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Influence of the lake shore on the reproduction of the pied flycatcher Ficedula hypoleuca, and the redstart Phoenicurus phoenicurus in Finnish Lapland

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The study is based on material collected at Kilpisjärvi (63°03'N, 20°50'E) in 1966—1981. *F. hypoleuca* colonized the area in the 1950s, whereas *Ph. phoenicurus* is indigenous. The study area was divided into two sub-areas, 20—150 m and 200—650 m from the shore, respectively. *F. hypoleuca* began to lay about 2 days later near the shore of Lake Kilpisjärvi than further away, and due to the 'calendar effect' its clutch size was smaller near the shore. Laying advanced about 0.5 days/100 m increase in distance away from the lake. Significantly more eggs failed to hatch far from the shore than near it but nestlings did equally well in both sub-areas. *Ph. phoenicurus* was relatively insensitive to the effects of the shore. It started to lay in relatively cold weather and at the same time in both sub-areas. Its hatching success was good near the shore, and it produced equally many fledglings in both sub-areas. In both sub-areas the total nesting success (%) was better in *Ph. phoenicurus* than in *F. hypoleuca.* A good food supply was perhaps one reason for the successful hatching of the species near the shore. In a Swedish study, the nesting success of several passerines (e.g. *F. hypoleuca*) was found to be highly impaired near the shores of Lake Tjulträsk, further south in Swedish Lapland, probably due to poisoning. Results presented from Kilpisjärvi indicate that pollutants have not yet reached northernmost Lapland on a large scale. The effects of low temperature on the breeding performance of *F. hypoleuca* is discussed.

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1. Introduction

From climatological and phytogeographical investigations we know that large bodies of water tend to retard the advancement of spring. In Alaska, for instance, summer temperatures on the coastal tundra are several degrees lower than those inland, as a result of the combined effect of the cold sea surface and stratus cloud cover (Barry et al. 1981).

During my ornithological field work at Kilpisjärvi, NW Finnish Lapland, in 1973—1981 I noticed that mountain birches started to leaf later near the shore of Lake Kilpisjärvi than further away, apparently mainly due to the cooling effect of melting ice and cold water. Therefore, I tested whether the proximity of the shore also retarded the breeding schedule of birds and whether it had other effects on their reproduction.

The species studied were the pied flycatcher *Ficedula hypoleuca* and the redstart *Phoenicurus phoenicurus.* The former colonized the Kilpisjärvi area fron the south in the 1950s, and the latter is indigenous to the mountain birch woodland of Lapland. Thus, this paper also examines possible differences in the capacity of these two hole-nesting passerines to adapt to northern conditions.

2. Study area

The study area was a mountain birch wood (about 69°03'N, 20°50'E) between the shore of Lake Kilpisjärvi (473 m above sea level) and the tree-line (600 m; for further details, see A. Järvinen 1980). Lake Kilpisjärvi is relatively large (about 37 km^2) and in 1973—1981 its ice cover broke up completely on June 17 ± 3 days (SD; own observations).

The road that runs through the study area divided the nests into two convenient groups: A) 20—150 m and B) 200—650 m from the shore. The altitude above sea level was about 480±2 m (SD) in sub-area A and about 530±30 m in sub-area B. The material was collected in 1966—1981. All the nests were in nest-boxes. In sub-area A there were about 64 boxes and in sub-area B about 65 boxes each year. The nest-box density in sub-area A was greater than in sub-area B. There were more nest-boxes with large (45 mm), and less nest-boxes with small

(30 mm) entrance holes (preferred by *Ph. phoenicurus* and *F. hypoleuca*, respectively), in sub-area B than in sub-area A.

3. Results

3.1. Ficedula hypoleuca

The results are summarized in Table 1. Near the shore, laying started about 1.8 days later than further away (t=2.82, P<0.005), which explains the smaller average clutch size near the shore (observed clutch size 5.49, predicted clutch size according to the 'calendar theory' 5.50; see v. Haartman 1967, A. Järvinen & Lindén 1980). In the whole material (n=352), laying advanced about 0.5 days/100 m increase in distance from the lake (r=—0.20, P<0.001). As the season progressed, clutch size declined in the same way in both sub-areas (x=1=1 June):

y(near)=—0.077x+6.54; r=—0.483, P<0.001
y(far)=—0.085x+6.66; r=—0.523 P<0.001

The cooling effect of the lake apparently attenuated further away from the shore: the slope of the regression line clutch size/ distance was 0.0021 near (20—150 m) the shore vs. 0.0007 far (200—650 m) from it. However, a logarithmic curve fitted to all data points (n=352) did not give a close fit, although the correlation coefficient was statistically significant:

y=0.124 ln$x$+4.923; r=0.12, P<0.05

Significantly more eggs failed to hatch far from the shore than near it: the ratios of unhatched to hatched eggs were 1:4.2 and 1:7.0, respectively (X^2=15.21, P<0.001). In both sub-areas, however, nestlings did equally well: the ratios of dead to fledged young were 1:4.2 and 1:4.1, respectively (X^2=0.05, P<0.80).

