Three new species of *Pseudorhabdosynochus* (Monogenea, Diplectanidae) from several species of *Cephalopholis* and *Epinephelus* (Perciformes, Serranidae) from Thailand

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**Abstract** – *Pseudorhabdosynochus suratthaniensis* n. sp. is described from the gills of *Cephalopholis argus; P. cephalopholi* n. sp., from the gills of *C. sonnerati*; and *P. samaesarnensis* n. sp., from the gills of *Epinephelus lanceolatus*. These fish were all caught in the Gulf of Thailand. *Pseudorhabdosynochus suratthaniensis* n. sp. is distinguished from congeneric species by the structure of its sclerotized vagina, which has a wide sclerotized trumpet and a single large primary chamber, and by the number of rows of rodlets in each of its squamodiscs. *Pseudorhabdosynochus cephalopholi* n. sp. is also distinguished by the structure of its sclerotized vagina that, like the *P. suratthaniensis* n. sp., has a sclerotized trumpet, but it also has a long coiled or curved primary canal near its midlength, and a distal part with a primary chamber and a secondary chamber communicating with the primary chamber through a short secondary canal. In addition, *P. cephalopholi* n. sp. is distinguished by some sclerotized organs (ventral and dorsal hamuli, ventral bar, and quadriloculate organ) with different lengths, and by the number of rows of rodlets in each of its squamodiscs. *Pseudorhabdosynochus samaesarnensis* n. sp. is distinguished by its sclerotized vagina that has an anterior cup-shaped trumpet and a short or straight or curved primary canal. For Thailand, these are the first species of *Pseudorhabdosynochus* described from species of *Cephalopholis* and the second species of *Pseudorhabdosynochus* described from *Epinephelus*.

**Key words:** *Pseudorhabdosynochus suratthaniensis, Pseudorhabdosynochus cephalopholi, Pseudorhabdosynochus samaesarnensis, Cephalopholis sonnerati, Epinephelus lanceolatus.*

**Résumé** – Trois nouvelles espèces de *Pseudorhabdosynochus* (Monogenea, Diplectanidae), parasites de plusieurs espèces de *Cephalopholis* et *Epinephelus* (Perciformes, Serranidae) de Thaïlande. *Pseudorhabdosynochus suratthaniensis* n. sp. est décrit à partir des branches de *Cephalopholis argus, P. cephalopholi* n. sp. des branches de *C. sonnerati*, et *P. samaesarnensis* n. sp. des branches d’*Epinephelus lanceolatus*. Ces poissons ont tous été pêchés dans le golfe de Thaïlande. *Pseudorhabdosynochus suratthaniensis* n. sp. se distingue des espèces congénères par la structure de son vagin scléréifié, qui possède une large trompette scléréifiée et une seule grande chambre primaire, et par le nombre des rangées de bâtonnets dans chacun de ses squamodiscus. *Pseudorhabdosynochus cephalopholi* n. sp. se distingue également par la structure de son vagin scléréifié qui, comme *P. suratthaniensis* n. sp., a une trompette scléréifiée, mais a également un long canal primaire enroulé ou incurvé près de sa mi-longueur et une partie distale avec une chambre primaire et une chambre secondaire communiquant avec la chambre primaire par un court canal secondaire. De plus, *P. cephalopholi* n. sp. se distingue par certains organes scléréifiés (hamuli ventraux et dorsaux, barre ventrale et organe quadriloculé) de longueurs différentes, et par le nombre des rangées de bâtonnets dans chacun de ses squamodiscus. *Pseudorhabdosynochus samaesarnensis* n. sp. se distingue par son vagin scléréifié qui a une trompette antérieure en forme de coupe et un court canal primaire droit ou courbe. Pour la Thaïlande, il s’agit de la première espèce de *Pseudorhabdosynochus* décrite à partir d’espèces de *Cephalopholis* et de la deuxième espèce de *Pseudorhabdosynochus* décrite à partir d’*Epinephelus*.

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Introduction

Groupers (Serranidae, Epinephelinae) are bottom-associated fishes found in tropical and subtropical seas. Most species occur in coral reefs, but some live in estuaries or on rocky reefs [11]. The Epinephelinae are divided into five tribes that comprise about 234 species of marine fishes in 32 genera [28]. The hybrid grouper, a cross of the female tiger grouper *E. fuscoguttatus* and the male giant grouper *E. lANCEOLATUS* (tiger grouper × giant grouper or TGGG), has taken the Asian aquaculture industry by storm since 2006. TGGG is widely cited as the most successful hybrid combination, as it is able to grow quickly [2, 6]. In Thailand, the peacock hind *Cephalopholis argus* (Bloch & Schneider), the tomato hind *C. sonnerati* (Valenciennes), the coral hind *C. MINIATA* (Forskål), the giant grouper *Epinephelus lanceolatus* (Bloch), and the whitespotted grouper *E. coeRDeOpunctatus* (Bloch) occur in mangroves; the cloudy grouper *E. erytharus* (Valenciennes) occurs in seagrass beds; and the orange-spotted grouper *E. COOides* (Hollander) occurs in both mangroves and seagrass beds [29]. Species of *Pseudorhabdosynochus* Yamaguti, 1958 are mostly found on the gills of groupers mainly of the genus *Epinephelus* and appear to be specific to their host [18, 22]. *Pseudorhabdosynochus* currently has 96 valid species [10]. Four of those species — *P. argus* Justine, 2007, *P. minutus* Justine, 2007, *P. urceolus* Mendoza-Franco, Violante-González & Herrera, 2011, and *P. megamareiae* Kritsky, Bakenhaster & Adams, 2015 — have been described from four species of *Cephalopholis* — *C. argus*, *C. sonnerati*, *P. samaesarnensis* (Steindachner), and *C. cruenta* (Lacepède) [15, 24, 26], respectively. In this paper, we describe three new species — *P. suratthaniensis* n. sp. found on the gills of *C. argus*, *P. cephalopholi* n. sp. found on the gills of *C. sonnerati*, and *P. samaesarnensis* n. sp. found on the gills of *E. lANCEOLATUS* — in the Gulf of Thailand. *Pseudorhabdosynochus* argus and *P. minutus* had earlier been described from *C. argus* and *C. sonnerati* off Nounéa, New Caledonia [15], respectively; in this paper, we describe a second species of *Pseudorhabdosynochus* from these fish. In addition, we describe the first species of *Pseudorhabdosynochus* from *E. lANCEOLATUS*: *Pseudorhabdosynochus samaesarnensis* n. sp.

