Oikos 29: 336–341. Copenhagen 1977

Severe eggshell defects and impaired reproductive capacity in small passerines in Swedish Lapland

N. E. I. Nyholm
H. E. Myhrberg

Department of Zoology, University of Lund

Nyholm, N. E. I. and Myhrberg, H. E. 1977. Severe eggshell defects and impaired reproductive capacity in small passerines in Swedish Lapland. – Oikos 29: 336–341.

The breeding biology of the Pied Flycatcher *Ficedula hypoleuca* Pallas was studied, 1965–76, in a subalpine woodland on a mountain in the Ammarnäs area, Swedish Lapland. In nestboxes placed near the shore of Lake Tjulträsk, the reproductive capacity was significantly decreased as compared with that in nestboxes more distant from the lake. The eggshell quality, clutch size, hatching success, incubation, and the health of the breeding birds were highly impaired in the vicinity of the shore. It was shown that deficient breeding in the Pied flycatcher also occurred at another lake in the Ammarnäs area, indicating that the breeding deficiencies were an expression of a general "lake-effekt" in the area. Similar impaired breeding was observed in three other small passerine birds species. Bluethroat *Luscinia svecica* L., Reed Bunting *Emberiza schoeniclus* (L.) and Willow Warbler *Phylloscopus trochilus* (L.) breeding near Lake Tjulträsk.

The symptomes indicate that the affected birds were poisoned.

N. E. I. Nyholm and H. E. Myhrberg, Dept of Zoology, Helgonavägen 3, S-223 62 Lund, Sweden.

Исследовали биологию размножения *Ficedula hypoleuca* Pallas в 1965–1976 гг в субальпийских лесах в горах района Аммарнес (Шведская Лапландия). В гнездовых ящиках, расположенных у берегов озера чьюлтреск, способность к размножению значительно ниже в сравнении с более удаленными от озера участками. Качество яйцевой скорлупы, величина выводка, вылупление, инкубация и состояние вылупившихся птенцов было намного хуже вблизи берега. Показано, что недостаточное размножение *F. hypoleuca* наблюдалось и у другого озера в районе Аммарнес, что говорит о том, что это – результат общего »озерного эффекта« на данной территории. Сходное ослабление размножения наблюдалось у трех других мелких видов воробьиных *Luscinia svecica* L., *Emberiza schoeniclus* (L.) и *Phylloscopus svecica* L., размножающихся у озера чьюлтреск. Некоторые признаки указывают на то, что птицы, подверженные влиянию этого »озерного эффекта«, были отравлены.

Accepted 8 June 1977

1. Introduction

In 1965–1976 the breeding biology of a nestbox population of the Pied Flycatcher *Ficedula hypoleuca* Pallas was studied in a subalpine birch woodland on the southern slope of a mountain in the Ammarnäs area, Swedish Lapland (65° 58′N, 16° 13′ E). Every year a large proportion of the flycatchers which bred in the vicinity of Lake Tjulträsk showed severe breeding disturbancies which were manifested by among other things, the laying of eggs with defective shells. These findings prompted us to investigate the occurrence, character and extent of breeding defects in the Pied Flycatcher, Bluethroat *Luscinia svecica* L., Reed Bunting *Emberiza schoeniclus* (L.) and Willow Warbler *Phylloscopus trochilus* (L.), all abundant in the Ammarnäs area (Enemar and Sjöstrand 1970). This paper reports the first results of that investigation. Various chemical analyses are in progress to reveal the cause of the above breeding disturbancies.

2. Material and methods

This report is based on 888 Pied Flycatcher broods in about 200 nestboxes in 1965 to 1976; 10 Bluethroat broods, 10 Reed Bunting broods and 8 Willow Warbler broods in 1976.

The Pied Flycatchers were studied in nestboxes, which were placed in groups in different parts of the woodland. One group extended along the shore of Lake Tjulträsk (530 m. a.s.l.). In that group (Fig. 1) the nestboxes were placed in rows roughly parallel to the shore, the nearest of them 25–40 m from the shore (Nestbox category I) and the others about 50 to 120 m from the shore (Nestbox category II). A further group of nestboxes was placed 3–4 km from the lake (Nestbox category III).

