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The first record from Laos of *Plotosus canius* (Teleostei: Plotosidae)

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We record the first capture from Laos of the diadromous eel-tail catfish *Plotosus canius* as a single specimen of total length 1111 mm from Phapheng Channel, which is the most easterly anabranch of the Mekong in the Khone Falls system in southern Laos. The capture location is about 2.5 km downstream of Phapheng Waterfall and about 2.1 km upstream of the Cambodian border with Laos. As the location is about 720 km from the sea and at least 500 km upstream of any possible saline influence, this record shows that some large individuals of this diadromous species, which breeds in brackish waters, may penetrate long distances into freshwaters, where they feed on crabs and molluscs.

Introduction

Plotosus canius is an eel-tail catfish species widespread in the Indo-pacific Region from Sri Lanka to New Guinea. It is found in estuaries and turbid coastal waters (Gomon, 1984), and in the 'lower parts' of rivers, including the Mekong River system in Cambodia and Vietnam (Rainboth, 1996); however the upstream limit of its distribution in the Mekong or other rivers has not been defined.

Plotosus canius is important in coastal and estuarine fisheries (Leh et al., 2012; Usman et al., 2013a). It has an extended breeding season (Usman et al., 2013a–b) and likely spawns in brackish water, based on optimal sperm survival at 0.9 % salinity (Amornsakun et al., 2018). *Plotosus canius* produces relatively few large eggs, consistent with parental care (Usman et al., 2013a; Amornsakun et al., 2018). It is possible that male fish construct nests and guard their fry, as described for another estuarine plotosid *Cnidoglanis macrocephalus* (Laurenson et al., 1993) and for a freshwater plotosid *Tandanus tandanus* (Whitley, 1941).

Kottelat (2001) recorded 415 indigenous species of fish from the Mekong River basin in Laos. Among these he included *Plotosus canius* as being: 'tentatively recorded from Laos; its presence needs confirmation'. This tentative record by Kottelat referred to a note by Roberts (1993) who listed fishes observed or possibly known to fishermen at Hang Khone Village on the southern (downstream) shore of Khone Island, downstream of Khone Falls and about 800 m across the river from the border with Cambodia (Figs. 1–2). Roberts' species list for Khone Falls reads as follows: "?*Plotosus canius* (not observed)", as it was based only on interviews with fishermen.

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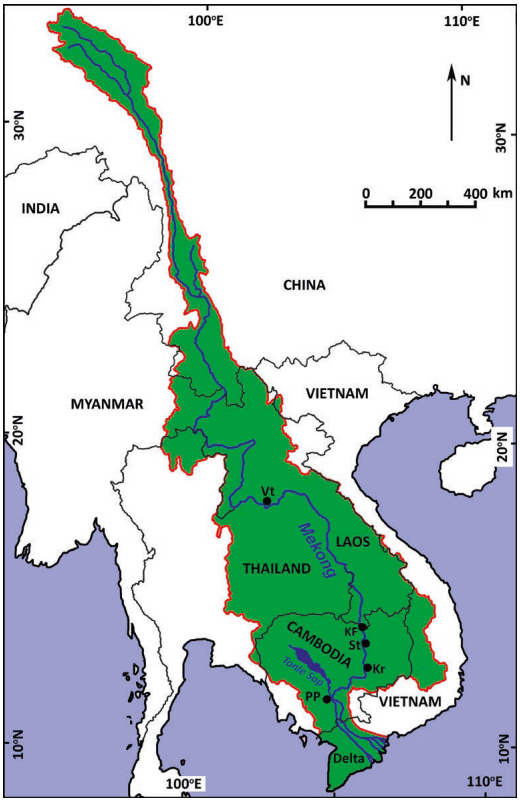

Fig. 1. Mekong River basin showing the location of Khone Falls. KF, Khone Falls; St, Stung Treng; Kr, Kratie; PP, Phnom Penh; Vt, Vientiane. Black lines are national borders; the red line is the basin boundary.

Khone Falls refers to the location where the Mekong River splits into seven main anabranches which flow southwards across the Great Fault Line of southern Laos, dropping about 20–30 m over about 5 km (Figs. 1–2). The fast-flowing channels of Khone Falls are punctuated by rapids, cascades and waterfalls which form partial or complete barriers to upstream migration by fish, depending upon species, size, location and season (Roberts & Baird, 1995).

