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Naricolax hoi n. sp. (Cyclopoida: Bomolochidae) from *Arius maculatus* (Siluriformes: Ariidae) off Taiwan and a redescription of *N. chrysophryenus* (Roubal, Armitage & Rohde, 1983) from a new host, *Seriola lalandi* (Perciformes: Carangidae), in Australian waters

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Abstract We propose that *Naricolax stocki* (Roubal, 1981) (Cyclopoida: Bomolochidae) of Ho & Lin (2005), reported from the spotted catfish *Arius maculatus* (Thunburg) off Taiwan, represents a new species, *N. hoi* n. sp. *N. hoi* can be distinguished from six known congeners by the shape of the rostral area, the maxillary armature and the structural details of legs 3 and 4. *N. chrysophryenus* (Roubal, Armitage & Rohde, 1983) is redescribed on the basis of recently collected material from wild and farmed yellowtail kingfish *Seriola lalandi* Valenciennes in southern and eastern Australian waters, providing the first record of *Naricolax* Ho, Do & Kasahara, 1983 from a carangid host. A key to the species of *Naricolax* is provided.

Introduction

Members of the bomolochid copepod genus *Naricolax* Ho, Do & Kasahara, 1983 parasitise the nasal cavity of marine teleost fishes. The majority of *Naricolax* species have been recovered from hosts collected off Taiwan, while there are single species records from Korea, Japan and New Zealand (Table 1). Two species, *N. stocki* (Roubal, 1981) and *N. chrysophryenus* (Roubal, Armitage & Rohde, 1983) have been previously reported from off Australia; however, there has been some taxonomic confusion regarding the generic status of these species.

N. stocki was first documented as *Bomolochus stocki* from the black bream *Acanthopagrus australis* (Günther) off New South Wales, Australia and in the Hauraki Gulf, New Zealand by Roubal (1981) prior to the erection of *Naricolax* in 1983. Byrnes (1986) subsequently reported *B. stocki* from *A. australis*, *A. butcheri* (Munro), *A. berda* (Forsskål) and *A. latus* (Houttuyn) in Australian waters. Recently, Ho & Lin (2005) transferred *B. stocki* to *Naricolax* and also reported this species from the spotted catfish *Arius maculatus* (Thunburg) off Taiwan. However, our recent examination of Ho & Lin's (2005) *N. stocki* material revealed that their specimens do not match the description of *N. stocki* previously reported from Australia by Roubal (1981) and Byrnes (1986). We propose herein that the Taiwanese *N. stocki* of Ho & Lin (2005) represents a new species.

N. chrysophryenus was originally described as *Unicolax chrysophryenus* by Roubal et al. (1983) from the snapper *Chrysophrys auratus* (Forster) collected off eastern and southern Australia and

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Table 1 Hosts and localities of *Naricolax* spp. and important references

Species	Host	Locality	Reference
Naricolax atypicus Ho, Do & Kasahara, 1983	*Acanthopagrus schlegelii* (Bleeker)	Taiwan	Ho & Lin (2005)
	Hexagrammos otakii Jordon & Starks	Japan, Korea	
	Lateolabrax japonicus (Cuvier)	Korea	
Naricolax chrysophryenus (Roubal, Armitage & Rohde, 1983)	*Seriola lalandi* Valenciennes	Australia	Present study
	Chrysophrys auratus (Forster)	Australia	Roubal et al. (1983)
		New Zealand	Sharples & Evans (1993)
Naricolax hoi n. sp.	*Arius maculatus* (Thunberg)	Taiwan	Present study
Naricolax insolitus Ho & Lin, 2003	*Pampus argenteus* (Euphrasen)	Taiwan	Ho & Lin (2003)
Naricolax longispina Ho & Lin, 2005	*Leiognathus equulus* (Forsskål)	Taiwan	Ho & Lin (2005)
Naricolax stocki (Roubal, 1981)	*Acanthopagrus australis* (Günther)	Australia	Roubal (1981), Byrnes (1986)
	A. butcheri (Munro)		Byrnes (1986)
	A. berda (Forsskål)		Byrnes (1986)
	A. latus (Houttuyn)		Byrnes (1986)

New Zealand. Byrnes (1986) later transferred *U. chrysophryenus* to *Bomolochus* von Nordmann, 1832; however, Sharples & Evans (1993) rejected the transfer and placed the species back in *Unicolax* Cressey & Cressey, 1980. Lin & Ho (2006) re-examined the work of both Roubal et al. (1983) and Sharples & Evans (1993), and transferred this species to *Naricolax* based on its fish nostril habitat and possession of a spine on the basal segment of the antennule and two medial setae on the middle segment of the leg 3 endopod. A recent parasite survey revealed several specimens of *N. chrysophryenus* infecting wild and farmed yellowtail kingfish *Seriola lalandi* Valenciennes in eastern and southern Australian waters. We felt it timely to provide a detailed redescription of *N. chrysophryenus*, as many characters were overlooked or incorrectly reported by Roubal et al. (1983).

Materials and methods

Wild *Seriola lalandi* were caught by line near Sir John Young Banks, New South Wales. Wild and farmed *S. lalandi* were caught by line in Arno Bay and Boston Bay in Spencer Gulf, South Australia. Live *S. lalandi* were bathed individually in 5–20 litres of freshwater for 10 min to kill and detach parasitic crustaceans. Bath water was filtered through a 75 µm mesh and detached parasites were fixed in 10% formalin. Samples were sorted under a dissecting microscope and crustaceans were removed with fine-tipped forceps and stored in 70% ethanol.

Preserved copepods were soaked in lactic acid for at least 24 h prior to examination using an Olympus BX-50 compound microscope. Selected specimens were measured using a calibrated eyepiece micrometer and/or dissected according to the wooden slide procedure of Humes & Gooding (1964). Drawings were made with the aid of a camera lucida. The anatomical terminology follows Dojiri & Cressey (1987) and Huys & Boxshall (1991). Parasite prevalence and intensity, followed by the range of parasites recovered in parentheses, are given in whole numbers and follow Bush et al. (1997). The fork length range of parasitised hosts is presented in millimetres, followed in parentheses by the fork length range of all fish examined and the total number of hosts studied.

Type-material and vouchers of *Naricolax* species were examined for comparative purposes. One ♂ allotype (USNM 184960) and 2 ♀♀ paratypes (USNM 184961) of *N. atypicus* Ho, Do & Kasahara, 1983 from *Hexagrammos otakii* Jordon & Starks were borrowed from the National Museum of Natural History (USNM), Smithsonian Institution, Washington, DC, USA. The Australian Museum (AM), Sydney, Australia lent specimens of *N. stocki* of Roubal (1981) (AM P.29951 = ♀ holotype; AM P.29952 = 5 ♀♀ paratypes) and *N. chrysophryenus* of Roubal et al. (1983) (AM P.32750 = 1 ♂ paratype; AM P.32751 = 5 ♀♀ paratypes). Seventeen ♀♀ and 11

♂♂ of *N. stocki* and 5 ♀♀ of *N. atypicus* collected off Taiwan from *Arius maculatus* and *Acanthopagrus schlegelii* (Bleeker), respectively, were kindly lent by Dr Ching-Long Lin (Department of Aquatic Biosciences, National Chiayi Univeristy, 300 University Road, Chiayi 60083, Taiwan). Host and locality records for all known *Naricolax* species are shown in Table 1.

Family Bomolochidae Sumpf, 1871
Genus *Naricolax* Ho, Do & Kasahara, 1983

Naricolax hoi n. sp.

Type-host and locality: *Arius maculatus* Thunburg (Siluriformes: Ariidae); off Chiayi County, Taiwan.
Site: Nares.
Prevalence and intensity: See Ho & Lin (2005).
Material examined: 17 ♀♀ and 11 ♂♂ kindly lent by Dr Ching-Long Lin.

Type-material: Since material of *N. hoi* (as *N. stocki*) was not deposited by Ho & Lin (2005), we have deposited the following specimens in the Australian Museum (AM) Crustacea collection, College Street, Sydney, New South Wales 2010, Australia, with approval from Dr Ching-Long Lin. Holotype: ♀, whole specimen, AM P.73324. Allotype: ♂, whole specimen, AM P.73325. Paratypes: ♀, dissected and mounted on glass slide, AM P.73331; 4 ♀♀, whole specimens, AM P.73326; ♂ dissected and mounted on glass slide AM P.73332; 2 ♂♂, whole specimens, AM P.73327.
Etymology: The species is named for Professor Ju-Shey Ho in recognition of his valuable contribution to parasitic copepod systematics.

