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Revision of the worm eel genus *Neenchelys* (Ophichthidae: Myrophinae), with descriptions of three new species from the western Pacific Ocean

Hsuan-Ching Ho^{1*}, John E McCosker² and David G Smith³

Abstract

Background: The Indo-Pacific snake eel genus *Neenchelys* is a small group of moderately to extremely elongated fishes (family Ophichthidae), which comprises seven nominal species previously. Intensive collections on this group have led to the findings of taxonomic problems, as well as new taxa. This study is aimed to review the group on the basis of all known specimens, to verify the species, and to describe the new species.

Results: Six valid species are recognized: *Neenchelys microtretus* Bamber from the Suez, Red Sea; *N. buitendijki* Weber and de Beaufort from Indonesia, Bombay, India, and Malaysia; *N. cheni* (Chen and Weng), a senior synonym of *N. retropinna* Smith and Böhlke, from Taiwan, Vietnam, Australia, and the Gulf of Oman; *N. daedalus* McCosker from Papua New Guinea; *N. parvipectoralis* Chu, Wu and Jin from the South China Sea off Taiwan and Vietnam; and *N. mccoskeri* Hibino, Ho and Kimura from Japan and Taiwan. Three new species - *N. diaphora* sp. nov., *N. pelagica* sp. nov., and *N. similis* sp. nov. - are described from Taiwan and Japan. These new species differ from the congeners in body proportions, meristics, and morphology. A lectotype for *N. buitendijki* is designated.

Conclusions: Totally, nine species are recognized in *Neenchelys*, including three new species, with most species showing range extension in the Indo-west Pacific region. Diagnosis, detailed morphometric and meristic data, and ecological note for each species are provided. New diagnostic characters are used for recognizing the species, with a key to the species of *Neenchelys* provided. The recent discovery of new Asian species suggests that more remain to be discovered.

Keywords: Pisces; Anguilliformes; Ophichthidae; Myrophinae; *Neenchelys*; Taiwan

Background

The ophichthid eel genus *Neenchelys* Bamber 1915 is a group of small elongate ophichthid eels, subfamily Myrophinae, characterized by a posterior nostril opening on the side of the head above the lip and by having one or two preopercular pores and a pectoral fin. Species of *Neenchelys* inhabit the western Pacific and Indian oceans, and some, like species of *Benthenchelys* Fowler 1934 (see Castle 1972), are unique among ophichthids, nearly all of which are benthic burrowers as juveniles and adults, in inhabiting the midwater realm throughout their lives.

Since the genus was established, only few species were described under it: *Neenchelys buitendijki* Weber and de Beaufort 1916 from Indonesia, *Neenchelys parvipectoralis* Chu, Wu and Jin 1981 from China, *Neenchelys daedalus* McCosker 1982 from Papua New Guinea, *Neenchelys retropinna* Smith and Böhlke 1983 from Gulf of Oman, and *Neenchelys mccoskeri* Hibino, Ho and Kimura 2012 from northwestern Pacific Ocean.

Although McCosker (1982) separated *Neenchelys* from the closely related New World genus *Pseudomyrophis* Wade 1946 by its having well-developed pectoral fins and lacking the third preopercular pore, some members of *Neenchelys* in the Indo-western Pacific possess a minute pectoral fin. All species of *Neenchelys* have two rather than three preopercular pores (except for *N. parvipectoralis* which usually has one), a significant character among many species of ophichthids (McCosker 1977).

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McCosker and Chen (2000) recorded *N. retropinna* from Taiwan. Mohamed (1958) and Ho et al. (2012) recorded *N. buitendijki* from Bombay, India, the Arabian Sea, and Malaysia. Ho et al. (2010) discovered the missing type series of *Myrophis cheni* Chen and Weng 1967 and suggested that it might be a member of *Neenchelys* and that *N. retropinna* was its junior synonym. We concur. Ho et al. (2010) also reported on six specimens of *N. parvipectoralis* from waters off Taiwan. Machida and Ohta (1993) recorded a specimen of *N. daedalus* from Japan, and Chen (2007) recognized an additional specimen from Taiwan. Both specimens belong to a new species described herein.

In recent investigations, we discovered three undescribed species of *Neenchelys* from the waters of southern Taiwan, one of which is presumably a midwater species and the others are presumably demersal species. The addition of three new species described herein brings the total number of species in *Neenchelys* to nine.

It is the purpose of this paper to describe and name the three new species, review all Indo-Pacific species of *Neenchelys*, and provide a key to their identification.

Methods

Measurements are straight line, made either with a 300-mm ruler with 0.5-mm gradations (for total length (TL), trunk length, and tail length) and recorded to the nearest 0.5 mm, or with dial calipers (all other measurements) and recorded to the nearest 0.1 mm. Body length comprises the head (HL) and trunk lengths. The HL was measured from the snout tip to the postero-dorsal margin of the gill opening, the trunk length was taken from the end of the head to the mid-anus, and the maximum body depth did not include the median fins. The head pore terminology followed that of McCosker et al. (1989: 257) in that the supraorbital pores are expressed as the ethmoidal pore + pores in the supraorbital canal, e.g., 1 + 4, and the infraorbital pores are expressed as pores along the upper jaw + those in the vertical part of the canal behind the eye ('postorbital pores'), e.g., 4 + 2, in that the last pore included along the upper jaw is frequently part of the postorbital series.

Vertebral counts (which include the hypural) were taken from radiographs. The mean vertebral formula (MVF) is expressed as the average of the predorsal, preanal, and total vertebrae (Böhlke 1989). All specimens examined in this study were preserved in formaldehyde and then transferred to ethyl alcohol or isopropyl alcohol. Specimens examined in this study are deposited at the Australian Museum, Sydney, Australia (AMS); Academy of Natural Sciences, Philadelphia, PA, USA (ANSP); Institute of Zoology, Chinese Academy of Sciences, Beijing, China (ASIZB); Biodiversity Research Center, Academia Sinica, Taipei, Taiwan (ASIZP); Natural History Museum, London,

UK (BMNH); Fisheries Research Laboratory, Mie University, Mie, Japan (FRLM); California Academy of Sciences, California, USA (CAS); National Science Museum, Tokyo, Japan (NSMT-P); Pisces Collection, National Museum of Marine Biology & Aquarium (NMMB-P); Shanghai Ocean University, Shanghai, China (formerly Shanghai Fishery College; SFC); Laboratory of Aquatic Ecology, Department of Aquaculture, National Taiwan Ocean University (TOU-AE); Smithsonian Institution, National Museum of Natural History, Washington D. C., USA (USNM); and Zoölogisch Museum, Amsterdam, The Netherlands (ZMA). Institutional abbreviations follow Fricke and Eschmeyer (2013, online version).

Systematics

Neenchelys Bamber 1915

Synonymy: *Neenchelys* Bamber 1915: 479 (type species: *Neenchelys microtretus* Bamber 1915, by monotypy); Mohamed 1958: 511; McCosker 1977: 60; McCosker 1982: 62; McCosker et al. 1989: 270; Smith and McCosker 1999: 1663.

Diagnosis: Ophichthid eels, subfamily Myrophinae, tribe Myrophini (*sensu* McCosker 1977) with the following characteristics: body robust to extremely elongate, cylindrical anteriorly, and somewhat laterally compressed posteriorly; head and trunk shorter than tail; dorsal fin origin variable, from anterior trunk region to slightly behind level of anus; pectoral fin variable in size, from minute to moderately developed; snout broad, tumid, overhanging lower jaw; lips without barbels; anterior nostril tubular, posterior nostril an elongate slit in upper lip beneath lower margin of orbit; gill opening round and constricted; cephalic pores developed, one or two preopercular pores (usually two, except for *N. parvipectoralis*); teeth small, conical, mostly uniserial on jaws and vomer; coloration uniform although slightly darker dorsally, median fins often black-edged posteriorly.

Distribution and ecological notes: Members of *Neenchelys* can be found in the Indo-west Pacific region from the Red Sea east to Papua New Guinea, north to Japan, and south to western Australia. As stated above, some species of *Neenchelys* are remarkable in that they are known or suspected to live in midwater as adults. All but three (*Benthenchelys* spp.) of the more than 260 other known species of ophichthids (McCosker 2014) are fossorial and burrow in sand, gravel, or muddy substrates.

Remarks: On the basis of a 185-mm specimen, Bamber (1915) created the family Neenchelidae and a new genus and species. The family was subsequently included within the Ophichthidae (Böhlke 1960; Nelson 1966, 1967). Species of *Neenchelys* are most closely related to those of the New World genus *Pseudomyrophis*. Previous researchers (including Gareth J. Nelson and the late James E. Böhlke) suggested that the two genera might be synonymous;

however, based on trenchant differences displayed by the leptocephali, Leiby (1984) strongly advised that the genera are valid. We concur with this.

There are now nine known species; however, the recent discovery of four new Asian species suggests that more remain to be discovered.

Etymology: From the Greek *neo* (new) and *enchelys* (eel). Treated as feminine according to Opinion 915 of the *Bulletin of Zoological Nomenclature* (1970).

***Neenchelys buitendijki* Weber and de Beaufort 1916**

Common name: Fintail serpent eel

(Figure 1 A,B,C,D and Tables 1 and 2)

Synonymy: *Neenchelys buitendijki* Weber and de Beaufort 1916: 268, Figure one hundred sixteen (type localities: Bay of Batavia, Java, and probably Moluccas, Indonesia); Mohamed 1958: 513; Ho et al. 2012: 949.

Material examined: Syntype (herein designated to be the lectotype): ZMA.102.171 (218 mm TL), 'Moluccas,

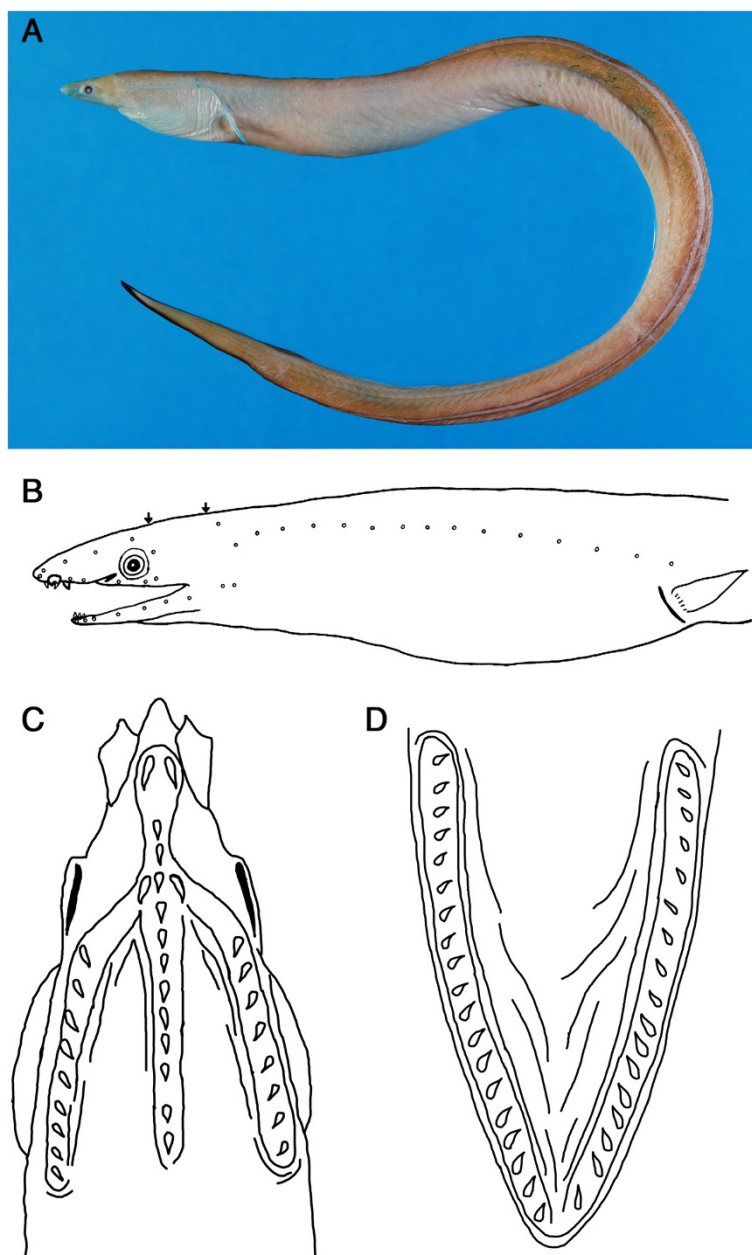


Figure 1 *Neenchelys buitendijki* Weber and de Beaufort 1916. (A) NMMB-P13649, 239 mm TL, Matang, Malaysia, preserved condition. (B) Lateral view of head, with arrows indicating the frontal pore (left) and median supratemporal pore (right). (C) Upper jaw teeth. (D) Lower jaw teeth. (B-D) From NMMB-P13651, 211 mm TL.

