Articles

THE FEEDING SPECIALIZATION IN CHIRODERMA DORIAE (PHYLLOSTOMIDAE, STENODERMATINAE) WITH COMMENTS ON ITS CONSERVATION IMPLICATIONS

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Taddei (1973, 1980) demonstrated that feeding habits of some Neotropical fruit-eating bats, such as *Chiroderma doriae* has specific food requirements. As we report below, this author presented consistent evidence associating *C. doriae* to fruits of *Ficus*, a resource that may play a keystone role in tropical forests (Terbogh, 1986, Shanahan *et al*. 2001). However, very few data on the feeding habits of this bat have appeared in the literature and the feeding specialization reported by Taddei (1973, 1980) has been largely overviewed (Nowak 1994, Eisenberg & Redford 1999, Shanahan *et al*. 2001).

During recent fieldwork at the Botanical Garden of Rio de Janeiro, southeastern Brazil, we obtained new data on the feeding ecology of *C. doriae* bringing additional support for the contention that this bat has specific food requirements. On the basis of fecal sample analysis and captive feeding experiments we have noticed that *C. doriae* as well as its congener *C. villosum* act as seed predators, rather than dispersers, of the small *Ficus* seeds (Nogueira & Peracchi, in press). This previously undocumented feeding strategy in bats was observed for individuals of both sexes, all age classes, all reproductive status, and in both dry and wet seasons. The utilization of seeds, in addition to fruit pulp, probably represents an improvement in the acquisition of nutrients available in figs, evincing a specialized potential to explore this resource.

Below we briefly review available data concerning feeding habits of *C. doriae* and its poorly known congeners, as well as report data on capture sites of *C. doriae*. Since this bat is widely recognized as an endangered species (Aguiar & Pedro 1998, Aguiar *et al*. 1998, Bergallo *et al*. 2000, Hutson *et al*. 2001), in sequence we present some comments on potential conservation implications for bats with specialized fig diet. Our main objective with this contribution is to emphasize that current evidence associating *C. doriae* to native figs seem to be consistent enough to influence further studies and conservationist strategies related to this bat.

Cover photo: *Noctilio leporinus* - Marco Aurélio R. Mello

FEEDING EVIDENCES AND CAPTURE SITES

Taddei (1973, 1980) conducted the first comprehensive study on the feeding habits of *Chiroderma*. Between 1967 and 1978 this author sampled 56 specimens of *C. doriae* in the state of São Paulo, southeastern Brazil, all of these specimen were captured close to fig trees (*Ficus enormis* and *Ficus* sp.). A single specimen was netted carrying the fruit from *Chlorophora tinctoria*, another Moraceae. According to Taddei (1973, 1980) *C. doriae* is a relatively abundant species, but only when figs are fruiting and encountred areas where these plants are also abundant. He also reported that several attempts to maintain this species in captivity by providing fruits regularly consumed by other frugivorous bats were unsuccessful. Positive results, with specimens being kept for a 30-day period, were only obtained when native figs were offered to them. In almost all aspects, these observations about *C. doriae* are also valid for *C. villosum*, but data on this latter species only appeared in Taddei's (1973) doctorate thesis. The unique difference was that *C. villosum* was relatively less abundant then *C. doriae*.

Although scarce and usually based on few specimens, subsequent data on the diet of *Chiroderma* seem to confirm Taddei's (1973, 1980) observations. These data came from studies in Panama (*C. trinitatum* and *C. villosum*, Bonaccorso 1979, Wendeln *et al*. 2000), Brazilian Amazon (*C. trinitatum*, Reis & Peracchi 1987, Taddei *et al*. 1990), and southern-southeastern Brazil (*C. doriae*, Sipinski & Reis 1995, Esbérard *et al*. 1996a, Faria 1996, Pedro & Taddei 1997, Tavares, 1999). With the exception of *C. trinitatum* (Bonaccorso 1979) and *C. villosum* (Wendeln *et al*. 2000) in Panama, and *C. doriae* in Rio de Janeiro, Brazil (Esbérard *et al*. 1996a), all other specimens reported in such studies only exhibited evidence of *Ficus* consumption. From a sample of 32 specimens, Esbérard *et al*. (1996a) reported the following records: one individual carrying a mature fig, another with pollen on its head, and three fecal samples containing, respectively, seeds of *Ficus* sp., *Piper* sp., and fruit pulp. Although *Piper* and floral resources may further prove to be important food items to *C. doriae*, we believe that these records alone constitute a weak support for the contention that this bat is not a fig specialist, as argued by Esbérard *et al*. (1996a).

