Appendix E: 2018-047: Barramundi Origins: Determining the contribution of stocking to the Barramundi catch on Queensland's east coast

Background

Significant stocking of Barramundi fingerlings (*Lates calcarifer*) has occurred in Queensland since the 1980s, with over 14 million released into impoundments (dams and weirs) and waterways (DAF, unpublished data). Fingerlings are sourced from hatcheries that breed, hatch, and rear fish through their early life stages. In the Dry Tropics Region (the focus of this project's research) over 3.7 million Barramundi fingerlings have been stocked between 1988 to 2020, with the primary focus on boosting local recreational fisheries (S. Leahy, unpublished data). One in five Australian adults participate in recreational fishing every year and contributes $11 billion to the Australian economy (DAFF, n.d.).

During moderate or exceptional wet seasons, large flows enable stocked fish to move downstream into the wild-capture marine and estuarine commercial fisheries (Wesche et al, 2013). The contribution of the hatchery-born fish to the wild-capture commercial fishery on Queensland's east coast is uncertain. This uncertainty confounds underlying changes in the natural population and the effects of stocking, and results in uncertainty in the necessary management practices required along with assuring the health of wild populations.

Determining the origin of a Barramundi is challenging as it requires a method that is accurate, cost-effective, and replicable at a fishery-relevant scale. Genetic methods such as microsatellite parentage analysis can demarcate hatchery-origin from wild-origin fish, however, it can be expensive when applied at a larger scale (Toomey et al, 2016).

An increasingly common method is to compare the otoliths of hatchery-origin and wild-origin fish. The otolith is a structure found in all vertebrates, and due to differences in ambient water chemistry and diet experienced by hatchery-origin and wild-origin fish, their otoliths have different mineral and chemical composition (Pracheil et al, 2014; Hüssey et al, 2020). These chemical differences can be measured directly using Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) to quantify the otolith's core microchemistry. Alternatively, Near Infrared Spectroscopy (NIRS) is a potential method that could measure chemical differences through optical light and could prove a cost-effective method (Wright et al, 2021). The research aimed to identify the most appropriate method to determine the proportion of Barramundi in the Queensland's east coast wild-capture fishery that is of hatchery origin.

Description of the project

Table 37 Project summary of project 2018-047

Project code	2018-047
Title	Barramundi Origins: Determining the contribution of stocking to the Barramundi catch on Queensland's east coast
Research organisation	Department of Agriculture and Fisheries (QLD), James Cook University, and the University of Western Australia
Principal investigator	Dr Susannah Leahy
FRDC project manager	Toby Piddocke

Period of funding	November 2018 – November 2020
FRDC investment	$261,777
FRDC program allocation	10% Adoption, 10% Communities, 40% Environment, 30% Industry, 10% People

Rationale	In 2017 the Queensland RAC identified a priority "to determine the proportion of Queensland East Coast (marine and estuarine) wild Barramundi catch that is of hatchery origin" due to limited understanding on stocking's contribution to the natural population. Further, this project identified a need to evaluate methods for their suitableness to effectively and efficiently determine fish origins.
Objectives	• Develop a near infrared spectroscopy (NIR) model, an otolith microchemistry model, and a genetic parentage analysis that can distinguish between wild-origin and hatchery-origin barramundi • Compare and evaluate the three different methods and complete a cost-benefit analysis • Determine the proportion of the QLD East Coast wild-catch Barramundi population that is of hatchery origin versus wild-origin to understand the contribution of stocking on the population
Activities and outputs	• Following the major Townsville floods in February 2019, fish samples were collected in 2019 and 2020 directly from the wild-capture marine and estuarine fisheries • Provenance-determination methods were assessed based on their relative accuracy and replicability (replicability in other Barramundi regions and as a routine monitoring tool) • Provenance determination using otolith microchemistry (LA-ICP-MS) was found to be the best approach (highly accurate, >98%) compared to using otolith NIRS and microsatellite parentage analysis • The wild-capture marine and estuarine Barramundi fishery in the Dry Tropics region was determined to be primarily composed of wild-born fish (>95%), and stocking is not significantly supplementing the population • Stocked fish represented 3% of the Barramundi fishery, but hatchery ancestry was detected in 21% of the catch, indicating that stocked fish breed with wild fish and contribute genetic material • Juvenile access to suitable freshwater habitats was found to be important in sustaining the Barramundi fishery • The project was communicated to end users, including fish stocking community groups, the wider recreational fishing community, Barramundi aquaculture facilities, fishery managers, stock assessment scientists, fishery working groups, and the wider fisheries science community
Outcomes	• Strong representation of hatchery ancestry among the wild-born population encouraged policy changes of fish stocking regulations to support local genetic diversity and evolutionary traits • Otolith microchemistry (LA-ICP-MS) has high potential for use in other regions for origin determination and for the collection of fish movement history data and habitat use • Improved information for stock assessments

