Predation risk of whole-clutch filial cannibalism in a tropical skink with maternal care

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Filial cannibalism, the process of eating one’s own offspring, is relatively common in some animal species and has been particularly well studied in fishes. However, whole-clutch filial cannibalism committed by terrestrial vertebrate parents has rarely been reported. In this study, I describe the existence of whole-clutch filial cannibalism in the long-tailed skink, Mabuya longicaudata, on Orchid Island, Taiwan. When skinks encountered intruders against which they could defend themselves, such as the egg-eating snake, Oligodon formosanus, and the agamid, Japalura swinhonis, most M. longicaudata females would either attack (O. formosanus) or ignore (J. swinhonis) the predator, but when the frequency of intrusions by the intruder, O. formosanus, increased, whole-clutch filial cannibalism occurred. When females feel threatened by O. formosanus, the best choice (especially for gravid females) may be to eat their entire clutch of eggs. This behavior has evolved in this skink, thus providing a rare case of whole-clutch cannibalism by a mother reptile. Two existing hypotheses (decreasing brood size and brood age) to explain whole-clutch filial cannibalism suggest that cannibalistic parents may eat the entire clutch when the costs of caring outweigh the expected benefits. In the current study, my results suggest that whole-clutch filial cannibalism is primarily induced by the presence of predators. Thus, I suggest a hypothesis of predation risk of whole-clutch filial cannibalism, in which filial cannibalism by M. longicaudata increases as the predation risk to its offspring increases. Key words: eggs cannibalized by a skink, Mabuya longicaudata, pregnancy, snake-induced behavior. [Behav Ecol 19:1069–1074 (2008)]

INTRODUCTION

Over the past several decades, the study of filial cannibalism (eating of one’s own offspring) has gained prominence in evolutionary biology, with empirical data supporting several hypotheses for its adaptive significance. Both partial-clutch cannibalism (consuming part of a clutch) (Rohwer 1978; Sargent 1992) and whole-clutch cannibalism (consuming the entire clutch) (Coleman et al. 1985; Lindström and Sargent 1997; Manica 2002a) have been well documented in the laboratory and field in a number of systems (Manica 2002b). The energy-based hypothesis regards filial cannibalism as a trade-off between current and future reproductive success (Rohwer 1978; Sargent 1992; Manica 2002b). This hypothesis predicts that animals should consume some of their eggs in an effort to maintain their energetic needs for future survival and reproduction, and if this energetic need is great enough, they should consume the entire clutch (Rohwer 1978).

Furthermore, Manica (2002b) summarized information on whole-clutch cannibalism after reviewing teleost fish and found that most predictions of whole-clutch filial cannibalism were explained as follows: 1) brood size, that is, when the brood size decreases, and thus, the benefit of caring is experimentally reduced, parents become more likely to engage in cannibalism (Manica 2002b); 2) timing of cannibalism, that is, as egg age increases, the incidence of cannibalism decreases (Lavery and Keenleyside 1990b; Manica 2002a); 3) parent physical condition, that is, when the male condition decreases, the frequency of cannibalism increases (Petersen 1990; Okuda and Yanagisawa 1996a); 4) availability of mates, that is, cannibalistic males always remated within a shorter period than males whose brood had been removed on the first day of care (Okuda and Yanagisawa 1996b); 5) sex of the cannibal, that is, males are more cannibalistic than females with biparental care (Schwank 1986; Lavery and Keenleyside 1990a); and 6) certainty of paternity, that is, cannibalism should be more common in broods with a lower certainty of paternity.

Filial cannibalism committed by females has been observed in several animal species, in which females consume viable eggs, presumably to rapidly improve their own physical condition thus increasing maternal survival and future reproductive success and foraging success (Somma 2003; Lourdais et al. 2005). However, females should cannibalize less often than males and only as a desperate way out of a bad situation. They may consume an entire clutch if they have to abandon it, and there is a low likelihood that any eggs will survive without care. The conditions under which females are expected to practice whole-clutch cannibalism are largely unknown, but it seems that factors such as expected future reproduction would influence filial cannibalism (Williams 1966).

