Chapter 7

Responses of water chemistry, fish and aquatic invertebrates to flow variability in Lower Gwydir channels and floodplain waterholes

Key findings

- Levels of total nitrogen, total phosphorous, temperature, pH, turbidity, dissolved organic carbon, suspended solids and chlorophyll a did not differ between channels, although nutrient levels did vary significantly along the Gingham Watercourse (but not the Lower Gwydir or Mehi rivers).
- There was no clear effect of discharge level on water temperature, pH or turbidity. Electro-conductivity, dissolved organic carbon and chlorophyll a showed weak though inconsistent relationship with discharge level. Levels of total nitrogen, total phosphorous and suspended solids were generally higher and more variable during periods of lower discharge.
- The April 2007 ECA release into the Gingham Watercourse occurred during a period of minimal discharge within the other two study watercourses. Total nitrogen, total phosphorus, soluble reactable phosphorous and turbidity varied in response to this release, but not chlorophyll a, dissolved organic carbon, electro-conductivity or suspended solid load.
- Nine native and 3 exotic fish species were encountered within the three Lower Gwydir channels. Fish assemblages differed significantly between and along channels. The exotic European carp was the second most abundant species, and contributed more than 50% of total fish biomass.
- The effects of discharge level and season on fish abundances were difficult to separate although were probably additive, including for ECA releases. Discharge effects on overall native abundances were inconsistent over time. Shifts in exotic abundances usually paralleled those of native species, although exotic abundances were generally lower.
- Fish assemblage structure varied over time in each channel, although the extent of shifts between sampling trips did not appear to relate to the preceding discharge conditions.
- The size-structure of native (spangled perch, bony bream) and exotic (European carp) fishes was dominated by juveniles. Spawning responses to the December 2006 (Lower Gwydir River, bony bream) and April 2007 (Gingham Watercourse, spangled perch) were evident.
- Yabbies and shrimps displayed wide temporal fluctuation in abundances, but there was no consistent temporal pattern between channels. There was some evidence of longitudinal distribution within channels, but no clear relationship between abundances and discharge.
- Micro-invertebrate assemblages varied more between sampling methods (water column, benthic-core sediment, benthic-core liquid) than sites across river channels.
- Micro-invertebrate assemblages from the benthic-core sediment (Lower Gwydir River, October 2006 to May 2007) varied seasonally but not with discharge at the temporal scale of sampling.

Management recommendations

- Include event-based in-stream monitoring in relation to reporting ecological outcomes from future Lower Gwydir ECA releases.
- 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.

7.1 Introduction

In recent years, there has been an increasing acknowledgement of the poor state of Murray-Darling Basin (MDB) river systems. Issues concerning the general lack and low quality of water have received particular media attention, and it is now widely recognised that there is a link between the ecological deterioration of the MDB and changes to the natural flow regime due to river regulation. Changes to the frequency, amplitude, duration and timing of flood events are thought to have been, at least in part, responsible for the deterioration of the riverine ecosystem of many Australian waterways. However, despite changes in hydrology affecting the riverine ecosystem at all levels, special attention has usually been given to native fish populations. Reasons for this include the cultural significance of fish for indigenous Australians, the popularity of recreational fishing, and because fish are an animal group more noticed by the general public than, for example, zooplankton or macroinvertebrates.

Native fish populations of the MDB are thought to be in very low levels compared to pre-European settlement times (MDBC, 2004). Changes in the flow regime, reduction in habitat quality and barriers to migration are seen as some of the major causes for this decline. Alterations to the natural flow regime are thought to be particularly detrimental as many species are believed to depend on natural flood events for successful recruitment (Harris & Gehrke, 1994; Humphries *et al.*, 1999; Wilson & Wright, 2005). One strategy to overcome this is the use of environmental water allocations aimed at reinstating particular aspects of the natural flow patterns. Nevertheless, while it is thought that these should benefit the riverine ecosystem, including populations of native fishes, we still have only a limited understanding of their effectiveness.

The Water Sharing Plan (WSP) for the Gwydir Regulated River Water Source includes environmental water contingencies that are to be released for the benefit of the Lower Gwydir floodplain (NSW DIPNR, 2005a), including for the maintenance of native fish and other in-stream fauna. This ecosystem is thought to support a diverse range of native fishes (Siebentritt, 1999), although also substantial numbers of introduced fish. However, there is a paucity of scientific data describing relationships between hydrology and fish populations in the MDB, including how the magnitude and timing of environmental flows may benefit native fishes. Moreover, flow requirements, and thereby the necessity of floods for spawning, undoubtedly differ between species (Harris & Gehrke, 1994). To date, the notion that native fish need floods to successfully reproduce has been mainly based on early experiments in aquaculture and for larger species like Murray cod and golden perch (e.g. Lake, 1967). However, more recent studies have highlighted that many native fishes may also reproduce in years of low flow (Humphries *et al*., 1999) or in response to shifts in water temperature independently of flow variability (Humphries, 2005; Koehn & Harrington, 2006). There is also little scientific evidence to suggest that native Australian fishes extensively use the inundated floodplain to reproduce (Gehrke, 1991), contrary to earlier assumptions based on studies conducted overseas (e.g. the Flood Pulse Concept; Junk *et al.*, 1989). Nevertheless, it appears that fish recruitment can be more successful in years of high flow events and large floods (Balcombe & Arthington, 2009) in some circumstances.

Apart from fish, zooplankton are probably the main other faunal group for which relationships between flow variability and biotic response have been examined in floodplain river systems. These biota are particularly adapted to flow variability and extended periods of low or no flow through their use of egg-bank resting stages in floodplain sediments (e.g. Boulton *et al.*, 2006). Yet, this lifehistory strategy highlights the dependence of these ecosystems on hydrological connectivity between channels and their floodplain (e.g. Jenkins and Boulton, 2003), either to allow for critical ontogenetic shifts or for fluxes in prey items and other materials between the two environments.

In order to successfully manage and maximise positive ecological outcomes of environmental water, we clearly need more knowledge on the flow responses of fish and other aquatic fauna in the MDB. Here, we describe responses of water chemistry, invertebrate and fish parameters to flow variability and ECA releases in Lower Gwydir aquatic habitats, from October 2006 to February 2009.

7.2 Materials and methods

Sampling sites and timing. The core objective of this research is to provide information to underpin future environmental flow decisions for the Lower Gwydir floodplain. Accordingly, study sites were selected along the Lower Gwydir River and Gingham Watercourse, the current primary focus of ECA releases in the catchment (Table 7.1; Fig. 7.1). A further set of sites were selected along the Mehi River to act as a control for any responses to flows along the former two watercourses. Three sites were selected along each watercourse, spaced from approximately 3 to 54 km apart in channel distance. This layout was chosen to represent the range in available riverine habitat along an upstream-downstream gradient, and to allow for the detection of parallel patterns in any response to individual flow events. Sites along the Mehi River were generally spaced more widely than those along other watercourses due to the greater sinuosity of the channel.

Three sites were also selected in floodplain waterholes to the north of the Gingham Watercourse. These lie above the usual flood limits of flows along the three study watercourses and were included to act as a second level of control for any observed flow responses along the Gingham or Gwydir channels.

Water physico-chemical parameters, invertebrates and fish were sampled on ten occasions between October 2006 and February 2009 which comprises three sampling seasons (2006/07, 2007/08, 2008/09) (Table 7.2). Additional sampling of water chemistry only was undertaken towards the end of an ECA release in April 2007. Sampling dates were chosen to allow before and after monitoring of ecological responses to ECA releases along the Gwydir River and Gingham Watercourse and to capture any seasonal variation in riverine communities.

Water chemistry. Three replicate water samples were collected in acid-washed bottles from each site and retained unfiltered and frozen for later laboratory analyses of total nitrogen and total phosphorus, or as filtered samples for analysis of nitrate/nitrite (NOx), soluble reactable Phosphorus, dissolved organic carbon (DOC), chlorophyll *a* (Chl*a*), and suspended solids. Additionally, we measured pH, turbidity, electric conductivity (EC), water temperature and dissolved oxygen (DO) in the field using a Horiba portable water analysis instrument.

Fish assemblages. A set of four fyke nets (two large – 12 mm stretched mesh, 1.1 m diameter, 7.5 m wings; two small – 2 mm mesh, 0.4 m diameter, 1.2 m wings) were set overnight (18 - 20 hours) and collected the next morning. The width at which each fyke's wings were set was recorded and, along with the set time, was used in calculations of

Table 7.1. Site names, codes and locations for the three study watercourses and floodplain waterholes. Distances were calculated using Google Earth and represent distances between actual sampling points. Within each watercourse, sites are listed from upstream to downstream.

River	Site name	Code	Coordinates	Distance from next upstream site (km)	Altitude (m ASL)
Gingham Watercourse	"Willowlee"	WIL	29° 22.067' S 149° 38.358' E	0	186
	"Westholme"	WES	29° 16.613' S 149° 24.008' E	31.7	174
	"Boyanga" Waterhole	BOY	29° 12.568' S 149° 14.302' E	24.7	165
Gwydir River	Brageen Crossing	BRA	29° 23.827'S 149° 32.576' E	0	193
	"Allambee"	ALL	29° 20.585'S 149° 25.520' E	16.7	183
	"Birrah"	BIR	29° 21.675'S 149° 21.337' E	8.4	181
Mehi River	DS Combadello Weir	COM	29° 33.668'S 149° 39.675' E	0	192
	Hickey Bridge	HIC	29° 34.089'S 149° 24.364' E	54.1	178
	"Derra"	DER	29° 31.647'S 149° 16.031' E	34.0	166
floodplain	"Talmoi" Waterhole	TAL	29° 16.181'S 149° 32.364' E	0	178
	"Tillaloo" Waterhole	TIL	29° 14.492'S 149° 28.942' E	5.2	175
	"Baroona" Watehole	BAR	29° 14.424'S 149° 28.356' E	2.7	175

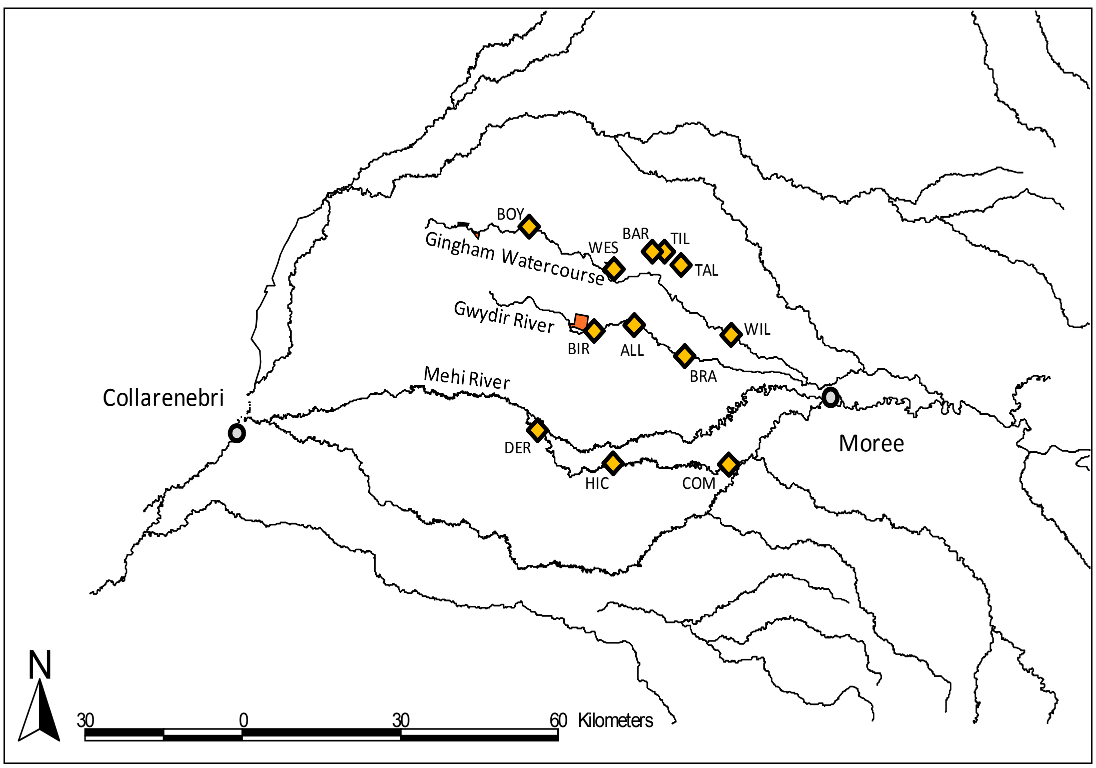

Figure 7.1. Location of in-stream sampling sites (yellow diamonds) along the three study reaches and the floodplain waterholes, Lower Gwydir floodplain. Site codes are as per those given in Table 7.1.

Table 7.2. Summary of field work undertaken in channels and floodplain waterholes of the Lower Gwydir floodplain, October 2006 to February 2009.

Season	Month	Function	Dates	Sites sampled
Field-season 1: 2006/07	October 2006	Pre flows	5 – 7 October 7 – 9 October 10 – 12 October 11 – 12 October 10 – 11 October	Mehi River (2 of 3) Gwydir River (all) Gingham Watercourse (all) Baroona Waterhole Talmoi Waterhole
	December 2006	Pre Gwydir ECA release	7 – 9 December 9 – 11 December 10 – 14 December 11 – 12 December 12 – 13 December 12 – 13 December	Mehi River (all) Gwydir River (all) Gingham Watercourse (all) Baroona Waterhole Tillaloo Waterhole Talmoi Waterhole
	February 2007	Post Gwydir ECA release	3 – 5 February 30 Jan. – 1 Feb. 31 Jan. – 4 Feb. 1 – 2 February 2 – 3 February 2 – 3 February	Mehi River (all) Gwydir River (all) Gingham Watercourse (all) Baroona Waterhole Tillaloo Waterhole (only partially due to drying) Talmoi Waterhole (only partially due to drying)
	March 2007	Pre Gingham ECA release	30 March – 1 April 29 – 31 March 27 – 29 March 27 – 28 March	Mehi River (all) Gwydir River (all) Gingham Watercourse (all) Baroona Waterhole (only partially due to drying)
	May 2007 #1	Late Gingham ECA release	2 May 2 – 3 May 2 – 3 May	Mehi River (all – water chemistry only) Gwydir River (all – water chemistry only) Gingham Watercourse (all – water chemistry only)
	May 2007 #2	Post Gingham ECA release	17 – 18 May 15 – 17 May 14 – 16 May	Mehi River (2 of 3 due to rainfall and site access) Gwydir River (all) Gingham Watercourse (all)
Field-season 2: 2007/08	Nov 2007	Pre Gingham & Gwydir ECA release	8 – 10 Nov 6 – 8 Nov 5 – 7 Nov	Mehi River (all) Gwydir River (all) Gingham Watercourse (all)
	Jan 2008	Post Gingham & Gwydir ECA release	3 – 5 Jan 2 – 4 Jan 2 – 3 Jan	Mehi River (all) Gwydir River (all) Gingham Watercourse (2 of 3 due to flooding)
	Feb 2008	Post Gingham & Gwydir ECA release	3 – 5 Feb 2 – 4 Feb 2 – 3 Feb	Mehi River (all) Gwydir River (all) Gingham Watercourse (2 of 3 due to flooding)
Field-season 3: 2008/09	Dec 2008	Pre Gingham & Gwydir ECA release, after natural flow event	19 – 20 Dec 15 – 17 Dec 16 – 18 Dec	Mehi River (all) Gwydir River (2 out of 3 due to flooding) Gingham Watercourse (2 of 3 due to flooding)
	Feb 2009	During Gingham & Gwydir ECA release	12 – 13 Feb 9 – 10 Feb 11 – 12 Feb	Mehi River (all) Gwydir River (2 out of 3 due to flooding) Gingham Watercourse (2 of 3 due to flooding)

standardised catch per unit effort. Fish were identified in the field, measured (standard length (SL) to the nearest mm) and either released unharmed (native fish) or euthanized and disposed of (exotic species). Length-weight relationships for all study species were available from nearby northern Murray-Darling Basin catchments (principally the Macintyre and Warrego rivers: G. Wilson, unpublished data) and were used to estimate the biomass of Lower Gwydir samples.

Crustaceans (*Cherax destructor* yabbies, *Macrobrachium* freshwater shrimps) and three turtle species were also trapped in the fyke nets. Yabbies were counted in the field and released. *Macrobrachium australiense* shrimp were counted and a random sample of 100–150 was retained in 70% ethanol from the small fyke nets for laboratory measurement of their carapace lengths (0.1 mm) to determine population size structure. Turtles were identified to species, their carapace length measured (mm), and then released.

