



Anatomy of soft body of *Pugilina cochlidium* (Linnaeus, 1758) and *P. erecta* (Vermeij & Raben, 2009) (Neogastropoda: Melongenidae) from Thondi Coast-Palk Bay in Tamil Nadu, India

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(With 3 figures)

Abstract

The species of *Pugilina cochlidium* (Linnaeus, 1758) and *P. erecta* (Vermeij & Raben, 2009) has been studied in the present study. The female can be differentiated from the male by the absence of the cephalic penis and a complicated genital apparatus visible through the mantle skirt in both the sexes. In other aspects of the external features of female are quite to males. In both species the digestive system was similar with few differences in structure between each other. It consists of buccal mass, proboscis, salivary glands, accessory salivary glands, oesophagus, stomach, intestine, rectum and anus. The nervous system in both *P. cochlidium* and *P. erecta* is constituted by six ganglia which forms the circumoesophageal ganglionic ring. Among the neogastropods there is a similarity in the organization of the reproductive systems. The female reproductive system is more complicated than that of male. The sexes are separated in these two species. The gross morphology of the reproductive system of *P. cochlidium* and *P. erecta* was almost similar. The present study aims to describe the digestive system, nervous system and reproductive system of two gastropods species *P. cochlidium* and *P. erecta*.

Keywords: gastropoda, melongenidae, *Pugilina cochlidium*, *P. erecta*, anatomy.

Anatomia do corpo mole de *Pugilina cochlidium* (Linnaeus, 1758) e *P. erecta* (Vermeij & Raben, 2009) (Neogastropoda: Melongenidae) de Thondi Coast-Palk Bay em Tamil Nadu, na Índia

Resumo

As espécies de *Pugilina cochlidium* (Linnaeus, 1758) e *P. erecta* (Vermeij & Raben, 2009) foram tomadas no presente estudo. A fêmea pode ser diferenciada do macho pela ausência do pênis cefálico e um complicado complexo genital visível através da saia do manto em ambos os sexos. Em outros aspectos das características externas da fêmea são bastante semelhantes aos dos machos. Em ambas as espécies, o sistema digestivo era semelhante, com poucas diferenças de estrutura entre si. Consiste em massa bucal, probóscide, glândulas salivares, glândulas salivares acessórias, esôfago, estômago, intestino, reto e ânus. O sistema nervoso em *P. cochlidium* e *P. erecta* é constituído por seis gânglios que formam um anel ganglionar circunoesofágico. Entre os neogastrópodes, há uma semelhança na organização dos sistemas reprodutivos. O sistema reprodutivo feminino é mais complicado que o masculino. Os sexos são separados nessas duas espécies. A morfologia macroscópica do sistema reprodutivo de *P. cochlidium* e *P. erecta* foi quase similar. O presente estudo tem como objetivo descrever o sistema digestivo, sistema nervoso e sistema reprodutivo de duas espécies, *P. cochlidium* e *P. erecta*.

Palavras-chave: gastropoda, melongenidae, *Pugilina cochlidium*, *P. erecta*, anatomia.

1. Introduction

The phylogenetic analyses of the higher classification of neogastropoda have been studied based on the anatomical characters of the digestive system especially on the foregut

(Andrews, 1991; Ball et al., 1997; Benny et al., 1996; Brown, 1969; Carriker et al., 1963, 1967; Carriker and Williams, 1978; Carriker, 1981; Chétatl and Fournié, 1969;

Greene and Köhn, 1989; Harasewych, 1984; Hou et al., 1990; Kantor and Taylor, 2002; Kantor, 1996; Kantor and Harasewych, 1994; Lus, 1981; Marcus and Marcus, 1962a, b; McLean, 1971; Merdsoy and Farley, 1973; Nylén et al., 1969; Person et al., 1967; Taylor et al., 1993). It is generally accepted the evolution of the order, as well as that of other caenogastropods, was determined mainly by the changes in the anatomy of the digestive system (Kohn, 1983) while similarity of shells is often the result of convergence.