Table 1 Morphometric data of five *Neenchelys* species, expressed as percentage of total length, trunk length, and head length

	<i>N. buitendijki</i>			<i>N. cheni</i>			<i>N. daedalus</i>	<i>N. diaphora</i> sp. nov.		<i>N. mccoskeri</i>	
	<i>n</i> = 7		Lectotype	<i>n</i> = 17			<i>n</i> = 2	Holotype	Types (<i>n</i> = 3)	<i>n</i> = 31	
Total length (mm)	170-239		334	334-414			273-342	478	264-478	283-522	
% Total length	Mean (range)	SD		Mean (range)	SD				Mean (range)	Mean (range)	SD
Head length	12.2 (11.0-14.1)	1	8.6	9.5 (8.6-12.2)	0.8	6.9-7.8	10.1	9.8 (9.3-10.1)	7.1 (6.4-7.7)	0.3	
Predorsal length	17.3 (16.7-18.6)	0.8	37.7	40.0 (37.7-41.9)	1.4	14.5-15.4	22.6	22.4 (21.9-22.8)	23.0 (21.1-25.6)	1	
Trunk length	29.3 (26.8-32.4)	1.7	27.2	28.6 (26.9-31.1)	1	19.0-19.6	25.3	25.1 (23.8-26.3)	33.1 (30.9-36.6)	1.3	
Preanal length	42.7 (41.0-46.5)	2.3	36.2	38.1 (36.2-39.8)	1.1	25.9-27.4	35.6	35.0 (33.7-35.6)	40.1 (34.6-43.7)	1.7	
Tail length	59.7 (55.2-61.8)	2.2	64.4	61.8 (60.2-64.4)	1.1	72.6-74.1	64.9	65.2 (64.4-66.3)	59.6 (56.5-62.8)	1.5	
% Trunk length											
Gill opening to dorsal fin origin	18.1 (16.6-19.2)	1.1	106.9	107.3 (97.4-116.8)	4.1	38.5-40.0	49.2	50.2 (49.2-51.3)	48.1 (43.6-53.4)	2.5	
% Head length											
Pectoral fin length	21.8 (15.0-25.5)	3.5	13.2	13.3 (10.3-16.4)	1.5	22.1-23.4	26.8	26.2 (25.0-26.8)	2.6 (1.5-3.5)	0.6	
Snout length	15.6 (13.6-17.6)	1.3	22.6	21.7 (19.1-24.2)	1.3	16.6-17.8	19.4	19.2 (19.0-19.4)	19.7 (15.8-23.1)	1.8	
Eye diameter	4.8 (4.4-5.3)	0.3	7.3	7.9 (6.2-10.2)	1.1	5.1-5.6	6.6	6.5 (6.1-6.8)	6.4 (4.0-8.4)	0.9	
Upper jaw length	28.3 (26.5-32.4)	2	30	32.2 (26.6-37.1)	2.7	24.3-26.4	29.3	30.4 (29.3-31.3)	30.7 (27.9-37.2)	2	
Interorbital width	7.5 (7.1-8.5)	0.5	12.5	13.4 (10.8-15.6)	1.4	8.4-8.7	13.6	13.8 (13.3-14.6)	12.6 (10.4-16.1)	1.5	
Postorbital length	78.5 (72.4-83.4)	4.1	75.6	73.6 (69.5-75.6)	1.8	-	72.2	75.4 (72.2-79.0)	75.3 (70.2-82.5)	3	
Gill opening height	12.9 (11.8-15.7)	1.6	6.6	8.2 (5.6-13.5)	2.4	-	12.6	11.0 (8.8-12.6)	8.7 (6.3-11.9)	1.3	
Depth at head	22.8 (17.6-36.2)	6.6	30	31.5 (27.2-37.3)	3.3	-	35.7	32.3 (30.3-35.7)	32.4 (25.0-42.0)	4.2	
Depth at anus	34.9 (30.9-38.5)	2.8	24.4	26.1 (19.4-30.1)	3	27.6-27.7	39.2	40.6 (32.6-50.0)	35.1 (28.7-48.7)	4.3	
Width at anus	25.7 (20.7-30.5)	4.1	17.1	19.4 (16.1-23.5)	2.2	16.4-17.9	33.8	32.8 (27.2-37.5)	31.1 (24.2-37.4)	3.7	

Indonesia'. Non-types: Malaysia: NMMB-P13649 (239 mm), offshore, 04°49'30.42"N, 100°29'11.76"E, Matang, small otter trawl, 6 October 2009; NMMB-P13650 (198 mm), mudflat, Matang, 04°51'1.26"N, 100°31'10.8"E, small otter trawl, 3 m, 1 December 2009; NMMB-P13651 (211 mm),

offshore, 04°49'54.18"N, 100°29'37.38"E, Matang, small otter trawl, 3.3 m, 16 January 2010; NMMB-P13652 (225 mm), mudflat, 04°50'53.64"N, 100°30'49.32"E, Matang, small otter trawl, 1.9 m, 16 January 2010; NMMB-P13653 (192 mm), mudflat, Matang, 04°50'48.48"N, 100°

Table 2 Meristic data of five *Neenchelys* species treated in present study

	<i>N. buitendijki</i>		<i>N. cheni</i>		<i>N. daedalus</i>	<i>N. diaphora</i> sp. nov.		<i>N. mccoskeri</i>
	<i>n</i> = 7	Lectotype	<i>n</i> = 17		<i>n</i> = 2	Holotype	Types (<i>n</i> = 3)	<i>n</i> = 36
Total vertebrae	135-140	181	180-183		225-235	186	177-186	172-184
Predorsal vertebrae	18-20	58	56-60		31	34	34 or 35	34-41
Preanal vertebrae	49-51	55	52-58		58 or 59	54	54 or 55	62-67
Prepectoral pores	13 or 14	11	10-12		14	15	13-15	9-11
Predorsal pores	20-22	58	57-64		-	36	35-38	37-44
Preanal pores	51-54	55	52-67		-	56	56-59	62-69
Infraorbital pores	5 + 1	6	5 + 1 or 2 (mainly 6)		5 + 1	5 + 1	5 + 1	5 + 1
Supraorbital pores	1 + 4	5	1 + 4 or 5 (mainly 5)		1 + 4	1 + 4	1 + 4	1 + 4
Mandibular pores	7	5	5 or 6 (mainly 5)		5	6	6	7
Preopercular pores	2	2	2		2	2	2	2
Supratemporal pores	3	3	3		3	3	3	3
Frontal pore	1	1	1		1	1	1	1

31°31.74'E, 2.1 m, small otter trawl, 3 August 2010; Univ. of Malaya uncat. (2, 170 to 209 mm), Malaysia, no other data.

Diagnosis: A species of *Neenchelys* distinguished by having a combination of the following characters: a robust body, its depth 19 to 32 times in TL; HL 7.8 to 8.5 in TL; snout pointed; pectoral fin well developed, longer than snout, 4.0 to 4.8 in HL; origin of dorsal fin relatively forward, 0.4 to 0.5 times HL behind gill opening; predorsal length 5.7 to 6.0 in TL; gill opening large, its height 6.8 to 8.5 in HL; teeth conical, slender, uniserial in jaws and vomer; total vertebrae 135 to 148; MVF 19-50-140. Single median temporal and interorbital pores; supraorbital pores 1 + 4; infraorbital pores 5 + 1 (1 or 2 pores between anterior and posterior nostrils); mandibular pores 7; preopercular pores 2; supratemporal pores 3. Cephalic lateral line pores 13 or 14; predorsal pores 20 to 22; preanal pores 51 to 54. Coloration in preserved specimens pale brown dorsally and paler ventrally, with black posterior portions of dorsal and anal fins.

Distribution and ecological notes: Known from the type material, captured in Indonesia, from Bombay, India (Mohamed 1958), and from a shallow-water (<5 m) mud-flat at the bottom of a river mouth at Matang, western Malaysia (Ho et al. 2012).

Remarks: This species has received little attention since its original description which was based on a 129-mm specimen from Java and another (218 mm) 'most probably from the Moluccas.' Their designation of a holotype is not clear. We herein recognize the larger syntype, ZMA.102.171 (218 mm TL), as the lectotype of *N. buitendijki*. Mohamed (1958) reported on 15 specimens (58.5 to 273 mm TL) collected along with shrimp at 8 to 10 fathoms (15 to 18 m) from Bombay. Nelson (1966) extensively analyzed the osteology of specimens from Bombay and referred the species of *Neenchelys* to the subfamily Echelinae (=Myrophinae) of the Ophichthidae. *Neenchelys buitendijki* is most similar to *N. parvipectoralis* and *N. microtretus* in having a relatively short and stout body. It differs from them by having a pointed snout and well-developed pectoral fin. Mohamed (1958) gave 145 to 148 total vertebrae for his Indian specimens. However, all seven specimens we examined from Malaysia have slightly fewer total vertebrae, at only 135 to 140. The difference may be attributable to geographic variation. More specimens from other localities in the Indo-west Pacific region are needed to understand the geographic variation of this species.

***Neenchelys cheni* (Chen and Weng 1967)**

Common name: Chen's worm eel

(Figure 2A,B,C,D and Tables 1 and 2)

Synonymy: *Myrophis cheni* Chen and Weng 1967: 39, Figure twenty-nine (type locality: Tungkan, Taiwan);

Chen 2007:13. '*Neenchelys'cheni* (Chen and Weng 1967): Ho et al. 2010: 24 (designation of lectotype). *Neenchelys retropinna* Smith and Böhlke 1983: 80, Figure one to three (type locality: Gulf of Oman). Paxton et al. 1989: 119; McCosker and Chen 2000: 356 (first record from Taiwan).

Material examined: Types: *Myrophis cheni*: Lectotype: NMMB-P3019, formerly THUP 3234 (350 mm), Tungkan Fishing Port, SW Taiwan, May 1966. Paralectotype: NMMB-P1534, formerly THUP 3328 (335 mm), Tungkan Fishing Port, SW Taiwan, September 1966. *Neenchelys retropinna*: holotype: ANSP 131512 (320 mm), ANTON BRUUN cruise 4-B, sta. 256-A, Gulf of Oman, 26°10'N, 57°02'E, 55 to 64 m, bottom trawl, 30 November 1963. Paratypes: ANSP 131513 (sex indeterminate, 289 mm), same data as for ANSP 131512; AMS I. 21847-017 (sex indeterminate, 305 mm), Arafura Sea, Australia, 10°02'S, 133°58'E, R/V *SOELA*, bottom trawl, 80 to 84 m, 17 November 1980.

Non-types: NMMB-P1535 (324 mm), Tungkan Fishing Port, SW Taiwan, 21 March 1979. NSYSU 3683 (386 mm), SW Taiwan, 22°32'N, 120°07'E, 50 to 100 m; TOU-AE 2850 (342 mm), Changbin, Taitung, E Taiwan, 31 July 2006, coll. M.-L. Chiou; TOU-AE 3535 (399 mm), Changbin, Taitung, E Taiwan, 8 February 2007, coll. M.-L. Chiou; NMMB-P12485 (376 mm), NMMB-P12486 (335 mm), NMMB-P12487 (338 mm), Da Nang, Vietnam, 9 April 2011; NMMB-P12491 (5, 381 to 414 mm), Da Nang, Vietnam, 11 April 2011; NMMB-P12503 (3, 367 to 389 mm), NMMB-P12505 (335 mm), Da Nang, Vietnam, 9 April 2011.

