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EXPLORING THE INTRICATE MORPHO-ANATOMY OF *TONNA DOLIUM* (CAENOGASTROPODA: TONNIDAE) FROM THE GULF OF MANNAR, INDIA

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ABSTRACT: The study provides a detailed morpho-anatomical description of *Tonna dolium* (Linnaeus, 1758), a commercially important tonnid gastropod, based on specimens collected from the Gulf of Mannar, India. The research examines the shell characteristics, head-foot morphology, mantle organs, visceral mass, reno-pericardial system, digestive system, reproductive system, and central nervous system of *T. dolium* through dissections and histological analysis. Key anatomical features are described and illustrated, including the proboscis structure, radula morphology, esophageal glands, and genital systems of both males and females. Comparisons are made with previously studied tonnid species, particularly *Tonna galea* and *Tonna pennata*. Notable distinctive features of *T. dolium* include the narrow gill and osphradium, radularrachidian with two pairs of secondary cusps, and confinement of seminal vesicles within the pallial oviduct. This comprehensive anatomical study contributes to a better understanding of tonnid taxonomy and provides insights into the adaptations of *T. dolium* for its predatory lifestyle in tropical marine ecosystems.

INTRODUCTION: The Tonnidae represent a charismatic caenogastropod family comprising medium-sized to very large sea snails, commonly referred to as tun shells. The term "tun" alludes to the shell's shape, resembling the wine casks known as "tuns". Characterized by thin yet robust shells, Tonnidae species typically feature reduced opercula. They inhabit sandy areas across tropical seas worldwide. As carnivores, they bury themselves in the substrate, primarily preying on echinoderms, particularly sea cucumbers, and occasionally crustaceans and bivalves.

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Larger species are known to capture fish, utilizing their expandable proboscis to engulf the entire prey. Females deposit rows of eggs, which hatch into free-swimming larvae that remain planktonic for several months before settling on the seafloor [1]. This protracted planktonic larval phase facilitates extensive dispersion and widespread distribution of most species within the family.

Despite the ecological importance of tonnids, our understanding of the anatomy of most species is limited, primarily based on their shells alone [2, 3]. Enhanced knowledge of each species' anatomy contributes to a better understanding of their taxonomy and ecological significance within their respective ecosystems [4]. *Tonna dolium* is a species distributed throughout the Indian Ocean and western Pacific Ocean. Its shell can easily reach lengths of 200 mm and is distinguished by its vibrant colors, making it highly sought after for

handicrafts and collections. In this context, the present study aims to shed light on certain aspects of the anatomy and morphology of a commercially important species, *Tonna dolium* (Linné, 1758), utilizing samples collected from the Gulf of Mannar, India.

MATERIAL AND METHODS: *Tonna dolium* were collected from the Gulf of Mannar Marine Biosphere Reserves in India, situated on southeast coast of India, extending from Adams Bridge to the Cape Comorin. Indian part of Gulf of Mannar covers approximately an area of 10, 500 km^2 along the 8°48'– 9°14'N to 79°9'– 79°14'E. There are about 21 islands covering an area of 625 hectare and the coral reefs fringing and patchy types extend from Rameswaram to Tuticorin (8°50' – 9°10'N) covering a distance of 140 km. This marine province is highly productive and biologically very rich includes mangroves, seaweeds, seagrasses, sponges, corals, gorgoniids, echinoderms, mollusks, fishes, turtles, sea snakes and marine mammals.

The depth of the Gulf of Mannar beyond the island chain ranges from 3.5 to 15 m with a sudden fall after that giving oceanic condition. This marine ecosystem supports a wide variety of flora and fauna of taxonomic and economic importance. For the present study the snails were collected from the landed by-catch from fishing trawlers operated for crabs and prawns from the shallow water regions of the Gulf of Mannar coast of Tuticorin.

The soft parts were extracted by breaking open the shell or by boiling in water or in mild alkaline solution. After removing the specimen, the shells were cleaned using brush with detergent powder. The morphology of the shell and ornamental pattern of the shell were studied. Dissections were carried out in living as well as in preserved animals for studying the different systems.