Invertebrate assemblages. Five random sediment core samples were collected at each site on each sampling trip. A corer (50 mm diameter, 110 mm depth) was inserted into the sediment to a depth of 10 mm and the enclosed sediment and overstanding liquid was transferred to a 250 mL container. Samples were allowed to settle and then the liquid was decanted from the sediment and both sub-samples preserved in 70% ethanol for later sorting. In the laboratory, these samples were sorted under a dissecting microscope to count and identify taxa. Invertebrate taxa were identified to lowest practical level (family or genus). Benthic samples were collected in Season 1 and 2. Additionally, we collected five replicate pelagic samples by pumping 5 L of water from the water column using a small boat bilge pump. Samples were filtered through a 56 ųm net and retained in a 200 mL jar in 70% ethanol for laboratory processing.

7.3 Results

Hydrology. The watercourses of the Lower Gwydir floodplain showed a highly variable hydrograph throughout the study period (Fig. 7.2). Flow releases occurred regularly in all three study watercourses, and there was considerable inter-annual variability between the three seasons. There was a particularly pronounced difference in discharge during the main spring-summer fish-breeding period of each season (Table 7.3). For example, total discharge more than doubled in the Gingham in the second season and doubled again in the third season. Total flows were similar in the first two Gwydir seasons, but there was a significant increase in the third. Contrary to that, the Mehi experienced the highest total discharge in the first season. Other changes were observed in median flows, with a doubling in median flows in the second and third season in the Gingham and Gwydir, but an approximately 50% reduction of median flows in the Mehi in the second season and a return to similar levels in the third season.

Water chemistry – general and spatial patterns. A range of physico-chemical water parameters was measured in the Lower Gwydir waterways (Table 7.4.). Values were averaged over all the measurements taken in the three watercourses for each of the three field seasons (October 2006–February 2009). Levels of total phosphorus (TP) were high even for a lowland river, especially in the first (2006/07) season. Similarly, total nitrogen (TN) was excessively high on most occasions. These measurements show that nutrient concentrations have the potential to lead to nuisance algae problems in the Lower Gwydir catchment. Turbidity levels were high as well. There was minimal fluctuation in values between seasons.

There were only limited differences in physico-chemical water parameters between the three Lower Gwydir watercourses (Fig. 7.3). Mean nutrient concentrations and turbidity were excessive in all three rivers, and there was some evidence of increasing nutrient concentration from upstream to downstream in the Gingham Watercourse (Fig. 7.4).

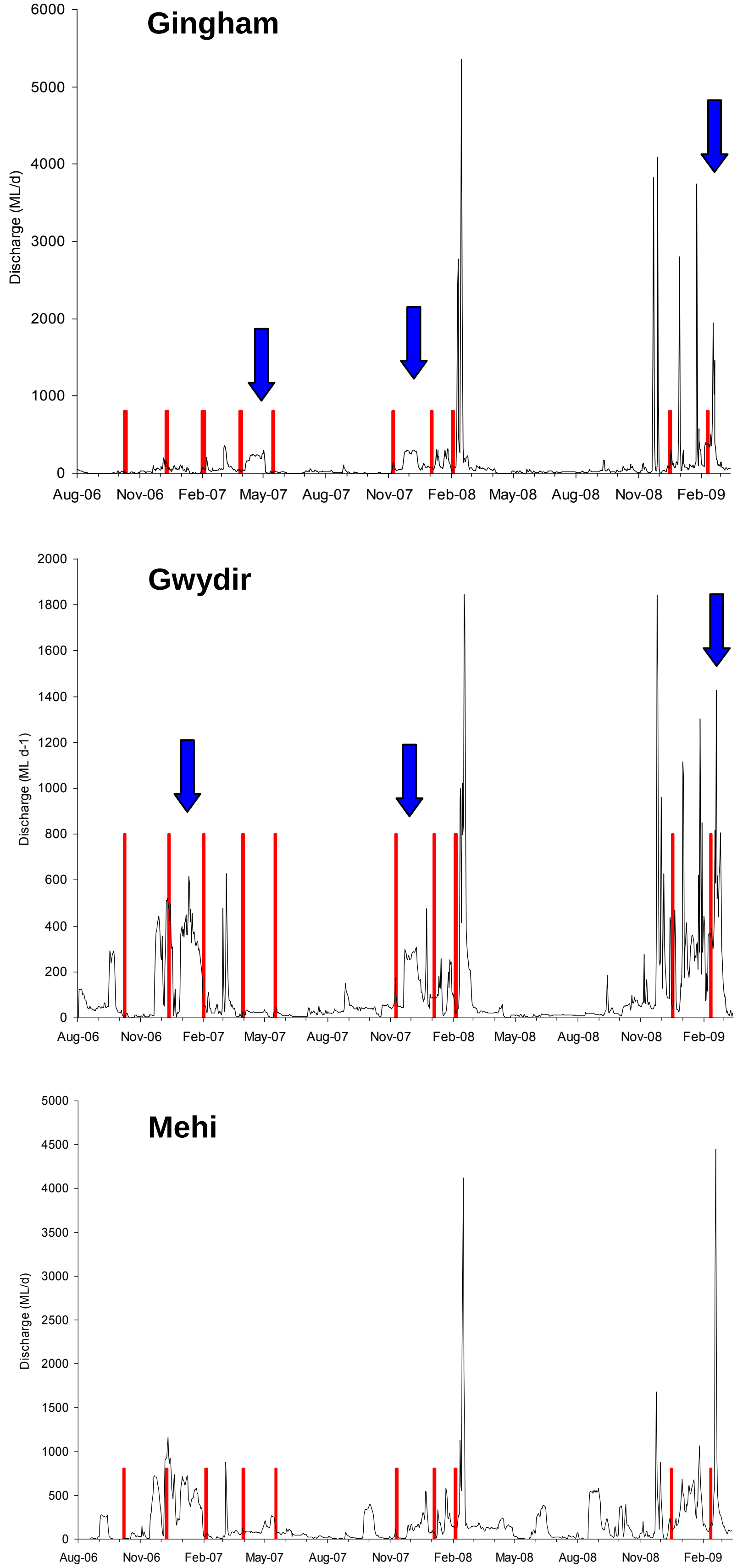

Fig. 7.2. Discharge variability in the Gingham Watercourse and Gwydir and Mehi rivers, over the study timeframe. Red bars indicate time of sampling, and the timing of ECA releases is indicated by blue arrows.

Table 7.3. Discharge during the main fish spawning season in the 2006/07, 2007/08 and 2008/09 field seasons.

Channel	Total discharge (ML)			Median discharge (ML)		
	Oct. - Dec. 06	Oct. - Dec. 07	Oct. - Dec. 08	Oct. - Dec. 06	Oct. - Dec. 07	Oct. - Dec. 08
Gingham	3783	8344	19301	26.5	50.0	48.5
Gwydir	11798	10539	16608	16.5	57.7	65.3
Mehi	27305	10375	16770	117.1	58.4	105.4

Table 7.4. Average (± standard deviation), minimum and maximum water quality parameters measured over the three sampled seasons in the three study watercourses. (NOx = concentration of Nitrite and Nitrate, SRP = soluble reactive phosphorus, TN = total nitrogen, TP = total phosphorus, EC = electrical conductivity, DOC = dissolved organic carbon, SS = suspended solids, and Chla (corr) = chlorophyll a – phaeophytin). Turbidity was measured in the field as denoted with an asterisk.

	season	NOx (mg/L)	SRP (mg/L)	TN (mg/L)	TP (mg/L)	EC (us/cm)	Turbidity (NTU)*	DOC (mg/L)	SS (mg/L)	Chla corr. (ug/L)
Mean ± SD	06/07	0.019 ±0.022	0.037 ±0.032	1.3 ±1.4	0.18 ±0.19	328 ±153	352 ±240	122 ±215	9.3 ±6.7	33.5 ±61.8
	07/08	0.012 ±0.006	0.021 ±0.013	0.8 ±0.4	0.10 ±0.06	318 ±113	264 ±120	49 ±27	5.8 ±2.3	20.6 ±8.5
	08/09	0.013 ±0.006	0.038 ±0.007	0.8 ±0.3	0.16 ±0.06	354 ±85	254 ±123	135 ±85	8.9 ±1.7	32.0 ±13.8
Min	06/07	0.005	0.008	0.5	0.05	160	47	20	1.1	4.1
	07/08	0.006	0.008	0.5	0.05	227	80	1	2.5	7.4
	08/09	0.010	0.030	0.5	0.09	219	80	46	6.6	15.7
Max	06/07	0.112	0.138	8.5	1.07	968	999	1660	36.8	596.2
	07/08	0.042	0.079	2.5	0.38	669	650	122	11.4	50.2
	08/09	0.029	0.056	1.3	0.27	441	550	294	12.4	54.9

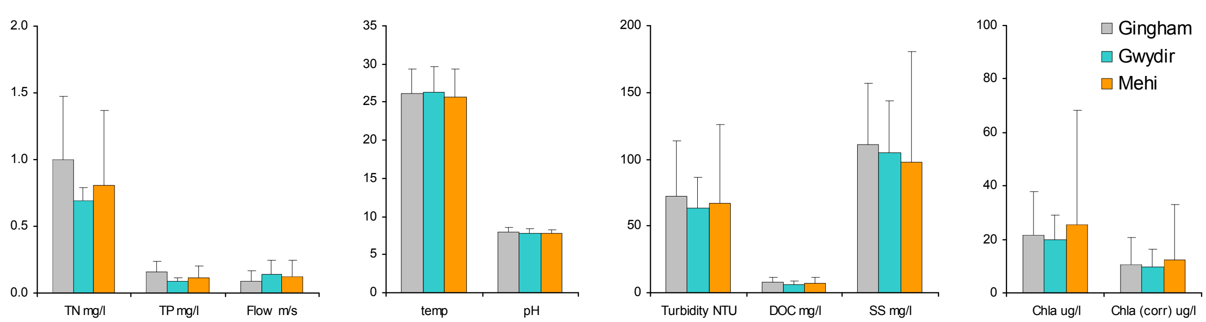

Fig. 7.3. Mean (±SD) physico-chemical water parameter values for the three study watercourses, October 2006 to February 2008. Codes and units of the parameters are the same as in Table 7.3.

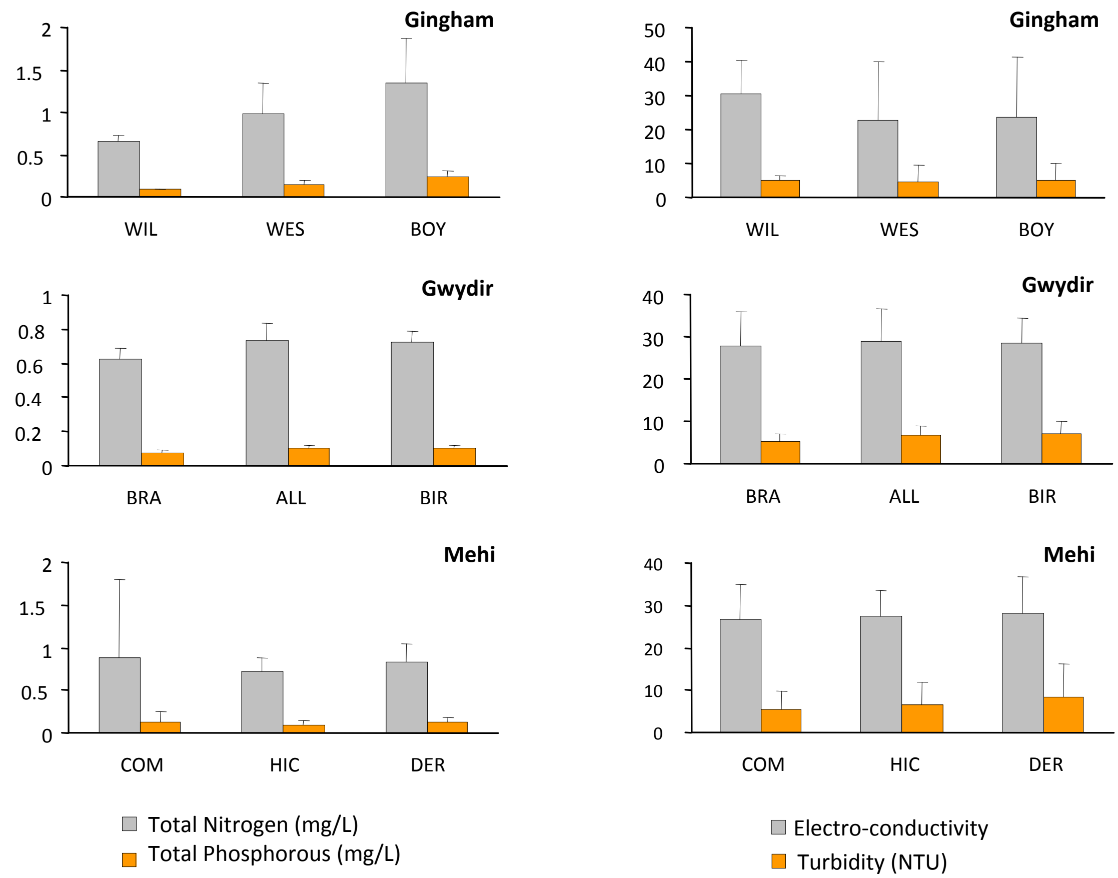

Fig. 7.4. Variability in total nitrogen and phosphorus concentration(TN, TP), electro-conductivity (EC) and turbidity (NTU) along the upstream-downstream gradient in the three study watercourses, October 2006 to February 2009. Error bars indicate the standard deviation.

***Water chemistry – temporal patterns*.** Parameters displayed differing temporal patterns in relation to flow variability.

Water temperature and pH – Water temperature varied is a predicable seasonal manner, and showed little response to flows within the study watercourses (Fig. 7.6a). Similarly, pH varied little throughout the study period (Fig. 7.6a).

Turbidity and electro-conductivity – Turbidity was particularly variable between sites in all watercourses, but particularly in the Gingham Watercourse (Fig. 7.6ab) where there was no clear effect of discharge. There was also an unclear relationship between flows and turbidity in the Lower Gwydir River, where peaks occurred during periods of both high (December 2006, January 2007) and low (May 2007) discharge. Electro-conductivity was generally lower

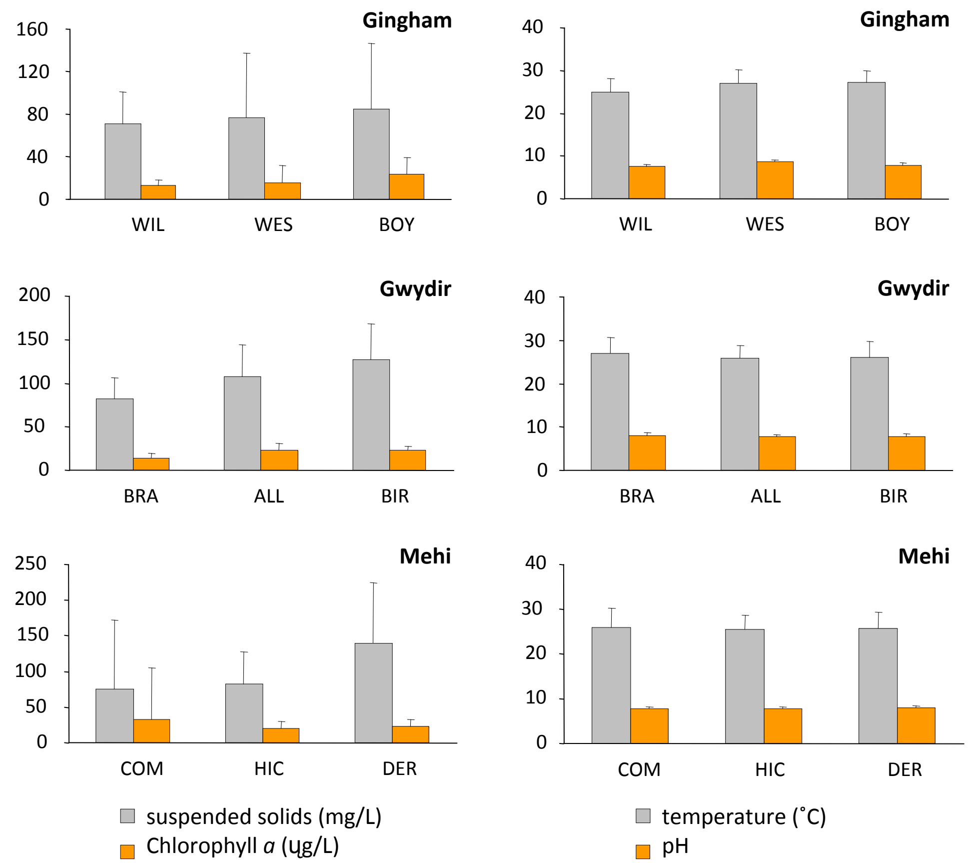

Fig. 7.5. Longitudinal variation in mean suspended solid load (SS), chlorophyll *a*, water temperature and pH along the three study watercourses, October 2006 to February 2009. Error bars indicate the standard deviation.

following flow events in all watercourses (e.g. before and after the April 2007 and November ECA releases in the Gingham Watercourse (Fig. 7.6a).

