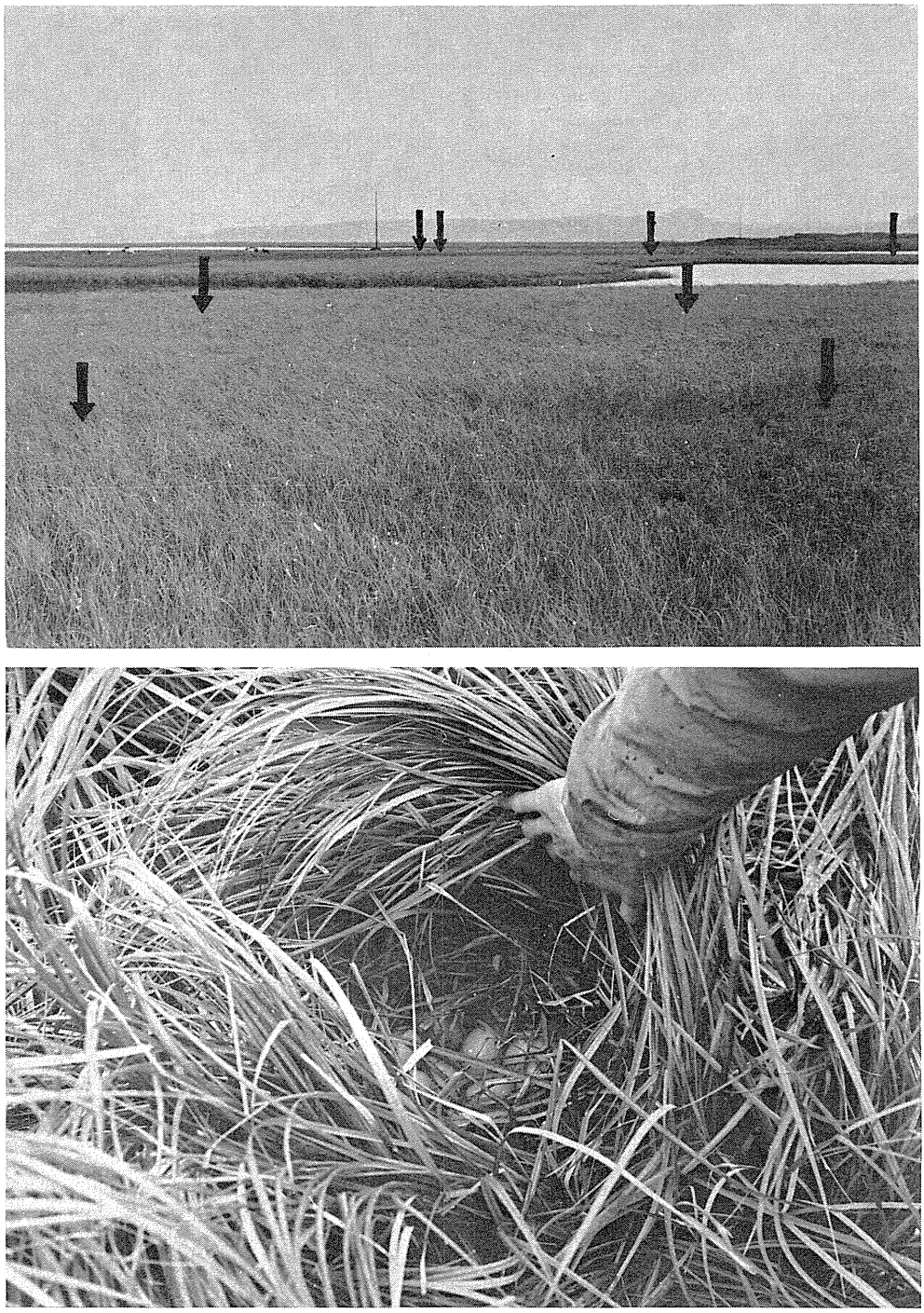

Fig. 3: The main present nesting area for ducks in Vikingavatn, in shallow water with lush sedge vegetation. Nest sites are indicated by arrows. One of the nest sites is also shown.
Det vigtigste nuværende redeområde for ænder i Vikingavatn, i lavt vand med tæt sivvegetation. Pilene viser redesteder. En af rederne vises også.

pronounced now, particularly in the Barrow (see p. 92).

