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Response of the sea cucumber *Holothuria cinerascens* to the predatory gastropod *Tonna perdix*

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Abstract

The process of a predatory gastropod (*Tonna perdix*) interacting with its sea cucumber (*Holothuria cinerascens*) prey was recorded in a reef tidal pool in Southern Taiwan. The sea cucumber reacted by taking in large quantities of water to increase its size (4.4-fold volume increase); its diameter expanded from 3 to 7 cm, though its length decreased from 15 to 12 cm. The engorged sea cucumber did not attempt to escape, but contracted its mouth, anus, tube feet, and dorsal papilla, and tilted 90 degrees on the sea floor. The small *T. perdix* (3 cm shell length) made an attempt to engulf its prey's posterior end but failed; instead, it approached and made contact with the body and anterior end of the sea cucumber for three minutes before moving away. A small wound was evident on the posterior end of the sea cucumber. The sea cucumber maintained its swollen state until the tide rose an hour later. This report confirms that the predator-induced swelling behavior of *H. cinerascens* previously observed in the laboratory also occurs *in situ*, and this reaction may have prevented this sea cucumber from being consumed.

Key words: anti-predator defense, ecology, gastropod, *Holothuria cinerascens,* predation, sea cucumber, *Tonna perdix*

Introduction

Few animals are known to eat sea cucumbers, as most sea cucumbers have toxic chemicals distributed throughout their bodies (Bakus, 1968, 1973, 1974, 1981). Four gastropod species are known to prey on sea cucumbers, and 14 sea cucumber species are known to be eaten (Table 1;

Table 1. Gastropod predators of holothurians. All studies were conducted in the laboratory unless otherwise noted.

Predators	Holothurian prey	Study site	Reference
Amphissa columbiana	*Psolus chitonoides*	Washington, USA	Bingham & Braithwaite, 1986
Tonna galea	*Holothuria polii*	Mediterranean	Toscano et al., 1992
	H. tubulosa	Mediterranean	Toscano et al., 1992
	H. forsaklii	Mediterranean	Toscano et al., 1992
	H. sanctori	Mediterranean	Toscano et al., 1992
T. perdix	*H. atra*	Guam,	Kropp, 1982
	H. cinerascens	Guam,	Kropp, 1982
		Taiwan[a]	Herein
	H. hilla	Guam	Kropp, 1982
	H. leucospilota	Taiwan[a]	Herein
	Stichopus chloronotus	Guam	Kropp, 1982
	S. horrens	Guam	Kropp, 1982
T. zonatum	*H. insignis*	Hong Kong	Morton, 1991
	H. fuscocinerea	Hong Kong	Morton, 1991
	H. leucospilota	Hong Kong	Morton, 1991
	H. scabra	Hong Kong	Morton, 1991

[a]documented *in situ*.

Kropp, 1982; Toscano et al., 1992; Francour, 1997). Most of these predation events have been observed in the laboratory (Table 1). For instance, the tropical and sub-tropical tonnid gastropods *Tonna perdix* and *T. zonatum* have been assumed to be highly specialized predators of holothurians (Kropp, 1982; Morton, 1991) based on laboratory studies. We propose herein that the scarcity of predation records *in situ* is probably due to the fact that both gastropods and holothurians are nocturnal and so such predation events have been overlooked by scientists.

In the reef intertidal zones of Southern Taiwan, *T. perdix* regularly feeds on sea cucumbers, particularly *Stichopus horrens* and *Holothuria leucospilota* (authors' personal observations). *T. perdix*

may also feed on *Holothuria cinerascens,* which is abundant in Southern Taiwan in tide pools near the low tide line (authors' personal observations). *H. cinerascens* nearly always hides in rock crevices, feeding on drifting algae and organic materials by extending its branched feeding tentacles. Rarely are individuals exposed in tidal pools. In this work, we describe for the first time successful anti-predatory behavior of an exposed *H. cinerascens* individual upon attack by a small *T. perdix* gastropod.

