A Strategic Framework to accelerate urgent **conservation action for ASAP Freshwater Fishes in Southeast Asia**

IUCN SSC Species Survival Commission

ASAP! ASIAN SPECIES ACTION PARTNERSHIP

Shoal

Mandai NATURE

This Framework was developed through a collaboration among the IUCN SSC ASAP, SHOAL, and Mandai Nature.

The **IUCN Species Survival Commission's Asian Species Action Partnership (ASAP)** is a partnership platform to end species extinctions in Southeast Asia with a focus on Critically Endangered land and freshwater vertebrate species. In particular, ASAP prioritises catalysing conservation action for the most neglected and overlooked species, and a key pillar of work is to strengthen conservation capacity of national organisations and individuals to meet the conservation needs of the region. Given the lack of conservation attention for freshwater fishes, this is a high priority taxonomic group for ASAP and this project is closely aligned with ASAP's overall goal and objectives. ASAP currently has over 200 organisations signed up to the Partnership and runs small grant programmes and has training opportunities for its partners. Through the network developed through this project, ASAP is committed to provide longer-term support including grant and training opportunities to benefit freshwater fish conservation.

SHOAL was created as a response to the global neglect of freshwater species, particularly those species out of sight, living under water. The SHOAL Initiative aims to end the extinction of freshwater species by mobilising and resourcing an acceleration and escalation of action across the globe. In part, the inspiration for SHOAL originated from assessments and concerns raised in the Indo-Burma hotspot and through the IUCN SSC ASAP. For this reason, Southeast Asia was identified as the first priority for SHOAL. It is the intention of SHOAL to create more fish conservation in the region by supporting local partners through a collaborative strategy as this project is aimed to achieve. The SHOAL Initiative is hosted by Synchronicity Earth and Re:wild.

Mandai Nature is dedicated to advancing efforts on biodiversity conservation in Asia, with a focus on averting species extinction, especially in Southeast Asia by delivering conservation programmes at scale with partners, as well as convening partnerships and collaborative alliances to address critical conservation outcomes. As the conservation arm of Mandai Wildlife Group, we also work closely with the Group to apply holistic conservation approaches by integrating ex situ and in situ conservation action. Mandai Nature hosts the IUCN SSC Asian Species Action Partnership (ASAP) secretariat and Conservation Planning Specialist Group (CPSG) Southeast Asia Resource Centre. In 2022, we established the IUCN SSC Centre for Species Survival: Southeast Asia, in collaboration with IUCN Species Survival Commission (SSC). Mandai Nature was jointly established by Temasek and Mandai Wildlife Group.

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A Strategic Framework to accelerate urgent **conservation action for ASAP Freshwater Fishes in Southeast Asia**

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Foreword

It is my privilege to introduce this much-needed framework to accelerate conservation action for Critically Endangered freshwater fish in Southeast Asia. This timely initiative was made possible by the dynamic partnership between IUCN SSC Asian Species Action Partnership, SHOAL, and Mandai Nature.

Southeast Asia is a region of unparalleled freshwater fish diversity with large and charismatic migratory species found in the region's extensive river basins and highly localised, endemic species found in specialised habitats. Freshwater fish are an integral component of Southeast Asian ecosystems. Many local communities rely heavily on them for livelihoods and nutrition and they contribute significantly to ecosystem health and ecosystem services. However, persistent threats from habitat loss, degradation and fragmentation, as well as invasive species, unsustainable offtake and impacts from climate change, have led to their rapid decline. The loss of freshwater fish has reverberating impacts on both ecological and human systems.

This strategic framework addresses 90 Critically Endangered freshwater fishes from across 11 countries in Southeast Asia. Freshwater fish species, often overlooked and underrepresented in conservation efforts, require urgent and targeted attention for populations to survive and thrive. The framework encapsulates a comprehensive strategy, grounded in science and knowledge from experts to conserve and recover these Critically Endangered fish populations.
In light of the threats facing Southeast Asia's freshwater fish, it is my hope that this framework will act as a clarion call to key stakeholders to align their goals with the priorities and recommendations outlined, to drive investment and conservation action. The success of our efforts to save Critically Endangered freshwater fishes in Southeast Asia hinges on our collective action and shared commitment to aid their recovery.

Sincerely,

Jon Paul Rodriguez
Chair, IUCN Species Survival Commission

Lake Lindu, Sulawesi, Indonesia. Photo: Mohammad Herjayanto.

Summary

1. Purpose, content, and methods

a. Purpose of Framework

i. The Asian Species Action Partnership (ASAP), convened by the IUCN Species Survival Commission (SSC), is a partnership platform bringing together a network of organisations with the collective aim of averting extinctions in Southeast Asia. The ASAP programme covers 11 countries (Brunei Darussalam, Cambodia, Lao PDR, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste and Vietnam).

ii. There are 90 Critically Endangered freshwater fishes (excluding euryhaline species) listed under the ASAP programme, and there are seven euryhaline ASAP Species. These seven species have not been included in this Strategic Framework, as they are primarily found in marine environments, current knowledge is limited, and the conservation interventions needed for these species are most likely to be based in marine habitats, placing them outside the scope of this document. This framework focuses on fishes that spend the entirety of their life cycles solely in freshwater.

iii. Freshwater fishes make up the largest number of species of all taxa within the ASAP list of focal species[1] and the majority receive little to no conservation action. There is an urgent need for conservation action to prevent further extinctions.

iv. This strategic framework for action is designed to accelerate the immediate conservation of these 90 species of ASAP freshwater fishes. It is not meant to be an action plan for the conservation of all freshwater fishes in Southeast Asia, nor is it a comprehensive collation of individual action plans for each of the ASAP freshwater fishes. This framework provides a strategic analysis of the 90 species to identify, frame, direct and describe actions to facilitate and catalyse efforts required to immediately halt population declines and support the recovery of these fishes.

b. Content summary

i. *Context of the framework*

Freshwater habitats cover less than 1% of the Earth's surface yet host 51% of all known fish species (Strayer and Dudgeon, 2010; Fricke et al., 2023). More than 200 million people rely on freshwater fish for sustenance, and at least 60 million for their primary means of income (Hughes, 2021). Globally, freshwater fisheries are valued at approximately US$ 38 billion per year (Hughes, 2021), recreational fishing at more than US$ 100 billion per year (Funge-Smith and Bennett, 2019; Hughes, 2021), and the aquarium fish and product trade at US$ 15-30 billion (Penning et al., 2009).

Freshwater vertebrate populations are declining at twice the rate of those in terrestrial or marine ecosystems (Grooten and Almond, 2018), and about one third of freshwater fish species are threatened with extinction (IUCN, 2022). Eighty-three freshwater fish species have been categorised as Extinct by the IUCN Red List, with nearly 3,000 more assessed as globally threatened and over 2,500 categorised as Data Deficient (IUCN, 2022). In 2020, 16 freshwater fish species were declared Extinct, 15 of which were from a single lake in Southeast Asia (ASAP, 2020), highlighting the dire state of many species within this biodiverse region. The freshwater fish diversity of Southeast Asia is exceptionally high, with 5,645 described species as of October 2022 (FishBase, 2022), making up more than 30% of all freshwater fish species known globally at that time. Many species have limited distributions or are single site endemics, making them particularly vulnerable to extinction.

ii. *Methods used to compile the framework*

For each ASAP freshwater fish species, data on taxonomy, distribution, habitat, identified threats, and IUCN Red List assessment status were drawn from the IUCN Red List of Threatened Species™ (IUCN, 2022). Further information was also extracted from the Assess-to-Plan workshop report on Sundaic freshwater fishes from 2020 (Lees et al., 2020). Data on the biology, ecology, and husbandry of each of the ASAP freshwater fishes were collated from extensive reviews of scientific and grey literature, as well as

[1] ASAP Species are defined as Critically Endangered land and freshwater vertebrate species found in Southeast Asia. This Strategic Framework includes all ASAP listed fishes but does not include fishes that are considered as estuarine or brackish for most of their life cycle.

Lake Lindu, Sulawesi, Indonesia. Photo: Mohammad Herjayanto.

sourced from hobbyist groups, forums, and other online platforms. Data were augmented through expert consultations and compiled into a database. From this database, a systematic process was applied to create the framework. As actions are most often conceived and delivered within individual countries (rather than regionally or by taxonomic group), emphasis has been placed on sorting the actions by country.

2. Results of the data synthesis

a. There are 97 Critically Endangered fishes that spend at least some portion of their life in fresh or brackish waters, but only 90 species that are purely freshwater residents. With 48 species, Indonesia hosts the largest number of ASAP freshwater fish species, representing more than half of all species on the list. Lao PDR follows, with 13 listed species, then the Philippines and Thailand with 12 species each, Malaysia and Vietnam with nine freshwater fish species, and Cambodia with seven species. One species is found in Myanmar, and one was recently found in Singapore. This is the present status, but there are likely more species to be found and added to the list as more data and information from countries such as Myanmar become available.

b. Twenty-two families of freshwater fishes are represented in the ASAP freshwater fish list. Three families (Cyprinidae, Osphronemidae, Melanotaeniidae) represent almost half of the fishes. Cyprinidae is a very diverse family and many of the larger-sized or more valuable species important for fisheries on the ASAP list fall within this family. The Osphronemidae ASAP freshwater fishes are mostly range-restricted peat swamp forest and blackwater forest stream specialists. The Melanotaeniidae, like the Osphronemidae species, are often very range restricted and found in the east of the region.

c. Only one species is not endemic to the region. 90% are single country endemics and 81% are single site or range restricted endemics.

3. Summary of the Strategic Framework

The table below provides a summary of the actions described in the framework (Tbl. 1). As all the ASAP freshwater fishes are Critically Endangered and therefore of immediate conservation concern, actions are categorised based on the relevant urgency of the need to implement action. Potential key stakeholders have been identified to help direct actors and define roles for specific actions. A broad assessment of the scale of effort required to implement actions and achieve the desired outcomes has been assigned to each action. However, this table is by no means fully comprehensive and there may be additional needs, stakeholders and actions that should be considered for more detailed planning and implementation. The table also provides references to the section of the Framework where more detail on the action can be found.

TABLE 1

Summary of the actions described in the framework

	Action	Urgency	Potential lead stakeholder(s)	Scale of effort required	Detail Section
A	**REGIONAL ACTIONS**				
A1	**Southeast Asian regional strategy and action for freshwater fish and other freshwater species conservation** In part, the reason for the high proportion of ASAP Species represented by fishes is because of limited institutional capacity, support, and engagement related to the protection and management of freshwater ecosystems in Southeast Asia. Action to solve this problem would both support the recovery of ASAP freshwater fishes and other threatened taxa, and prevent further additions to the list of threatened species.	High	Southeast Asian government agencies, ASEAN, Multilateral agencies, and large-scale donors.	Large-scale. The effort would need to be broad and comprehensive with a very strong policy component. It would need to be led by the relevant agencies from the Southeast Asian countries.	Beginning of section 4
A2	**Large migratory fishes** The ASAP list of freshwater fishes includes five very large migratory fishes which are found mainly in the Mekong River. Each of these fishes require complex individual recovery plans and cooperation across the Mekong countries and share similar necessary actions. They are best suited to a regionally coordinated approach.	Very High	Mekong River Commission and many coordinated partners from each country.	High investment required. Many local actions combined with basin-wide coordination and action on connectivity issues.	4.2.1
A3	**Peat swamp forest species** Similar threats and conservation strategies suggest that these species are best tackled through a regional coordinated initiative. Because of the rapid destruction of this rare habitat, the need for urgent action is very high.	Very High	A coordinated network of action partners (in situ and ex situ). This may include representatives from the agricultural sector with a stake in the conservation of this habitat type.	Large-scale investment in habitat protection, primarily in Indonesia and Malaysia. While the extent of the habitat in total is relatively large in scale, many of the individual interventions at the site scale can be relatively small scale, requiring minimal resources. There may be opportunities to reduce threats through policy changes such as banning the conversion of peat swamp forests.	4.2.2
A4	**Individual Species Action Plans** It is beyond the scope of this plan to provide individual action plans for each species. Broad recommendations are provided in this framework, but each of the species will require plans (to varying degrees of detail) to ensure that the right measures are taken by the right people in the right places.	High	Organisations working on individual species (in situ and ex situ).	Varies according to the species.	4.2.3
B	**POLICY ACTIONS**				
B1	**Water infrastructure** Dams, navigation infrastructure, and flood control measures are a threat to a high proportion of ASAP Species, and many will not recover without a policy shift toward smart infrastructure.	High	National government water agencies, river basin management authorities.	Large-scale. There are many ongoing initiatives underway across the region with varying levels of success. Local mitigation efforts may be required to conserve specific habitats for species.	4.3.1

TABLE 1 Summary of the actions described in the framework (cont.)

	Action	Urgency	Potential lead stakeholder(s)	Scale of effort required	Detail Section
B2	**Sustainable fisheries** As only a few of the ASAP freshwater fishes are primarily threatened by overfishing, targeted policy action for those that are immediately threatened by unsustainable fisheries will make a significant positive contribution to their recovery.	Medium	Coordinated action with government agencies, fishing communities and other relevant stakeholders.	Local-scale and targeted approaches for specific species. Large-scale, coordinated, transnational, and research actions are required for large Mekong species.	4.3.2
B3	**Ornamental trade regulation** Most of the ASAP freshwater fishes are traded for home and public aquaria. Many are very popular in the trade. At present there is very little data on the scale or impact of the trade and few mechanisms to support sustainability. The aquaria trade itself can be a strong ally for conservation of ASAP freshwater fishes.	Very High	Ornamental fish trade, organisations linked to species and/or wildlife trade.	Large-scale. However, incremental and targeted changes can be made with limited resources.	4.3.3
B4	**Invasive species control** Invasive species are a threat to most of the ASAP freshwater fishes, particularly lake fishes and fishes with restricted ranges. Control of the release of potentially invasive fishes is needed across the region, matched with policy-led solutions for existing threats to specific ASAP Species.	Very High	Academic researchers, IUCN Invasive Species Specialist Group (ISSG).	Large-scale. A programme of research and regulation across the region is required to improve policy-led action.	4.3.5
B5	**National Biodiversity Action Plans** To gain governmental support and financing for ASAP freshwater fishes, a key route is to ensure that the ASAP Species are specifically mentioned in all the region's National Biodiversity Action Plans.	High	Relevant national government ministries and departments.	Medium-scale. Targeted national advocacy with national government sectors.	4.3.6
B6	**Conservation areas and habitat protection** The most immediate and effective species conservation method is to create conservation areas and protect habitat for each of the ASAP freshwater fishes.	Very High	National governments, local governments, and local communities.	Medium-scale. Identification and design of potential conservation areas will require a relatively low level of resources, while implementation and ongoing management may require a significantly high level of resources.	4.3.7
C	**TARGETED NATIONAL ACTIONS**				
C	 **Cambodia** Seven ASAP freshwater fishes are found in Cambodia and are all associated with the Mekong/Tonle Sap systems. Five of the species are large migratory fish. All these species are (potentially) found in Thailand, Lao PDR and Vietnam as well.				
C2	Large Mekong Migrants	Very High	Mekong Basin governments, Mekong River Commission, local communities, international researchers, and ex situ institutions.	Large-scale. Requires coordinated action with many local-scale actions in key habitats and fishing communities. Medium-scale.	4.7.1
C3	Siamese Tiger Perch *Datnioides pulcher*	High	Fisheries Department, Universities, and the aquaria hobby.	Requires multinational coordinated efforts.	4.7.1

TABLE 1 Summary of the actions described in the framework (cont.)

	Action	Urgency	Potential lead stakeholder(s)	Scale of effort required	Detail Section
D	 **Indonesia** Indonesia is by far the most important country for action for ASAP freshwater fishes. Forty-eight species (53% of all ASAP freshwater fishes) are found in Indonesia.				
D1	Sulawesi Lakes	Very High	Local governments, local communities, NGOs, international researchers, mining companies.	Large-scale. Relevant to the size and number of lakes. The primary threat is invasive species.	4.7.2
D2	West Papua and Papua	Very High	Local governments, local NGOs, communities, researchers.	Local-scale. Requires direct and targeted effort for a high number of locations and species.	4.7.2
D3	Peat swamp forest fishes	Very High	National and local government, local NGOs, protected areas, plantation companies, local communities.	Large-scale. Based on the number of species and localities. However, local action and attention may be the sole need at each site.	4.7.2
D4	*Rasbora tawarensis* and *Poropuntius tawarensis*	High	Local governments, Fisheries Department, local NGOs.	Medium-scale. Focused on one lake and one economically important species, but effort needed is medium-scale based on threat levels.	4.7.2
D5	*Betta fusca*	Medium	Local NGOs, researchers, protected area managers.	Small-scale. Primarily survey work to determine distribution of the species but may require significant investment to conserve the species.	4.7.2
D6	Javan "lost" species	Low	Local NGOs, researchers.	Small-scale. Individual efforts for each species.	4.7.2
E	 **Lao PDR** Thirteen ASAP freshwater fishes from two distinct groups occur in Lao PDR. In addition to the Mekong River ASAP freshwater fishes, four species are associated with fast-flowing headwaters in the Annamite mountains.				
E1	Fast Flowing Annamite Headwaters	High	Researchers, local NGOs, protected area department/managers, and local government; with potential involvement of the aquaria hobby.	Small- to medium-scales. Small-scale efforts are required to increase understanding of these species and to identify conservation initiatives. Conservation initiatives may require large-scale investment of resources due to threats such as dams and river degradation.	4.7.3

TABLE 1 Summary of the actions described in the framework (cont.)

	Action	Urgency	Potential lead stakeholder(s)	Scale of effort required	Detail Section
E2	Large Mekong Migrants	Very High	Mekong Basin governments, Mekong River Commission, local communities, international researchers, ex situ institutions, and Wonders of the Mekong Project.	Large-scale. Coordinated regional action with many local-scale actions in key habitats and fishing communities.	4.7.3
F	 **Malaysia** Nine species occur in Malaysia. Almost all of them are endemic, and they can largely be categorised into three groups: peat swamp forest fishes, island endemics, and riverine fishes.				
F1	Peat swamp forest fishes	Very High	Local NGOs, protected area departments/ managers, plantation companies, local communities.	Large-scale. Based on the number of species and localities, but local action and attention may be all that is needed at each site.	4.7.4
F2	Island endemics	Very High	Local NGOs, researchers, local communities, and local governments.	Small-scale. May be sufficient to design and implement conservation solutions for these species.	4.7.4
F3	Riverine species	Medium - Very High	Researchers, local, national and international NGOS, Fisheries Department.	Medium to Large-scale. The two Possibly Extinct species require further survey work to determine persistence. If they are confirmed to be extant, design and implementation of conservation actions are needed. *Probarbus jullieni* requires a larger-scale investment of resources across multiple countries with a wide variety of partners (in situ and ex situ).	4.7.4
F4	 **Myanmar** Only one ASAP freshwater fish is known from Myanmar.				
F5	*Systomus compressiformis*	Very High	Local government, local NGOs, and researchers.	Medium-scale. While this species is only found in one lake, the effort required to tackle the threats to this lake may be significant.	4.7.5

TABLE 1 Summary of the actions described in the framework (cont.)

	Action	Urgency	Potential lead stakeholder(s)	Scale of effort required	Detail Section
F6	 **Philippines** There are 12 ASAP freshwater fishes found in the Philippines and they are all endemic.				
F7	Lake endemics	Very High	Local governments, local NGOs, and researchers.	Large-scale. High levels of investment will be required to reverse the threats to these lakes, where many species have already gone extinct.	4.7.6
F8	*Caecogobius cryptophthalmus* (cave species)	High	Local government (tourism and wildlife departments), local NGOs, and researchers.	Small-scale. Relatively little investment is required to improve the habitat conditions and secure populations of this species.	4.7.6
F9	Riverine species	High	Local government, local NGOs, and researchers.	Medium-scale. Substantial investment is required to eliminate or mitigate the threats to these species, but the initial steps are to conduct surveys and research.	4.7.6
G	 **Thailand** There are 12 ASAP freshwater fishes found in Thailand. Among these 12 species, there are eight associated with large river channels, one is associated with limestone karst, one with rice paddies, and one with cave systems.				
G1	Large River (Mekong, Mae Khlong, Chao Phraya) species	Very High	National government, Mekong Basin governments, Mekong River Commission, local communities, international researchers, ex situ institutions, and Wonders of the Mekong Project.	Large-scale. Coordinated action with many local-scale actions in key habitats and fishing communities is required.	4.7.8
G2	*Betta simplex*	High	Local government and communities, Tourism and Agriculture departments, and aquarium hobbyists.	Small-scale. Direct targeted action and ex situ captive breeding efforts may be sufficient.	4.7.8
G3	*Nemacheilus troglocataractus*	High	Local government and communities, Tourism and Agriculture departments, aquarium hobbyists.	Small-scale. Direct and targeted action, with surveys and research, and ex situ captive breeding efforts.	4.7.8
G4	*Trigonostigma somphongsi*	High	Local government, NGOs, local communities, researchers, and aquarium hobbyists.	Small-scale. Direct targeted action, including wetland restoration, with surveys and research, and ex situ captive breeding efforts.	4.7.8

TABLE 1 Summary of the actions described in the framework (cont.)

	Action	Urgency	Potential lead stakeholder(s)	Scale of effort required	Detail Section
H	 **Vietnam** Nine ASAP freshwater fishes are found in Vietnam. Four species are endemic to Vietnam and the Annamite Mountains region. Five species are associated with the main channel of the Mekong and may be found in the other lower Mekong countries.				
H1	Fast Flowing Annamite Headwaters	Very High	Researchers, local NGOs, protected area departments/ managers, and local government, with potential involvement of the aquarium hobby.	Small- to medium-scale. Small-scale efforts are required to increase the understanding of these species and identify effective conservation actions. Conservation initiatives may require larger-scale investment of resources due to the potential threats, such as dams and river degradation.	4.7.9
H2	Large river channels	Very High	National government, Mekong Basin governments, Mekong River Commission, local communities, international researchers, ex situ institutions, and Wonders of the Mekong Project.	Large-scale. Coordinated regional action, with many local-scale actions in key habitats and fishing communities.	4.7.9
I	**Ex situ conservation action** Forty-nine species (54% of ASAP freshwater fishes) are recommended for active collection for ex situ conservation.				
I1	A detailed analysis of the suitability and relevance of ex situ breeding as a conservation tool is presented. Species recommended for ex situ action are listed. The possibility of breeding large numbers of fish in relatively small facilities, matched with the potential to partner with aquaria and skilled hobbyists, makes ex situ conservation of fishes a powerful tool for species recovery. Ex situ work should be linked to in situ efforts that create enabling conditions for reintroductions.	Very High	Zoos, aquaria, breeding centres, hobbyists.	Medium- to small-scale. Low levels of resource allocation are required immediately but will need long-term and sustainable continuity. Potential for involvement of the home aquaria hobby.	4.4
J	**Survey and Research priorities** Given the precarious status of ASAP freshwater fishes, urgent and direct actions to implement all of the recommendations in this Strategic Framework are needed. However, the majority of ASAP freshwater fishes require more survey and research work, as action is hampered by a major lack of data and knowledge for each of the species. It is important to restrict this exploratory work only to that which will immediately inform the design of conservation actions for the species or habitats. Some survey and research priorities that would also help improve the efficacy of immediate direct actions are listed.				
J1	**Geographic priorities** Five areas required substantial immediate investigation, as the status of the ASAP Species is unknown in these areas (Philippines, Sulawesi, Annamite Region, peat swamp forests in Malaysia and Indonesia, West Papua).	Medium	NGOs, universities, and museums.	Small-scale. Low amounts of resources are required for surveys.	4.5
J2	**Ecological and biological priorities** Ecological and biological parameters relevant to life cycles of the ASAP freshwater fishes are generally poorly understood, and additional data could enable effective conservation. However, immediate conservation actions based on existing knowledge should not be delayed by further investigations when prioritising use of resources.	Low	NGOs, universities, museums.	Small-scale. Low level of resources required for basic ecological/biological research.	4.5

TABLE 1 Summary of the actions described in the framework (cont.)

	Action	Urgency	Potential lead stakeholder(s)	Scale of effort required	Detail Section
J3	**Impact priorities** There are three areas of research related to specific threats and issues that are severely hampering conservation success. These research foci are recommended as immediate actions to improve the design of conservation actions. • Status of the aquarium trade • Invasive species eradication, control, and impact mitigation • Impacts of climate change particularly for rainbowfish of West Papua	Medium	NGOs, universities, museums, research institutions, government research departments.	Medium-scale. Medium levels of investment are required to support research and technical experts.	4.5
K	**Possibly Extinct species** Eighteen ASAP freshwater species are listed as Possibly Extinct. Some of these species require immediate attention given the possibility that they simply may have been overlooked or understudied (active search), while for others it may not be feasible to conduct expeditions solely to search for them. In some cases, incidental identifications (passive search) or work by those with specific interests would be the most feasible way to determine whether Possibly Extinct species persist.				
K1	Active search	Medium to High	Researchers, organisations, and interested parties.	Small-scale. Only limited resources may be required.	4.6
K2	Passive search	Low to Very Low	Local organisations, governments, and interested parties.	Small-scale. The probability of rediscovery is low, therefore immediate investment is not encouraged.	4.6
L	**Operational Actions**				
L1	**Capacity** There is a desperate need to strengthen capacity in the region to enable effective implementation of conservation measures. Many opportunities exist to collaborate and coordinate between interested parties.	Very High	Governments, donors, international NGOs, universities; local students, conservationists, and resource managers.	Large-scale. High investment required.	4.7
L2	**Funding** The region suffers from relatively low levels of investment in freshwater conservation. Therefore, implementation of this framework depends upon scaling up funding to increase capacity and support action.	Very High	Governments, donors, international NGOs.	Large-scale. High investment required.	4.7
L3	**Governance and facilitation** – See section 5.3 The Strategic Framework will be overseen, coordinated and facilitated by the ASAP programme together with key partners such as SHOAL. It is hoped and anticipated that many other stakeholders will engage in the implementation of the recommended actions and coordinate with ASAP. The Framework will be reviewed and revised at regular intervals and subsequent action plans for different components of the Framework will follow. An annual update on the progress of the application of the Framework will be published.				
L4	**Government engagement** – See section 5.4 Very often the most powerful and long-term implementors will be government bodies, particularly at the local level. Government bodies can provide longevity for investments, integrate them into broader planning and policies, and provide consistent funding and capacity.				

