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FOOD TRANSIT RATES IN CAPE GANNETS AND JACKASS PENGUINS¹

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Key words: Food transit rates; seabirds; carmine red marker.

Food transit rates in the Jackass Penguin (*Spheniscus demersus*), a piscivorous seabird, are slower (Duffy et al. 1985) than rates of birds with other diets (Warner 1981). However, digestive performance by the Jackass Penguin may not be typical of fish-eating seabirds. Food transit rates through the digestive tracts of volant seabirds might be faster than those of flightless species, since meals would represent a considerable addition to the body mass that would have to be lifted during flight. Rapid digestion and extraction of water from prey would reduce meal-mass (Ashmole 1971). We tested this hypothesis by comparing transit rates through the digestive tracts of Cape Gannets (*Morus capensis*) with existing data on Jackass Penguins and Cape Gannets (Davies 1956, Duffy et al. 1985).

MATERIALS AND METHODS

To measure transit time through the entire gut, the methods of Duffy et al. (1985) were followed. Four captive adult Cape Gannets were maintained on a diet of thawed Cape pilchard (*Sardinops ocellata*) supplemented by vitamin and salt tablets. Live fish (*Tilapia sparminii*) were injected intramuscularly with 0.5 ml of 10% carmine red solution and killed two hours later. Live pilchard were not available. Two experiments of 24- and 43-hr duration with two and three birds, respectively, were conducted. In both experiments the birds were starved for 24 hr to ensure empty stomachs and were then fed 10 *Tilapia* each. The average meal size per bird was 263 g (10% of gannet body mass, 2.6 kg) and 183 g (7% of gannet body mass) for the 24- and 43-hr experiments, respectively. Wilson et al. (1985) concluded that meal size did not affect digestion rate of Jackass Penguins, so we assumed that that the difference in meal size did not affect digestion by Cape Gannets.

During the experiment, individual birds were kept on a wire-mesh grid and the feces collected on plastic sheets

beneath the cages. The sheets were changed every hour. The methods of Duffy et al. (1985) were slightly modified during preparation of the samples to ensure a more rapid stabilization of the color of the solution: the feces were washed off the plastic sheets with distilled water and passed through a small meshed sieve. The resulting solution was made up to a constant volume (300 ml). Samples of the solution were analyzed for the red color of carmine using a spectrophotometer set at 520 nm.

Data were expressed as cumulative percentages hr⁻¹ of the total amount of marker recovered in 24 and 43 hr and the time taken for 5%, 50% and 95% of the marker to be recovered. The mean retention time (t) was calculated:

$$t = \frac{\sum_{i=1}^n x_i t_i}{\sum_{i=1}^n x_i}$$

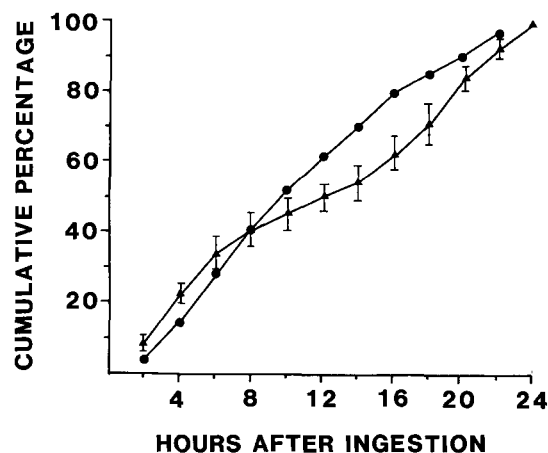


FIGURE 1. Cumulative percentage of carmine from *Tilapia* meals excreted by Cape Gannets (▲; $n = 5$) and Jackass Penguins (●; $n = 6$; Duffy et al. 1985) over 24 hr. Vertical bars are standard deviations.

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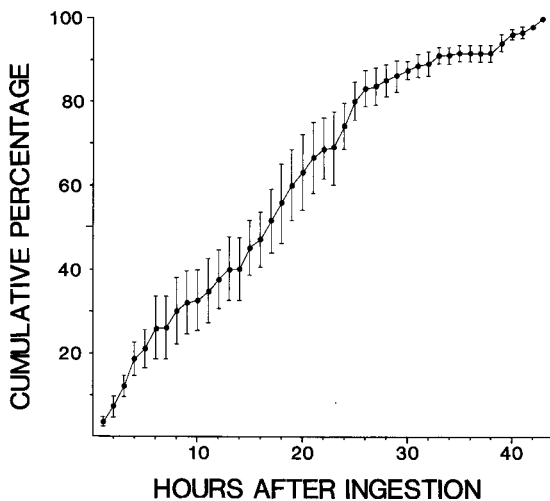


FIGURE 2. Cumulative percentage of carmine excreted from *Tilapia* meals by Cape Gannets ($n = 3$) over 43 hr. Vertical bars are standard deviations.

where x_i is the amount of marker excreted at time t_i (Warner 1981). Because we were dealing with relative and not absolute marker concentrations, we included the data from the first 24 hr of the 43-hr experiment in the comparison of gannet transit rates with those of penguins, thus increasing the gannet sample size from two to five.