The progress of the breeding of the other three species, in a zone about 50 m broad along the shore of Lake Tjulträsk, was compared with that in an area about one kilometer from the shore.

The breeding was followed in detail. Thus, the dates of laying, clutch size, eggweights before and during the incubation, and hatching success were some of the variables recorded.

The ultrastructure of the eggshells was studied in a Cambridge Stereoscan (Mark II:A). Becking's (1975) nomenclature was used for describing the crystalline zones observable in the radially fractionized eggshells.

3. Observations

3.1. Ficedula hypoleuca

Eggshells. Defective egsshells were found every year in 30–40% of the Pied Flycatcher clutches in the narrow zone along the shore of Lake Tjulträsk where nestboxes Category I had been placed. In 1965 to 1976 eggshell defects were observed in all nestboxes except one in that zone, but not in the other nestboxes, though the nearest of them were placed only 25 m more distant from the shore (Fig. 1).

In most cases only one or a few of the eggs in a clutch had a defective shell. These eggs were always the one(s) laid last.

The affected eggshells were characterized by an abnormal porosity, which often caused a softening of the shell. Usually the shell was unevenly affected, the pointed end of the egg being the most defective part (Fig. 2). In more severely affected eggs the entire shell was soft, and in extreme cases hard shell constituents were totally lacking so that the egg was held together only by the shell membranes.

Ultrastructural studies of the normal Pied Flycatcher eggs revealed that the outer shell surface was smooth and compact (Fig. 3). The radially fractionized normal eggshell showed the typical zonation of the calcite columns, with a zone of cones, a palisade layer, and a surface crystalline layer (Fig. 4).

The ultrastructure of the defective eggshells varied. The "soft" eggshell, e.g. that of the pointed end of the egg shown in Fig. 2, was characterized by incomplete formation of the calcite columns. These columns were conic and therefore gave the shell a rough surface (Fig. 5). The softness of the shells was due to the columns remaining unconnected to one another, and to the occurrence of areas in which no calcite crystallization had occurred (Fig. 6).

Clutch size. The data on the clutch size and the hatching success of the Pied Flycatcher are given in Tab. 1. Different categories of clutches are represented: A.-Clutches which were hatched; B.-Clutches which

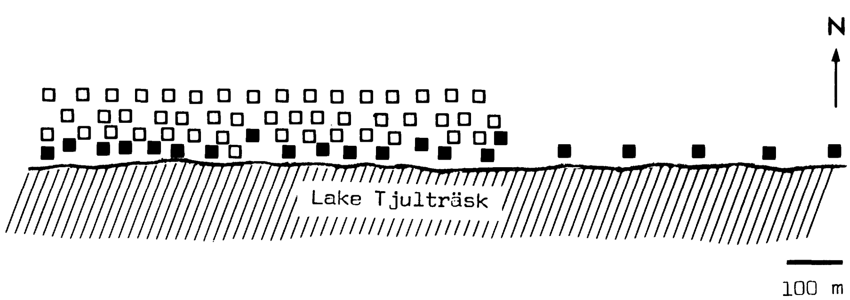


Fig. 1. Schematic drawing of the nestbox group which is placed along Lake Tjulträsk. The filled squares represent nestboxes in which defective eggshells were found in 1965–1976.

Tab. 1. Clutch size and hatching success in the Pied Flycatcher *Ficedula hypoleuca*, 1965–1976.

