Stocking fish in inland waters: Opportunities and risks for sustainable food systems

Abstract

Stocking is one of the foremost tools in the inland fisheries management toolbox, but it comes with both opportunities and risks. Stocking is often used as compensation for depleted wild populations, particularly where recruitment processes have been disrupted, but it can introduce disease, disrupt community structures, reduce genetic integrity, and cause conflicts between fishery stakeholders. Despite its widespread use, examples of effective stocking for food fisheries in inland waters are sparse in the peer-reviewed literature. Nevertheless, it is well established that stocking is frequently used to maintain fish yield, so there is need to conduct the practice in a robust manner that minimises the potential risks. This paper serves as the front matter for a special section of *Fisheries Management and Ecology* focused on fresh waters feeding the world, which resulted from two panel sessions, one focused on aquaculture and one focused on stocking, hosted by the international InFish research network (https://infish.org/). The paper highlights current practices of fish stock enhancement in inland waters for food, examines potential synergies and interactions of stock enhancement programmes with aquaculture, and provides an outline framework for responsible management of fish stock enhancement.

Keywords: Aquaculture, culture-based fisheries, fisheries enhancement, fisheries management, habitat degradation.

Running title: Stocking for inland food fisheries

Introduction

Freshwater aquatic biodiversity and catches from inland fisheries contribute about 10% of global capture fisheries (11.7 million tonnes in2020: FAO 2022) but are declining in many of parts of the world (FAO 2022). This is being driven by rapid changes in the form and function of many inland water bodies in response to direct and indirect anthropogenic pressures and a failure to manage the fisheries themselves (Dudgeon, Arthington, Gessner, Kawabata, Knowler, …. Sullivan, 2006; Reid, Carlson, Creed, Eliason, Gell, … Cooke, 2019). This is of great concern in inland waters, especially in tropical regions, where they support a high diversity of species, many endemic to the water bodies of concern, and contribute significantly to food security of an estimated one billion people and sustainable livelihoods of rural populations, particularly in least developed countries (Funge-Smith & Bennett, 2020; Lynch, Cooke, Deines, Bower, Bunnell, Cowx, … Rogers, 2016; Welcomme, Cowx, Coates, Béné, Funge-Smith, Halls & Lorenzen 2010; Youn, Taylor, Lynch, Cowx, Beard, Bartley & Wu 2014). It is unlikely that many of the anthropogenic changes to inland waters will be reversed, especially in the least developed countries, so future management will have to respond to the altered conditions if production of inland fisheries for consumption is to be maintained or enhanced.

Sustaining inland fisheries systems requires that they are managed to control fishing effort and maintain, protect, and restore the quality of aquatic ecosystems, including fish habitat, and if necessary, improve the status of the fish stocks for harvesting, leisure activities or conservation (FAO 1997). The balance between management interventions varies between countries and regions (Petr 1998). Inland fisheries management in high income countries focuses almost exclusively on recreation and conservation, whereas the objective in low- and middle-income countries remains largely on food security (Welcomme et al. 2010). This is not a static situation, as there is also a shifting emphasis in low- and middle-income countries towards recreational fisheries and conservation as a result of globalisation, changing demographics and the influence of multilateral environmental agreements such as the Convention for Biological Diversity (FAO 2015; Funge-Smith

& Bennett 2020). Aquaculture is also playing an increasingly dominant role in meeting the growing demand for aquatic food as well as the conservation of aquatic biodiversity (Brummett, 2023; de Silva & Funge-Smith, 2005; Fiorella, 2023).

Inland waters, therefore, face many challenges for the management of fish. Typical management of inland fisheries is based on four main interventions: (1) control of the exploitation through input/output controls such as closed seasons, closed areas, and gear and access restrictions; (2) protection of key fish habitats to ensure sustainable stock recruitment and conservation of threatened species; (3) restoration and improvement of key habitats; and (4) supplementation through stocking and introductions of fish (Welcomme, 2001). The outcomes of these management interventions are often poorly documented, and there are strong regional biases that limit reporting to those countries where the activity is most prevalent. This is certainly the case for stocking, with sparse peer-reviewed literature that evaluates successful examples of stocking for food fisheries in inland waters. We acknowledge that grey literature has much to contribute to this space, but there are still limited examples of assessments of post-stocking outcomes (Cowx et al, 2015).

