

Chapter 9

Environmental flow management and monitoring in the Lower Gwydir floodplain

Management recommendations

- Expectations of what ecological responses might be achieved by a particular release need to be realistic. Any one release is unlikely to satisfy the hydrological requirements of all aquatic biota or ecosystem components.
- It may be necessary to establish a more variable hydrograph for future ECA releases, in order to satisfy as many ecological objectives as possible.
- 'Piggy-backing' ECA flows on bulk stock and domestic or irrigation releases may be an effective strategy for facilitating multiple releases of differing stage height. However, the delivery point(s) for these flows and the channel reaches where the ecological outcomes are desired would need to match, and it will be necessary to establish whether there is significant loss of ecological response (e.g. larval fish) from abstraction of the associated consumptive flows.
- Recognise that ecological responses to flow events will likely differ seasonally. Although significant flood events have occurred in winter in the Lower Gwydir floodplain, the region has a summer-dominant rainfall pattern and the timing of future ECA events should match this whenever possible.
- ECA events should also maximise the duration of wetland inundation. The best means of achieving this in the Lower Gwydir appears to be through piggy-backing releases onto natural flow events.
- Ensure that the Gwydir Environmental Management Plan and the Gwydir Wetlands Decision Support System software both incorporate the latest scientific findings on Lower Gwydir aquatic ecological responses to flow variability.
- Include event-based monitoring of both in-stream and floodplain wetland environments in reporting ecological outcomes from Lower Gwydir ECA releases. Long-term data sets will be necessary to adequately determine the extent to which Lower Gwydir aquatic populations fluctuate in response to seasonal, hydrological and structural habitat factors. Prioritise the collection of data on water chemistry, fish populations, wetland vegetation and waterbirds.
- Continue monitoring of the grazing exclosures. Ensure their future protection, and promote their benefits to relevant landholders.
- Ensure that future monitoring be undertaken at a temporal scale relevant to the monitored parameters, and that it includes independent control/reference areas.
- Maintain a close communication link between the ECAOAC and any research or agency staff directly involved in future monitoring and research activities.
- Establish a central repository of long-term ecological data on the Lower Gwydir wetlands ecosystem.
- Ensure that data and other scientific information are made available in a timely manner to inform management plans and adaptive management processes. These may include, for example, incorporation into decision support tools such as ecosystem response models, modification of spatial and temporal monitoring and data collection techniques, or improved management practices to support species such as fish and waterbirds.
- Support future research on the response of wetland soils to inundation and their role in supporting wetland condition and function.

- Support future research on the population ecology of fish, particularly the effect of flow variability on early growth and body condition.
- Establish the effects of in-stream barriers on Lower Gwydir fish assemblages.
- Establish whether Lower Gwydir fish assemblages vary with structural habitat within and between channels.

9.1 Introduction

The present study provides the first integrated assessment of aquatic ecological responses to flow variability in the Lower Gwydir wetlands ecosystem. This work particularly builds on earlier studies by Rob McCosker on the responses of wetland vegetation to floodplain inundation, and confirmed some of the initial interpretations of how flow structures the ecology of this floodplain. However, it also includes information on a suite of in-stream parameters including fish, microinvertebrates and water chemistry for which there has been little or no prior knowledge available on Lower Gwydir flow responses. While it focused on the before—after monitoring of individual environmental flow events, it also allowed an assessment of how discharge may influence variables such as fish assemblage structure in a more general manner. This chapter uses these outcomes to recommend how best to continue building the information base on responses to flow variability in this ecosystem.

9.2 Environmental flow design and management

Aquatic ecological responses to ECA releases are likely to vary between the two seasonal periods in which such events are likely to occur (Table 9.1), and these differences should be considered when deciding on their timing. However, within any one season, release responses are also likely to vary between events of differing hydrological characteristics. ECA releases throughout the study period were of a limited and relatively stable stage height, designed to deliver the volume anticipated to be necessary to inundate the core wetland and to minimise losses onto the floodplain upstream of the target area(s). Minimising the upstream floodplain inundation may have limited the in-channel responses of some water chemistry parameters and faunal assemblages. If so, there are two key management implications that future ECA management should consider.

