Feasibility of recreational scalefish enhancement in Tasmania

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Executive Summary

Recreational fishing plays a significant social and economic role in Tasmania, with one in four residents participating annually. The most recent statewide survey reported that recreational fishers retained over 830,000 finfish and released or discarded an additional 1.2 million. The recreational fishery in Tasmania is of great importance to many people and generates both economic and social value. Traditional fisheries management utilises output controls such as catch and size limits to reduce the chance of overfishing, or to recover overfished stocks. More recently, stock enhancement is emerging as an additional management tool to complement traditional fisheries management strategies.

This report evaluates the feasibility of enhancement across three distinct species, each representing different ecological contexts and management considerations:

- Sand Flathead, a ubiquitous and heavily targeted species with a depleted stock.
- Pink Snapper (*Chrysophrys auratus*), a popular mainland recreational species that is increasing in abundance in Tasmanian waters due to ocean warming. Snapper is now caught regularly along the north and southeast coasts, with suitable conditions expected to expand under continued warming.
- Estuary Perch (*Percalates colonorum*), an estuarine, catadromous species now limited in Tasmania to a single remnant population in the Arthur River. While popular on the Australian mainland, its enhancement in Tasmania presents both conservation and fishery development opportunities.

Each species offers a unique case study in enhancement potential. Sand Flathead provides an opportunity to rebuild a high-value recreational fishery. Pink Snapper represents a proactive enhancement opportunity in response to climate-driven range expansion. Estuary Perch highlights the potential for integrated conservation and recreational objectives.

Beyond stock rebuilding, enhancement of alternate species could reduce pressure on Sand Flathead by diversifying angler opportunities. This report discusses the ecological risks associated with enhancement and provides guidance on mitigation strategies to ensure enhancement actions are aligned with long-term sustainability goals. To minimise any unintended consequences, it is critical that any stock enhancement is conducted ethically, precautionarily and scientifically.

The report uses EnhanceFish, a decision support tool developed by the Lorenzen lab at the University of Florida (Lorenzen and Medley 2006). It primarily provides a quantitative assessment of aquaculture-based fisheries enhancements to determine whether releases of hatchery fish are likely to increase yields in a fishery, assess the likely impacts of releases on wild stocks and support the development of optimal release and harvesting regimes.

The management controls used in the model are fishing effort (*E*), stocking numbers and stocking size. Asymptotic effort (*E*) and the rate of instantaneous fishing mortality (*F*) are directly related through the concept of catchability (*q*), but important to note, they are not the same.

Sand Flathead

Sand Flathead is the most frequently caught marine finfish species, accounting for nearly 50% of retained catch. Despite recent management reforms that substantially reduced bag limits and adjusted size limits, Sand Flathead stocks remain classified as "Depleted". This prolonged fishing pressure has resulted in reduced size and age structure in key areas, particularly near population centres in southeast Tasmania.

To support long-term recovery, the Department of Natural Resources and Environment Tasmania (NRE Tas) has implemented the Flathead for the Future (FFF) program and will be developing a formal harvest strategy for Sand Flathead. These interventions focus on reducing effort, improving institutional management and recreational fisher engagement and education on fisheries stock status. However natural recovery is expected to take some years, even under significant catch reduction strategies. To accelerate this process and support broader recreational fishing objectives, stock enhancement is being explored. Stock enhancement involves releasing captive-reared fish as a complementary approach to traditional output-based management controls.

The D'Entrecasteaux Channel was selected as a focal trial area. Recent stock assessments indicate low abundance of legal-sized fish in the channel, suggesting heavy fishing pressure and prolonged size-selective mortality potentially causing fishing-induced evolution.

Following the implementation of new regulations in 2023 for Sand Flathead in the D'Entrecasteaux Channel that drastically reduced daily bag limits and adjusted size limits, in this report we assume the effective fishing effort to be E = 0.01 yr^{-1}. These regulations have effectively created a catch-and-release fishery, expected to support biomass recovery over time, assuming high compliance and low post-release mortality.

A baseline biomass for the D'Entrecasteaux Channel was established using the 2012/13 estimated recreational catch data (50 t), which was then halved (25 t) based on an assumption of a 50:50 sex ratio to represent females only due to sexual dimorphism in the species.

The total estimated recreational catch in the Channel (50 t) reported by Lyle et al. 2014, was halved (25 t) on the assumption of a 50:50 catch of females and males so that the Beverton-Holt stock-recruitment model was fit to the life history parameters of females only. This estimated the female equilibrium biomass in the Channel at 358 t.

Current fishing effort (E = 1 yr^{-1}) was calibrated to fishing mortality (F) based on the latest stock assessment. Consistent with the stock assessment, the EnhanceFish model projections indicate equilibrium biomass is approximately 10% of unfished levels (B/B_0), with yield at 55% of maximum. Maximum sustainable yield occurs at E = 0.28 yr^{-1}. Following major regulatory changes introduced in 2023, including a reduction in daily bag limits from 20 to 2 fish and a shift in legal size limits from 32 to 35 cm minimum legal size limit and the introduction of a maximum size limit of 40 cm, fishing effort was nominally set at E = 0.01 yr^{-1}, representing a functional closure (or catch and release fishery) as less than 1% of the fish in the region are exploitable based on the size structure of the stock in the region and the current size limit regulations. While these interventions will facilitate natural biomass recovery the timeline remains uncertain.

The EnhanceFish model showed that at higher fishing efforts (E > 1), very few fish survive beyond age four. Under enhancement scenarios, increasing the size of stocked fish improved biomass outcomes. For example, releasing fish at 9 cm resulted in a 5% additional increase in equilibrium biomass compared to stocking at 4 cm, with hatchery-origin individuals contributing approximately 18% of total biomass under low fishing pressure, i.e., $E = 0.01 – 0.27\ yr^{-1}$.

Stocking up to 100,000 individuals per year further increased biomass, with hatchery and stocked fish representing up to 10% of the equilibrium biomass. However, this effect was modest relative to that achieved through regulatory controls, based on an assumed current $E = 0.01\ yr^{-1}$ under the current possession and size limits. Cost-benefit analyses indicated that releasing larger fish (≥9 – 10 cm) produced the highest survival gains and biomass returns. If effort levels are later increased to maximise yield ($E \approx 0.27\ yr^{-1}$), stocking at 10 cm offered the best economic return on the sizes assessed but larger individuals would likely further improve this result. An assessment would need to be made during the rearing process of the trade-off of size and mortality of captive reared individuals.

The focus of this study, the D'Entrecasteaux Channel, has potentially undergone fishing-induced genetic and phenotypic shifts. Enhancement via hatchery stocking not only offers a mechanism to boost biomass but also the opportunity to reintroduce alternative phenotypes/genotypes, potentially counteracting the legacy of size-selective fishing pressure.

Together, these results support a combined strategy of sustained low fishing effort using recently introduced output control measures and targeted enhancement to rebuild and maintain Sand Flathead stocks in the D'Entrecasteaux Channel, with broader applicability to similarly depleted estuarine fish populations.

Snapper

Southeast Tasmania was identified as a suitable region to assess Snapper stock enhancement due to increasing sea temperatures, growing recreational fishers' interest, and the potential for spillover benefits to adjacent areas. Snapper are increasingly caught in these regions, and reproductive activity has been observed on the north coast of Tasmania, indicating the species is likely to expand its range as waters warm.

A baseline biomass for southeast Tasmania was established using 2022/23 recreational catch data and modelled with the Beverton-Holt Spawning Stock Biomass model in EnhanceFish. Maximum sustainable yield (10.1 t) was estimated to occur at $E = 0.67\ yr^{-1}$, although this would reduce B/B_0 to 21%, approaching the overfishing threshold. A more precautionary approach, would maintain effort at $E = 0.14\ yr^{-1}$, resulting in B/B_0 = 50% and an estimated catch of 8.37 t.

At current estimated effort levels ($E = 0.14\ yr^{-1}$), the model suggests little potential for altering the population's size structure. However, at $E = 0.67\ yr^{-1}$, growth overfishing becomes a concern. Enhancement through stocking was shown to significantly increase equilibrium biomass, particularly when larger individuals were released. Releasing fish at 7 cm increased biomass by 7% compared to releasing at 4 cm, while releasing at 10 cm increased biomass by 36% over 4 cm (and 29% over 7 cm). The additional benefits of the additional biomass increase need to be weighed against the higher cost of releasing larger fish; these aquaculture costs were unknown at the time of writing. At the highest stocking level assessed (100,000 fish annually), hatchery-origin fish exceeded the biomass contribution of the wild population when stocked at ≥10 cm.

Under current effort levels (E = 0.14 yr^{-1}), enhancement via hatchery stocking showed strong potential to boost biomass. Releasing 20,000 fish increased equilibrium biomass by 7% (6.3 t), while 100,000 fish increased it by 30% (27 t). Beyond approximately 47,000 stocked fish, hatchery-origin individuals surpassed wild-origin fish in their biomass contribution.

Cost-benefit analysis indicated that the greatest return per individual released occurred when stocking larger Snapper (≥10 cm). These benefits were maintained across effort scenarios, though at E = 0.67 yr^{-1}, where yield is maximised, growth overfishing is likely. Thus, optimal stocking strategies should pair larger fish releases with conservative effort management.

Overall, these results highlight that stocking Snapper in southeast Tasmania has strong potential to enhance biomass, buffer against overfishing risk, and provide a valuable alternative species for recreational fishers as Sand Flathead stocks recover.

Estuary Perch

Estuary Perch are currently confined to Tasmania's Arthur River, though historical records suggest a broader distribution in northern estuarine systems. The EnhanceFish model was used to assess the feasibility of enhancing the remnant Arthur River population through hatchery-based stocking.

Model outputs indicated that fishing effort below E = 0.41 would not substantially affect the population's size structure. However, given the extremely low abundance of Estuary Perch in the system, any extractive fishing (even under a catch-and-release regime) could present a high risk of population collapse. A precautionary approach is recommended, including research into post-release mortality and behavioural impacts of capture.

Stocking simulations showed a strong positive relationship between the size at release and the resulting biomass increase. Releasing fish at 4 cm produced a 41% increase in equilibrium biomass, while 7 cm fish yielded a fivefold (500%) increase at the maximum assessed stocking level of 20,000 individuals. Notably, increasing the release size from 7 cm to 8 cm resulted in an exponential biomass gain of nearly 2,852%. These results highlight the critical importance of release size, though they must be tempered by the model's exclusion of carrying capacity constraints, and real-world outcomes would likely be lower.

At a selected stocking size of 7 cm, the model was used to evaluate a range of release numbers. Stocking 10,000 fish increased female equilibrium biomass by 5.2 t (297%), while stocking 20,000 fish increased it by 7.1 t (405%). In all stocking scenarios, hatchery-origin fish quickly became the dominant biomass contributors in the system.

Cost-benefit analysis revealed that under minimal fishing pressure, stocking Estuary Perch at 8 cm offered the best return in biomass for investment due to significantly improved survival. Under higher fishing effort (approaching yield-maximising levels), releasing 6 cm fish provided the best yield-to-cost ratio. However, the system's low natural biomass makes a harvest-oriented fishery unlikely to be sustainable, reinforcing the need for a conservation-focused enhancement strategy.

These results underscore the potential for enhancement to rebuild and safeguard the only remaining Estuary Perch population in Tasmania, while highlighting the importance of cautious effort management and careful consideration of release size and capacity limitations.

Conclusion

The modelling undertaken in this study offers valuable theoretical insights into the potential benefits and trade-offs of stock enhancement strategies for species such as Sand Flathead, Snapper, and Estuary Perch in Tasmania. These insights are, however, shaped by a range of assumptions and uncertainties. The feasibility of enhancement depends not only on technical considerations, such as hatchery production, post-release survival, and the costs of growing larger, more robust fish but also on broader factors, including ecological carrying capacity, habitat suitability, and the genetic integrity of both wild and hatchery populations. Biosecurity concerns, genetic risks (such as inbreeding, domestication selection, and loss of diversity), and ecological risks (including competition, displacement, and unintended food web changes) highlight the need for careful broodstock management, genetic monitoring, and ecological evaluation, particularly in systems already under stress.

Species-specific findings reinforce the need for tailored approaches: Snapper show promise for enhancement under warming conditions, Estuary Perch may benefit from population buffering, and Sand Flathead present challenges due to potential past fishing-induced selection. The findings of this study reinforce that stock enhancement is a complex and nuanced management option. One that must be carefully tailored to species biology, ecological context, and stakeholder priorities. Enhancement should be pursued as a complementary measure rather than as a substitute for robust fisheries management frameworks.

Ultimately, the success of any enhancement program will depend not only on biological outcomes, but also on achieving a transparent, inclusive process that balances risks, costs, and community expectations. This will require targeted investment in monitoring, adaptive management, and meaningful stakeholder engagement to secure social licence and long-term support. A fundamental component of success will be access to sustainable funding. Models such as those applied in Victoria and New South Wales, as well as inland Fisheries in Tasmania, where general recreational fishing licence revenue contributes to enhancement programs, provide useful examples of how user-pays approaches can support long-term viability. With sound science, responsive governance, and shared objectives, enhancement can make a meaningful contribution to fishery sustainability and resilience, particularly in the face of environmental change and recruitment variability.

Introduction

Recreational fishing makes an important contribution to social and economic activities in Tasmania, with one in four Tasmanians participating at least once a year (Tracey & Stark, 2024). The most recent survey of recreational fishing in Tasmania estimated that over 830,000 finfish were retained and 1.2 million were released or discarded (Tracey & Stark, 2024).

Several species targeted by recreational fishers are assessed as depleting or depleted (Sharples et al. 2024). Ongoing fishing pressure, combined with ocean warming in the region (Fogarty and Pecl 2021; Twiname et al. 2020) and potentially other anthropogenic factors, means the recovery of some stocks remain uncertain.

Output-based management strategies aim to reduce fishing effort, either to address the immediate challenges of a depleting or depleted stock or to maintain effort at a sustainable level. Along with strengthening management frameworks and developing education and stewardship programs, these strategies can help reduce fishing impacts and support the restoration of spawning biomass to sustainable and productive levels. However, signs of recovery can take years to manifest, and additional methods to further support recovery can be considered. Stocking has the potential to accelerate the rehabilitation of overexploited fisheries and enhance the productivity of those that remain relatively healthy (Bell et al. 2006).

Restocking involves the release of cultured juveniles to rebuild spawning biomass to levels capable of sustaining regular harvests. While, 'stock enhancement', involves the release of hatchery-reared juveniles to mitigate recruitment limitations, thereby augmenting natural population growth (Bell et al. 2006). Throughout this document, we use the term "stocking" to refer to both methods, except when a scenario specifically refers to only one of them. Fish stocking is an important and widely used tool in fisheries management to replenish, maintain or enhance fish populations in freshwater environments, and is increasingly being applied to fisheries in estuarine and marine environments (Welcomme and Bartley 1998; Bell et al. 2006). Successful stocking can yield significant ecological, production and social benefits (Lorenzen 2005). However, careful development and implementation of these programs are required, as there are many documented examples of failure (Butcher 2006; Kitada, 2018).

