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OBSERVATIONS OF FLOTSAM ENTRAPMENT IN THE NORTHERN DIAMOND-BACKED WATERSNAKE (*NERODIA R. RHOMBIFER*)

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***Abstract*.—Small areas of protected land may act as islands of suitable habitat surrounded by human development. Although these areas receive protection, we have observed one way that the surrounding human population can still endanger the welfare of its inhabitants. During our observations of the Northern Diamond-backed Watersnake (*Nerodia r. rhombifer*) in a semi-protected nature park surrounded by human development, we encountered 13 individuals entangled with flotsam. Of the 220 juvenile through adult snakes that we captured, 12 were encircled by various types of objects (e.g., finger cots; latex sheaths that cover a single digit, dental elastics, and plastic bottle neck rings) within the first half of their body; a 13th individual was observed but was not captured. The injuries resulting from these rings ranged from superficial wounds to death. We conducted behavioral experiments to determine if entanglement was due to attraction or to incidental entrapment during activity, with the latter being more likely. Our observations show that becoming trapped in refuse may be an important source of impairment and mortality in limbless reptiles, as has been previously documented in other species.**

Key Words.—conservation; litter; mortality; plastic; snakes; urban biology

INTRODUCTION

Human impact in small semi-protected areas is difficult to control when urbanization surrounds the lands. Nearby human influence can lead to greater incidences of littering, poaching, and the destruction of grounds. The Edinburg Scenic Wetlands is one such island of semi-protected land that is located within the city of Edinburg, Hidalgo County, Texas, USA. The World Birding Center manages The Edinburg Scenic Wetlands as a subset of the Edinburg Municipal Park (managed by the city of Edinburg). The Edinburg Scenic Wetlands are semi-protected in that deleterious human activity is strongly discouraged through posted regulations, but is not actively monitored. There are two 4 ha ponds on the 16 ha property that are connected by a canal. One pond, at the northern end of the site and the focus of the current study, receives treated effluent wastewater from the City of Edinburg (Fig. 1). The second pond, located south of the first, receives untreated canal water. The Edinburg Scenic Wetlands acts as an island of semi-protected habitat, surrounded by residential and other disturbed habitat, which hosts a myriad of aquatic and semi-aquatic animals.

FIGURE 1. The north pond at the Edinburg Scenic Wetlands (Edinburg, Hidalgo County, Texas, USA) . The concrete structures in the background are part of the water treatment system. (Photographed by Jason Ortega)

As a by-product of an ongoing study of the population dynamics of the Northern Diamond-backed Watersnake (*Nerodia r. rhombifer*) at the Edinburg Scenic Wetlands, we have observed a way in which the surrounding human populous, through littering and/or poor trash management, has affected the well-being of these animals. Litter most typically occurs as flotsam (floating debris in the water) in the form of synthetic materials, such as plastics. Previous studies have documented the deleterious effects of flotsam on wildlife; the best documented is the ingestion and entanglement in flotsam by sea turtles (Fritts 1982; Laist 1997; Cannon 1998; Mascarenhas et al. 2004). Isolated incidents of terrestrial snakes becoming entangled in synthetic materials have been reported (Campbell 1950; Fauth and Welter 1994; Stuart et al. 2001). Excluding Platypus (*Orinithorhynchus anatinus*) entrapment reported by Serna and Williams (1998) and Northern Watersnake (*Nerodia sipedon*) entrapment (Herrington 1985; Fauth and Welter 1994; Ron Black, pers. comm. in Walley et al. 2005), no other reports of flotsam affecting freshwater tetrapods, ophidian or otherwise, apparently exist.

We encountered 13 snakes caught in pieces of ring-shaped flotsam over a three-year period. While the exact source of flotsam is unknown, we documented several instances in which objects had severely injured or led to the death of snakes. Our observations suggest that refuse entrapment may be an important source of impairment and mortality in limbless reptiles, as has been previously documented in other reptilian species. Here we present the first, multiply documented incidences of *N. rhombifer* entrapment and we attempt to elucidate why the entanglement occurs.

