Early stakeholder cohesion in wild-capture freshwater ornamental fisheries can support conservation outcomes

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Main text

Freshwater fishes are the amongst the most threatened taxa globally, with an 84% decline in wild populations between 1970 and 2016 (WWF, 2020; IUCN, 2023). Disproportionate and persistent loss is driven by a milieu of pressures including habitat loss, rising temperatures, degradation and pollution, habitat fragmentation, invasive species and over exploitation (Reid et al., 2019). Urgent action is needed to implement active conservation measures which result in tangible change, yet progress is stilted, often due to lack of necessary baseline data on distribution, population status, and threats as well as clashes between critical stakeholders. One such clash and threat is exploitation through the wild capture freshwater ornamental fish trade (OFT) and the conservation community (Maceda-Veiga et al. 2014; Raghavan et al. 2016; Evers et al. 2019). The OFT is thought to contribute around US$15-30 billion to the global economy every year (Evers et al. 2019) and is supported by an enormous network of industry bodies, hobbyists, fishers, breeders and import/exporters (King, 2019).

Maintaining levels of exploitation that support human wellbeing and livelihood while ensuring sustainability of the population is the key goal of any wildlife management approach. Due to the widespread data deficiencies in the trade, regarding harvesting level, governance, and taxonomic impediments, the OFT is generally perceived to be a negative influence opposing conservation goals, particularly as rarity often equates to desirability and associated high trade value. On this basis, the OFT can be categorised as a conflict fishery which is exhibiting symptoms of a wicked problem (Fig 1; Rittel and Webber, 1973; Levin et al. 2012; Reid et al. 2017). Whereupon there are multiple stakeholders with conflicting perceptions and values attributed to a multifaceted problem with no obvious right or wrong solution, combined with lack of a strong central authority to enforce solutions or manage the problem and a conundrum where the causative agents of the problem may also be the solution (Rittel and Webber, 1973; Levin et al. 2012). In this case, the stakeholders are represented by: 1) conservation organisations who want to preserve species and ecosystems; 2) researchers who want to understand the fishery dynamics, ecology and evolution of the fishery species, 3) hobbyists who want to buy and keep the species, 4) fishers and fish collectors who sell fishes for income but also often keep the species as hobbyists and have valuable local ecological knowledge. Overlap between stakeholders is broad, making strict boundaries between socio-ecological behaviour hard to define.

This is not a unique conflict or wicked problem ascribed to freshwater ornamental fisheries alone. The marine ornamental fish trade has seen a similar trajectory where animal rights and conservation movements have halted profitable and ecologically sustainable fisheries (e.g. the yellow tang (*Zebrasoma flavescens, Bennett, 1828*) in Hawai'i) resulting in overfishing in certain patches and fishers swapping to less sustainable practices to make up for the economic loss (Tissot and Hallacher, 2003). Marine ornamental fisheries are now a deeply contested and conflicting issue which are regularly on the agenda at global conservation meetings such as CITES and COP. The freshwater OFT has not received anywhere near as much media attention or conservation attention as the marine OFT. Nonetheless, ensuring

persistence of the species that make up the OFT is crucial for local livelihoods, supports global trade and a posits a hopeful conservation opportunity if approached delicately (Tlusty et al. 2008).

We propose that early partnership, community engagement and management can foster an attitude of shared ownership in freshwater OFT fisheries rather than a tragedy of the commons, wicked problem, situation. Using the Indonesian wild Betta OFT as a case study, we show how conservation organisations, fishers, and hobbyist networks can support one another to a common goal to reduce the complexity of the wicked problem. We highlight the '*Betta burdigala* Project' as a framework to follow for freshwater conservation which supports humans and nature.

Indonesian wild betta trade

Indonesia is the world's largest archipelagic state, and a freshwater megabiodiversity hotspot (Cribb and Ford, 2009; von Rintelen et al., 2017; Kurniawan et al., 2021). Characterised by an array of freshwater habitats, including rice paddy fields, irrigation canals, volcanic lakes, and threatened blackwater peat swamps (Medrano, 2023; Patricio et al., 2023). There are an estimated 630 endemic freshwater fish species in Indonesia, with their restricted distribution ranges making them particularly vulnerable to anthropogenic and environmental threats (Hubert et al., 2015). Out of the 90 critically endangered freshwater fish listed by the Asian Species Action Partnership (ASAP), 48 are native or endemic to Indonesia (Patricio et al., 2023). However, many species are still data deficient and/or not formally described. Key threats include over exploitation, extreme range restriction and peat swamp habitat loss/destruction (Hubert et al. 2015; Patricio et al., 2023).

