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Predator–prey relationship between the nototheniid fish *Trematomus bernacchii* and the Antarctic scallop *Adamussium colbecki* at Terra Nova Bay (Ross Sea)

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Abstract: Little information is available regarding predator–prey interactions in High-Antarctic coastal systems. In this study, the predation of *Trematomus bernacchii* (Pisces: Nototheniidae) on *Adamussium colbecki* (Mollusca: Pectinidae) is described and the related impact on the population structure of the mollusc is hypothesized. Fishes and scallops were collected during several expeditions between 1990/91 and 1997/98 summers, in nearshore waters at Terra Nova Bay (Antarctica). *Adamussium colbecki* was the main food item of *T. bernacchii* and an ontogenetic prey-size selection was observed. The predation was mainly on medium size classes of the scallop. These were lacking in the *A. colbecki* population sampled in the same period suggesting that the impact of fish-feeding on the size structure of the natural population of the mollusc may be substantial. Two size classes of the *Adamussium* population were not preyed on. Large adults avoid predation either because of the limits for mouth gape in the fish or by swimming avoidance capability, while smaller scallops may not be preyed upon because they are attached through byssus threads to very mobile large adults.

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Introduction

The widespread distribution and high abundance of both the fish *Trematomus bernacchii* Boulenger and the mollusc *Adamussium colbecki* Smith led to them being considered key-species in the framework of the international EASIZ Project (Ecology of the Antarctic Shelf-Ice Zone), launched by SCAR (Scientific Committee of Antarctic Research) in 1994. The project focused on improving knowledge of the High Antarctic coastal ecosystem.

These two species are also the most abundant components in terms of biomass of the fish fauna and macroinvertebrate benthic community of Terra Nova Bay (Cattaneo-Vietti *et al.* in press, Vacchi *et al.* 1999). In the Southern Ocean *Trematomus bernacchii* has a wide bathymetric range to 600 m depth (Gon & Heemstra 1990), although its maximum abundance is between 0–100 m depth at Terra Nova Bay (Vacchi *et al.* 1999). Dietary studies identify this trematomid as a generalist and opportunistic consumer, preying on sedentary and motile benthic organisms, by an ambush and a hunt and peck feeding mode (Hureau 1970, Daniels 1982, Kiest 1993, Foster & Montgomery 1993, Montgomery *et al.* 1993, Vacchi *et al.* 1994). None of these studies or those on demersal fishes of High-Antarctic Zone, have dealt with predator–prey patterns of feeding. *Adamussium colbecki* inhabits the continental shelf from 0 to nearly 1500 m (Dell 1972), although it was only found up to 80 m depth at Terra Nova Bay. It occurs at high population densities in coarse and medium grain sediments (Cattaneo-Vietti *et al.* 1997, Chiantore *et al.* 1999). This suspension-feeding bivalve community can play a significant role in pelagic-benthic coupling of the flow of organic material (Cattaneo-Vietti *et al.* in press).

Among the coastal fishes of Terra Nova Bay, *T. bernacchii* is the only species that feeds on the Antarctic scallop (Vacchi *et al.* 1994, Vacchi & La Mesa 1995, La Mesa *et al.* 1997). Use of this food resource by *T. bernacchii* is not reported from other Antarctic localities (Adélie Land: Hureau 1970, Antarctic Peninsula: Moreno 1980, Daniels 1982, McMurdo Sound: Foster & Montgomery 1993, Kiest 1993, Montgomery *et al.* 1993), except in Lutzow-Holm Bay, where Naito & Iwami (1982) recorded an occasional use of this prey. Other potential scallop predators are starfish, such as *Notasterias armata* and *Lophaster gaini*, but predation by them was rarely observed in McMurdo Sound (Stockton 1984, Berkman 1990), and *Odontaster validus* Koehler in Terra Nova Bay (M. Chiantore, personal communication 1997).

A better knowledge of the predator–prey interaction between the fish and the bivalve could aid our understanding of the structure and function of the local littoral ecosystem. Furthermore, as stated by Hureau (1994), there is a lack of information about the impact that Antarctic coastal fish may have on a prey resource, since assessment of such features has so far only been attempted in relation to krill and other zooplankton.

This paper reports on a study of the predator–prey relationship in respect of the importance of the mollusc as a food item, the feeding tactics adopted and the impact of fish-

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feeding on the scallop population structure.

Materials and methods

The study area was in the coastal waters near the Italian Antarctic Station (74°41'42"S, 64°07'25"E) at Terra Nova Bay, in the western Ross Sea.