Also changes in percentuel species composition on de different nesting areas were examined (present material including both nests and birds on water behaving as if having nests nearby). The most significant changes were a drastic relative decline of wigeon nests on all habitats, of scaup nests on all habitats but especially the non-marshy types and in particular islands (dominance value reduced from 40.6 to 7% here), and of long-tailed duck on islands. The tufted duck is increasing proportionally everywhere, although slightly on non-marshy places and islands. As consequence of the very sharp decline of the scaup from islands and non-marshy coasts, both mallard, gadwall, Barrow, and mergansers increased proportionally here.

During the sixties both scaup, tufted duck, gadwall, long-tailed duck, mergansers and maybe even wigeon showed a significant island-nesting tendency, whilst only pintail, teal and scoter preferred mainland nesting (Bengtson 1971). It may be no accidence that those species which have not abandoned island-nesting yet and not declined markedly, are cave-nesting (Barrow's Goldeneye, mergansers). The 1974 data may indicate that even the wigeon is beginning to utilize holes when nesting on islands: Among 300 wigeon nests found on islands by Bengtson (1971, Table 4), only 6 were in holes. Out of 9 wigeon nests found on islands in 1974, 5 were in holes in the lava.

A comparison of nest frequency per species with the frequency of the species in the total population, and, in addition, a counting of the percentage of females among ducks on water after the 5th June were made to indicate, roughly, the non-breeding frequency.

Higher nest frequency than expected by chance in greylag goose, mallard, teal and wigeon may be due to their tendency to lay eggs early. However, this can hardly be the reason for the high nest frequency of the typical wetland species, pintail, tufted duck and long-tailed duck. The tufted duck amounted 44.4% of the total duck population but signed up for 48.3% of the nest records. Only 12.8% of tufted ducks on water after 5th June were females, as compared to 28.8% for dabbling ducks and an average of 36.6% for *all* diving ducks.

An apparently lower nest frequency in red-breased merganser is certainly because it is a late breeder. Evidence is not conclusive to conform statistically an apparent low nest frequency in teal and scoter. However, indices of low nest frequency in Barrow's goldeneye and scaup are more worthy of attention: Whilst the scaup signed up for 21% of the total duck population, it contributed only 14.6% of the nest records. 35.2% of scaups seen on water after 5th June were females. (According to Bengtson 1973, Table 4, egg-laying starts on average only three days later than in tufted duck, so the difference in nesting frequency between them must be real). It appears from Table 1 that most scaups occurred near non-marshy coasts prior to egg-laying. The nests were concentrated in marshy places (Table 2), but well into June there were still large numbers of scaups to be seen off the non-marshy coasts, birds which apparently did not nest or which at least would breed very late. This was also the case for the Barrow in many places. Out of 77 territorial Barrow drakes controlled by the 7th of June (the day when the first hatching was stated), 47 were still together with the female on water. Average 3.1 old Barrow nest holes were found for each hole in occupancy. Many occupied Barrow-holes were on the central parts of the larger islands, and not so much concentrated in cliffs just above the shore line as previously.

An even more striking result was obtained at Vikingavatn. The main previous nesting places for waterfowl were on isles with short grass vegetation and scattered, low shrub, in some places also herb vegetation (*Angelica archangelica, Caltha palustris*) (Photo Fig. 2). There might probably have been some 300 duck nests here previously. We found a single mallard nest. Four nests were found widely spaced on areas with similar vegetation on the mainland. Three of these had already been robbed by nest predators.

The only important duck nesting areas were in some bays close to the farms. The shores were broadly fringed with dense and tall vegetation of *Carex rostrata* var. *utriculata,* some bays being completely filled up with sedges. The environs were all cultivated land. About 50 pairs of black-headed gulls and 19 pairs of arctic terns nested here, and a total of 29 duck nests were found (2 mallard, 1 wigeon, 23 tufted duck, 2 scaup, 1 long-tailed duck). 12 nests were on low, wet, mossy isles with short sedges and herbs in the flooded sedge marsh: 5 were on damp places on the main shore; 3 were hidden in dense tussocks in flooded sedge marsh; 8 were bulky, floating cups built of dry and green sedges, placed very well concealed in uniform, ac-