Remarks

Morphological comparisons between the five nominal *Naricolax* species revealed the species identified as *N. stocki* from Taiwan by Ho & Lin (2005) is not conspecific with Roubal's (1981) *N. stocki* from Australia. The Taiwanese and Australian *N. stocki* differ primarily in total body length, shape of the rostral area, the maxillary armature and the structural details of legs 3 and 4. Specifically, the Taiwanese *Naricolax* species possesses: (1) a relatively smaller body size [total length of 1.46 mm reported in Ho & Lin (2005)]; (2) a T-shaped rostral area (Fig. 1A); (3) a terminal process and three elements on the maxillary basis (Fig. 1B) [Ho & Lin (2005) overlooked the syncoxal seta and one of the two naked elements on the basis]; (4) serrate and relatively longer outer exopod spines on legs 3 and 4 (Fig. 1C,D); (5) two nearly subequal spines on the terminal endopod segment of leg 3 (Fig. 1C); (6) a long, medial plumose seta and short, medial intermediate spine on the proximal and middle endopod segments, respectively, of leg 4 (Fig. 1D); and (7) a serrate outer apical spine that is longer than the innermost apical element on the terminal endopod segment of leg 4 (Fig. 1D).

In marked contrast, the Australian *Naricolax stocki* has: (1) a relatively larger body size [total length of 2.25 mm reported in Roubal (1981)]; (2) an arrowhead shaped rostral area (Fig. 2A); (3) a terminal process and two elements on the maxillary basis (Fig. 2B); (4) spinulate and relatively shorter outer exopod spines on legs 3 and 4 (Fig. 2C,D); (5) two considerably unequal spines on the terminal endopod segment of leg 3 (Fig. 2C); (6) the inner margin of the proximal and middle endopod segments of leg 4 each armed with a long plumo-spinulate seta (= element with setules proximally and spinules distally) (Fig. 2D) [although one abnormal female paratype bears two plumo-spinulate setae on the middle endopod segment]; and (7) a finely spinulate outer apical spine that is shorter than the innermost apical element on the terminal endopod segment of leg 4 (Fig. 2D). These numerous morphological differences support our proposal to separate the Taiwanese and Australian specimens into two species. As the Taiwanese species is in need of a new specific name, we propose to name it *Naricolax hoi* n. sp.

Naricolax chrysophryenus (Roubal, Armitage & Rohde, 1983) Lin & Ho, 2006

Type-host and locality: *Chrysophrys auratus* (Forster) (Perciformes: Sparidae): Coffs Harbour, New South Wales (30°22′S, 153°08′E).
Other localities ex C. auratus: Wallaroo, South Australia (34°05′S, 137°30′E) and Hauraki Gulf, New Zealand (36°15′S, 174°50′E), see Roubal et al. (1983); Okakari Point (36°16′S, 176°47′E) and Kawau Bay (36°26′S, 174°46′E), New Zealand, see Sharples & Evans (1993).

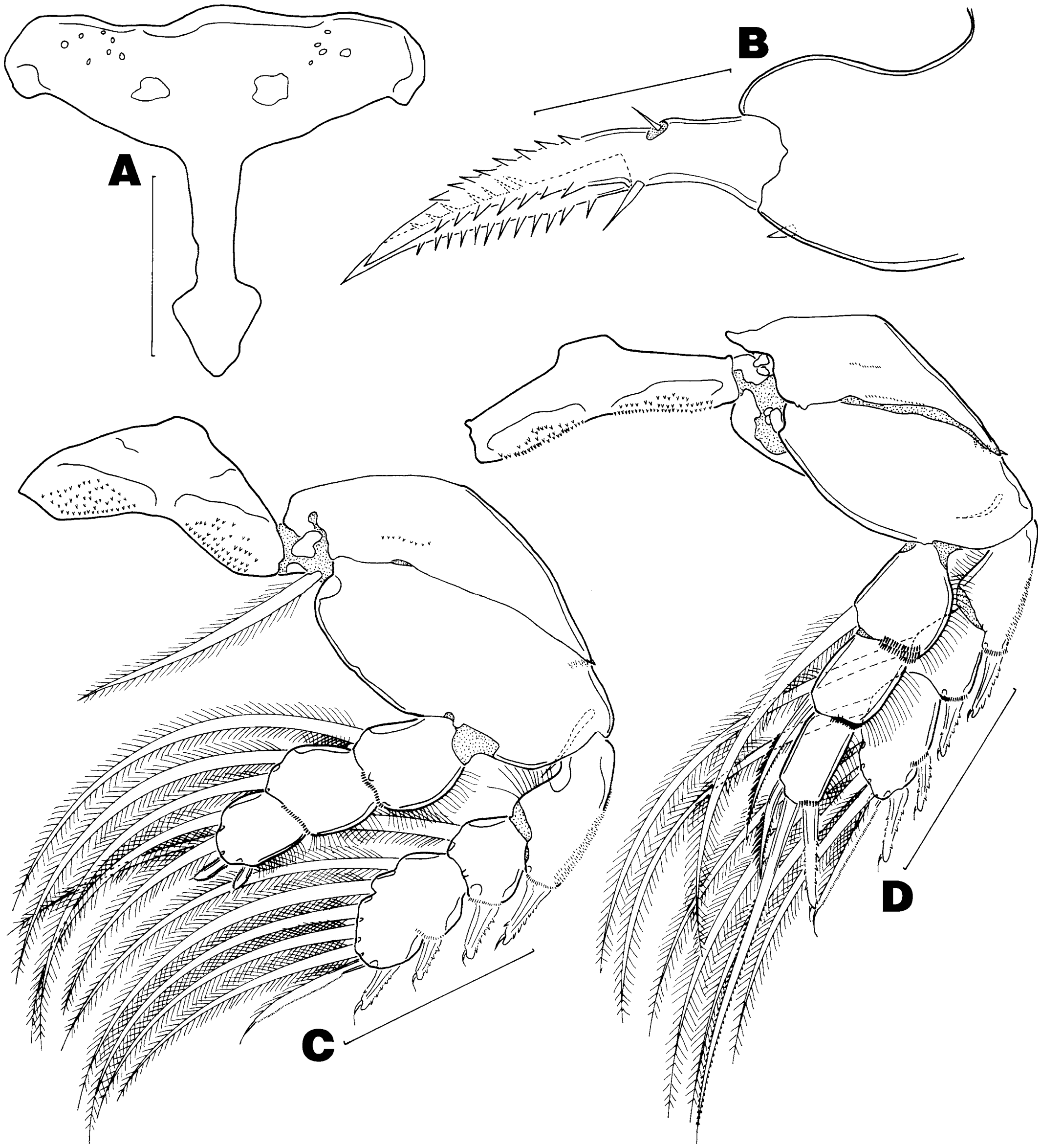

Fig. 1 *Naricolax hoi* n. sp., adult female. A, rostral area, ventral; B, maxilla, dorsal; C, leg 3, anterior; D, leg 4, anterior. *Scale-bars*: A, 50 µm; B, 25 µm; C,D, 100 µm

Other host and localities: *Seriola lalandi* Valenciennes (Perciformes: Carangidae): Sir John Young Banks, New South Wales, Australia (34°56′52″S, 150°55′45″E); Arno Bay, Spencer Gulf, South Australia (33°55′21″S, 136°36′14″E) and; Boston Bay, Spencer Gulf, South Australia (34°44′3″S, 135°55′46″E).

Site: The collection method prohibited identification of the microhabitat. However, all previously described *Naricolax* spp. infect the nasal cavity of their hosts.

