Diatoms as food source indicator for some Antarctic Cumacea and Tanaidacea (Crustacea)

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Abstract: The gut contents of three species of cumaceans: *Eudorella splendida, Vaunthompsonia inermis* and *Campylaspis maculata*, and three species of tanaids: *Nototanais antarcticus, N. dimorphus* and *Peraeospinosus pushkini* from the shelf of Admiralty Bay and two cumaceans: *Diastylis mawsoni* and *Ekleptostylis debroyeri* from the deeper Antarctic shelf were studied. With the exception of *Campylaspis maculata*, which is a predator or scavenger, and *Ekleptostylis debroyeri*, whose gut was filled with mud only, detritus was an important diet component of all the species studied. On the basis of qualitative and quantitative components of diatom taxa it can be concluded that the food of *Diastylis mawsoni* comes from the pelagial, whereas the food of the other peracarids is of benthic origin. Species inhabiting the shallowest waters consume almost exclusively epipelic food, whilst those living below the euphotic zone feed mostly on particles sedimented from the pelagial; taxa occurring at intermediate depths feed on pelagic matter, but also of epiphytic and of epipelic origin.

Introduction

Cumacea and Tanaidacea are comparatively small marine benthic malacostracan crustaceans found from the upper sublittoral to hadal depths. Cumaceans typically dig in soft seabed sediment (Schram 1986) while most tanaids of the suborder Tanaidomorpha live in tubes or tunnels constructed from sand grains, mud, and detritus glued together by the secretions from tegumental glands (Holdich & Jones 1983).

Most studies on cumaceans and tanaids have dealt with their taxonomy, so the role of these peracarids in the trophic chain is poorly known. In some papers these crustaceans are recognized as a component of the diet of demersal fishes (Gnewuch & Crocker 1985) or larger invertebrates (Johnson & Attramadal 1982). On the other hand little is known about the food or feeding preferences of either cumaceans or tanaids. The former are thought to be deposit feeders (Dennell 1934), scrapers (Dixon 1944), and also predators or scavengers (Kaestner 1967) whilst most tanaids are classified as sediment feeders (Kudinova-Pasternak 1991) or seston feeders (Dennel 1937, Lang 1956). Dennell (1937) noted that the movements of appendages responsible for respiration could also be used for filtration of food. Direct observations have indicated that some tanaids are herbivores (Johnson & Attramadal 1982, Kudinova-Pasternak 1991) whilst Kusakin & Tzareva (1974), Sieg (1979), Thurston & Billet (1987), Kudinova-Pasternak (1991) observed that some tanaids temporarily inhabit holothurians cloacae. A functional analysis of mouth parts and other appendages led researchers to the conclusion that these crustaceans might also be predators/scavengers (Kudinova-Pasternak 1991, Gutu 1986).

The gut contents of cumaceans have not previously been studied. The only paper concerning the functional morphology of tanaid mouth parts along with an analysis of their gut contents is that by Kudinova-Pasternak (1991).

The purpose of the present paper is to document the food sources of some common Antarctic cumaceans and tanaids. Our study was based on stomach content analysis, with special attention paid to the identification of diatoms. These algae have an exceptional value since they can be identified down to a low taxonomic level, and this identification may be done on the basis of the fragments of silicified frustules which are commonly found in the guts of herbivorous/detritivorous invertebrates. Since the ecological preferences of particular diatom species are comparatively well known it is possible to deduce valuable information on the source of food and method of feeding, e.g. filtrating from the water column, collecting from the seabed, or scraping from sand grains or from macroalgae.

Materials and methods

Material for this study was collected mostly in Admiralty Bay, King George Island, South Shetland Islands, during Antarctic summers of the years 1977–93, at depths ranging from 6 to 530 m. Stomach content analysis was carried out using *c.* 20 specimens of each of three species of cumaceans and three species of tanaids. The cumaceans studied were *Eudorella splendida* (Zimmer, 1902), collected in January, March and May; *Vaunthompsonia inermis* (Zimmer, 1909), sampled mostly in January, September and November; and *Campylaspis*

Table I. Qualitative food particle composition found in gut contents in cumaceans and tanaids.

