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DE GRUYTER

New Species of *Falcaustra* (Nematoda: Kathlaniidae) in *Batagur trivittata* (Testudines: Geoemydidae) from Myanmar

Charles R. Bursey[1]* and Steven G. Platt[2]

[1]Department of Biology, Pennsylvania State University, Shenango Campus, Sharon, Pennsylvania, 16146 USA;
[2]Wildlife Conservation Society – Myanmar Program, No. 12, Nanrattaw St., Kamayut Township, Yangon, Myanmar

Abstract

Falcaustra tintlwini sp. nov. (Ascaridida, Kathlaniidae) from the large intestine of *Batagur trivittata* (Testudines, Geoemydidae) is described and illustrated. *Falcaustra tintlwini* represents the 20th Oriental species assigned to the genus and is distinguished from other Oriental species by the distribution pattern of the caudal papillae (6 precloacal, 12 postcloacal, and 1 median), length of spicules (0.43-0.50 mm) and absence of a pseudosucker.

Keywords

Nematoda, *Falcaustra tintlwini* sp. nov., Testudines, *Batagur trivittata*, Myanmar

Introduction

The Burmese Roofed turtle, *Batagur trivittata* (Duméril and Bibron, 1835), IUCN listed as critically endangered, is endemic to the larger rivers (Ayeyarwady, Chindwin, Sittang, and Thanlwin) of Myanmar (formerly Burma) (Rhodin *et al.* 2017). Historical sources indicate that these large riverine turtles were once abundant, but precipitously declined as the result of long-term chronic egg harvesting, loss of sandbank nesting habitat, and incidental take in fisheries gear (Rhodin *et al.* 2011; Horne *et al.* 2012). By the late 1990s, *B. trivittata* was feared extinct until two small remnant populations were discovered in the Dokhtawady and Chindwin Rivers (Platt *et al.* 2005; Kuchling *et al.* 2006). Today, only a single population consisting of about 12 adults remains in the wild (Cilingir *et al.* 2017) making *B. trivittata* among the most critically endangered turtles in the world (Rhodin *et al.* 2011; Horne *et al.* 2012). *Ex-situ* conservation efforts for *B. trivittata* were initiated in 2002 (Kuchling and Tint Lwin 2004; Platt and Platt 2016) and >700 individuals are held in three captive-breeding and head-starting centers (Cilingir *et al.* 2017). To our knowledge there is only one relevant parasitological study: Sullivan (1976) described a trematode, *Parapleurogonius brevicecum*, taken from an individual turtle purchased at a local market in Kuala Lumpur, Malaysia, in November, 1974, which he identified as *Batagur trivittata*. Sullivan (1974) was unable to identify the specific provenance of the individual, but stated that the turtle was captured in the "Selangor (Malaysian) jungle". Because *B. trivittata* is restricted to Myanmar (Rhodin *et al.* 2017), Sullivan (1974) is almost certainly in error, most likely having confused *B. borneoensis* for *B. trivittata* due to similarities in body size and coloration of males of the two species, particularly during the breeding season (see reference figures in Rhodin *et al.* 2017). Therefore, we believe our study constitutes the only report of endoparasites from *B. trivittata*.

Species of *Falcaustra* Lane, 1915 occur in the digestive tracts of fish, amphibians, and reptiles (Bursey *et al.* 2000). Of the 104 nominal species (Bursey *et al.* 2018), 19 are known from the Oriental Region. The purpose of this paper is to describe a new species of *Falcaustra* from the large intestines of *Batagur trivittata*.

Materials and Methods

Nematodes were collected 1 March 2017, during the annual deworming of a group of head-started, subadult *B. trivittata* housed at a rearing facility (described in Platt *et al.* 2017) in Limpha Village, Sagaing Region, Myanmar. Turtles are regularly dewormed once every year in February or March with Panacur, orally administered at a dosage of 50 mg/kg of body weight. These turtles originated from eggs deposited by wild

*Corresponding author: cxb13@psu.edu

females in sandbanks along the Chindwin River near Limpha Village (Platt and Platt 2016; Platt *et al.* 2017). The nematodes were fixed in alcohol and later cleared in undiluted glycerol for examination with a light microscope. Drawings were made with the aid of a microprojector. Measurements are in µm with mean ± 1 SD and range in parenthesis, unless otherwise stated. Selected nematode specimens were deposited in the Harold W. Manter Laboratory (HWML), University of Nebraska, Lincoln, Nebraska, USA.