RESULTS AND DISCUSSION

Rate of recovery of carmine appeared to be relatively constant throughout the 24-hr sample period (Fig. 1), but there was some evidence of an asymptote being reached after about 32 hr in the 43-hr samples (Fig. 2), suggesting that digestion was complete. In the 43-hr experiment, green bile appeared in two of the three birds at 28 and 39 hr. The occurrence of bile suggests that increases in optical density after about 30 hr are likely to be the result of increasing production of bile, rather than further recovery of carmine.

Comparison of the cumulative percentages of marker excreted by Cape Gannets and Jackass Penguins (Fig. 1) over 24 hr suggests a slightly faster rate for gannets than penguins in the first eight hours after ingestion, but a reversal of the rates thereafter. However, the time needed to excrete 5%, 50% and 95% of the markers did not differ significantly at the 0.05 level (Table 1). The mean retention times of markers were 12.17 hr in gannets and 11.13 hr in penguins; again the difference is not significant at the 0.05 level.

Earlier work has shown that the percentages of ingested meals left in the stomach of gannets were 70% at 1 hr ($n = 1$); 65% and 59% at 2 hr ($n = 2$); and 50% at 3 hr ($n = 1$; Davies 1956). In penguins ($n = 2$ for each sample), 87% was left after 1 hr; 88% at 2 hr, and 71% at 3 hr (Wilson et al. 1985). The sample sizes are too small to test the significance of the differences, and the methods used to recover food were quite different; Davies killed his birds and extracted meals by dissection, whereas Wilson et al. used a stomach pump (Wilson 1984). Nevertheless, if the results are representative, they suggest that both species have basically similar rates of food passage through the entire digestive tract but that breakdown of meals and clearance through the anterior portions is more rapid in the gannet. The gannet, the flying species, appears to digest food more rapidly initially than does the flightless penguin, perhaps facilitating reduction of the energetic cost of flying.

TABLE 1. Times (hr) necessary to excrete different amounts of markers (t = mean time to excretion; JP = Jackass Penguin, $n = 6$ birds; CG = Cape Gannet, $n = 5$ birds). The t -statistics were not significant at the 0.05 level.

| Percentage | Mean (hr) | | Standard deviation | | t -statistic |
|------------|-----------|-------|--------------------|------|----------------|
| | JP | CG | JP | CG | |
| 5% | 2.83 | 1.55 | 1.25 | 0.61 | 2.215 |
| 50% | 10.33 | 12.81 | 1.86 | 3.03 | 1.672 |
| t | 11.13 | 12.17 | 1.17 | 1.74 | 1.183 |
| 95% | 21.08 | 22.11 | 0.92 | 1.55 | 1.503 |

Maximum continuous power for flight (Berger and Hart 1974) is:

$$P = 0.29 W^{0.72} \text{ kcal hr}^{-1}$$

so a 50% reduction in the mass of a meal after digestion will represent a savings of only 4% of total power needed for a meal equal to 10%, and 7% of the power for a meal equal to 20% of body mass of a Cape Gannet (2.6 kg). While the energetic costs of transporting undigested food appears to be small, Davies (1955) reports that "gorged birds sitting on the water experience great difficulty in becoming airborne and if alarmed will regurgitate stomach contents vigorously before taking off." Captive White-chinned Petrels (*Procellaria aequinoctialis*), another flying species, showed a similar rate of stomach evacuation (73% remaining after 1 hr; 63% after 2 hr; and 19% after 4 hr) to that of the Cape Gannet, again faster than that of the Jackass Penguin (Jackson and Ryan, unpubl.).

We suggest that our results be repeated for other seabirds with particular attention to passage rates in the anterior parts of the digestive tract, where rapid removal of water may be the most efficient way to rapidly remove mass from meals.

