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SHORT COMMUNICATION

Loggerhead turtles *Caretta caretta* (Linnaeus) preying on the invading gastropod *Rapana venosa* (Valenciennes) in the Río de la Plata Estuary

Alvar Carranza[1,2], Andrés Estrades[2,3], Fabrizio Scarabino[2,4] & Angel Segura[2,5]

1 UNDECIMAR, Facultad de Ciencias, Iguá, Montevideo, Uruguay
2 Museo Nacional de Historia Natural, Montevideo, Uruguay
3 KARUMBE, Biodiversidad y Conservación, Av. Rivera, Montevideo, Uruguay
4 Dirección Nacional de Recursos Acuáticos, Constituyente, Montevideo, Uruguay
5 Sección Oceanología, Facultad de Ciencias, Iguá, Montevideo, Uruguay

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Correspondence
Alvar Carranza, UNDECIMAR, Facultad de Ciencias, Iguá 4225, C.P. 11400, Montevideo, Uruguay.
E-mail: alvardoc@fcien.edu.uy

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Abstract

Here we report the first observations of loggerhead turtles *Caretta caretta* preying on a conspicuous molluscan invader, the rapa whelk *Rapana venosa*. An average number of 136 opercula were found in stomach contents of five turtles, the curved carapace length ranging in from 51 to 112 cm. No other alimentary items were found in the turtles analyzed. We suggest that the rapa whelk may constitute up to 100% of the diet for immature and mature loggerheads in the Río de la Plata estuary (Uruguay), highlighting the plastic nature of the foraging behavior of loggerheads.

Introduction

Loggerhead turtles *Caretta caretta* (Linnaeus, 1758) are an endangered species (IUCN 2009) distributed worldwide, inhabiting continental shelves, bays, lagoons, and estuaries in the temperate, subtropical, and tropical waters of the Atlantic, Pacific, and Indian Oceans (Dodd 1988). In the Southwestern Atlantic, the occurrence of immature and adult loggerheads from nesting beaches of Brazil, USA, and Australia is common (Caraccio *et al.* 2008). The nearest nesting colony of loggerhead turtles to the Río de la Plata Estuary is located in the state of Espiritu Santo, Brazil. The classification of developmental stages of Uruguayan loggerheads are based on nesting data from Brazilian rockeries, showing that the minimum nesting size of a female is a 83 cm curved carapace length (CCL; Baptistotte *et al.* 2003). Thus, CCLs from Uruguay, ranging from 51 to 112 cm (López-Mendilaharsu *et al.* 2006), indicate the presence of both juveniles and mature individuals. Adult loggerheads nesting in these regions undertake feeding migrations over the continental shelf (Almeida *et al.* 2000; Laporta & Lopez 2003). Large juveniles and adults feed in the Southwestern Atlantic shore upon a variety of benthic invertebrates, such as crustaceans (*e.g. Libinia spinosa*, *Loxopagurus loxochelis*), mollusks (*Buccinanops cochlidium*, *Pachycymbiola brasiliana*), and fishes discarded from coastal fisheries (Estrades *et al.* 2007; Martinez-Souza 2009). Because loggerheads have very powerful jaws, they are capable of crushing the shells of seemingly invulnerable prey such as the gastropod *Strombus gigas* and the bivalves *Tridacna maxima* and *Tridacna fosor* (Mortimer 1995).

Rapana venosa (Valenciennes, 1846) (rapa whelk), a large, predatory gastropod and one of the most unwelcome and conspicuous invading mollusks, was introduced during the 1990s in the Río de la Plata Estuary (Scarabino *et al.* 1999; Pastorino *et al.* 2000). This species has been shown to be widespread in the area, reaching very high densities all along the Río de la Plata Estuary, both in hard and soft bottoms (Giberto *et al.* 2006; Scarabino *et al.* 2006; Carranza