Dissolved organic carbon and chlorophyll a – Dissolved organic carbon (DOC) levels showed a weak negative relationship with discharge in the study system (Fig. 7.6b), although this was not always consistent and was less clear in the Mehi River. Chlorophyll *a* was more variable between sites (Fig. 7.6b). It showed a similar relationship with flow to that of DOC in the Gingham Watercourse, although the opposite trend in at least the Lower Gwydir River. These pattens might indicate a relationship between riverine productivity and discharge, although the inconsistencies suggest that this may depend on the timing of flow events and vary between channels.

Total nitrogen and total phosphorous – Total nitrogen levels were generally higher and more variable within channels during periods of lower discharge, such as in October 2006, and February and November 2007 in the Gingham Watercourse (Fig. 7.6b). By contrast, total phosphorous levels varied little throughout the study period (Fig. 7.6b).

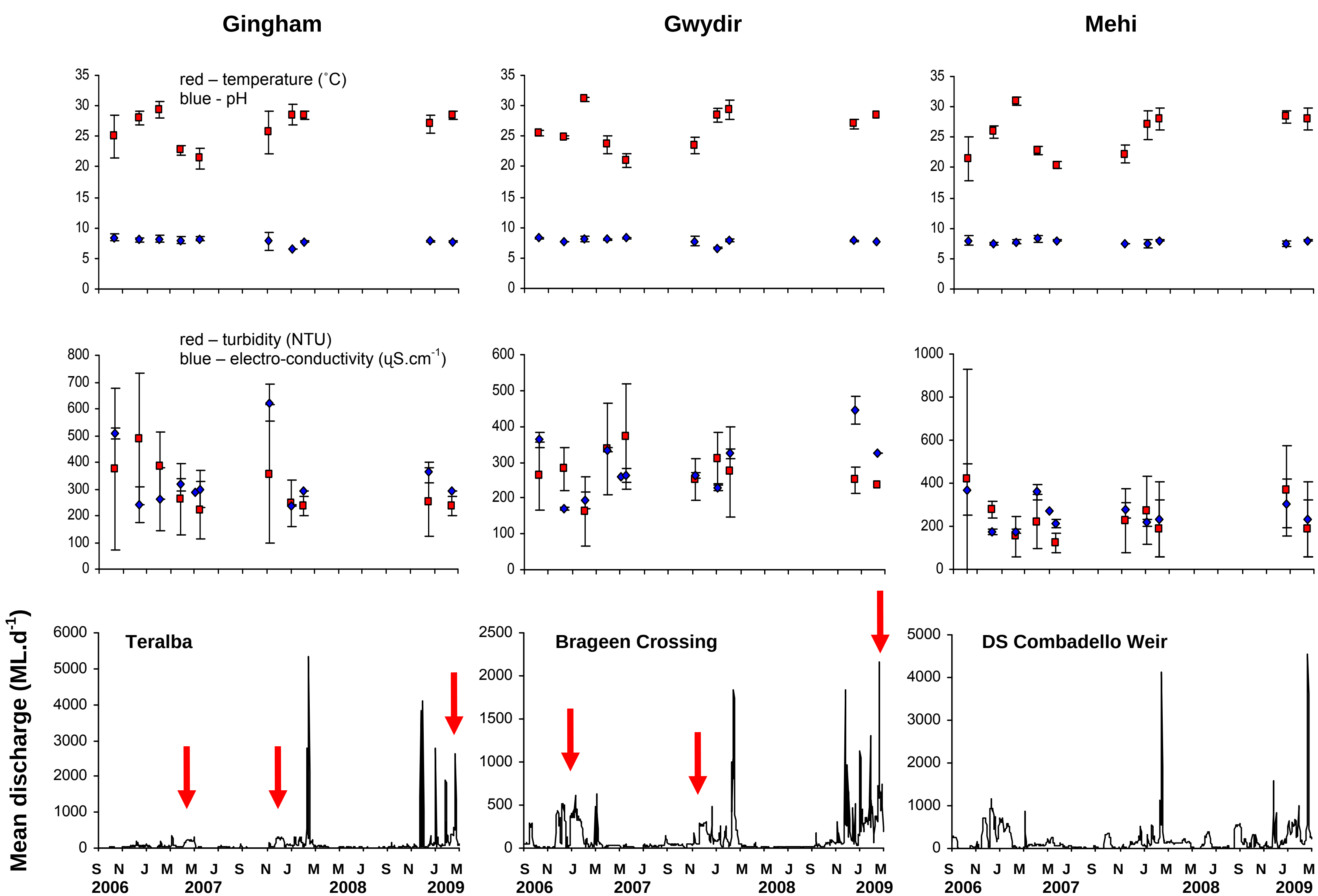

Fig. 7.6a. Mean pH, water temperature, electro-conductivity, turbidity and discharge within the three study watercourses, October 2006 to February 2009. The discharge hydrograph is shown for each watercourse, with ECA releases indicated by red arrows.

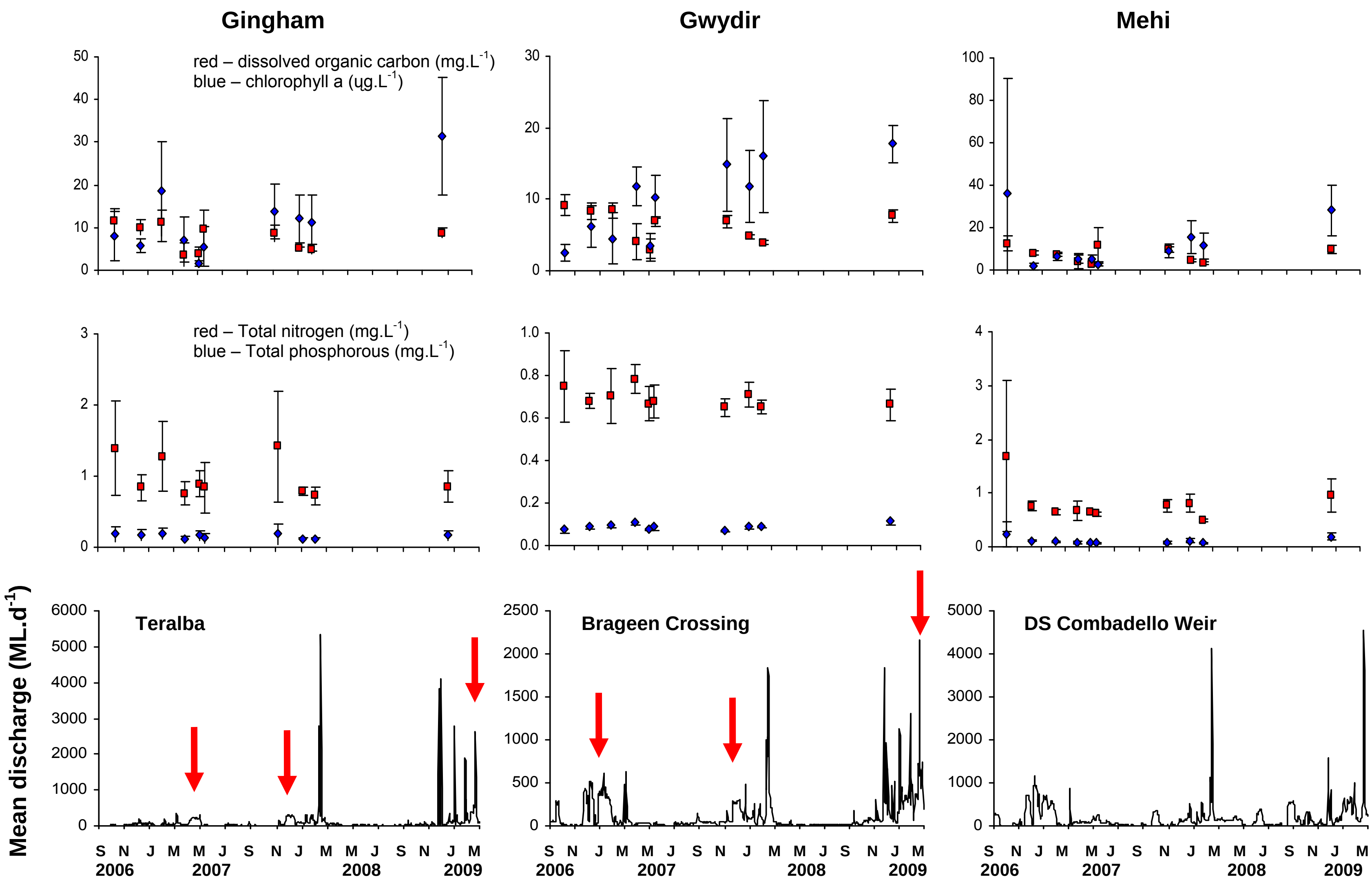

Fig. 7.6b. Mean concentration of dissolved organic carbon, chlorophyll *a* (phaeophytin corrected), total nitrogen, total phosphorous and discharge within the three study watercourses, October 2006 to February 2009. The discharge hydrograph is shown for each watercourse, with ECA releases indicated by red arrows.

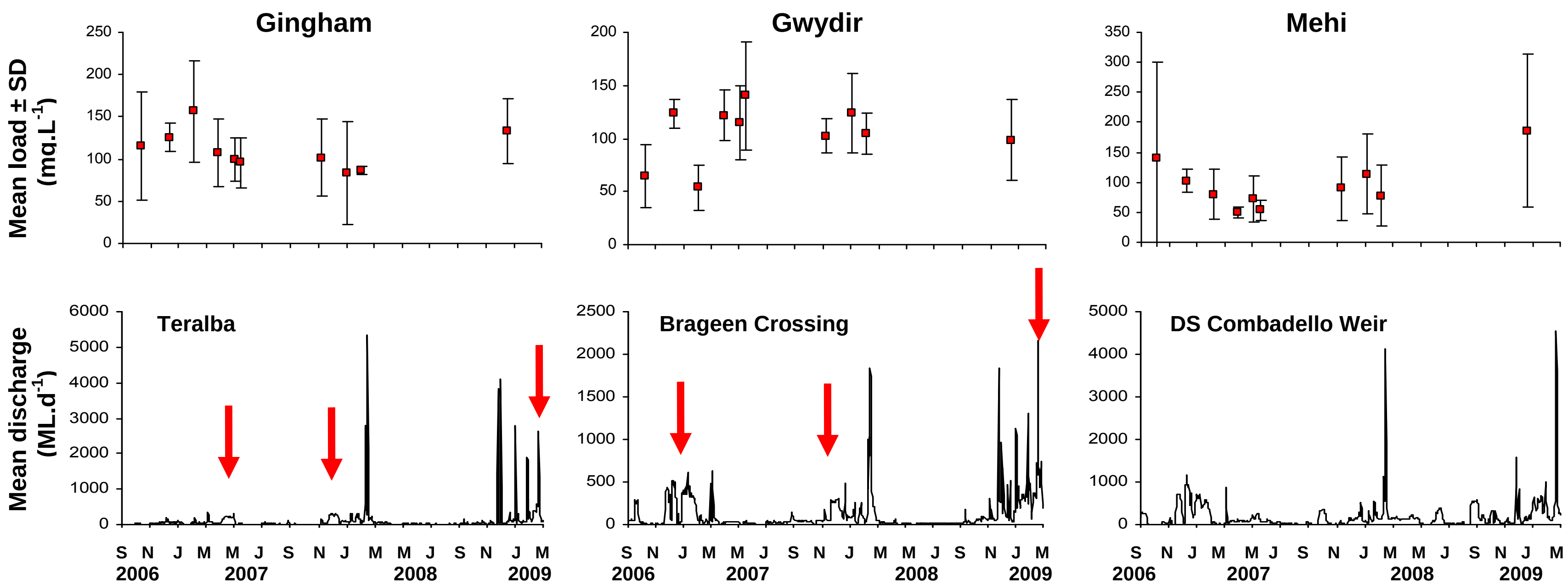

Fig. 7.6c. Mean suspended solid concentration and discharge within the three study watercourses, October 2006 to February 2009. The discharge hydrograph is shown for each watercourse, with ECA releases indicated by red arrows.

Suspended solid load – Similar to total nitrogen, suspended solid load was generally lower during low discharge conditions, although there were inconsistencies in this trend (Fig. 7.6c).

Fish – assemblage composition. We collected a total of 12,138 fish (8646 natives, 3492 exotics) from 12 taxa throughout the study (Table 7.5). Nine species were native fish, while three were exotic. However, the Lower Gwydir fish community was numerically dominated overall by only three native fish species. Bony bream was by far the most abundant species, accounting for nearly 50% of all specimens caught and present in 90% of samples. Carp gudgeon and spangled perch were the other abundant native fishes. Murray cod and golden perch were relatively uncommon (each less than 1% abundance).

The exotic pest species carp and goldfish were widely dispersed throughout the study sites and carp was the second most abundant species. In terms of biomass, carp was the most important species, responsible for more than 50% of the total fish biomass in Lower Gwydir waterways. The larger native fish (Murray cod and golden perch) also accounted for a significant portion of the total biomass due to their average large size.

There was a marked and consistent difference in fish community composition between the three studied waterways (Fig. 7.7), with each of the watercourses numerically dominated by a different native fish species. While carp gudgeon was the most common native fish in the Mehi River, bony bream dominated the Lower Gwydir River fish community. In the Gingham Watercourse, spangled perch and bony bream were jointly the most abundant native species. Other native fish were generally uncommon. A higher percentage of exotic fishes (carp and goldfish) occurred in the Lower Gwydir River and Gingham Watercourse than the Mehi River. In terms of biomass, exotics were especially dominant in the Gingham Watercourse, with carp comprising about 80% total fish biomass. This difference in fish community composition between the rivers could have been due to differences in habitat quality in the three rivers, with the Gingham Watercourse being the most degraded channel, largely lacking riparian cover and in-stream structure (coarse woody debris), both important habitat features for native fish.

There was a general increase in the relative abundance of exotic species from upstream to downstream in the Mehi River (Fig. 7.8), but no longitudinal trend was evident in either the Gingham Watercourse or Lower Gwydir River. However, longitudinal patterns were apparent in most native species (Fig. 7.8). For example, bony bream increased downstream in all watercourses, as did spangled perch in the Lower Gwydir and Mehi rivers. Conversely, the ‘miscellaneous native’ species peaked at the upstream site in each watercourse and declined downstream. Carp gudgeon mirrored this trend in the Lower Gwydir and Mehi rivers, but displayed an opposite pattern in the Gingham Watercourse.

Fish – temporal variation in abundances. The variable hydrograph made it difficult to interpret temporal changes in fish abundance, and numbers fluctuated widely between months and waterways (Fig.7.9). While the effect of ECA releases on native fish abundances was difficult to separate from that of seasonal factors, the influence of these was probably additive. For example, the lack of any significant shift in native fish abundances following the April 2007 ECA release in the Gingham Watercourse contrasted with a strong response following the November 2007 release in the same channel. A similar effect of discharge was also apparent in the Mehi River.

However, discharge effects on overall abundances were inconsistent over time. For example, discharge responses differed considerably in both the Gingham Watercourse

Table 7.5. Fish species detected in the three Lower Gwydir study watercourses, October 2006 to February 2009. Exotic fishes are marked with an *. Total biomass estimates were calculated from length-weight regressions.

Common name	Scientific name	Total abundance	Total biomass (g)	Percent abundance	Percent biomass	Percent occurrence
bony bream	*Nematalosa erebi*	5,921	86,924.07	48.8%	20.9%	90.3%
spangled perch	*Leiopotherapon unicolor*	1,117	16,075	9.2%	3.9%	71.0%
carp gudgeon	*Hypseleotris* spp.	1,229	402	10.1%	0.1%	76.3%
Australian smelt	*Retropinna semoni*	34	23	0.3%	0.0%	26.9%
un-specked hardyhead	*Craterocephalus stercusmuscarum*	91	87	0.7%	0.0%	33.3%
rainbowfish	*Melanotaenia fluviatilis*	171	255	1.4%	0.1%	45.2%
golden perch, yellow belly	*Macquaria ambigua*	43	19,863	0.4%	4.8%	31.2%
Murray cod	*Maccullochella peeli*	21	60,073	0.2%	14.5%	26.9%
eel-tailed catfish	*Tandanus tandanus*	19	6,093	0.2%	1.5%	25.8%
European carp *	*Cyprinus carpio*	3,060	220,800	25.2%	53.2%	67.7%
goldfish *	*Carassius auratus*	318	4,401	2.6%	1.1%	59.1%
mosquitofish *	*Gambusia holbrooki*	114	70	0.9%	0.0%	37.6%
Total		**12,138**	**415,066.4**			

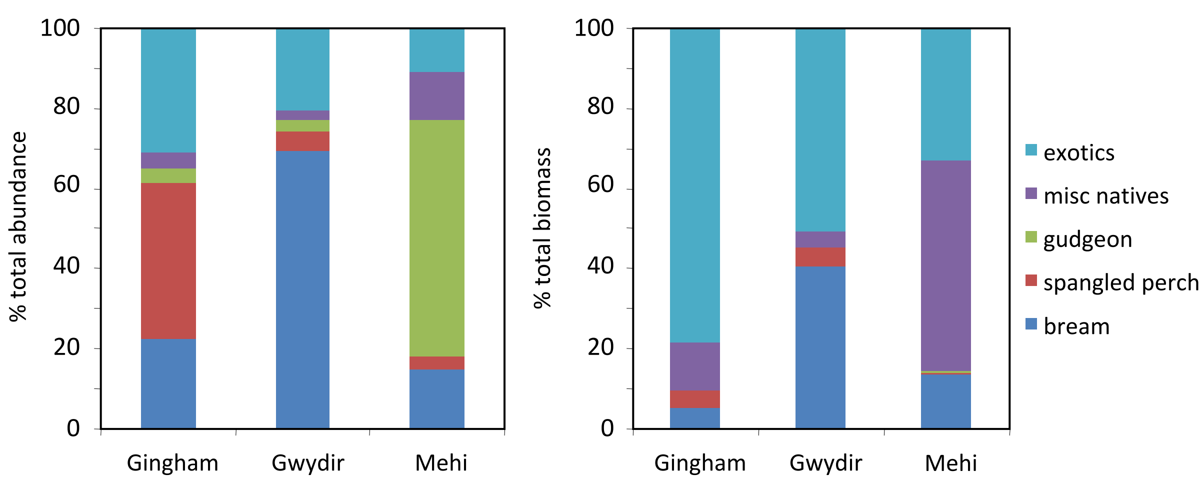

Fig. 7.7. Fish community composition in the three study watercourses, October 2006 to February 2009, presented as % of total abundance and % of total biomass. Miscellaneous natives comprise all the rarer taxa: Murray cod, golden perch, hardyhead, Australian smelt and eel-tailed catfish).