		Clutches with normal eggshells only			Clutches with defect shells
		Ia[x]	II[x]	III[x]	Ib[x]
A	Size of the clutches which were incubated until hatched	4.9 ± 0.19 (47)[y]	5.3 ± 0.07 (198)	5.6 ± 0.04 (417)	4.0 ± 0.37 (9)
B	Size of clutches which were incubated but abandoned before hatched	3.8 ± 0.29 (23)	4.9 ± 0.25 (30)	5.4 ± 0.13 (47)	3.7 ± 0.26 (27)
C	Size of clutches which were abandoned before incubation	2.3 ± 0.34 (24)	2.4 ± 0.24 (27)	3.3 ± 0.32 (22)	2.2 ± 0.29 (17)
D	Hatching success	77.9% (201)[z]	86.5% (965)	91.1% (2212)	55.6% (36)

[x] Ia and Ib Clutches in the nestboxes of the row nearest the shore of Lake St. Tjulträsk, 25–40 m from the shore.
II Clutches in nestboxes placed 50–120 m from the shore.
III Clutches in a nestbox group 3–4 km from the lake.
The densities of the breeding populations of Pied Flycatcher were similar in the various nestbox groups.
[y] Mean clutch size ± s.e. (number of clutches).
[z] Percentage of eggs that hatched, in the clutches Category A. (total number of eggs).

Statistical calculations: A–C, Student's t-test; D, according to Sokal and Rohlf (1968).

A Ia –A Ib	$p = 0.05$	B Ia–B II	$p < 0.01$	D Ia–D Ib	$p < 0.01$
–A II	$p < 0.05$	–B III	$p < 0.001$	–D II	$p < 0.01$
–A III	$p < 0.001$	B Ib–B II	$p < 0.01$	–D III	$p < 0.001$
A Ib –A II	$p < 0.001$	B II –B III	$p < 0.05$	D II–D III	$p < 0.001$
A II –A III	$p < 0.001$	C Ia–C III	$p = 0.05$		
A Ia –B Ia	$p < 0.01$	C Ib–C III	$p < 0.05$		
A Ib –B Ib	n.s.	C II–C III	$p < 0.05$		
A II –B II	$p = 0.05$				
A III–B III	$p < 0.05$				

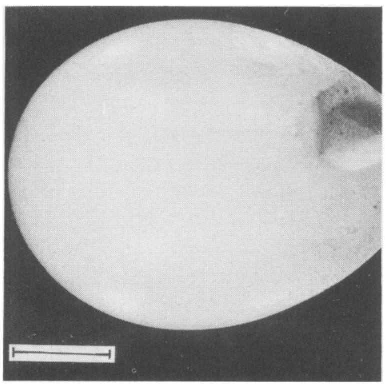


Fig. 2. Egg of Pied Flycatcher. The pointed end is seriously affected – "soft shelled".

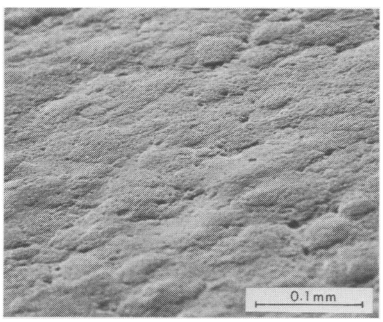


Fig. 3. The normal structure of the surface of a Pied Flycatcher egg. The surface is smooth and compact.

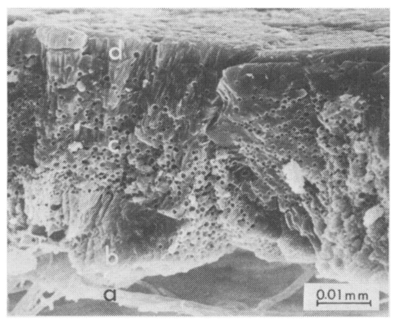


Fig. 4. Radially fractioned normal Pied Flycatcher egg. a. Eggshell membrane; b. Zone of cones; c. Palisade layer; d. Surface crystalline layer.

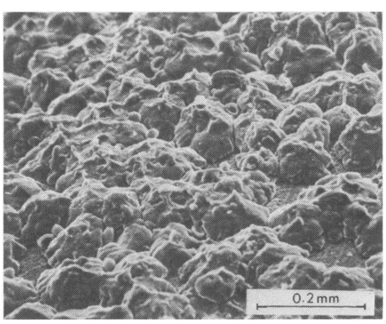


Fig. 5. Ultrastructure of the surface of a "soft" Pied Flycatcher eggshell. The calcite columns are malformed and conic. In several areas which lack calcite the shell membrane is bare.