Despite the prevalence of filial cannibalism in some taxa (i.e., insect and fish), it has rarely been examined in terrestrial vertebrates such as reptiles. For example, Thomas and Manica (2003) described an assassin bug (Rhinocoris tristis) in which males typically ate eggs around the periphery of the brood, which were those most likely to have been parasitized by wasps and suggested that male used eggs as an alternative source of food. However, most reports of reptiles focused on female infanticide (destroying eggs or killing young of other group members), presumably to increase the odds that one’s own offspring that are not killed will thrive as a result of decreased competition with other young (O’Riain et al. 2000; Macedo et al. 2001; Sherman 2003).

In an earlier study, I described the parental care behaviors of the long-tailed skink, Mabuya longicaudata, which include actively defending against an egg predator snake (Oligodon formosanus). Females guard their eggs for at least 1 week to defend the eggs from egg-eating snakes, and the parental care...
period ranges from 7 to 35 (mean, 26) days. At the oviposition site, I previously demonstrated that removal of maternal egg guarding by *M. longicaudata* resulted in a significant reduction in hatching success due to egg predation caused by the reptile egg-eating snake, *O. formosanus*, a major predator of eggs of *M. longicaudata* (Huang 2006b). This antipredator behavior is exclusive to Orchid Island, Taiwan, and has not been found elsewhere in the range of this species on the main island of Taiwan (Huang 2006b). *Mabuya longicaudata* also recognizes the predatory snake, *Elaphe carinata*, and when that species enters a skink nest, the skink escapes and never returns (Huang 2006b).

It has been suggested in the fish literature that filial cannibalism should be affected by predation risk, but there is no empirical evidence for this prediction. Lindström (1998) reported that no additional sand goby fish (*Pomatoschistus minutus*) eggs disappeared when an egg predator crab (*Carcinus maenas*) was present relative to when it was absent. That result suggests that the presence of a predator does not affect filial cannibalism in that species. In this paper, I investigated a new example of the effect of predation risk of whole-clutch filial cannibalism in a maternal caring skink (*M. longicaudata*). The predation risk hypothesis predicts that a maternal caring skink will consume her own eggs when an egg-eating snake enters the nest in high frequencies and will ignore a nonpredator sympatric lizard; and skinks gravid with a future clutch should consume their own eggs with higher frequencies than would nongravid skinks. Therefore, I documented an experimental manipulation in which a parental female *M. longicaudata* would eat its entire clutch of eggs when the intrusion frequency into the nesting site by the egg predator, *O. formosanus*, increased to a certain level.

**MATERIALS AND METHODS**

**Species and study area**

*Mabuya longicaudata* is the largest skink in Taiwan and occurs over a wide distribution range (Huang 2006a). This species is very abundant in low-elevation areas of the southern part of the main island of Taiwan and adjacent offshore islands including Orchid Island. Skink eggs used in the present study were observed in holes in a concrete wall along a mountain road (100–150 m in elevation) on Orchid Island (22°09’2”N, 121°34’E), Taitung County, Taiwan. In natural environments, mother skinks of *M. longicaudata* spend most of the active season dispersed over large areas, but some of them congregate at the concrete holes to lay eggs. The breeding period lasts for 6 months, from March to August, clutch sizes range from 2 to 15 (mean, 6.5) eggs, and some females raise more than one clutch per reproductive season; thus, some of the females are gravid while guarding eggs from a previous clutch (Huang 2006a). Twenty-two cases of female skinks becoming gravid while still providing parental care for the current clutch were found from 2001 to 2006 (Huang WS, unpublished data).

**Marking and censusing of skinks**

My assistants and I visited all nests in the area at the peak of the breeding season from May to August 2003–2006. To ensure that all breeding attempts were detected, all nests were checked every 6 h, with the exact hour varied so that each hour in a day was used at least 3 times every year. For example, if a nest was first checked at 0600, 1200, 1800, and 2400 h, on the following day, it was checked at 0700, 1300, 1900, and 0100 h, and so on. Female skinks were recorded as either being present at the nest or not. My team investigated all nests on the first day we arrived on Orchid Island. The study sites were visited 4 times per day between May and August. We recorded clutch size, oviposition date, and hatching date. The belly of each captured skink was gently probed to determine whether it was gravid by detecting eggs in the belly. For identification, each female was individually marked by gluing a 1-cm² numbered, colored piece of plastic paper onto the back for short-term surveys, and a passive integrated transponder tag was inserted for longer term studies. Skinks were weighed on an electronic balance (to the nearest ±0.01 g) and then released at the site of capture.

