Pectinaria chilensis NILSSON, 1928 (POLYCHAETA: PECTINARIIDAE): TAXONOMIC CHARACTERIZATION, NEW DISTRIBUTIONAL RECORDS AND ECOLOGICAL NOTES FROM THE CHILEAN COAST

Rodrigo A. Moreno, Nicolás Rozbaczylo, Roger D. Sepúlveda, Franklin D. Carrasco and Raúl Soto

SUMMARY

The taxonomy, geographical distribution, and ecological aspects of Pectinaria chilensis *are reviewed. Specimens were collected in sublittoral soft bottoms, between 45 and 93m depth, at four localities in northern Chile. These specimens are compared with individuals collected from 17m depth at Coronel, Gulf of Arauco, Chile, the type locality of the species. A taxonomic characterization, illustrations and a list of new localities in the geographical distribution of this species are presented. Ecological information (bathymetry, sediment type, total organic matter content and dissolved O_2 concentration of sea water above the bottom) is included, as well as a key for differentiating the two Pectinariidae species registered in Chile to date.*

RESUMEN

Se revisa Pectinaria chilensis *de la costa de Chile a partir de ejemplares recolectados en fondos blandos sublitorales, entre 45 y 93m de profundidad, en cuatro localidades del norte de Chile. Estos especímenes fueron comparados con ejemplares recolectados a 17m de profundidad en Coronel, Golfo de Arauco, Chile, localidad tipo de la especie. Se incluye una caracterización taxonómica, ilustraciones, y nuevas localidades en la distribución geográfica de la especie. Se provee información del hábitat (batimetría, tipo de sedimento, contenido de materia orgánica total y O_2 disuelto de fondo) y se incluye una clave para diferenciar las dos especies de Pectinariidae registradas en Chile.*

Introduction

The family Pectinariidae Quatrefages, 1865 includes the tubiculous polychaetes known as "ice cream cone worms" or "trumpet worms" due to their characteristic cone-shaped tubes. The tubes are constructed of sand grains and/or shell fragments and foraminifera, in a one- or two-layered arrangement (Day, 1967; Wolf, 1984; Rouse and Pleijel, 2001). These polychaetes are found throughout the world, though they are rarely found in large numbers. They form a group that is anatomically complex, yet relatively uniform in their morphological characteristics (Rouse and Pleijel, 2001). Pectinariidae form a clade with the Ampharetidae and Alvinellidae and belong to the Terebellida (Rouse and Fauchald, 1997). Evidence of monophyly in this group has been based on their conical tubes of unique shape and construction, the presence of a cephalic veil, and the development of a flattened scaphe, with spine-like chaetae (Fauchald and Rouse, 1997).

According to Wolf (1984) the number of genera within Pectinariidae has been confusing. Day (1967) recognized only two genera: *Petta* Malmgren and *Pectinaria* Savigny, including within the latter the subgenera *Lagis, Amphictene,* and *Pectinaria*. Fauchald (1977) considered the preceding three subgenera, together with *Cistenides* Malmgren, as separate genera, thus recognizing five genera in the family (*Petta, Lagis, Amphictene, Cistenides* and *Pectinaria*). Pettibone (1982) recognized only three genera (*Amphictene*, *Petta*, and *Cistena*), considering *Pectinaria*, *Cistenides*, and *Lagis* as synonyms of *Cistena*. Holthe (1986) in his study of the family recognized only two genera, *Pectinaria* and *Petta*, and four subgenera within *Pectinaria* and accepted a total of 46 nominal species as valid within the two genera. The same author considered *Lagis*, *Amphictene*, and *Cistenides* to be subgenera of *Pectinaria*. Hutchings (2000) recognized about 51 described species and suggested the need for a review of the family, with better definitions of the genera, and an adequate evaluation of their status.