(season 1 vs 3) and Mehi River (season 2 vs 3). Responses of exotic fish usually paralleled

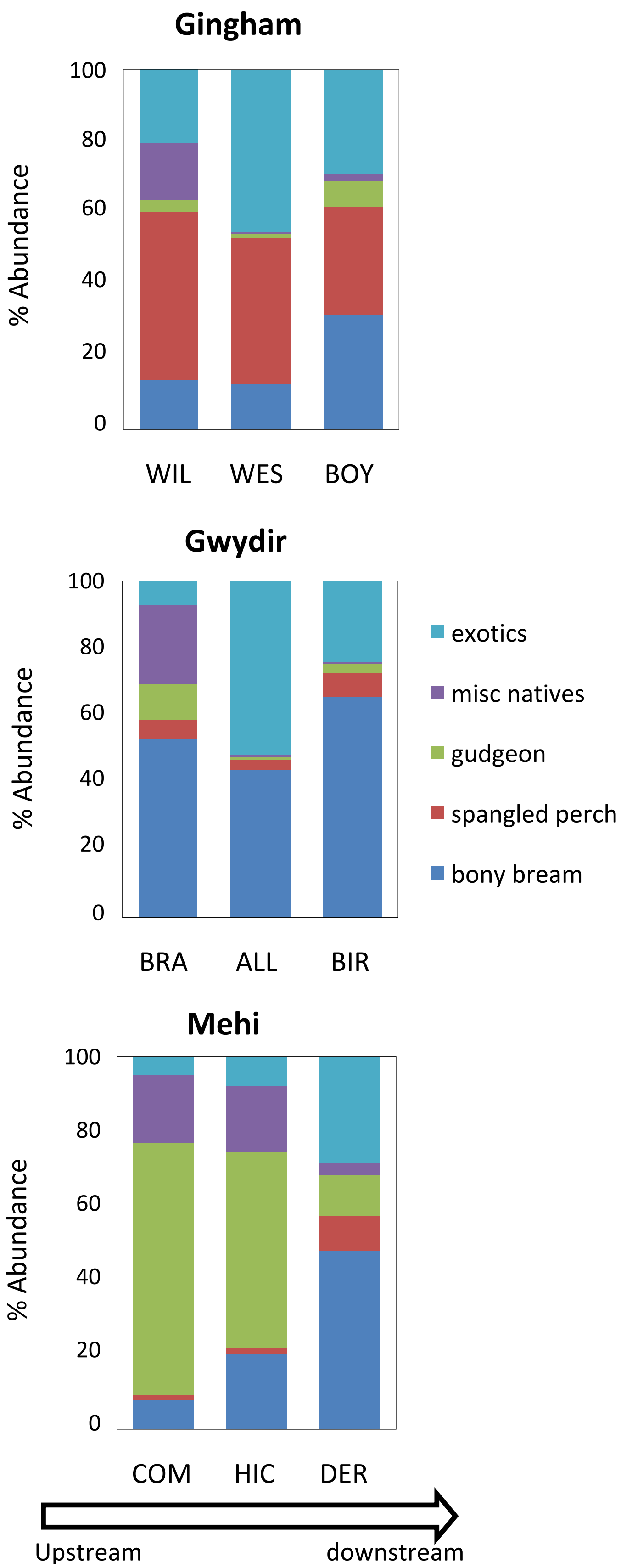

Fig. 7.8. Fish community composition among sites in each of the three study watercourses. Sites are arranged in a upstream to downstream gradient. Exotics comprise carp, goldfish and *Gambusia*; miscellaneous natives include all the rare natives as outlined in Fig. 7.7. Sites codes are as outlined in Table 7.1.

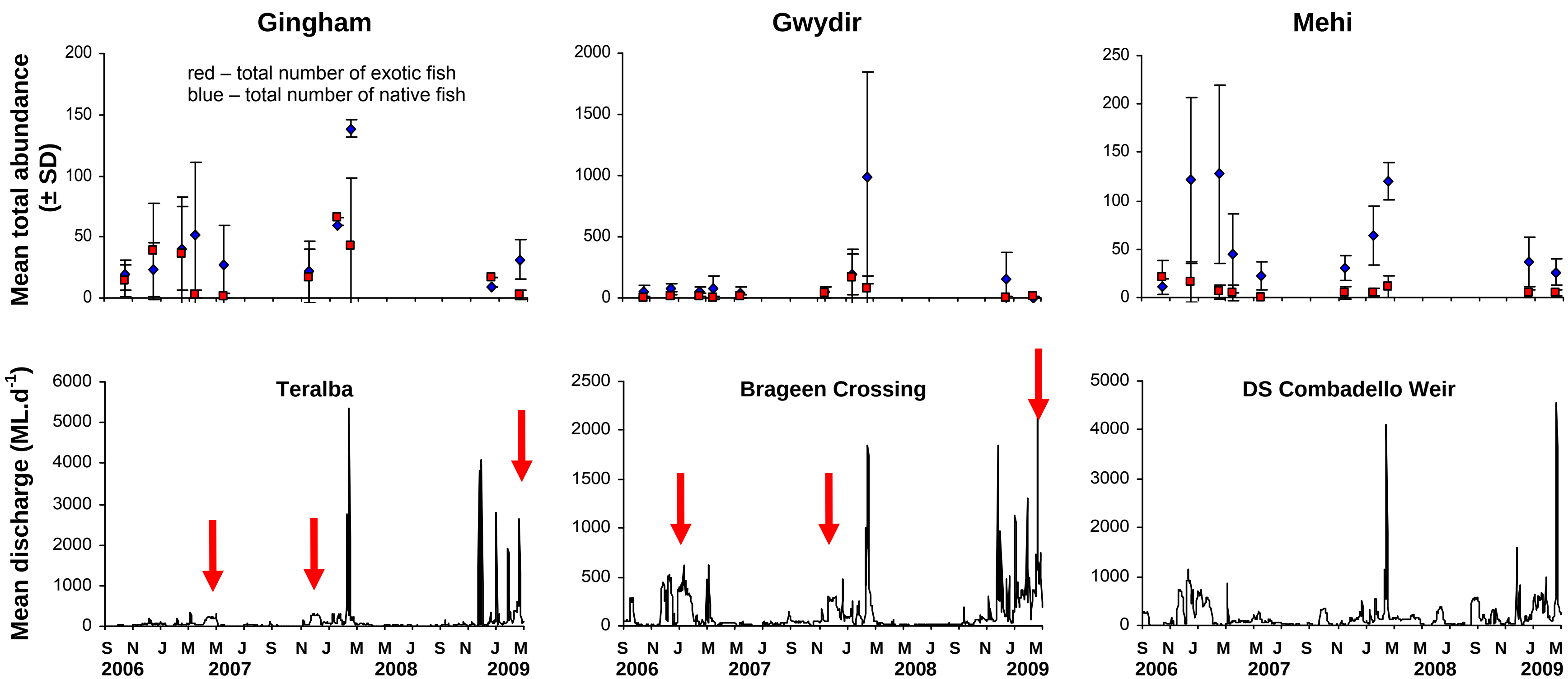

Fig. 7.9. Mean abundance of native and exotic fish per site and daily discharge within the three study watercourses, October 2006 to February 2009. The discharge hydrograph is shown for each watercourse, with ECA releases indicated by red arrows. Abundance data were corrected for sampling effort.

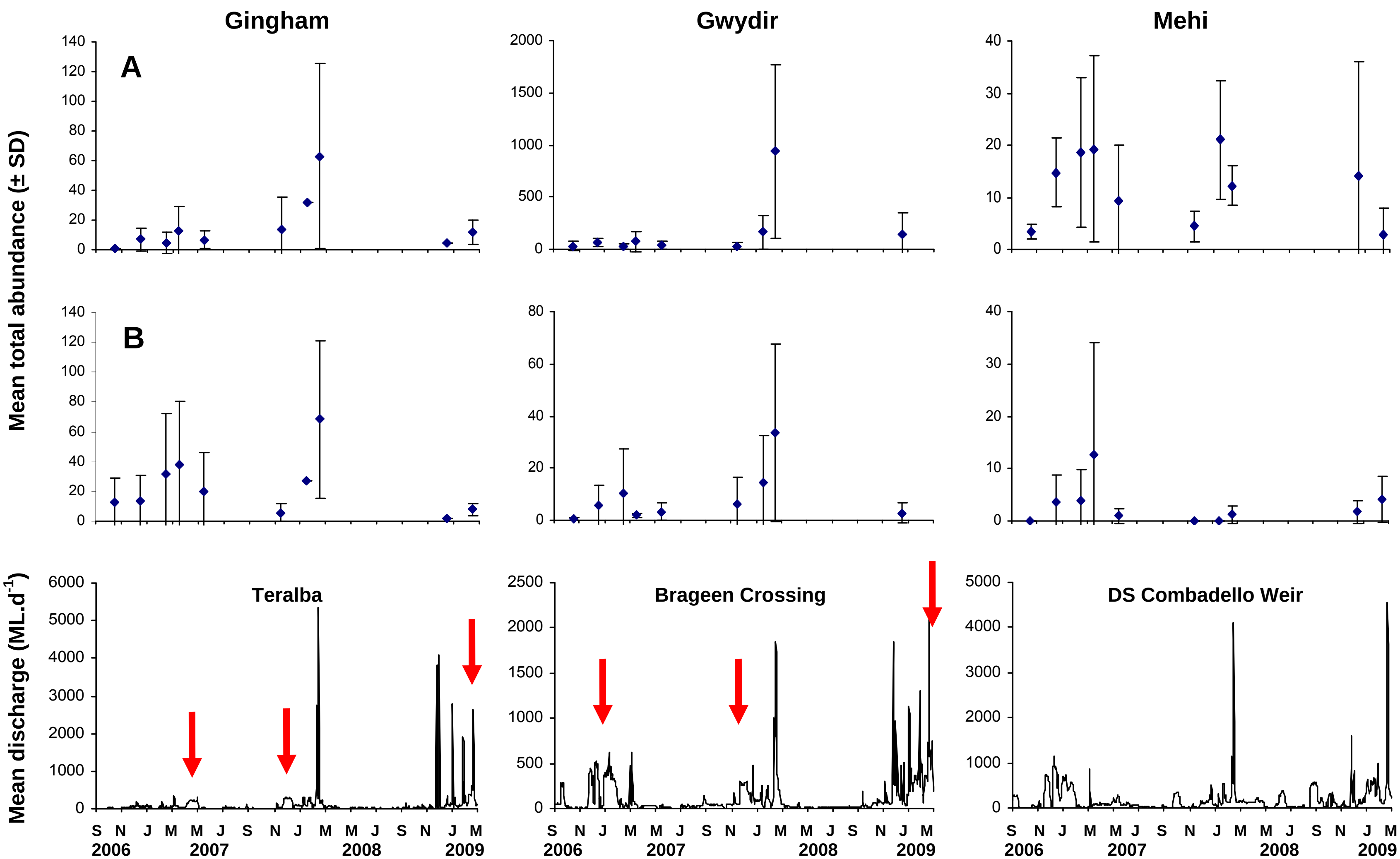

Fig. 7.10a. Mean abundance of (A) bony bream (*Nematolosa erebi*) and (B) spangled perch (*Leiopotherapon unicolor*) per site and daily discharge within the three study watercourses, October 2006 to February 2009. The discharge hydrograph is shown for each watercourse, with ECA releases indicated by red arrows. Abundance data were corrected for sampling effort.

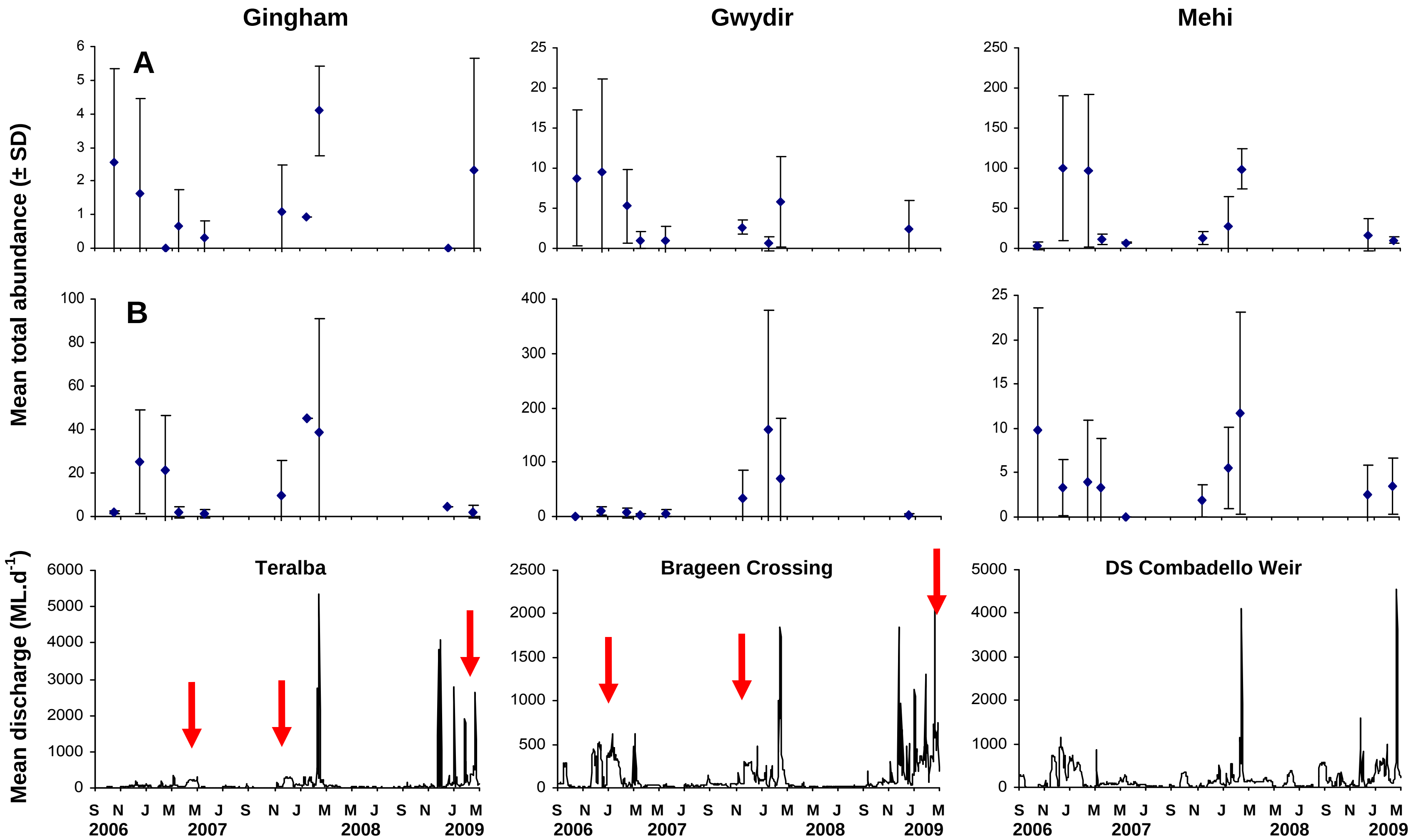

Fig. 7.10b. Mean abundance of (A) carp gudgeon (*Hypseleotris* spp.) and (B) European carp (*Cyprinus carpio*) per site and daily discharge within the three study watercourses, October 2006 to February 2009. The discharge hydrograph is shown for each watercourse, with ECA releases indicated by red arrows. Abundance data were corrected for sampling effort.

that of native fish (e.g., Mehi River, season 2), although their abundances were generally much lower than that of native species. In the Gingham Watercourse and Lower Gwydir River, abundances of bony bream, spangled perch, carp gudgeon and European carp were higher in the second field season than the first (Fig. 7.10a,b). While this mirrored overall discharge volumes at the seasonal scale in these channels, a similar response was not evident in the third field season. Whether increases in fish numbers were a result of localised spawning in the Lower Gwydir system or from having been flushed in from upstream is unclear. This point is discussed in more detail in *Population size structure* below.