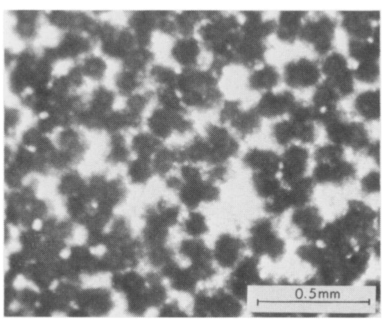
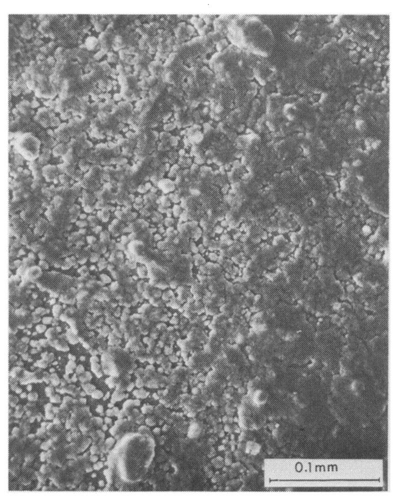


Fig. 6. "Soft" Pied Flycatcher eggshell which is illuminated from below. Several light areas show sites with no calcite columns.

Fig. 7. Defective Bluethroat eggshell. Detailed view, see Fig. 8.



were incubated, but abandoned before being hatched; C.-Clutches which were abandoned before incubation. The categories Ia, II and III represent clutches with normal eggs in nestboxes at different distancies from the Lake. In Ib the clutches contained eggs with defective shells, all in the nestboxes nearest the Lake.

The clutches category A were largest in the nestboxes of category III. In the nestboxes of the categories I and II the sizes of the clutches were significantly smaller, and smallest in category I (Tab. 1). Moreover, clutches with shell defects (A Ib) were significantly smaller than clutches without shell defects in the same nestbox category (A Ia).

The sizes of the clutches in which incubation was discontinued before hatching (B) were smaller than in the broods that hatched (A), except for the clutches with defect eggshells (Ib).

The sizes of the clutches which were abandoned before incubation were similar in the nestboxes of the categories I and II, but larger in the category III.

Hatchability. The hatchability of the eggs was lowest in those clutches with defect eggshells (D Ib, Tab. 1). In the clutches without shell defects the hatching success was significantly higher. Within that category the hatchability varied strongly, being the lowest in the zone nearest the shore (Ia), intermediate in the nestboxes Category II, and highest in Category III.

Abandonment of clutches. Category I differed significantly from II and III (Tab. 2). In category I, moreover, the clutches which contained eggs with a defective shell (Ib) were abandoned more frequently than those without such defects (Ia). Only 17% of the Ib-clutches were incubated until they had hatched.

Tab. 2. Frequencies of abandoned clutches in the Pied Flycatcher *Ficedula hypoleuca*, 1965–1976.

	Nestbox category[x] Ia	Ib	II	III
Abandoned clutches (%)	50	83	22	14
(n)	(94)	(53)	(255)	(486)

Statistical calculations (According to Sokal and Rohlf 1968)

Ib–Ia	$p < 0.001$
Ia–II	$p < 0.001$
II–III	$p < 0.01$

[x] See Tab. 1.

Breedings at another lake in the Ammarnäs area. Pied Flycatcher broods were studied 1975 and 1976 also in nestboxes placed along Lake Bissajaure (570 m a.s.l.), 12 km east of Lake Tjulträsk.

Similarly impaired reproductive capacity and eggshell defects were observed in the nestboxes at Lake Bissajaure. Thus, 37% (11 out of 30) of the clutches in nestboxes 10–50 m from the shore contained eggs with defective shells. Also one clutch out of 16 in the nestboxes 50–75 m from the shore contained defective eggs.

3.2. Luscinia svecica

Eggs with defective shells were found in one Bluethroat nest out of six investigated, in the 50 m zone bordering Lake Tjulträsk.