**Experiments with predator introduction**

**Predator species**

To avoid any effect on the experimental skinks’ responses resulting from variations in intruders’ body sizes (Snout-vent length [SVL] and body mass), I statistically analyzed the body size (SVL) and body mass of the chosen intruders (the egg predator snake, *O. formosanus*, and the nonthreatening lizard, *Japalura swinhonis*) before the experiment. These 2 sympatric species were chosen for the experiments in order to compare their effects on defensive responses by the skink. Prior to testing, the snakes and lizards were individually housed in 35- × 25-cm rectangular plastic cages that were half full of sand with a cardboard box inside for shelter. Snakes were fed egg yolk, lizards were given 5 crickets once a day, and both were provided water ad libitum while caged. At the conclusion of the study, the snakes and lizards were released at their initial capture site no more than 24 h after capture.

**Experimental nests**

To distinguish between the effects of the 2 intruder species on the skinks’ responses, I observed gravid *M. longicaudata* in the concrete holes until they had oviposited. The eggs were exposed in the concrete hole. After skink oviposition, I recorded the mother skink’s SVL and clutch size. Individual skinks with SVL of 114–116 mm (mean ± standard deviation of 115.3 ± 3.2 mm) and a clutch size of 5–7 (6.3 ± 1.0) eggs were chosen for the experiments. To avoid any effect on the experimental skinks’ responses resulting from variations in SVL or clutch size of *M. longicaudata*, I statistically analyzed the body sizes (SVL) and clutch sizes of chosen skinks/fresh nests (no more than 8 h after oviposition) before the experiment. The intruded nests were randomly divided into 2 treatments: once/day and 3 times/day by intruders, *O. fomosanus* and *J. swinhonis*. Each intruder (*O. fomosanus* and *J. swinhonis*) was gently released into 20 guarded nests, respectively. Forty *O. fomosanus* and 40 *J. swinhonis* different individuals and 80 control nests were used in this study.

**Responses of the skink and experimental duration, intrusion frequency, and timing of observations after the release of intruders**

To generate an encounter, *O. fomosanus* or *J. swinhonis* was gently placed into the open end of a pipe that contained a female skink with her clutch. Responses (see below) of *M. longicaudata* were recorded after the snake or lizard reached the nest. I used each skink for only one test sequence. The experimental frequency was either once/day or 3 times/day in each nest. All first releases of an intruder into the nests occurred at 0900 h, with the second release at 1300 h and the third release at 1700 h on the same day for the 3 times/day group. The immediate responses of the skinks and the responses within 24 h after the test were either observed with the naked eye or recorded by video (Sony DCR-TRV 510). A skink running off after the first encounter in the 3 times/day
group rendered the other 2 encounters meaningless. If a skink abandoned its nest when an intruder entered the hole, its clutch was protected by a plastic net until the clutch hatched. To avoid modifying skink behavior and to preserve the independence of each trial, a given nest was never used twice in the current study.

Immediate responses of skinks

Three categories of responses were recorded; 1) attack, when the skink immediately attacked the intruder; 2) short term, when the skink ran away after the intruder had entered its nest; and 3) ignoring, when the skink remained at its nest and neither attacked nor escaped from the intruder (Huang 2006b). I immediately removed the intruder from the nest after recording the reactions of the skink in each encounter.

The 24-h response to an encounter with an intruder

I checked natural nests (without any treatment; n = 80) and experimental nests 24 h after the test to determine the responses by the mother skink to the intrusion by the predator. There were 4 responses by skinks after the intruder had left the nest: 1) no change, when the skink did nothing to its eggs and cared for them as usual; 2) egg hiding, when the skink used small rocks or soil to hide its eggs but provided no other care; 3) filial cannibalism, when the skink ate its eggs by either completely swallowing all eggs or eating the egg contents and leaving the egg shells in the nest after the last intruder had left the nest within 24 h; and 4) clutch abandonment, when the skink did nothing to the eggs but left the nest and never returned before eggs hatched or disappeared.

Ethical notes

To minimize stress to the tested animals (intruding snakes and lizards), I carried out each treatment a maximum of 20 times. To test for impacts of treatments, I followed females that were individually marked with 1-cm² numbered, colored, and plastic paper (Tunyin, Taipei, Taiwan) glued onto their backs.