Suggested urgent broad actions

While this Strategic Framework is not meant to serve as an action plan, eight urgent priorities can be drawn from the framework to help initiate and direct immediate action (Tbl. 2). The list of priorities is not fully comprehensive, but if efforts are directed at these eight priorities in the immediate future significant progress towards recovering many ASAP freshwater fishes can be achieved.

TABLE 2

Eight urgent priorities

	Broad immediate actions	Explanation	References to relevant sections of the framework
1	**Very local site-based foci with low to medium resources required**	The majority of ASAP freshwater fishes are confined to small, restricted habitats where local, well-designed, and targeted action can ensure substantial advances supporting the survival and recovery of species. Each of these interventions requires relatively small amounts of resources, but community and local government engagement is critical. Essential aspects of actions to recover ASAP freshwater fishes can be achieved with individual and dispersed efforts targeting these fishes and habitats.	Lake endemics, peat swamp forest fishes, cave endemics, island endemics, restricted range species, West Papua Rainbowfish, *Betta simplex*.
2	**Large-scale internationally coordinated multi-species efforts**	Some of the fishes, particularly those in the large rivers such as the Mekong, are migratory and require very large-scale complex interventions. Action is needed immediately before it becomes completely impossible to find solutions for these species.	Mekong and river migrants.
3	**Trade and fisheries issues**	The trade in fishes, either as a food source or as ornamental fish for the aquarium trade, is poorly understood. While such harvest clearly poses a threat, the impacts are not always clear. However, the higher economic value of fishes harvested for trade may provide some solutions for these species. Therefore, relevant research would be extremely helpful at this stage for many targeted species.	Sustainable fisheries and ornamental trade regulation.
4	**Field surveys and research**	Effective conservation for many of the species is hindered by a lack of data and information. More surveys and research for these ASAP freshwater fishes should be promoted as much as possible. This is particularly the case for species considered to be Possibly Extinct, and active searches are recommended. However, direct conservation action should be undertaken once the minimal amount of information needed for designing conservation actions becomes available, while surveys and ecological research continue.	Further survey and research priorities, possibly extinct species.
5	**Ex situ breeding**	Almost all of the ASAP freshwater fishes have precariously small populations in the wild. Therefore, assurance populations are needed immediately. Other species would benefit from population supplementation, given it is possible to raise high numbers of fry to the age where their survival in the wild is enhanced before they are released.	Ex situ conservation priorities and opportunities.
6	**Invasive species solutions**	Many of the fishes, particularly lake endemics, are threatened principally by invasive species and no in situ conservation efforts will succeed until solutions to this threat are in place. It is critical that a concerted international effort is undertaken to find these solutions.	Lake endemics.

TABLE 2 Eight urgent priorities (cont.)

	Broad immediate actions	Explanation	References to relevant sections of the framework
7	**Conservation protection**	All the ASAP freshwater fishes require specific in situ conservation measures to reduce the impact of threats and to give habitats and populations the opportunity to recover. Some ASAP freshwater fishes may already be present within sites that have active conservation measures, though they may not presently benefit from those measures. Immediate action to identify conservation measures, such as community-based conservation areas, nature reserves, and other forms of species and habitat protection would provide a significant contribution to securing the future of these most threatened species.	All ASAP freshwater fishes.
8	**Networking and strengthening capacity of key stakeholders**	No impact will be achieved without an immediate significant effort to increase the capacity across the region to assess, plan, and act for the ASAP freshwater fishes. Connecting, training, and supporting a network of partners and stakeholders to undertake effective action should be a top priority, especially for any coordinated regional efforts.	All ASAP freshwater fishes.

Surveying streams for fish. Taken in 2014. Photo: Nam Ngiep.

1

Introduction

1.1 IUCN SSC ASAP and ASAP Freshwater Fishes

The Asian Species Action Partnership (ASAP), convened by the IUCN Species Survival Commission (SSC), is a partnership bringing together a network of organisations with the collective aim of averting species extinctions in Southeast Asia.

Southeast Asia is a region with high levels of anthropogenic-induced biodiversity loss. Without urgent intervention, ecosystems within this region risk losing significant proportions of their unique and rich biodiversity. ASAP works to catalyse and support conservation actions to save the Critically Endangered land and freshwater vertebrate species found in Southeast Asia.

ASAP has identified all Critically Endangered freshwater fishes found in Southeast Asia to assess threats, determine priorities, and operationalise conservation actions for these species. Critically Endangered species, as determined by the IUCN Red List of Threatened Species™, are those facing the most imminent risk of extinction in the wild.

This document is based on the December 2022 publication of the IUCN Red List of Threatened Species™ as well as some new information released in April 2023. This strategic framework focuses on 90 species that occur solely in freshwater and does not include euryhaline species. These 90 fishes represent diverse taxonomy, morphology, ecological function, and life history traits. The species range in size from some of the smallest to some of the largest in the world. Some live in large transboundary rivers like the Mekong, and migrate long distances through several countries, while others survive in small pockets of remnant wetland habitats that are quickly shrinking. Formulation of an efficient conservation framework is critical for development of effective and sustained actions for each of these Critically Endangered freshwater fish species.

1.2 Purpose of this document

This Strategic Framework for action is designed to accelerate the immediate conservation of 90 species of freshwater ASAP freshwater fishes. Estuarine and euryhaline species have not been included. The daunting complexity of considering the conservation of this large number of species that are relatively obscure, data poor, highly threatened, and distributed throughout a large international region, has potentially been a significant barrier to catalysing effective and efficient conservation. This piece of work and its presentation in this document is meant, first and foremost, to break down the challenge by exposing avenues through the complexity and sort actionable tasks into potential programmes of work. The document is not meant to be simply read through from cover to cover, although this might be a good place to start to have an initial overview. It is meant, rather, to be a reference document for those who are seeking to understand the priorities and considerations required to meet the challenge of tackling such a large number of species demanding urgent attention. Future users may be nationally based conservation agencies wishing to make a contribution to one or more species, or donors seeking to be informed about priorities. It may be government officials seeking to develop policy to reduce the loss of the most threatened species in their country or at a regional level. As a reference document, it has deliberately been presented by looking at the challenge from various viewpoints, allowing users to refer to the specific

***Oryzias soerotoi* habitat, Lake Tui, Sulawesi, Indonesia. Photo: K. Yamahira.**

sections most relevant to them. This means some information may have been provided more than once to reduce the likelihood of missing critical considerations when exclusively using single sections of the framework.

The document also provides some background on the causes of fish declines in the region, summarising currently available data for ASAP freshwater fishes and describing the primary action categories that should be considered when designing conservation interventions. Available data on these fishes, including information on threat drivers, are herein summarised and strategies for designing conservation interventions are recommended. It is not meant to be an action plan for conservation of all freshwater fish in Southeast Asia, nor is it a comprehensive collation of individual action plans for each of the ASAP freshwater fishes. This framework is entirely focused on identifying and ordering actions to facilitate better understanding of the types of initiatives required to put an immediate halt to the population declines of these Critically Endangered species and facilitate their recovery.

1.3 Designing the Strategic Framework

For each ASAP freshwater fish, data on taxonomic status, distribution, habitat, identified threats, and IUCN Red List assessment status were distilled from the IUCN Red List of Threatened Species™ (IUCN, 2021). Further information was also extracted from the Assess-to-Plan workshop report on Sundaic freshwater fishes (Lees et al., 2020). Data on the biology, ecology, and husbandry of each of the ASAP freshwater fishes were collated from extensive reviews of scientific and grey literature, as well as sourced from hobbyist groups, forums, and other online platforms. Data were augmented through expert consultations and compiled into a database.

Once the database was compiled, categories of actions were accumulated, sorted, and categorised based on predicted user needs (i.e., dependent on the particular interest of the user of the Strategic Framework) and on identification of the least number of approaches needed to facilitate efficient implementation. This process resulted in a first draft of the framework. An expert group was then convened to review the framework and contribute input on structure, content, and accuracy. This input was incorporated into a second iteration of the framework, which underwent an additional round of expert review to refine and produce the final framework document.

Crafting the framework was complicated, as it covers a large number and wide variety of species from many different habitats, facing an array of multiple threats within several countries. The framework uses a strategic focus to direct action rather than drilling down to detailed actions for individual species.

2

Setting the context for the Strategic Framework

2.1 Decline of freshwater fishes

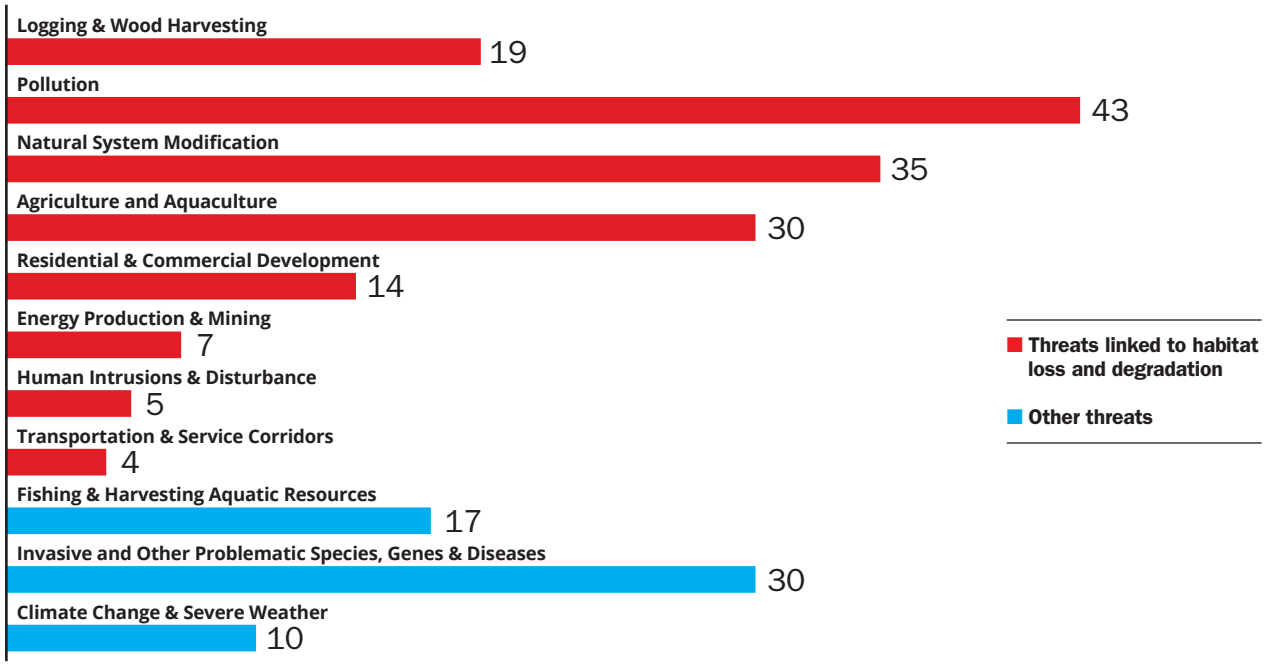
We are in the midst of a freshwater biodiversity crisis. Freshwater vertebrate populations are declining at twice the rate of those in terrestrial or marine ecosystems (Grooten and Almond, 2018), and about one third of freshwater fish species are threatened with extinction (IUCN, 2022). On average, populations of migratory freshwater fishes have dropped by 76% globally between 1970-2016 (Deinet et al., 2020) and populations of large species (freshwater megafauna) have shown declines of 88% between 1970-2012 (He et al., 2019).

Eighty-three freshwater fish species have been categorised as Extinct by the IUCN Red List, with nearly 3,000 more assessed as globally threatened and over 2,500 categorised as Data Deficient (IUCN, 2022). In 2020 alone, 16 freshwater fish species were declared Extinct and 15 of them were Southeast Asian species (ASAP, 2020), highlighting the dire state of many species within this biodiverse region. Ninety species of fishes restricted to freshwater systems in Southeast Asia have been assessed as Critically Endangered (IUCN, 2022).

FIGURE 1

IUCN Red List Threats

The numbers of ASAP freshwater fishes impacted by specific threat categories as defined by the IUCN Red List of Threatened Species™. Threats associated with habitat loss are shown in red bars, and additional threat categories are shown in blue bars.



The freshwater fish diversity of Southeast Asia is exceptionally high, with 5,645 described species as of October 2022 (FishBase, 2022), making up more than 30% of all described species at that time. Many species have limited distributions or are single site endemics, making them particularly vulnerable to extinction.

2.2 Decline of ASAP Freshwater Fishes

Many ASAP freshwater fishes face multiple threats, as identified by assessments for the IUCN Red List of Threatened Species™. Threats associated with habitat loss and degradation affect nearly all ASAP freshwater fishes.

Broad threats of primary concern for ASAP freshwater fishes include:

■ Habitat loss and degradation

The primary threat to nearly all ASAP freshwater fishes is the rapid loss and degradation of their natural habitats. Natural system modifications as a specific threat category alone impacts 35 ASAP freshwater fishes. Many of the species are facing additional threats connected to habitat loss. Deforestation, conversion of wetlands, aquaculture and agriculture production, mining, hydropower development, and urban development are rapidly expanding in the region. These activities directly reduce the extent of suitable habitat, cause habitat fragmentation, and impact water quality.

- **Pollution**

  At least 43 ASAP freshwater fish species are impacted by pollution. Chemical and nutrient pollution has increased drastically in Southeast Asia following rapid urban and agricultural development. Illegal gold mining in rivers is widespread, releasing toxic mercury into waterways. Fertiliser and pesticide runoff from agriculture, domestic waste discharge from human settlements, as well as excessive nutrient inputs from livestock operations, are directly impacting fish health, food webs, dissolved oxygen levels, and water quality.

- **Dams and other man-made infrastructure and river modifications**

  There has been a massive push for the construction of hundreds of hydropower dams in Southeast Asia in recent years, as the rivers of the region are perceived by some as an "untapped" natural resource that can fuel economic development. In many cases, not enough is known about the native fish communities in areas slated for dam development to develop appropriate strategies to mitigate negative impacts from the dam or to design effective fish passages for migratory species. Dams alter sediment transport, flow regimes, water quality and temperature, convert lotic habitat to lentic reservoir habitat (that is generally unsuitable for native species adapted to life in flowing waters), disrupt larval transport, isolate populations, reduce gene flow, and eliminate access to large extents of habitat and/or spawning sites.

The Pak Mun dam and upstream of the Lower Mun River in Thailand. Taken in 2018. © Teerapong Pomun.

Habitat of *Parosphromenus deissneri* on Bangka Island, Indonesia. The forest was burned down for agricultural land use. Taken in 2019. Photo: S.J.D.

Signs of illegal logging in *Betta burdigala* habitat on Bangka Island, Indonesia. Taken in 2018. Photo: Wentian Shi.

Illegal tin mining near *Parosphromenus deissneri* habitat. Taken in 2019. Photo: S.J.D.

Overharvest

Freshwater fishes provide the primary source of protein and livelihoods for millions of people in Southeast Asia. Fishers typically keep, and consume or sell, just about every species they can catch. There has been a shift from traditional fishing techniques, which were often designed to target specific and abundant species, to the widespread use of fine mesh gill nets and electrofishing that indiscriminately capture a wide variety of species at different life stages. While most ASAP freshwater fish species are so rare that they do not typically sustain targeted fisheries, there are some species that have become rare due to harvest, in particular large species like the Mekong Giant Catfish and Jullien's Golden Carp, as well as some lake endemics such as *Rasbora tawarensis* and *Poropuntius tawarensis*.

Ornamental fish trade

Southeast Asia supplies the world with many attractive fish species that are popular in the global aquarium trade, including some that are threatened or naturally rare and collected from the wild to meet consumer demand. Some species can fetch very high prices, driving a strong incentive for exploitation. The extent and scope of the trade are not well documented and hence are almost completely unregulated. While laws protecting some species exist, they are seldom enforced adequately.

Invasive species

Invasive species are non-native species that have been introduced to a locality where they do not naturally occur, and that have a negative impact on resident native species, their habitat, or on ecological processes. Invasive species are one of the most significant threats to the ASAP freshwater fishes. At least 30 ASAP Species are threatened by invasive species (IUCN, 2022), primarily through competition for food and habitat, alteration of water quality and macrophyte cover, and via predation of eggs, larvae, juveniles, and mature individuals. Invasive species are of particular concern for endemic ASAP Species in ancient lakes, and those with highly restricted ranges. The sources of invasives can primarily be traced to aquaculture, the aquarium trade, or intentional stocking.

Climate change

Models from the Intergovernmental Panel on Climate Change indicate that maximum flows will increase, and minimum flows will decrease in rivers such as the Mekong (Hijoka et al., 2014). This could lead to massive bank erosion and associated increases in sedimentation in the wet season, and dangerously low flow levels in the dry season that would impact recruitment of many native freshwater fishes. Climate change has also been the largest identified threat for a significant proportion of Critically Endangered fish species from Papua, with fluctuations in water level further restricting distributions while simultaneously increasing risk of predation.

3

Synthesis of the available data on ASAP Freshwater Fishes

The full annotated list of the ASAP freshwater fishes is provided in Annex A.

The list of ASAP freshwater fishes, like all assessments of Red List species, is based on the best available data and expert consultations. Still, knowledge gaps that exist for Southeast Asian freshwater fishes may influence the number of species included in the ASAP list. More than 800 of Southeast Asia's freshwater fish species (approximately 32% of the total number of freshwater fish species in all of Southeast Asia) are listed as Data Deficient (IUCN, 2022). Significant numbers of these species might be categorised as Critically Endangered if sufficient data were available. Additionally, many Red List assessments are more than 10 years old and therefore need reassessment which may result in a change of status for some species.

Though the IUCN Red List of Threatened Species™ serves as the world's most comprehensive inventory of the global conservation status of biological species, many information gaps exist that influence the Red List's coverage despite best efforts by researchers and conservationists worldwide. Lack of taxonomic knowledge and survey effort are major factors that affect accuracy, and certain geographical regions in Southeast Asia remain poorly surveyed, such as the Philippines, Myanmar, Wallacea, and the Annamites region of Lao PDR and Vietnam. These locations, with high levels of species richness and endemism, likely host species yet unknown to science, which are perhaps already threatened. In turn, increased survey coverage may or may not provide information demonstrating range expansions for known threatened species formerly thought to be more restricted.

As additional research and data become available, the species which should be included in a framework such as this will vary. An update of this framework will be led by ASAP every four years to incorporate new data to ensure the ASAP list is as comprehensive as possible over time.

3.1 Distribution by country

Indonesia hosts the largest number of ASAP freshwater fishes (48 species, representing more than half of all species on the list). Lao PDR follows, with 13 listed species, then the Philippines and Thailand with 12 species each, Malaysia and Vietnam with nine species each, and Cambodia with seven species. One species is found in Singapore and one in Myanmar (Fig. 2).

3.2 Endemism

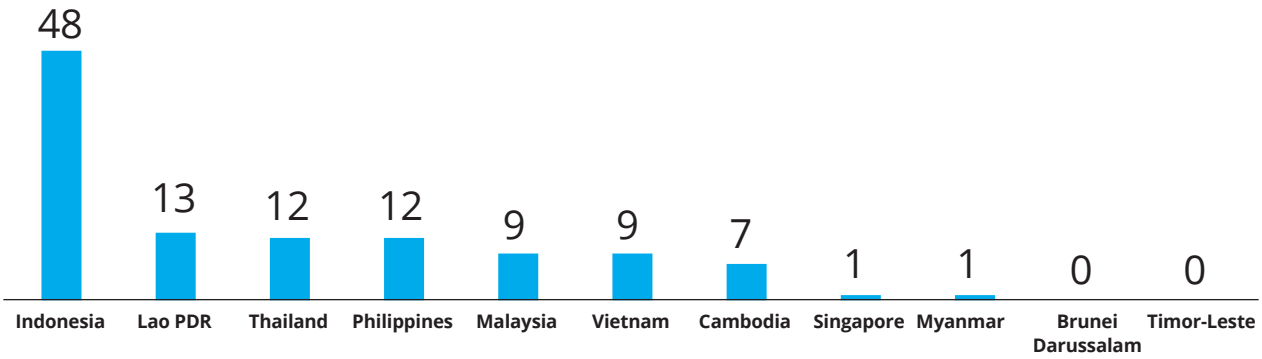
Eighty-nine ASAP freshwater fishes (98%) are endemic to the region. Only one species is found outside of the region, *Pangasius sanitwongsei*, which is believed to be in sections of the Mekong River in China. 81 species (90%) are endemic to a single country* and 73 (81%)* are understood to be single site endemics or range restricted species. A further our species are listed as potentially being single site endemics but there is limited understanding of their true status. It should be noted that for many of the species there are minimal data on their distributions and status, and therefore it may be possible that many of them have wider distributions than we are aware of today. In 2023, whilst compiling this framework, two species were found far outside their known range, indicating this may be the case for additional species.

*This figure reflects the recent discovery, reported in 2023, of *Encheloclarias kelioides* in Singapore (Tan et al., 2023), well outside its known range from two sites in southern Peninsula Malaysia and the discovery of *Clarias batu* outside of Tioman Island in several locations in Peninsula Malaysia (Ahmad, A, pers. comm., April 2023).

FIGURE 2

ASAP Freshwater Fishes by Country

The number of ASAP freshwater fish species per country in Southeast Asia. As some species range across multiple countries, the sum of species in all countries combined is larger than the ASAP Species total of 90.



3.3 Taxonomic distribution

While the ASAP freshwater fishes list comprises members from 22 different families, 48 species (53% of the total) come from only three families: Cyprinidae (19%), Osphronemidae (18%), and Melanotaeniidae (17%) (Tbl. 3). A further 16 species (18%) come from another three families: Balitoridae, Gobiidae and Adrianichthyidae. These trends illustrate how the habitat requirements and life histories of specific families of freshwater fish in the region render them disproportionately susceptible to specific anthropogenic threats.

Osphronemidae is represented in the ASAP list by 16 species, which is 12% of the total global diversity of this family. These fish, mostly range-restricted peat swamp forest and blackwater forest stream specialists, have been drastically impacted by peat swamp forest and lowland forest conversion across the Malay Peninsula, Sumatra, Borneo, and associated islands. In addition to being important food fishes, some osphronemid species, such as *Betta* spp., and *Parosphromenus* spp., exhibit beautiful colouration and interesting behaviour, and are targeted for the aquarium trade.

Melanotaeniidae are similarly well-represented in the ASAP list with 15 species (13% of the total global diversity). Like the osphronemids, many of these rainbowfishes are highly range restricted. They face severe threats from climate change - mediated fluctuations in water levels, which render them particularly susceptible to predation during the dry season. Like the osphronemids, these rainbowfishes are colourful and face additional threat from collection for the aquarium trade.

The family Cyprinidae is represented in the ASAP list by 17 species, which constitute just over 1% of the global diversity of this highly speciose and widely distributed family. However, they are strongly represented in the ASAP Species list with species from major rivers as well as lake endemics. Many of them were historically of commercial significance yet drastic reductions in their populations mean they can no longer support such fisheries. In this list of cyprinids, the devastating effects of dams, overharvesting, and invasive species are working in concert. This creates complex problems which will need to be addressed via multiple avenues, if these fish are to be saved from the brink of extinction. Fifteen *Barbodes* spp. endemic to Lake Lanao in the Philippines, representing a highly remarkable taxonomic radiation, have recently been declared extinct (IUCN, 2020).

TABLE 3

ASAP Freshwater Fish Families

Family	Species per family	% ASAP Species
Cyprinidae	17	19%
Osphronemidae	16	18%
Melanotaeniidae	15	17%
Balitoridae	7	8%
Adrianichthyidae	5	6%
Gobiidae	4	4%
Clariidae	3	3%
Eleotridae	3	3%
Atherinidae	2	2%
Bagridae	2	2%
Pangasiidae	2	2%
Siluridae	2	2%
Akysidae	1	1%
Ambassidae	1	1%
Butidae	1	1%
Clupeidae	1	1%
Cobitidae	1	1%
Datnioidae	1	1%
Nemacheilidae	1	1%
Pseudomugilidae	1	1%
Sisoridae	1	1%
Zenarchopteridae	1	1%

4

Freshwater Fish Conservation in Southeast Asia

While this framework focuses on specific considerations that should be applied for development of actions and strategies that are relevant directly for ASAP Species, the following key approaches should be considered in any regional or national action plans for broader freshwater fish conservation in the region:

Awareness

Freshwater fishes have been relatively overlooked and neglected within the global species conservation realm, and the situation is no different in Southeast Asia. The minimal attention, funding and effort paid to freshwater fish conservation partially stem from a substantial lack of widespread knowledge and awareness of the rich biodiversity that exists underwater, largely out of sight, and the threats they are facing. Awareness is an essential first step for catalysing engagement and action, and therefore, it is not surprising that freshwater fishes make up the largest proportion of all ASAP Species groups.

While freshwater fishes have been largely ignored by decision makers and the conservation community, they are of exceptionally high importance for millions of people in the region who rely on them for subsistence, and who often hold extensive knowledge. Raising awareness, particularly among decision makers, the public, and the broader conservation community, should be the initial priority for any regional strategy. In addition to benefitting ASAP freshwater fishes, heightened awareness could motivate a broad spectrum of conservation actions that would benefit many taxonomic groups reliant on freshwater ecosystems.

The Lower Mun River in Thailand, a tributary of the River Mekong. Photo: Teerapong Pomun

Capacity

Strengthening capacity for Southeast Asian nationals must be a central component of all conservation action plans developed for threatened freshwater species in the region. Currently, efforts focused on freshwater fishes are centred around fisheries management and wider river basin management rather than on conservation of threatened species. Increased local capacity for effective planning and implementation of conservation actions for threatened fishes in Southeast Asia is desperately needed. International conservation organisations working in the region do not have dedicated programmes for freshwater fishes, and government

agencies with responsibility for freshwater species or systems management also focus heavily on fisheries rather than conservation, with minimal governmental support for species-level conservation action. Most of the past and ongoing work has been led by universities and museums that primarily conduct research to collect taxonomic and inventory data.