Diagnosis: A species of *Neenchelys* distinguished by having a combination of the following characters: body moderately elongate and relatively compressed, depth at anus 3.3 to 5.2 times in HL, 29 to 40 in TL; HL 10.1 to 11.6 in TL; origin of dorsal fin relatively posterior, at about same vertical level as or slightly posterior to origin of anal fin, predorsal length 2.4 to 2.7 in TL; tail length 1.6 to 1.7 in TL; pectoral fin moderate in size, shorter than snout length, 7.0 to 7.8 in HL; snout relatively long, 4.1 to 5.2 in HL; total vertebrae 180 to 183; MVF 59-56-181. Single median temporal and interorbital pores; supraorbital pores 1 + 4 or 1 + 5; infraorbital pores 5 + 1 or 5 + 2 (2 pores between anterior and posterior nostrils); mandibular pores 5 or 6; preopercular pores 2; supratemporal pores 3. Cephalic lateral line pores 10 to 12; predorsal pores 57 to 64; preanal pores 52 to 67. Coloration in preservative pale brown, slightly darker dorsally, fins pale except median fins which darken approximately one head length before the tail tip.

Distribution and ecological notes: Known from southern Taiwan, Vietnam, Australia (Paxton et al. 1989), and the Gulf of Oman (Smith and Böhlke 1983). In Taiwan, most specimens were collected by midwater trawl together

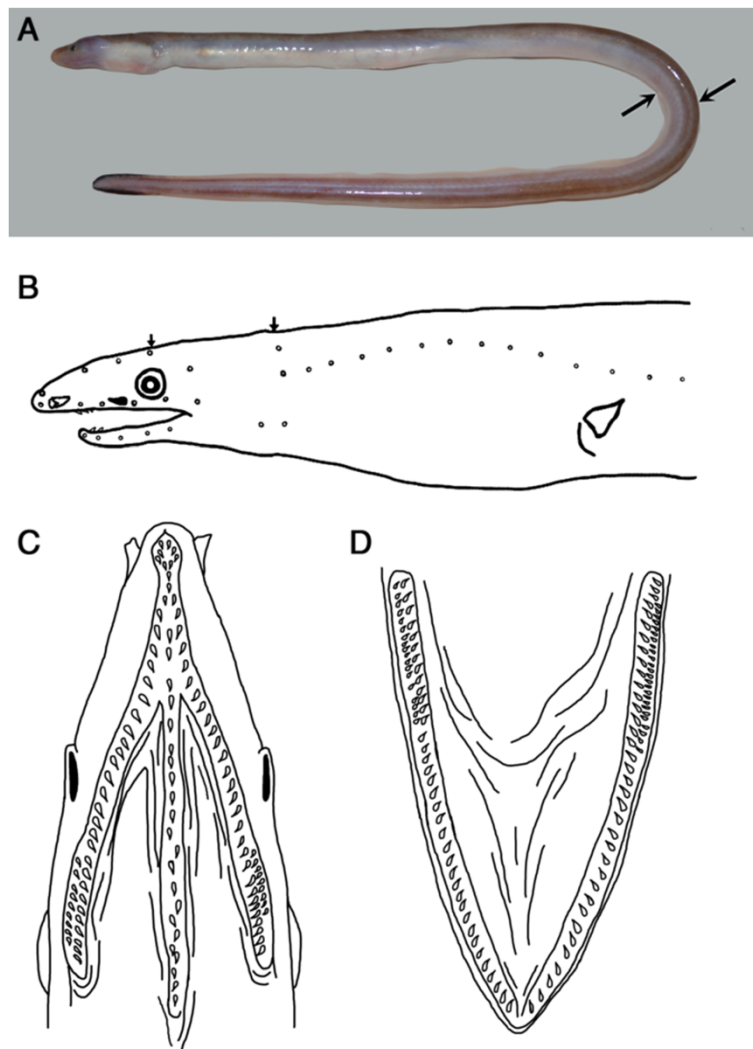


Figure 2 *Neenchelys cheni* (Chen and Weng 1967). (A) NMMB-P12505, 350 mm TL, Danang, Vietnam, with arrows indicating the origin of the dorsal fin (right) and anal fin (left), fresh condition. (B) Lateral view of the head, with arrows indicating the frontal pore (left) and median supratemporal pore (right). (C) Upper jaw teeth. (D) Lower jaw teeth. (B-D) From lectotype, NMMB-P3019, 350 mm TL.

with many mesopelagic fishes, suggesting that adults have a pelagic lifestyle. However, the type series of *N. retropinna* came from bottom trawls.

Remarks: The type specimens of *M. cheni* were rediscovered by Ho et al. (2010). They redescribed the two specimens, selected a lectotype, and referred the species to *Neenchelys*. They further stated that '*N. retropinna* and "*N.*"*cheni* are very likely conspecific.' Our examination of additional specimens supports their actions.

Smith and Böhlke (1983) mentioned that the maxillary teeth are uniserial in the type series of *N. retropinna*. However, there is one short outer row of smaller teeth along the posterior portion of the maxillary in the type series of *N. cheni* and in all Vietnamese specimens. It is notable that NSYSU 3683 has more complicated intermaxillary and vomerine dentition. There is one extra

curved row of small teeth before the anterior intermaxillary tooth and many more teeth occupying the anterior palate, followed by two irregular series of vomerine teeth which gradually become uniserial posteriorly. That specimen is neither large nor small, and we are unable to assign significance to its dental condition.

Numbers of predorsal and preanal pores showed a higher variation than those of other species, especially the preanal pores (52 to 67). Based on our observations, the position of the dorsal fin origin is variable, slightly before or behind the anus, which the number of predorsal pores is highly related to. Although large variations of these two lateral line counts are atypical for ophichthids, our data suggest that *N. cheni* might have a larger variation of the preanal pore number than its congeners.

***Neenchelys daedalus* McCosker 1982**

Common name: New Guinea worm eel
(Figure 3A,B,C,D and Tables 1 and 2)

Synonymy: *Neenchelys daedalus* McCosker 1982: 63, Figure four (type locality: Astrolabe Bay, Papua New Guinea).

Material examined: Holotype: AMS I. 19690–012 (342 mm), Astrolabe Bay, Madang, Papua New Guinea (05°24'S, 145°52.5'E). Paratype: CAS 50708 (272 mm), collected with holotype.

Diagnosis: A species of *Neenchelys* distinguished by having a combination of the following characters: body elongate and relatively compressed, its depth 46 to 52 times in TL; origin of dorsal fin at about midtrunk, 1.0 to 1.1 in HL behind gill opening; predorsal length 6.5 to 6.9 in TL; head 13 to 15 in TL, trunk 5.1 to 5.3 in TL; tail 1.3 to 1.8 in TL; pectoral fin elongate, nearly as long

as upper jaw; teeth slender, conical, uniserial throughout; coloration uniformly tan, except belly which is dark brown to black, fins colorless; vertebrae 225 to 235, MVF 31-58-230. Single median temporal and interorbital pores; supraorbital pores 1 + 4; infraorbital pores; 5 + 1 (2 pores between anterior and posterior nostrils); mandibular pores 5; preopercular pores 2; supratemporal pores 3. Body coloration in isopropyl alcohol uniformly tan, except belly which is dark brown to black; fins colorless.

Distribution and ecological notes: Known only from the type material, collected from Papua New Guinea by midwater trawl at 0 to 256 m over a 'rough peak > 500 fms [914 m] bottom' at 18:50 to 21:00.

Remarks: This species has not been correctly reported since its original description. It and species of *Benthenchelys* and perhaps two other congeners described herein are the

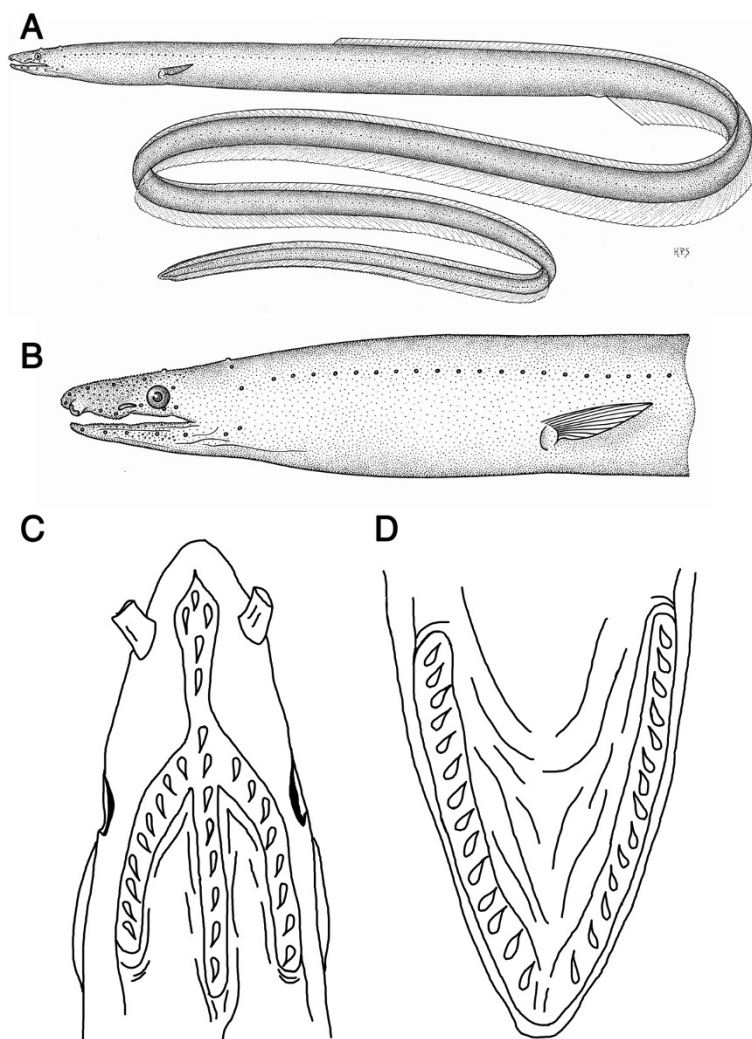


Figure 3 *Neenchelys daedalus* McCosker 1982. (A) Drawing of holotype. (B) Lateral view of head. (C) Upper jaw teeth. (D) Lower jaw teeth. (A, B) From AMS I. 19690–012, holotype, after McCosker (1982). (C, D) From CAS 50708, paratype, 272 mm TL.

only ophichthids known to occupy the midwater realm as adults.

The original description of *N. daedalus* mentioned 11 other Pacific specimens from Papua New Guinea and the Banda Sea that were collected in midwater but differed in having more vertebrae. They were tentatively identified as *N. daedalus*; however, McCosker (1982: 65) treated them as non-paratypes and stated 'they are all smaller specimens and appear identical in proportions to the new species. They differ considerably, however, in total vertebral numbers: the holotype and paratype have 235 and 225, respectively, whereas eight of the others had 251–274 (mean = 266.8) vertebrae. I am unable to account for such a large mean vertebral difference and broad range in vertebral number for conspecifics in such close geographical proximity, and therefore have not made them type-specimens.' We now recognize that these belong to a new species, *Neenchelys similis* sp. nov., which is described in this revision.