Camera lucida drawings were made with the help of a stereozoom microscope and measurements were recorded with stage and ocular micrometers. The specimens destinated to anatomical study were kept in 75% magnesium chloride for relaxation, and afterwards dissected. Figures were drawn using a binocular stereozoom microscope using *Camera lucida*. For histological studies, the tissue samples were taken from proboscis, oesophagus, salivary gland, stomach, intestine, rectum, ovary, testis, mantle, ctenidium and osphradium. These different soft tissues were fixed in aqueous Bouins and Zenker's solution. Sections of 6-8 µ thickness were made from different organs and stained in Delafieldhematoxylin with eosin as a counter stain. Freshly killed specimens were used for the study of digestive and reproductive systems, as the genital complex was more readily visible. Measurements were made with ocular and stage micrometers and the drawings were made. Only preserved animals were used to study the nervous system, as minute nerves stood out prominently in it.

RESULTS: *Tonna dolium* Linné, 1758 **Fig. 1-3** *Buccinum dolium* Linné, 1758[5]: 735 (sp. 380), 1767[6]: 1197 (sp 442).

Tonna dolium: Winckworth & Tomlin [7], 1933: 209: Kilias [8], 1962: 22; Cernohorsky [9], 1972; Nazneen & Begum [10], 1988: 28; Wilson [11], 1993: 253; Steyn & Lussi [12], 2005: 66;Vos, 2007 [13]: 48, 2012 [14]: 13, 2013 [15]: 29; Liu [16], 2008: 488 (sp 822); Mollusca Base [17], 2024.

Description: Shell **Fig. 1A-F** of ~100 mm, globose, walls thin; ~1.3x wider than long. Spire blunt, ~20% of shell length; 5-6 convex whorls. Basic color whitish to light brown **Fig. 1B, E.** Protoconch light brown, or 3-whorls *Fig. 1C, F*.

Sculptured by strong spiral ribs, 2 in spire whorls **Fig. 1C, C, E, F,** 6-7 in body whorls equally spaced; each rib tall, wide, pigmented with brown, relatively uniform patches along them; patches in ribs aligned axially; interspaces between main ribs ~twice their width; secondary, unpigmented ribs located between pair of main, pigmented ribs, with approximately 1/5 main ribs width.

Dorsal to canal 6-7 narrow, oblique ribs located close from each other, extending narrowly to ventral region, flanking smooth middle and inferior region of canal, ending in pointed flap turned forwards flanked right side of canal; this edge flanked by 2-3 low, longitudinal folds. Periostracum thin, usually deciduous. Aperture ample, rather elliptic; occupying ~75% of shell length, ~50% of shell width **Fig. 1A, D.** Outer lip thick, undulated because of shell sculpture.

Inner lip with superior half convex, covered by very thin, transparent callus not exceeding aperture; inferior half concave in superior region, straight inferiorly, edging canal. Canal short, turned forwards and slightly to right, opened ~20% shell width. Umbilicus absent. Pseudoumbilicus narrow, edging inner margin of right canal edge **Fig. 1A, D.**

Head-foot Fig. 2A. Head (he) wide, occupying ~half of foot width. Tentacles (te) lateral located, eyes on outer base, on small tubercles. Foot (ft) wide, ample, stubby. Color of exposed areas light brown, with dark brown irregular spots. Rhynchostome (ry) wide, weakly protruded between tentacles.

Mantle organs Fig. 3A. Pallial cavity (py) of ~1 whorl, rather triangular, ample anteriorly. Mantle edge (mb) simple, thick. Siphon (si) long, uniform pale brown in color. Gill (gi) elliptic, ~3-times longer than wide, occupying ~80% of cavity length, ~half of its width; anterior end bluntly pointed, away from mantle edge; posterior end sharp pointed, touching kidney.