Methods

From November 2014 to October 2020 we monitored fish abundance and diversity at Khone Falls, using several kinds of gillnets, traps (including fyke nets) and cast-nets at 12 locations upstream and downstream of Khone Falls (Fig. 2). Gillnets and traps are passive fixed gears which were set overnight, beginning one hour before sunset. Cast-netting began about one hour after sunrise for about 30 minutes, after which the gillnets and traps (including fyke nets) were retrieved. All fish were identified then measured and weighed individually. More details are provided in Hortle et al. (2014) and in other reports in preparation. The monitoring program is ongoing, supported by 16 fishermen who are paid to work full-time for the Don Sahong Hydropower Company to monitor fish and fisheries, to carry out works to improve fish passage, and to assist in fisheries management (Hortle & Phommanivong, 2019). In October 2020, the fishermen were aged 25–57 years; they had all fished since childhood and they had 16–48 years of fishing experience (total 483 man-years).

Results

From November 2014 to October 2020, the 16 fishermen caught approximately 260 000 fish in 179 species in the monitoring program. Among these fish, only a single *Plotosus canius* was captured. The fish was caught in a fyke net set overnight (5–6 August 2016) in about 1 m of water near the eastern shore of Phapheng Channel, the most easterly of the Khone Falls channels, as shown in Figure 2. Capture coordinates are 13°56.4' N 105°59.1' E. The location is about 2.5 km downstream of Phapheng Falls and about 2 km upstream of the Cambodian border. The channel is about 300 m wide and more than 20 m deep in places, with a bedrock and sand substrate, and the river is generally fast-flowing and turbulent. During August 2016, the river was in flood and was highly turbid, as is usual for the monsoon season (Fig. 3).

The *Plotosus canius* specimen was alive when caught. It was euthanized at the site laboratory and measured 1111 mm total length (TL) and 1060 mm standard length (SL) and it weighed 8200 g (± 20 g) (Fig. 4). The fish was readily identifiable by key characters as noted by Gomon (1984) and Rainboth (1996). Diagnostic of Plotosidae, its second dorsal, caudal and anal fins were confluent, and it possessed a dendritic organ. *Plotosus* is distinguished from the only other Mekong plotosid genus, *Cnidoglanis*, by having gill membranes which are free from the isthmus,

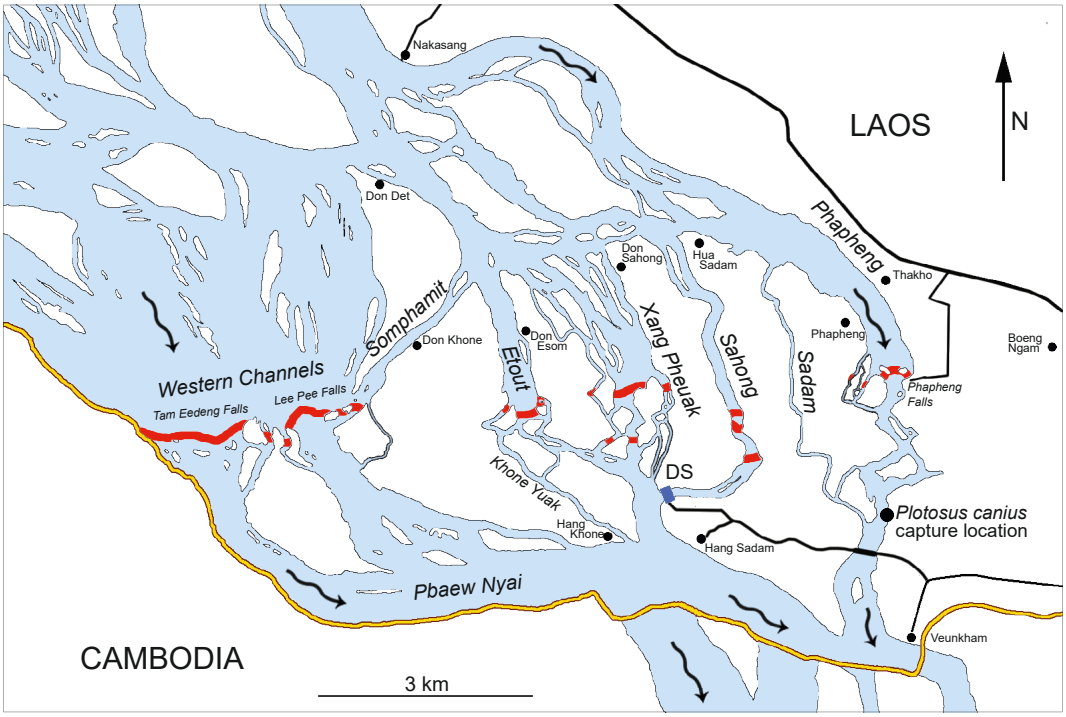

Fig. 2. Khone Falls showing the main Mekong anabranches and the capture location of *Plotosus canius*. Red lines indicate rapids, cascades or waterfalls. DS, Don Sahong Dam Site. Arrows indicate flow direction, northwest to southeast.

