Northern Basin Toolkit Ecological Prioritisation of Proposed Project

Report from independent expert ecological panel

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Summary

The Australian, Queensland and New South Wales governments are currently seeking to invest in a range of complementary measures to improve the ecological outcomes of water management in the northern Murray-Darling Basin and support the environmental objectives of the Basin Plan. Broadly termed 'Toolkit measures', these are environmental works and measures aimed at improving ecological outcomes by enhancing habitat for aquatic organisms, building ecological resilience and protecting or enhancing the delivery of environmental water by addressing constraints.

Engaged as an independent expert ecological panel, we assessed 27 project proposals provided by Queensland and New South Wales, following the *Northern Basin Toolkit Ecological Prioritisation Framework*, according to five criteria: 1. Ecological benefits and dis-benefits; 2. Spatial scales of ecological benefits and dis-benefits; 3. Temporal scales of ecological benefits and dis-benefits; 4. Scientific confidence and 5. Synergies.

Most project proposals were focused on providing ecological outcomes for native fish, particularly by enhancing fish passage. Only eight projects were judged likely to generate moderate to significant benefits for vegetation and waterbirds with no projects specifically targeting waterbirds. Some degree of risk, either in relation to possible perverse outcomes or trade-offs, were identified for most projects.

Most proposed projects are likely to generate ecological benefits at local (site and reach) scales with some also accruing significant benefits at catchment scales and a few at sub-basin to basin scales, especially those targeting Ramsar sites. Moderate to significant dis-benefits can be expected across all scales but especially catchment scales where trade-offs are involved. Projected frequencies of ecological benefits are moderate to high with dis-benefits most likely to occur with low to moderate frequency. Benefits of most projects are likely to be permanent and enduring.

We had moderate to high scientific confidence in the projected ecological benefits and dis-benefits and proposed techniques in most cases. We also assessed outcomes as being highly measurable in all cases. However, adequate monitoring and evaluation approaches were not provided in any proposal, particularly as risks and trade-offs were not explicitly considered.

All of the proposed toolkit projects were considered to have some degree of ecological merit and worthy of further development at some stage in the future, if not during the current investment round. Seven projects, however, all scoring greater than 50 %, were deemed to be particularly worthwhile in relation to their potential to generate significant and broad ecological outcomes for multiple taxa, low ecological risks or risks that have the potential to be well managed through careful planning and operations, high significance across multiple spatial scales, frequent and enduring benefits and a high degree of potential for synergies to generate ecological outcomes across the northern Basin. These comprised three projects addressing constraints in the Gwydir, two projects (one in Queensland and

one in New South Wales) focusing on improving fish passage, and two projects (also one in each State) concerning enhanced capacity to manage flows into two Ramsar sites (Narran Lakes and Macquarie Marshes).

Ten projects scoring below 30 % were deemed to have very low, narrow or uncertain ecological merit, relatively high ecological risk and mostly small spatial scales of influence as well as few if any synergies. These included four projects proposing re-introductions of threatened fish species, a project seeking to reconnect billabongs in the Barwon-Darling, and several fishway projects in geographically remote or disconnected locations.

Based on the results of our scoring, and reflecting our qualitative ecological evaluation, we suggest two major options for selecting proposals to progress to the stage of business case development at the current time.

- Option 1. Fund the seven highest ranking projects: Gwydir Constraints Measures projects for the Gingham watercourse, Lower Gwydir watercourse and Mehi River, the NSW Fish for the Future Barwon-Darling and Border Rivers fishways project and the Queensland Border Rivers fishways project and the two projects enhancing watering for the Macquarie Marshes and Narran Lakes. All of these projects were considered to be very worthwhile with a good likelihood of broad and enduring ecological outcomes and risks that can be well managed. With a total estimated cost of $106.59M, funding these projects would leave a reasonable balance that could fund the next most highest-ranking project (i.e. Queensland's Reconnecting Catchments project) or, as we strongly recommend, providing significant support for the development of a robust and spatially and thematically integrated monitoring, evaluation and research (MER) programme specifically focused on addressing evaluation questions related to Toolkit measures as well as informing improved development and prioritisation of remaining toolkit proposals for future funding opportunities.

- Option 2. Develop integrated cross-border project bundles, e.g. a "Border Rivers Linkages" project promoting improved fish passage and habitat along the entire length of the Darling-Barwon-Macintyre system. Bundling projects with clear areas of alignment and compatibility so that they were designed and implemented in an integrated way, could generate much greater ecological benefits over significantly larger scales as well as providing opportunities to reduce costs through economies of scale, including the development of a targeted, integrated MER programme.

We also highlight key matters for consideration in the development of business cases including:

- Detailed hydrologic models (including climate change projections)

- Detailed investigations of current ecological condition and proposed outcomes (species presence, condition, other threats etc.)
- Detailed design considerations for technical works
- Operational considerations (including maintenance)
- Trade-offs and associated mitigation strategies
- Timelines for proposed works & trajectories of change
- Detailed MER plans (with integration?)
- Cost-benefit considerations
- Strong community engagement & co-design

Finally, we note that despite some challenging aspects, largely associated with an insufficiency of information in the feasibility studies provided, application of the prioritisation framework was fit for purpose, facilitating a robust and relatively unbiased approach to ranking the proposed projects, despite their inherent differences.

Contents

1. Introduction

1.1 Background and context

The northern Murray-Darling Basin represents a substantial portion of the Murray-Darling Basin, delineated by the catchments of the Barwon-Darling river system and its tributaries upstream of Menindee Lakes. Comprising significant areas of both southern Queensland and northern New South Wales, the northern Basin encompasses a complex system of diverse human and ecological communities with many and varied water needs. The region has a unique climate, characterised by high levels of hydrologic variability, contributing further to a complex water management context.

In 2016, the Murray-Darling Basin Authority (MDBA) completed a four-year review of water resources management in the northern Basin, including an assessment of ecological and community needs. A major recommendation of this review was a 70 GL reduction to the 390 GL per year water recovery target in the northern Basin, accompanied by a commitment from the federal, Queensland and New South Wales governments to implement a range of complementary measures to improve the ecological outcomes of water management in the northern Basin and support the environmental objectives of the Basin Plan. Broadly termed 'Toolkit measures', these are environmental works and measures aimed at improving ecological outcomes by enhancing habitat for aquatic organisms, building ecological resilience and protecting or enhancing the delivery of environmental water by addressing constraints (MDBA, 2019).

A range of Toolkit proposals for the northern Basin have been developed by Queensland and New South Wales and feasibility studies for these presented to the Australian government. These proposals are now subject to a Ministerial approval process with projects selected for progression to business case development expected to be announced by the end of 2020 and final projects to be completed by 2024. To contribute to this decision-making process, an independent expert panel was established to evaluate the ecological merit of project proposals and score and rank these according to a pre-established prioritisation framework. This report presents our findings.

1.2 Aims and approach

We assessed 27 projects based on feasibility studies submitted by Queensland and New South Wales state governments (Table 1). These included 14 project proposals from Queensland - seven fish passage projects, one cold-water pollution project, one riverine fish habitat improvement project, three threatened species recovery project, one fish exclusion screen project and one project concerning bifurcation weirs in the Lower Balonne. Nine project proposals from New South Wales were evaluated – five projects concerning Gwydir Constraints Measures, one billabong restoration project, an enhanced watering project for the Macquarie Marshes, a flow capacity and fish passage project for the Cudgegong and a multi-faceted Fish for the Future project. We also individually

assessed each of the four components of the Fish for the Future project as these aligned well with Queensland fish-focused proposals on fishways, cold-water pollution, exclusion screens and threatened species recovery.

We scored these 27 'projects' against 96 criteria following the *Northern Basin Toolkit Ecological Prioritisation Framework* (MDBA, 2019), drawing on information provided in feasibility study, and accompanying, documents. Two workshops were also held in which Queensland and New South Wales proponents presented further information and clarified questions regarding each submission. We conducted several rounds of independent scoring of each project informed by discussions of the panel as a whole. Final individual scores were then integrated and aligned to generate consensual scores for each project which were normalised following the prioritisation framework guidelines.

1.3 Structure of this report

This report presents the findings of the independent expert ecological panel. Detailed raw scores for each criterion for each project are provided (Appendix 1), as well as discussion regarding key considerations underpinning scoring decisions (Appendix 2). The main body of the report provides a summary of these findings with respect to each criterion and a ranking of project proposals by their total normalised scores (Table 2). Comments are also provided regarding the application of the prioritisation framework. Recommendations are then given regarding selection of projections for progression to the business case development stage as well as key matters that require consideration during this stage.

Table 1. Northern Basin Toolkit Proposals assessed by the independent ecological expert panel.

Proponent	Feasibility Proposal	Project ID	Project Name	Proposed Ecological Outcomes	Proposed Works	Estimated Cost
NSW	NSW Fish for the Future	NFFF	Fish for the Future	Fish	Various	$105.8M
NSW	NSW Fish for the Future	NFFF_1	Reconnecting the Northern Basin	Fish	Barwon-Darling fishways Border rivers fishways	$36.7M $15.2M
NSW	NSW Fish for the Future	NFFF_2	Addressing cold water pollution	Fish	Multi-level offtake Pindari Dam	$14.0M
NSW	NSW Fish for the Future	NFFF_3	Fish-friendly water extraction	Fish	Screens Barwon-Darling Screens Gwydir	$11.2M $6.4M
NSW	NSW Fish for the Future	NFFF_4	Threatened Species Recovery	Fish	Hatchery, restocking and habitat rehabilitation	$9.0M
NSW	NSW Gwydir Constraints Measure	NGCM_1	Gingham Watercourse	Fish, Waterbirds, Vegetation		$19.1M
NSW	NSW Gwydir Constraints Measure	NGCM_2	Lower Gwydir Watercourse	Fish, Waterbirds, Vegetation		$10.6M
NSW	NSW Gwydir Constraints Measure	NGCM_3	Mallowa Watercourse	Fish, Waterbirds, Vegetation		$25.1M
NSW	NSW Gwydir Constraints Measure	NGCM_4	Ballin-Boora Creek	Fish, Waterbirds, Vegetation		$1.25M
NSW	NSW Gwydir Constraints Measure	NGCM_5	Mehi River	Fish, Waterbirds, Vegetation	Removal of 11 structures	$1.5M
NSW	NSW Project Scoping Initiative	NPSCI_1	NSW Barwon-Darling billabong restoration	Fish, Waterbirds, Vegetation	4 sites (no comp) 4 sites (compensation)	$1.07M $10.70M
NSW	NSW Project Scoping Initiative	NPSCI_2	Macquarie Marshes enhanced watering	Fish, Waterbirds, Vegetation	Oxley Break Mumblebone Breaks	$1.15M $1.34M

NSW	NSW Project Scoping Initiative	NPSCI_3	Cudgegong River flow capacity and fish passage	Fish, Vegetation	Raising RW Bridge Fish Passage (Mudgee)	$1.12M $5.12M
QLD	Addressing Cold Water Pollution	QCWP_1	Border Rivers	Fish	Multi-level offtake Glenlyon Dam	$3M
QLD		QCWP_2	Bringing back riverine habitat for native fish	Fish	Lower Balonne (Habitat) Condamine (Habitat) Border Rivers (Habitat) Warrego (Habitat) Moonie (Habitat) Condamine (Habitat) Riparian works	$1.5M $2.5M $1M $1M $500K $500K $16.25M
QLD	Fish friendly water extraction	QFFWE_1	Condamine-Balonne & Border Rivers	Fish	Screens Border Rivers Screens Lower Balonne Screens Upper Condamine	$2M $2M $2M
QLD		QFFWE_2	Enhance the Flexibility and Capability for Distributing and Managing Low Flows Through the Lower Balonne River System Bifurcation Weirs	Fish, Waterbirds, Vegetation	Replace existing weirs	$4M
QLD	Improving Within-Catchment Fish Resilience	QICFR_1	Border Rivers	Fish	Fishway Boomi Fishway Boggabilla Fishway Goondiwindi Fishway Bonshaw Fishway Glenarbon Removal Cunningham Weir	$4M $2M $2M $3M $3M $3M
QLD	Improving Within-Catchment Fish Resilience	QICFR_2	Upper Condamine	Fish	Cecil plains Talgai and Lemon Tree	$2.5M $5M
QLD	Improving Within-Catchment Fish Resilience	QICFR_3	Condamine & Balonne	Fish	Fishway Surat Weir Fishway Cotswold Weir	$3M $3M

					Fishway Condabri Weir Fishway Chincilla Weir	$2.5M $2M
QLD	Improving Within-Catchment Fish Resilience	QICFR_4	Lower Balonne	Fish	Fishway Cubbie Intake Fishway Gurrawarra Weir FIshway Brenda Weir Fishway Whyenbar Regulator Fishway Hastings Weir	$6M $4M $1M $2M $1.5M
QLD	Improving Within-Catchment Fish Resilience	QICFR_5	Narran River	Fish	Fishway Clyde Weir Fishway Wynella Weir FIshway Mooredale/Killarney Fishway Bangate Fishway Narran Park Fishway Police Lagoon Fishway Wilby Wilby Fishway New Angledool FIshway Clyde-Cavillon Bil Bil Weir removal Bangate bridge removal	$3M $2.65M $3.3M $2.5M $2M $3.4M $1M $1M $500K $200K $150K
QLD	Improving Within-Catchment Fish Resilience	QICFR_6	Warrego	Fish	Fishway Cunnammulla Weir	$3M
QLD	Reconnecting catchments	QRC	Condamine-Balonne	Fish	Fishway Jack Taylor Dam Fishway Beardmore Dam	$6M $9.5M
QLD	Threatened species re-establishment	QTSR_1	silver perch, purple-spotted gudgeon and olive perchlet	Fish	Silver perch (condamine) Purple spot/Olive perchlet	$1.24M $1.24M
QLD	Threatened species re-establishment	QTSR_2	River blackfish	Fish	Reintroductions, Hatchery, translocation	$1.5M
QLD	Threatened species re-establishment	QTSR_3	Murray cod and freshwater catfish in the Paroo River	Fish	Reintroductions, Hatchery, translocation	$2.0M

2. Results

2.1 Scoring summary for individual criteria

Summaries of scores for each criterion and total scores are provided here. For a detailed rationale behind scoring decisions along with considerations for business case development for each project, please refer to Appendices 1 and 2.

2.1.1 Criterion 1 – Ecological benefits and dis-benefits

The majority of project proposals submitted clearly focus on delivering benefits to native fish (Table 1), largely through four approaches, i.e. enhancing fish passage, exclusion screens, improving fish habitat and species re-introductions. Many projects also have river flow and connectivity objectives, but again these are largely related to improving fish passage, mostly longitudinally, and mostly in an upstream direction, along the main stems of key watercourses. Relatively few projects (8 of 27) are likely to have moderate to substantial benefits for vegetation or waterbirds, with no projects specifically targeting waterbirds (Appendix 1 and 2). These eight projects mainly comprise those focused on delivering improved watering regimes to significant areas of wetland vegetation and waterbird breeding habitat, e.g. NGCM_1 and 2. Some projects also propose measures to improve fish habitat by directly enhancing riparian (or aquatic) vegetation condition (e.g. QCWP_2).

Risks of ecological dis-benefits were identified for most projects, with the exception of the two fish exclusion screening projects (Appendix 2). In general, these risks either entailed possible perverse outcomes, especially the spread of invasive species (e.g. carp, lippia), or trade-offs. Increasing connectivity and watering of wetlands that are known carp hotspots, for example, have the potential to promote carp recruitment and spread in the northern Basin. Similarly, increased frequency and extent of wetland watering without sufficient durations of inundation risk promoting the establishment of invasive plant species or encroachment of wetland vegetation of terrestrial species. Such responses have been observed, for example, with respect to Moira grass wetlands in Barmah Forest (Collof *et al.*, 2014). Increased watering frequency with reduced durations may also shift the structure, and therefore ecological function, of some key wetland vegetation communities. For example, lignum shrubland with high value for waterbird breeding habitat is typically sustained by longer and deeper inundation periods than other areas of lignum shrubland. Increasing flood frequency without adequate flow durations risks promoting lignum recruitment and altering shrubland structure such that its value for waterbird breeding may decline (Capon *et al.,* 2009). With regards to trade-offs, many of the projects focusing on enhancing longitudinal river flow and connectivity, for instance, are likely to result in reduced lateral flows and connectivity in other areas with the potential for significant ecological impacts (e.g. declining vegetation condition).

In general, projects that scored highly for Criterion 1 were those likely to provide benefits to multiple taxa (i.e. fish, vegetation and waterbirds) with minimal risk of ecological dis-benefits or at least risks that have the potential to be effectively managed (Figure 1, Appendix 1). Projects with expected outcomes in high conservation value areas, especially Ramsar sites, also tended to score highly. Projects with low scores against this criterion were mostly those with a high degree of uncertainty regarding likely benefits (e.g. threatened species recovery projects), relatively narrow scope for benefits (e.g. QICFR_5 and 6), or a high degree of perceived risk for perverse outcomes (e.g. NPSCI_1).