Firstly, expectations of what ecological responses might be achieved by a particular release will need to be realistic. Any one release is unlikely to satisfy the hydrological requirements of all aquatic biota, particularly in cases like the 2006–2007 releases where the overriding objective was to retain as much water as possible in the channel upstream of the core wetland target. Similarly, there are also likely to be differences in the response time among ecological parameters and assemblages that need to be accounted for. For example, while we detected changes in nutrient availability within the Gingham Watercourse following the largely in-channel April 2007 ECA, shifts in parameters such as dissolved organic carbon and the various physico-chemical parameters were less evident at the temporal scale of our sampling. If the Lower Gwydir ECA program is to operate in an adaptive management framework, it will need to be borne in mind that past releases may have been designed for a narrow set of ecological objectives. Responses of other ecosystem components to previous

Table 9.1. Summary of anticipated responses to ECA releases in spring-summer and autumn-winter in the Lower Gwydir wetlands, based on findings from the present study.

1. Plant functional groups

Late spring to summer	Autumn to early winter
<p>Amphibious responder taxa</p> <ul style="list-style-type: none"> Increased cover of common taxa such as <i>Ludwigia peploides</i>, <i>Ludwigia octovalvus</i>, <i>Eleocharis sphacelata</i>, <i>Myriophyllum</i> spp., <i>Marsilea drummondii</i> and <i>Persicaria orientalis</i>. At sites where flooding is prolonged <i>Azolla filiculoides</i>, <i>Damasonium minus</i>, <i>Lemna minor</i>, <i>Nymphoides crenata</i> and <i>Potamogeton tricarinatus</i> may occur. Flowering and seed setting expected. <p>Amphibious tolerator taxa</p> <ul style="list-style-type: none"> Increased cover of common taxa such as <i>Paspalum distichum</i>, <i>Eleocharis plana</i>, <i>Cyperus difformis</i>, <i>Typha domingensis</i> and <i>Persicaria decipiens</i>. Flowering and seed setting expected. <p>Terrestrial damp taxa</p> <ul style="list-style-type: none"> Reduction in cover of common taxa as cover of amphibious taxa increases. <i>Phyla canescens</i> cover is reduced where inundation depth favours growth of tall taxa such as <i>Eleocharis plana</i> or <i>Typha domingensis</i>. <p>Terrestrial dry taxa</p> <ul style="list-style-type: none"> Reduction in cover is common as inundation causes death of flood intolerant taxa such as <i>Cirsium vulgare</i> (thistle). 	<p>Amphibious responder taxa</p> <ul style="list-style-type: none"> Increased cover of taxa such as <i>Myriophyllum</i> spp., <i>Marsilea drummondii</i> and <i>Ludwigia peploides</i> occurs. Very limited (if any) flowering or seed setting. <p>Amphibious tolerator taxa</p> <ul style="list-style-type: none"> Increased cover of taxa such as <i>Paspalum distichum</i> but growth stops as dormancy develops in response to winter frosts. Small increase in cover by <i>Eleocharis plana</i>, <i>Cyperus difformis</i> and <i>Persicaria decipiens</i>. Very limited (if any) flowering or seed setting. <p>Terrestrial damp taxa</p> <ul style="list-style-type: none"> Small increases in cover of <i>Phyla canescens</i> may occur at sites experiencing shallow flooding. Growth may become more prolific in early spring as temperatures increase. Other cool season annuals such as <i>Rorippa</i> spp. and <i>Aster subulatus</i> may germinate in high numbers once flood waters recede. <p>Terrestrial dry taxa</p> <ul style="list-style-type: none"> Flooding at this time stimulates germination of <i>Medicago</i> spp. in wetlands that experience shorter flood duration. <i>Cirsium vulgare</i> (thistle) seeds may also germinate in large numbers following flood recession. <i>Malva parviflora</i> and <i>Einardia nutans</i> common at sites where flood duration is short.