Table 2: A comparison of percentual distribution of nest records on various nesting habitats during 1961 - 69 (after Bengtson 1970, table 4) and in 1974. (Nest site types are: H = holes and cavities, mainly in lava on dry, in part rocky coasts and islands; A = *Angelica* vegetation, chiefly on small, rocky islands in Mývatn; HM = herb and grass meadows, chiefly in drier terrain types; HS = high scrub (more than 0.5 m), chiefly on drier ridges on pothole areas, but also very densely on some islands in Mývatn; LS = low shrub, chiefly in marshy terrain on pothole areas; C = wet sedge meadows in the pothole areas).
Sammenligning af de fundne andereders procentvise fordeling på forskellige redehabitater i tiden 1961 - 69 (Bengtson 1970, tabel 4) og i 1974. Redehabitaterne er: H = hulheder, mest i lavaen ved tørre, til dels klippefyldte kyster, og på øerne; A = Angelica *vegetation, der mest findes på stenede øer i Mývatn; HM = enge med græs og urter, mest tørt terræn; HS = højt krat (mere end 0,5 m) på tørre steder i sumpområderne, og meget tæt på enkelte øer; LS = lavt krat, navnlig i sumpområder; C = våde sivskove i sumpområderne.*

Year	1961-69							1974						
Nest-site cover	H	A	HM	HS	LS	C	/n	H	A	HM	HS	LS	C	/n
km. nest searching	-	175	245	276	460	355		-	21	62	60	117	82	
Anas platyrhynchos	+	20	28	7	37	5	286	-	4	15	8	73	4	26
Anas strepera	-	39	22	8	28	2	261	-	17	33	8	42	-	12
Anas acuta	-	6	12	6	71	6	17	-	-	-	-	100	+	7
Anas crecca	-	1	9	20	67	3	207	-	-	9	18	73	-	11
Anas penelope	3	9	13	18	59	6	933	9	2	5	17	68	-	54
Aythya marila	+	22	6	21	43	8	2016	-	4	8	15	68	5	80
Aythya fuligula	+	19	5	15	42	19	1530	+	3	5	15	67	10	265
Clangula hyemalis	-	10	5	13	58	14	348	-	-	4	17	71	8	18
Melanitta nigra	4	4	2	25	65	1	308	-	-	-	13	87	-	8
Bucephala islandica	94	+	-	4	1	-	426	98	-	-	-	2	-	49
Mergus serrator	63	4	-	18	15	+	332	42	-	-	33	25	-	12
Mergus merganser	60	10	-	20	10	-	10	100	-	-	-	-	-	2

tually flooded sedge swamp. The water depth in these sedge swamps was 30 - 80 cm, and the two latter nest categories were 15 - 40 m offshore, 1 - 70 m from open water. Fig. 3 a, b shows part of this nesting area together with one of the nests. Later 5 nests were found in similar places elsewhere in the district, but with a total of 49 km nest-searching routes (by 3 - 4 persons) the nest density must have been very low. The sex-ratio and numbers of ducks on water might indicate a total of 50 - 60 incubating females in the district. According to local people the nesting in sedge vegetation is a very recent nesting habit. Is is certainly unusual in Iceland. Three previous seasons with systematic searching for grebe nests in nearly every sedge-bed in the Mývatn area did not reveal a single duck nest on a site similar to that shown on Fig. 3.

DISCUSSION

Certainly, several factors are involved in the decline of the duck populations at Mývatn and other Icelandic nesting areas — some have already been discussed briefly by Bengtson (1972) and Gudmundsson (1951).

Recent environmental changes of the Mývatn area include development of less suited vegetation for duck nesting on some islands due to reduced sheep grazing, and a rapid silting-up of the lake and consequent development of extensive and dense submergent vegetation which makes it less attractive for feeding of diving ducks (except tufted duck). Whether this is also accompanied by changes in the populations of limnic invertebrates is not known. Anyway, these changes are certainly proceeding at a very slow rate. Except in the extreme summer 1970, when the midge swarmings failed completely and caused a catastrophic food shortage for most ducks, there is little evidence of direct food competition or signs that the populations, or the breeding, should chronically be affected by food supply (Bengtson 1972 a, 1973 b, Fjeldså 1973). Judging from the ecological studies done in Mývatn so far, I am inclined to regard the present waterbird populations as being far

below the carrying capacity set by food supply.