Fish were caught by gill nets fished between 30 and 538 m depth in 1990/91 and 1997/98 summers. All the specimens caught were measured for total length (cm), weighed to the nearest gram below, sexed and staged according to Everson (1977).

Stomach contents of 435 fishes were analysed. A quali–quantitative assessment of the diet was based upon 343 individuals. Diet was expressed as numerical (N%) and wet weight (W%) percentage composition for each prey (Hyslop 1980) and summarized in the dietary coefficient (Q), which is the product of N% and W% (Hureau 1970). Following this procedure, the food spectrum is composed of main food ($Q > 200$), secondary food ($200 > Q > 20$) and accidental food ($Q < 20$). The consumption of food was also evaluated in terms of the frequency of occurrence (FO); i.e. the number of stomachs containing a particular prey item as a percentage of the total number of fish examined (Hyslop 1980).

Scallops were sampled in summer from 1993/1994 to 1995/1996. Quantitative sampling was performed with a Van Veen grab (surface 60 x 35 cm), between 30 and 130 m depth, and through visual observation carried out using a remotely operated vehicle (ROV). Biological and demographic data were obtained by dredge samples collected between 40 and 80 m depth. As a routine, all the individuals were measured

Table I. Trophic spectrum of *Trematomus bernacchii* by the most important prey categories.

Prey categories	FO	N%	W%	Q
Adamussium colbecki	42.3	11.3	47.7	540.1
Amphipods	12.8	49.9	3.6	177.7
Polychaetes	36.7	8.9	11.3	100.2
Opistobranchs	9.6	3.8	14.9	56.5
Limacina helicina	8.5	17.1	0.5	9.2
Fish	3.8	0.7	11.8	8.7
Others	13.1	8.2	7.3	59.8

FO = frequency of occurrence, N% = percentage composition by number, W% = percentage composition by weight, Q = dietary coefficient.

Table II. Diet comparison by percentage weight (W%) at sites of differing *A. colbecki* density.

Prey categories	W%	
	low density	high density
Adamussium colbecki	9.1	79.0
Polychaetes	23.9	5.6
Opistobranchs	52.9	< 0.1
Fish	7.4	7.4
Others	6.7	8.0

