

# Chapter 3

## Conceptual models of ecological response to flow variability in Lower Gwydir floodplain aquatic habitats

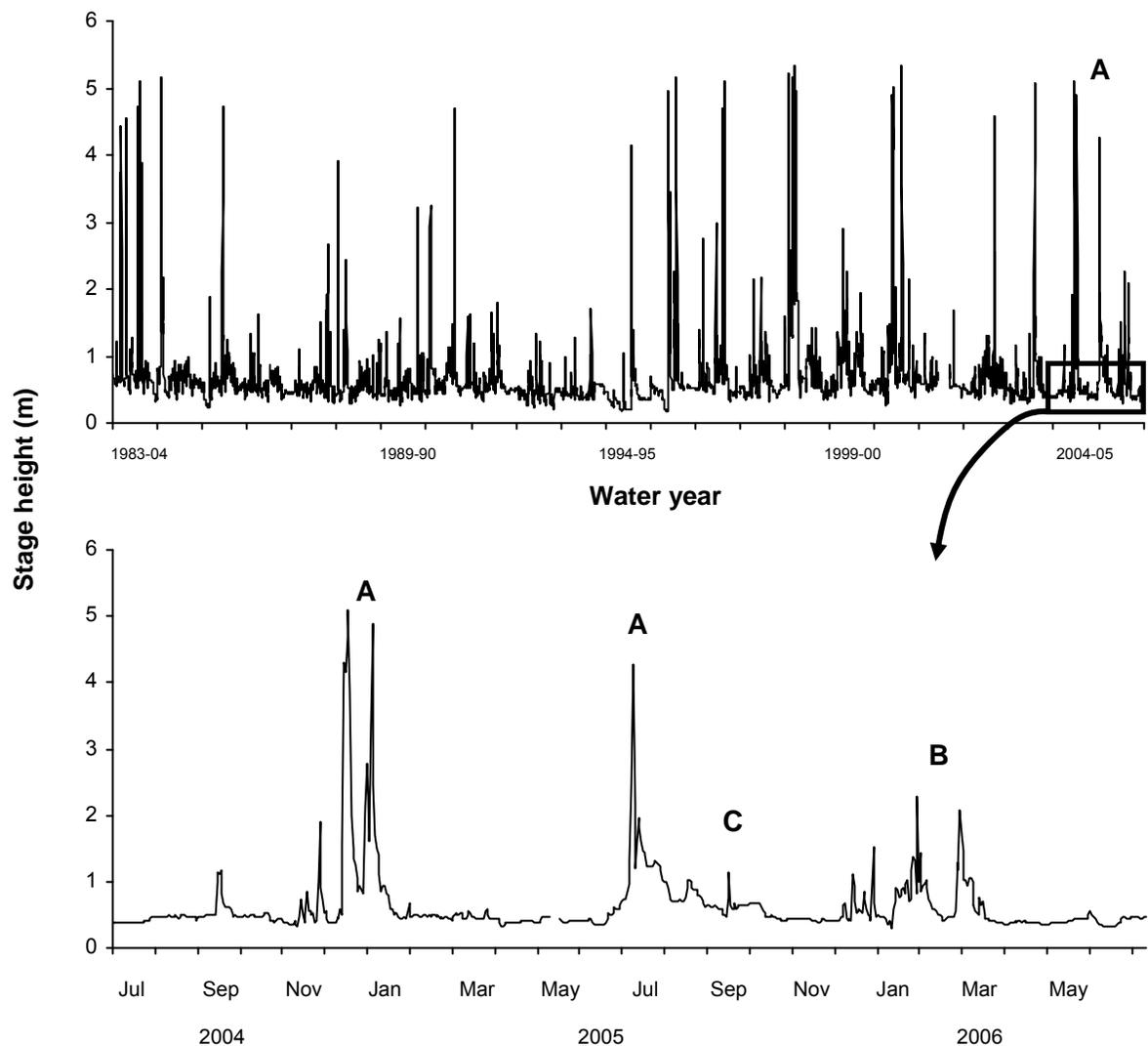
### 3.1 Introduction

Conceptual models are an integral step in undertaking any ecological study, and help in developing the final research questions, sampling designs and choice of ecosystem components or population/life history variables to be monitored (e.g. Jackson *et al.*, 2000). For environmental flow determinations, conceptual models may be an invaluable tool for communicating key messages of probable ecosystem response(s) to management interventions (Acreman, 2005; Fitz *et al.*, 1996).