Prevalence and intensity: Sir John Young Banks: number of infected wild fish = 1; prevalence 4%; intensity 1; host size 850 FL (460–950 FL, n = 25). Arno Bay: number of infected wild fish = 2; prevalence 17%; mean intensity 2 (1–3); host sizes 370 and 468 FL (330–580 FL, n = 12); number of infected farmed fish = 3; prevalence 33%; mean intensity 3

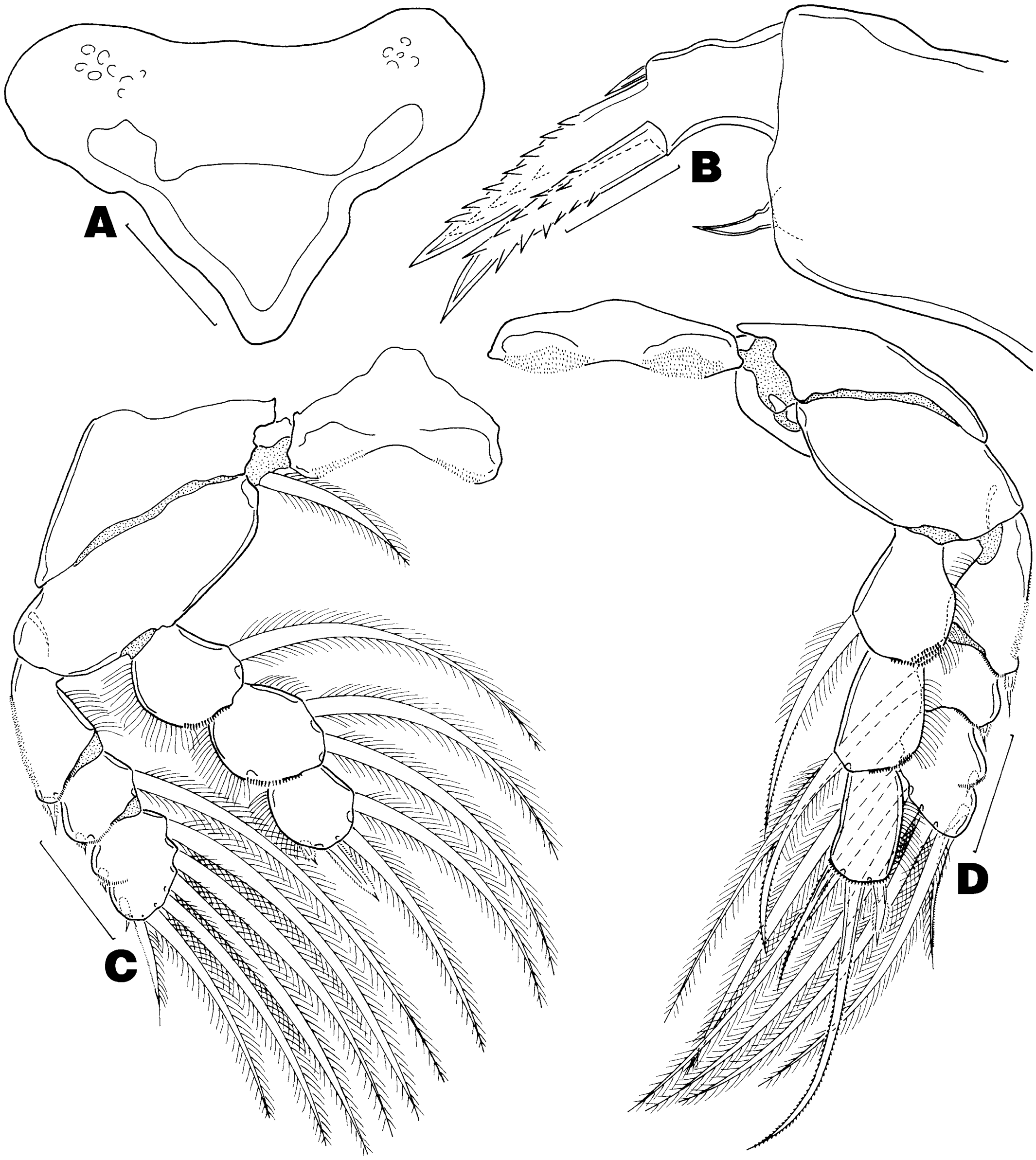

Fig. 2 *Naricolax stocki* (Roubal, 1981), adult female. A, rostral area, ventral; B, maxilla, dorsal; C, leg 3, anterior; D, leg 4, anterior. *Scale-bars*: A, 50 μm; B, 25 μm; C,D, 100 μm

(1–4); host sizes 545–590 FL (471–653 FL, n = 10). Boston Bay: number of infected wild fish = 0 (340–412 FL, n = 8); number of infected farmed fish = 1; prevalence 17%; intensity 1; host size 403 FL (293–500 FL, n = 6).

Material examined: 11 ♀♀ and 5 ♂♂ total: 1 ♀ collected on 25 June 2003 from wild *S. lalandi* at Sir John Young Banks; 6 ♀♀ and 2 ♂♂ collected on 29 May 2003 and 1 ♀ collected on 15 March 2005 from farmed *S. lalandi* at Arno Bay; 1 ♀ and 1 ♂ collected on 28 November 2003 and 1 ♀ and 2 ♂♂ on 12 March 2005 from wild *S. lalandi* at Arno Bay; 1 ♀ collected on 23 April 2004 from farmed *S. lalandi* at Boston Bay.

Deposition of vouchers: Voucher specimens of *N. chrysophryenus* are deposited in the South Australian Museum (SAMA) in the Marine Invertebrate Collection (C), North Terrace, Adelaide, South Australia 5000, Australia. ♀, whole specimen, ex wild *S. lalandi*, 25 June 2003, Sir John Young Banks, SAMA

C6240; ♀, abnormal, whole specimen, ex farmed *S. lalandi*, 29 May 2003, Arno Bay, SAMA C6285; ♀, dissected and mounted on a glass slide, ex farmed *S. lalandi*, 29 May 2003, Arno Bay, SAMA C6286; 5 ♀♀, whole specimens, ex farmed *S. lalandi* 29 May 2003 and 15 March 2005, Arno Bay, SAMA C6287–6291; 2 ♀♀ whole specimens, ex wild *S. lalandi* 28 November 2003 and 12 March 2005, Arno Bay, SAMA C6292 and C6293; ♀, whole specimen, ex farmed *S. lalandi*, 23 April 2004, Boston Bay SAMA C6294; ♂, whole specimen, ex farmed *S. lalandi*, 29 May 2003, Arno Bay, SAMA C6284; ♂, abnormal, whole specimen but with right leg 3 rami and right leg 4 exopod dissected and mounted on a glass slide, ex farmed *S. lalandi*, 29 May 2003, Arno Bay SAMA C6295; ♂, dissected and mounted on a glass slide, 28 November 2003, ex wild *S. lalandi*, Arno Bay, SAMA C6296; 2 ♂♂, whole specimens, ex wild *S. lalandi*, 12 March 2005, Arno Bay SAMA C6297 and C6298.

Redescription (Figs. 3–9)

Adult female (Figs. 3A–6C)
Total body length (excluding setae on caudal rami) 1.49 mm ($n = 5$). Prosome (Fig. 3A) 0.89 mm long and 0.78 mm wide, composed of cephalothorax (first pedigerous somite fused with cephalosome) and 3 free pedigerous somites. Cephalothorax with dorsomedial pair of nipple-like protuberances near anterior margin (Fig. 3A,B). Urosome (Fig. 3A) 0.60 mm long, composed of fifth pedigerous somite, genital double-somite and 3 free abdominal somites. Genital double-somite (Fig. 3A) wider (278 μm) than long (214 μm). Ventral surface of anal somite (Fig. 3C) with 2 dense patches of minute spinules. Caudal ramus (Fig. 3C) longer (74 μm) than wide (44 μm), bearing patch of minute spinules on ventral surface and 6 naked setae (seta I absent); seta V longest.

Rostral area (Fig. 3D) arrow-head shaped. Antennule (Fig. 3E) 5-segmented; armature formula: 4 + 1 spine, 23, 4, 2 + 1 aesthetasc and 7 + 1 aesthetasc. Distal-most and proximal-most seta on first and second segment, respectively, sparsely plumose. Spine on first segment (Fig. 3F) armed with apical setiform element and furnished with row of setules on dorsal surface. Antenna (Figs. 3G, 4A) composed of coxobasis and 2 endopod segments. Coxobasis longest, bears long naked seta distally. Proximal endopod segment with medial naked seta. Distal endopod segment spinulate along ventral surface and distomedial process; armed with distolateral pectinate blade, 4 claw-like spines and 3 naked setae.

Labrum (Fig. 4B) with 2 dense patches of minute spinules on ventral surface and tuft of setules on each protruded distolateral corner. Mandible (Fig. 4C) forming medial process, bears 1 unilaterally and 1 bilaterally spinulate blades. Paragnath (Fig. 4D) furnished with 2 patches of setules and row of spinules around distal margin. Maxillule (Fig. 4E) lobate, bears 3 long pilose setae and 1 short naked seta. Maxilla (Fig. 4F,G) 2-segmented; syncoxa bears 1 naked subapical seta; basis forms spinulate terminal process armed with 1 bilaterally spinulate spine and 2 naked elements; terminal process with multiple rows of spinules along anterior margin and 1 row of spinules along posterior margin. Maxilliped (Fig. 4H) 3-segmented; syncoxa bears 1 distomedial pilose seta; basis with proximolateral protrusion and 2 large, distomedial pilose setae; free endopod segment forms sigmoid-shaped claw armed with large, basal pilose seta.