Bonaccorso (1979) did not report identification of all plants used by *C. trinitatum* in Panama, but mentioned *Ficus* as the most important genus, having been found in 60% of the five available fecal samples. Better supported by an exceptional large sample size, data from Wendeln *et al.* (2000) also corroborate a diet specialization. They reported that 98% of the 60 fecal samples obtained from Panamanian *C. villosum* indicated *Ficus* consumption.

Data in the localities and particular sites where *C. doriae* has been sampled also appear to be in agreement with the feeding specialization of this bat on native *Ficus*. In São Paulo, southeastern Brazil, Faria (1995) reported the occurrence of *C. doriae* at the Reserva de Santa Genebra, a 250-ha urban forest fragment where at least four native species of *Ficus* are used by bats. Phenological studies in this area have shown that the *Ficus* community guarantees a year-round food supply for vertebrate frugivores (Figueiredo, 1996). The unique series of *Chiroderma* (5 specimens) obtained by Teixeira and Peracchi (1996) in a year-round study at the Parque Estadual da Serra da Tiririca, in the state of Rio de Janeiro, was obtained in a single night when the nets were opened close to a fruiting *Ficus gomeleira*. In the city of Rio de Janeiro, the majority of the 32 specimens of *C. doriae* (ca. 80%) reported by Esbérard *et al.* (1996a) were sampled at the Maciço da Tijuca, where several native species of *Ficus* have been documented (Carauta 1989, 1993). Furthermore, in two other localities listed by these authors the captures were performed close to individuals of *F. tomentella* (Esbérard 1998).

Among the several localities where *C. doriae* has been found, one, the Quinta da Boa Vista, in Rio de Janeiro (Esbérard *et al.* 1996a), deserves particular attention due to its unique characteristics. This small urban park (ca. 50 ha) is totally surrounded by densely populated areas, but harbors several individuals of *F. tomentella* among its almost 2,300 trees. Although the presence of *C. doriae* in this area needs to be better investigated, it indicates some flexibility of this species to colonize or at least forage in urban areas if its particular food resource is available. The most widespread *C. villosum* was not sampled at Quinta da Boa Vista (Esbérard *et al.* 1996b), and at the Botanical Garden of Rio de Janeiro it was recorded in much lower density than *C. doriae* (ratio of approximately 1:5; M.R. Nogueira, unpublished data), corroborating data presented by Taddei (1973). Assuming that our sampling method at the Botanical Garden was adequate, it shows that this species may be more prone to local extinction than its sympatric congener.

In all respects our observations at the Botanical Garden of Rio de Janeiro confirm the *Chiroderma*-fig association (Nogueira and Peracchi, in press; M.R. Nogueira, unpublished data). As far as we know, our total sample of *C. doriae* (86 captures) is the largest ever reported from a single locality. This can be attributed not only to our capture effort under fruiting fig trees (49 individuals in eight netting sessions), but also to the abundance of these trees in the Botanical Garden and in the adjacent Tijuca National Park. At least five adult individuals of *F. tomentella* and two of *F. cyclophylla* are scattered over the 54-ha area of the arboretum, and frugivorous bats caught in this area have defecated seeds of at least three other species of native *Ficus* that may also be used by *Chiroderma*. From a total of 100 specimens of *Chiroderma* sampled at the Botanical Garden, 54 were captured under fruiting figs, 39 in association to other resources (*e.g.*, trials, flowering trees, bodies of water), but when *Ficus* fructification was indirectly recorded (figs carried into the nets and fig-seeds present in fecal samples), and only seven (7%) were obtained in nights when we failed to find evidence of *Ficus* fructification. A comparison of these proportions with those recorded in the same study for *Artibeus obscurus* (a common fig-eater in the Botanical Garden) illustrates the strong association between *C. doriae* and fruiting fig trees ($X^2 = 94.71$, d.f. 2, $P < 0.001$). We recorded 32 captures of *A. obscurus* under fruiting figs, 191 when secondary evidence of *Ficus* fructification was found, and 97 during nights with no evidence of fig availability.

Conducted prior to our fieldwork under fruiting figs, netting sessions close to *Caryocar* flowering trees at the Botanical Garden of Rio de Janeiro resulted in a sample of 12 specimens of *C. doriae* and four of *C. villosum*. None of these, however, had pollen loads on their pelage or wing membranes, as detected in specimens of *Artibeus* captured in the same nets. Since *Artibeus* fecal samples containing fig-seeds indicated that figs were fruiting during most of the netting sessions under flowering trees, we suspect that the capture of *Chiroderma* under this circumstance was not associated to floral resources. An alternative explanation to the presence of these bats under flowering trees could be their attraction to distress calls that other stenodermatines frequently emitted when they were being taken from the nets.