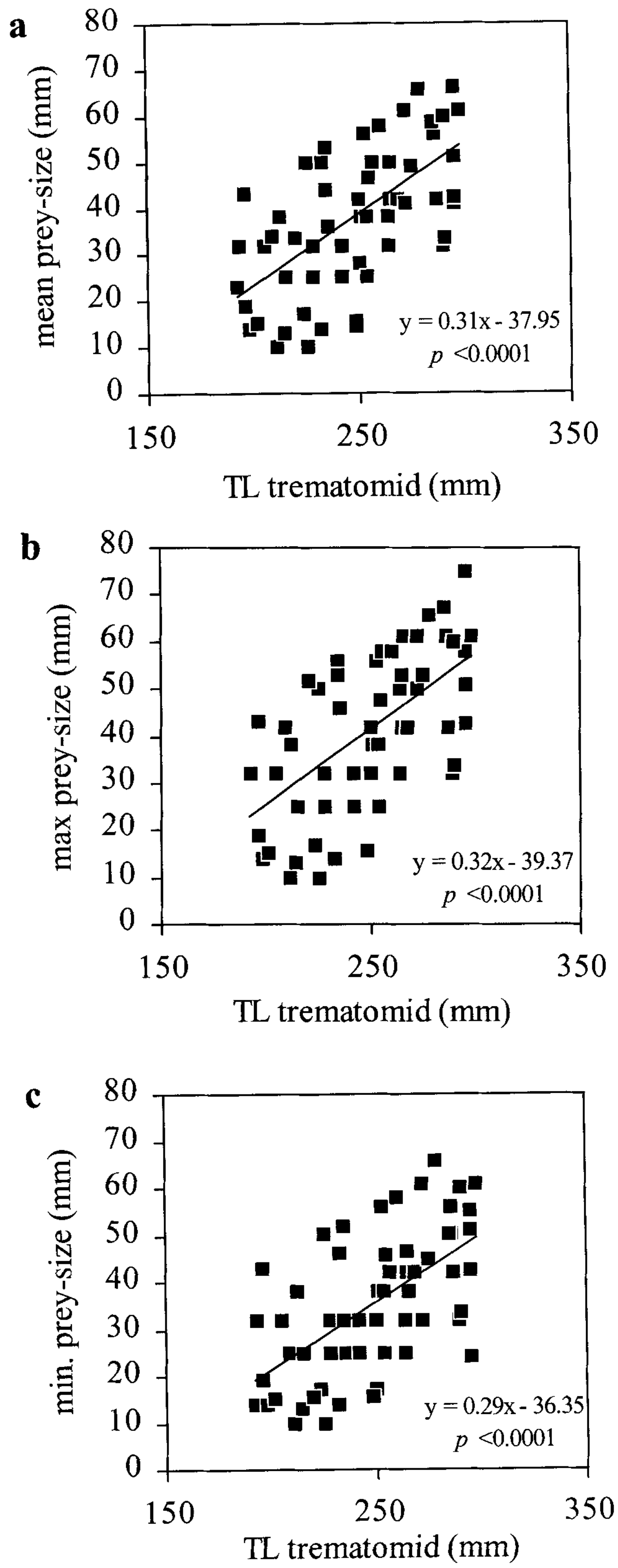

Fig. 1. Prey-size of the food item *Adamussium colbecki* regressed on trematomid size (i.e. total length), **a.** mean, **b.** maximum, **c.** minimum prey-size.

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for shell length, height and width.

Since scallops are patchily distributed (Chiantore *et al.* 1999) and *T. bernacchii* is sedentary (Kawaguchi *et al.* 1989), two groups of fish were chosen in relation to high or low availability of this prey resource (more or less than 5 ind m^{-2}, respectively). Thus we have considered only fish samples collected in the bathymetric area of scallop between 40–80 m depth and where scallop abundance values were available (Chiantore *et al.* 1999). The diet of the two groups was compared by means of percentage composition by weight because it best approximates the energetic gain for the predator.

Using log transformed data, regression parameters between shell length and digestive gland weight were estimated for freshly collected scallops. In order to evaluate the size classes of preyed scallops, such regression parameters were applied to gland remains found in the stomach contents of fish.

Prey-size selection of *T. bernacchii* on *A. colbecki* was estimated from a total of 57 specimens. Mean, minimum and maximum prey-size were regressed on trematomid size (i.e. total length). Relationships having *F*-ratios (regression SS/total SS) at $P < 0.05$ were considered significant. Regression *F*-tests were made using the software package SPSS, and Dixon's tests were used to identify occasional outliers for removal (Sokal & Rohlf 1995).

Results

A preferential predator–prey relationship was observed between *T. bernacchii* and the scallop. *Adamussium colbecki* was found in 40.4% of the stomachs examined (FO), constituting the 43.6% of the diet by weight with a dietary coefficient Q of 498.3. In the summer 1990/91 and 1997/98 the Antarctic scallop represented the most important prey in the diet of *T. bernacchii* (Table I).

The relative abundance of this food resource in the environment effects the diet of *T. bernacchii*. Indeed, almost 80% by weight of the diet of the fish sample caught near dense beds of the molluscs was represented by the scallop (Table II).

Prey-size of scallops increased with size of *T. bernacchii*. Relationships were highly significant for mean, minimum and maximum prey-size, showing a clear ontogenetic prey-size selectivity (Fig. 1a–c).

Trematomus bernacchii does not feed on the whole scallop prey-size range, but prefers medium size classes (Fig. 2). Only three ingested specimens of the scallop exceed 65 mm shell length, although the maximum size of the natural population of scallops recorded in Terra Nova Bay was 94 mm. Size-frequency distribution of the natural population shows a modal length class at 70–75 mm and a persistent lack of size classes between 40–55 mm (Fig. 2).

Discussion

At Terra Nova Bay the Antarctic scallop *A. colbecki* constituted the main food item of the nototheniid fish *T. bernacchii*. Diet composition accurately reflected the relative amount of this prey resource in the coastal environment. As *T. bernacchii* is likely to be the only fish species using the scallop as a food resource at this location, it may obtain a competitive advantage by feeding on this large sized mollusc at this site. Indeed, size of Antarctic benthos as food is generally considered a limiting factor for growth of fishes (Kock 1992), since groups of large size with hard exoskeletons or shells make up most of the organisms and are therefore infrequently utilized by fish (Eastman 1993).

