The weakening of eggshells of the laughing dove, *Streptopelia senegalensis* (Linn.)

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Eggshells of *Streptopelia senegalensis* dating from 1899 to 1983 were studied to determine whether a change had occurred in the mass of the shells, the length section, breadth (width) section, thickness and index. A significant difference was determined in both mass and index of the more recent eggs (after 1957) compared with older eggs. The two groups of eggs represent periods prior and subsequent to the introduction of agricultural pesticides in southern Africa. Although no definite link has been established the results merit further experimental studies to determine whether the observed changes could be ascribed to the increased usage of agricultural pesticides.
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Eierdoppe van *Streptopelia senegalensis* wat dateer vanaf 1899 tot 1983 is ondersoek om vas te stel of daar 'n verandering in die eierdopmassa, lengtedeursnee, dwarsdeursnee, dikte en indeks oor hierdie periode was. Daar is 'n betekenisvolle verskil aangetref in beide die eierdopmassa en -indeks van die resente eiers (na 1957) in vergelyking met die ouer eiers. Die twee groepe eiers verteenwoordig die tydperke voor en na bekendstelling van landbouplaagdoders in Suidelike Afrika.
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Insecticides have been in use for a long period of time and some well-known substances such as DDT and BHC were known for years before their facility as pesticides was discovered. The basis for the synthesis of modern pesticides is mainly to be found in the period between the two world wars (Moore 1965). The history of pesticides in South Africa also goes back a long way, because as early as 1947 the Act on Fertilizers, Animal feeds, Agricultural substances and Veterinary substances (Act 36 of 1947) was promulgated to control the sale and use of, amongst others, pesticides. By 1961 the following organochlorine pesticides were already in use in South Africa: Aldrin, BHC, chlordane, Dieldrin, endrin, methoxychlor, chlorobenzilate, dicofol and camphechlor (Sweet, personal communication).

Pesticides are used against harmful or unwanted species but may have deleterious effects on non-target species. The effect of pesticides on natural populations, however, is very variable and it has been found that individuals of the same species will respond differently. A large variety of responses can therefore be expected in nature (Moore 1965).

A great deal of work has already been done on the incidence of persistent pesticides in the tissue and eggs of birds, for example by Ratcliffe (1967); Potts (1968); Krantz, Mulhern, Bagley, Sprunt, Ligas & Robertson (Jr.) (1970); Mulhern, Reichelr, Locke, Lamont, Belisle, Cromartie, Bagley & Prouty (1970); Fourie & Hattingh (1979).

Some organochlorine pesticides are very persistent and they are, in addition lipophilic. The pesticides thus have the ability to accumulate in biological systems, which is especially dangerous for organisms at high trophic levels such as birds of prey (Ratcliffe 1967 & 1970). The bioaccumulation has already been determined with isolated animals such as penguins (Ballschmiter, Scholz, Buchert, Zell, Figg, Polzhofer & Hoerschelmann 1981) and in places such as the Antarctic (Holden & Marsden 1967).

Significant decreases in the numbers of birds of prey which could not be explained with reference to intensified hunting by man or animal or by an increase in the incidence of disease have been reported (Moore 1965). An increase in the number of shell breakages has also been observed. Ratcliffe (1967) explained this as the induction of a calcium deficiency which culminates in the release of premature eggs. He found that the introduction of DDT for general use (1945 – 46) concurred significantly with the change in the thickness of shells.

Pesticides will have an effect on non-target species but the extent of this effect will differ in various species. To establish a link between the presence of a pesticide and the prevalence

of a species is very difficult. However, such a link can be indicated through experimental studies.

The purpose of this study was to determine whether changes have occurred in eggs of a non-predatory bird over a period of time representing both the periods prior and subsequent to the introduction of agricultural pesticides in Southern Africa. Should significant changes be found it would merit further experimental studies to establish whether a causal relationship between pesticides and the observed changes exists.

Material and Methods

Fresh eggs were gathered in the vicinity of Boskop Dam in the Western Transvaal; others were obtained from the Transvaal Museum and the distribution of these is from the whole of Southern Africa.

The eggs supplied by the museum were dry enough for the investigation. The fresh eggs were emptied by means of an opening in the median level more or less in the middle of the length of the egg, and they were then rinsed to remove the contents thoroughly. The eggs were dried overnight at 70°C before the mass of the eggshells could be determined.

Samples for determining thickness were taken in the same places where the eggs were emptied, as this is also the area where the shell thickness is the most constant. In view of the fact that the eggs obtained from the museum are irreplaceable it was essential to damage the eggs as little as possible. A very tiny sample (1 mm^2) was required to study both the thickness and the morphology.