Materials and Methods

On April, first, 2015, while conducting nightly field work during low tide at the intertidal zone of the Houbihu reef flat in Southern Taiwan (21°56'57"N, 120°44'53"E), we photographed (Fig. 1) and video-recorded (see online supplemental video.) the reaction of an *H. cinerascens* sea cucumber to the approach, and subsequent attack, of a small *T. perdix* gastropod (3 cm shell length) in a 30-cm deep tide pool. We measured the diameter and length of the sea cucumber both before and after the encounter to estimate its size/volume.

Results

The 15-cm long sea cucumber *H. cinerascens* laid on sea floor with its entire body exposed on rocky bottom. The small *T. perdix*, whose proboscis was extended, crawled quickly towards the sea cucumber. As the gastropod approached, the sea cucumber initially showed no response. However, as *T. perdix* made contact with the sea cucumber's posterior end, the sea cucumber retracted violently and began to swell (a 9-s process). *T. perdix* opened its proboscis and tried to hold onto and/or bite the posterior end of the sea cucumber. *T. perdix* continued to enlarge its proboscis as the sea cucumber engorged itself with seawater. However, the diameter of the sea cucumber was larger than the size of the proboscis of *T. perdix*. Then, *T. perdix* released *H. cinerascens* and crawled around it towards its anterior end (Fig. 1a). A small wound leaking with white tissue was evident on the posterior end of *H. cinerascens* once the gastropod detached itself (Fig. 1b).

As mentioned above, *H. cinerascens* reacted to the presence of the *T. perdix* gastropod by taking in large quantities of water to increase its size, and specifically its diameter, which expanded from 3 to 7 cm. The length, however, shortened from 15 to 12 cm. The total volume increased approximately 4.4-fold. Since it was in a relatively calm and stagnant tidal pool, the sea cucumber did not drift, move, or, in other words, attempt to escape. Instead, it retracted its mouth, anus, tube feet, and dorsal papilla. The only sign of any movement was its tilting about 90 degrees on the sea floor, but it did not tilt away from the gastropod.

The small gastropod did not enlarge its proboscis again after leaving the posterior

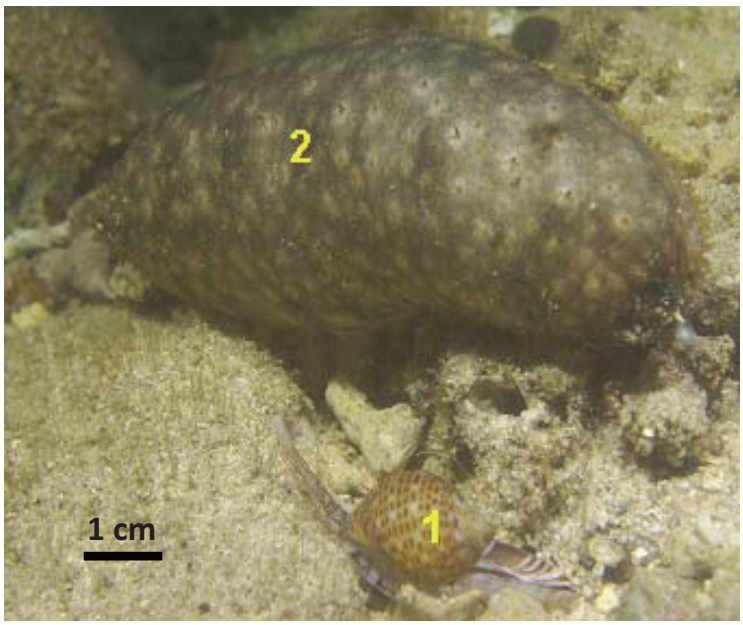

Fig. 1a. A small gastropod (*Tonna perdix*) (1) approaches an expanded sea cucumber (*Holothuria cinerascens*) (2). A supplemental video of this interaction can be found online: http://210.243.41.4/Default.aspx?tabid=495