	detritus	mineral particles	bacteria	sponge spicules	remains of invertebrates	diatoms
Cumacea						
Eudorella splendida	x	x				x
Vaunthompsonia inermis	x	x	x			x
Campylaspis maculata					x	x
Diastylis mawsoni	x					x
Ekleptostylis debroyeri	x					
Tanaidacea						
Nototanais antarcticus	x	x	x			x
Nototanais dimorphus	x	x				x
Peraeospinosus pushkini	x	x		x		x

maculata (Zimmer, 1907), which was most numerous in the samples from March. The tanaid *Nototanais antarcticus* (Hodgson, 1902) was collected April, May, November and December; *N. dimorphus* (Sars, 1886) was collected mainly in March and November; and *Peraeospinosus pushkini* (Tzareva, 1982) was most numerous in January, March, November and December. The bulk of the material collected in Admiralty Bay originated from the shallow shelf, with only a few specimens with filled stomachs from deeper stations. We therefore decided to include some specimens of two Antarctic cumaceans from the deeper Antarctic shelf (aphotic zone) in our study. They were *Diastylis mawsoni* (Calman, 1918), caught in the Weddell Sea at a depth of 622 m in February (loaned by Rhur Universität, Bochum) and *Ekleptostylis debroyeri* Błażewicz et Heard, 2001, found in the Bransfield Strait at a depth of 491 m (62°18'9"S, 58°41'7"W) in December (loaned by Humboldt Museum, Berlin).

Fig. 1. Percentage of four ecological groups of diatoms in the gut contents of particular cumacean and tanaid species. Depth range of sampling is given in brackets. a = limit of phytoplankton diatoms growth (Lipski & Rakusa-Suszczewski 1993), b = limit of benthic diatoms growth (Ligowski 1993). Depth limit (in metres) of macroalgal occurrence after Zielinski (1990).

Stomach contents were prepared on a microscope cover slip in a drop of distilled water. After drying, the stomach contents were embedded in Naphrax (Northern Biological Supplies Ltd.). Using the oil immersion of objectives enabled the identification of the remains of diatom frustules to the lowest possible taxa level. These diatoms were divided into four ecological groups:

epilithic - sticking to hard bottom;

epipelic - inhabiting the soft bottom surface;

pelagic (planktonic and sympagic); and

epiphytic - overgrowing macroalgae (and their rhizoids).

All the frustules of diatoms from guts were counted. Diatoms taxa whose frustules exceeded 5% of the total number of the cells in a sample were recognized as dominants. Microscopic analysis was done using the Nikon Optiphot-2 with oil immersion planapochromatic objectives (N.A. = 1.4) and Nomarski differential interference contrast.

Results

Detritus accompanied by mineral particles was the main component of stomach contents in the guts of three cumaceans (*Eudorella splendida*, *Vaunthompsonia inermis*, *Diastylis mawsoni*) and three tanaids (*Nototanais antarcticus*, *N. dimorphus* and *Peraeospinosus pushkini*) and were accompanied by diatom frustules. Amongst the food particles found (Table I) only diatom frustules or their remains could be identified at the generic or species' level and compared with their distribution in natural habitats (Table II).

The list of 110 identified diatoms comprises 12 epilithic taxa, 29 epipelic taxa, 19 epiphytic taxa, and 50 pelagic taxa (Table II). Except for *Campylaspis maculata*, the stomachs of all other crustaceans studied contained fine detritus. It was remarkable that the guts of *Ekleptostylis debroyeri* contained only fine detritus and that no diatom remains or mineral particles were found (Table I).

Pelagic diatoms were significant in the diet, usually exceeding 40% of all diatoms found in the gut contents (Fig. 1). Analysis of the gut contents of *Nototanais antarcticus*, caught in the shallowest water (6 m), revealed that over 97% of the diatoms
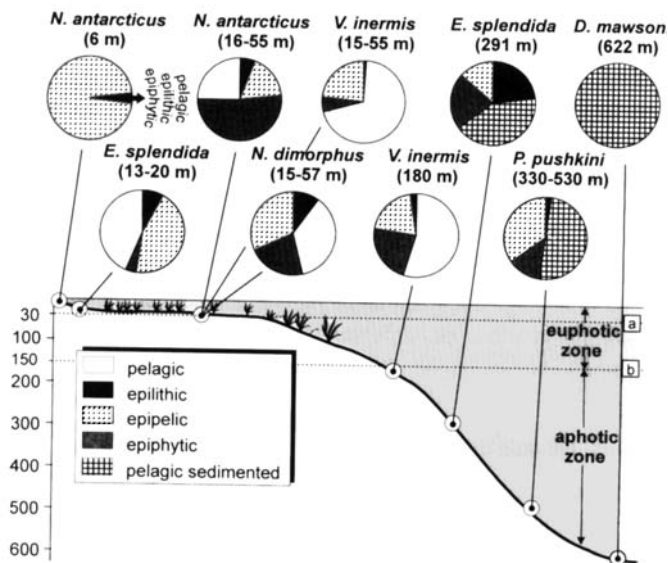
Table II. Habitat preferences of diatom taxa found in gut contents of Cumacea and Tanaidacea.

