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Pea-crab (*Pinnotheres* sp.) as commensal inside the shells of edible wedge clams and their predators along southwest coast of India

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Original Article

Abstract

Pea-crab (*Pinnotheres* sp.) is a commensal organism found inside the shells of wedge clams, *Donax* sp. and *D. faba* at Panambur beach along Karnataka coast of India whereas pea-crab was not found in either *D. faba* and *D. scortum* in Padukere beach. At Panambur beach, the pea-crabs in *Donax* sp. and *D. faba* were found when the size was greater than 10 mm. The presence of pea crabs inside the shells of wedge clams was greater during monsoon seasons which in general is the breeding period of marine organisms. The number of pea-crab fluctuated between different seasons. Predation by the crab (*Ocypode ceratophthalmus*), birds *(Calidrius minuta, Corvus splendens, Tringa terek* and *Charadrius mongolus*) and humans on *Donax* spp. occurred during the study period.

Keywords*: Pea-crab, wedge clam, commensal, predators, Karnataka*

Introduction

The genus *Donax* inhabits dynamic environments, i.e., high energy beaches of temperate and tropical coastal regions (Ansell, 1983). Donacids are wedge-shaped, which is likely to be an adaptation for migrating between tide levels and for rapid burrowing (Stanley, 1970). Several species of *Donax* have distribution range extending from east to west coasts of India. The filter-feeding wedge clams, *Donax* (Bivalvia: Donacidae) species are dominant macrofaunal species on shallow bottoms (from 0 to 20 cm depth) along Karnataka coast (Singh, 2013). They inhabit high-energy environments with strong wave action and with numerous suspended particles. Along the southeast coast of India, wedge clams are commercially important (Dharmaraj *et al.*, 2005).

Trematode larvae are one of the most important parasites in clams of the family Donacidae (Lauckner, 1983), although few species have been studied in detail (Ansell, 1983). Many of the trematode parasites found in the genus *Donax* occur in the visceral mass causing castration of infected bivalves (Pelseneer, 1896; Loesch, 1955; Wade, 1967). In the study of *Donax trunculus* infected by *Bacciger bacciger*, the visceral mass and the foot are completely filled with sporocysts, which causes

complete castration in heavily infected individuals (Ramadan and Ahmad, 2010). They can infect the liver and all the visceral mass in heavy infections, with individuals assuming a flaccid consistency (Palombi, 1934). The gonad is the first organ to be infected and may be destroyed completely. In recent study, *B. bacciger* infections can cause other negative effects, i.e., suggesting death of parasitized hosts (de Montaudouin *et al*., 2014). In a case, the connection between the severe mortalities of Dutch cultured mussels in the autumn and the simultaneous high numbers of *Mytilicola intestinalis* was observed by Korringa (1950). Later it was realized that this was the causative agent of mass-mortalities of mussels in Holland and Germany (Meyer and Mann, 1950).

Based on earlier research on bivalves, predation is often considered to be the most important cause of mortality (Nakaoka, 1996; der Veer *et al*., 1998), but, the predation is not always lethal. Palombi (1934) suggested that during the gonadal maturation period there was an increase in mortality, because, instead of burrowing, infected clams frequently lie exposed to predators on the surface of the sediment. Apart from this, predation of *Donax* species occurs when the loss of siphons occures by nipping and cropping predators, mainly crustaceans (Leber, 1982a, b; De Vlas, 1985; Salas *et al*., 2001), birds (Ansell *et al*., 1999) and fish (Trevallion *et al*., 1970; Ansell, 1983, 1992). Ansell *et al.* (1999) have reported that only flatfishes are foot-nipping predators. On the other hand, Salas *et al.* (2001) found that crustaceans like *Liocarcinus vernalis* and *Portumnus latipes* are also foot-nipping predators and these species are the main predators of the clams. Ansell (1992) observed tissue remains of *Donax vittatus* from Scottish beaches content in the stomachs of the portunid crabs, *L. holsatus* and *Carcinus maenas*. However, Silas and Alagarswami (1965) reported that a few species of the genus *Pinnotheres* are known to be definite parasites of some bivalves, while the great majority of the pea-crabs may be classed as obligate commensals and live in bivalve molluscs, echinoderms and ascidians. Smith (1975) reported that colour polymorphism provides crypsis for juvenile donacids (*Donax faba*) and in adults provides visual predators (*Ocypode*) with intraspecific choice as an alternative to interspecific options. Lastly, he concluded that polymorphism in colour is especially important in tidal migrant species which are particularly vulnerable to visual predation during migration. In this case, for *D. variabilis*, Moment (1962) suggested that polymorphism in colour is important in preventing predators (birds) forming searching images (Tinbergen, 1960). Studies on parasites/commensals and predation for the wedge clams which may or may not affect the health of donacid populations have not been carried out in India till now. The present study is concerned with the pea-crab, *Pinnotheres* species and to discover whether this animal is parasite/commensal or not inside the shells of wedge clams, *Donax faba* and *D. scortum* along Karnataka coast of southwest coast of India.

