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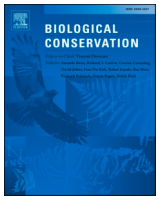

Short communication

Rediscovery and future approaches to conservation of the elusive giant salmon carp *Aaptosyax grypus*, a Critically Endangered megafish in the Mekong

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ABSTRACT

The Critically Endangered giant salmon carp (*Aaptosyax grypus*) is an endemic mega fish from the Mekong River basin. It had not been recorded in the wild since 2005, and was considered as possibly extinct. Here, we report the capture of three new specimens between 2020 and 2023. Those recent observations indicate that the species persists, and that one or more populations of *A. grypus* inhabit the Cambodian Mekong and its tributaries. Though the rarity of *A. grypus* makes it difficult to set specific conservation actions, we suggest building on the recent development of environmental DNA techniques and citizen science to investigate *A. grypus* geographic range and habitats as a first step before initiating actions to conserve its habitats. Given the emblematic species status of *A. grypus,* its conservation could have an umbrella effect contributing more broadly to the conservation of the globally significant freshwater biodiversity in the Mekong Basin ecosystem.

1. Introduction

Mega freshwater fish (defined as those reaching >30 kg body mass) are among the most globally threatened taxa with estimated population declines of 94 % since 1970 (Carmona et al., 2021; He et al., 2019). Most mega freshwater fish species occur in large tropical rivers in Asia and South America (He et al., 2019). Still, Asian rivers face severe anthropogenic pressures, mainly from overfishing, damming, and habitat degradation (e.g., Chevalier et al., 2023; Su et al., 2021; Winemiller et al., 2016), that exert a particular threat to the large and slow life-paced species (Toussaint et al., 2021). An ongoing issue for Asia's mega freshwater fish is a lack of conservation attention, with populations largely unmonitored, unprotected, and generally data-poor, which ultimately constrains our ability to identify population strongholds and develop conservation initiatives to ensure their persistence (Darwall et al., 2011; He et al., 2021).

Within Asia, the Mekong River is home to several mega freshwater fish species (Hogan and Lovgren, 2023). Among them, the Mekong giant salmon carp (*Aaptosyax grypus*) (Fig. 1) is a large-sized Cyprinid fish (up to 130 cm and 30 kg) endemic to the Mekong River Basin, with a strictly freshwater life cycle (Taki et al., 2021). It is considered to occur in the Mekong River from Vientiane, Laos, through Thailand and into the northern part of Cambodia (Baird and Mean, 2005; Froese and Pauly, 2023; Kottelat, 2001; Rainboth, 1996, 1991; Taki et al., 2021;

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Vidthayanon, 2011), although its spatial range remains speculative and unresolved due to the rarity of observation cases (Vidthayanon, 2011). It is also considered to be one of the most threatened species in the Mekong River and is listed as Critically Endangered on the IUCN Red List (Vidthayanon, 2011). Moreover, this species was not observed or captured for 15 years (2005–2020), and was thus suspected to be extinct.

Here, we report the recent capture of three new specimens of *A. grypus* at two locations in Cambodia between 2020 and 2023 (Fig. 2). These accounts confirm the species is not extinct and, constitute the first specimen-based records of *A. grypus* from the Cambodian Mekong system. We detail the location of these captures with regard to their historical distribution and propose a range of management initiatives for consideration by authorities that would improve our knowledge of this species and lead to the ability to identify and protect important habitat areas, that would likely have flow-on benefits to the Mekong Rivers other threatened freshwater fishes.