Adamussium colbecki is preferentially preyed upon in the size range 25–64 mm shell length. *Trematomus bernacchii* showed a clear prey-size selective response on the *Adamussium* size range used. According to optimal foraging theory, predators should bypass small prey below some threshold value (i.e. foraging time/return) in order to maximize their rate of energy gain (Pyke 1984). However, all size classes up to

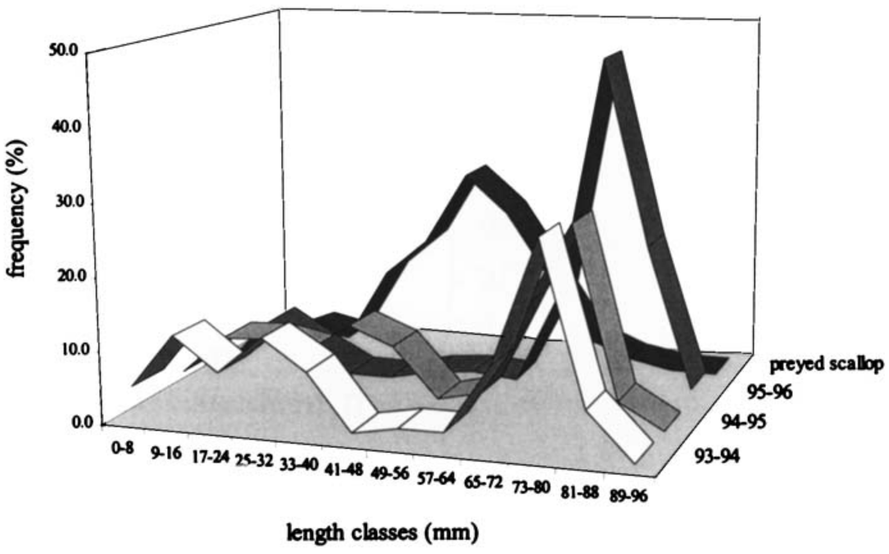

Fig. 2. Size frequency distributions of *Adamussium colbecki* population during summer 1993/94, 1994/95 and 1995/96 and of the preyed scallop (summers 1990/91 and 1997/98).

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94 mm shell length are available to the predator. This prey selection patterns implies that individuals below and above the size classes used are exempt from predation pressure.

Mechanical constraints such as mouth gape limitation or predation inability due to evasiveness of prey may determine predation avoidance for the large adult individuals (> 65 mm). In particular *A. colbecki*, like other pectinids, is able to perform swimming movements, that may be significant in escape from predators (Peterson *et al.* 1982).

No information is available about the feeding process of *T. bernacchii* on the scallops. The usual finding in the stomachs of few fragments of the shells, leads us to consider that soft parts may be ingested separately or that shells are crushed by jaw teeth and then spat out. The latter pattern of ingestion may be allowed by the thinness of the shells, although the anatomy of the mouth of *T. bernacchii* shows a poor development of the pharyngeal bones and teeth, used for crushing in other perciforms.

The swimming effectiveness of *A. colbecki* is higher in larger adults and probably protects them from predation. Conversely, juveniles of *A. colbecki*, being attached through byssus threads to adult valves, benefit from the potential of the adult to perform faster and more extensive swimming, saving energy and indirectly escaping from predation (Cattaneo-Vietti *et al.* 1997). The most vulnerable size is that immediately following detachment of the juveniles from their adult hosts, perhaps because of their shell shape which does not allow high swimming effectiveness at this size (Ansell *et al.* 1998). Consequently, we hypothesize *T. bernacchii* exploits mostly free-living individuals of scallop which have not yet developed high swimming effectiveness or yet reached a limiting size for mouth gape of the predator.

Thus peculiar size structure characterizes these scallop populations, with a persistent deficiency of medium size classes. *Trematomus bernacchii* predation pressure would seem to be one cause of the lack of these size classes in scallop population of Terra Nova Bay, but a similar deficiency has been attributed to alternate reproductive output or recruitment success (Stockton 1984). On the other hand, Davis & Marshall (1961), refer to the metabolic changes due to sexual maturation which take place in just detached individuals of *Aequipecten irradians*, which, moreover, cannot take advantage of the organic matter resuspended by adult shell clapping. Predation by starfish on Antarctic scallops cannot be evaluated due to the paucity of data. Although the asteroid *O. validus* is very abundant at scallop beds, this scavenger species has been observed preying only on specimens of very large size off *Adamussium*, both *in situ* and in aquaria (M. Chiantore, personal communication 1997).

Owing to the key role of both these species in Terra Nova Bay, the probable impact of predation of *T. bernacchii* on the population structure of *A. colbecki* may be considered useful for generating hypotheses on fish-invertebrate macrobenthic species interactions in High-Antarctic coastal systems. This interaction must be taken into account in evaluating the environmental conditions determining the distribution and abundance of the two species.

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