Ponder (1973) studied the anatomy of the digestive system of neogastropoda. Buccinoidea is one of the generally accepted monophyletic groups in neogastropods. Six families are usually included into this superfamily: buccinidae, fasciolaridae, nassariidae, melongenidae, columbellidae and colubrariidae. Carriker (1943) has studied the structure and function of the proboscis in the common oyster drills *Urosalpinx cinerea* (Say, 1822). Ward (1965) has described the digestive tract and its relation to feeding habits in the stenoglossan prosobranch *Coralliophila erosa* (Röding, 1798). Houston (1976) has studied the structure and function of neogastropod reproductive systems with special reference to *Columbella fuscata* G.B. Sowerby, 1832. The anatomy of the various proboscis types has been investigated by Greene and Kohn (1989) and Medinskaya (1992). Medinskaya (1992) has investigated the anatomy of the proboscis walls in neogastropods and its connection with diets and feeding mechanism. Medinskaya (1992) has investigated the anatomy of the proboscis walls in Neogastropods and its connection with diets and feeding mechanism. Taylor et al. (1993) has studied the foregut anatomy, feeding mechanisms, relationships and classification of the Conoidea. Ball et al. (1997) has studied the ontogeny of the pleuroembolic proboscis in *Nucella lapillus*. Numerous studies have been made on various aspects of the digestive system by Fretter and Graham (1962), Wu (1965a), Bhanu et al. (1981), Tagore (1989), Guohua et al. (1990), Andrews (1991), Jaramillo (1991) and Middlefart (1992a, b).

Smith (1967, 1980, 1981) studied the neogastropod stomach, with notes on the digestive diverticula and intestine. Ponder (1968, 1970) studied the anatomical notes on two species of the colubrariidae. Medinskaya (1993, 1999) studied the anatomy of the stomach of some neogastropoda from the offshore zone of the Japan sea. Taylor (1978) and Taylor et al. (1980, 1993) studied the foregut anatomy, feeding mechanisms, relationships and classification of Conoidea (Gastropoda). Tan and Phuah (1999) observed the diet and feeding habits of *P. cochlidium* (Linnaeus, 1758) (Neogastropoda: Melongenidae) in Singapore. Kantor and Tursch (2001) have been observed the feeding of *Oliva* genus. Kantor and Taylor (2002) studied the foregut anatomy and relationships of raphitomine gastropods. In neogastropod there is a similarity in the organization of the reproductive systems. The works carried out on the reproductive system are the following: Fretter (1941), Fretter and Graham (1962), Purchon (1968), Stephen and Blaber (1970), Houston (1971), Bhanu et al. (1981, 1982), Hawkins and

Hutchinson (1988), Gallardo and Garrido (1989), Hou et al. (1990), Cantillanez et al. (2011), Cantillanez and Avendaño (2013) The present study aims to describe the digestive system, nervous system and reproductive system of two species *P. cochlidium* and *P. erecta* (Vermeij & Raben, 2009) that are a very important fisheries resources in local fisheries in Thondi Coast-Palk Bay in Tamil Nadu, India (De los Ríos et al., 2020).

2. Material and Methods

Collected specimens were obtained from Thondi Coast-Palk Bay in Tamil Nadu, India (9°44' N; 79°19' E) in January 2009. For anatomical studies, the soft body, inside the shell was obtained by cracking open the shell. The animal was kept for relaxation in 75% magnesium chloride. Dissections were made in seawater in a dissecting dish under a stereo zoom binocular microscope. The reproductive system was studied mostly in fresh animals as the genital ducts and genital complex are more readily visible. Measurements were made with ocular and stage micrometers and the drawings were made obtained at laboratory. Only preserved animal were used to study the diminute nerves stood out prominently after fixation under direct illumination. The mean size of *P. cochlidium* specimens were 98.71 mm and 114.29 mm for male and female respectively, whereas the for *P. erecta* were 94.28 mm and 106.70 mm for male and female respectively, 30 specimens for each sex for each species (60 specimens for species) were studied.