1.1. Distribution range and historical records of A. grypus

Aaptosyax grypus was historically known by local fishers but was formally described in 1991 from the Mekong River at Khong Chiam District, Ubon Ratchathani, Thailand (Rainboth, 1991). *A. grypus* can be easily known by a conspicuous knob at the tip of the lower jaw and upper jaw with a distinct s-bend shape, adipose eyelid well developed, covering one third of the eye and 74–85 pore lateral-line scales (Kottelat, 2001; Rainboth, 1996, 1991; Taki et al., 2021). In historical records, it has been reported widely from the lower Mekong Basin in Thailand and Laos (Rainboth, 1991). It was later reported from Cambodia (Kottelat, 2001; Rainboth, 1996; Taki et al., 2021; Vidthayanon, 2011); but a lack of photographs or voucher specimens precluded the certainty of this species in the Cambodian range. Still, ecological knowledge reports the species is migrating from O Krieng in Sambo District Kratie in Cambodia to Klong Kaem in Ubon Ratchathani, Thailand (Poulsen et al., 2004; Poulsen and Valbo-jørgensen, 2000). It has also been reported that *A. grypus* might migrate up the Mekong River and cross the Khone Falls during the early rainy season in June (Baran et al., 2005).

Historical records indicate a restricted range of the species in the Mekong River, with observations extending from the mainstream Mekong River in Laos and Thailand, and tributaries of Banghiang River in Laos, and Mun and Songkhram Rivers in Thailand (Fig. 2). Still, observations remain rare, with no more than 20 observations of the species since the species description in 1991 (Table 1). Moreover, the number of specimens captured for each observation was low, and excluding accounts of vague quantitative descriptions such as ‘few’ or ‘many’ in the literature, no more than 30 individuals had been observed. Moreover, observation frequency was low with most observation reports occurring between the seventies and nineties (Table 1). Observations were even