The need to both understand and evaluate the benefits, trade-offs and impacts of stocking fish in inland waters for food is a fundamental prerequisite to improve the outcomes of stock enhancement as a management strategy (Cowx 1994, 1999). To provide a better understanding of the role of stock enhancement activities in supporting food production, the international inland fisheries research network InFish (https://infish.org/) hosted two online panel sessions on aquaculture and stocking based on presentations and submitted papers around this theme. This paper serves as an introductory editorial for this collection of papers in *Fisheries Management and Ecology* focused on fresh waters feeding the world.

Current practices of fish stock enhancement for food in inland waters

A variety of strategies are used throughout the world to improve production of fish species favoured by commercial or recreational interests to make up for shortfalls in production arising from overfishing or environmental change, (Cowx, 1994, 1999; Welcomme & Bartley, 1998; see Figure 1). Perhaps the most common strategy for enhancing wild fisheries is the stocking of individuals or introduction of species. The FAO Term Portal (https://www.fao.org/faoterm/) provides the following definition this type of enhancement of a fishery as: "*Activities aimed at supplementing or sustaining the recruitment of one or more aquatic species and raising the total production or the production of selected elements of a fishery beyond a level, which is sustainable through existing natural processes. In this sense stock enhancement includes enhancement measures, which may take the form of: introduction of new species; stocking natural and artificial water bodies, including with material originating from aquaculture installations; fertilization; environmental engineering including habitat improvements and modification of water bodies; altering species composition including elimination of undesirable species or constituting an artificial fauna of selected species; genetic modification and introduction of non-native species or genotypes".* (FAO Term Portal, 2023a). This is usually achieved by the stocking or introduction of target species, either deliberately (legally and illegally) or accidentally, to improve the quality and diversity of fisheries or to compensate for the loss productivity (Cowx 1994, 1999; Cowx, Funge-Smith & Lymer, 2015; Lorenzen, 2014).

Stocking of hatchery-reared fish into natural and artificial waterbodies is frequently carried out in many countries (e.g., Cowx, Funge-Smith & Lymer, 2015; Molony, Lenanton, Jackson & Norriss, 2005) and can play an important role in mitigating or offsetting negative anthropogenic impacts on aquatic ecosystems, fish stocks, and inland fisheries. Fisheries enhancements have the goal to supplement or sustain the recruitment of aquatic organisms, or compensate for lost recruitment due to environmental perturbation, or increasing the population or production of a fishery up to or beyond the naturally sustainable level (de Silva, 2015). Whilst stocking is a practice frequently used by states, fisheries owners, managers, and scientists (Klefoth, Wegener, Meyerhoff & Arlinghaus, 2023), there is growing evidence that stocking alone does not necessarily improve catches or harvest yields, even when the stocking activity is well managed and takes into account many of the wider issues that may impinge on the outcome of the stock enhancement intervention (Arlinghaus, Riepe, Theis, Pagel & Fujitani, 2022; Arthur, Valbo-Jørgensen, Lorenzen & Kelkar, 2023; Cowx et al., 2015; Claussen & Philipp, 2023). This is often because the limitations to natural recruitment processes, or over-harvesting, especially of juvenile fish (or stocked individuals intended in the case of enhancement), are not addressed by the stocking activity, and pressures persist on the sustainability of the target fish stock. Nevertheless, there are cases where stocking for food is successful, especially in recruitment-limited man-made systems such as reservoirs, seasonal irrigation tanks and rice-fish irrigated systems (FAO 2015 and examples therein).

In such cases, stocking activities are implemented to exploit the available ecosystem productivity to the full extent. Stocking can help establish culture-based fisheries in both open and closed water bodies (Arthur et al., 2023; de Silva, 2015; Lorenzen, 2008, 2014), compensate for loss due to environmental perturbation and degradation, such as loss of connectivity and pollution, enhance fish yield in water bodies that have limited natural recruitment and/or poor species diversity (Arthur et al, 2023), or to support aquaculture-based activities (Fiorella, 2023). There are also occasions where food fish have been introduced into water bodies to enhance biodiversity and establish successful fisheries (Brummett, 2023; Gozlan, Britton, Cowx & Copp, 2010); e.g., introducing kapenta (*Limnothrissa moidon*) into Lake Kariba and Lake Itezhi-tezhi in Zambia to exploit the vacant pelagic niches in the newly created impoundments have created successful and productive fisheries (Cowx 1997). However, examples of successful, cost effective, routine stocking of fish in inland waters in the peer reviewed literature are rarely documented (Cowx, 1999) and limited mostly to smaller water bodies and isolated systems (FAO, 2015). Further, the desired "demographic boost" to wild target stock is often not demonstrated (Claussen and Philipp, 2023).

