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FOOD-HANDLING DIFFICULTIES FOR SNAIL KITES CAPTURING NON-NATIVE APPLE SNAILS

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Abstract.—The non-native channeled apple snail, *Pomacea insularum*, has spread rapidly in a number of wetlands and lakes in Florida that fall within the range of the endangered Snail Kite (*Rostrhamus sociabilis*). We observed Snail Kites foraging on *P. insularum* on a central Florida lake and found that the kites had difficulties capturing and consuming the large non-native snails. Kites dropped 44% of channeled apple snails captured, compared to a 0% drop rate by kites capturing native apple snails (*P. paludosa*), and 1% reported by another study. Kites also took longer to extract the flesh from *P. insularum* compared to *P. paludosa*, but this may be offset by the larger caloric value of the former. The extremely high drop rate may preclude some Snail Kites (e.g., juveniles) from meeting their caloric needs, but this and many other questions regarding the potential impact of the spread of *P. insularum* needs to be investigated more thoroughly.

There has been a rapid expansion of non-native channeled apple snails in peninsular Florida wetlands and lakes. Rawlings et al. (2007) used genetic analyses recently to identify the most widespread non-native apple snail as *Pomacea insularum* (not *P. canaliculata* as previously thought). Another non-native, the spike-topped apple snail (*P. diffusa*) has existed in Florida for decades, but its populations remain restricted to a few small areas and their potential impacts appear less of a concern (Rawlings et al. 2007).

Growing concern about the invasive *P. insularum* stems, in part, from its rapid expansion into the range of the endangered Florida Snail Kite (*Rostrhamus sociabilis plumbeus*). Questions have been raised regarding the kites' ability to rely on the much larger *P. insularum* as a substitute for its normal prey, the native Florida apple snail (*P. paludosa*) (Rawlings et al. 2007). Takekawa and Beissinger (1983) reported that kites can capture and consume non-native spike-topped apple snails, and we had anecdotal evidence that kites also consumed *P. insularum*.

The Snail Kite has structural attributes in its claws and beak that make it adept at capturing and consuming the golf-ball sized native apple snail (Snyder and Snyder 1969). Florida apple snail adults typically range in size from 30-45 mm in height (see Fig. 1 for standard shell measurements) and rarely exceed 60 mm (Hanning 1979, Sykes 1987, Darby, unpublished data). In contrast, *P. insularum* found in