Material and methods

Panambur (12º56'18.02"N; 74º48'14.37"E) located in Dakshina Kannada district and Padukere (13º20'51.80"N; 74º41'30.92"E) in Udupi district of Karnataka were selected for the study (Fig. 1). Collection of *Donax* sp. was made from March 2008 to February 2009 and *D. faba* from April 2009 to March 2010. Live specimens were collected at monthly intervals. The coastal Karnataka region is characterized by three distinct seasons, pre-monsoon (February-May), south west monsoon (June-September) and post-monsoon (October-January).

All *Donax* species lie buried in sand in the surf zones. Majority of *D. scortum* population was found along the mid intertidal zone at Padukere. Specifically, *D. scortum* was more abundant on the flatter portions in Padukere beach where the wave wash is more uniform, thus providing better conditions for filter-feeding. *Donax* species were collected with the help of a shovel and sieve (0.5 mm). A total of 3,499 individuals of *Donax* sp. and 1,416 of *D. faba* from Panambur beach were collected, whereas a total of 2,367 *D. scortum* and 1,404 of *D. faba* specimens were collected from Padukere beach, and brought to laboratory for further analysis. In the laboratory, the clams were subjected to morphometric analysis with the help of Vernier calipers. Shell length (maximum anterio-posterior distance) was measured (FAO, 1998). The meat of the wedge clams was removed with the help of a stainless steel knife. The meat was transferred into a petri dish without losing the mantle fluid. With the help of a needle and forceps the flesh was checked for live pea-crabs. Consequently, mantle, mantle fluid, ctenidia, gonad, gut, muscle, hepatopancreas etc., were examined separately for the presence of commensals/associates/parasites under different

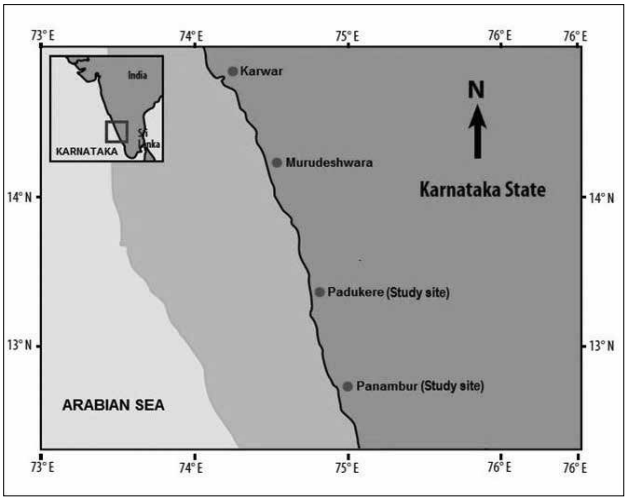

Fig. 1. Location of study areas along Karnataka coast, India

magnifications of stereo zoom microscope. Later the pea-crabs found inside the shells were counted (Fig. 2). The pea-crabs found from the clams were preserved in 10% formalin, during the study period, predators of *Donax* species was also examined carefully in both the selected beaches. Identification of crabs and birds was conducted with the handbooks of Sethuramalingam and Khan (1991), and Sathiyaselem and Rao (2014) respectively. The data on biological variables (clams) were subjected to cluster analysis (CA) using SPSS software (ver. 16.0) to understand the relationship between the months with reference to clams.