Other changes in the Mývatn area is the great increase of tourism and activity of bird photographers and bird watchers. Together with the industrial exploitation of the diatomite deposits in the northern part of the lake, and also the consequent expansion of local settlement, this is certainly a factor of some significance. Incessant disturbance by man may be the direct cause of some displacement of nesting areas and desertion of some, indeed less important, nesting areas to the northeast and south of Mývatn. Disturbance of loafing sites during spells of bad weather may have a serious impact on the survival of young. The ducks also avoid feeding in the area where the diatomic deposits are exploited.

Many local farmers will blame bird watchers (including the present author) for searching the nesting areas about the time of egg-laying as mainly responsible for the disappearance of ducks, but certainly that is to overrate this factor. Very few non-local persons ever have access to the islands in the main basin of Mývatn, where duck nesting has declined as much as on non-marshy mainland habitats. The extensive egg-collection done by local people has diminished much. Further, there are many nesting concentrations close to farms, and here the boys will often check the duck nests almost daily, obviously without causing them to leave. The human interference is ignorable at Vikingavatn, Laxamýri and other duck localities at the coast.

Other human influences are bird kills in fishing-nets (Gardarsson 1961, Bengtson 1972 a, p. 42 - 43), which takes a considerable share, particularly of the female long-tailed ducks and scoters.

All these factors may possibly have some very long-term effects upon the duck populations, but can hardly be blamed responsible for the more drastic recent changes.

The duck populations at Mývatn show considerable and irregular yearly variations (Fig. 1, Bengtson 1972 a). The separate species fluctuate, however, individually (except maybe long-tailed duck/common scoter, and tufted duck/scaup). Annual variations in reproductive success of the ducks had no appreciable effect upon variations in the adult population in subsequent years, and there was no close correlation between average reproductive success of each species and its population trend. This makes it likely that factors outside the breeding season, viz. in the winter quarters, are involved (Bengtson 1972, p. 57). This might well be the cause of, e.g., the decline of the populations of long-tailed ducks and common scoter, which probably are much damaged by oil-pollution at sea.

The present documentation of changes in habitat selection for nesting might suggest that another factor is involved in the very recent accentuation of the decline, namely predation. Predation by arctic skuas, *Stercorarius parasiticus,* great black-backed gulls, *Larus marinus,* ravens, *Corvus corax,* and mink, *Mustela vison,* accounts for the destruction of 19% of the duck-eggs during the laying period, another 17.5% of the full-laid clutches, and maybe about 25% of the young hatched (Bengtson 1972 a). Together with the effects of a very hazardous summer climate, it causes the production of progeny to be very low. Although unlogical it might seem, this probably largest European nesting concentration of fresh-water diving ducks does not appear to be self-maintaining.

The nest predation is highest in habitats with short grassy or herbaceous vegetation, lower on shrub meadows and marshy places, and particularly low in colonies of black-headed gulls. Indeed, egg losses in gulleries seem almost to be limited to some desertation, particularly of dump-nests and yard-eggs. Egg losses are low also for nests in holes in the lava, or below dense and tall shrubbery.

The former preference for island-nesting might have evolved as a protection against predation by arctic foxes, *Alopex lagopus* (which have now disappeared from the study areas). The island nesting preference was superior to nesting-cover preference, except in the mallard, teal and scoter. Today this has changed in most species.

Dense *Angelica* vegetation, a much frequented nest-cover type on islands, gives sufficient cover against aerial predators, but the stony and rocky coasts and islets where this vegetation grows most densely is much frequented by the mink. The mink will often follow the firm shore-lines of the non-marshy coasts when hunting. They will thus have a great chance of running across those duck nests which occur concentrated in patches of lush herbage near the shore line, just inside the shore ridge of wave-exposed coasts, or on small islets with dense *Angelica* vegetation just off the coast. Many mink burrows were found along such coasts, and also on the larger islands and even some of the smaller

far off-shore isles. In these places the mink may even be a menace to hole nesting ducks: Three mink-killed Barrow females were found in their nest holes, and also mink-taken Barrow eggs were found. Also in the sixties, mink predation was the only significant cause of nesting failures in the Barrow, next to the heavy losses due to desertation on crowded places with much aggressive interference (Bengtson 1972, Tables 21, 22, 28).