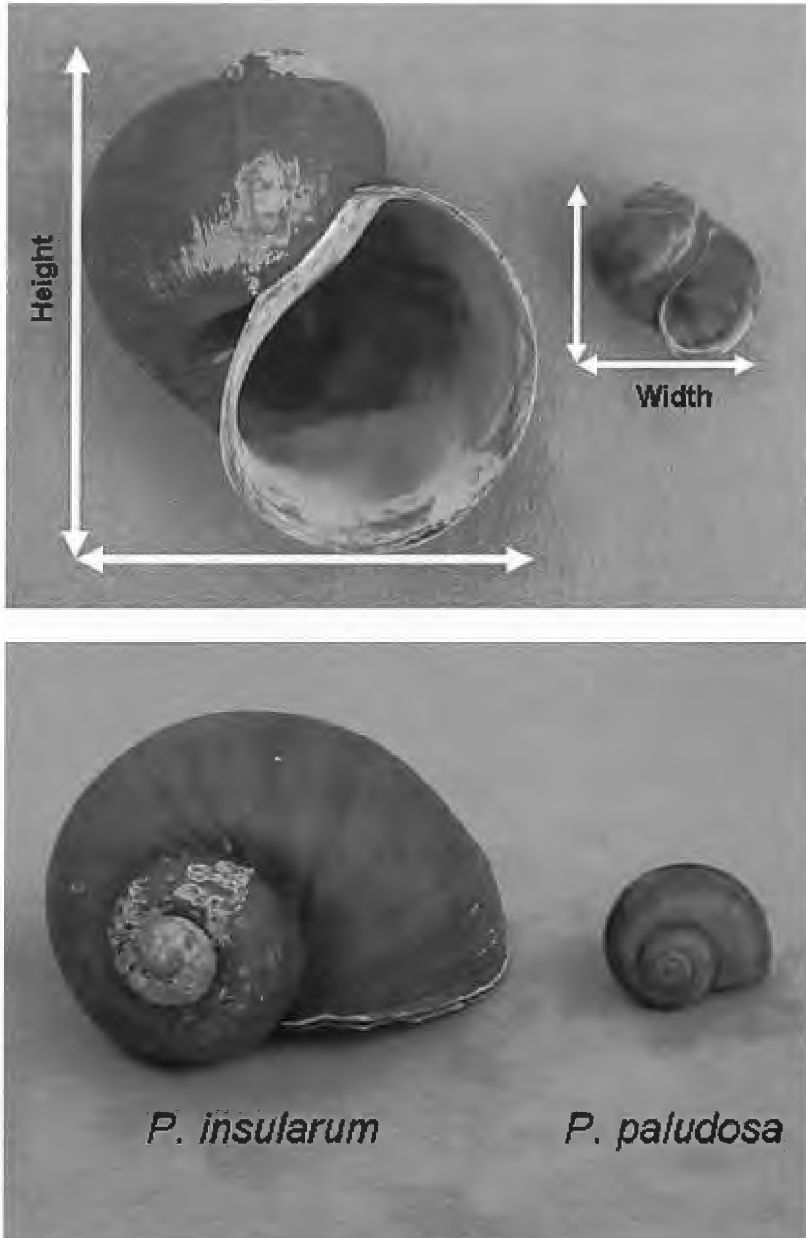

Figure 1. ***Top panel*****—view showing height (H) and width (W) measurements of a typical-sized *P. insularum* found on LTOHO (81 mm W × 93 mm H) (*left*) and a typical-sized *P. paludosa* found on LKISS (31 mm W × 34 mm H) (*right*). See text for details on sizes from field samples. *Bottom panel*—an additional perspective of the same specimens to illustrate the much larger overall size of *P. insularum*.**

Florida often exceed 90 mm in height (pers. obs., also see Rawlings et al. 2007). We hypothesized that kites may experience difficulties capturing and consuming the large non-native apple snails.

STUDY SITE AND METHODS

We observed Snail Kites foraging on channeled apple snails in Goblets Cove (28°13.4N, 81°21.0W) on Lake Tohopekaliga (LTOHO), Osceola County, as part of a larger on-going study of apple snails on central Florida lakes. Only the channeled apple snail was found in Goblets Cove at the time we made our foraging observations. For comparison, we observed Snail Kites capturing native snails around Ox Island (27°56.2N, 81°13.6W) on nearby Lake Kissimmee (LKISS), Osceola County.

We observed kites foraging on channeled apple snails on LTOHO on 22 and 23 October 2004 in three different locations approximately 1-2 km apart along the shoreline. Based on plumage markings and the different locations, we were reasonably confident that we observed 10 different birds, but we could only be certain of distinguishing between individuals within a given day ($n = 4$ and $n = 6$). Two observers watched foraging kites from a stationary or slow moving airboat (see Bennetts et al. 2006). When a kite captured a snail, one observer kept sight of the kite with a binocular. Incidences of kites dropping captured snails were recorded. When the kite landed on a perch with a captured snail, we started a stop watch. We recorded the 'extraction time' as the time it took for the kite to extract and swallow the snail flesh. We inspected discarded shells under accessible kite perches to confirm that they were eating only the channeled apple snail.

We recorded the frequency of kites dropping native snails on LKISS in spring 2005. Extraction times were not recorded. We inspected accessible kite perches to confirm they were eating only the native apple snail.