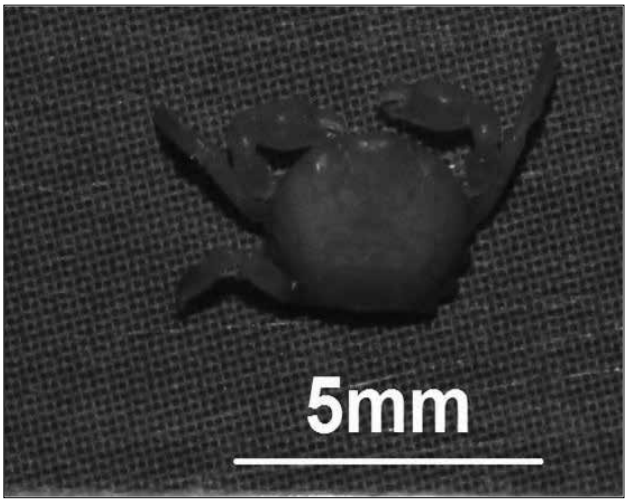

Fig. 2. Pea-crab (*Pinnotheres* sp.) found inside the shells of *Donax* sp. and *D. faba*

Results

In the present study, it was difficult to make any observations on the sexuality of the clams in relation to the infestation by *Pinnotheres* sp. After the removal of the crabs from the donacids no damage was found in the smooth parts of the clams under the stereo microscope. From Table 1, it is shown that *Pinnotheres* sp. was found inside the shells of *Donax faba* collected from Panambur beach, whereas it was not found in *D. faba* in Padukere beach throughout the study period. Though *D. scortum* is very large in size, no pea-crabs were found during the study. In case of *Donax* sp. collected from Panambur beach, pea-crabs were found in all months except September, December and February (Table 1). Crabs were most abundant in June (36), with the lowest numbers in July (2), October (2) and January (2). In one case, two pea-crabs were found inside one wedge clam (*Donax* sp.). At Panambur, in *D. faba*, the maximum number of crabs was found in June (3) and the minimum number was (1) in February.

The size ranges of donacids with mean and standar deviation collected from both the sites are given in Table 2 and 3 for each species. In Panambur beach, the pea-crabs in *Donax* sp. and *D. faba* were found when the size was greater than 10 mm. *Donax* sp. and *D. faba* sizes ranged from 3.8 (September 2008) to 24.4 mm (December 2008) and 4.4 (June 2009) to 25.5 mm (December 2009) respectively at Panambur. In case of Padukere, *D. scortum* and *D. faba*, the sizes varied from 11.8 (February 2009) to 69.8 mm (April 2009) and 4.8 (March 2010) to 25.8 mm (October 2009) respectively. All crabs found were alive with no occurrence of dead crabs in the opened shells.

Table 1. Pea-crab found inside the body of clams in Panambur and Padukere beaches during the study period

Panambur beach				Padukere beach			
Donax sp.		*Donax faba*		*Donax scortum*		*Donax faba*	
Month	No. of crabs	Month	No. of crabs	Month	No. of crabs	Month	No. of crabs
Mar 08	3	Apr 09	-	Feb 09	-	May 09	-
Apr	3	May	-	Mar	-	Jun	-
May	9	Jun	-	Apr	-	Jul	-
Jun	36	Jul	3	May	-	Aug	-
Jul	2	Aug	-	Jun	-	Sep	-
Aug	8	Sep	-	Jul	-	Oct	-
Sep	-	Oct	2	Aug	-	Nov	-
Oct	2	Nov	-	Sep	-	Dec	-
Nov	3	Dec	-	Oct	-	Jan 10	-
Dec	-	Jan 10	-	Nov	-	Feb	-
Jan 09	2	Feb	1	Dec	-	Mar	-
Feb	-	Mar 08	-	Jan 10	-	Apr	-
Total no. of crabs	68	Total no. of crabs	6	Total no. of crabs	-	Total no. of crabs	-
Total no. of clams	3499		1416		2367		1404

