structed (fig.). PX (25 µg ml^{-1}) administered to the medium bathing the shark's head skin surface did not elicit observeable behavioral responses (within 10 min). However, when added to the medium bathing the shark's pharynx and the gills, PX immediately caused the shark to struggle severely.

Discussion. Free-swimming sharks previously were noted to respond to *Pardachirus* fish by avoidance, struggling and mouth paralysis while attempting to bite them[3] and PX also was shown to elicit a similar effect when applied to a shark positioned in a tank[16]. Therefore, it is likely that the struggling and mouth paralysis elicited by administration of PX into the medium of the pharyngeal cavity and the gills is related to its repellent action in sharks. At present, it is difficult to draw a connection between a transient increase in gill permeability to urea and the induced behavioral responses. Merely by increasing the seawater temperature from 15°C to 30°C evokes a 15-fold increase in the leakage of urea in sharks[23]. However, these sharks did not struggle or show mouth paralysis similar to those produced by PX. Therefore, an increase in gill permeability to urea alone does not appear to be the direct stimulus for the above PX-induced behavioral effects but rather resulted from an impairment of chemoreceptors situated in the gill and/or pharyngeal cavity. In the whole fish it is difficult to separate the water body which bathes the gills from these which flow through the pharyngeal cavity. Therefore, presently we cannot conclude as to PX acts on both of these organs or on one of them to produce its noxious effect. However, it was rather unexpected to find that the shark's main sensory system located at the head surface does not mediate PX's repellent action. In *S. acanthias* the gills are known to have respiratory and nonrespiratory function[17]. This study suggests that they could also mediate sensory responses to repellent substances. The in vivo results presented in this study are with agreement with the in vitro results from the isolated killifish gill-like epithelia.

In those studies PX elicited a net sodium flux from seawater side toward the body and an about equal leak on both sides to inulin[24]. The possible biological significance of the detergent property of the Moses sole secretion, could be that it promotes its spreading and absorption from the water into which it is released by the flatfish and facilitates its noxious action upon the gill and/or pharyngeal cavity membranes of predators.

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Sahara stopover in migratory flycatchers: fat and food affect the time program

H. Biebach[1]

Max-Planck-Institut für Verhaltensphysiologie, Vogelwarte Radolfzell, Radolfzell und Andechs, D-8138 Andechs (Federal Republic of Germany), 4 June 1984

Summary. Migrating spotted flycatchers, resting and feeding in an oasis, have longer stopover periods when fat reserves on arrival are low. In the laboratory migratory activity could likewise be suppressed by a combination of two factors: low fat reserves and the possibility of feeding.

Key words. Bird migration; stopover; fat reserves; time program.

The temporal course of fall migration in long-distance migrants is partly based on an endogenous[2], genetically determined program[3,4], which defines the onset and end of migration in inexperienced young birds. So far all efforts to manipulate this program experimentally by altering environmental factors[5] or the physiology[6-9] of the birds have failed. Food deprivation experiments at the beginning of or during the migration period did not affect migratory activity unless fat reserves were completely depleted[9]. This suggests a relatively inflexible endogenous program. On the other hand, field observations of short-distance migrants indicate relationships between migratory behavior, weather and physiology[10–12]. Here it is reported that spotted flycatchers (*Muscicapa striata*), resting and feeding in an oasis in the Libyan desert on their way to the African wintering area had longer stopover periods when fat reserves upon arrival were low. In an experiment simulating the situation encountered by a bird in an oasis, migratory activity could likewise by suppressed by a combination of two factors; low fat reserves and the possibility of feeding.

Material and methods. The field work was carried out at the oasis Baharia (28° 30'N, 28°55'E) in the Libyan desert, Egypt, where we measured body mass (to the nearest 0.1 g), fat score, feeding behavior and length of stopover periods. The subcutaneous fat reserves in the interclavicular fossa were scored[13] from 1 (not fat), 2 (trace of fat), 3 (solid sheet of fat decurved down), 4 (fat filling) to 5 (fat bulging out). This fat score can be taken as a good measure for total body fat.

Birds were caught with mist nets and individually color banded. The stopover period of birds at the oasis could thus be monitored by daily observations or by retraps. The time between the first and last trapping or observation was the minimum stopover period. The minimum stopover time was probably close to the actual stopover time because the oasis was only 28 ha and as a result easy to survey. Spotted flycatchers are very conspicuous because of their habit of sitting on the tops of bushes.