This report evaluates the feasibility of stocking three species, each with distinct biological traits, providing a diverse set of case studies:

- The Southern Sand Flathead (*Platycephalus bassensis*) is a widespread species and the most popular recreational finfish in Tasmania. It is currently classified as depleted across much of the state.
- Snapper (*Chrysophrys auratus*) is a well-known recreational species on mainland Australia and is expanding its range and increasing in abundance in Tasmania, particularly along the northern, eastern, and southeastern coasts. This range expansion is attributed to warming coastal waters, and suitable habitats for Snapper are expected to increase further with ongoing ocean warming in the region (Graba-Landry et al. 2023).
- Estuary Perch (*Percalates colonorum*), another popular recreational species on the mainland, is limited to a single river system in Tasmania. This restricted distribution presents important challenges for both conservation and stocking efforts.

Sand Flathead

The Southern Sand Flathead, hereafter referred to as Sand Flathead, remains the most significant recreational marine finfish species in Tasmania. Despite recent management interventions and substantial reductions in catch, the species continues to account for approximately 50% of all finfish retained by recreational fishers across the state (Tracey & Stark, 2024).

Sustained recreational fishing pressure over recent decades has led to notable changes in the size and age structure of Sand Flathead populations, particularly in areas of high fishing intensity near major population centres. The Institute for Marine and Antarctic Studies (IMAS) initiated a Sand Flathead monitoring program in 2012. Data from this program led to the stock being classified as "Depleting" in 2015 and subsequently as "Depleted" in 2022, a status it retains as of the most recent assessment (Krueck et al. 2025).

To support recovery efforts, the Department of Natural Resources and Environment Tasmania (NRE Tas) established the Flathead for the Future (FFF) program—a collaborative, multi-agency initiative designed to guide stock rebuilding. A formal harvest strategy specific to Sand Flathead will also be developed to further support long-term stock recovery. As part of these efforts, significant changes were made to output-based management controls, including the introduction of region-specific size and bag limits for recreational fishers and the complete prohibition of commercial harvest of Sand Flathead.

High levels of fishing mortality—especially when size-selective—can impose strong evolutionary pressures on fish populations, leading to changes in growth rates, maturation timing, and other life-history traits (Biro and Post 2008). Size-selective fishing typically targets larger individuals, which can result in evolutionary shifts towards slower growth, earlier maturation, and reduced genetic robustness within the population (Waples and Audzijonyte 2016). It is hypothesised that size-based selectivity is a contributing factor to the decline in the biomass of Sand Flathead in Tasmania.

Evidence of substantial fishing pressure on Sand Flathead is pronounced once individuals reach the minimum legal size, producing an almost knife-edge effect on population size structure in regions such as southeastern Tasmania (Krueck et al. 2025). There has also been a significant reduction in the average size of Sand Flathead caught from southeast Tasmania over the last three decades (IMAS, *unpublished data*). Despite this, molecular assessments using neutral genetic markers indicate that the Sand Flathead population in Tasmania is panmictic and maintains good overall genetic diversity across the state (Green et al., in prep). Differences in traits including increased growth and fitness may be purely phenotypic or may be able to be identified using more selective genetic markers such as adaptive single nucleotide polymorphisms (SNPs) and epigenetic methylation data. Currently, it is unclear what the biological mechanism is for the observed differences and if genetic, it will be important to incorporate larger growing broodstock from the northeast of Tasmania to support recovery efforts in southeastern areas.

Stock enhancement using the larger phenotype Sand Flathead from the northeast as broodstock to support rebuilding of the stock in southeast Tasmania has been proposed as potential strategy to help rebuild the depleted population in the area. However, the model does not accommodate for multiple life history parameters, as such we parameterised the model using life history traits of fish from the southeast. If enhancement efforts using the larger phenotype individuals are successful, the expected benefits are likely to be substantially greater than reported here.

Snapper

Southeastern Australia is recognised as a global ocean warming hotspot, with sea surface temperatures increasing at nearly four times the global average (Pecl et al. 2014). This accelerated warming is primarily attributed to the climate-driven intensification and southward extension of the East Australian Current (Cai et al. 2005; Suthers et al. 2011; Oliver and Holbrook 2018). As a result, numerous marine species have exhibited poleward range shifts and out-of-range occurrences, with documented changes spanning a wide range of taxa (Robinson et al. 2015; Sunday et al. 2015; Pecl et al. 2019; Wolfe et al. 2025). Among these are several species of interest to recreational fishers within their endemic range, including Yellowtail Kingfish (*Seriola lalandi*), King George Whiting (*Sillaginodes punctatus*) and Snapper (*Chrysophrys auratus*), a long-lived teleost fish belonging to the family Sparidae.

Snapper are now more predictably encountered in northern Tasmania, and becoming more common in southern Tasmania. Although Snapper are becoming more common in the recreational fishery in Tasmania it is still unclear if they are breeding in Tasmania, or if they are overwintering (REDMAP). As ocean temperatures rise, it is expected that the species will increase its presence in Tasmanian waters and will become an increasingly popular target for recreational fishers (Graba-Landry et al. 2023). There is potential to enhance the natural increase of Snapper populations in southeast Tasmania with stocking as waters warm toward conditions suitable for sustaining natural breeding populations of the species. We assess the feasibility of this scenario.

Estuary Perch

Estuary Perch is an estuarine-dependent, catadromous species that inhabits the tidal reaches of rivers, lakes, and coastal lagoons from the Richmond River in northern New South Wales (NSW) to the mouth of the Murray River in South Australia (Cadwallader and Backhouse 1983; McDowall 1996). Historically present in several northern Tasmanian estuaries, the species is now restricted within Tasmania to a single remnant population in the Arthur River (Yick et al. 2025). Estuary Perch are long-lived, with individuals known to exceed 40 years of age (Walsh et al. 2010).

The species is generally considered to complete its entire life cycle within individual estuaries (Williams 1970; McCarraher and McKenzie 1986; Walsh et al. 2012; Walsh et al. 2013). However, some evidence suggests limited connectivity, as a small number of larvae have been recorded entering river mouths from the ocean on flood tides, and anecdotal accounts describe adult offshore movements associated with high freshwater discharge events (Trnski, Hay, and Fielder 2005). They spawn in lower estuarine habitats for up to three months between late-winter and early summer with spawning activity driven by temperature (Yick et al. 2025). However, recruitment is unpredictable and highly variable due to environmental factors impacting the survival and retention of eggs and larvae in the estuaries, resulting in populations with strong, weak and missing cohorts (Van Wyk 2015; Walsh et al. 2010).

Despite their historical abundance, Estuary Perch have experienced marked declines in distribution and abundance throughout Australia, primarily attributed to overfishing, altered hydrological regimes, and climate change (Walsh et al. 2010; Stoessel et al. 2018). These pressures have prompted increasing interest in the use of hatchery-reared fish to supplement and restore wild populations. For example, their popularity as a quality sports fish in Victoria has resulted in a stock enhancement program as a way of conserving existing populations and diversifying recreational fishing opportunities.

In Tasmania, a survey conducted in 2014–2015 estimated the size of the Arthur River population at approximately 825–2,375 individuals (Yick et al. 2025). The population exhibited extremely low genetic diversity and was genetically distinct from mainland populations, likely a consequence of long-term geographic isolation. While the population remains reproductively active and appears demographically stable, its restricted distribution, small size, slow growth rate, and highly variable recruitment render it vulnerable and in need of targeted conservation efforts.

To address these concerns, the Inland Fisheries Service is considering initiating a series of investigations to evaluate the feasibility of conservation and enhancement strategies for Estuary Perch in Tasmania. These include:

- Assessing whether the current level of genetic diversity within the Arthur River population is sufficient to support a successful captive breeding and restocking program.
- Investigating the viability of hatchery-rearing Estuary Perch from broodstock collected from the Arthur River.
- Evaluating the potential for establishing insurance populations through the release of hatchery-reared into selected coastal lagoons, supported by ongoing post-release monitoring; and
- Assessing the feasibility of augmenting the existing Arthur River population or reintroducing the species into previously occupied river systems through targeted stocking.

We assess the feasibility of restocking in the Arthur River to increase biomass, noting however that the model does not consider the carrying capacity of the system.

Summary

This study is an important first step in assessing the feasibility of using captive breeding to stock fish species of value to recreational fishers in Tasmania. We conducted enhancement modelling using existing knowledge where possible, and plausible estimates for other aspects, such as hatchery parameters, from other captive rearing projects undertaken in Australia.

The output from this feasibility study can be used to frame the next steps for enhancing recreational fishing in Tasmania. This may include complementing management efforts to rebuild Sand Flathead stocks through enhancement or developing opportunities to enhance the stock of other species in Tasmania as an alternative or complement to flathead fishing, by diversifying the range of popular species available.

Objectives

1. Assess the economic and biological feasibility of enhancement of Sand Flathead with specific focus on faster, larger growing fish.
2. Assess the economic and biological feasibility of enhancement of Estuary Perch and pink Snapper as alternate stock enhancement species to Sand Flathead.
3. Provide guidance on other ecological or stock issues associated with enhancement including mitigation strategies.
4. Provide guidance on costs for enhancement operations including as either government-pays or a user-pays licence model (as per Tasmanian inland fisheries).

Methods and Results

EnhanceFish

EnhanceFish uses a suite of equations to account for each part of the enhancement process. Growth is modelled using a density-dependent von Bertalanffy function. Natural mortality through juvenile and adult stages is described by a length-dependent mortality model, where mortality is inversely proportional to the length of the fish. Prior to recruitment, mortality is also density dependent. The natural mortality rates of introduced and wild fish may differ. Pre-juvenile fish are managed through stocking, while post-juvenile fish are managed through fishing effort. The fish are classified into three categories, wild, hatchery and stocked. Wild fish are the natural population; stocked fish are those reared in aquaculture facilities and then released; and hatchery fish are naturally recruited as offspring from stocked fish.

The disaggregation of the population allows modelling the effect of different natural mortality, and recruitment rates. Natural selection will act to move the rate of return of enhanced fish toward that of the wild component at a rate equal to heritability (h^2). While it is assumed that interbreeding between wild and hatchery genotypes, the model does not provide for inclusion of different life history traits of the mixed phenotype.

The management controls used in the model are fishing effort (E_∞), stocking numbers and stocking size. Asymptotic effort (E_∞) and the rate of instantaneous fishing mortality (F) are directly related through the concept of catchability (q). Asymptotic effort (hereinafter referred to as Effort (E)) refers to the effort required to maintain a constant fishing mortality (F) at a given level, and is calculated as:

$$E = \frac{F}{q}$$

Where:

E = fishing effort (e.g., days fished, number of hooks, hours trawled)
F = instantaneous fishing mortality rate (per year)
q = catchability coefficient (the fraction of the stock caught per unit of effort).

The impact of each control can be examined in isolation or in pairs. For example, we can examine the impact of stocking size (release size of stocked fish) by running the model for a range of sizes and examine the change in population numbers, whilst other controls are kept constant. Alternatively, we can examine how the population shifts when we vary stocking size and fishing effort concurrently through a range of values (remaining controls are kept constant).

In this current assessment, we developed EnhanceFish model scenarios for different fishing effort, stocking size and stocking numbers for each species assessed to examine the impacts of enhancement. The species-specific parametrisations and scenarios are described below.

Sand Flathead

EnhanceFish was used to assess scenarios that involved varying management controls, fishing effort, stocking size, and numbers. The model was parameterised using spatially explicit life history values and based on females only to match stock assessment reports as the species exhibits sex-specific growth dimorphism (Krueck et al 2025, Table 1).

Spatial domain

Sand Flatheads are ubiquitous around the coast of Tasmania, inhabiting primarily shallow waters, inlets and estuaries, but can be found down to 100 m deep. The scale of an enhancement project to recover stocks all around Tasmania was considered unrealistic due to the scale and cost involved. Therefore, the D'Entrecasteaux Channel (Figure 1) was chosen to trial the feasibility study for the following reasons:

1. It is a popular area for recreational fishing due to its proximity to Hobart, the capital city of Tasmania, sheltered waterways and multiple high quality boat ramps serving as access points.
2. Recent stock estimates reveal low relative abundance of legal-sized fish in the D'Entrecasteaux channel, suggesting the population is heavily fished and has been subject to size-selective mortality and potential fishing induced evolution for a protracted period.
3. The area is a natural geographic bottleneck which, in combination with findings of limited movement of Sand Flathead in estuarine areas, minimises the potential movement of stocked fish to other regions, hence, providing an opportunity to enhance stock rebuilding in an important area for the recreational fishery.
4. There is potential spill over benefits to other areas through egg and larval dispersal. These areas include the Derwent River, Storm Bay and Norfolk and Fredrick Henry Bays; all popular recreational fishing areas, close to the main population centre of Hobart and all subject to overfishing with Sand Flathead stocks reported as depleted.

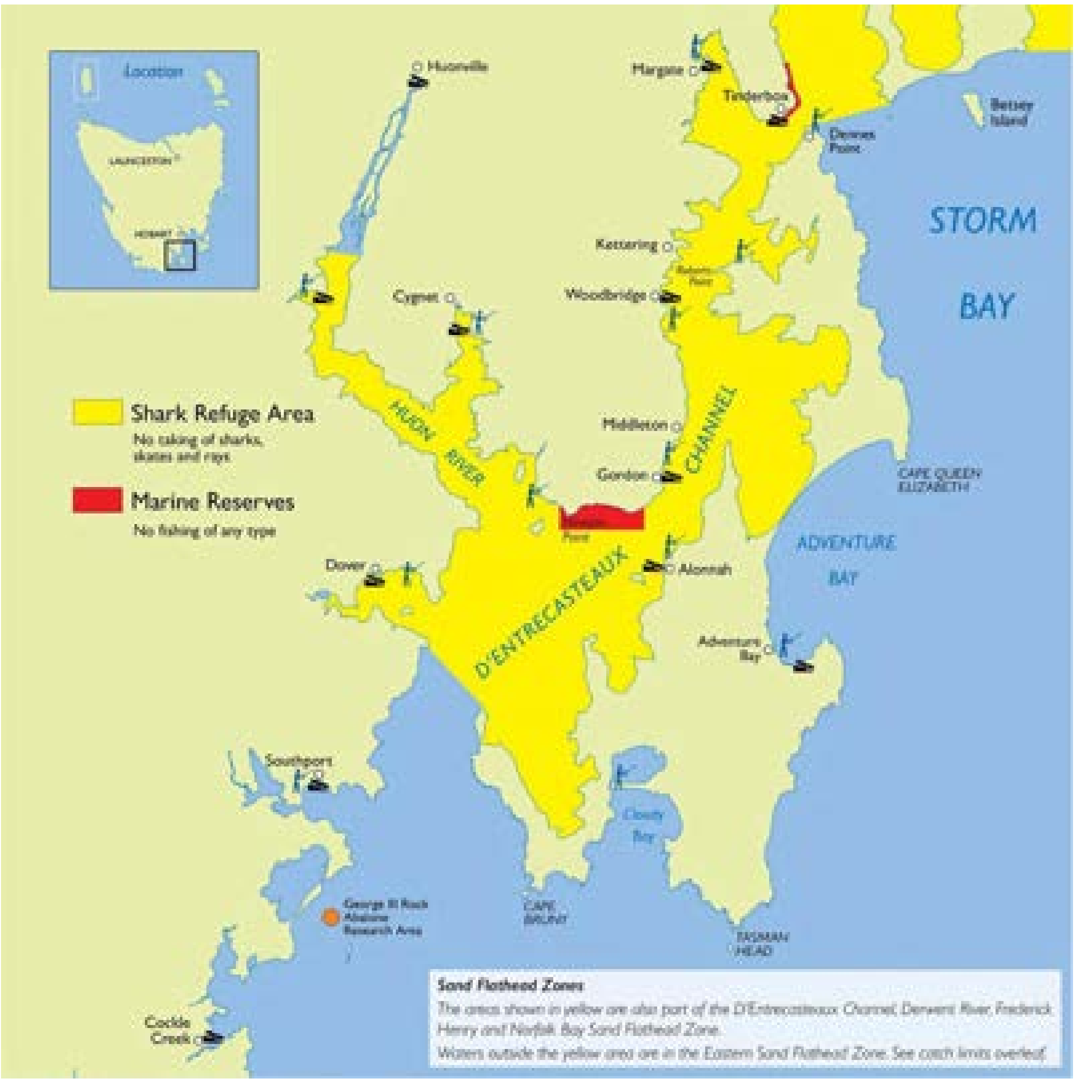

Figure 1. The D'Entrecasteaux channel in southeast Tasmania. Image source: Department of Natural Resources and Environment Tasmania (NRE Tas), showing the spatial management zones, including for Sand Flathead.