Table 2. Shell size studied to count the number of pea-crab from Panambur beach

Donax sp.				*Donax faba*			
Month	Length (mm)			Month	Length (mm)		
	Min	Max	Mean±SD		Min	Max	Mean±SD
Mar 08	6.8	23.3	18.68-3.35	Apr 09	13.2	24.3	19.1-2.06
Apr	6.3	23.8	18.20-3.19	May	8.5	23.3	18.5-1.91
May	4.7	22.7	17.66-4.06	Jun	4.4	25.0	16.5-5.39
Jun	10.2	23.8	20.09-2.06	Jul	15.0	23.8	19.4-1.99
Jul	15.0	23.8	19.72-1.73	Aug	11.7	23.0	20.3-1.91
Aug	4.9	23.9	18.31-4.18	Sep	6.8	23.0	18.5-3.74
Sep	3.8	23.6	19.03-4.27	Oct	7.2	23.8	17.6-5.07
Oct	5.8	22.8	13.97-5.46	Nov	7.8	23.7	14.5-5.63
Nov	4.3	24.3	16.01-7.02	Dec	11.4	25.5	20.5-2.77
Dec	4.8	24.4	13.42-5.18	Jan 10	9.2	24.9	21.7-2.50
Jan 09	4.4	23.5	13.14-4.64	Feb	5.8	24.6	17.8-5.04
Feb	5.0	24.2	15.32-4.10	Mar 08	9.4	25.4	22.3-2.03

The hierarchical cluster analysis (CA) using SPSS software was carried out to uncover the relationship between the months in which the pea-crabs were found in *Donax* sp. collected in Panambur beach (Fig. 3). Due to the low abundance of *D. faba* collected from Panambur beach CA was not performed. Similarly, the CA was also not performed for *D. scortum* and *D. faba* collected from Padukere beach since no pea-crabs were found. The hierarchical cluster analysis showed four major groups (Cluster 1, 2, 3 and 4). Cluster 1 (or Group) consists of February, October and December. Cluster 2 consists of January, March, April, July, October and November. Cluster 3 includes two months (May and August), whereas Cluster 4 consists of only June separately. Cluster 4 is because of maximum density of clams reported in the present study during monsoon season.

At the study areas, it was observed that *Donax* species were predated by crabs (*Ocypode ceratophthalmus*) and birds (*Calidrius minuta*, *Corvus splendens*, *Tringa terek* and *Charadrius mongolus*). Due to their large size, *Donax scortum* meat was consumed by fishermen as culinary food. In one case, meats of all *Donax* species were used as fish bait. Fishermen also used the donacids in poultry farms. Large sized *D. scortum* were very strong, thick and heavy when they were mature, capable of closing their shells tightly so that the shells could not be opened easily to take out meat by predators.

Ocypode ceratophthalmus, *Calidrius minuta*, *Corvus splendens*, *Tringa terek* and *Charadrius mongolus* mainly fed on wedge clams, *Donax* sp. (found in Panambur) and *D. faba* (found in Panambur and Padukere) mainly except *D. scortum*. The above predators were very common at the study areas, feeding on *D. scortum* juveniles. Marks were observed on clam beds, which were left over after the predators picked up *Donax*, mostly by birds during ebb tide. An interesting observation in the field was that freshly opened shells were laid down widely in the beds indicating that some predators may have eaten only meat by removing/sorting out the shells. On the other hand, birds usually swallowed the whole body of the clams. Crab like *O. ceratophthalmus* picked up *Donax* species, cracked it open with its larger chela at both the beaches and then ate the flesh.

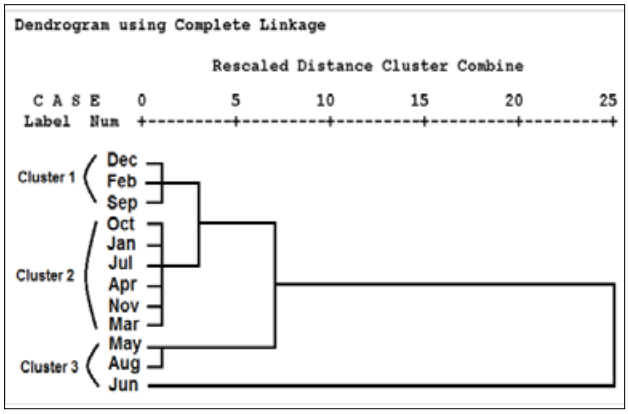

Fig. 3. Pea-crab (*Pinnotheres* sp.) found inside the shells of *Donax* sp. and *D. faba*