Epilithic
    Achnanthes charcotii M. Peragallo
    Achnanthes delicatula (Kütz.) Grunow
    Achnanthes groenlandica Grunow in Cleve et Grunow
    Achnanthes vincentii Manguin
    Fragilaria striatula Lyngbye
    Fragilaria sp.
Epipelic
    Amphora bongrainii M. Peragallo
    Amphora peragallorum Van Heurck
    Amphora terroris Ehrenberg
    Amphora sp.
    Chaetoceros (resting spores)
    Gomphonema minusculum Cleve
    Gomphonema sp.
    Grammatophora angulosa Ehrenberg
    Grammatophora marina Kützing
    Gyrosigma compactum (Grev.) Cleve
    Gyrosigma subsalinum v. *antarctica* Frenquelii et Orlando
    Gyrosigma sp.
    Navicula antarctica Frenguelli
    Navicula complanatoides Hustedt
    Navicula cristata v. *curta* Peragallo
Epiphytic
    Cocconeis litigiosa Van Heurck
    Cocconeis costata Gregory
    Cocconeis costata v. *hexagona* Grunow
    Cocconeis costata v. *kerguelensis* Cleve
    Cocconeis gautieri Van Heurck
    Cocconeis illustris Schmidt
    Cocconeis infirmata Manguin
    Cocconeis melchiori Frenguelli
    Cocconeis orbicularis Frenguelli et Orlando
    Cocconeis schuetti Van Heurck
Pelagic
    Actinocylus actinochilus (Ehrenberg) Simonsen
    Asteromphalus sp.
    Azpeitita tabularis (Grunow) Fryxell et Sims
    Chaetoceros tortissimus Gran
    Corethron pennatum (Grunow) Ostenfeld
    Coscinodiscus oculoides Karsten
    Coscinodiscus sp.
    Dactyliosolen antarcticus Castracane
    Diploneis sp.
    Eucampia antarctica (Castracane) Mangin
    Fragilariopsis curta (Van Heurck) Hustedt
    Fragilariopsis cylindrus (Grunow) Krieger
    Fragilariopsis kerguelensis (O'Meara) Hustedt
    Fragilariopsis obliquecostata (Van Heurck) Heiden
    Fragilariopsis rhombica (O'Meara) Hustedt
    Fragilariopsis ritscherii Hustedt
    Fragilariopsis separanda Hustedt
    Fragilariopsis vanheurcki (M. Peragallo) Hustedt
    Fragilariopsis sp.
    Nitzschia decipiens Hustedt
    Nitzschia grundleri v. *antarctica* Heiden
    Nitzschia mediconstricta Hustedt
    Nitzschia neglecta Hustedt
    Nitzschia stellata Manguin
    Nitzschia taeniformis Simonsen

Gomphonemopsis littoralis (Hendey) Medlin
Licmophora antarctica Carlson
Licmophora belgicae M. Peragallo
Licmophora juergensii Agardh
Licmophora sp.
Parlibellus rhombicus (Greg.) Cox

Navicula directa (W. Smith) Ralfs
Navicula frigida Manguin
Navicula glaciei Van Heurck
Navicula marnieri Manguin
Navicula sp.
Odontella litigiosa (Van Heurck) Hoban
Odontella weissflogii (Janisch) Grunow
Paralia sol (Ehrenberg) Crawford
Pinnularia quadratarea (W. Schmidt) Cleve
Pinnularia quadratarea v. *soederlundii* Cleve
Pinnularia quadratareoides Heiden
Pleurosigma directum Grunow
Thalassiosira (resting spores)
Trachyneis aspera (Ehrenberg) Cleve

Entopyla ocellata (Arn.) Grunow
Pseudogomphonema kamtschaticum (Grunow) Medlin
Rhabdonema arcuatum (Agardh) Kützing
Rhabdonema sp.
Rhoicosphenia adolfi W. Schmidt
Rhoicosphenia spp.
Tabulariopsis australis D.M. Williams
Trigonium arcticum Grunow
Trigonium sp.