& Rodríguez 2007; Cortelezzi *et al.* 2007; Carranza *et al.* 2008, 2010; Lanfranconi *et al.* 2009), thus constituting both a threat to native bivalves (*e.g.* the blue mussel *Mytilus edulis*; Scarabino *et al.* 1999; Carranza *et al.* 2010) and a potential resource for predators of benthic animals. Harding & Mann (1999) suggested that sea turtles and blue crabs may be potential predators of *R. venosa* in Chesapeake Bay. However, until now, there was no evidence of predation on rapa whelks in the Río de la Plata Estuary, and there were no previous reports of predation by loggerheads (or any other predator) on this gastropod in invaded natural habitats worldwide (*e.g.* Dodd 1988; Harding & Mann 1999; Frick *et al.* 2001). Thus, the objectives of this paper are (i) to report predation by loggerheads on *R. venosa* in the Río de la Plata Estuary, (ii) to analyze quantitative aspects of this novel predator–prey interaction (*e.g.* gut content analyses, size–frequency distributions of ingested rapa whelks) by discussing the results in the context of the ecological features of both species.

Material and Methods

Digestive tract contents were examined from five loggerhead turtles stranded on the beaches or captured by the Uruguayan fleet between March 2002 and November 2008 (Table 1, Fig. 1). All turtles were found dead and

Table 1. Identification code, collection dates, Uruguayan locations (latitude and longitude). curved carapace length (CCL), and status (S/C = stranded or by-catch) of the examined animals. Each code represents one of the five turtles examined.

code	date	location	latitude	longitude	sex	CCL (cm)	S/C
CCV 014	Feb 2002	Carrasco, Montevideo	34° 53′569	56° 03′389	N/A	60.0	Stranded
CCV 254	Mar 2006	Carrasco, Montevideo	34° 53′112	56° 02′286	Male	105.5	Stranded
PRO 1	Mar 2006	Argentine-Uruguayan Common Fishing Zone	35° 58′000	56° 09′000	Male	107.0	Trawl by-catch
CCV 317	Feb 2008	Carrasco, Montevideo	34° 53′050	56° 02′220	Male	108.5	Stranded
CCV 318	Feb 2008	Belo Horizonte, Canelones	34° 46′647	55° 38′630	Male	109.0	Stranded