Materials and methods

One specimen of *C. argus* (total length, 303 mm and weight, 443 g) was obtained from a jetty in Surat Thani province, Southern Thailand in June 2019. Four specimens of *C. sonnerati* (total length, 230–247 mm and weight, 234–287 g), and nine specimens of *C. MINIATA* (total length, 210–340 mm and weight, 169–637 g) were obtained from a jetty in Surat Thani province, Southern Thailand in May 2019. One specimen of *E. lANCEOLATUS* (total length, 520 mm and weight, 5000 g) was obtained from a local fisherman on Samae-Sarn Island in the Gulf of Thailand, Chonburi province, Eastern Thailand in September 2020. Four specimens of *E. coeRDeOpunctatus* (total length, 290–330 mm and weight, 378–557 g), four specimens of *E. COOides* (total length, 350–470 mm and weight, 617–1500 g), five specimens of *E. erytharus* (total length, 245–275 mm and weight, 260–338 g), four specimens of *E. malabaricus* (total length, 360–370 mm and weight, 759–844 g), and eleven specimens of *E. fuscoguttatus* (total length, 250–350 mm and weight, 270–914 g) were obtained from a local fisherman on Libong Island in the Andaman Sea, Trang province, Southern Thailand in April 2020. Three sea cage-cultured hybrid groupers (TGGG) (*E. fuscoguttatus* × *E. lANCEOLATUS*) (total length, 380–480 mm and weight, 1100–2600 g) were obtained from a local farmer in Ban Laem Hin, Phang-Nga province in the Andaman Sea, Southern Thailand in May 2020. All the fish were dead and were immediately transported in a cool box to the laboratory. Their gills were removed and placed in Petri dishes that contained seawater. Monogeneans were individually picked off the gills with a fine needle with the aid of a stereomicroscope and put on slides. They were prepared with ammonium picrate-glycerin, referred to as “Picrate” (see [13]) according to [25]. Then, their soft internal organs and haptoral hard parts were immediately examined. The slides were later sealed with Canada balsam [13]. Specimens were photographed using an Olympus DP 70 microscope (Olympus Corporation, Japan) and a Zeiss Axioscam 506 color microscope (Carl Zeiss AG, Germany) for drawing. Various sclerotized organs were measured based on a previous study (see Fig. 1 in [13, 14]; their nomenclature follows [14]). Measurements are in μm and given as mean followed by (minimum–maximum, n) between parentheses. Specimens were deposited in Lee Kong Chian Natural History Museum National University of Singapore (herein abbreviated as ZRC), Natural History Museum, National Science Museum, Technopolis, Pathum Thani Province, Thailand (herein abbreviated as THNHM) and Zoological Museum, Kasetsart University (herein abbreviated as ZMU).

**Pseudorhabdosynochus suratthaniensis** n. sp.

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**Type-host:** *Cephalopholis argus* (Bloch & Schneider) (Perciformes, Serranidae).

**Type-locality:** Surat Thani Province, the lower Gulf of Thailand, Southern Thailand (9°49′10.1″N 99°55′31.1″E), June 2019.

**Type-material:** Holotype, ZRC.PLA.1115; 2 paratypes, ZRC.PLA.1116-17; 2 paratypes, THNHM-Iv-19363-64; 15 paratypes, ZMU-PM-002039-53.

**Site in host:** Gills.

**Infection indices:** Prevalence 100% (one specimen examined and infected); 36 helminth specimens on the single grouper examined.

**Etymology:** The species name “suratthaniensis” is treated as an adjective and was derived from the name of the province “Surat Thani”, where the host fish *Cephalopholis argus* was collected.

**Description (Figs. 1 and 2)**

[Based on 20 specimens]. Body (including haptor) 759 long (619–977, n = 20); maximum width 169 (121–216, n = 20). Tegument smooth. Anterior region with 3 pairs of lateral head...
organs and 2 pairs of eye-spots; anterior pair smaller than posterior pair. Pharynx median, spherical, 45 (32–54, n = 20) × 45 (30–54, n = 20). Esophagus absent. Intestinal bifurcation immediately follows pharynx. Haptor differentiated from rest of body, 222 wide (177–277, n = 20), with 2 similar squamodiscs, 2 pairs of lateral hamuli, 3 bars, and 14 marginal hooklets. Dorsal and ventral squamodiscs round-shaped, made up of rows of rodlets, 1–2 central rows oval and closed. Dorsal squamodisc 53 long (41–64, n = 20), 55 wide (40–67, n = 20), with 9–11 rows of rodlets, of which the 1–2 innermost rows form closed ovals. Ventral squamodisc 59 long (47–73, n = 20), 57 wide (41–69, n = 20), with 8–11 rows of rodlets, of which the 1–2