Legs 1–4 biramous (Figs. 5A–6A) and trimerous, except leg 1 exopod indistinctly trimerous. Armature on rami of legs 1 to 4 as follows (Roman numerals = spines; Arabic numerals = setae; int. = intermediate spine):

	Coxa	Basis	Exopod	Endopod
Leg 1	0–1	1–1	I-0; III, I, 6	0–1; 0–1; I, 5
Leg 2	0–1	1–0	I-0; I-1; III, I, 5	0–1; 0–2; II, 3
Leg 3	0–1	1–0	I-0; I-1; II, I, 5	0–1; 0–2; II, 2
Leg 4	0–0	1–0	I-0; I-1; II, I, 5	0–1; 0–1; I, 2 int.

Leg 1 (Fig. 5A) protopod and rami flattened and enlarged. Intercoxal sclerite large, T-shaped, ornamented with 2 dense patches of minute spinules. Coxa with row of setules on lateral margin. Basis ornamented with 1 large and 1 small patch of spinules on anterior surface. Inner coxal seta large, thumb-shaped; inner basal seta naked, reduced. Outer exopod spines (Fig. 5B) bear flagelliform tip and scale-like denticles on dorsal surface; third outer spine shortest, discernible in posterior aspect only. Terminal exopod spine (Fig. 5A,B) short, bilaterally spinulate. Each endopod segment with row of setules on lateral margin; proximal and middle endopod segments with distal

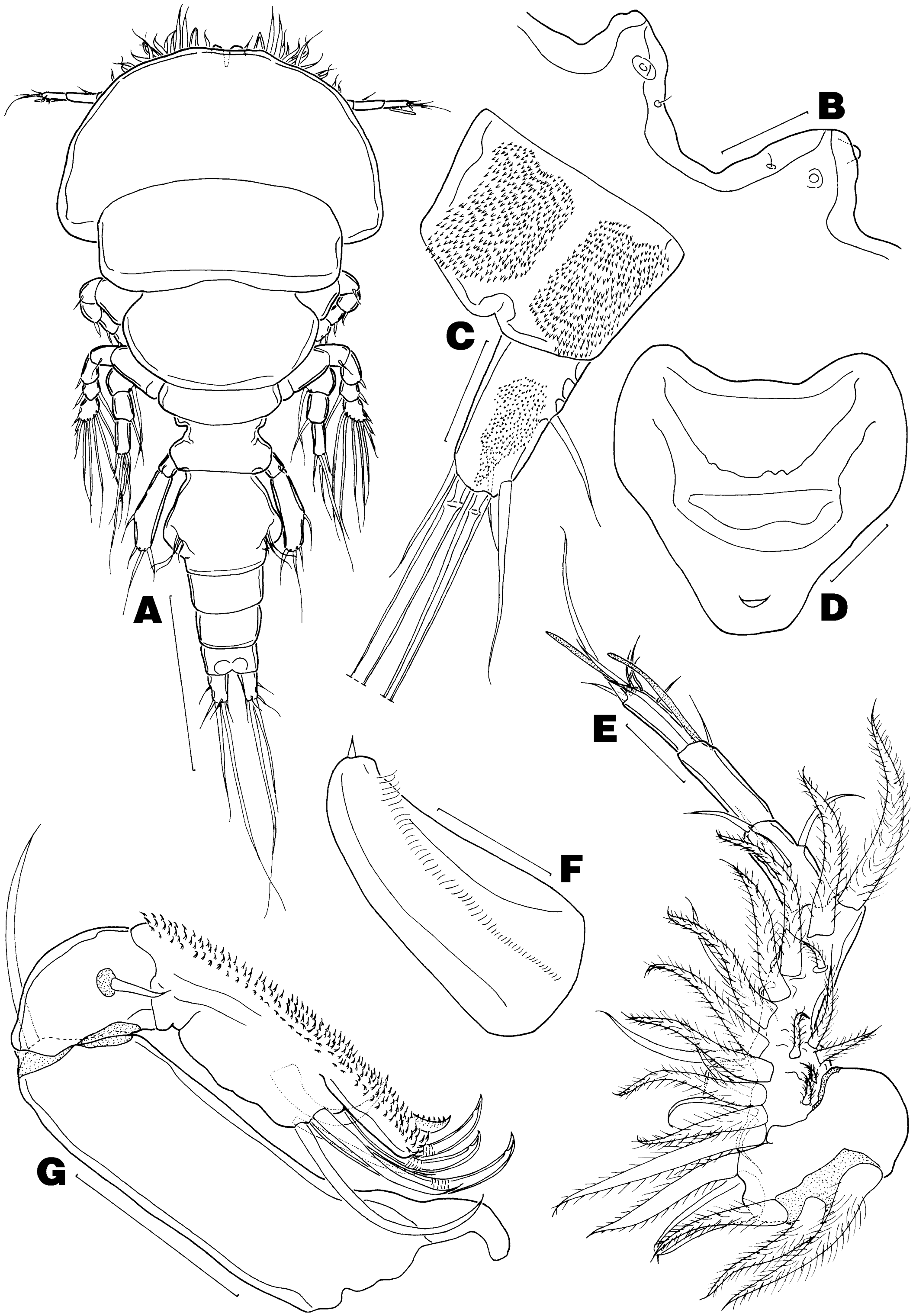

Fig. 3 *Naricolax chrysophryenus* (Roubal, Armitage & Rohde, 1983), adult female. A, habitus, dorsal; B, cephalothoracic protuberances, posterior; C, anal somite and right caudal ramus, ventral; D, rostral area, ventral; E, antennule, ventral; F, antennular spine, dorsal; G, antenna, medial. *Scale-bars*: A, 400 μm; B,D,F, 25 μm; C,E,G, 50 μm

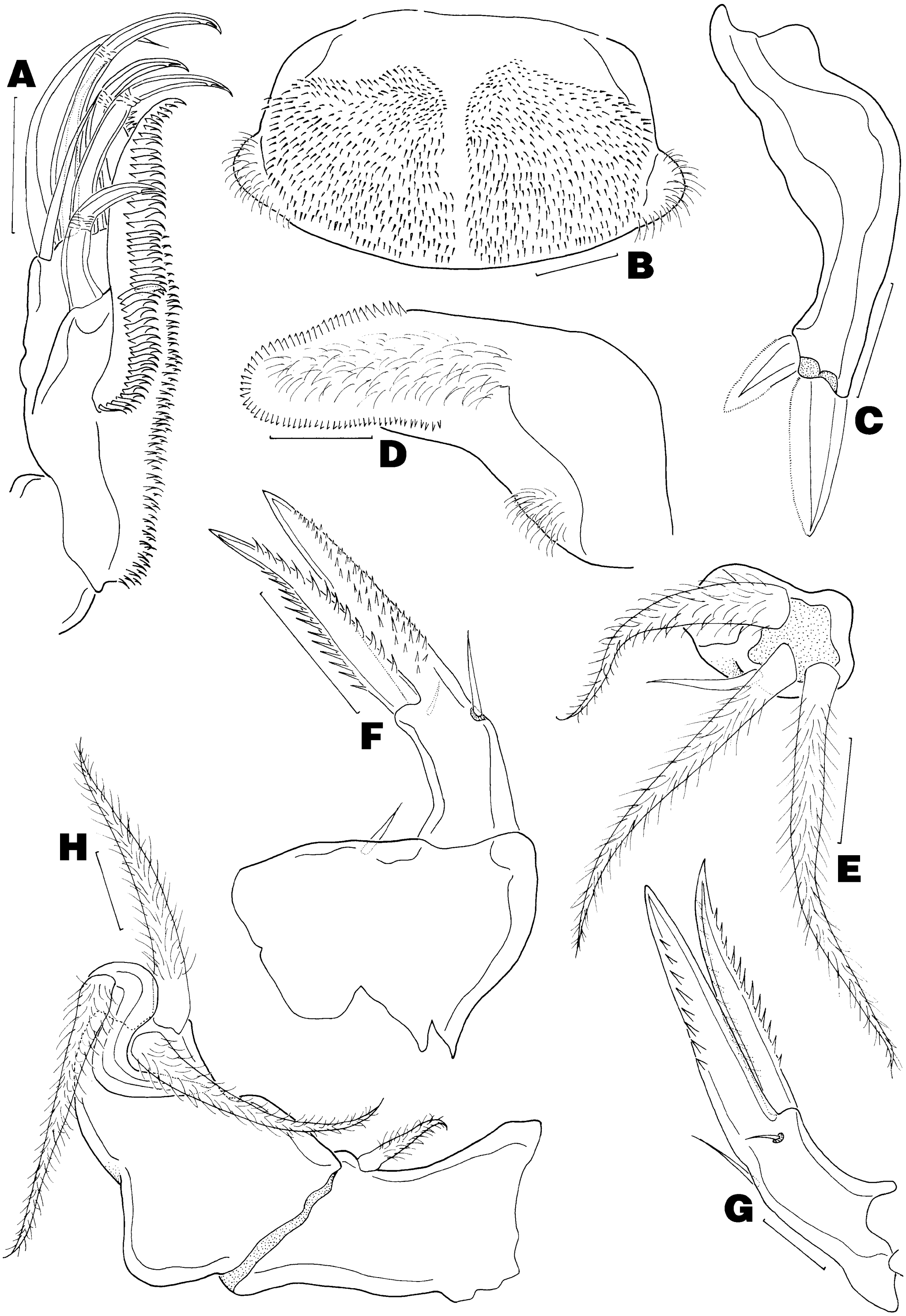

Fig. 4 *Naricolax chrysophryenus* (Roubal, Armitage & Rohde, 1983), adult female. A, distal antennal segment, lateral; B, labrum, dorsal; C, mandible, anterior; D, paragnath, ventral; E, maxillule, ventral; F, maxilla (row of spinules on posterior margin of terminal process omitted), anteroventral; G, distal maxillary segment (rows of spinules on anterior margin of terminal process omitted), posteroventral; H, maxilliped, posterior. *Scale-bars*: A–C,E,F,H, 25 µm; D,G, 12.5 µm