Nitzschia turgiduloides Hasle
Nitzschia sp.
Porosira glacialis (Grunow) Jörgensen
Porosira pseudodenticulata (Hustedt) Jousé
Proboscia alata (Brightwell) Sundström
Proboscia inermis (Castracane) Jordan et Ligowski
Proboscia truncata (Karsten) Nöthig et Ligowski
Rhizosolenia antennata (Ehrenberg) Brown
Rhizosolenia sp.
Schimperiella antarctica Karsten
Stelarima microtrias (Ehrenberg) Hasle et Sims
Synedropsis hyperboreoides Hasle, Syvertsen et Medlin
Synedropsis laevis (Heiden) Hasle, Medlin et Syvertsen
Synedropsis recta Hasle, Medlin et Syvertsen
Synedropsis sp.
Thalassiosira antarctica Comber
Thalassiosira gracilis (Karsten) Hustedt
Thalassiosira gracilis v. *expecta* (Van Land.) G.Fryxell et Hasle
Thalassiosira lentiginosa (Janisch) G.Fryxell
Thalassiosira ritscherii (Hustedt) Hasle
Thalassiosira scotia Fryxel et Hoban (resting spores)
Thalassiosira tumida (Janisch) Hasle
Thalassiosira sp.
Thalassiothrix antarctica Schimper ex Karsten
Thallasionema nitzschioides (Grunow) Mereschkowsky

found in their guts were epipelic forms. Epipelic diatoms usually constituted 15–40% of all identified diatoms in the diet of species living in deeper water, followed by epiphytic forms, whose number rarely exceeded 20%. In the guts of *N. antarcticus,* found at depths ranging from 16 to 55 m, epiphytic diatoms dominated. The least numerous diatoms in the gut contents were epilithic forms. Their number usually did not surpass a few percent of the total number of identified diatoms, with the exception of *E. splendida* found in the aphotic zone (291 m).

The guts of *Campylaspis maculata* were filled with a reddish, amorphic, organic substance with polychaete setae, fragments of worms, and remains of crustaceans (e.g. Calanoida).

The stomachs of all females with a developed marsupium were always empty.

Discussion

Epipelic diatoms prevailed in the sediments of the shallowest waters. This fact explains the clearly higher share of these diatoms in the diet of *N. antarcticus* collected at a depth of 6 m.

Epipelic diatoms are present in sediment down to the lower limit of light penetration. The situation in the deeper sublittoral, 150–200 m, is different with pelagic diatoms enriching the sediment and occurring together with epipelic diatoms. This is reflected in the gut contents of taxa found in the photic zone, e.g. *E. splendida, N. dimorphus, N. antarcticus* and *V. inermis* (Fig. 1). One could assume that in the stomachs of detritivores living in the aphotic zone, where fresh plant material is inaccessible, only sedimented pelagic diatoms should be found. Indeed, in the stomachs of *Diastylis mawsoni* and *Ekleptostylis debroyeri,* occurring in the aphotic zone (below 180 m), neither epipelic, epiphytic, nor epilithic diatoms were found. Instead, fine detritus filled the stomachs of *Ekleptostylis debroyeri,* whilst only pelagic diatoms were found in the stomachs of *Diastylis mawsoni.* Different results were obtained for the stomach contents of *E. splendida* and *P. pushkini* collected in the aphotic zone. Along with pelagic diatoms epipelic and epiphytic taxa were also found. A detailed analysis revealed that the bulk of these epipelic taxa were resting spores, which are transported by water currents from the photic zone. On the other hand, epiphytic diatoms were represented almost exclusively by one species (*Cocconeis costata*) usually occurring on macroalgae, but also common in the water column of Admiralty Bay (Ligowski 1986).