Figure 1. Pseudorhabdosynochus suratthaniensis n. sp. from Cephalopholis argus in the lower Gulf of Thailand. (A) COMPOSITE drawing (mainly from holotype), dorsal view. (B) Male quadriloculate organ, dorsal view. (C) Sclerotized vagina, dorsal view. (D) Ventral hamulus. (E) Dorsal hamulus. (F) Ventral bar. (G) Dorsal (lateral) bar. (H) Ventral squamodisc. (I) Dorsal squamodisc. (J) Hooklet. Scale-bars: (A) 200 μm; (B)-(J) 50 μm.
innermost rows form closed ovals. Ventral hamulus with distinct guard and expanded deep root, elongated shaft slightly arched and recurved toward the tip, outer length 49 (44–53, n = 20), inner length 43 (39–47, n = 20). Dorsal hamulus with indistinct guard and expanded deep root, elongated straight shaft and recurved toward the tip, outer length 42 (40–46, n = 20), inner length 27 (25–31, n = 20). Dorsal (lateral) bar straight, with flattened medial extremity and cylindrical lateral extremity, 69 long (56–72, n = 20), 19 wide (16–22, n = 20). Ventral bar 93 long (85–100, n = 20), 18 wide (15–21, n = 20), with constricted median portion, pointed ends and visible groove that extends to both thin extremities. Male quadriloculate organ divided into 4 chambers, inner length 73 (65–84, n = 20), fourth chamber ends in sclerotized cone, 19 long (14–22, n = 20), prolonged by sclerotized tube, 19 long (16–23, n = 20), end of tube prolonged by filament of variable length. Testis subspherical, intercecal. Ovary pretesticular, encircles right intestinal cecum. Vitelline follicles lateral, coextensive with intestinal ceca and confluent in large zone posterior to testis and terminate anterior to peduncle, leaving free space around squamodiscs. Egg not seen.

Sclerotized vagina with a complex structure, aspect changes slightly according to specimen and orientation (Figs. 2A–2F). Sclerotized vagina comprises anterior trumpet, followed by primary canal, primary chamber and secondary canal; trumpet in continuity with primary canal short, straight, or curved (Figs. 2A and 2D), heavily sclerotized and widens into single large and thick-walled primary chamber; secondary canal connected to primary chamber around base of vagina. Total length of sclerotized vagina (measured from distal extremity of trumpet to base of vagina) 40 (36–45, n = 20), length variable because of variation in curvature of primary canal. Primary chamber subspherical 19 long (15–23, n = 20), 17 wide (16–20, n = 20).

**Differential diagnosis**

*Pseudorhabdosynochus suratthaniensis* n. sp. is easily distinguished from other species of *Pseudorhabdosynochus* by the structure of its sclerotized vagina and the number of rows of rodlets in each of its squamodiscs. Another *Pseudorhabdosynochus* species that has a vaginal structure similar to that of *P. suratthaniensis* n. sp. is *P. urceolus* from *C. panamensis* from Taboga Island in Panama. The general structure of the sclerotized vagina appeared to be similar to that of the *P. suratthaniensis* n. sp. *Pseudorhabdosynochus urceolus* can be distinguished by the following characteristics: the size of its sclerotized vagina (29 versus 40 μm in *P. suratthaniensis* n. sp.); the morphology of its sclerotized vagina, with a bell-shaped opening that is not in *P. suratthaniensis* n. sp; and its chamber structure, with a small

Figure 2. Variations (A)–(F) of the sclerotized vagina of *Pseudorhabdosynochus suratthaniensis* n. sp. from *Cephalopholis argus* in the lower Gulf of Thailand. Abbreviations: Tr – trumpet, Ca1 – primary canal, Ch1 – primary chamber, Ca2 – secondary canal. Scale-bar: 50 μm.
In addition, the squamodiscs of *P. urceolus* have numerous rows of rodlets, that is, 14–15 rows of rodlets and a 0–1 innermost row that form complete concentric rings; but the squamodiscs of *P. suratthaniensis* n. sp. have 8–11 rows of rodlets and 1–2 innermost rows that form closed oval [26]. *Pseudorhabdosynochus bouaini* Neifar & Euzet, 2007 from *E. costae* (Steindachner) out of Sfax, Tunisia has a sclerotized vagina similar to that of *P. suratthaniensis* n. sp. It is characterized by an anterior trumpet, followed by a short and heavily sclerotized primary canal progressively in the heavy primary chamber. However, the distal part of the primary chamber has two small sclerotized protuberances in *P. bouaini* (which are not in *P. suratthaniensis* n. sp) [27].

**Pseudorhabdosynochus cephalopholi** n. sp.

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*Type host:* Cephalopholis sonnerati (Valenciennes) (Perciformes, Serranidae).

*Other host:* C. miniata (Forsskål) (Perciformes, Serranidae).

*Type locality:* Surat Thani Province, the lower Gulf of Thailand, Southern Thailand (9°48'10.1"N 99°55'31.1"E), May 2019.

*Type material:* Holotype, ZRC.PLA.1118; 2 paratypes, ZRC.PLA.1119–20; 2 paratypes, THNHM-Iv-19365–66; 20 paratypes, ZMKU-PM-002054–73; 2 paratypes from other host, C. miniata, ZMKU-PM-002074–75.

*Site in host:* Gills.

*Infection indices:* Prevalence 100% (4/4); mean intensity 62.5 individuals/fish (250/4).

*Etymology:* Species name derived from *Cephalopholis*, which is the name of the host genus (both type-host and other host). This monogenean species seems to be specific to this host genus.