Table 9.1 continued.

2. Key native and alien plants

Late spring to summer	Autumn to early winter
<ul style="list-style-type: none"> Extended vigorous growth of native wetland species; flow would coincide with peak growth period of key native wetland plants such as <i>Paspalum distichum</i>, <i>Eleocharis sphacelata</i>, <i>Bolboschoenus fluviatilis</i> and <i>Typha domingensis</i>. <i>Phyla canescens</i> cover may decrease at sites where inundation is 15-20 cm or greater. Cover may increase along margins of wetted sites where inundation depth is shallow. Germination of weed species such as water hyacinth (<i>Eichhornia crassipes</i>) may occur. Alien grass species such as <i>Echinochloa</i> sp. may occur along margins of wetted sites. Poison pratia (<i>Pratia concolor</i>) may increase in pastures where it is established. 	<ul style="list-style-type: none"> Growth period for native perennial grasses is short as dormancy is induced by cold winter temperatures. Growth period of C₄ perennial species such as <i>Paspalum distichum</i> is limited by cold temperatures in winter months. Limited short-term growth response by <i>Typha domingensis</i> and <i>Bolboschoenus fluviatilis</i>. Main growth response most likely to occur in spring. <i>Phyla canescens</i> cover may increase rapidly in early spring as this species resumes growth prior to the native species <i>Paspalum distichum</i> and can take advantage of the moisture in the soil profile following flooding.

3. Native and alien fish species

Late spring to summer	Autumn to early winter
<ul style="list-style-type: none"> Moderate to high recruitment response likely in both native and alien (European carp, goldfish) species. Recruitment is likely to be enhanced when flows coincide with peak spawning periods (September – October) in temperature-cued species such as Murray cod and eel-tailed catfish. 	<ul style="list-style-type: none"> Low recruitment response likely in both native and alien species.

4. Timing of flow in relation to natural hydrological seasonality

Late spring to summer	Autumn to early winter
<ul style="list-style-type: none"> High likelihood of natural flows from unregulated tributaries for 'piggy-backing' ECA releases. Flow timing coincides with peak in annual rainfall. 	<ul style="list-style-type: none"> Low likelihood of natural flows from unregulated tributaries for 'piggy-backing' ECA releases. Seasonal rainfall is likely to be low at this time.

releases may not reflect the potential of alternative ECA hydrographs to achieve a broader suite of ecological outcomes.

Secondly, it may be necessary to establish a more variable hydrograph for ECA releases, in order to satisfy as many ecological objectives as possible. For example, if a release is made to inundate core wetland area, it may be worth considering a preceding release with greater upstream spillage, and a shorter duration and more gradual descending limb. Wetting of the bank profile by the initial flow might also help reduce upstream losses from the second release.

The current operational rules for the ECA account are legislated by the Gwydir River water sharing plan, including rates of accrual and the maximum volumes allowed to be held at any one time. Under these existing rules, and with the limited account volumes under the current drought conditions, multiple releases may be difficult to achieve from ECA water alone. 'Piggy-backing' ECA flows on bulk releases for stock and domestic or irrigation purposes might be an effective strategy for facilitating multiple releases of differing stage height. However, the delivery point(s) for these flows and the channel reaches where the ecological outcomes are desired would need to match. Furthermore, releases for abstractive purposes may also be characterised by the significant loss of any ecological response (e.g. zooplankton, fish larvae, or nutrients) from the channel (Baumgartner *et al.*, 2007). Nevertheless, amalgamating abstractive and environmental releases from Copeton Dam would be expected to reduce the overall level of transmission loss and such a strategy may be worth considering further.

