Since Eylmann's day, a fourth pattern, produced by White-winged Chough *Corcorax melanorhamphos* using a valve or an intact mussel in its bill to pick or chisel open another intact mussel, has also been reported (Hobbs 1971; McDonald 1970).

I would like to thank John Calaby who helped me find some of the references and Vivian Courto for details about the life of Erhard Eylmann.

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# Poison in *Pitohui* Birds: Against Predators or Ectoparasites?

**Bent Otto Poulsen**

Zoological Museum, University of Copenhagen, Universitetsparken 15, DK 2100, Denmark

EMU Vol. 94, 128-129, 1994. Received 13-4-1993, accepted 23-6-1993

Dumbacher *et al.* (1992) reported three New Guinea passerine birds in the genus *Pitohui* to be poisonous. They contained varied concentrations of the steroidal alkaloid homobatrachotoxin, a substance hitherto found only in neotropical poison-dart frogs of the genus *Phyllobates* (Dendrobatidae). They found the concentrations of homobatrachotoxin to be highest in the skin and feathers. Dumbacher *et al.* (1992) suggested the substance might be a chemical defense against natural predators such as snakes, raptors, and possibly some arboreal marsupials.

From the concentrations of homobatrachotoxin presented in their paper, I calculated that the most poisonous frog *Phyllobates terribilis* contained 200-500 μg toxin per 0.1 g of skin. The most poisonous bird Hooded Pitohui *Pitohui dichrous* contained only 0.3-0.5 μg toxin per 0.1 g of skin, i.e. three orders of magnitude less. Potential predators of warning-coloured poison-dart frogs range from similar size spiders through small reptiles to birds, but they normally avoid the frogs (Crump 1983; Fritz *et al.* 1981; Szelistowski 1985). It may thus require considerably higher concentrations of toxin to affect seriously predators of even much smaller size than the pitohui predators suggested by Dumbacher *et al.* (1992).

The possible evolution of homobatrachotoxin in pitohuis raises certain difficulties in considering the proposed bird predators. A raptor such as an *Accipiter* will catch and kill the pitohui in its talons before the poison gets in contact with its mucous membranes. In this context it is difficult to imagine how a few, slightly toxic mutant individuals in an ancestral unpoisonous population of pitohuis could have survived in favor of unpoisonous individuals, eventually evolving into a poisonous population. In poison-dart frogs, predators such as spiders taste the poison on the skin with their legs and pedipalps without puncturing and killing the frogs with their chelicerae (Szelistowski 1985). Snakes may also taste the poison on the skin of bird nestlings without killing them (D. Murray & B. Beehler pers. comm.). In both cases natural selection may work directly on the genetic variation in the population. A raptor may feel the contact with a pitohui unpleasant, but it will only avoid killing the species in the future, if it recognises the species as unpleasant before the attack. In this context Dumbacher *et al.* (1992) mentioned that warning colours (see below) and a strong sour odour accompanied the toxin in pitohuis. However, raptors normally hunt by sight instead of using the sense of smell, which is poorly developed.

Considering warning colours present in Hooded Pitohui Dumbacher *et al.* (1992) suggested an evolution of mimics in four races of the less poisonous Variable Pitohui *Pitohui kirhocephalus*. They do resemble the more poisonous model Hooded Pitohui, but according to the literature (Beehler *et al.* 1986) the model and the mimic species do not appear to live together, a necessary condition for Batesian mimicry to function. When a mimic is congeneric, it is also difficult to exclude the possibility that the plumage resemblance simply is due to phylogenetic relationship. If the four races were mimics, it would be wasteful from an evolutionary point of view to produce the toxin when protection is accomplished by mimicking the morphology of the model. One may perceive the Variable Pitohui plumages (black/chestnut; brown/chestnut; gray/chestnut/yellowish) as a warning colouration, but it is not typical (black/red; black/yellow; black/orange; yellow) as found in many arthropods, frogs and snakes (Solbrig & Solbrig 1981).

Rather, I suggest that the poisonous skin and feathers of *Pitohui* birds primarily evolved as an ectoparasite repellent. This is in accordance with the principal site of toxin accumulation (skin and feathers), the small concentrations of toxin in *Pitohui*s and a possible way of toxin evolution.

Considering the often heavy infestation by ectoparasites on birds (especially pitohuis, B. Beehler pers. comm.), and the difficulties of reaching all parts of the plumage with the bill while preening, birds may need additional devices to keep their ectoparasites at a low level. Bird uropygial gland secretions often contain effective bacteriocides and fungicides. This function is well documented (Jacob 1978) but usually neglected in the ornithological literature. In this context it is not difficult to imagine that such substances may have an arthropod repellent effect as well. Unfortunately, no experimental data on the effects of preen gland secretions on arthropod ectoparasites are available to date. Research on ectoparasites on *Pitohui* birds would probably help to clarify some of the above suggestions.

## Acknowledgements

This paper was written under a grant (11-9116) from The Danish National Science Research Council, Copenhagen. I thank Jon Fjeldså, Jørgen Rabøl, José Cardoso da Silva, Michael M. Svendsen and the referees Bruce Beehler and Durno Murray for valuable comments on the manuscript.

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