Parameterisation

The life history parameters of wild, stocked and hatchery fish were set equal but reproductive success of stocked and hatchery fish were assumed to be at 80% of wild fish. The total estimated recreational catch in the Channel (50 t) reported by Lyle et al. 2014, was halved (25 t) on the assumption of a 50:50 catch of females and males so that the model was fit to the life history parameters of females only, noting sex-specific dimorphism is present for the species (Krueck et al. 2025). The model was parameterised based on the life history estimates derived from IMAS fishery-independent sampling in southeast Tasmania, and as such represent the life history parameters of 'stunted' individuals (Table. 1). The model is unable to incorporate wild and stocked fish with different life history traits, which would account for the different phenotypes.

Table 1.Parameterisation values for the EnhanceFish model for Sand Flathead based on life history traits estimated for southeast Tasmania.

Parameter	Definition	Parameter value	Reference/Notes
Life Cycle			
L_0	Length at larval/juvenile transition (settlement)	2 cm	Jordan et al. 2001 Lorenzen & Camp 2019
L_r	Length at mortality shift	10 cm	Calculated from model
a_r	Age at mortality shift	1 year	
Growth			
L_∞	Asymptotic Length	49.26 cm	Krueck et al. 2025
K	Growth rate	0.31 yr^{-1}	Krueck et al. 2025
a	Coefficient of length-weight relationship	$2.2e^{-9}$	Coulson et al. 2022
β	Exponent of length-weight relationship	3.2	
Natural mortality			
M_w	Mortality of wild phenotype	0.28 yr^{-1}	Krueck et al. 2025
M_s	Mortality of hatchery phenotype at	0.28 yr^{-1}	Assumed*
Reproduction			
L_m	Length at maturity	26 cm (50%)	Krueck et al. 2025
p	Steepness of maturity curve	-1 (arbitrarily chosen to give 95% maturity by 29cm)	
r	Relative reproductive performance of stocked fish	0.8	
Recruitment			
a^*	Initial slope of stock-recruitment relationship (How many recruits per unit biomass (t))	calculated (20,569)	Calculated in model based on catch and life history parameters
b^*	Asymptotic recruitment level (at what point adding more recruits has no impact)	Calibrated (2,080,575)	
Fishing			
F_∞	Fishing effort asymptote	1	Length and selectivity parameters are used to implement the size limit in the model.
L_c	Gear selection length	32 cm	
q	Steepness of selectivity curve.	-5	
Evolution			Assumed based on Lorenzen (2001).
h^2	Heritability of life history traits	0.2	

*While it may be expected that hatchery reared juveniles have a higher mortality rate than wild fish, we have assumed it will be similar by careful consideration of husbandry methods including pre-release conditioning (e.g. predator exposure, live feed training), use of phenotypically robust wild broodstock to maintain adaptive traits, rearing in enriched environments to mimic natural habitat complexity.

Model Scenarios

Stock enhancement scenarios were developed to examine the impact of different control measures (fishing effort, stocking numbers and release size of individual fish) on the existing population of Sand Flathead in the D'Entrecasteaux Channel (Figure 2). For each scenario we varied one of these values while keeping the others constant (Table 2).

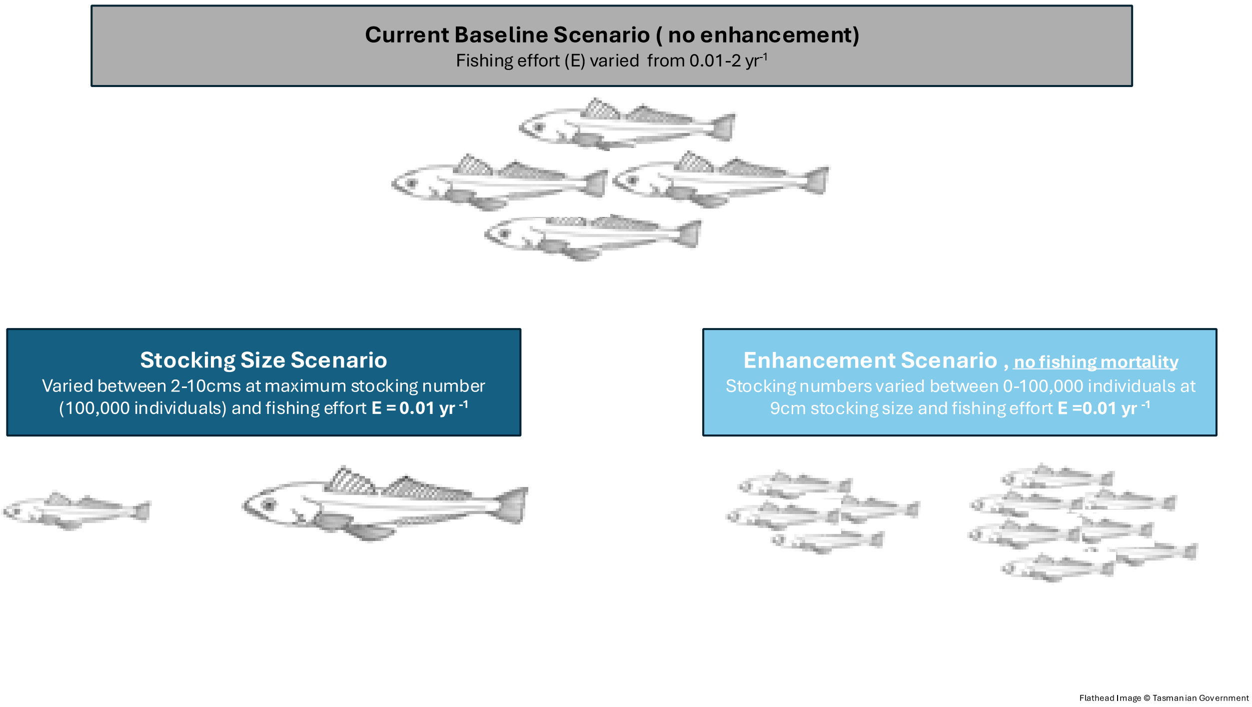

Figure 2. Sand flathead modelling scenarios.

Scenario 1: Baseline without enhancement Fishing effort varied from (*E*) 0.01 – 2 yr^{-1}, with no stocking with the maximum equilibrium biomass estimated at 358 t in model simulations using the best available data.

Scenario 2: Exploring individual stocking sizes Initial individual stocking size varied between 2-10 cm, with stocking numbers set at 100,000 individuals yr^{-1} and E = 0.01 yr^{-1}.

Scenario 3: Exploring stocking quantity Stocking numbers varied between 0 - 100,000 individuals yr^{-1}, with individual stocking size = 9 cm and E = 0.01 yr^{-1}.

Table 2. Summary of scenario parameters assessed for Sand Flathead. A range of values for one parameter are explored in each scenario, this is indicated in bold.

Scenario	Effort (yr^{-1})	Stocking Size (cm)	Stocking Number (yr^{-1})	Biological Parameters
1	**0.01 - 2**	NA	0	Baseline
2	0.01	**2-10**	100k	Baseline
3	0.01	9	**0-100k**	**Baseline**

Scenario 1: Baseline without enhancement

A baseline of female Sand Flathead biomass (358 t) was established based on the reported catch (25 t females only) of Sand Flathead by recreational fishers in the D'Entrecasteaux Channel in 2012/13 (Lyle et al. 2014), within the EnhanceFish software using the Beverton-Holt Spawning Stock Biomass model. Equilibrium biomass was then assessed against a range of fishing effort (*E*) values (Figure 3).

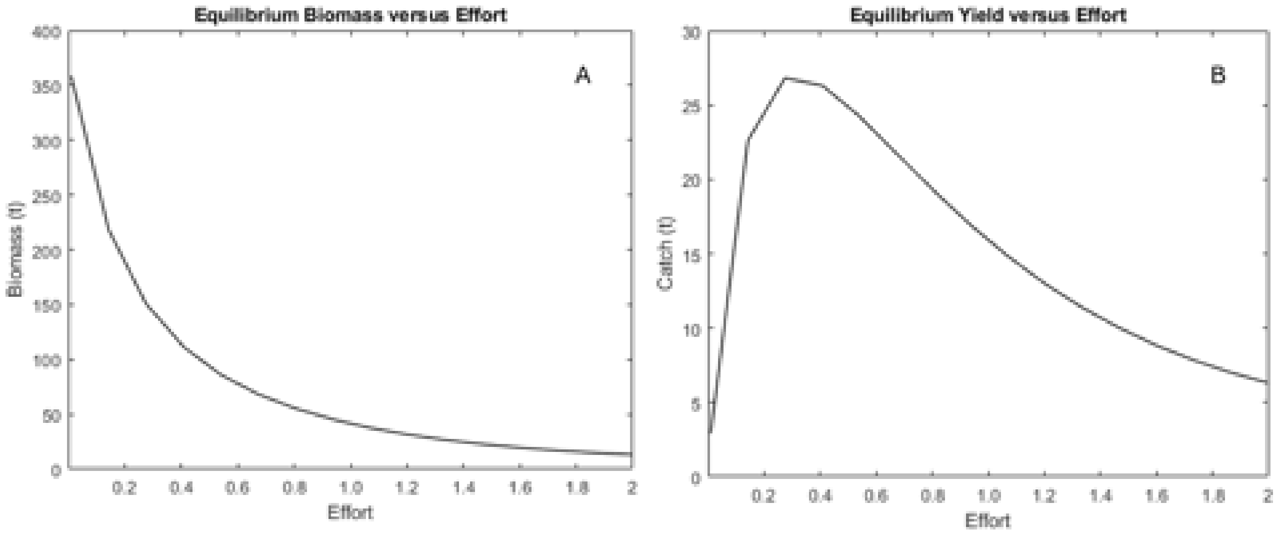

Figure 3. (A) Change in equilibrium biomass and (B) yield with fishing effort for the Sand Flathead fishery in D'Entrecasteaux Channel with no enhancement, based on 2012/2013 data.

At E = 1 yr^{-1} the equilibrium biomass was estimated to be approximately 10% of the biomass relative to no fishing (Figure 3), a proxy equivalent to the B/B_0, as estimated by the Length-based Bayesian Biomass (LBB) estimation approach presented by (Krueck et al. 2025). At the same level of effort, yield is estimated at 55% of maximum, with maximum yield occurring at an E of 0.28 yr^{-1} (Figure 3).

The EnhanceFish model is not designed to determine the time required for a stock to return to a target level. However, it can indicate the level of effort (proxy for F) needed to achieve different levels of B/B_0. For example, reaching a target of B/B_0 of 40% without enhancement would occur at E = 0.28 yr^{-1} in an equilibrium state (Figure 3). As previously mentioned, this is also the level of effort at which yield would be maximised (Figure 3).

In 2023, new management regulations for Sand Flathead in the D'Entrecasteaux channel were introduced. These included reducing the bag limit from 20 fish to 2 fish per person per day, increasing the minimum legal size limit from 32 cm to 35 cm, and introducing a maximum legal size limit of 40 cm. Based on the size distribution of Sand Flathead caught in the channel (Krueck et al., 2025), approximately 1% of Sand Flathead would be above the minimum or below the maximum legal size limits. This has significantly reduced fishing effort which is nominally assumed to be E = 0.01 yr^{-1}. Functionally, these regulations have created a catch-and-release-only fishery, with extractive fishing mortality now occurring only due to the very small harvest of fish within the slot limit. While non-compliance remains a concern, the post-release mortality is estimated to be low (Lyle et al. 2007) and consequently, this functional closure is expected to allow the biomass to recover over a yet unknown period.

A caveat to a predictable return to target biomass levels is the confounding factor of size-selective mortality driven by a long history of overfishing larger individuals, which has disproportionately removed larger Sand Flathead from the population while affording protection to smaller individuals that do not reach the size-limit. This has likely led to significant changes in the phenotypic and possibly genotypic composition of the Sand Flathead in the channel region that can reach the minimum legal-size limit. Subsequently, the phenotype of these 'stunted' individuals are contributing disproportionately through the spawning biomass to the gene pool in the area. This functionally results in a stunted stock and potentially Fishing Induced Evolution (FIE) of the population. Consequently, the period required to increase biomass may be extended as the average size of individuals decreases. This shift also affects the value of the fishing experience, as fewer individuals will be available based on the minimum size limit and a reduced yield from harvested individuals due to the prevalence of smaller fish.

The EnhanceFish model shows the effect of increased fishing effort with a dramatic decline in the number of fish at a given age as *E* increases. For instance, fish begin to become exposed to the fishery between three and five years of age. In an equilibrium state, with effort (*E*) >1 there would be expected to be very few fish greater than four years of age (Figure 4).

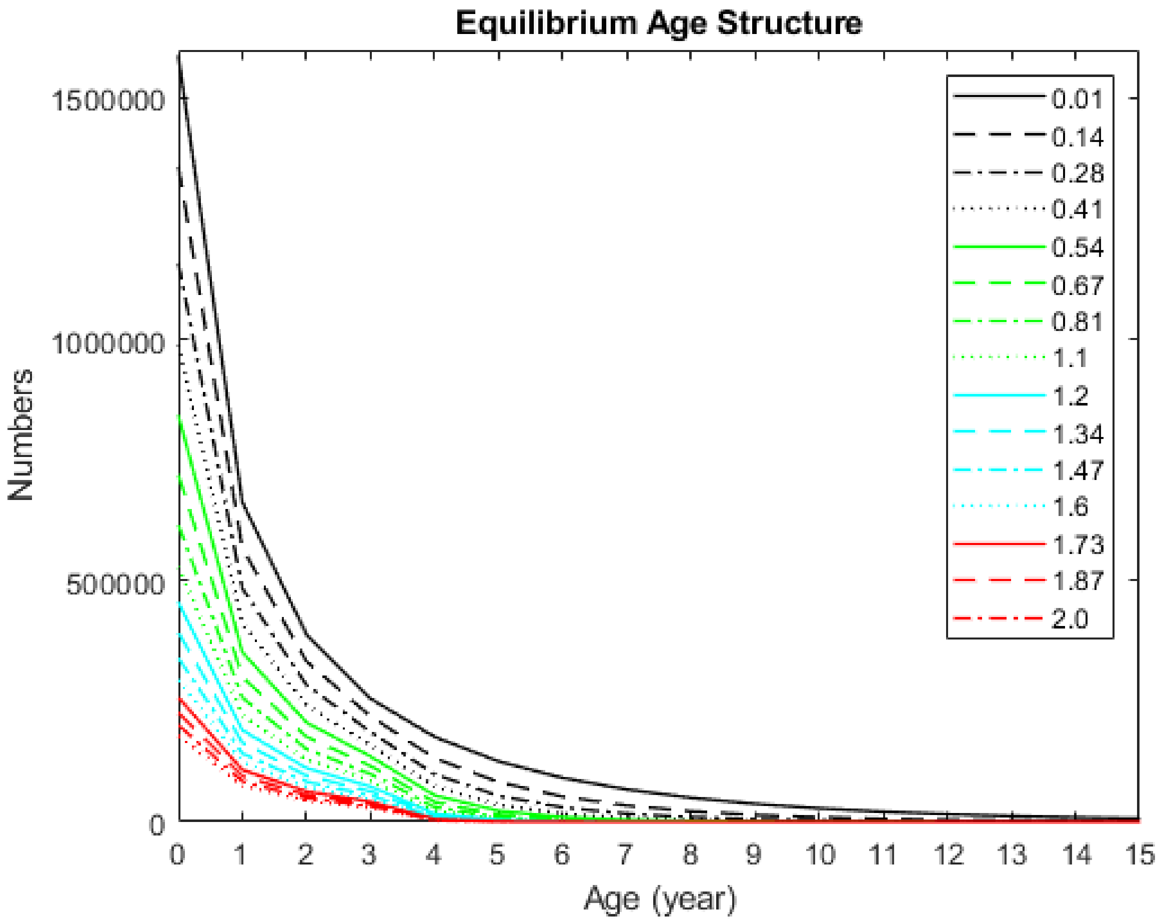

Figure 4. Age structure of the Sand Flathead in D'Entrecasteaux for different levels of fishing effort (in box).