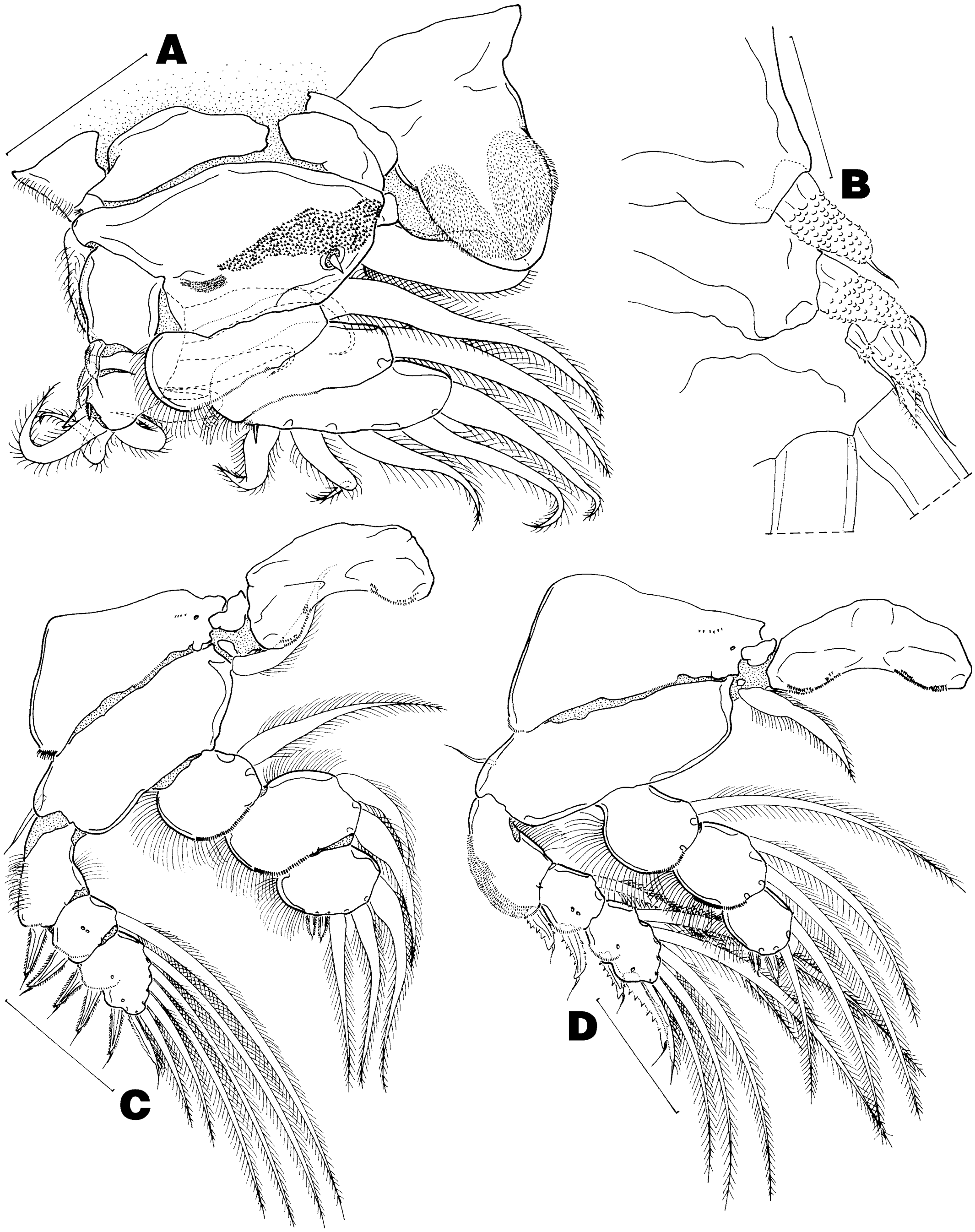

Fig. 5 *Naricolax chrysophryenus* (Roubal, Armitage & Rohde, 1983), adult female. A, leg 1, anterior; B, outer exopodal spines of leg 1, posterior; C, leg 2, anterior; D, leg 3, anterior. *Scale-bars*: A,C,D, 100 µm; B, 25 µm

row of spinules. Naked spine on terminal endopod segment reduced. Leg 2 (Fig. 5C) intercoxal sclerite with rows of spinules on posterior margin. Coxa bears 3 rows of spinules (2 on anterior surface, 1 on distolateral margin). Basis unornamented. Each exopod segment with outer row of minute spinules. Proximal exopod segment with setules on outer and inner margins. Outer exopod spines and terminal endopod spines each bilaterally spinulate and bear flagelliform tip. Ornamentation of endopod similar to that in leg 1, except with additional setules on inner margin of inflated middle segment. Leg 3 (Fig. 5D) ornamented as in leg 2, except proximal exopod segment ornamented with rows of minute spinules on outer margin and middle endopod segment lacks inner setules. Outer exopod spines bilaterally serrate; terminal endopod spines similar to those in leg 2. Middle and terminal endopod segments narrower than those in leg 2. Leg 4 (Fig. 6A) ornamented as in leg 3, except with naked coxa and additional outer row of spinules on terminal exopod and endopod segments. Serrations on outer exopod spines smaller and more numerous than those in leg 3. Inner element on middle endopod segment plumo-spinulate. Outer serrate apical spine with flagelliform tip and shorter than innermost apical element. Leg 5 (Fig. 6B) uniramous, 2-segmented. Protopod segment armed with 1 dorsolateral naked seta and outer row of minute spinules; exopod segment bears numerous patches of spinules, 3 spinulate spines and 1 naked seta. Leg 6 (Fig. 6C) vestigial, represented by 3 naked setae at egg sac attachment area.

Abnormal adult female (Fig. 6D–G)

Abdomen (Fig. 6D) 2-segmented. Middle exopod segments of legs 3 (Fig. 6E) and 4 (Fig. 6F) lacking outer spine. Middle endopod segment of leg 4 (Fig. 6G) lacking inner plumo-spinulate seta. Distal segment of leg 5 (Fig. 6D) armed with 2 elements. Leg 6 (Fig. 6D) represented by naked seta.

The abnormal female and male of *N. chrysophryenus* occurred on the same individual farmed fish host from Arno Bay.

Adult male (Figs. 7A–9C)

Total body length (excluding setae on caudal rami) 0.81 mm (*n* = 2). Prosome (Fig. 7A) 450 µm long and 340 µm wide, comprising cephalothorax and 3 free pedigerous somites. Cephalothorax lacking dorsomedial pair of nipple-like protuberances. Urosome (Fig. 7A) 365 µm long, comprising fifth pedigerous somite, genital somite and 2 free abdominal somites. Genital somite (Fig. 7B) longer (175 µm) than wide (147 µm), with paired ventral apertures; opercula unarmed. Ventral surface of anal somite (Fig. 7C) bears 2 short and 2 long transverse rows of spinules and 2 large patches of spinules. Caudal ramus (Fig. 7A) longer (40 µm) than wide (22 µm), bears similar elements as in female.

Antennule (Fig. 7D) 6-segmented; articulation between second and third segments more discernible in dorsal aspect; armature formula: 5, 13, 7, 4, 2 + 1 aesthetasc and 7 + 1 aesthetasc. Labrum (not illustrated) similar to that of female, except with 2 dense patches of long setules on dorsal surface. Maxilliped (Fig. 7E,F) 4-segmented; syncoxa (not illustrated) bears 1 naked seta; basis elongate, bears 2 unequal naked setae, large patch of denticles on posteromedial surface and row of minute spinules along anteromedial margin; proximal endopod segment small, unarmed; terminal endopod segment forms curved claw bearing 1 long posterior seta, 1 short and 1 minute anterior setae (minute seta visible in anterior aspect only) and row of denticles on inner margin.