Osphradium (os) ~4-times longer than wide, ~half gill's length, ~1/3 gill's width; pointed anteriorly, rounded posteriorly. Wide area between gill and rectum. Hypobranchial gland **Fig. 3D**: hg narrow, zigzagging anterior half of rectum left edge. Rectum (rt) relatively wide; anus (an) slightly siphoned, at some distance from mantle edge. Pallial genital structures located between rectum and right edge, described below.

Visceral mass Fig. 3A. With about half of pallial size, ~2.5 whorls. Narrow stomach and reno-pericardial organs as anterior ~1/3 structures. Posterior ~2/3 with gonad mostly occupying right and dorsal region, digestive gland (dark brown) in left and columellar-ventral region.

Reno-pericardial System Fig. 2G. Kidney wide **Fig. 3A**: ki, ~1/3 whorl. Nephrostome (ne) as sphincter clearly surrounded by muscle fibers; located in middle of reno-pallial membrane. Kidney lobes brownish-green, fulfilling most inner space. Nephridial gland (ng) thin, cream in color. Ad-rectal sinus well-developed, similar to ureter, extending from up to aperture near anus **Fig. 3D**: at. Histologically, rectal gland composed of columnar ciliated epithelium cells; intestine lined by ciliated epithelium containing muscle fibers and ciliated cells. Pericardial area with ~half volume of kidney; auricle (au) very wide, with flaccid, transparent walls; ventricle (ve) rounded, with very thick walls.

Digestive system Fig. 2B-F, H. Proboscis (pb) well-developed, walls thick muscular; several pairs of longitudinal retractor muscles **Fig. 2D, E**: rm originated in haemocoel floor and lateral walls. Mouth wide, bilabial **Fig. 2B, C**: mo. Pair of jaw plates **Fig. 2B, C, E**: jw elliptic, with well-developed hook in their lateral edges.

Radula **Fig. 1G**: rachidian occupying ~half of radular ribbon, central cusp large, triangular, pointed, flanked by 2 pairs of secondary cusps; lateral and both marginal teeth similar to each other, hook-like, base side, tapering abruptly as wide curve inwards up to sharp pointed tip. Esophagus (es) with large pair of parallel folds **Fig. 2B, C, E:** ef, and esophageal midventral mucous ridge (mv) between them; these folds and mucous ridge entering into esophageal ventral caecum **Fig. D, E, F**: *etc*.

Esophageal caecum (ec) as blind-sac, ~3-times longer than wide, located just posterior to nerve ring level; internally several transverse, thin-walled septa fulfilled by gland. Histologically esophagus lined with ciliated columnar, containing mucocytes and basement membrane. Stomach narrow, of difficult individualization. Intestine **Fig. 2H:** in narrow, as simple loop, lacking typhlosole. Rectum and anus described above.

Genital system. **Male**. Testis **Fig. 3A**: ts described above. Seminal vesicle **Fig. 3A**: sv large, spheric, located just posterior to kidney. Narrow visceral vas deferens suddenly increasing in right-posterior side of pallial cavity, becoming wide, swollen spermatic groove **Fig. 2A, 3B, C**, working as prostate, running along right edge of pallial cavity up to penis base. Penis **Fig. 2A, 3B, C**: pe originated posterior to right tentacle, straight, broad, with ~1/5 of pallial cavity volume. Penis groove (pd) running straight along penis up to tip. Penis tip with transverse terminal flap **Fig. 3C:** pp, as penis groove end.

Female Fig. 3D. Ovary with similar character as testis. Very narrow visceral oviduct (vo) running in

columellar surface of visceral mass, inserting in tip of narrow projection of albumen gland (ag). This projection having series of small seminal vesicles in a side (sv). Remaining albumen gland (ag) wide, occupying posterior ~1/4 of pallial oviduct.

Capsule gland (cg) occupying remaining anterior ~3/4 of pallial oviduct, lacking clear separation with albumen gland. Capsule gland anteriorly ending in short atrium turned to right, opening in very small female pore (fo). Bursa copulatrix (bc) narrow and long, with ~70% of pallial oviduct length, ~1/5 its width; inserted in genital atrium, just posterior to its pore. Female pore (fo) relatively distant from anus (an).