In high income countries, the most successful stock enhancement programmes have been associated with put-and-take fisheries where any water body is stocked with harvestable-sized fish that are retained by the angler after capture for consumption, and intensive recreational fisheries where stocking increases the chances of capture. By contrast, successful programmes in lower-income countries, especially in Asia, are particularly associated with fisheries in seasonal and perennial reservoirs. These are intensively stocked on a periodic or annual basis to increase yield (De Silva & Funge-Smith, 2005; Miao, de Silva & Davy, 2010; Pushpalatha, Kularatne, Chandrasoma & Amarasinghe, 2021) and are harvested to achieve high production (or availability for recreational fishing). This maximization of catch by exploiting the natural production of systems is akin to extensive aquaculture practices (De Silva, 2015; Lorenzen, Juntana, Bundit & Tourongruang, 1998).

In its most intensive form, where there is no expectation of sustained natural recruitment, this is termed culture-based fisheries and the FAO definition is *"Culture-based fisheries involve enhancement in the form of introduction of new species; stocking natural and artificial water bodies; fertilisation; environmental engineering, including habitat improvements and modification of water bodies; altering species composition; constituting an artificial fauna of selected species; genetic modification of introduced species"* (FAO Term Portal, 2023b). This is akin to aquaculture, which is defined as *"The farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or* *corporate ownership of the stock being cultivated, the planning, development and operation of aquaculture systems, sites, facilities and practices, and the production and transport"* (FAO Term Portal, 2023c). True culture-based fisheries (in contrast to enhanced fisheries) could be reported statistically as aquaculture production as the level of manipulation and ownership of the stock aligns more closely to aquaculture than wild capture fisheries.

It should be noted that dedicated hatcheries may also be used to support conservation or restoration goals for endangered or locally extinct fish populations (e.g., Rio Grande silvery minnow *Hybognathus amarus* in the arid southwestern United States; Osborne, Carson & Turner, 2012; Osborne, Perez, Altenbach & Turner, 2013). There is usually some expectation that the enhanced stock will subsequently achieve some level of natural recruitment. Hatchery programmes that are operated for conservation purposes and those that provide seed for stocking or enhancement of capture fisheries will necessarily have different design criteria and vary in types and levels of risk they pose to wild fish (Cowx 1994; Lorenzen, Beveridge & Mangel, 2012; Osborne, Dowling, Scribner & Turner, 2020).

Stock enhancement activities that involve the transfer of fish between water bodies carry potential risks (Hickley & Chare, 2004). These include negative consequences related to effects of competition and predation, the transference of disease, disruption of genetic diversity, impacts on habitat functionality (see Claussen & Philipp 2023 and Cowx 1994 for further exposition of these issues) and conflicts on access and fishing rights. These consequences become more likely with the degree of stocking that takes place (Hickley & Chare, 2004) and thus increase the requirement for effective regulatory frameworks and guidelines on stock enhancement to prevent or mitigate negative impacts.

Interactions with aquaculture

With the growing demand for fish products from an expanding human population, there has been a rapid expansion of aquaculture across the globe. Aquaculture can take many different forms at different levels of intensity, from small-scale backyard ponds to highly intensive, technologically complex recirculation systems (FAO 2022; Short, Gelcich, Little, Micheli, Allison, … Zhang, 2021). Some widely practiced culture-based fisheries systems even have close synergies with wild capture fisheries enhancement (de Silva 2015; Lorenzen, 2008).