Two conceptual models were constructed for the Lower Gwydir floodplain study area and its aquatic ecological responses to flow variability. Separate models were developed for in-stream patterns and processes and those occurring in aquatic patches on the floodplain itself (wetland areas). Both models focus on ecosystem components that the project team anticipated having the capacity for monitoring in the present study. As such, these models ignore (for instance) the contribution of basal components such as bacteria to the functioning of this ecosystem. Similarly, they do not explicitly include carbon variables such as dissolved organic carbon, although do include nutrient mobilisation as a more general process. Nevertheless, data on dissolved organic carbon (and other nutrients) were collected during the present study.

Three broad flow-event categories were considered based on recent hydrological data (Fig. 3.1) and the current uses for water in the study ecosystem: (A) large, overbank flows resulting from unregulated, natural flooding; (B) flows of smaller duration and height, largely remaining in-channel, resulting from either regulated (principally Environmental Contingency Allocation releases) or unregulated flows; and (C) low-level managed releases of limited stage variability and longer duration, such as for the purposes of bulk irrigation transfers or stock and domestic supply. Each of these flow types is likely to occur along any of the main Lower Gwydir watercourses (Mehi River, Gwydir River/Big Leather Watercourse, Gingham Watercourse, Carole Creek) and so provide a useful framework for understanding the likely ecological responses to flow variability beyond specific study sites.

The conceptual models were constructed in a 'bottom-up' fashion, with a primary focus on the response (positive or negative) of consecutive food-web components to shifts in the state of lower trophic levels. They consider flow variability to have an overarching influence on ecosystem function through various life history adaptations of the native fauna and flora (Bunn & Arthington, 2002; Lytle & Poff, 2004; Poff & Ward, 1989; Puckridge *et al.*, 1998) and the opportunities for exploiting vacant niches by invasive species, particularly plants. The influence of flows on the Lower Gwydir floodplain is firstly tracked in-stream through physical



**Fig. 3.1.** Stage variability in the Gwydir River at Brageen Crossing, 1983-84 to 2005-06 water years. Flows for the 2004-2005 and 2005-2006 water years (box in upper graph) are expanded in the lower graph to distinguish between the three general flow categories. Data are provisional daily means, sourced from the NSW Department of Water and Energy.

changes to the channel environment to the algal assemblages, macrophytes, invertebrates, and fish. Secondly, the influence of flow is examined from the channel to the floodplain itself, through overbank flows, the resulting transport of sediment onto the floodplain and the subsequent effects on invasive and native vegetation, habitat access for fish, and the diversity and abundance of aquatic invertebrates. Both models acknowledge that biotic responses to flow variability will vary seasonally, particularly for floodplain plants and processes such as egg-bank emergence of microinvertebrates and fish spawning.

Flow variability and its alteration may be characterised over a hierarchy of temporal and spatial scales, with concomitant effects on different aspects of the lifehistory of aquatic species and the structuring their assemblages (Bunn & Arthington, 2002; Lytle & Poff, 2004; Poff & Ward, 1989; Puckridge *et al.*, 1998; Thoms & Parsons, 2003). In this way, flow *regime* is viewed as representing flow conditions over 100s to 1000s of years and the regional scale. Flow *history* describes variability operating over 10s to 100 yrs and the catchment scale, while the flow *pulse* depicts changes in stage height or discharge over the temporal scales of days to weeks and spatial scale of patches to reaches within a catchment. The present conceptual models have been developed primarily at the latter spatial (patch, reach) and temporal (flow pulse; days to weeks) scales, in line with the levels at which field-based components of the research were conducted. For example, flow pulses of sufficient stage height are proposed as allowing channel — floodplain connections that fish might utilise for accessing floodplain waterholes or other inundated patches. This would conceivably allow short-term opportunities for foraging, spawning or habitat recolonisation.