Ultrastructural examination revealed serious defects in the surface crystalline layer in that half of the egg which formed the pointed end. There isolated crystals covered only part of the underlaying crystalline layer (Figs 7 and 8).

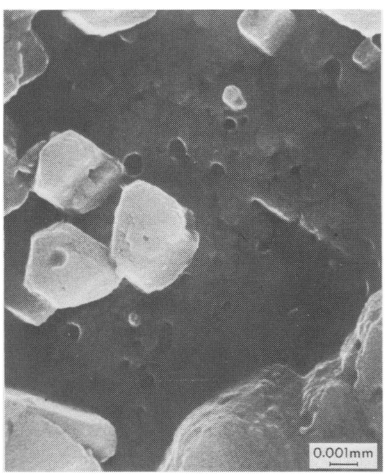


Fig. 8. Detail of the defect Bluethroat eggshell shown on Fig. 7. Isolated crystals of the surface layer only partly cover the underlying layer.

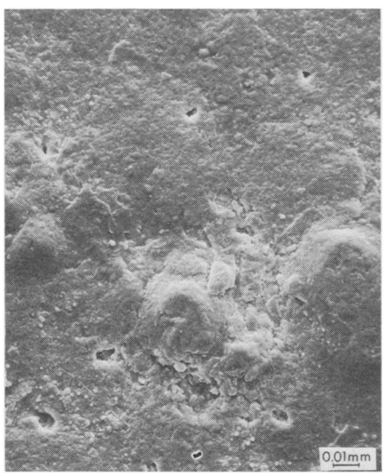


Fig. 9. Defect Reed Bunting eggshell. Several enlarged pores open on to the surface.

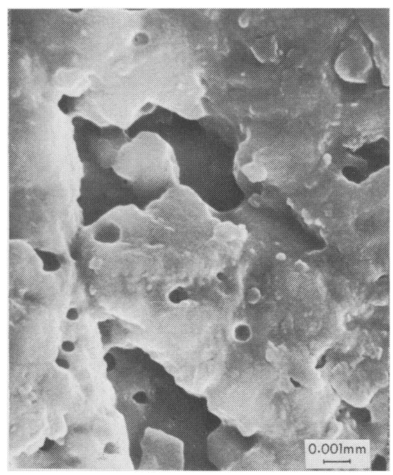


Fig. 10. Detail of the surface of a defective Reed Bunting eggshell. The surface crystalline layer is seriously affected.

Besides these rather superficial defects the eggshell obviously also showed more serious defects, which were manifested by an increased weight loss of the eggs and drying up of the yolk and white during incubation.

All of the eggs of the Bluethroats which nested in the area about 1 km from the lake had normal shells.

The clutch sizes were smaller and the hatching success less good in the vicinity of the lake (Tab. 3), and the clutch which contained the defective eggshells was the smallest.

3.3. Emberiza schoeniclus

Structural deficiencies in shells of the Reed Bunting were noted in one nest out of six investigated along Lake Tjulträsk. The pattern of the defects resembled that seen in the Bluethroat, i.e. limited mainly to the surface crystalline layer (Fig. 9). Like the eggs of the Bluethroat, they showed an increased weight loss or drying up of their contents during incubation, probably as a result of increased evaporation through enlarged pores (Fig. 10).

The mean clutch size was similar in the vicinity of Lake Tjulträsk and in the area about 1 km from the Lake (Tab. 3), but the hatching success was decreased near the shore. As in the Bluethroat the defective eggshells were found in the smallest clutch.

3.4. Phylloscopus trochilus

In contrast with the above mentioned species, the eggshells of the Willow Warbler were invariably smooth and compact. That the shells were intact was also indicated by normal rate of weight loss during incubation. However, while the pigmentation of the eggs was considered normal in the nests found in the area about 1 km from the Lake Tjulträsk (Fig. 11), that of the eggs in the vicinity of the lake was invariably (18 eggs in 4 nests) distinctly abnormal, with less or even total lack of pigmented spots (Figs 12 and 13).

In the nests near the shore the mean clutch size and the hatching success were decreased (Tab. 3).