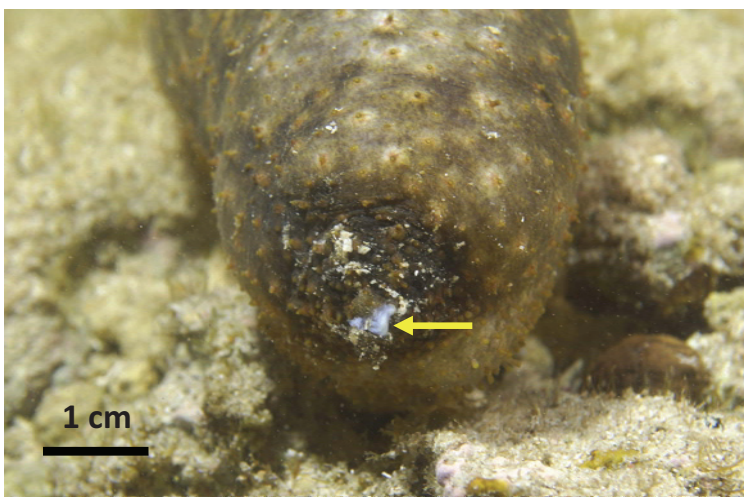

Fig. 1b. A small wound from which white tissue (arrow) was protruding on the posterior end of the sea cucumber (*H. cinerascens*); this wound appeared after the *T. perdix* attack .

end of the sea cucumber, but instead approached and made contact with the body of sea cucumber with its proboscis . The gastropod crawled near the sea cucumber for three minutes, mostly around the anterior and posterior ends of the animal, before moving away. *T. perdix* left at normal speed with its proboscis extended as if it were still searching for food. It made no effort to attack the *H. cinerascens* individual again. Afterwards, we did not see it attack another sea cucumber within one hour. It crawled into a rock crevice and disappeared. The sea cucumber maintained its expanded status until the tide rose, over an hour later.

Discussion

Holothurians have evolved eight types of anti-predatory structures and/or mechanisms (Table 2): 1) thick body walls (including well-developed ossicles), 2) toxic and/or noxious skin and organs, 3) swelling or stiffening of the body, 4) evisceration or autotomy (including releasing the Cuvierian tubules and shedding pieces of the body wall), 5) swimming/escaping, 6) a nocturnal lifestyle, 7) cryptic or burrowing behavior, and 8) brooding (association of embryos/juveniles with an adult) (Kropp, 1982; Bingham & Braithwaite, 1986; Lawrence, 1987). Amongst these, *H. cinerascens* is cryptic, nocturnal, and engages in swelling when approached by predators.

Tonna galea, *T. perdix*, and *T. zonatum* are important predators of tropical and sub-tropical sea cucumbers. They prey on 13 of the 14 species (93%) of shallow-water sea cucumbers that have been observed to be eaten, and they appear to prefer members of the genera *Holothuria* and *Stichopus* (Table 1). Indeed, Morton (1991) suggested that the Tonnidae are highly specialized and exclusive predators of holothurians. Laboratory experiments have reported that *Tonna* spp. prey on many species of sea cucumbers (Table 1; Kropp, 1982; Morton, 1991). Kropp (1982) documented *T. perdix* attacking five holothurian species in the laboratory: *Stichopus chloronotus*, *S. horrens*, *Holothuria atra*, *H. cinerascens,* and *H. hilla*. Morton (1991) reported that a laboratory-reared *T. zonatum* fed on *H. cinerascens, H. insignis, H. fuscocinerea,* and *H. leucospilota*. Morton (1991) also documented holothurians reacting violently to hunting *T. perdix* individuals, typically by taking in large quantities of water to increase their size (and notably their diameter, as was observed herein). *H. scabra* and *H. leucospilota* become buoyant and, by writhing, achieve some simple swimming motions to attempt to escape or disturb the activities of the predator, but such activities usually did not prevent them from being consumed in laboratory studies. However, this could be due to the limited space of the aquaria used (Morton 1991).

Table 2. Anti-predation strategy of holothurians.