Results. The flycatchers landed in the oasis preferably in the forenoon. 84% (N = 234) stayed for the rest of the day and continued migrating the same evening. The others, however (16%, N = 45) stayed for more than two days and a few could even be seen after four weeks. Birds with a minimum stopover period between 2 and 29 days ($\bar{x} = 9.2$ days ± 6.1 SD) were significantly lighter ($\bar{x} = 13.9 \pm 1.7$ SD) when caught for the first time (arrival mass) than birds resting for only one day ($\bar{x} = 16.6$ g ± 1.6 SD, Wilcoxon-Mann-Whitney-U-test $p < 0.001$, fig. 1). 68% of the birds with an arrival mass below 15 g had a stopover period of more than one day compared to the birds over 15 g of which only 6% stayed longer than one day. Birds avobe 15 g had a significantly (Wilcoxon-Mann-Whitney-U-test $p < 0.001$) higher fat score (3.7 ± 0.75 SD) than those below 15 g (2.0 ± 0.88 SD). All these data indicate a strong effect of the birds' fat reserves on the stopover period. Direct observations, analysis of stomach contents[14] in 16 birds and the fact that the mean body mass increased by 2 g between 6 and 18 h during the day showed that practically all spotted flycatchers were feeding while they were in the oasis.

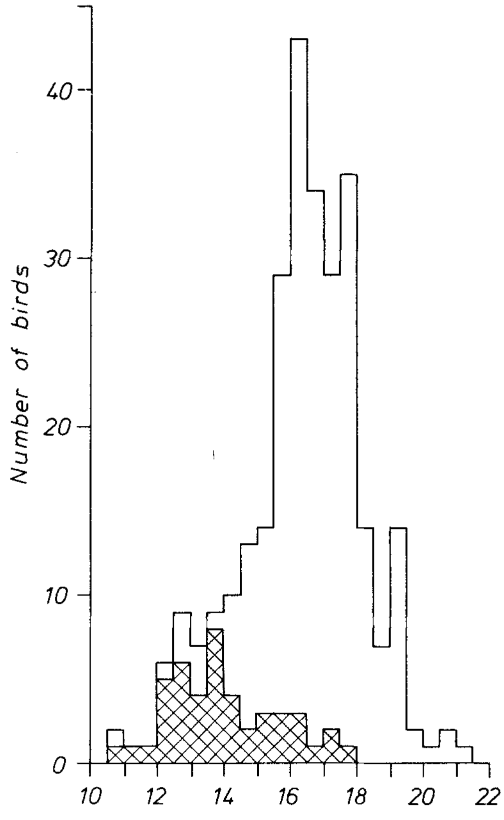

Figure 1. Frequency distribution of the body mass of migrating spotted flycatchers (*Muscicapa striata*) on arrival in an oasis in the Libyan desert, Egypt. Squares with crosses indicate birds which stayed between 2 and 29 days; empty squares indicate birds with stopover periods of only 1 day. The two groups are significantly different with respect to body mass and fat reserves (see text).

With this information about the behavior in a natural stopover place we designed the following experiment in the laboratory. Ten spotted flycatchers were hand-raised and kept in 120 × 120 × 50 cm cages in a room with the natural light conditions of Andechs (48°N, 11°11'E), Bavaria, and a constant air temperature of 20 ± 2°C (range). Migratory restlessness which is mainly expressed as whirring at night was recorded with an ultrasonic system[15]. All birds were fed a mixture of boiled eggs, dried insects and a few mealworms. The birds' body mass increased spontaneously in mid-August, the time when they also started to show migratory restlessness. After they had reached a steady level of about 20 g birds were deprived of food for five days until body mass decreased to about 14 g (fig. 2). With this body mass there were still some fat depots. The birds were then re-fed so that their body mass

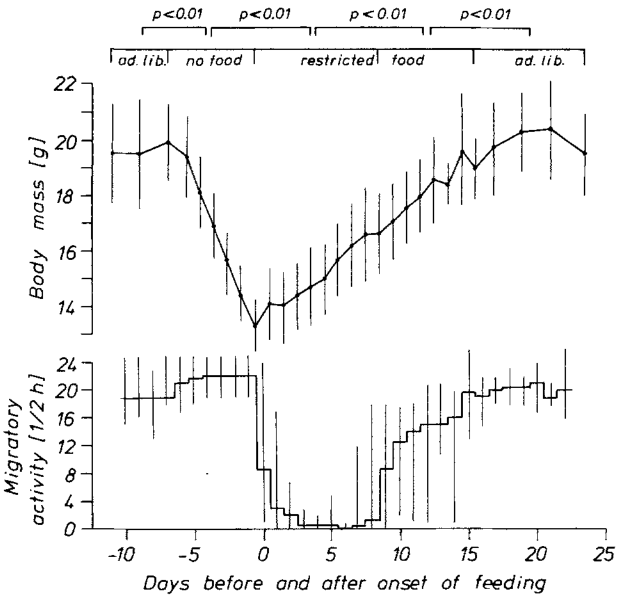

Figure 2. Migratory activity of 10 spotted flycatchers with different feeding schedules and body mass. Two identical sets of experiments were made, beginning at different times (5 September and 25 October) during the fall migratory period. There was no difference between the two groups, therefore the data were pooled and plotted on a relative time scale with 0 being the night following the first day with restricted food. Body mass was taken in the morning (9.00), then food was given according to the schedule and migratory activity was recorded the following night. The probability of a difference between the migratory activities during the different experimental stages is given on top (sign-test). Lines in the upper graph connect the means of body mass; vertical bars are standard deviations. In the lower graph horizontal lines give the median, the vertical bars the 95% confidence interval.

increased by 0.4 g per day, which corresponds to the daily mass increase found in other, similar bird species preparing to cross the desert[15]. After about 12 days food was again given ad libitum.