Indonesian freshwater fish exports are valued at $27.8 million, making up 10% of the global exports of freshwater fish for 2021 alone (Tarihoran et al., 2023). Due to insufficient volumes of reliable data, the impact of wild capture is unknown, and thus creates complications for regulation and monitoring, especially for threatened species. In the past, wild harvesting has caused massive population depletion with some popular species such as the brightly coloured rainbow fishes e.g. a *Melanotaenia* spp. almost reaching extinction (Allen, 2007; Evers et al., 2019). As a result, this species was classed as endangered (Allen, 1996; Allen and Kadarusman, 2020), and now only farmed animals are permitted to be exported for the trade (Nugraha et al., 2015) to reduce pressure on wild populations. However, this is not the case for many species of Osphronemidae (e.g. the bettas and gouramis), whereupon the vast majority of those on the global market are wild caught with zero trade regulation, even though most of their species are threatened according to the IUCN Red List (Low, 2019;

Low, 2020). Similarly, only a few cases of wild bettas (*Betta* spp.) originate from captive breeding, with most being collected from the wild (Giam et al., 2012).

Expert knowledge and well documented biological research is essential to ensure suitable and evidenced based conservation measures. The wild bettas are characteristic of this, as there exist many unresolved species complexes and cryptic diversity which requires molecular analysis and paleogeographic knowledge (Panjipan et al. 2014; Zhang et al. 2022; Panthum et al. 2023; Syarif et al. 2023). Taxonomic impediments and lack of baseline ecological data hamper freshwater conservation actions globally, but the wealth of local and indigenous knowledge held by fishers is often overlooked (Ortega and Hildalgo, 2008; Kadykalo et al. 2020). For example, due to the nature of the commodity, knowing where to find rare fish and not over-exploiting the population is critical to maintaining a source of income. Logically, fishers should be compelled to act as custodians of the resource and be invested in protecting the habitat that supports it (Tlusty et al. 2008). Therefore, fish collectors are invaluable sources of knowledge regarding species localities and requirements. Local hobbyists and collectors ought to not be squeezed out of research and conservation discussion as alienation only exacerbates pre-existing perceptions and problems between other stakeholders. Collaboration between local and indigenous fishers and research teams should be promoted as a two-way learning opportunity rather than avoided due to conflict in conservation-exploitation perceptions.

Indonesian betta fish represent a niche rarity in the trade due to their limited range distributions, bright colours, and interesting breeding habits (e.g. mouthbrooding, paternal care, bubble nesting). Thus, they often fetch higher selling prices than captive populations, particularly for rarer or threatened species (Nur et al., 2022). Although these species are largely held by specialist hobbyists, the demand within the global OFT is steadily increasing, with high selling prices promoting exploitation of these fish from their wild populations (Nur et al., 2022; Patricio et al., 2023; Priyadi et al., 2024). However, the rise in trade over social media, particularly through sites like Facebook and Instagram (Widjaja, 2015; JS pers obs) means that international buyers can contact specialist collectors directly, and export these fish where there is limited regulation, subsequently also reducing the availability of accurate trade data (Patricio et al., 2023). Through these informal marketplaces it is possible to buy a pair of critically endangered point endemic *Betta burdigala, Kottelat & Ng, 1994* for US$15 (JS pers. obs). Exploitation of freshwater fish for the global market represents a constant source of high income (relative to GDP) to those who engage in it, however, fish collecting can be a risky and dangerous endeavour. A more transparent understanding of the volume and origin of animals can only be obtained by forging good relationships with fishers, researchers and central governance systems where the fear of livelihood loss or punitive measures is not present or mitigated through alternative livelihood schemes such as eco-tourism or catch quota development.

The distribution of fish internationally through seller, hobbyist and zoo/aquaria networks can confuse our understanding of the actual volume of species being caught and sold, however, these networks can be crucial to generating trust and supporting in and ex situ conservation. For example, the Parosphromenus Project (https://parosphromenus-project.org/) – is an organisation which fosters and supports collaborations between institutions and hobbyists to prevent the extinction of *Parosphromenus* species. The project aims to help hobbyists successfully breed and maintain ex-situ populations of many different *Parosphromenus* species but does not currently support in-situ conservation (Patricio et al., 2023). Similarly, the International Betta Congress (https://www.ibcbettas.org/), exists to promote interest in the genus while providing resources and technical information on the breeding and maintenance of *Betta* spp. for competitions as well as preserving wild populations. Hobbyists regularly share breeding tips for species to allow observation of interesting behaviours as well as sharing or selling offspring of rare species. YouTube videos are an untapped resource for breeding and rearing techniques for at least 33 species of native Indonesian Betta species (DSB unpublished data). The trade requires faith in good actors, as the lack of taxonomic expertise can result in incorrect and misleading sales, such as the least concern *P. bintan*, Kottelat & Ng, 1998, being mis-sold as the critically endangered *P. gunawani,* Schindler & Linke, 2012 (CBD, 2023; TPP, 2024). The hobbyist breeder community overlaps with the fisher and fish collecting community, as well as formalised captive breeding programs (national and international) (Reid et al. 2013). Each holds different values relating to the conservation of the species but each ultimately bears responsibility for ensuring traceability and transparency in acquisition of fish and the persistence of species in the wild (Reid et al. 2013; Marchio, 2018).