**Description (Figs. 3 and 4)**

[Based on 25 specimens]. Body (including haptor) 393 long (260–645, *n* = 25), maximum width 106 (83–126, *n* = 25). Tegument smooth. Anterior region with 3 pairs of lateral head organs and 2 pairs of eye-spots; anterior pair smaller than posterior pair. Pharynx median, spherical, 24 (18–31, *n* = 25) × 24 (19–31, *n* = 25). Esophagus absent. Intestinal bifurcation immediately follows pharynx. Haptor differentiated from rest of body; 216 wide (167–261, *n* = 25), with 2 similar squamodiscs, 2 pairs of lateral hamuli, 3 bars, and 14 marginal hooklets. Dorsal and ventral squamodiscs round-shaped, made up of rows of rodlets; rodlets similar in width in all rows except last row with thin and separate rodlets; central rows form closed oval. Dorsal squamodisc 39 long (30–56, *n* = 11), 41 wide (32–57, *n* = 11), with 8–10 rows of rodlets, the innermost of which form closed oval. Ventral squamodisc 39 long (34–43, *n* = 11), 43 wide (37–49, *n* = 11), with 8–10 rows of rodlets, the innermost of which form closed oval. Ventral hamulus with distinct guard and expanded deep root, elongated shaft and recurved toward the tip, outer length 41 (37–46, *n* = 25), inner length 31 (29–36, *n* = 25). Dorsal hamulus with indistinct guard and expanded deep root, elongated shaft and recurved toward the tip, outer length 35 (32–38, *n* = 25), inner length 22 (19–25, *n* = 25). Dorsal (lateral) bar straight, elongated, with flattened medial extremity and cylindrical lateral extremity, 72 long (64–79, *n* = 25), 10 wide (7–14, *n* = 25); visible groove that extends to both thin extremities. Male quadriloculare organ divided into 4 chambers, inner length 40 (33–46, *n* = 25), fourth chamber ends in sclerotized cone, 10 long (7–12, *n* = 25), lengthened by sclerotized tube, 11 long (6–14, *n* = 25). Testis subspherical, intercetal. Ovary pretesticular, encircles right intestinal cecum. Vitelline follicles lateral, coextensive with intestinal ceca, confluent posterior to testis region and terminate anterior to peduncle. Egg (Fig. 3D) 86 long (74–91, *n* = 4), 51 wide (38–64, *n* = 4).

Sclerotized vagina with a complex sclerotized structure, aspect changes according to specimen and orientation (Figs. 4A–4I). Sclerotized vagina comprises anterior trumpet, followed by primary canal, primary chamber, secondary canal, secondary chamber, and accessory structure; trumpet in continuity with primary canal tube, long, coiled (Fig. 4F), or curved (Figs. 4A–E and 4G–4I) at around midlength, heavily sclerotized, progressively into primary chamber or form a bend in posterior region and progressively into primary chamber (Fig. 4H); secondary chamber communicates with primary chamber through a short secondary canal, and accessory structure connected to secondary chamber. Total length of sclerotized vagina (measured from distal extremity of trumpet to base of vagina, not considering curved length along coil or curve of primary canal) 25 (19–30, *n* = 25), length variable because of variation in coil or curvature of primary canal.

**Differential diagnosis**

*Pseudorhabdosynochus cephalopholi* n. sp. is distinguished from other *Pseudorhabdosynochus* species by the structure of its sclerotized vagina, in addition to the differing lengths of some sclerotized organs and the number of rows of rodlets in each squamodisc. *Pseudorhabdosynochus minutus* from *C. sonnerati* out of the Barrier reef off Nouméa, New Caledonia has the following characteristics. The general morphology of its sclerotized vagina and its size (25 μm), body size (270–550 μm versus 260–645 μm in *P. cephalopholi* n. sp.), number of rows of rodlets in each squamodisc (10–11 rows of rodlets and a 0–1 closed oval), and host species (*C. sonnerati*) are similar to those of *P. cephalopholi* n. sp. *Pseudorhabdosynochus minutus* can be distinguished, however, by the chamber structure of its sclerotized vagina (*P. minutus* has spherical chambers, unlike the chambers in *P. cephalopholi* n. sp.). *

*Pseudorhabdosynochus argus* from *C. argus* out of the Barrier reef off Nouméa, New Caledonia has a sclerotized vagina similar to that of *P. cephalopholi* n. sp., characterized by an anterior trumpet followed by a long primary canal. *Pseudorhabdosynochus argus* can be distinguished, however, by the size of its sclerotized vagina (38 μm vs. 25 μm in *P. cephalopholi* n. sp.); the morphology of its sclerotized vagina, with the primary canal coiled in its anterior part, just after the trumpet (see [15]), unlike in *P. cephalopholi* n. sp.; its body size (888 μm versus...
Figure 3. *Pseudorhabdosynochus cephalopholi* n. sp. from *Cephalopholis sonnerati* in the lower Gulf of Thailand. (A) Composite drawing (mainly from holotype), dorsal view. (B) Male quadriloculate organ, dorsal view. (C) Sclerotized vagina, dorsal view. (D) Egg. (E) Ventral hamulus. (F) Dorsal hamulus. (G) Dorsal (lateral) bar. (H) Ventral bar. (I) Dorsal squamodisc. (J) Ventral squamodisc. (K) Hooklet. Scale-bars: (A) 100 μm; (B)–(K) 50 μm.
393 μm); and the different lengths of its sclerotized organs: of its ventral hamulus, outer length of 53 μm versus 41 μm and inner length of 44 μm versus 31 μm; of its dorsal hamulus, outer length of 44 μm versus 35 μm and inner length of 27 μm versus 22 μm; of its ventral bar, 79 μm long versus 104 μm long; of its quadriloculate organ, inner length of 58 μm versus 40 μm; and of the cone of its quadriloculate organ, 22 μm long versus 10 μm long (Table 1). *Pseudorhabdosynochus* sp. Justine, 2007 from *C. boenak* (Bloch) out of Heron Island, Queensland, Australia has a sclerotized vagina similar to that of *P. cephalopholi* n. sp., characterized by an anterior trumpet followed by a long primary canal. *Pseudorhabdosynochus* sp. can be distinguished by the following: the morphology of its primary canal, the shapes of its chambers, and the number of rows of rodlets in each of its squamodiscs (7 rows of rodlets, including 0–2 closed rows versus 8–10 rows of rodlets and an innermost row closed oval in *P. cephalopholi* n. sp.). *Pseudorhabdosynochus* sp. generally resembles a dwarf