	• Potential increases in habitat restoration projects, e.g., installing of fishways and habitat remediation to increase juvenile Barramundi access to freshwater habitats
Potential impacts	• Maintenance of stocking rates for recreational opportunities, enhancing wellbeing and promoting outdoor activities • Improved genetic fitness of Barramundi through policy changes - improving ecological systems and social license of stocking groups • Cost savings gained for future research • Increase in Barramundi population, and its resilience, through increased resources, and efficiency of resource allocation in habitat restoration projects • Increase in Barramundi TACC for QLD's wild-catch commercial fisheries, noting that the quantity of Barramundi wild-catch is currently in a period of uncertainty with gillnet fishing closures • Increased research capacity for origin of fish and lifecycle analysis • Improved relationships and increased engagement with community and community groups

Project investment

A breakdown of FRDC investment in the project and contribution by others by financial year is shown in Table 38.

Table 38 Total investment in project 2018-047 from FRDC (nominal dollar terms)

Year ending June 30th	FRDC ($)	Others* ($)
2018/19	$84,084	$177,468
2019/20	$100,733	$193,717
2020/21	$43,960	$77,742
2021/22	$30,000	-
2022/23	$3,000	-
Total	**$261,777**	**$448,927**

Source: Documents provided by FRDC.

*Contributions to the project cost not sourced from FRDC e.g. in-kind contributions

For the BCA, the cost of managing the FRDC funding was added to the FRDC contribution for the project using a management cost multiplier of 1.157. As per impact assessments in previous years, this multiplier was estimated based on a five-year average of the ratio of total FRDC non-project cash expenditure to project expenditure as reported in FRDC's Cash Flow Statement (FRDC Annual Reports, 2019-2023). No multiplier was applied to the investment by other contributors, as it was assumed that project management and administration were included in the value of funding provided.

In undertaking the impact assessment, all past costs were expressed in 2023/24-dollar terms using the Implicit Price Deflator for GDP.

Summary of impacts

Table 39 below provides a summary of the expected triple bottom line impacts (economic, environmental, and social) from the project.

Table 39 Triple bottom line impacts, including those valued as part of this evaluation (in bold)

Economic	• **Cost savings for future research through identification of otolith microchemistry (LA-ICP-MS) as most appropriate method for origin determination and life history** • **Maintenance of wild-catch fish health continuing the potential for wild-catch Barramundi commercial and recreational sectors**
Environmental	• Greater genetic fitness of native Barramundi populations and other native populations of stocked species in QLD • Increase in native Barramundi population, and its resilience, through increased resources, and efficiency of resource allocation, to habitat restoration projects
Social	• **Reduction in likelihood of fish stocking restrictions due to improved social license of stocking** • **Experiential and wellbeing benefits of access to recreational fishing** • Increased scientific and research capacity • Improved relationships and increased engagement with various stakeholders and groups, including Local Councils, Fisheries Managers, Stocking Groups, Habitat Restoration Groups, and recreational fishers • Contribution to Australia's global position in fisheries research and management through international PhD student and project published in an international scientific journal (North America)

Public versus private impacts

The potential impacts identified from the project are likely to accrue both to public and private beneficiaries. Public benefits may be realised through improved habitat restoration activities, maintenance of stocking for the recreational fishing industry and greater research capacity.

Distribution of private impacts

Private impacts realised from this project are likely to be primarily distributed amongst fishers in the the wild-catch commercial fishery in Queensland and their supply chains. Although not quantified below, further benefits may be seen in other states through more effective management practices informed by this project.

Impacts on other Australian industries

No direct impacts to other Australian primary industries were identified.

Impacts overseas

Other countries that engage in stocking practices may face similar uncertainties around the contribution of stocking to native populations, and benefit from how this project informs best practice. Further, the project provides an evaluation of methods, determining the otolith microchemistry approach for origin determination as superior and hence may inform any origin determination studies' approach.

Quantification of impacts

This project has contributed to cataylsing policy changes to regulate stocking groups. Specifically, the project highlighted the movement of genes from hatcheries to stocking impoundments, and into wild-capture fisheries. This flow of genes highlighted the importance of maintaining genetic fitness in hatcheries that are used for stocking. Therefore, policy changes are seeking to regulate stocking groups to source their fingerlings from hatcheries that are meeting certain standards that promote genetic fitness. These regulations will affect Barramundi but will also be applicable to other species which are stocked. This includes Freshwater Catfish, Golden Perch, Mary River Cod, Murray Cod, Northern Saratoga, Redclaw, Silver Perch, Sleepy Cod, Snubnose Garfish, Sooty Grunter, and Southern Saratoga (QLD government, 2020).