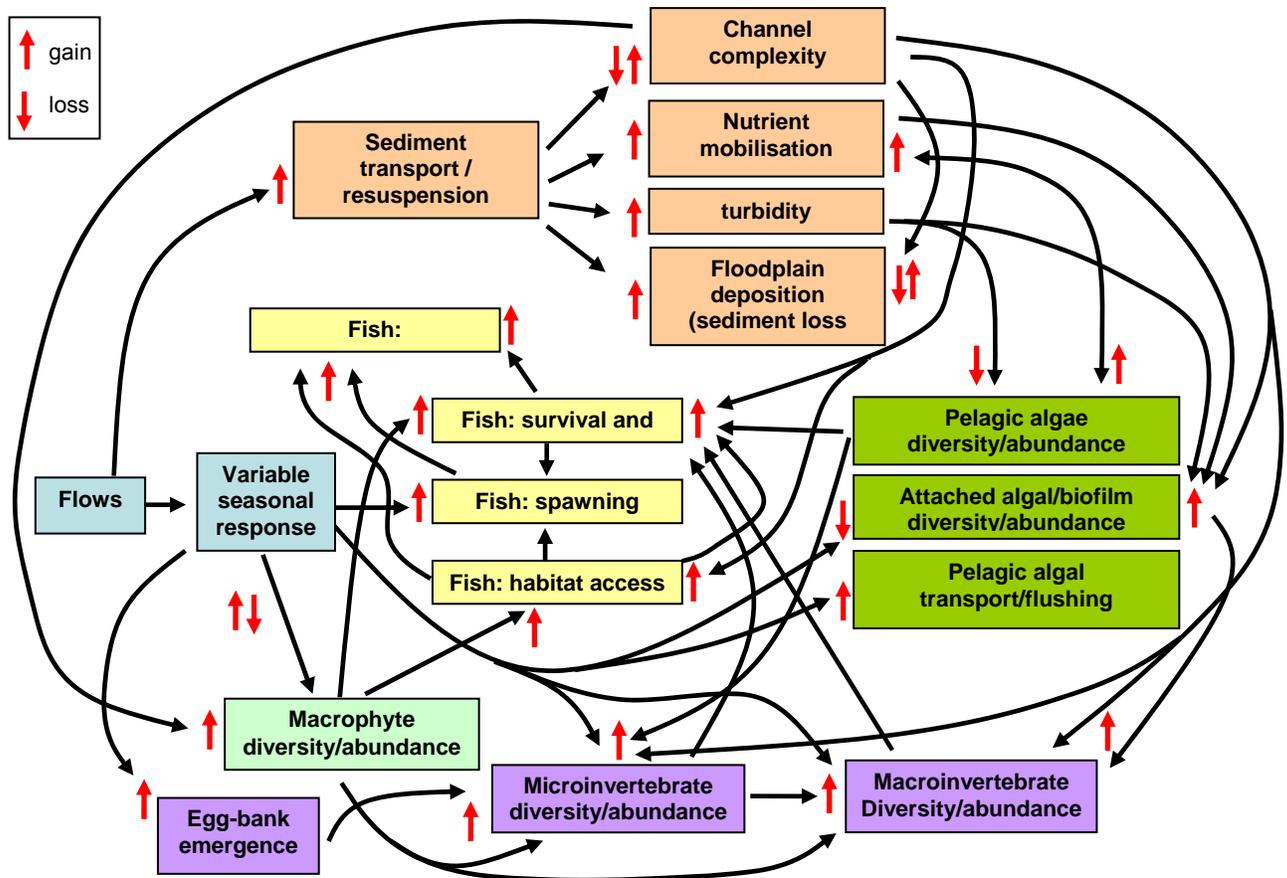
### 3.2 In-stream responses

The conceptual model for this portion of the Lower Gwydir aquatic ecosystem is shown in Fig. 3.2. Responses of different physical and biotic components to flow variability are discussed individually below.

**Channel structure.** Flow pulses of most sizes will impact the physical structure of the stream channel, through the transport and (in the case of finer particles) resuspension of sediment. This would be expected to temporarily raise in-stream turbidity levels and potentially lead to mobilisation of particulate carbon and available nutrients such as dissolved organic carbon or nitrogen and phosphorus. Flows remaining largely in-channel and of limited stage variability would be expected to lead to a loss of channel bed complexity as sediment is shifted off banks, bars and benches and into deeper parts of the ‘thalweg’. Alternatively, flows of this nature could potentially increase the leveeing of channels through their deposition of sediment along the bank crest, thus reducing future floodplain connectivity at a given level of discharge.