Marshy areas are, on the other hand, unsuited for mink hunting. Although it frequently takes to water when hunting, the extensive, dense sedge vegetation which gives minimal view, must make the hunting very unprofitable. The marshy areas near Mývatn and Vikingavatn are completely flat. From nowhere can a small mammal get a sufficient view to spot nest sites at a distance. Unlike at non-marshy shores, the duck nests are further not concentrated along a natural line, but occur scattered. Such nests as those in the sedge marshes at Vikingavatn (Fig. 3) are certainly very safe against any predator.

Many local farmers both at Mývatn, Vikingavatn and elsewhere claim that the mink is increasing. The observation data are too few and accidental to justify any population estimate, but the frequency of mink-kills found may support that the assertion is correct. Bengtson recorded only some 10 - 20% mink-kills among the ducks found dead (Comm. in litt.). Among 21 fresh duck casualties found in 1974, 11 were mink-kills. (In Vikingavatn even a greylag female was found killed by mink on nest on an island). Also 30 elder, not too incomplete, carcasses comprised a roughly similar share of mink-kills (although exact figures are hard to give). All 51 casualties gave some 40 - 49% mink-kills.

It is not likely that direct killing of ducks and robbing of their eggs is sufficient to explain the drastic decline of the waterfowl. But once the ducks have had experiences with this predator, its mere presence might be sufficient to cause displacement of the nesting habitats, or to keep the birds from breeding. This might explain the high percentage of apparently non-breeding ducks off the non-marshy coasts. A similar suppression of breeding by the mere presence of land predators is well known, e.g. in the arctic, where eiders and long-tailed ducks desist from breeding if late breaking up of the ice gives arctic foxes access to their traditional nesting islands.

A comparison, species for species, of changes in habitat selection and population changes, fits well with the hypothesis that mink predation along non-marshy shorelines, particularly on places with lush herbage, is a main factor in the very recent acceleration of the population decline: Mallard and gadwall previously selected quite similar nesting cover (Table 2), but differed as the mallard nested more scattered, away from water, and not selecting islands particularly, the gadwall closer to water and preferring islands with herbage cover. The mallard remains constant; the gadwall has begun to decline. Teal and wigeon both prefer to nest scattered among shrub, away from water. They differ as the wigeon shows also in island-nesting tendency and often nested among *Angelica*. This might explain the recent acceleration of its population decline which contrasts against the more stable population of the teal. The pintail, selecting wide, damp mainland shrub meadows, often with gulleries, remains stable. Scaup and tufted ducks have abandoned former breeding habitats on islands and along coasts with lush herbage. However, due to preference of deeper feeding areas, the scaup may still be more attracted to those parts of the mývatn area which happens to have non-marshy coasts, and they remain off-shore without nesting. The tufted duck is more attracted to wet places with sedges and has the stronger affinity with gulleries of the two. These differences may explain why the decline of the scaup is now accelerating strongly, while the tufted duck remains more stable. The long-tailed duck appears to have abandoned island-nesting which was often close to water, among *Angelica,* but as its main habitat is in very wet shrub meadows, often in gulleries, like in the tufted duck, its rate of decline does not seem to accelerate. Also the rate of decline of the common scoter, which prefers mainland shrub meadows with some distance to water, remains unchanged. Barrow's goldeneye and the mergansers nest relatively well protected in holes and crevices (although not completely safe for the mink), and they may thus continue to maintain high island populations. Possible changes in habitat selection has, however, been mentioned for the Barrow, and the estimated number, 1426 birds, may possibly suggest that even this previously very constant population is beginning to decline.

It may be mentioned, finally, that the horned grebe, which nests in sedge vegetation in the water (mink predation only stated in very small sedge-beds near firm shores) remains

very stable. Estimated breeding numbers were 250 pairs (1958), 240 - 270 pairs (1966), 257 pairs (1969), 230 - 245 pairs (1970) (Fjeldså 1973) and 230 - 245 pairs (1974). In Vikingavatn Bengtson (in litt.) found fully 30 breeding pairs during previous counts and 33 pairs were found in 1974.