During the period preceding food deprivation, migratory restlessness had a value of about 19 half-hours/night (median). During food deprivation this value increased in all birds slightly, but significantly (sign-test, $p < 0.01$) to 21 half-hours/night. As soon as food was given again 8 birds immediately stopped showing migratory restlessness. In two birds it took three days before migratory restlessness ceased. There was practically no migratory restlessness while the birds deposited fat, until they reached a body mass between 16 and 17 g. From then onwards migratory restlessness developed gradually and eventually reached the initial level although body mass still increased.

Discussion. Two factors seem to be critical for the suppression of migratory restlessness during the night:

1) the body mass or the fat reserves and 2) the possibility of foraging or of gaining mass during the day.

The data on experimental and free-living birds are in accordance: in the field most birds (94%) arriving in the oasis with a body mass above 15 g continued to migrate the following night; in the laboratory, birds above 16–17 g showed migratory restlessness. Birds between 12 and 15 g at the oasis with the possibility of foraging interrupted migration and had a mean stopover period of nine days; the experimental birds with body masses between 13.5 and 16 g terminated migratory restlessness when food was given. This suggests that migratory timing in the flycatcher is not rigidly, endogenously fixed, but rather that the birds are equipped with a mechanism which allows adjustment to different environmental and physiological factors.

The time- and energy-related decisions can be summarized by the following hypothesis: An endogenous program has different setpoints of fat reserves during the migratory period in autumn. A bird with fat reserves above the setpoint will fly during the nights and rest during the days.

If the bird falls short of the setpoint it will interrupt migration provided that it has the chance to refill the fat depots. As soon as fat levels are above the setpoint it continues to migrate. If the feeding conditions are not sufficient for fat accumulation it will not stop for more than one day, and will continue to migrate until an adequate stopover place is reached. Superimposed on such a mechanism may be an endogenous program for the amount of migratory activity and a changing responsiveness to weather conditions. Besides the ecological context of these findings we now have, for the first time, a tool to manipulate migratory activity of captive long-distance migrants. This will enable researchers to tackle the problem of the internal mechanisms involved during the interaction of migratory activity, fat deposition and feeding.

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Natural selection for resistance to mercury pollution

R. Baker, B. Lavie and E. Nevo

Institute of Evolution, University of Haifa, Mount Carmel, Haifa 31999 (Israel), 12 June 1984

Summary. The survival under conditions of mercury pollution of two natural populations of the marine gastropod *Cerithium rupestre*, derived from mercury-polluted and mercury-free sites, was tested in the laboratory. The results indicate a significantly higher survival rate for animals derived from the mercury-polluted site, in each of six repetitive experiments. We conclude that mercury resistance in marine organisms is reinforced in mercury polluted sites, presumably by natural selection for increased resistance. The evolution of metal tolerance in marine organisms may be as fast as that of metal tolerance in plants and the evolution of industrial melanisms in moths.

Key words. Cerithium rupestre; gastropods; mercury pollution; mercury resistance; metal tolerance.

Evolutionary adaptation to a changing biotic or physical environment depends on available genetic diversity and on natural selection. We have shown earlier that allozyme genotypes are sensitive to and vary with the quality and quantity of specific thermal and heavy metal[1], as well as organic[2] pollutants. In multiple repetitive laboratory experiments we have shown significant differential viability due to diverse pollutants among allozyme genotypes of barnacles, shrimps and marine gastropods. We hypothesized that the differential viability found is associated with the different degree of heavy metal inhibition uniquely related to each specific heavy metal pollutant. Likewise, we have demonstrated in two closely related species of the marine gastropod *Monodonta* parallel gentoypic differentiation as a response to pollution.

Recently, we tested the geographic distributions of mercury tolerant allozyme genotypes of the enzyme phosphoglucomutase (Pgm) in the shrimp *Palaemon elegans* and the enzyme phosphoglucose isomerase in the marine gastropod *Monodonta turbinata* in a mercury-polluted site versus several unpolluted sites on the Israeli coast of the Mediterranean Sea. For both enzymes the level of mercury-tolerant allozyme genotypes was higher in the polluted than in the unpolluted sites[3]. The results