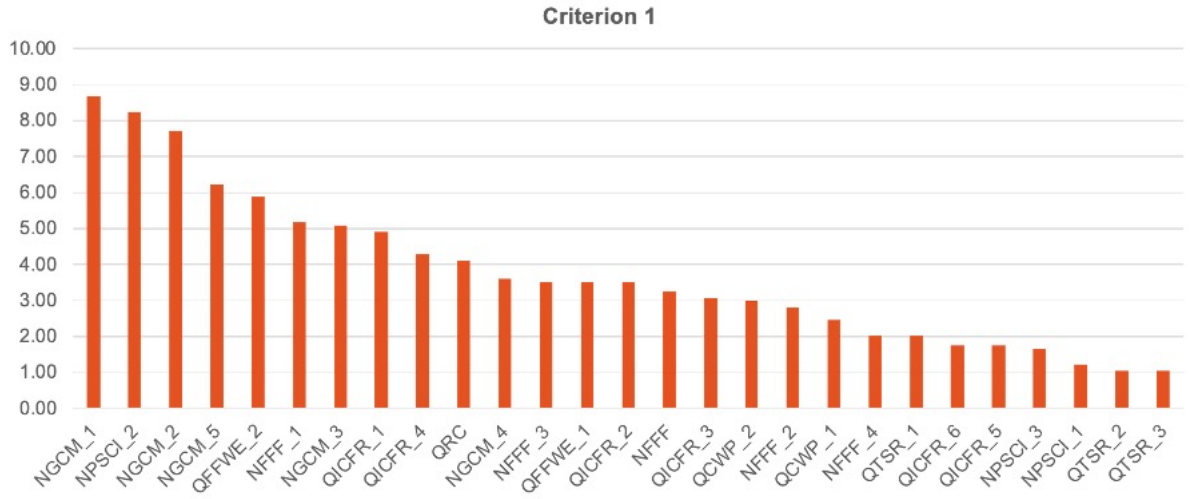

Figure 1. Normalised scores of Northern Basin Toolkit Proposals for Criterion 1 – ecological benefits and dis-benefits. N.B. See Table 1 for key to Project IDs.

2.1.2 Criterion 2 – Spatial scales of ecological benefits and dis-benefits

Most projects were deemed to provide moderate to significant ecological benefits at the specific site and reach scales associated with their proposed works. A considerable number of projects, however, were also judged likely to accrue significant benefits at catchment scales, especially through gains in connectivity. Several projects, especially those targeting Ramsar sites, are also likely to generate moderate to high benefits at a sub-basin to Basin scale (Appendix 1). Where the potential for ecological dis-benefits to occur was identified, these are expected to be moderate to significant across all scales but especially at catchment scales due to the trade-offs involved.

Projects which scored highly in relation to this criterion again included those associated with Ramsar sites and those providing benefits to multiple taxa as well as those with benefits to connectivity likely to have catchment to sub-basin ecological outcomes (Figure 2). Projects with low scores for Criterion 2 included those with a high potential for reach-scale to catchment-scale dis-benefits (e.g. NPSCI_1)

or projects where ecological benefits are unlikely to accrue over greater spatial scales due to their geographic location and/or barriers (e.g. QICFR_5).

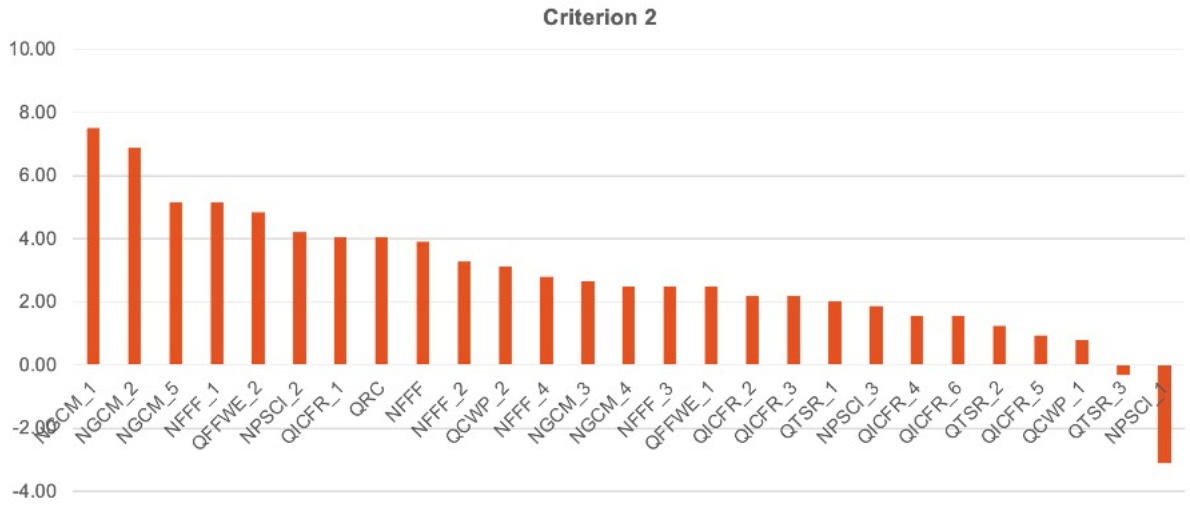

Figure 2. Normalised scores of Northern Basin Toolkit Proposals for Criterion 2 – spatial scales of ecological benefits and dis-benefits. N.B. See Table 1 for key to Project IDs.

2.1.3 Criterion 3 – Temporal scapes of ecological benefits and dis-benefits

Expected ecological benefits were deemed likely to occur with moderate to high frequency, especially for native fish. In contrast, projected dis-benefits are expected to occur at low to moderate frequencies. Most ecological benefits have the potential to be enduring and permanent because of their capacity to enhance both population condition and ecological resilience. High and low scoring projects for this criterion tended to reflect similar patterns in scoring for Criterion 1 and 2 (Figure 3).

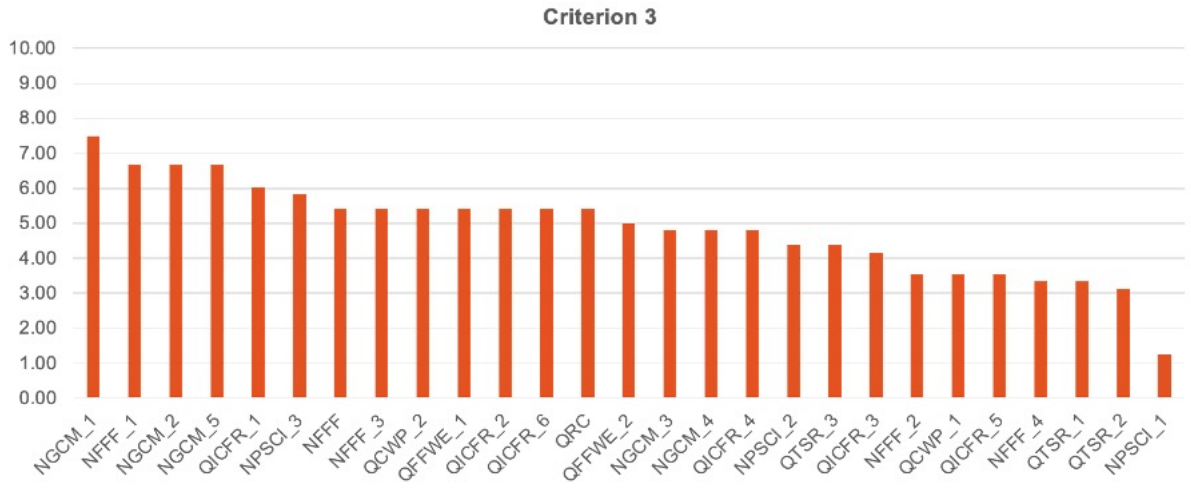

Figure 3. Normalised scores of Northern Basin Toolkit Proposals for Criterion 3 – temporal scales of ecological benefits and dis-benefits. N.B. See Table 1 for key to Project IDs.

2.1.4 Criterion 4 – Scientific and technical confidence

The panel had a moderate degree in confidence in the science underpinning expected outcomes and a moderate to high degree of confidence in proposed techniques in all cases. We had least confidence in proposals associated with fish threatened species re-introductions and habitat improvement, although these still scored moderately well under this criterion (Appendix 1). In many instances, proponents did not provide adequate evidence to support claims made regarding expected outcomes. Additionally, there were substantial concerns raised with respect to many proposals regarding the risk of investing in infrastructure with a high probability of becoming stranded (e.g. due to low flows) in the not too distant future.

We considered the ecological outcomes of all projects to be extremely measurable, but no projects were deemed to have adequate monitoring and evaluation programmes developed at this stage. Although MER was discussed with respect to quite a few projects, none of these explicitly considered monitoring of potential risks or trade-offs and many failed to provide a long term monitoring strategy and how it would (a) ensure the toolkit measures were "compliant" with design specifications and (b) measured benefits which accrue over the long term (at a large spatial scale).

Scoring for Criterion 4 was quite flat with relatively little differentiation between projects (Figure 4). Those which scored mostly highly were those projects associated with a higher degree of confidence in proposed techniques.

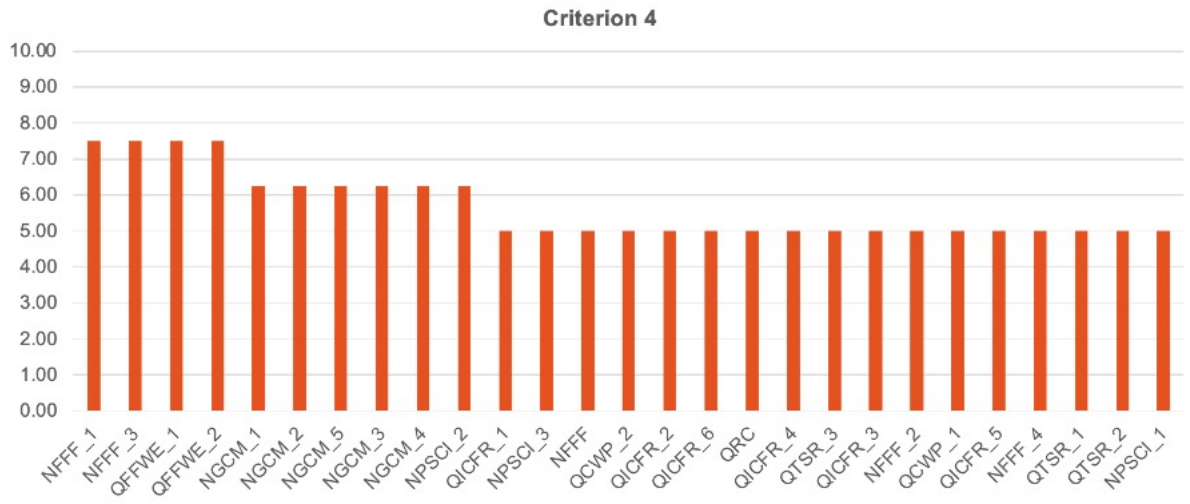

Figure 4. Normalised scores of Northern Basin Toolkit Proposals for Criterion 4 – scientific and technical confidence. N.B. See Table 1 for key to Project IDs.

2.1.5 Criterion 5 - Synergies

Many projects were deemed to have a high potential for within-catchment synergies where these were co-located at a catchment-scale (e.g. in the Border Rivers), especially with regard to native fish outcomes. Some projects were also identified as likely to generate significant sub-basin to basin scale synergies. In particular, the four projects likely to benefit Ramsar sites (i.e. NGCM1 and 2, QFFWE_2 and NPSCI_2) have a high potential to result in healthier wetlands at nationally significant waterbird breeding sites (i.e. Gwydir wetlands, Narran Lakes and the Macquarie Marshes), resulting in more resilient northern Basin waterbird populations. Projects with low scores for Criterion 5 were mainly those which were relatively isolated due to their geographic location and/or barriers (e.g. QICFR_5; Figure 5).

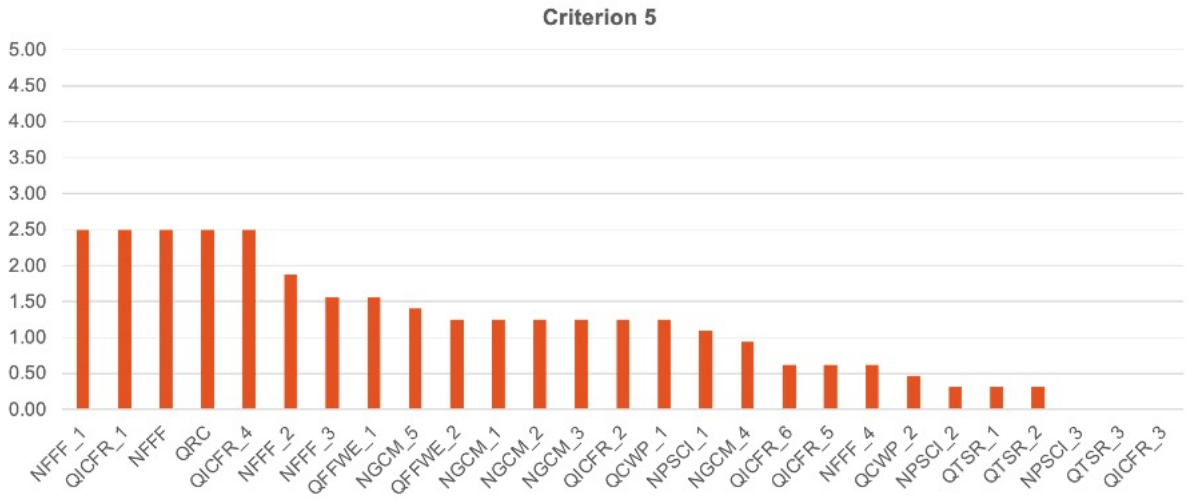

Figure 5. Normalised scores of Northern Basin Toolkit Proposals for Criterion 5 – synergies. N.B. See Table 1 for key to Project IDs.

2.2 Overview of cumulative project scores

Total normalised scores ranged from 31.8/45 to 5.45/45 (Figure 6, Table 2). The seven mostly highly ranked projects (i.e. NGCM_1, NGCM_2, NFFF_1, NGCM_5, QFFWE_2, NPSCI_2 and QICFR_1), all scoring over 50 %, were all deemed to have the potential to generate significant and broad ecological outcomes for multiple taxa, were associated with low ecological risks or those that have the potential to be well managed through careful planning and operations, significance across multiple spatial scales, frequent and enduring benefits and a high degree of potential for synergies to generate ecological outcomes across the northern Basin (Figure 6)..

In contrast, ten projects were identified as having either relatively low or highly uncertain ecological merit and/or high risk: NFFF_4, QICFR_3, QCWP_1, QICFR_6, NPSCI_3, QICFR_5, QTSR_2, QTSR_3 and NPSCI_1 (Figure 6). All of these projects were judged to have very narrow or uncertain ecological benefits that are likely to occur over relatively small scales (except NFFF_4) with few, if any, synergies with other toolkit proposals. In particular, the threatened species reintroduction projects proposed for both Queensland and New South Wales were widely considered to have a high risk of failure at the present time, especially before other toolkit measures have been implemented or without mitigation of threats contributing to species' declines in the first place. NPSCI_1 was also unequivocally identified as the project entailing the highest potential for perverse outcomes (e.g. loss of refuge habitat, declining vegetation condition etc.) based on the information provided (Appendix 2).

Figure 6. Total normalised scores of Northern Basin Toolkit Proposals. Green dashed lines indicate projects scoring ~ > 50 % and < 30 % respectively. N.B. See Table 2 below for key to Project IDs and total normalised scores.

Table 2. Northern Basin Toolkit Proposals ranked by total normalised scores.

Rank order	Project ID	Project Name	Total Normalised Score
1	NGCM_1	Gwydir Constraints Measures - Gingham Watercourse	31.18
2	NGCM_2	Gwydir Constraints Measures - Lower Gwydir Watercourse	28.76
3	NFFF_1	Reconnecting the Northern Basin	27.00
4	NGCM_5	Gwydir Constraints Measures - Mehi River	25.71
5	QFFWE_2	Enhance the Flexibility and Capability for Distributing and Managing Low Flows Through the Lower Balonne River System Bifurcation Weirs	24.47
6	NPSCI_2	Macquarie Marshes enhanced watering	23.40
7	QICFR_1	Improving Catchment Fish Resilience - Border Rivers	22.52
8	QRC	Reconnecting catchments - Condamine-Balonne	21.10
9	NFFF_3	Fish-friendly water extraction	20.49
10	QFFWE_1	Fish Friendly Water Extraction - Condamine-Balonne & Border Rivers	20.49
11	NFFF	Fish for the Future	20.07
12	NGCM_3	Gwydir Constraints Measures - Mallowa Watercourse	20.04
13	QICFR_4	Improving Catchment Fish Resilience - Lower Balonne	18.15
14	NGCM_4	Gwydir Constraints Measures - Ballin-Boora Creek	18.08
15	QICFR_2	Improving Catchment Fish Resilience - Upper Condamine	17.36
16	QCWP_2	Bringing back riverine habitat for native fish	16.99
17	NFFF_2	Addressing cold water pollution	16.50
18	QICFR_3	Improving Catchment Fish Resilience - Condamine & Balonne	14.42
19	NPSCI_3	Cudgegong River flow capacity and fish passage	14.38
20	QICFR_6	Improving Catchment Fish Resilience - Warrego	14.36
21	NFFF_4	Threatened Species Recovery	13.79
22	QCWP_1	Border Rivers	13.03
23	QTSR_1	Threatened species recovery - silver perch, purple-spotted gudgeon and olive perchlet	12.69
24	QICFR_5	Improving Catchment Fish Resilience - Narran River	11.86
25	QTSR_2	Threatened species recovery - River blackfish	10.74
26	QTSR_3	Threatened species recovery - Murray cod and freshwater catfish in the Paroo River	10.12
27	NPSCI_1	NSW Barwon-Darling billabong restoration	5.45

2.3 A note regarding the application of the prioritisation framework

The final results of scoring (Table 6, Appendix 1) conducted following the prioritisation framework (MDBA, 2019) broadly accorded with the expert panel's qualitative assessments of the proposed projects. Although projects with probable benefits for multiple taxa (e.g. NGCM_1 and NGCM_2) clearly scored highly following this process, it is reassuring to see that robust proposals focusing solely on native fish outcomes (e.g. NFFF_1 and QICFR_1) also emerged as projects with relatively high ecological merit. This is largely because these projects were expected to contribute benefits over a large spatial scale, and thus, scored highly on the catchment and reach scale metrics.