Firstly, this policy change will likely preserve the social license of stocking groups to operate in QLD, and therefore mitigate losses to the recreational fishing sector that relies on stocking. Secondly, by proactively recognizing the potential genetic harm caused by current stocking practices - in addition to increased investment focused on habitat restoration projects - the project has promoted a healthy Barramundi population. This benefit was quantified for the recreational Barramundi sector but was not quantified for the Barramundi commercial sector due to the implementation of gillnet bans which has led to uncertainty for the commercial sector. The policy changes will also lead to other benefits not quantified, including positive environmental impacts. Although this project is likely to inform best practice policies in other states, this benefit was not quantified considering its uncertainty.

Additionally, the project determined the origins of barramundi, and similar origin-determination methods could be applied to other species where there may be uncertainty regarding the contribution of stocking to the population. This impact was conservatively quantified, assuming cost savings for future research for the next 5 years.

Estimated benefits

Table 40 Benefit assumptions

Variable	Assumption	Source/ Explanation
Impact 1: Maintenance of the social license of stocking programs in QLD		
a) Value of recreational fishing in QLD for locations where stocking occurs	$100M	Stocking Impoundment Permit Scheme (SIPs) estimated benefit (QLD Government, 2020)
b) Potential impact to recreational value due to decreased social license	5%	1% impact over 5 years, analyst's estimate
c) Consequence of a decrease in social license	$5M	a x b
d) Annual increase in risk	0.45%	Analyst assumption
e) Annual addition to consequence likelihood	$22,500	d x e, accumulates each year for 15 years, then decreases for 15 years, reflecting a shift in likelihood
Impact 2: Healthy native Barramundi population to non-commercial sectors		
f) Barramundi caught by non-commercial sectors	370, 880kg	Kg caught by charter, indigenous and recreational sectors in WA, NT and QLD (modified to account for native catch) (Barramundi SAFS, 2023)

g) Value of catching Barramundi (per fish)	$100	Adjusted value of $153 to reflect more conservative approach considering criticisms within Rutledge et. al 1990.
h) Weight (per fish)	3kg	Rutledge et. al 1990
i) Annual consequence without project	0.25%	Analyst assumption
j) Annual mitigated consequence	$30, 900	i x g x (f / h) Accumulates each year for 15 years, then decreases for 15 years, due to probability of counterfactual occurring
Benefit 3: Efficiencies to future projects		
k) Cost savings when applied to future projects	5%	Analyst assumption
l) Number of future projects per year	2	Analyst assumption informed by researchers
m) Cost of project	$375,000	Analyst assumption - half of this project's cost
n) Number of years before superseded	5	Analyst assumption, findings would have likely occurred under the counterfactual in the near-term
o) Annual cost savings	$37,500	k x l x m

Adoption costs

It is estimated that there are additional costs of $25,000 involved in changing regulations and updating stakeholders.

Counterfactual

It is assumed that without a change in policy and proactive management, there would have been consequences to the genetic diversity of wild populations of stocked fish. Not only would this have negative impacts to the environment, but is also expected to cause partial closures and/or costly mitigation measures for stocking groups.

Attribution

The benefits are expected in the main to be attributable directly to the project.

Table 41 Attribution of benefits for project 2018-047

Variable	Assumptions
FRDC costs	39%
Other project party	58%
Future development	3%

Total	100%

Adoption

The policy changes are expected to occur within the next year. The benefits in research capacity and knowledge are already being utilised in similar projects.

Results

Table 42 below presents the modelled investment performance from the project. All past costs and benefits were expressed in 2023/24-dollar terms using the Implicit Price Deflator for GDP, while all future costs and benefits were discounted to 2023/24 using a discount rate of 5%. A reinvestment rate of 5% was used for estimating the modified internal rate of return (MIRR). The analysis used the best available estimates for each variable, notwithstanding a level of uncertainty for many of the estimates. All analyses ran for the length of the investment period plus 30 years from the last year of investment (2023/24) to the final year of benefits assumed.

Table 42 shows the total investment returning a net present value (NPV) of $5.25 million and a favourable Benefit Cost Ratio (BCR) of 6.7. Table 43 shows the FRDC investment returning an NPV of $2.1 million and BCR of 6.7.