Description

***Falcaustra tintlwini* sp. nov**. (Figs 1–8)

General: Family Kathlaniidae Lane, 1915. Nematodes with cylindrical body tapering posteriorly, truncate anteriorly. Cuticle with fine, regular, transverse striations. Mouth bounded by 3 lips, each with a pair of sessile papillae at anterior margin. Amphids flat, one on each ventrolateral lip. Esophagus with distinct isthmus, valved bulb. Excretory pore at level of isthmus. Long tail conical in both sexes.

Male (holotype, 11 paratypes): Length 18.54 ± 2.49 mm (15.0–22.0 mm); width at level of esophageal-intestinal junction 371 ± 68 (255–485). Lips 112 ± 11 (102–128) wide, 48 ± 6 (38–51) long. Esophagus 2,108 ± 180 (1,879–2,472) in length consisting of corpus with short anterior muscular portion 90 ± 10 (76–102) in length and long posterior glandular portion 2,017 ± 178 (1,790–2,370) in length by 119 ± 12 (102–129) wide throughout; isthmus 232 ± 30 (153–280) in length by 127 ± 12 (102–140) wide; and valved bulb 276 ± 45 (204–332) in length by 229 ± 35 (179–293) wide. Nerve ring 587 ± 84 (512–768) and excretory pore 1,703 ± 178 (1,472–2,048) from anterior end, respectively. Pseudosucker absent. Approximately 18 pairs of poorly defined oblique ventral muscles in a single field beginning slightly anterior to cloaca and extending anteriorly. Conical tail 2,016 ± 143 (1,856–2,240) in length. Nine pairs of caudal papillae (three pairs precloacal, six pairs postcloacal; of the postcloacal papillae, five pairs ventral in position, equidistant from each other, and located near middle of tail, one pair ventral in position, slightly behind cloacal meatus, single median papilla immediately anterior to cloacal meatus. Phasmids 1000 from posterior end, lateral to fifth (from anterior) post cloacal papillae. Spicules similar in shape, 487 ± 37 (434–561) in length, approximately 50 wide at midpont, slightly curved, alate, distal end blunt, proximal end slightly expanded. Gubernaculum 186 ± 19 (166–230) in length, blunt distal tip.

Female (allotype, 11 paratypes): Length 18.88 ± 2.74 mm (15.0–24.0 mm), width at level of esophageal-intestinal junction 481 ± 87 (306–587). Lips 131 ± 17 (102–153) wide, 60 ± 13 (38–77) long. Esophagus consisting of corpus 2,087 ± 177 (1,574–2,265) in length with anterior muscular portion 89 ± 10 (76–102) in length, posterior glandular portion 1,984 ± 187 (1,472–2,176) in length by 115 ± 18 (89–140) wide throughout; isthmus 247 ± 24 (204–281) in length by 126 ± 22 (77–168) wide; valved bulb 289 ± 33 (204–332) in length by 244 ± 33 (179–292) wide. Nerve ring 561 ± 43 (512–640) and excretory pore 2,205 ± 162 (1,984–2,560) from anterior end. Vulva transverse slit, 11.80 ± 1.77 mm (9.0–15.0 mm) from anterior end; vagina directed anteriodorsally, giving rise to two divergent uteri. Eggs (n = 20) oval, 118 ± 7 (104–128) in length by 79 ± 5 (73–85) wide, thick shelled, unembryonated. Rectum separated from intestine by well-developed valve; thick cuticular lining present. Tail conical, 2,518 ± 310 (2,048–2,944) in length.