Aquaculture is increasingly cited as the primary strategy to increase the supply of aquatic foods as it offers the potential for expansion and intensification beyond the limits that are placed on natural environmental productivity. Aquaculture is also considered as a substitute to offset the impact of environmental degradation or modification of inland ecosystems on wild capture fishery productivity. As a consequence, government policies are being increasingly oriented towards promotion of aquaculture as a source of livelihood for fishers who can no longer be supported by the fishery (Brummett, 2023). However, aquaculture is essentially a farming activity, requiring capital and private rights to land or water to secure a harvest (FAO Term Portal 2023c). As with agriculture, aquaculture requires the input of seed fish, feed and/or fertiliser, and thus, in most cases, it needs to be supported by supply industries and distribution networks. This means aquaculture in the private sector is usually taken up by the wealthy, whereas fisheries use common pool resources and are accessible to the poor (Lorenzen, 2008). Aquaculture is therefore rarely taken up by full-time fishers (Lorenzen, 2008), giving rise to social problems as they are typically unable to make the transition from capture to culture in the face of degradation of the wild capture fishery resource (Lorenzen 2007; Lorenzen, Beveridge & Mangel, 2012). In this context, it should be recognised that the only human intervention associated with wild inland capture fisheries is the harvesting of the wild fish.

Fisheries enhancements, by contrast, are intended to supplement the stock or augment the recruitment of aquatic organisms, thereby increasing the stock or production of a fishery beyond the naturally sustainable level to the benefit of those exploiting the production, typically fishers (Lorenzen 2007; Lorenzen et al. 2012). Stocking of this nature carries ecological, genetic and disease risks (see Cowx 1994 and Claussen & Philipp 2023), and it needs to be carried out using established protocols (see Cowx et al. 2015). Stocking for culture-based fisheries is carried out by introduction of fish from aquaculture hatcheries into existing or human-built water bodies (e.g., seasonal and perennial reservoirs, rice fields) that are typically recruitment limited and do not naturally support significant fishery activity (de Silva 2003; Lorenzen 2007; Lorenzen et al. 2012). The species used are typically, but not exclusively, those that are already commonly bred and used in aquaculture. Risks to fish populations in such water bodies are fewer because the water body tends to be depauperate of stock or the species is incapable of reproduction in in the water body. Impacts from the introduction of disease or escape and establishment of introduced species beyond the water body are still possible.

Aquaculture, as indicated, tends to draw upon a limited range of species about which the breeding and rearing technologies are well known and understood. This means that aquaculture practices are typically centred around a small number of species, resulting in many being translocated between countries explicitly for farming (Gozlan et al., 2015). Once introduced, the stock produced may also be used for culture-based fisheries or fishery enhancement. Typical examples are tilapia, and Indian and Chinese carp species. Only a few countries have dedicated, indigenous species breeding hatcheries for enhancement of large, perennial natural and human-made, open-water bodies (e.g., Thailand).

In some sense, stocking open water bodies to enhance capture fisheries, such as culture-based fisheries, stocking of impoundments, and aquaculture seek to achieve the same objectives – meeting the demands for food. However, interactions between the two sectors can be quite contentious if one action impacts the productivity of the other (Fiorella, 2023). For example. the use of non-native species in aquaculture has resulted in numerous introductions (i.e., escapes) into river basins, and many species have become established in the wild, often to the detriment of the wild fish stocks through predation, competition, spread of parasites and disease and genetic erosion (Cowx, 1999; Gozlan et al., 2015). Fisheries and aquaculture can also potentially impact each other in ways such as stocking for enhanced or culture-based fisheries encouraging increased fishing pressure and potentially impacting associated, non-stocked wild species in the fishery. Disease transmission can occur from farmed to wild fish or the reverse when wild fry are grown in aquaculture facilities (Lorenzen 2007, 2008; Lorenzen et al. 2012).

Having highlighted the potential negative impacts of stocking, benefits can still accrue where stocked fisheries improve yield and contribute to food security of rural communities if both the fisheries and stocking activities are managed responsibly. There are government policies and economic incentives promoting aquaculture or investment in stocking programmes (Brummett, 2023), and it is worth reiterating that competent, objective evaluations can provide the basis for judging the effectiveness and benefit or risk outcomes of different stocking interventions. This may also help to reframe the common narrative of two systems in conflict and that responsible stocking and aquaculture can co-exist as resilient food systems (Brummett 2023).

A framework for responsible management of stock enhancement

Fish stock enhancement is an important tool in the management of food fisheries, and the need for stocking of inland waters to at least maintain food fish yield will remain for the foreseeable future. The potential for a successful outcome is often limited because the specific objectives of the exercise in relation to perceived problems and available resources are not fully appraised from the onset (Cowx et al., 2015). Many projects are ill conceived and do not fully address the issues that have led to the need to improve the fishery and possible constraints on the enhancement procedures adopted (Joffre et al. 2021). Furthermore, they often have little consideration for wider cross-sector and environmental issues, particularly in relation to long-term impacts (Claussen & Philipp 2023). To be environmentally and socially acceptable and economically viable, there is also a need to evaluate the risks posed at an early stage to identify appropriate options for increasing the production of fish (Cowx 1994, 2015).