Table 42 Investment criteria for total investment in Project 2018-047 ($M)

Year	0	5	10	15	20	25	30
PV Benefits	$0.08	$1.07	$2.66	$4.45	$5.59	$6.08	$6.16
PV Costs	$0.91	$0.91	$0.91	$0.91	$0.91	$0.91	$0.91
NPV	-$0.83	$0.16	$1.75	$3.53	$4.68	$5.17	$5.25
BCR	0.1	1.2	2.9	4.9	6.1	6.7	6.7
IRR	-35%	7%	16%	19%	19%	19%	19%
MIRR	-5%	6%	8%	9%	10%	9%	9%

Table 43 Investment criteria for FRDC investment in Project 2018-047 ($M)

Year	0	5	10	15	20	25	30
PV Benefits	$0.03	$0.43	$1.07	$1.78	$2.24	$2.44	$2.47
PV Costs	$0.37	$0.37	$0.37	$0.37	$0.37	$0.37	$0.37
NPV	-$0.33	$0.06	$0.70	$1.42	$1.87	$2.07	$2.10
BCR	0.1	1.2	2.9	4.9	6.1	6.7	6.7
IRR	N/A	7%	16%	19%	20%	20%	20%
MIRR	-5%	6%	8%	9%	10%	9%	9%

The flow of total undiscounted costs and benefits from the project is presented in Figure 5 below.

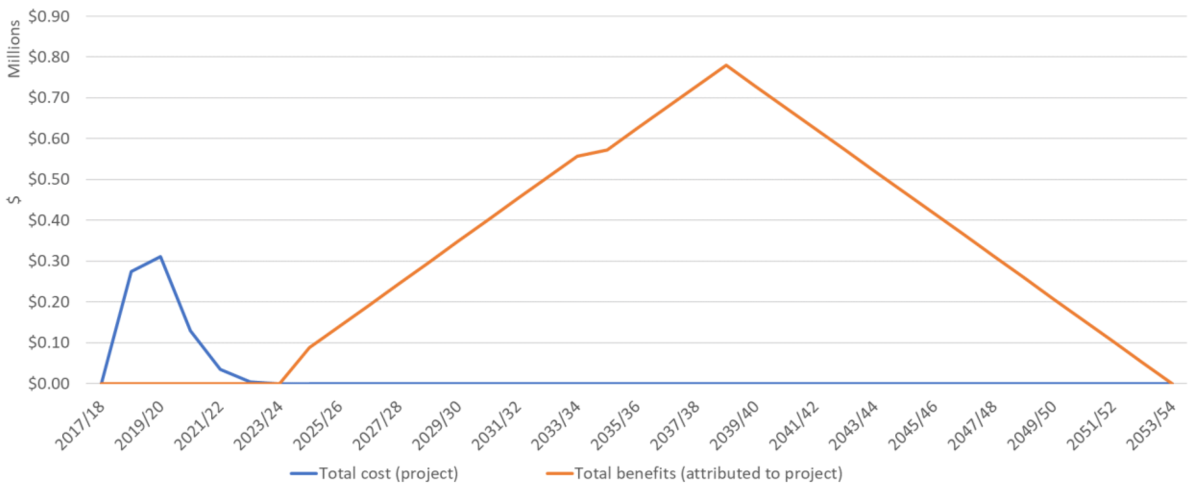

Figure 5 Flow of undiscounted costs and benefits from the project.

Sensitivity Analysis

A sensitivity analysis was carried out to determine how the investment performance (NPV, BCR and MIRR after 30 years) would change based on changes to the discount rate and other key variables. The results are presented in Table 44 below and show that the project will deliver a positive NPV ($M) across all modelled scenarios.

Table 44 Sensitivity analysis

Changes to key variables	NPV ($M)	BCR	MIRR
Standard assumption	5.25	6.7	9%
Adjusted discount rate			
4%	6.07	7.6	8%
6%	4.55	6.0	10%
Value loss to SIPs under counterfactual (%)			
2.5%	4.01	5.4	8%
7.5%	6.49	8.1	9%
Impact to recreational value			
0.2%	4.57	6.0	9%
0.3%	5.93	7.5	9%

Confidence ratings

The accuracy of the assessment is highly dependent on:

- The extent to which the analysis captures and quantifies the various benefits from the project, including non-market benefits (i.e. coverage of benefits), and
- The level of confidence in the accuracy of assumptions used (i.e. confidence in assumptions).

An assessment of coverage and confidence ratings for this project is presented below in Table 45.

Table 45 Coverage and confidence ratings

Factor	Rating	Comment
Coverage of benefits	Medium	The benefits that are considered most likely to occur have been quantified. However, this project represents a breadth of findings which could lead to many other impacts.
Confidence in assumptions	Low	Although the value add of the project is clearly large, the assumptions are often based on conservative estimates due to a lack of alternatives.