Discussion

Donax species is known to get infested by a variety of parasites, including a species of *Rickettsia* (Comps and Raimbault, 1978). Most of *Pinnotheres* species are shallow water inhabitants found in bivalves, holothurians and ascidians (Silas and Alagarswami, 1965). A perusal of literature showed that similar damages to the soft parts of bivalves are known to be caused by some species of *Pinnotheres* (Orton, 1921; Strauber, 1945; Sandoz and Hopkins, 1947; Berner, 1952). Johnson (1968) sought to associate the occasional mass mortalities of certain *Donax* species with parasitic infestations. A few donacids which were examined were seen to show no traces of damage and it can be presumed that this may have been on account of disinfestation of the clam. In contrast, Silas and Alagarswami (1965) stated that when they opened the clam, *Meretrix casta*, some damages were observed in the meat of this species, which were not likely to have been caused by pea-crabs. In recent report, a very low infestation rate with *Pinnotherus* sp. and gregarine spores were recorded in other bivalve species, *Perna viridis* from Kerala coast (Prema *et al.*, 2009). Infestation of pea-crabs was not found in *Donax* sp.and *D. faba* from the same sandy beach. The presence of pea-crabs inside the shells of wedge clams was high during monsoon seasons (Table 1), perhaps due to the breeding period of marine organisms. The pea-crabs were totally absent inside the shells of *D. faba* and *D. scortum* at Padukere. It is possible that their occurrence depends on habitat and environmental factors.

Table 3. Shell size studied to count the number of pea-crab from Padukere beach

Donax scortum				*Donax faba*			
Month	Min	Max	Mean±SD	Month	Min	Max	Mean±SD
Feb 09	11.8	64.8	49.70-11.21	May 09	7.6	24.4	12.91-5.42
Mar	22.0	56.8	30.45-7.44	Jun	6.0	24.5	16.95-6.04
Apr	25.2	69.8	54.46-5.02	Jul	6.8	25.7	15.11-5.81
May	25.5	69.4	51.21-8.05	Aug	5.6	24.5	14.32-5.36
Jun	32.8	59.4	53.10-4.07	Sep	9.2	22.3	13.16-1.69
Jul	34.5	62.5	53.63-5.96	Oct	6.8	25.8	13.52-4.12
Aug	25.0	62.0	52.27-6.40	Nov	9.3	18.6	13.87-2.31
Sep	28.4	64.0	51.37-7.17	Dec	10.5	21.9	18.13-1.53
Oct	26.9	62.6	49.67-8.13	Jan 10	9.8	22.3	18.83-1.75
Nov	33.5	64.4	51.78-6.46	Feb	5.5	24.5	16.67-4.92
Dec	35.6	62.6	52.74-4.29	Mar	4.8	22.8	11.06-5.48
Jan 10	33.5	64.8	53.70-4.46	Apr	5.8	23.0	10.42-4.99

The ability to burrow and the spatial scale suggest that competition is not a significant factor among the burrowers on sandy beaches (Branch, 1984). Rather, predation is much more likely to be an important factor than competition (Peterson *et al*., 2000). Different species of parasites/commensals in *Donax* spp. from different geographical regions are mentioned in Table 4. Appukuttan and Nair (1980) observed several genera of crabs, *Thalamita* sp. and *Procellana* sp. on culture ropes of *Perna indica*. *Pinnotheres* sp. was found inside the body of mussel, *Perna indica* as a commensal. They suggested that *Modiolus* sp. settlement seems alone to compete for space. In a case, *Pinnotheres* sp. was found in mussels, but no incidence of damage was noticed in them, which is in agreement with the present finding. In *Donax* sp. and *D. faba*, presence of *Pinnotheres* sp. was observed when the clams reached a size greater than 10 mm. Occurrence of greater numbers of pea-crab in monsoon season inside the shells of wedge clams is due to the breeding period of marine organisms along the southwest coast of India. The proportion of infected individuals by *Bacciger bacciger* on both male and female of *D. trunculus* was studied by Ramón *et al.* (1995). They found that the overall prevalence of infection by *B. bacciger* was 8.4%, increasing with the size to 23% in *D. trunculus* from 35-36 mm in shell length and individuals less than 19 mm long were not infected.