Central nervous system Fig. 2F Ganglia spaced, located away from each other. Nerve ring (nr) located in base of proboscis **Fig. 2D**, with calibrous anterior nerves to proboscis and buccal mass.

Legends L: Fig. 1, *Tonna dolium* shells and radula of studied population from India: A-C, shell #1 (L 110 mm), frontal, dorsal and apical views; D-F, shell #2 (L 90 mm), frontal, dorsal and apical views; G, radula in SEM, scale= 0.5mm.

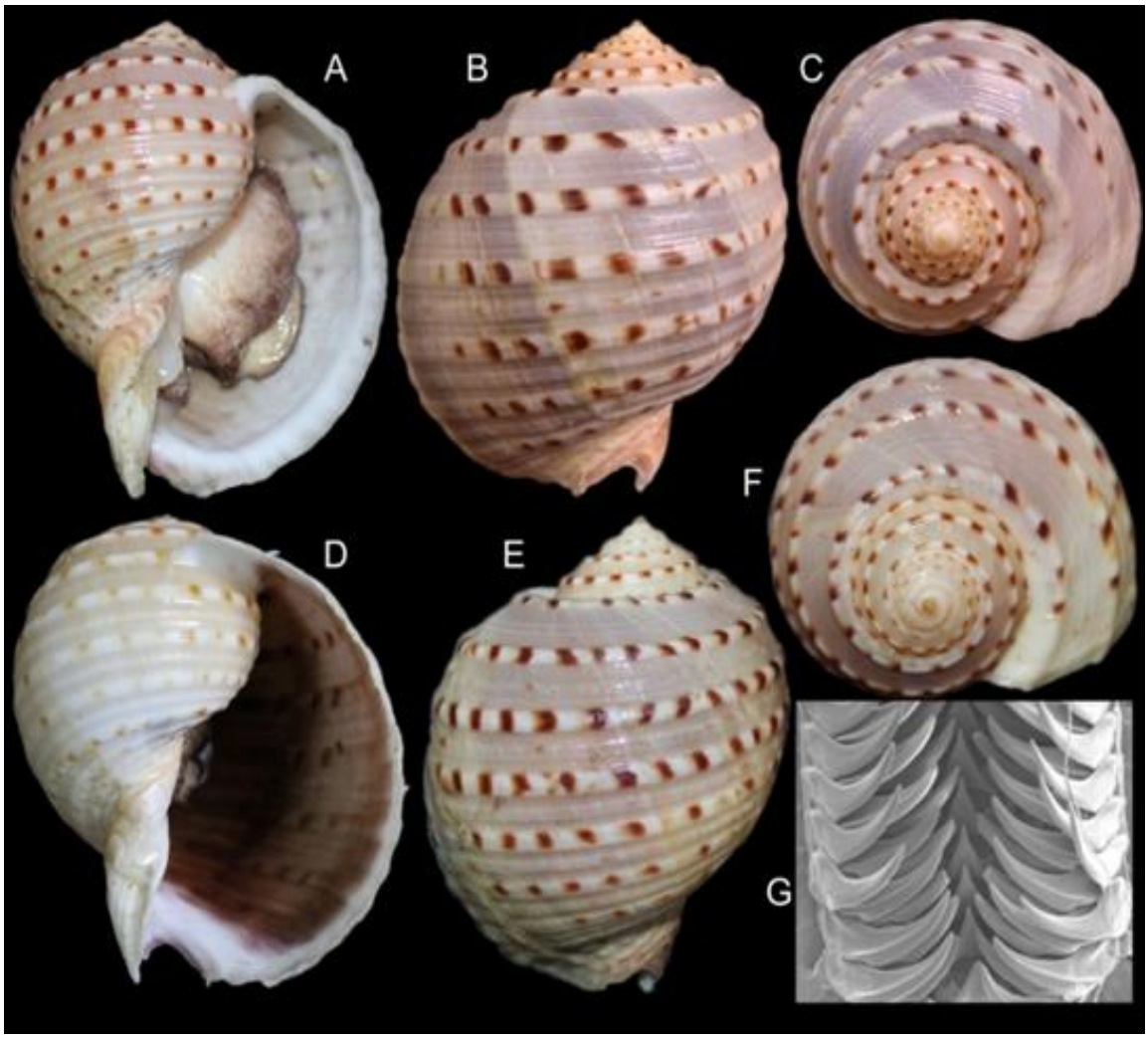

FIG. 2, *TONNA DOLIUM* ANATOMICAL DRAWINGS: A, HEAD-FOOT, MALE, DORSAL-ANTERIOR VIEW; B, SEMI-SCHEMATIC REPRESENTATION OF ESOPHAGEAL FOLDS AND BUCCAL MASS STRUCTURES, TOPOLOGY OF MOUTH ALSO SHOWN; C, ANTERIOR REGION OF PROBOSCIS, DORSAL VIEW, OPENED LONGITUDINALLY; D, SEMI-SCHEMATIC REPRESENTATION OF HAEMOCOELIC STRUCTURES, HAEMOCOEL AND PROBOSCIS OPENED LONGITUDINALLY, SOME STRUCTURES DEFLECTED; E, FOREGUT, DORSAL VIEW, PROBOSCIS AND ESOPHAGUS OPENED LONGITUDINALLY; F, NERVE RING AS IN SITU, DORSAL VIEW; SOME ADJACENT STRUCTURES ALSO SHOWN; G, RENO-PERICARDIAL STRUCTURES, VENTRAL VIEW, VENTRAL PERICARDIAL MEMBRANE REMOVED; H, SEMI-SCHEMATIC REPRESENTATION OF DIGESTIVE TUBES AS *IN-SITU*, TOPOLOGY OF ADJACENT STRUCTURES SCHEMATICALLY SHOWN. SCALES = 30 MM.