As a result, more strategic planning approaches to stock enhancement are necessary to draw attention to the many problems that must be resolved within a wider fisheries sector context, especially regarding the provision of fish for food and livelihoods, before stock enhancement programmes are likely to be successful. To support these efforts, various guidelines have been developed (e.g., Cowx 1994, 1999, Cowx et al., 2015; Lorenzen et al. 2008; Radinger et al., 2023) to provide decision-making frameworks to evaluate ecological, fishery, socio-economic and implementation criteria to maximise the success of any stock enhancement activities. Figure 2 provides an example of a generic framework developed for stocking practices in Asia (FAO 2015). This framework, which is applicable to all types of stocking, whether for increased catch for food or recreational purposes or to support conservation of threatened species, adopts a step-wise approach to the assessment and enables decisions to be made on the efficacy and suitability of stocking to improve fisheries.

Once a fishery has been identified as a candidate for stock enhancement, a thorough assessment of the status and limitations of the fishery needs to be carried out to identify bottlenecks constraining the potential performance of the fishery and to determine if stocking is a viable option for enhancement. This is needed to answer a fundamental issue that is often neglected before a stocking programme is undertaken: “Why does the fish stock need enhancement?” It is a question that is rarely answered before stocking programmes take place, possibly because it is often a reflection of poor management of the environment or the fish stocks themselves (Cowx 1999).

Stock enhancement is frequently required because the fishery has been over-exploited in the past or has suffered some environmental perturbation. In many instances, the first issue to be addressed is whether the constraints acting on the fishery can be removed and the fishery enhanced based on natural production and fishery management actions or environmental improvements. Thus, in the first instance, alternative strategies for fisheries enhancement, including habitat improvement and appropriate management of the resources, are now being recommended by multiple researchers (Cowx et al., 2015; Claussen & Philipp, 2023; Radinger et al., 2023; Taylor, Chick, Lorenzen, Agnalt, Leber, … Loneragan, 2017; Welcomme et al., 2015). This is critical because stock enhancement measures are only likely to succeed when factors limiting stock improvement have already been addressed or reduced (e.g., reduction in fishing pressure, water quality improvement, habitat rehabilitation, or removal of barriers to migration). However, it should be noted that seeking alternative approaches to stocking is likely not applicable in culture-based fisheries and those reliant on large-scale stocking, such as in reservoirs or temporary water bodies, where the objective is to increase yield from the water body.

If stock enhancement is considered necessary and appropriate, the proponent can also review the wider social, political, and economic issues and constraints that are likely to affect the long-term success of stock enhancement programmes before accounting for them in any stock enhancement design. In addition, issues such as the availability of the stocking material, both in the short and long-term, could be assessed, as lack of such input material is often a root cause for failure of stocking programmes.

In an ideal scenario, the stock enhancement proposal can then be evaluated against ecological and environmental risk criteria and include a cost-benefit analysis. In particular, concerns have been expressed about the potential risks associated with stocking of fish, especially with respect to ecological imbalance, transfer of disease, erosion of genetic integrity, and change in fish community structure (see Claussen & Philipp, 2023). Thus, the overall feasibility of the action can be assessed in terms of environmental and ecological risk, bio-economic gain, and practicality. Explicit recognition of the implications of stocking in terms of social and environmental benefits and costs are also needed to assess the feasibility of any action (Arthur et al., 2023). Without such action, any benefits accruing from the stocking programme are likely to be dissipated quickly, and stocking will have to be done on a continuous basis, as is commonly practiced in most stocked fisheries.

If at any stage of these assessments the risks, costs, feasibility, or potential benefits are deemed unacceptable, the programme can be rejected and alternative strategies considered. It should be noted that when conducting the decision-making process for enhancement activities, there are many questions that need to be answered, and these require a degree of technical understanding of the risks, likelihoods, and consequences. Where no such information or expertise is available, the precautionary approach should be applied when considering the potential adverse impacts of stocking in terms of environmental, genetic, and ecological interactions.