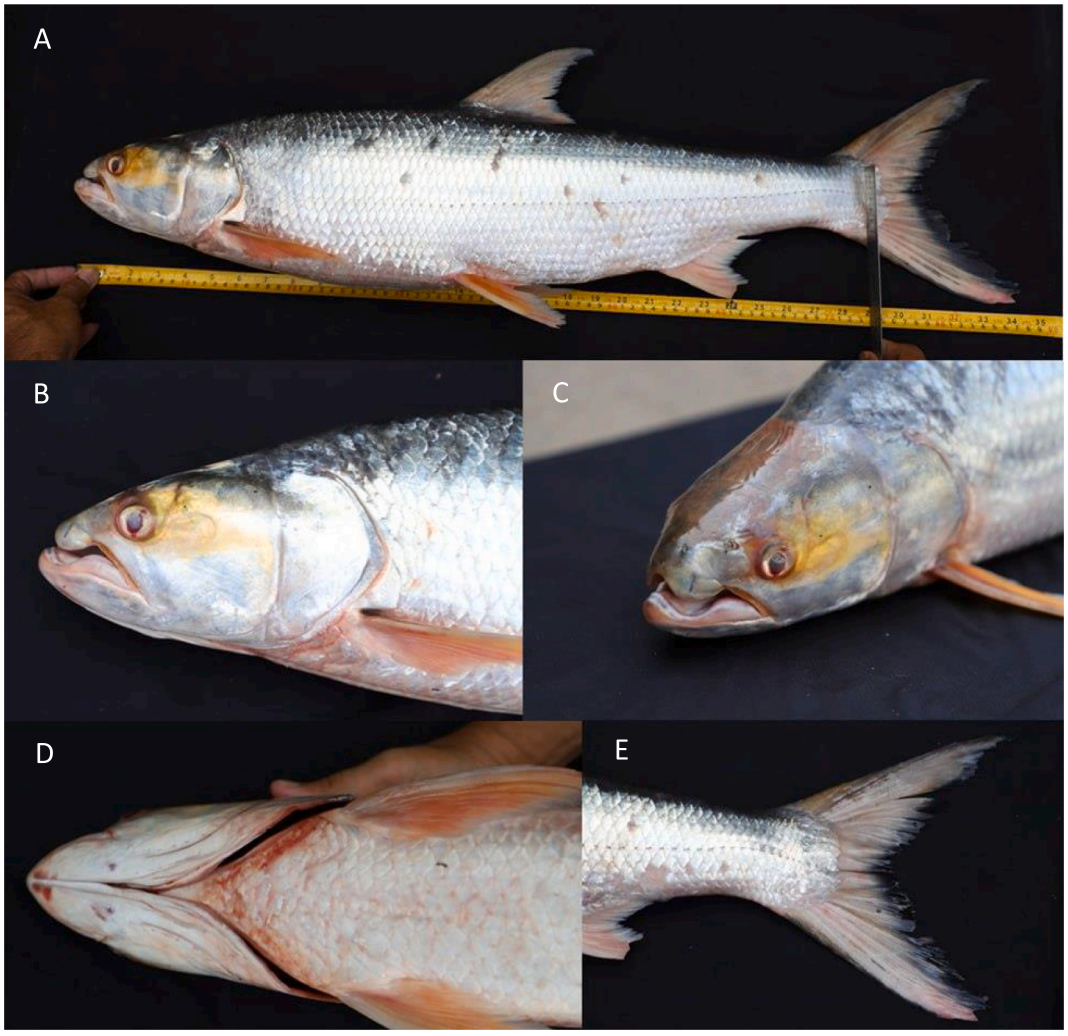

Fig. 1. Photographs of the Mekong giant salmon carp (*Aaptosyax grypus*), taken from a specimen collected from the upstream portion of the lower Sesan II reservoir, Sesan River, Sesan District, Stung Treng Province, Cambodia in June 08, 2022. A. lateral view of complete specimen; B. lateral view of head; C. dorsal view of head; D. ventral view of head; E. lateral view of caudal fin.