***Neenchelys diaphora* sp. nov.**

Common name: Longfin worm eel

(Figure 4A,B,C,D,E and Tables 1 and 2)

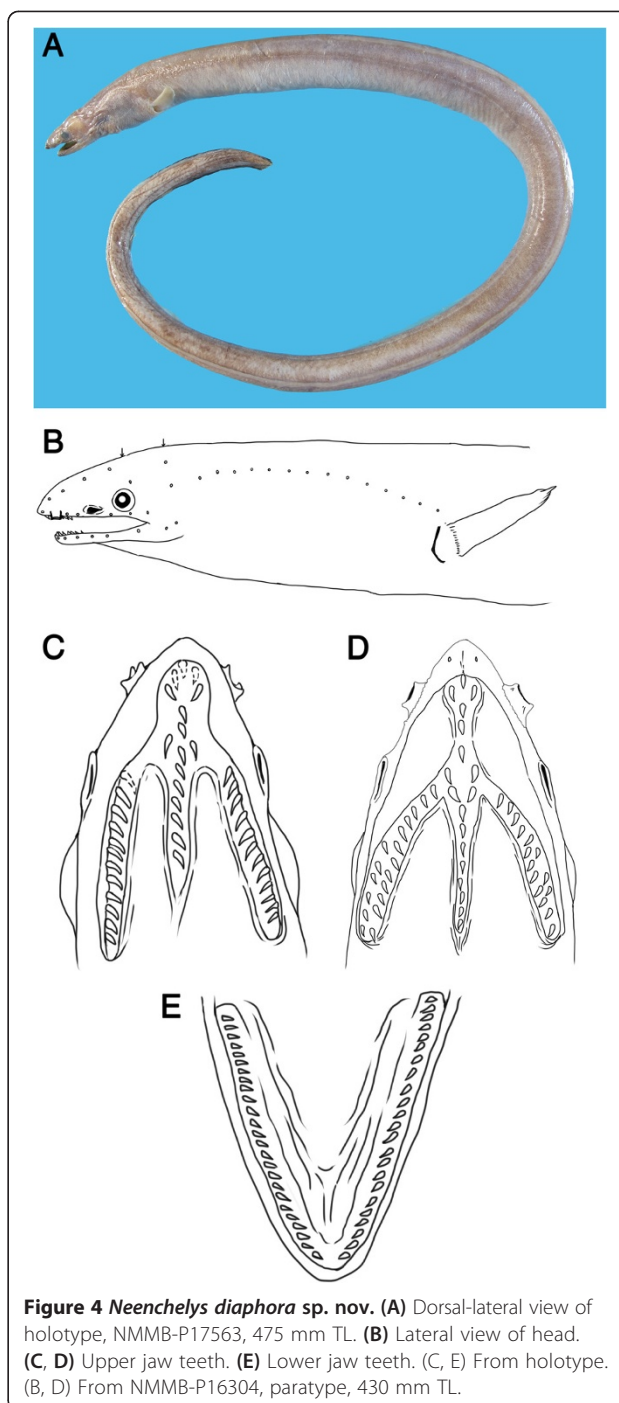
Holotype: NMMB-P17563 (475 mm), a ripe female, Tungkang Fishing Port, SW Taiwan, northern South China Sea, otter trawl, 25 November 2011.

Paratype: NMMB-P16304 (430 mm), a ripe female, Tungkang Fishing Port, SW Taiwan, northern South China Sea, otter trawl, 19 March 2012, coll. H.–C. Ho; NMMB-P17553 (264 mm), sex indeterminate, Tungkang Fishing Port, SW Taiwan, northern South China Sea, otter trawl, 9 November 2012, coll. H.–C. Ho.

Etymology: From the Greek *diaphoros*, meaning different. Initially, the holotype was recognized as being closely similar to *Neenchelys pelagica* sp. nov. described below. With the newly collected specimens, we were able to confirm its differentiation and describe it as a new species.

Diagnosis: A species of *Neenchelys* distinguished in having a combination of the following characters: body relatively cylindrical, 2.8 to 3.3 times in HL, 28 to 35 in TL; dorsal fin origin at midpoint of trunk, 1.2 to 1.5 times in HL behind gill opening; predorsal length 4.4 to 4.6 in TL; HL 9.9 to 10.8 in TL; tail 1.5 to 1.6 in TL; pectoral fin well developed and relatively large, 3.7 to 4.0 in HL; total vertebrae 177 to 186; MVF 35–54–181. Cephalic lateral line pores 13 to 15; predorsal pores 35 to 38; preanal pores 56 to 59.

Description: Morphometric and meristic data are provided in Tables 1 and 2. The following proportions are given for the holotype, followed by values of the paratypes in parentheses. In TL: HL 9.9 (9.9 to 10.8); predorsal length 4.4 (4.4 to 4.6); trunk length 4.0 (3.8 to 4.2); preanal length 2.8 (2.8 to 3.0); tail length 1.5 (1.5 to 1.6).



In HL: pectoral fin length 3.7 (3.7 to 4.0); snout length 5.2 (5.2 to 5.3); eye diameter 15.2 (14.8 to 16.3); upper jaw length 3.4 (3.2 to 3.4); interorbital width 7.3 (6.9 to 7.5); gill opening height 8.0 (8.0 to 11.3); body depth at gill opening 2.8 (2.8 to 3.3); body depth at anus 2.6 (2.0 to 3.1); body width at anus 3.0 (2.7 to 3.7).

Body moderately elongate; somewhat cylindrical with tail gradually compressed posteriorly; depth of body

relatively uniform, tapering gradually to tail tip; depth of head subequal to that of body. Tail moderately long, anus at anterior 1/3 of body length. Dorsal and anal fins low and fleshy, continuous with a small but distinct rayed caudal fin; origin of dorsal fin about one HL before a vertical through origin of anal fin. Pectoral fin relatively well developed, broad at base, and pointed posteriorly.

Head profile terete; snout acute anteriorly, tip of snout projecting well beyond lower jaw. Anterior nostril tubular, directed anteroventrally, its tube distinctly notched dorsally. Posterior nostril in front of lower margin of eye, opening directed ventrally, appearing in lateral aspect as a diagonal slit, the posterior end of which is highest. Behind and below nostril and parallel to it with a groove that is longer than nasal slit. Snout broad and tumid, housing an extensive nasal organ on either side. Lower jaw included, its tip reaching a line between anterior margins of anterior nostrils. Angle of gape about one eye diameter behind a vertical through posterior margin of pigmented eyeball. Tongue not free, well attached to mouth floor. Gill opening a narrow vertical slit, situated at anteroventral corner of pectoral fin base.

Head pores small (Figure 4B), single median temporal and interorbital pores. Supraorbital pores 1 + 4; infraorbital pores 5 + 1 (2 pores between anterior and posterior nostrils). Mandibular pores 6; preopercular pores 2; supratemporal pores 3.

Teeth slender (Figure 4C,D,E), pointed, tips directed posteriorly, anteriormost one in each series longest. Intermaxillary teeth 5 (3 to 5), well separated from that of vomer; vomerine teeth uniserial, with 1 (1 or 2) pair of side teeth between second and third (or first and second) teeth, terminating posteriorly before end of maxillary tooth row (Figure 4C; about same level in 430-mm paratype, Figure 4D); maxillary uniserial (two irregular rows in 430-mm paratype, Figure 4D), with 12 (10 to 12) teeth, terminating posteriorly at gape; dentary with 23 to 25 (21 to 25) uniserial teeth, its end terminating at that of opposite maxillary tooth row.

Lateral line incomplete, pores small and inconspicuous, extending to about one HL before caudal fin. Cephalic lateral line pores 15 (13 to 15), predorsal pores 36 (35 to 38), and preanal pores 56 (56 to 59).

Coloration when fresh uniformly brownish gray with posterior end of dorsal and anal fin margins edged black; in preservative gray to light brown, with posterior end of dorsal and anal fins edged black.

Distribution and ecological notes: Known from the type series collected from SW Taiwan, the northern portion of the South China Sea. Specimens were collected together with *N. parvipectoralis* and *N. mccoskeri*, indicating that this species may have a benthic lifestyle and probably feeds on benthic fishes and/or invertebrates.

Remarks: *Neenchelys diaphora* sp. nov. is most similar to *N. pelagica* sp. nov. described below in having a similar appearance and proportional measurements. It differs from *N. pelagica* sp. nov. by having a total of 177 to 186 vertebrae ($n = 4$) (vs. 169; $n = 3$), a relatively large gill opening (8.8% to 12.6% vs. 6.6% to 7.9% HL); six mandibular pores (vs. seven); and a benthic (vs. pelagic) life style. It is also similar to those species with well-developed pectoral fins, i.e., *N. cheni*, *N. daedalus*, and *N. buitendijki*. It differs from *N. cheni* by the dorsal fin origin being situated at the midpoint of the trunk (vs. above the anus), a larger pectoral fin, and an MVF of 35-54-181 (vs. 59-56-181). It differs from *N. daedalus* by having a relatively stouter body (body depth 28 to 35 vs. 46 to 52 in TL), an MVF of 35-54-181 (vs. 31-58-230), and different body proportions (see Table 1). It differs from *N. buitendijki* by having a relatively rounded snout (vs. pointed), an MVF of 35-54-181 (vs. 19-50-140), and different body proportions (see Table 1). *Neenchelys diaphora* sp. nov. is also similar to *N. mccoskeri* in general appearance but differs in having a well-developed pectoral fin (vs. a minute pectoral fin) and an MVF of 35-54-181 (vs. 37-65-179).

***Neenchelys mccoskeri* Hibino, Ho and Kimura 2012**

Common name: McCosker's worm eel

(Figure 5A,B,C,D and Tables 1 and 2)

Synonymy: *Neenchelys mccoskeri* Hibino, Ho and Kimura 2012: 343, Figures one to three (type locality: Tungkang Fishing Port, SW Taiwan).

Material examined: Holotype: NMMB-P 15557 (512 mm), male, Tungkang Fishing Port, SW Taiwan, 28 February 2011, bottom trawl, collected by H.-C. Ho. Paratypes: Taiwan: Tashi, NW Taiwan: ASIZP 60870 (449 mm), 25 February 2000, coll. J.-X. Wang; Tungkang Fishing Port, SW Taiwan: ASIZP 70422 (324 mm), 1 July 2001, coll. P.-L. Lin; CAS 231943 (324 mm), female with immature ova, collected with holotype; NMMB-P2915 (300 mm), 21 March 1979; NMMB-P11541 (3, 298 to 371 mm), bottom trawl, 10 September 2009; NMMB-P11542 (492 mm), bottom trawl, 10 December 2010; NMMB-P11543 (290 mm), bottom trawl, 28 January 2011; NMMB-P12001 (298 mm), bottom trawl, 18 February 2011; NMMB-P13721 (365 mm), bottom trawl, 13 September 2011; NMMB-P15544 (385 mm), bottom trawl, 1 March 2011; NMMB-P15545 (4, 300 to 381 mm), bottom trawl, 2 July 2011; NMMB-P15546 (358 mm), bottom trawl, 10 August 2011; NMMB-P15547 (8, 292 to 522 mm), bottom trawl, 20 October 2011; NMMB-P15548 (4, 280 to 353+ mm), bottom trawl, 25 October 2011; NMMB-P 15549 (3, 394 to 503 mm), bottom trawl, 28 January 2012; USNM 398566 (412 mm), 14 November 2009, coll. D.G. Smith and H.-C. Ho; USNM 400343

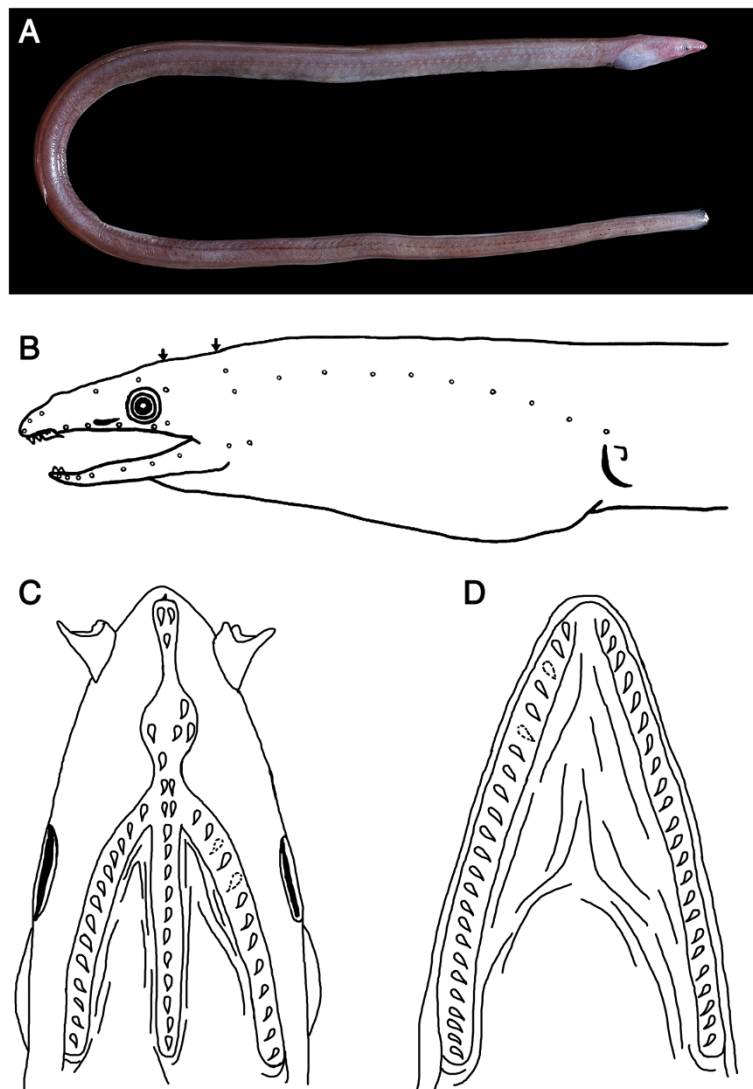


Figure 5 *Neeenchelys mccoskeri* Hibino, Ho and Kimura 2012. (A) NMMB-P15542, paratype, 492 mm TL, Tungkang, Taiwan, fresh condition. (B) Lateral view of head, with arrows indicating the frontal pore (left) and median supratemporal pore (right). (C) Upper jaw teeth. (D) Lower jaw teeth. (B-D) From NMMB-P 15557, holotype, 512 mm TL.