Another underlying problem is that many stocking activities have been carried out for decades and have not been subjected to appropriate auditing, or in the case of more recent programmes, adequate prior evaluation. This is despite there being national and international regulations and codes of practice on stocking, (see FAO Code of Conduct for Responsible Fisheries -FAO 1996, 1997; ICES, 2005; IUCN/SSC, 1995). In many cases, there appears to be little control over whether the enhancement activity is appropriate or necessary. In other words, precautionary approaches to stock enhancement activities (e.g., establishing reference points, contingency plans, pre-agreed actions, burden of proof and reversibility) have been limited (FAO 1996).

Consequently, after implementation, or to assess ongoing stocking programmes, it is also desirable to evaluate stocking programmes based on ecological, economic, genetic, disease and parasite risks, and social aspects. In this context, an evaluation plan, proportionate to the scale and potential impacts of the stocking programme, can be prepared and executed. This can run over at least a 3-5-year period, preferably longer where intensive stocking or predatory species are concerned, and include technical, ecological, genetic, and social considerations. To ensure that this monitoring and evaluation of stocking is conducted holistically, there is a need for clearly defined criteria and indicators to measure performance. Such criteria and indicators (see Table 1 for examples) can be based on the objectives of the stocking, as determined when planning the stock enhancement.

Following this framework can help ensure that all stock enhancement programmes are properly formulated and planned before implementation, and indiscriminate and often futile stocking activities are avoided. The FAO (2015) framework or other similar, practical guidelines can support stocking of various fish species in a range of water-body types to meet specific objectives. To improve the likelihood of success, stock enhancement programmes could be independently assessed to ensure that the wider environmental, ecological, and socio-economic issues are thoroughly reviewed and considered, and any potential negative impacts are mitigated or minimised. In such cases, stocking can potentially support sustainable fisheries with little or no detectable detrimental effects (Cowx, 1999).

Fish stock enhancement is practiced widely across the globe, and despite the plethora of risks to the native fish stocks and receiving water body, is likely continue for the foreseeable future. It is therefore advantageous that such stocking is carried out in an environmentally and socially acceptable and economically viable way. The issues raised in the InFish seminars and reported in the associated papers (Arthur et al., 2023; Brummett, 2023; Claussen & Philipp, 2023; Fiorella, 2023), coupled with the management framework illustrated in this paper, could all be considered before existing stocking programmes are continued or new programmes promoted.

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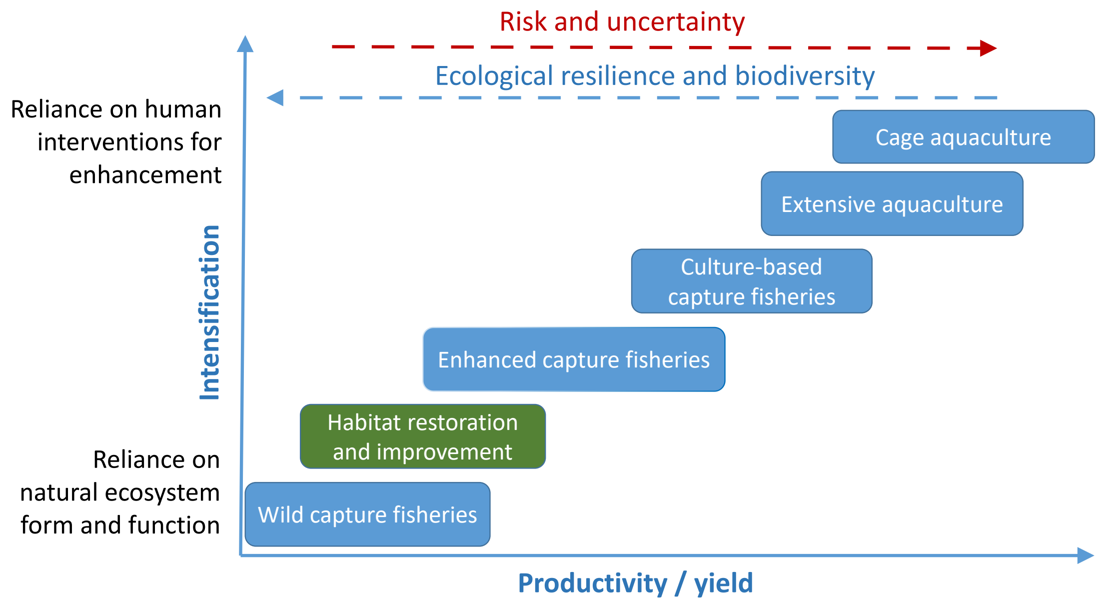