However, during larger, overbank flow events, sediment resuspension and transport would be expected to enhance channel bed complexity as unconsolidated sediment is shifted from all parts of the channel including the scouring of deeper holes. At the same time, however, overbank flows along an agricultural landscape, and following the current period of drought, would be expected to return a quantity of sediment off the floodplain into adjacent channel and wetland patches. Shifts in channel bed complexity would be expected to have parallel influences on the diversity and abundance of most floral and faunal biotic components. Similarly, nutrient mobilisation from the channel sediment or bed would likely increase rates of primary production and the diversity/abundance of algal and macrophyte assemblages. By contrast, parallel rises in turbidity would reduce the channel’s photosynthetic depth, potentially impacting algal and macrophyte assemblages to varying degrees.

Seasonal, temperature-related modification of the effects of flows on the channel would be expected to result primarily from reduced rates of nutrient processing by bacteria during cooler months and any associated shifts in nutrient bioavailability.



**Fig. 3.2.** Conceptual model of in-stream aquatic ecological responses to flow variability on the Lower Gwydir floodplain. Black arrows indicate linkages between ecosystem components and processes; shorter red arrows indicate the proposed direction of any effect.

**Macrophytes.** These are a limited ecosystem component in most parts of Lower Gwydir watercourses, but are nonetheless likely to be important in sites where they do occur. In some areas, their proliferation is likely to have resulted from reductions in flow variability and longer flow duration from stock and domestic supplies in particular. Prominent species include *Persicaria*, *Ludwigia* and *Typha*.

Flow variability is likely to promote the growth and seed production of a range of macrophyte species, and shifts in sediment transport, channel complexity and nutrient availability will also promote diversity and abundances. Increased low- or no-flow periods of a more natural duration, frequency and timing would be expected to reduce the areal extent and diversity of some beds. However, larger events would be expected to act as a pulse disturbance and cause major disruption to beds of more delicate species such as *Ludwigia*. Recovery from these events would depend on the flow duration and associated settling of suspended sediments and drops in turbidity. By contrast, critical recolonisation of sites downstream may also occur during such flows, either through dislodged plants setting root or the germination of dispersed seed. Similarly to algae, macrophytes would also be expected to respond more

rapidly to flow pulses during the warmer months when reductions in the photosynthetic depth or the destruction of beds would be offset to a greater degree by higher growth rates.

**Invertebrates.** Microinvertebrates and macroinvertebrates are considered separately here, particularly due to the greater capacity of microinvertebrates for desiccation resistance and subsequent egg-bank emergence, and the different positioning of the two groups in aquatic food web structures. Microinvertebrate diversity and abundances would be expected to increase during and following flow pulses, and over any subsequent low-flow period with concomitant rises in pelagic algal cell densities. Wetting of the bank and structures such as in-channel benches or bars may also boost microinvertebrate densities through egg-bank emergence, although the importance of this process would vary with flow height, duration and temperature seasonality. Subsequent local boosts in algal productivity and the transport of particulate carbon may also benefit microinvertebrate densities.

