Eggshell thickness in eleven sea and shore bird species of the Bothnian Bay

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Pulliainen, E. & A. Marjakangas 1980: *Eggshell thickness in eleven sea and shore bird species of the Bothnian Bay.* — Ornis Fennica 57:65—70.

Eggshell thickness was studied in 11 sea and shore bird species (*Aythya fuligula, Mergus merganser, Anser anser, Numenius arquata, Larus marinus, L. fuscus, L. argentatus, L. canus, L. ridibundus, Hydroprogne caspia* and *Sterna paradisaea)* nesting in 1977—78 on islands of the Bothnian Bay, and compared with corresponding data on eggs collected in northern Europe in 1869—1952, 80 % before 1938. When account is taken of a natural 8 % thinning in the eggshell during incubation found here in *Gallus gallus* and *L. ridibundus,* the only statistically significant changes in eggshell thickness were an increase of 5.2 % in *Sterna paradisaea,* and a decrease of 6.4 % in *Larus argentatus.* It seems unlikely that the latter change is due to the effects of DDE or any other pollutants.

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Introduction

In a number of avian species eggshell thickness has been found to be negatively related to residues of organochlorine compounds in the egg, especially pp'-DDE, the main fat-soluble metabolite of pp'-DDT (see e.g. Ratcliffe 1970, Cooke 1973, 1979a, b, Newton & Bogan 1974, 1978, Cooke et al. 1976). The Baltic Sea is known to be one of the most polluted water areas in northern Europe, and high concentrations of DDT and PCBs have been recorded in its animals (e.g. Jensen et al. 1969, 1972, Olsson et al. 1973, Helle et al. 1976a). A decline in reproduction due to pollutants has been recorded in the White-tailed Eagle *Haliaeetus albicilla* (Henriksson et al. 1966, Palokangas et al. 1970, Koivusaari et al. 1972, 1976) and in the Ringed Seal *Pusa hispida* (Helle 1974, 1977, Helle et al. 1976a, b).

Jensen et al. (1969), Odsjö et al. (1972) and Lemmetyinen et al. (1977) have studied DDT and PCB residues in several bird species nesting in the southern part of the Gulf of Bothnia and the northern Baltic. The results of these workers and the observation of a correlation between high pollutant levels and pathological changes in the uteri of Ringed Seals in the northern part of the Gulf of Bothnia (Helle et al. 1976b) prompted the present study of eggshell thickness in some typical sea and shore birds nesting in the area.

Material and methods

The present paper is based on the following material and investigations:

(a) Shell samples of hatched eggs belonging to 443 clutches of 11 sea and shore bird species were collected on islands of the Krunnit group in the Bothnian Bay (65°23'N, 24°50'E) in the summers of 1977 and 1978. One sample usually represented at least two eggs from the clutch.

(b) Comparative material was compiled from eggs of 82 clutches of the same species collected in northern Europe in 1869—1952, 80 % dating back beyond 1938. All the eggs had been taken from the nests before incubation or at a very early stage of incubation. A total of 186 eggs were studied, two to three from each clutch.

(c) It was evident at the outset of the present study that the shells of eggs become thinner during incubation. Since the present samples were from hatched eggs and the comparative material from unincubated or only briefly incubated eggs, it was necessary to obtain a "natural thinning index" in order to compare the two sets of data. For this purpose measurements were made of the thicknesses of the shells of unincubated and hatched eggs of the domestic hen *Gallus gallus* and the Black-headed Gull *Larus ridibundus*, the former in the experimental laboratory of the Association of Finnish Poultry Farmers and the latter in a colony nesting on Hailuoto, near Oulu.

(d) The thicknesses of the eggshells, without membranes, were measured with the aid of a binocular microscope fitted with a calibrated eye-piece (magnification ×500), the measuring unit being 0.02 mm. The accuracy of this device was ± 0.5 unit. The eggshells collected from the Krunnit islands were measured on samples taken from the equator of the shell, and those from the earlier collections at the rims of the holes made on emptying the eggs. The same person performed all the measurements with the same equipment and using the same technique.

Each result is the mean of five measurements made on each sample (see also Capen 1977). The variance within these measurements was relatively small; for example, analysis of variance applied to the Black-headed Gull data from Krunnit material, showed a mean square of 4.880 between samples, but only 0.233 within samples ($F=20.94$; $P<0.001$; no. of samples 30).

Results

The shells of unincubated eggs of the domestic hen are on average 7.94 % thicker than those of hatched eggs of the same species, and a corresponding figure of 8.19 % was obtained for the Black-headed Gull (Table 1). Kreitzer (1972) reported a 7.3 % decrease in shell thickness between unincubated and incubated eggs of the Quail *Coturnix c. japonica*, and Rothstein (1972) observed a similar difference in the Cedar Waxwing *Bombycilla cedrorum*. Capen (1977) found a 4.3 % decrease in shell thickness over approximately 11 days of incubation in the White-faced Ibis *Plegadis chichi*. Simkiss (1967) estimated that 5 % of the calcium in an eggshell may be used by the developing chicken embryo. The figure of 8 % is therefore used here as the "natural thinning index".