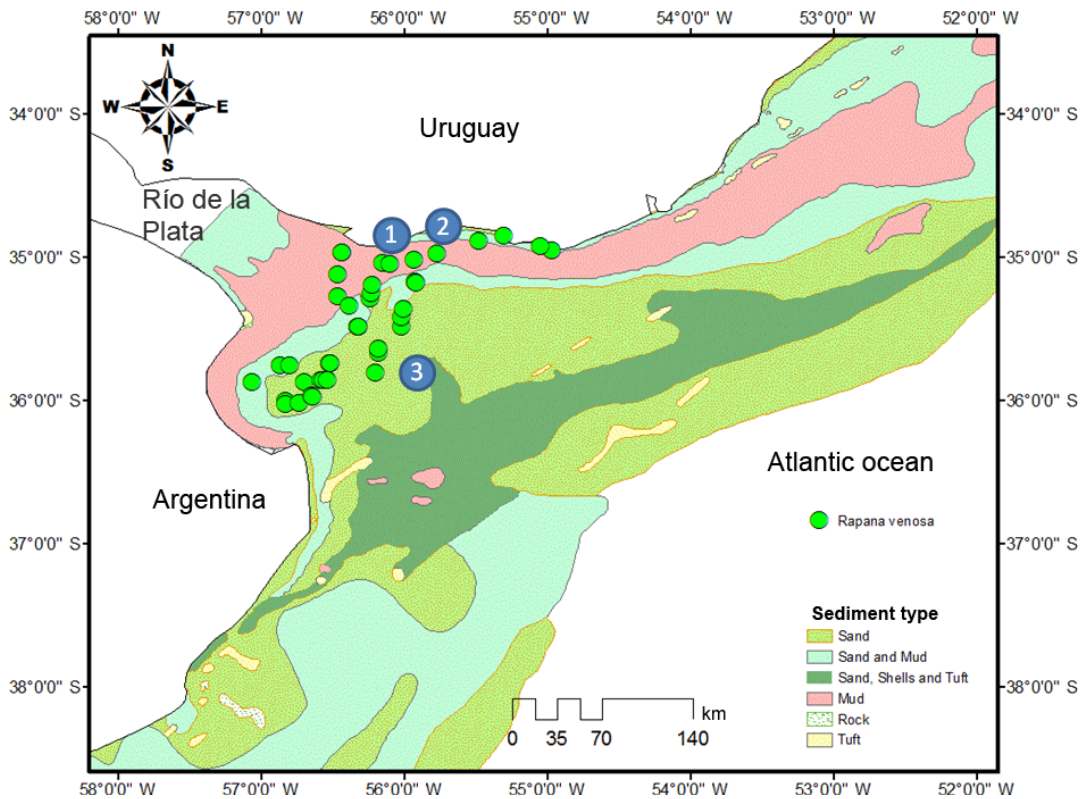

Fig. 1. Map of the Río de la Plata estuary, indicating locations of collection of sea turtles. 1: Carrasco, Montevideo; 2: Belo Horizonte, Canelones and 3: Argentine–Uruguayan Common Fishing Zone. Known records of *Rapana venosa* are also indicated (gray circles), as well as a coarse characterization of sediment type.

Table 2. Digestive tract analysis summary. Identification code, item, and presence or number of items (total wet weight, g) found inside entire digestive tract (stomach and/or intestines) of the examined loggerheads. When possible, gut content was isolated to digestive tract location (intestine or stomach); N/F indicates opercula were not found in the indicated region, N/A indicates tract location was not available as the contents could not be isolated to a particular tract region. In all cases, rapa whelks accounted for 100% of gut content.

code	item	all tract (total)	intestine	stomach
CCV 014	Opercula	16 (26)	16 (26)	N/F
	Foot/visceral mass/mantle	Present	Present	N/F
	Shell fragments	Present	Present	N/F
CCV 254	Opercula	150 (702)	N/A	N/A
	Foot/visceral mass/mantle	Present	N/A	N/A
	Shell fragments	Present	N/A	N/A
	Rapana egg capsules	Present	N/A	N/A
PRO 1	Opercula	118 (583)	N/A	N/A
	Foot/visceral mass/mantle	Present	N/A	N/A
	Shell fragments	Present	N/A	N/A
	Rapana egg capsules	Present	N/A	N/A
CCV 317	Opercula	129 (1946)	117 (196)	12 (22)
	Foot/visceral mass/mantle	(1366)	(891)	(475)
	Shell fragments	(362)	(347)	(15)
	Rapana egg capsules	N/F	N/F	N/F
CCV 318	Opercula	144 (649)	132 (214)	12 (21)
	Foot/visceral mass/mantle	(137)	(131)	(106)
	Shell fragments	(177)	(173)	(4)
	Rapana egg capsules	N/F	N/F	N/F

were identified and classified by size (CCL) and gender. The turtles were examined to analyze diet and the entire contents of the gut, stomach and/or intestinal tract were collected following necropsies. The mouth cavity and esophagus of each specimen were also inspected. Identity, quantity, and wet weight of prey items were determined. Diet data are presented in Table 2 as the number and wet weight for each item, discriminated by their location along the digestive tract (when available).

To depict both the feeding preferences of *Caretta caretta* and to identify on which population component of *Rapana venosa* it is preying, we estimated the shell length of the gastropod based on opercula measurements. To this end, the ingested opercula were measured for their maximum linear dimension, and then the shell length of the gastropods was estimated using a regression model. The shell length *versus* operculum relationship was generated using 250 live-collected rapa whelks from Maldonado Bay (April 2010), ranging in size from 52 to 120 mm in shell length (Carranza *et al.* 2010). With this model, we constructed a shell length frequency distribution of the gastropods found in the digestive tract of the examined loggerhead individuals.