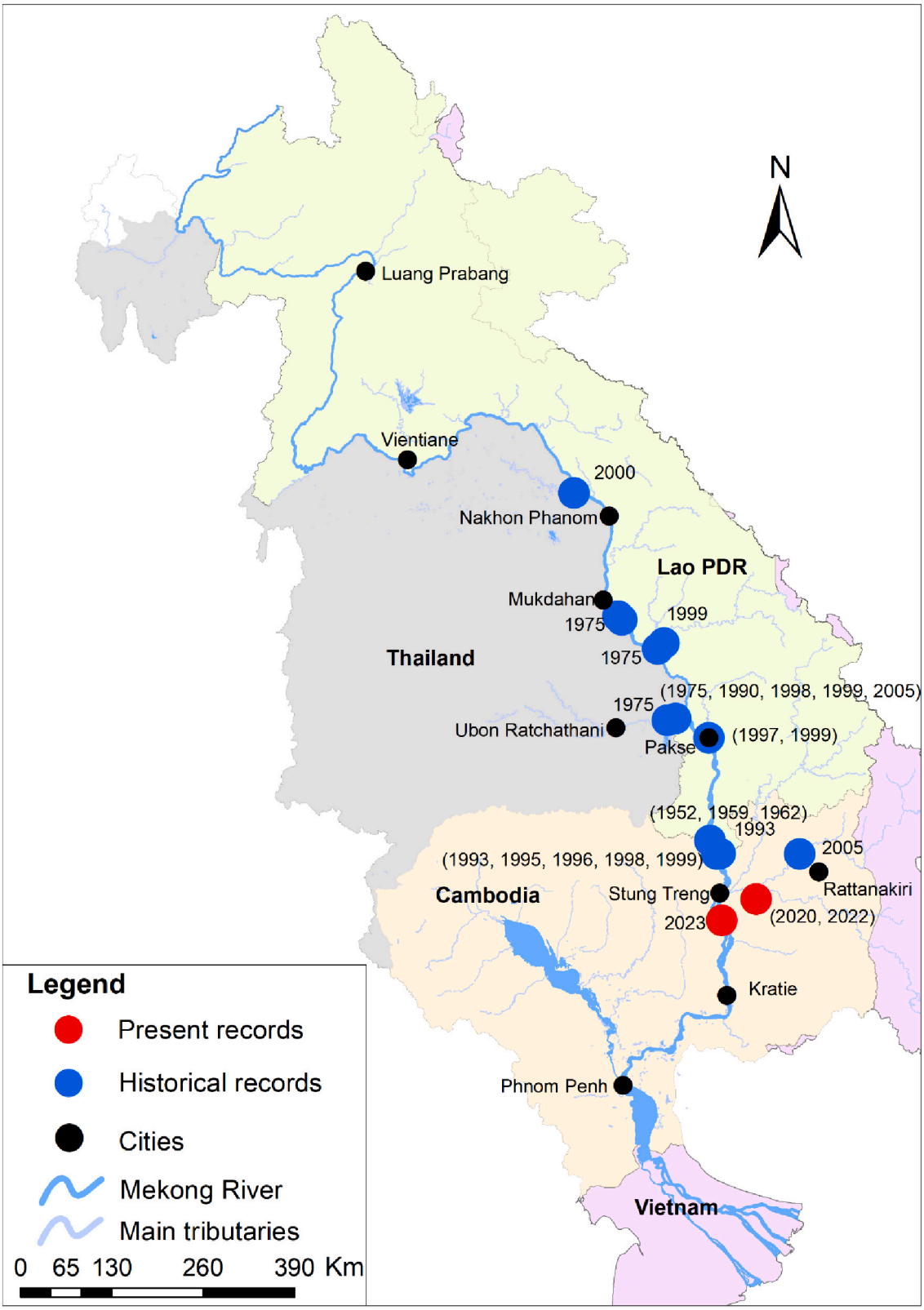

Fig. 2. Map of the Mekong River basin showing the historical and new records of the Mekong giant salmon carp (*Aaptosyax grypus*). Blue dots represent the historical records; red dots represent the recent records in Stung Treng Province, Cambodia. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Synthesis of the observation records of *Aaptosyax grypus* indicating the date of capture, the number of specimens, the locality and country, the geographical coordinates and the reference. The recent records reported in this study are bolded.=.

Date	Number of specimens	Locality	Country	Coordinates	Reference
1952–1962	Many	Ban Dom Som	Laos	14.070353°, 105.848910°	Roberts and Warren, 1994
1975	2	Khong Chiam, Mun River	Thailand	15.302711°, 105.402444°	Rainboth, 1991
1975	5	Khon Chiam district, Mekong River	Thailand	15.323870°, 105.490817°	Rainboth, 1991
1975	2	Ban Bung Khi Lek, Mekong River	Thailand	16.033575°, 105.300540°	Rainboth, 1991
1975	1	Ban Tha Kai, Mekong River	Thailand	16.333056°, 104.921011°	Rainboth, 1991
1975	2	Mukdahan, Mekong River	Thailand	16.371527°, 104.880713°	Rainboth, 1991
1990	3	Khong Chiam, Mekong River	Thailand	15.323870°, 105.490817°	Roberts, 1993
1993	2	Lee Pee waterfall	Laos	13.949179°, 105.911793°	Roberts and Warren, 1994
1993	2	Ban Hang Khone, Khone Falls	Laos	13.937685°, 105.948042°	Baird et al., 1999
1995	1	Ban Hang Khone, Khone Falls	Laos	13.937685°, 105.948042°	Baird et al., 1999
1996	2	Ban Hang Khone, Khone Falls	Laos	13.937685°, 105.948042°	Baird, 1998
1997	1	Pakse Market	Laos	15.119121°, 105.798592	Baird et al., 1999
1998	1	Khong Chiam, Mekong River	Thailand	15.323870°, 105.490817°	Tomoda, 2011
1998–1999	8	Khone Falls	Laos	13.932736°, 105.919896°	Tomoda, 2011
1999	1	Khong Chiam, Mekong River	Thailand	15.323870°, 105.490817°	Tomoda, 2011
1999	1	Pakse Market	Laos	15.119121°, 105.798592	Hogan, unpubl.
1999	Few	Banghiang River	Laos	16.094842°, 105.369493°	Taki et al., 2021
Before 2000	Few	Songkram River	Thailand	17.634171°, 104.411899°	Poulsen and Valbo-Jørgensen, 2000
Before 2000	Few	Mun River	Thailand	15.302711°, 105.402444°	Poulsen and Valbo-Jørgensen, 2000
2001	Few	Ubon Rathchathani, Mekong	Thailand	na	Taki et al., 2021
2005	2	Phnom Kok Village, Sesan River	Cambodia	13.926450°, 106.786670°	Baird and Mean, 2005
2005	1	Khong Chiam, Mekong River	Thailand	15.323870°, 105.490817°	Grudpan, unpubl
2020	1	Sesan Reservoir	Cambodia	13.468756°, 106.329236°	This study
2022	1	Sesan Reservoir	Cambodia	13.468756°, 106.329236°	This study
2023	1	Siem Bok District, Mekong River	Cambodia	13.252529°, 105.968967°	This study