The length and the diameter of the eggs were determined by means of a Mitutoyoto nonius compass (0,05 mm accurate) and the thickness of the shell was determined from Scanning Electron Microscope photos and correlated with a Starrett micrometer accurate to 0,001 mm. The mass of the fresh eggs and the mass of the eggshells were determined with a Sartorius electronic balance accurate to 0,001 g.

Variation in size and mass may occur in eggs of the same brood, nevertheless the mean size, mass and eggshell shape often remain constant for eggs from the same female over years, and may be used for a more reliable identification of a bird than the use of eggshell pigmentation and colour. Furthermore it seems as if there is not necessarily a decrease in the eggshell mass and size between subsequent eggs in one brood. The biggest or heaviest egg can be laid at any stage. In nature birds do not live long enough for age to have an effect on the mass and the size of the egg.

Asmundson & Baker (1940) have done a great deal of work with regard to the percentage eggshell per egg as a function of the shell thickness, egg volume and egg shape. They have found that there is a relationship between the percentage eggshell per egg and the density of the eggshell and of the egg. Seeing that eggshell density and density of the eggs could not be determined in this study, more attention was directed to the work of Ratcliffe (1967), which deals with the deter-

Table 1 Eggshell thickness, length, breadth, mass and index of *S. senegalensis*

Museum No.	Date year	Length mm	Breadth mm	Thickness mm	Mass g	Index
34665	1899	25,4	21,1	0,0689	0,370	0,690
34665	1899	26,8	21,2	0,0617	0,380	0,668
34657	1902	24,4	20,3	0,1120	0,369	0,745
34657	1902	27,6	20,0	0,1040	0,396	0,717
34673	1904	27,4	19,9	0,0842	0,328	0,602
34673	1904	26,5	19,8	0,0767	0,324	0,617
34671	1905	26,1	19,0	0,1050	0,355	0,716
34671	1905	25,2	20,5	0,1059	0,338	0,655
34666	1905	24,9	19,5	0,0565	0,300	0,617
34667	1905	26,2	19,4	0,0817	0,292	0,574
34667	1905	25,4	18,1	0,0690	0,304	0,660
34668	1906	25,5	20,6	0,1030	0,321	0,611
34668	1906	25,7	20,6	0,1140	0,354	0,668
34663	1917	24,6	19,7	0,0753	0,345	0,713
34676	1917	24,5	19,6	0,0671	0,254	0,528
34669	1920	24,7	19,8	0,0995	0,321	0,656
34669	1920	25,7	20,6	0,0968	0,353	0,667
34659	1929	26,8	22,0	0,1070	0,314	0,533
34661	1929	26,2	19,9	0,0947	0,299	0,573
34661	1929	25,7	19,8	0,0830	0,294	0,578
34658	1935	24,1	20,3	0,0959	0,343	0,702
Average		25,7 ± 0,9	20,2 ± 0,8	0,090 ± 0,12	0,341 ± 0,06	0,62 ± 0,06
34677	1957	25,9	20,5	0,0618	0,260	0,489
34678	1958	26,5	20,0	0,1000	0,316	0,597
50286	1958	26,5	20,0	0,1320	0,260	0,491
50286	1967	25,6	20,0	0,0795	0,324	0,633
50286	1967	26,0	20,3	0,1010	0,302	0,573
	1983	25,6	19,2	0,0854	0,286	0,581
	1983	26,1	20,6	0,0725	0,318	0,592
	1983	25,6	18,7	0,0495	0,283	0,590
	1983	26,2	18,0	0,0907	0,232	0,492
Average		26,0 ± 0,4	19,1 ± 0,9	0,086 ± 0,02	0,287 ± 0,03	0,56 ± 0,05