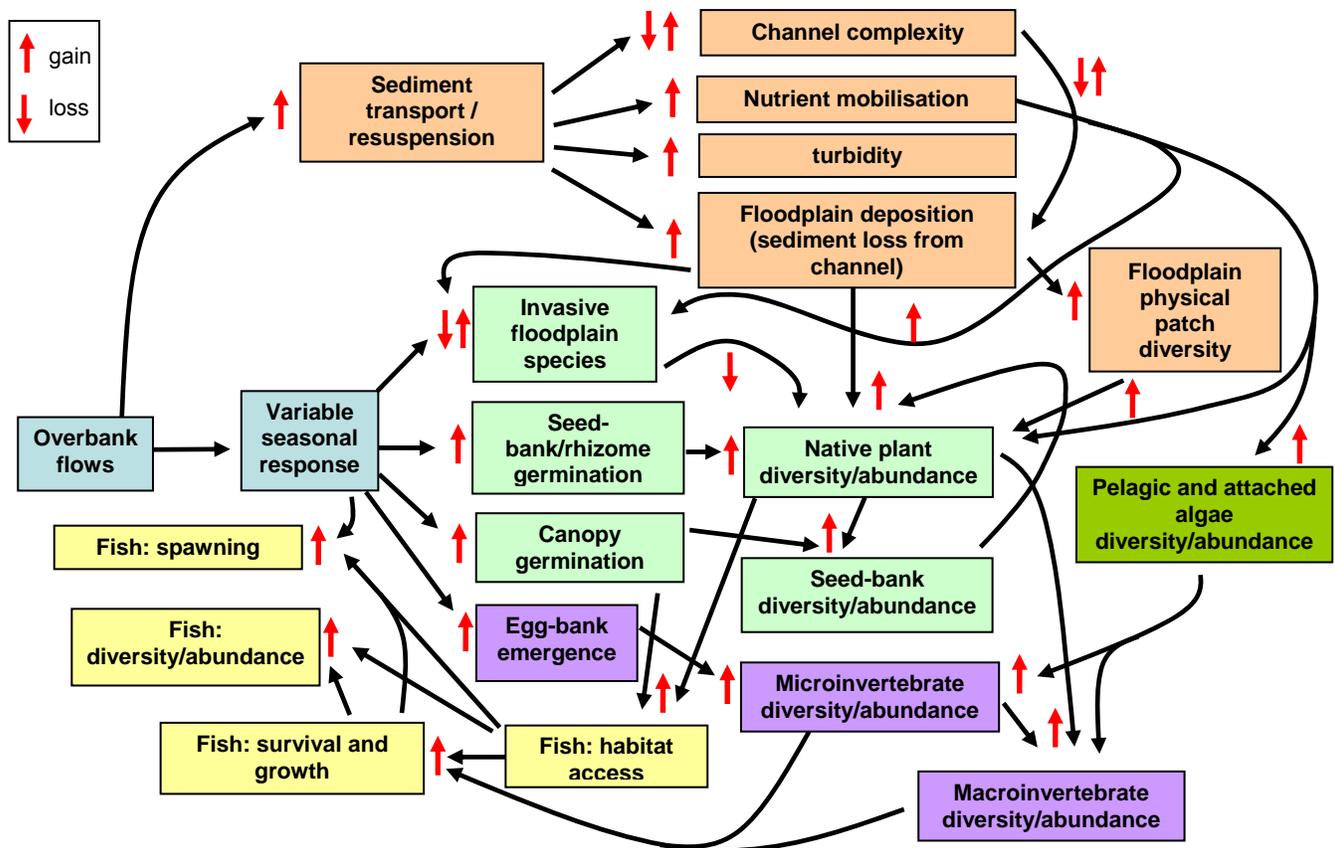
Increased macroinvertebrate diversity and abundances would also result from increased flow variability, initially through changes in algal or microinvertebrate prey levels, adult emergences and their subsequent breeding. Shifts in macroinvertebrates would be slower to occur than that of microinvertebrates, partially as a 'trophic cascade' effect, but also due to differences in reproductive mode between the two groups. However, the diversity of both invertebrate groups would be enhanced through the creation of a range of microhabitat types during periods of greater flow variability. These would include macrophyte beds, woody debris ('snags') transported by raised channel flow velocities, and a greater diversity of channel bed structures.

**Fish.** Fish will be influenced by flows through both physiological (e.g. gonad maturation, growth rates) and behavioural (e.g. spawning, habitat access) mechanisms and a mix of direct and indirect effects. Growth and survival of all lifehistory stages will be enhanced by the generation of food resources during and following flow events, as discussed above for invertebrates and algae. Changes in macrophyte beds and channel structure will have parallel effects on the survivorship, diversity and/or abundance of fish assemblages through changes in habitat access. In addition, flows would be expected to have a direct influence on the initiation of spawning activity in numerous native species, although the rate of gonad maturation and subsequent larval survivorship would be expected to be lower over winter. Flows with low stage variability would also be expected to produce a lesser spawning response.

### 3.3 Floodplain responses

The conceptual model for this portion of the Lower Gwydir aquatic ecosystem is shown in Fig. 3.3. Responses of different physical and biotic components to flow variability are discussed individually below.