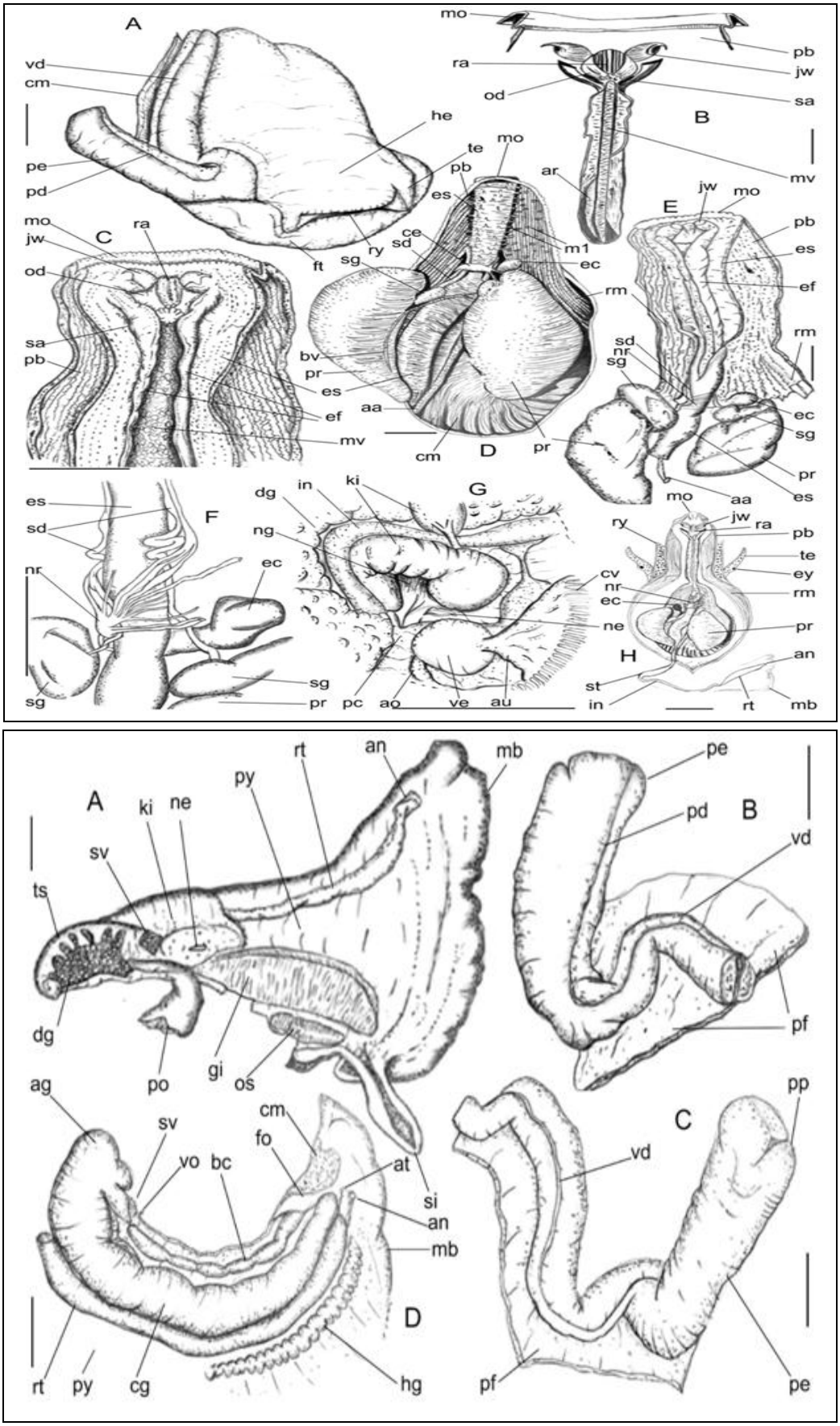

FIG. 3: *TONNA DOLIUM* ANATOMICAL DRAWINGS: A, PALLIAL ROOF AND VISCERAL MASS, MOSTLY VENTRAL VIEW; B, PENIS AND ADJACENT REGION OF PALLIAL FLOOR, ANTERIOR VIEW; C, SAME, DORSAL VIEW; D, PALLIAL OVIDUCT AND ADJACENT STRUCTURES, VENTRAL VIEW. SCALES = 30 MM

DISCUSSION: The anatomical features of *Tonna dolium* bear resemblance to those of a few tonnid species with documented anatomy [2]. These features include morphological adaptations for predation, such as a well-developed siphon and osphradium (see **Fig. 3A**), a large and elongated proboscis equipped with well-developed annexed glands, including esophageal caecum, salivary glands, and proboscis glands **Fig. 2D, E, F**. Additionally, *T. dolium* exhibits an esophageal glandular mucous groove, a characteristic shared with other tonnids **Fig. 2B, C, E:** mv. The radula is characterized by pointed, hook-like teeth **Fig. 1G** and a pair of jaw plates with well-developed, sturdy hooks **Fig. 2B, C:** jw.

Despite the shell similarity between *T. dolium* and *T. galea* [5], anatomically, *T. dolium* bears more resemblance to *T. pennata* (Mörch, 1852) (Simone, 1995[2], referred to as *T. maculosa*). Both species exhibit a similar shape of the penis, characterized by a terminal flap **Fig. 3B, C**, as opposed to the terminal, elongated papilla observed in *T. galea*. The pallial oviduct of *T. dolium* also shares more similarities with that of *T. pennata*, featuring the visceral oviduct connected to a projection of the albumen gland **Fig. 3D** and a larger component of the female genital pore of the capsule gland, in contrast to the bursa copulatrix observed in *T. galea*. The main distinctive features of *T. dolium* include the proportionally narrow shape of both the gill and the osphradium **Fig. 3A**, the radular rachidian bearing two pairs of secondary cusps, and the confinement of the seminal vesicles within the pallial oviduct **Fig. 3D**: sv.

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CONFLICT OF INTEREST: The authors have no conflict of interest

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