Integrated River Basin Management

A multitude of competing and increasing demands for water resources has driven inequitable and unsustainable water allocations that favour economic growth above all else. The resulting environmental consequences are quite evident throughout much of Southeast Asia and play a major role in the decline of freshwater fishes. Current watershed management strategies rarely incorporate practices that safeguard biodiversity and ecosystem services, but instead are heavily weighted towards maximising economic gains. This has led to a boom in hydropower development, rapidly rising pollution levels, and extensive deforestation. Integrated River Basin Management (IRBM), which accounts for the broad spectrum of both land and water resource demands within a watershed to balance economic, social, and environmental needs (Komatina, 2018), must be incorporated into broader policies and conservation action plans. Local watershed management coalitions should be established and supported at the catchment level. Relevant government agencies should apply IRBM practices for resource use planning, infrastructure development decisions, and regulations associated with a variety of land use types.

Mainstreaming and integrating fish conservation within priority development objectives

Social and economic development are often of higher priority for the governments of Southeast Asian countries. It is not rare to see fisheries highlighted as a priority economic focus in regional and national development plans. However, there has been no systematic consideration of ecological balance and natural production within these plans, so considerable threats to the fish diversity in the region have arisen from unsustainable development plans. It is critical that clear policies for the conservation, protection, and recovery of freshwater ecosystems and species diversity are built into development objectives and that more resources are committed to lead and manage effective implementation.

Mitigating the impacts of climate change

Not only does climate change intensify the existing threats facing freshwater fishes, but associated changes in water temperature also affect physiology and behaviour, influencing factors like habitat range and reproductive success (Macusi et al., 2015) that are major determinants of the probability of species persistence. Changes in seasonal water levels, higher frequency of flooding, and drought events are expected to have especially high impacts (Xenopoulis et al., 2005), along with higher sedimentation rates and reduced water quality. Recent modelling suggests that the freshwater fish species richness of Southeast Asia's river basins could drop by 24-58% by 2070 (Manjarrés-Hernández et al., 2021).

Policies that support clean water, protect ecosystem services, sustain biodiversity dependent on healthy watersheds, and expand restoration of freshwater ecosystems (Albert et al., 2021) are urgently needed to mitigate impacts of climate change. Riparian habitat restoration, forest restoration, wetland site protections and associated environmental flow needs, and engineering of new wetlands are all actions that can be undertaken in the near term. Political, social, financial, and technical support and engagement will be required to foster such actions.

Minimising the impact from dams and other water infrastructure

The boom in hydropower development and expansion of industrial agriculture and urban areas that require water infrastructure development represents a major threat to many species. Currently, fisheries agencies and threatened species experts have minimal influence when it comes to approval of construction permits for dams or other water infrastructure. There is a need to integrate reviews by fisheries agencies on dam construction proposals and potential biological impacts with the findings applied to determinations regarding approval of new dam construction. Specific regulations need to be established to limit amounts of water withdrawals, construction of infrastructure that abstracts water for agricultural, urban, or industrial uses, or that creates barriers to fish migration, with these regulations developed in partnership with fisheries agencies. Priority rivers and stretches that are the most important for the survival of threatened fishes and/or support distinct populations should be identified, and dam or infrastructure development should be prohibited in those locations. Regulations should specify exact locations where new infrastructure development is fully banned, based on the identification of critical habitats and migration routes that are essential for the survival of freshwater fishes.

Pollution Control

Rapid expansion of industrial, urban, and agricultural development in many parts of Southeast Asia has led to increases in effluents and pollutant runoff, causing substantial declines in water quality and increased concentrations of toxins that negatively impact fish survival rates. Buffer zones where specific land use practices are prohibited (such as intensive cattle

ranching and agriculture) should be delineated around water bodies that are deemed as critical habitat for threatened native freshwater fishes. Currently, water quality standards that control industrial or urban effluents, or polluted runoff, do not exist in many areas. Often where they do exist, monitoring is not regularly conducted to enable enforcement of such standards. Standards should be set where they're currently lacking, effluent monitoring should be mainstreamed, and substantial fines for excessive effluent releases that exceed legal limits delineated under water quality standards should be formalised. Additionally, many communities need improved access to appropriate domestic waste disposal facilities. In some locations, it is normal practice to dispose of household waste by dumping it into nearby rivers.

Halting the negative impacts from gold and river aggregate mining

Mining of riverbeds for gold, sand, and other river aggregates is a major industry in many waterways of Southeast Asia and is often unregulated or loosely regulated. Additionally, small-scale gold mining in rivers is common and widespread, resulting in high levels of mercury contamination which bioaccumulates in many fishes. This activity should be banned in most locations and such regulations must be enforced. Small-scale gold mining is illegal in some areas, but rarely are these rules enforced. Strict limits on river aggregate mining such as sand mining should be set, which specify allowable quantities, locations, and times of year when mining is allowed, to reduce negative impacts on threatened species. A permit lottery system could be an effective mechanism for controlling the number of such operations. Fisheries agencies should have authority to review mining permit requests and be required to report on potential biological impacts. The findings of fisheries agencies should be obligatorily factored into cost-benefit analyses that control determinations on approval of mining permits.

Eliminating invasive species

The accidental or deliberate introduction of alien species, particularly fishes that become invasive, threatens many native fishes throughout the world including in Southeast Asia. Invasive fishes often outcompete native species for food, prey on eggs, juveniles, and adult native species, alter habitat structure and aquatic flora assemblages, and decrease water quality. They are particularly a problem for species restricted to one or more lakes. Invasive species introductions are sometimes the result of escape from aquaculture but are more often driven by purposeful releases to boost and supplement local fisheries (see aquaculture below). This is also true for ornamental fishes. They are often escapees but more frequently are introduced by deliberate releases of unwanted or excess fish. In some cases, as in Lake Matano in Sulawesi, the fish are released to breed the fish for sale into the aquaria trade. Strict measures from national governments are required to halt any wild release of non-native species and to ensure that any aquacultural activities meet the highest standards to reduce the chance of accidental release.

The fishing team of Yayasan Bumi Saweridaging removing invasive fish from Lake Mahalona in Sulawesi, Indonesia. © Yayasan Bumi Saweridaging.

Promoting best practice aquaculture

Aquaculture has been a traditionally common practice for people in Southeast Asia. As in many countries around the world, intensive and large-scale aquaculture practices have been adopted in all of the Southeast Asian countries. The primary purpose is often to increase fish production to support livelihoods, and to increase food supply and critical sources of protein, often to support some of the poorest communities in the world. Species such as the Mozambique Tilapia (*Oreochromis mossambicus*), Walking Catfish (*Clarias batrachus*), Common Carp (*Cyprinus carpio*), and Climbing Perch (*Anabas testudineus*) are the most common and concerning in Southeast Asia, given their high potential to become invasive. These species have been accidentally and deliberately introduced to natural freshwater systems and have since become established sufficiently to threaten native fishes. Aquaculture operations can also release substantial amounts of pollutants and nutrients that impact water quality and native fishes.

4.1 Action Categories

There is a total of 90 ASAP freshwater fish species for which one or more next-step conservation action categories have been identified. Actions needed have been identified based on assessments from the IUCN Red List of Threatened Species™ (IUCN, 2021) and expert consultation.

Eight categories of action have been listed as relevant to more than one of the ASAP freshwater fishes. To simplify often complex action requirements and provide a rapid reference to the actions needed for each species or groups of species, these actions are listed and defined below (Tbl. 4). In all cases, actions are defined in more detail within the framework.

TABLE 4

Relevant Action Categories

	Action category	Explanation of action required
1	**Site or habitat protection and restoration**	By far the most common action required for each of the ASAP Species is protection of their habitats from further destruction or degradation. In many cases, this may include creation of a legal protection status or may simply require local agreements, policies, and practices. In cases where some protection exists, the protection may need to be expanded, the capacity to manage and protect the site may need to increase or a greater input of resources and financing may need to be invested. Most of the sites play a critical role for local people or businesses and therefore policies of total exclusion may not be appropriate or even achievable. This action aims to ensure the necessary conditions for recovery are in place and that systems are designed to maintain the correct and necessary management in perpetuity.
2	**Policy**	A policy action is intended to create or amend a government, community, corporate or other governance-based policy or process. Changing policy is usually required to put in place the correct processes or practices that will create the necessary conditions for effective management of a threatened species. See section 4.3 for more detailed discussion on policy actions.
3	**Species management**	While for most species, elimination or reduction of the threat will support a resurgence of the population, many species also require clear, targeted interventions to increase and recover populations such as specific actions to increase habitat, provide supplementary feeding, create breeding habitat, reduce competition, halt disease, removal of predators, or ex situ interventions.
4	**Further information/survey/ research**	A particular type of species management is required for those ASAP Species that migrate between sites. A wide variety of actions are required to ensure the best conditions for migratory fish, particularly those with long-distance, transboundary migrations as part of their life cycle.
5	**Invasive species**	Conservation and management programmes will benefit from more information on all ASAP freshwater fishes. Basic data on ecology, population status, and threats are lacking for a majority of the 90 species. This action is listed as a priority specifically for species where such information is lacking, and therefore hampers effective management and conservation action. See section 4.6 for more detailed discussion on survey and research priorities. Many species are suffering from the negative impacts of non-native invasive species and action is required to halt those impacts. Control and/or eradication of invasives should be undertaken where feasible, while education and legislation to limit introductions should be widely implemented. Clear policies and the adoption of best practices are required to stop the accidental or deliberate release from aquaculture facilities of non-native and potentially invasive species.
6	**Ornamental fish trade management and regulation**	Many of the ASAP freshwater fishes are collected and sold as ornamentals for the aquarium trade, but for many ASAP Species found in the trade the impact of this industry is not well understood. In many cases, regulation of the trade may be required to ensure that the collection is halted entirely or maintained at sustainable levels. See section 4.3.3 for more detailed discussion on ornamental fish trade regulation.

TABLE 4 Relevant Action Categories (cont.)

	Action category	Explanation of action required
7	**Ex situ conservation**	Establishing ex situ populations of ASAP freshwater fish species may be necessary when threats persist without signs of abating, or when survival in the wild is unlikely. This is the case for 49 of the 90 fish species. Prior to ex situ conservation intervention, evaluations should be carried out on whether it is possible to keep the species in captivity, and an evaluation of opportunities to restore the conditions required for the population to survive in the wild. In some cases, it may also be considered best to keep an assurance ex situ population to ensure that if there is a crisis in the future, some individuals will survive. Ex situ conservation has been identified as a potential conservation action for about half of the species in this list. See section 4.4 and Annex A for more detailed discussion on ex situ conservation.
8	**Education and awareness raising**	Some species require specific education and awareness-raising interventions with targeted groups such as local government bodies and stewards, conservation implementers, fishing communities, or aquarium fish traders and hobbyists as a significant component of a conservation strategy. As freshwater fish in their natural habitats are often not directly visible, they often go unnoticed or are ignored – this holds true even for visually attractive species (e.g., *Betta* and *Parosphromenus* spp.). Outreach efforts can be a valuable tool for various stewards (e.g., local communities, resource managers), first to raise awareness of the presence of these Critically Endangered species within their localities and to garner conservation support, and then to advise on how to best protect them.

4.2 Regional Priority Actions

There are three cross-cutting, non-policy, themes that are relevant for many ASAP freshwater fishes and that would involve multiple countries. These are best discussed in detail separately and are referred to under other sections when necessary and appropriate. A short summary describing seven ASAP freshwater fish species not entirely confined to freshwater is also included in this section.

4.2.1 Action for Large Migratory Freshwater Fishes

This group is highlighted as their populations have generally experienced the most severe declines because their body sizes, life histories, and highly migratory nature require unique and multi-faceted conservation strategies, often involving multiple stakeholders and countries. Actions needed to conserve them will benefit additional groups of ASAP Species. Most of these species migrate long distances upstream to spawn, spurred by natural seasonal flow fluctuations. The larvae depend on seasonal flooding to provide nursery habitat, and often need to drift far downstream to reach suitable nursery habitat. These species require large-scale connectivity to successfully complete their life cycles. Existing dams on the Mekong and its tributaries have significantly impacted these life cycles and represent a severe threat to the survival of these species. They range across multiple countries throughout different seasons, requiring coordinated action among countries and multiple government agencies at the transnational basin scale. They are primarily distributed within three basins of the region: the Mekong, Chao Phraya, and Mae Klong.

There are five large migratory ASAP Species:

1 **Mekong Giant Salmon Carp (*Aaptosyax grypus*)**
The maximum standard length recorded by scientists is 130 cm and it can weigh over 30 kg (Roberts, 1993), but the size at sexual maturity is not known. Its upstream migration patterns are thought to be linked with spawning activity. It's estimated that the population declined by more than 90% between 2001–2011 (Vidthayanon, 2011).

2 **Jullien's Golden Carp (*Probarbus jullieni*)**
This species has been recorded in the Mekong Basin in Thailand, Vietnam, Cambodia and Lao PDR, and from Malaysia in the Pahang, Terengganu, and Perak basins. In Thailand, it is also known from the Chao Phraya and Mae Klong basins. Size, weight, and age at maturity are unknown. It has been observed to reach lengths of 150 cm (Baird et al., 1999), with a maximum published weight of 70 kg (Roberts and Baird, 1995). Its upstream migration patterns are linked with spawning activity, and it is heavily targeted by fishers in these periods.

3 Giant Carp (*Catlocarpio siamensis*)
This species is found in the Mae Klong, Mekong and Chao Phraya basins in Thailand, Cambodia, Lao PDR and Vietnam, the Chao Phraya no longer has wild populations. The size, weight, and age at maturity are unknown. It can possibly grow up to 300 cm in length (Baird et al., 1999), and the maximum published weight is 300 kg (Roberts and Warren, 1994). Spawning locations are unknown, and it may have declined by 80-95% between 1981–2011 based on catch data (Hogan, 2011a).


Mekong Giant Catfish. Photo: Mekong Community Institute Association (MCI).

4 Mekong Giant Catfish (*Pangasianodon gigas*)
Size, weight, and age at maturity are unknown. It can potentially reach lengths of 300 cm (Baird et al., 1999) and the maximum published weight is 350 kg (Kottelat, 2001). Knowledge of its spawning migration patterns is very limited, and only one potential spawning site has been identified based on Local Ecological Knowledge surveys. It's estimated that the population declined by more than 80% between 1998–2011 (Hogan, 2011b).

5 Giant Pangasius (*Pangasius sanitwongsei*)
This species is known from the Chao Phraya and Mekong basins but is no longer found in the Chao Phraya. It still occurs in the Mekong Basin in Cambodia, China, Lao PDR, Thailand, and Vietnam. Size, weight, and age at maturity are unknown. Individuals up to 300 cm in length (Davidson, 1975) have been observed and the maximum published weight is 300 kg (Roberts and Vidthayanon, 1991). Substantial declines in catches and sightings have been reported by fishers, and some state the fish has disappeared from their harvests completely (Meynell, 2003; as reported by Jenkins et al., 2009).

Relatively little is known about the life histories of these five species, their current distributions, locations of critical habitats like spawning sites, and current population estimates. Given this lack of information, further research is a high priority for these fishes. Some of these species, such as the Mekong Giant Salmon Carp, have not been observed in the wild for years and it is unknown whether they continue to persist.

In the past, all these species were prized targets for fishers, and their declines have been partially caused by decades of overharvest. More recently the development of dams along migration routes is having a serious and yet unknown impact, potentially preventing spawning. Today, the abundances of four out of the five species have dropped so low that they are rarely, if ever, caught. Jullien's Golden Carp is still targeted by fishers and sold in markets. Though international trade is banned, as it is listed under Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), international trade still occurs (Baird, 2006). The Mekong Giant Catfish has also been listed under CITES Appendix I. This species is regularly sold in restaurants and markets, where it is sourced from aquaculture facilities.

Priority actions to conserve large migratory ASAP freshwater fishes

Persistence Surveys
Currently, it is unknown whether the Mekong Giant Salmon Carp continues to persist in the wild, and several other large migratory fishes have not been observed for years. An extensive expedition to determine whether the Mekong Giant Salmon Carp has been extirpated should be undertaken immediately. Such an expedition is a fundamental prerequisite for designing effective conservation actions for this species. Surveys to determine presence/absence of other large migratory fishes that have not been observed for multiple years are also called for.

Environmental DNA Analyses
Environmental DNA (eDNA) analyses should be applied to gain additional knowledge that cannot be accessed with conventional survey methods and are particularly relevant for large migratory species because these fishes are extremely difficult to detect with conventional survey methods (Bellemain et al., 2016). eDNA surveys should be undertaken to collect broad baseline biodiversity data (i.e., all aquatic organisms) and information on species richness levels in specific

sites, especially in locations where minimal surveying with conventional methods has been conducted or where dam construction is proposed. Results of eDNA analyses would help to determine the current ranges of ASAP Species, as well as identify critical refuge habitats and spawning sites. This information would enable the development of effective site-based protections and transboundary conservation strategies.

Fish Reserves

Recent research from Thailand found that fish biomass, density, and species richness were substantially higher in reserves, compared to nearby areas (Koning et al., 2020). Many fish reserves have been established throughout the Mekong Basin, but the process has been somewhat piecemeal and opportunistic. It is recommended that this approach be expanded where appropriate through a coordinated process that accounts for the importance of connectivity between spawning and rearing habitats. More work is needed to assess the effectiveness of reserves for protecting large migrants, and to design management strategies that address the unique needs of these species. Surveys to identify existing reserves that benefit large migratory fishes should be conducted, and those locations should be prioritised for conservation actions. Additional work to identify key sites for the establishment of new reserves designed specifically for large migrants is a top priority.

Key Habitat Identification and Protection

More surveys, using both conventional and eDNA methods, are necessary to identify the locations of key habitats and to design site-specific protections for these locations. Identification of spawning and rearing habitats is of particularly high importance, as such sites are prerequisite for the persistence and recovery of large migrants. It is likely that many of these sites have already been lost, and those that remain are rapidly being degraded or destroyed entirely. Immediate action should be taken to identify existing key habitats and robust protection mechanisms that account for multiple types of threats at a variety of scales should be implemented.

***Betta cracens* habitat, Bangka Island, Indonesia. Image taken in 2019 after the damage in 2018. Photo: Dai Jianhui/S.J.D.**

Species-specific Action Plans

Species-specific conservation action plans based on current knowledge, as well as new information gathered through the actions listed above, must be drafted as soon as possible. Such plans would help to mainstream essential conservation actions into government policies, expand and improve relevant legislation, empower networks of local conservationists to implement effective actions, and stimulate funding at the level required to ensure the persistence and promote the recovery of these iconic fishes.

Updated IUCN Red List Assessments

Over the past decade the health of some rivers and their large migratory fishes has been rapidly deteriorating due to a boom in development, while the intensity of threats has spiked simultaneously. Given this, the information and status designations in IUCN Red List assessments for four of the large migratory species may no longer be accurate, and likely exclude data gathered in recent years that would enable design of more effective conservation actions. While updated Red List assessments may provide more current information about the most recent developing threats impacting these species, it is important to note that Red List assessments are a compilation of all available data. Therefore, we recommend completing the data-gathering action points addressed above prior to conducting reassessments. Currently there is no need to update the assessment for *Probarbus jullieni*, as it was completed in 2019. The remaining four large migratory species require updated assessments, as it has been more than 10 years since they were originally assessed:

- *Aaptosyax grypus* was last assessed in 2011
- *Catlocarpio siamensis* was last assessed 2011
- *Pangasianodon gigas* was last assessed in 2011
- *Pangasius sanitwongsei* was last assessed in 2009

4.2.2 Action for Peat Swamp Forest Species

Sixteen of all ASAP freshwater fish species are stenotopic or associated with peat swamp forests of Indonesia or Malaysia. These two countries alone maintain 62% of global tropical peat swamp forests (Page et al., 2006).

Peat swamp forests are a habitat type where waterlogged or flooded areas undergo eutrophication caused by deposition of plant material over long periods, resulting in the formation of peat domes atop which forest grows. These permanently flooded and anaerobic conditions result in decay, causing large areas of peat to form. The waters here can be very acidic, with a high concentration of plant tannins which make the water brown and dark, hence giving it the name "blackwater". Peat swamp forests are commonly found in lowland areas, and therefore have been hit hard by forest clearance for settlements and large-scale agricultural plantations, in particular for oil palm. While peat swamp forests are hotbeds of plant and freshwater fauna diversity, they are inaccurately believed to be less biodiverse than other types of lowland forest, often resulting in them being preferentially cleared. In many cases, only tiny remnants of previously vast peat swamp forest areas remain, and in these remnants, often in a single patch of forest, the few remaining individuals of an entire species cling precariously to existence. For some species, their native habitat has been completely cleared, and man-made ditches (in plantations or along roads) harbour the last dwindling populations.

The primary conservation action for all these species is site protection to prevent any further losses of habitat, proceeded by surveys to ascertain distribution limits and the status of populations.

These species are extremely beautiful, small, colourful fish. For this reason, many of the species are highly sought after by the ornamental fish trade (see Tbl. 5). While most of them are largely only held by specialist hobbyists, demand in the global marketplace for many species is steadily increasing. In some cases, such as for the *Parosphromenus* genus, a dedicated conservation action led by hobbyists to hold assurance populations already exists, where they learn breeding techniques and ensure ex situ protection. Some experts believe that it may be possible to create habitat for these species within plantations (together with a ban on use of herbicides and other chemicals), which may give these fishes an opportunity for recovery.

While some of these species are on the brink of extinction, their conservation is potentially straightforward. Opportunities to gain support from the aquarium trade can be explored. In 2020, an action plan was designed for peat swamp forest fishes in Malaysia and similar plans are underway for Indonesia.

***Betta cracens* habitat, Bangka Island, Indonesia. Taken in 2018. Photo: Wentian Shi/S.J.D.**

TABLE 5

ASAP Peat Swamp Forest Species in the Ornamental Trade

Species	Distribution	Point endemic
Betta burdigala	Banka Island, Sumatra, Indonesia	Yes
Betta chloropharynx	Banka Island, Sumatra, Indonesia	Possibly
Betta cracens	Jambi, Sumatra, Indonesia	Possibly
Betta hendra	Central Kalimantan, Indonesia	No
Betta miniopinna	Bintan Island, Sumatra, Indonesia	Possibly
Betta omega	Johor, Malaysia	Yes
Betta pardalotos	South Sumatra, Indonesia	Possibly
Betta pinguis	West Kalimantan, Indonesia	Possibly
Betta rutilans	West Kalimantan, Indonesia	No
Encheloclarias kelioides	Johor, Malaysia	Possibly
Parakysis notialis	South Kalimantan, Indonesia	Possibly
Parosphromenus alfredi	Johor, Malaysia	Yes
Parosphromenus gunawani	Jambi, Sumatra, Indonesia	Possibly
Parosphromenus ornaticauda	West Kalimantan, Indonesia	Yes
Parosphromenus phoenicurus	Riau, Sumatra, Indonesia	Possibly
Parosphromenus quindecim	West Kalimantan, Indonesia	Possibly

4.2.3 Individual Species Action Plans

Detailed action plans for individual species should be undertaken as and when appropriate and when there is a clear mechanism for implementing the action plan. While each species requires carefully considered actions to ensure that the desired impact occurs, it is not recommended that action be delayed until a formal conservation planning process is carried out. For many of the ASAP Species, there is a significant gap in understanding of the species and lack of available data.

4.2.4 Euryhaline species

Seven species are listed by ASAP that are primarily marine but are known or suspected to spend some component of their life cycle in freshwater or brackish habitats (Tbl. 6). Very little is known about each species and the conservation of each species is most likely to be marine or coastal based. For those reasons, this framework does not detail action for these species – particularly at the country level. However, they are all highly threatened and deserve immediate conservation attention. Until now, conservation efforts have largely focused on understanding their population distributions and status, and mitigating the threats from overharvesting and trade by commercial and artisanal fisheries.

TABLE 6

ASAP Euryhaline Species

Species	Species
Glaucostegus granulatus	No information is available on this species' use of freshwater. It is generally found in the northern Indian Ocean in intertidal and neritic marine habits.
Glaucostegus typus	This species is reported to live and breed in freshwater but there is little information on this aspect of its life cycle. It is found in coastal areas, mangroves and deeper marine habitats across Southeast Asia.
Glyphis gangeticus	This species has a patchy distribution in the Indo-West Pacific. It is truly euryhaline and is known from the Kinabatangan and Yangon rivers in Southeast Asia.
Pastinachus stellurostris	Known from shallow marine waters close to the shore and in particular within mangroves. The species has been recorded on the coastline of Kalimantan, is suspected to live in the Gulf of Thailand and is possibly much more widely distributed.
Pristis clavata	Once possibly widespread in Indo-West Pacific, it is now considered to be restricted to Indonesia, Papua New Guinea and northern Australia coastlines. It is an estuarine specialist able to withstand low salinity levels.
Pristis pristis	This species has a widespread global circumtropical distribution and is considered to be extant in Indonesia and the Philippines in Southeast Asia. It is the most euryhaline species of these seven species and is known to use freshwater for significant parts of its life cycle.
Pristis zijsron	An Indo-Pacific species, resident throughout the coasts of Southeast Asia. Less is known about any freshwater use by this species but it is known from mangroves and estuaries.

4.3 Policy actions

Very often policy actions can be the most efficient method for achieving broader impact, and may provide efficient solutions for many ASAP freshwater fishes. However, if the policies are not effectively implemented, large gaps and failures in the response for a species can result.

While there are many policy actions required for freshwater fish conservation in the region, most are more appropriate for a wider regional freshwater fish action plan (see Tbl. 1, section A). There are, however, several key policy actions that have been identified that would have a direct impact for ASAP Species. The actions listed below are directly relevant to the conservation success for one or more of the ASAP Species.

4.3.1 Water infrastructure

Water infrastructure is defined here as the construction of dams, irrigation systems, harbours, flood regulation and navigation systems or any other construction that alters or degrades freshwater ecosystems. Water infrastructure is a significant threat to most ASAP freshwater fishes, primarily related to construction of hydropower dams and infrastructure to regulate flooding in large rivers and lakes.