(430 mm), 8 November 2009, coll. D.G. Smith and H.-C. Ho; USNM 401023 (413 mm), 28 February 2011, coll. D. G. Smith and H.-C. Ho; USNM 401029 (374 mm), collected with USNM 400343. Other material: NSYSU 3682 (2, 317, 356 mm), Tungkang Fishing Port, SW Taiwan, bottom trawl, April 1999.

Diagnosis: A species of *Neeenchelys* distinguished in having a combination of the following characters: robust body, its depth 31 to 87 times in TL; HL 13.0 to 15.6 in TL; snout pointed; pectoral fin minute, a tiny transparent flap; a pointed appendage on posterior rim of anterior nostril; origin of dorsal fin at middle of trunk, 2.0 to 2.7 times in HL behind gill opening; predorsal length 3.8 to 4.8 in TL; gill opening small, its height 9.9 to 15.8 in HL; teeth conical, slender, uniserial in jaws and vomer;

total vertebrae 172 to 184; MVF 37-65-179. Single median temporal and interorbital pores; supraorbital pores 1 + 4; infraorbital pores 5 + 1 or 5 + 2 (2 pores between anterior and posterior nostrils); mandibular pores 6 or 7; preopercular pores 2; supratemporal pores 3. Cephalic lateral line pores 9 to 11; predorsal pores 37 to 44; preanal pores 62 to 69. Coloration when fresh, head brown anteriorly, body pinkish gray with black posterior end of median fin margins; when preserved, head and body entirely pale gray to brown with scattered melanophores dorsally; fins colorless, but edge of posterior dorsal and anal fins blackish.

***Neeenchelys microtretus* Bamber 1915**

Common name: Small-fin worm eel

(Figure 6 and Tables 3 and 4)

Synonymy: *Neenchelys microtretus* Bamber 1915: 479, pl. 46, Figure three (type locality: Suez).

Material examined: Holotype: BMNH 1915.10.25.1 (183 mm), Suez, Egypt, Gulf of Suez, Red Sea.

Diagnosis: Body robust, its depth 26 times in TL; pectoral fin minute, about equal to eye; origin of dorsal fin about 3/4 HL behind gill opening, well in advance of level of anus; head about 9.2 in TL; tail 1.7 in TL; teeth slender, conical, uniserial throughout; vertebral formula 24-56-151. Single median temporal and interorbital pores; supraorbital pores 1 + 4; infraorbital pores 5 + 1 (2 pores between anterior and posterior nostrils); mandibular pores 5; preopercular pores 2; supratemporal pores 3. Coloration when preserved 'uniform (in spirit)' (cf. Bamber 1915: 479).

Distribution: Known only from holotype, collected from the Red Sea.

Remarks: This species remains known only from the holotype. The original description was very brief and lacked measurements other than the TL (as '185 mm'). One of us (JM) examined the fragile type specimen and obtained the following measurements (in mm): TL 183, HL 20, trunk length 57, tail length 106, dorsal fin origin 35, snout ~3.5, jaw ~5.5, eye ~1.0, depth behind gill openings ~7. This species is extremely similar to the subsequently described species, *N. parvipectoralis*. It may prove to be a senior synonym of *N. parvipectoralis* when more specimens become available.

***Neenchelys parvipectoralis* Chu, Wu and Jin 1981**

Common name: Mini-fin worm eel

(Figure 7A,B,C,D and Tables 3 and 4)

Synonymy: *Neenchelys parvipectoralis* Chu, Wu and Jin 1981: 24, Figures four to five (type locality: Pingtan Island, Fujian Province, China); Ho et al. 2010: 29 (description of Taiwanese specimens).

Material examined: Holotype: ASIZB 73634 (formerly Shanghai Fishery University A01383) (tail partially broken), Pingtang Island, Fujian Prov., China. Non-types: China: ASIZB 29188 (112 mm), Nan-ao, Canton [Guangzhou],

11 March 1954; ASIZB 50977 (120 mm), Xan-wei, Canton, 16 October 1956; ASIZB 73631 (118 mm), South China Sea, 1956; ASIZB 73633 (123 mm), South China Sea, 1956; SFC 11619 (155 mm), Pingtang Island, Fuqing, March 1976; SFC 7-4978-1 (177 mm), Shawei, Fuqing, November 1963; SFC 14031 (147 mm), Pingtang, Fuqing, no date. Taiwan (all specimens from Tungkan Fishing Port, SW Taiwan): NMMB-P2912 (6, 163 to 238 mm), no date; NMMB-P11145 (8, 228 to 302 mm), 4 September 2008; NMMB-P11146 (175 mm), 30 October 2010; NMMB-P11977 (158 mm), 28 January 2011; NMMB-P13732 (64, 195 to 285 mm), 13 September 2010; NMMB-P13780 (3, 179 to 241 mm), 21 July 2011; NMMB-P13839 (275 mm), 5 October 2010; NMMB-P14019 (2, 157 to 281 mm), 6 September 2011; NMMB-P14076 (4, 166 to 202 mm), 10 August 2011; NMMB-P14245 (17, 220 to 290 mm), 6 September 2011; NMMB-P15551 (32, 198 to 290 mm), 2 July 2011; USNM 398480 (233 mm), 12 November 2009; USNM 398509 (252 mm), 12 November 2009; USNM 399863 (228 mm), 8 November 2009; USNM 399945 (6, 155 to 240 mm) November 2009. Vietnam: ASIZP 71605 (328 mm) Nha Trang, 16 April 2009; ASIZP 71608 (282 mm), Nha Trang, 18 April 2009; NMMB-P12501 (261 mm), Da Nang, 9 April 2011; NMMB-P12477 (4, 202 to 226 mm), Phen Thiet, 25 November 2010.

Diagnosis: A species of *Neenchelys* distinguished by the combination of the following characters: stout and cylindrical body, depth at gill openings 23 to 29 times in TL, 1.7 to 3.0 in HL; pectoral fin minute, a small transparent flap; origin of dorsal fin in anterior trunk region, 0.5 to 0.7 in HL behind gill opening, predorsal length 5.7 to 6.4 in TL; HL 8.8 to 9.9 in TL; tail 1.6 to 1.8 in TL; a slender pointed appendage on lower rim of anterior nostril; total vertebrae 138 to 148; MVF 20-55-143. Single median temporal and interorbital pores; supraorbital pores 1 + 4; infraorbital pores 5 + 1 (2 pores between anterior and posterior nostrils); mandibular pores 6 or 7 (mainly 6); preopercular pores 1 or 2 (mainly 1); supratemporal pores 3. Cephalic lateral line pores 12 to 14; predorsal pores 19 to 24; preanal pores 53 to 59. Coloration

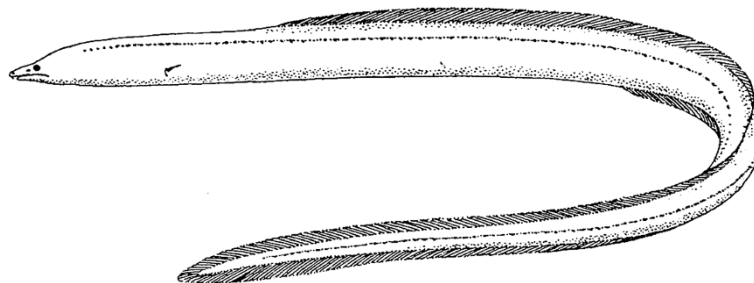


Figure 6 *Neenchelys microtretus* Bamber 1915, original drawing of holotype, after Bamber (1915).

Table 3 Morphometric data of four *Neenchelys* species, expressed as percentage of total length, trunk length, and head length

	<i>N. microtretus</i>	<i>N. parvipectoralis</i>		<i>N. pelagica</i> sp. nov.		<i>N. similis</i> sp. nov.	
	Holotype	n = 16		Holotype	Types (n = 3)	Holotype	Types (n = 4)
Total length (mm)	183	163-302		392	327-392	677	580-756
% Total length		Mean (range)	SD		Mean (range)		Mean (range)
Head length	10.9	10.7 (10.1-11.3)	0.3	10	10.0 (9.8-10.2)	6.1	6.4 (6.1-6.6)
Predorsal length	19.1	16.7 (15.7-17.5)	0.6	22.4	22.2 (20.8-23.3)	14	14.0 (12.9-14.8)
Trunk length	31.1	32.1 (30.6-34.0)	1.1	23.9	24.0 (23.1-25.0)	21.4	21.2 (20.7-21.8)
Preanal length	42.1	43.1 (41.4-44.4)	1	33.9	34.0 (33.3-34.8)	28.1	27.7 (26.7-28.3)
Tail length	57.9	57.5 (55.6-62.9)	1.8	66.1	66.2 (65.7-66.7)	72.4	72.4 (72.4-72.9)
% Trunk length							
Gill opening to dorsal fin origin	26.3	19.3 (15.3-22.3)	1.9	52	50.6 (45.8-54.0)	36.9	36.1 (31.6-38.6)
% Head length							
Pectoral fin length	-	2.7 (1.4-4.2)	1.1	22.9	23.6 (21.6-26.2)	26.0	25.0 (24.0-26.0)
Snout length	17.5	15.5 (13.8-17.5)	1	18.1	17.9 (17.4-18.1)	18.3	17.2 (15.6-17.5)
Eye diameter	5	6.2 (5.0-7.1)	0.5	7.4	6.6 (6.1-7.4)	5.3	5.4 (4.9-5.9)
Upper jaw length	27.5	27.7 (24.1-30.8)	2.1	28.2	28.3 (27.7-29.1)	28.9	30.1 (27.2-32.8)
Interorbital width	-	11.3 (8.0-13.1)	1.4	13	12.4 (12.0-13.0)	9.2	7.7 (6.3-9.2)
Postorbital length	-	79.6 (74.7-86.1)	3.7	74.3	75.4 (70.3-81.7)	81.9	79.3 (77.2-81.9)
Gill opening height	-	10.0 (6.7-13.5)	1.6	7.9	7.3 (6.6-7.9)	8.2	6.8 (5.2-8.2)
Depth at head	35	37.8 (33.5-41.7)	2.5	35.9	32.3 (30.3-35.9)	34.9	31.7 (29.7-34.9)
Depth at anus	-	38.8 (31.6-44.0)	3.8	36.1	33.6 (32.1-36.1)	37.8	35.0 (32.9-35.4)
Width at anus	-	29.1 (24.1-34.6)	2.5	32.3	29.7 (26.7-30.0)	24.8	24.7 (22.9-28.0)

uniformly pinkish yellow when fresh, creamy white when preserved, posterior margins of median fins blackened.