CONCLUSION AND SUGGESTIONS

The recent accentuation of the decline of waterfowl populations are due to changes in some species only, and all these changes are strongly associated with certain breeding habitats. The further successful propagation of the populations may seem dependent upon selection of marshy nesting habitats, particularly isles with protective gulleries surrounded by flooded sedge meadows. The changes in habitat selection suggest strongly that predation is involved as a main cause of displacement of nesting areas, desisting from breeding and the consequent accentuation of the decline. The evidence indicates that the mink may in this respect be the most serious predator.

For management of these waterfowl populations serious attempts to control the mink population would therefore seem advisable. A thorough evaluation of possible changes of population numbers and ecology throughout the year of larger seagulls and ravens in Iceland, in connection with recent changes of land-use, fisheries and disposal of vastes near growing human settlements, and attempts to control also their populations, would also seem advisable. Means to protect the waterfowl against human influence should possibly focuse upon protection of places with colonies of black-headed gulls. Fortunately, this species does not seem to decline in Mývatn, and human influence, e.g., by egg-collection appears to be slight (Fjeldså 1975).

ACKNOWLEDGEMENTS

My sincerest acknowledgements are due to stud.real. Jan Erling Wasmuth and stud.real. Stein Skogstad (University of Tromsø, Norway0 for assistance during the field work. The work was supported financially by the Nordic Council for Terrestrial Ecology, and with part of the equipment from the Zoological Museum, University of Copenhagen. My thanks are also due to dr. Finnur Gudmundsson for pleasant discussion, and to dr. Arnthor Gardarsson and dr. Sven Axel Bengtson for informations and comments (in litt.).

SUMMARY

During a study of the egg-laying of waterfowl in Iceland in May/June 1974 the author censused the populations in the lakes Mývatn and Vikingavatn. Bengtson (1972 a) has documented a current decrease of the breeding populations in the very productive Lake Mývatn. They declined from nearly 50.000 spec. about 1961 to fully 30.000 spec. in 1970. The 1974 figure was about 15.500 spec. The deteriorated situation is largely due to a catastrophic decline of the scaup, wigeon and gadwall. Also long-tailed ducks and common scoters have declined much, but the rate does not seem to accelerate. Table 1 gives a status of the 1974 population, showing also the percentual species composition in different main habitats. Fig. 1 shows population curves for 10 duck species from 1961 to 1974. The decline in the smaller lake Vikingavatn was similar.

The vegetation cover at 546 nest-sites in Mývatn in 1974 was compared with Bengtson's (1970) results for 6674 nests and earlier experience from the area by the present author (973 nests).

It appears that former nesting habitats on meadows and among herbage on drier terrain and the islands in Lake Mývatn had been nearly deserted. Breeding ducks remained mainly among low scrub in marshy areas, particularly in colonies of black-headed gulls surrounded by flooded sedge marsh. Tufted duck and long-tailed duck showed the greatest affinity to gulleries. The teal nested very independently of gulls, while Barrow's goldeneye and mergansers preferred cavities in the lava, or below tall scrubbery away from gulleries. The non-breeding frequency appeared very high among scaups and Barrow's.

In Vikingavatn the former nesting grounds on the islands (Fig. 2) had been abandoned, and the remaining duck nests were in extensive sedge marshes. Many of them were in temporarily flooded places (Fig. 3).

The population decline may have several causes which are discussed briefly. The very recent accentuation seems, however, to be due to predation of eggs and in particular the apparently increasing population of mink. Displacement of nesting areas were away from the habitats most frequented by mink. And the population decline affects chiefly those duck species which preferred these habitats for nesting (drier, in part stony, coasts and islands with grasses and lush herbage along the shore-line), and which had not managed to shift over to marshy places.