less frequent in the early 2000s with only three specimens observed between 2000 and 2005, and no new specimens were reported for 15 years, indicating a possible extinction of the species (Vidthayanon, 2011).

Here, we report three new occurrences of *A. grypus*, associated with the conservation of the captured specimens, that occurred in Cambodia between 2020 and 2023 (Fig. 1, Table 1). Two of these reports (one specimen captured on October 11, 2020 and the other on June 08, 2022, Fig. 1) were from the lower Sesan 2 reservoir, Sesan River, Stung Treng province, north-eastern Cambodia. The third report was a specimen captured on the Mekong River in Siem Bok District, Stung Treng Province, Cambodia, on October 02, 2023. The specimen captured in 2020 was not conserved, but good quality photographs are available, allowing to confirm species identification. The other two specimens were captured by local fishers and the specimens were stored and deposited in the specimen room of the Inland Fisheries Research & Development Institute (IFReDI), Fisheries Administration, Cambodia. The specimens captured in 2022 and 2023 were adults (body mass of 6 kg and 5 kg with a total length of 88 cm and 72.5 cm, respectively), leaving no doubt about the species identification.

Those three contemporary records provide the first accounts of this species since 2005, and thus confirm the persistence of the species. Moreover, these captures occurred out of the historical range of the species (Fig. 2), extending it to the mainstream Cambodian Mekong River, as well as the Sesan River in Cambodia. Despite the rarity of the catches, these recent observations call for the consideration of *A. grypus* in future conservation assessments (e.g., IUCN Red List) and ensure this species inclusion in relevant national threatened species conservation planning in Cambodia. It will also facilitate the appropriate inclusion of national jurisdictions in future transboundary conservation planning.

1.2. Directions for the management and conservation of A. grypus

The scarcity of *A. grypus* occurrences, as well as the general lack of knowledge on the species' habitats and ecology, makes it difficult to set specific conservation actions. Therefore, a prerequisite to the development of specific management plans is to investigate the spatial distribution and habitat of the species.

To improve knowledge on the contemporary range of *A. grypus*, we suggest building on the recent emergence of environmental DNA (eDNA) techniques, as already applied for the detection of rare species such as the Mekong giant catfish (*Pangasianodon gigas*) in the Mekong River (Bellemain et al., 2016; Osathanunkul, 2022). While existing genetic reference libraries perform well for common Mekong species, fin clips from recently captured specimens can now be used to sequence mtDNA from *A. gyrpus*, enhancing the capacity for targeted detection using quantitative eDNA techniques such as qPCR or digital PCR (Jerde et al., 2021). Priority should also be given to identifying sites of live fish captured by local fishers. Through their local ecological knowledge of the species, it may be possible to identify key habitat and fishery landing sites for future monitoring and also to inform areas for in-depth study of abundance, age structure, habitat use, and movement through, telemetry or capture-mark-recapture techniques. This could help identify core habitat areas for *A. grypus,* as was done for the giant freshwater whipray (*Urogymnus polylepis*) and other large fishes inhabiting the Mekong River (Lee et al., 2023; Naughton et al., 2021). In addition, ichthyoplankton surveys could provide precious information on the occurrence and abundance of *A. grypus* larvae and juveniles and thus check for species recruitment.