Significant flood events have occurred in winter in the Lower Gwydir floodplain, although the region has a largely summer-dominant rainfall pattern and the timing of future ECA events should match this whenever possible. While the ECA release from December 2006 to January 2007 along the Lower Gwydir River occurred in the natural period of peak flows, the April 2007 release into the Gingham Watercourse was at the end of this period and was followed by cold winter conditions. Although both releases triggered a vegetation response (chapter 6), few species were able to set significant quantities of seed following the April release as subsequent cold conditions appeared to kill off much of their above-ground reproductive biomass. Although our in-stream monitoring wasn't specifically structured to examine this issue, the late timing of this release may also have influenced the apparent low recruitment response in spangled perch. Rates of most aquatic ecological processes are at least partially driven by temperature (Boulton & Brock, 1999), and ECA releases made under warmer conditions are likely to achieve the greatest ecological benefit (Table 9.1).

Managers of ECA events should also attempt to maximise the duration of inundation. The best means of achieving this in the Lower Gwydir appears to be through piggy-backing releases onto natural flow events. When the soil is already wet, the spatial extent and duration of ECA inundation increases markedly as less surface water is lost into the soil profile. Such releases may also have reduced transmission losses, and will assist in synchronising ECA flows with the natural hydrology. This strategy also allows for the partial compensation of any natural flow abstracted through current supplementary access rules. However, the invariable time delay between confirmation of supplementary access to an event and the arrival of ECA water from Copeton Dam means that this practice will usually result in two separate flow pulses.

Management tools. Managing any future ECA release program for the Lower Gwydir should be made within a framework of the Gwydir Wetlands Adaptive Environmental Management

Plan, and be guided by the Gwydir Wetlands Decision Support System (DSS) software product. Moreover, the Gwydir Wetlands Adaptive Environmental Management Plan will establish benchmarks of ecological condition for a number of aquatic ecosystem components, against which any future shifts in ecological condition should be considered. Both of these tools are currently being finalised through the New South Wales Department of Environment, Climate Change and Water.

9.3 Monitoring

Determining the ongoing Lower Gwydir flow requirements will require a mix of ongoing monitoring, incorporation of the findings into the Gwydir Wetlands DSS, and utilisation of this tool by relevant flow managers. It should be recognised that ecological responses to ECA releases will invariably differ from those due to natural flood events which typically have a greater stage height and total level of discharge. We recommend that future monitoring (and research) focus on responses to each of these flow types in order to establish a thorough picture of both trend and condition.

Spatial and temporal design. The variable nature of dryland river ecology means that data sets longer than the present 3-year study will be essential if we are to fully appreciate the responses of the Lower Gwydir ecosystem to managed releases or flow variability more generally. This should include measurement of responses to individual ECA events, but also provide data from a longer sequence of varying seasonal and discharge conditions. Such a program should be structured in an event-based way but also allow for monitoring of low-flow and winter periods away from the usual spring-summer interval of higher flows.

The ‘boom-bust’ dynamics of biota in dryland floodplain rivers must be acknowledged in any monitoring program of ecological responses to flow variability in this ecosystem. Long-term reference data sets will be necessary to understand the extent to which aquatic populations fluctuate in response to seasonal and hydrological cycles and structural habitat factors. Such data would allow a better understanding of the trade-offs or ecological costs of water resources developments that dampen the natural flow variability, as well as providing a reference against which to measure any gains from environmental flow programs. However, shorter-term monitoring sequences will still be necessary to delineate responses to specific flow events.

Nevertheless, the difficulties in tracking responses to specific flow events should not be underestimated in flow-managed river systems like those on the Lower Gwydir floodplain where releases are being made for a variety of consumptive and environmental purposes. Clearly, ECA managers need to prioritise which ecological parameters they wish to promote with a particular release, especially in circumstances where releases may be recommended for a narrow set of ecological criteria. Future monitoring programs will need to make the final choice of ecological variables, sampling sites and timing with such management decisions in mind. However, it will also be necessary to maintain a close communication link between the ECAOAC and any research or agency staff directly involved in the associated monitoring activities.