However, following the prioritisation framework was not without its challenges – many of which were associated with the level of detail and evidence provided in feasibility studies to support assertations made regarding expected ecological outcomes, especially a lack of detail in many cases on focal taxa targeted by projects and/or current ecological character and condition of proposal study areas. Similarly, insufficient information regarding proposed techniques, especially with regards to operational and maintenance concerns, hampered scoring in some instances. The panel used expert judgement where possible but the level of detail in feasibility proposals was the main determinant of the ability to score projects more accurately. Projects with lower levels of detail were much harder to score against the 96 different criteria.

The expert panel also deliberated multiple interpretations of 'connectivity' – e.g. longitudinal versus lateral hydrologic connectivity as well as ecological connectivity, which in some instances (e.g. waterbirds and aerial seed dispersal) may align poorly with the direction of flows. Our interpretation of connectivity underpinning our scoring encompasses both hydrological and ecological in the spirit of the assessment.

Finally, we faced challenges associated with the treatment of potential trade-offs, e.g. where substantial benefits in one area may be offset by moderate dis-benefits in other areas. In such cases, we separated these so as to score benefits and dis-benefits separately, letting the scoring framework balance overall weighting of outcomes in such instances.

Overall, however, we found the prioritisation framework to be fit for purpose, facilitating a robust and relatively unbiased approach to ranking the proposed projects, despite their inherent differences.

3. Recommendations

3.1 Toolkit investment options

All of the proposed toolkit projects were considered to have some degree of ecological merit and worthy of further development at some stage in the future, if not during the current investment round. Based on the results of our scoring, and reflecting our qualitative ecological evaluation, however, we suggest two major options for selecting proposals to progress to the stage of business case development at the current time.

- Option 1. Fund the seven highest ranking projects (Figure 6, Table 2): NGCM_1, NGCM_2, NFFF_1, NGCM_5, QFFWE_2, NPSCI_2, QICFR_1.

All of these projects were considered to be very worthwhile with a good likelihood of broad and enduring ecological outcomes and risks that can be well managed. The total estimated cost of these proposals is $106.59M, which would leave a reasonable balance that could be used to fund the next most highest-ranking project (i.e. QRC). Alternatively, we strongly recommend that significant investment and attention is given to the development of a robust and spatially and thematically integrated MER programme specifically focused on addressing evaluation questions related to Toolkit measures (i.e. are interventions working as expected?). This MER programme could also be designed to inform improved development and prioritisation of remaining toolkit proposals for future funding opportunities.

It should be noted that the two fish exclusion screening projects (i.e. NFFF_3 and QFFWE_1) also scored relatively highly and were associated with low risks in relation to a high likelihood of important ecological outcomes. We are very supportive of these projects being implemented as part of a package of initial toolkit measures if funding were available and suggest that this might be one area where industry co-funding (e.g. from the cotton industry) could by sought to bolster the current toolkit investment package.

- Option 2. Develop integrated cross-border project bundles.

Many of the projects presented by Queensland and New South Wales have clear areas of alignment and compatibility which, if these projects were designed and implemented in an integrated manner, would likely generate much greater ecological benefits over significantly greater scales as well as providing opportunities to reduce costs through economies of scale. Bundling projects in this way would also facilitate the development of targeted, integrated MER as discussed under Option 1.

One example of how a cross-border project bundle might work is a theoretical “Border Rivers Linkages” project. Based on the submitted feasibility concepts assume, such a bundle could comprise the following projects being selected for business case development:

- NFFF_1: Reconnecting the Northern Basin
- QICFR_1: Improving within-catchment fish resilience: Border Rivers
- NFFF_3: Fish friendly water extraction
- NFFF_2: Addressing cold water pollution
- QCWP_1: Addressing CWP Border Rivers
- QCWP_2: Bringing Back habitat for Riverine fish
- NGCM_5: Mehi River

With a total cost approximating $120M, this package of toolkit measures would likely generate benefits that would accrue at the sub-basin to basin scale for multiple taxa. For instance, fish passage would be effectively improved from Menindee along the entire length of the Darling-Barwon-Macintyre system; over 1,000km of reconnected habitat including QLD tributaries (Nichols *et al.* 2012). Ensuring that all irrigation pumps are screened would then ensure any spawned and recruited fish in that length avoid extraction (Baumgartner and Boys 2012). Addressing cold water pollution would improve river metabolism in upper reaches and lead to macrophyte production and habitat improvements along with expected fish-related outcomes (Lugg 1999; Lugg and Copeland 2014a; Todd *et al.* 2005). Riverine habitat restoration could further support native fish outcomes as well as generating benefits for vegetation and waterbirds. Further, proponents of the Mehi River project indicate that successful completion would physically connect the Barwon with the Gwydir (Powell, Letcher *et al.* 2008). This could potentially open more longitudinal habitat but would also provide the ability to link parts of the Gwydir wetlands into an integrated landscape (Carpenter-Bundhoo *et al.* 2020; Mawhinney 2003).

Successful implementation of such a package of measures would require strong inter-jurisdictional coordination. Additionally, this proposed bundle may require development of a single business case which captures those elements and also more strongly defines the operating scenario, implementation (including MER), feasibility and ecological benefits.

We have provided a single example of a potential cross-border bundle of toolkit projects but there are numerous other examples which could be drawn from the feasibility proposals that could equally work at scale. It was beyond the scope of the expert panel under our current terms of reference to develop such bundles, but it would be relatively straightforward for proponents to develop several such packages. Encouraging the development of integrated, cross-border business cases would maximise ecological benefits, at scale, from the current Northern Basin toolkit investment.

3.2 Considerations for business case development

Based on our assessment of the feasibility studies presented, we also offer some suggestions regarding key considerations for business case development for selected projects. Specific details in relation to individual project proposals are provided in Appendix 2.

- Detailed hydrologic models

  All project proposals need to be supported by improved hydrological modelling to inform design and operational considerations, especially in relation to climate change projections and third-party impacts on other water users. In particular, there are concerns regarding the efficacy and impacts (e.g. weir pool drawdown) of fish ladders in channels likely to be subject to increasing periods of low flows. Additionally, hydrologic modelling is required to enable investigation of trade-offs in numerous projects (e.g. NPSCI_2) between enhanced longitudinal connectivity and reduced lateral connectivity.

- Detailed ecological models

  Most projects require detailed investigations regarding the current ecological character and condition of the target biota and/or ecosystems (e.g. species presence and abundance, condition, other threats etc.) to inform design and operational considerations as well as expected ecological outcomes.

- Design considerations for technical works

  For projects involving the construction or installation of physical infrastructure (e.g. fishways or exclusion screens), consideration needs to be given to the particular requirements of focal species and geographical settings.

- Operational considerations

  All projects require careful consideration of operational scenarios including maintenance of physical infrastructure and rules for responding to risks and mitigating trade-offs.

- Trade-offs and associated mitigation strategies

  For projects likely to involve trade-offs, e.g. between longitudinal and lateral connectivity, explicit consideration of these trade-offs is required, including an assessment of the potential ecological risks involved (and key knowledge gaps associated with these) as well as appropriate mitigation strategies.

- Timelines for proposed works and trajectories of expected outcomes

  Numerous projects propose works which are likely to have very tight schedules for planning, design and construction given the timeframe for implementation. Similarly, the timeframe for expected ecological outcomes in many cases, is likely to exceed this period.

- Detailed MER plans

  Robust MER will be critical to the successful adaptive management of selected Toolkit measures as well as the development and prioritisation of future project proposals. We strongly recommend a hierarchical and spatially and thematically structured approach to MER (e.g. Capon et al. 2020) that will enable key evaluation questions regarding the efficacy of interventions to be addressed across multiple scales.

- Cost-benefit considerations

  Several projects appear to be excessively expensive in relation to the likely ecological outcomes generated. More detailed value propositions are required.

- Strong community engagement & co-design

  All proponents acknowledge that engagement of community and indigenous groups will be a key component of projects and this will require significant attention during business case development. Ideally, this engagement should follow principles of co-design (Reichert *et al.* 2007, Garcia *et al.* 2020) throughout the development of business cases. By far, the best way to garner broader engagement, buy-in and ownership of toolkit measures over the next five years will be to include all interest groups as business cases are developed. As such, the business cases need to clearly identify meaningful roles for community and indigenous groups and provide written evidence of acceptance and buy-in for the developed business cases (Jackson 2006). Meaningful engagement and involvement should endure beyond 2024.

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Appendix A. Raw scores for each project assigned by the expert panel according to Northern Basin Toolkit Ecological Prioritisation Framework (MDBA, 2019)

CRITERIA (A)	CRITERIA (B)	CRITERIA (C)	NFFF	NFFF_1	NFFF_2	NFFF_3	NFFF_4	NGCM_1	NGCM_2	NGCM_3	NGCM_4	NGCM_5	NPSCI_1	NPSCI_2	NPSCI_3	QCWP_1	QCWP_2	QFFWE_1	QFFWE_2	QICFR_1	QICFR_2	QICFR_3	QICFR_4	QICFR_5	QICFR_6	QRC	QTSR_1	QTSR_2	QTSR_3
CRITERION 1- ECOLOGICAL BENEFITS AND DIS-BENEFITS																													
Objectives	Relative contribution to BWS Expected Environmental Outcomes	Native Fish	4	4	4	4	4	4	1	1	1	4	1	1	1	4	1	4	1	4	1	1	1	1	1	4	4	1	4
		Vegetation	0	0	0	0	0	4	4	1	1	1	0	4	1	0	4	0	1	0	0	0	0	0	0	0	1	1	0
		Waterbirds	0	0	0	0	0	1	1	1	0	0	0	4	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
		River flows and connectivity	1	4	1	1	0	4	4	1	1	4	1	4	1	0	0	1	4	4	4	4	4	1	1	4	0	0	0
	Rel contribution to WRP and LTWP ecological objectives and/or: QLD - mitigation of key threats/stressors identified in those plans	Native Fish	4	4	4	4	1	4	1	1	1	4	1	1	1	4	1	4	1	4	1	1	4	1	1	4	1	1	1
		Vegetation	0	0	0	0	0	4	4	4	4	4	0	4	1	0	4	0	1	0	0	0	0	0	0	0	0	0	0
		Waterbirds	0	0	0	0	0	1	1	1	0	0	0	4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
		River flows and connectivity	1	4	1	1	0	4	4	4	1	4	1	4	4	0	0	1	4	4	4	1	4	1	1	4	0	0	0

	NSW - implements complementary action investment opportunities																													
Enhanced environmental outcomes	Magnitude of enhanced ecological outcomes in high environmental value area	Native Fish	4	4	4	4	1	4	1	1	1	4	1	4	0	4	4	4	1	4	1	1	4	1	1	4	1	1	1
		Vegetation	0	0	0	0	0	4	4	4	4	4	0	4	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
		Waterbirds	0	0	0	0	0	4	4	0	0	0	0	4	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
		River flows and connectivity	1	4	1	1	0	4	4	4	1	1	1	4	1	0	0	1	4	4	1	1	4	1	1	4	0	0	0	0
	Magnitude of enhanced ecological outcomes in areas with degraded environmental value	Native Fish	3	3	3	3	1	3	1	1	1	1	1	1	1	3	0	3	1	1	3	3	3	3	3	1	1	1	1	1
		Vegetation	0	0	0	0	0	3	3	3	3	3	0	3	1	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0
		Waterbirds	0	1	0	0	0	3	3	1	1	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		River flows and connectivity	1	3	1	1	0	3	3	3	3	3	1	3	1	0	0	1	1	3	3	1	3	1	1	1	0	0	1	1
	Magnitude of enhancement of ecological outcomes of environmental water recovery and delivery (planned/held)	Native Fish	4	4	4	4	4	1	1	1	1	4	1	4	0	4	1	4	4	4	4	4	4	1	1	4	4	1	1	1
		Vegetation	0	0	0	0	0	4	4	4	4	4	0	4	1	0	4	0	4	0	0	0	0	0	0	0	0	0	0	0
		Waterbirds	0	0	0	0	0	4	4	1	0	0	0	4	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
		River flows and connectivity	1	4	1	1	1	4	4	4	1	4	1	4	1	0	0	1	4	4	4	4	4	1	1	4	0	0	0	0

High environmental outcomes	Magnitude of benefits to unique/functionally important populations/communities	Native Fish	4	4	1	4	4	4	4	1	1	4	1	1	0	1	1	4	1	4	1	1	1	1	1	1	4	1	1
		Vegetation	0	0	0	0	0	4	4	4	4	4	0	4	1	0	4	0	1	0	0	0	0	0	0	0	0	0	0	0
		Waterbirds	0	0	0	0	0	4	4	1	0	0	0	4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		River flows and connectivity	1	4	1	1	0	4	4	1	1	4	1	4	1	0	0	1	1	4	1	1	1	1	1	4	0	0	0	
	Magnitude of benefits to populations/communities/sites of conservation significance	Native Fish	4	4	4	4	4	1	1	1	1	1	1	1	0	4	1	4	4	4	4	4	4	1	1	1	4	4	1	
		Vegetation	0	0	0	0	0	4	4	4	4	4	0	4	0	0	4	0	4	0	0	0	0	0	0	0	0	0	0	0
		Waterbirds	0	0	0	0	0	4	4	1	0	0	0	4	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
		River flows and connectivity	1	4	1	1	0	4	4	1	1	4	1	4	0	0	0	1	4	4	4	4	4	1	1	4	0	0	1	
Ecological risks	Magnitude of ecological risk of not proceeding with project		4	4	1	4	4	4	4	4	1	1	1	1	1	4	1	4	1	4	4	4	4	4	4	4	4	1	1	
	Magnitude of ecological risk of proceeding with project		-1	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	0	0	0	0	0	0	0	0	-1	-1	0	-1	
	Adequacy of mitigation strategy for unintended ecological consequences/risks		0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	
CRITERION 1 TOTALS			**37**	**59**	**32**	**40**	**23**	**99**	**88**	**58**	**41**	**71**	**14**	**94**	**19**	**28**	**34**	**40**	**67**	**56**	**40**	**35**	**49**	**20**	**20**	**47**	**23**	**12**	**12**	
CRITERION 2- SPATAL SCALES OF ECOLOGICAL BENEFITS AND DIS-BENEFITS																														
Magnitude of protected ecological	Basin/sub-basin	Native Fish	4	4	1	1	4	0	1	0	0	1	0	0	0	1	1	1	0	1	1	1	0	0	0	1	4	0	0	
		Vegetation	0	0	0	0	0	4	4	1	1	1	0	1	0	0	4	0	1	0	0	0	0	0	0	0	1	0	0	
		Waterbirds	0	0	0	0	0	4	4	0	0	0	0	4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	
		River flows and connectivity	0	4	0	0	0	1	1	1	0	1	0	1	0	0	0	0	1	1	1	1	0	0	0	1	0	0	0	
	Catchment	Native Fish	4	4	4	4	4	1	1	0	0	4	0	0	0	1	1	4	0	4	1	1	0	0	0	4	4	0	0	

benefits at:		Vegetation	0	0	0	0	0	4	4	4	4	4	0	1	0	0	4	0	1	0	0	0	0	0	0	0	0	0	0	0
		Waterbirds	0	0	0	0	0	4	4	0	0	0	0	4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		River flows and connectivity	4	4	4	1	0	4	4	1	1	1	1	1	0	0	0	1	4	4	1	1	0	0	0	4	0	0	0	0
	Reach	Native Fish	4	4	4	4	4	4	1	0	0	4	1	1	1	1	1	4	4	4	1	1	1	1	1	4	4	4	1	
		Vegetation	1	0	0	0	1	4	4	4	4	4	0	4	1	0	4	0	4	0	0	0	0	0	0	0	0	0	0	0
		Waterbirds	0	1	0	0	0	4	4	0	0	0	0	4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		River flows and connectivity	4	4	4	1	0	4	4	1	1	4	1	4	4	0	0	1	4	4	1	1	1	1	1	4	0	0	0	
	Site	Native Fish	4	4	4	4	4	4	4	1	1	4	4	1	1	4	1	4	4	4	4	4	4	4	4	4	4	4	4	1
		Vegetation	1	0	0	0	4	4	4	4	4	4	0	4	1	0	4	0	4	0	0	0	0	0	0	0	0	0	0	0
		Waterbirds	0	0	0	0	0	4	4	1	1	1	0	4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		River flows and connectivity	4	4	4	1	1	4	4	4	4	4	4	4	4	0	0	1	4	4	4	4	4	4	4	4	4	0	0	0
Magnitude of projected ecological dis-benefits at:	Basin/sub-basin	Native Fish	-1	0	0	0	-1	0	-1	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	-1	0	-1	
		Vegetation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Waterbirds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		River flows and connectivity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Catchment	Native Fish	-1	0	0	0	-1	0	-1	0	0	0	-4	0	0	0	0	0	-1	0	0	0	0	0	0	0	-1	0	-1	
		Vegetation	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Waterbirds	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		River flows and connectivity	0	0	0	0	0	-1	-1	-1	-1	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Reach	Native Fish	-1	0	-1	0	-1	-1	-1	0	0	0	-4	-1	0	-1	0	0	-1	0	0	0	0	-1	0	0	-1	0	-1	
		Vegetation	0	0	0	0	0	-1	-1	-1	-1	-1	-4	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