Table 4. Different parasites/commensals found in *Donax* spp. recorded by several authors.

Sl. No.	Species (Host)	Species (Parasite/Commensal)	Source
1	*Donax* sp.	Crab-*Pinnotheres rathbunae*	Schmitt (1973)
2	*Donax* sp.	Bucephalid larva	Hopkins (1951)
3	*Donax* sp.	Protozoa-*Blastocystis* sp.	Pérez-Cordón *et al.* (2007)
4	*Donax* sp.	Crab-*Pinnotheres barbatus*	Silas and Alagarsiwami
5	*Donax* sp.	Crab-*Pinnotheres rouxi*	(1965)
6	*D. denticulatus*	Hydroid-Unidentified hydroid Alga-Unidentified filamentous green alga	Wade (1967)
7	*D. gouldii*	Trematode-*Postmonorchis donacis*	Young (1953)
8	*D. gouldi*	Trematode-*Postmonorchis donacis*	Love (1991)
9	*D. variabilis*	Trematode-*Bucephalus loeschi, Choanura cercaria, Dichotoma cercaria, Gymnophalline cercaria, Lobatostoma* sp., *Metacercaria* sp., *Parvatrema donacis, Dichotoma cercaria*	Hopkins (1958)
10	*D. variabilis*	Trematode-*Cercaria pocillator*	Holliman (1961)
11	*D. variabilis*	Trematode- *Gymnophallus* sp. Alga-*Enteromorpha flexuosa*	Loesch (1955)
12	*D. denticulatus*	Trematode- *Cercaria caribbea*, Protozoa, Unidentified flagellates	Wade (1967)
13	*D. rugosus*	Crab-*Pinnotheres mccainae*	Manning and Holthuis (1981)
14	*D. striatus*	Hydroid-Unidentified hydroid	Wade (1967)
15	*D. trunculus*	Trematode-*Postmonorchis donacis*, *P. variabilis, P. orthopristis*	Carella *et al.* (2013)
16	*D. tumida*	Trematode- *Gymnophallus* sp.	Loesch (1996)
17	*D. tumida*	Trematode-*Cercaria choanura*	Hopkins (1958)
18	*Donax* sp.	Crab-*Pinnotheres* sp.	Present study (Panambur beach)
19	*D. faba*	Crab-*Pinnotheres* sp.	Present study (Panambur beach)
20	*D. scortum*	-	Present study (Padukere beach)
21	*D. faba*	-	Present study (Padukere beach)

The genus *Donax* are rapid burrowing clams (Ramón *et al*., 1995; Gasper *et al*., 1999), whose compressed shape and regular surface make easier burrowing into bottom sediments (Vermeij, 1978). This contribute in avoiding predators and consequently decreases mortality (Zaklan and Ydenberg, 1997). The result of Stenton-Dozey and Brown (1994) revealed an intimate correlation between depth segregation and temperature, where the juveniles are positioned higher in the mid-tide area and exposed to higher temperatures than in the surf area occupied by mature ones (adults). This pattern made by the juveniles is helpful in increasing burrowing speed and protecting from predation and dislodgement. Similarly, the same observation occurred in juveniles of *Donax* sp., *D. faba* and *D. scortum*, which protected them from predators. The predators associated with *Donax* species reported by various authors are mentioned in Table 5.

The macrobenthos of exposed beaches are highly mobile and lie concealed underneath the sand, both for protection from predators and to avoid desiccation. They are capable of burying remarkably quickly after being washed out of the sediment (McLachlan, 1983). Maximum organic material and wave action may also help to protect from predators (Ansell and Trueman, 1973). In both study sites (Panambur and Padukere), *Calidrius minuta*, *Tringa terek*, *Corvus splendens* and *Charadrius mongolus* were very common. Balley (1983) suggested that differential tidal migrations might be explained by predation effects on different size groups. His predation hypothesis suggested that juveniles actively migrate upshore to escape predation by fish and other large animals and move back to the swash to escape predation by birds. Alternatively, differences in burrowing rate may lead to size separation, with adult clams more likely to be transported downshore in the swash zone as they cannot burrow fast enough to maintain position, specifically in cold water (McLachlan and Young, 1982; Donn, 1990).