In fall 2004, we used throw traps and dip nets in Goblets Cove on LTOHO to sample apple snails, a method that does not bias against capturing any snail sizes as long as they exceed 13 mm (Darby et al. 1999). We measured the shell widths (nearest mm, using vernier calipers) of 64 live channeled apple snails captured in throw traps. We also recorded shell widths for 22 native snails taken from throw traps in the vicinity of foraging kites on LKISS in spring 2005. Snails sampled in throw traps on LTOHO and LKISS were immediately returned to the water because our research on trends in snail abundance was on-going. Shells of snails consumed by kites were not measured, in part, because we could not be certain which snail in a pile of shells under a perch was the one just consumed. Also, in many cases, we could not access the perches because they were surrounded by impenetrable vegetation. Qualitative assessment of shells in piles beneath several accessible perches confirmed that the kites were eating snails of a size similar to those that we measured from throw traps.

As a routine part of our field sampling, we measured only shell width to represent overall snail size. In hindsight (after collecting kite foraging data), we realized that heights of those found in the field might be of interest for overall size comparisons of native vs. non-native snails. Heights of shells for which we had field measurements of widths were estimated as follows. First, we measured heights and widths from similarly sized empty shells stored in the lab ($n = 15$ for *P. paludosa* and $n = 15$ for *P. insularum*) and calculated an average height to width ratio. Then, we multiplied the average ratio (= 1.15 for both species) by the shell width recorded from field specimens in order to estimate their height. Although this approach may not be sufficiently precise to distinguish subtle differences in shell morphology (e.g., to compare species or gender within a species), it allowed us to quantify the large size differences between the native and the non-native snails. We also used a standard electronic laboratory scale to weigh one whole frozen specimen of *P. insularum* and *P. paludosa*, comparable in size to those on which kites foraged.

Results

We recorded 25 cases of Snail Kites capturing a channeled apple snail. Kites dropped eleven of these captured snails (44%) before reaching a perch. Most often, kites held the captured snail for one to two seconds before dropping it (qualitative assessment). The tendency to drop channeled apple snails varied widely between kites (Table 1). We approached locations where the snails were dropped and never saw floating, empty shells. This was confirmation that kites were not mistakenly grabbing and then dropping empty shells. Also, the splash associated with dropped shells suggested that whole snails, not just relatively light, empty shells, were being dropped. In 136 records of a kite capturing a native snail on LKISS, no snails were dropped.

For those kites that made it to a perch with a channeled apple snail, the extraction time was, on average (± SD), 333 ± 178 s (n = 10). Shell widths of *P. insularum* found in throw traps on LTOHO were on average 81 mm ± 6 mm (SD), and estimated heights averaged 95 mm ± 7 mm; these were also the approximate sizes found under kite perches (qualitative assessment) (see Fig. 1). The smallest shell found was 77 mm in height. On LKISS, native apple snail shells found under kite perches always exceeded 20 mm in width (qualitative assessment). Sykes (1987) reported no snails <20 mm under kite perches. Average widths and estimated heights collected from throw traps were 31 ± 8 mm and 35 ± 9 mm, respectively (four snails that were <20 mm were excluded from calculations to better reflect on what kites were foraging) (see Fig. 1). Whole frozen specimens representing the approximate average sizes of *P. insularum* and *P. paludosa* weighed 174 g and 35 g, respectively.

Table 1. The number of channeled apple snails captured by Snail Kites, the number dropped before getting to a perch, and the time (in seconds) required to extract and consume the snail's flesh in those cases where the Snail Kite ate the snail.

Date	Kite number	Channeled apple snails captured	Channeled apple snails dropped	Extraction time (s)
22 Oct	1	4	4	no data
22 Oct	2	6	4	no data
22 Oct	3	3	2	62
22 Oct	4	1	0	440
23 Oct	1	3	1	280, 586
23 Oct	2	1	0	220
23 Oct	3	3	0	588
23 Oct	4	1	0	463
23-Oct	5	1	0	189
23 Oct	6	2	0	299, 200

DISCUSSION

Snail Kites dropped the large channeled apple snails 44% of the time, compared to 1% or less noted for kites capturing native snails (Cary 1985, Sykes et al. 1995, this study). Channeled apple snails weighed approximately five times as much as native apple snails. Beissinger (1990) reported the time for a Snail Kite to extract and eat the flesh from Florida apple snails as 95.7 ± 37.3 s (SD), or roughly one third the extraction times we recorded for kites eating the large non-native. Takekawa and Beissinger (1983) provided no indication that kites had trouble foraging on non-native apple snails, but this likely reflects the fact that the kites they observed were eating spike-topped apple snails, which are similar in size to the Florida native (Thompson 1984, Rawlings et al. 2007).