Tab. 3. Clutch size and hatching success in Bluethroat *Luscinia svecica*, Reed Bunting *Emberiza schoeniclus* and Willow Warbler *Phylloscopus trochilus* in nests at different distancies from Lake Tjulträsk, 1976.

	Clutch size			Portion of eggs hatched	
	Mean	Range	n	%	n[xx]
Bluethroat					
Along the shore	5.2	3–7	6	64.5	31
About 1 km from the lake	6.0	6	4	95.8	24
Reed Bunting					
Along the shore	5.2	4–6	7[x]	64.5	31
About 1 km from the lake	5.0	5	3	100	15
Willow warbler					
Along the shore	4.5	3–6	4[x]	33.3	13
About 1 km from the lake	5.8	5–6	4[x]	94.1	17

[x] One of the nests was robbed.

[xx] Total number of eggs.

4. Discussion

In three of the species studied, Pied Flycatcher, Bluethroat and Reed Bunting, the deficient crystalline layers of the eggshells showed that shell formation was impaired. The contents of the eggs with this defect withered during incubation.

Every year from 1965 to 1976 a high proportion of the eggshells of the Pied Flycatcher were partly or totally "soft'. The softness was due to incomplete formationof the calcite columns which therefore remained unconnected to one another, and to the occurrence of areas in which no calcite crystallization had occurred. As the areas, in which the shell membrane was bare, often corresponded in size to those covered by the individual calcite columns (Fig. 6), they were probably the sites where functional centres of crystallization (mammillary cores) had failed to develop.

In the Pied Flycatcher (the only species in which the order of laying was determined) the defective eggs were always those laid last, and the pointed end was the part affected most. This suggests a successive reduction of the shell-forming capacity during the laying. The

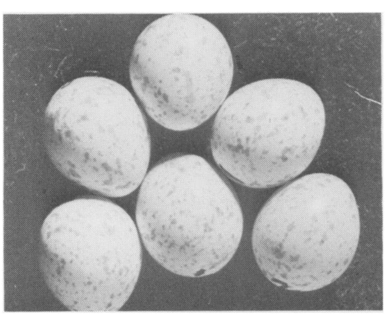
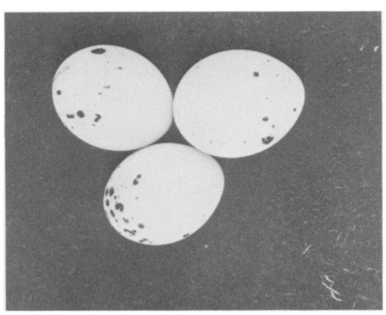
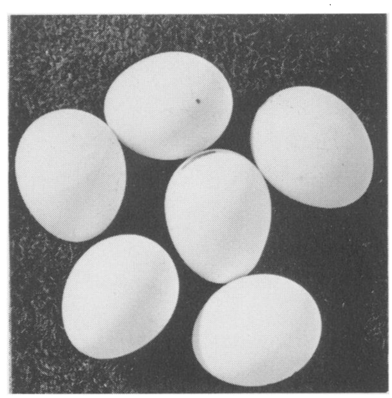


Fig. 11. Clutch of normally pigmented Willow Warbler eggs.





Figs. 12–13. Clutches of distinctly abnormally pigmented Willow Warbler eggs.

affected mineralization of the eggs might reflect failing formation of functional mammillary cores (see above), or a deficient supply of eggshell material, or both, in the isthmus and in the shell gland of the egg channel, respectively. The occurrence of defective eggshells was combined with a reduced clutch size. This was indicated in the only clutch with defective shells of the Bluethroat and Reed Bunting, but was well established in the Willow Warbler and Pied Flycatcher. Thus, in the latter species, the sizes of the complete clutches with shell defects (Categories A Ib and B Ib, Tab. 1) were significantly smaller than the complete clutches without shell defects in the same nestbox category (A Ia and B Ia). The sizes of the clutches without shell defects increased with the distance from the Lake Tjulträsk (except in the Reed Bunting). In the Pied Flycatcher the sizes of complete clutches in the nestbox categories were: III > II > Ia ($p < 0.001$ and $P < 0.05$, respectively; Tab. 1).