Legs 1–4 biramous (Figs. 8A–9B) and trimerous, except leg 4 endopod bimerous. Armature on rami of legs 1 to 4 as follows (Roman numerals = spines; Arabic numerals = setae; int. = intermediate spine):

	Coxa	Basis	Exopod	Endopod
Leg 1	0–1	1–1	1–0; 1–1; 7	0–1; 0–1; I, 5
Leg 2	0–1	1–0	I-0; I-1; II, I, 5	0–1; 0–2; II, 3
Leg 3	0–1	1–0	I-0; 0–1; II, I, 5	0–1; 0–2; II, 2
Leg 4	0–0	1–0	I-0; 0–1; II, I, 4	0–1; I, 2 int.

Leg 1 (Fig. 8A) intercoxal sclerite rectangular, spinulate along posterior margin. Coxa bears numerous rows of spinules on anterior surface and row of long setules on distolateral margin. Basis with several patches of spinules on anterior surface and spinous process protruding between rami. Inner basal seta plumose, reduced. Outer margin of exopod segments with row of setules. Outer seta on proximal and middle exopod segments pilose; terminal exopod segment with 1 long pilose seta, 1 short naked seta and 5 long plumose setae. Endopod ornamented as in female, except with additional row of spinules on terminal segment. Terminal endopod spine short, bilaterally serrate. Leg 2 (Fig. 8B) intercoxal sclerite wider than that of leg 1. Ornamentation of coxa and basis similar to those in female except with only 2 rows of spinules (1 on anterior surface, 1 on distolateral margin). Exopod with similar ornamentation pattern to that in female leg 4. Ornamentation of endopod similar to that in leg 1. Outer exopod and terminal endopod spines each bilaterally serrate and bear flagelliform tip. Leg 3 (Fig. 9A) similar to leg 2,

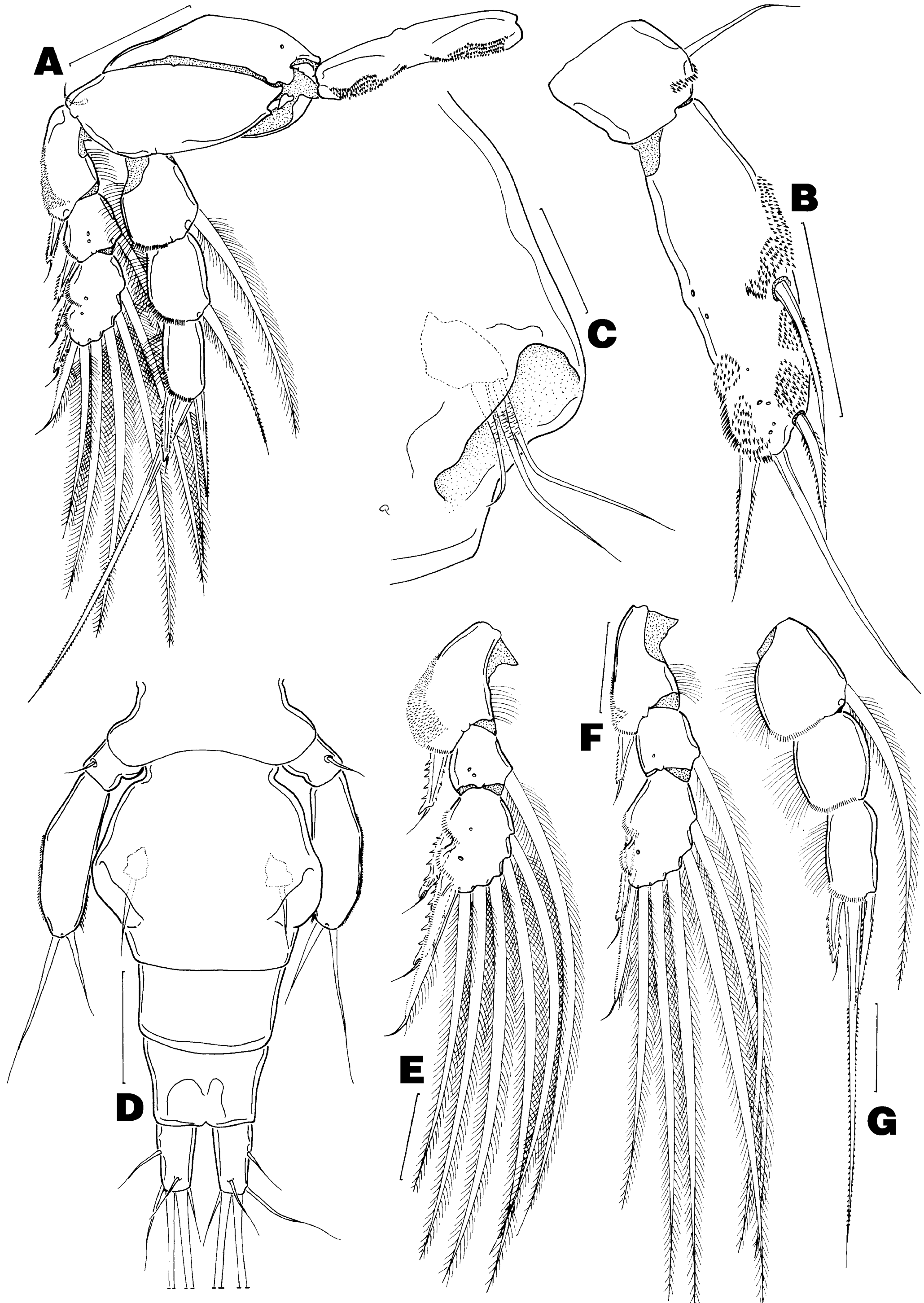

Fig. 6 *Naricolax chrysophryenus* (Roubal, Armitage & Rohde, 1983), normal adult female (A–C), abnormal adult female (D–G). A, leg 4, anterior; B, leg 5, dorsomedial; C, leg 6, dorsal; D, urosome, dorsal; E, leg 3 exopod, anterior; F, leg 4 exopod, anterior, G, leg 4, endopod, anterior. *Scale-bars*: A,B, 100 µm; C,E–G, 50 µm; D, 200 µm