Distribution and ecological notes: Known from southern coasts of China and southern Taiwan. Specimens were recently collected from Vietnam off Nha Trang, Da Nang, and the Mekong River mouth area (the latter according to 11 April 2011 correspondence from

K. Shibukawa, Nagao Natural Environment Foundation, Tokyo, Japan). The localities and method of capture suggest that this species is demersal, inhabiting depths of <300 m. A 237-mm specimen (NMMB-P2912) with fully ripe eggs suggests that this is a small species. The largest specimen examined was 328 mm TL.

Table 4 Meristic data of four *Neenchelys* species treated in present study

	<i>N. microtretus</i>	<i>N. parvipectoralis</i>	<i>N. pelagica</i> sp. nov.		<i>N. similis</i> sp. nov.	
	Holotype	n = 41	Holotype	Types (n = 3)	Holotype	Types (n = 4)
Total vertebrae	151	138-148	169	169	261	260-265
Predorsal vertebrae	24	18-23	31	31-34	32	32-36
Preanal vertebrae	56	53-57	53	52-54	68	68-70
Prepectoral pores	-	12-14	14	14	16	15 or 16
Predorsal pores	-	19-24	36	36 or 37	36	35-37
Preanal pores	-	53-59	57	56 or 57	71	70 or 71
Infraorbital pores	5 + 1	5 + 1	5 + 1	5 + 1	5 + 1	5 + 1
Supraorbital pores	1 + 4	1 + 4	1 + 4	1 + 4	1 + 4	1 + 4
Mandibular pores	5	6 or 7 (mainly 6)	7	7	7	7
Preopercular pores	2	1 or 2 (mainly 1)	2	2	2	2
Supratemporal pores	3	3	3	3	3	3
Frontal pore	1	1	1	1	1	1

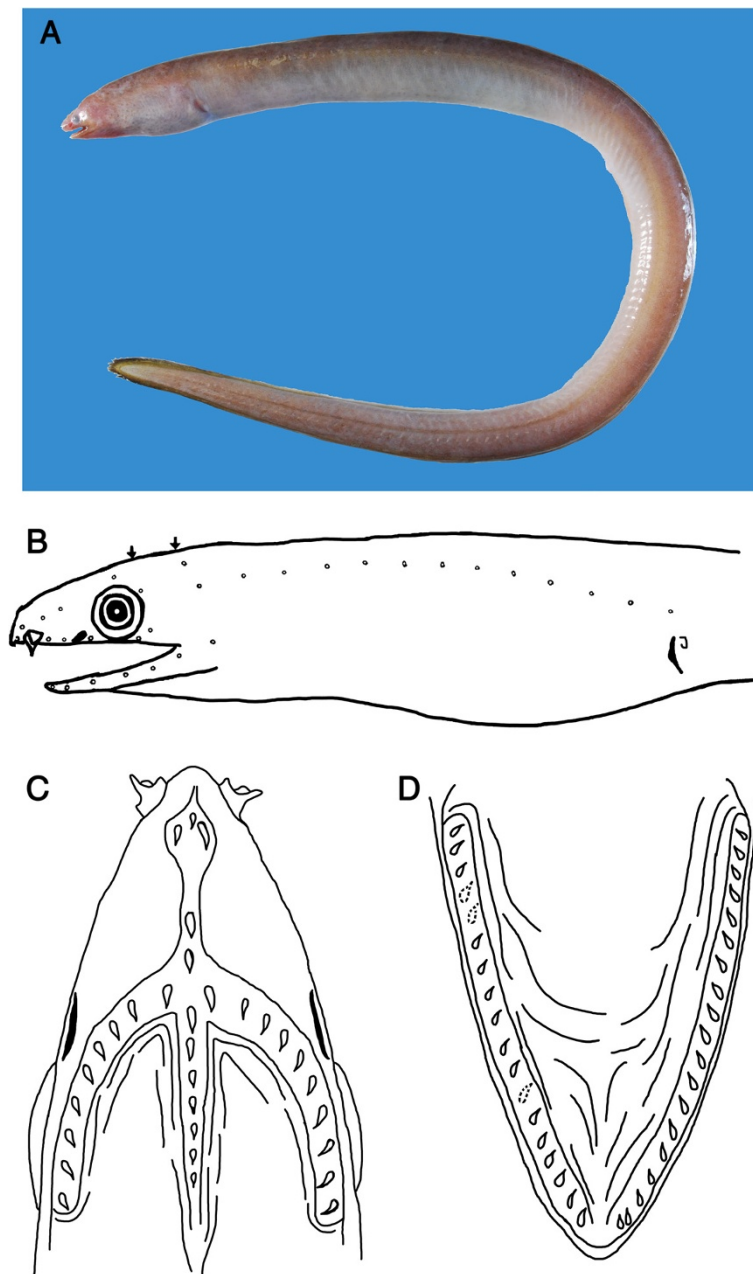


Figure 7 *Neenchelys parvipectoralis* Chu, Wu and Jin 1981. (A) NMMMB-P15551, 290 mm TL, Tungkan, Taiwan, fresh condition. (B) Lateral view of head, with arrows indicating the frontal pore (left) and median supratemporal pore (right). (C) Upper jaw teeth. (D) Lower jaw teeth. (B-D) From NMMB-P15551, 238 mm TL.

Remarks: This species was only known from the holotype collected from Pingtan Island, China, until Ho et al. (2010: 29) redescribed it on the basis of six specimens from Taiwan. Additional specimens were collected in southern Taiwan and Vietnam by bottom trawling at 100 to 300 m in depth. The first author also examined three specimens (SFC 11619, SFC 7-4978-1, and SFC 14031) labeled as paratypes of *N. parvipectoralis*. The original description (Chu et al. 1981) was stated to be based on a

single specimen; however, we presume that the authors examined these three additional specimens, which were also not treated as types by Chu et al. (1981).

As stated earlier in this paper, we were unable to differentiate between *N. parvipectoralis* and *N. microtretus*. The vertebral difference between the two species (*N. microtretus* 151 vs. *N. parvipectoralis* 138 to 148) is minor but might be significant. The only known specimen of *N. microtretus* from the Red Sea has a vertebral

count beyond the range of Asian specimens of *N. parvipectoralis*. Considering the frequency of endemism in the Red Sea, we think this may be significant. The holotype of *N. microtretus* is a small, damaged specimen. Because these two taxa come from such disparate locations, we await adequate material of both species before a determination can be made.

***Neenchelys pelagica* sp. nov.**

Common name: Pelagic worm eel

(Figure 8A,B,C,D and Tables 3 and 4)

Holotype: NMMB-P15556 (392 mm), a ripe female, Tungkang Fishing Port, SW Taiwan, northern South China Sea, midwater shrimp trawl, 10 September 2009, coll. H.-C. Ho.

Paratypes: CAS 231943 (327 mm), a ripe female, USNM 401022 (353 mm), a fully ripe female, collected together with the holotype.

Etymology: From the Latin *pelagica*, in reference to its mesopelagic habitat.

Diagnosis: A species of *Neenchelys* distinguished by the combination of the following characters: body moderately elongate, relatively cylindrical, body depth 2.8 to 3.1 times in HL, 28 to 31 in TL; dorsal fin origin at midpoint of trunk, 1.0 to 1.4 times in HL behind gill opening; predorsal length 4.3 to 4.8 in TL; HL 9.8 to 10.2 in TL; tail 1.5 in TL; pectoral fin well developed and relatively large, 3.8 to 4.6 in HL; total vertebrae 169; MVF 33-53-169. Cephalic lateral line pores 14; predorsal pores 36 or 37; preanal pores 56 or 57.

Description: Morphometric and meristic data are provided in Tables 3 and 4. The following proportions are given for the holotype, followed by values of the type series in parentheses. In TL: HL 10.0 (9.8 to 10.2); predorsal length 4.5 (4.3 to 4.8); trunk length 4.2 (4.0 to 4.3); preanal length 2.9 (2.9 to 3.0); tail length 1.5 (1.5). In HL: pectoral fin length 4.4 (3.8 to 4.6); snout length 5.5 (5.5 to 5.7); eye diameter 13.6 (13.6 to 16.5); upper jaw length 3.5 (3.4 to 3.6); interorbital width 7.7 (7.7 to 8.3); gill opening height 12.7 (12.7 to 15.1); body depth at gill opening 27.8 (27.8 to 33.6); body depth at anus 2.8 (2.8 to 3.1); body width at anus 3.1 (3.1 to 3.7).

Body moderately elongate, somewhat cylindrical, tail gradually compressed posteriorly; depth of body relatively uniform, tapering gradually to tail tip; depth of head subequal to that of body. Tail moderately long, anus at first 1/3 of body length. Dorsal and anal fins low and fleshy, continuous with a small but distinctly rayed caudal fin; origin of dorsal fin about one HL before a vertical through origin of anal fin. Pectoral fin relatively well developed, broad at base and pointed distally.

Head profile terete; snout acute anteriorly, tip of snout projecting well beyond lower jaw. Anterior nostril tubular, directed anteroventrally, its tube distinctly notched

dorsally. Posterior nostril in front of lower margin of eye, opening directed ventrally, appearing in lateral aspect as a diagonal slit, the posterior end of which is highest. Behind and below nostril and parallel to it with a groove that is longer than nasal slit. Snout broad and tumid. Lower jaw included, its tip reaching a line drawn between anterior margins of anterior nostrils. Angle of gape about one eye diameter behind a vertical through posterior margin of pigmented eyeball. Tongue well attached to mouth floor. Gill opening a narrow vertical slit, situated at anteroventral corner of pectoral fin base.

Head pores small (Figure 8B). Single median temporal and interorbital pores; supraorbital pores 1 + 4; infraorbital pores 5 + 1 (2 pores between anterior and posterior nostrils). Mandibular pores 7; preopercular pores 2; supratemporal pores 3.

Teeth slender (Figure 8C,D), pointed, tips directed posteriorly, anteriormost one in each series longest. Intermaxillary teeth 2 (2 or 3), well separated from that of vomer; vomerine teeth 8 (7 or 8), uniserial, with a pair of side teeth between second and third teeth, terminating posteriorly before end of maxillary tooth row; maxillary with 12 to 15 (10 to 15) small uniserial teeth, terminating posterior to gape; dentary with 19 to 21 (17 to 21) small uniserial teeth, terminating opposite end of maxillary teeth.

Lateral line incomplete, pores small and inconspicuous, extending to about one HL before caudal fin. Cephalic lateral line pores 14; predorsal pores 36 or 37; preanal pores 56 or 57.

Coloration: When fresh, pale gray with posterior end of dorsal and anal fin margins edged in black; in preservative, pale gray to light brown, with posterior end of dorsal and anal fins edged in black.

Distribution and ecological notes: Known from the type series collected from SW Taiwan, the northern portion of the South China Sea. Specimens were collected together with several mesopelagic fishes (myctophids, nemichthyids, nettastomatids, and *Harpadon* spp.), indicating that this species, like *N. daedalus*, may have a mesopelagic lifestyle and probably feeds on mesopelagic fishes and/or invertebrates.