A comparison of the thicknesses of the eggshells collected from the Krunnit islands with those from the museum collections is made in Table 2. The only statistically significant differences occur in the Herring Gull *Larus argentatus* and the Arctic Tern *Sterna paradisaea*. In the former species the recent samples from nature are 6.4 % thinner than those in the museum collections, while in the latter the difference, 5.2 %, is in the opposite direction.

Discussion

Eggshell thinning exceeding 20 % has generally been found to result in reproductive failure and population decline in the species involved (Keith & Gruchy 1972, Stickel 1975), but the biological significance of thinning by less than 10 % is not well understood (Faber & Hickey 1973, Morrison & Kiff 1979).

The results of the present study were somewhat surprising when one takes into account the level of pollution in the present study area, inhabited by these sea and shore birds in summer, and the fact that these birds generally use industrialized and polluted Western Europe as their migration route or wintering area (e.g. Grenquist 1965,

TABLE 1. Shell thicknesses of unincubated and hatched eggs in the domestic hen *Gallus gallus* and the Black-headed Gull *Larus ridibundus*. The measurement unit is 0.02 mm.

	Number of eggs	Shell thickness		*t*-test	Difference between the means (%)
		Range	Mean ± *SE*		
Hen					
— unincubated eggs	10	15.5—17.6	16.50±0.25	3.212**	7.94
— hatched eggs	16	13.5—17.3	15.19±0.28		
Black-headed Gull					
— unincubated eggs	10	7.2—9.5	8.18±0.21	2.598*	8.19
— hatched eggs	12	6.7—8.3	7.51±0.15		

TABLE 2. Shell thicknesses of eggs of 11 sea and shore bird species collected in the period 1869—1952 (A) and thicknesses of eggshells of the same species collected in 1977 and 1978 on the Krunnit islands in the Bothnian Bay (B). The measurement unit is 0.02 mm. The measurements for material A have been corrected with a "natural thinning index" of 8 %.

Species	Material	No. of samples	Shell thickness		*SD*	*t*-test
			Range	Mean ± *SE*		
Tufted Duck	A	18	10.0—14.4	12.40±0.30	1.29	1.819^{ns} 1)
Aythya fuligula	B	31	10.6—14.6	13.01±0.15	0.83	
Goosander	A	15	12.6—17.9	15.91±0.33	1.34	0.664^{ns}
Mergus merganser	B	10	13.5—17.3	15.56±0.38	1.21	
Grey Lag Goose	A	12	23.2—28.3	26.39±0.44	1.53	0.964^{ns}
Anser anser	B	22	23.2—31.9	27.08±0.47	2.20	
Curlew	A	22	9.0—11.9	10.31±0.18	0.82	0.290^{ns}
Numenius arquata	B	22	8.6—11.2	10.24±0.16	0.78	
Great Black-backed Gull	A	8	13.5—14.4	14.04±0.12	0.34	0.904^{ns} 1)
Larus marinus	B	6	13.0—16.4	14.47±0.46	1.12	
Lesser Black-backed Gull	A	12	10.3—12.4	11.30±0.21	0.71	1.133^{ns}
Larus fuscus	B	127	8.7—13.3	11.00±0.08	0.89	
Herring Gull	A	14	11.5—14.7	12.79±0.26	0.97	2.474^{*} $P<0.05$
Larus argentatus	B	47	9.8—14.9	11.97±0.16	1.12	
Common Gull	A	18	8.0—12.3	9.60±0.25	1.07	0.674^{ns}
Larus canus	B	15	7.2—11.7	9.33±0.32	1.23	
Black-headed Gull	A	36	6.2—11.1	7.93±0.16	0.99	0.572^{ns}
Larus ridibundus	B	30	6.5—10.7	8.07±0.18	0.99	
Caspian Tern	A	16	10.3—13.2	11.44±0.18	0.72	0.948^{ns}
Hydroprogne caspia	B	118	7.5—12.9	11.24±0.07	0.80	
Arctic Tern	A	15	5.4—6.5	5.91±0.09	0.37	2.388^{*} $P<0.05$
Sterna paradisaea	B	15	5.4—6.7	6.22±0.09	0.34	

1) using Cochran's approximation method (Mäkinen 1968).

Saurola 1978). Nine of the 11 species studied actually showed no statistically significant changes in eggshell thickness.