**Figure 4.** Variations (A)–(I) of the sclerotized vagina of *Pseudorhabdosynochus cephalopholi* n. sp. from *Cephalopholis sonnerati* in the lower Gulf of Thailand. Abbreviations: Tr – trumpet, Ca1 – primary canal, Ch1 – primary chamber, Ca2 – secondary canal, Ch2 – secondary chamber, As – accessory structure. Scale-bar: 50 μm.
Table 1. Measurements of *P. cephalopholi* n. sp. from the type host, *C. sonnerati*, *C. miniata*, and two previously described *Pseudorhabdosynochus* species from *Cephalopholis* spp. The measurements of *P. cephalopholi* n. sp. were taken from flattened specimens in ammonium picrate-glycerin.

| Species host | P. cephalopholi n. sp. | P. cephalopholi n. sp. | P. argus C. argus | P. minutus C. sonnerati |
|--------------|---------------------|---------------------|------------------|------------------------|
|              | *C. sonnerati*      | *C. miniata*        | (From Justine, 2007 [15]) | (From Justine, 2007 [15]) |
| Total body length | 393 (260–645, n = 25) | 408 (327–582, n = 8) | 888 (750–1200, n = 16) | 363 (270–550, n = 4) |
| Body width | 106 (83–126, n = 25) | 99 (80–116, n = 8) | 260 (200–320, n = 16) | 131 (90–170, n = 4) |
| Haptor width | 216 (167–261, n = 25) | 206 (167–240, n = 8) | 211 (185–240, n = 4) | |

**Quadriloculate organ**

|                | *P. cephalopholi* n. sp. | *P. cephalopholi* n. sp. | *P. argus C. argus* | *P. minutus C. sonnerati* |
|----------------|--------------------------|--------------------------|---------------------|--------------------------|
| Inner length   | 40 (33–46, n = 25)       | 40 (34–46, n = 8)        | 58 (55–63, n = 24)  | 49 (45–53, n = 9)        |
| Cone length    | 10 (7–12, n = 25)        | 10 (9–10, n = 8)         | 22 (12–26, n = 24)  | 6 (4–7, n = 9)          |
| Tube length    | 11 (6–14, n = 25)        | 12 (11–15, n = 8)        | 20 (15–25, n = 24)  | 10 (6–14, n = 9)        |
| Sclerotized vagina length | 25 (19–30, n = 25) | 25 (21–28, n = 25) | 38 (35–41, n = 24) | 25 (24–30, n = 9) |

**Dorsal hamulus**

|                | *P. cephalopholi* n. sp. | *P. cephalopholi* n. sp. | *P. argus C. argus* | *P. minutus C. sonnerati* |
|----------------|--------------------------|--------------------------|---------------------|--------------------------|
| Outer length   | 41 (37–46, n = 25)       | 41 (40–44, n = 8)        | 53 ± 2.2 (47–56, n = 48) | 44 (41–45, n = 18)        |
| Inner length   | 31 (29–36, n = 25)       | 31 (30–32, n = 8)        | 44 ± 1.6 (38–46, n = 48) | 33 (30–38, n = 18)        |

**Ventral bar**

|                | *P. cephalopholi* n. sp. | *P. cephalopholi* n. sp. | *P. argus C. argus* | *P. minutus C. sonnerati* |
|----------------|--------------------------|--------------------------|---------------------|--------------------------|
| Length         | 104 (90–114, n = 25)     | 101 (97–105, n = 8)      | 79 (71–84, n = 24)  | 99 (93–104, n = 9)       |
| Width          | 10 (8–14, n = 25)        | 9 (9–10, n = 8)          | 20 (17–23, n = 24)  | 10 (9–11, n = 9)        |

**Number of rows of rodlets**

|                | *P. cephalopholi* n. sp. | *P. cephalopholi* n. sp. | *P. argus C. argus* | *P. minutus C. sonnerati* |
|----------------|--------------------------|--------------------------|---------------------|--------------------------|
| 8–10 (n = 11)  | 8–10 (n = 2)             | 9–11 (n = 7)             | 10–11 (n = 10)      |                          |

Type-host: *Epinephelus lanceolatus* (Bloch) (Perciformes, Serranidae).

Other hosts: *E. coioides* (Hamilton), *E. erythrurus* (Valenciennes), *E. coeruleopunctatus* (Bloch), *E. malabaricus* (Bloch & Schneider), sea cage-cultured hybrid grouper (TGGG) (*E. fuscoguttatus* ♀ × *E. lanceolatus* ♂) and *E. fuscoguttatus* (Forskål) (Perciformes, Serranidae).

Type-locality: Samaesarn Island in the Gulf of Thailand, Chonburi Province, Eastern Thailand (12°34’30.9”N 100°57’33.7”E), September 2020.