Remarks: *Neenchelys pelagica* sp. nov. is most similar to *N. diaphora* sp. nov. described above. For a detailed comparison, see that of *N. diaphora* sp. nov. *Neenchelys pelagica* sp. nov. is also similar to *N. cheni*, *N. daedalus*, and *N. buitendijki* in having a well-developed pectoral fin. It differs from *N. cheni* by the dorsal fin origin being situated at midtrunk (vs. about above the anus), a larger pectoral fin, and an MVF of 33-53-169 (vs. 59-56-181). It differs from *N. daedalus* by having a more robust body (body depth 28 to 34 in TL vs. 46 to 52 in TL), an MVF of 33-53-169 (vs. 31-58-230), and different body proportions (see Tables 1 and 3). It differs from *N. buitendijki* by

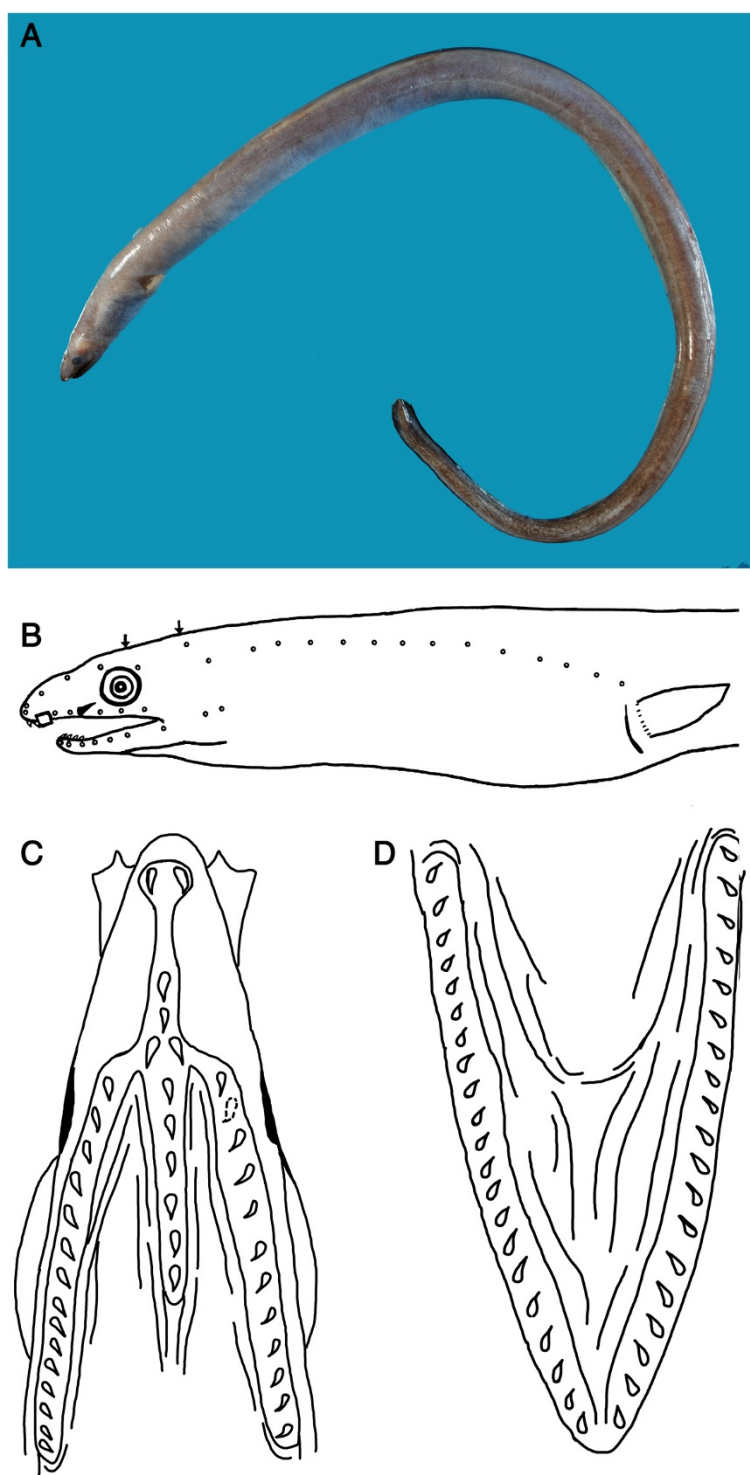


Figure 8 *Neeenchelys pelagica* sp. nov. (A) Holotype, NMMB-P15556, 392 mm TL, Tungkang, Taiwan, preserved condition. (B) Lateral view of head, with arrows indicating the frontal pore (left) and median supratemporal pore (right). (C) Upper jaw teeth. (D) Lower jaw teeth.

having a relatively rounded snout (vs. pointed), an MVF of 33-53-169 (vs. 19-50-140), and different body proportions (see Tables 1 and 3).

***Neeenchelys similis* sp. nov.**

Common name: Slender worm eel
(Figure 9A,B,C,D and Tables 3 and 4)

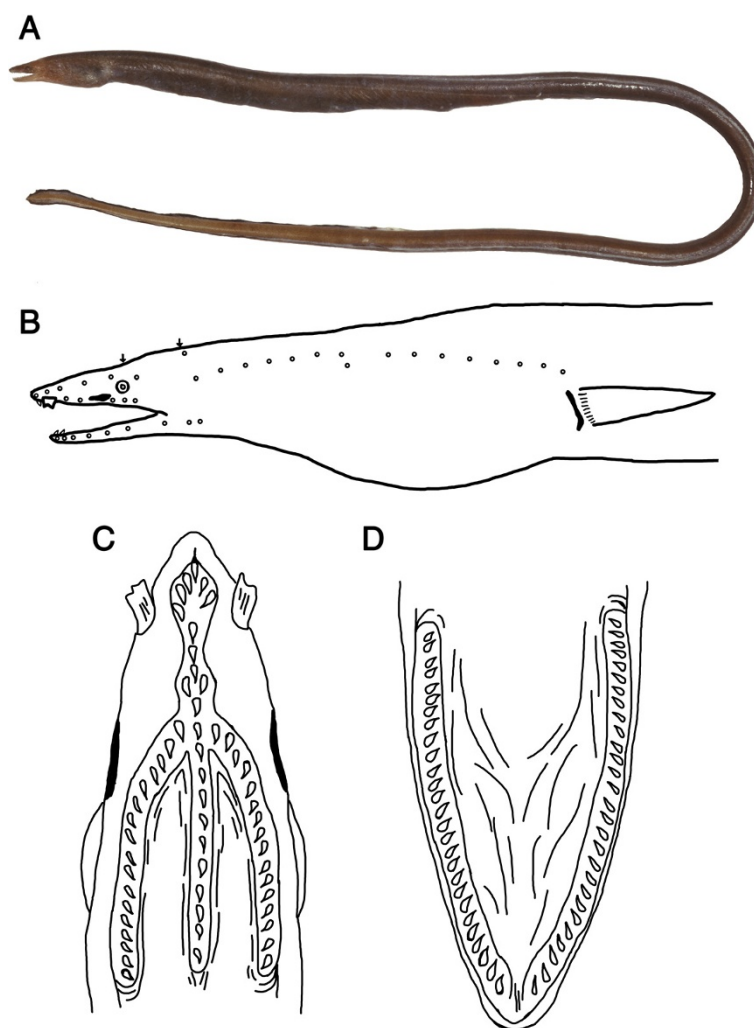


Figure 9 *Neenchelys similis* sp. nov. (A) Holotype, ASIZP 59925, 677 mm TL, Yilan, Taiwan, fresh condition. (B) Lateral view of head. (C) Upper jaw teeth. (D) Lower jaw teeth.

Synonymy: *Neenchelys daedalus* (non McCosker): McCosker 1982: 65 (non-types); Machida and Ohta 1993: 391 (description, Japan); Nakabo 2002: 217 (illustrated key, Japan); Chen 2007: 16 (description, Taiwan).

Holotype: ASIZP 59925, 677 mm, female with immature eggs, Tashi Fishing Port, Ilan, NE Taiwan, bottom trawl, 20 March 1998, coll. M.-L. Chiou.

Paratype: NSMT-P105355 (580 mm), 35°00'N, 138°40' E to 34°58.02'N, 138°40'E, Suruga Bay, Japan, 1,376 to 1,450 m, beam trawl, 13 November 1983, field no. ORIUT.KT.8318.11.0101. FRLM 38980 (756 mm), Nayaura, Minamiise, Mie, Japan, round haul net, 22 April 2011, coll. M. Okada. FRLM 42319 (714 mm), Nieura, Minamiise, Mie, Japan, round haul net, 6 March 2011, coll. M. Okada.

Non-types: AMS I.19707-017 (5, 172 to 187 mm), CAS 50709 (2, 187 to 225 mm), CAS 50710 (190 mm), ANSP 149295 (2, 175 to 185 mm), Manus Island, Papua New

Guinea, 04°15'S, 145°11'E, 6-ft IKMT, 0 to 125 m, over a bottom at 750+ m, FRV TAGULA, 22 October 1969, coll. J. E. Paxton; SIO 77 to 171 (144 mm), Banda Sea, 105 km SW of Buru I., 04°30.5'S, 125°34.6'E, 0 to 1500 m over a 3,600-m bottom, 26 August 1976, coll. J. Coatsworth.

Etymology: From the Latin *similis*, like, in reference to its similarity to its congener, *N. daedalus*.

Diagnosis: A species of *Neenchelys* distinguished by the combination of the following characters: body extremely elongate and slightly compressed, its depth 2.6 to 3.0 times in HL, 43 to 48 in TL; dorsal fin origin at anterior 1/3 of trunk, 1.0 to 1.3 times in HL behind gill opening; predorsal length 6.8 to 7.7 in TL; head relatively short, 15.1 to 16.3 in TL; trunk 4.6 to 4.8 in TL; tail extremely long, 1.4 in TL; pectoral fin well developed, longer than snout. Total vertebrae 260 to 265; MVF 34-68-262. Cephalic lateral line pores 15 to 16; predorsal pores 35 to 37; preanal pores 70 or 71.

Description: Morphometric and meristic data are provided in Tables 3 and 4. The following proportions are given for the holotype, followed by all types in parentheses. HL relatively short, 16.3 (15.1 to 16.3) in TL; origin of dorsal fin about 1 to 1.3 HL behind a vertical through gill opening, predorsal length 7.1 (6.8 to 7.7) in TL; trunk relatively short, its length 4.7 (4.6 to 4.8) in TL; anus at first 1/3 to 1/4 of body length; origin of anal fin immediately behind anus, preanal length 3.6 (3.5 to 3.7) in TL; tail relatively long, tail length 1.4 (1.4) in TL.

Body elongate, trunk somewhat cylindrical with gradually compressed tail posteriorly; body width at anus 4.0 (3.6 to 4.4) in HL; body depth relatively uniform, depth at anus 2.6 (2.6 to 3.0) in HL, tapering gradually to tip of tail; depth of head subequal to depth of body, 2.9 (2.9 to 3.4) in HL. Dorsal and anal fins low and fleshy, continuous with a small but distinct rayed caudal fin. Pectoral fin well developed, broad at base and pointed distally, its length 3.8 (3.8 to 4.2) in HL.

Head terete in profile; snout acute anteriorly and broad dorsally, snout length 5.5 (5.5 to 6.4) in HL; tip of snout projecting well beyond lower jaw; eye covered by a thick and semitransparent membrane; orbital width 18.9 (16.9 to 20.4) in HL; interorbital space relatively narrow, slightly elevated, its width 10.9 (10.9 to 15.9) in HL; postorbital space relatively wide, its width 1.2 (1.2 to 1.3) in HL. Anterior nostril tubular, directed anteroventrally, its tube distinctly notched. Posterior nostril before lower margin of eye, opening directed ventrally, appearing in lateral aspect as a diagonal slit, the posterior end of which is highest. Behind, below, and paralleling the nostril with a groove that is longer than nasal slit. Lower jaw included, its tip reaching a line drawn between anterior margins of anterior nostrils. Angle of gape about one eye diameter behind a vertical through posterior margin of pigmented eyeball; rictus length 3.5 (3.0 to 3.7) in HL. Tongue well attached to mouth floor. Gill opening a narrow vertical slit situated at anteroventral corner of pectoral fin base, its height 12.2 (12.2 to 19.4) in HL.

Head pores small (Figure 9B), difficult to observe. Single median temporal and interorbital pores; supraorbital pores 1 + 4; infraorbital pores 5 + 1 (2 pores between anterior and posterior nostrils); mandibular pores 7 (6 or 7); preopercular pores 2; supratemporal pores 3. Lateral line incomplete, pores small and inconspicuous, extending posteriorly to about 2/3 of TL. Cephalic lateral line pores 16 (15 to 16); predorsal pores 36 (35 to 37); preanal pores 71 (70 or 71).

Teeth (Figure 9C,D) slender, pointed, tips directed backward, anterior few teeth in each series longest. Intermaxillary teeth 6 (5 to 6), well separated from those on vomer; vomerine teeth 15 (12 to 15), uniserial with a pair of side teeth between third and fourth teeth (between second and

third in paratype), terminating posteriorly before end of maxillary tooth row; maxillary with 16 or 17 (16 to 18) small teeth, uniserial, terminating posterior to gape; dentary with 27 or 28 (26 to 28) small teeth, uniserial, terminating opposite end of maxillary tooth row (based on holotype and NSMT-P105355).