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GALAPAGOS MOCKINGBIRD KLEPTOPARASITIZES CENTIPEDE¹

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Key words: *Galápagos; mockingbirds; Mimidae; Nesomimus; centipedes; Scolopendra; kleptoparasitism; opportunistic foraging.*

Kleptoparasitism of arthropods by birds is rare. In a review of kleptoparasitism in birds, Brockman and Barnard (1979) cited two examples involving arthropod hosts: anti-birds occasionally steal prey from tropical army ants; and a few North American land birds, especially House Finches (*Carpodacus mexicanus*; Brockman 1980), sometimes kleptoparasitize digger wasps. Here I describe an additional example of a bird kleptoparasitizing an arthropod. In this instance, a Galápagos mockingbird, *Nesomimus parvulus*, stole food from a Galápagos centipede, *Scolopendra galapagaea*.

I made the following observations on Isla Genovesa, Galápagos, during my research on cooperative breeding in Galápagos mockingbirds (see Kinnaird and Grant 1982; Curry, in press). While making a routine census of the study area on 9 January 1985, I encountered a banded adult mockingbird that was inspecting shallow crevices between flat plates of lava that covered the ground. Shortly after I found the bird, it stopped foraging and walked to the edge of a narrow crevice where a centipede about 20 cm long was moving in the litter. The mockingbird stood motionless watching the centipede for 20 sec and then suddenly thrust its head into the crevice. It withdrew immediately holding in its bill a large wingless cricket that had either been flushed or captured by the centipede. The bird jumped upward, avoiding the head of the centipede which partially emerged from the crevice, and backed away a few meters. The centipede immediately resumed foraging in the crevice.

The mockingbird ate the cricket and returned to its position above the crevice. After staring downward for 60 sec, the mockingbird again reached into the crevice. This time I saw it take another large cricket directly from the centipede's mouthparts. The centipede crawled completely out of the crevice and approached the mockingbird; the bird jumped back with its wings raised and retreated. After the bird had moved off about 3 m, the centipede returned to the crevice. The mockingbird spent 3 min eating this cricket and then returned to the crevice at the point where I had last seen the centipede. The bird waited at the crevice 70 sec and then walked away, resuming normal foraging; it did not search further for the centipede.

This is a clear but isolated case of kleptoparasitism by a mockingbird. It is the only observation of its kind I have made in Galápagos, though I spent 20 months studying mockingbirds between 1981 and 1985. I know of no previous reports of kleptoparasitism by mockingbirds in the islands.

Why isn't kleptoparasitism of centipedes by Galápagos mockingbirds more common? Opportunistic behavior should facilitate the evolution of kleptoparasitism (Brockman and Barnard 1979), and the four species of Galápagos mockingbirds (*Nesomimus* spp.) are certainly opportunistic. Throughout the archipelago mockingbirds have broad diets that include many different animal foods including insects, lizards, carrion, feces, seabird regurgitate, and seabird eggs (Bowman and Carter 1971), morsels picked from the teeth of sleeping sea lions (*Zalophus californianus*) (Trimble 1976) and, on some islands, ticks and live skin pulled from land iguanas (*Conolophus subcristatus* and *C. pallidus*) (Christian 1980). Española Mockingbirds (*N. macdonaldi*) even feed on blood from live marine iguanas (*Amblyrhynchus cristatus*), sea lions, and seabird chicks (Curry and Anderson, in prep.). The incident described above is an additional example of a Galápagos mockingbird opportunistically exploiting another animal, yet kleptoparasitism of this kind occurs only rarely.

Four factors are probably involved in preventing kleptoparasitism of centipedes by Galápagos mockingbirds from becoming more common.

1) Mockingbirds seldom interact with centipedes. Centipedes are neither abundant nor gregarious in the habitats where I studied, and they are primarily nocturnal. When centipedes are active during daylight hours they tend to remain hidden under lava plates. Encounter rates are probably low enough to prevent mockingbirds from specializing as centipede kleptoparasites even though large crickets, such as those I saw taken from the centipede, are valuable food items that are readily eaten by adult mockingbirds or fed to nestlings.

2) Centipedes are valuable mockingbird prey. When a mockingbird finds a centipede, it usually tries to eat it rather than attempting to kleptoparasitize it. I frequently saw mockingbirds, sometimes in groups, attack and kill centipedes on Genovesa, Española, and Champion, and I saw them feed small centipedes to nestlings on Genovesa and on Santa Cruz. Bowman and Carter (1971) also saw mockingbirds eat centipedes on Darwin and Santa Cruz. Occasional kleptoparasitism of centipedes by mockingbirds, then, has probably derived from predation (Brockman and Barnard 1979).

3) Most centipedes are small. These are probably unable

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