In the interrelation between hydroid and *Donax variabilis*, the hydroid defended donacid against a common predator, *Trachinotus carolinus* (Manning and Lindquist, 2003). Against crabs, *Ocypode quadrata* and *Arenaeus cribrarius*, however, the hydroid offered no protection for its host and instead facilitated predation. Most species are preyed upon by fish, birds and mammals (Penchaszadeh and Olivier, 1975; Peterson,

Table 5. Various predators associated with *Donax* spp. reported by several authors.

Sl. No.	Prey	Predator	Source
1	*Donax* sp.	Crab-*Pinnotheres barbatus*	Schmitt (1973)
2	*D. cuneatus*	Crabs-*Ocypode ceratophthalma*	Wong (1989)
3	*D. deltoides*	Gastropod-*Polinices incei*	Morton (2008)
4	*D. denticulatus*	Crab-*Arenaeus cribrarius*, *Callinectes exasperates, Ocypode albicans*, Gastropod-*Terebra cinerea* Bird-*Crocethia alba* Mammal-Pig	Wade (1967)
5	*D. faba*	Crab-*Ocypode ceratophthalmus* Birds-*Crocethia alba*	Smith (1975)
6	*D. faba*	Gastropod-*Polinices tumidus*	Ansell and Morton (1987)
7	*D. faba*	Crab-*Scylla serrata*, *Portunus pelagicus*	Patterson and Samuel (2005)
8	*D. gouldi*	Fish-*Emzbiotoca jacksoni*,*Micrometrus* sp.	Young (1953)
9	*D. gouldi*	Bird-Gulls Fish-Rays, corvina, surf perches	Coe (1955)
10	*D. gouldi*	Fish-Rays, Spotfin croakers, Surfperches, Sea gulls	Love (1991)
11	*D. hanleyanus*	Crab-*Ocypode quadrata*	Veloso *et al.* (2006)
12	*D. hanleyanus*	Gastropod-*Olivancillaria vesica auriculari* Bird-*Hemipodus olivieri*	Herrmann (2008)
13	*D. incarnatus*	Fish-*Chelonodon patoca, Sphaeroides oblongus, Lagocephalus lunaris, Lagocephalus inermis*	Ghosh *et al.* (2005)
14	*D. navicila* (=D. *californicus*)	Echinoderm-*Luidia foliata*	Phillips (1970)
15	*D. parvula* (=D. *fosson*)	Crab-*Arenaeus cribrarius*, *Ocypode quadrata*, *Ovalipes ocellatus* Fish-*Menidia menidia, Trachinotus carolinus*	Leber (1982b)
16	*D. pulchellus*	Crab-Ghost crab Bird-Wading bird	Akita *et al.* (2014)
17	*D. semistriatus*	Crab-*Portumnus latipes*, *Liocarcinus vernalis*, *Atelecyclus undecimdentatus*	Salas *et al.* (2001)
18	*D. semigranosus*	Crab-*Ocypode ceratophthalma*	Wong (1989)
19	*D. serra*	Crab-*Ocypode punctatus*	Du Preez (1981)
20	*D. serra*	Birds-*Haematopus moquini*,*Larus dominicanus*	Wade (1991)
21	*D. serra*	Bird-*Larus dominicanus*	Laudien (2002)
22	*D. sordidus*	Crab-*Ocypode punctatus*	Du Preez (1981)
23	*D. striatus*	Gastropod-*Naticamarochiensis*	Beasley *et al.* (2005)
24	*D. trunculus*	Crab-*Atelecyclus undecimdentatus, Portumnus latipes, Liocarcinus vernalis*	Salas *et al.* (2001)
25	*D. variabilis*	Fish-*Menidia menidia*, *Menticirrhus americanus, Paralichthys* sp., *Trachinotus carolinus*, Crab-*Ocypode quadrata, Arenaeus cribrarius* Bird-*Crocethia alba*	Leber (1982a)
26	*D. variabilis*	Crab-*Arenaeus cribrarius, Ocypode quadrata, Ovalipes ocellatus* Fish-*Menidia menidia, Trachinotus carolinus*	
27	*D. variabilis*	Fish-*Trachinotus carolinus* Crab-*Arenaeus cribrarius, Ocypode quadrata*	Manning and Lindquist (2003)
28	*D. variabilis*	Fish-*Trachinotus carolinus*	Dixon and Lankford (2011)
29	*D. variabilis*	Fish-*Trachinotus carolinus*	Horton and Lankford (2011)
30	*D. variabilis*	Fish-*Menticirrus littoralis, Menticirrus littoralis*	Ryan and Lankford (2011)
31	*D. variabilis*	*Ocypode quadrata*	Wolcott (1978)
32	*D. venustus*	Crab-*Atelecyclus undecimdentatus, Portumnus latipes, Liocarcinus vernalis*	Salas *et al.* (2001)
33	*D. vittatus*	Crab-*Atelecyclus undecimdentatus, Portumnus latipes, Liocarcinus vernalis*	Salas *et al.* (2001)
34	*D. vittatus*	Crab-*Liocarcinus holsatus, Carcinus maenas*	Ansell (1992)
35	*D. vittatus*	Fish-*Gadus morhua*	Burrows and Gibson (1994)
36	*D. vittatus*	Fish-*Gadus morhua*	Burrows *et al.* (1994a)
37	*D. vittatus*	Fish-*Gadus morhua*	Burrows *et al.* (1994b)
38	*D. vittatus*	Crab-*Portumnus latipes, Liocarcinus vernalis, Atelecyclus undecimdentatus, Carcinus maenas*	Salas *et al.* (2001)
39	*D. sordidus*	Crab-*Ovalipes punctatus*	Du Preez (1981)
40	*Donax* sp.	Crab-*Ocypode ceratophthalmus* Bird-*Corvus splendens*, *Tringa terek*, *Calidrius minuta*,*Charadrius mongolus* Mammal-Humans	Present study (Panambur beach)
41	*D. faba*	Crab-*Ocypode ceratophthalmus* Bird-*Corvus splendens*, *Tringa terek*, *Calidrius minuta*,*Charadrius mongolus* Mammal-Humans	Present study (Panambur beach)
42	*D. scortum*	Crab-*Ocypode ceratophthalmus* Bird-*Corvus splendens*, *Tringa terek*, *Calidrius minuta*,*Charadrius mongolus* Mammal-Humans	Present study (Padukere beach)
43	*D. faba*	Crab-*Ocypode ceratophthalmus* Bird-*Corvus splendens*, *Tringa terek*, *Calidrius minuta*,*Charadrius mongolus* Mammal-Humans	Present study (Padukere beach)