Water infrastructure has been the target of many freshwater conservation actions in the region in the past. There has been, and continues to be, discussion and consideration at the policy level in all the Southeast Asian countries regarding broader implementation of such actions which would strongly benefit freshwater species in the region.

Recommended actions

- Independent and transparent Environmental and Strategic Impact Assessments
- Ban construction of dams in protected areas and in locations where they will have a significant impact on a protected area and/or sites of high conservation value
- Increase the influence and power of fisheries management agencies in dam construction permitting decisions
- Ensure species access to and protection of all spawning sites for migratory species
- Require fish passage mechanisms that have been proven effective for large species
- Mandate dam release management regimes that mimic natural flows
- Ensure the free flow of sediment below the dam where possible
- Leave buffer areas around rivers undeveloped to allow for natural seasonal flooding

More specifically, it is critical that full consideration of the needs of migratory fishes is immediately and comprehensively recognised in all strategic infrastructure planning taking place under the Mekong, Tonle Sap, and Chao Phraya River Basin management plans. The primary ASAP freshwater fishes that should be considered include large-bodied species, late to mature species, species with very specific/limited windows of migration timing, species with few known spawning sites, and long-distance migrants.

More detail on this topic can be found at the beginning of section 4.

4.3.2 Sustainable fisheries

Overfishing has historically been a powerful driver of decline for many freshwater fish species (Allan et al., 2005), to the point where only a few species of ASAP freshwater fishes currently have populations large enough to sustain a viable fishery. The species which are no longer targeted, because their populations have dropped so dramatically that they are nearly impossible to catch anymore, mainly include the large migratory fishes ranging throughout the larger rivers such as the Mekong and its main tributaries. There is only one ASAP freshwater fish species, *Rasbora tawarensis*, where unsustainable harvest levels have been identified as the primary threat. The large migratory fishes of the Mekong are important fisheries species and harvesting is a threat, but dams and habitat destruction are presently the greater threats to these species. Because the use of indiscriminate fishing methods is so widespread, even though they may be aimed at more abundant species, most harvests inevitably threaten ASAP Species as well. As fishing for abundant species continues to threaten ASAP freshwater fishes, actions to minimise bycatch and increase survival and recruitment rates are important tools in improving the chances for ASAP Species to recover.

Recommended actions

- More widespread regulations on allowable fishing gear/method types and associated enforcement plans are needed (i.e., ban on destructive fishing methods – such as use of poisons, explosives, and electrofishing).
- Harvest of some species should be banned entirely (via both national and international regulations), while species-specific harvest limits should be set for others. Additionally, regulation of the harvest of specific life stages and/or size limits should be instituted.
- Community-based Fish Conservation Zones have proven to be a successful approach and should be expanded where appropriate. This approach to sustaining fisheries at the site level has become a significant and effective means of conserving biodiversity at a local scale and is therefore very relevant for many of the ASAP freshwater fishes (see section 4.3.2 for more discussion on this approach).

4.3.3 Ornamental trade regulation

Twenty-eight species are known to be in the aquarium trade whilst other ASAP freshwater fishes, if available, would be potentially sought after for the aquarium trade. Commercial captive breeding has helped address and, in some cases, largely satisfied the demand for a few of these species which have been threatened by unsustainable exploitation in the past (e.g., Redtail Sharkminnow) but for other species this potentially remains a serious threat. There is a severe paucity of information on harvesting rates and the impact of the trade on all the ASAP freshwater fishes.

Indiscriminate collection of masses of "pretty fish" for sale in local markets to inexperienced owners may be a very significant aspect of the collection which is not easily determined. In contrast, expert breeders and hobbyists often have a more targeted approach to collection of a few individuals. There have also been more recent shifts in how the rarer fish species are being traded online, with interested buyers from all over the world being able to contact those who specialise in finding and catching specific fish species, and then ship the fish internationally where there are very limited regulations and legislation in place, making accurate trade volumes extremely difficult to assess.

There are potentially two positive aspects of the interest by hobbyists. The first is the opportunity to establish sustainable harvesting/marketing as a local economic incentive for sustaining protection of the species and the habitat. Secondly, as some of these species are suitable for keeping in aquariums and there is a great deal of enthusiasm and knowledge of how to breed them in captivity, there is an opportunity for ex situ breeding and potential reintroduction by professional breeding institutions and individuals. Ongoing efforts by the Goodeid Working Group, for example, are safeguarding several species of goodeids from global extinction; similarly, the Parosphromenus Project is working hard to coordinate efforts between hobbyists and institutions all over the world in a bid to protect *Parosphromenus* species from extinction.

The ornamental fish trade has also been heavily implicated as a route of introduction of invasive species (often through the release of unwanted stock/pets by hobbyists). This has been the cause of many native species declines and therefore there is a critical need to educate, and where possible legislate, and enforce regulations controlling release of aquarium fish into the wild (See introduction to section 4 and section 4.3.5).

Recommended actions

- As a matter of urgency, one of the most important actions for ASAP freshwater fishes is to gain a better understanding of the population status (including recruitment rates), the protection status, and the frequency and intensity (actual and potential) of collection of each of the existing and potential ornamental species.
- With this information, a new regulatory framework and appropriate monitoring (with links to national CITES plans) must swiftly be put in place in each of the Southeast Asian countries. This should include mechanisms to maximise the opportunities for sustainable harvesting as an incentive for protection and full engagement of the traders and hobbyists in the conservation of these species.

It is important to note that in many cases, the threats from habitat loss and invasive species are usually much more serious and immediate than the population declines caused by direct targeted collection for the aquaria trade. However, as population numbers are already so critically low for ASAP Species, any cause of further decline is of great concern.

4.3.4 Agriculture

Species with agricultural practices identified as a threat to their survival include all of the peat swamp forest species, as well as several Papuan rainbowfish. The threat largely stems from conversion of habitat for agriculture, mainly large-scale plantations such as oil palm, acacia, and pineapple. Changes in the drainage to support neighbouring plantations can also indirectly threaten peat swamp forest species fishes by drying out the peat, reducing the extent of habitat and causing fires. Small-scale habitat conversion in wetlands, including alterations to the hydrology of a system, is a concern for many species as well. Agricultural run-off is also listed as a threat for some species. This threat may well be underestimated, particularly when it relates to chemical pollution entering aquatic habitats via run-off.

Recommended actions

- Protection of habitat for vulnerable ASAP freshwater fishes including peat swamp forest fishes, forest stream and lake species will halt direct conversion.
- Species vulnerable to runoff should be protected through regulations (particularly on the use of poisons, pesticides, and herbicides) and through training and engagement with local stakeholders in best practices in ecologically sensitive areas such as habitats with ASAP freshwater fishes.

4.3.5 Invasive species and the role of aquaculture

For ASAP freshwater fishes, the threat from the introduction of invasive species has resulted from deliberate efforts to "improve" the fisheries productivity of a river or lake. Many governments actively promote aquaculture to improve livelihood opportunities and food security options but best practices in the control of potential invasives are often not applied. Establishment of invasive species populations also often occurs through accidental release or escape from aquaculture farms. Many of the most problematic invasive species across the region are commonly farmed for food and accompany human expansion into natural areas. This invasion route is the one that is the most heavily implicated in ASAP Species decline, with its extremely deleterious effects on native biodiversity demonstrated in lakes across Southeast Asia. The Mozambique Tilapia (*Oreochromis mossambicus*), Walking Catfish (*Clarias batrachus*), and Common Carp (*Cyprinus carpio*), all among the world's 100 most invasive species, are widespread and highly problematic in the region. Snakeheads (*Channa* sp.) and Climbing Perch (*Anabas testudineus*) are two other farmed species that have also been implicated in ASAP Species decline.

Deliberate release of unwanted aquarium fish species by hobbyists is yet another problem and has been implicated in the decline of native species globally. The magnitude of this pathway can be very substantial: the city-state of Singapore recorded the presence of 123 alien freshwater fish species in 2020, with the vast majority of them thought to originate from discards or escapes from the ornamental fish trade (Tan et al., 2020). In Taal Lake in the Philippines, Jaguar Guapote may pose a threat to populations of two ASAP Species (*Exyrias volcanus* and *Silhouettea flavoventris*), while goldfish have been identified as an invasive species that threatens the Vogelkop Blue-eye (*Pseudomugil reticulatus*) in Indonesian Papua. Flowerhorn Cichlid, a hybrid fish that has surged in popularity in the hobby over the past couple of decades, gravely threaten entire ecosystems hosting many highly endangered native species in Sulawesi's lakes – three ASAP freshwater fish species are among them (*Adrianichthys kruyti*, *Adrianichthys roseni*, *Mugilogobius amadi*). Mercy release, the Buddhist religious practice of releasing captive animals to accrue good karma, is yet another pathway for invasive freshwater species establishment. Non-native species from markets (including species brought in both for aquaria and for food) are often used for this purpose, resulting in the sustained release of non-natives into waterbodies.

Recommended actions

- National policies for the control and eradication of invasive species from sites where threatened species occur are a priority where possible. Such policies are particularly important in lakes with high levels of vulnerable endemic fishes such as those which hold ASAP Species in Sulawesi, the Philippines and Papua, and pre-emptive action in other lakes can also go a long way in safeguarding other native freshwater species from further endangerment in the future.
  - Establish legislative frameworks to support proactive species invasion risk mitigation.
  - Improve legislation, enforcement and guidance for controlling fish farming practices.
  - Species selection for fish farming with preference for native species.
  - Risk assessments required when non-native species are cultured.
  - Containment – Best Management Practice (BMP) guidelines (e.g., procedures and infrastructure to minimise escapement).
  - Penalties for lapses.

- Improve legislation to combat deliberate release by fish farmers (commercial and artisanal), aquaria hobbyists and for religious release.
- Launch a programme of education and outreach to shift practices to avoid future release of non-native fishes and to incentivise removal of invasive fishes.

■ Preventative policies that may reduce risks for ASAP freshwater fishes in the future include:

- Mandate that fisheries agencies are not allowed to promote, support, breed, or intentionally introduce non-native species.
- Set overarching national policies that ban introductions of non-native species by all civilians.
- Facilitate aquaculture production of native species and implement strict enforceable standards for aquaculture of non-native species that ensure fish cannot escape enclosures, and only allow aquaculture of non-native species in locations that are fully isolated from other water bodies.

Urgent action is required to remove invasive fishes in lakes with high levels of endemic and vulnerable species. Priority sites include:

- Lake Poso, Sulawesi, Indonesia
- Malili lakes, Sulawesi, Indonesia
- Lake Lanao, Philippines
- Lake Taal, Philippines
- Various lakes (and ponds) in Papua with ASAP freshwater fishes

4.3.6 National Biodiversity Strategy and Action Plans, and other prioritisation processes

A National Biodiversity Strategy and Action Plan (NBSAP) is the expression by a national government of their plans to conserve their national biodiversity, as part of the commitments (article 6) under the Convention of Biological Diversity (CBD). These plans are then used to prioritise government and donor allocations of resources and attention. At present, freshwater fishes are largely overlooked in countries' NBSAPs in the region and with the post-2020 Kunming-Montreal Global Biodiversity Framework, there is the opportunity to ensure ASAP freshwater fishes conservation needs are included in updated NBSAPs. Regional cooperation and collaboration among Southeast Asian countries should be a core component of updated NBSAPs.

Another important prioritisation process is the identification of Alliance for Zero Extinction (AZE) sites and Key Biodiversity Areas (KBAs), defined as "the most important places in the world for species and their habitats". The KBA Programme supports the identification, mapping, monitoring, and conservation of KBAs and once listed they may receive priority attention for conservation by donors, conservation agencies and governments. An immediate priority is to identify which KBAs support specific ASAP freshwater fishes and identify gaps to guide future KBA designation.

There are other prioritisation processes that have been designed for specific purposes such as the Critical Ecosystem Partnership Fund (CEPF) Ecosystem Profiles. It is important to ensure that these processes recognise any ASAP freshwater fish or their habitat when they are eligible.

4.3.7 Habitat protection

The most common and most direct tool used for biodiversity conservation is the creation of a conservation area. This is a site where habitat and species conservation are prioritised by the stewards of that habitat. These can range from strictly protected areas and national parks to very local conservation sites such as sacred sites.

As a priority, it is important to have all the ASAP freshwater fishes under some level of protection. This should include diverse approaches including IIndigenous and community conserved areas (ICCAs) and Other Effective Area-based Conservation Measures (OECMs), allowing greater representation of freshwater ecosystems. Some species already fall within existing conserved areas but may not be included or even recognised in the management strategies.

Community-based conservation areas, or specifically in this context Community Fish Conservation Zones (CFCZs), are a particular type of habitat protection that has been implemented in some parts of the region and may provide an excellent approach for the in situ protection and recovery of ASAP freshwater fishes. CFCZs have mainly been used to improve the natural recovery and protection of local wetlands to improve or maintain productive fisheries for local communities, often heavily reliant on fish for their food security and livelihoods. However, increasingly they are used for targeted species conservation. Southeast Asia, particularly the Mekong basin has many successful examples of successful

implementation of this approach. Used correctly, this approach can be applied to all the ASAP freshwater fishes as a direct and potentially effective method to support their protection and recovery.

4.4 Ex situ conservation priorities and opportunities

In situations where in situ amelioration of threats is impractical or very difficult to implement, ex situ measures can be brought in as a means of safeguarding a species under human care for potential future reintroductions, essentially buying time for threats to be mitigated in a species' natural range.

Because ASAP freshwater fishes are Critically Endangered and at risk of global extinction, they should all be assessed and considered for inclusion in ex situ conservation efforts. Securing assurance populations should be a high priority for eligible species. For those species which are already being held in captivity, assessment of the quality of the species for conservation breeding needs to be undertaken. While a focused and thorough assessment of the ex situ potential for each ASAP Species is needed, this report provides a preliminary list of species that may have good potential for ex situ conservation (Tbl. 7) and have been identified because they meet at least some of the following criteria:

- IUCN Red List recommendation for ex situ conservation
- Likelihood of in situ protection/threat amelioration is low
- Urgent action is required
- Species is already present in captivity
- Life history and husbandry considerations are suitable
- Captive breeding records and guidelines already exist
- Feasible in terms of level of resources required (body size, manpower etc.)
- Few potential problems exist, such as genetic diversity and potential loss of behavioural traits exhibited in the wild

Ex situ conservation for the massive, largely migratory species will be more difficult for zoo and hobbyist-led organisations, due to space and resource constraints. Thankfully, four of these large fishery-significant species (*Catlocarpio siamensis*, *Pangasianodon gigas*, *Pangasius sanitwongsei*, *Probarbus jullieni*) are already part of stock enhancement programmes under the Mekong River Commission, an intergovernmental initiative between Cambodia, Lao PDR, Thailand, and Vietnam tasked with responsible and environmentally sound development of the Mekong River. To this end, young fingerlings of these species are being released into the Mekong River with the aim of strengthening wild populations, though the overall target of restoring sustainable populations of these species in the wild will require a lot more work and coordination (particularly when considering effects of dams, and water and fisheries management (see section 4.2.1)). In the ex situ realm, research into the genetic diversity of captive broodstock is necessary to ensure the health and robustness of fish both for captive breeding and subsequent release.

Zoos, aquaria, and hobbyist-led organisations can play an important role in establishing conservation breeding populations of small-bodied, range-restricted, non-migratory species which face loss of habitat integrity in the wild (habitat destruction, invasive species, pollution, climate change) and/or overharvesting for the aquarium trade.

A potential set of hosts exist within the home aquaria hobby. Ex situ breeding by these hobbyists has been successful for a number of species as demonstrated by the work of the Goodeid Working Group and the Parosphromenus Project. Engaging hobbyists will add a valuable set of resources such as additional manpower, husbandry knowledge and the potential to maintain larger numbers of fish in captivity. However, to be truly helpful and effective, high levels of coordination will be required, there will be fluctuating commitment levels, and differences in fishkeeping culture across communities may hamper continuity within the breeding programmes. There is a need to catalyse a paradigm shift in hobbyists' mindsets - from consumerism to preservation and conservation.

A detailed discussion regarding the considerations and methods for creating an ex situ programme for ASAP freshwater fishes is provided in Annex A.

TABLE 7

List of ASAP freshwater fishes recommended for ex situ management efforts

Ex situ management is a recommended conservation tool for 49 species (54% of ASAP freshwater fishes).

Species	Present in aquarium trade?	Has been bred in captivity	Ex situ population actively maintained?	Immediate actions needed to drive ex situ conservation management
Balantiocheilos ambusticauda (PE)	No	No (congener *Balantiocheilos melanopterus* commercially bred in farms)	No	Surveys to determine if species is extant.
Betta burdigala	Rarely (mostly wild caught)	Yes	Yes (Pridgen Conservation Breeding Ark in Indonesia)	Identification and recruitment of ex situ organisations which can contribute. Investigate genetic diversity of ex situ population.
Betta chloropharynx	No	Yes	None known, but high potential exists	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ populations. Investigate genetic diversity of ex situ populations.
Betta cracens	No	Yes	None known, but high potential exists	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population. Investigate genetic diversity of ex situ populations.
Betta fusca (PE)	No	No (many congeners bred by hobbyists and farms)	No	Surveys to determine if species is extant.
Betta hendra	Occasional	Yes	Yes (Pridgen Conservation Breeding Ark in Indonesia)	Identification and recruitment of ex situ organisations which can contribute. Investigate genetic diversity of ex situ population.
Betta miniopinna	Occasional	Yes	Yes (Pridgen Conservation Breeding Ark in Indonesia)	Identification and recruitment of ex situ organisations which can contribute. Investigate genetic diversity of ex situ population.
Betta omega	Rarely	Yes	Unknown	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ populations.
Betta pardalotos	Rarely	Yes	Unknown	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population.
Betta pinguis	Rarely	Yes	Unknown	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population.
Betta rutilans	Occasional	Yes	Yes (Pridgen Conservation Breeding Ark in Indonesia)	Identification and recruitment of ex situ organisations which can contribute. Investigate genetic diversity of ex situ population.
Betta simplex	Occasional	Yes	Unknown	Identification and recruitment of ex situ organisations which can contribute Sourcing of founder individuals for ex situ population.

TABLE 7 **List of ASAP freshwater fishes recommended for ex situ management efforts** (cont.)

Species	Present in aquarium trade?	Has been bred in captivity	Ex situ population actively maintained?	Immediate actions needed to drive ex situ conservation management
Catlocarpio siamensis	Yes	Yes (farm-bred; needs large water bodies)	Yes (national government-led breeding and release programs)	Identification and recruitment of ex situ organisations which can contribute. Investigate genetic diversity of farmed/hatchery populations.
Chilatherina sentaniensis	Rarely	Yes	Yes (zoo)	Identification and recruitment of ex situ organisations which can contribute. Investigate genetic diversity of ex situ population.
Clarias batu	No	No (congeners are regularly bred)	No	Sourcing of founder individuals for ex situ population.
Clarias sulcatus	No	No (congeners are regularly bred)	No	Sourcing of founder individuals for ex situ population.
Datnioides pulcher	Yes	Yes (farm-bred)	No	Identification and recruitment of ex situ organisations which can contribute. Investigate genetic diversity of farmed/hatchery populations.
Epalzeorhynchus bicolor	Yes	Yes (farm-bred)	No	Identification and recruitment of ex situ organisations which can contribute. Investigate genetic diversity of farmed/hatchery populations.
Oryzias soerotoi	Unknown	Yes	None identified	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population.
Oryzias timorensis (PE)	Unknown	Yes	None identified	Surveys to determine if species is extant.
Pangasianodon gigas	No	Yes (farm–bred; needs large water bodies)	Yes (national government-led breeding and release programs)	Identification and recruitment of ex situ organisations which can contribute. Investigate genetic diversity of farmed/hatchery populations.
Pangasius sanitwongsei	Occasional	Yes (farm–bred; needs large water bodies)	Yes (national government-led breeding and release programs)	Identification and recruitment of ex situ organisations which can contribute. Investigate genetic diversity of farmed/hatchery populations.
Parosphromenus alfredi	Rarely	Yes	Yes (hobbyists)	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ populations. Investigate genetic diversity of ex situ populations.
Parosphromenus gunawani	Rarely	Yes	Yes (hobbyists)	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ populations. Investigate genetic diversity of ex situ populations.
Parosphromenus ornaticauda	Rarely	Yes	Yes (hobbyists, zoo)	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ populations. Investigate genetic diversity of ex situ populations.
Parosphromenus phoenicurus	Rarely	Yes	Yes (hobbyists)	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ populations. Investigate genetic diversity of ex situ populations.

TABLE 7 **List of ASAP freshwater fishes recommended for ex situ management efforts** (cont.)

Species	Present in aquarium trade?	Has been bred in captivity	Ex situ population actively maintained?	Immediate actions needed to drive ex situ conservation management
Parosphromenus quindecim	Rarely	Yes	Yes (hobbyists)	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ populations. Investigate genetic diversity of ex situ populations.
Probarbus jullieni	Yes	Yes (farm-bred)	Yes (national government-led breeding and release programs)	Identification and recruitment of ex situ organisations which can contribute. Investigate genetic diversity of farmed/hatchery populations.
Rasbora tawarensis	No	No (many congeners bred by hobbyists & farms)	No	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population.
Sewellia albisuera	Occasional	Yes	No	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population.
Sewellia breviventralis	Occasional	Yes	No	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population.
Trigonostigma somphongsi	Occasional	Yes	Yes	Identification and recruitment of ex situ organisations which can contribute. Investigate genetic diversity of ex situ populations.
Xenopoecilus sarasinorum	No	Yes	Yes	Identification and recruitment of ex situ organisations which can contribute. Investigate genetic diversity of ex situ populations.
Melanotaenia bowmani	Rarely	Yes	No	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population.
Melanotaenia corona (PE)	No	No (many congeners bred by hobbyists & farms)	No	Surveys to determine if species is extant.
Melanotaenia klasioensis	Rarely	Yes	No	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population. Research on breeding requirements.
Melanotaenia kokasensis	No	No (many congeners bred by hobbyists & farms)	No	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population. Research on breeding requirements.
Melanotaenia lacunosa	No	No (many congeners bred by hobbyists & farms)	No	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population. Research on breeding requirements.
Melanotaenia longispina	No	No (many congeners bred by hobbyists & farms)	No	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population. Research on breeding requirements.

TABLE 7 **List of ASAP freshwater fishes recommended for ex situ management efforts** (cont.)

Species	Present in aquarium trade?	Has been bred in captivity	Ex situ population actively maintained?	Immediate actions needed to drive ex situ conservation management
Melanotaenia mairasi	Rarely	Yes	No	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population.
Melanotaenia parva	Rarely	Yes	No	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population.
Melanotaenia sneideri	No	No (many congeners bred by hobbyists & farms)	No	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population. Research on breeding requirements.
Melanotaenia susii	Rarely	Yes	No	Identification and recruitment of ex situ organisations which can contribute Sourcing of founder individuals for ex situ population.
Melanotaenia urisa	No	No (many congeners bred by hobbyists & farms)	No	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population. Research on breeding requirements.
Mogurnda aiwasoensis	No	No (congeners bred by hobbyists & farms)	No	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population. Research on breeding requirements.
Mogurnda kaimana	No	No (congeners bred by hobbyists & farms)	No	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population. Research on breeding requirements.
Mogurnda mbuta	No	No (congeners bred by hobbyists & farms)	No	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population. Research on breeding requirements.
Poropuntius tawarensis	No	No (congeners bred by hobbyists & farms)	No	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population. Research on breeding requirements.
Pseudomugil reticulatus	Rarely	Yes	No	Identification and recruitment of ex situ organisations which can contribute. Sourcing of founder individuals for ex situ population.

4.5 Further survey and research priorities

All ASAP freshwater fishes require more survey work to ascertain their distribution, population status, habitat use and other biological and ecological parameters important for their conservation. However, all ASAP Species require urgent direct conservation action and therefore surveys and research that do not provide a significant contribution to advancing conservation immediately should not be prioritised. 73% of the species were identified as needing immediate survey work as a priority conservation action.

4.5.1 Geographic Priorities

Several locations have been deemed priorities based on the relatively minimal surveying and research efforts conducted and level of currently available data on several species, when compared with other locales in Southeast Asia:

- Philippines
- Sulawesi
- Annamitesin in Lao PDR and Vietnam
- Peat swamp forests in Malaysia and Indonesia
- West Papua

4.5.2 Ecological and biological priorities

For many ASAP freshwater fishes, little is known about their ecology and biology. There is a great need for more data so that effective conservation strategies can be designed and implemented. Key information needs include:

- Population status
- Life history traits
- Habitat requirements
- Diets
- Distributions
- Spawning sites for Mekong giants

4.5.3 Impact priorities

As this framework has described, there are a multitude of issues impacting ASAP freshwater fishes. When it comes to the needs for further research, there are several issues that have been studied and the associated available data are often sufficient to proceed with designing conservation strategies. However, there are several issues impacting ASAP freshwater fishes that have not been well-studied. The issues below have been identified as priorities based on the relative lack of data that are needed to design conservation solutions:

- Status of the aquarium trade
- Invasive species eradication, control, and impact mitigation
- Impacts of climate change, particularly for West Papua rainbowfish

Researchers carrying out surveys for *Xenopoecilus sarassinorum* in Lake Lindu, Sulawesi, Indonesia. Photo: Muhammad Herjayanto.

4.6 Possibly Extinct species

There are 18 fish species that have been assessed as Critically Endangered - Possibly Extinct. These are species where the available evidence indicates there is a high likelihood they have gone extinct. A significant proportion (~20%) of the ASAP freshwater fishes have been assigned to this category.

Table 8 below provides a list of the ASAP freshwater fishes that have been assessed as Possibly Extinct and includes detail on their broad location, the status of our knowledge on their persistence, and the action recommended for that species. The recommended actions have been divided into two categories: (1) Active search and (2) Passive search. Searching for these potentially extinct species requires significant investment of time and resources and therefore any search should be undertaken with this in mind.

Active Search

A Possibly Extinct fish has been categorised under "active search" when it is considered that there is a strong likelihood of confirming the persistence of the species. In most cases under this category, the species may have been possibly overlooked due to insufficient survey work and future surveys can be well-targeted and/or there is evidence of persistence based on local ecological knowledge. Under "active search", it is recommended that a specific search targeted for that species should be undertaken as a matter of urgency.