Scenario 2: Exploring individual stocking sizes

The size of captively reared individuals at the time of stocking has a minor effect on the rate of biomass increase up until 7 cm in length. For example, the contribution to biomass of releasing fish at 7 cm would result in a 1% greater increase in equilibrium biomass relative to releasing at 3 cm (Figure 5). Above 7 cm, however the rate of biomass increase improved. With fish released at 9 cm, the increase in biomass was 5%. At 9 cm, the hatchery and stocked fish will contribute 18% of the total biomass relative to wild fish. This has benefit if the intent is to introduce a replacement pheno-genotype to the stock in the area.

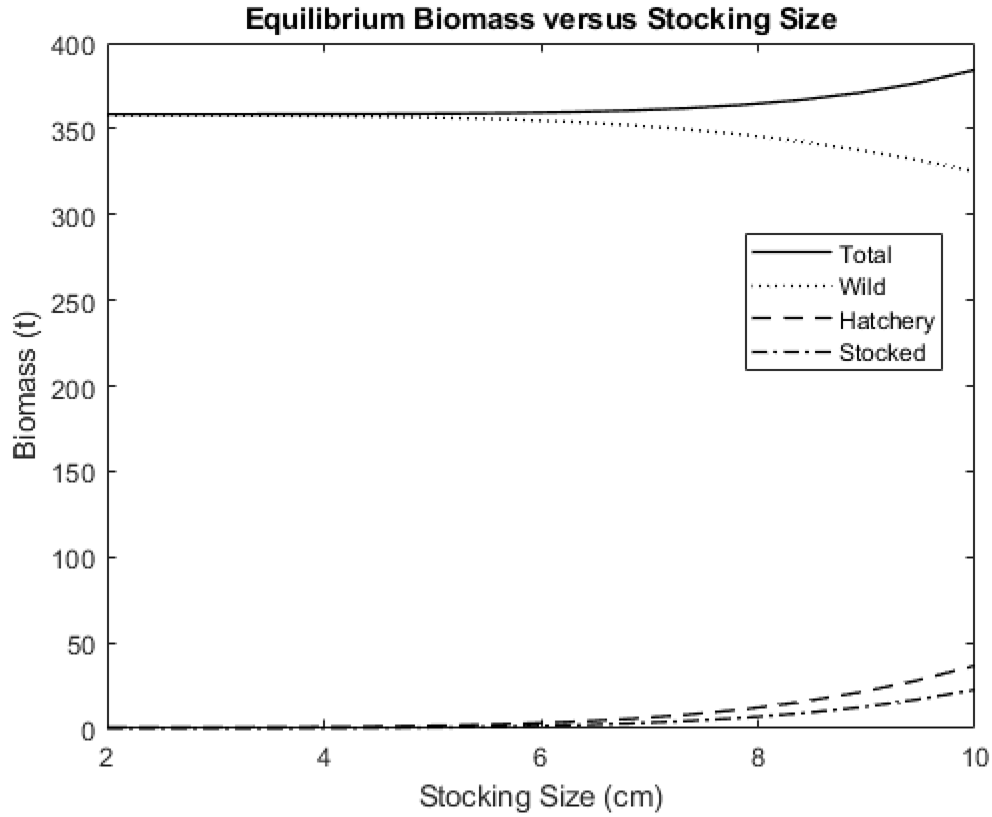

Figure 5. The modelled increase in biomass of the Sand Flathead stock in the D'Entrecasteaux Channel based on the stocking size of individual captive reared fish. The modelled scenario presented was set with stocking number = 100,000 individuals yr^{-1} and effort (E) = 0.01 yr^{-1}.

Scenario 3: Exploring stocking quantity

The enhancement scenario was considered with a negligible effect of fishing mortality. As previously discussed, the current management regulations in the Channel have created a functional catch and release fishery, with very few individuals reaching the slot limit and available to harvest, hence E was nominally set at 0.01 yr^{-1}. The individual stocking size was set at 9 cm based arbitrarily on the results presented in Figure 5, which show a benefit of growing fish in captivity to this size prior to release. A final decision would be based on the trade-off between the additional cost to growing individuals to a larger size compared to the benefit of their increased survival probability. Stocking numbers were then assessed from zero to 100,000 individuals a year to assess the effect on equilibrium biomass.

Stocking of captive reared fish (hatchery + stocked) has a positive effect on total biomass (Figure 6). Although this effect was not substantial relative to the effect of the output management controls, represented by the low level of E (0.01 yr^{-1}) in the region (Figure 6). Although this result would differ if fish were being extracted by the fishery, with enhancement having a greater effect. At the highest stocking numbers considered, the captive bred individuals (hatchery + stocked) will contribute approximately 13 t (4%) increase in biomass and represent 10% of the equilibrium biomass relative to wild fish (Figure 6). Importantly, however, as described in the methods, the model is unable to utilise two sets of life history parameters, including growth rates. If larger growing phenotypes are used as broodstock and the trait of larger size at age persists in their new environment, the realised increase in equilibrium biomass would likely increase significantly.

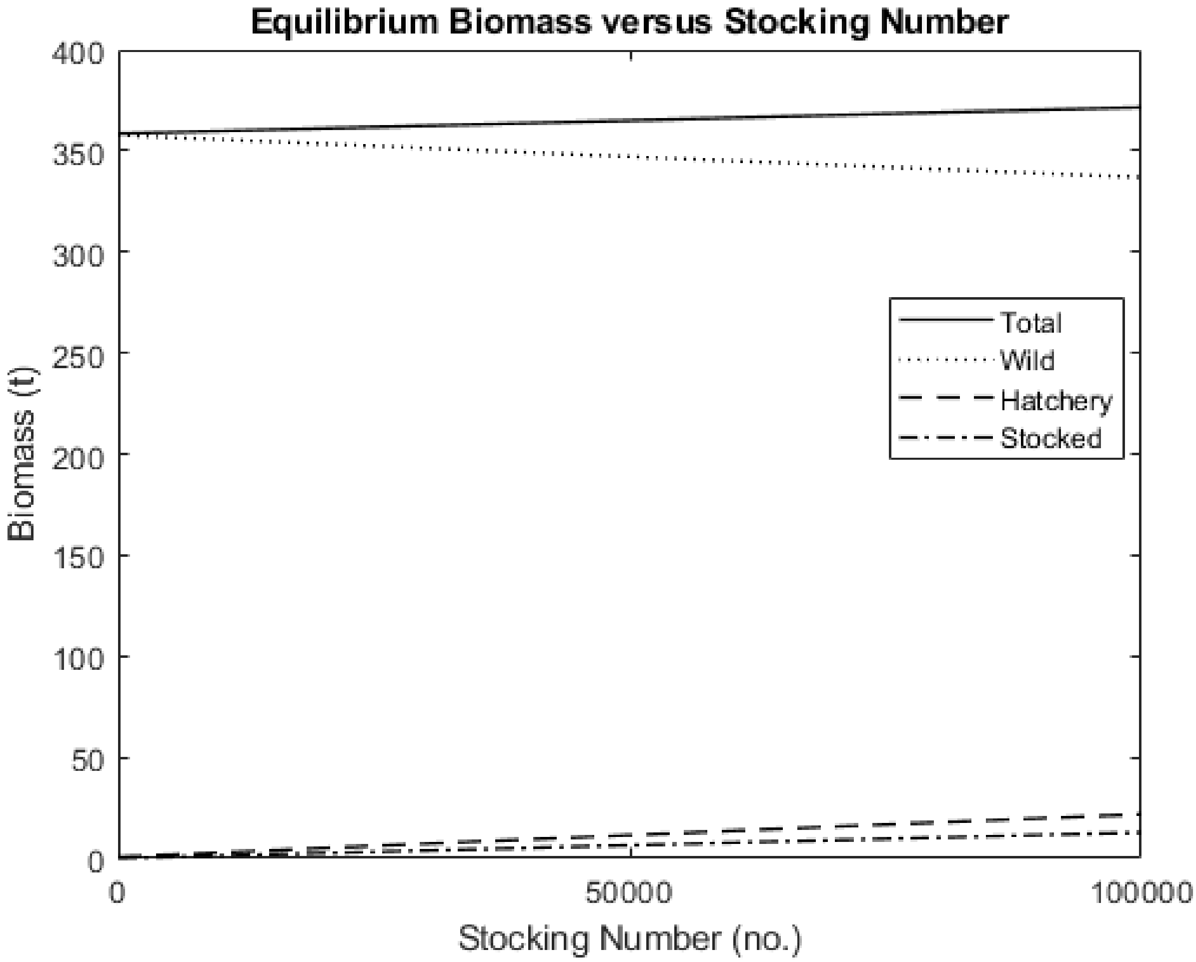

Figure 6. The modelled increase in biomass of the Sand Flathead stock in the D'Entrecasteaux Channel based on the stocking number of individual captive reared fish. The modelled scenario presented was set with stocking size of individual fish = 9 cm and effort (E) = 0.01 yr^{-1}.

The stocking model indicates that in a scenario with minimal fishing effort that the greatest cost benefit to biomass increase would be realised when stocking bigger fish (10 cm). The benefit of increased chance of survival of growing them to a larger size out ways the cost of doing so. If fishing effort was controlled at approximately E=0.54 yr^{-1} yield would be most effectively maximised relative to cost (Table 3).

Table 3. Increased biomass and catch resulting from releasing 10,000 individual Sand Flathead annually for selected release sizes and levels of effort. Cost to produce an individual is nominally set at $1.50 to release at 4 cm with a 50-cent increase in cost for a two-centimetre increase in release size. The dark green indicates the most cost-effective approach for biomass and yield increase, then the graduation to lighter greens indicates the second and third most cost effective approach.

Release size (cm)	Effort (Yr^{-1})	Biomass increase (kg)	Annual catch increase (kg)	Nominal cost per fish ($)	Cost benefit biomass (Kg/$)	Cost benefit catch (Kg/$)
4	0.01	0.001	0.000	1.50	0.000	0.000
4	0.27	0.001	0.000	1.50	0.001	0.000
4	0.54	0.001	0.000	1.50	0.001	0.000
6	0.01	0.009	0.000	2.00	0.005	0.000
6	0.27	0.009	0.002	2.00	0.004	0.001
6	0.54	0.010	0.003	2.00	0.005	0.001
8	0.01	0.061	0.000	2.50	0.024	0.000
8	0.27	0.046	0.008	2.50	0.019	0.003
8	0.54	0.048	0.014	2.50	0.019	0.005
10	0.01	0.295	0.002	3.00	0.098	0.001
10	0.27	0.231	0.041	3.00	0.077	0.014
10	0.54	0.247	0.070	3.00	0.082	0.023

Snapper

EnhanceFish was used to assess scenarios that involved varying management controls, fishing effort, stocking size and numbers for Snapper (Figure 8). The model was parameterised using spatially explicit life history values (Table 3).

Spatial domain

Snapper is a range extending species that are likely to increase in numbers around Tasmania as ocean temperatures increase (Wolfe et al. 2020; Graba-Landry et al. 2023) The species is increasingly encountered on the southeast coast of Tasmania, particularly around Storm Bay and surrounding estuaries and embayments (REDMAP) (Figure 7). Southeast Tasmania was selected as the domain to assess the feasibility of enhancement for the following reasons:

1. It is a popular area for recreational fishing due to its proximity to Hobart, sheltered waterways and multiple high quality boat ramps serving as access points.
2. Increasing water temperature on the east and southeast coast of Tasmania are likely to continue and provide an environment conducive of greater abundance of Snapper in the future.
3. Increasing the abundance of alternate species that are popular for recreational fishing will provide different species to facilitate a displacement of effort, thereby relieving some pressure on Sand Flathead populations in the area.
4. There is potential spill over benefits to other areas through egg and larval dispersal. These areas include the Derwent River, the D'Entrecasteaux Channel and Storm Bay, all popular recreational fishing areas, close to the main population centre of Hobart.

Figure 7. Southeast Tasmania which includes the areas Norfolk and Fredrick Henry Bays the Derwent River and the D'Entrecasteaux Channel which are all included in the region selected for the Snapper enhancement feasibility scenarios. Image source: Department of Natural Resources and Environment Tasmania (DNRET).

Parameterisation

For the model simulations we assume a self-recruiting population in southeast Tasmania. The catch of Snapper in the southeast region was 2.5 t in 2022/23 (IMAS, Unpublished data). To establish a baseline equilibrium biomass, we used life history parameters for Snapper (Table 4) and the estimated catch of 2.5 t. The EnhanceFish model estimates the stock-recruitment relationship based on these inputs. Importantly, it is to be noted that the biomass estimate may be an under-estimate as the species is likely not fully exploited by the recreational sector as, a group, they are still developing technique and knowledge on maximising catchability.

The life history parameters of wild, stocked and hatchery fish were set equal but reproductive success of stocked and hatchery fish was nominally assumed to be at 80% of wild fish.

Table 4. Parameters required for EnhanceFish for Snapper.

Parameter	Definition	Snapper	Reference/Notes
Life Cycle			
L_0	Length at larval/juvenile transition (settlement)	3.5 cm	Parsons et al. 2014
L_r	Length at recruitment	14 cm	Lorenzen 2019
a_r	Age at recruitment	1 year	Calculated using EnhanceFish
Growth			
L_∞	Asymptotic Length	79.2 cm	Stewart et al. 2010
K	Growth rate	0.08 yr^{-1}	Stewart et al. 2010
g	Competition coefficient	Default	
a	Coefficient of length-weight relationship	$4.7e^{-8}$	Campbell et al. 2009
β	Exponent of length-weight relationship	2.79	Campbell et al. 2009
Natural mortality			
M	Mortality of wild phenotype	0.16 yr^{-1}	Then et al. 2015
M	Mortality of hatchery phenotype	0.16 yr^{-1}	Assumed*
Reproduction			
L_m	Length at maturity	38.9 cm (50%)	Stewart et al. 2010
p	Steepness of maturity curve	-1	
r	Relative reproductive performance of stocked fish	0.8	Assumed
Recruitment			
a^*	Initial slope of stock-recruitment relationship (How many recruits per unit biomass (t))	9,069	
b^*	Asymptotic recruitment level (at what point adding more recruits has no impact)	65,575	
Fishing			
F_∞	Fishing effort asymptote	1 yr^{-1}	
L_c	Gear selection length	30 cm	
q	Steepness of selectivity curve.	-1	
Evolution			
h^2	Heritability of life history traits	0.2	Assumed based on Lorenzen (2001).