Fish – spatio-temporal variation in assemblage structure. To analyse possible spatio-temporal patterns in fish assemblages, we performed ordinations on the fish abundance data. These plots display samples according to their similarities in species composition, reflecting both species richness and abundance. Samples similar in species composition are grouped closely together, and dissimilar samples are spaced more widely in the plot.

At the larger watercourse scale, data averaged over the three respective sites in each river revealed a distinct fish assemblage in each waterway (Fig. 7.11). The Lower Gwydir River fish assemblage appeared to vary the most between trips. We excluded one outlier (Lower Gwydir River, February 2009) from the grouping as this sampling point was grouped very far from the remaining samples from this river, probably due to the unusually low number of fish (especially bony bream – 3 fish instead of usually several hundred) at this time.

When samples from consecutive trips are connected by arrows, the nature of changes in fish assemblages over time becomes clearer (Fig. 7.12). Fish communities appeared to vary over time in different ways between the three watercourses. However, temporal variation appeared lower than the spatial variability, suggesting that structural characteristics or related hydrological differences between study reaches were explaining more of the differences between fish communities than seasonal fluctuations. This implies that any influence of flow variability on the Lower Gwydir fish fauna differed between watercourses, and that in-stream habitat may also have had a significant interactive effect. The strong change in the Lower Gwydir River community is clearly visible as a deviation in the ordination plot for the last four sampling trips (seasons 2 and 3), due to large fluctuations in fish numbers during those sampling trips. Fish communities in the other two channels remained more stable over time.

Fish – small-scale assemblage variability. At the smaller, within-watercourse scale, fish assemblage patterns were organized in a slightly different way. Sites within watercourses tended to group together (Fig. 7.13), although there was also a strong overlap between sites from different watercourses. However, there were also significant within-watercourse patterns that appeared to represent a longitudinal trend. The Gingham Watercourse at “Willowlee” was separated from the two downstream sites, while the two upstream sites differed from the downstream site at “Birrah” and “Derra” in the Gwydir and Mehi rivers, respectively.

To further investigate the possible impacts of flows and hydrological variables on fish assemblage composition, we conducted ordinations for all three rivers separately, connected consecutive months and indicated the timing of flow events (Fig. 7.14). Additionally we created a plot that shows the median discharge in the preceding 30 days prior to fish sampling (Fig. 7.15). In the Mehi River and Gingham Watercourse, the fish community seems to change in a seasonal fashion. These trajectories reflected a circular pattern, with the May 2007 samples grouped close to those from October 2006. However, this pattern was less pronounced in the Lower Gwydir River, and the fish community changed dramatically in

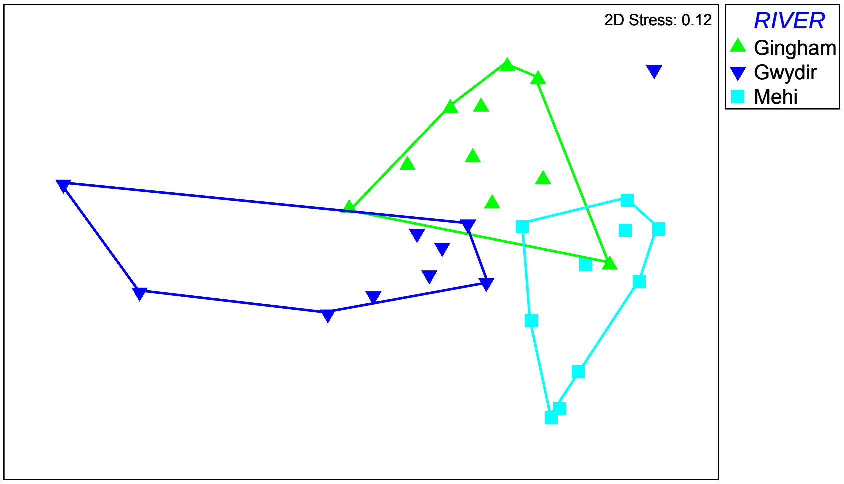

Fig. 7.11. Spatial variation in fish assemblages between the three study watercourses. Each point indicates the fish community at a given sample date in each river (average of the three sites). There are three distinct fish assemblages in the three rivers. Outlines indicate the spread of the data. One outlier of the Gwydir River samples (February 2009) was not included in the outlines.

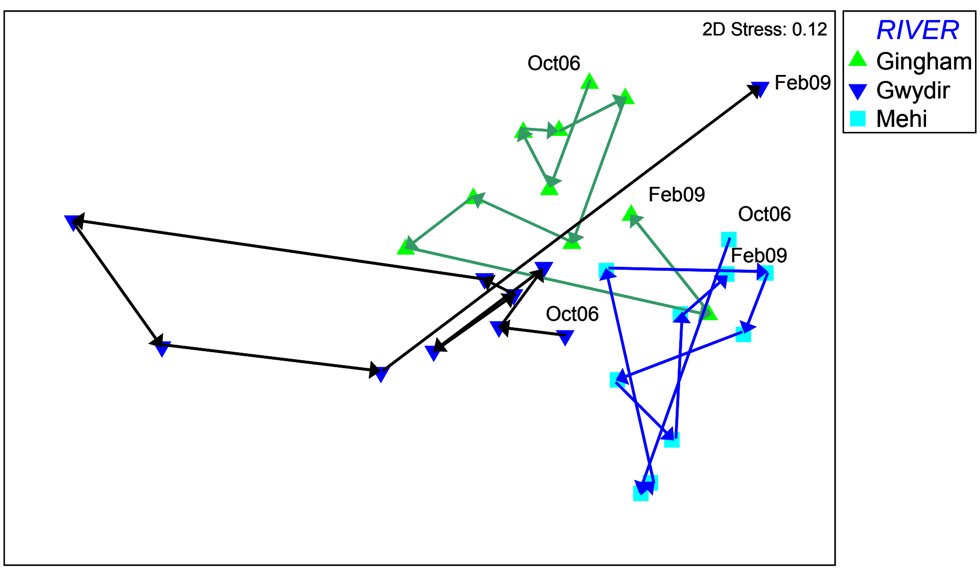

Fig. 7.12. Temporal changes in fish assemblages in the three study watercourses. Arrows connect consecutive sample dates, from October 2006 to February 2009. Note the strong deviation in the last four samples of the Gwydir samples.

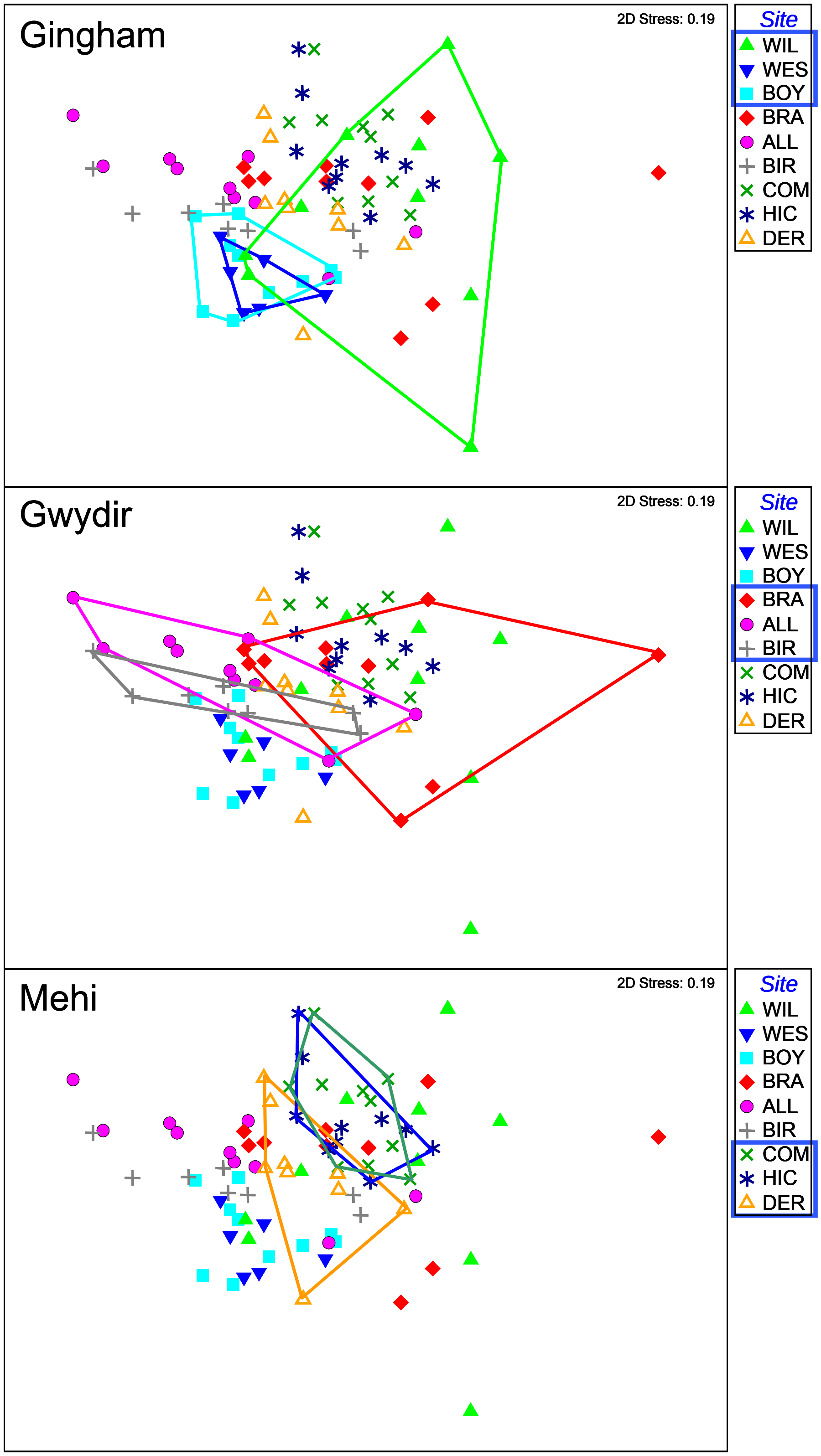

Fig. 7.13. Small spatial scale variability in fish communities between Lower Gwydir sample sites, October 2006 to February 2009.

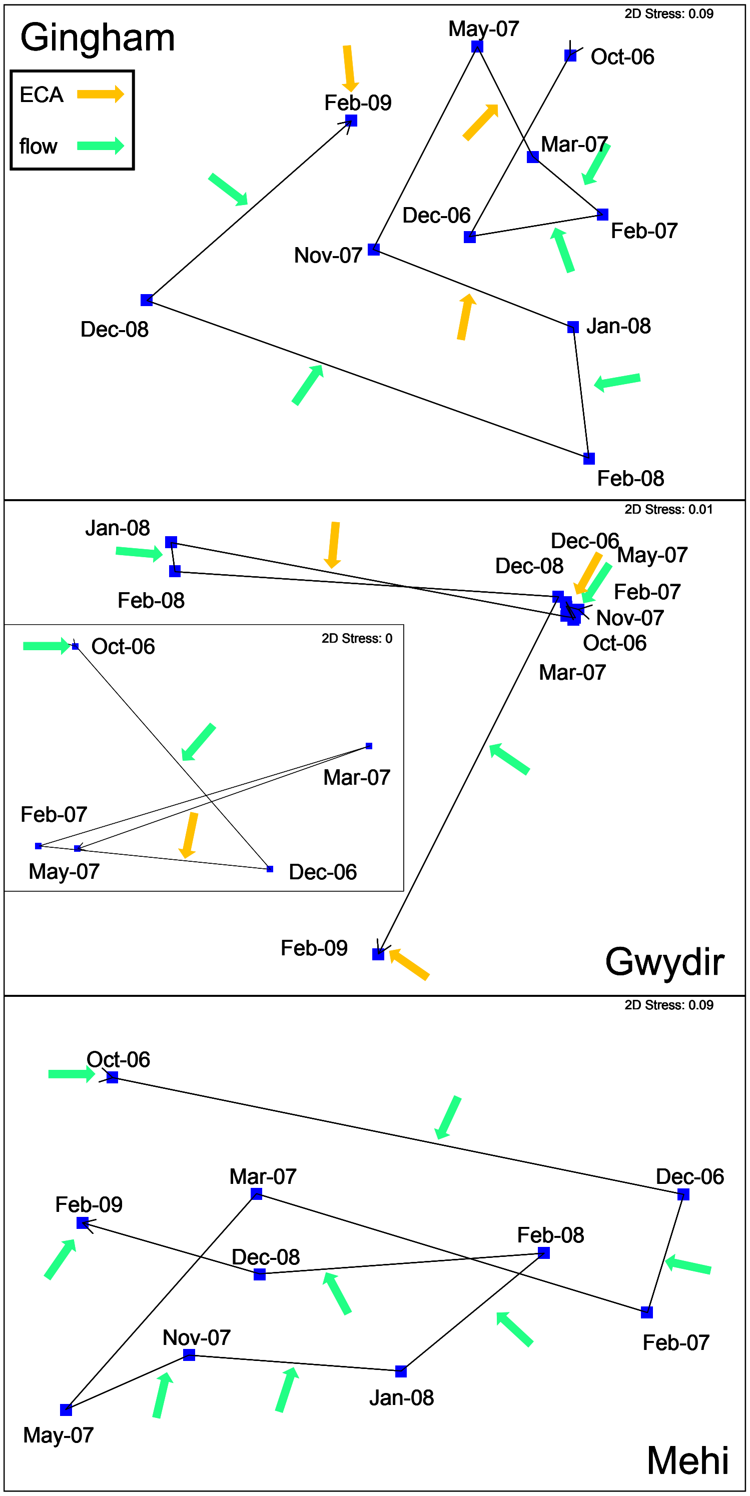

Fig. 7.14. Ordination showing the temporal changes in fish assemblages separately for each of the three rivers. Arrows connect consecutive sample dates, October 2006 to February 2009. Green arrows indicate the timing of flow events, orange arrows mark ECA releases. The inlay in the Gwydir plot shows an ordination of the first season only as the pattern are not visible in the plots containing all seasons.

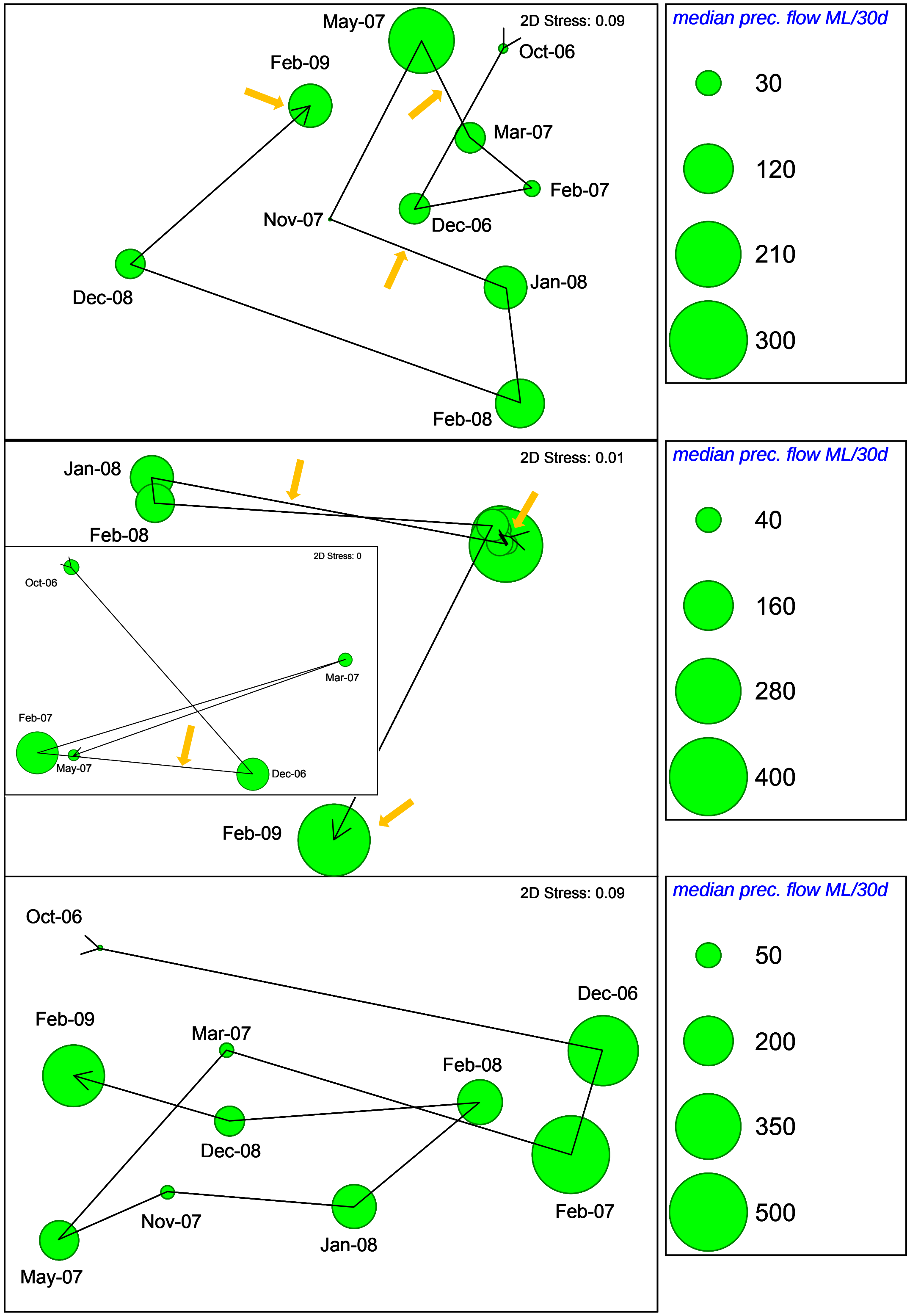

Fig. 7.15. Temporal shifts in fish assemblage structure in each of the three study watercourses. Arrows connect consecutive sample dates, from October 2006 to February 2009. Orange arrows mark ECA releases. The green balloons indicate the median discharge in the previous 30 days before sampling.

the last four sampling occasions, particularly due to the high fluctuation in carp and bony bream numbers (high in season 2, very low in season 3).