DANSK RESUME

Nye ændringer i andefuglebestandene i søerne Mývatn og Vikingavatn, Island.
I forbindelse med en undersøgelse over æglægningen hos andefugle i Island i maj - juni 1974 udførtes optællinger af andebe-

standene i søerne Mývatn og Vikingavatn. I den meget produktive sø Mývatn har Bengtson (1972 a) påvist en jævn nedgang i ynglebestandene, fra nær 50.000 eks. omkring 1961 til godt og vel 30.000 eks. i 1970. Antallet i 1974 var ca. 15.500 eks., og den forværrede situation manifesterede sig navnlig i en voldsom nedgang af Bjergand, Pibeand og Knarand. Også Havlit og Sortand er gået meget tilbage, dog uden at nedgangen synes at accellerere. Tabel 1 viser status for bestandene i 1974, med den procentvise artsfordeling i forskellige habitater. Fig. 1 viser bestandskurver for 10 andearter fra 1961 til 1974. Den mindre sø Vikingavatn viste tilsvarende forhold.

Redehabitaterne for 546 andereder i Mývatn 1974 blev sammenlignet med Bengtsons (1970) resultater for 6674 reder. Det viser sig, at tidligere redehabitater på græsmarker og i urtevegetation i de mere tørre terræntyper og på øerne i Mývatn nærmest er forladt. De fleste ynglende ænder findes nu tilbage i lavt krat i sumpområderne, navnlig i hættemågekolonier omgivet af oversvømmede sivområder. Den stærkeste præference for hættemågekolonier viste Troldand og Havlit. Krikanden yngler meget uafhængig af mågekolonier, og Islandsk Hvinand og Skalleslugere foretrak huler i lavaen eller under krat i helt andre områder end ved mågekolonierne. Det synes som om mange Bjergænder og Islandske Hvinænder ikke yngler.

I Vikingavatn var de tidligere redeområder på øerne (Fig. 2) helt forladt, og de tilbageblevne ænder ynglede ude i de store sivområder, hvor de tildels byggede flydende reder (Fig. 3).

Bestandsnedgangen har uden tvivl flere årsager, som kort diskuteres. Den allernyeste forværring af situationen synes dog at hænge sammen med æg-prædation og navnlig med en formentlig tiltagende bestand af mink. Forflytningen af yngleområderne sker netop bort fra de terræntyper, minken synes at foretrække. Bestandsnedgangen rammer navnlig de arter, som foretrak disse terræntyper (tørre, delvis stenede kyster og øer med græs og rig urtevegetation langs vandet), og som ikke i tilstrækkelig grad har kunnet skifte over til de sumpede lokaliteter.

LITERATURE

Bengtson, S.-A. 1970: Location of nest-sites of ducks in Lake Mývatn, northeast Iceland. – Oikos 21, 218 - 229.

Bengtson, S.-A. 1971: Habitat selection of duck broods in Lake Mývatn area, northeast Iceland. – Ornis Scand. 2, 17 - 26.

Bengtson, S.-A. 1972 a: Reproduction and fluctuations in the size of duck populations at Lake Mývatn, Iceland. – Oikos 23, 35 - 58.

Bengtson, S.-A. 1972 b: Food and feeding of diving ducks breeding at Lake Mývatn, Iceland. – Ornis Fenn. 48, 77 - 92.

Fjeldså, J. 1973: Territory and the regulation of population density and recruitment in the horned grebe *Podiceps auritus arcticus*, Boje 1822. – Vid. Meddr. Dansk Nat.hist. Foren. 136, 117 - 189.

Fjeldså, J. 1975: En taksering af Hættemåge *Larus ridibundus* og Havterne *Sterna paradisaea* i Mývatn-området, nordøst - Island. – Dansk orn. Foren. Tidsskr. 69, 65 - 72.

Gardarsson, A. 1961: Fugladaudi av völdum netja i Mývatni. – Náttúrufrædingnum 31, 145 - 168.

Gudmundsson, F. 1951: The effects of the recent climatic changes on the birdlife of Iceland. – Proc. Xth Int. Orn. Congr., Uppsala, 502 - 514.

Lindegård, C. & P. Jónasson, in press: Life cycles of *Chironomus hyperboreus* Staegerland and *Tanytarsus gracilentus* (Holmgren) (Chironomidae, Diptera) in Lake Mývatn, northern Iceland.

Steffánsson, U. 1971: Fáeinir athuganir á efnafrædi Mývatns sumarid 1969. – Náturufrædingnum 40, 187 - 196.

MS received 3rd March 1975

Author's address:
Zoological Museum,
University of Copenhagen,
Universitetsparken 15,
DK - 2100 Copenhagen Ø.