*While it may be expected that hatchery reared juveniles have a higher mortality rate than wild fish, we have assumed it will be similar by careful consideration of husbandry methods including pre-release conditioning (e.g. predator exposure, live feed training), use of phenotypically robust wild broodstock to maintain adaptive traits, rearing in enriched environments to mimic natural habitat complexity.

Model Scenarios

Stock enhancement scenarios were developed to examine the impact of different control measures (fishing effort, stocking numbers and release size of individual fish) on the existing population of Snapper in southeast Tasmania (Figure 8). For each scenario we varied one of these values while keeping the others constant (Table 5).

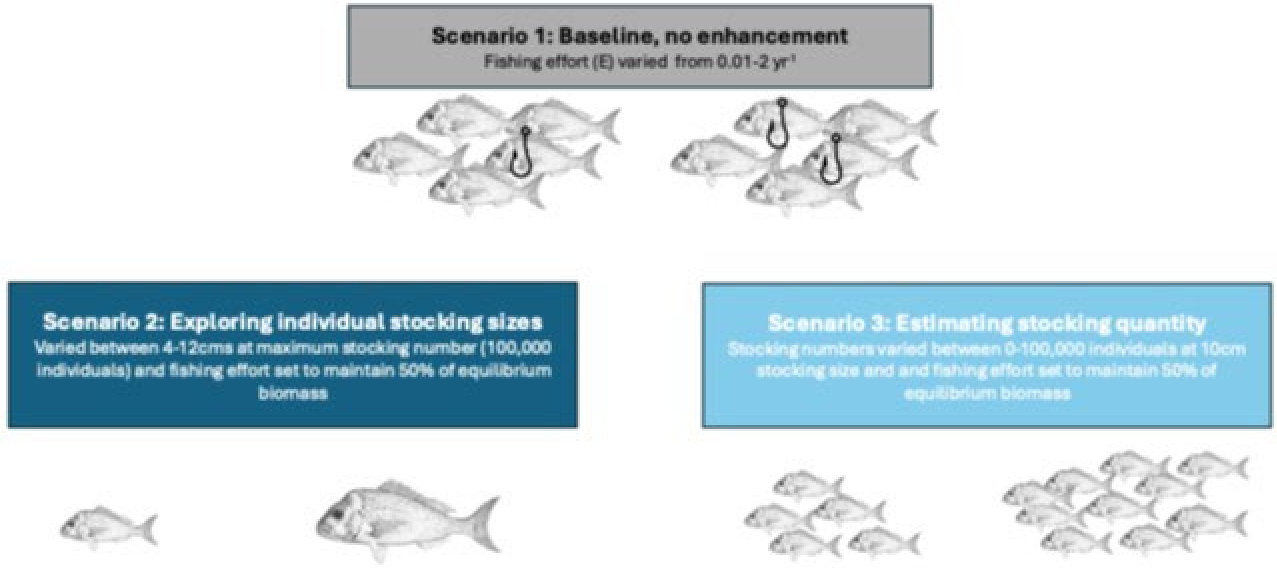

Figure 8. Snapper modelling scenarios.

Scenario 1: Baseline without enhancement Fishing effort varied from (*E*) 0.01 – 2 yr^{-1}, with no enhancement of the stock with the maximum equilibrium biomass estimated at 166 t.

Scenario 2: Exploring individual stocking sizes Initial individual stocking size varied between 4-12 cm, with stocking numbers set at 100,000 individuals and effort set at a value to maintain 50% of the equilibrium biomass estimated at $E = 0.14\ yr^{-1}$.

Scenario 3: Exploring stocking quantity Stocking numbers varied between 0 -100,000 individuals, with individual stocking size = 10 cm and effort set at a value to maintain 50% of the equilibrium biomass estimated at $E = 0.14\ yr^{-1}$.

Table 5. Summary of scenario parameters assessed for Snapper. A range of values for one parameter are explored in each scenario, this is indicated in bold.

Scenario	Effort (yr^{-1})	Stocking Size (cm)	Stocking Number	Biological Parameters
1	**0.01 - 2**	NA	0	Baseline
2	0.14	**4-12**	100k	Baseline
3	0.14	10	**0-100k**	Baseline

Scenario 1: Baseline without enhancement

A baseline of Snapper biomass was established based on the reported catch of Snapper by recreational fishers in southeast Tasmania in 2022/23 (IMAS unpublished data), within the EnhanceFish software using the Beverton-Holt Spawning Stock Biomass model.

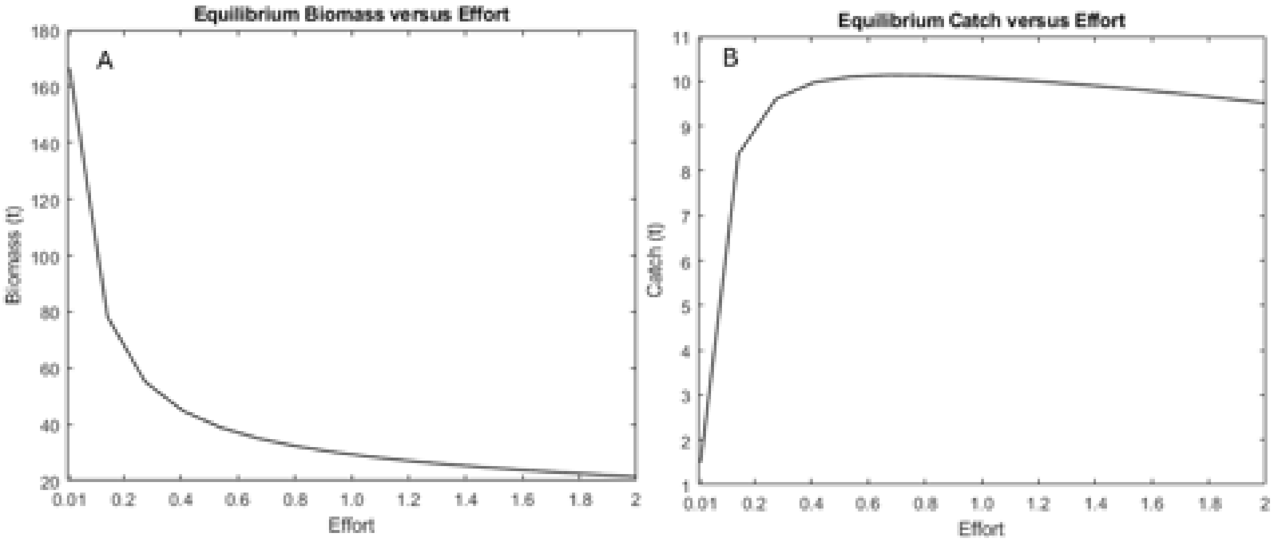

Figure 9. (A) Change in equilibrium biomass and (B) yield with fishing effort for Snapper in southeast Tasmania with no enhancement, based on 2022/23 catch data.

The model estimates yield to be maximised at $E = 0.67$ yr^{-1} equating to a catch of 10.1 t but as this is a developing population due to range extension, effort at this level would result in a B/Bo of 21% which is close to the trigger of 20% indicating a near depleted population. A more conservation approach, in line with the values anecdotally espoused by the recreational sector would be to implement an E of 0.14 yr^{-1} which would result in a 50% B/Bo and a catch of 8.37 t (Figure 9).

The EnhanceFish model indicates that there is no substantial chance of altering the size structure of the Snapper population in the southeast at the current estimated E of 0.14 yr^{-1}. Although at the maximised yield ($E = 0.67$ yr^{-1}) the likelihood of growth overfishing may be realised (Figure 10).

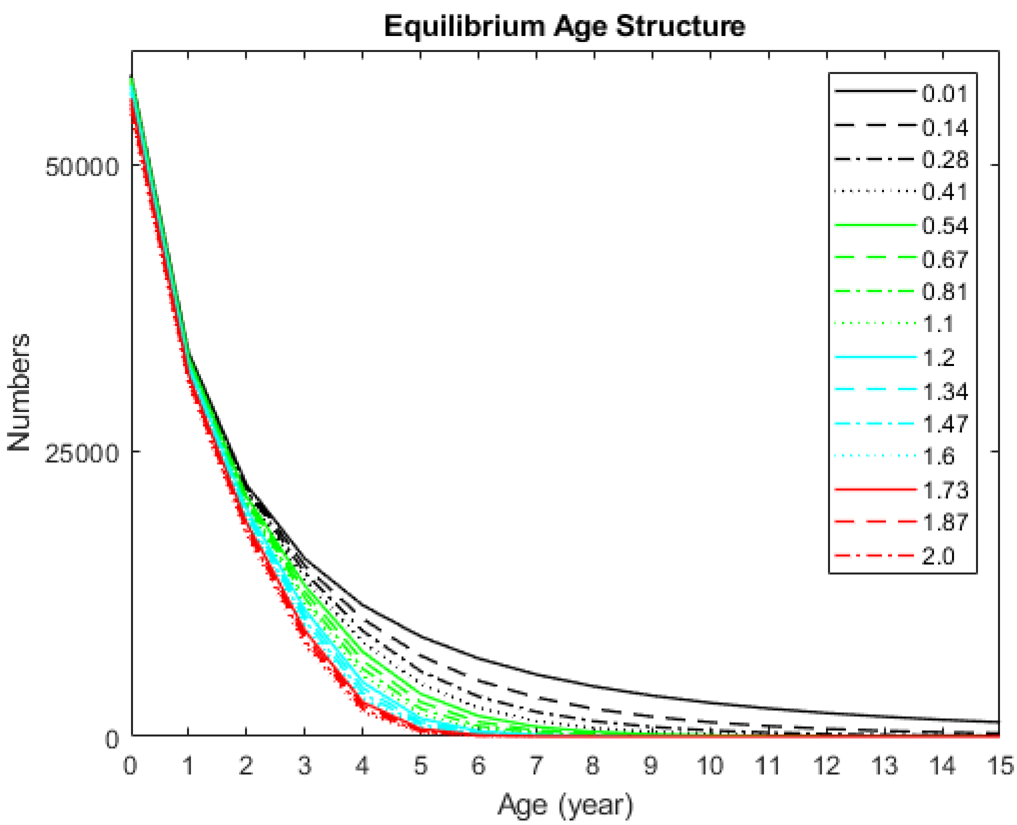

Figure 10. Age structure of Snapper in southeast Tasmania for different levels of fishing effort (in box).

Scenario 2: Exploring individual stocking sizes

The size of captively reared individuals at the time of stocking has a significant effect on the rate of biomass increase, with an approximately exponential increase in biomass for each centimetre increase in release size for the size range assessed. For example, the contribution to biomass of releasing fish at 7 cm would be result in a 7% greater increase in equilibrium biomass relative to releasing at 4 cm and at 10 cm would result in a 36% increase relative to releasing at 4 cm and 29% increase relative to releasing at 7 cm (Figure 11). Given the relatively small natural population, and at the maximum assessed stocking number (100,000 yr^{-1}), the stocked and hatchery reared fish would contribute more to the equilibrium biomass than the wild population above 10 cm (Figure 11).

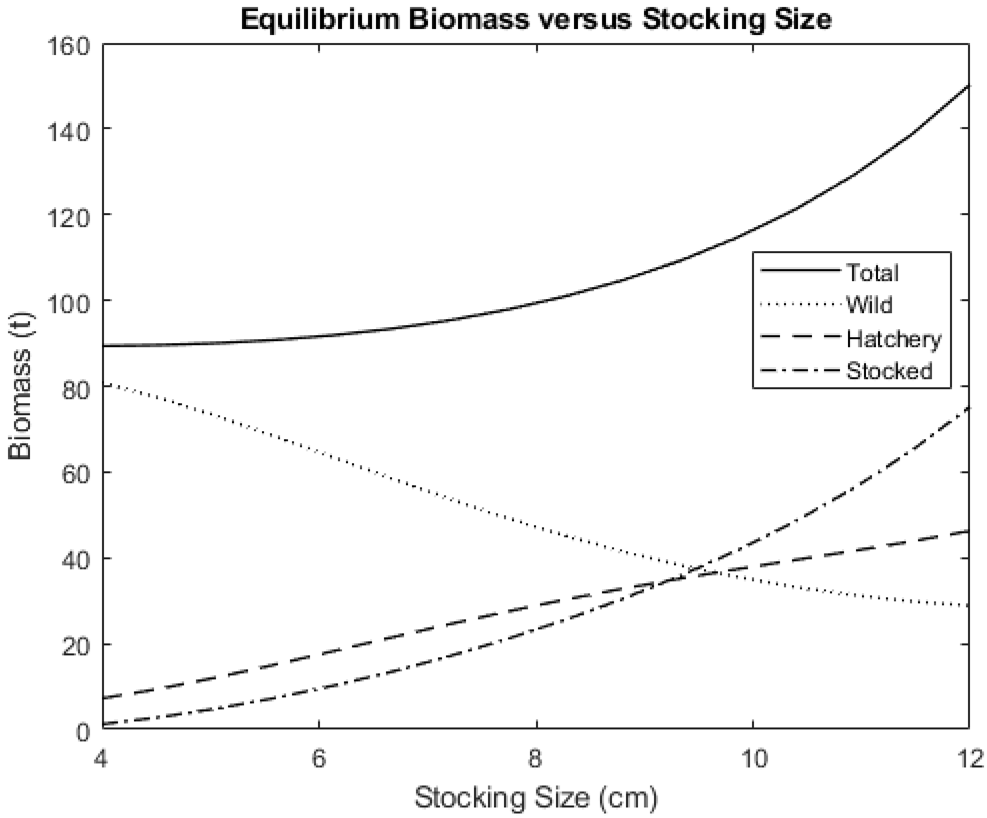

Figure 11. The modelled increase in biomass of Snapper in southeast Tasmania based on the stocking size of individual captive reared fish. The modelled scenario presented was set with stocking number = 100,000 individuals and effort (E) = 0.14 yr^{-1}.

Scenario 3: Exploring stocking quantity

The enhancement scenarios were assessed at the current estimated E = 0.14 yr^{-1} and individual stock size = 10 cm based arbitrarily on the results presented in Figure 11, which show a benefit of growing fish in captivity to this size prior to release. Stocking numbers were then assessed from zero to 100,000 individuals to assess the effect on equilibrium biomass.

Stocking of captive reared fish has a significant positive effect on total biomass (Figure 20). Releasing 20,000 individuals into the channel would increase equilibrium biomass by 6.3 t (7%) and with 100,000 individuals introduced equilibrium is estimated to increase by 27 t (30%) (Figure 12). The captive bred individuals (hatchery + stocked) relative to wild fish would contribute a greater proportion above a stocking number of approximately 47,000 individuals (Figure 12).