MATERIALS AND METHODS

Snake capture and processing.—We captured snakes entangled in flotsam either during routine searches and radio telemetry, or through donations by visitors of the Edinburg World Birding Center. Searching occurred at night, typically lasting an average of four hours (2000–2400). We collected animals along the shoreline of the northern pond and interconnecting canal as encountered in the water. We processed all collected snakes, whether entrapped in flotsam or not, by recording mass (g), snout-vent length (SVL), tail length, head width, and head length. We used a squeeze box (Quinn and Jones 1974) and a measuring tape to measure length, with values being recorded to the nearest 0.1 cm. We used regression analysis and T-tests for statistical comparisons at an alpha level of 0.05.

We measured the snout to wound distance of flotsam-entrapped individuals with a tape measure, as well as body width and height anterior to, at, and posterior to the wound (taken with digital calipers; VWR International, West Chester, Pennsylvania, USA, to the nearest 0.1 mm). Body measurements taken anterior and posterior to the wound were measured 1–2 cm away from the wound. We removed the flotsam item from the snake and the treated the wound by the application of a topical antibiotic. The internal inner diameter of each flotsam item was measured using digital calipers and the item was saved. We euthanized any animal judged to be in poor condition (extreme emaciation and lethargy) with an overdose of Halothane. Snakes deemed releasable had a microchip (AVID, Folsom, Louisiana, USA) inserted into the body cavity for future identification and were released at their point of capture.

Behavioral trials.—We used snakes collected from the Edinburg Scenic Wetlands that were not entangled in flotsam in behavioral trials. We wanted to determine if *N. rhombifer* entanglement was due to attraction toward refuse or due to incidental entrapment during activity. The role of a perch (a branch) in entanglement was also examined: would the branch aid the animal in freeing itself or would it promote entrapment, as the animal slithers around it? Fifty-four individual snakes (juvenile to young adult) were placed in one of two treatments: each consisted of a 10-gallon aquarium filled with ~ 9 L of water that had either a random number of flotsam (one to six) only or a random number of flotsam and a branch that emerged from the water. The experimental flotsam items were plastic bottleneck rings and finger cots of various colors and of appropriate sizes for the tested snakes (appropriate items had a diameter less than the thickest part of the animal being tested). Photoperiod was 12L:12D and temperature was 24° ± 2°C. The snakes remained in the aquaria for 24 hours and then the snake was freed from the item (if necessary). During the course of the 24 hours, each snake was observed at various times to ensure the animal's safety. A Fisher's exact test (Zar 1984) was used to analyze the resulting data.

TABLE 1. Summary of the processing data from the Northern Diamond-backed Watersnake (*Nerodia r. rhombifer*) at the Edinburg Scenic Wetlands (Edinburg, Hidalgo County, Texas, USA) in this study; OID = object inner diameter, DAW = snake diameter anterior to wound, WD = wound diameter, DPW = snake diameter posterior to wound.

Snake	Sex	Mass (g)	SVL (cm)	Object	Object distance from snout (cm)	OID (mm)	DAW (mm)	WD (mm)	DPW (mm)
A	♀	457.9	73.5	large yellow bottle ring	29.8	32.5	33.3	28.8	35.1
B	♂	276.4	65.1	small white bottle ring	30.7	25.0	22.0	21.9	26.6
C	♂	194.4	59.9	finger cot	22.2	19.3	26.1	16.6	28.1
D	♀	608.9	85.2	large white bottle ring	42.2	31.4	31.4	32.1	34.4
E	♂	117.3	51.4	purple rubber band	12.5	17.8	13.9	17.0	22.1
F	♂	91.6	42.2	yellow rubber band	15.9	15.5	16.7	17.1	17.6
G	♀	846.0	82.1	blue bottle ring	15.7	34.5	32.0	29.3	37.7
H	♂	116.2	48.6	white bottle ring	8.5	13.0	11.9	12.8	13.7
I	♀	930.6	88.9	standard rubber band	30.2	35.1	30.9	32.0	36.9
J	♀	377.4	75.3	white bottle ring	34.2	31.0	29.7	25.0	31.9
K	♂	262.1	63.3	juice carton pull tab ring	17.6	22.4	23.9	17.5	21.0
L	♀	600.9	79.2	blue bottle ring	20.5	33.8	29.2	28.7	33.9

FIGURE 2. Examples of ring-shaped flotsam that were removed from around the bodies of Northern Diamond-backed Watersnake (*Nerodia r. rhombifer*) captured in the Edinburg Scenic Wetlands, Edinburg, Hidalgo County, Texas, USA. (Photographed by Jason Ortega)