The food preferences of cumaceans and tanaids are poorly known. Most of these crustaceans have been considered as "comb feeders" due to the numerous setae on their mouthparts (Dennel 1934, 1937, Kaestener 1967). Dennell (1934, 1937) observed that the forward and backward movements of the maxillae, maxillulae, and maxillipeds 1 of *Diastylis bradyi* (Cumacea) and *Apseudes talpa* (Tanaidacea) draw water into the "filtering chamber". Water filtered by the setal system is passed to the branchial chamber, while suspended matter is combed-off by the maxillipeds and delivered to the mouthparts proper. Among the tanaids studied here none could be classified as a filter (seston) feeder, but it is very probable that one cumacean (*Ekleptostylis debroyeri*) obtains food in this way. This is supported by the fine detritus filling its gut as well as by its delicate and setose mouthparts (Błażewicz-Paszkowycz & Heard 2001).

Kudinova-Pasternak (1991) noted fine detritus mixed with mineral particles in the stomachs of two tanaids, *Paraleptognathia* (=*Leptognathia*) *gracilis* (Kröyer, 1842) and *Typhlotanais elegans* Kudinova-Pasternak, 1978, classifying them as detritivores. *Eudorella splendida, V. inermis, N. antarcticus, N. dimorphus, P. pushkini* and *D. mawsoni* in the present study obviously belong to this group since similar ingredients were found in their gut contents. Mineral particles in their gut contents, as well as a significant amount of typically benthic (epipelic) diatoms, together with pelagic ones, suggest that food is swept from the bottom; pelagic diatoms are undoubtedly dead specimens that have sedimented out from the water column. Such behaviour has already been observed in some tanaids, which can emerge partially or wholly from their tubes to graze on the surrounding substratum (Johnson & Attramadal 1982, Kudinova-Pasternak 1991), although they can also feed on microorganisms co-existing in their tubes (Delille *et al.* 1985, Bird & Holdich 1985).

All species studied live buried in seabed sediments. Therefore the presence of epiphytic diatoms in their guts suggests that they were scratched from rhizoids. Johnson & Attramadal (1982) noted that *Tanais dulongi* could climb on macroalgae and scrape epiphytes from their surfaces. On the contrary, no cumacean was observed feeding this way, although it is known that some members of the Bodotriidae feed on algae growing on grains of sand (Dixon 1944). Grains of an appropriate size are picked up from the bottom by the first pair of peraeopod, turned by specially modified maxillipeds 3 (strongly enlarged, flattened merus, and carpus), and epiphytes cleaned off by the first and second pairs of maxillipeds (Dixon 1944).

Kaestner (1967) noted fragments of foraminiferan tests and amphipod appendages held within the feeding parts of some cumaceans of the genus *Campylaspis.* Our analysis of the gut contents of *C. maculata* indicates that this species might be a predator. Such a feeding mode can be confirmed from the morphology of its mouthparts. The molar process of its mandible is elongated, stout, and jagged, the exopodites and endopodites of the second maxilla are reduced while propodites bear few setae. Stout maxillipeds lack setae and their terminal articles are reduced (maxilliped 1) or modified to teeth (maxilliped 2).

Although some tanaids are presumed to be predators (Gutu 1986), none of the tanaids studied was suspected of feeding in this way. It is interesting that *Nototanais dimorphus,* which was classified in this paper among the detritivores, have been observed feeding on larval stages of polychaetes (Olivier & Slattery 1985). It is very probable that this species is an

omnivore. A similar opinion was expressed on *Heretotanis oerstedi* (Kröyer, 1842), which devours nematodes together with detritus (Bückle-Ramirez 1965). The members of the deep-water Neotanaidomorpha are thought to be detritivores that occasionally prey on small invertebrates (Gardiner 1975, Kudinova-Pasternak 1991). Kudinova-Pasternak (1991) found detritus mixed with mineral particles, sponge spicules, diatom frustules, benthic foraminiferans, remains of small animals, polychaetae setae in the stomachs of *Gigantapseudes adactylus* Kudinova-Pasternak, 1978 and *Neotanais kurchatovi* Kudinova-Pasternak, 1975 and, in *G. adactylus,* also fragments of echinoids.

Our observations indicate that the crustaceans studied, except for *Campylaspis maculata* which is scavenger/predator, are detritivores. Detailed analysis of diatom taxa found in the guts has allowed us to conclude that food is collected from different bottom habitats.

Acknowledgements

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