3. Results

3.1. Digestive system

The present study in both species the digestive system was similar with few differences in structure between each other. It consists of buccal mass, proboscis, salivary glands, stomach, intestine, rectum and anus. The digestive system of *P. cochlidium* and *P. erecta* is shown in (Figure 1). The proboscis in the present study, these two species showed the most conspicuous feature of the digestive system in the massive proboscis of pleuroembolic type, which is oval with two folded lips (Figure 1). In both the species the oesophageal region is extremely long and completed (Figure 1). The salivary gland in both species the salivary gland is a white mass, which surrounds the organ of oesophagus. In both the species the salivary glands are bilobed in structure. Each lobe is of the compound acinous type (Figure 1).

The stomach for both the species *P. cochlidium* and *P. erecta* the stomach is almost similar in structure. It is pale brown in colour. In two species the length and width of the stomach was measured about 53 to 60 mm in length in *P. cochlidium* and 75 mm to 80 mm in *P. erecta*. Internally the stomach is a simple sac with two folds. The stomach is very small, tubular, simple and U-shaped. The oesophagus is broad, opening ventrally into the posterior part of the stomach. A posterior mixing area is absent. The posterior

oesophagus is lined with well-developed longitudinal folds. The folds on the dorsal side of the oesophagus are continuous with longitudinal folds on the outer stomach wall. The gastric chamber is subdivided into dorsal and ventral channels by a distinct and tall longitudinal fold on the inner stomach wall. The ventral channel is represented by the oesophageal groove, occupying a mid-ventral position which is continuous with the rather deep intestinal groove that is lined with tall, longitudinal, but narrow folds. The dorsal channel of the gastric chamber is lined with oblique, longitudinal folds that are much larger and more raised on the outer stomach wall (Figure 1).

The digestive gland for both species *P. cochlidium* and *P. erecta* the digestive gland is a brown coloured mass which surrounds the stomach all its length except its dorsal surface. In the two species it coils in a counter clockwise direction together with the stomach and the gonad. The duct of the digestive gland is of dichotomous branching type and opens into the stomach by way of the two apertures (Figure 1). The intestine for two species, *P. cochlidium* and *P. erecta* the intestine leaves the stomach at the end of the style sac region and the colour of the intestine is pale brown. It leads posterior to the oesophagus and ventrally to the heart and dorsoventrally compressed rectum. The intestinal wall is smooth bearing the major and minor typhlosoles leading out from the stomach. These are prominent features in the proximal portion of the intestine only and thereafter they gradually disappear (Figure 1). The rectum begins where the intestine is dorsoventrally flattened in both species *P. cochlidium* and *P. erecta*. The wall of the rectum is longitudinally folded. The anus opens into the right corner of the mantle cavity and terminates in a papilla like projection. The wall of the anus is distinctly folded into ridges and grooves. A dark brown coloured rectal gland is present near the anus (Figure 1).

3.2. Nervous system

The nervous system in both *P. cochlidium* and *P. erecta* is constituted by six ganglia which forms a ring the circumoesophageal ganglionic ring. The central nervous system of *P. cochlidium* and *P. erecta* consists of an oesophageal nerve ring, a visceral ganglion and two pleurovisceral connectives. The oesophageal nerve ring is formed by the fusion of several ganglia, including a pair of cerebral ganglia, pleural ganglia, pedal ganglia, buccal ganglia and a supra oesophageal ganglia. These ganglia are connected by commissures and connectives. However, the other ganglionic inner nerves were not able to be traced (Figure 2).