Statistical analysis

I used analysis of variance (ANOVA) to determine if there were any differences in clutch size and body size of the skinks with body sizes of the 2 intruders. I used t-test to determine if there were any differences in clutch sizes between mother skinks that consumed all their own clutch (filial cannibalism) and those that did not. I used chi-squared analysis to determine if there were any differences in the immediate responses of the skinks when intruders entered the nests. I used Fisher’s exact test to determine if there were differences in the frequency of natural intrusions between the once/day and 3 times/day treatments and any differences in the frequency of filial cannibalism between gravid and nongravid females and in the responses after 24 h by M. longicaudata when sympatric reptiles entered the nests.

RESULTS

To make sure that any difference between 1 versus 3 times/day intrusion was not due to variation in intruders body sizes (SVL and body mass), I confirmed that there was no difference in the egg predator snake (O. formosanus with an SVL range of 36–40 cm and a body mass range of 30–40 g; \( F_{1,38} = 0.55, P = 0.75 \) for SVL; \( F_{1,38} = 0.75, P = 0.81 \) for body mass; by ANOVA) and the non–egg predator lizard (J. swinhonis with an SVL range of 68–74 mm and a body mass range of 9.0–11.2 g; \( F_{1,38} = 0.67, P = 0.71 \) for SVL; \( F_{1,38} = 0.80, P = 0.86 \) for body mass; by ANOVA) used for the 2 treatments. I also tested that the skink used in the experiments did not differ in body size nor clutch size compared with natural nests \( (F_{1,156} = 1.2, P = 0.31 \) for SVL; \( F_{1,156} = 1.0, P = 0.39 \) for clutch size; by ANOVA). Likewise, skinks that consumed all their own clutch (filial cannibalism) and those that did not differ significantly in clutch size \( (t = 0.60, \text{degrees of freedom} [df] = 16, P = 0.55, \text{t-test}) \).

Immediate responses of M. longicaudata females to intruders

At nests with eggs, females usually reacted strongly to O. formosanus, that is, 17 attacked, 2 escaped, and 1 ignored the intruder for the once/day treatment, whereas 53 (17, 18, and 18 for the first, second, and third intrusions, respectively) attacked, 3 abandoned the nest for the short term (1, 1, and 1 for the first, second, and third intrusions, respectively), and 4 ignored (2, 1, and 1 for the first, second, and third intrusions, respectively) the intruder for the 3 times/day treatment. These response frequencies did not differ between once/day and 3 times/day (the first, second, and third intrusions) treatments \( (\chi^2 = 0.67, 0.36, \text{and } 0.36, \text{respectively}, df = 2, P = 0.71, 0.83, \text{and } 0.83 \text{ for first, second, and third intrusions, respectively} \) by chi-squared test), whereas most of the skinks ignored the intruding J. swinhonis (1 attacked, 1 abandoned the nest for the short term, and 18 ignored the intruder for the once/day treatment, whereas 5 (2, 2, and 1 for the first, second, and third intrusions, respectively) attacked, 4 (1, 2, and 1 for the first, second, and third intrusions, respectively) abandoned the nest for the short term, and 51 (17, 17, and 17 for the first, second, and third intrusions, respectively) ignored the intruder for the 3 times/day treatment \( (\chi^2 = 0.83, df = 2 \text{ for all 3 intrusions}; \text{by chi-squared test}) \). There was a highly significant difference in responses both in the once/day \( (\chi^2 = 29.8, P < 0.0001) \) and 3 times/day \( (\chi^2 = 23.7, 29.8, \text{and } 29.8, P < 0.0001 \text{ for the first, second, and third intrusions, respectively}; df = 2) \) between skinks that encountered O. formosanus versus those that encountered J. swinhonis. All females that escaped returned to their nests within 2 h after the intrusion tests. Skinks did not differ in their responses to the once/day and to the 3 times/day treatments.

The 24-h response of M. longicaudata after an encounter with an intruder

I divided all female responses into 4 categories: no change, egg hiding, filial cannibalism, and abandonment. Egg-guarding female skinks generally ignored J. swinhonis, and females at the 40 test nest sites (including both the once/day and 3 times/day treatments) exhibited no changes after a J. swinhonis intrusion. Filial cannibalism was visually observed when the intruder, O. formosanus, was taken away from the test nests. Filial cannibalism on response to O. formosanus was more frequent in the 3 times/day treatment \( (P = 0.01, df = 3) \); by Fisher’s exact test; Figure 1). Likewise, filial cannibalism was greater when the intruder was O. formosanus than when the intruder J. swinhonis \( (P < 0.0001, df = 3) \); by Fisher’s exact test) and in natural nests \( (P < 0.0001, df = 3) \); by Fisher’s exact test) with the 3 times/day treatment but not with the once/day treatment \( (P = 0.11 \text{ and } 0.82; \text{when O. formosanus was compared with J. swinhonis and with natural nests, respectively, df = 3; Fisher’s exact test}) \). There was no significant difference between the natural nests and J. swinhonis treatments \( (P = 0.10, df = 3; \text{Fisher’s exact test}) \).