The collection of information on observed and captured specimens could be enhanced by developing a communication network among fishers, local communities, NGOs and researchers. This could be done using social media to raise awareness of the need to improve our understanding on the population status of *A. grypus* and facilitate the inclusion of local fishers in data collection through citizen science (Di Minin et al., 2015). There may be scope to explore incentives for local fishers to engage in data collection and encourage live release of specimens (pictures or videos could be used as proof) (e.g., Booth et al., 2023). Furthermore, focused landing surveys could result in the opportunistic collection of deceased specimens, providing an opportunity for the study of the biology and ecology of the species through sclerochronology techniques (study of elemental and isotopic variations in biological hard parts) to determine characteristics of age and growth, trophic ecology, and migration patterns (Elsdon et al., 2008). Considering the restricted capacity and resources for fisheries research in the lower Mekong, the development of citizen science approaches could play an important role in further informing the contemporary range and frequency of *A. grypus* interactions with fishers, and would assist in

identifying key areas and fisheries in Laos, Thailand, and Cambodia to develop monitoring and conservation initiatives. Enhanced engagement with local fishers to raise awareness and assist in data collection of *A. grypus* would also likely increase community buy-in toward future avenues to pursue legislated protections against landing and trade of this, and other threatened mega freshwater fish species within the lower Mekong. Acquiring more data on *A. grypus* distribution might also, in the future, allow to develop site occupancy modelling accounting for probability of detection, as suggested by (Mackenzie et al., 2018, 2002).

Once the core habitat areas of *A. grypus* are identified, we suggest developing conservation planning and management of local protected areas. Such protected areas should consider species' needs, but also resource use requirements of local people (Azevedo-Santos et al., 2019). Such protected area co-construction between local people and environmental managers could be supported through Community Fisheries (CFi) legislation in Cambodia and community-established and monitored fish conservation zones in Lao PDR (Baird and Flaherty, 2005). The challenge of conserving populations of threatened mega freshwater fish is highly complex, and particularly for those that require transboundary cooperation in the implementation of conservation initiatives. Owing to the increasing number of highly threatened mega freshwater fish in the Lower Mekong River Basin, we encourage the co-development of conservation planning across relevant Mekong nations and suggest that the implementation of conservation initiatives that are conducted in close collaboration with local communities would provide the best prospect of preventing future extinctions.

Such management initiatives will benefit not only the target species, but probably also the whole Mekong ecosystem through an umbrella effect (Fleishman et al., 2000; Roberge and Angelstam, 2004). Despite the limited current knowledge on the biology of *A. grypus*, Baird et al. (1999) indicate that the adult fish inhabits deep water areas, which are currently considered important zones for many species (Campbell et al., 2020). Thus, conserving the habitat of *A. gypus* will reinforce the Fish Conservation Zones already identified in the Mekong main channel. Moreover, *A. grypus,* a top-predator fish, might, despite its rarity, have an important contribution to the Mekong food web by contributing to the top-down regulation of the trophic cascade (Estes et al., 2011). We, therefore, appeal for conservation actions to ensure the sustainability of the rare and elusive *A. grypus* in the Mekong River system. Such studies should pave the way for the conservation of many other threatened, but overlooked, mega fishes over the world.

CRediT authorship contribution statement

Bunyeth Chan: Writing – original draft, Visualization, Investigation. **Zeb S. Hogan:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Investigation, Funding acquisition, Data curation, Conceptualization. **Michael I. Grant:** Writing – review & editing, Validation, Investigation. **Samol Chhuoy:** Writing – review & editing, Software. **Chheana Chhut:** Writing – review & editing, Resources. **Kong Heng:** Writing – review & editing, Data curation. **Sébastien Brosse:** Writing – review & editing, Validation, Supervision, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Zeb Hogan reports financial support was provided by USAID. Sébatien Brosse reports financial support was provided by CEBA and TULIP.

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Data availability

Data will be made available on request.

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