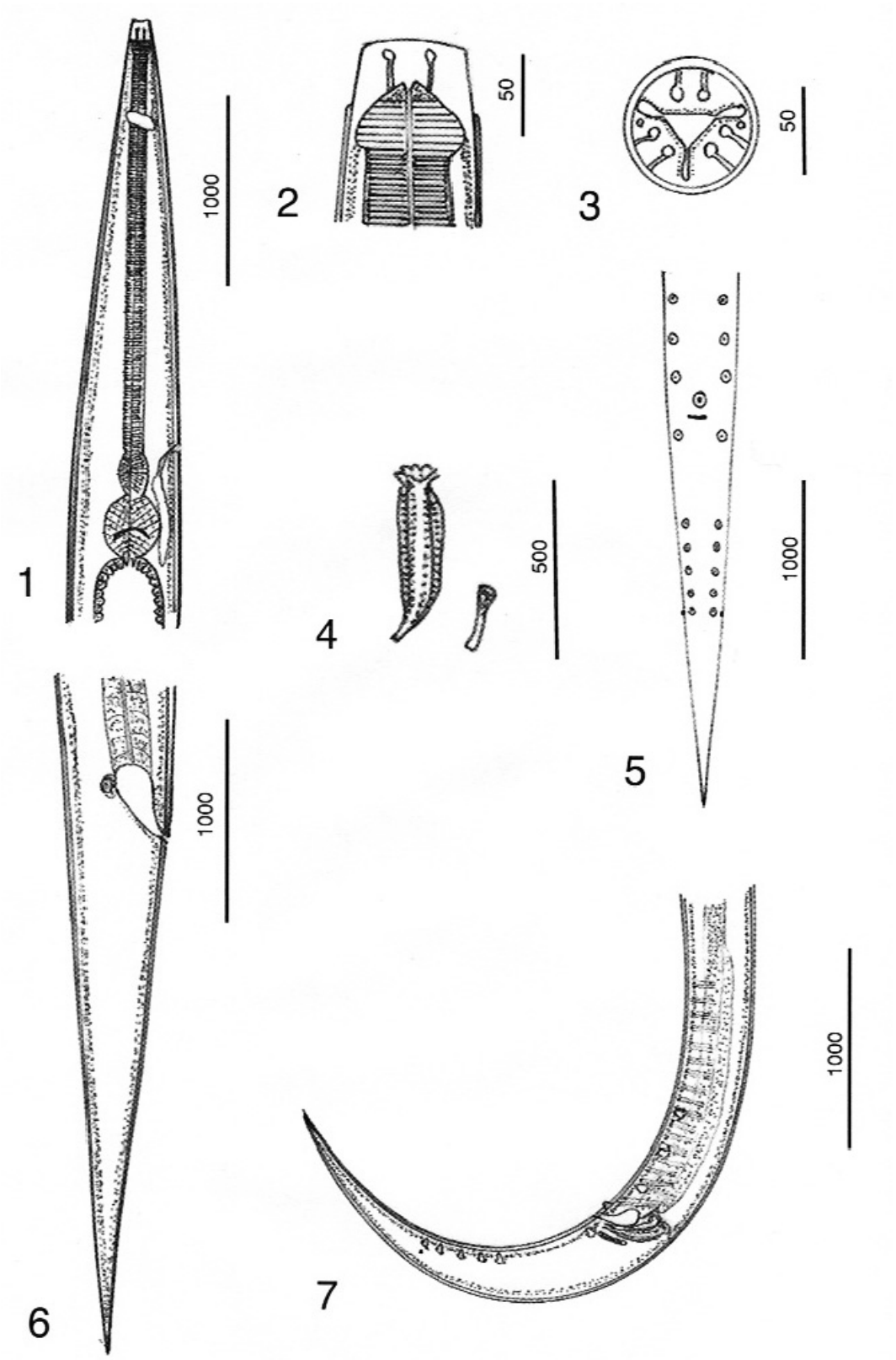
Taxonomic summary

Type host*:* subadult *Batagur trivittata* (Duméral and Bibron, 1835), Burmese Roofed Turtle. Collection date: 1 March, 2017.
Type locality: Limpha Village, Sagaing Region, Myanmar.
Site of infection: Large intestine (collected from fecal mass).
Type specimens*:* Holotype male, HWML 110372; allotype female, HWML 110373; paratypes HWML 110374; voucher HWML 110375.
Etymology: The new species is named for Myanmar's foremost exotic animal veterinarian Tint Lwin.