Recently, Hutchings and Peart (2002), recognized 53 species in 5 genera, previously indicated by Fauchald (1977), based on a review of the Pectinariidae in Australian waters. For the genus *Pectinaria* there are 22 rec-

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Rodrigo A. Moreno. Marine Biologist, Universidad Arturo Prat, Chile. M.S. in Zoology, Universidad de Concepción (UdeC), Chile. Researcher, Chilean Biodiversity Program, Universidad Arturo Prat. e-mail: ramorenom@yahoo.com

Nicolás Rozbaczylo. Biology Professor, Universidad de Chile (UCh). Professor, Department of Ecology, Pontificia Universidad Católica de Chile. Address: P.O. Box 114-D, Santiago, Chile. e-mail: nrozbac@bio.puc.cl

Roger D. Sepúlveda. Marine Biologist, Universidad Católica de la Santísima Concepción, Chile. M.S. in Zoology, UdeC, Chile. Ph.D. Student, Institute of Ecology and Evolution. Universidad Austral de Chile. e-mail: rogersepulveda@uach.cl

Franklin D. Carrasco. Biologist, M.S. and Ph.D. in Zoology, UdeC, Chile. Professor, UdeC. e-mail: fcarrasc@udec.cl

Raúl Soto. Biology Professor, Universidad de Chile (UCh). M.S. in Zoology, UdeC, Chile. Professor, Universidad Arturo Prat, Chile. e-mail: rsoto@unap.cl

RESUMO

Revisa-se Pectinaria chilensis *da costa do Chile a partir de exemplares recolhidos em fundos brandos sub-litorais, entre 45 e 93m de profundidade, em quatro localidades ao norte do Chile. Estes espécimes foram comparados com exemplares recolhidos a 17m de profundidade em Coronel, Golfo de Arauco, Chile, localidade padrão da espécie. Se inclui uma caracterização taxonômica, ilustrações, e novas localidades na distribuição geográfica da espécie. Se fornece informação do hábitat (batimetria, tipo de sedimento, conteúdo de matéria orgânica total e O_2 dissolvido de fundo) e se inclui uma clave para diferenciar as duas espécies de Pectinariidae registradas no Chile.*

ognized species around the world, including 2 new species (*P. dodeka* and *P. kanabinos*) for the Australian fauna (Hutchings and Peart, 2002).

On the Southeastern Pacific coast of Chile, Pectinariidae is represented by two genera: *Pectinaria* and *Cistenides*, with one species each: *Pectinaria chilensis* Nilsson, 1928 and *Cistenides ehlersi* Hessle, 1917 (Rozbaczylo, 1985). The aim of the present study was to review *P. chilensis* from the Chilean coast, to conduct a taxonomic characterization, to illustrate morphological aspects, and to present new localities in the geographical distribution of the species. We present data on bathymetry, sediment type, total organic matter content, and dissolved O_2 in the water above the bottom at the sample locations. We also include a taxonomic key to differentiate the two species of Pectinariidae recorded in Chile to date.

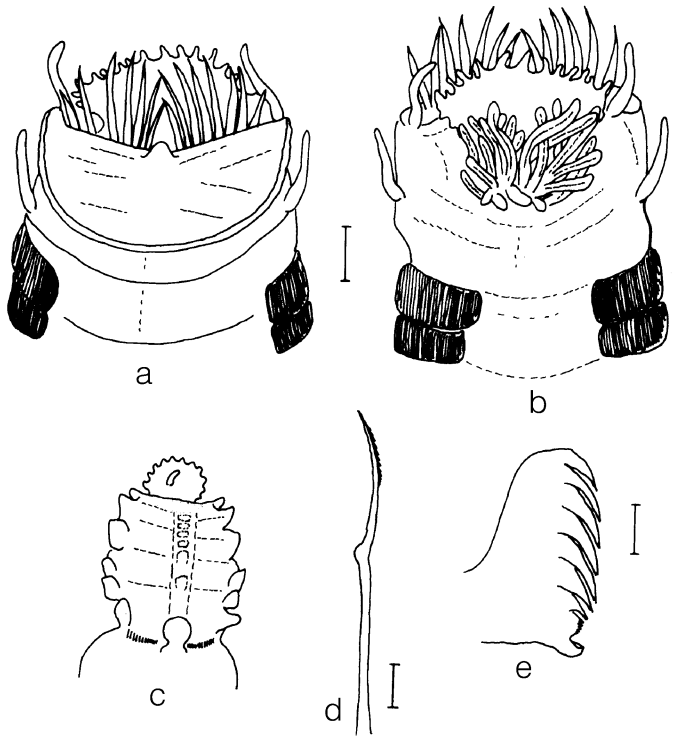

Figure 1. *Pectinaria chilensis*. a: anterior end in dorsal view; b: anterior end in ventral view; c: scaphe in dorsal view; d: limbate setae from notopodium; e: neuropodial uncinus in lateral view. (Scales: a-c= 1mm; d= 0.1mm; e= 0.01mm).