Results

In the zone where turtles were collected in the Río de la Plata, seawater temperatures reach maximum seasonal values (average = 22 °C; SD = 1.1 °C) in austral summer. During this season, average salinity ranges from 10 to 25 (Guerrero *et al.* 1997).

Stranded turtles were fresh and, based on their general condition, most likely died 48–72 h before being analyzed. Analyses revealed high numbers of opercula belonging to *Rapana venosa*, as well as mantle and foot tissue, shell remnants, and ovigerous capsules from the whelks. Opercula were all fairly well preserved. In all the examined turtles, the whelk accounted for 100% of gut content. The average number of opercula was 135.6. One turtle (CCV 254) contained some 150 opercula, representing 702 g in wet weight, together with some egg capsules of the whelk (Table 2).

The least-squares linear regression model, based on maximum opercula linear dimension, explained nearly 60% of the variance in shell length ($R^2 = 0.59$, $P < 0.05$; $y = 27.72 + 1.31x$). Using this model and based on the 559 opercula examined, the average shell length of the ingested gastropods was 89.0 mm, ranging from 55.3 to 117.0 mm. There were clear differences in the average shell length of the gastropods ingested among turtles, with one individual (CCV 014) showing a preference for comparatively small-sized gastropods (Fig. 2).

Discussion

To our knowledge, this is the first report of loggerhead turtles preying on the invading gastropod *Rapana venosa*, and the first record of any predator of the snail in an

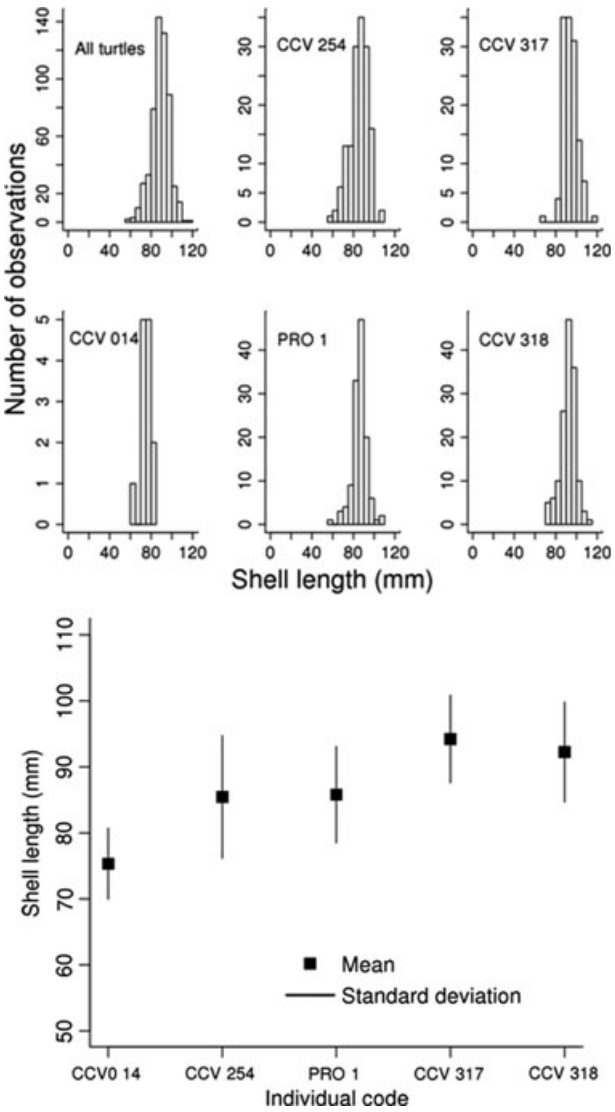

Fig. 2. Upper panel: shell-length frequency distribution of ingested *Rapana venosa*. Measurements were estimated by means of a regression model based on the relationship of operculum to shell length (see text for details). Lower panel: Mean (± SD) shell length of ingested *Rapana venosa* discriminated by loggerhead individuals.