In the Arctic Tern the recent eggshells were even thicker than those collected several decades earlier, a result which may be due to such factors as geographical location, genetics, and the physiology and diet of the females (see review by Capen 1977). The absence of any sign of eggshell thinning in the Arctic Tern supports the finding of Lemmetyinen et al. (1977), who reported that "in the southern part of the Gulf of Bothnia no incidence of developmental defects in Arctic Terns caused by chlorinated hydrocarbons was recorded during the productivity study in 1965—1973", although DDE residues were found in adult and young birds.

The 6.4 % thinning observed in the eggshells of the Herring Gull is statistically significant. As this species is regarded as one of the most resistant to the effects of DDE (Keith & Gruchy 1972), it seems probable that the change in thickness is due to one of the factors suggested above in the case of the Arctic Tern, rather than to DDE or some other environmental pollutant. Fimreite et al. (1977) recorded a significant negative correlation between eggshell thickness and DDE levels in the Herring Gull at one of their nine sites on the Norwegian coast, but regarded this result as artificial. Jørgensen & Kraul (1974) found that eggs of the Herring Gull from the Baltic Sea were thinner, lighter and more contaminated with DDE and PCB than eggs from other colonies on the Danish coast, though their electron microscope findings revealed no significant differences between the colonies. Herring Gulls are generally known in Finland as feeders upon garbage (e.g. Stenman et al. 1972), and even gulls nesting on the islands and rocks off the coast make daily visits to garbage sites on mainland (E. Helle, pers. comm.). In contrast, a number of the species which showed no sign of eggshell thinning, e.g. *Mergus merganser, Hydroprogne caspia* and *Sterna paradisaea,* feed mainly on fishes and other marine animals known to accumulate pollutants in the food chains.

Acknowledgements. We wish to thank Mr. Erkki Elomaa, Mr. Juha Valkama and Mr. Olli Oksanen for technical assistance in the field, the Association of Finnish Poultry Farmers for incubating eggs of the domestic hen, Mr. Eino Merilä for collecting the Black-headed Gull eggs on Hailuoto, and the Tauno Tönning Foundation for grants to finance this work.

Selostus: **Yhdentoista meri- ja rantalintulajin munankuoren paksuudesta Perämerellä**

Kesinä 1977 ja 1978 kerättiin Iin Krunnien saarilta ja luodoilta tukkasotkan, isokoskelon, merihanhen, isokuovin, merilokin, selkälokin, harmaalokin, kalalokin, naurulokin, räyskän ja lapintiiran kuoriutuneiden munien kuoria 443 pesyeestä, joista kutakin edusti ainakin kaksi munaa. Kuoren paksuutta binokulaarimikroskoopin avulla mitattaessa jätettiin ottamatta huomioon kalvojen paksuus. Tutkimuksen alkuvaiheessa havaittiin, että munankuori ohenee haudonnan aikana. Tätä tutkittiin sittemmin kanan ja naurulokin munista (taul. 1). Vertailuaineistona oli Helsingin yliopiston eläinmuseon ja maatalous- ja metsäeläintieteen laitoksen munakokoelmien munia samojen lajien 82 pesyeestä vv. 1869—1952, 80 % ennen v. 1938, Pohjois-Euroopasta. Koska nämä munat olivat kerättäessä vain hiukan tai ei lainkaan haudottuja, on niiden kuorien paksuuksista vähennetty 8 % luonnollista ohenemista, jotta ne on saatu vertailukelpoisiksi luonnosta haudotuista munista kerätyn aineiston kanssa. Aineistojen vertailu esitetään taulukossa 2.

Ainoastaan harmaalokilla ja lapintiiralla vertailuryhmien munien kuorten paksuudet

poikkesivat tilastollisesti merkitsevästi toisistaan. Harmaalokin munat olivat äskettäin kerätyssä aineistossa 6.4 % ohuempikuorisia kuin museoaineistossa, kun taas lapintiiralla ne olivat 5.2 % paksumpikuorisia. Pohdinnassa päädytään siihen, että kumpikin näistä tuloksista on mahdollisesti muun syyn kuin DDE:n tai jonkin muun ympäristömyrkyn aiheuttama, sillä harmaalokin munien kuorten tiedetään olevan varsin kestäviä näiden saasteiden vaikutuksille ja harmaalokit käyttävät paljon kaatopaikkajätteitä ravinnokseen. Sen sijaan sellaisilla kalan ja merieläintensyöjillä kuin isokoskelo, räyskä ja lapintiira ei todettu munankuoren ohentumista, vaikka juuri näillä lajeilla voisi olettaa myrkkyjen rikastuvan ravintoketjun yläpäähän. Capen'in (1977) laatiman katsauksen mukaan mm. maantieteellinen sijainti, perinnölliset tekijät ja munivan linnun fysiologia ja ravinnonlaatu vaikuttavat munien kuorten paksuuteen, mistä tekijöistä jokin saattaa olla syy siihen, että lapintiiralla museonäytteiden munat olivat paksukuorisempia kuin äskettäin luonnosta kerätyt munat.

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Received December 1979