RESULTS

We captured 220 animals as part of the ongoing study, with 12 animals entangled in ring shaped flotsam within the first one-half of their snout-vent length (Table 1). Seven of the flotsam items were plastic bottle rings used to secure the bottle cap to a soda or water bottle; two were dental elastics or similar rubber bands; one was a finger cot; one was a pull-tab from a juice carton; and one was a standard rubber band (Fig. 2). The ring size was positively associated with snake size (ring size in mm = 0.4201(SVL in cm) – 5.3101; $R^2 = 0.8679$).

The severity of the wounds was variable (Fig. 3). Of the 12 captured snakes that were entangled, all but two were released after having their items removed; one animal was euthanized in the laboratory and one individual was found dead (snakes E and K, respectively). The dead and euthanized animals had nearly complete blockage of their esophagi with rotting fish masses (Fig. 4). Necropsies of both snakes showed that the flotsam rings impaired the passage of ingesta through the gastrointestinal tract, as there was an accumulation of rotting fish just anterior to the ring. There was clearly one fish caught in the gastrointestinal tract just anterior to the ring in snake K. In snake E, there was a bolus made up of several fish present, which was the cause of the large mass just anterior to the flotsam ring.

Flotsam entrapment occurred equally in males and females. There was no overlap in the sizes (mass and SVL) of entrapped males and females (Fig. 5) and the difference in sizes between males and females was statistically significant (T-tests, all $P < 0.002$). Entrapped males and females comprised the 53^{rd}–82^{nd} and 67^{th}–82^{nd} percentiles, respectively, of their sex's size distribution. When compared to the overall population, the majority of the entrapped snakes showed a poorer body condition (indicated by falling below the length-mass regression line; Fig. 5). On average entrapped snakes were 13% and 7% lighter, than expected for females and males, respectively, for a given SVL from this population (non-significant sex effect based on T-tests of the length-mass residuals, all $P > 0.503$).

One individual found entangled had been previously captured before it became trapped in flotsam (K). At the time of initial capture, snake K had a mass of 257.8 g and a SVL of 61.0 cm. He was found dead and entangled in flotsam nearly three months later with no appreciable change in size. Two animals that were freed from flotsam and released were recaptured (snakes A and J). Snake A was recaptured eight months after she