		Waterbirds	0	0	0	0	0	0	0	0	0	0	-4	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		River flows and connectivity	-1	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0
		Native Fish	-1	0	-1	0	-1	-1	-1	-1	-1	0	-4	-4	0	-1	0	0	-1	0	0	0	0	-1	0	0	-1	0	-1
		Vegetation	0	0	0	0	0	-1	-1	-1	-1	-1	-4	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Waterbirds	0	0	0	0	0	0	0	0	0	0	-4	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Site	River flows and connectivity	0	0	-1	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0
CRITERION 2 TOTALS			**25**	**33**	**21**	**16**	**18**	**48**	**44**	**17**	**16**	**33**	**-20**	**27**	**12**	**5**	**20**	**16**	**31**	**26**	**14**	**14**	**10**	**6**	**10**	**26**	**13**	**8**	**-2**
CRITERION 3- TEMPORAL SCALE OF ECOLOGICAL BENEFITS AND DIS-BENEFITS																													
		Native Fish	4	4	1	4	1	4	1	1	1	4	1	1	1	1	1	4	1	1	1	1	4	4	4	1	1	1	4
		Vegetation	0	0	0	0	0	4	4	1	1	1	0	1	1	0	4	0	1	0	0	0	0	0	0	0	0	0	0
Temporal frequency of ecological benefit(s)		Waterbirds	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
		River flows and connectivity	1	4	1	1	0	4	4	4	4	4	1	4	4	1	0	1	1	4	4	1	1	1	4	4	0	0	0
		Native Fish	4	4	1	4	1	1	0	1	1	4	1	1	4	1	4	4	1	4	4	4	4	1	4	4	1	1	1
		Vegetation	4	4	4	4	4	1	1	1	1	1	0	1	4	4	4	4	1	4	4	4	4	4	4	4	4	4	4
Temporal frequency of ecological dis-benefit(s)		Waterbirds	4	4	4	4	4	4	4	4	4	4	0	1	4	4	4	4	1	4	4	4	4	4	4	4	4	4	4
		River flows and connectivity	4	4	4	4	4	1	1	1	1	1	1	1	4	4	4	4	1	4	4	4	4	1	4	4	4	4	4
		Native Fish	4	4	1	4	1	4	4	1	1	4	1	1	1	1	1	4	4	4	1	1	1	1	1	1	1	1	4
		Vegetation	0	0	0	0	0	4	4	4	4	4	0	4	1	0	4	0	4	0	0	0	0	0	0	0	0	0	0
		Waterbirds	0	0	0	0	0	4	4	1	1	1	0	4	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Duration of ecological benefit		River flows and connectivity	1	4	1	1	1	4	4	4	4	4	1	1	4	1	0	1	4	4	4	1	1	1	1	4	1	0	0
CRITERION 3 TOTALS			**26**	**32**	**17**	**26**	**16**	**36**	**32**	**23**	**23**	**32**	**6**	**21**	**28**	**17**	**26**	**26**	**24**	**29**	**26**	**20**	**23**	**17**	**26**	**26**	**16**	**15**	**21**

CRITERION 4- SCIENTIFIC CONFIDENCE																														
Degree of Confidence	Scientific confidence in estimated ecological benefits and dis-benefits	1	2	1	2	1	1	1	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
	Degree of Confidence in, and understanding of, the proposed technique	1	2	1	2	1	2	2	2	2	2	1	2	1	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1
	Measurability of ecological benefits and dis-benefits	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
M&E	Adequacy of proposed M&E of projected ecological benefits and risks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CRITERION 4 TOTALS		**4**	**6**	**4**	**6**	**4**	**5**	**5**	**5**	**5**	**5**	**4**	**5**	**4**	**4**	**4**	**6**	**6**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**
CRITERION 5- SYNERGIES																														
Magnitude of enhancement of targeted ecological outcomes FOR other priority toolkit projects	Native fish	4	4	4	4	1	1	1	1	1	4	1	0	0	4	1	4	1	4	0	0	4	1	1	4	1	1	0		
	Vegetation	0	0	0	0	0	1	1	1	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0		
	Waterbirds	0	0	0	0	0	1	1	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0		
	River flows and connectivity	4	4	0	1	1	1	1	1	1	1	1	0	0	0	0	1	1	4	4	0	4	1	1	4	0	0	0		
Magnitude of enhancement of targeted ecological outcomes BY other priority toolkit projects	Native Fish	4	4	4	4	1	1	1	1	1	1	4	0	0	4	1	4	1	4	0	0	4	1	1	4	1	1	0		
	Vegetation	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0		
	Waterbirds	0	0	0	0	0	1	1	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0		
	River flows and connectivity	4	4	4	1	1	1	1	1	1	1	1	0	0	0	0	1	1	4	4	0	4	1	1	4	0	0	0		
CRITERION 5 TOTALS		**16**	**16**	**12**	**10**	**4**	**8**	**8**	**8**	**6**	**9**	**7**	**2**	**0**	**8**	**3**	**10**	**8**	**16**	**8**	**0**	**16**	**4**	**4**	**16**	**2**	**2**	**0**		

Appendix B. Assessment of individual projects

NSW Project Scoping Initiative: Barwon-Darling billabong restoration (NPSCI_1)

This project proposes the removal of block banks and other infrastructure from eight billabongs that have been used as water storages in the Barwon-Darling river system. With an estimated cost of $11.77 million for works and potential compensation for associated loss of water storages (e.g. construction of new turkey nest dams), this project is presented as having benefits to fish, vegetation and waterbirds by facilitating the restoration of a more historical flow regime and connectivity between these billabongs and the river. In particular, the feasibility study suggests that this project will return low flows to these billabongs which currently have more permanent inundation regimes due to this infrastructure (NSW DPIE 2020a).

SCORES

1: 1.23/10
2: -3.13/10
3: 1.25/10
4: 5.00/10
5: 1.09/5

TOTAL NORMALISED SCORE: 5.45/45
RANKED SCORE: 27th (of 27 scored projects)

1: Ecological benefits and dis-benefits

Conceptually, this project has the potential to provide significant benefits to fish, and possibly waterbirds and vegetation, by increasing lateral hydrologic connectivity. Insufficient explanations of the proposed benefits are provided, however, especially with regards to waterbirds and vegetation. There is little discussion of the species or communities that would benefit and in what way. Consequently, while we feel confident in assigning a moderate score for benefits associated with native fish (due to current understanding of the function of these habitats) and river flows and connectivity, we find insufficient evidence to inform an assessment of benefits for vegetation and waterbirds.

Indeed, vegetation fringing these billabongs may exhibit undesirable responses to a loss of hydrologic permanency in these billabongs, e.g. declining tree health and mortality, exotic species invasions and terrestrial vegetation encroachment. Additionally, these billabongs may currently provide significant refuge habitat to waterbirds and other amphibious and terrestrial fauna in this landscape by holding water for longer periods of time than they would if connected to the river. In an otherwise dry (and drying) landscape, these sites could therefore be critical roosting and feeding sites for some species of waterbirds. However, it is not possible to adequately assess this, as no data was provided by the

proponents. Without this understanding, this project has significant potential to generate dis-benefits for vegetation and waterbirds.

Some assumed benefits of the project (e.g. implications for overbank flows and the inundation of wetland habitat) also appear to be largely dependent upon flows. Given the challenges facing the Darling in recent years, the impact of diverting water onto the floodplain, and consequences of this for flows in the main channel and longitudinal connectivity, need to be addressed in greater detail.

This project also poses a significant risk by facilitating carp breeding events during inundation. Carp are known to be prolific breeders in such wetland habitats (Haynes *et al.* 2009). Discussions with proponents identified this as a risk but no mitigation strategies were discussed or offered.

2: Spatial scales of benefits and dis-benefits

Moderate benefits of this project for native fish and river flows and connectivity would largely be at catchment scales and smaller with significant benefits only accruing at the site scale.

Risks posed by this project however could potentially have a significant impact at a catchment scale (carp) as well as at reach and site scales (vegetation and waterbirds). A single female carp can produce 3 million eggs (Smith and Walker 2004), so the spatial scale of an event could be significant. The inaugural inundation of Chowilla Floodplain in the Murray led to a carp population density of 1m fish per hectare (Fredberg *et al.* 2018). Such an event would have a disastrous impact on the Darling, which is recovering from significant recent fish kills. At the catchment scale there may also be a moderate disbenefit associated with a reduction in longitudinal connectivity.

3: Temporal scales of benefits and dis-benefits

Improvement of lateral connectivity has been assumed to occur with moderate frequency and medium duration due to the episodic nature of flows in the Darling system. Similarly, the frequency of any associated river flow and (longitudinal) connectivity dis-benefits has been judged as moderate due to the episodic nature of flows in the Darling. Any declines in vegetation condition and waterbird refuge habitat that may ensue as a result of this project, however, would be continual and enduring. Likewise, carp breeding could occur on every inundation event depending on time of year.

4: Scientific and technical confidence

Because of the lack of necessary detail provided in the feasibility study (e.g. hydrological modelling, current ecological condition), our confidence in the estimated benefits and proposed technique is low to moderate (although we have scored favourably in this instance under the assumption that business case development will give more thorough consideration to possible trade-offs etc.

No MER is outlined in the feasibility proposal.

5: Synergies

This project has moderate potential for reciprocal synergies with NFF_4 as these billabongs, with restored connectivity, may provide recruitment and/or receiving sites for native fish introduced in the Barwon-Darling system. Similarly, this project may create further connections for native fish targeted under the NFF_1 initiative. However, such synergies are only considered low to moderate given the spatial scale of this proposal and the temporal frequency of expected improved river flow connectivity.

Considerations for business case development:

- A detailed hydrological analysis is required, including duration, timing and frequency of inundation events, under current and projected flow scenarios to better explore the potential impacts on longitudinal connectivity and justify the proposed ecological benefits (especially for floodplain vegetation)
- An assessment of the current ecological condition and role of these billabongs, especially regarding riparian vegetation and waterbird habitat and use, is required to understand potential benefits and risks.
- The possibility of a carp spawning event needs to be acknowledged and effectively mitigated (Hillyard 2011; Hillyard, Smith *et al.* 2010; Stuart, Williams *et al.* 2006).

NSW Project Scoping Initiative: Macquarie Marshes enhanced watering (NPSCI_2)

This project comprises two components designed to enhance environmental watering of the Macquarie Marshes including the Macquarie Marshes Ramsar site. With a total estimated cost $2.49 million, this project proposes the construction of: i) a regulator at Oxley Break No. 3, in addition to complementary stream stabilisation works, and ii) two weir structures at the Mumblebone breaks. Both of these components are intended to enable the retention and control of flows in the Macquarie River so that more extensive watering of the Macquarie Marshes is enabled.

SCORES

1: 8.25/10
2: 4.22/10
3: 4.38 /10
4: 6.25/10
5: 0.31/5

TOTAL NORMALISED SCORE: 23.40/45
RANKED SCORE: 6th (of 27 scored projects)

1: Ecological benefits and dis-benefits

This project has a high potential to support significant ecological benefits for native fish, vegetation, waterbirds and river flows and connectivity in the Macquarie Marshes, particularly the Ramsar site. By facilitating the improved longitudinal connectivity and management of flows in the Macquarie River, this project will also provide an opportunity to significantly enhance the outcomes of environmental watering. The Macquarie Marshes is a key site for waterbird breeding and also supports large areas of high conservation value and functionally significant wetland vegetation. This project is likely to have positive outcomes for both waterbirds and vegetation where greater flows are delivered. The abundance of several fish species listed in the BWS can also be expected to increase, including a possible 25 % increase in Murray cod and golden perch populations.

With improvements to longitudinal connectivity in the Macquarie River, however, trade-offs in connectivity are accrued with other areas (e.g. Bulgeraga) currently receiving water 'lost' from the Macquarie River likely to experience impacts. Resulting declines in vegetation condition in these areas, for example, could have further implications depending on the ecological functions currently supported (e.g. waterbird foraging areas). There is also a significant risk of carp breeding events during inundation. Carp are known to be prolific breeders in wetland habitat (Haynes *et al.* 2009). Discussions with proponents identified these as risks but no mitigation strategies were discussed or offered.

Additionally, he proponents state that there will be a 25% increase in Murray cod and golden perch populations but do not justify why "25%" is an appropriate number with no consideration given to how a 25% increase in top order carnivores might influence the system. Indeed, there is a risk that this could be a disbenefit (i.e. unintentional overstocking) in the context of how the marshes operate (Eby *et al.* 2006). Such population increases would also necessitate sufficient habitat and food to support this extra biomass (Arlinghaus and Mehner 2005).

2: Spatial scales of benefits and dis-benefits

Because the Macquarie Marshes contains wetland areas of high international, national and regional ecological significance, especially for waterbirds, this project has the potential to generate positive outcomes across multiple scales, including at a Basin scale. Due to the mobility of waterbirds, any benefits achieved at this site have the potential to positively impact populations of waterbirds at a Basin scale. Due to the high conservation value of many vegetation communities within the Macquarie Marshes, moderate benefits for vegetation at Basin and catchment scales, and substantial benefits at reach and site scales, can also be expected. Benefits for native fish are expected to mainly accrue at reach and site scales.

The potential ecological dis-benefits noted under Criterion 1 are anticipated at a catchment scale and smaller. In particular, the risk posed by carp breeding is considered to be substantial at a site scale but these could disburse regionally.

3: Temporal scales of benefits and dis-benefits

We consider this project to have a high potential for long-term and enduring benefits for the Macquarie Marshes. Due to the likely flow volumes involved and the fact that water delivery can be augmented from planned and held environmental water holdings, this proposal would appear to entail a high temporal frequency of river flow and connectivity benefits. The frequency of benefits to waterbirds, vegetation and native fish is likely to be moderate, i.e. in relation to occasions when there is sufficient water in the wetland, although these benefits can be expected to accrue over time.

The frequency of any dis-benefits generated by this project associated with trade-offs in connectivity can similarly be expected to persist and accumulate over time.

4: Scientific and technical confidence

We have high confidence in the understanding of the proposed technique but suggest there are important uncertainties associated with the ecological outcomes as a result of the trade-offs involved that require further consideration.

5: Synergies

This project has potential synergies with several other proposed projects that are likely to have significant benefits for key waterbird breeding sites in the northern Basin and Ramsar sites especially (i.e. NGCM_1, NGCM_2 and QFFWE_2). Because waterbirds are highly mobile, there is likely to be considerable movement between these sites and improvements to their condition and capacity to support waterbird breeding can be expected to have cumulative benefits.

Considerations for business case development:

- A detailed hydrological analysis is required, including duration, under current and projected flow scenarios, to better explore the potential inundation outcomes of this project to inform appropriate management for ecological outcomes, especially for vegetation and waterbirds.
- An assessment of the current ecological condition, role and value of areas that will be subject to reduced flow reductions and connectivity (e.g. Bulgeraga) is required to understand potential trade-offs.
- The proponents may also like to make use of the modelling provided by the NSW Fish for the Future team to predict the actual increase in fish numbers that could be expected. This would then require a robust monitoring program to measure the expected outcomes.
- The possibility of carp spawning events needs to be acknowledged and effectively mitigated (Hillyard 2011; Hillyard, Smith *et al.* 2010; Stuart, Williams *et al.* 2006).
- MER should also consider responses in areas subject to trade-offs (e.g. Bulgeraga).

NSW Project Scoping Initiative: Cudgegong River flow capacity and fish passage (NPSC1_3)

The third project presented under the Project Scoping Initiative package proposes works at six sites on the Cudgegong River around Mudgee, including raising of the Rocky Waterhole Bridge and modification of existing weirs. With an estimated cost of $6.24 million, this project seeks both to improve the capacity to release bankfull and overbank flows in the Cudgegong River, i.e. without inundation of the bridge, and to promote fish passage in this reach.

SCORES

1: 1.67/10
2: 1.88/10
3: 5.83/10
4: 5.00/10
5: 0.00/5

TOTAL NORMALISED SCORE: 14.38/45
RANKED SCORE: 19th (of 27 scored projects)

1: Ecological benefits and dis-benefits

This project has the potential to deliver moderate benefits for native fish and possibly riparian vegetation depending on flow scenarios, although the proponents state that "no connectivity outcomes regarding overbank flows are expected". This is not a high value area for native fish, being downstream of Windamere Dam and upstream of Burrendong Dam. Benefits for waterbirds are highly uncertain based on current knowledge of habitat use in this area. Moderate to high improvements in river flows and (longitudinal) connectivity can be expected. Due to the small scale of the proposal, however, it is not likely to make a significant relative contribution to the Basin Watering Strategy for river flows and connectivity.

The works proposed in this project are for a stretch of river with no planned or held environmental water.

There do not appear to be any clear dis-benefits associated with this project. Cold water pollution could potentially undermine any ecological gains in this reach however as the proponents do not explain if Windamere Dam has a thermal pollution issue or not, despite literature indicating this possibility (Lugg and Copeland 2014b; Ryan *et al.* 2001).

2: Spatial scales of benefits and dis-benefits

This project concerns a reach between two major dams (Burrendong and Windamere) in the Macquarie catchment. Consequently, proposed benefits are only likely at reach and site scales.

3: Temporal scales of benefits and dis-benefits

Given that the Cudgegong River is regulated river with environmental water holdings, the temporal frequency of river flow and connectivity benefits should be frequent and enduring. Moderate frequency and duration of benefits to fish and riparian vegetation can also be expected with appropriate maintenance (e.g of fish passage) and operations (e.g. flows).

4: Scientific and technical confidence

We have moderate confidence in the proposed technique and the understanding of is ecological outcomes.

5: Synergies

This project does not have any clear synergies with other proposals presented in the toolkit.

Considerations for business case development:

As is stands, the two projects proposed in the Macquarie catchment (NPSCI_2 and NPSCI_3) are separated by Burrendong Dam. This detracts from any meaningful opportunities to link projects and create longitudinal benefits (Benn and Erskine 1994). We suggest that it could be worth the proponents re-scoping the NPSCI_3 proposal to focus on reaches downstream of Burrendong Dam. The new barrier at Gin Gin provides a significant opportunity to co-design a project with the potential for substantial environmental benefits. Furthermore, the thermal curtain at Burrendong Dam, while plagued with reliability issues since construction, provides significant benefits to the downstream environment when functioning. Refocusing this project to assist with thermal pollution mitigation and aligning with Gin Gin works, may provide a package of work which provides greater benefits to the Macquarie catchment including the Marshes.