Conservationists from Progres organising nets during a search for Critically Endangered fish species in Lake Poso, Sulawesi. © Progres

Passive Search

For those species categorised under "passive search", it is considered that a specific search for this species may not be feasible to ascertain if the species persists or not. This may be because the evidence of the persistence of the species indicates that it is unlikely to be found or that the area to be searched is so large and vague, that targeted searches are impossible and therefore unlikely to be efficient. For these species, it is recommended not to undertake specific searches but rely on related work in the areas that may by chance provide evidence of the persistence of the species. Raising awareness of the potential survival of the species in the area will help to improve the chance that it may be found. This should not, however, exclude interest from those that have the funds, resources and particular interest to search for these species. It is only recommended that active search species should be prioritised where possible.

If any of these species are found in the wild, the status of the population and threats should be ascertained immediately, individuals should be collected and prioritised for ex situ conservation (unless the survey discovers a population that has a high chance of recovering naturally with simple protection methods) and conservation action to protect the remaining population must be enacted immediately.

TABLE 8

List of ASAP freshwater fishes that have been assessed as Possibly Extinct

Species	Location	Status	Action recommended
Adrianichthys kruyti	Lake Poso	Not recorded since 1983. Recent searches (2012 and 2017) were unsuccessful. Sampling not sufficient to determine extinction.	Active search. Gaps in previous surveys leave some chance of finding the species.
Adrianichthys roseni	Lake Poso	Not seen since it was first described in 1978. Recent searches (2012 and 2017) were unsuccessful. Sampling not sufficient to determine extinction.	Active search. Gaps in previous surveys leave some chance of finding the species.

TABLE 8 List of ASAP freshwater fishes that have been assessed as Possibly Extinct (cont.)

Species	Location	Status	Action recommended
Mugilogobius amadi	Lake Poso	It has not been scientifically recorded since 1978. Local reports claim it was present until 1983.	Active search. Gaps in previous surveys leave some chance of finding the species.
Balantiocheilos ambusticauda	Thailand	Not observed since 1974. Extensive surveys in Thailand have not found the species. None exist ex situ. Possibly present in Lao PDR or Cambodia but considered unlikely.	Active search. There is some likelihood that this species does still occur but has been overlooked. As it is one of only two members of its genus and its congener is also declining rapidly in the wild, specific searches may be worthwhile although they may be very difficult.
Barbodes lindog	Lake Lanao	Not observed despite recent searches, but recent searches were not fully extensive.	Active search. Gaps in previous surveys leave some chance of finding the species.
Barbodes sirang	Lake Lanao	Not seen despite recent searches, but recent searches were not fully extensive.	Active search. Gaps in previous surveys leave some chance of finding the species.
Barbonymus platysoma	Java	Not seen in over 100 years. Only known from a single specimen collected in 1855. Exact location and habitat are unknown.	Passive search. Failed extensive searches and loss of habitat make an active search unfeasible.
Hemileiocassis panjang	Java	Not seen in over 80 years. Only known from a single specimen. Unlikely to have survived anthropogenic pressures.	Passive search. Failed extensive searches and loss of habitat make an active search unfeasible.
Kryptopterus mononema	Java	Not seen for over 180 years despite extensive surveys. Habitat has been destroyed. The only chance of survival would be presence in other areas not yet surveyed.	Passive search. Failed extensive searches and loss of habitat make an active search unfeasible.
Lobocheilos lehat	Java	Not seen since 1858 despite extensive surveys. Habitat has been destroyed. The only chance of survival would be presence in other areas not yet surveyed.	Passive search. Failed extensive searches and loss of habitat make an active search unfeasible.
Betta fusca	Medan, Sumatra	Very likely to be found. Recent reports of potential observations not yet confirmed.	Active search. Very likely to be found with limited survey effort.
Hyalobagrus ornatus	Muar River, Peninsular Malaysia	Not recorded since its description in 1904. Extensive surveys since then have failed to detect it.	Passive search. Previous extensive searches were unsuccessful. Large area to survey prohibits efficient searches.
Lepidocephalus pahangensis	Pahang River, Peninsular Malaysia	Last collected in 1933 and not found during extensive searches in 2016 and 2018.	Passive search. Previous extensive searches were unsuccessful. Large area to survey prohibits efficient searches. It may possibly have been overlooked as it may be a deep-water species.
Oryzias timorensis	Central Timor	An endemic species from Timor and only known from 10 specimens collected in 1911. Many searches undertaken have failed to find the species.	Active search. Despite the fact that searches for this species have not detected any individuals, it may be best to place this in the active search category as it is less likely to be found without an active search.

4.7 Targeted priority actions by country (in alphabetical order)

4.7.1 Cambodia

Cambodia is home to seven ASAP freshwater fish species, all of which inhabit the Mekong and/or Tonle Sap River systems and are also potentially present in neighbouring countries.

TABLE 9

ASAP freshwater fishes in Cambodia: their habitats, threats and recommended conservation actions

Habitat type/Location	Species	Threats	Conservation actions
Larger river channels (Mekong drainage)			
Mekong River (larger channels), Stung Treng	*Aaptosyax grypus*	Urbanisation, dams and pollution (agricultural, urban, and industrial) leading to habitat loss and degradation. Overharvesting. Habitat fragmentation (due to dams).	Surveys on the abundance, distribution, and migratory behaviour are urgently needed. Once the ecology of the species is understood, the protection of spawning sites, rearing areas, and migratory pathways is a priority. Small no-fishing zones in these habitats are a solution. Research is especially needed into the migratory patterns of the species.
Mekong River and floodplain, Tonle Sap River and floodplain. Stung Treng, Kratie, Ratnakiri, Kompong Cham, Kandal, Kompong Chhnang, Battambang, Siem Reap, Kompong Thom, Pursat	*Datnioides pulcher* *Catlocarpio siamensis* *Pangasius sanitwongsei* *Pangasianodon gigas*		
Mekong River (larger channels), Stung Treng, Ratnakiri, Kratie, Kompong Cham, Kandal	*Probarbus jullieni*		
Mekong River (large channels)	*Balantiocheilos ambusticauda*	There have been reports of the species in Cambodia, but no authentic specimens are known.	

Detailed discussion covering some species known from Cambodia can be found in section 4.2.1

4.7.2 Indonesia

Because of its geographic location straddling the three megadiverse tropical biological regions of Sundaland, Wallacea, and New Guinea, as well as its dynamic geological history, Indonesia's more than 17,000 islands host a vast array of endemic flora and fauna - among them an incredible diversity of fish species. Many described species have already gone extinct, and a high proportion of the ASAP freshwater fishes considered to be Possibly Extinct were once found in the most populous and better studied islands of Indonesia such as Java. Yet more species, many likely already facing threat of extinction, potentially inhabit the many relatively poorly surveyed islands of this massive archipelago. The large areas of freshwater habitat, diversity of species, the high degree of endemism and the recent, rapid expansion of development in many areas of Indonesia have meant that it has the highest number of ASAP freshwater fishes for any of the Southeast Asian countries. In total, 48 ASAP freshwater fishes are found in Indonesia, split across all major habitat types.

TABLE 10

ASAP freshwater fishes in Indonesia: their habitats and recommended conservation actions

Species	Category	Habitat	Key actions
7 species (see below)	Sulawesi ancient lakes	Deep lake habitat	Immediate surveys, elimination of invasive species, ex situ conservation for each species.
21 species (see below)	West Papua lakes and streams	Various habitats including lakes, springs, streams, but all very localised and restricted	Immediate surveys, protection of habitats, ex situ conservation for each species.

TABLE 10 **ASAP freshwater fishes in Indonesia: their habitats and recommended conservation actions** (cont.)

Species	Category	Habitat	Key actions
13 species (see below)	Peat swamp forest specialists	Peat swamp forests	Immediate surveys, protection of habitats, ex situ conservation for each species.
4 species (see below)	Javan lost species	Various	These species have not been recorded for a very long time and will be difficult to find, so only those with a specialist interest should search for these species.
Rasbora tawarensis, *Poropuntius tawarensis*	Lake Tawar endemics	Both species are endemic to Lake Tawar	A comprehensive programme of habitat improvement, captive breeding, and sustainable harvesting practices is required.
Betta fusca	No specific category	Streams, rivers	Immediate surveys, protection of habitats, ex situ conservation for each species.
Oryzias timorensis	Timor endemic	Unknown	Immediate surveys, protection of habitats, ex situ conservation if a population is found in the wild.

Sulawesi ancient lakes

Seven ASAP freshwater fish species are found in lakes in Sulawesi. Three of them occur in Lake Poso, each considered to be Possibly Extinct. Surveys supported by ASAP in 2022 and 2023 found no evidence of these species in the lake. As with most of the flora and fauna of Sulawesi, there is a high level of endemism in the fish fauna. In fact, the lakes are considered to be an incredible example of island adaptive radiation for freshwater species (Herder et. al., 2006). However, very little is known about all these species.

All seven of these species are found in tectonic lakes (of varying depths) in the centre and the north of the island. Alongside these species, the lakes harbour many other rare and threatened species, and therefore conservation action directed at these species will have a much broader impact for biodiversity overall. The main threat is from the introduction of invasive fishes, primarily released to boost local fisheries but also the flowerhorn cichlid, an aquarium hybrid, has been released and is believed to be responsible for the decline of many native fishes and invertebrates.

Conservation activities are limited particularly as options are hampered by the challenges of eliminating invasive species from large, deep interconnected lake and river systems. Immediate surveys are required to ascertain the population status of each of the species. In the case of the three Lake Poso species, it is important to assess if the species are still extant and if so to rapidly ascertain the population sizes. It is likely that ex situ breeding is a priority particularly as they may be easily bred and kept in captivity.

TABLE 11

Endemic ASAP freshwater fishes from Sulawesi lakes

Scientific name	Family	Location	Threats	Conservation needs	Possibly Extinct
Adrianichthys kruyti	Adrianichthyidae (Ricefish)	Lake Poso	Invasive species	Immediate surveys, elimination of invasive species, ex situ breeding	X
Adrianichthys roseni	Adrianichthyidae (Ricefish)	Lake Poso	Invasive species	Immediate surveys, elimination of invasive species, ex situ breeding	X
Mugilogobius amadi	Gobiidae (Gobies)	Lake Poso	Invasive species	Immediate surveys, elimination of invasive species, ex situ breeding	X
Oryzias soerotoi	Adrianichthyidae (Ricefish)	Lake Tui	Invasive species	Immediate surveys, elimination of invasive species, ex situ breeding	

TABLE 11 **Endemic ASAP freshwater fishes from Sulawesi lakes** (cont.)

Scientific name	Family	Location	Threats	Conservation needs	Possibly Extinct
Paratherina labiosa	Telmatherinidae (Sailfin silversides)	Lake Wawontoa	Sedimentation due to deforestation	Immediate surveys, threat assessment, habitat restoration	
Tondanichthys kottelati	Zenarchopteridae (Halfbeaks)	Lake Tondano	Sedimentation and pollution	Immediate surveys, threat assessment, habitat restoration	
Xenopoecilus sarasinorum	Adrianichthyidae (Ricefish)	Lake Lindu	Invasive species, human settlement around lake	Immediate surveys, elimination of invasive species, ex situ breeding	

Papua and West Papua

Another large grouping of ASAP freshwater fish species is found in the Papua and West Papua provinces of Indonesia. A total of 21 species are present in these two provinces, making up 23% of the total number of ASAP freshwater fishes. Most of the species are from the rainbowfish family Melanotaeniidae. Many are only known from a single site, have not been recorded recently, or are only known from a single specimen.

The species can be roughly sorted into three categories based on threat (Tbl. 12). Eight species are listed as threatened by climate change. These species are from the Bird's Neck area, live in small pools of water that regularly dry out, and are very susceptible to further drought caused by climate change.

As many of these species are confined to lakes, they are susceptible to invasive species, so these lakes have been added to the list of lakes that require attention for invasive species.

TABLE 12

Species Categories based on Threats

Threatened by climate change	Threatened by human incursions in the form of logging and land-clearing for settlement (and possibly invasive species)	Insufficient information about the habitat or threats
Mogurnda aiwasoensis	*Pseudomugil reticulatus*	*Parambassis altipinnis*
Mogurnda kaimana	*Chilatherina sentaniensis*	*Melanotaenia corona*
Sashatherina gigantea	*Melanotaenia bowmani*	*Melanotaenia ajamaruensis*
Pelangia mbutaensis	*Melanotaenia klasioensis*	*Mogurnda mbuta*
Melanotaenia lacunosa	*Melanotaenia kokasensis*	*Glossolepis dorityi*
Melanotaenia mairasi	*Melanotaenia longispina*	
Melanotaenia parva	*Melanotaenia urisa*	
Melanotaenia sneideri	*Melanotaenia susii*	

As these fishes are found in a similar area and are mainly part of the same family, the first suggested action would be to define a specific action plan for all of the species and begin to tackle their conservation needs as one programme rather than species by species or by threat. Each species requires more information on its status and distribution (five of which suffer from a paucity of data). Bearing in mind the significant number of fishes, action should be initiated as a very high priority.

Rainbowfish are very popular in the home aquaria hobby and there may be some threats and potential conservation opportunities related to the trade (see section 4.3.3).

Peat swamp forests of Kalimantan and Sumatra

A broader discussion on peat swamp forest species conservation is provided as a regional action in Section 4.2.2

Eleven species are confined largely to peat swamp (blackwater) habitat that hosts an array of diversity and unique freshwater fishes, many of which have naturally small distributions. Two species are further thought to be stenotopic to peat swamp forest/blackwater habitat, but this cannot be confirmed because of insufficient data on their distributions. This fragile habitat is facing rapid destruction and degradation and therefore is the highest priority for fish conservation in the region. Indonesia supports the largest areas of this habitat type in Asia, and it is very likely that the list of ASAP freshwater fishes will expand in the future unless urgent direct action is taken to halt further loss of habitat and ensure the persistence of individual species.

Two direct actions are required for these species. The first is to stop any further decline or degradation of their remaining habitat. The second is to ensure that there are viable ex situ populations to serve as assurance populations if remaining habitat is lost.

ASAP peat swamp forest/blackwater fishes:

- *Betta burdigala* (Banka Island)
- *Betta chloropharynx* (Banka Island)
- *Betta hendra* (Kalimantan)
- *Betta miniopinna* (Bintan Island)
- *Betta pardalotos* (Sumatra)
- *Betta pingius* (Kalimantan)
- *Betta rutilans* (Kalimantan)
- *Parosphromenus ornaticauda* (Kalimantan)
- *Parosphromenus gunawani* (Sumatra)
- *Parosphromenus phoenicurus* (Sumatra)
- *Parosphromenus quindecim* (Kalimantan)
- (*Betta cracens* – Sumatra – unclear if it is stenotypic to peat swamp forests)
- (*Parakysis notialis* – Kalimantan – unclear if it is stenotypic to peat swamp forests)

In addition to the three major habitat types, there are a number of species that need targeted attention because of very specific relevant conditions.

Rasbora tawarensis and *Poropuntius tawarensis*

These two species are endemic to Lake Laut Tawar in Sumatra, Indonesia. Both of these species are threatened by increasing levels of agriculture, tourism, and urbanisation on the shores of Lake Tawar which pose increasing detrimental impacts on the lake. *Rasbora tawarensis* is the only species that has been specifically listed as threatened mainly due to unsustainable fishing practices. Pollution and the impacts of climate change are also both listed as key threats to both species. The rasbora, well known as depik, is highly favoured as a food source and forms a key part of tourism attraction to the lake. There is also a potential threat from invasive fishes recorded in the lake such as Common Carp (*Cyprinus carpio*).

A concentrated and dedicated conservation programme, in partnership with the local government, targeted at restoring the lake and supporting the recovery of these species has a strong chance of success if sufficient resources are allocated.

Betta fusca

This species is described from only two specimens collected in the Medan area in 1908. There are some records of the species collected in the 1950s and deposited in the University of Michigan Museum of Zoology (Tan, H.H., pers. comm, March 2020). Although fish are very commonly sold as this species in the aquarium trade, these are unlikely to be this species (Shi, W., pers. comm., November 2021). The true taxonomic status of this species is not clear. It is very likely that there is in fact a species to be found in this area, which may be new or may be *Betta fusca*. It is recommended that a dedicated search for this species is undertaken (see section 4.8).

Javan "lost" species

Another group of ASAP freshwater fishes are four Possibly Extinct Javan species that have not been recorded for many years, over one hundred years in some cases:

- *Barbonymus platysoma* (last seen in 1855 and described from a single specimen)
- *Hemileiocassis panjang* (not seen in 80 years)
- *Kryptopterus mononema* (not seen in the last 170 years)
- *Lobocheilos lehat* (last seen in 1858, when it was first described)

As these species have not been recorded for so long and they previously were known from areas that are now densely populated, dedicated searches are considered to have a low chance of success and therefore it is not recommended that investment is directed at these species. However, if there are entities willing to provide those resources and undertake the search, or if any of these species are found coincidentally, then immediate action to secure the habitat and establish an assurance population must be implemented.

Oryzias timorensis

One species that does not fall into the above groups is *Oryzias timorensis*. This species is known from fewer than 10 specimens collected in 1911 in Timor. It has not been found in recent surveys in Timor-Leste and is now considered Possibly Extinct. A search, followed by an ex situ programme and habitat protection (and potentially restoration), is urgently needed to save this species from extinction.

4.7.3 Lao PDR

Thirteen species are found in Lao PDR, of which four are restricted range endemics. The fishes fall into two distinct habitat categories in the ASAP Species list: species inhabiting faster-flowing headwaters of the Annamite mountains, and large-bodied riverine species from the middle and lower Mekong Basin.

TABLE 13

Actions by Habitat Type

Habitat type/Location	Species	Threats	Conservation actions
Faster-flowing headwaters (Annamite region)			
Upper parts of the Nam Kading basin	*Scaphognathops theunensis*	Dam construction. Overfishing (susceptible to electro-fishing and other indiscriminate methods), habitat degradation through dam construction, urbanisation and siltation caused by deforestation practices, water pollution and siltation caused by gold mining activities. All species are collected for the aquarium trade.	Further surveys to understand the status and distribution of each of the species is the most immediate need. Protection of habitats. Ex situ breeding to establish assurance populations. Research into the impacts and opportunities related to the aquarium trade.
Nam Leuk catchment	*Schistura leukensis* *Schistura tenura*		
Nam Phao, a tributary of the Nam Theun, Bolikamsai Province	*Oreoglanis lepturus*		
Larger river channels (Mekong drainage)	*Aaptosyax grypus* *Ceratoglanis pachynema* (unconfirmed) *Datnioides pulcher* *Catlocarpio siamensis* *Pangasius sanitwongsei* *Pangasianodon gigas* *Probarbus jullieni*	Urbanisation, dams and pollution (agricultural, urban and industrial) leading to habitat loss and degradation. Overharvesting. Habitat fragmentation (due to dams).	Surveys on the abundance, distribution, and migratory behaviour are urgently needed. Once the ecology of the species is understood, the protection of spawning sites, rearing areas, and migratory pathways is a priority. Small no-fishing zones in these habitats are a solution. Research is especially needed into the migratory patterns of the species.

The conservation of the four headwater ASAP Species in the Annamite Mountains is hindered by a severe lack of information on species taxonomy and distribution. Dedicated efforts to properly survey and catalogue freshwater fish diversity and distribution is a necessary first step to understanding and hopefully safeguarding Lao PDR's freshwater fish species. Effective conservation measures can then be designed. Many of these measures are likely to focus on the many deleterious effects related to dams. Harvest for commerce and sustenance may also need to be addressed; while the impact of the aquarium trade on Annamite headwater species needs to be better understood. Ex situ breeding of each of the four fishes should be undertaken as soon as possible.

Datnioides pulcher clings on in the middle and lower Mekong with rare reports coming in from Lao PDR, and low numbers exported out of Vietnam and Lao PDR for the aquarium trade. It was extirpated from Thailand in the 1990s, where it used to exist in the Mae Klong and Chao Phraya basins. Collection for the aquarium trade remains a major driver of continued decline, with persisting targeted collection and export even with populations already at critically low levels. The species also faces the ubiquitous threat of habitat alteration and loss, with dams, weirs and locks hampering lateral movement between main river channels and tributaries. The above-mentioned threat mitigation measures addressing habitat alteration will also benefit this species, but additional efforts to assess and combat collection for the ornamental trade will be needed as well. These include policy-level changes banning or regulating the trade in wild-caught fish, coupled with education and outreach efforts. Also, this species has reportedly been successfully bred in captivity in Thailand in recent years - conservation breeding and release, done with proper research and consideration of genetics, could also be an effective tool.

For information on Mekong River species, see section 4.2.1

4.7.4 Malaysia

The nine freshwater ASAP Species in Malaysia are comprised of highly range-restricted peat swamp forest species (three species), island endemics (three species), and riverine fish (three species, of which two are Possibly Extinct).

TABLE 14

Actions by Habitat Type

Habitat type/Location	Species	Threats	Conservation actions
Peat swamp forest			
Johor State, close to Mawai and Desaru	*Parosphromenus alfredi*	Peat swamp forest conversion, drainage, fires for agricultural plantations such as oil palm, acacia, and pineapple. Potential overharvesting for the aquaria trade.	Surveys are required to ascertain a more accurate understanding of the population status and distribution of each species.
Johor State, remnant peat swamp forest, roadside ditches, and small highly modified streams within oil palm estates, southwestern Johor	*Betta omega*		
Johor and Pahang State, Sedili and Bebar River drainage	*Encheloclarias kelioides*		
Island stream endemics			
Pahang State, Tioman Island - endemic to a single cave (island endemic)	*Speonectes tiomanensis*	This species is restricted to one cave habitat. Drought is the greatest threat, and this may stem from climate change.	Research is needed into its population dynamics, distribution and ecology. Monitoring of population and habitat trends. Site protection.
Pahang State, Tioman Island - forested hill streams (island endemic)	*Clarias batu*	The expansion of tourist facilities such as roads, hotels and an airport is a potential threat to the last remaining individuals of this species. *However, a recent DNA analysis as part of a conservation project for this species, under ASAP, has potentially discovered that this species is present on mainland Peninsular Malaysia and sufficiently widespread to reduce its threat status.	Possibly no action is now needed if the presence on mainland Peninsular Malaysia is confirmed. If presence is not confirmed, ex situ breeding and reintroduction into protected river stretches on Tioman Island are the most immediate conservation actions required.
Terengganu State, Redang Island - forested hill stream headwaters (island endemic)	*Clarias sulcatus*	Tourism development and water extraction are the greatest threat to this species.	Full surveys. Ex situ breeding (for future reintroduction). Habitat protection.

TABLE 14 Actions by Habitat Type (cont.)

Habitat type/Location	Species	Threats	Conservation actions
River channel			
Johor State, Muar River	*Hyalobagrus ornatus* (Possibly Extinct)	As the status and distribution is not known, the direct threats cannot be ascertained but logging, deforestation, urban development, pollution resulting from industrial and agricultural point and non-point sources, and agriculture occur extensively in the Muar River drainage.	Surveys to find this species are the immediate priority. If individuals are found, appropriate actions can then be defined for its conservation.
Pahang and Perak State	*Probarbus jullieni*	This species is impacted by overfishing, habitat destruction, and large dams. The species cannot survive in reservoirs.	Research into population trends and threats to the species and its habitats is needed. The species would benefit from fishing regulations to control overharvest and protected areas to safeguard spawning sites. The species has been listed under CITES and management measures have been undertaken in Vietnam, Cambodia and Lao PDR.
Pahang State Pahang River	*Lepidocephalus pahangensis* (Possibly Extinct)	As the status and distribution is not known, the direct threats cannot be ascertained but logging, deforestation, urban development, pollution resulting from industrial and agricultural point and non-point sources, and agriculture occur extensively in the Pahang River drainage.	Surveys to find this species are the immediate priority. If individuals are found, appropriate actions can then be defined for its conservation.

Peat swamp forest species

All three ASAP peat swamp forest-associated species are found in Peninsular Malaysia. More than half of the peat swamp forests there have been cleared or degraded (World Wildlife Fund, 2002).

The peat swamp forests that used to exist along the western coast are largely gone, with remnant patches on the east coast forming most of the remaining habitat. Despite the critical condition of this habitat type, peat swamp forests here continue to be gravely threatened by logging, tin mining, agriculture (e.g., rice, oil palm, rubber), and water extraction.

For the other two peat swamp forest specialist ASAP Species, single site protection has been identified as the most urgent conservation action. Both *Parosphromenus alfredi* and *Betta omega* are restricted to tiny remnant patches of highly disturbed swamp forest in the southern part of Johor, each with an area of occurrence of about 4 km^2. Both of these tiny sites remain unprotected and face continued degradation and destruction for oil palm plantations and development, and both species face imminent extinction if conservation action is not implemented in the near future. Beyond these two species, multiple other Endangered peat swamp forest-associated species (e.g., *Parosphromenus tweediei*, *Betta persephone*) also exist in remnant habitat patches in Johor. Protection of the habitats of these two ASAP Species, as well as additional sites in southern Peninsular Malaysia, can thus have substantial cumulative positive impacts for species beyond *Parosphromenus alfredi* and *Betta omega*.

Ex situ conservation could be the species' only hope of avoiding extinction. The Parosphromenus Project is a dedicated project, led by aquaria hobbyists, to both provide security for this genus in assurance populations but also to support in situ protection and conservation.

Research into the taxonomy and genetics of the *Parosphromenus* species from southern Peninsular Malaysia is also necessary given present uncertainty over species limits. Species limits between ASAP Species *Parosphromenus alfredi* and

other Endangered sister taxa such as *Parosphromenus tweediei* will need to be properly investigated and delineated for effective conservation plans to be developed.