3.2.1. Reproductive system

Among the neogastropods there is a similarity in the organization of the reproductive systems. The reproductive system of various members of family melongenidae has been the subjects of several studies by virtue of their diverse modes of reproduction. The female reproductive system is more complicated than that of male. The sexes are separated in these two species in the gross morphology of the reproductive system of *P. cochlidium* and *P. erecta*. (Figure 3).

3.2.2. Male reproductive system

The male reproductive system consists of the following parts: Testis, vesicular seminalis, vas deferens, prostate gland and penis. The male reproductive system of *P. cochlidium* and *P. erecta* (Figure 3). Testis (Figure 3) in these two

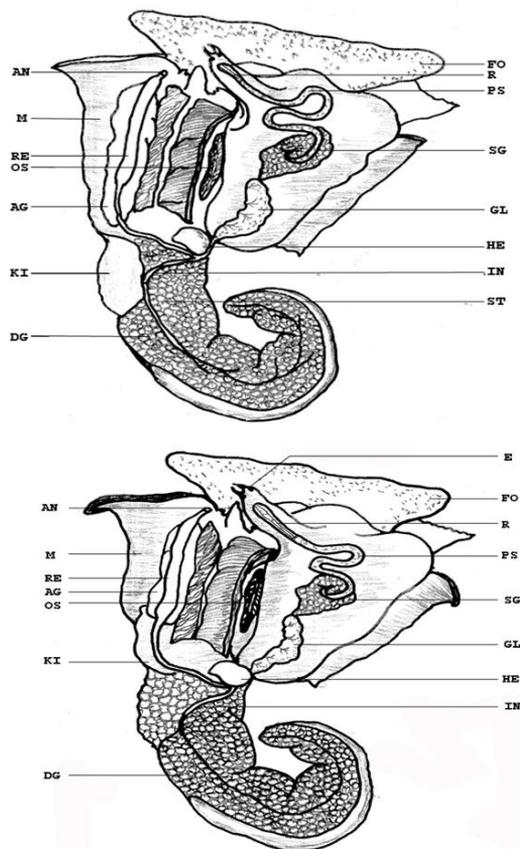


Figure 1. Digestive system in *P. cochlidium* (up) and *P. erecta* (down). Abbreviations: AG -Albumen gland; AN - Anus; DG-Digestive gland; E - Eye; FO-Foot; GL - Gill; HE - Heart; IN-Intestine; KI - Kidney; M-Mantle; OS - Osphradium ; PS-Prostate gland; R-Radula; RE - Renal duct ; SG-Salivary gland; ST- Stomach.

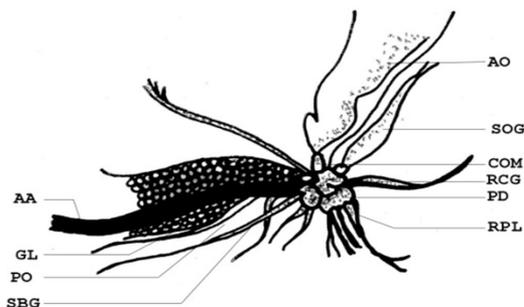


Figure 2. Nervous system of *P. cochlidium* and *P. erecta*. Abbreviations: AA - Anterior aductor; AO-Anterior oesophagus; COM- Commissure; GL -Gill; PD-Pedal Ganglion; RCG-Right Cerebral ganglion; RPL- Right Pleural Ganglion; PO-Posterior oesophagus; SOG Supra oesophageal ganglion.