Figure 1. Production from different capture and culture systems (Modified from Welcomme and Bartley, 1998)

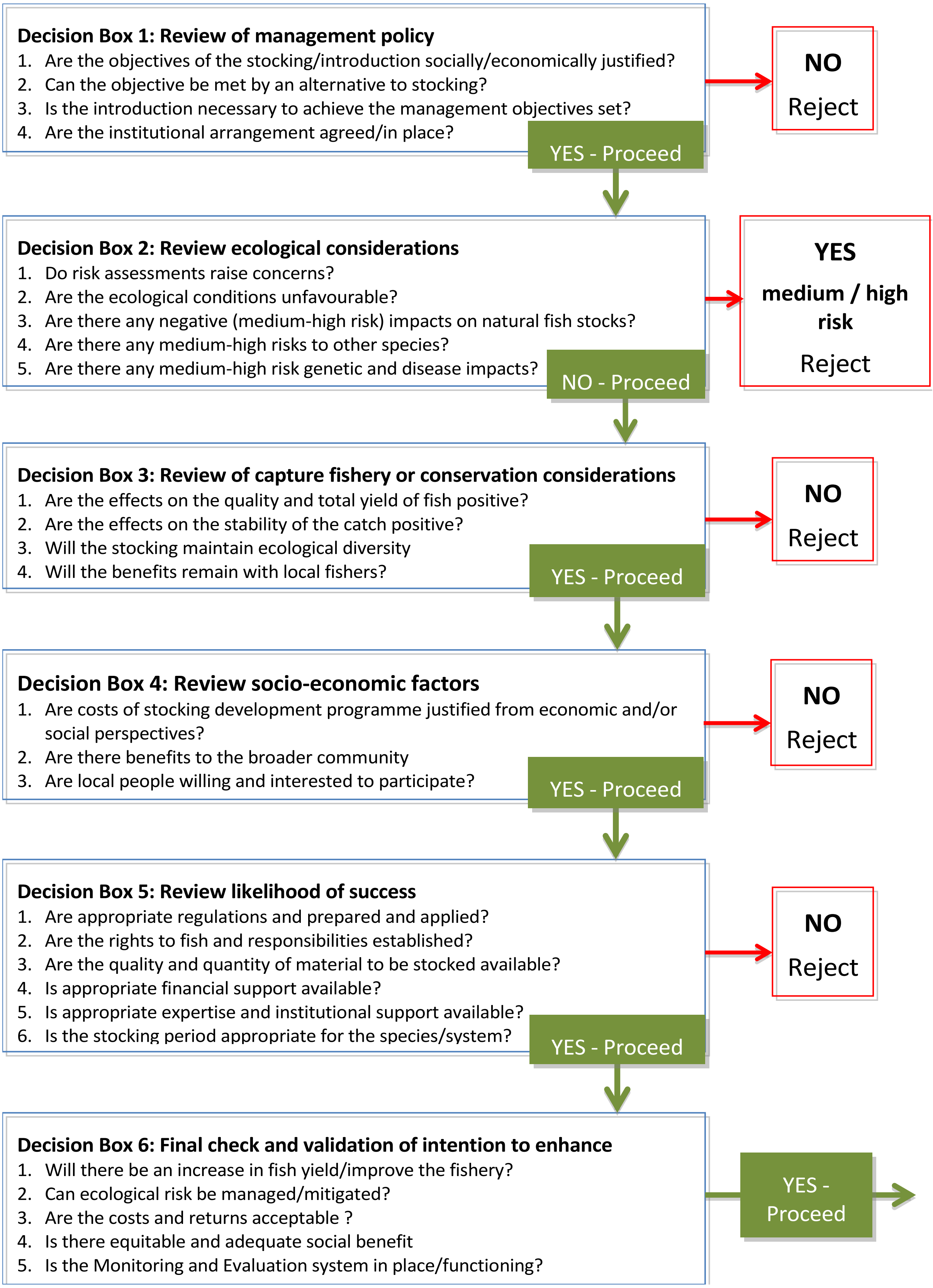

Figure 2. Suggested protocol for evaluating a stocking programme to minimise the potential risk, maximise the potential benefits, and monitor the success of the project. The stocking programme

should be rejected or revised if answers to the questions are unacceptable (FAO 2015 modified from Cowx, 1999)