As we discuss in the paper describing fig-seed predation (Nogueira & Peracchi, in press), data gathered in the Botanical Garden of Rio de Janeiro indicate that *C. doriae* and *C. villosum* are more specialized in the use of figs than any other frugivorous bat studied. They use a strategy that is, in part, similar to that observed in other fruit-eating bats (Fleming 1986), but include additional steps that make it possible for them to optimize nutrient gain. A basic question regarding the possible dependence of *C.*

doriae on wild species of *Ficus*, is to which extent this bat is able to survive on an exclusive fig diet. Wendeln *et al.* (2000) argued that, by feeding on a combination of *Ficus* species, even bats that do not digest seeds could obtain a complete set of nutrients. Taking into account that seed predation is expected to result in a significant additional intake of protein and energy (Morrison 1980), it seems reasonable to assume that a strict fig diet is possible for *C. doriae*.

CONSERVATION IMPLICATIONS

Due to its restricted geographic range (eastern and central Brazil to Paraguay, Gregorin 1998; López-González *et al.* 1998; Vizotto and Guerra, 1981) and occurrence in habitats under severe anthropogenic pressure (e.g., Atlantic Rain Forest), *C. doriae* is widely recognized as a "threatened" species (Aguiar and Pedro 1998, Aguiar *et al.* 1998, Bergallo *et al.* 2000; Hutson *et al.*, 2001). Little is known about its tolerance to habitat disturbance, and assignments of rarity (e.g., Marinho-Filho, 1985; Reis *et al.*, 2000) need to be interpreted with caution. To access local abundance of *C. doriae* it appears essential to estimate local abundance of native species of *Ficus* and conduct an adequate sampling effort at these potentially selected food resources. Such an approach, however, will require a close monitoring of individual trees, since fruiting periods in *Ficus* are very short (1-2 weeks) and unpredictable (Morrison 1978).

Although additional studies are necessary to evaluate to which degree populations of *C. doriae* really depend on wild *Ficus* to maintain their viability, data gathered here seems to be consistent enough to sustain that the status of *Ficus* populations should be considered when the conservation of this bat is under discussion. The typical phenology (intra-tree synchrony and inter tree asynchrony) that makes *Ficus* specially suited to sustain specialized consumers is also essential to maintain the life cycle of their species-specific pollinator wasps (Frank 1989, Figueiredo & Sazima 1997). According to McKey (1989), when the fig population in a particular area is reduced below a minimum critical size, which can result from fragmentation, temporal gaps between flowering trees may lead to the local extinction of the fig-wasps and, consequently, of the fig population itself. It is important to emphasize that the presence of fig trees in an area does not mean fig (fruit) availability (Mello-Filho *et al.* 2000). In Brazil several fig species are classified as "endangered" or "vulnerable" (Carauta 1989) and human intervention through the cultivation of seedlings in conservation units has been considered an important strategy to avoid their local extinction (Mello-Filho *et al.*, 2000).

Using a common and widespread fruit bat (*Artibeus jamaicensis*) as an example, Shanahan *et al.* (2001) argued that an animal species that is a fig specialist at one site or time may not be elsewhere. As far as we know, there is no evidence suggesting that such plasticity could also characterize *C. doriae*. If this bat is not a seasonal or a regional specialist, as we suspect, areas where species of *Ficus* occur at low densities or are absent will not harbor its populations. In a long-term study conducted by Mello (2002) in the fragmented landscape of the Reserva Biológica Poço das Antas, state of Rio de Janeiro, this prediction seems to have been confirmed. Not a single specimen of *Chiroderma* was found, though almost 2600 bats had been captured. In accordance with Mello (pers. comm.), a lot of *Cecropia pachystachya* seeds were present in fecal samples obtained from stenodermatine bats collected in this area but no sample was positive for fig-seeds. At least four species of *Ficus* are known to occur in Poço das Antas (Guimarães 1988), but we are not aware of their reproductive potential.

Another point that deserves further attention is that not all sets of bat-consumed *Ficus* species may be equally adequate to sustain the populations of *C. doriae*. Studying bat-fig relationships in a forested site in Panamá, Kalko *et al.* (1996) found a positive correlation between the size of the fruits and the body mass of the bats that forage on them. At the Botanical Garden of Rio de Janeiro *F. clusiifolia* was frequently found in fructification during our study, but fecal sample analyses showed that medium to large bats (>20g) do not forage on its small fruits (4-8 mm in diameter).

