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# Egg Mercury Levels Decline with the Laying Sequence in Charadriiformes

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Whereas pollutants do not differ in concentration among eggs of one clutch in some bird species (e. g. Helander et al. 1982, Newton et al. 1989), in gulls, terns and grebes several organochlorines show intraclutch variation: Concentrations increase with the laying sequence (Common Tern Sterna hirundo, Nisbet 1982; Herring Gull Larus argentatus, Mineau 1982, Becker et al. 1989; Great-crested Grebe Podiceps cristatus, Lukowski 1978).

Heavy metals, however, are not so intensively studied with respect to intraclutch variation. In contrast to lead and cadmium, mercury is accumulated in great quantities in eggs (e. g. Fimreite 1979, Becker et al. 1989). Variation in mercury levels between the eggs of one clutch were low compared to interclutch variability in the White-tailed Sea Eagle (Haliaeetus albicilla, Helander et al. 1982) and the Peregrine (Falco peregrinus, Newton et al. 1989). In gulls, however, intraclutch variation was significant and characterized by higher mercury levels in the first than in subsequently laid eggs (Herring Gull, Becker et al. 1989; also in Great Black-backed Gull Larus marinus, Johansen 1978), which is the opposite to the trend in organochlorine levels (see above).

In this paper I report on investigations of intraclutch variation in mercury levels in three Charadriiform-species, Herring Gull, Common Tern and Oystercatcher (Haematopus ostralegus). The results confirm those previously reported in gulls and point to the importance of the egg in reducing the females' mercury burden.

## MATERIALS AND METHODS

In 1988 clutches with known laying sequence (a-, b- and c-egg) were gathered after completion at the Jade Bay,

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Wadden Sea, FRG: 15 3-egg-clutches of Common Terns originate from Minsener Oldeoog (53.46N 08.00E), 8 3-egg- and 3 4-egg-clutches of Oystercatchers came from Augustgroden salt marsh (53.28N 08.20E). The eggs were wrapped in aluminium foil and frozen. Herring Gull clutches were collected on Mellum (53.43N 08.09E) in 1979/1980 (see Becker et al. 1989). The determination of total mercury was carried out by cold vapour atomic absorption (see Kruse 1979, Becker et al. 1985). The mercury values are given in mg/kg fresh egg mass. F-values were determined by analysis of variance (related samples, two-way classification without interactions). Significance of differences between eggs was tested by the non-parametric Wilcoxon-Wilcox multiple comparison method.

RESULTS AND DISCUSSION

In Herring Gulls and Common Terns significant differences were detected not only between clutches - that is between the females - but also among the eggs of one clutch (table 1). Highest mercury levels were found in the first egg of all species, with significantly lower levels in the third egg in Herring Gull and Common Tern. The second egg contained intermediate concentrations. In the first laid egg the residues detected were 39% higher than in the last egg in Herring Gulls, 37% higher in Common Terns and 10% higher in Oystercatchers. This species also showed declining mercury residues with the laying sequence, although not significant. In a few 4-egg clutches the reduction in mercury concentrations with advancing laying sequence was also evident: Oystercatcher (n = 3): a: 0.27 ± 0.07, b: 0.23 ± 0.03, c: 0.21 ± 0.08, d: 0.22 ± 0.03; Herring Gull (Becker et al. 1989), female 1: a: 0.38, b: 0.38, c: 0.33, d: 0.20; female 2: a: 0.45, b: 0.32, c: 0.29, d: 0.26. The observed intraclutch differences are strengthened concerning the total mercury content per egg, as in larids egg mass is reduced with egg sequence (e.g. Nisbet 1982).

An interspecific comparison reveals highest mercury levels in Common Tern- and lowest in Oystercatcher-eggs (table 1), corresponding to results from a bigger data set of Becker et al. (1985), who found that the interspecific differences in mercury levels were significant in these species on the German Wadden Sea coast.

The fact that both intra- and interclutch variance are contributing to the variance in the total data set leads to relatively low correlation coefficients between eggs compared with other chemicals (table 2; e. g. Mineau 1982, Becker et al. 1989). In the three species, lowest correlation coefficients were detected

Table 1. Intraclutch variation of mercury levels in three species of Charadriiformes.

| | Herring Gull n = 24 | Common Tern n = 15 | Oystercatcher n = 8 |
|---|---|---|---|
| a-egg | $0.43 \pm 0.18^{C}$ (0.20 - 0.82) | $0.59 \pm 0.20^{C}$ (0.33 - 1.13) | $0.22 \pm 0.08$ (0.12 - 0.31) |
| b-egg | $0.37 \pm 0.16$ (0.13 - 0.63) | $0.46 \pm 0.16$ (0.22 - 0.76) | $0.21 \pm 0.05$ (0.12 - 0.27) |
| c-egg | $0.31 \pm 0.12^{a}$ (0.13 - 0.51) | $0.43 \pm 0.15^{A}$ (0.20 - 0.79) | $0.20 \pm 0.07$ (0.08 - 0.30) |
| F within clutches | $15.2^{***}$ | $6.3^{**}$ | 0.4 |
| F between clutches | $10.1^{***}$ | $2.9^{**}$ | $5.0^{**}$ |