Other locality: Libong Island in the Andaman Sea, Trang Province, Southern Thailand (7°13’00.3”N 99°21’36.0”E), April 2020; Ban Laem Hin, Phang-Nga Province in the Andaman Sea, Southern Thailand (8°10’55.5”N 98°20’35.3”E), May 2020.

Type-material: Holotype, ZRC.PLA.2041; 2 paratypes, ZRC.PLA.2042-43; 2 paratypes, THINHM-Iv-19367-68; 1 paratype, ZMKU-PM-002079-80; 2 paratypes from other host, *E. coioides*, ZMKU-PM-002077-78; 2 paratypes from other host, *E. erythrurus*, ZMKU-PM-002079-80; 2 paratypes from other host, *E. coeruleopunctatus*, ZMKU-PM-002081-82; 2 paratypes from other host, *E. malabaricus*, ZMKU-PM-002083-84; 1 paratype from other host, sea cage-cultured hybrid grouper (TGGG) (*E. fuscoguttatus* ♀ × *E. lanceolatus* ♂), ZMKU-PM-002085.

Site in host: Gills.

Infection indices: Prevalence 100% (one specimen examined and infected); 12 helminth specimens on the single grouper examined.

Etymology: The species name “samaesarnensis” was derived from “Samaesarn Island”, where the host fish *Epinephelus lanceolatus* was collected.

Description (Figs 5 and 6)

[Based on 6 specimens]. Body (including haptor) 745 long (679–821, n = 6); maximum width 198 (160–234, n = 6). Tegument scaly (observed in some specimens). Anterior region with
Figure 5. *Pseudorhabdosynochus samaesarnensis* n. sp. from *Epinephelus lanceolatus* from Samaesarn Island in the Gulf of Thailand. (A) Composite drawing (mainly from holotype), dorsal view. (B) Male quadriloculate organ, dorsal view. (C) Sclerotized vagina, dorsal view. (D) Ventral hamulus. (E) Dorsal hamulus. (F) Dorsal (lateral) bar. (G) Ventral bar. (H) Dorsal squamodisc. (I) Ventral squamodisc. (J) Hooklet. Scale-bars: (A) 200 μm. (B)-(J): 50 μm.
3 pairs of lateral head organs and 2 pairs of eye-spots; anterior pair smaller than posterior pair. Pharynx median, spherical, 45 (39–47, n = 6) × 45 (39–47, n = 6). Esophagus absent. Intestinal bifurcation immediately follows pharynx. Haptor differentiated from rest of body, 220 wide (178–243, n = 6), with 2 similar squamodiscs, 2 pairs of lateral hamuli, 3 bars, and 14 marginal hooklets. Squamodiscs round-shaped, made up of rows of rodlets, the innermost 1–2 rows of which form closed ovals and last row of which are thinner and separated. Dorsal squamodisc 53 long (51–54, n = 4), 47 wide (44–50, n = 4), with 9–12 rows of rodlets, the innermost 1–2 rows of which form closed ovals. Ventral squamodisc 52 long (49–56, n = 4), 45 wide (41–52, n = 4), with 9–10 rows of rodlets, the innermost 1–2 rows of which form closed ovals. Ventral hamulus with distinct guard and expanded deep root, elongated shaft slightly arched and recurved toward the tip, outer length 48 (45–51, n = 6), inner length 37 (35–39, n = 6). Dorsal hamulus with indistinct guard and expanded deep root, elongated shaft slightly arched and recurved toward the tip, outer length 41 (40–41, n = 6), inner length 25 (24–27, n = 6). Dorsal (lateral) bar straight, with flattened medial extremity, 61 long (57–67, n = 6), 17 wide (16–19, n = 6). Ventral bar elongated, with constricted median portion and tapered ends, 94 long (92–96, n = 6), 15 wide (14–16, n = 6); visible groove that extends to both thin extremities. Male quadriloculate organ with fourth (posterior) chamber slightly more sclerotized than 3 anterior chambers, inner length 56 (51–60, n = 6), fourth chamber ends in sclerotized cone, 12 long (10–13, n = 6), prolonged by sclerotized tube, 15 long (13–17, n = 6), end of tube prolonged by filament of variable length. Test is subspherical, intercecal. Ovary pretesticular, encircles right intestinal cecum. Vitelline follicles lateral, coextensive with intestinal ceca and terminate anterior to the peduncle. Egg not seen.

**Sclerotized vagina** with a complex sclerotized structure, aspect changes according to specimen and orientation (Figs. 6A–6F). Sclerotized vagina comprises anterior cup-shaped trumpet, followed by primary canal, primary chamber and accessory structure; thick-walled anterior cup-shaped trumpet in continuity with short straight or curved primary canal (Fig. 6A), thick-walled sclerotization and widens into a thick-walled primary chamber; accessory structure connects to the primary chamber. Total length of sclerotized vagina (measured from distal extremity of trumpet to base of vagina, not considering curve along primary canal) 27 (25–29, n = 6), length variable because of variation in curvature of primary canal.