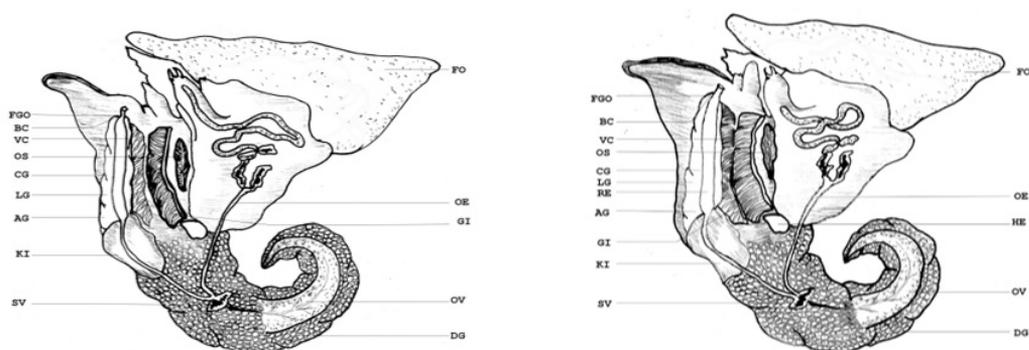


Figure 3. Reproductive system in *P. cochlidium* (up) and *P. erecta* -Male (down). Abbreviations: AG-Albumen gland; BC-Bursa copulatrix; CG-Capsular gland; DG-Digestive gland; FO-Foot; FGO-Front genital opening; GI-Gill; KI-Kidney; LG-Leiblein gland; OE- Oesophagus; OS- Osphradium; OV-Ovary; PG- Prostate Gland; PE- Penis; RE- Renal duct; TE- Testes; VD-Vas-deferens; VS- Vesicular seminalis.

species, testis lies on the ventral surface of the visceral mass, where its tubules form a compact mass and do not ramify through the digestive gland. In fully matured condition, the colour of the testis is brick red in *P. cochlidium* and *P. erecta*. During the breeding season the testis occupies a greater part of the visceral mass. The testis is made up of numerous follicles, and small duct lets, which join to form a genital duct called vas deferens. The vas deferens is thrown into numerous convolutions and coils, which serve as vesicular seminalis. The noticeable differences between two species were that the testis appears to be small and shorter in *P. cochlidium* and in *P. erecta* it appears large and elongate. In both species, the vesicular seminalis is formed by the union of several duct lets from the globules of testis, which serves as to store the sperms during breeding season. For this purpose, it is thrown into numerous convolutions. When the sperm is packed into the vesicular seminalis, which is dull brick red in colour.

The vas deferens is situated from the testies, on the columellar side of the visceral mass in both species *P. cochlidium* and *P. erecta* the coiled vas deferens which passes anteriorly in a superficial position leads to the gut and the pericardium of the right posterior corner of the mantle cavity and it opens into the prostate gland. At this point the vas deferens lies embedded in the penis, which is situated just posterior to the right cephalic tentacles (Figure 3). The prostate gland commences at the posterior end of the pallial cavity in both species *P. cochlidium* and *P. erecta* receives in the vas deferens. Size of the prostate gland depends on the reproductive stage of the animal and it is well developed in matured animal in its breeding season (Figure 3). The vas deferens opens at the posterior end of the prostate gland which runs through it as a slit like lumen and the width of the prostate gland is uniform throughout the length until the region where it joins the vas deferens. It is well known that the prostate gland provides a liquid medium for the spermatozoa so that it could be transferred from male to female (Figure 3). In the present study, the penis is noted to be slightly flattened dorso ventrally

and its duct is not centrally placed but lies towards the outer edge. In two species *P. cochlidium* and *P. erecta* it has a strong broad base with round coiled proximal end. The pallial vas deferens which enters the penis and its base runs through the penis towards its tip on the outer edge. The male reproductive system of *P. cochlidium* differs from that *P. erecta* in the following aspects. In *P. cochlidium* the length of the vas deferens which starts from the vesicular seminalis is slightly longer than that of *P. erecta*. The size and shape of the prostate gland is narrow and elongated in *P. cochlidium* whereas in *P. erecta* it is broad and short. The penis is more dorsoventrally flattened in *P. erecta* than in *P. cochlidium* (Figure 3).