Among birds there is a conspicuous case of feeding specialization on wild figs. The threatened vulturine parrot (*Psittrichas fulgidus*), endemic to the island of New Guinea, is considered an extremely specialized frugivore feeding on a few species of *Ficus* (Mack & Wright 1998). An occasional consumption of flowers is possible, but Mack and Wright (1998) believe that, alone, it would not represent an adequate diet. The active flight capacity of bats and birds, which may imply in an ability of commuting and foraging over wide areas, appears to be an essential requirement for such extreme specialization on figs. Studying the role of figs as a potential keystone resource for frugivorous vertebrates in African rain forests, Gautier-Hion and Michaloud (1989) concluded that they constitute a major food item for large bats only, which are known to have wide-ranging abilities. Mack and Wright (1998) discussed the range requirements of vulturine parrots and pointed out that although daily home range may be quite small (enclosing a few fruiting figs), the year-round home range needs to be much larger, particularly where figs occur at low densities. If the

feeding specialization emphasized here is correct, similar range requirements can be expected to be valid for *C. doriae* populations. Studies focusing on this testable hypothesis could bring important insights to our knowledge of this bat and help in the generation of more effective plans for its conservation.

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FISH CONSUMPTION BY NOCTILIO LEPORINUS *(LINNAEUS, 1758) IN GUARATUBA BAY, SOUTHERN BRAZIL*

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ABSTRACT

Throughout 1999, the fishes consumed by *Noctilio leporinus* were documented in a salt-water ecosystem, by analysing the feces of bats captured in mist nets. Of the 55 samples analyzed the most frequent fish species were *Atherinella brasiliensis, Mugil curema, Cetengraulis edentulus, Opisthonema oglinum* and *Harengula clupeola*. The quantitative result was similar to that obtained in other studies conducted in Puerto Rico, but not qualitatively.

Keywords: Noctilionidae, bat diet, piscivorous bats, mangrove ecossistem

INTRODUCTION

Feces collection of bats which have been captured in order to study the diet in tropical biomes, are more common for fruit-eating species (Sipinski & Reis 1995). Therefore, studies involving carnivorous or piscivorous species are very limited (Nowak 1994). The recent studies available in the literature about the diet of *N. leporinus* use different study methods, such as stomach content analysis of captured bats (Cervantes & Solorzano 1991) or collection of fecal material deposited in their shelters (Hood & Jones 1984, Brooke 1994). In Brazil, the study by Willig (1985) verified that *N. leporinus* consumes fish and insects, but does not specify which one or the frequency with which these items occur in the diet.

The aim of the present study was to obtain data about fish consumption by *N. leporinus* in a salt-water ecosystem on the southern coast of Brazil by collecting and analyzing feces obtained from bats captured during their foraging activities. The study was carried out in Guaratuba Bay (Chaves *et al.* 1998) from January to December 1999. Four nights of capture were carried out every month, between 18.00 and 06.00 o'clock, using three mist nets of 2.6x9 m in size, with a black mesh and 38mm in length (CH9 Avinet, Inc. USA model), located perpendicularly to the bank and above the water surface. Each captured bat was placed in a black cotton bag, remaining there until 12.00 o'clock the following day, in order to obtain the feces. These samples were preserved in 10% formol and later analyzed in the laboratory. Each captured bat was released the night after it was captured, at dusk.

The fish scales found in the bat's scats were compared with those from the collection of the Departamento de Zoologia at the Universidade Federal do Paraná. It was not possible to identified the invertebrates found in the scats, because the material was very fragmented.

Fecal samples from 55 individuals of *N. leporinus* were obtained, containing six fish families distributed in eight species. The Atherinopsidae family was the most frequent in the scats, followed by the Mugilidae, Clupeidae (sardines) and Engraulidae (anchovies) families. The Centropomidae and Carangidae were the least frequent in the *N. leporinus* diet (Table 1). Most of the samples collected (68.75%) only had one species of fish, while 14 samples (29.16%) contained two species and one sample (2.08%) contained three different fish species.

The data obtained in this study show that the ichthyofauna present in the *N. leporinus* diet is varied. Quantitatively, this result was similar to that obtained by Brooke (1994), who recorded eight fish species from eight different families in Puerto Rico. However, qualitatively, the fish species present in the diets were different, even though both studies presented Atherinopsidae and Clupeidae families in the *N. leporinus* diet. This must be due to the particularities of the ichthyofauna in each study location.

The Mugilidae, Centropomidae and Carangidae families identified in the bats of Guaratuba were not cited by Brooke (1994). But Cichlidae (*Oreochromis*