Fig. 3. Phapheng Channel (right) and Sadam Channel (left) looking upstream towards Phapheng Falls on 6 August 2016. The capture location is in the right foreground, near the edge of Phapheng Channel.

and a second dorsal fin which originates above or behind the pelvic-fin insertion, as evident in Figure 4. *Plotosus canius* is distinguished from the only other Mekong congener, *P. lineatus*, by a pair of long nasal barbels which extend beyond the eye, and by a uniformly coloured body, as evident in Figures 4 and 5.

We determined that the fish was male by the size and shape of its urogenital papilla and its broad head (Usman et al., 2013a; Amornsakun et al., 2018). During dissection we noted that its testes were well-developed, but not active. Its undifferentiated gut was approximately half-full of fragments of crabs and molluscs, with some detritus and sediment, with the food items dispersed along the length of its gut. It had 5 rows of large conical or molariform mandibular teeth (Fig. 5), as well as grinding maxillary, vomerine and pharyngeal teeth, as noted and illustrated by Usman et al. (2013a: fig. 4).

Plotosus canius is not regionally rare and the specimen was large, so we did not retain it, rather it was eaten by the local fishermen who rely upon their daily catches for food. We consider that the photographs of the specimen are sufficient to document its occurrence in Laos for the first time.

Discussion

Plotosus canius is apparently rarely caught at Khone Falls, given its extremely low incidence in our samples and based on its unfamiliarity to the 16 experienced full-time fishermen, none of whom had seen a specimen of this species before the capture in 2016. They all referred to it as likely to be a kind of 'pa duk', which is the Lao name for *Clarias* species (Clariidae), true freshwater catfishes which are somewhat similar in general appearance to *Plotosus*. The fishermen subsequently heard some tentative reports that over many years of fishing at Khone Falls some of their friends may have caught one or two specimens of *P. canius*, which were however much smaller in size (~50 cm TL) than the specimen recorded herein.

Gomon (1984) noted that *Plotosus canius* is 'reportedly caught around 80 cm and may reach 150 cm in length' but cited no actual records. Kottelat (2001) noted that this species reaches 'up to 850 mm SL' (approximately 890 mm TL), presumably based on his field notes and museum records. Recent literature records, from studies in coastal or estuarine habitats, include measurements of 3272 fish, among which the largest *P. canius* recorded was 700 mm TL (Table 1), so the specimen from Khone Falls may be the largest specimen ever recorded. The fish from Khone Falls was a mature male; while we could find no records of the length at maturity of males, females have been recorded as mature at 350 mm TL (Dewanti et al., 2012).

Plotosus canius is commonly caught in the Mekong River delta in Vietnam (Fig. 1), from where Vu et al. (2020) recorded its capture by trawling at three sites which covered the range of salinity along the Mekong, from coastal brackish water to completely fresh water near the border with Cambodia, about 200 km inland. Databases of catches recorded by Mekong River fishers and compiled by the Mekong River Commission from 2003 to 2013 (unpublished) also show *Plotosus canius* as a common record in the Mekong distributaries in the Vietnam delta, but it was very rarely recorded in the Mekong in Cambodia. However, *P. canius*

Table 1. Literature records of *Plotosus canius*. Total length (TL) in millimetres.

Source	Sex	n	TL Minimum	TL Maximum	Location
Sinha (1981)	Male	326	114	612	India
	Female	501	86	683	
Sinha (1984)	Mixed	480	38	538	India
Khan et al. (2002)	Female	52	365	692	Bangladesh
Dewanti et al. (2012)	Female	30	350	700	Indonesia
Leh et al. (2012)	Mixed	1390	41	520	Malaysia
Usman et al. (2013b)	Female	32	412	600	Malaysia
Usman et al. (2016)	Male	172	228	629	Malaysia
	Female	169	246	600	
Amornsakun et al. (2018)	Female	120	409	605	Thailand
Total		3272	38	700	

Fig. 4. *Plotosus canius*, 1060 mm SL, not preserved Phapheng Channel, Khone Falls, Laos.

Fig. 5. *Plotosus canius*, 1060 mm SL, not preserved, anterior view showing its large conical or molariform mandibular teeth.

might in fact be more common in Cambodia than reported by fishers who rarely or never see it, and who may misidentify it as a species of *Clarias*.