Island stream endemics

The next trio of ASAP freshwater fish from Malaysia are the three island endemic species of *Speonectes tiomanensis*, *Clarias batu*, and *Clarias sulcatus*. *Speonectes tiomanensis* and *Clarias batu* are both found only on the island of Tioman off Peninsular Malaysia's eastern coast, with the latter inhabiting cool, clear, fast-flowing forest streams while the former is further restricted to a single pool in a cave (Gua Tankok Air) on Gunung Kajang, the highest mountain on Tioman. While *Speonectes tiomanensis* is afforded some protection by the relative inaccessibility of its singular cave habitat, the extremely limited distribution and low population numbers render the species extremely vulnerable to any disturbance not only to the cave, but also the surrounding landscape. In the mid-2010s, there were some signs that the forest was drying out at the lower slopes (Tan, H.H., pers. comm., September 2021). Changes to the water table because of surface and groundwater extraction, and possibly climate change, could result in the drying out of the habitats of both *Speonectes tiomanensis* and *Clarias batu*. While the latter's distribution is not quite as restricted as that of the former, it faces additional threats in the form of habitat encroachment for agriculture and tourism development, and potentially from invasive species like *Oreochromis mossambicus* and *Barbonymus schwanefeldii*.

In view of these threats, *Speonectes tiomanensis* first requires survey effort to determine its population status. *Clarias batu* likewise requires research effort into its distribution, population trends, and the effects of water extraction and invasive species stocking. For both species, improved site protection is the most important direct conservation action. While the forested interior of Tioman has been protected as a wildlife reserve since 1972, increased efforts related to enforcement and regulation can greatly aid the protection of both these species as well as Tioman's other threatened and/or endemic species (e.g., the critically endangered Pulau Tioman Ground Snake *Gongylosoma mukutense*). The effects of climate change and water extraction on the water table, habitat destruction for tourism and agriculture, and invasive species introductions will also need to be monitored and regulated.

Northwards along the Peninsular Malaysian coast, off Terengganu, is the island of Redang, on which can be found the endemic species *Clarias sulcatus*. This species faces two of the same threats faced by *Clarias batu* in Tioman: tourism infrastructure development and water abstraction. In addition, plans for an airport on Redang as well as occasional fishing for sport and consumption further threaten *C. sulcatus*. Like Tioman, its habitat on Redang is afforded some protection as a forest reserve. However, there are no regulations to restrict extraction of this species from the reserve.

A recent DNA analysis as part of a conservation project for *Clarias batu*, under ASAP, has potentially discovered that this species is also present on mainland Peninsular Malaysia and sufficiently widespread to reduce its threat status. The actual status of this species is yet to be determined (Ahmand, A., pers. comm., April 2023).

Riverine species

The list for Malaysia includes three river species. Two of these species (*Lepidocephalus pahangensis* and *Hyalobagrus ornatus*) have not been recorded for many years (last recorded 90 and 110 years ago respectively) and are classified as Possibly Extinct. No conservation measures can be recommended at this stage, given that there is almost no information on the ecology and status of these two species. Cautionary policies such as eliminating pollution and reducing riparian forest clearance should be prioritised in the potential habitat of these species. Surveys for these two species are needed to ascertain if they continue to persist.

The other river channel species, *Probarbus jullieni*, was found throughout mainland Southeast Asia and is now known only from the Mekong basin and two rivers in Malaysia. The species is a high value food fish and as it becomes increasingly rare, its market price is also further incentivising and intensifying capture from the wild. There are several fisheries-based breeding programmes for the species (which may have a benefit for conservation but also may be a threat) and there are ongoing efforts to tackle the large-scale issues such as damming of migration routes on the Mekong River. However, more coordination and direct conservation efforts are required to secure, stabilise and recover wild populations of this species.

4.7.5 Myanmar

Systomus compressiformis is the only species of Critically Endangered fish listed for Myanmar. The species is endemic to Lake Inle but is listed as Possibly Extinct. Surveys to ascertain its status are therefore the most immediate priority. Inle Lake itself supports 17 endemic fish species and is a priority site for conservation action.

The low numbers of Critically Endangered fishes in Myanmar could very possibly be the result of a lack of knowledge on the fishes of this country; however, the possibility that at present there may be less threat to freshwater fishes here also cannot be fully ruled out. Further work (though outside the scope of this Framework) to ascertain the status of freshwater fishes in Myanmar is a high priority.

TABLE 15

Actions by Habitat Type

Habitat type/Location	Species	Threats	Conservation actions
Lake Inle	*Systomus compressiformis* (Possibly Extinct)	Overharvesting, pollution, agricultural runoff, invasive species and habitat degradation are listed as potential reasons for the species disappearance.	Surveys are needed to confirm if the species is still extant in the lake, and further conservation actions can then be designed if it is found. Inle Lake supports 17 endemic fishes and therefore is a high priority for conservation itself.

4.7.6 The Philippines

The Philippines harbours 12 ASAP freshwater fish species. Seven of these 12 species are lake endemics, while three others inhabit river systems, one species is a cave habitat specialist and another may be more linked to estuarine habitats. All species are endemic to the Philippines.

TABLE 16

Actions by Habitat Type

Habitat type/Location	Species	Threats	Conservation actions
Lake endemics			
Lake Lanao Mindanao/Lanao del Sur Province	*Barbodes lindog* (PE) *Barbodes sirang* (PE)	Invasive species are the main cause of the decline of endemic fish in the lake. However, the lake is also impacted by agricultural, industrial, and domestic wastewater pollution, aquaculture activities and destructive fishing methods.	New persistence surveys are required to understand the status of these species. If individuals are found, an ex situ breeding programme is required for potential reintroduction if solutions to the threats are found.
Lake Manguao in Palawan	*Barbodes manguaoensis* *Bostrychus expatria*	Introduction of exotic species and habitat destruction due to mining operations, deforestation, and tourism-related activities, such as the building of cottages and pollution from sewage.	Research is needed to determine the population sizes and trends, life history, and ecology. Municipal action is required to reduce the pollution into the lake and find solutions to the impacts of invasive species.
Laguna de Bay Luzon/Laguna Province	*Neostethus ctenophorus* (PE)	The lake is threatened by agricultural, industrial, and domestic wastewater pollution, invasive alien species, aquaculture activities, and sedimentation.	Research on population status, life history, ecology, use, trade and threats is needed.

TABLE 16 Actions by Habitat Type (cont.)

Habitat type/Location	Species	Threats	Conservation actions
Lake endemics			
Taal Lake Luzon/Batangas Province	*Exyrias volcanus* (PE) *Silhouettea flavoventris* (PE)	Overexploitation, pollution, habitat degradation and destruction, invasive species, and proliferation of aquaculture, among others.	Both species require further study and survey work, first to find out if they are still extant and then to determine conservation measures if they are found.
River species			
Cascade River and the brackish waters of Murcielagos Bay, Mindanao	*Barbodes cataractae* (PE)	Little is known about this species. Its river habitat is threatened by pollution and sedimentation. In Lake Lanao, this species is threatened by invasive species, overfishing, and destructive fishing methods.	Further survey work is required to ascertain the status of this species. Conservation actions can only be prescribed once individuals are found but they may only survive via ex situ methods until the threats are overcome.
Calasiao River Luzon/Pangasinan Province	*Neostethus robertsi*	Rivers in Calasiao, like all the other rivers/tributaries connected to the Agno River Basin, are threatened by pollution from mining, agricultural, domestic and industrial wastes and sedimentation.	Surveys are needed to ascertain the status of this species and determine specific conservation measures.
Agus River and its tributaries in Mindanao	*Barbodes joaquinae*	Dams.	Information on this species is very limited. Research on distribution, population size and trends, and use and trade should be prioritised to develop appropriate conservation measures for this species.
Cave specialist			
Subterranean waterways in the Calbiga cave system (Samar Island National Park) Visayas/Samar Province, Eastern Samar Province, Northern Samar Province	*Caecogobius cryptophthalmus*	Calbiga Cave is in danger mainly due to the growing demand for recreational sites and tourism-related activities.	This species falls within a protected area and is only accessible to experienced cavers. Conservation action should be mainly focused on research into the status and ecology of the species.
Other			
Unknown but only recorded from Manila Bay so assumed brackish or estuarine with potential freshwater use.	*Clupea manulensis* (PE)	Major threats to Manila Bay include overfishing, illegal fishing practices, destruction of habitats and pollution.	Surveys for this species are an immediate priority. So little is known about it, any prescription for conservation actions would be premature.

The five Philippine lake-endemic ASAP Species (from Lakes Lanao, Manguao, Taal and Laguna de Bay) face similar challenges to lake endemics elsewhere in Southeast Asia: invasive species, pollution, fisheries, effluents associated with forestry, agriculture, and urbanisation, and water level fluctuations due to human use and climate change. Lake Lanao is perhaps the most prominent example of the devastating effects of these challenges. Lake Lanao is one of the world's 15 ancient lakes, with an estimated age of two million years, making it the oldest lake in Southeast Asia. With a surface area of 370km^2, it is also the second largest lake in the Philippines. Its age and size have allowed it to support an adaptive radiation of native cyprinid species (genus *Barbodes*) that speciated to fill a wide range of trophic niches- an Asiatic counterpart to Africa's more famous Rift Valley cichlid radiations. Lanao's formerly richly diverse cyprinid fauna is now largely gone - 15 species were declared Extinct in 2020, with only two species (*B. lindog* and *B. sirang*) left listed as Critically Endangered - Possibly Extinct.

While endemic cyprinids used to support commercial and large subsistence fisheries in the lake, landings are now composed almost entirely of exotic species, as a result of accidental releases. In particular, the invasive Snakehead Gudgeon (*Giuris margaritacea*) has been identified as the main driver of endemic cyprinid extinction in Lanao, where it is numerous and widespread. Local experts strongly recommend that any native *Barbodes* found from Lake Lanao be brought in for ex situ breeding, which represents the best hope for these cyprinids. The University of the Philippines' College of Fisheries has the facilities to lead such captive breeding initiatives. At the same time, in situ research and conservation action (both at Lake Lanao and other smaller lakes in the region) should be focused on the eradication of the Snakehead Gudgeon, if possible. These efforts will also benefit other *Barbodes* species in the region that have substantially declined, including *Barbodes tumba* and perhaps *Barbodes joaquinae* from the Agus River, which drains Lake Lanao. Benign reintroduction or assisted colonisation of the lake and other water bodies nearby with captive-bred *Barbodes* can then be the next step (Torres, A., pers. comm., June 2021).

While civil unrest has greatly hampered research and conservation efforts in Mindanao in recent history, collaborations with local government units and the Mindanao State University can help alleviate this issue, especially as ongoing rehabilitation of Marawi and surrounding towns has made it safer to travel in and around the region. This situation is foreseen to be sustained at least for several years. Prompt action in securing necessary funding and kickstarting surveys and collection (of *Barbodes*) for captive breeding as well as research into Snakehead Gudgeon eradication is thus urgently needed if these species are to have any hope of survival (Torres, A., pers. comm., June 2021).

Two other Possibly Extinct species from Lake Taal in Batangas Province (*Exyrias volcanus* and *Silhouettea flavoventris*) face similar challenges, as does *Neostethus ctenophorus* from Laguna de Bay, southeast of Metro Manila. The Jaguar Guapote (*Parachromis managuensis*) and tilapia (*Oreochromis* sp.) are the invasive species most closely associated with the declines of the two ASAP Species from Lake Taal. The establishment of a Jaguar Guapote population is likely the result of fish released by hobbyists (Guerrero III, 2014; Corpuz et al., 2016). Both *Exyrias volcanus* and *Silhouettea flavoventris* are additionally threatened by pollution, and neither species has been detected in at least the last 30 years. Survey work to determine if they persist is the next identified action for these species. *Neostethus ctenophorus*, one of the highly interesting priapium fish (Phallostethidae) from Laguna de Bay has not been detected since its description in 1937. Surveys to determine if the species still survives are needed, and any discovery of surviving fish must be followed by swift action given the threat of invasive species, aquaculture, pollution, and sedimentation from rapid industrialisation in the region.

The Philippines hosts three river and stream dwelling ASAP Species. *Barbodes joaquinae* inhabits fast-flowing rapids in tributaries of the Agus River, which drains Lake Lanao. While dams have affected this species since the 1970s by limiting available habitat, much remains unknown. Research aimed at uncovering information on the species (distribution, population size, life history and ecology, human use, and other threats) has been identified as the next action for this poorly understood species. Another riverine species is the priapium fish *Neostethus robertsi*, from the Calasiao River in Luzon. Policy-level change related to addressing pollution, sedimentation and discharge from deforestation and mining, agriculture, industry, urbanisation, and other human activities is the identified next action for this species. The Calasiao watershed has been designated by the Philippines' Department of Environment and Natural Resources as part of the Sinocalan-Dagupan River System Water Quality Management Area, for protection and rehabilitation; this could prove to be a useful springboard to call attention and rally efforts to protect this ASAP Species.

The cave dwelling *Caecogobius cryptophthalmus* from Samar Province survives in the Calbiga Cave System, which is part of the Samar Island National Park. Despite being a protected area, the cave system faces potential threat from future development for tourism. Efforts to shore up site protection of this fish's habitat, coupled with research into its distribution, population size, life history and ecology, and other threats (including incursion by tourists) have thus been identified as the next needed conservation actions to safeguard its survival.

Lack of taxonomic and distribution knowledge is a considerable problem in the Philippines for many reasons. While a significant body of taxonomic work on the Philippines' freshwater fish fauna had been done in the early 1900s, destruction of museum collections, including a great deal of freshwater fish type materials, was a huge impediment and made freshwater species discovery and taxonomy very difficult (Tan, H.H., pers. comm., June 2021).

4.7.7 Singapore

Until 2023, no Critically Endangered freshwater fishes were listed for Singapore. However, in 2023, *Encheloclarias kelioides* was found in Nee Soon Swamp Forest as reported by Tan et al. (2023). Previously the only known location for this species was southern Peninsular Malaysia (and an uncertain record in Sumatra, Indonesia). The species had not been seen, until this point, since its first description from specimens found in Malaysia in 1992. Despite this new location in a highly protected area in Singapore, Tan et al. (2023) recommend that its IUCN Red List status should remain as Critically Endangered but with the change from Possibly Extinct to extant.

4.7.8 Thailand

With several of Southeast Asia's major rivers flowing through Thailand, and a long history of river use and modification by humans, nine of Thailand's 12 total ASAP freshwater fishes are associated with larger river channels, two inhabit smaller waterways in karst and cave areas, and one is associated with slow, acidic rivers. One species, *Datnioides pulcher* is now considered to be extirpated in Thailand.

TABLE 17

Actions by Habitat Type

Habitat	ASAP Species	Threats	Conservation actions
Large river channels			
Mae Khlong drainage (larger channels) Kanchanaburi, Ratchaburi, Samut Songkhram Provinces	*Balantiocheilos ambusticauda* (PE in Thailand) *Catlocarpio siamensis*	Urbanisation, dams, and pollution (agricultural, urban and industrial), causing habitat loss and degradation. Overharvesting. Habitat fragmentation (due to dams). *Balantiocheilos ambusticauda* was once considered over-collected for the aquarium trade, but its decline was also linked to factors such as pollution and habitat degradation.	Surveys on the abundance, distribution, and migratory behaviour are urgently needed. Once the ecology of the species is understood, the protection of spawning sites, rearing areas, and migratory pathways are a priority. Small no-fishing zones in these habitats can be a solution. Research is especially needed into the migratory patterns of the species.
Chao Phraya drainage (larger channels) Nakhon Sawan, Uthai Thani, Chai Nat, Sing Buri, Ang Thong, Ayutthaya, Pathum Thani, Nonthaburi, Bangkok, Samut Prakan Provinces	*Balantiocheilos ambusticauda* (PE in Thailand) *Epalzeorhynchos bicolor* *Catlocarpio siamensis* *Pangasius sanitwongsei* (PE in Thailand)		
Mekong drainage (larger channels) Chiang Rai, Loei, Nong Khai, Bueng Kan, Mukdahan, Amnat Charoen, Nakhon Phanom, Ubon Ratchathani Provinces	*Aaptosyax grypus* *Catlocarpio siamensis* *Pangasianodon gigas* *Pangasius sanitwongsei* (PE in Thailand)		
Subterranean river system			
Chao Phraya drainage (cave stream), Kanchanaburi Province	*Nemacheilus troglocataractus*	Disturbance from cave visitors is the main threat to this fish. Harvest for the aquarium trade is an occasional threat.	More information about this species is required before further conservation action can be prescribed.
Lower turbid river habitat with mud substrate			
Bang Pakong drainage (larger channels), Chachoengsao Province	*Ceratoglanis pachynema*	This species is sensitive to pollution from industrial, domestic and agricultural sources.	Surveys and research on the distribution, biology and specific potential threats are required as the immediate first step.

TABLE 17 Actions by Habitat Type (cont.)

Habitat type/Location	Species	Threats	Conservation actions
Lowland, slow flowing vegetated rivers and marshes			
Deeply vegetated slow moving river, Ratchaburi Province	*Trigonostigma somphongsi*	Habitat degradation from wetland conversion for farmland and urbanisation, particularly related to the loss of vegetation. The species may also be taken in mixed catches.	Habitat and population surveys. Restoration of wetlands. Ex situ conservation from captive stock to support remaining wild populations. Protection of wild populations.
Karst springs and creeks			
Karst areas in Krabi Province	*Betta simplex*	Habitat conversion and degradation, pollution from agricultural chemicals, and collection for the aquarium trade.	Research and monitoring of populations in its habitat are needed to develop a management plan as soon as possible.

For species inhabiting the larger river channels see section 4.2.1.

Ceratoglanis pachynema faces pressure as a target of artisanal fisheries and occasionally the aquarium trade and is also threatened by pollution. The aquarium trade has been thought to be a major cause of decline historically for *Balantiocheilos ambusticauda* and possibly *Epalzeorhynchos bicolor*, though habitat alteration and pollution may well have been the main culprits, especially for the latter. Currently, habitat loss and pollution due to dam construction, agriculture and infrastructure development are the main ongoing threats.

Trigonostigma somphongsi suffers largely from habitat degradation and is also possibly taken in mixed catches. The first wild population of this species since its description (Meinken, 1958) was detected in 2014 (Petsut et al., 2014) in a floodplain of the Bang Pakong - as a horizontal seasonal migrant which migrates out into the floodplain to breed, careful management of water flows will be critical to its survival. This species can be found in the aquarium trade from captive-bred sources, proving that ex situ breeding is possible if needed.

Balantiocheilos ambusticauda, is considered Possibly Extinct in Thailand while it is believed to still persist in Cambodia and Lao PDR. However, there is no evidence of this species ever being in these countries. It is believed that is potentially a Thai endemic which is now possibly extinct. Numerous surveys have not found the species in recent years. Urgent surveys need to be undertaken to assess if it is still extant. Such surveys will also benefit *Epalzeorhynchos bicolor*, which is highly localised within the Chao Phraya Basin - presence of farm-bred populations of this species also possibly opens the option of conservation breeding for reintroduction. Research into the levels of genetic variability present in captive populations, to gauge suitability for release, will be necessary. Ex situ conservation measures are also potentially applicable to other species presently being bred under human care, including *Pangasianodon gigas*, *Catlocarpio siamensis*, *Pangasius sanitwongsei*, and *Probarbus jullieni*.

Datnioides pulcher is now considered extinct in Thailand. This species has reportedly been successfully bred in captivity in Thailand in recent years - conservation breeding and release, done with proper research and consideration of genetics, could also be an effective tool. For more details on the species please see Lao PDR or Vietnam sections.

Besides the fish from the large river channels, the other two inland freshwater ASAP Species in Thailand are *Betta simplex*, from a small region of karst landscape in Krabi, and *Nemacheilus troglocataractus*, known only from the Sai Yok Noi cave in Kanchanaburi Province. The habitat of *Betta simplex* is presently not protected - habitat conversion/destruction remains a threat, as does collection for the aquarium trade. The habitat of *Nemacheilus troglocataractus*, while under protection as part of Sai Yok National Park, is heavily visited by tourists and faces pressure from human use of the stream. Additionally, the species' occasional presence in the aquarium trade indicates that there is some level of illegal collection taking place. For both species, single site habitat protection is urgently needed, coupled with research and monitoring related to the aquarium trade. Information on trade presence and volumes of both these species will give valuable insight into how great of a threat the aquarium trade poses, and better inform the need for additional conservation measures (e.g., increased protection from harvest, ex situ breeding). As both these species are only known from single locations, improved site protection has the potential to provide effective conservation outcomes. This is especially true for *Betta simplex*, whose habitat is completely unprotected. For *Nemacheilus troglocataractus*, visitor control and increased protection from poaching could be effective.

4.7.9 Vietnam

All nine of Vietnam's ASAP Species fall into one of two habitat categories: species inhabiting faster-flowing headwater habitats, and larger river-dwelling species inhabiting the middle and lower Mekong drainage.

TABLE 18

Actions by Habitat Type

Habitat type/Location	Species	Threats	Conservation actions
Faster-flowing headwaters (Annamite region)			
Thua Thuen Hue province	*Schistura spiloptera*	Overfishing (susceptible to electro-fishing and other indiscriminate methods). Habitat degradation through dam construction, urbanisation and siltation caused by deforestation.	Further surveys to understand the status and distribution of each of the species. Protection of habitats. Ex situ breeding to establish assurance populations.
Rivers Ko and Tan, Phu Yen Province	*Schistura nasifilis* (PE)		
Quang Nam Da Nang Province	*Sewellia albisuera*		
Pako River (Sesan River basin) in central Vietnam	*Sewellia breviventralis*	Water pollution and siltation caused by gold mining activities. All species are collected for the aquarium trade.	Research into the impacts and opportunities related to the aquarium trade.
Larger river channels (Mekong drainage)	*Datnioides pulcher* *Catlocarpio siamensis* *Pangasius sanitwongsei* *Pangasianodon gigas* *Probarbus jullieni*	Urbanisation, dams and pollution (agricultural, urban and industrial) leading to habitat loss and degradation. Overharvest. Habitat fragmentation (due to dams).	Surveys on the abundance, distribution, and migratory behaviour are urgently needed. Once the ecology of the species is understood, the protection of spawning sites, rearing areas, and migratory pathways is a priority. Small no-fishing zones in these habitats are a solution. Research is especially needed into the migratory patterns of the species.

The main threats headwater species in the Annamites face are the building of dams and associated changes to habitat, including changes to water flow as well as related pollution and sedimentation, and potential harvest for the aquarium trade.

There is a severe lack of knowledge on species taxonomy and distribution in the Annamites - as the accuracy of the Red List is reliant on this knowledge, this uncertainty is a massive impediment to work here. Large swathes of the Annamites remain poorly surveyed. It is likely that multiple undescribed species are present. Of the few that have been properly described, many of these descriptions were based off a few specimens collected at a handful of locations, with their range sizes and distributions remaining unknown (Bui, H.M., pers. comm., February 2021).

As such, surveys to assess presence of these ASAP Species in areas around their type localities and determine their known ranges are very important. There is an ongoing effort by a team of researchers in Vietnam to revise and update the entire freshwater fish fauna in the country - when completed, this will be an extremely valuable resource, and contributions to speed up the process will greatly benefit conservation efforts here.

Dams continue to be a huge threat in Vietnam, even at higher altitudes. While the smaller headwater-inhabiting ASAP freshwater fishes do not undertake the same longer-distance migrations that the larger lowland species do, dams (and associated development) nonetheless introduce comprehensive habitat change that impacts their continued survival. All four Annamite ASAP Species listed here inhabit clear, highly oxygenated, fast-flowing waters; dam-building drastically alters water flows and replaces flowing waters with comparatively still and stagnant reservoirs. Dams also impact eutrophication and siltation rates, and associated development results in pollution and further degradation through the degradation of surrounding terrestrial habitats.

Organisations working on policy-level discussions surrounding dams need to be identified. Improved coordination among them, working on different aspects/effects of the dam-building process, can provide enhanced conservation benefits. These include engagement in both opposing rampant dam construction and promoting construction/design that mitigate impacts as much as possible. Measures to control pollution and siltation, properly manage water flows, and safeguard natural habitats should all be carefully considered and implemented where deemed appropriate.

Collection of these headwater fish species for the aquarium trade is a growing threat, with the efficiency of global commerce resulting in the availability of new and novel species to hobbyists worldwide. Fish from the genera *Sewellia* and *Schistura* face considerable collection pressure in the wild, and proper fisheries management is critical if wild populations are to survive this. Research on trade volumes and how collection is impacting populations in the wild are urgently needed. Identification of organisations working on policy change related to sustainable fisheries will also be important, and targeted consumer behaviour initiatives to encourage use of more sustainable fishing practices can also be very impactful.

Datnioides pulcher clings on in the middle and lower Mekong with rare reports coming in from Lao PDR, and low numbers exported out of Vietnam and Lao PDR for the aquarium trade. It was extirpated from Thailand in the 1990s, where it used to exist in the Mae Klong and Chao Phraya basins. Collection for the aquarium trade remains a major driver of continued decline, with persisting targeted collection and export even with populations already at critically low levels. The species also faces the ubiquitous threat of habitat alteration and loss, with dams, weirs and locks hampering lateral movement between main river channels and tributaries. Above-mentioned threat mitigation measures addressing habitat alteration will also benefit this species, but additional efforts to assess and combat collection for the ornamental trade will be needed as well. These include policy-level changes banning, or at least regulating, the trade in wild-caught fish coupled with efforts in education and outreach. Also, this species has reportedly been successfully bred in captivity in Thailand in recent years - conservation breeding and release, done with proper research and consideration of genetic diversity, could also be an effective tool.

For the larger riverine species in the Mekong, see section 4.2.1.

Fishers on the Mekong River. Taken in 2013. Photo: Teerapong Pomun.

5

Operational considerations

Although this is not an Action Plan for ASAP freshwater fish conservation, it is important to describe some of the key operational considerations that may be helpful to those intending to be informed or use this document to initiate action.

5.1 Capacity

Effective conservation of 90 species will require a high level of expertise, cooperation, collaboration, and partnership throughout each of the ASAP countries.

Present status of implementation capacity

Most technical experts on freshwater fishes distributed in Southeast Asia are fish taxonomists from universities and museums, and occasional government fisheries departments or research divisions. While taxonomists have been critical for research and understanding fish diversity, distributions, and conservation status, they have rarely been involved in in situ conservation action. In general, museum and university collections are located outside of countries where conservation action is needed and national collections are often limited, forcing local scientists to rely on resources that are often found outside of Southeast Asian countries.