Materials and Methods

Specimens of *P. chilensis* were collected as a part of three separate, larger studies: 1) The Benthic Macrofauna Diversity of Northern Chile Project, with samplings conducted between Sept 1998 and May 2003 at three localities, including Arica (18º20'S), the continental shelf off Iquique Bay (20º11'S) and Patillos (20º45'S), between 45 and 93m depth; 2) The Minera Escondida Ltda. Environmental Project, with samplings conducted from 1990 to 2002 in Punta Coloso, Antofagasta (23º45'S) at 60m depth; and 3) a regional control program for wastewater treatment, with samplings conducted in Nov 2002 in Coronel, Gulf of Arauco (36º42'S), at 17m depth.

Four sediment subsamples were obtained at each locality using a 0.1m^2 Van Veen grab. Three of these subsamples were used to obtain polychaetes, and the fourth was used to determine sediment characteristics. Polychaetes were separated from the sediment using an 0.5mm mesh sieve. Specimens were fixed in 10% seawater-formalin solution. Specimens of *P. chilensis* were quantified, measured and transferred to a 70% ethanol solution containing 8% glycerine for long-term preservation. Folk (1974) was followed for evaluations of sediment characteristics/type. Total organic matter (TOM) was estimated by weight loss after ignition of dried material in a furnace for 2h at 550ºC (Buchanan, 1971). Dissolved O_2 content of seawater from each sample station was determined by the Winkler titration method (Strickland and Parsons, 1972), for samples collected in Niskin bottles 0.5m over the bottom.

Illustrations of the species were prepared using a camera lucida mounted on a Wild M-5 stereo microscope. Identified specimens were deposited in the *Colección de Flora y Fauna Profesor Patricio Sánchez*, located in the Ecology Department at the *Pontificia Universidad Católica de Chile*, Santiago (SSUC), catalogued under the following numbers: SSUC 6980 to 6983.

Results

Pectinaria chilensis Nilsson, 1928: 37-40, fig. 11; Hartman, 1941: 333 pl. 50 figs. 12, 15, pl. 51, fig. 19.

Material examined: 92 specimens. Arica (n=6), Continental shelf off Iquique Bay (n=7); Patillos (n=2); Punta Coloso (n=61); Coronel (Gulf of Arauco) (n=16).

Description: Individual polychaetes reached up to 44mm in length and 6mm in width at the opercular level. The operculum (Figure 1a) is a thick muscular plate which forms the anterodorsal surface of the (fused) prostomium and peristomium. There are two anteroventral groups of stout, flattened golden paleae, which are slightly dorsally curved and arranged in two oblique, overlapping rows, with seven to eight paleae per row. The operculum is surrounded dorsally and ventrally by a raised, smooth, opercular border. Ventrally, below the paleae is a thin membrane called the cephalic veil, which is bounded by about 30 to 32 thin papillae, which form a hood in front of the mouth. Approximately 32 oral tentacles of different size form two groups, arising at the point where the cephalic membrane attaches at the mouth (Figure 1b). Each individual has two pairs of tentacular cirri: the anterior pair is lateral and slightly ventral to the paleae and the posterior pair is located laterally to the mouth and connected by a long transverse ventral ridge.