**Differential diagnosis**

*Pseudorhabdosynochus samaesarnensis* n. sp. is distinguished from other *Pseudorhabdosynochus* species by the structure of its sclerotized vagina. *Pseudorhabdosynochus samaesarnensis* n. sp. has a vaginal structure similar to that of *P. nhatrangensis* from *E. coioides* (Hamilton) and *E. bleekeri* (Vaillant) off Vietnam. The structure of their sclerotized vagina was found to be very similar, but the number of rows of rodlets found in *P. nhatrangensis* was always 10 [7], while

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![Figure 6. Variations (A)–(F) of the sclerotized vagina of *Pseudorhabdosynochus samaesarnensis* n. sp. from *Epinephelus lanceolatus* and *E. coioides* in the Gulf of Thailand. Abbreviations: Tr – trumpet, Ca1 – primary canal, Ch1 – primary chamber. As, accessory structure. Scale-bar: 50 μm.](image-url)
Table 2. Measurements of specimens of *P. samaesarnensis* n. sp. from the type host, *E. lanceolatus* from the Gulf of Thailand, compared with *P. nhatrangensis* from *E. coioides* and *E. bleekeri* from Nha Trang Bay, Vietnam.

| Species host | *P. samaesarnensis* n. sp. *E. lanceolatus* | *P. nhatrangensis* *E. coioides* and *E. bleekeri* (details from Dang et al., 2013 [7]) |
|--------------|-----------------------------------------|-------------------------------------------------------------------------------------|
| Total body length | 745 (679–821, n = 6) | 458 (370–570, n = 10) |
| Body width | 198 (160–234, n = 6) | 155 (120–185, n = 10) |
| Haptor width | 220 (178–243, n = 6) | 157 (130–188, n = 7) |
| Quadriloculate organ |  |  |
| Inner length | 56 (51–60, n = 6) | 58 (52–65, n = 10) |
| Cone length | 12 (10–13, n = 6) | 14 (12–15, n = 10) |
| Tube length | 15 (13–17, n = 6) | 21 (18–25, n = 10) |
| Sclerotized vagina length | 27 (25–29, n = 6) | 29 (25–33, n = 10) |
| Ventral hamulus |  |  |
| Outer length | 48 (45–51, n = 6) | 48 (40–58, n = 10) |
| Inner length | 37 (35–39, n = 6) | 38 (33–40, n = 10) |
| Dorsal hamulus |  |  |
| Outer length | 41 (40–41, n = 6) | 38 (33–43, n = 10) |
| Inner length | 25 (24–27, n = 6) | 24 (23–25, n = 10) |
| Ventral bar |  |  |
| Length | 94 (92–96, n = 6) | 95 (90–103, n = 10) |
| Width | 15 (14–16, n = 6) | 11 (9–14, n = 10) |
| Dorsal bar |  |  |
| Length | 61 (57–67, n = 6) | 61 (55–68, n = 10) |
| Width | 17 (16–19, n = 6) | 12 (11–14, n = 10) |
| Number of rows of rodlets | 9–12 (n = 4) including 1–2 closed ovals | Always 10 (n = 6) and 1 closed circle |
| Prevalence | 100% (one specimen examined and infected) | 27% (12/45) on *E. coioides* and 10% (4/40) on *E. bleekeri* |

Note that *P. nhatrangensis* is not a valid species.

in *P. samaesarnensis* n. sp., the rows were found to vary in number from 9 to 13. In addition, the specimens of *P. samaesarnensis* n. sp. from *E. lanceolatus* were larger than those of *P. nhatrangensis* from *E. coioides* and *E. bleekeri* (Table 2). However, *P. nhatrangensis* Dang, Bristow, Schander & Berland, 2013 is not a valid species because the article was not compliant with the new Article 8.5.3 of the International Code of Zoological Nomenclature (ICZN) [3].

**Discussion**

Species of *Pseudorhabdosynochus* parasitize marine fish, especially groupers (Serranidae, Epinephelinae) [3, 5, 21, 24, 33], and have hitherto been considered strictly host-specific or “specialists,” that is, found in a single species [12–16, 20, 22, 33]. However, other *Pseudorhabdosynochus* species occur on several host species, such as *P. cyanopodus* Sigura & Justine, 2008 on *E. cyanopodus* (Richardson) and *E. chlorostigma* (Poey) and *P. samae-sarnensis* E. cyanopodus (Richardson) and *E. cyanopodus* [4, 24, 34]. The sclerotized vaginae are characteristic of individual species and are important for species identification [5, 12–14, 17, 21, 23, 26, 31–33].

Three new species of *Pseudorhabdosynochus* are described. *Pseudorhabdosynochus surathanischenis* n. sp. was found on a single host species, *C. miniata*, while *P. samaesarnensis* n. sp. were found on two host species and seven host species, respectively. *Pseudorhabdosynochus cephalopholi* n. sp. was found on *E. coioides* and *C. miniata*, and its morphometric data from both *C. sonnerati* and *C. miniata* are similar in size (Table 1). In addition, the structures of the sclerotized vaginae are no different (*P. cephalopholi* n. sp., which is rare in *C. miniata*). *Pseudorhabdosynochus samaesarnensis* n. sp. was found on seven host species: *E. lanceolatus*, *E. coioides*, *E. erythrurus*, *E. coeruleopunctatus*, *E. malabaricus*, sea cage-cultured hybrid grouper (TGGG) (*E. fuscoguttatus* × *E. lanceolatus*) 3, and *E. fuscoguttatus*, and the morphometric data of *P. samaesarnensis* n. sp. from the six hosts are similar in size (Table 1). In addition, the structures of the sclerotized vaginae are no different. This table does not include the details of *P. samaesarnensis* n. sp. from *E. fuscoguttatus* because its specimens are incomplete and are found in low numbers (prevalence: about 9.1%). *Pseudorhabdosynochus samaesarnensis* n. sp. has a structure of the sclerotized vagina different from other species previously found in host fish – *E. coioides* [1, 9, 37–39], *E. erythrurus* [30], *E. coeruleopunctatus* [35], *E. malabaricus* [20], and sea cage-cultured hybrid
Table 3. Measurements of *P. samaesarnensis* n. sp. from the type host, *E. lanceolatus* and its other hosts, *E. coioides*, *E. erythrurus*, *E. coerulopunctatus*, *E. malabaricus*, and sea cage-cultured hybrid grouper (TGGG) (*E. fuscoguttatus* ♀ × *E. lanceolatus♂).