Relationship between filial cannibalism and gravid females

Among the 12 cases of egg loss described above, all clutches were completely consumed by M. longicaudata. Three clutches
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O. formosanus were excluded from further analyses. Two natural intrusions were eaten by some other unidentified animals in the 3 times/day and three times/day. Egg-guarding females 20 for each treatment) (c). Intruders were experimentally released once/day and three times/day. Egg-guarding females generally ignored J. swinhonis. Filial cannibalism increased when the frequency of O. formosanus being placed into guarded nests increased from once/day to three times/day. n = the sample size.

Figure 1
Natural nests (n = 80) (a) and four 24-hour responses by egg-guarding female skinks (Mabuya longicaudata) (no change, egg hiding, filial cannibalism, and escape) when faced with two intruders: a sympatric lizard, Japalura swinhonis (JS) (n = 20 for each treatment) (b), and the reptile egg-eating snake, Oligodon formosanus (OF) (n = 20 for each treatment) (c). Intruders were experimentally released into nests once/day and three times/day. Egg-guarding females generally ignored J. swinhonis. Filial cannibalism increased when the frequency of O. formosanus being placed into guarded nests increased from once/day to three times/day. n = the sample size.

DISCUSSION
Predation risk hypothesis for whole-clutch filial cannibalism in M. longicaudata

My data show that M. longicaudata females frequently engage in filial cannibalism soon after they are disturbed by O. formosanus. Whole-clutch filial cannibalism of eggs usually occurred in a nest within 24 h after the intruder had entered the nest but female skinks ignored the non-egg predator, J. swinhonis. Therefore, the current data support my prediction that a maternal caring skink will consume her eggs when an egg-eating snake, O. formosanus, enters the nest with a high intrusion frequency but will ignore the nonpredator sympatric lizard, J. swinhonis. This response of skinks may reflect a trade-off in value of current reproduction (ignore nonthreaten intruder, J. swinhonis) versus future reproduction (engaged whole-clutch filial cannibalism in an effort to maintain gravid females energetic needs for future reproduction with a high intrusion frequency of egg predator, O. formosanus).

In an aquarium study, Lindström (1998) found that male sand gobies (P. minutus) are sensitive to the costs and benefits of parental care and abandon care if the clutch is small and care is likely to be costly when fighting an egg-predating crab (C. maenas) because there is a risk of injury to the male and an interaction with a crab could make the male more conspicuous to predators. That study also showed that the presence of an egg predator did not affect filial cannibalism as the male goby did not consume the entire brood. Likewise, Manica (2004) introduced conspecifics and egg predators into nests of scissor-tail sergeant (Abudelfyu sexfasciatus), but, while conspecific intrusions led to an increase in partial cannibalism due to a decrease in paternity certainty, neither type of intrusion led to whole-clutch cannibalism.

Studies of whole-clutch (brood) filial cannibalism in teleost fish support 2 basic predictions, that increasing clutch size and clutch age, but have not addressed whether parental reproductive status (Manica 2002b). However, in the current study, whole-clutch filial cannibalism in M. longicaudata seemingly reflects parental reproductive status (being gravid or not) rather than the clutch size. Gravid females were more likely to cannibalize their clutch than nongravid females; however, clutch size did not differ between filial cannibalistic and non-cannibalistic skinks. I did not test the effect of clutch age on cannibalism. One would expect filial cannibalism to occur more frequently with gravid females whose energy needs are more immediate compared with nongravid females. This is consistent with gravid females having greater energetic needs (Huang 2006a). Alternatively, it is possible that gravid females have greater expected future reproductive success, and this alone likely affects their cannibalistic decisions regarding the current brood. Results of an earlier study showed that the loss of mass by females is rapidly balanced by a gain in mass during subsequent foraging bouts, and the snout-vent length and body mass did not significantly differ between females that showed parental care and those that did not, clearly suggesting that females maintain substantial body reserves throughout the parental care process, probably by engaging in subsequent active foraging bouts outside the nest (Huang 2007). Thus, the energy requirement hypothesis seemingly does not fully satisfactorily explain the current findings of filial cannibalism by M. longicaudata. Furthermore, filial cannibalism in M. longicaudata was closely associated with the frequency of intrusions by the predator, O. formosanus, but not with another nonthreatening lizard. Therefore, both predation risk and parental reproductive status appear to contribute to filial cannibalism in M. longicaudata.