Two achaetous segments follow this ridge, each bearing a lateral pair of lamellate branchiae similar in size (although the first pair are slightly longer than the second pair). The number of setigerous segments is always 16; setigers 1-3 only have notosetae; setigers 4-15 have uncini and notosetae, and setiger 16 only notosetae; the last segment bears a reduced parapodium which lacks setae. The notosetae (Figure 1d) are simple (limbate), and similar along the entire length of the body. The uncini (Figure 1e) show a basal trough-like structure and two rows of both major and minor teeth. There are approximately 15 acicular scaphal setae on each side of the anterodorsal margin of the scaphe, of which five or six of the inner setae are smaller. There is an approximately circular anal flap on the posterior-dorsal margin of the scaphe (Figure 1c); the anal flap has a crenulate margin, and its upper side has an anal cirrus, which is conspicuous and located approximately at the center.

Observations: *P. chilensis* Nilsson, 1928 was originally described from a single specimen collected at Coronel, Gulf of Arauco (VIII Region, Chile; Rozbaczylo, 1985). Hartman (1941) reported the presence of the species at Independencia Bay, Peru from 27 specimens collected between the shore and 38m depth. *P. chilensis* has been recorded in the coast of Chile by Oyarzún *et al.* (1987) at Talcahuano (36º38'S), and by Carrasco *et al.* (1988) and Carrasco and Gallardo (1994), and Carrasco (1996) at Concepcion Bay (36º40'S), together with some ecological data on the species.

The samples reviewed in the present study, from Coronel and northern Chile, agree well with the original description made by Nilsson (1928), as well as with Hartman's (1941) description, except for the number of opercular paleae (seven or eight paleae on each side in our samples compared with eight or nine cited in the original description, and nine or ten indicated by Hartman for the Peruvian specimens). Nilsson (1928) suggested that the cephalic membrane possesses about 60 papillae, while in our specimens the number of papillae is only around 30; the latter number is, however, comparable with the number observed by Hartman (1941) for the Peruvian specimens, which had 30 to 60 filiform papillae on the free edge. These differences are considered to be intraspecific variation.

Distribution and bathymetry: Records of *P. chilensis* from new localities allow the extension of its geographic range in Chile, to over 18º of latitude, reaching from 36º42' S (i.e. the type locality) to 18º20'S (Arica). Thus, the geographic distribution of the species ranges from Independencia Bay, Peru, to the Gulf of Arauco, Chile, reaching a maximum depth of 93m.

Physical and chemical parameters: *P. chilensis* was found associated principally with fine sandy and muddy sediments, with organic matter content greater than 5%, and dissolved O_2 concentration of less than 1.0ml·l^{-1} in the overlying water above the bottom (Table I).

Ecological notes: Pectinariids are sedentary free-living tubiculous polychaetes which typically inhabit muddy, or fine sandy bottoms, and are selective subsurface deposit-feeders. The anterior end of the tube is oriented with the mouth facing downwards, while the posterior (narrow) end projects slightly above the sediment surface so that the opercular paleae can be used to excavate within the sediment (Wolf, 1984).

Specimens collected from the continental shelf off Iquique Bay coexist with mats of the giant filamentous sulfur bacteria *Thioploca* spp. and the deposit-feeding amphipod, *Ampelisca araucana* Gallardo. These species have been observed at high densities in environments of the Peru-Chile Undercurrent (PCU), i.e. the Gulf of Arauco, Chile, where sediments are often hypoxic (Carrasco and Gallardo, 1983).

TABLE I
ENVIRONMENTAL PARAMETERS AT EACH SAMPLED LOCALITY ALONG THE CHILEAN COAST WHERE *P. chilensis* WAS PRESENT, BETWEEN 1998 AND 2003

Locality	Sediment type	Total organic matter (%)	Dissolved O_2 content (ml·l^{-1})	Depth (m)
Arica	Fine sands	5.92	0.94	58
Continental shelf off Iquique Bay	Mud	9.41	0.37	93
Patillos	Fine sands	5.89	0.91	45
Punta Coloso	Fine sands	5.24	0.5	60
Coronel (Gulf of Arauco)	Mud	*	*	17

* Not available.