NSW Gwydir Constraints Measures Package:

This package of five projects addresses constraints to environmental water delivery in the Gwydir River system, each project focusing on a different watercourse as follows (NSW DPIE 2020b). These projects will improve the capacity to deliver environmental flows in the western Gwydir catchment which reconnect rivers, floodplains and wetlands. This will be achieved by addressing operational barriers to flow delivery (e.g. limitations on flow timing and maximum discharge rates) as well as through the removal and modification of existing, and some construction of new, physical barriers to flow (e.g. block banks, roads, levees, weirs, water storages, diversion channels etc.).

While we have scored these projects individually (as presented), we provide a combined discussion of our rationale due to the relative similarities of the measures proposed and their general outcomes.

➢ *Gingham Watercourse (NGCM_1)*

With an estimated cost of $19.1 million, this project will address operational and physical constraints on the Gingham watercourse with the potential to support improved environmental watering and inundation of large areas of floodplain and wetland vegetation, including areas listed as internationally significant under the Ramsar Convention, as well as to increase connectivity longitudinally along dominant flow paths. In particular, this proposal aims to improve delivery of moderate sized flood events - a key flood size that has been particularly reduced by river regulation

SCORES

1: 8.68/10
2: 7.50/10
3: 7.50/10
4: 6.25/10
5: 1.25/5

TOTAL NORMALISED SCORE: 31.18/45
RANKED SCORE: 1st (of 27 scored projects)

➢ *NSW Gwydir Constraints Measure: Lower Gwydir Watercourse (NGCM_2)*

With an estimated cost of $10.16 million, this project will address operational and physical constraints on the Lower Gwydir watercourse with the potential to support improved environmental watering and inundation of large areas of floodplain and wetland vegetation, including areas listed as internationally significant under the Ramsar Convention, as well as to increase connectivity longitudinally along dominant flow paths. This particular component

seeks to improve the passage of small overbank events from 10-30GL which can achieve uninterrupted inundation to over 3,000 ha of wetlands between September and March.

SCORES

1: 7.72/10
2: 6.88/10
3: 6.67/10
4: 6.25/10
5: 1.25/5

TOTAL NORMALISED SCORE: 28.76/45
RANKED SCORE: 2nd (of 27 scored projects)

➢ *NSW Gwydir Constraints Measure: Mallowa Watercourse (NGCM_3)*

With an estimated cost of $25.1 million, this project will address operational and physical constraints on the Mallowa watercourse with the potential to support improved longitudinal connectivity along Mallowa Creek and to enhance environmental watering and inundation of large areas of floodplain and wetland vegetation, including historic colonial waterbird breeding habitat. This particular project seeks to increase the passage of moderate-sized events (up to 15 GL) as well as uninterrupted inundation of core wetland habitat (100 ha) for over four months at a moderate 350ML/day. Relative to the spatial scale of expected benefits (mostly to 100 ha of wetland), this project appears to be extremely expensive.

SCORES

1: 5.09/10
2: 2.66/10
3: 4.79/10
4: 6.25/10
5: 1.25/5

TOTAL NORMALISED SCORE: 20.04/45
RANKED SCORE: 12th (of 27 scored projects)

➢ *NSW Gwydir Constraints Measure: Ballin-Boora Creek (NGCM_4)*

With an estimated cost of $1.25 million, this project seeks to improve the passage of base flows and small overbank flows along the Ballin-Boora Creek watercourse. In particular, thii

project seeks to connect this anabranch of the Mehi River through construction of a regulator and sill to restore hydraulic variability, fish passage and floodplain vegetation inundation.

SCORES

1: 3.60/10
2: 2.50/10
3: 4.79/10
4: 6.25/10
5: 0.94/5

TOTAL NORMALISED SCORE: 18.08/45
RANKED SCORE: 12th (of 27 scored projects)

➢ *NSW Gwydir Constraints Measure: Mehi River (NGCM_5)*

The fifth and final project under the Gwydir Constraints Measure feasibility proposal focuses on the Mehi River (NSW DPIE 2020b). With an estimated cost of $1.5 million, this project will remove 11 structures along the Mehi which are currently known to impede flows thereby enhancing connectivity between the Mehi and Barwon rivers.

SCORES

1: 6.23/10
2: 5.16/10
3: 6.67/10
4: 6.25/10
5: 1.41/5

TOTAL NORMALISED SCORE: 25.71/45
RANKED SCORE: 4th (of 27 scored projects)

1: Ecological benefits and dis-benefits

All of these projects have the potential to deliver significant ecological benefits to native fish, vegetation, waterbirds and river flows and connectivity, with the capacity to make moderate to substantial contributions to the BWS Expected Environmental Outcomes and long-term watering plan ecological objectives as well as the mitigation of key threats and stressors. NGCM_1 and NGCM_2 are particularly significant for their capacity to deliver substantial benefits to waterbirds by supporting likely improvements to the condition of key nesting habitat. Substantial benefits to riparian, floodplain and wetland vegetation can also be expected, particularly given the high conservation value

of many vegetation communities in this catchment. Increased fish movement may also be supported by these projects during watering events with positive outcomes expected especially for rare fish species favoured by more reliable hydrology. River flow outcomes associated with delivery of planned and held environmental water will in all likelihood experience substantial improvements with these proposals as will the capacity to enhance ecological outcomes of environmental watering.

These projects present some risks, however, most notably with respect to invasive species. Carp, for instance, pose a substantial problem to several of these projects with the lower Gwydir region known to be a carp recruitment hotspot (Southwell *et al.* 2015), although where, within the Lower Gwydir, carp spawning is most prevalent remains unknown. The significant inundation period to be targeted by NGCM_2 of September to March is perfect for carp recruitment and could support them from spawning, larval stages right through until young-of-year (YOY) recruitment. The proponents have verbally acknowledged the risk presented by carp although no written consideration of this or potential mitigation strategies are presented in the feasibility study. Increased frequency and extents of floodplain and wetland inundation with insufficient durations also have the potential to promote the growth and invasion of exotic plants (e.g. lippia). It is also very likely that these projects will involve considerable trade-offs in which some floodplain and wetland areas will experience reduced lateral connectivity as a result of interventions to increase longitudinal connectivity with potential ecological implications, particularly for vegetation.

2: Spatial scales of benefits and dis-benefits

The magnitude of projected benefits of NGCM_1 and NGCM_2 for vegetation and waterbirds are expected to be substantial across all scales because of the high conservation and functional value of these wetlands and floodplains. Native fish and river flow and connectivity outcomes are also likely to be substantial for these two projects at a catchment scale and smaller, with Basin scale outcomes low because of a lack of longitudinal connectivity to the Barwon-Darling. Because of the high conservation value of floodplain and wetland vegetation expected to benefit under projects NGCM_3, NGCM_4 and NGCM_5, substantial benefits can also be expected across all scales although only low to moderate benefits are anticipated for waterbirds and native fish, the exception being the likelihood of greater catchment-scale benefits for native fish under NGCM_5 because of the potential for significant improvements to connectivity.

Potential dis-benefits presented by these projects (i..e to native fish, vegetation and river flows and connectivity) are likely to occur at catchment scales and smaller although elevated carp breeding in the Lower Gwydir could potentially have Basin-scale consequences.

3: Temporal scales of benefits and dis-benefits

The frequency of projected benefits is assumed to be moderate to high for most outcomes associated with most projects in this package, with higher scores given to NGCM_1, NGCM_2 and NGCM_5. Projected dis-benefits where expected are likely to occur with moderate frequency excepting the risk of carp breeding in the Lower Gwydir which may be high. The duration of projected ecological benefits is likely to be long-lasting for NGCM_1 and NGCM_2 across the board and amongst all projects for vegetation and river flows and connectivity.

4: Scientific and technical confidence

We have a high degree of confidence in the proposed technique and a moderate level of confidence in the understanding of projected ecological benefits. However, there are considerable uncertainties associated with potential trade-offs and ecological dis-benefits. These will all be highly measurable although current MER proposals do not give this consideration.

5: Synergies

All of these projects have a moderate potential for synergies with each other if delivered as a package. NGCM_1 and NCGM_2 in particular, and to a lesser extent NCGM_3, also have the potential for reciprocal synergies with other Toolkit proposals that are likely to provide benefits to waterbirds (i.e. NPSCI_2 and QFFWE_2) as collectively these projects can be expected to deliver cumulative, Basin-scale outcomes for waterbirds. There is also the potential for reciprocal synergies with NFFF_3 (fish friendly water extraction) and NFFF_4 (threatened species recovery), both of which propose sites in the Gwydir system.

Considerations for business case development:

- For all of these projects, greater acknowledgement and consideration of potential trade-offs is required, including possible ecological dis-benefits in areas subject to reduced lateral connectivity as a result of enhancements to longitudinal connectivity.
- Control plans for invasive species, including carp as well as key weeds (e.g. lippia) should be included in the business cases developed for all of these projects. These should include consideration of what levers could be used in the event that watering induced large-scale carp (or similar) breeding (Conallin *et al.* 2012a; FRDC 2018).
- These projects would benefit from a whole of lower Gwydir fish conceptual model and demonstrating the magnitude of fish-related benefits from the works.

- With respect to NGCM_3 specifically, the estimated cost needs to be significantly justified relative to the spatial benefits of low flows and more frequent inundation of the Mallowa system.
- With respect to NGCM_5 specifically, there is a significant opportunity here to create a physical connection with the Barwon River. Outlining how this initiative could link with other projects proposed for the Border Rivers would significantly enhance this business case.

NSW Fish for the Future (NFFF)

The NSW Fish for the Future project comprises four sub-themes focused predominantly on outcomes for fish, with an overall estimated cost of $105.8 million including costs for theme administration and MER (NSW DPIE 2020c). The first theme, costed at $51.9 million, addresses the problem of restricted fish passage in the Darling-Barwon-Macintyre system via a proposal to install a series of 22 fishways. The second theme, with an estimated cost of $14 million addresses the problem of cold-water pollution downstream of Pindari Dam in the Border Rivers system via the automation of operations for an existing multi-level offtake to allow greater control of flow releases. The third theme targets the significant problem of aquatic animal entrainment from main rivers into irrigation systems via water resources infrastructure, e.g. pumps (Baumgartner and Boys 2012), through the installation of exclusion screens at sites in both the Barwon-Darling and Gwydir River systems with an estimated total cost of $17,6 million. Finally, the fourth theme concerns the recovery of threatened species via a breeding and restocking programme and complementary habitat rehabilitation with an estimated cost of $9 million.

Because of the diverse nature of the works proposed under the themes presented in this package, we have scored each sub-project individually as well as scoring the project collectively. Explanations of our scoring are provided at the level of sub-projects below. In general, however this project was scored as having moderate to substantial benefits, as well as some moderate dis-benefits with respect to native fish and river flows and connectivity. No significant clear benefits to vegetation or waterbirds, however, were apparent.

SCORES

1: 3.25/10
2: 3.91/10
3: 5.42/10
4: 5.00/10
5: 2.50/5

TOTAL NORMALISED SCORE: 20.07/45
RANKED SCORE: 11th (of 27 scored projects)

NSW Fish for the Future: Reconnecting the northern Basin (NFFF_1)

The first theme of the NSW Fish for the Future project concerns the reconnection of fish passage in the northern Basin via the installation of fishways. This theme has an estimated cost of $36.7 million for works (12 structures) proposed in the Barwon-Darling system and $15.2 million for works (10 structures) proposed in the Border Rivers.

SCORES

1: 5.18/10
2: 5.16/10
3: 6.67/10
4: 7.50/10
5: 2.50/5

TOTAL NORMALISED SCORE: 27.00/45
RANKED SCORE: 3rd (of 27 scored projects)

1: Ecological benefits and dis-benefits

The series of 22 fishways proposed here, incorporating upstream and downstream migration pathways, along with the removal of some tributary barriers, is expected to have substantial benefits for native fish and river flows and connectivity along hundreds of kilometres of mainstem habitat in the Barwon-Darling and Macintyre river systems. These benefits have the potential to contribute significantly to BWS expected environmental outcomes and ecological objectives of long-term watering plans with benefits expected in areas of high conservation value and functional importance as well as degraded areas. This sub-project also has a strong potential to enhance outcomes for native fish of environmental water delivery.

Risks associated with this sub-project include the potential for promoting upstream passage of invasive species (e.g. carp). Additionally, the more frequent and prolonged occurrence of low flow conditions in these watercourses may prevent successful operation of these fishways for an increasing period of time. A fishway needs water to function and at the lower end of Darling's flows, for instance, between 25-70ML per day could be drawn through the structure, resulting in drawdown of weir pools. There will also be a point where there is insufficient flow for fishways to work. At this point the barriers they are fitted to will prevent migratory fish movements. Finally, the timeframe proposed for implementation of this sub-project is considered to be very tight, presenting a risk to its successful completion.

2: Spatial scales of benefits and dis-benefits

Projected ecological benefits are likely to accrue across multiple reaches and catchments. Historical data has shown that, when passage is possible, fish will swim from the Murray River, up the full length of the Darling and make use of Queensland tributaries (Reynolds 1983). When projected across multiple species and size classes, the benefits could therefore be substantial.

Potential ecological dis-benefits associated with increased upstream passage of invasive fish species are expected to be relatively low.

3: Temporal scales of benefits and dis-benefits

Benefits and dis-benefits to native fish and connectivity will clearly occur and accrue when the proposed fishways are operating, which in turn will be governed by hydrology.

4: Scientific and technical confidence

The proponents have suggested a series of designs which are technically accepted and demonstrated to work in the local context (Stuart *et al.* 2008).

The proponents also step out a monitoring and evaluation program that poses a range of post-construction questions regarding fish passage and movement effectiveness. A range of different approaches are proposed including otolith microchemistry, PIT tagging, direct trapping and surveys. However, the proponents also present the outcomes of some predictive ecological modelling (Native Fish Population Case studies). These demonstrate the magnitude of expected benefits (population scale for several species) under a range of implementation scenarios. However, there are some limitations. The proponents present modelling of outcomes in relation to screens (and silver perch) from the Namoi River, but the Namoi is not one of the target sites of any proposed projects. This calls into question the transferability of the data to other catchments. Further, the Murray cod model which is presented shows the expected outcomes if Copeton Dam was remediated. In the Toolkit proposals, however, the proponents have proposed Pindari Dam for remediation. This begs the question that if such significant effort was put into modelling as a basis for predicting ecological benefits, why was the modelling not focused on the target sites and reaches? Or, alternatively, why wasn't screening and thermal pollution mitigation for the Namoi and Gwydir suggested?

5: Synergies

All of the sub-projects presented in the Fish for the Future package clearly have a high potential for reciprocal synergies with each other and may also enhance a range of upstream projects, potentially opening up fish migration pathways into southern Queensland and NSW tributaries.

Considerations for business case development:

If proceeding to business case stage, there will need to be an indication of how well these structures will perform under projected climate change scenarios (Anonymous 2016). The proposed fishways will not work if the Darling River experiences further periods of low or no flow and also risk drawing down weir pools during periods of low flow.

Implementation is also a key consideration here. The proponents need to step out a plan so that 22 fishways can be detail designed and constructed by 2024. This will be a substantial logistical challenge notwithstanding potential construction delays and locating enough contractors to complete the works.

Regarding MER, the proponents really need to develop a strong framework which has sufficient statistical power to detect changes in populations arising from the proposed work. If models are to be used as the basis for predicting benefits, then these need to be developed for the target reaches at the appropriate level of implementation, across multiple species (not just silver perch and Murray cod). The MER program should then be structured to validate and test the models.

NSW Fish for the Future: Addressing cold water pollution (NFFF_2)

Thermal pollution is a significant problem across the entire Murray-Darling Basin, affecting up to 2,200 river kilometres per year (Lugg and Copeland 2014b). Ecological impacts of cold-water pollution include reduced river metabolism, growth rates and elimination of spawning cues across a range of aquatic taxa (Copeland and Lugg 2014). This sub-project presents a plan, based on the outcomes of feasibility studies, to implement cold water pollution mitigation at Pindari Dam in the Border Rivers system. If successfully implemented, improved thermal regimes could be restored to 220 km of Northern Basin streams. There is an existing multi-level offtake at Pindari Dam and the proposal is to "automate" the operation of the existing solution to allow great control over releases.

SCORES

1: 2.81/10
2: 3.28/10
3: 3.54/10
4: 5.00/10
5: 1.88/5

TOTAL NORMALISED SCORE: 16.50/45
RANKED SCORE: 17th (of 27 scored projects)

1: Ecological benefits and dis-benefits

This sub-theme has the potential to deliver substantial benefits for native fish as well as connectivity, through the removal of a behavioural barrier (i.e. cold water). These benefits have the potential to contribute significantly to BWS expected environmental outcomes and ecological objectives of long-term watering plans with benefits expected in areas of high conservation value and functional importance as well as degraded areas. This sub-project also has a strong potential to enhance outcomes for native fish of environmental water delivery.

Blue-green algae poses a significant risk associated with this proposal. The proponents state that there has been a failure to operate multi-level offtakes in the past because reservoirs have a tendency to develop blue-green algal blooms. These blooms present a risk to human health and multi-level offtakes cannot therefore be used when these occur, with cold hypolimnetic releases continuing instead. If this situation occurred in Pindari Dam, thermal pollution would therefore be reinstated, potentially undoing the benefits of any river recovery in a single event involving the reinstatement of hypolimnetic releases.