Table 1. Criteria and associated indicators recommended for the holistic evaluation of outcomes of existing stocking programmes (From Cowx et al., 2015)

Biological and environmental criteria	**Criteria**	**Indicator(s)**
	Efficient use of natural productivity	Fish yield, fish size at harvest, recapture rate
	Minimized mortality at stocking	Post-release survival
	No significant genetic or health impacts	Genetic quality and health status of seed
Environmental impacts and/or benefits	Ecosystem services within target area maintained (e.g., food, water, energy) according to objectives	Provisioning, regulating, supporting and cultural ecosystem services indicators through measurement of changes to: – Physical habitat – Water quality – Trophic structure – Biodiversity
	Biodiversity not impacted negatively Surrounding ecosystem (external to target area) and watersheds not adversely impacted	Abundance of key species and habitat Habitat disturbance Presence of undesirable species
Social and economic criteria	**Criteria**	**Indicator**
Economics and economic efficiency	Increased revenue from production, processing or distribution of target species (or from the whole fishery)	Improvement of household incomes;* related businesses/services; total value of the fishery
	Economic/financial sustainability** and reduced dependence on external financial support	Income or revenues meet the costs of stocking and are sufficient to sustain the stocking activity. Change in level/regularity of financial support
	Positive economic impact within the broader community directly resulting from the fishery and related activities	Community infrastructure built by fishery or taxes or license fees collected from fishery Human development index in community
	Economic opportunities from existing ecosystem services are sustained or compensated	Value of appropriate ecosystem services
Social and livelihoods benefits and/ or impacts	Livelihoods of people in the community improved as a result of the stocking and related activities	Income from fishing activities Employment from fishing activities
	Livelihood options increased in target area Nutritional and food security increased in community Community development and social cohesion increased	Time allotted to fishing and other activities (i.e., changes in labour patterns) Fish consumption and nutritional status (e.g., stunting, growth rate) Development of social activities and community infrastructure Migration to/from community

	Women and marginalized and vulnerable groups engaged in stocking and related activities	Community groups and fishing associations Participation in stakeholder consultations and in production, harvest, processing, distribution and marketing activities

Governance criteria	**Criteria**	**Indicator**
Rights and equity	The distribution of benefits from the intervention are equitable considering multiple objectives	Benefits*** for individual/household for specified stakeholders and target beneficiaries Impacts on non-target beneficiaries
	Appropriate**** tenure/access ensured for resources (water, land etc.)	Access to resources (water, land etc.) for stakeholders Tenure arrangements, consideration of the impact of external factors
	Mechanism in place to reduce and resolve arising conflicts	Incidence/severity of conflicts Policy and legal frameworks for conflict resolution
	Recognition and respect of users' rights and rights of traditional users	Incidence of rights violations, coordination impedes development of
Institutional sustainability	Coordinated institutional mechanism(s) between water management environment agency and government arrangements/agencies responsible for assigning rights facilitates the establishment of responsible stocking initiatives	Institutional mechanism(s) or lack of legitimate stocking initiatives
	Fishery stakeholders empowered to lead management, monitoring and decision-making processes, leading to community management or co-management and consequent reliance on government institutional support for this	Fishery management groups Fishery co-management arrangements capable of developing regulations and implementing monitoring, control and surveillance (MCS)
	Effective enforcement and compliance with regulations	Incidence of non-compliance Effective management action taken in the case of non-compliance
	Stocking initiative is effectively or integrated into the existing wider fishery and does not compromise effective fishery management and/or maintenance of habitat integrity	Impacts or conflicts in the wider fishery environment resulting from the stocking activity Fishery management plan in place, with considerations for stocked fish

* Improvement in incomes assumes that incomes are equitably distributed and not subject to elite capture by a limited group.
** Note that economic sustainability and cost recovery may not be an objective in a rural development or livelihood support programme. Equally, a conservation objective may not have an economic objective as it is a public good. Sustained resourcing or financing may be secured via government support.
*** Benefits may be defined according to the system and context: quantitative (food, catch, financial, income, savings) or qualitative (livelihood opportunities, social capital).
**** Including women, and marginalized and vulnerable groups.