3.2.3. Female reproductive system

In two species *P. cochlidium* and *P. erecta* the ovary lies in the upper part of the visceral coil, intermingling with the digestive gland. In a fully matured animal the ovary occupies 1/3 of the visceral coil. The structure, position and colour of the ovary are similar in *P. cochlidium* and *P. erecta* (Figure 3). In both species the oviducts spreads over the surface of the digestive gland in the visceral mass and from it, a thin walled oviduct leads forwards and ventrally on the right side of the viscera. The junction of oviduct with the albumen gland is characterized with the presence of another duct called the gonopericardial duct. The gonopericardial duct opens into the wall of the pericardium and near the opening, it is thick and muscular. The oviduct in two species joins with the albumen gland on its ventral aspects (Figure 3). In two species albumen glands, *P. cochlidium* and *P. erecta* the first and posterior most part of the pallial oviduct has an albumen gland into which the visceral oviduct opens. The albumen gland is an inverted 'U' shaped loop like structure with the two arms close to each other. It is pale yellow in colour. The oviduct opens into the first distal limb of the capsular gland and its opening is guarded by sphincter muscles which may regulate the passage effects. The albumen gland opens into the posterior ventral wall of the capsule gland on the right side of the ventral channel (Figure 3). In between

the intestine gland a thick blackish brown colour strip like structure is present which is called ingesting gland. This gland communicates with the ventral canal. In *P. erecta*, this gland occupies more area than in *P. cochlidium*. In *P. erecta*, the dorsal part of this gland is more elevated, and its base is narrow, whereas in *P. cochlidium* there is a broad base and not that much elongated dorsal part (Figure 3). In two species the capsular gland leads forward on the right side of the mantle cavity and on dissection it can be seen as an opaque white or yellowish mass which is divided into right and left glandular lobes. These lobes are joined dorsally and ventrally by a comparatively thin and narrow wall forming a dorsal and ventral suture. Throughout the length of the capsular gland a channel called ventral channel runs on the ventral aspects of the ventral channel gland which is a closed duct. Posteriorly the ventral channels lead to the duct of the ingesting gland and receptaculum seminalis and anteriorly to the bursa copulatrix (Figure 3). In general, organization of the male and female reproductive system of *P. cochlidium* and *P. erecta* follows the same general neogastropod pattern. The bursa copulatrix is in the proximal part of the pallial oviduct situated ventrally. It is a pouch like structure which receives the sperm along with prostatic secretion during copulation. It is connected with the ventral channel on its posterior end.

4. Discussion

4.1. Digestive organs

The mouth is over hung by the outer muscular rim of the peristomal rim, which is very similar to *U. cinerea* (Carriker, 1943). In *P. cochlidium* the proboscis measures about 8 to 10 cm in length and 0.2 to 0.5 cm in width and in *P. erecta* it was measured about 7 to 10 cm in length and 0.3 to 0.5 mm in width. In both forms the colour of the proboscis is white. The odontophore and radular sac lies within the proboscis. The odontophore is composed of the retractor muscles, cartilaginous rod and the radular sac. The proboscis in *P. cochlidium* and *P. erecta* are similar to the description of the proboscis and this similar observation has been made by Tagore (1989) in *Thais* species and *Thais haemastoma* (Linnaeus, 1767) by Roller et al. (1984).

It is most conveniently divided into 3 parts, the anterior, mid and posterior oesophagus (Graham, 1941, 1949). The anterior oesophagus begins above the opening of the radular sac. Its dorsal folds are the continuations of the prominent dorsal folds of the wall of the buccal cavity. The mid oesophagus can be subdivided into two portions on the basis of structural differences in the organ of nerve ring portion and the convoluted portion. Posterior and mid oesophagus becomes extremely narrow and slightly turned to the left side of the median axis (Figure 1). The posterior oesophagus is slender and long. The junction where the mid oesophagus joins with the posterior oesophagus is marked by a constriction along with the reduction in diameter of posterior oesophagus. These glands of paired salivary gland and accessory salivary gland are associated with the oesophagus, which opens into the mid oesophagus.