The timing of flows and the median discharge level seemed to explain less in the observed patterns. Sometimes there were big differences in fish assemblages of consecutive months, even though there was minimal flow in the preceding 30 days. In particular, strong changes in season 2 (January and February 2008) in the Lower Gwydir River did not appear to have been associated with any exceptionally high flow events prior to our sampling.

Fish – population size structure. We analysed length frequency distributions of bony bream, spangled perch, carp gudgeon and the exotic European carp and for the three study watercourses to identify the timing of recruitment in these species. Data on Murray cod, golden perch and un-specked hardyhead are also presented for the Mehi River.

Bony bream. Up to three bony bream cohorts were evident in each season throughout the study period (e.g. Gingham Watercourse, February 2008, Fig. 7.16). For the first season, abundances were limited in the Gingham Watercourse and Mehi River, although recent spawning activity/recruitment was still apparent at least in March and May 2007 (Gingham) and December 2006 and March 2007 (Mehi). Size structure in the Gingham Watercourse in May 2007 suggested a possible link between spawning activity and the April ECA release, although the Gwydir May size structure also provided some evidence of recent spawning in the absence of ECA flows.

The Lower Gwydir River population also provided some evidence of a spawning response to the December 2006 – January 2007 ECA release (Fig. 7.17). Bony bream size-structure in both the Lower Gwydir River and the floodplain waterholes prior to this flow event was dominated by fish of around 40–60 mm and 90–110 mm in length. Following the ECA flow, fish in the floodplain waterholes still largely reflected the pre-release size-structure, while the appearance of new individuals became progressively clearer in the Lower Gwydir River over the two months following the release. Fish in this younger cohort were around 20–39 and 40–79 mm in February and March, respectively. Preliminary knowledge of size-at-age relationships in this species (Heagney *et al.*, 2008), suggests that these fish were largely derived from spawning during the ECA flow.

In the second season, recent spawning activity was apparent in all populations (Gingham: November, January; Gwydir: January, February; Mehi: January, February), although it was unclear whether any had been initiated by the December ECA release into both the Lower Gwydir River and Gingham Watercourse. It is interesting to note that while the number of mature bony bream was very limited in both the Lower Gwydir River and the Gingham Watercourse throughout the study period, there were a number of large specimens in the Mehi River despite the relatively low abundance of this population. This lack of mature fish may have important implications for local recruitment, and suggests that there is limited suitable habitat for mature bony bream in the system, that mortality is high, or that fish emigrate away from our study sites before reaching maturity.

Spangled perch. Recruitment of spangled perch occurred throughout the study period, although with considerable variability between channels (Fig. 7.18). In the first season, recent spawning activity was particularly apparent in the Gingham Watercourse (December, March and May), Gwydir (December and possibly May) and Mehi (February). Along with previous size-at-age data from the nearby Macintyre River, this suggests that the ECA release may have initiated spawning activity in the Gingham Watercourse, but not the Lower

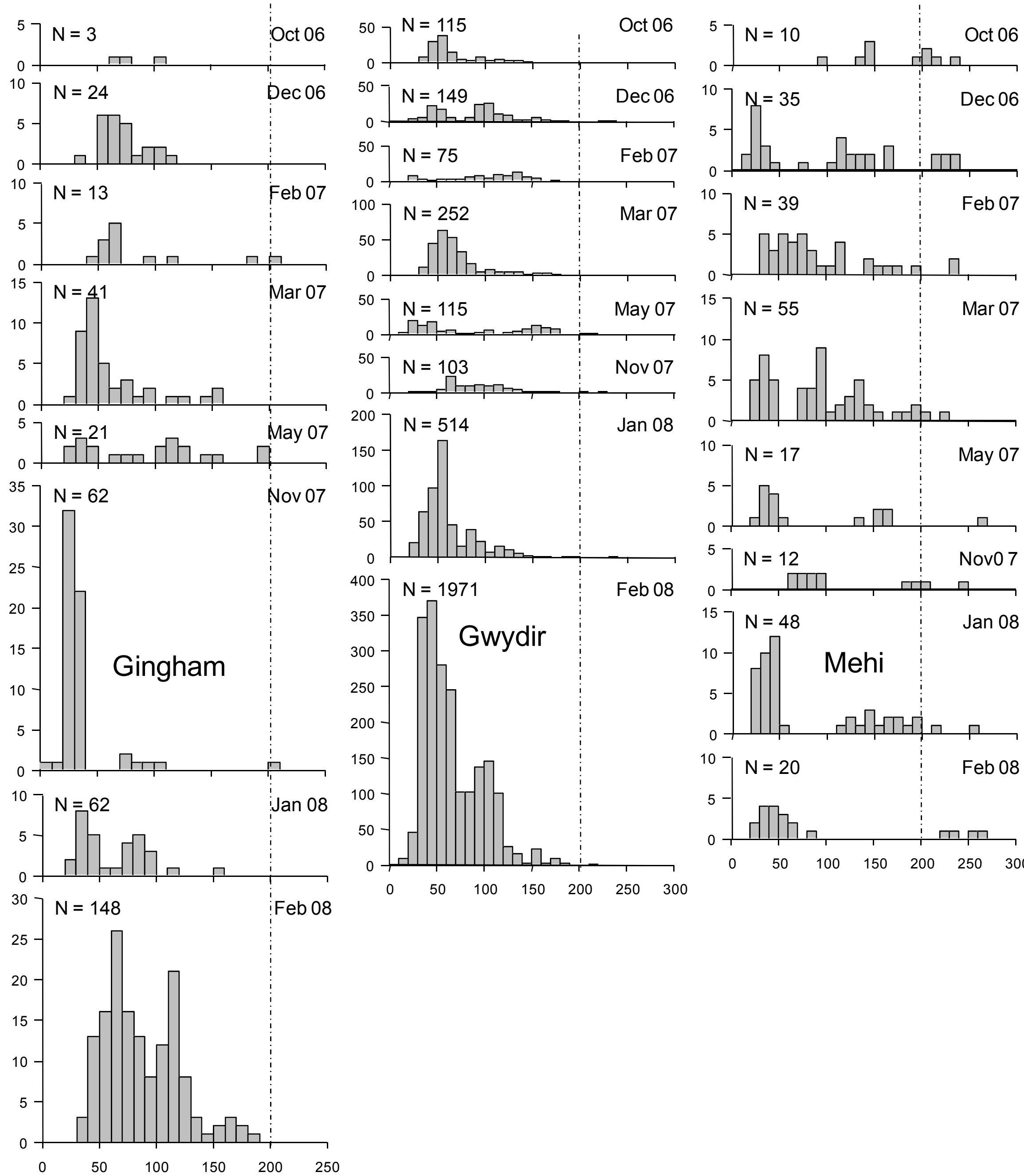

Fig 7.16. Length-frequency distribution of bony bream (*Nematolosa erebi*) among the three Lower Gwydir study watercourses, October 2006 to February 2008. The vertical line indicates the approximate length at maturity.

Gwydir River. Interestingly, the February 2007 Mehi River recruitment did not appear to result in any significant presence in this river in the second season.

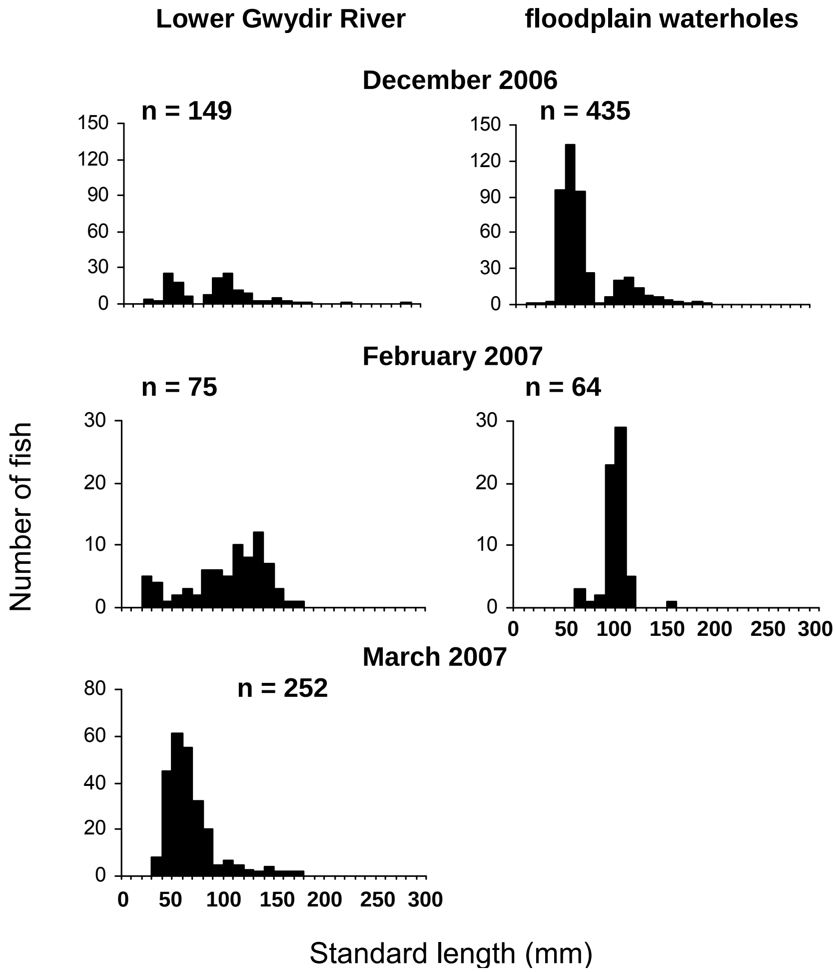

Fig. 7.17. Changes in bony bream (*Nematolosa erebi*) size-structure before and after a December 2006 to January 2007 ECA release into the Gwydir River. Floodplain waterholes nearby were not subject to the same flow-pulse. No bony bream were detected in the floodplain waterholes in March.

In the second season, significant recent spawning was evident in only the Gingham Watercourse in January, while limited numbers of small fish were also apparent in the Lower Gwydir River in January and in all channels in February. Again, these size structures and previous size-at-age data from the Macintyre River suggest that ECA flows may have initiated spawning in both channels, although weakly so in the Lower Gwydir River.

European carp. Only limited spawning/recruitment of carp was detected in all channels in the first season (Fig. 19), and abundances were consistently low in the Mehi River throughout the study period. Abundances were also low in the Lower Gwydir River throughout the first season. In the Gingham Watercourse, recent spawning was evident in October, December and February, but not in May following the April ECA release. In the second season, significant recent spawning was apparent in all months for the Gingham and Gwydir, although only in February 2008 in the Mehi. Mature-sized fish (> ca 300 mm) were present in all channels in both seasons.

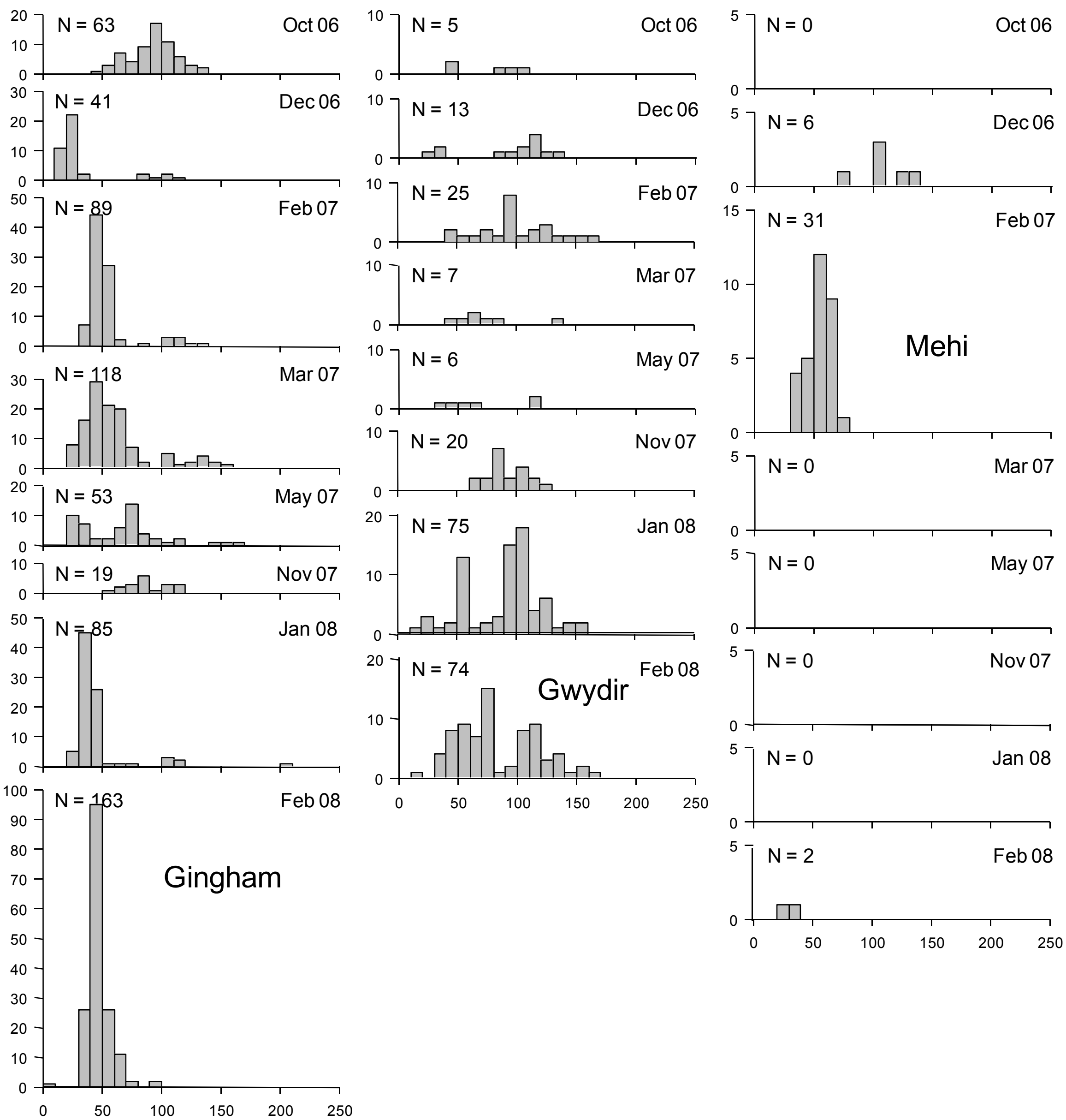

Fig. 7.18. Length-frequency distribution of spangled perch (*Leiopotherapon unicolor*) among the three Lower Gwydir study watercourses, October 2006 to February 2008. Size at maturity is not indicated for this species due to known variability in this parameter (G. Wilson, pers. obs.).

Carp gudgeon. Large abundances of this species were only encountered in the Mehi throughout the study period (Fig. 7.20). Interestingly, the smallest fish in this river were sampled in February 2007 after a period of low flows. ECA releases did not appear to have initiated significant spawning/recruitment in either the Gingham Watercourse or Lower Gwydir River.