3.2. Phoenicurus phoenicurus

Due to the great number of nest-boxes with large entrance holes, about two thirds of the pairs nested in sub-area B. The laying date of *Ph. phoenicurus* was relatively insensitive to the effects of the shore: in both sub-areas laying started, on average, on the same day (Table 1). The average clutch size near the shore, though smaller, was therefore not related to the date.

The slope of the regression line clutch size/laying date (n=98) was not as steep as that for *F. hypoleuca:*

y=—0.046x+6.89; r=—0.396, P<0.001

Table 1. Date of laying, clutch size and number of hatched and fledged young of *F. hypoleuca* and *Ph. phoenicurus* in relation to distance from the lake shore (±*SD*, number of nests in parentheses). Kilpisjärvi 1966—1981.

Distance	Date of laying (June)	Clutch size	Hatched	Fledged
F. hypoleuca				
A) 93± 28 m (232)	13.7±5.8	5.49±0.93	4.80±1.50	3.85±2.13
B) 417±147 m (120)	11.9±4.9	5.64±0.81	4.56±1.78	3.68±2.22
Ph. phoenicurus				
A) 61± 27 m (22)	7.0±6.6	6.45±0.81	5.95±1.64	5.45±2.01
B) 389±153 m (50)	6.8±6.6	6.69±0.73	5.55±1.93	5.48±1.89

The clutch size of *Ph. phoenicurus* is generally not as closely correlated to the date as in *F. hypoleuca* (A. Järvinen, unpubl.).

As in *F. hypoleuca*, hatching success far from the shore was poorer than near the shore: the ratios of unhatched to hatched eggs were 1:4.9 and 1:11.9, respectively (X^2=6.34, P<0.012). On the other hand, fledging success far from the shore was superior to that near the shore: the ratios of dead to fledged young were 1:76.7 and 1:10.9, respectively (Fisher exact probability test, P=0.0014). Thus, in both sub-areas *Ph. phoenicurus* produced equally many fledglings, whereas *F. hypoleuca* produced slightly, though not significantly (t=0.69, P<0.50), more fledglings/nest near the shore (Table 1).

4. Discussion

The altitude above sea level (mean 480±2 m in sub-area A, and 530± 30 m in sub-area B) had no visible negative effects on the breeding performance of *F. hypoleuca* and *Ph. phoenicurus* populations at Kilpisjärvi. On the west coast of North America, for instance, the season is retarded by about four days for each 100—125 metres of increase in altitude (the 'bioclimatic law' of Hopkins 1938). Nest-box studies in Fennoscandia (Meidell 1961) and Central Europe (Zang 1980) demonstrated that laying of *F. hypoleuca* was retarded by 1.70—1.75 days/100 m alt., clutch size decreasing in Central Europe by 0.14 eggs/100 m alt. (Zang 1980).

In fact, the clutch size of *F. hypoleuca* increased at Kilpisjärvi with increasing altitude, due to the advancement of laying by about 3.2 days/100 m alt. In the nests situated highest up in the mountain (alt. 570±7 m, n=15) the average date of laying and clutch size did not differ from the average of nests situated 200—650 m away from the shore (alt. 530±30 m, n=120): dates 11.93 (June) ±5.51 (*SD*) and 11.90±4.94, and clutch sizes 5.53±0.64 and 5.64±0.81, respectively.

The clutch size of *Ph. phoenicurus* was also greater higher up the mountain at Kilpisjärvi, but this difference was not related to advanced date of laying (Table 1). As pointed out to me by A. Enemar, if more *Ph. phoenicurus* pairs tended to breed in sub-area A in warm (and early) springs, this would level out possible differences in laying date (and clutch size) between sub-areas A and B. However, the pairs seemed to settle in the sub-areas in almost equal proportions, both in warm and cold springs (X^2=0.10, P=0.75). In conclusion, the effects of altitude, now probably masked by those of the distance from the shore, might have manifested themselves if the altitudinal range had been greater.