invaded ecosystem. Whereas loggerhead post-hatchlings feed on a variety of neustonic items, evidence of their pelagic existence (Boyle & Limpus 2008), immature and mature stages present a benthic foraging ecology, also supplementing their natural diets with discarded fish from fisheries (Plotkin *et al.* 1993; Tomas *et al.* 2001). In this context, several authors reported shelled gastropods in the loggerhead diets (Dodd 1988; Frick *et al.* 2001; Tomas *et al.* 2001; Estrades *et al.* 2007; Martinez-Souza 2009; Wallace *et al.* 2009; Lazar *et al.* 2010). Harding & Mann (1999) suggested that sea turtles can be predators of rapa whelks in Chesapeake Bay. However, to date, there have been no published reports on this particular interaction. In the Río de la Plata Estuary, the high number of snails consumed by turtles demonstrates the importance of the whelk for turtle diets. We believe that the reported 100% gut content measurement is not an overestimation of the importance of the whelk. Although opercula may persist longer in the digestive tract, we also found soft tissues of the rapa whelk, which are much more sensitive to digestion than other prey usually consumed by the loggerhead (*e.g.* fishes, crabs) (F. Scarabino and A. Estrades, personal communication). This predator–prey interaction is nonetheless particularly relevant from both ecological and socioeconomic perspectives, as the loggerhead turtle is a charismatic, flagship and endangered species, and *R. venosa* is considered to be among the 100 worst alien species in the European Invasive Alien Species Gateway (DAISIE 2010), one of two marine gastropods on this list.

Although there were differences in the range of shell lengths of ingested gastropods among turtles, all estimated figures suggest that *Caretta caretta* preys on adult *R. venosa* (Saglam & Duzgunes 2007; Saglam *et al.* 2009). These authors reported that the size at maturity of *R. venosa* is about 40 mm, and all the examined opercula suggest that ingested gastropods are larger than this figure. Harding (2003) analyzed the predation patterns of the blue crab *Callinectes sapidus* on the rapa whelk in Chesapeake Bay, and suggested that the rapid growth and shelf features of *R. venosa* create both a habitat and a size refuge for blue crab predation at a shell length of 60–80 mm. However, this is not the case for this predator–prey interaction, as loggerheads prey upon whelks well above these sizes. Further, the maximum estimated size for an ingested whelk was 117 mm, very close to the maximum size (120 mm) reported for the study area (Giberto *et al.* 2006). In a wider context, the estimated size range of rapa whelks found in loggerhead gut contents falls within the published range of sizes observed in established populations (Giberto *et al.* 2006; Lanfranconi *et al.* 2009) in the Río de la Plata area. Although one turtle (CCV 254) contained some egg capsules of the whelk, this should not be interpreted as evidence of foraging on egg capsules, as eggs can be attached to the shell (F. Scarabino, personal communication). The timing of the observations also suggests that the predation events coincided with the summer reproductive period of the whelk (Pastorino *et al.* 2000; Giberto *et al.* 2006; Carranza *et al.* 2010).

Conclusions

Understanding ecosystem responses to human-induced change is a challenge for the scientific community

worldwide, as species interactions are often non-linear and hard to predict (Walther *et al.* 2002). Given that the whelk represented 100% of the gut content of the analyzed turtles, *Caretta caretta* may well be an important control for populations of this extremely successful invading gastropod. The lack of estimates of the population sizes of both *Rapana venosa* and loggerhead in the Río de la Plata Estuary and of the predation rates of the sea turtles on these gastropods, preclude a quantitative estimation of the impact of this trophic relationship for these populations. However, our findings highlight the plasticity of the opportunistic, generalist foraging strategy of loggerheads (Dodd 1988; Wallace *et al.* 2009), and demonstrate a novel trophic link between one of the more conspicuous invading mollusks and a seriously threatened species.

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