Holothurian prey	Anti-predation strategy	Predators	Reference
Holothuria atra	Swelling	*T. perdix*	Kropp, 1982
H. cinerascens	Swelling	*T. perdix*	Kropp, 1982; Herein
H. forsaklii	Cuvierian tubule evisceration	*Tonna galea*	Toscano et al., 1992
H. fuscocinerea	Swelling	*T. zonatum*	Morton, 1991
H. hilla	Swelling	*T. perdix*	Kropp, 1982
H. insignis	Swelling	*T. zonatum*	Morton, 1991
H. leucospilota	Swelling, Buoyant writhing	*T. zonatum*	Morton, 1991
H. leucospilota	Swelling	*T. perdix*	Herein
H. sanctori	Cuvierian tubule evisceration	*Tonna galea*	Toscano et al., 1992
H. scabra	Swelling Buoyant writhing	*T. zonatum*	Morton, 1991
Parastichopus californicus	Swimming	*Luidia foliolata*, *Dermasterias imbricate* (sea star)	Margolin, 1976
Psolus chitonoides	Toxicity, Well-developed ossicles	*Amphissa columbiana* (gastropod)	Bingham & Braithwaite, 1986, Lawrence, 1987
Stichopus chloronotus	Body wall shedding	*T. perdix*	Kropp, 1982
S. horrens	Body wall shedding, Nocturnal	*T. perdix*	Kropp, 1982; Herein

Kropp (1982) described how *T. perdix* preys on *H. cinerascens* in the laboratory; a 16-cm long prey specimen expanded to sphere-like proportions and was demonstrated to have survived the attack. It did sustain four abrasion-like wounds and one penetrating wound to the mesentery surrounding the viscera. This sea cucumber maintained its spherical shape for >70 min. We observed that the expanded state of *H. cinerascens* lasted for >60 min, suggesting that it was intensely stressed by the *T. perdix* specimen. Three small *H. cinerascens* specimens (12-14 cm), however, were consumed by a large *T. perdix* gastropod (Kropp 1982). Swelling appears to be a common anti-predatory mechanism adopted by many holothurians, especially for members of the family Holothuriidae found in reef areas (Table 2).

Field records of predation of sea cucumbers are limited, probably due to the nocturnal behavior of both predators and prey. We have three other, unpublished, nocturnal observations of *T. perdix* preying on two other species of sea cucumber, *S. horren* and *H. leucospilota*, in tidal pools at the same study. In two cases, the sea cucumbers escaped. Specifically, when attacked by *T. perdix*, *S. horren* left its dorsal tunic to the predator while the remainder of its body escaped. A large *T. perdix* (8 cm shell length) engulfed a whole *H. leucospilota*, yet an expanded *H. leucospilota* drifted away via wave action. In most laboratory studies, sea cucumber prey are nearly always consumed by *T. perdix*, though this may be due to the inherent lack of water motion in such studies; in other words, sea cucumbers may be more likely to escape *in situ* due to predator disturbance/prey escape due to wave action. Wave action may further agitate the sea cucumbers, making their expanded, buoyant, or writhing bodies hard to grab by the proboscises of gastropods and thereby giving them a greater chance of escape. In this study, the expanded *H. cinerascens* specimen was in a calm tide pool and did not writhe its body to a significant extent or float away. Although this sea cucumber ultimately survived gastropod attack, the latter did appear to have bitten the former, and it is possible that small *T. perdix* individuals may use this quick-bite strategy to acquire food and energy without necessarily consuming the prey source in its entirety. Though wounding may not necessarily be avoidable, swelling may be an effective anti-predation strategy for *H. cinerascens* in response to attack by small gastropods like *T. perdix*.

Conclusions

We hypothesize that, upon sensing the approaching predator, the *H. cinerascens* specimen observed herein took in water to expand its body enough to prevent being consumed by the relatively smaller

gastropod. Since the expanded sea cucumber was far too large for the small *T. perdix* individual to consume, the gastropod may have finally given up. Therefore, we confirm that the predator-induced swelling behavior of *H. cinerascens* observed in laboratory also occurs in the field. If the swelling is extensive enough, this behavior may prevent predation, though an observation of a greater number of predator-prey interactions will be required to conclusively determine the most common anti-gastropod predation mechanism utilized by this species of sea cucumber.

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