| Host                          | *E. lanceolatus* | *E. coioides* | *E. erythrurus* | *E. coerulopunctatus* | *E. malabaricus* | Sea cage-cultured hybrid grouper (TGGG) |
|-----|-----------------|---------------|----------------|----------------------|------------------|---------------------------------------|
| Total body length             | 745 (679–821, *n* = 6) | 657 (436–826, *n* = 10) | 666 (598–799, *n* = 10) | 644 (437–774, *n* = 10) | 618 (368–777, *n* = 10) | 732 (624–857, *n* = 10) |
| Body width                    | 198 (160–234, *n* = 6) | 143 (92–179, *n* = 10) | 134 (88–180, *n* = 10) | 135 (108–162, *n* = 10) | 132 (94–161, *n* = 10) | 130 (97–173, *n* = 10) |
| Haptor width                  | 220 (178–243, *n* = 6) | 186 (150–221, *n* = 10) | 182 (147–229, *n* = 10) | 189 (156–219, *n* = 10) | 182 (148–228, *n* = 10) | 198 (161–222, *n* = 10) |
| Quadriloculate organ           |                 |               |                |                     |                  |                                       |
| Inner length                  | 56 (51–60, *n* = 6) | 53 (46–57, *n* = 10) | 52 (46–56, *n* = 10) | 51 (43–57, *n* = 10) | 51 (44–59, *n* = 10) | 52 (44–58, *n* = 10) |
| Cone length                   | 12 (10–13, *n* = 6) | 12 (10–13, *n* = 10) | 12 (10–14, *n* = 10) | 12 (10–14, *n* = 10) | 12 (10–13, *n* = 10) | 11 (10–13, *n* = 10) |
| Tube length                   | 15 (13–17, *n* = 6) | 13 (11–15, *n* = 10) | 13 (12–15, *n* = 10) | 13 (11–16, *n* = 10) | 14 (11–15, *n* = 10) | 14 (12–15, *n* = 10) |
| Sclerotized vagina length     | 27 (25–29, *n* = 6) | 25 (23–27, *n* = 10) | 27 (25–29, *n* = 10) | 27 (24–29, *n* = 10) | 25 (23–28, *n* = 10) | 27 (24–31, *n* = 10) |
| Ventral hamulus               |                 |               |                |                     |                  |                                       |
| Outer length                  | 48 (45–51, *n* = 6) | 43 (40–45, *n* = 10) | 43 (41–45, *n* = 10) | 44 (41–46, *n* = 10) | 45 (41–48, *n* = 10) | 45 (43–48, *n* = 10) |
| Inner length                  | 37 (35–39, *n* = 6) | 34 (33–36, *n* = 10) | 34 (33–36, *n* = 10) | 34 (33–36, *n* = 10) | 36 (34–37, *n* = 10) | 35 (34–37, *n* = 10) |
| Dorsal hamulus                |                 |               |                |                     |                  |                                       |
| Outer length                  | 41 (40–41, *n* = 6) | 38 (37–40, *n* = 10) | 39 (37–40, *n* = 10) | 39 (38–40, *n* = 10) | 39 (36–41, *n* = 10) | 39 (38–41, *n* = 10) |
| Inner length                  | 25 (24–27, *n* = 6) | 25 (23–26, *n* = 10) | 25 (24–26, *n* = 10) | 25 (24–27, *n* = 10) | 25 (23–27, *n* = 10) | 25 (23–27, *n* = 10) |
| Ventral bar                   |                 |               |                |                     |                  |                                       |
| Length                        | 94 (92–96, *n* = 6) | 90 (85–98, *n* = 10) | 92 (84–100, *n* = 10) | 92 (83–96, *n* = 10) | 87 (82–92, *n* = 10) | 87 (83–95, *n* = 10) |
| Width                         | 15 (14–16, *n* = 6) | 14 (12–16, *n* = 10) | 14 (12–15, *n* = 10) | 15 (13–17, *n* = 10) | 15 (10–17, *n* = 10) | 15 (12–17, *n* = 10) |
| Dorsal bar                    |                 |               |                |                     |                  |                                       |
| Length                        | 61 (57–67, *n* = 6) | 58 (56–60, *n* = 10) | 55 (50–59, *n* = 10) | 56 (53–59, *n* = 10) | 58 (53–63, *n* = 10) | 59 (55–64, *n* = 10) |
| Width                         | 17 (16–19, *n* = 6) | 17 (14–20, *n* = 10) | 15 (12–17, *n* = 10) | 17 (14–20, *n* = 10) | 18 (13–21, *n* = 10) | 18 (13–21, *n* = 10) |
| Number of rows of rodlets     | 9–12 (*n* = 4) including | 10–13 (*n* = 4) including | 9–12 (*n* = 5) including | 10–11 (*n* = 2) including | 10–12 (*n* = 7) including | 10–12 (*n* = 5) including |
| Prevalence                    | 100% (one specimen examined and infected) | 100% (4/4) | 100% (5/5) | 100% (4/4) | 100% (4/4) | 100% (3/3) |
We hypothesized that *P. cephalopholi* n. sp. and *P. samaeasenensis* n. sp. have low specificity to their hosts and that their infestations of more than one congeneric host species help to perpetuate this parasitic species [36].

**Conflict of interest**

The authors declare that they have no conflict of interest in relation to this article.

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