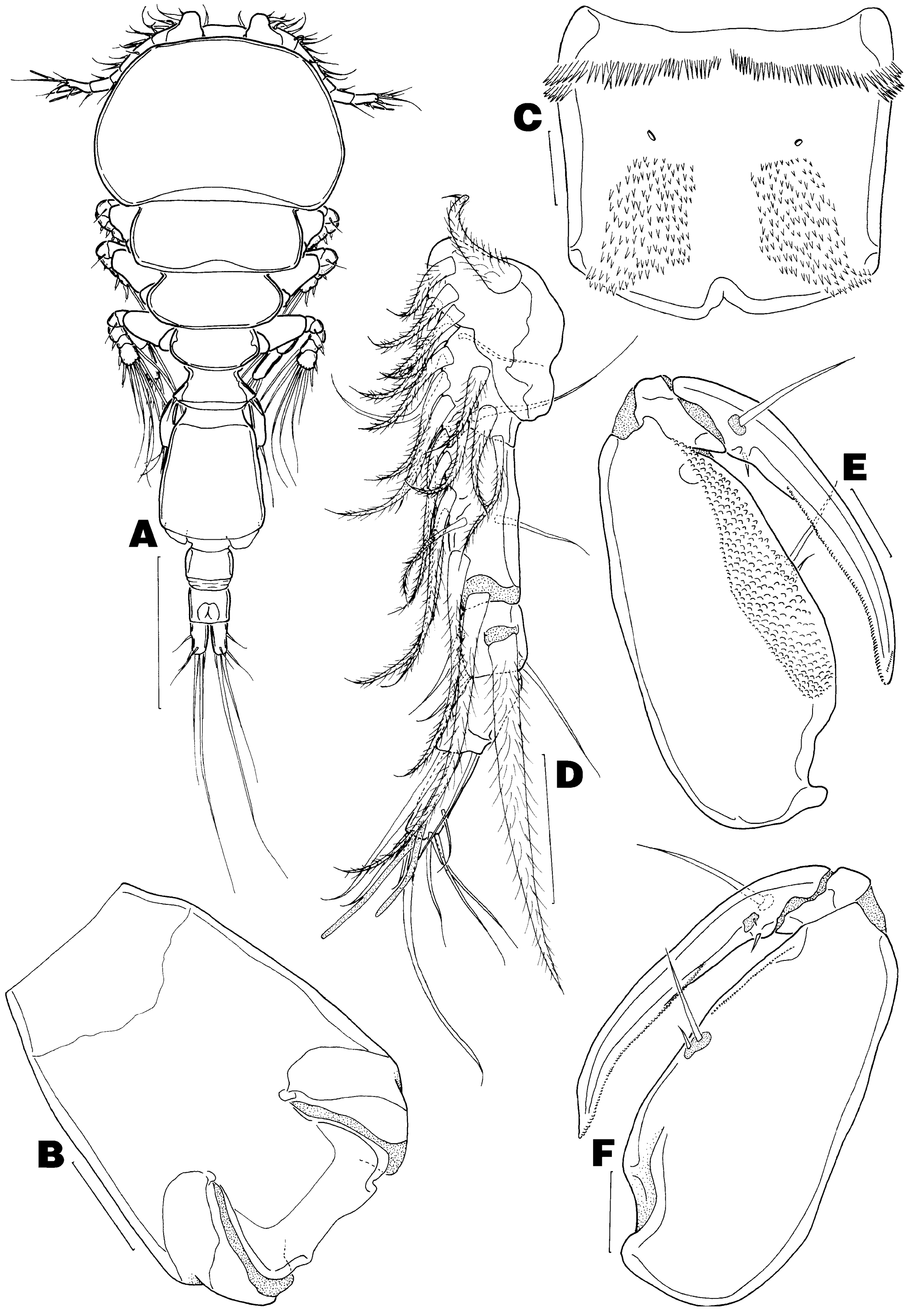

Fig. 7 *Naricolax chrysophryenus* (Roubal, Armitage & Rohde, 1983), adult male. A, habitus, dorsal; B, genital somite, ventral; C, anal somite, ventral; D, antennule, ventral; E, maxilliped (syncoxa omitted), posterior; F, same, anterior. *Scale-bars*: A, 200 μm; B,D, 50 μm; C, 12.5 μm; E,F, 25 μm

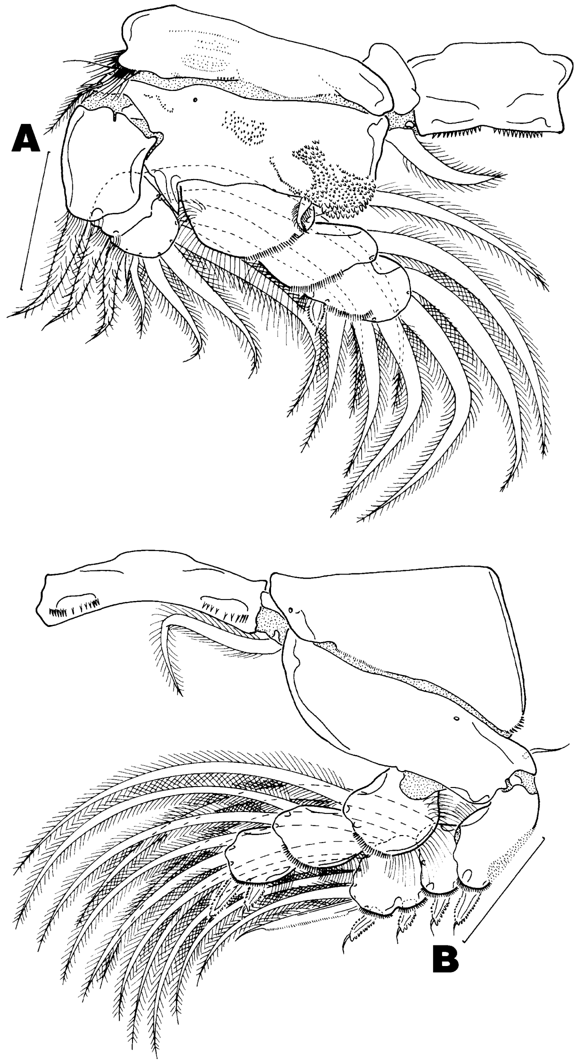

Fig. 8 *Naricolax chrysophryenus* (Roubal, Armitage & Rohde, 1983), adult male. A, leg 1, anterior; B, leg 2, anterior. *Scale-bars*: 50 μm

except middle exopod segment lacks outer spine and outer row of spinules, and terminal endopod segment armed with 1 less seta. Leg 4 (Fig. 9B) intercoxal sclerite with relatively more numerous and larger spinules than those of preceding legs. Coxa and basis unornamented. Exopod similar to that of leg 3, except with 1 less seta on terminal segment. Ornamentation of endopod similar to those of preceding legs. Outer terminal spine bilaterally serrate with flagelliform tip; innermost intermediate spine with long fine spinules proximally and minute spinules distally. Leg 5 (Fig. 9C) 2-segmented; protopod segment (not illustrated) bears naked seta; exopod segment with numerous minute spinules along dorsal surface, long fine spinules distoventrally, 1 long intermediate spine and 1 short bilaterally spinulate spine. Leg 6 absent.

Abnormal adult male (Fig. 9D–F)

Each operculum on genital somite (Fig. 9D) armed with distal naked seta. Middle exopod segments of legs 3 (Fig. 9E) and 4 (Fig. 9F) bear outer spine. Terminal exopod segment of leg 4 with formula II, I, 5 on right side (Fig. 9F) and II, I, 4 on left side (not illustrated).

Remarks

The bomolochid material from *Seriola lalandi* is unequivocally a member of *Naricolax* based on the presence of a spinous fourth element on the first antennulary segment and two inner setae on the middle endopod segment of leg 3 in the adult female. Furthermore, after examining intact and dissected material of *N. chrysophryenus* of Roubal et al. (1983) from the Australian Museum, we conclude that our material is identifiable with *N. chrysophryenus* with additional observations and modifications as follows.

For the adult female: the nipple-like protuberances on the cephalothorax were overlooked; the antennule is 5-segmented, not 4-segmented as in figure 42 of Roubal et al. (1983); the armature formula of the antennule is identical to our material rather than, when corrected for the 5-segmented condition, 4 + 1 spine, 19, 3, 2 + 1 aesthetasc and 7, as in figure 42 of Roubal et al.; the second antennal segment bears only one seta, not two as shown in figure 41 (one of the two setae in figure 41 actually arises from the proximal segment); the terminal antennal segment bears four claws and three setae as for *N. chrysophryenus* from *S. lalandi*, not six setae as shown in figure 41; the distal maxillary segment bears a spinulate terminal process armed with one bilaterally spinulate spine and one naked element, not one terminal process and one spinulate spine as in figure 40 (the second naked element in our material may have broken off the single *U. chrysophryenus* specimen that was dissected); the maxilliped is 3-segmented, not 2-segmented as drawn in figure 39; the basal seta in figure 39 represents the element on the proximal maxilliped segment; Roubal et al. (1983) stated that the basal maxilliped segment (= middle segment) bears three distal setae, but it really bears only two setae with the remaining seta originating from the distal claw; the exopod of leg 1 is