2: Spatial scales of benefits and dis-benefits

This sub-project has moderate to substantial potential benefits for native fish and connectivity across all scales with benefits becoming more significant at catchment and reach scales, especially along 220 km of watercourse downstream of the dam. Because of the threat posed by blue-green algae, however, there are also moderate risks at these smaller scales.

3: Temporal scales of benefits and dis-benefits

The proposed benefits are expected to occur with moderate frequency and duration, cumulatively in all years when a critical blue-green algal event does not occur. However, in years when blue-green algae does pose a risk, dis-benefits are likely. In the discussion with NSW regarding this project, it was indicated that blue green algal events occur in most years.

5: Scientific and technical confidence

It is interesting that there are currently seven multi-level offtakes in NSW alone, yet none are deemed a success (Copeland and Lugg 2014). This is largely because blue-green algal blooms significantly impact their operation. Given this, it is perplexing that a significant upgrade to "automate" an existing inefficient solution is proposed. The supporting "scoping" document contained a ranking system by which several options were considered but involved a weighting placing "cost" and "maintenance" as more important than "algal outbreaks". Consequently, other solutions (such as surface fans and air compressors) were ruled out.

With respect to MER, and of relevance to all the sub-projects in the Fish for the Future package, is the proponents use of predictive ecological modelling (Native Fish Population Case studies). These case studies demonstrate the magnitude of expected benefits (population scale for several species) under a range of implementation scenarios. There are, however, some significant limitations to these predictions. The Murray cod model, for example, presents expected outcomes if Copeton Dam, rather than Pindari Dam, was remediated. If such significant effort was put into modelling as a basis for predicting the benefits, why was the modelling not focused at the target sites and reaches? Or, why didn't the proponents suggest screening and thermal pollution mitigation for the Gwydir as number one priority?

5: Synergies

All of the sub-projects presented in the Fish for the Future package clearly have a high potential for reciprocal synergies with each other and this theme will certainly aid all other projects being proposed in the 220 km stretch downstream of Pindari Dam.

Considerations for business case development:

- Thorough consideration of the implication of expected blue-green algal events need to be accounted for to ensure that the solution can adequately mitigate cold-water pollution under a range of likely scenarios.
- Additional modelling is required to understand expected benefits downstream of Pindari Dam.
- Other solutions to the problem of cold-water pollution which have a higher chance of success need to be considered.

NSW Fish for the Future: Fish-friendly water extraction (NFFF_3)

This sub-project addresses the significant problem of aquatic animal entrainment from rivers into irrigation systems (Baumgartner and Boys 2012). This is of significant concern across the Northern Basin and is exacerbated by the large quantities of water abstracted annually for agricultural use. Over 90 million fish are estimated to be extracted from main river channels each year; along with turtles, invertebrates and platypus (NSW DPI, *pers. comm*). This initiative seeks to install exclusion screens, to prevent the entrainment of aquatic biota, at selected sites on the Gwydir and Border Rivers.

SCORES

1: 3.51/10
2: 2.50/10
3: 5.42/10
4: 7.50/10
5: 1.56/5

TOTAL NORMALISED SCORE: 20.49/45
RANKED SCORE: 10th (of 27 scored projects)

1: Ecological benefits and dis-benefits

As per other sub-projects in the NSW Fish for the Future, this proposal can be expected to have significant benefits for native fish and connectivity. These benefits have the potential to contribute significantly to BWS expected environmental outcomes and ecological objectives of long-term watering plans with benefits expected in areas of high conservation value and functional importance as well as degraded areas. This sub-project also has a strong potential to enhance outcomes for native fish of environmental water delivery. The proposal does not overly impact river flows, but in a sense eliminates a threatening, and unnatural, lateral connectivity problem.

Both NSW and QLD (QFFWE_1) proponents claim that up to12,000 native fish per day can be entrained at a single pump. When this is extrapolated over multiple pumps across entire reaches, significant gains in native fish numbers could be realised via these projects.

No ecological dis-benefits have been identified. The main risk to this activity is non-adoption by farmers. The majority of pumps across the northern basin are privately held and operated. Missing from the business cases was any evidence that private landholders were (a) willing to participate, (b) had offered their sites to be screens and (c) will agree to own and maintain the screen for its effective life (stated by NSW to be 50 years – but this needs to be validated) and (d) agree to replace the screen once it has reached the end of its effective life. If not, then the benefits will not be realised.

2: Spatial scales of benefits and dis-benefits

This sub-project has moderate to substantial potential benefits for native fish and connectivity across all scales with benefits becoming more significant at catchment and reach scales but no identified ecological dis-benefits. With predicted benefits to up to 12,000 fish per day at each site, benefits at reach scales will be cumulative and accrue as each new site is screened.

3: Temporal scales of benefits and dis-benefits

This sub-project has the capacity to deliver frequent and enduring benefits to native fish and connectivity. Indeed, benefits can be expected to be continuous during pumping season if screens are adequately maintained and operated. The proponents state that exclusion screens will last 50 years; although this should be validated and evidenced in the business case.

4: Scientific and technical confidence

There is a high degree of confidence in the proposed technique and its projected ecological outcomes. In the past few years, significant technological gains in this area have been made. Functional and well-designed exclusion screens are currently installed at the Cohuna Offtake (Gunbower Creek - Victoria) and the Trangie Nevertire Irrigation Scheme (Macquarie Catchment – NSW) (NSW DPI and ARI, unpublished data). Central Tablelands LLS is also installing screens at several sites on the Lachlan River. A set of national design guidelines is now available and there are Australian manufacturers with considerable experience designing and installing the technology (Boys, Baumgartner *et al.* 2012). Investigations demonstrate that screens are working for both adult and larval fish (Boys *et al.* 2013).

The proponents present a monitoring and evaluation program that poses a range of post-construction questions regarding fish passage and movement effectiveness. A range of different approaches are proposed including otolith microchemistry, PIT tagging, direct trapping and surveys. The proponents also present the outcomes of some predictive ecological modelling (Native Fish Population Case studies) which demonstrate the magnitude of expected benefits (population scale for several species) under a range of implementation scenarios. The proponents present modelling of outcomes in relation to screens (and silver perch) from the Namoi River, however, rather than the Border and Gwydir Rivers for which this sub-project is proposed. Furthermore, the Namoi is not a target of any proposed projects. This calls into question the transferability of the data to other catchments and why the population models were not developed for the Border Rivers and Gwydir, where the proposed screening sites are located.

5: Synergies

All of the sub-projects presented in the Fish for the Future package clearly have a high potential for synergies with each other. This theme is particularly likely to benefit other projects in the Gwydir and Border Rivers with expected outcomes for native fish but is unlikely to benefit itself from any of these.

Considerations for business case development:

- Predictive modelling needs to be undertaken in both the target locations (Gwydir and Border Rivers) to validate the expected benefits.
- Suitable screen designs with respect to target species (and life history stages) will require thorough consideration.
- Strong support for proposed screening sites needs to be obtained from farmers (or pump owners). This needs to be in the form of a contractual agreement where they agree to have the pump screened, and also assume the ongoing operations and maintenance. Essentially, they need to assume ownership and the associated responsibilities. There also needs to be some sort of compliance framework built into the MER strategy where the sites are visited regularly, and their operational efficacy validated.
- The MER approach needs to demonstrate the numbers of fish entrainment which have been reduced (and hence now remain in the river) because of screen installation

NSW Fish for the Future: Threatened species recovery (NFFF_4)

The project proposes a hatchery production, translocation and habitat rehabilitation for native fish. The project is well justified because in some area's species have declined to the point where they are locally extirpated. No amount of environmental water will help them recover and these fish need to be reintroduced (Cottingham *et al.* 2020). However, it is equally important that the factors leading to their decline have been identified and controlled to the point where reintroduction is likely to be successful. The proponents suggest a three-year program of production and reintroduction at several sites across the Northern Basin.

SCORES

1: 2.02/10
2: 2.81/10
3: 3.33/10
4: 5.00/10
5: 0.63/5

TOTAL NORMALISED SCORE: 13.79/45
RANKED SCORE: 21st (of 27 scored projects)

1: Ecological benefits and dis-benefits

The benefits of this proposal to native fish have the potential to contribute significantly to BWS expected environmental outcomes and ecological objectives of long-term watering plans with moderate to significant benefits expected in areas of high conservation value and functional importance as well as degraded areas. Significant benefits to unique populations can also be expected. This sub-project has a strong potential to enhance outcomes for native fish of environmental water delivery.

There are several risks to reintroduction programs both from an implementation and sustainability perspective. Particular challenges, which were highlighted by the proponents, include broodstock collection, management, maintaining genetic diversity, determining appropriate stocking numbers and locations (Anonymous 2007). The proponents also stated that habitat and aquatic vegetation may need to be reintroduced to maximise the chances of success, but the specifics of this habitat will depend on the species being reintroduced and possibly location. There are further risks that for at least two of the proposed "Fabulous Four" species, the hatchery propagation techniques are not well understood nor developed. Further to this, is a lack of information on habitat requirements these fish need for feeding, spawning and nursery. Without this information, reintroductions may have limited success. Consequently, there is a concern that the proposed three-year implementation period may not be long enough to deliver tangible long-term benefits.

2: Spatial scales of benefits and dis-benefits

If large numbers of fish can be bred (or translocated) and reintroduced, the spatial scales of the benefits generated could be significant. However, there was insufficient detail in the feasibility study to ascertain how confident the proponents are regarding long-term success. Indeed, numerous aspects of the program are not well developed.

Likely dis-benefits can all be managed but if not managed well, the spatial extent of these could be severe. The business case will need to determine how well all of the risks listed above will be managed.

3: Temporal scales of benefits and dis-benefits

Enduring benefits from this project will accrue largely with robust implementation, requiring coordination across several disciplines to achieve real success. Similarly, disbenefits could accrue with poor implementation. Overstocking, genetic failure, poor reintroduction processes, inability to support the populations and river management failures, for example, could all create perverse outcomes for this work.

4: Scientific and technical confidence

The is high confidence in these techniques with regarding breeding of silver perch and freshwater catfish. These species have had decades of research and well-established methods exist (Lake 1967; Rowland *et al.* 1995). Both species are produced in government and commercial hatcheries and this experience can be leveraged. Strong hatchery spawning techniques have also been developed for purple-spotted gudgeon but presently there is little knowledge on how to scale these to generate large quantities (Hammer, Barnes *et al.* 2012; Llewellyn 2006). Indeed, releases of juvenile fish have been largely unsuccessful. Olive perchlet remain an enigma. There has been some success with pond spawning for this species but the mechanisms by which to translate this into consistent, annual, production are still far from developed (McNeil *et al.* 2008). Furthermore, there has been little research conducted into the release of hatchery-bred fish into the wild.

In terms of habitat reintroduction, there is much lower scientific confidence. For instance, what are the habitat needs of YOY fish versus adult fish? What species of macrophytes will be produced, how many and where will they be re-planted (and will they survive themselves)? What is the best form of larval nutrition? Can fish be released as fingerlings or do they need to be released as fry? These are all critical aspects of a reintroduction program but have not been adequately presented in the business case.

MER will be critical to the success of this project, especially given there are so many unknowns at this stage. Developing a robust monitoring plan which canvasses hatchery production, restocking, survival and long-term population reestablishment is therefore essential.

5: Synergies

If well-planned and executed this sub-theme could augment, and in turn be augmented, by any of the proposed initiatives in the NSW Fish for the Future package.

Considerations for business case development:

- Careful consideration of the timeline is required. Three years does not seem long enough to achieve everything in the planned feasibility study. This is a significant body of work and would likely take longer to gain tangible outcomes.
- Attention needs to be given to identifying suitable hatchery production techniques for each of the "fabulous four".
- Detailed scoping and evaluation are required for reintroduction techniques (with demonstrated proof of reestablishment potential for each of the four species).
- An evaluation of existing threats which have caused these native fish species to decline is also required, especially to demonstrate that these have actually been ameliorated and controlled.
- Suitable aspects of habitat (i.e. re-snagging and macrophytes) are well known for all life history stages for each species. If so, these habitat requirements need to be well established prior to any reintroduction. However, whether three years is enough to achieve this is a matter of concern.
- Proponents need to design a robust monitoring program that can be implemented to monitor the receiving streams pre- and post-reintroduction.
- The budget is sufficient to achieve all of the stated outcomes. This will need detailed treatment in the business case.

QLD Improving within-catchment fish resilience

Six projects have been put forward by Queensland under the umbrella of Improving within-catchment fish resilience, each project focusing on a different river system. All of these projects focus primarily on outcomes for native fish, especially with regards to the improvement of fish passage by addressing barrier to movement.

While we have scored these projects individually (as presented), we provide a combined discussion of our rationale due to the relative similarities of the measures proposed and their general outcomes.

➢ *QLD Improving within-catchment fish resilience: Border Rivers (QICFR_1)*

The first project in this suite, with an estimated cost of $17 million, seeks to improve fish passage in the Border Rivers system (Macintyre and Dumaersq Rivers) via the installation and modification of fishways as well as the removal of Cunningham Weir.

SCORES

1: 4.91/10
2: 4.06/10
3: 6.04/10
4: 5.00/10
5: 2.50/5

TOTAL NORMALISED SCORE: 22.52/45
RANKED SCORE: 7th (of 27 scored projects)

➢ *QLD Improving within-catchment fish resilience: Upper Condamine (QICFR_2)*

The second project for Improving within-catchment fish resilience in QLD proposes the construction of fishways at Cecil Plains Weir, Talgai Weir and Lemon Tree Weir in the Upper Condamine at a total estimate cost of $7.5 million. Four target native fish species are listed in the feasibility study but presumably these fishways will also pass other species.

SCORES

1: 3.51/10
2: 2.19/10
3: 5.42/10
4: 5.00/10
5: 1.25/5

TOTAL NORMALISED SCORE: 17.36/45
RANKED SCORE: 15th (of 27 scored projects)

➢ QLD Improving within-catchment fish resilience: Condamine & Balonne (QICFR_3)

The third of Queensland's Improving within-catchment fish resilience proposals seeks to improve fish passage in the Condamine & Balonne at Surat, Cotswold and Condabri Weirs, with additional considerations for Chinchilla Weir. With an estimated total cost of $10.5 million, the rationale of the project is that a hydrological analysis determined that the drown out frequency of these structures is too infrequent to support reliable passage for native fish.

SCORES

1: 3.07/10
2: 2.19/10
3: 4.17/10
4: 5.00/10
5: 0.00/5

TOTAL NORMALISED SCORE: 14.42/45
RANKED SCORE: 18th (of 27 scored projects)

➢ QLD Improving within-catchment fish resilience: Lower Balonne (QICFR_4)

The fourth of Queensland's Improving within-catchment fish resilience projects, with a total estimated cost of $14.5 million, proposes the installation of fishways at Cubbie Intake, Gurrawarra Weir, Weilmoringle Weir, Gurrawarra Weir, Brenda Weir, Whyenbah regulator and Hastings B1 regulator on the Culgoa River in the Lower Balonne system. The project is focused solely on fish passage reinstatement in areas where barriers exist.

SCORES

1: 4.30/10
2: 1.56/10
3: 4.79/10
4: 5.00/10
5: 2.50/5

TOTAL NORMALISED SCORE: 18.15/45
RANKED SCORE: 13th (of 27 scored projects)

➢ QLD Improving within-catchment fish resilience: Narran River (QICFR_5)

The fifth of Queensland's Improving within-catchment fish resilience projects, with a total estimated cost of $19.7 million, seeks to install a series of fishways which, combined with

strategic barrier removal, will allow fish to move freely along the Narran River, potentially connecting the Narran Lakes with the Barwon. Proponents state that the Narran River has no downstream connectivity, however, and that this reach is of lower priority than other sites in the region.

SCORES

1: 1.75/10
2: 0.94/10
3: 3.54/10
4: 5.00/10
5: 0.63/5

TOTAL NORMALISED SCORE: 11.86/45
RANKED SCORE: 24th (of 27 scored projects)

➢ QLD Improving within-catchment fish resilience: Warrego (QICFR_6)

The sixth and final of Queensland's Improving within-catchment fish resilience projects, seeks to install a series of fishways, combined with strategic barrier removal, to allow fish to move freely along the Queensland reach of Warrego River at Cunnamulla Weir up to the Ward River, with a total estimated cost of $3 million. The project has been scoped to benefit freshwater catfish and silver perch.

SCORES

1: 1.75/10
2: 1.56/10
3: 5.42/10
4: 5.00/10
5: 0.63/5

TOTAL NORMALISED SCORE: 14.36/45
RANKED SCORE: 20th (of 27 scored projects)

1: Ecological benefits and dis-benefits

The objective of the QLD Improving within-catchment fish resilience projects is to reconnect hundreds of kilometres of mainstem riverine habitat for native fish, although it should be noted that propose works only target upstream fish passage. All of these projects have the potential to deliver moderate to substantial ecological benefits to native fish and river flows and connectivity, with the capacity to make moderate to substantial contributions to the BWS Expected Environmental

Outcomes and long-term watering plan ecological objectives as well as the mitigation of key threats and stressors. All six projects also have the potential to generate benefits for native fish and connectivity in high conservation value areas as well as degraded areas and will enhance ecological outcomes of environmental watering. Several of the projects (i.e. QICFR_4, QICFR_5 and QICFR_6), however, fail to identify target species and propose fishway designs that are currently poorly scoped (QICFR_5 and QICFR_6).

All projects also scored relatively well on all river flow and connectivity sub-criteria due to their capacity to deliver substantial longitudinal connectivity benefits without any impacts on lateral connectivity. In general, less significant outcomes for connectivity were expected for QICFR_5 and QICFR_6, the latter only likely to provide site-based benefits in a single river at specified reaches of the Warrego.

The only ecological dis-benefits considered to be of moderate risk for this suite of projects are associated with QICFR_5 as the Narran Lakes have the potential to be a carp spawning hotspot. If spawning events occur, then the proposed fishways may facilitate region-scale movements of carp out of the lakes and into the Barwon River.