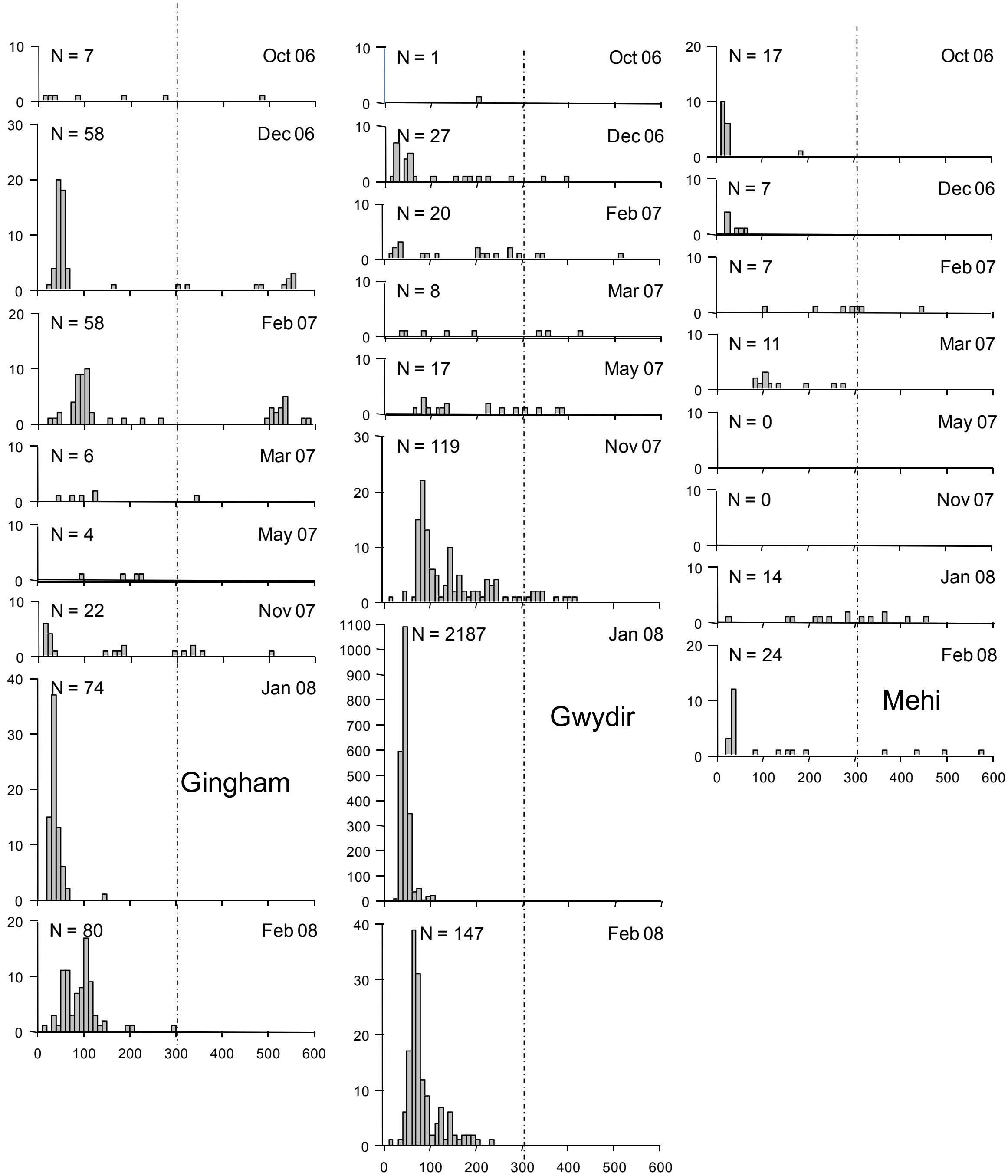

Fig. 7.19. Length-frequency distribution of European carp (*Cyprinus carpio*) among the three Lower Gwydir study watercourses, October 2006 to February 2008. The vertical line indicates the approximate length at maturity.

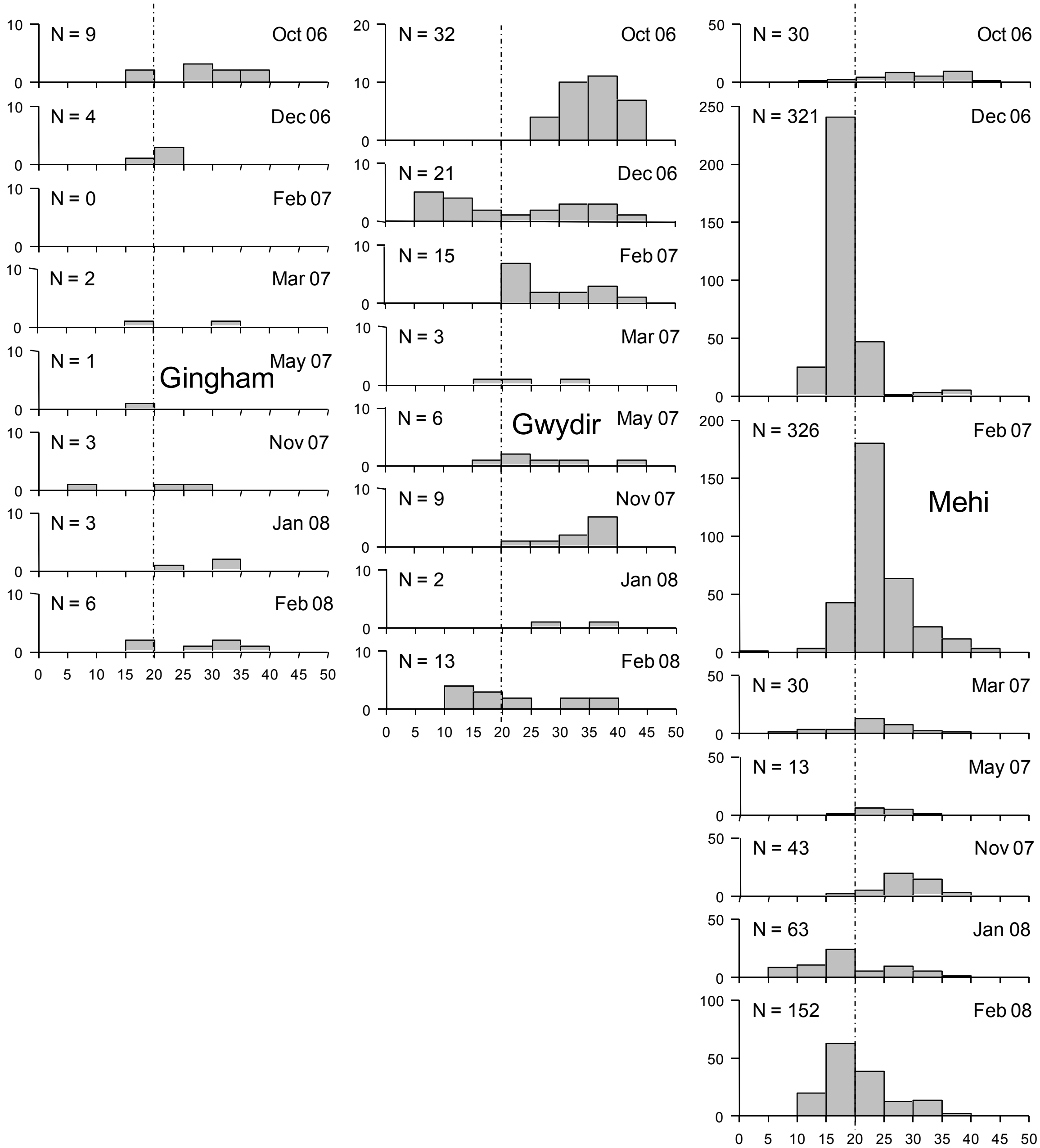

Fig. 7.20. Length-frequency distribution of carp gudgeon (*Hypseleotris* spp.) among the three Lower Gwydir waterways, October 2006 to February 2008. The vertical line indicates the approximate length at maturity.

Other species – Mehi River. Murray cod recruits were only collected in December and February of the first season (Fig. 7.21). No particularly small golden perch were sampled throughout the study period, suggesting an absence (or only low levels) of local spawning activity. Un-specked hardyhead juveniles were observed in February and (particularly) November 2007.

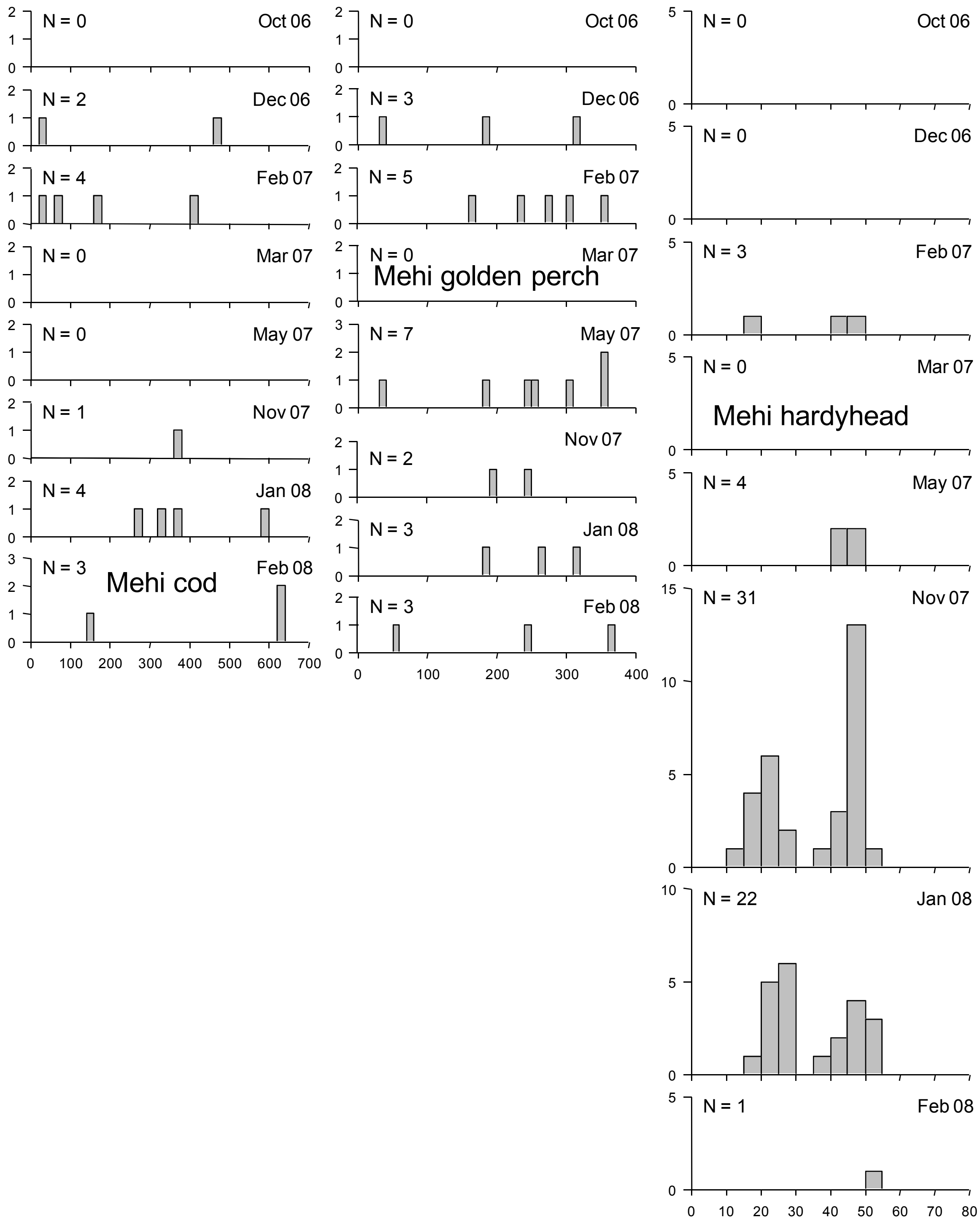

Fig. 7.21. Length-frequency distribution of Murray cod, golden perch and un-specked hardyhead in the Mehi River, October 2006 to February 2008.

Invertebrates. We firstly compared the invertebrate communities sampled by the different collecting methods (corer – benthic; corer – liquid; pelagic pump) from a single site per

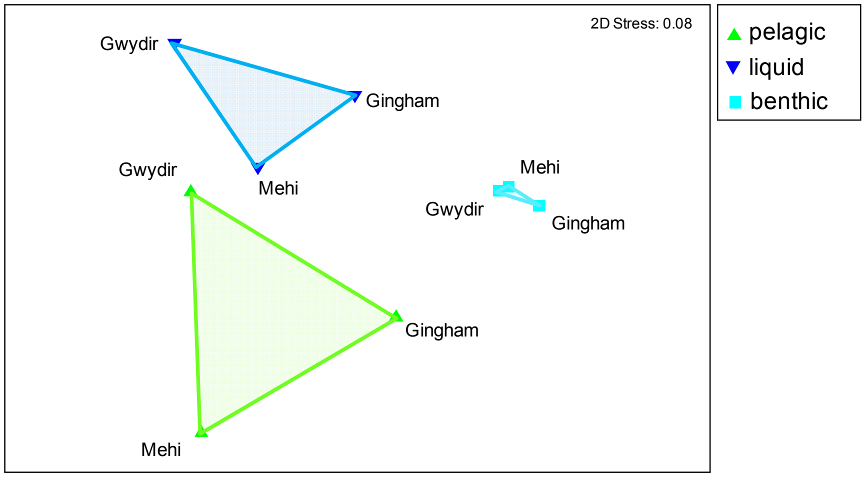

Fig. 7.22. Ordination (MDS) of the sampled invertebrate community (averaged over samples) from one site of each river in October 2006. Sediment core samples yield the benthic (sediment) sample itself and the decanted liquid. Pump samples yield the pelagic invertebrate community.

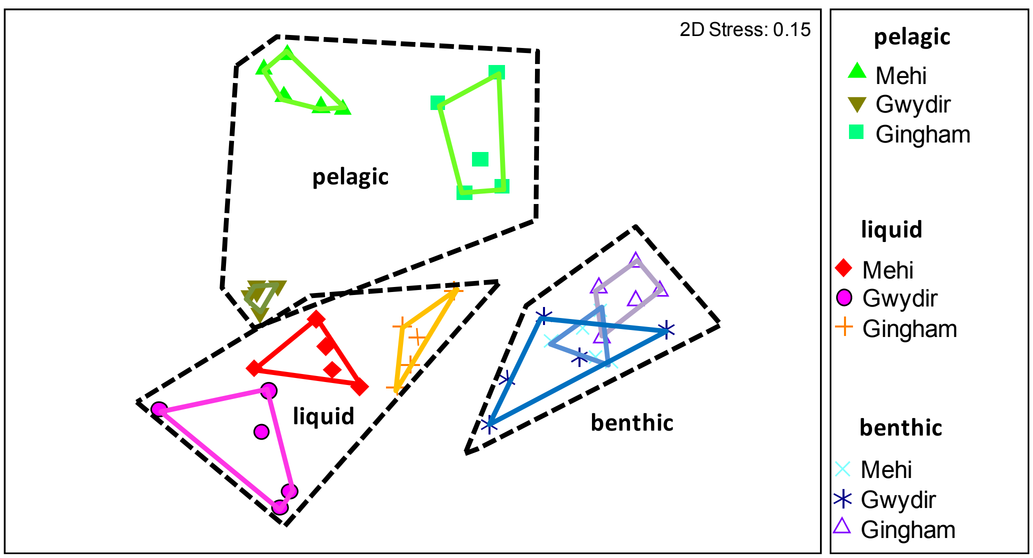

Fig. 7.23. Ordination of the invertebrate community of individual samples collected in October 2006 in one site from each of the three Lower Gwydir study watercourses.

watercourse from the first sampling trip (October 2006). The invertebrate communities of these sample fractions differed considerably (Fig.7.22), and variability between methods was higher than that between the three watercourses.

When the invertebrate abundance data were analysed through ordination, the similarity between individual samples became clearer (Fig. 7.23). Again, the highest degree of variability in invertebrate communities was between collecting methods. The pelagic community showed the highest spatial difference in invertebrate communities. In contrast, the general uniformity of the benthic samples might greatly improve the ability to measure the effect of flow events on invertebrate communities as there is less 'background noise' among these data.

As processing of invertebrates is a time intensive laboratory procedure, we processed three of the five replicate samples taken from each site. This decision was made due to the apparent similarity in species between replicate samples as demonstrated through multivariate analysis. Species richness and diversity analysis (data not presented here) revealed that benthic samples had a taxonomically richer invertebrate community than either of the pelagic samples, potentially yielding more information per unit effort. For that reason, we concentrated on processing these samples.

Temporal variation in macrocrustacean abundances. Freshwater shrimp and yabby abundances fluctuated in a complex pattern between sampling trips (Fig. 7.24). For example, the number of shrimp from the Mehi River in a single trip ranged between ca. 6000 shrimps in October 2006 to well below a 1000 shrimp a few months later in May. Unlike for fishes, there was no consistent seasonal trend in shrimp or yabby abundances. While there was a general increase in shrimp numbers in the Gingham Watercourse from October 2006 to May 2007 and an autumn peak, shrimp numbers in the Lower Gwydir and Mehi rivers were highest in spring. Additionally, shrimp and yabby numbers fluctuated widely in each of the watercourses, with sudden reductions in abundances and subsequent recovery to previous levels within a few months. As with fish, the complex temporal changes in crustacean numbers made it difficult to pinpoint possible beneficial effects of ECA releases (or any releases) on crustacean abundance. Shrimp numbers either increased (Gingham Watercourse, November 2007 release) or decreased (early season Gwydir and Mehi) following flow events. Yabby numbers fluctuated in a similar way and were not correlated with shrimp numbers.