Remarks

The structure of the esophagus of *Falcaustra tintlwini* allows its assignment to Kathlaniidae Lane 1914. Chabaud (1978) characterized *Falcaustra* as having a generally spherical isthmus immediately anterior to the esophageal bulb. Lane (1915) described the posterior portion of the esophagus to be hourglass shaped, while Chitwood and Chitwood (1974) stated that the isthmus in kathlaniid nematodes is subspheroid. This character is evident in *F. tintlwini.* Anderson *et al.* (2009) in their key to the Kathlaniidae use lip structure, i.e., "three or six well-developed lips present" vs. "lips poorly developed" to define the genus *Falcaustra*. A distinct lip development is evident in *F. tintlwini*.

Species of *Falcaustra* are distinguished on the basis of male characteristics: number and arrangement of caudal papillae, length of spicules, and presence or absence of a pseudosucker. Of the 35 species previously reported from the Oriental biogeographical region (Table I), 19 have been described from turtle hosts, *F. annandalei*, *F. bengalensis*, *F. duyagi*, *F. falcatai*, *F. fernandois*, *F. greineri*, *F. heosemydis*, *F. kempi*, *F. kinsellai*, *F. kutcheri*, *F. manouriacola*, *F. onama*, *F. pillaii*, *F. purvisi*, *F. rangoonica*, *F. roberti*, *F. siamensis*, *F. stewarti*, *F. testudinisi*, of which, a pseudosucker is absent in 9, *F. bengalensis*, *F. falcate*, *F. fernandoi*, *F. greineri*, *F. heosemydis*, *F. kutcheri*, *F. pillaii*, *F. stewarti*, *F. testudinis.* Of these, adcloacal papillae are absent in *F. bengalensis*, *F. greineri*, *F. heosemydis*, *F. stewarti* and *F. tintlwini* sp. nov. *F. bengalensis* has 38 postcloacal papillae, *F. stewarti* 30–34, *F. greineri*, 14; F. *heosemydis* has 12 as does *F. tintlwini* sp. nov. However, *F. tintlwini* has the longest tail of any currently described species of *Falcaustra* that infect Oriental turtles (Table I).



Figs 1 – 8. *Falcaustra tintlwini sp. nov.* **1. –** Female, anterior end, lateral view. **2. –** Female, anterior end, dorsal view. **3. –** Female, en face view. **4. –** Egg. **5. –** Male, papillae arrangement. **6. –** Female, posterior end, lateral view. **7. –** Spicules and gubernaculum. 8**. –** Male, posterior end, lateral view. Measurements in micrometers

Table I. Selected characteristics of male individuals of species of *Falcaustra* from the Oriental biogeographical region*