There are very few examples of implementation of in situ conservation action for threatened fishes in Southeast Asia and so the general capacity for effective implementation of this framework is limited. There are no dedicated non-governmental organisations with an ongoing specific focus on the conservation of Critically Endangered freshwater fishes. Although there has been an increase in the number of fish conservation projects being initiated, the number of such projects is low. For ex situ conservation action, there is some technical expertise scattered across the region and there is a large knowledgeable community of home aquaria hobbyists that provide opportunities to expand capacity for this part of the programme of work. Government fisheries departments in all of the countries do have some level of technical capacity for managing, monitoring and mobilising action, but this is normally focused on commercial fisheries and hatchery science. This expertise has seldom been applied for conservation purposes. There is a very serious gap in the capacity to understand the ecology, breeding behaviour, population status, habitat management needs, and effectively address threats in the region. Furthermore, expertise in the design of projects, proposal writing, and project implementation is clearly lacking and is a severe hindrance to future success. Every effort needs to be made to change this situation if there is to be any hope for this framework to be fully realised.

Local knowledge and community-based management

One of the opportunities that does exist in the region is a vast amount of very valuable local ecological knowledge. As freshwater fish and their habitats have been and are still a critical part of the daily lives of many villagers and local communities, local knowledge is still accessible. It can prove to be an important source of information on the status, distribution, ecology, and breeding behaviour of these species. In many cases, community management of local wetlands is already providing active conservation management for some species. However, this is mostly done without the knowledge of the global conservation status of the species. There are numerous and growing examples of community-organised action to create fish conservation areas where multiple benefits provide an incentive for sustainable management of rivers, swamps, and lakes by local communities (Koning et al., 2020).

Fish ladder. Taken in 2013. © Teerapong Pomun.

Local action and support for conservation efforts are required for all the ASAP freshwater fishes. Therefore, maximising the engagement and collaboration of local communities is not just an opportunity to create significant levels of capacity but is also essential to the success of any planned interventions.

Skill and knowledge sharing, networks, and partnerships

One method to help overcome the serious gaps in capacity is to increase the level of networking and sharing of skills and information, especially by linking fish taxonomists and researchers with conservation implementers and community groups on the ground. At present there is very little collaboration of this type, even at the national level. This would enable leaders of individual projects to increase their capacity without immediate investment or training. Targeted training could also be provided to networks rather than team by team, community, or project. There are a considerable number of experts and organisations outside of the region that can and are interested in providing direct technical support and other forms of capacity to projects. Sharing his significant capacity would certainly be an important short-to-medium term extra input to accelerate implementation of the Framework.

Opportunities to overlap and integrate with long-term conservation programmes

There are many existing and ongoing conservation initiatives in the region, including investment in protected areas, that overlap with the ASAP freshwater fishes conservation priorities that presently have neglected attention to fishes. A very simple activity would be to map these interventions and negotiate with the stakeholders to encourage them to include fish management needs and considerations.

5.2 Funding

Funding for freshwater fish conservation has been notoriously limited on a global scale. Every effort needs to be applied to encourage donors and those in charge of government budgets to make more funds available. As funds do become available, it is also important that potential implementation partners have the capacity to obtain and manage these funds, as well as deliver on the expectations of the donor or financier. It is therefore important to understand that funding and capacity are intrinsically coupled.

Table 1 in the summary of this document identifies the scales that each of the suggested work areas and activities will require. Fortunately, many of these activities require relatively low amounts of funding and could be supported by a number of small grant schemes targeting small local organisations. These schemes can help propel action for many species but would need longer-term more sustained funding to maintain activities and progress. At the same time, many of the more complex activities that require large investments are linked to other development needs such as inland fisheries, flood control and sustainable river management. It is possible to add considerations for the relevant ASAP freshwater fishes into investment plans.

While some funding options already exist, a significant increase in available amounts of funding is needed as soon as possible. Therefore, the role of programmes such as ASAP should be to help attract and facilitate more funding opportunities as an immediate priority.

5.3 Governance and facilitation

This framework has been prepared to facilitate immediate action under the ASAP programme. The purpose of the ASAP programme is to facilitate and support action for these high priority species. Therefore the overview of this Strategic Framework will be led by the programme, together with willing partners such as SHOAL and Mandai Nature, and hopes to bring in other key stakeholders over time. The aim is to update the Framework at regular intervals and perhaps subsequent action plans for different components of the Framework will follow. Regular updates on the progress of the application of the Framework will be published.

5.4 Government engagement

While it is likely that much of the implementation will be catalysed and led by non-governmental organisations, universities, and communities, very often the most powerful and long-term implementors will include government bodies - particularly at the local level. Government bodies can provide longevity to the investment, can integrate it into broader planning and policies and can provide regular funding and capacity.

5.5 Stakeholders

Successful conservation of Critically Endangered fishes is highly dependent on a variety of stakeholders and will only be successfully implemented through their participation and engagement.

■ Local Communities, fisher associations, and people's organisations

Essential stakeholders are local communities that live near, and directly rely on, freshwater habitats and ASAP freshwater fishes. They have the best opportunity to be effective long-term stewards of ASAP freshwater fishes if provided with the appropriate support and empowerment. Without their engagement, all efforts are likely to fail.

■ Local businesses, landowners, and corporations

Many of the factors identified as threats to the ASAP freshwater fishes stem from the negative impacts of economic activities in the region. This includes habitat clearance for agricultural land and plantations, mining, aquaculture operations, and water pollution from industrial effluents. Addressing these issues will be required for many species and therefore engaging with the relevant businesses or landowners at some level will be essential. These businesses can also be very powerful supporters of protection and restoration of habitats, building the capacity of other stakeholders and providing solutions to conservation challenges.

■ Governments

Government bodies at all levels have a key role in setting the right policies, providing financial and technical support for action, and driving action - including education and awareness raising. In many cases, government fisheries departments are the key agencies responsible for delivering and enforcing policy interventions, monitoring harvest, tracking population status, and assessing biological impacts of development. Gaining their support and participation will be essential for implementation of any actions requiring government involvement.

Swiss ichthyologist and Eurasian freshwater fishes specialist Maurice Kottelat working in the field. © Maurice Kottelat

Donors

While figures for investment in freshwater conservation in Southeast Asia or globally are unknown, only 1.8% of total environmental conservation funding was directed towards freshwaters in Europe in 2018 (Maasri et al., 2022). This level of funding does not align with the exceptionally high level of extinction risk freshwater fishes are facing, as they are the most threatened group of vertebrates on the planet. Communicating the urgency of the situation to donors and engaging them to provide support are essential prerequisites for implementation of conservation actions on the ground.

Zoos, aquaria and breeding centres

Ex situ conservation is a major priority for a significant proportion of the species and zoos and aquaria will play the leading role in this activity.

Home aquaria Industry and hobbyists

The aquarium hobby as a whole has had minimal engagement with freshwater fish conservation, but organisations such as the Parosphromenus Project have demonstrated the extraordinary potential the hobby and its associated industry holds to support conservation of ASAP freshwater fishes.

Researchers and conservation networks/societies

While research plays a lesser role in this plan, the institutions and related conservation networks and societies have the potential to be major players in the delivery of action by supporting with data and information exchange, sharing results of their research, promoting, supporting and catalysing action and training local communities, governments and other stakeholders.

Non-governmental organisations

Where gaps in the capacity of governments or other stakeholders exist, NGOs can provide a powerful, swift response to the actions needed to halt the further decline of threatened species.

Academia

Data and knowledge are vital components for directing action by each of the stakeholders and for monitoring the impacts of varying interventions. Research is an essential element underpinning this strategic framework. In many cases, it is fundamental to enabling any conservation action.

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Annexes

Annex A: List of all ASAP freshwater fishes

?: Unknown
EX: Extinct
PE: Possibly Extinct

BR: Brunei Darussalam
KH: Cambodia
ID: Indonesia

LA: Lao PDR
MY: Malaysia
MM: Myanmar

PH: Philippines
SG: Singapore
TH: Thailand

TL: Timor-Leste
VN: Vietnam

Scientific Name	Common Names	Habitat	Red List Criteria	Population Trend	Highly restricted range	Country Endemic	BN	KH	ID	LA	MY	MM	PH	SG	TH	TL	VN
Aaptosyax grypus	Mekong Giant Salmon Carp, Sanak, Pa sanak, Pa sanak gnai, 曲鯉	Large river, open water	A2acd	Decreasing	N	N	-	PE	-	Y	-	-	-	-	PE	-	-
Adrianichthys kruyti	Duck-billed Buntingi, Duck-billed Poso minnow, Nokkamedaka, Entenschnabelkärpfling, 怪頷鮰	Lake, open water	D (PE)	Unknown	Y	Y	-	-	PE	-	-	-	-	-	-	-	-
Adrianichthys roseni	Buntingi, Rosen's buntingi	Lake, open water	D (PE)	Unknown	Y	Y	-	-	PE	-	-	-	-	-	-	-	-
Balantiocheilos ambusticauda	Siamese Bala-shark, Burnt tail fish, Pla hang mai, Süsisaba-paunsuu	Lowland riverine and marshland floodplains	D (PE)	Decreasing	N	Y	-	?	-	?	-	-	-	-	PE	-	-
Barbodes cataractae		Lake, river	D (PE)	Unknown	Y	Y	-	-	-	-	-	-	Y	-	-	-	-
Barbodes joaquinae		Streams with rocky substrates and boulders	B1ab(iii)	Unknown	Y	Y	-	-	-	-	-	-	Y	-	-	-	-
Barbodes lindog		Lake, inhabiting shallow waters close to shore	D (PE)	Unknown	Y	Y	-	-	-	-	-	-	Y	-	-	-	-
Barbodes manguaoensis		Lake, open water	B1ab(iii)	Unknown	Y	Y	-	-	-	-	-	-	Y	-	-	-	-
Barbodes sirang		Lake, open water	D (PE)	Unknown	Y	Y	-	-	-	-	-	-	Y	-	-	-	-
Barbonymus platysoma	Barbodes platysoma, Lai pardpuntius, Parmička širokotělá, 扁体四须鲃	Rivers	D (PE)	Unknown	?	Y	-	-	PE	-	-	-	-	-	-	-	-
Betta burdigala	Rottwein-Kampffisch, Kuparitaistelija, 邦加搏鱼	Peat swamp forest, shallow water, under leaf litter	B2ab(iii)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Betta chloropharynx	Viherleukataistelija, 绿咽搏鱼	Peat swamp forest, deeper blackwater pools	B2ab(iii)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-

Annex A (cont.)

Scientific Name	Common Names	Habitat	Red List Criteria	Population Trend	Highly restricted range	Country Endemic	BN	KH	ID	LA	MY	MM	PH	SG	TH	TL	VN
Betta cracens	Ikan bettah	Peat swamp forest, deeper pools and shallow channels	B2ab(iii)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Betta fusca	Dusky betta, Dunkler Kampffisch, Ruskotaistelija, 棕抟鱼	Forest-stream specialist	D (PE)	Unknown	?	Y	-	-	PE	-	-	-	-	-	-	-	-
Betta hendra	Ikan bettah	Peat swamp forest, shallow water under leaf litter and roots	B2ab(iii)	Unknown	N	Y	-	-	Y	-	-	-	-	-	-	-	-
Betta miniopinna	Red fin betta, Minitaistelija, 红鳍抟鱼	Peat swamp forest, shallow water under leaf litter and roots	B2ab(iii)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Betta omega		Originally peat swamp forest, blackwater roadside ditches in palm-oil plantations	B2ab(iii,v)	Decreasing	N	Y	-	-	-	-	Y	-	-	-	-	-	-
Betta pardalotos	Ikan bettah	Peatland stream, blackwater	B2ab(iii)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Betta pinguis	Empala, Emplasek, Ikan bettah	Peatland stream, blackwater	B2ab(iii,v)	Decreasing	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Betta rutilans	Rusotaistelija, 红搏鱼	Peat swamp forest, shallow water under leaf litter and roots	B2ab(iii)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Betta simplex	Krabi mouth-brooding betta, Mustasaumataistelija, 塘搏鱼	Karst pools	B1ab(iii)+2ab(iii)	Unknown	Y	Y	-	-	-	-	-	-	-	-	Y	-	-
Bostrychus expatria		Lake, open water	B1ab(iii)	Unknown	Y	Y	-	-	-	-	-	-	Y	-	-	-	-
Caecogobius cryptophthalmus		Cave dwelling	B1ab(iii)	Unknown	Y	Y	-	-	-	-	-	-	Y	-	-	-	-
Catlocarpio siamensis	Giant carp, Siamese giant carp, Catla, Giant barb, Kaho, Pla kaho, Pla kra ho, Ca ho, Cá hô, Kahor, Kolreang, Kulreang, Trey kahao, Trey kaho, Trey kolriang, Trey krawhao, Trey kromawl, Pa kaho, Siamesisk karpe, Veleparma thajská, Hiidpardkala, Jättibarbi, Siamesisk jättekarp, 暹罗印度鲤, Катля, ปลากระโห้	Large river, open water (adult fish), floodplain (mainly young fish)	A2abcd	Decreasing	N	N	-	Y	-	Y	-	-	-	-	Y	-	Y

Annex A (cont.)

Scientific Name	Common Names	Habitat	Red List Criteria	Population Trend	Highly restricted range	Country Endemic	BN	KH	ID	LA	MY	MM	PH	SG	TH	TL	VN
Ceratoglanis pachynema	Club-barbel sheatfish, Pla ked, Pla ket, Pla sai yu, ปลาสายยู, ปลาเกด	Large river, open water, favours turbid water	A2e	Decreasing	N	N	-	-	-	?	-	-	-	-	Y	-	-
Chilatherina sentaniensis	Sentani rainbowfish, Hewu, Kaskado, lake Sentani-regnbuefisk, Sentani vikerateriin, Okrakirjokala, Sinisateenkaarikala, Sentani-Regenbogenfisch, 印度尼西亚唇银汉鱼, радушница сентанская	Lake, open water	A1ace	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Clarias batu		Streams with rocky substrates and boulders	B1ab (ii,iii,v)	Decreasing	Y	Y	-	-	-	-	Y	-	-	-	-	-	-
Clarias sulcatus		Forest streams	B1ab(ii,iii) +2ab(ii,iii)	Decreasing	Y	Y	-	-	-	-	Y	-	-	-	-	-	-
Clupea manulensis		Unknown, possibly river delta, brackish habitat	D (PE)	Unknown	Y	Y	-	-	-	-	-	-	PE	-	-	-	-
Datnioides pulcher	Siamese tiger perch	Large river, open water	A2acd	Decreasing	N	N	-	Y	-	Y	-	-	-	-	EX	-	Y
Encheloclarias kelioides	Vähäkonnamonni, 马来西亚鳗胡鳗	Peat swamp forest, benthic burrower	B1+2bcde (PE)	Decreasing	N	Y	-	-	-	-	PE	-	-	-	-	-	-
Epalzeorhynchos bicolor	Redtail shark, Redtailed shark, Redtail sharkminnow, Redtailed sharkminnow, Red-tailed labeo, Redtailed black shark, Pla cha lam hang daeng, Pla hang daeng, Pla song kruang, Pla song krueng, Labeo červenoocasé, Labeo dvoubarevné, Mřenka zlatoocasá, Parmička červenoocasá, Rødfinnet Hajbarbe, Rødhale, Rødhalet Hajbarbe, Kahevärviline narmasmokk, Kahevärviline sarvkoon, Tulipyrstö, Feuerschwanz, Feuerschwanz-Fransenlipper, Grubowarg dwubarwny, Eldstjärt, 双色角鱼, 双色野鲮, ปลากรงเครื่อง, ปลาหางแดง	Fast-flowing streams with coarse substrate, bentho-pelagic	B1ab(iii,v)+ 2ab(iii,v)	Unknown	?	Y	-	-	-	-	-	-	-	-	Y	-	-
Exyrias volcanus		Lake, open water	D (PE)	Unknown	Y	Y	-	-	-	-	-	-	PE	-	-	-	-
Glossolepis dorityi	Grime Rainbowfish	Lake margins with abundant vegetation growth	B2ab(v)	Decreasing	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Hemileiocassis panjang		River, benthic	B2ab(iii) (PE)	Unknown	Y	Y	-	-	PE	-	-	-	-	-	-	-	-

Annex A (cont.)

Scientific Name	Common Names	Habitat	Red List Criteria	Population Trend	Highly restricted range	Country Endemic	BN	KH	ID	LA	MY	MM	PH	SG	TH	TL	VN
Hyalobagrus ornatus	Zwergstachelflossenwels, 饰带黄颡鱼	Unknown but possibly large rivers with muddy substrate	B2ab(iii) (PE)	Unknown	Y	Y	-	-	-	-	PE	-	-	-	-	-	-
Kryptopterus mononema	单丝缺鳍鲶	River	B2ab(iii) (PE)	Unknown	Y	Y	-	-	PE	-	-	-	-	-	-	-	-
Lepidocephalus pahangensis		River, benthic & possibly burrowing species	D (PE)	Unknown	Y	Y	-	-	-	-	PE	-	-	-	-	-	-
Lobocheilos lehat		Unknown	D (PE)	Decreasing	?	Y	-	-	PE	-	-	-	-	-	-	-	-
Melanotaenia ajamaruensis		Clear, moderate to slow-flowing streams, not known	B2ab(v)	Decreasing	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Melanotaenia bowmani	Bowman's Rainbowfish	Fast-flowing streams over rocky bottoms in secondary and primary rainforest	B1ab(iii)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Melanotaenia corona		Unknown	B2ab(iii)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Melanotaenia klasioensis	Klasio Rainbowfish	Streams with rocky substrates and boulders	B1ab(iii)	Stable	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Melanotaenia kokasensis	Kokas Rainbowfish	Streams and pools, karst	B2ab(iii)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Melanotaenia lacunosa	Mbuta Rainbowfish	Forest stream	B1ab(iii)	Stable	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Melanotaenia longispina	Longspined Rainbowfish	River,stream	B2ab(v)	Stable	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Melanotaenia mairasi	Lake Furnusu rainbowfish	Lake margins with abundant vegetation growth	B1ab(iii)	Stable	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Melanotaenia parva	Lake Kurumoi Rainbowfish	Lake and stream	B2ab(iii,v)	Unknown	Y	Y	-	-	PE	-	-	-	-	-	-	-	-
Melanotaenia sneideri	Kumawa Rainbowfish	Lake and stream	B1ab(iii,v)+ 2ab(iii,v)	Decreasing	Y	Y	-	-	Y	-	-	-	-	-	Y	-	-
Melanotaenia susii	Susi Rainbowfish	Streams and pools, karst	B1ab(ii,iii,v)+ 2ab(ii,iii,v)	Unknown	Y	Y	-	-	-	Y	-	-	-	-	-	-	-

Annex A (cont.)

Scientific Name	Common Names	Habitat	Red List Criteria	Population Trend	Highly restricted range	Country Endemic	BN	KH	ID	LA	MY	MM	PH	SG	TH	TL	VN
Melanotaenia urisa	Urisa Rainbowfish	Springs, streams, brackish	B1ab(iii)+2ab(iii)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Mogurnda aiwasoensis	Aiwaso Mogurnda	Shallow areas of lake	B1ac(i)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Mogurnda kaimana	Kaimana Mogurnda	Lake, inhabiting shallow waters close to shore	B1ab(iii)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Mogurnda mbuta	Mbuta Mogurnda	Forest stream	B1ab(iii)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Mugilogobius amadi	Also known as Weberogobius amadi, Bungu, Poso bungu, 阿马韦氏鰕虎鱼	Lake, benthopelagic	D (PE)	Unknown	Y	Y	-	-	PE	-	-	-	-	-	-	-	-
Nemacheilus troglocataractus	Blind cave loach, Mřenka skrytá, Koopa-kivitrulling, 穴条鳅	Headwater streams in cave system, rocky substrate, bentho-pelagic	B1ab(iii,v)+ 2ab(iii,v)	Decreasing	Y	Y	-	-	-	-	-	-	-	-	Y	-	-
Neostethus ctenophorus		Lake, open water	D	Unknown	Y	Y	-	-	-	-	-	-	PE	-	-	-	-
Neostethus robertsi		River	B1ab(iii)+ 2ab(iii)	Unknown	Y	Y	-	-	-	-	-	-	Y	-	-	-	-
Oreoglanis lepturus		Hill stream, benthic	B1ab(ii,iii,v)+ 2ab(ii,iii,v)	Unknown	Y	Y	-	-	-	Y	-	-	-	-	-	-	-
Oryzias soerotoi		Lake, inhabiting shallow waters close to shore	B1ab(iii)+ 2ab(iii)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Oryzias timorensis		Forest stream	D (PE)	Unknown	Y	Y	-	-	PE	-	-	-	-	-	-	-	-
Pangasianodon gigas	Mekong giant catfish, Giant catfish, Trey reach, Trey réach, Trey riech, Pa beuk, Pa boeuk, Buk, Pla buk, Pla hua kum hang hum, Pla ma fai, Pla nang, Cá hat, Cá tra dầu, Mekong-malle, Jättihaimonni, Silure de verre géant, Mekongwels, Siluro gigante, Mekongjättemal	Large river, open water	A4abcd	Decreasing	N	N	-	Y	-	Y	-	-	-	-	Y	-	Y
Pangasius sanitwongsei	Giant Pangasius, Chao Phraya giant catfish, Dog-eating catfish, Pangasid catfish, Trey po pruy, Pa leum, Pba leum, Pla thepa, Pla the pa, Pla the pha, Tepa, Cá vô cò, Cá Vồ cờ, Langfinnet hajmalle, Paroon shark, Paronihaimonni, ปลาเทพา	Large river benthopelagic	A2acd	Decreasing	N	N	-	Y	-	Y	-	-	-	-	Y	-	Y

Annex A (cont.)

Scientific Name	Common Names	Habitat	Red List Criteria	Population Trend	Highly restricted range	Country Endemic	BN	KH	ID	LA	MY	MM	PH	SG	TH	TL	VN
Parakysis notialis		Forest stream	B2ab(iii)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Parambassis altipinnis	High-finned Glassfish	Stream with abundant vegetation	B1ab(iii)+ 2ab(iii)	Decreasing	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Paratherina labiosa		Lake	B1ab(iii)	Decreasing	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Parosphromenus alfredi		Peat swamp forest	B2ab(iii,v)	Decreasing	Y	Y	-	-	-	-	Y	-	-	-	-	-	-
Parosphromenus gunawani		Peat swamp forest	B2ab(iii)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Parosphromenus ornaticauda	Korugurami, 饰尾副斗鱼	Peat swamp forest	B2ab(iii)	Decreasing	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Parosphromenus phoenicurus		Peat swamp forest	B2ab(iii)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Parosphromenus quindecim		Peat swamp forest	B2ab(iii)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Pelangia mbutaensis	Mbuta Rainbowfish	Forest stream	B1ab(iii)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Poropuntius tawarensis	Kawan	Lake	B1ab(iii)	Decreasing	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Probarbus jullieni	Jullien's golden carp, Seven-line barb, Seven-striped barb, Esok, Giant river carp, Isok barb, Trasork, Tray trawsawk, Trey trasak, Trey trâsâk, Trey trawsak, Eun, Pa eun, Pa eun ta deng, Pa uhn, Pba eun, Pba eun dta deng, Ikan temoleh, Temelian, Temoleh, Pbla yesok, Pla eesok, Pla eun, Pla ye sok, Pla ye sok tead, Pla ye sok ted, Pla ye sok tong, Pla yee sok, Pla yisok, Cá chài sóc, Cá trà soc, Parmička Julienova, Syvstribet karpe, Punasilim-suurparrak, Punasilmäbarbi, Barbeau de Jullien, Карп Джульена, Carpilla ikan temoleh, Meklongbarb, ปลายี่สก, ปลายี่สกทอง, ปลายี่สกเทศ, ปลาเอิน, 穗须原鲃	Deep reaches in large river	A2d	Decreasing	N	N	-	Y	-	Y	Y	-	-	-	Y	-	Y
Pseudomugil reticulatus	Vogelkop Blue-Eye	Forest streams	B1ab(v)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Rasbora tawarensis	Lake Tawar rasbora, Depik, Razbora tavarská, Tawari rasboora, 塔瓦兰波鱼	Lake, open water	CR, B1ab(iii)	Decreasing	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Sashatherina gigantea	Giant Hardyhead	Lake, open water	B1ac(i)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-

Annex A (cont.)