Conclusions

Project 2018-047: Barramundi Origins: Determining the Contribution of Stocking to the Barramundi Catch on Queensland's East Coast determined that only a small proportion of Queensland East Coast wild catch Barramundi was of hatchery origin and allowed for an understanding of stocking's contribution to the natural population in terms of genetic material. This has contributed to developing policy changes that will likely maintain the social license of stocking programs in QLD, and therefore uphold its associated recreational fishing value. Further, this project may be utilized by other jurisdictions nationally to inform best practice policies.

The project also found that juvenile access to suitable freshwater habits was important in sustaining the Barramundi fisheries, likely encouraging increased investments into such projects. This - in conjunction with the policy changes aimed to promote genetic fitness – will likely contribute to the maintenance of Barramundi populations throughout QLD, NT, and WA.

The project evaluated methods of origin-determination, finding that otolith microchemistry (using LA-ICP-MS) was the most suitable, likely producing efficiencies and cost savings for future research projects seeking to determine the origins of fish species to improve stock assessments.

The numerous positive impacts that were identified from the project, and the adopted assumptions of this analysis, estimates that the project investment will likely deliver a significant positive economic benefit (BCR 6.7), which remains positive under all scenarios modelled.

References

DAFF (Department of Agriculture, Fisheries and Forestry). (n.d.) *Recreational Fishing.* Australian Government. [online]. Retrieved from: https://www.agriculture.gov.au/agriculture-land/fisheries/recreational#:~:text=1%20in%205%20Australian%20adults%20participate%20in%20recreational,jobs%20and%20%2411%20billion%20to%20the%20Australian%20economy.

Hüssy, K., Limburg, K.E., de Pontual, H., Thomas, O.R.B., Cook, P.K., Heimbrand ,Y., Blass, M. & Sturrock, A.M. (2020). *Trace Element Patterns in Otoliths: The Role of Biomineralization.* Reviews in Fisheries Science & Aquaculture, 1-33..

Leahy, S.M., Jerry, D.R., Wedding, B.B.C., Robins, J.B., Wright, C.L., Sadekov, A., Boyle, S., Jones, D.B., Williams, S.M., McCulloch, M.T., Grauf, S., Pavich, L., McLennan, M., Sellin, M.J., Goldsbury, J., Saunders, R.J., Queensland Department of Agriculture and Fisheries, James Cook University, & the University of Western Australia. (2022). *Barramundi origins: determining the contribution of stocking to the barramundi catch on Queensland's east coast*. Project 2018-047, prepared for FRDC. https://www.frdc.com.au/project/2018-047 Cairns, Australia. CC BY 3.0.

Pracheil, B.M., Hogan, J.D., Lyons, J. & McIntyre, P.B. (2014). *Using hard-part microchemistry to advance conservation and management of North American freshwater fishes*. Fisheries 39(10), 451-465.

QLD Government. (2020). *Policy for fish stocking in Queensland.* Retrieved from: https://www.daf.qld.gov.au/?a=109113:policy_registry/fish-stocking-in-qld-policy.pdf

Rutledge, W., Rimmer, M., Russell, J., Garrett, R. and Barlow, C. (1990). *Cost Benefit of Hatchery-reared Barramundi, Lates calcarifer (Bloch), in Queensland*. Aquaculture and Fisheries Management, 21: 443-448.

Toomey, L., Welsford, D., Appleyard, S.A., Polanowski, A., Faux, C., Deagle, B.E., Belchier, M., Marthick, J. & Jarman, S. (2016). *Genetic structure of Patagonian toothfish populations from otolith DNA*. Antarctic Science 28(5), 347-360.

Wesche, S., Lucas, T., Mayer, D.G., Waltisbuhl, D. & Quinn, R. (2013). *Gladstone Harbour Fish Health Investigation 2011-2012*. Queensland.

Wright, C., Wedding, B.B., Grauf, S. & Whybird, O.J. (2021) *Age estimation of Barramundi (Lates calcarifer) over multiple seasons from the southern Gulf of Carpentaria using FT-NIR spectroscopy*. Marine and Freshwater Research 72(9), 1268-1279.

Acknowledgements

GHD would like to thank Toby Piddocke, Project Manager at FRDC for their guidance and feedback throughout the impact assessment process. GHD extends particular thanks to Dr Susannah Leahy, Principal Investigator, Senior Fisheries Scientist from the Queensland Department of Agriculture and Fisheries (August 29th 2024) and Tim Lucas from the Queensland Department of Agriculture and Fisheries (September 10th 2024) for their time during the project's consultation phase.