Type host	Body length	Spicule length	Papillae pattern**	Pseudosucker		Tail length	Reference
***Falcaustra* sp.**	(mm)	(mm)		(mm)			
F. annandalei (Baylis and Daubney, 1922) Chabaud and Golvan, 1957 = *Zanclophorus annandalei* Baylis and Daubney, 1922	turtle	15.5–15.9	2.20–2.30	12 – 0 – 8 + 1	one	0.45–0.50	Baylis and Daubney, 1922
F. barbi Baylis and Daubney, 1922 = *Spironoura kalasiensis* Karve and Naik, 1951 = *Spironoura sudanensis* Khalil, 1962	fish	15.2–16.5	1.13	6 – 0 –14 + 1	one	0.60	Baylis and Daubney, 1922
F. bengalensis Manna and Mahapatra, 1989	turtle	12.7–13.5	0.45–0.51	8 – 0 –38	absent	not stated	Manna and Mahapatra, 1989
F. brevicaudatum (Khan and Yaseen, 1969) Soota, 1983 = *F. brevicaudatum* Khan and Yaseen, 1969	fish	10.2–11.5	0.5 + 1.77	10 –2 – 8	one	0.38	Khan and Yaseen, 1969
F. chauhani (Soota, 1975) Petter, 1979 = *Spironoura chauhani* Soota, 1975	fish	7.7—10.8	0.41–0.44	6 – 6 –8 + 1	absent	0.33–0.44	Soota, 1975
F. desilvai Bursey, Goldberg and Bauer, 2009	lizard	6.3–8.0	0.96–1.05	12 –2 –10 + 1	absent	0.21–0.29	Bursey *et al*., 2009
F. dubia Yuen, 1963	frog	13.5–14.0	1.54–1.69	6 – 2 –12 + 1	one	0.29–0.30	Yuen, 1963
F. duyagi (Tubanqui and Villaamil, 1933) Freitas and Lent, 1941 = *Spironoura duyagi* Tubangui and Villaamil, 1933	turtle	11.5–13.0	0.75–0.90	10 –0 –10 + 1	two-three	0.47–0.50	Tubangui and Villaamil, 1933
F. falcata (Linstow, 1906) Lane, 1915 = *Oxysoma falcata* Linstow, 1906 = *Oxysoma kachugae* Steward, 1914 = *Spironoura brevispiculata* Baylis, 1935	turtle	13.0–14.0	0.35–0.45	4 – 2 –14 + 1	absent	0.58	Lane, 1915
F. fernandoi (Sathananthan, 1972) Baker, 1987 = *Spironoura fernandoi* Sathananthan, 1972	turtle	7.0	1.70–1.80	6 –6 –8 + 1	absent	0.36	Sathananthan, 1971
F. greineri Bursey and Kinsella, 2003	turtle	14.0–17.5	1.07–1.33	6–0–14 + 1	absent	0.64–0.89	Bursey and Kinsella, 2003
F. heosemydis Bursey, Goldberg and Miller, 2004	turtle	13.2–14.7	0.79–0.89	10 –0 –12 + 1	absent	0.54–0.61	Bursey *et al*., 2004
F. kalasiensis (Karve and Naik, 1951) Vassiliades and Troncy, 1973 = *Spironoura kalasiensis* Karve and Naik, 1951	fish	11.4–11.7	0.45–0.55	6 – 0 –14 + 1	one	0.44–0.45	Karve and Naik, 1951
F. kaverii (Karve and Naik, 1951) Vassiliades and Troncy, 1973 = *Spironoura kaverii* Karve and Naik, 1951	fish	13.7–15.5	2.00–2.23	6 –0 –16 + 1	one	0.48–0.51	Karve and Naik, 1951
F. kempi (Baylis and Daubney, 1922) Chabaud and Golvan, 1957 = *Zanclophorus kempi* Baylis and Daubney, 1922	turtle	10.9–12.8	2.90	10 –0 –8 + 1	one	0.45–0.55	Baylis and Daubney, 1922
F. khadrai (Karve, 1941) Chabaud and Golvan, 1957 = *Spironoura khadrai* Karve, 1941	fish	1.2–14.3	0.35–0.38	10 –0 –10 + 1	absent	0.36–0.37	Karve, 1941
F. kinsellai Bursey and Freeman 2005	turtle	9.6–10.2	0.43–0.45	6 –6 –10 + 1	one	0.43–0.51	Bursey and Freeman, 2005
F. kutcheri Bursey, Platt and Rainwater, 2000	turtle	13.0	0.38	8 –2 – 10 + 1	absent	0.92	Bursey *et al*., 2000
F. leptocephala Baylis and Daubney, 1922	fish	19.0	1.00	6 – 4 – 10 + 1	absent	0.70–0.85	Baylis and Daubney, 1922
F. malaiysiaia Bursey, Goldberg and Grismer, 2014	lizard	8.3–8.9	1.31–1.37	6 – 2 – 12 +1	one	0.31	Buraey *et al*., 2014