In particular, it will be critical that any future monitoring program be able to account for likely differences in temporal scale of response among biotic or other variables, as not all responses will be adequately detected by a single monitoring sequence. For example, while

responses of wetland vegetation and some fish species were still evident 1–2 months after the April 2007 ECA event, elevated nutrient levels were already diminishing a week after cessation of the release. Although a multi-indicator monitoring program can provide an integrated picture of ecosystem responses to an environmental flow event, it will invariably be necessary to monitor different variables at varying temporal scales, from days to weeks or months following the onset of a flow event.

Any future monitoring program for the Lower Gwydir floodplain will need to include a careful array of reference/control sites away from the target of any future ECA flows. In the present study, we incorporated both floodplain waterholes and the Mehi River into our design, neither of which currently receives ECA flows. The floodplain waterholes provide reference/control sites in the absence of all but the largest flow events, although they are likely to dry out after 12–18 months of no inflow. The likelihood of longitudinal variation will also need to be borne in mind. We recommend that at least three sites be included per channel along a similar positioning to that used here, although it may not be necessary to monitor all variables at each site. However, the choice of which sites to monitor for any suite of variables should be made carefully, and not necessarily based on patterns in local species richness. For example, while fish assemblage composition was generally more diverse in our upstream sites, environmental flow releases also need to supply appropriate flow conditions to reaches at the end of channels. Rigorous monitoring will need the capacity to establish the nature of any ecological responses to flow releases in these lower reaches as well.

Variables. The findings from the present study provide some guidance on which variables and parameters to consider in future aquatic monitoring of the Lower Gwydir floodplain. These should also be selected with the factors discussed in chapter 4 in mind (Table 4.2). However, consideration also needs to be given to the resources available for monitoring (cost differences among variables, number of sites, temporal replication), and comparison of the spatial and temporal scale of response to flow events with the characteristics of the imminent release or question that requires answering.

It is recommended that monitoring of the present suite of water chemistry parameters be continued. These samples/measurements are generally easy to process in the field and appropriate laboratory facilities are locally accessible. They generally also provide indications of short-term response to flow events and may provide additional evidence for mechanisms underpinning recruitment responses in fish or other in-stream fauna. However, while we detected short-term nutrient responses to ECA flows, it would be useful to include direct measures of benthic productivity in future monitoring. Although not undertaken in this study, such monitoring would provide an indication of the incorporation of nutrients and carbon into the aquatic food chain (Fellows *et al.*, 2007).

Zooplankton abundances in dryland river systems can fluctuate over brief time frames (Jenkins & Boulton, 2003, 2007) and, similar to water chemistry parameters, may provide insights into how other food-chain components are sustained by a particular flow event. Microinvertebrates may also be important in identifying ecosystem thresholds and resilience. However, zooplankton assemblages also tend to be highly patchy in space and over seasonal cycles (Shiel *et al.*, 2006), which may make it difficult to detect ECA responses without considerable sampling and laboratory effort. Increasing the frequency of floodplain wetland inundation along dryland rivers will benefit zooplankton assemblages (Jenkins & Boulton, 2007) and there is scope to use zooplankton emergence from egg-banks as an indicator of ECA response in the Lower Gwydir.

Until further details are available from the NSW Integrated Monitoring of Environmental Flows program, it is difficult to judge whether monitoring macroinvertebrates should be continued or not. Nevertheless, refined techniques have been developed for identifying and grouping macroinvertebrates responsive to changes in hydrology (Choy *et al.*, 2000; Marshall *et al.* 2001), and these will assist in making more defensible links between hydrology and ecology and in identifying river stress. Macroinvertebrates are also fundamental components of river health assessments, and long-term data sets can provide a valuable resource.