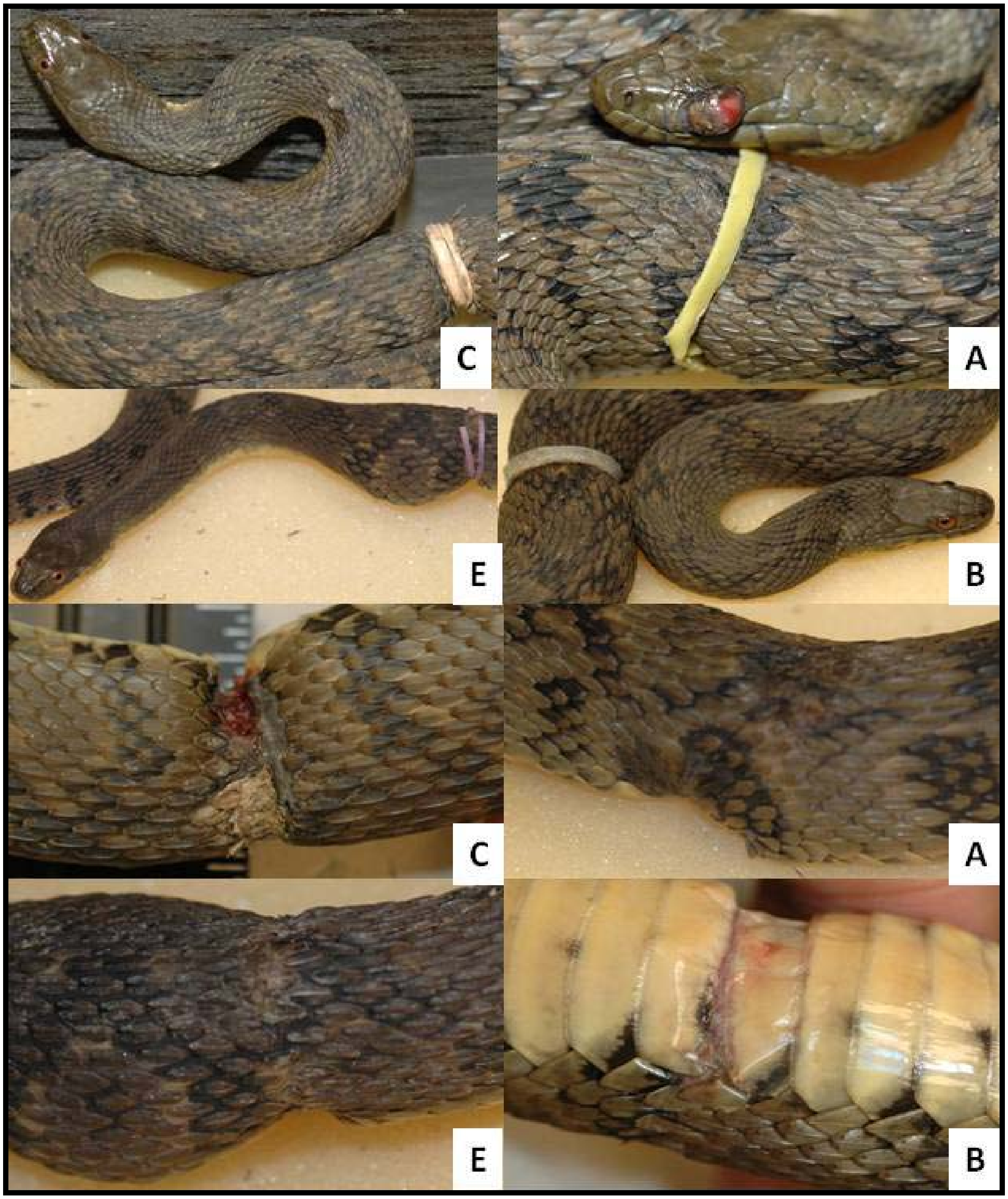

FIGURE 3. Examples of *Nerodia r. rhombifer* from Edinburg Scenic Wetlands, Edinburg, Hidalgo County, Texas, USA, entangled in flotsam (upper panels) and the resulting wounds (lower panels). The letters correspond to the snake's identification used in Table 1. (Photographed by Jason Ortega)

was flotsam-free and released. In that time, her mass nearly doubled (from 457.9 to 774.3 g) and she grew to 80.8 cm, an increase of 7.3 cm. Snake J was recaptured a year after release and gained 112.3 g for a total mass of 489.7 g (with no increase in length).

The behavioral trials yielded the following results: three of 27 snakes became entangled in flotsam when just flotsam was present and two of 27 became entangled in flotsam when a branch was included (no significant branch effect; Fisher's exact test, P = 1.0). These values