Although deemed to be low, numerous other risks associated with these projects were also identified as follows. In particular, and as per the NSW Fish for the Future proposals, low flows may mean these proposed fishways do not operate. Given the likelihood of a drier future, low flow impacts could therefore be significant. Fishways need water to function and, at the lower end of Darling's flows, between 25-70ML per day could be drawn through a structure, drawing down weir pools in turn. There will be a point where there is insufficient flow for fishways to work. At this point the barriers they are fitted to will prevent migratory fish movements.

In all instances, the proposed fishways will also provide an upstream colonisation pathway for invasive fish (Stuart *et al.* 2006). Upstream passage of invasive species (carp) has not been included as something that warrants mitigating (Butler and Wahl 2010).

Downstream movement of fish also needs some consideration. For instance, with respect to QICFR_1, there are undershot gates at Boggabilla which are known to have significant impacts on the survival of eggs and larvae. Installing a forward tilting gate in one of the bays will mitigate this risk but it is unclear if this is included in the budget. The Denil fishway at Boggabilla is a concern as it is a high-water use design and this design has performed very poorly on the Murray for similar target species. There are some additional barriers downstream of the proposed sites in QICFR_2. Although the proponents state "these drown out frequently", a full hydrological assessment is needed to validate this claim. If the systems are to be drier into the future, this assumption may risk projects not achieving their intended outcomes. There are risks associated with both QICFR_4 and QICFR_5 that fish that are passed upstream may not be able to return to downstream refuge pools. There is some

potential that QICFR_4 and QICFR_5 could inadvertently lead to overstocking in the remnant pools with potential risks to aquatic food web.

With respect to QICFR_3, Chinchilla Weir has a bypass fishway proposed, but this design has "never before been implemented in the QLD MDB" according to the proponents. Chinchilla Weir is suggested to be a site that could experience "high costs". It will be a challenging site and there will be significant consideration needed to locate an appropriate entrance location as the weir itself is quite a unique design. Similarly, a bypass fishway is proposed under QICFR_4, but this design has "never before been implemented in the QLD MDB" according to the proponents. A rock ramp fishway is proposed, but this was deemed to require replacement at Goondiwindi Weir. Additionally, two weirs under both QICFR_4 and QICFR_5 are privately-owned meaning owners will need to accept risks and agree to take on the operations and long-term maintenance. Ineffective fishway designs, maintenance and operations can result in decades of poor passage and not achieve outcomes (Mallen-Cooper and Brand 2007)

Minimal disbenefits anticipated from QICFR_6, but the proponents state that there are a number of road crossings which could impede fish passage. If the proponents do not consider the impact of the road crossings on fish passage, then the anticipated benefits may be overestimated.

2: Spatial scales of benefits and dis-benefits

Moderate to substantial benefits to native fish and river flows and connectivity can be expected from of QICFR_1, QICFR_2 and QICFR_3 while all projects in this suite will have moderate to substantial benefits at reach and site scales. With respect to of OIFR_1, historical data has shown that, when passage is possible, fish will swim from the Murray River up the full length of the Darling and make use of Queensland tributaries. When projected across multiple species and size classes, the benefits of this project could therefore be substantial. Benefits of QICFR_2 and QICFR_3 would also accrue across multiple reaches. For QICFR_2, there are potential linkages from these reaches to downstream fish communities, but these depend upon frequent drownout of downstream weirs and funding of other fish passes to connect fish populations at a landscape scale. Benefits of QICFR_4 will largely accrue in the Culgoa River along 489 km of river habitat, the main benefits being connection of waterholes after extended dry periods. Benefits of QICFR_5 are very confined to barriers in the Narran River although this project may generate some connectivity to the Barwon River if implemented in a strategic sense. So, while the project appears to immediate open 57 km of river directly, up to 200 km of river upstream may also benefit if the Barwon River is taken into account. Similarly, benefits of QICFR_6 will likely be limited to barriers along 338 km of the Warrego River along 338 km of river directly although, as per QICFR_5, up to 816 km river upstream could also benefit if the Darling River is taken into account.

The moderate ecological dis-benefits identified for this suite of projects associated with QICFR_5 in terms of carp spawning and spread were deemed to be risks mainly at reach and site scales.

3: Temporal scales of benefits and dis-benefits

The frequency and duration of projected benefits across this suite of projects is likely to be moderate to high. The critical factor here is hydrology, which will need to be carefully considered during the design phase. However, whenever operating these fishways will reduce accumulations (good for fish, not so good for waterbirds), allow the passage of invasive species and draw down weir pools. The moderate ecological dis-benefits identified for this suite of projects associated with QICFR_5 in terms of carp spawning and spread are scored as having moderate frequency and duration.

4: Scientific and technical confidence

These proposals present a series of designs which are technically accepted and demonstrated to work in the local context. For QICFR_3, QICFR_4 and QICFR_5, the vertical slot fishways are well accepted and known to work across the MDB. The proposed bypass fishway, however, is yet to be trialled in the QLD MDB. For QICFR_6, the proponents state that they feel a vertical slot fishway above 4.5 m high will be sub-optimal. However, there is no evidence of this and the supporting document cited here doesn't actually support what the proponents have cited. Vertical slot fishways can function efficiently to much higher levels but the trade-off is a greater construction cost.

The feasibility study clearly states that these proposals do not currently include a commitment to MER nor ongoing operations and maintenance of the proposed works. This really needs to be a feature of these projects if proceeding to business case development with investigations required pre-construction to ensure the target species are actually present.

For QICFR_3, the feasibility study states that "the QLD government is in the process of securing funding for an acoustic tagging program". However, no consideration is given to which species would be tagged. At least two of the target species, olive perchlet and southern purple spotted gugdeon, are far too small to be considered for this method highlighting the need for MER methods =to be applicable to the target species with well-defined questions posed.

For QICFR_4 and QICFR_5, the feasibility study states that MER programs should focus on "fish passage" and "fishway maintenance", but this is a very simplistic set of requirements and may not demonstrate whether the project is contributing to its objective of improved fish passage in the Culgoa. A robust MER program will require a combination of fishway trapping, community surveys, tracking, and possibly microchemistry approaches in addition to, as the proponents highlight, a series of compliance testing to ensure the fishways are performing as per the design specification.

5: Synergies

QICRF_1 will improve connectivity for native fish upstream of Mungindi. This project therefore has the potential to enhance benefits of NSW Fish for the Future project, especially NFFF_1. This project would be seriously disadvantaged if NFFR_1 is not funded and this would represent a lost opportunity to connect the Darling if QICFR_1 is not considered as a holistic proposal with the NSW submission.

All of the other projects in this suite will likely enhance upstream projects and, in turn, will be seriously disadvantaged if downstream fish passage initiatives are not funded and if drown out events do not occur on the downstream dams or, in the case of QICFR_6, road crossings.

Considerations for business case development:

- Significant work is required to attempt to link up all fish passage projects into a single initiative which has a strategic, and large-scale, conceptual basis. The current splitting of projects into individual sites completely undermines the ability to connect fish at the landscape scale. NSW and QLD really need to collaborate on finding ways to bring their suite of fish passage projects together into a coherent, landscape-scale, package.
- Functionality in terms of species and hydrology needs to be matched with NSW proposals. There is no point having design criteria in NSW which is different from QLD. There needs to be a defined, accepted, landscape scale solution if region-scale benefits are to accrue. This can be achieved by establishing a NB Fish Passage Taskforce analogous to the Sea to Hume model.
- Any solution for the Northern Basin Toolkit needs to have a life of at least 50 years to match the expected implementation period of the basin plan.
- Downstream passage is not a strong feature here but presumably passing fish upstream (for whatever ecological reason) will require downstream movements (either active or passive) at some stage. The NSW suite of projects have considered the downstream components in all work and this also needs to feature more prominently in the QLD proposals (Baumgartner, Reynoldson *et al.* 2006).
- For QICFR_1, the weir removal component is exciting and, as few have been undertaken in the MDB, should have a strong M&E program around it to highlight the benefits. It could act as a template for further removals if well planned. The proponents need to work with NSW and VIC to obtain data on Mildura and Euston sites. These were retrofitted with Denil Inserts "which is proposed for Boggabilla" but are largely considered failures. It would be disastrous to replicate those failures at Boggabilla as it is such a critically-located site on the Macintyre system. Strongly advise against a Denil solution.
- For QICFR_1, Note that two of the proposed sites, Goondiwindi and Boggabilla, have existing fishways but $4m is required to refurbish. That suggests there are concerns over their functionality. The business case needs to ensure that the fishways have a long expected design life and won't require further refurbishment (and hence millions) to create an enduring outcome at these locations.

- For QICFR_2The downstream barriers are a concern and could limit the benefits here if they do not drownout. A full hydrological analysis is needed to validate this.
- For QICFR_3, Entrance location at Chinchilla Weir may require cutting into the weir itself which could increase costs significantly
- For QICFR_5, Cubbie Weir and Gurrawarra Weir are privately owned. The business case would need to include written agreement from the private owners for the structures to be retrofitted with fishways and that they will agree to operate and maintain the structures post-construction.
- Additionally, for QICFR_4 and QICFR_5, no specific fish species are listed as beneficiaries of this project. It is strongly recommended that these are listed and their ecology conceptualised as part of the detail design process. For QICFR_6, Only two species are listed here as beneficiaries (silver perch and freshwater catfish). But there is little detail on how the species will benefit and if the work links into a broader recovery strategy.
- For QICFR_5, The proposed package of works is $20M; which appears quite expensive considering the proponents label this project a “low” priority. There should be some work ranking the proposed benefits of this work against the other projects packaged as part of the toolkit program.

QLD Reconnecting catchments: Condamine-Balonne (QRC)

The proposal seeks to reinstate fish passage at two significant structures, Jack Taylor and Beardmore Dams, as the two main barriers disconnecting southern streams from the Condamine and Maranoa Rivers.

SCORES

1: 4.12/10
2: 4.06/10
3: 5.42/10
4: 5.00/10
5: 2.50/5

TOTAL NORMALISED SCORE: 21.10/45
RANKED SCORE: 8th (of 27 scored projects)

1: Ecological benefits and dis-benefits

The main objectives of this proposal are to provide regular opportunities for four target species to move upstream and avoid unspecified impacts in the system. In terms of risks, upstream passage of invasive species (carp) has not been included as something that warrants mitigating. Additionally, low flows may mean the fishways cannot operate continuously although proponents state that existing "pass through" flow rules could help. If fish are passed upstream, there will also be a need to ensure that they can return to downstream refuge pools.

2: Spatial scales of benefits and dis-benefits

Benefits of this project would largely accrue in upstream reaches of the Condamine River with the main benefits being the connection of waterholes after extended dry periods.

With regards to possible risks and dis-benefits, low flow impacts could be significant. A fishway needs water to function and at the lower end of Darling flows it could be drawing between 25-70ML per day through the structure. This will drawdown weir pools with significant impacts at site and reach scales. There will be a point where there is insufficient flow for fishways to work. At this point, the barriers they are fitted to will prevent migratory fish movements at the site and reach scale.

The fishways will also provide an upstream colonisation pathway for invasive fish, with reach-scale

3: Temporal scales of benefits and dis-benefits

Benefits of this project will accrue when the fishways are operating and are therefore likely to have moderate to high frequency and duration. The critical factor here is hydrology, which will need to be

carefully considered during the design phase. Likewise, whenever operating the fishways will also, however, allow the passage of invasive species and draw down weirpools.

4: Scientific and technical confidence

These barriers are quite large and will therefore require some innovative engineering design. Proponents state that "the appropriate design is yet to be determined" but also that "the construction of two Deelder locks at St George will create local jobs". This really needs to be clarified whether Deelder locks are preferred or if other options are being considered. Deelder locks perform well but there are engineering problems with the gate operations which will need to be resolved if these are the preferred solution. They also do not pass fish downstream. Deelder locks have been installed at smaller sites on the Murray River but larger lock systems have also been installed on the Burnett River. Lock systems work conceptually. However, the Burnett sites were damaged by floods and have not been replaced. The Deelder lock at Balranald on the Murrumbidgee River had actuator burnout and has not been replaced. The sites on the Murray have also been plagued by operational issues with gate operation. At these sites, fish passage is blocked whenever there is an operational failure. This decreases the confidence that lock systems are a good long-term prospect for fish passage.

A robust MER program will require a combination of fishway trapping, community surveys, tracking, and possibly microchemistry approaches in addition to, as the proponents highlight, a series of compliance testing to ensure the fishways are performing as per the design specification.

5: Synergies

This project will benefit projects upstream. Additionally, the project would be seriously disadvantaged if downstream fish passage initiatives were not funded and if drown out events do not occur on the downstream dams.

Considerations for business case development:

- Significant work is required to attempt to link up all fish passage projects into a single initiative which has a strategic, and large-scale, conceptual basis. The current splitting of projects into individual sites undermines the ability to connect fish at the landscape scale. NSW and QLD need to collaborate on finding ways to bring their suite of fish passage projects together into a coherent, landscape-scale, package.
- Downstream passage is not a strong feature here but presumably passing fish upstream (for whatever ecological reason) will require downstream movements (either active or passive) at some stage. The NSW suite of projects have considered the downstream components in all work and this also needs to feature more prominently in the QLD proposals.
- Functionality, in terms of species and hydrology, needs to be matched with NSW proposals. There is no point having design criteria in NSW which is different from QLD. There needs to be a defined, accepted, landscape scale solution if region-scale benefits are to accrue. This

can be achieved by establishing a Northern Basin Fish Passage Taskforce analogous to the Sea to Hume model.

- Any solution for the Northern Basin toolkit needs to have a life of at least 50 years to match the expected implementation period of the basin plan, yet fish locks have failed to operate consistently for that time in other areas. The problems plaguing other fish locks need to be solved and applied here.

QLD Addressing cold water pollution: Border Rivers (QCWP_1)

This project addresses the significant problem of cold-water pollution downstream of Glenlyon Dam in the Border Rivers via the retrofitting of a thermal curtain, multi-level offtake or destratification system with an estimated cost $3 million (excluding maintenance).

Thermal pollution is a significant problem across the entire MDB impacting up to 2,200 river kilometres per year (Lugg and Copeland 2014b). The impacts are reduced river metabolism, growth rates and elimination of spawning cues across a range of taxa. This project steps out a plan, based on the outcomes of feasibility studies, to implement cold water pollution mitigation at Glenlyon Dam. If implemented, normal thermal regimes would be restored to downstream reaches. The proposed solution is to install a thermal curtain or multi-level offtake.

SCORES

1: 2.46/10
2: 0.78/10
3: 3.54/10
4: 5.00/10
5: 1.25/5

TOTAL NORMALISED SCORE: 13.03/45
RANKED SCORE: 22nd (of 27 scored projects)

1: Ecological benefits and dis-benefits

Proponents state that the project will benefit fish but there are also clear benefits for water quality, birds and aquatic vegetation that could accrue if well implemented. Restoring a normal thermal regime to the stretch of river downstream of Glenlyon Dam will benefit multiple taxa and improve river metabolism.

As per NFFF_2 above, blue Green Algae is a significant risk. The proponents state that there has been a failure to operate multi-level offtakes in the past and that this is because reservoirs develop blue green algal blooms. These blooms are a risk to human health and when they occur; multi-level offtakes cannot be used and hypolimnetic releases continue. In which case, thermal pollution would be reinstated. This is a significant risk. Multiple years of river recovery could be undone by a single event which sees the reinstatement of hypolimnetic releases.

The proponents state that installing the solution will require flow cessation and dam lowering for a significant period of time which may be unfeasible.

2: Spatial scales of benefits and dis-benefits

The proponents state that the benefits will extend 30-40 km downstream of the dam. All areas downstream of the dam will be subject to ecological dis-benefits, however, if the solution does not work.

3: Temporal scales of benefits and dis-benefits

As per NFFF_2, the proposed benefits are expected to occur with moderate frequency and duration, cumulatively in all years when a critical blue-green algal event does not occur. However, in years when blue-green algae does pose a risk, dis-benefits are likely.

4: Scientific and technical confidence

There is a significant risk that the requested budget ($3M) is insufficient for the scale of solutions proposed. The proponents state that the "cost of various options varies by millions of dollars", suggesting that substantial development work is still needed.

The proponents state that M&E has not been factored into the project costing but acknowledge that it is required.

5: Synergies

This project will certainly aid all other projects being proposed downstream.

The proponents also state that the project will be enhanced by Dumaresq River habitat improvements. Additionally, there are clear benefits and links which could also be drawn from NSW projects which are not adequately captured in the feasibility proposal.

Considerations for business case development:

- Thorough consideration of the implication of expected blue-green algal events need to be accounted for to ensure that the solution can adequately mitigate cold-water pollution under a range of likely scenarios.
- Additional modelling is required to understand expected benefits downstream of Glenlyon Dam.
- Other solutions to the problem of cold-water pollution which have a higher chance of success need to be considered.

QLD Bringing back riverine habitat for native fish (QCWP_2)

This project seeks to restore native fish habitat by restoring riparian and aquatic habitat. With an estimated total cost of $42.2 million, proposed works include revegetation, re-snagging, installation of rocky and small woody habitat and enhancing riparian areas through fencing and associated measures to exclude livestock from the bed and banks of watercourses in the Lower Balonne, Upper Condamine and tributaries, Border Rivers, Warrego River and the Condamine-Balonne.