**Physical patch structure.** The transport of sediment and finer silt, and associated nutrients and organic matter, onto the floodplain is a key benefit of flooding along lowland rivers (McGinness, 2007). Such materials will be deposited in low-lying areas such as in-channel benches, anabranch channels (a key transport pathway in their own right: McGinness *et al.*, 2002) and other wetland types. In a physical sense, the invariably uneven spatial patterns of deposition would increase the patch complexity of the floodplain, with subsequent benefits for a variety of floral and faunal assemblages. Overbank flows may also redistribute any



**Fig. 3.3.** Conceptual model of floodplain / wetland aquatic ecological responses to flow variability on the Lower Gwydir floodplain. Black arrows indicate linkages between ecosystem components and processes; shorter red arrows indicate the proposed direction of any effect.

sediment deposits from previous floods and soils from agricultural areas, some of which would end up in aquatic areas including the nearby channel. In a chemical sense, deposited materials would add significant nutrient and coarser particulate carbon loads to the floodplain and, in turn, help boost rates of vegetation and algal productivity. At the same time, overbank flows would return significant quantities of finer silt and dissolved organic carbon back to the river channel from features such as anabranches (Thoms *et al.*, 2005; McGinness, 2007). The actual process of floodplain inundation would also lead to a release of carbon, nitrogen and phosphorus from leaf litter and soils (Robertson *et al.*, 1999; Baldwin & Mitchell, 2000).

**Floodplain vegetation.** Sediment deposition during overbank flows, and the associated nutrient and organic-matter content, would promote the germination and/or growth of a range of floodplain plants. The actual movement of water across the floodplain would also disperse floating species such as *Azolla* and the highly invasive water hyacinth. Floods of relatively low depth (< 200 mm inundation) and duration may enhance lippia (*Phyla canescens*) growth and its subsequent dispersal through dislodged leaves and stem fragments (McCosker, 1999). This would potentially reduce native plant assemblages. Managed floods outside of the spring and summer reproductive season of native species may also differentially benefit lippia at the expense of species like *Bolboschoenus* or *Eleocharis* (B. Southeron, pers.

comm.). Similarly, as lentic areas dry out again, terrestrial weeds such as noogoora burr (*Xanthium occidentale*) would germinate from the seed-bank, absorbing nitrogen and phosphorus from the sediments in the process.

**Macrophytes.** Lentic populations of emergent species such as *Persicaria* would respond to overbank flows through the germination of new plants from either seed-banks or rhizomes. In turn, these beds would provide refuge and a food source for aquatic invertebrates and fishes. Unlike in channel environments, flows over most floodplain areas would not be expected to cause significant damage to existing beds. Similarly, increases in turbidity would not be expected to have a significant effect on emergent species. As lentic areas dry out following flood recession, the release of nitrogen into the soil from decaying macrophytes (e.g. *Azolla*, *Lemna*, water hyacinth, emergents) would potentially boost the recolonisation of these areas by terrestrial plants.

**Invertebrates** Overbank flows will promote the emergence of microinvertebrates and some aquatic macroinvertebrate groups from the sediment, either from egg-banks or other sources such as soil cracks or vegetation. Overbank flows would also be expected to transport invertebrates onto the floodplain from upstream areas, although this response would increase with distance downstream. Both supply mechanisms would enhance lentic and in-stream populations as well as replenishing the soil egg-bank following recession of the flows. Invertebrates would further benefit from the generation of algae on the floodplain as a key food source during flooding.

**Fish.** Northern Murray-Darling Basin floodplain lentic environments (billabongs, lagoons, waterholes etc) appear to be a preferred habitat for species such as the olive perchlet (*Ambassis agassizii*), and generally contain more species than adjacent river channels (Wilson & Wright, 2005). Overbank flows will provide such species with opportunities for recolonising floodplain areas (lotic to lentic, lentic to lentic), shifts back to the adjacent channel, and for foraging or spawning on the floodplain itself. Overbank events would also promote the growth and survival of floodplain populations through increased prey abundances, and the return of nutrient and prey-enriched water back into the adjacent channel would similarly benefit in-stream species.