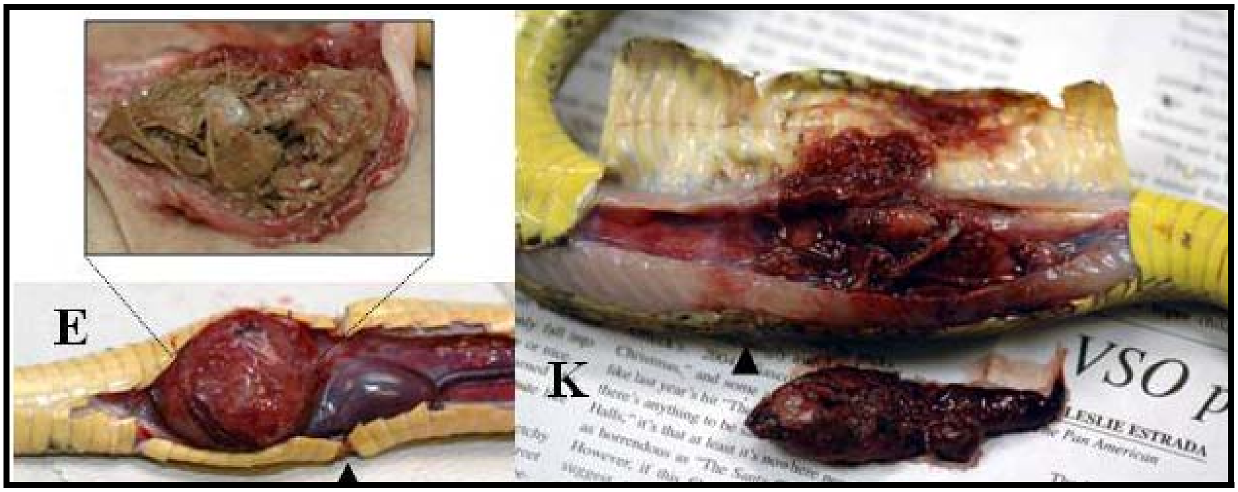

FIGURE 4. Results of the necropsies of Northern Diamond-backed Watersnakes (*Nerodia r. rhombifer*) E and K at the Edinburg Scenic Wetlands (Edinburg, Hidalgo County, Texas, USA). Anterior is to the left for snake E and to the right for snake K. The arrow indicates where the flotsam rings were located. (Photographed by Jason Ortega)

only show the entrapment of animals at the 24-hour mark. It was noted that in both treatments, some individuals did become temporarily entangled in the flotsam, but by the 24-hour mark had freed themselves of the item. One snake became entrapped in three flotsam rings during the test period. Overall, approximately 9% of the snakes became entangled in the behavioral trials.

DISCUSSION

Reports of snake entanglement have been limited for the most part to plastic and metal fencing or netting materials (*Coluber constrictor*, *Crotalus atrox*, *Elaphe obsoleta*, *Lampropeltis getula* and *L. triangulum*, *Masticophis flagellum*, *Nerodia sipedon*, *Pituophis catenifer*, and *Sistrurus catenatus*; Fauth and Welter 1994; Stuart et al. 2001; Bonine et al. 2004; Walley et al. 2005 and citations therein) and a beer can (*Nerodia sipedon*; Herrington 1985). The majority of these studies implicate either incidental entrapment or entrapment during foraging events. Lutterschmidt and Schaefer (1996) further demonstrated the ability of avian mist nets to be an effective means of capturing semi-aquatic snake species. Our observations represent the first report of plastic or rubber ring entrapment by any snake species, aquatic or not. Interestingly, our observations closely reflect those reported for the Platypus (Serna and Williams 1998).

Injuries resulting from flotsam constriction vary depending on several factors: how long the snake has been entangled, its age at entanglement, where on the animal's body the item is caught, what the item is made of, and the size of the item (circumference). Short-term entrapment causes minor abrasions, particularly with plastic bottle rings that have an abrasive inner surface. If the animal is a full-grown adult and the item is somewhat loose, injuries are typically limited to skin abrasion (e.g., snake B). Acute entrapment with an elastic item causes injury in the form of a furrow of bent scales and some necrosis of the skin. Very small items that fit tightly on an animal can cause a great deal of internal injury in a small amount of time. Severe constriction of the body cavity along the first quarter of the animal's length can greatly impair the feeding capabilities of these animals (e.g., snakes E and K). Chronic entrapment of young snakes can cause severe indentations in the body cavity as seen in snake C (Fig. 3).

The behavioral trials offered contextual information of how and why these snakes become entangled. The data suggest that these animals are not inherently attracted to the flotsam. If animals are drawn to flotsam items for some reason, we would expect to observe a higher incidence of entanglement in the trials. During both treatments, more individuals were seen with rings around their bodies than were found entangled at the 24-hour mark. This suggests that when snakes initially encounter a ring around their body, they may attempt to free themselves of the object. The snakes can free themselves of the flotsam with or without the presence of an object for leverage. The substrate available to these animals also seems to have no affect on how often they become entangled in flotsam; with or without places to perch, the majority of the animals tested did not become entangled. An attempt was made to test if the animals became entangled during a predatory event but their refusal to eat live ornamental fish prevented any data from being collected. Thus, the most likely cause