F. manouriacola Bursey and Rivera, 2009	turtle	18.0–25.5	4.67–4.80	10 –2 –8	one	0.64–0.74	Bursey and Rivera, 2009
F. nilgiriensis (Soota and Chaturvedi, 1971) Petter, 1979	fish	7.5–9.6	0.24–0.35	6–0–14 + 1	absent	0.29–0.35	Soota and Chaturvedi, 1971
= *Spironoura nilgiriensis* Soota and Chaturvedi, 1971							
F. onama (Karve, 1927) Freitas and Lent, 1941	turtle	8.3–8.5	0.81	6 –4 –10 + 1	one	0.38	Karve, 1927
= *Spironoura onama* Karve, 1927							
F. pahangi Yuen, 1963	toad	11.0	3.98	10 –0 –12 + 1	one	0.30	Yuen, 1963
F. pillaii (Sathananthan, 1972) Baker, 1987	turtle	9.0–10.4	1.33	6 –6 –10 + 1	absent	0.48–0.58	Sathananthan, 1972
= *Spironoura pillaii* Sathananthan, 1972							
F. purchoni Yuen, 1963	toad	10.0–11.0	1.07–1.15	8 – 0 –10 + 1	one	0.33–0.36	Yuen, 1963
F. purvisi (Baylis, 1933) Chabaud and Golvan, 1957	turtle	21.0–24.0	2.40–3.60	6 –6 –8	one	0.45–0.50	Baylis, 1933
= *Zanclophorus purvisi* Baylis, 1933							
F. rangoonica (Chatterji, 1936) Freitas and Lent, 1941	turtle	8.8–10.2	0.35–0.50	6 –4 –10 + 1	one	0.85	Chatterji, 1936
= *Spironoura ragoonica* Chatterji, 1936							
F. roberti (Chou and Lowe, 1984) Bursey and Kinsella, 2003	turtle	6.10–11.0	0.55–0.60	10–0–10	two	0.33–0.37	Chou and Lowe, 1984
= *Spironoura roberti* Chou and Lowe, 1984							
F. siamensis Baylis, 1920	turtle	15.9	0.86	6 –2– 12 + 2	three-four	0.9	Baylis, 1920
F. stewarti Baylis and Daubney, 1922	turtle	17.0–20.4	0.50–0.56	6– 0 –30/34 + 1	absent	1.40–1.70	Baylis and Daubney, 1922
F. stromateii (Bilqees and Khanum, 1971) Soota, 1983	fish	7.3	0.33 + 1.0	10 –2 – 10	one	0.24	Bilqees and Khanum, 1971
= *Kathlania stomateii* Bilquees and Khanum, 1971							
F. testudinis Baylis and Daubney, 1922	turtle	10.2–10.4	0.80	6 – 4 –12 + 1	absent	0.81	Baylis and Daubney, 1922
F. tintlwini sp. nov.	turtle	15.0–22.0	0.43–0.56	6 – 0 – 12 + 1	absent	2.86–2.24	This study
F. trilokiae (Singh, 1958) Chabaud, 1978	frog	6.9–9.6	0.25–0.29	4 –0 –6 + 1	absent	0.48–0.5	Singh, 1958
= *Velariocephalus trilokiae* Singh, 1958							