Although the causes for M. longicaudata egg loss have not been clearly elucidated, a higher frequency of intrusion
causing filial cannibalism is now more thoroughly documented. This phenomenon of filial cannibalism by mothers may include third causalities. First, *M. longicaudata* does not have to invest much effort in building a nest because the nest holes are already present, and therefore building a nest site requires very little energy compared with other nest-building animals, but a high frequency of intrusions might induce filial cannibalism. This is contrasted with high investments in reproduction by some animals exhibiting filial cannibalism (but see Manica and Johnstone 2004). For example, among processes related to pregnancy in captive rainbow boas (*Epicrates cenchria maurus*), substantial costs are imposed not only in terms of depleted energy stores but also by reductions in a female’s dorsal musculature due to mobilization of protein reserves during pregnancy (Lourdais et al. 2004). Thus, postparturient females are weak (with the mass of a clutch of eggs being about half of a mother’s body mass) and take several weeks to recover from this condition. In this respect, ingestion of nonviable eggs may allow a mother to more quickly recoup energy and restore her body musculature.

Second, the frequency of filial cannibalism increased with intrusions by *O. formosanus* between the 2 treatments (Figure 1b, c). It is reasonable that female skinks were able to deter the intruder during the first intrusion when facing *O. formosanus*, but when the intrusion frequency increased, the skink recognized that *O. formosanus* was a threat to her eggs, and so she ate her eggs in the 3 times/day treatment. A possible alternative idea is that predation risk of filial cannibalism may be due to the energy required by a mother skink to frequently fend off predators in denser nesting sites compared with those in a natural setting, and so this may be a good place for predators to gather, creating even more energetically costly work for female skinks.

Therefore, the current data suggest that increased predation could be a cue to female skinks that the value of the current brood is lower than possible future broods and thus females begin to eat their own eggs to recoup some energy for future broods, and they may also save energy by not having to consistently defend their nests. Third, the principle of parental allocation and adaptive whole-clutch filial cannibalism suggests that if the costs outweigh the benefits of continued care, then whole-clutch cannibalism reflects an end to care and the recruitment of resources from the clutch toward future reproductive success. Besides, a permanently abandoned clutch would be easily located and consumed by *O. formosanus*; therefore, gravid skinks adopt whole-clutch cannibalism as the best way out of a bad situation.

**Filial cannibalism by the skink, *M. longicaudata*, versus intrusion frequency**

I found that egg losses were closely associated with the frequency of intrusion *O. formosanus* as well as with the reproductive status of the female. More cannibalism occurred following a higher rate of intrusion. My results showed that with filial cannibalism by *M. longicaudata*, the female consumed the entire clutch and defended the eggs regardless of the size of the clutch. These results contrast with those for the sand goby and scissortail sergeant possibly because *M. longicaudata* always was able to get the predator to leave without harm to the skink or eggs and thus there being no risk of injury from an encounter (Huang 2006b). But when filial cannibalism occurred, *M. longicaudata* would consume the entire clutch, leaving no eggs in the nest.

**CONCLUSION**

The occurrence of maternal filial cannibalism in this skink was strongly correlated with the intrusion frequency. The data showed that filial cannibalism frequently occurred with gravid females when the intrusion frequency increased. My data indicate that *M. longicaudata* females are more likely to commit filial cannibalism when they are gravid than when they are not. When facing a potential egg-eating snake (*O. formosanus*), the gravid females in this population may use a filial cannibalism strategy to recoup as much of the available energy as possible for use in future clutches. Although females can also invest in their own eggs through protecting them against predators or aggression, it is likely that even though there is a great chance of defeating defensible intruders such as *O. formosanus*, filial cannibalism is the optimal choice when a higher frequency of intrusions occurs. Because filial cannibalism has long been viewed as a trade-off between current and future reproductive success (Lindström 1998; Manica 2002b), the current study of predation risk filial cannibalism in *M. longicaudata* is seemingly consistent with this idea.

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