Coloration: In preservative uniform yellowish brown, with posterior portion of dorsal and anal fins edged in black.

Distribution and habitat: Known from Japan, Taiwan, New Guinea, and the Banda Sea. It was collected in mid-water at depths of 0 to 1,500 m over bottom depths to 3,600 m.

Remarks: McCosker (1982) included this species under his newly described *N. daedalus*, noting the difference in vertebral number and excluding them from the type series. Specimens were subsequently reported from Japan (Machida and Ohta 1993) and Taiwan (Chen 2007); we describe them as this new species. It is notable that the non-types have a wider range of total vertebrae than those of type series (251 to 274 vs. 260 to 265). It may provide a broader range of the total vertebrae when more specimens are available.

After this paper was accepted, before going in press, Mr. Y. Hibino (personal communication, 23 June 2013) of Mie University kindly informed the senior author the presence of two specimens of *N. similis* sp. nov. collected from Mie, Japan. The senior author examined the photos and the morphological and meristic data of these two specimens which agree well with those of type series. These two specimens were recognized as additional paratypes of *N. similis* sp. nov., and these data were combined into the text and tables.

A key to species of *Neenchelys*

- 1A. Origin of dorsal fin above or behind level of anal opening.....*N. cheni* (Indo-west Pacific)
- 1B. Origin of dorsal fin well before anal opening.....2
- 2A. Pectoral fin minute, a tiny flap, shorter than snout.....3
- 2B. Pectoral fin well developed, longer than snout.....5
- 3A. Head short, 13.0 to 15.6 times in TL; total vertebrae 172 to 184.....*N. mccoskeri* (West Pacific: Japan and Taiwan)
- 3B. Head long, 8.8 to 9.9 times in TL; total vertebrae 138 to 151.....4
- 4A. Total vertebrae 151.....*N. microtretus* (Red Sea)
- 4B. Total vertebrae 138 to 148.....*N. parvipectoralis* (South China Sea)
- 5A. Body and tail extremely elongate, body depth behind gill openings 54 to 55 in TL; total vertebrae 225 to 265.....6
- 5B. Body and tail moderately robust, body depth behind gill openings <40 in TL; total vertebrae <170.....7

- 6A. Lower jaw with five mandibular pores; total vertebrae 225 to 235.....*N. daedalus* (Papua New Guinea)
- 6B. Lower jaw with six or seven mandibular pores; total vertebrae 251 to 274.....
.....*N. similis* sp. nov. (West Pacific: Japan and Taiwan)
- 7A. Dorsal fin origin at anterior 1/5 of trunk, 0.4 to 0.5 HL behind gill opening; total vertebrae 135 to 148.....*N. buitendijki* (Indo-west Pacific)
- 7B. Dorsal fin origin at midpoint of trunk, 1.0 to 1.4 HL behind gill opening; total vertebrae 169 or more.....8
- 8A. Total vertebrae 169; mandibular pores 7; gill opening height 6.6% to 7.9% of HL.....
.....*N. pelagica* sp. nov. (South China Sea: Taiwan)
- 8B. Total vertebrae 177 to 186; mandibular pores 6; gill opening height 8.8% to 12.6% of HL.....
.....*N. diaphora* sp. nov. (South China Sea: Taiwan)

Results and discussion

Smith and Böhlke (1983: 83) discussed the problem of defining genera among the myrophine eels in which the posterior nostril opening is above the lip. Two of the characters they emphasized, the degree of development of the pectoral fin and the position of the dorsal fin origin, now appear less significant. The pectoral fin of the species treated here varied from well developed to rudimentary, and the dorsal origin varied from shortly behind the gill opening to behind the anus. Of the five groups mentioned by Smith and Böhlke (1983), *Benthenchelys* is the most distinct and can largely be eliminated from the discussion. It is small, short-headed, and large-eyed and possesses osteological characters that merit its recognition as a tribal sister group to the Myrophini (McCosker 1977). They also separated *N. daedalus* from other species known at the time (*N. microtretus*, *N. buitendijki*, and *N. parvipectoralis*) by its pelagic habits and dorsal fin origin, but as we have shown, this species conforms well with the others. That leaves only *Neenchelys* (as treated here) and *Pseudomyrophis* (which is known from the Atlantic and eastern Pacific).

A monotypic myrophine genus, *Pylorobanchus* (type species *Pylorobanchus hoi* McCosker, Chen and Lin, in McCosker et al. 2012), was recently described by McCosker et al. (2012) based on a series of large deep-water eels captured off eastern Taiwan. It is similar to species of *Neenchelys* and *Pseudomyrophis* in having the posterior nostril above the upper lip, but differs in being much more robust, having elongate jaws that do not completely close, and in possessing a third preopercular pore.

Eels of the genus *Neenchelys* appear to represent a closely related group, characterized by the position and form of the posterior nostril. It is a somewhat elongate slit on the side of the head above the lip, oriented

obliquely in an anteroventral to posterodorsal direction, and is completely exposed (i.e., without a flap). Other characters include the terete form of the head and the presence of at least a rudimentary pectoral fin. A few other Indo-west Pacific myrophines, e.g., species of *Skythrenchelys* and *Muraenichthys*, also have the posterior nostril above the lip, but they greatly differ in appearance, with shorter heads and blunter snouts (Castle and McCosker 1999). Their posterior nostril is smaller than that of *Neenchelys* and is preceded by a dermal flap. Moreover, they lack all traces of a pectoral fin.

Species of *Neenchelys* most closely resemble those of *Pseudomyrophis*, which are found in the Atlantic and eastern Pacific. They share numerous osteological characters and have a similar posterior nostril condition. Prior to subsequent descriptions of several species of both genera, Nelson (1966) examined the osteology of *N. buitendijki* and commented upon Wade's description of *Pseudomyrophis micropinna* Wade 1946, the type of his new genus. Nelson stated that 'there is no character significant enough to maintain *Pseudomyrophis* as a genus distinct from *Neenchelys*. *Pseudomyrophis nimius* Böhlke 1960, on the other hand, seems distinctive enough to be placed in a genus of its own.' McCosker (1977: 60–61) was later able to examine the osteology of *P. micropinna* and *P. nimius* and found them to be congeners. He separated species of *Neenchelys* from those of *Pseudomyrophis* on the basis of snout shapes (conical vs. broad), third preopercular pore (absent vs. present), and subopercle condition (small and subrectangular vs. produced posteriorly along the ventral and posterior margins of the opercle).

The larvae provide further evidence for distinguishing between *Neenchelys* and *Pseudomyrophis*. Castle (1980) described larvae of two species of *Neenchelys* from the western Pacific as being characterized by a short gut, relatively deep body, four gut swellings, and a distinctive series of lateral pigment spots. There are three horizontally elongate streaks of melanophores along the midline at about midbody, with an additional group of melanophores just above and below the posterior lateral streak (Figure 10A). These larvae are quite distinct from those described for *Pseudomyrophis* (Blache 1977: 98–204; Leiby 1989: 774–786), which are more elongate, with more gut swellings and more lateral melanophores (Figure 10B). Significantly, larvae of the *Neenchelys* type have never been found in the Atlantic, where adults of *Pseudomyrophis* occur.

Species of *Neenchelys* are characterized by variations in several characters. *Neenchelys daedalus* and *N. similis* sp. nov. have extremely elongate bodies, with a maximum depth of 43 to 52 in TL. *Neenchelys mccoskeri* is moderately elongate, with a maximum body depth of 31 to 57 in TL. The remaining species are more robust,

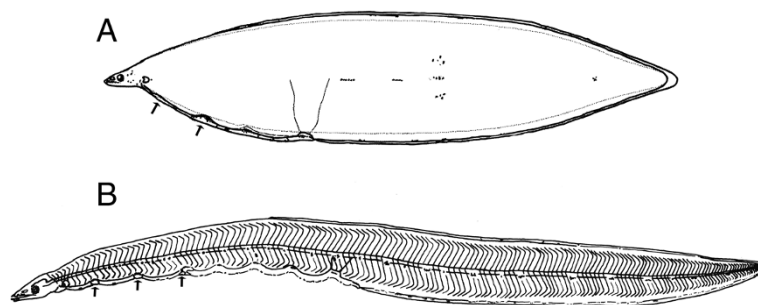


Figure 10 *Neenchelys microtretus* (A), leptocephalus, 75 mm TL. Modified from Castle, 1980, Figure one A. *Pseudomyrophis* sp. (B), euryodontic stage, FDNR 16560L, 45 mm TL. Modified from Leiby, 1989, Figure seven hundred and seventy four. Arrows indicate the liver lobes. Not to scale.

with body depths of 19 to 40 in TL. *Neenchelys diaphora* sp. nov., *N. cheni*, *N. mccoskeri*, and *N. pelagica* sp. nov. are the largest of the species, reaching about 400 mm TL or more. The remaining species grow to about 300 mm.

The pectoral fin varies greatly in size. *Neenchelys buitendijki*, *N. daedalus*, *N. diaphora* sp. nov., *N. pelagica* sp. nov., and *N. similis* sp. nov. have a well-developed pectoral fin, 20% or more of the HL. *Neenchelys cheni* has a smaller but still prominent pectoral fin, at 10.3% to 16.4% of HL. In *N. mccoskeri*, *N. microtretus*, and *N. parvipectoralis*, the pectoral fin is reduced to little more than a rudiment, of no more than 1.2% to 4.2% of the HL (data only from *N. mccoskeri* and *N. parvipectoralis*, but presumed for *N. microtretus*). The position of the dorsal fin origin also greatly varies among species. In *N. cheni*, it is far posterior, over or behind the anus. In *N. diaphora* sp. nov., *N. mccoskeri*, and *N. pelagica* sp. nov., the dorsal origin is at about midtrunk. The dorsal origin of the remaining species is at the anterior 1/5 to 2/5 of the trunk.

Sensory pores on the head and body show some variation among species. The infraorbital series contains 5 + 1 pores in all species, except for *N. cheni* and *N. mccoskeri* which occasionally have 5 + 2. Supraorbital series contains 1 + 4 pores in all species, except for *N. cheni* which occasionally has 1 + 5. Mandibular pores number 5 or 6 (mainly 5) in *N. cheni*, *N. daedalus*, and *N. microtretus*; 6 in *N. diaphora* sp. nov.; 6 or 7 in *N. parvipectoralis*; and 7 in *N. buitendijki*, *N. mccoskeri* (6 or 7, mainly 7), *N. pelagica* sp. nov., and *N. similis* sp. nov. Predorsal lateral line pores vary among species, reflecting a variation in the position of the dorsal fin origin. The number of preanal pores can also be used to distinguish some of the species.

Finally, species differ in their habitat. *Neenchelys daedalus*, *N. pelagica* sp. nov., and *N. similis* sp. nov. are the only members of the Ophichthidae other than *Benthenchelys* that live in midwater as adults. There is some evidence that *N. cheni* may live pelagically as well,

at least in part of its life, but the remaining species are all benthic. It is possible that pelagic-living species tend to have a well-developed pectoral fin, whereas bottom living species have strongly reduced pectoral fins. Some members with a well-developed pectoral fin might be benthopelagic, living and/or feeding near the bottom.

Conclusions

The knowledge of the Indo-west Pacific worm eel genus *Neenchelys* has been greatly improved. Totally, nine species are recognized currently, including three newly described species. Data are provided on the basis of type series together with specimens newly collected from a broader range. New diagnostic characters are employed for recognizing the congeners and to establish the new species. A key to all known species of *Neenchelys* is provided for the first time. This study would provide a good example in terms of understanding the world eel diversity and their geographic distributions. Intensive collections are needed for further understanding of the biology and ecology of this group.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

H-CH collected most specimens for this study, conducted the eel study in Taiwan, gathered all information, and prepared the early draft. H-CH, JEM, and DGS conceived the study, each examined at least part of the type series of those nominal species, provided data, discussed the taxonomic problems, and completed the manuscript. All authors read and approve the final manuscript.

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