Concentration in mg/kg fresh mass. First line: mean ± $s_d$, second line in brackets: minimum - maximum. The Herring Gull data are taken from Becker et al. (1989). p-values according to analysis of variance and Wilcoxon-Wilcox multiple comparison: ** $p < 0.01$, *** $p < 0.001$; A, C: significant difference between a- and c-egg (A, C: $p < 0.001$; a, c: $p < 0.01$).

between a- and c-egg, highest coefficients between b- and c-egg. Thus in general the second or third egg are more characteristic for the mercury contamination of the clutch or of the respective female than the first egg.

Becker et al. (1989) showed that mercury concentrations in clutch and liver of the same female Herring Gulls sampled after egg-laying were significantly correlated revealing that highly contaminated females also lay highly contaminated eggs. However, the lowest correlation coefficients were found between liver and first egg values, the highest coefficients between liver and second or third egg levels (a-egg/liver 0.73, $p < 0.01$; b-egg/liver 0.99, $p < 0.001$; c-egg/liver 0.81, $p < 0.01$; $n = 12$). Accordingly the levels of the last laid eggs correspond more closely to the liver contents after production of the clutch than the first egg mercury levels.

Besides excreta - and eggs in case of females - birds lower their body burden of mercury primarily through moult (Fimreite 1979). In Adelie Penguins (<u>Pygoscelis adeliae</u>, Honda et al. 1986) the plumage contains about 60% of the body mercury content, and in Bonaparte's

Table 2. Correlation coefficients (Pearson) between the mercury levels in the three eggs of clutches of three species (cf. table 1).

| egg | Herring Gull n = 24 | Common Tern n = 15 | Oystercatcher n = 8 |
|---|---|---|---|
| a/b | 0.79*** | 0.44 | 0.68 |
| a/c | 0.71*** | 0.17 | 0.42 |
| b/c | 0.85*** | 0.65** | 0.74* |

p-values: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Gulls (Larus philadelphia) 93% after moult (Braune & Gaskin 1987). The increasing body depollution with the moulting period is indicated by the fact that primary feathers replaced early in the moulting sequence have higher levels of mercury than those moulted later (Furness et al. 1986, Braune & Gaskin 1987).

A similar decrease of mercury concentrations in sequentially laid eggs reported in this paper in Common Terns and Herring Gulls as well as in Great Black-backed Gulls (Johansen 1978) indicates that female gulls and terns lower their body burden progressively through deposition of mercury in the eggs. In Mallards (Anas platyrhynchos) fed with mercury Heinz (1976) found that mercury concentrations decreased in eggs in the course of the experiment. Accordingly female Mallards had lower body levels than males, which were unable to eliminate mercury through eggs. In the egg, mercury is accumulated mainly in its methylated form (> 90%, Fimreite 1979) comparable to the plumage (Thompson & Furness 1989). Concentrations in tissues increase with mercury levels in the diet (Tejning 1967, Heinz 1976), and highly contaminated females lay highly contaminated eggs (see above, Becker et al. 1989).

Honda et al. (1986) argue, however, that the removal of mercury through egg-laying was negligible in Adelie Penguins. Thompson (1989) calculated that mercury contents in muscle and liver of female Guillemots (Uria aalge; a seabird of comparable size to the Herring Gull) decreased by 58 µg between pre- and postbreeding samples. This decrease, however, was evident in male Guillemots, too, and seems to exceed the possible mercury loss by the single Guillemot egg. Nevertheless, the 3-egg clutch of gulls and terns has more than would be needed to account for a similar mercury depollution during the breeding season: In the Herring Gull, elimination through the 3-egg clutch was about 96 µg (0.37

mg/kg, table 1, which is 32 µg/egg; mean egg mass without shell = 85 g, Schönwetter 1967). However, there seem to be no studies yet to quantify the amount of mercury loss via the clutch in comparison with that via the plumage in Charadriiformes. Such studies should be initiated.

The lower intraclutch variation in the Oystercatcher compared to Common Tern and Herring Gull may be due to the lower contamination of this species. In addition the egg-/body-mass ratio is much higher in larids and terns (e. g. Common Tern: egg-mass about 15% of body-mass; egg-mass = 20 g, body-mass = 130 g, Frank & Becker 1991; Oystercatcher: egg-mass about 8% of body-mass; egg-mass = 45 g, body-mass = 536 g, Bezzel 1985). The high energy demand of egg production in terns and gulls is provided to a great extent through the male's courtship feeding (Nisbet 1977, Norstrom et al. 1986). During egg production the enhanced food consumption involves a higher ingestion of mercury; egg-mercury levels at least in part reflect the contamination of the breeding area (Becker et al. 1985).