Similarly to some other primarily marine fishes (Roberts & Baird, 1995), Khone Falls may be the upstream limit of the distribution of *Plotosus canius* in the Mekong River, as the fast-flowing anabranch channels which cross the falls are probably an impenetrable barrier to this species, which is adapted to relatively quiescent coastal and estuarine waters.

The capture of this large specimen of *Plotosus canius* 720 km upriver, and at least 500 km upstream of any saline influence, suggests that this species gains some significant benefit(s) from persisting in ascent of freshwater rivers. As discussed at length by Gross (1987), marine fishes may move into freshwaters as a direct response to environmental factors such as temperature, water level and food availability, or to avoid competition. The Mekong is noteworthy for high diversity and productivity of crabs and molluscs (Cumberlidge

et al., 2012; Köhler et al., 2012; Ngor et al., 2018), which are abundant at Khone Falls where they are not heavily fished. These invertebrates likely provide a rich food source for *P. canius*, a benthic fish, which in brackish coastal waters feeds primarily on crabs and molluscs (Sinha, 1984; Leh et al., 2012), which we also found in the gut of this specimen caught at Khone Falls. As the fish was caught at least 500 km upstream of any marine influence, and most items in its gut were fresh, we assume that the unidentifiable fragments of molluscs and crabs originated from recent feeding in fresh water.

Table 2. Summary of number of records of museum specimens of *Plotosus canius* by country and habitat of capture locality, from www.fishnet2.net.

Country	Marine or brackish	Unknown locality	Fresh-water habitat	Total
Australia	17		2	19
Bangladesh	1	1		2
Brunei	2			2
Cambodia	0	1	5	6
India	5	9	3	17
Indonesia	4	12		16
Japan	1			1
Malaysia	24	2	2	28
Myanmar	1	2	2	5
Papua New Guinea	5			5
Philippines	16			16
Singapore	12	2		14
Sri Lanka	0	4		4
Thailand	31	7	2	40
Vietnam	2	3	1	6
Unknown	0	14		14
Total	121	57	17	195

To compare our observation with the extent of upstream penetration by *Plotosus canius* in other river systems, location records of all catalogued museum specimens of *P. canius* were downloaded from the online portal of www.fishnet2.net, which accesses data from 76 fish collections (Table 2). The 195 records include at least 501 specimens, but 39 of the records did not provide a count of individuals. As shown in Table 2, most records were from marine or brackish water habitats, or lacked specific locality data, with only 27 records (or 9 %) from freshwaters. These records are summarised in Table 3, which shows the distance from the sea to the collection locality along the main channel of the river/stream system. Apart from the six records from the Mekong system, the furthest inland record is from the Baram River in Sarawak, Malaysia, where two *P. canius* were collected about 260 km inland. Further research to provide a more complete understanding of the abundance in freshwater and the geographic extent of freshwater penetration by *P. canius* and other diadromous fishes would be of inter-

Table 3. Details of the 17 records of 20 museum specimens of *Plotosus canius* from freshwater habitats, showing distance inland of capture localities, from www.fishnet2.net.

Country	Locality	Distance inland (km)	Number of specimens	Date
Australia	Small Coastal Creek	33	1	1975
Australia	Adelaide River, Northern Territory	69	1	1996
Cambodia	Mekong River system, Tonle Sap, Chnok Trou	390	2	1962
Cambodia	Mekong River system, Tonle Sap, Chnok Trou	390	2	1962
Cambodia	Mekong River system, Tonle Sap, Chnok Trou	390	1	1962
Cambodia	Mekong River system, Tonle Sap, Chnok Trou	390	1	1962
Cambodia	Mekong River system, Tonle Sap, Chnok Trou	390	1	1962
India	Sundarbans, Uttarbhag, Lower Bengal	98	1	1940
India	Hooghly River Calcutta	130	1	1937
India	Hooghly River tributary, Calcutta	123	1	1865
Malaysia	Baram River Sarawak	260	1	1898
Malaysia	Baram River Sarawak	260	1	no data
Myanmar	Yangon	no data	2	1937
Myanmar	Yangon River system	no data	1	no data
Thailand	Chao Phraya River, Bangkok	51	1	1862
Thailand	Bang Pakong River	no data	1	2001
Vietnam	Mekong River, Can Tho	90	1	no data

est, considering the hypothesis expounded by Roberts (1989) that "fishes with diadromous life histories generally do not survive where primary freshwater fishes are dominant".

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