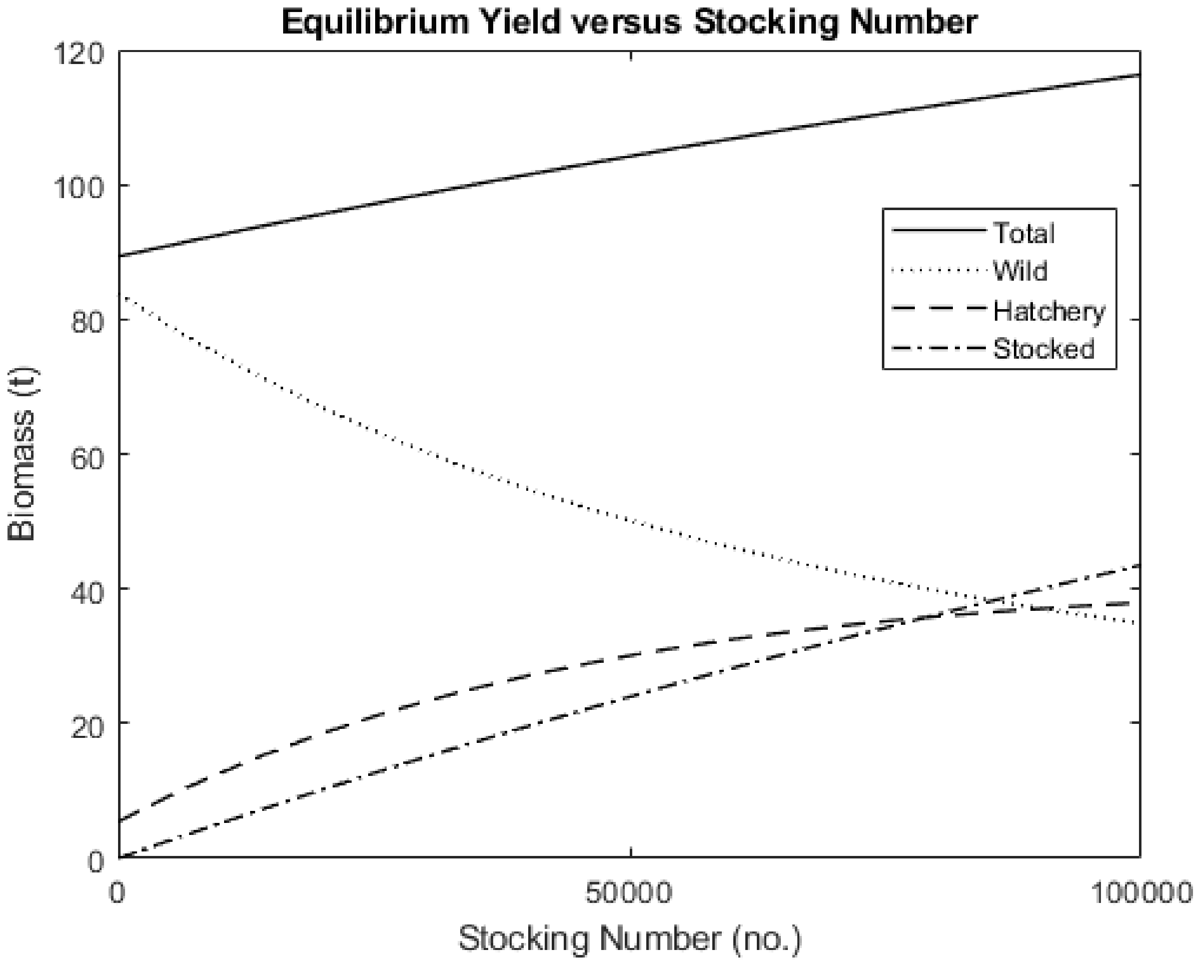

Figure 12. The modelled increase in biomass of Snapper in southeast Tasmania based on the stocking number of individual captive reared fish. The modelled scenario presented was set with stocking size of individual fish = 10 cm and effort (E) = 0.14 yr^{-1}.

The stocking model indicates that in a scenario with current fishing effort, the greatest cost benefit to biomass increase would be realised when stocking bigger Snapper (10 cm). The benefit of increased chance of survival of growing them to a larger size outweighs the cost of doing so. If fishing effort was controlled at approximately a level to maximise yield, releasing 10 cm fish would also result in the best cost benefit for yield (Table 6), although it is worth noting that at that level (0.67 yr^{-1}), growth overfishing may occur.

Table 6. Increased biomass and catch (Kg) resulting from releasing 10,000 individual Snapper annually for selected release sizes and levels of effort. Cost to produce an individual is nominally set at $1.50 to release at 4 cm with a 50-cent increase in cost for a two-centimetre increase in release size. The dark green indicates the most cost-effective approach for biomass and yield increase, then the graduation to lighter greens indicates the second and third most cost effective approach.

Release size (cm)	Effort (Yr^{-1})	Biomass increase (Kg)	Annual catch increase (kg)	Nominal cost per fish ($)	Cost benefit biomass (Kg/$)	Cost benefit catch (Kg/$)
4	0.14	0.001	0.000	1.50	0.000	0.000
4	0.41	0.000	0.000	1.50	0.000	0.000
4	0.67	0.000	0.000	1.50	0.000	0.000
6	0.14	0.024	0.003	2.00	0.012	0.001
6	0.41	0.014	0.003	2.00	0.007	0.002
6	0.67	0.012	0.003	2.00	0.006	0.002
8	0.14	0.114	0.012	2.50	0.046	0.005
8	0.41	0.067	0.015	2.50	0.027	0.006
8	0.67	0.054	0.016	2.50	0.021	0.006
10	0.14	0.321	0.034	3.00	0.107	0.011
10	0.41	0.186	0.041	3.00	0.062	0.014
10	0.67	0.148	0.043	3.00	0.049	0.014

Estuary Perch

EnhanceFish was used to assess scenarios that involved varying management controls, fishing effort, stocking size and numbers (Figure 14). The model was parameterised using spatially explicit life history values (Table 7).

Spatial domain

Estuary Perch are only found in the Arthur River in Tasmania (Figure 13), although they are thought to have inhabited other estuarine systems in northern Tasmania in the past (Yick et al. 2025). The model was used to assess enhancement on the current population in Arthur River.

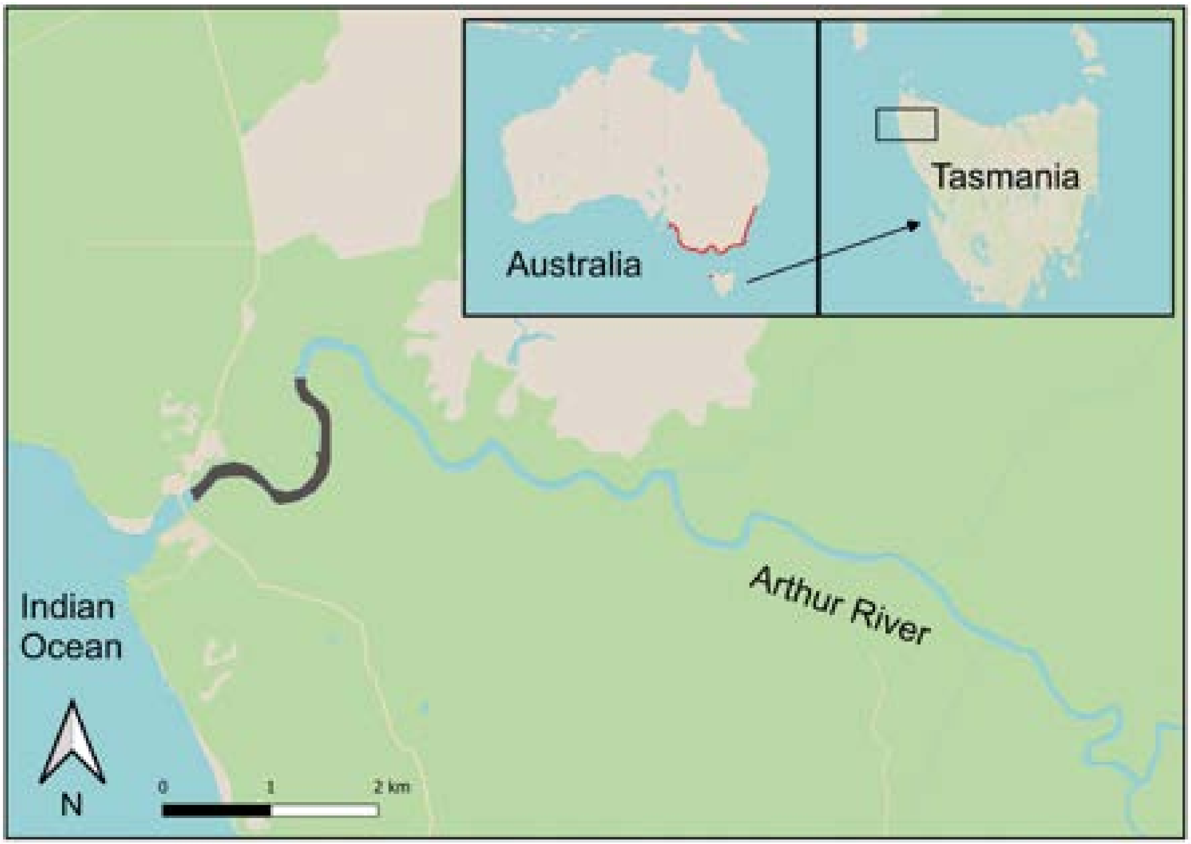

Figure 13. The Arthur River on the west coast of Tasmania and the known distribution of Estuary Perch within the estuary (grey shaded area). Their distribution across Australia is indicated on the insert figures in red. Source: Yick et al., (2025).

Parameterisation

Estuary Perch are currently not fished in the Arthur River. However, we evaluated stock enhancement scenarios with and without fishing. Based on recent sampling, the population is estimated to be approximately 825 to 2,375 individuals (Yick et al. 2025), ranging in size from 150 g (male, 20 cm) to 1.82 kgs (female, 47 cm). These findings are consistent with the 2014/15 survey with mean length of 20 cm. Using a standard length-weight relationship, the estimated standing biomass is 0.6-1.9 tonnes.

The higher end of this range was used to set the baseline biomass at 1.9 tonnes. The life history parameters of wild, stocked and hatchery fish were set equal but reproductive success of stocked and hatchery fish were assumed to be at 80% of wild fish. The model was parameterised based on the life history estimates of Estuary Perch derived from sampling in the Arthur River and presented in (Table 7).

Table 7. Parameters required for EnhanceFish for Estuary Perch.

Parameter	Definition	Estuary Perch	Reference/Notes
Life Cycle			
L_0	Length at larval/juvenile transition (settlement)	2 cm	Yick et al. (2025)
L_r	Length at mortality shift	8 cm	Lorenzen (2019)
a_r	Age at mortality	2 years	Calculated using EnhanceFish
Growth			
L_∞	Asymptotic Length	41.0 cm	Yick et al. (2025)
K	Growth rate	0.11 yr^{-1}	Yick et al. (2025)
g	Competition coefficient	Default	
a	Coefficient of length-weight relationship	2.12^{-8}	Yick et al. (2025)
β	Exponent of length-weight relationship	3.05	
Natural mortality			
M	Mortality of wild phenotype	0.2 yr^{-1}	Estimated
$M_{1,s}$	Mortality of hatchery phenotype	0.2 yr^{-1}	Assumed*
Reproduction			
L_m	Length at maturity	20 cm (50%)	Yick et al. (2025)
p	Steepness of maturity curve	-1	
r	Relative reproductive performance of stocked fish	0.8	
Recruitment			
a^*	Initial slope of stock-recruitment relationship (How many recruits per unit biomass (t))	2103	Calibrated in EnhanceFish based on biomass of 1.8 tonnes.
b^*	Asymptotic recruitment level (at what point adding more recruits has no impact)	3557	
Fishing			
F_∞	Fishing effort asymptote	1 yr^{-1}	
L_c	Gear selection length	22 cm	
q	Steepness of selectivity curve.	-1	
Evolution			
h^2	Heritability of life history traits	0.2	Assumed based on Lorenzen (2001).

*While it may be expected that hatchery reared juveniles have a higher mortality rate than wild fish, we have assumed it will be similar by careful consideration of husbandry methods including pre-release conditioning (e.g. predator exposure, live feed training), use of phenotypically robust wild broodstock to maintain adaptive traits, rearing in enriched environments to mimic natural habitat complexity.

Model Scenarios

Stock enhancement scenarios were developed to examine the impact of different control measures (fishing effort, stocking numbers and release size of individual fish) on the existing population of Estuary Perch in the Arthur River (Figure 14). For each scenario, we varied one of these values while keeping the others constant (Table 8).

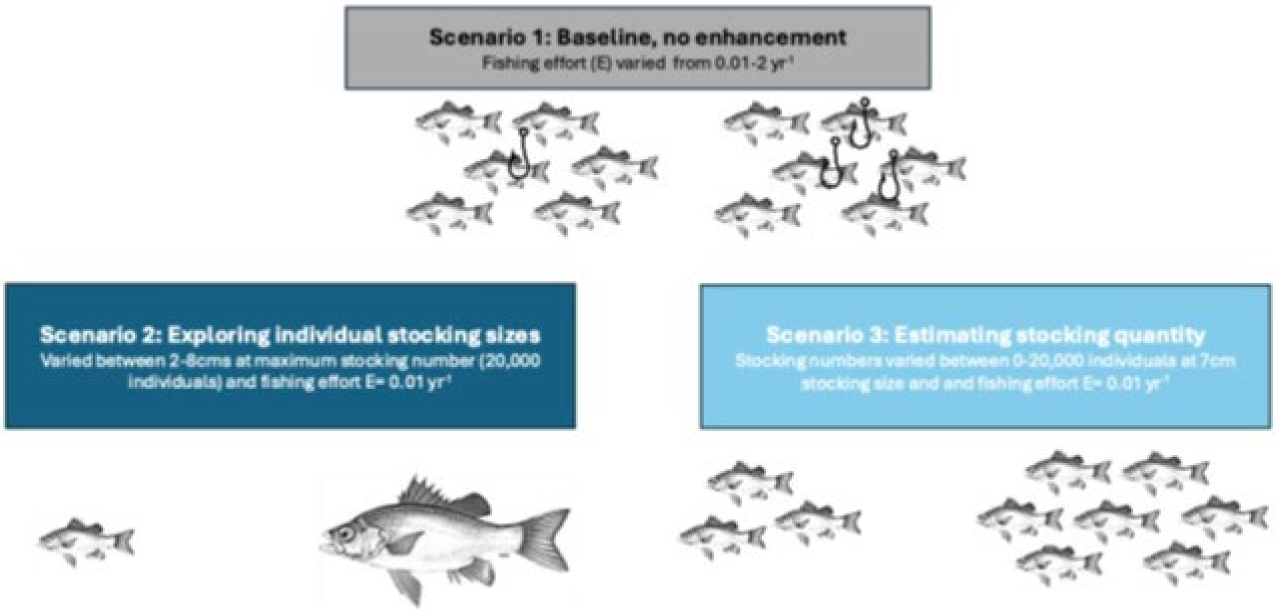

Figure 14. Estuary perch model scenarios.

Scenario 1: Baseline without enhancement Fishing effort varied from (E) 0.01 – 2 yr^{-1}, with no enhancement of the stock with the maximum equilibrium biomass estimated at 1.9 t.

Scenario 2: Exploring individual stocking sizes Initial stocking size varied between 2-8 cm, with stocking numbers set at 20,000 individuals yr^{-1} and E = 0.01 yr^{-1}.

Scenario 3: Exploring stocking quantity Stocking numbers varied between 0 -20,000 individuals yr^{-1}, with stocking size = 7 cm and E = 0.01 yr^{-1}.