We found no reports of any of the three subspecies of Snail Kites (*R. s. plumbeus*, *R. s. sociabilis*, *R. s. major*) foraging on *P. insularum*, noting that the range of this snail overlaps with *R. s. sociabilis* in South America (Sykes et al. 1995, Rawlings et al. 2007). *R. s. sociabilis* also occurs in wetlands supporting *P. urceus* (Burky et al. 1972, Donnay and Beissinger 1993), another apple snail with shell height >100 cm; again, we found no reports of kites eating these large snails. Although studies have shown that kites select larger snails (i.e., they rarely eat snails <20 mm shell length), the upper limit of what they can handle has never been questioned. In reports of snail sizes consumed by kites (with only four snail species noted, *P. paludosa, P. doliodes, P. scalaris, P. canaliculata*), the largest snail eaten was 86 mm shell length (Tanaka et al. 2006), and they rarely consumed snails > 60 mm (Beissinger 1983, Bourne 1985, Bourne 1993, Tanaka et al. 2006, also see review by Sykes et al. 1995). Snail kites may simply be less proficient at grasping the 95 mm (average) *P. insularum*, noting that kite claw plus toe lengths are 49 to 68 mm (Sykes et al. 1995). The 175 g average weight of *P. insularum* might have been a challenge as well, given that this is approximately 45%, 43% and 37% of the total weight of juvenile, adult male, and adult female kites, respectively (Valentine-Darby et al. 1997). We suspect that the high degree of individual variation in drop rates reflected age and/or inexperience, with juveniles more likely to drop snails compared to adults.

Longer extraction times for *P. insularum* may simply reflect the effort required to extract a larger amount of flesh from the shell, and this could be offset by the caloric gain. However, kites expend more energy in getting an exotic snail to the perch; they dropped 44% of the exotic snails captured. Quantifying this tradeoff in caloric gain relative to the additional effort of capture would require more thorough examination. A simplistic example follows: a juvenile kite that captures and consumes four native snails (35 g each) obtains a 140-g prey item with the cost of carrying 9% of its body mass (on four flights to a perch); it spends 384 s to consume the prey. In comparison, a juvenile kite that captures four exotic snails (174 g each) but drops three, obtains 174 g of snail (24% more than if eating four natives), but carries 45% of its own body mass (on one full flight to a perch and three flights to the point of dropping snails); it takes 333 s to consume the prey. Clearly, the net caloric gain is not directly proportional to the larger size prey, and under some circumstances, depending on the individual drop rate, there could be a net loss when attempting to forage on *P. insularum*. We have particular concern for juveniles that may exhibit high drop rates which may lead to insufficient calorie intake. Newly fledged kites, when capturing *P. paludosa*, were described as 'proficient at capturing snails but unskilled at extraction' (Sykes et al. 1995). Bennetts and Kitchens (1999) identified 30-60 d post fledging as being the period of greatest risk of mortality for Florida snail kites, and alluded to their inexperience in foraging on their own. The large size of *P. insularum* may exacerbate the potential for newly fledged kites to suffer mortality associated with food handling difficulties, and there could be demographic consequences for Snail Kites reflected in lower juvenile survival (e.g., see Dreitz et al. 2004). Other questions, such as the potential for parasites harbored by *P. insularum* to harm kites (Rawlings et al. 2007) and their potential impacts on wetland vegetation (Carlsson et al. 2004), should also be investigated.

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