1979; Salas *et al*., 2001). Table 5 shows various prey-predator associations reported by several researchers. In some case, the main invertebrate predators are gastropods and crabs. The putunid, *Ovalipes punctatus* is a predator of *D. sordidus* and *D. serra* on Eastern Cape beaches of South Africa. Du Preez (1981) studied predation of *Donax* and *Bullia* by this species. Different species of gastropods are also major predators, as seen from Table 5. Phillips (1970) found that of 10 individuals of *Luidia foliata* (echinoderm) collected from intertidal zones, 9 contained *D. navicula*, the total of *Donax* ingested being 51. Ansell (1983) stated that tidal migrations help clams to maintain a position in the environment that minimizes predation risk and their feeding rates.

Smith (1975) studied predation by *Ocypode ceratophthalmus* in East Africa. He reported that this crab selected different colour morphs of *Donax faba* differentially under certain conditions. Further, he stated that selection was found to be stabilizing at high densities and apostatic at low densities. Many *Donax* species show similar polymorphism in habitat to that of *D. faba*

(Nolte, 1954; Macnae and Kalk, 1962) which is in agreement with the present study. Therefore, *O. ceratophthalmus* might have selected different colour morphs of *D. faba* differentially at both the sites as Smith (1975) stated about colour polymorphism provides crypsis for juveniles, and in adults provides visual predators (*Ocypode*) with intraspecific choice.

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