SCORES

1: 2.98/10
2: 3.13/10
3: 5.42/10
4: 5.00/10
5: 0.47/5

TOTAL NORMALISED SCORE: 16.99/45
RANKED SCORE: 16th (of 27 scored projects)

1: Ecological benefits and dis-benefits

The main objectives of this project are to generate outcomes for native fish by restoring riverine habitat. Based on the information provided, moderate benefits are expected. Since this project directly includes re-establishment of riparian and aquatic vegetation, significant benefits for vegetation are also probable. Conceptually, the project has benefits but what is lacking is significant detail on how the project will be implemented and where. There is little detail on the types of interventions that will be implemented, at what scale and how these will be maintained over the long term.

Minimal dis-benefits were identified although fencing riparian zones does pose risks to terrestrial fauna (e.g. barriers to drinking water) and may be undesirable from a social or cultural perspective.

2: Spatial scales of benefits and dis-benefits

Moderate to significant benefits to native fish and vegetation are expected across all spatial scales. There is potential to general large-scale outcomes, but these are scattered among many other projects. It is impossible to determine at what scale the benefits will actually accrue because the level of thinking and planning was not presented clearly in the feasibility proposal. Most of this detail will be fleshed out at the business case stage, so this project was particularly difficult to score. There is also an assumption that all species will benefit if habitat changes are made, but some may disbenefit if the habitat shifts a lot from its present state.

3: Temporal scales of benefits and dis-benefits

Improvement of habitat could be an enduring outcome, but some of the proposed works will need some form of maintenance to remain effective. These considerations, however, are not discussed in the proposal and funding request. Dis-benefits are not strongly recognised and the degree to which alien fish may benefit is not explored.

4: Scientific and technical confidence

The panel had moderate confidence in the science and techniques described. We had high confidence in some aspects (e.g. re-snagging), but others, such as aquatic vegetation reintroduction, are not well explained. The use of fish hotels is alos indicated but there is little published literature on their effectiveness. A significant amount of "re-fencing" is proposed (1,200km) but no indication of where and what design will be used. Furthermore, there is a risk identified that landholders may not engage.

5: Synergies

This project has the potential for synergies with multiple other projects in relation to native fish outcomes depending on where this project was conducted.

Considerations for business case development:

- More details are required regarding the specific techniques that will be applied and at what scales.
- More evidence is needed regarding the types of interventions and evidence of their previous success (i.e. fish hotels).
- A strong restocking strategy and understanding of the numbers and locations required with respect to threatened species reintroductions is needed to inform this habitat rehabilitation initiative to create synergies.
- Alignment with NFFF_4 should be considered as this NSW project is very similar in scope and budget.
- Ecological impacts of altering habitat at a site need consideration, i.e. will some species actually dis-benefit from proposed changes?

QLD Threatened species re-establishment:

Three projects are proposed regarding the recovery of threatened species in Queensland as follows:

➢ Silver perch, purple-spotted gudgeon and olive perchlet (QTSR_1)

This project is one of three proposed by Queensland which seek to re-establish threatened species within watercourses of the Queensland portion of the northern Basin. With an estimated total cost of $1.48 million, this first project proposes a series of hatchery production and translocation to re-establish three species of native fish (silver perch, purple-spotted gudgeon and olive perchlet) in the Condamine and Border Rivers systems.

SCORES

1: 2.02/10
2: 2.03/10
3: 3.33/10
4: 5.00/10
5: 0.31/5

TOTAL NORMALISED SCORE: 12.69/45
RANKED SCORE: 23rd (of 27 scored projects)

➢ River blackfish (QTSR_2)

The second project proposed by Queensland seeking to re-establish threatened species within watercourses of the Queensland portion of the northern Basin focuses on river blackfish. This project proposes to extend the core range of this species in the upper Condamine for an estimated total cost of $1.5 million.

SCORES

1: 1.05/10
2: 1.25/10
3: 3.13/10
4: 5.00/10
5: 0.31/5

TOTAL NORMALISED SCORE: 10.74/45
RANKED SCORE: 25th (of 27 scored projects)

➢ Murray cod and freshwater catfish in the Paroo River (QTSR_3)

The third and final project proposed by Queensland regarding the re-establishment of threatened species, with an estimated total cost of $2 million, concerns Murray cod and freshwater catfish in the Paroo River.

SCORES

1: 1.05/10
2: -0.31/10
3: 3.96/10
4: 5.00/10
5: 0.00/5

TOTAL NORMALISED SCORE: 10.12/45
RANKED SCORE: 26th (of 27 scored projects)

1: Ecological benefits and dis-benefits

These projects all have the capacity to generate moderate to significant benefits for native fish. There are also clear benefits for water quality and riparian and aquatic vegetation that could accrue if well implemented.

There are several risks to reintroduction programs both from the implementation and sustainability perspective. Matters, which were highlighted by the proponents, include broodstock collection, management, maintaining genetic diversity, determining appropriate stocking numbers and locations. The proponents also stated that habitat and aquatic vegetation may need to be reintroduced to maximise the chances of success. This habitat will depend on the species being reintroduced and may also be specific to location. There are further risks that for at least two of the proposed species, the hatchery propagation techniques are not well understood nor developed (olive perchlet and purple-spotted gudgeon). Further to this is a lack of information on habitat requirements, requirements for these species with respect to feeding, spawning and nursery habitat also require greater understanding. Without this information, reintroductions may have limited success.

There are also potential ecological risks associated with removing fish from a site to translocate elsewhere.

2: Spatial scales of benefits and dis-benefits

The spatial scales of ecological benefits will depend on the success of reintroductions. If large numbers of fish can be bred (or translocated) and reintroduced, then this could be significant.

However, there was not enough detail in the proposal to ascertain how confident the proponents are regarding long-term success. There are still parts of the program which are not well developed.

The dis-benefits can all be managed, although if not managed well, the magnitude of these could be severe. The proponents also need to identify the risks of removing fish for translocation and ensure there are no disbenefits to the "source" systems.

3: Temporal scales of benefits and dis-benefits

The benefits from these projects will accrue largely with robust implementation, requiring coordination across several disciplines to achieve real success. Impacts on wild populations need to be adequately controlled. Hatchery management and production must be first class. Re-stocking activities need to encourage long term survival. River management must be complementary and support the re-established populations. These four priority areas need to be addresses should this proceed to business case.

Again, disbenefits could accrue with poor implementation. Overstocking, genetic failure, poor reintroduction processes, inability to support the populations and river management failures could all create perverse outcomes for this work.

4: Scientific and technical confidence

For silver perch and freshwater catfish, there can be high confidence in the projected outcomes and techniques. These species have had decades of research and well-established methods exist. Both species are produced in government hatcheries and commercially and this experience can be leveraged. Purple-spotted gudgeon have strong hatchery spawning techniques developed, but presently there is little knowledge on how to scale to large quantities. Releases of juvenile fish have been largely unsuccessful. Olive perchlet remain an enigma. There has been some success with pond spawning for this species, B=but the mechanisms by which to translate this into consistent, annual, production is still some time off. There has been little research conducted into the release of hatchery-bred fish into the wild.

In terms of habitat reintroduction, this requires more planning. For instance, what are the habitat needs of YOY fish vs adult fish? What species of macrophytes will be produced, how many and where will they be re-planted? What is the best form of larval nutrition? Can fish be released as fingerlings or do they need to be released as fry? These are all critical aspects of a reintroduction program but have not been adequately presented in the business case.

Monitoring & evaluation will be critical to the success of this project. There are so many unknowns at this stage so developing a robust monitoring plan which canvasses hatchery production, restocking, survival and long-term population reestablishment is essential. Again, this project does not currently

include an adequate monitoring plan or estimation of costs. If budgeted properly it may be that the inclusion of M&E costs would make some of these projects unviable and a poor investment.

5: Synergies

These projects have the potential for synergies with multiple other projects in relation to native fish outcomes if these were well planned and executed.

Considerations for business case development:

- Hatchery production techniques need to be sufficiently investigated for each of the species.
- Reintroduction techniques need to be sufficiently scoped and understood for each species.
- Existing threats which have caused these species to decline require amelioration.
- A robust monitoring program needs to be implemented to monitor the receiving streams pre and post reintroduction
- Suitable aspects of habitat (I.e. re-snagging and macrophytes) need to be understood for all life history stages for each species and well established prior to any reintroduction. However, whether three years is enough to achieve this is a matter of concern.
- Need to determine if "fish hotels", as stated in the introduction document, have enough scientific data supporting their appropriateness as a solution worthy of significant investment.
- NSW are proposing an almost-identical project. Here the proponents have stated that "Different regulations and stocking program arrangements mean implementation will be necessarily be separate on either side of the border" and that this will be an impediment to collaborating. An equally valid response could be that the states align stocking procedures and protocols and mutually commit to standardising regulations and implementation.
- As pitched, the project will be duplicated in both states yet, ecologically, there is nothing stopping a fish stocked in QLD migrating to NSW or vice versa. There needs to be a mutual, genuine, commitment to work together and avoid duplication or facilities and resources especially where there is a limited pool available for Northern Basin toolkit projects and where both states have identified the same species.
- Consideration needs to be given to the most efficient locations for fish breeding (Bribie Island?) for these projects.
- With respect to the third project targeting Murrray cod and freshwater catfish in the Paroo River, a major assumption by the proponents is that the two main threats that led to the decline (excessive drought and impact of alien species) have been sufficiently ameliorated to the point where these threats no longer exist. Specifically, the proponents state that the reintroduction of Murray cod will sufficiently place enough predation pressure on carp that the risk to freshwater catfish nests/eggs is supressed. The basis for this is stated as "well accepted anecdotal observations". The panel strongly refutes this claim. Carp presently occupy the most biomass of any species across the entire MDB. This is despite Murray cod

reintroductions and stockings occurring for decades. Further, studies of Murray cod diets indicate that, whilst they do eat carp, that they also eat other fish, crustaceans and other food sources. The anecdotal observations are a leap of faith which significantly undermine the feasibility of this proposal.

- The business cases for these projects need to give details about the number of fish to be stocked, where they will be sourced and how genetic diversity will be managed. The way in which the stocked population will interact with the receiving population also needs to be explained. Strong evidence, as opposed to anecdotal evidence, needs to be supplied for the carp control assumptions.

QLD Fish friendly water extraction: Condamine-Balonne & Border Rivers (QFFWE_1)

This project, like NSW's NFFF_3, addresses the significant problem of aquatic animal entrainment from main rivers into irrigation systems (Baumgartner and Boys 2012) through the installation of exclusion screens in the Border Rivers, Lower Balonne and Upper Condamine with an estimated total cost of $6 million.

The project is addressing the significant problem of aquatic animal entrainment from main rivers into irrigation systems. It is a significant issue across the Northern Basin which is exacerbated by the large quantities of water abstracted annually for "productive" agricultural use. It is estimated that over 90 million fish are extracted from main river channels each year; which can also include turtles, invertebrates and platypus. The initiative seeks to install exclusion screens into demonstration reaches in the Border Rivers, Lower Balonne and Upper Condamine.

SCORES

1: 3.51/10
2: 2.50/10
3: 5.42/10
4: 7.50/10
5: 1.56/5

TOTAL NORMALISED SCORE: 20.49/45
RANKED SCORE: 9th (of 27 scored projects)

1: Ecological benefits and dis-benefits

This proposal can be expected to have significant benefits for native fish and connectivity. These benefits have the potential to contribute significantly to BWS expected environmental outcomes and ecological objectives of long-term watering plans with benefits expected in areas of high conservation value and functional importance as well as degraded areas. This sub-project also has a strong potential to enhance outcomes for native fish of environmental water delivery. The proposal does not overly impact river flows, but in a sense eliminates a threatening, and unnatural, lateral connectivity problem.

Both NSW and QLD proponents claim that up to12,000 native fish per day can be entrained at a single pump. When this is extrapolated over multiple pumps across entire reaches, significant gains in native fish numbers could be realised via these projects.

No ecological dis-benefits have been identified. Impingement of fish is a risk and there is a need to ensure that suitable screens are installed that prevent fish from being impinged on them. If this is not ameliorated during design, all it does is transfer the entrainment loss to an impingement loss and the gains are not realised. However, this risk can be fully resolved with good design.

The main risk to this activity is non-adoption by farmers. The majority of pumps across the northern basin are privately held and operated. Missing from the business cases was any evidence that private landholders were (a) willing to participate, (b) had offered their sites to be screens and (c) will agree to own and maintain the screen for its effective life (stated by NSW to be 50 years – but this needs to be validated) and (d) agree to replace the screen once it has reached the end of its effective life. If not, then the benefits will not be realised.

2: Spatial scales of benefits and dis-benefits

This sub-project has moderate to substantial potential benefits for native fish and connectivity across all scales with benefits becoming more significant at catchment and reach scales but no identified ecological dis-benefits. With predicted benefits to up to 12,000 fish per day at each site, benefits at reach scales will be cumulative and accrue as each new site is screened.

3: Temporal scales of benefits and dis-benefits

This sub-project has the capacity to deliver frequent and enduring benefits to native fish and connectivity. Indeed, benefits can be expected to be continuous during pumping season if screens are adequately maintained and operated. The proponents state that exclusion screens will last 50 years; although this should be validated and evidenced in the business case.

4: Scientific and technical confidence

There is a high degree of confidence in the proposed technique and its projected ecological outcomes. In the past few years, significant technological gains in this area have been made. Functional and well-designed exclusion screens are currently installed at the Cohuna Offtake (Gunbower Creek - Victoria) and the Trangie Nevertire Irrigation Scheme (Macquarie Catchment – NSW) (NSW DPI and ARI, unpublished data). Central Tablelands LLS is also installing screens at several sites on the Lachlan River. A set of national design guidelines is now available and there are Australian manufacturers with considerable experience designing and installing the technology (Boys, Baumgartner *et al.* 2012). Investigations demonstrate that screens are working for both adult and larval fish (Boys *et al.* 2013).

The proponents acknowledge that M&E is needed to increase irrigator uptake, but this is not currently costed in the proposal.

5: Synergies

This project will certainly help fish passage and flow-related outcomes for native fish. The main benefits are that fish spawned/recruited from watering events will no longer be extracted into irrigation systems but will remain in the river and lead to improve populations.

Considerations for business case development:

- Predictive modelling needs to be undertaken in both the target locations (Condamine-Balonne and Border Rivers) to validate the expected benefits.
- Suitable screen designs with respect to target species (and life history stages) will require thorough consideration.
- Strong support for proposed screening sites needs to be obtained from farmers (or pump owners). This needs to be in the form of a contractual agreement where they agree to have the pump screened, and also assume the ongoing operations and maintenance. Essentially, they need to assume ownership and the associated responsibilities. There also needs to be some sort of compliance framework built into the MER strategy where the sites are visited regularly, and their operational efficacy validated.
- The MER approach needs to demonstrate the numbers of fish entrainment which have been reduced (and hence now remain in the river) because of screen installation

QLD Enhance the flexibility and capability for distributing and managing low flows through the Lower Balonne River system bifurcation weirs (QFFWE_2)

This project seeks to upgrade a series of ageing bifurcation weirs to increase the level of control over low flow events in the Lower Balonne system. It will provide operational efficiencies and greater flexibility for delivering water through the system. Of all the projects proposed by QLD, this was by far the most detailed and well thought out. The project has been well-scoped and significant supporting documents were included which matched the scoring rubric closely. The project appears to be very good value-for money and will provide benefits to fish, vegetation, waterbirds and river flows and connectivity.

SCORES

1: 5.88/10
2: 4.84/10
3: 5.00/10
4: 7.50/10
5: 1.25/5

TOTAL NORMALISED SCORE: 24.47/45
RANKED SCORE: 5th (of 27 scored projects)

1: Ecological benefits and dis-benefits

This was the only Queensland project which sought to provide benefits for all target objectives (native fish, vegetation, waterbirds and river flow/connectivity). Because the project seeks to enhance the capacity to control flows, especially low flows, in the lower Balonne watercourses, including the Narran River into Narran Lakes Ramsar site, the ecological benefits could be substantial. For waterbirds, the benefits are likely to occur mainly via an enhanced capacity to better manage the tail ends of floods to ensure maximum water is delivered to Narran Lakes to extend habitat condition for fledged birds (since waterbirds need high flows for breeding).

The main risk identified for this project is that the solution appears to be limited to providing operational flexibility for a single watering event. Given the constraints within the system, it will be operated on an event-specific basis. This may generate potential perverse outcomes if altered watering regimes involve a greater frequency and extent of wetting without sufficient depth or duration to limit the establishment of exotic plant species (e.g. lippia) or encroachment of terrestrial vegetation.

2: Spatial scales of benefits and dis-benefits

This project has the potential to generate moderate to significant benefits for all themes across all scales, with the exception of native fish at catchment and sub-basin scales.

3: Temporal scales of benefits and dis-benefits

Due to the volumes involved and the fact that delivery can be augmented from planned and held environmental water holdings, the proposal would appear to have a high temporal frequency of river flow connectivity benefits. In terms of river flows and connectivity the proposal would appear to have a low frequency of disbenefits. Due to the volumes involved and the fact that delivery can be augmented from planned and held environmental water holdings, the proposal would appear to have enduring flow connectivity benefits. Ecological benefits would be expected to endure as long as the design life of the proposed solution.

4: Scientific and technical confidence

There are several technical considerations for implementation which have already been scoped through an engineering consultant. They validated that the project is feasible but outlined several challenges to implementation. A major consideration is hydrology and more modelling is required to ensure the proposed solutions will perform as expected.

The proponents have not costed M&E into the feasibility study.

5: Synergies

The proposal has the potential for substantial enhancement of river flow connectivity for and by other projects owing to the high temporal frequency of improved river flow connectivity and the presence of large volumes of held environmental water.

Considerations for business case development:

- Better conceptualisation of the fish-related benefits would be useful. This should include development of a fisheries conceptual model and then how fish could be expected to respond under a range of anticipated operating scenarios.
- The project could potentially improve connectivity among refuge waterholes, especially under low flows, but hydrological modelling will be needed to validate this claim.