The third hatched chick has the disadvantage of higher organochlorine levels than it's siblings (see above). As mercury is most concentrated in the first egg and as levels in eggs and chicks from the same clutch are correlated strongly (Becker & Sperveslage 1989), the first hatched chick will be more endangered than the siblings by this toxic metal if critical levels are achieved.

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REFERENCES

Becker PH, Conrad B, Sperveslage H (1989) Chlororganische Verbindungen und Schwermetalle in weiblichen Silbermöwen (Larus argentatus) und ihren Eiern mit bekannter Legefolge. Vogelwarte 35: 1-10

Becker PH, Sperveslage H (1989) Organochlorines and heavy metals in Herring Gull (Larus argentatus) eggs and chicks from the same clutch. Bull Environ Contam Toxicol 42: 721-727

Becker PH, Ternes W, Rüssel HA (1985) Schadstoffe in Gelegen von Brutvögeln der deutschen Nordseeküste. 2. Quecksilber. J Orn 126: 253-262

Bezzel E (1985) Kompendium der Vögel Mitteleuropas. Nonpasseriformes. Aula Wiesbaden

Braune BM, Gaskin DE (1987) Mercury levels in Bonaparte's Gulls (Larus philadelphia) during autumn moult in the Quoddy region, New Brunswick, Canada. Arch Environ Contam Tox 16: 539-549

Fimreite N (1979) Accumulation and effects of mercury on birds. In: Niragu, JC (ed) The biochemistry of mercury in the environment. Amsterdam, Elsevier, p 601-627

Frank D, Becker PH (1992) Common Terns' (Sterna hirundo) body mass and incubation shifts related to different feeding conditions in the Wadden Sea. Ardea 80: in press

Furness RW, Muirhead SJ, Woodburn M (1986) Using bird feathers to measure mercury in the environment: Relationships between mercury content and moult. Marine Poll Bull 17: 27-30

Heinz GH (1976) Methylmercury: Second-year feeding effects on Mallard reproduction and Duckling behaviour. J Wildl Mgmt 40: 82-90

Helander B, Olsson M, Reutergardh L (1982) Residue levels of organochlorine and mercury compounds in unhatched eggs and the relationships to breeding success in white-tailed sea eagles Haliaeetus albicilla in Sweden. Holarct Ecol 5: 349-366

Honda K, Yamamoto Y, Hidaka H, Tatsukawa R (1986) Heavy metal accumulations in Adelie penguin, Pygoscelis adeliae, and their variations with the reproductive process. Mem Natl Inst Polar Res, Spec Issue 40: 443-453

Johansen O (1978) DDE, PCB og HG i egg av svartbak og gramake fra kolonier i More og Romsdal. Stavanger Mus Arbok 67-72

Kruse R (1979) Ein verlustfreier offener Aufschluß mit $HNO_3/HClO_3/HClO_4$ für die Bestimmung von Gesamt-Quecksilber in Fischen. Z Lebensm Unters Forsch 169: 259-262

Lukowski AB (1978) The content of organochlorine insecticides in the eggs and tissues of young individuals of the Great-crested Grebe (Podiceps cristatus L.) and of the Coot (Fulica atra L.) from the Masurian lakes. Ekol pol 26: 467-478

Mineau P (1982) Levels of major organochlorine contaminants in sequentially laid Herring Gull eggs. Chemosphere 11: 679-685

Newton I, Bogan JA, Haas MB (1989) Organochlorines and mercury in the eggs of British Peregrines Falco peregrinus. Ibis 131: 355-376

Nisbet ICT (1977) Courtship-feeding and clutch size in Common Terns. In: B Stonehouse (ed), Evolutionary ecology. Biology and Environment vol 2. London, Macmillan, p 101-109

Nisbet ICT (1982) Eggshell characteristics and organochlorine residues in Common Terns: Variation with egg sequence. Colonial Waterbirds 5: 139-143

Norstrom RJ, Clark TP, Kearney JP, Gilman AP (1986) Herring Gull energy requirements and body constituents in the Great Lakes. Ardea 74: 1-23

Schönwetter M (1967) Handbuch der Oologie. Band I (Nonpasseres). Akademie Verlag, Berlin

Tejning S (1967) Biological effects of methyl mercury dicyandiamide treated grain in the domestic fowl Gallus gallus L. Oikos Suppl 8: 1-116

Thompson DR (1989) A review of heavy metal levels in marine vertebrates and some studies of mercury in seabirds. Ph D Thesis, University of Glasgow

Thompson DR, Furness RW (1989) Comparison of the levels of total and organic mercury in seabird feathers. Marine Pollut Bull 20: 577-579

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