

TABLE 1. Analysis of variance of individual plumage character and hybrid index scores assigned to orioles collected at Big Springs, Nebraska in 1955-1956 (upper values) and Crook, Colorado (lower values).

Source of variation	Sum of squares	d.f.	Mean square	F
Individual plumage character scores				
Among plumage characters	117.22	8	14.65	9.64***
	190.78	8	23.85	20.92***
Between studies	0.44	1	0.44	.29 n.s.
	2.35	1	2.35	2.06 n.s.
Residual	478.56	314	1.52	
	316.15	278	1.14	
Hybrid index scores				
Between studies	4.69	1	4.69	.56 n.s.
	.78	1	.78	.10 n.s.
Residual	286.28	34	8.42	
	229.69	30	7.66	

n.s. = not significant at .05 level, *** $p < .001$.

braska and Crook, Colorado, that had been collected by Sibley and Short (1964). The character index scores that we assigned were compared to those of Sibley and Short (unpubl. data) using two statistical tests. First, we correlated the plumage character scores that we assigned to each specimen with scores assigned to the same specimens by Sibley and Short. All 20 correlation coefficients (nine for plumage character values and one for the hybrid index value for each of two localities) were significant at the .01 level.

Second, we compared the values assigned in the two studies by means of an analysis of variance (Table 1). The upper part of the table deals with the variation in individual plumage character scores, whereas the lower part concerns the hybrid index scores. Within the upper part, we partition the variance due to (1) inherent differences among the characters and (2) differences in the way individual character scores were assigned in the two studies. In the lower part of the table, only that variance due to differences between the assignment of scores is partitioned. For both localities the variance associated with the characters is significant ($P < .001$). That is, the among-character

variation associated with the nine plumage characters contributed significantly to the overall variance. On the other hand, the variance associated with the differences in the assignment of scores is not significant. It is not possible statistically to distinguish our scores from those of Sibley and Short (1964).

These results do not bear on the question of whether the hybrid index method adequately measures the degree of intermediacy of hybrid individuals. Rather, they show that using this technique, independent studies should obtain essentially identical results.

We thank L. L. Short for providing us with copies of the original scores assigned to specimens collected at Crook, Colorado and Big Springs, Nebraska.

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OLFACTION IN SNOW PETRELS

PIERRE JOUVENTIN

Birds were long considered to be chiefly visual animals but this idea has recently been questioned, owing to convergent findings in anatomy, ethology, and experimental physiology. Some birds seem to be much better at detecting odors than was thought formerly (Bang 1960, Cobb 1960a, Henton et al. 1966, Marshall 1960, Michelsen 1959, Stager 1964, Tucker 1965, Wenzel 1968, 1972, 1973).

Ornithologists have suggested olfactory capacities for certain procellariiformes (Murphy 1936, Miller 1942) and anatomists have demonstrated the remarkable development of the olfactory bulbs and sensory

epithelium (Bang 1960, 1966, 1971, Cobb 1960b). Bang and Cobb (1968) found the highest bulb/fore-brain index in this group (mean ratio of 29.4 for 11 species), second only to the Kiwi (*Apteryx australis*), which attains 34.0. The difficulty of keeping petrels in captivity doubtless explains the scarcity of experimental observations of their sense of smell.

I sought to study the olfactory capacities of the Snow Petrel (*Pagodroma nivea*), the species that is said to have the most highly developed olfactory bulbs (Bang 1965). Four non-breeding Snow Petrels were captured during the austral summer 1975-1976 at French base Pointe Géologie (Terre-Adélie) in Antarctica, but two could not be tested because they never adjusted to captivity, refusing all food. Owing to this difficulty, I had to diversify my techniques rather than repeat the same experiment.

I first accustomed the petrels to a diet of herring, which was odoriferous and similar to their usual diet of fish and shellfish. When they became used to taking pieces of fish, the birds became very tame, moving freely about the room, and experiments could begin.

For the first experiment, I hid about 20 g of fish in a piece of paper napkin, which was placed randomly, in a different way at each trial, among ten other control napkins that contained nothing. One of the petrels was then placed before the napkins; it walked among them and usually pecked at the one that contained the fish. In 14 2-min trials (10 with one bird, 4 with the other), only one attempt was directed toward a control napkin. I had to stop this experiment because the birds never succeeded in freeing the fish, and they became tired of this search for food of which they got only the smell.

In the second experiment, the petrels distinguished correctly between two opaque, invisibly perforated plastic drinking glasses, one of which concealed a piece of herring (8 out of 8 trials for one bird, 7 out of 7 for the other). They approached the glass under which the fish was hidden but could not overturn it to get the fish.

Since these birds seemed to have difficulty in solving new problems, I had to simplify the task for them. This supports Cobb's hypothesis (1960b) that learning capacity is inversely proportional to development of the olfactory bulbs. Plastic glasses split in half from top to bottom were then used to hide the piece of fish. A bird had only to get around the half glass in order to see and obtain the food. After a week of trials, the birds found the food regularly.

The same positive results were obtained with another method, discovered by chance. To avoid tainting the pieces of paper or the plastic control glasses, I always used the same hand to touch the fish. On five occasions (two for one of the birds, three for the other), the petrels were given a choice between hands. Each time, the birds pecked at the fingers which had touched the herring, ignoring the hand that lacked the fish odor.

Finally, I buried 15 pieces of fish in the snow inside a wire-netting pen. The petrels found 14 pieces within five min, whereas South Polar Skuas (*Catharacta maccormicki*) were never able to find a piece of fish that they had not seen me bury.

Although these few experiments by no means resolve the question of olfaction in the Snow Petrel, the results seem consistent and unambiguous. What is the biological meaning of such behavior? First, this sense of smell seems to play a part in the search for food because these birds have a varied diet, even feeding on dead seals. Snow Petrels, like Wilson's Petrels (*Oceanites oceanicus*), whose olfactory capacities have been demonstrated by Grubb (1972), are crepuscular. Along the edge of Antarctica, the limit of their range, days are short at the beginning and at the end of their summer nesting season.

Second, these birds generally nest in burrows between rocks, and regurgitate oily, partially digested food at the burrow entrance. They frequently squirt stomach oil during territorial disputes, and the oil (with its characteristic odor) accumulates to a thickness of up to 20 mm. The strongly smelling burrow of Leach's Petrel (*Oceanodroma leucorhoa*) was noted by Murphy (1936) and Stager (1967), both of whom suggested that the odor has a marking function. Grubb (1972, 1974) seems to have established that these petrels find their burrows by smell. It is probable that in the Snow Petrel also, odors emanate from the nest-hole entrance, guiding the bird to its burrow

among a jumble of rocks, even under a layer of snow, as reported by Falla (1937) and Brown (1966).

My work was supported by Expéditions Polaires Françaises and Terres Australes et Antarctiques Françaises. I thank C. Hopkins for help in translating and the reviewers for their comments.

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