The general aspects of the inhibitory effects of low temperature on the reproductive activity of birds were discussed by Marshall (1959). It is difficult to say whether the microclimatically cold shore affected the timing of breeding of *F. hypoleuca* directly or indirectly. The mean air temperature at the commencement of laying is close to the assumed average lower critical laying temperature of *F. hypoleuca* (about +5°C; A. Järvinen, unpubl.) suggesting a proximate influence. Between 1966 and 1980, the average air temperature near the shore at the altitude of 480 m was +6.4°C on June 12 and +8.2°C on June 14. The low temperature (+5.5—+6.5°C) on June 12 and during the preceding five-day period may have prevented the females from laying near the shore, all their energy being used for maintenance (in *F. hypoleuca* the average determinant day of egg-laying is presumably five days earlier than the date on which the female lays her first egg; v. Haartman 1956). A positive correlation between temperature and the rate of testicular development or egg production has been found earlier in several bird species (for a review, see Immelmann 1971). For instance, cold spells may temporarily inhibit ovulation.

It may be hypothesized that laying date is connected (via food) with the leafing of birches, which occurred on about June 12 in areas far from the shore (i.e. about 2—3 days earlier than near the shore). However, in early summer *F. hypoleuca* feeds mainly on ground- or on snow-living Arthropoda (especially spiders) and in both sub-areas the snow had already melted at the end of May or in the beginning of June. Thus the birds do not forage on the foliage during the early stages of breeding. Moreover, in southern Finland birches leaf several days before *F. hypoleuca* starts to lay (Slagsvold 1976), which seems to give additional evidence against the 'leafing hypothesis' as a causal explanation. It seems that in northernmost Lapland, where *F. hypoleuca* breeds at its physiological extreme, the 'triggering date' of a synchronizer (birch leafing) approaches the critical laying temperature.

There were no significant differences between the sub-areas in the total nesting success within the species, but in both sub-areas *Ph. phoenicurus* was more successful than *F. hypoleuca* (total nesting success near the shore 84 % and 70 %, and far from shore 82 % and 65 %, respectively). The good nesting success of *Ph. phoenicurus,* the fact that it laid in colder weather than *F. hypoleuca*, and the relative independence of its laying date on the proximity of the shore may be interpreted as evidence of the adaptation of the redstart to northern breeding conditions (cf. A. Järvinen 1978a, b). The rather poor fledging success of *Ph. phoenicurus* near the shore was probably a bias caused by the comparatively small number of clutches.

In later stages of breeding the phenological progress near the shore probably catches up with that far from shore, and the 'breeding values' of the sub-areas become the same. However, hatching success was notably better in nest-boxes near the shore than in nest-boxes further away (for *F. hypoleuca* 87.6 % and 80.9 %, and for *Ph. phoenicurus* 92.2 % and 83.0 %). Already in early June the shores of Lake Kilpisjärvi are surrounded by a few metres of ice-free water. Nyholm & Myhrberg (1977) and Nyholm (1981) emphasized that such areas are favoured feeding sites of birds, because of swarming Plecoptera and other insects. A good food supply is perhaps one reason for the strikingly successful hatching near the shore at Kilpisjärvi.

In Ammarnäs, Swedish Lapland, reproductive capacity decreased in those nests of *F. hypoleuca* which were situated near (20—40 m) the shore of Lake Tjulträsk, in comparison with nests further away (Nyholm & Myhrberg 1977). For instance, eggshell quality, clutch size and hatching success were greatly impaired in the vicinity of the shore. Similar effects of the lake were also observed in the bluethroat *Luscinia svecica,* the reed bunting *Emberiza schoeniclus* and the willow warbler *Phylloscopus trochilus.*

My results from Kilpisjärvi do not fully agree with those of Nyholm & Myhrberg (1977). The clutch sizes of *F. hypoleuca* and *Ph. phoenicurus* were lower near the shore at Kilpisjärvi, too. However, at Kilpisjärvi breeding success (hatching and fledging success) seemed to be better or as good near the shore as further away (Table 1).

Apparently the 'lake effect' has different origins at Kilpisjärvi and at Ammarnäs. Nyholm & Myhrberg (1977) suggested that the birds near the shore were poisoned via limnic insects. Detailed analyses showed that the birds were contaminated with aluminium (Nyholm 1981). Kilpisjärvi lies some 400 km north of Ammarnäs. The results presented in this paper — and the fact that *F. hypoleuca* also seems to breed normally in the shore zone of Lake Torneträsk in northern Swedish Lapland (Nyholm 1981) — indicate that pollutants from Central Europe and southern Fennoscandia have not yet reached northernmost Lapland on a large scale. For instance, in the Kilpisjärvi area the deposition of sulphate and nitrates, which correlate with the deposition of strong acids, are among the lowest in Finland, and are about 4—5 times less than in southern Finland (O. Järvinen 1982). In addition, the calcareous soils around Lake Torneträsk and Lake Kilpisjärvi may buffer aluminium leaching enhanced by acidic precipitation (see Nyholm 1981).

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