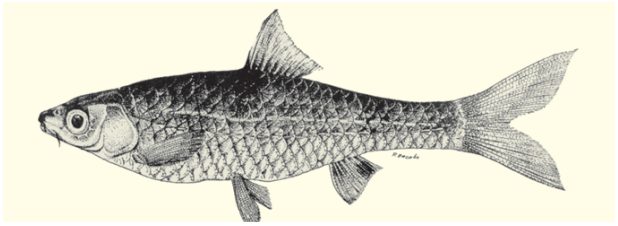
Scientific Name	Common Names	Habitat	Red List Criteria	Population Trend	Highly restricted range	Country Endemic	BN	KH	ID	LA	MY	MM	PH	SG	TH	TL	VN
Scaphognathops theunensis	Papak laoský, Laose lasnlõug, Punapyrstökiekkobarbi	Large river, open water, needs nearby sand banks for spawning	A2c; B1ab(ii,iii,iv)	Decreasing	Y	Y	-	-	-	Y	-	-	-	-	-	-	-
Schistura leukensis	Mřenka leucká, Leuki käärtrull	Hill stream, benthic	B1ab(iii)+2ab(iii)	Unknown	Y	Y	-	-	-	Y	-	-	-	-	-	-	-
Schistura nasifilis	Mřenka vietnamská, Niitnina-käärtrull, 丝鼻南鳅	Hill stream, benthic	C2a(i); D(PE)	Decreasing	Y	Y	-	-	-	-	-	-	-	-	-	-	PE
Schistura spiloptera	Mřenka kočinčínská, Mřenka Pellegrinova, Täppuim-käärtrull, 斑鳍南鳅, 潘氏南鳅	Hill stream, benthic	A2e; B1ab(i,ii,iv)	Decreasing	Y	Y	-	-	-	-	-	-	-	-	-	-	Y
Schistura tenura	Mřenka záhadná, Salesaba-käärtrull	Hill stream, benthic	B1ab(iii)+2ab(iii) (PE)	Decreasing	Y	Y	-	-	-	PE	-	-	-	-	-	-	-
Sewellia albisuera	Tikand-lasnuim	Hill stream, benthic	A2c+3c; B1b(i,ii)	Decreasing	Y	Y	-	-	-	-	-	-	-	-	-	-	Y
Sewellia breviventralis	Butterfly loach, Sevelie krátkobřichá, Pako lasnuim	Hill stream, benthic	A2ac	Decreasing	Y	Y	-	-	-	-	-	-	-	-	-	-	Y
Silhouettea flavoventris		Lake, unknown	D (PE)	Unknown	Y	Y	-	-	-	-	-	-	PE	-	-	-	-
Speonectes tiomanensis		Cave dwelling	B1ab(iii); D	Decreasing	Y	Y	-	-	-	-	Y	-	-	-	-	-	-
Systomus compressiformis	Parmička stlačená, Õhuke saagpuntius	Lake, open water	A2d; B1ab(i,ii,iii,v) (PE)	Decreasing	Y	Y	-	-	-	-	-	PE	-	-	-	-	-
Tondanichthys kottelati	Lake Tondano halfbeak	Lake	B1ab(iii)	Unknown	Y	Y	-	-	Y	-	-	-	-	-	-	-	-
Trigonostigma somphongsi	Somphongs's rasbora, Razbora menamská, Razbora zakrslá, Siamesisk dværgrasbora, Somphongsi kiillaikrasboora, Kääpiökiilakylki, Mustaeväbarbi, Siamesischer Zwergbärbling, 宋氏波鱼	River and floodplain - need aquatic vegetation for spawning	A2ac	Decreasing	Y	Y	-	-	-	-	-	-	-	-	Y	-	-
Xenopoecilus sarasinorum	Sarasins minnow, Soukkamedaka, Sarasins Schaufelkärpfling, 异色鮄, Synonym: Oryzias sarasinorum	Lake, open water	B1ab(iii)	Stable	Y	Y	-	-	Y	-	-	-	-	-	-	-	-

■ *Adrianichthys roseni*

■ *Balantiocheilos ambusticauda*

■ *Barbodes lindog*

■ *Barbodes sirang*



■ *Betta burdigala*

■ *Betta chloropharynx*

■ *Betta cracens*

■ *Betta hendra*

■ *Betta miniopinna*

Betta pinguis

Betta rutilans

Betta simplex

Catlocarpio siamensis

Ceratoglanis pachynema

Chilatherina sentaniensis

Datnioides pulcher

Encheloclarias kelioides

■ *Epalzeorhynchos bicolor*

■ *Glossolepis dorityi*

■ *Melanotaenia ajamaruensis*

■ *Melanotaenia corona*

■ *Melanotaenia kokasensis*

■ *Melanotaenia urisa*

■ *Mogurnda kaimana*

■ *Nemacheilus troglocataractus*

■ *Oryzias soerotoi*

■ *Pangasianodon gigas*

Parakysis notialis

Parosphromenus alfredi

Parosphromenus ornaticauda

Parosphromenus phoenicurus

Parosphromenus quindecim

Probarbus jullieni

Pseudomugil reticulatus

Schistura spiloptera

Trigonostigma somphongsi

Xenopoecilus sarasinorum

Annex B: Ex situ conservation priorities and opportunities

The role of ex situ conservation in preventing species extinction often generates rigorous debate, given its propensity to become cost-prohibitive or fail due to data deficiency and associated uncertainty in life history characteristics, taxonomy, genetics, and ecosystem function (Crawford et al., 2013; Michaels et al., 2014). Despite these potential pitfalls, ex situ conservation remains one of the only practical conservation interventions for species whose ranges have been severely reduced or degraded to the point that in situ intervention is no longer a feasible alternative (Conde et al., 2011). However, greater emphasis must be placed on ex situ conservation planning, which warrants a status review of the taxon's characteristics and threats, a concrete definition of the intended conservation outcome, and an understanding of the resources required to generate that outcome (Canessa et al., 2015; McGowan et al., 2017). In tandem with extinction risk assessments and wherever possible in coordination with in situ threat mitigation (IUCN, 2002), standardised selection processes for ex situ candidate species can provide a robust analysis of priority conservation needs, and also assist in the identification of data deficiencies that need to be addressed before precipitous declines in wild population status exclude ex situ efforts as a viable conservation action.

Important contributions by zoos, aquaria, and non-governmental organisations have proven the effectiveness of these conservation interventions in preventing the loss of freshwater ichthyofauna in several regions throughout the world (Carrizo et al., 2013; Sousa-Santos et al., 2014; Maceda-Veiga et al., 2016). However, the historical focus of these institutions has largely been restricted to terrestrial megafauna, birds, and other taxa that may not represent the greatest conservation need (Bowkett, 2009; Conde et al., 2011; Martin et al., 2014), primarily because they resonate with public audiences. As a result, freshwater ecosystems and the vast number of species that rely upon them have largely been ignored in ex situ conservation planning considerations (Carrizo et al., 2013; Pearce-Kelly et al., 2013). This underrepresentation is further exacerbated by the complexity of stakeholder groups interested in freshwater fish conservation (e.g., hobbyist organisations, industry) and uncertainty surrounding collaborative engagement strategies. Stronger impetus on inclusive partnerships between academia, public zoos and aquaria, and especially hobbyist organisations show considerable potential in furthering effective ex situ conservation efforts for freshwater fishes in Asia and elsewhere (Maceda-Veiga et al., 2016).

In situations where in situ amelioration of threats is impractical or very difficult to implement, ex situ measures can be utilised to safeguard a species under human care for potential future reintroductions, essentially buying time for habitat in a species' natural range to be protected or restored and threats to be mitigated. Given the precarious conservation status of ASAP freshwater fishes, ex situ management is a recommended conservation tool for 49 species (53% of ASAP freshwater fishes).

Overview of ASAP freshwater fishes ex situ conservation programme recommendations

ASAP freshwater fishes for which ex situ conservation is a recommended conservation tool can be separated into two fundamental groups, including 1. Species for which no known ex situ population exists, and 2. Species that are already included in ex situ populations. It is important to note that effective management of ex situ populations for both of these groups will require cross-collaboration across multiple stakeholder groups, including academia (e.g., genetic sequencing), industry (e.g., during transition from assurance population to reintroduction production states), zoos, aquaria, and NGOs (e.g, assurance populations), and hobbyist groups (e.g., founder individual sourcing). Specific consideration should be given to the flexible interplay that these stakeholder groups exhibit in ex situ conservation (Figure 1).

Timeline of various action outputs

The recommended ex situ framework for ASAP freshwater fishes is modelled on four sequential elements of ex situ conservation, including species acquisition, gene management, establishment of assurance populations, and use of assurance populations for reintroduction production. Definitions for these sequential steps are defined in Table 1. The endpoint of this process is defined by the successful establishment of a genetically robust ex situ population that is large enough to meet the desired reintroduction outcome of the species. Successful reintroduction and re-establishment of formerly occupied habitat will require a number of additional considerations, including inherent risk associated with species reintroduction and benign introductions and in situ conservation management, which are further explored below in *Reintroduction Considerations*.

TABLE 1

Key steps for ASAP freshwater fishes with ex situ conservation recommendations

Step	Priority	Definition
Species Acquisition	Very high	The successful capture or sourcing of no fewer than 15 founding individuals.
Gene Management	High	The identification and management of genetic diversity in founding individuals and assurance populations.
Assurance Population	High	The successful rearing and expansion of founding populations into a group of between 100-200 individuals.
Production	Case specific	The transfer from a state of assurance to one of production, at a scale that is appropriate to the desired reintroduction outcome.

For species that do not currently have a known ex situ population established, the following sequence of action steps are recommended with an ultimate goal of establishing a genetically robust ex situ assurance population, and include in sequence:

1. Prioritise species collection acquisitions relative to the perceived success in acquiring an appropriate number of founder individuals, successfully breeding the species, and successfully maintaining a genetically robust population suitable for future reintroduction (See Figure 2)
2. Identify suitable partner roles for a species or species group from relevant stakeholder list (See Figure 1)
3. Source an initial population of no less than 15 founding individuals
4. Maintain ex situ population between 100-200 individuals (assurance population)
5. Regularly monitor genetic diversity of assurance by use of non-lethal fin clips
6. Assessment of in situ conditions and reintroduction feasibility

7a. Phase shift from assurance to reintroduction production
7b. Maintenance of assurance population and formation of in situ conservation plan

For species that are already included in ex situ populations, the following sequence of action steps are recommended with an ultimate goal of ensuring the persistence of a genetically robust ex situ assurance population, and include:

1. Identify suitable partner roles for a species or species group from relevant stakeholder list (See Figure 1)
2. Assessment of in situ conditions and reintroduction feasibility

3a. Phase shift from assurance to reintroduction production
3b. Maintenance of assurance population and formation of in situ conservation plan

Ex situ conservation for the massive, largely migratory species will be more difficult for zoo and hobbyist-led organisations, due to space and resource constraints. Thankfully, four of these large fishery-significant species (*Catlocarpio siamensis*, *Pangasianodon gigas*, *Pangasius sanitwongsei*, *Probarbus jullieni*) are already part of stock enhancement programmes under the Mekong River Commission, an intergovernmental initiative between Cambodia, Lao PDR, Thailand, and Vietnam tasked with responsible and environmentally sound development of the Mekong River. To this end, young fingerlings of these species are being released into the Mekong River with the aim of strengthening wild populations, though the overall target of restoring sustainable populations of these species in the wild will require a lot more work and coordination (particularly in considering effects of dams, and water and fisheries management). In the ex situ realm, research into the genetic variability of captive broodstock is necessary to ensure the health and robustness of fish both for captive breeding and subsequent release.

Where zoos, aquaria, and hobbyist-led organisations can most contribute is in ex situ conservation of small-bodied, range-restricted, non-migratory species which face loss of habitat integrity in the wild (habitat destruction, invasive species, pollution, climate change) and/or overcollection or of species that are in urgent need of securing assurance populations.

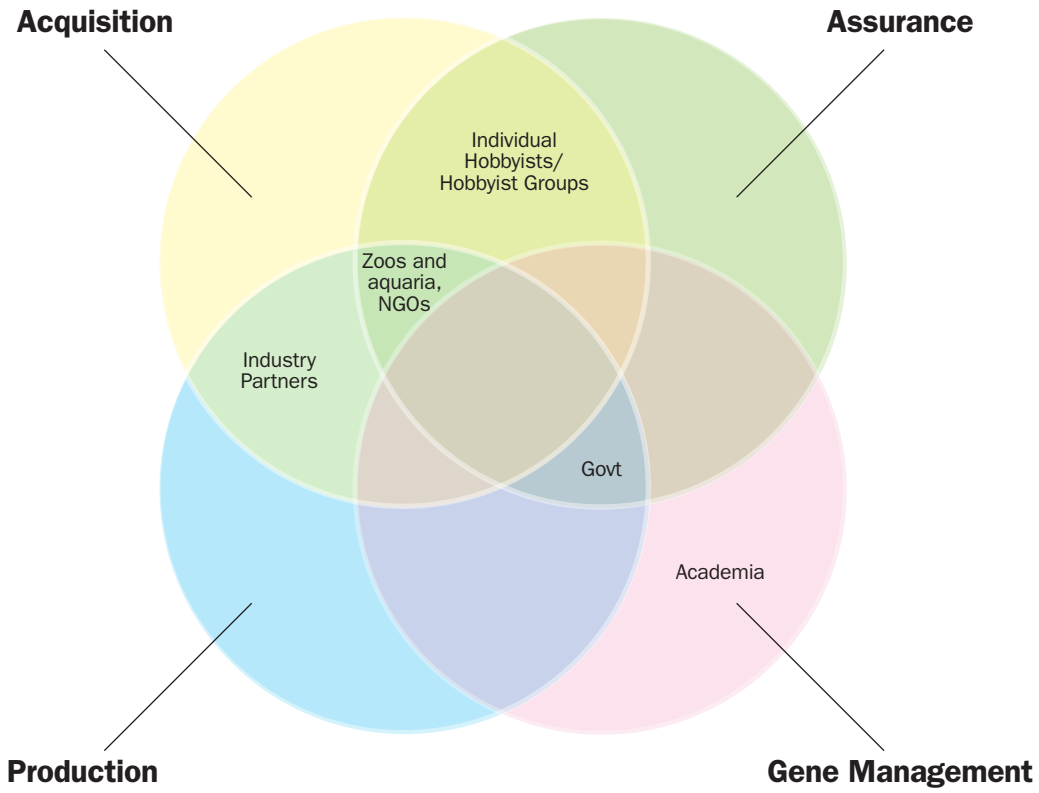
A number of these species are already present in aquaria - a few mostly captive-bred (e.g., *Epalzeorhynchos bicolor*, *Melanotaenia bowmani*, *Melanotaenia parva*), but mostly largely wild-sourced (e.g., *Betta*, *Parosphromenus*, *Sewellia* spp.).

Partner Identification

Identification of potential partners is a critical first step in establishing an effective ex situ conservation network. This is especially important for freshwater fishes, given they are the subject of considerable interest from non-traditional users like the ornamental industry and aquarium hobbyist communities. Potential stakeholders and conservation actors include but are not limited to academia, industry members, zoos, aquaria, NGOs, governmental entities, hobbyist groups and individual hobbyists. It is important to note that one of these stakeholder groups may serve multiple roles for ex situ conservation (Figure 1).

FIGURE 1

Perceived roles of various stakeholder groups



One key recommended objective of this action plan is to identify all relevant stakeholders both within and outside of Asia who have capacity to complete objectives within the acquisition, assurance, gene management, and production phases of this framework. This can be achieved through independent consultation, in-person workshops, or virtual forums.

Species Prioritisation

Most ASAP Species should be assessed for potential and inclusion in ex situ conservation efforts because they are Critically Endangered and at risk of global extinction. Therefore, securing assurance populations should be a high priority for eligible species. While a focused and thorough assessment of the ex situ potential for each ASAP Species is a necessary next step in prioritisation planning, this report provides a preliminary list of species that may be suitable candidates for ex situ conservation because they meet one or more of the following predictive indicators:

- IUCN Red List recommended for ex situ
- likelihood of in situ protection/threat amelioration is low
- urgent action is required
- already present in captivity
- life history and husbandry considerations are suitable
- captive breeding records, guidelines already exist
- feasible in terms of reasonable resources required (body size, manpower etc.)
- few potential problems exist such as genetic diversity, potential loss of wild behaviour

Given the critical need for ex situ conservation interventions for the 49 species of ASAP freshwater fishes recommended based on the indicators above, but limited funding to establish and maintain assurance populations for all of these species, it is important to prioritize species based on cost and effort incurred while acquiring founding individuals, establishing assurance populations, and shifting from assurance populations to production prior to reintroduction. Therefore, species prioritisation must consider any existing ex situ populations and their suitability for reintroduction, the

FIGURE 2

Prioritisation framework for species with no known ex situ population

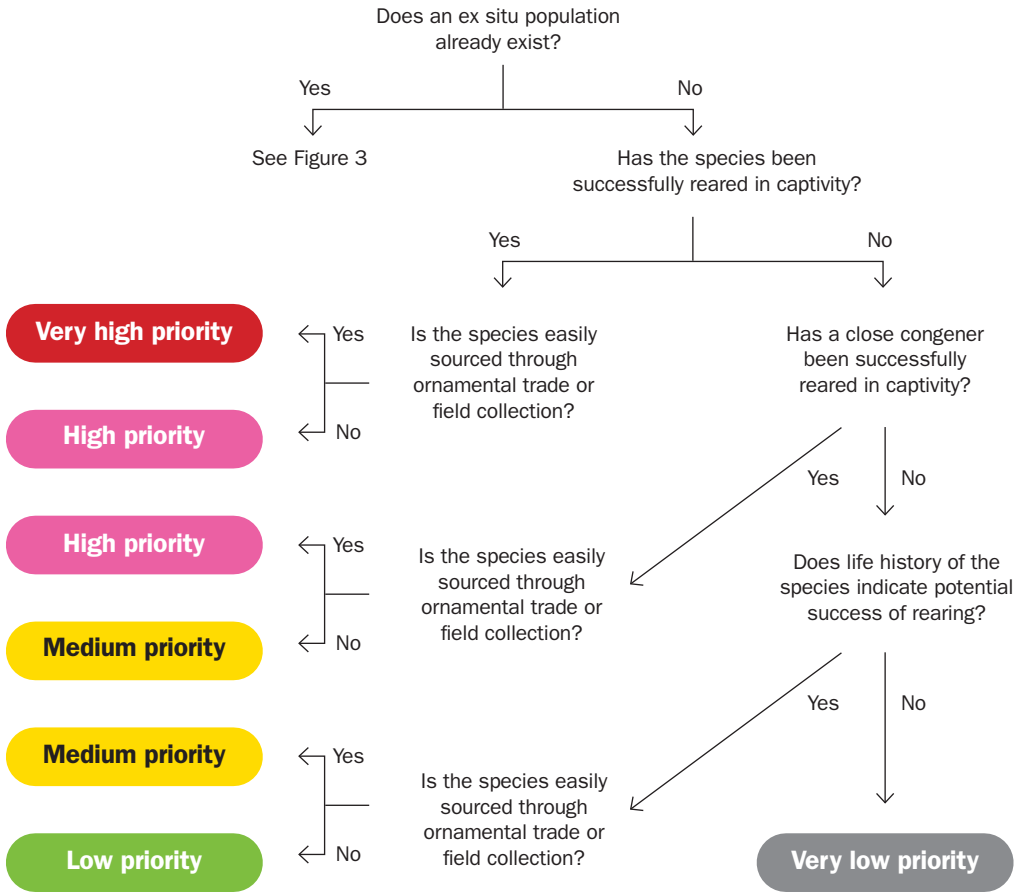
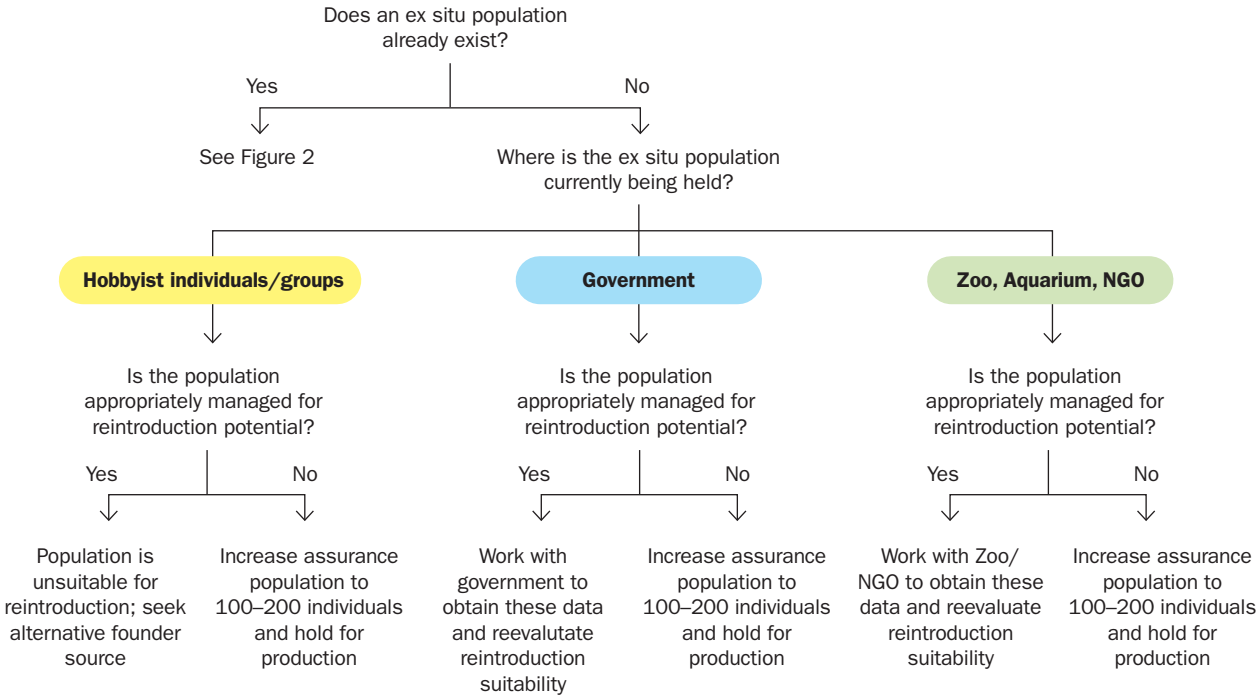


FIGURE 3

Decision-making framework for species that are included in one or more ex situ populations



state of knowledge about the species' life history, ease of reproduction in captive settings, frequency of occurrence within the ornamental aquarium trade, and accessibility of wild populations to source founding individuals for new ex situ populations (Figure 2 and Figure 3). Species prioritisation should be completed after all potential partners have been identified. Once species are prioritised, they should be aligned with appropriate partners and fundraising efforts should be mobilised to facilitate species acquisition and establishment of assurance populations.

Acquisition of Founder Populations

ASAP freshwater fishes may be inherently difficult to source given highly restricted ranges and low relative abundances within their remaining habitat. Furthermore, failed attempts at acquisition and establishment may lead to additional depletions in remaining wild populations, subsequently exhausting or severely reducing the amount of genetically diverse individuals available for future attempts. To account for these potential challenges, important considerations must be included in the sourcing process of founding populations, and ex situ populations must be carefully managed over time to mitigate the potential of inbreeding depression and losses in captive genetic diversity.

Available data suggest that ASAP freshwater fishes considered for ex situ management should be sourced from a minimum of 15 founders (Witzenberger and Hochkirk, 2011). Where appropriate, founding individuals should be sourced from geographically separate localities to reduce the relatedness potential of founding individuals (Witzenberger and Hochkirk, 2011). Species that are already represented and available within the ornamental aquarium trade, and those that are easily accessible for field collection should be prioritised where possible. Sourcing founding individuals from multiple collectors and/or importers is generally considered favourable, provided the chain of custody for those individuals is transparent enough to allow for the identification of distinct collection localities. Acquisition decision-making frameworks are provided above in Figures 2 and 3.

Species acquisition for all ASAP freshwater fishes is considered a very high priority, given the precarious nature of their conservation status in the wild. Inclusion of these species in managed ex situ populations may ultimately prevent their extinction if wild populations and remaining habitats are extirpated. Therefore, acquisition is a recommended priority if partners and resources are in place to maintain an assurance population with a minimum size of 100 individuals, but should proceed regardless of potential inability to effectively manage the genetic diversity of the assurance population and to scale assurance populations for reintroduction.

Gene Management

The management of genetic diversity in ex situ can directly influence the success of reintroduction and benign introduction for conservation purposes (IUCN/SSC, 2013). Given their importance, we recommend several action items to facilitate the appropriate management of genetic diversity for ASAP freshwater fishes held in ex situ populations.

General recommendations derived from a meta-analysis of ex situ populations across many taxa suggest that a minimum of 15 founder individuals and assurance populations of 100 or greater individuals yield acceptable genetic diversity and mitigate potential impacts due to inbreeding depression (Witzenberger and Hochkirk, 2011). These recommendations are used as a starting point and general guideline for the ASAP freshwater fishes action plan, but may also be adapted on a case-by-case basis where appropriate.

We also recommend the development of sampling protocols to ensure that most if not all ex situ populations are managed appropriately for reintroduction, including the use of standardised genetic markers (e.g., microsatellites), sample collection (e.g., non-lethal fin clips), and data management (e.g., a centralised genetic data repository). Sampling protocols should be applied to all founder individuals across all species, and randomly sampled at regular intervals from assurance populations.

Given multiple potential sources for founder individuals, and acknowledging that founders may be sourced from existing ex situ collections of unknown provenance, we recommend the development of guidance material targeted towards partners to ensure that where existing ex situ populations do exist, their genetic diversity is being documented and managed in a coordinated effort. Funding allocation and competency training should be prioritised to ensure genetic management of ex situ populations is a priority.

Establishment of Assurance Populations

Establishment of assurance populations is a recommended priority for all 49 species of ASAP freshwater fishes that meet the criteria for ex situ conservation. Assurance populations should be funded and prioritised based on perceived cost and effort required to acquire and successfully rear each species (Figure 2). Species acquisitions are discouraged in situations where resources and partner involvement are insufficient to ensure the establishment and maintenance of an assurance population (see additional considerations in *Acquisition of Founder Populations* and *Gene Management*). Establishment of assurance populations is recommended in all situations, regardless of the availability of funding or feasibility of execution in subsequent steps (e.g., upscaling assurance population to meet reintroduction targets), because they provide inherent protection against extinction if remaining wild populations are extirpated.

Shifting Assurance Populations into Production Populations

Assurance populations should be upscaled to facilitate successful reintroduction only when 1. In situ conservation management has removed or substantially reduced the primary threats to the species (e.g., invasive species have been eradicated from suitable habitat, protection of suitable habitat has been achieved through legislation), 2. The provenance and genetic diversity of the assurance population are known and deemed acceptable for reintroduction purposes, and 3. A reintroduction plan has been developed and the necessary partner and financial resources are in place to execute successful reintroduction. Note that the scope of production populations (e.g., number of individuals produced, means of production) will be case-specific, and therefore we recommend first prioritising the establishment of assurance populations.

Reintroduction Considerations and Risk Assessment

Where possible, ex situ conservation interventions should be closely aligned with in situ conservation interventions to facilitate the successful reintroduction of each species (IUCN, 2002). However, ex situ conservation can and does function as an effective tool in preventing species extinction in severe instances characterised by extremely limited geographic ranges, low population numbers, and where threats are likely to extirpate the species in the wild (Conde et al., 2011). Therefore, lack of in situ conservation efforts should not preclude conservation practitioners from establishing ex situ assurance populations, but these efforts should consider inherent risks associated with species reintroduction and attempt to mitigate them where appropriate.

We recommend that all ASAP freshwater fish reintroduction plans include a risk assessment as defined in IUCN's *Guidelines for Reintroductions and Other Conservation Translocations* (IUCN/SSC, 2013). The risk assessment should provide an evaluation of risk associated with seven main categories, including risk to the source population, ecological risk, disease risk, associated invasion risk, gene escape, socio-economic risk, and financial risk (IUCN/SSC, 2013).

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