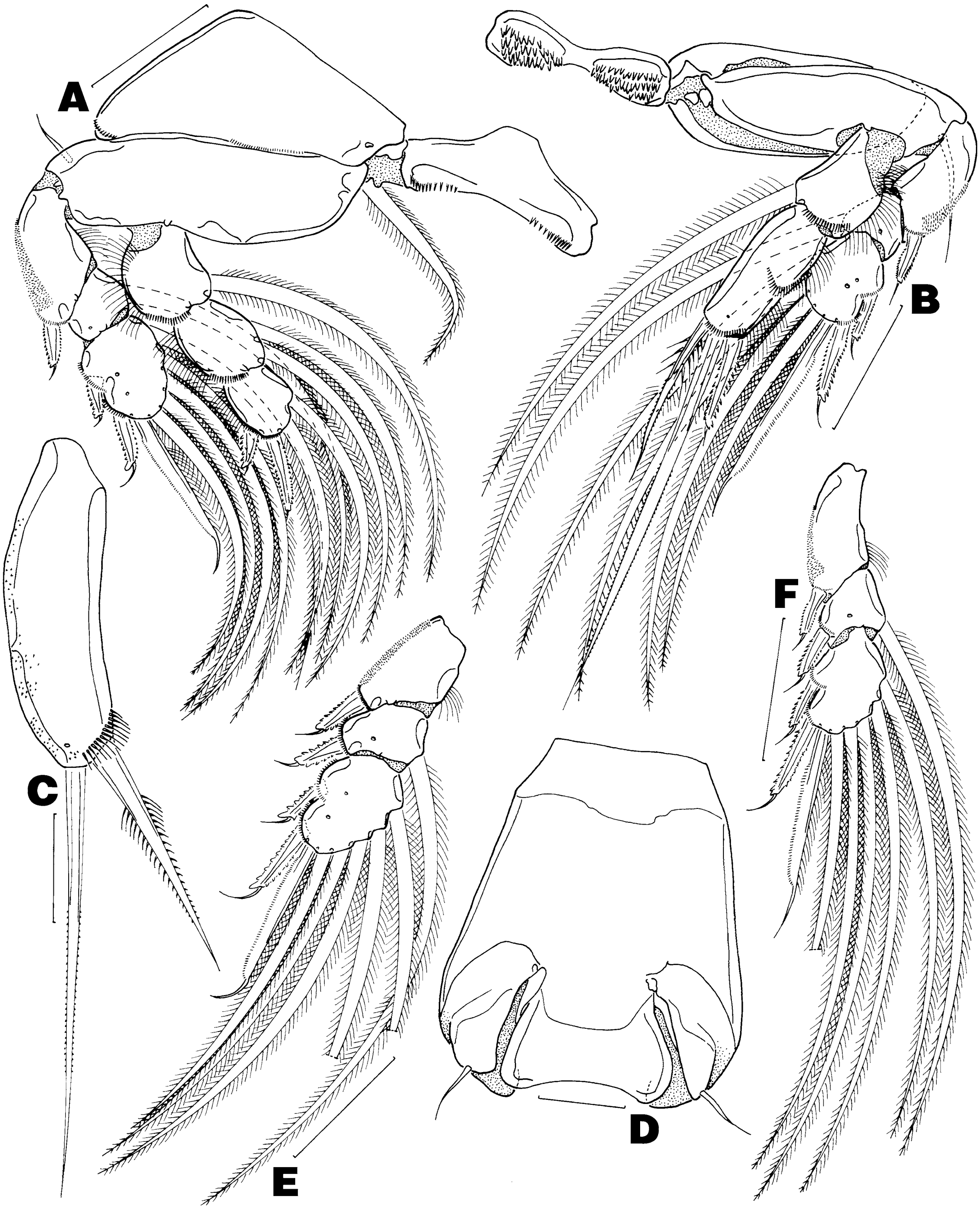

Fig. 9 *Naricolax chrysophryenus* (Roubal, Armitage & Rohde, 1983), normal adult male (A–C), abnormal adult male (D–F). A, leg 3, anterior; B, leg 4, anterior; C, distal segment of leg 5, medial; D, genital somite, ventral; E, leg 3 exopod, anterior; F, leg 4 exopod, anterior. *Scale-bars*: A,B,D–F, 50 μm; C, 25 μm

indistinctly 3-segmented, not entirely 3-segmented as drawn in figure 43; two of the four spines on the terminal exopod segment of leg 1 were overlooked (only two spines are illustrated in figure 43); the small outer spine on the terminal endopod segment of leg 1 was overlooked; the minute inner element on the coxa of leg 2, which is drawn above the long coxal seta in figure 47, is absent; the inner seta on the first exopod segment of leg 4 in figure 48 is absent; the inner element on the second endopod segment of leg 4 is plumo-spinulate, not plumose as in figure 48; the middle and inner apical elements on the terminal endopod segment of leg 4 are intermediate spines, not plumose as in figure 48; and lastly, the intercoxal sclerite, protopod and rami of legs 1 to 4 are ornamented similar to those in our specimens.

For the adult male: Roubal et al. (1983) did not mention the ornamentation pattern of the anal somite, but it is the same as *N. chrysophryenus* from *S. lalandi* examined herein; for the antennule, three setae were overlooked on segment 2 and one seta on segment 4; the terminal exopod segment of leg 1 bears seven elements, not eight as in their figure 55 (the innermost seta is actually the inner element on the second exopod segment); the middle and inner apical elements on the terminal endopod segment of leg 4 are intermediate spines, not plumose as in figure 58. The presence of the longitudinal row of spinules on the middle segment of the maxilliped and the two minute elements on the claw could not be verified because the male paratype was not dissected.

The only major difference between *N. chrysophryenus* from *S. lalandi* redescribed here and the specimens we examined of Roubal et al. (1983) from *Chrysophrys auratus*, involves the spine on the first antennular segment of the female. This spine is shorter and more robust, as well as bears a minute terminal element, in the specimens recovered from *S. lalandi*.

Discussion

N. hoi n. sp. is morphologically most similar to *N. chrysophryenus*. Both species possess in the adult female a terminal process and three elements on the maxillary basis, serrate outer exopod spines on legs 3 and 4 and an inner plumose seta on the proximal endopod segment of leg 4. *N. hoi* differs from *N. chrysophryenus* in terms of female features as follows: the cephalothorax lacks a dorsomedial pair of nipple-like protuberances near the anterior margin; the rostral area is T-shaped rather than arrow-head shaped; the terminal exopod segment of leg 1 bears a total of three spines rather than four spines; the middle endopod segment of leg 4 bears a medial intermediate spine rather than a medial plumo-spinulate seta; the inner plumose seta on the proximal endopod segment of leg 4 is more than twice, rather than 1.25 times, the length of the inner element on the succeeding segment; and the outer spine is longer, rather than shorter, than the innermost apical element on the terminal endopod segment of leg 4.

The adult male of *N. chrysophryenus* and *N. hoi* can be distinguished from each other by the presence in the former species of one short and one long transverse row of spinules on the ventral surface of the anal somite, row of minute spinules on the anteromedial margin of the maxilliped, serrate spines on the rami of legs 2 to 4 and minute spinules scattered along the dorsal surface of leg 5 exopod. The presence of spinulate ornamentation and the reduced inner seta on the basis of female leg 1, as well as the minute seta on the anterior surface of the maxilliped claw, inner seta on the basis of leg 1 and the short naked seta on the terminal exopod segment of leg 1 in the male in *N. chrysophryenus*, are all excluded as diagnostic features as these characters are also present in *N. hoi* but were overlooked previously by Ho & Lin (2005).

It is evident that *Naricolax* species may not exhibit a high degree of host-specificity as it infests seven host fish families (Ariidae, Carangidae, Hexagrammidae, Lateolabracidae, Leiognathidae, Sparidae and Stromateidae) representing three orders (Perciformes, Scorpaeniformes and Siluriformes) (Table 1). In contrast, the seven known species of *Unicolax*, that also infest the nasal cavity of their host, parasitise three host fish families (Centrolophidae, Scombridae and Sillaginidae) representing one order (Perciformes). Indeed, *N. chrysophryenus*, which is known to infest *Chrysophrys auratus* in eastern and southern Australia (Roubal et al., 1983), was recovered from wild and farmed *S. lalandi* in similar locations in the present study. The low host-specificity exhibited by *N. chrysophryenus* may be of concern to the Australian finfish aquaculture industry. However, the degree of host pathology associated with *Naricolax* infections has not been recorded.

The documentation of *N. hoi* n. sp. and the recent reassignment of *U. chrysophryenus* to *Naricolax* increases the number of *Naricolax* species to six. Although our sampling method prohibited determination of the microhabitat of *N. chrysophryenus* from *S. lalandi*, this species has been recovered previously from the nares of *P. auratus* (see Sharples & Evans, 1993). It would appear that at least two parasite species may exploit this microhabitat in *S. lalandi* in Australia, since *Dissonus hoi* Tang & Kalman, 2005 has been recovered from the nares of wild *S. lalandi* in South Australia (KSH, unpublished data).

Key to the species of *Naricolax* (based on adult females)

1. Seta V on caudal ramus modified into short curved hook; terminal exopod segment of leg 4 with formula II, I, 4 .... *N. insolitus* Ho & Lin, 2003

– Seta V on caudal ramus long, unmodified; terminal exopod segment of leg 4 with formula II, I, 5 2

2. Outer spine on middle exopod segment of leg 3 longer than two distal exopod segments combined .... *N. longispina* Ho & Lin, 2005

– Outer spine on middle exopod segment of leg 3 shorter than two distal exopod segments combined 3

3. Rostrum T-shaped; terminal endopod segment of leg 4 with outermost element longer than innermost element .... *N. hoi* n. sp.

– Rostrum not as above; terminal endopod segment of leg 4 with outermost element shorter than innermost element 4

4. Cephalothorax with dorsomedial pair of nipple-like protuberances near anterior margin; outer exopod spines of legs 3 and 4 serrate .... *N. chrysophryenus* (Roubal, Armitage & Rohde, 1983)

– Cephalothorax without dorsomedial pair of nipple-like protuberances near anterior margin; outer exopod spines of legs 3 and 4 finely spinulate 5

5. Spines on terminal endopod segment of legs 3 and 4 coarsely serrate .... *N. atypicus* Ho, Do & Kasahara, 1983

– Spines on terminal endopod segment of legs 3 and 4 finely spinulate .... *N. stocki* (Roubal, 1981)

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