Table 8. Summary of scenario parameters assessed for Estuary Perch. A range of values for one parameter are explored in each scenario, this is indicated in bold.

Scenario	Effort (yr^{-1})	Stocking Size (cm)	Stocking Number	Biological Parameters
1	**0.01 - 2**	NA	0	Baseline
2	0.01	**2-8**	20k	Baseline
3	0.01	7	**0-20k**	**Baseline**

Scenario 1: Baseline without enhancement

The model estimates yield to be maximised at E = 0.4 yr^{-1} equating to a catch of 0.1 t which would result in a reduction of equilibrium biomass to 0.7 t equivalent to a B/Bo of 37% (Figure 15). Given the low starting biomass, the stock in Arthur River would be at high risk of extinction if fishing was to occur, even at the low level of 100 kg harvested.

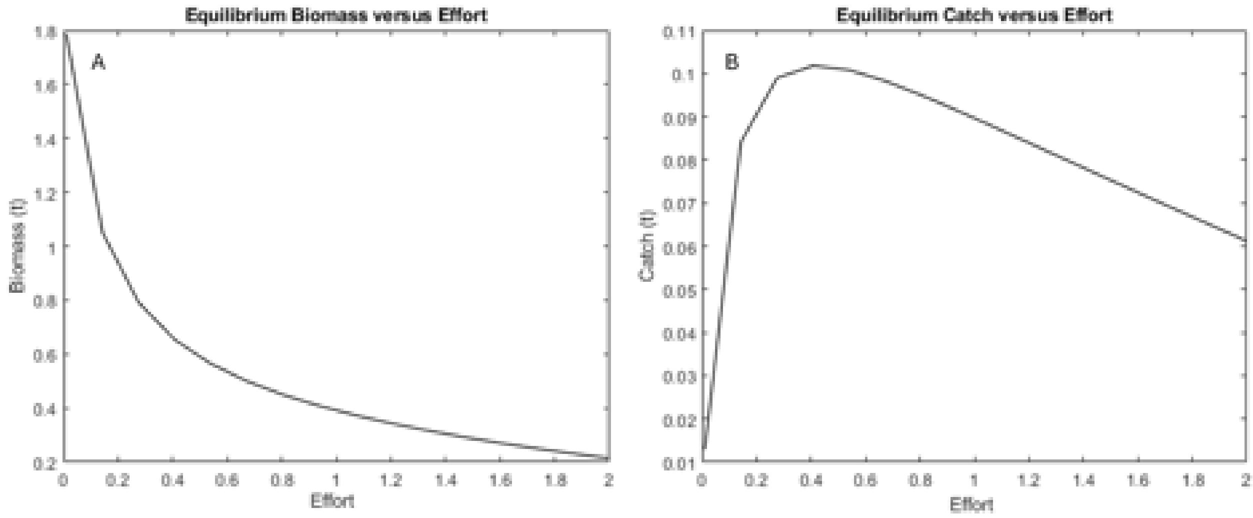

Figure 15. (A) Change in equilibrium biomass and (B) yield with fishing effort for Estuary Perch in the Arthur River with no enhancement.

Below *E* = 0.41, there is no substantial effect on the size composition of the population. Above this level of effort size composition would likely be impacted (Figure 16). Noting however, that the low number of fish in the system would make the population highly susceptible to collapse if fishing mortality was to be introduced. This would need to be carefully considered in context of a catch and release only fishery and a thorough understanding of the impacts of fishing on post release behaviour and mortality.

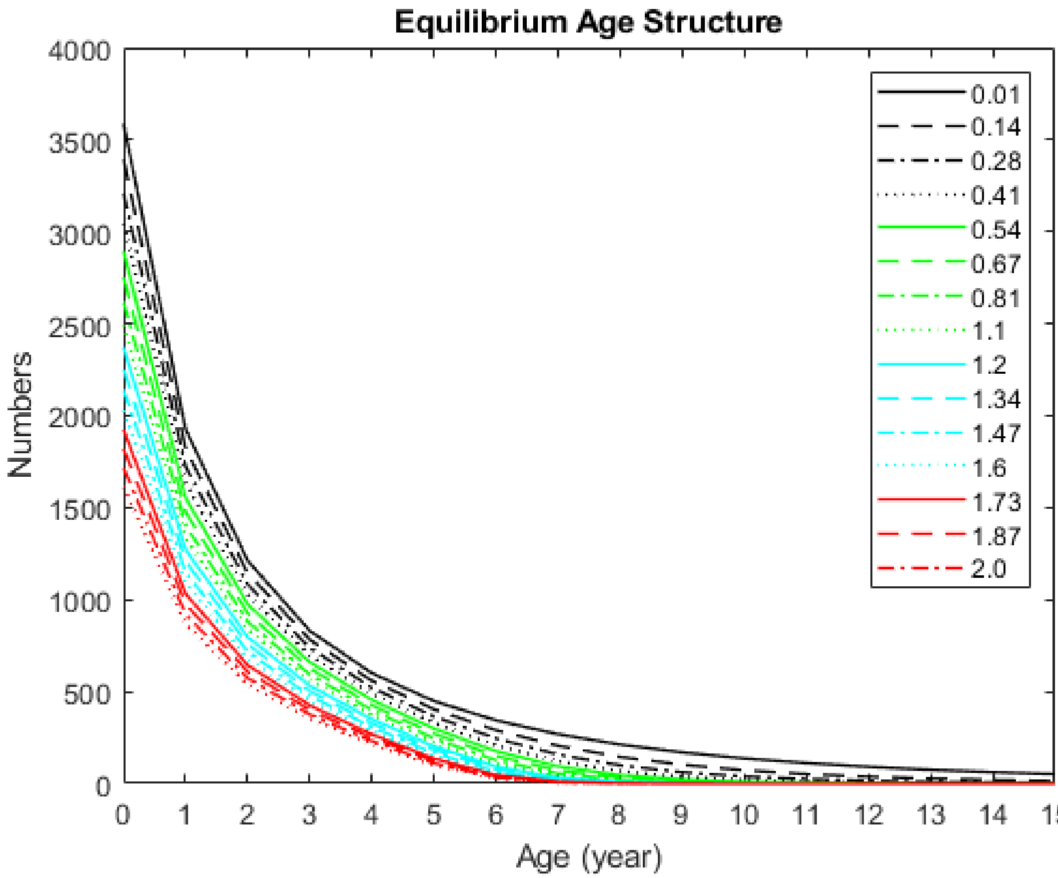

Figure 16. Age structure of the Estuary Perch in Arthur River for different levels of fishing effort (yr^{-1}) (in box).

Scenario 2: Exploring individual stocking sizes

The size of captively reared individuals at the time of stocking has a significant effect on the rate of biomass increase. At an individual stocking size of 4 cm the increase in equilibrium biomass would be approximately 41%, and at 7 cm the increase is estimated at 500% at the maximum assessed stocking number of 20,000 fish. However, from 7 – 8 cm the increase in biomass was substantial with an estimated increase in equilibrium biomass of 2,852% based on stocking 20,000 fish (Figure 17). Although the model does not account for the carrying capacity of the river, so it is likely that the equilibrium biomass would not achieve this degree of increase in a real-world scenario.

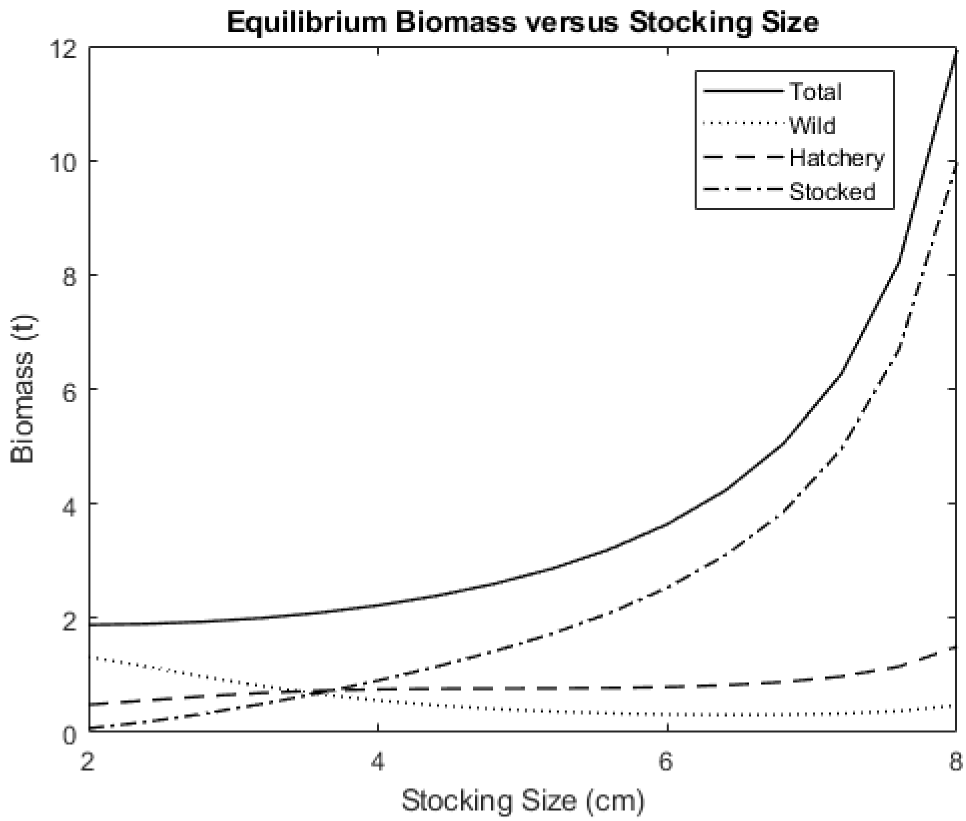

Figure 17. The modelled increase in biomass of the Estuary Perch stock in the Arthur River as stocking size of individual captive reared fish increases from 2 – 8 cm. The modelled scenario presented was set with stocking number = 20,000 individuals and effort (E) = 0.01 yr^{-1}.

Scenario 3: Exploring stocking quantity

The individual stocking size was set at 7 cm based arbitrarily on the results presented in Figure 17, which shows a significant benefit of growing fish in captivity to this size prior to release. A final decision would be based on the trade-off between the additional cost of growing individuals to a larger size compared to the benefit of their increased survival probability. Stocking numbers were then assessed from zero to 20,000 individuals to assess the effect on equilibrium biomass.

Stocking of captive reared fish has a significant positive effect on total biomass (Figure 18). Releasing 10,000 individuals into the Arthur River would significantly increase equilibrium biomass of females by 5.2 t (297%) and with 20,000 individuals increase by 7.1 t (405%) (Figure 18). Based on the assessed stocking numbers the captive bred individuals (hatchery + stocked) will quickly become the dominant contributors to the equilibrium biomass relative to wild fish (Figure 18).

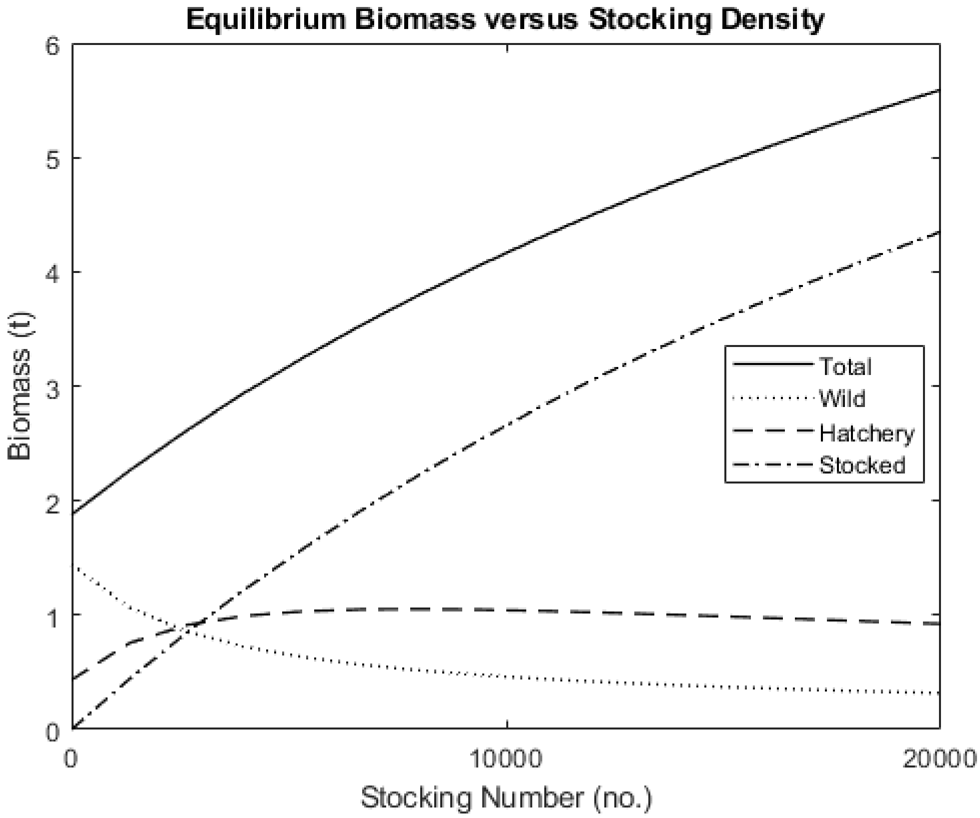

Figure 18. Equilibrium biomass of Estuary Perch changes with stocking number (stocking size = 7 cm, effort = 0.01 yr^{-1}) for wild, hatchery, stocked and combined population.

The stocking model indicates that in a scenario with minimal fishing effort the greatest cost benefit to biomass increase would be realised when stocking 8 cm Estuary Perch. The benefit of increased chance of survival of growing them to a larger size out ways the cost of doing so. If fishing effort was controlled at approximately a level to maximise yield, releasing 8 cm fish would result in the best cost benefit for yield (Table 9), although worth noting the low biomass in the system would likely not support a harvest fishery.

Table 9. Increased biomass and catch resulting from releasing 1000 individual Estuary Perch annually for selected release sizes and levels of effort. Cost to produce an individual is nominally set at $1.50 to release at 4 cm with a 50-cent increase in cost for a two-centimetre increase in release size. The dark green indicates the most cost-effective approach for biomass and yield increase, then the graduation to lighter greens indicates the second and third most cost effective approach.

Release size (cm)	Effort (Yr^{-1})	Biomass increase (Kg)	Annual catch increase (Kg)	Nominal cost per fish ($)	Cost benefit biomass (Kg/$)	Cost benefit catch (Kg/$)
4	0.01	0.017	0.000	1.50	0.011	0.000
4	0.27	0.008	0.001	1.50	0.005	0.001
4	0.54	0.006	0.001	1.50	0.004	0.001
6	0.01	0.029	0.000	2.00	0.014	0.000
6	0.27	0.015	0.002	2.00	0.007	0.001
6	0.54	0.012	0.002	2.00	0.006	0.001
8	0.01	0.066	0.000	2.50	0.026	0.000
8	0.27	0.033	0.004	2.50	0.013	0.002
8	0.54	0.027	0.005	2.50	0.011	0.002

Discussion & Conclusion

Assessing the feasibility of stock enhancement is inherently complex due to interactions among multiple factors, including stocking density, hatchery production costs, biological uncertainties such as post-release survival, and ecological impacts (Hilborn, 1998). The modelling approach adopted here provides a framework to examine these interactions, identify the most influential parameters, and highlight critical data gaps.