*Holt *et al*., 2013
**precloacal-adcloacal-postcloacal + median

Table II. Turtle hosts of Oriental species of *Falcaustra*

***Falcaustra* spp. (Oriental turtles)**	**Locality**	**Reference**	**Comment**
Host			
F. annandalei			
Indotestudo travancorica (Travancore Tortoise)	India	Baylis and Daubney, 1922	reported as *Testudo travancorica*
F. bengalensis Manna and Mahapatra, 1989			
Geoclemys hamiltoni (Black Pond Turtle)	India	Manna and Mahapatra, 1989	
F. duyagi			
Cuora amboinensis (Amboina Box Turtle)	Malaysia	Berry, 1984	
“	Philippines	Tubangui and Villaamil, 1933	reported as *Cyclemis amboinensis*
Cyclemys dentate (Asian Leaf Turtle)		Philippines	Schmidt and Kuntz, 1972
F. falcata			
Barbodes carnaticus (Carnatic carp)	India	Karve and Naik, 1951	reported as *Puntius carnatius*
Euphlyctis hexadactylus (Indian Bullfrog)	India	Naidu, 1975	reported as *Rana hexadactyla*
“	Sri Lanka	Baylis, 1935	reported as *Rana hexadactyla*
Melanochelys trijuga (Indian Black Turtle)	Sir Lanka	Linstow, 1906	reported as *Nicoria trijuga*
Batagur kachuga (Red-crowned Roofed Turtle)	India	Stewart, 1914	reported as *Kachuga lineata*
F. fernandoi			
Melanochelys trijuga (Indian Black Turtle)	Sir Lanka	Sathanathan, 1972	reported as *Geoemyda trijuga thermalis*
F. greineri			
Orlitia borneensis (Malaysian Giant Turtle)	Malaysia	Bursey and Kinsella, 2003	
F. heosemydis			
Heosemys depressa (Arakan Forest Turtle)	Burma	Bursey, Goldberg and Miller, 2004	
F. kempi			
Indotestudo elongata (Elongated Tortoise)	India	Baylis and Daubney, 1922	reported as *Testudo elongata*
F. kinsellai			
Heosemys grandis (Giant Asian Pond Turtle)	Malaysia	Bursey and Feeman 2005	
F. kutcheri			
Leucocephalon yuwonoi (Sulawesi Forest Turtle)	Sulawesi, Indonesia	Bursey, Platt and Rainwater, 2000	reported as *Geoemyda yuwonoi*
F. manouriacola			
Manouria impressa (Impressed Tortoise)	Malaysia	Bursey and Rivera, 2009	
F. onama			
Morenia ocellata (Burmese Eyed Turtle)	Burma	Chatterji, 1936	
Manouria emys (Brown Tortoise)	Burma	Karve, 1927	reported as *Testudo emys*
“		Singapore	Balasingam, 1964
F. pillaii			
Melanochelys trijuga (Indian Black Turtle)	Sri Lanka	Sathanathan, 1972	reported as *Geoemyda trijuga thermalis*
F. purvisi			

Heosemys grandis (Giant Asian Pond Turtle)	Malaysia	Baylis, 1933	
F. rangoonica			
Morenia ocellata (Burmese Eyed Turtle)	Burma	Chatterji, 1936	
F. roberti			
C uora amboinensis (Ambonia Box Turtl)	Singapore	Chou and Lowe, 1984	
F. siamensis			
Heosemys annandalii (Yellow-headed Temple Turtle)	Thailand	Baiylis, 1920	reported as *Hieremys annandalei*
Heosemys grandis (Giant Asian Pond Turtle)	Malaysia	Baylis, 1933	
F. stewarti			
Pangshura smithii (Brown Roofed Turtle)	India	Baylis and Daubney, 1922	reported as *Kachuga smithii*
Hardella thurgi (Brahminy River Turtle)	India	Baylis and Daubney, 1922	
B atagur dhongoka (Three-striped Roofed Turtle)	India	Jehan, 1970	reported as *Kachuga dhongoka*
Cuora mouhotii (Keeled Box Turtle)	South Vietnam	Berry, 1984	reported as *Cyclemys mouhoti*
F. tintlwini sp. nov.			
Batagur trivittata (Burmese Roofed Turtle)	Myanmar	This paper	
F. testudinis			
I ndotestudo elongata (Elongated Tortoise)	India	Baylis and Daubney, 1922	reported as *Testudo elongata*

Discussion

Of the 20 species of *Falcaustra* infecting Oriental turtles, 15 (75%) are known from a single host (Table II). Further study may increase host numbers for specific species. However, two approaches have been used to study host-parasite associations. The first, maximum co-speciation assumes that hosts and their parasites share such a specialized and exclusive evolutionary association (Clayton *et al.* 2004) that speciation in one lineage causes speciation in the other (synchronous co-speciation; Hafner and Nadler, 1988). The second, ecological fitting assumes that there is no co-evolution and that hosts and parasites may come from different places, have evolved their characteristics in different circumstances and form associations as a result of the characters that they carry at the time they encounter each other (Brooks *et al.* 2006). Virtually all helminths are ecological specialists, especially with respect to transmission patterns and host-site preference (Anderson 2000; Brooks and McLennan 2002). While both approaches appear to operate with the *Falcaustra*, the fate of endoparasites depends on the fate of their host. In the case of *F. tintlwini* sp. nov., we suggest it is also critically endangered.

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