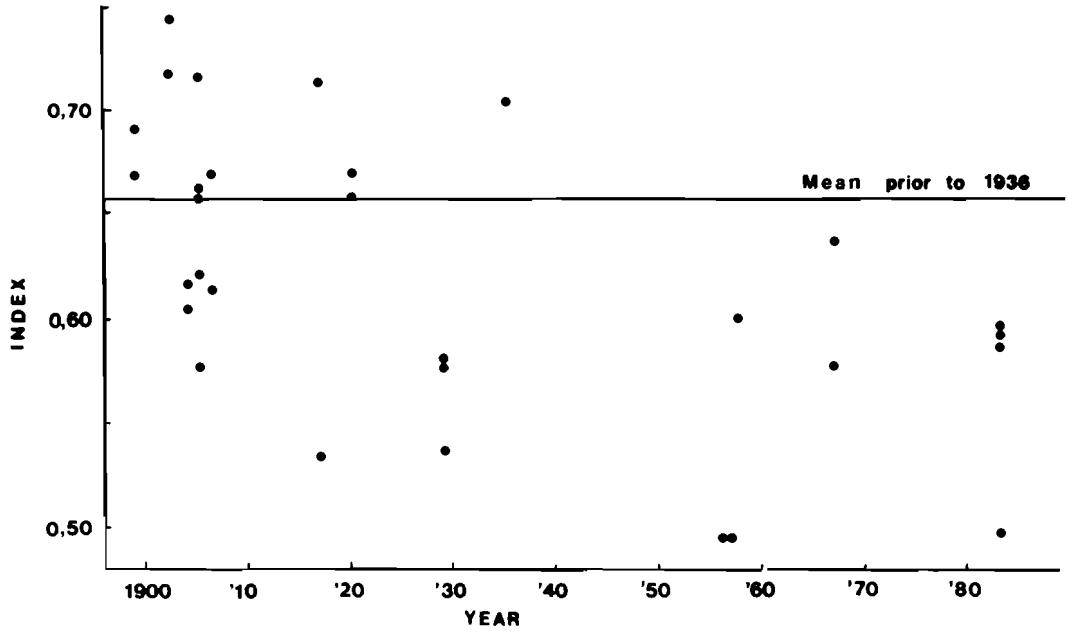

Figure 1 Distribution of the index of eggs of *S. senegalensis* collected from 1899 – 1983.

mination of an eggshell index which can be calculated from easily determinable values. In any species the eggshell mass is linked to the eggshell surface area as well as to the thickness and the density of the shell.

The eggshell index is determined by using three easily determinable variables, viz. length, breadth and mass:

$$\text{Eggshell index} = \frac{\text{length} \times \text{breadth}}{\text{mass}}$$

The relative eggshell mass is therefore expressed independent of individual variation in the size of the eggshell. This index can also be used for the determination of the thickness of the eggshell.

Results

In Table 1 eggshell length, breadth (width), mass, thickness and index are given.

The division of the eggs into two groups, viz. prior to 1936 and subsequent to 1956 is based on the introduction of organochlorine pesticides in the intervening years. The mean values of the eggshell qualities as well as the standard deviation for the two separate groups were calculated (Table 1) and show that in eggshell length, width and thickness no changes were evident. A difference could be discerned between the eggs prior to 1933 and after 1956 in eggshell mass and index.

The results indicate that there is a significant difference in both the mass and the eggshell index (P values 0,0168 and 0,0225).

Discussion

The comparison of eggshells of *S. senegalensis* which were collected from all over Southern Africa over a period of 84 years indicates that there was a decrease in the shell mass, without there being any signs of a parallel reduction in egg size or shell thickness. A decrease in shell density must therefore be responsible for the decrease in shell mass observed. The decrease may cause a decrease in structural strength of the eggshell and thus increase the risk of mechanical breakage. However, no such cases are known. The structural change of the eggshell may also be accompanied by metabolic changes in the female. Metabolic changes have been discovered in, amongst others, ATPase in the eggshell gland of hawks (Khan & Cutkomp 1982). Calcite depositing is a process where the active transport of calcite is needed over the outside of the eggshell gland and any change in the active ATPase concentration influences the quality of the eggshell (Lundholm 1982).

No significant decrease has occurred in length ($P=0,3617$), breadth ($P=0,2658$) or thickness ($P=0,1180$). However, a significant ($P=0,0168$) average decrease in the eggshell mass from 0,34 g to 0,287 g did occur (Table 1). This may be the effect of the locality because the majority of recent eggs came from an area with high agricultural activity. The calcium metabolism of birds is often influenced by organochlorine pesticides, it can thus be expected that the change in shell quality will differ from area to area. The problem is made even more complicated by the fact that some birds are regionally bound while others migrate.

Because eggshell mass is a factor in the determination of the eggshell index, this index will also show the trend observed with eggshell mass. The significant decrease ($P=0,0225$) is from 0,662 to 0,560 (Figure 1), which is equal to 0,102 or 15,4%. This decrease may lead to a weakening of eggshells but shell quality of the laughing dove is probably still adequate so that marked changes in the population density of this bird in the Western Transvaal are not yet noticeable.

No other environmental factor has changed significantly during the period represented, except for the introduction of organochlorine pesticides. For this reason it can be deducted that the organochlorine pesticides may be the cause of the change observed in the egg mass and index.

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