Key to the species of Pectinariidae recorded from Chile

1a Body with 16 setigerous of which 12 are uncinigerous; 7-10 pairs of opercular paleae; approximately 13-15 pairs of scaphal hooks; uncini with two rows of teeth....
..... *Pectinaria chilensis*

1b Body with 17 setigerous of which 13 are uncinigerous; 8-13 pairs of opercular paleae; about 10 pairs of scaphal hooks; uncini with a single row of teeth....
..... *Cistenides ehlersi*

Discussion

The results from our study suggest that *Pectinaria chilensis* may have a continuous distribution in warm temperate waters on the southeastern Pacific coast, from 14°15'S (Independencia Bay, Perú) to 36°42'S (Gulf of Arauco, Chile), within the Peruvian Province (3-4ºS-41ºS; Ekman, 1953), with a lack of records in intermediate areas between Antofagasta and the Gulf of Arauco. On the other hand, *Cistenides ehlersi* is distributed from Aysen (43ºS) to the Straits of Magellan (56ºS; Rozbaczylo, 1985), restricted to cold temperate waters of the Magellanic Province (41ºS-56ºS; Ekman, 1953).

On the continental shelf off Iquique Bay, *P. chilensis* coexists with *Ampelisca araucana* and *Thioploca* spp. mats. This relationship may be the result of the sediment and hydrographic characteristics recorded for the bottom of this locality, which has muddy sediments with a high content of total organic matter (>9.0%), and very low concentrations of dissolved O_2 (0.37ml·l^{-1}) at 93m depth, associated with the Equatorial Subsurface Waters mass (ESSW) of the Peru-Chile Undercurrent. These environmental conditions are favorable for the development and coexistence of populations of *A. araucana* (see Carrasco and Gallardo, 1983; Carrasco and Arcos, 1984) and *Thioploca* spp. mats (Gallardo, 1977; Fossing *et al.*, 1995), mainly due to the protection generated by this hypoxic barrier against predators and competing species, which are unable to enter waters with

severe hypoxia (<0.5ml·l^{-1}; Díaz and Rosenberg, 1995). On the other hand, the absence of *A. araucana* and *Thioploca* spp. at other localities analyzed could be explained by the presence of moderate hypoxia (2-0.5ml·l^{-1}; Díaz and Rosenberg, 1995), which does not provide an effective barrier against predators and competitors, and could eliminate or notably reduce populations of *A. araucana* and *Thioploca* spp., as well as the predominance of fine sandy sediments and low organic matter content. These conditions do not affect *P. chilensis*, since this species inhabits sediments ranging from fine sand to mud. Furthermore, this species has an opercular paleae, which can effectively close the entrance to the tube and may protect the worm from being eaten by predators (Hutchings, 2000).

The mixotrophic condition of *Thioploca* spp. based on the oxidation of hydrogen sulfide in the presence of low O_2 concentrations (Maier and Gallardo, 1984; Fossing *et al*., 1995) plays an important role in the biogeochemical control of the sediments (Schulz *et al*., 2000), detoxifying the upper sediment strata of H_2S, and thus generating favorable conditions for the colonization of aerobic organisms (Gallardo, quoted in Carrasco *et al*., 1999), which are able to tolerate low O_2 concentrations and are able to access the abundant, high quality organic matter accumulated in the sediments. This condition would explain our observations of an association between *P. chilensis* and *A. araucana* with *Thioploca* spp. mats in muddy sediments and hypoxic conditions on the continental shelf off Iquique Bay.

On the other hand, based on a study of biochemical adaptations of nine benthic polychaete species on the continental shelf off central Chile (Concepcion Bay), González and Quiñones (2000) indicated that *P. chilensis* only presented strong enzymatic activity for a pyruvate oxidoreductase, the alanopine dehydrogenase (ALPDH). The presence of more than one pyruvate oxidoreductase is typical for species that have to cope with both functional and environmental hypoxia (Gäde and Grieshaber, 1986). González and Quiñones (2000) conclude that *P. chilensis* presents a low capacity for coping with hypoxia. However, our findings of *P. chilensis* in hypoxic zones do not agree with the results of González and Quiñones (2000) for this species. Therefore, it is necessary to analyze specimens from a greater number of localities along the Chilean coast to establish whether *P. chilensis* presents a low capacity to adapt to the hypoxic conditions in the Humboldt Current System.

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