The position and shape of the lobes are closely related to the Muricid gastropod *Druparicina* (Wu, 1965a, b, 1973). The ducts of salivary glands are dichotomously branched and all the branches united to form a single tube.

The stomach was similar with descriptions of *Thais* sp. by Tagore (1989), in *C. ramosus* by Middlefart (1992a, b) and Stella (1995) in *Chicoreus species* and Ravichandran (2012) in *Ch. ponderosus*. The openings of the ducts of the digestive glands are large and oval. The anterior opening is located just anterior and ventral to the transverse fold, while the posterior one lies at the entrance of the oesophagus into the stomach. Duct pouches are not prominent and the typhlosoles are poorly defined. Tan and Phuah (1999) examined the feeding of the species of *P. cochlidium* in Singapore. The observations of digestive organs, are similar with descriptions of *Thais* sp. by Tagore (1989), in *C. ramosus* (Linnaeus, 1758) by Middlefart (1992a, b) and Stella (1995) in *Chicoreus species* and Ravichandran (2012) in *C. ponderosus*, *P. tupiniquim* (Abbate and Simone, 2015), *Thaisella guatemalteca* (Simone, 2017), and *Tudicla spirillus* (Linnaeus, 1767) (Harasewych, 2018).

4.2. Nervous system

The present results about nervous system anatomy are similar with descriptions made by Stella (1995) in *Chicoreus species* and Ravichandran (2012) in *C. ponderosus*, *Rapana venosa* (Valenciennes, 1846) (Guohua et al., 1990), *P. tupiniquim* (Abbate and Simone, 2015), *Thaisella guatemalteca* (Simone, 2017), and *Tudicla spirillus* (Linnaeus, 1767) (Harasewych, 2018).

4.3 Reproductive organs

The general scheme is similar with observations in *Nucella lapillus* (Linnaeus, 1758) and *Ocenebra crinacea* (Linnaeus, 1758) by Fretter (1941) and Stella (1995) in *Chicoreus species* and Ravichandran (2012) in *C. ponderosus*, *P. tupiniquim* (Abbate and Simone, 2015), *T. guatemalteca* (Simone, 2017), and *T. spirillus* (Linnaeus, 1767) (Harasewych, 2018). This similar observation for male reproductive organs has been made in *N. lapillus* and *O. crinacea* by Fretter (1941) and Stella (1995) in *Chicoreus species* and Ravichandran (2012) in *C. ponderosus*, *P. tupiniquim* (Abbate and Simone, 2015), *T. guatemalteca* (Simone, 2017), and *T. spirillus* (Linnaeus, 1767) (Harasewych, 2018). Whereas for female reproductive organs there are similarities with descriptions of Tagore (1989) in *Thais* sp. Stella (1995) in *Chicoreus species* and Ravichandran (2012) in *C. ponderosus*, *P. tupiniquim* (Abbate and Simone, 2015), *T. guatemalteca* (Simone, 2017), and *T. spirillus* (Linnaeus, 1767) (Harasewych, 2018).

The male and female reproductive system of two species agree well with the description given by Fretter (1941) for *N. lapillus*, Tagore (1989) for *Thais* sp. and Stella (1995) for *Chicoreus* sp and Ravichandran (2012) in *C. ponderosus*, *P. tupiniquim* (Abbate and Simone, 2015), *T. guatemalteca* (Simone, 2017), and *Tudicla spirillus* (Linnaeus, 1767) (Harasewych, 2018). In male, the prostate gland is a closed one which is slightly broader in diameter in *P. cochlidium*

and in *P. erecta*. In these two species it is basically organized on the same plan. In female the capsular gland is obvious because of the similar mode of reproduction and production of attached egg capsule.

In summary, the exposed results of soft body anatomy of *P. cochlidium* and *P. erecta* is similar to other gastropods species, and these results would be important for other basic and applied studies about both species that are an important fisheries resource.

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