Generating responses in wetland vegetation has been a key ecological objective for past ECA releases, and future monitoring of these assemblages in relation to ECA releases will need to continue. Fortunately, vegetation is one suite of ecological parameters for which we have Lower Gwydir data sets longer than the usual 2-3 years of ecological monitoring. These provide a unique opportunity to establish a long-term picture of ecological responses to a variety of flow types in this ecosystem. It is recommended that the range of fixed monitoring points established by UNE in the mid 1990s continue to be used, including the four sets of grazing exclosures on "Birrah", "Old Dromana", "Westholme", and "Crinolyn". These can also continue to provide information on the conditions under which grazing may alter the effects of inundation. It is critical that these exclosures be maintained and their protection promoted to relevant landholders. The usefulness of data obtained from these to date and the relatively low set-up costs of these structures suggests that similar exclosures and their monitoring should be considered for other wetland systems such as the Macquarie Marshes.

For a variety of reasons, we recommend that monitoring of fish be continued in Lower Gwydir channels. Fish are a key dietary component of a number of key waterbirds in the Lower Gwydir (e.g. Marchant & Higgins, 1990; Scott, 1997; Roshier *et al.*, 2002; Olsen *et al.*, 2006), and understanding the local responses of fish to flow variability will be an important consideration in managing any inland wetland ecosystem for waterbird outcomes. Fish also attract considerable public attention, and knowledge of their responses to a particular flow event can be a useful means of garnering support for aquatic management decisions. Responses of fish species and assemblages to flow variability are generally evident over spatial and temporal scales relevant to management of the Lower Gwydir wetlands ecosystem, and can be easily sampled with sufficient rigour to produce statistically meaningful information. Suitable data sets from fish sampling programs at an appropriate spatial and temporal scale of monitoring can be produced after days of effort rather than months as is the case for other aquatic faunal assemblages such as macroinvertebrates.

It will be vital that future fish monitoring facilitate a stronger understanding of the lifehistory of key fishes within the Lower Gwydir ecosystem. For example, the availability of an age-at-size relationship in bony bream and spangled perch allowed a preliminary match between the appearance of small fish and the timing of recent ECA flows. Although these were derived from sampling undertaken in the Macintyre River and other parts of the Lower Gwydir to the present sampling sites, they nonetheless allowed hypotheses of links between ECA releases and spawning activity in these species. Data are particularly needed on age-at-size, growth rate, spawning-timing, and migrations. It seems likely that it may be profitable to examine the effects of flow variability through lifehistory traits such as early growth and body condition in key species (cf. Heagney *et al.*, 2008).

Although not examined as part of this study, the waterbird assemblages and their breeding success are further ecological parameters that should be considered for ongoing monitoring in the Lower Gwydir wetlands. NSW DECCW has some historical data from the Lower

Gwydir (Spencer, 2009; Wilson *et al.*, in press) which, similar to wetland vegetation, provide a medium to long-term picture of flow responses.

Institutional arrangements. A concerted research effort on the flow ecology and management of the Lower Gwydir floodplain commenced in the mid 2000s, involving Commonwealth and New South Wales state funding, agency staff, and several universities. In order to maintain this momentum and to meet the invariable requirement for a longer-term monitoring program (*'Spatial and temporal design'* above), it is recommended that formal collaborative partnership arrangements be established between research organisations and management agencies. This would not only ensure that appropriate ecological monitoring is continued, but also help guide the analysis and reporting of data in a timely and tailored manner. It would also boost the interdisciplinary nature of any monitoring activity, promote the cost-effective use of resources, and provide a necessary quality-assurance mechanism for any data collection. Such an arrangement could be engaged by agencies directly or brokered through bodies such as the Border Rivers – Gwydir Catchment Management Authority, the Murray-Darling Basin Authority, or the National Water Commission. It could include university-based postgraduate students whose research can represent an extremely cost-effective means of examining ecological responses to flow over short to medium time scales (Likens *et al.*, 2009) and can add components to a longer-term research program. However, irrespective of the organisational structure, any future monitoring program should include careful networking of Lower Gwydir managers, researchers and the ECAOAC to ensure appropriate ownership and use of any findings.