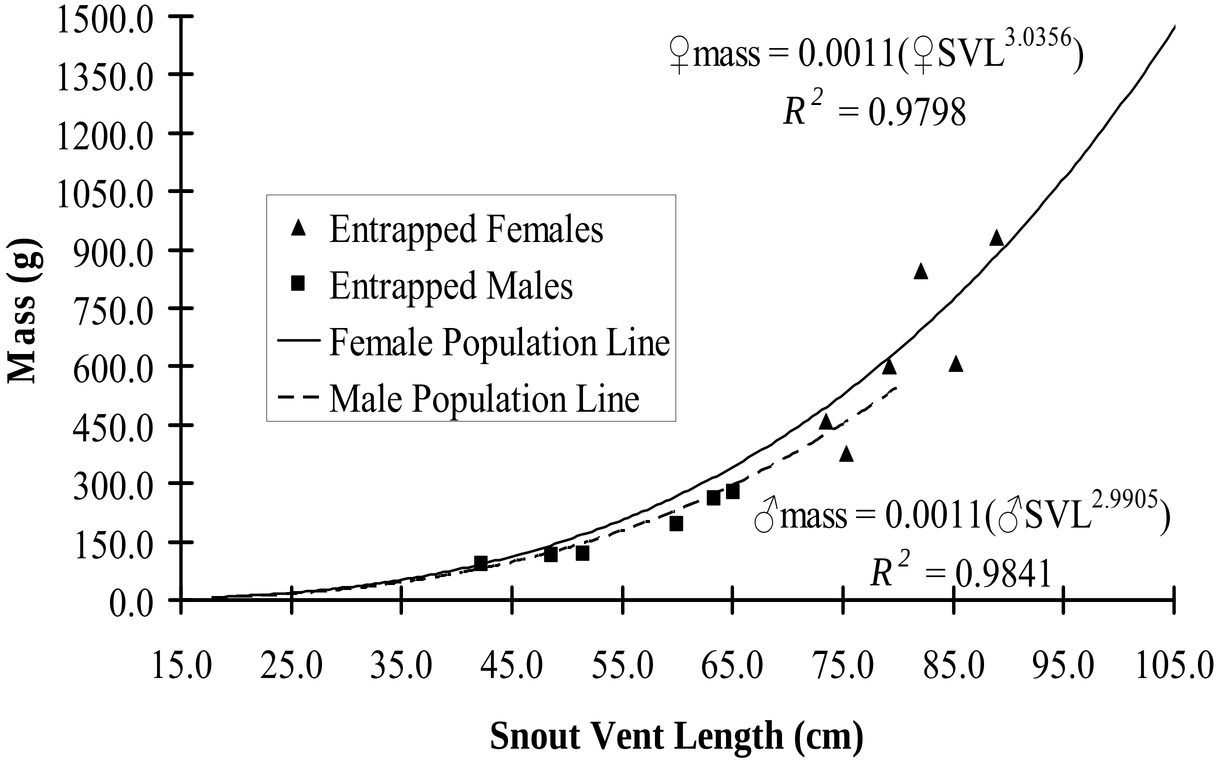

FIGURE 5. Length-mass regressions for female and male *Nerodia r. rhombifer* at the Edinburg Scenic Wetlands, Edinburg, Hidalgo County, Texas, USA (N = 77 of each sex) and locations of flotsam items on the entrapped snakes. Note the overall lower body condition of entrapped snakes and the lack of overlap in the size distribution between the sexes.

of their entrapment is due to random encounters with flotsam.

It is clear that flotsam items have a great effect on entangled animals. Based on limited recapture data, it appears that these animals rapidly improve their body condition after being freed from entanglement. Snake A doubled in mass in eight months while also growing longer in length, a feat not commonly seen in adult females of this species. Snake J also gained mass and her overall body condition did improve after flotsam removal. In addition to increases in body size, reproduction is possible after entrapment. Two other snakes (not reported here) from the population had scars consistent with ring entrapment, were gravid at the time of capture, and successfully produced small litters. The true benefit of being “flotsam-free” will become clearer as recaptures increase. The incidence of these animals being caught in flotsam may be far greater than we have recorded. There is the distinct possibility that injury due to flotsam may be a great source of mortality in this otherwise highly productive system.

What remains unclear is the source of the flotsam. The wide array of objects suggests that the flotsam may be coming in from the treated effluent wastewater that feeds the pond (Fig. 1). The sparse number of plastic bottles found within the pond suggests that littering by park patrons is not the major contributor of flotsam. As we continue monitoring the situation locally, we encourage others to be observant for similar deleterious situations in their focal populations.

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