The *Betta burdigala* Reintroduction Project

Betta burdigala is critically endangered and range restricted within Bangka Island (Low et al. 2019). Solutions are limited as closing of the fishery is likely to 1) not be enforced, 2) face backlash from the communities, 3) drive inequity between stakeholders, 4) cause loss of trust between actors, 5) increase rarity and therefore price and demand (Tlusty, 2002; Dee et al. 2014; Fig 2). However, not acting to manage the problem will result in an inevitable loss of biodiversity and is not a conscionable option. The '*Betta burdigala* Project' is a flagship project funded by The International Union for Conservation of Nature (IUCN) Species Survival Commission (SSC) / Asian Species Action Partnership (ASAP) and SHOAL that has identified and engaged with numerous stakeholders from the outset and promoted locally led community initiatives which have reduced the complexity and wickedness of the problem (**Fig 2a**). The overarching aims are to conserve and increase the number of wild *B. burdigala* through genetically informed captive breeding and reintroduction programs, achieve a better understanding of the natural range of *B. burdigala*, and perform knowledge sharing activities with local conservation entities, researchers, fishers and governance.

Through early discussion and inclusive approaches to conservation the project has managed to unite stakeholders by working with fishers and hobbyists to locate healthy founder populations of *B. burdigala* and engaging students, local government, conservation entities, and community groups to improve captive breeding endeavours which make use of their unique knowledge of the species biological requirements. This provides broodstock for future captive breeding and reintroduction, as over 400 F1 individuals have since been reintroduced into natural habitats with an ongoing stock assessment. By ensuring local governance and community representatives are involved in the co-design of the project, and actively engaged during sampling expeditions and media outputs the project has garnered social responsibility and increased feelings of custodianship, which is a key building block to creating community managed resources. Two Yayasans, Indonesian Trusts, are being created to support co-management of a putative protected area. Whereby one Yayasan is represented by the local community and the other is represented by the research community and both will work with local government to ensure suitable checks and balances in management. Beyond this, diversification of livelihoods through the development of a co-authored hobbyist book on the anabantid fish of Bangka will provide income for collectors to lift pressure on the fishery. Molecular assessments of *Betta burdigala* and other *Betta* spp. is contributing to critical eco-evolutionary knowledge on the diversification of Indonesian freshwater species (Valen et al. 2023). Thus, highlighting the myriad benefits to conservation, fundamental science, biodiversity and human wellbeing that can be achieved through such coordination.

Conclusion

Conservation of globally traded wild capture species is complex and requires understanding of the market forces which drive trade, and sensitive management approaches no matter the taxa (Reid et al. 2013; Evers et al. 2019; Challender et al. 2023). The true volume of wild capture freshwater fish is unknown, and legislator focus has been on prominent mega-fauna species such as sturgeon (*Acipenser* spp.), Juliens Golden Carp (*Probarbus jullieni,* Sauvage, 1880), Bonytongue/Asian Arowana (*Scleropages* spp) and Arapaima (*Arapaima spp.*) rather than small sized fish which are increasing in market demand with a rise in nano-aquarium popularity (Schmidt, 2017; CITES, 2024). Working cohesively with the diverse communities who interact with the ornamental aquarium trade and conservation initiatives is essential to derive ways of working which suit each context (Marchio, 2018). The international community of hobbyists, zoos, and aquaria should be utilised, as they can provide crucial contributions to ex-situ breeding, conservation, and research - particularly for range-restricted species (Macega-Veiga et al. 2014; Reid et al. 2017; Patricio et al., 2023).

Freshwater ornamental fisheries exploitation can be sustainable for both people and nature if managed properly. While over-exploitation is a threat, it is one of many, and the combined impact of multiple interacting stressors need to be addressed (Maxwell et al. 2016). Habitat

destruction and loss of peat swamp forests and flooded grassland habitats are a key driver of biodiversity loss in Southeast Asia (Posa et al. 2011). In the lifetime of this project (2023 - 2025), the team located a new habitat locality for *B. burdigala* thus extending the species range and population size. However, in June 2025, during seasonal surveying, this habitat was found drained and cleared for oil palm plantations (**Fig. 2b**) with only 17 *B. burdigala* able to be saved and brought back to facilities for preservation of genetic diversity. Thus, any progress towards practical and cohesive conservation will need to integrate urgent effective legislatory habitat protection, in combination with species protection while not isolating community members who rely on the trade for livelihoods.

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