The hatching success was reduced in all four species in the zone bordering the Lake. In the Pied Flycatcher, it showed the pattern identical to that of the clutch size, i.e. Category III > II > Ia > Ib. An identical pattern was also shown by the Pied Flycatcher concerning the frequency of abandonment.

The concordance of the patterns of deficiencies found at different phases of the breeding of the four small passerine bird species, makes it likely that they were due to a common factor(s). Besides possible specific effects upon the shell-forming process this factor(s) might have impaired the general condition of the birds affected. Such a possibility is strengthened by the fact that 7 (58%) adult Pied Flycatchers (6 females and 1 male) out of 12, which were found dead in their nests, bred in nestboxes which were in the zone nearest the shore (Category I) and which contained only about 5% of the total number of the Pied Flycatcher broods studied.

Abnormal eggshell formation has been observed in the field in several raptors and fisheating birds contaminated with organochlorine insecticides, PCB:s or various metallic pollutants in Europe and North America (Cooke 1973). Usually these eggs were thin-shelled. Only a few reports of "soft" shells have been published, e.g. in pelicans (Keith et al. 1970, Risebroough et al. 1971). Hickey and Anderson (1968) found decreased eggshell thickness to be combined with decreased clutch size and high embryonic mortality in Herring Gull (*Larus argentatus*), whose eggs were contaminated with DDE.

The above data concerning the breeding conditions of the four passerines show that the severe reduction of their reproductive capacity was distinctly related to the distance of their nests from the Lake Tjulträsk. The similar breeding impairment, which was recognized in Pied Flycatchers at Lake Bissajaure, indicates that the negative influence upon reproduction is a general "lake-effect" in the Ammarnäs area.

This effect was certainly not due to lack of food near the lakes. Actually, the food supply along the shore was probably more abundant than elsewhere in the forest in the beginning of the breeding season, when there are still a lot of snow patches in the forest, and the lakes are largely covered by ice. Insects (mainly Plecoptera) from the ice-free shore region of the lake swarm, and at least in those parts of the forest close to the shore these insects, together with spiders, constitute a significant part of the food of the small insectivorous passerines studied.

The symptomes described strongly indicate that the birds breeding in the vicinity of the lakes were poisoned, possibly via the limnic insects. Analyses for the detection of possible toxic substancies are in progress.

The findings in the present study are alarming since they clearly show impairment of reproductive capacity in naturally breeding small passerines in the wilderness of the Scandinavian mountain area, which is regarded as the "cleanest" part of Europe.

Acknowledgements – We are indebted to several of our colleagues for valuable support in the field work and to Mr J. Brown for correcting the English. The work was supported by grants from the Swedish Natural Science Research Council (2180–021, to A. Enemar) and National (Swedish) Environmental Protection Board (7–90/76).

References

Becking, J. H. 1975. The ultrastructure of the avian eggshell. – Ibis 117: 143–151.

Cooke, A. S. 1973. Shell thinning in avian eggs by environmental pollutants. – Environ. Pollut. 4: 85–152.

Enemar, A. and Sjöstrand, B. 1970. Bird species densities derived from study area investigations and line transects. – Bull. Ecol. Res. Comm. No 9, Lund: 33–37.

Hickey, J. J. and Anderson, D. W. 1968. Chlorinated hydrocarbons and eggshell changes in raptorial and fish-eating birds. – Science 162: 271–273.

Keith, J. O., Woods, L. A. and Hunt, E. G. 1970. Reproductive failure in brown pelicans on the Pacific coast. – Trans. N. Amer. Wildl. Conf. 35: 56–64.

Riseborough, R. W., Sibley, F. C. and Kirven, M. N. 1971. Reproductive failure of the brown pelican on Anacapa Island in 1969. – Am. Birds 25: 8–9.

Sokal, R. R. and Rohlf, S. J. 1969. Biometry – Freeman, San Francisco.