The enhancement modelling presented in this study is theoretical and subject to multiple uncertainties that could influence the outcomes. To contextualise our findings and support informed decision-making, several key considerations relating to feasibility, implementation, and species-specific dynamics are discussed.

Feasibility and Economic Trade-offs

Realising the benefits of releasing individuals at larger sizes requires a carefully managed captive rearing process (Hilborn, 1998). Husbandry practices, nutritional inputs, mortality during rearing, and the capacity of fish to transition to natural environments must all be optimised. High mortality rates in hatchery systems may necessitate the production of significantly more juveniles than the desired stocking number, further increasing costs. While sourcing juveniles from external suppliers could mitigate this need, doing so introduces potential biosecurity risks, particularly given that most commercial suppliers are located on mainland Australia. Furthermore, there are clear trade-offs between the size and cost of fish released. Larger individuals are generally more robust post-release but are costlier to produce. Conversely, smaller fish are more economical but may experience higher mortality rates in the wild. If hatchery-reared fish are poorly suited for survival in natural conditions, further refinement of rearing protocols may be necessary, potentially compounding production costs. It is recommended that there is an ongoing research need required in parallel to any stock enhancement process to robustly assess the most efficient and effective application of the approach to realise its full potential.

Importantly, enhancement should not be seen as a substitute for direct management measures such as fishing effort limitations. Instead, it may offer supplementary benefits under specific circumstances, such as countering fishing-induced selection for slower-growing individuals, as has been observed in flathead populations (Lorenzen 2005).

Ecological and Environmental Considerations

The ecological consequences of stock enhancement are a key consideration that can influence both feasibility and long-term outcomes (Brown and Day, 2002). Releasing fish into systems already at or near ecological carrying capacity may lead to competition with wild conspecifics or other species, displacement, or increased mortality (Lorenzen and Enberg, 2002). Similarly, enhanced stocks can alter food web interactions, shifting predation and prey dynamics in unintended ways.

Habitat suitability is also critical; survival of released individuals is strongly dependent on whether available habitat matches the life stage and ecological needs of those fish. Releases that do not consider habitat limitations may fail to achieve desired outcomes or result in ecological disruption.

For the case studies assessed here, system carrying capacity is likely not a constraint for Sand Flathead or Snapper but could be for Estuary Perch. Further, if estuarine systems that historically held Estuary Perch, but do not currently are to have the species re-introduced, careful consideration of habitat suitability, ecological phase shift, and environmental change in the systems would be required as well.

Ecosystem modelling of an increased abundance of Snapper in Tasmania does not predict any dramatic effects of endemic biota (Graba-Landry et al., 2022). As such increasing their population in the southeast through stocking is likely a low-risk scenario to existing ecosystems. For Sand Flathead, the species is endemic to southeast Tasmania and the D'Entrecasteaux Channel. Stocking, particularly of larger phenotype individuals, would not be expected to produce deleterious ecosystem effects. Rather, the objective would be to re-calibrate to a more natural size distribution by introducing larger phenotype individuals.

Genetic Considerations

Genetic considerations are central to the long-term success of enhancement programs (Robert 2009). Several assumptions underpinned this study, including that stocked and wild individuals interbreed at equal likelihood and that morphological traits such as body size are heritable from stocked fish. While these assumptions are necessary for modelling, empirical verification is critical. Genetic studies across families are needed to assess the heritability of traits and the frequency and nature of interbreeding in the wild.

Loss of genetic diversity remains a key risk; captive breeding can reduce genetic variation, increasing inbreeding and lowering population resilience (Araki et al. 2007), this would be particularly relevant for Estuary Perch given their current low genetic diversity in Tasmania. It is recommended that Estuary Perch broodstock is collected from the Arthur River, but careful consideration would need to be applied to ensure that the entire genetic diversity of the population is represented, particularly given the limited diversity reported for the species.

Domestication selection may also occur, whereby captive conditions select for traits unsuitable in the wild (e.g., boldness or altered predator responses). There is also a risk of genetic swamping, where the release of large numbers of hatchery fish alters wild gene pools, particularly if broodstock are not locally sourced. As such, it is highly recommended that if stocking of Estuary Perch or Snapper were to occur, that broodstock be selected from the Arthur River or southeast Tasmania, respectively.

Broodstock management practices are particularly important in mitigating genetic risks. Using wild-sourced broodstock, especially local genotypes, helps preserve adaptive traits, while rotating broodstock and avoiding repeated use of the same individuals reduces the risk of genetic bottlenecks. Strict health screening and quarantine procedures are essential to minimise the introduction of pathogens via captive broodstock (Samuels et al. 2024).

Even if fishing has altered the genetic composition of a population, enhancement alone will not restore genetic diversity unless it is accompanied by appropriate management controls, such as size limits and protection of spawning individuals. The introduction of a maximum size limit for Sand Flathead is a good example of a new management measure to complement enhancement efforts by protecting the larger phenotype individuals once they have grown through the slot limit. An additional measure to consider would be the closure of the region at the time and for the duration that it takes for the stocked individuals to grow through the slot limit. This would provide maximum protection of the stocked fish to ensure that they are given the best chance of contributing significantly to the spawning biomass. Further modelling may also identify ways to optimise management by lowering the slot limit at the time of re-opening to increase effort on the stunted population and increasing the probability of protection for the stocked, larger growing individuals.

Monitoring and Adaptive Management

Robust monitoring and adaptive management are vital for ensuring stock enhancement programs achieve their objectives and avoid unintended consequences. Marking and tracking released fish are essential for assessing survival, their contribution to fisheries, and broader ecological and economic impacts (Lorenzen 2005; Bell et al. 2008).

Baseline data and control sites are critical to evaluating whether observed changes result from enhancement activities or reflect natural variability. Programs must also adopt an adaptive management framework, using monitoring outcomes to inform adjustments in release strategies, hatchery protocols, and broader management actions. These should be considered based on the points raised in the previous section around management controls to optimise the potential of the stocking program

If any stocking is to occur in Tasmania, it is crucial that it is complemented with a monitoring program to measure success and adapt the process if required. Depending on the size of individuals stocked, this could be external passive tags, chemical, isotopic, genetic or a combination of these. The annual fishery independent survey of Sand Flathead conducted by IMAS would facilitate the ongoing monitoring but a communication campaign to fishers would also be required to provide a deep understanding of the importance of releasing stocked fish if caught as the intent is they are the breeding stock for future generations – this would be most relevant if external tagging was to occur.

Species-Specific Observations

Flathead

There is limited experience with captive breeding of flathead species in Australia. Dusky flathead (*Platycephalus fuscus*) was first bred in the 1990s, with a small-scale stocking trial in Queensland (Palmer et al. 2000; Butcher et al. 2000; Butcher 2006). More recently, the Victorian Fisheries Authority initiated a three-year trial to develop consistent hatchery protocols and produce fingerlings for release into East Gippsland estuaries. Similarly, NSW DPI has begun releasing hatchery-reared juvenile dusky flathead into Lake Macquarie. These efforts represent early steps in addressing knowledge gaps, particularly in breeding protocols, although it is not clear what monitoring approaches have been attempted on released individuals.

Understanding regional variation in growth dynamics may be critical to the recovery of Sand Flathead populations. One approach is through selective breeding of particular phenotypes and reintroducing these fish to areas where fast growing, larger individuals have been significantly reduced due to size-selective fishing. Observed differences in body size and size-at-age across Tasmania appear to be influenced by varying levels of recreational fishing pressure (Coulson, Ewing, and Marshell 2022). In areas with lower fishing intensity, such as northeastern Tasmania and Flinders Island, Sand Flathead grow larger at a given age compared to individuals in heavily fished regions, particularly in southeastern Tasmania (Coulson et al. 2022). This pattern suggests that fishing pressure significantly influences growth trajectories, potentially acting as a selective force that drives fisheries-induced evolution (FIE).

Snapper

Snapper (*Chrysophrys auratus*) is among the more advanced species for aquaculture and stock enhancement, with a history of large-scale releases in other countries. In South Australia, the decline in Snapper stocks has been attributed to episodic recruitment failure. To address this, the South Australian Research and Development Institute (SARDI) has led an enhancement program since 2021, releasing hatchery-reared juveniles into nursery habitats. Broodstock are maintained in controlled facilities, and juveniles are marked with alizarin complexone for future identification. Western Australia has also implemented stocking of Snapper.

Despite the scale of these efforts, recapture rates of hatchery fish remain low. In Western Australia, only four hatchery-reared Snapper have been identified among thousands of fish surveyed since 2014. Estimated survival rates suggest that less than 1% of hatchery fish may survive to reproductive age. These outcomes underscore the importance of evaluating cost-effectiveness and program design, including timing and location of releases, genetic compatibility, and early post-release survival.

Estuary Perch

For Estuary Perch (*Macquaria colonorum*), the modelling suggests that enhancement can buffer populations against recruitment failure. However, the absence of a dedicated population model for this species limits confidence in these findings. Developing a species-specific model, supported by field data for calibration and validation, would greatly improve predictive capacity.

In Tasmania, enhancement would require the development of a broodstock program, given biosecurity concerns with importing fish from other jurisdictions and the potential genetic effects of introducing the species from the mainland. On-island breeding remains the most secure long-term solution. The growing interest in Estuary Perch as a recreational species in Tasmania—combined with observed recruitment variability—makes it a promising candidate for enhancement, provided foundational data and infrastructure are developed. This would be particularly relevant if populations from estuaries where the species is now extinct could be reestablished.

Economic Viability and Stakeholder Considerations

Enhancement programs are inherently costly, and their economic viability depends on whether the benefits, such as increased catch per unit effort, improved fisher satisfaction, or socio-economic gains outweigh these costs. Sustained, long-term funding is typically required, as success often hinges on multi-year commitment. There are many examples that have been prone to failure (Hilborn, 1998).

Programs with strong support from fishers, communities, and agencies tend to have greater longevity and success. Stakeholder engagement is thus essential, helping to build public acceptance and social licence. Clear communication of program objectives and transparent monitoring foster trust and promote compliance. An ongoing stocking program would require ongoing funding. Perhaps the best model for this is reflected with the success of the stocking production programs in Victoria and New South Wales which are funded by their general recreational fishing licences, something that is currently not implemented in Tasmania.

Program design must also consider whether enhancement objectives align with resource users, whether targeting recreational or commercial sectors. Equity considerations are important; programs must ensure that benefits and risks are shared fairly across stakeholder groups (Taylor et al. 2017).

Synthesis and Future Directions

Across all species, the viability of enhancement is contingent on a combination of biological, genetic, ecological, economic, and social factors (Leber, 2013). Common requirements include reliable hatchery production, recapture identification techniques, population models to inform stocking strategies, and genetic and ecological monitoring to ensure long-term sustainability.

Species-specific considerations such as the potential for fishing-induced selection in flathead, highly variable recruitment in Snapper, or recruitment buffering in Estuary Perch must be addressed to design effective programs.

While stock enhancement offers a potentially useful tool in the fisheries management toolbox, it is not a silver bullet. Its success depends on rigorous planning, targeted implementation, and continuous evaluation (Hilborn, 1998). Enhancement may be most effective as a complementary measure to traditional management strategies, particularly in the context of environmental variability, declining recruitment, or changing species distributions.

The enhancement modelling presented in this study is theoretical and subject to multiple uncertainties that could influence outcomes. To contextualise our findings and support informed decision-making, future programs must explicitly address key genetic and ecological risks, optimise hatchery and broodstock protocols, incorporate adaptive management, and ensure strong stakeholder engagement. Ultimately, successful enhancement requires an integrated approach that balances biological and ecological realities with social and economic expectations.

If stock enhancement of any marine species is undertaken in Tasmania, it should be subject to annual, scientifically rigorous review to evaluate its ongoing benefits and to refine husbandry, release methods, and overall effectiveness. This includes the integration of enhancement activities into assessment models with greater flexibility than the modelling framework applied in this study. A key consideration is the monitoring of robust phenotypes introduced to counteract size-selective mortality. If successful, such strategies are likely to substantially improve the outcomes of enhancement efforts. For species such as Snapper and Estuary Perch, preliminary physiological and environmental assessments of temperature suitability for both the fish and their habitat are essential. Finally, it is critical that enhancement is carried out ethically, cautiously, and scientifically, with ongoing monitoring to mitigate any unintended consequences associated with stock enhancement.

Conclusion

The findings of this study reinforce that stock enhancement is a complex and nuanced management option. One that must be tailored to species biology, ecological context, and stakeholder priorities. While modelling provides valuable insights into potential outcomes and trade-offs, practical implementation will require careful attention to genetic integrity, ecological interactions, cost-effectiveness, and social licence. Enhancement should be pursued only where it complements, rather than replaces, robust fisheries management frameworks. With targeted investment in monitoring, adaptive management, and stakeholder engagement, enhancement has the potential to contribute meaningfully to fishery sustainability and resilience, particularly in the face of environmental change and recruitment variability. However, the success of any program will depend not only on biological outcomes but on achieving a transparent, inclusive process that balances risks, costs, and community expectations. A fundamental component of success will be access to long-term funding to support the program. A user pays model via general recreational fishing licence revenue has been successful in Victoria and New South Wales and inland waters in Tasmania.

Recommendations

Pursue a Combined Recovery Strategy for Sand Flathead

- Continue implementing reduced fishing pressure through current regulations.
- Supplement natural recovery with targeted hatchery enhancement in the D'Entrecasteaux Channel, given its limited connectivity and high recreational interest.
- Develop cost-effective rearing strategies to balance biological gains against economic feasibility.
- Ensure enhancement fish are at least genetically representative of wild populations or preferably selected to mitigate past selective pressure on larger fish.
- Hatchery work should focus on developing larger individual fish sizes, ideally around 9-10 cm prior to release to maximise survival and biomass gains.
- Releasing approximately 100,000 fish a year will have a marginal positive effect using broodstock from the depleted region and release number should aim to be maximised within budget. If larger size at age phenotypes can be integrated into the population the positive effect would be expected to be greater.
- Consider output management controls to add maximum protection to the reared fish once they enter the size slot limit where they become exposed to the fishery.
- Implement protocols to maintain genetic diversity and avoid domestication selection.
- Develop a monitoring program which includes tagging and genetic tracking to evaluate post-release survival, growth, potential reversal of fishing-induced selection, and contribution of enhancement to biomass recovery.

Leverage Enhancement to Diversify Recreational Fishing Opportunities

- There is opportunity to use enhancement to increase biomass of other popular recreational species which can be leveraged to diversify recreational fishing opportunity.
- Stocking Snapper in the southeast could provide a proactive management strategy, supporting emerging fisheries and relieving pressure on Sand Flathead.
- Consider range-expanding species like Snapper as part of Tasmania's long-term climate adaptation strategy in fisheries management.
- Align Enhancement with Climate Adaptation Planning
- Assess Economic Feasibility and Resource Needs
- Establish Long-Term Monitoring and Evaluation Frameworks - design enhancement programs with embedded monitoring of biomass, survival, genetic impacts, and fishery outcomes.
- Explore enhancement of Estuary Perch for combined conservation and recreational benefits.
- Regularly review outcomes to adjust stocking densities, sizes, and locations when developing stock assessments.
- Conduct cost-benefit analyses to support investment decisions, accounting for hatchery costs, survival rates, and recreational fishery value.
- If enhancement is seen as a core feature of fisheries management in Tasmania, secure long-term funding to support infrastructure, staffing, and genetic monitoring.

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