There also remains a clear need to establish a repository of long-term ecological data on the Lower Gwydir aquatic ecosystem. Some long-term data sets already exist on Lower Gwydir vegetation from earlier work through the University of New England, and the present analyses of how vegetation has responded to inundation and grazing (Chapter 5) greatly benefited from this. Some flow and water quality data also exist in state agencies. There is a number of ways in which this could be established, but records and biological reference collections may be best housed in research organisations where laboratory and other facilities offer the best chance of long-term protection and access. This should be governed by appropriate 'Memorandum of Understanding' agreements that identify the original sources of information and specify clear data-sharing mechanisms.

9.4 Key areas for future research

Soil ecology. Recent research by Wilson *et al.* (2008) found preliminary indications that critical soil chemistry parameters (nitrogen, phosphorous, organic matter content) vary with inundation history in the Lower Gwydir. This study also compared germinant emergence from the soil seed-bank among the same Lower Gwydir sites, and found that while germinant abundance may vary with inundation history, species diversity was similar between sites. In other words, soil chemistry and the soil seed-bank may provide a key mechanism for wetland recovery if flooding patterns are reinstated. We recommend that further investigations be undertaken of the impact of flooding frequency on soil condition and the response of floodplain soils to wetting and drying. This should be undertaken with the explicit goal of determining how best to incorporate monitoring of soil parameters into future ECA monitoring programs.

Fish population ecology. We also recommend expanding the current fish monitoring to establish a greater focus on the population ecology of individual species within the Lower Gwydir channels. In particular, a better understanding of how the early life history of individual species differs under varying flow conditions and among channels will boost our capacity to predict outcomes from alternative flow management scenarios. Parameters such as early growth rate and body condition are thought to be key drivers of recruitment success in fish (e.g. McCormick & Molony, 1992) and, in turn, may be important for population strength in lowland river systems (Mallen-Cooper & Stuart, 2003). Some research has established preliminary relationships between flow variability and spawning-timing and early growth in species such as Australian smelt and spangled perch, either in the Lower Gwydir (Heagney *et al.*, 2008; Wilson *et al.*, in press) or nearby (Wilson & Wright, 2005). However, more work is needed to confirm the consistency of these patterns over broader spatial and temporal scales. Firstly, it will be necessary to validate the periodicity of otolith increment formation in most Lower Gwydir native fishes, ideally through oxytetracycline trials, to support sound descriptions of growth and spawning-timing. Body condition should also be examined in relation to flow variability, and quantified in terms of the water, protein, lipid and carbohydrate levels before and after managed and natural flooding.

Effect of in-stream barriers. Numerous in-stream structures exist along the Lower Gwydir River and Gingham Watercourse (Mallen-Cooper, 2000). Determining the influence of these on local fish assemblage structure and movement will be critical if outcomes for fish from ECA releases are to be fully realised. A number of structures have a head-loss of around one metre (e.g. Tyreel Weir, Keytah Weir), and this will likely have a significant effect on upstream migration and possibly also survivorship and distance travelled during downstream larval drift. More stable flow conditions upstream of in-stream structures may also promote the survivorship of exotic species such as carp or goldfish. We recommend that dedicated monitoring examine differences in assemblage structure between upstream and downstream of key structures, and whether accumulation of individuals occurs downstream of structures during high and low flow conditions. Where impacts are detected, installation of fishways would be expected to have substantial benefits.

Effect of habitat structure on fish assemblages. We detected consistent differences in fish assemblage structure between and along the three study channels, possibly due to spatial differences in water quality or structural habitat. We recommend research to establish the extent to which structural habitat, in particular, is responsible for in-stream ecological condition in the Lower Gwydir. This should include relationships with riparian structure as well as channel parameters such as depth diversity, sediment composition and the extent of woody debris. Examining concomitant relationships with flow velocity would be a logical extension of this research. Rehabilitation of key structural habitat features such as riparian cover may prove a cost effective means of improving in-stream outcomes from ECA releases.