Spatial variation in macrocrustacean abundances. Shrimp abundances were relatively similar between the three rivers, although there were around twice as many yabbies recorded in the Lower Gwydir River than in the Gingham Watercourse or Mehi River (Fig. 7.25). *Macrobrachium* abundances in the Gingham Watercourse and *Cherax* abundances in the Mehi River both varied in a significant longitudinal trend, although not in other channels.

Benthic microinvertebrates – community composition. We identified a total 74 benthic invertebrate taxa from the core samples (Table 7.6). Rotifers were by far the most speciose (45 morpho-species). The rest of the taxa mainly comprised microcrustaceans (12 taxa), and various insect larvae (4 taxa). The community was numerically dominated by a few taxa, both by abundance and their ubiquitous occurrence in samples, including nematodes, chironomids, copepods and other microcrustaceans. Some of the rotifer taxa were very common as well with a total abundance numbering more than a thousand individuals (3 taxa) and being present in 36-64% of all samples. However, most other rotifer taxa were less abundant and occurred only in a few samples. Sixty three percent of rotifer taxa appeared in less than ten samples (approximately 15% occurrence) and more than half the taxa appeared in five or less samples. On average, we found 16 taxa and around 2000 individuals per sample.

Benthic microinvertebrates – spatial and temporal variation in abundances. There appeared to be an increase in Gwydir River total invertebrate abundances from upstream

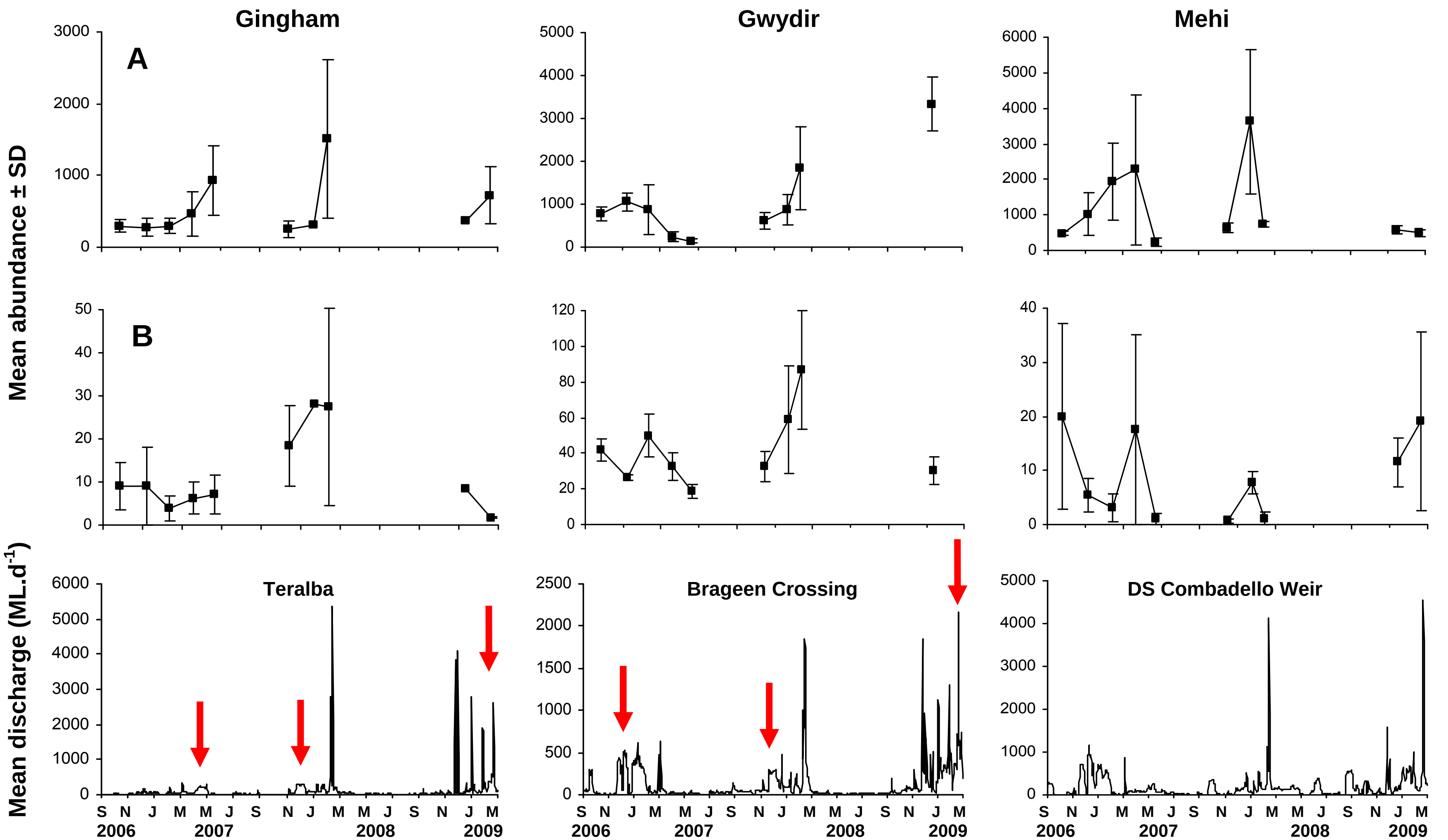

Fig. 7.24. Mean (A) freshwater shrimp (*Macrobrachium* sp.) and (B) yabby (*Cherax destructor*) abundance within the three study watercourses, October 2006 to February 2009. The discharge hydrograph is shown for each watercourse, with ECA releases indicated by red arrows.

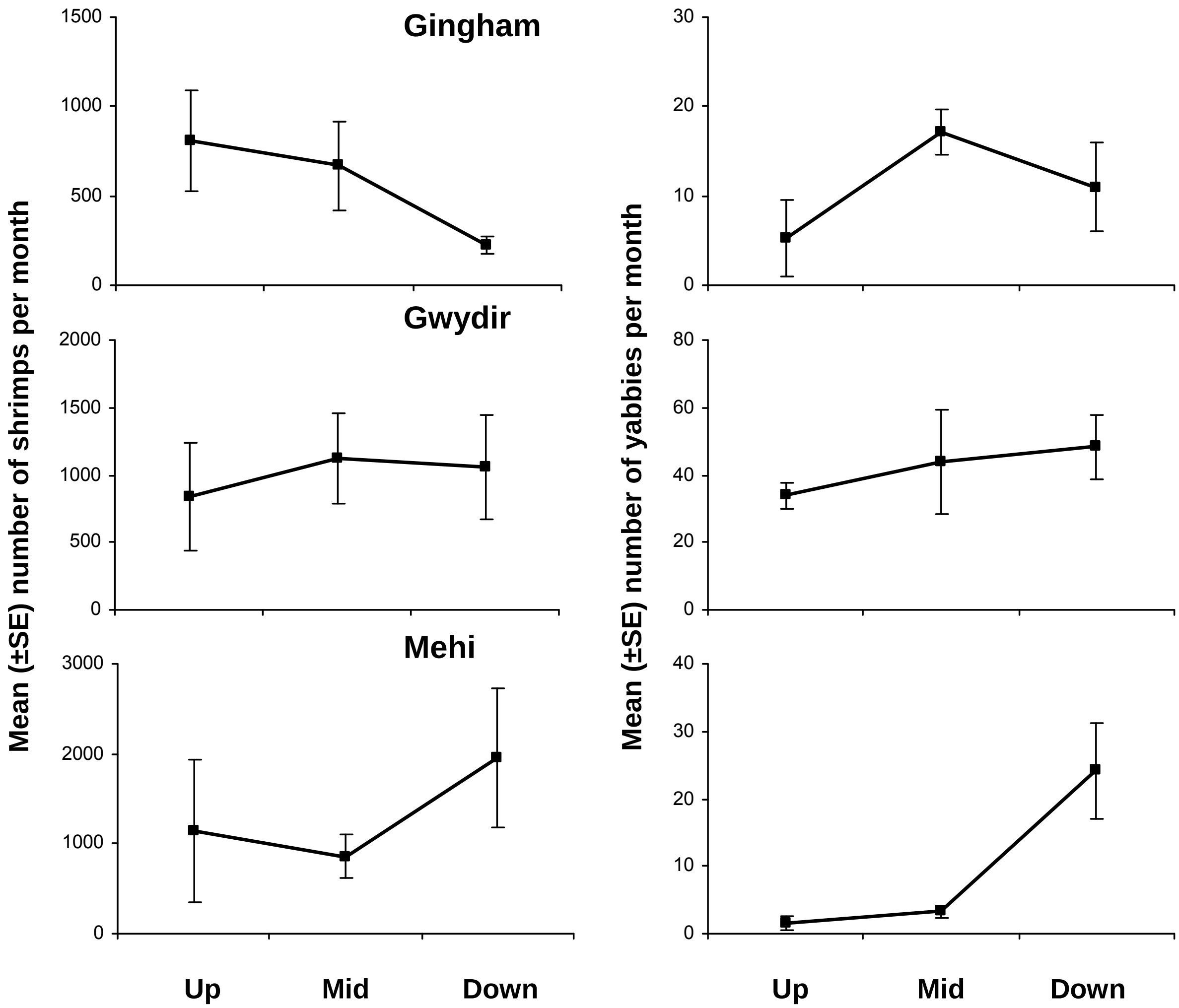

Figure 7.25. Spatial variability in freshwater shrimp (left, *Macrobrachium* sp.) and yabby (right, *Cherax destructor*) abundance within each of the three study watercourses, from the upstream to the downstream site, October 2006 to February 2009.

(Brageen Crossing) to downstream ("Birrah") (Fig. 7.26). The distribution of most of the more abundant invertebrate groups (nematodes, rotifers and micro crustaceans) also showed a similar pattern, with the exception of chironomids which did not differ between sites. In contrast, species richness did not vary significantly over the same gradient. Differences in substrate structure might explain these patterns. The substrate at Brageen Crossing is dominated by coarse sand and sedimentary rock, while "Allambie" has a mixture of sand and clay substrates and "Birrah" has a finer sand-silt mixture.

Temporal variation in microinvertebrate abundances was high. When averaged across the three Lower Gwydir River sites, abundances appeared unrelated to prior discharge conditions at the scale of our sampling (Fig. 7.27), with low abundances occurring in both periods of high and low discharge. However, when sites were examined separately, temporal fluctuations

Table 7.6. Benthic microinvertebrate community composition from benthic core samples. Rotifers (45 taxa) are not presented here as they were only sorted to morpho-species, so no detailed information is available on them. The data in the columns show total abundance of invertebrate taxa (most abundant taxa in bold), % occurrence of taxa on individual core samples, average ± SD abundance and minimum and maximum abundance of the taxa found in samples.

Taxonomic group		total abundance	% occurrence	mean abundance ± SD	min	max
Worms	nematodes	**85698**	99%	1158 ± 2221	3	16921
	oligochaets	1428	100%	19 ± 28	0	151
	Hirudina	11	8%	2 ± 1	1	4
Micro-crustaceans	nauplii	**6815**	63%	145 ± 212	3	822
	cyclopoids	**5479**	76%	96 ± 162	1	692
	calanoids	8	5%	2 ± 1	1	3
	harpactoids	171	21%	11 ± 8	1	25
	Daphnidae	33	7%	7 ± 5	1	12
	Ilyocryptidae	600	47%	17 ± 23	1	103
	Macrothricidae	**3307**	53%	83 ± 212	1	1275
	Chydoridae	**7348**	71%	139 ± 236	1	1273
	Moinidae	21	4%	7 ± 5	3	12
	Conchostraca	20	4%	7 ± 5	4	12
	Ostracod sp. 1	334	31%	15 ± 16	1	73
	Ostracod sp. 2	1998	68%	39 ± 46	1	197
Molluscs	Sphaeridae	86	16%	7 ± 12	1	43
Misc. Insecta	Ceratopogonidae	1159	77%	20 ± 34	1	172
	Trichoptera	16	11%	2 ± 1	1	4
	Simulidae	12	1%	12 ± 0	12	12
	Ephemeroptera	113	12%	13 ± 11	1	36
Chironomidae	Chironominae	**2608**	93%	37 ± 47	1	289
	Tanipodinae	1147	64%	24 ± 36	1	192
	Chironomidae pupae	10	11%	1 ± 0	1	2
Other	bryophytes	46	5%	12 ± 16	2	36
	sponges	155	21%	10 ± ± 14	1	52
	Hydra	134	16%	11 ± 11	1	33
	Collembola	92	1%	92 ± 0	92	92
	Tardigrada	2444	36%	91 ± 154	1	684
	mites	3	4%	1 ± 0	1	1
	total	**121296**				

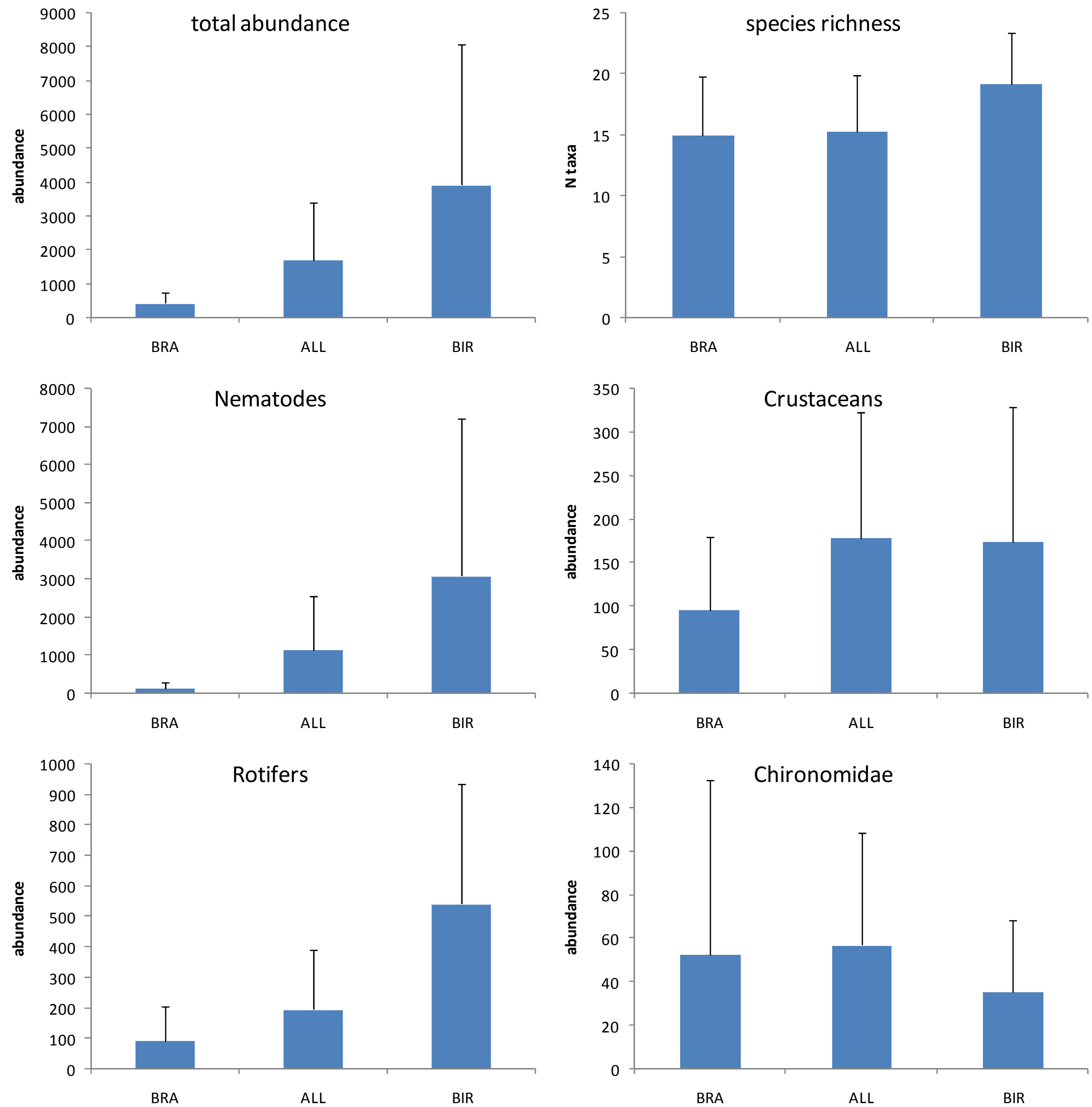

Fig. 7.26. Benthic microinvertebrate spatial variability in the Gwydir River, October 2006 to May 2007. The graphs show averages (+ SD) of total invertebrate abundance, taxa richness and abundances of the most common invertebrates.

varied between sites (Fig. 7.28). For example, Brageen Crossing showed virtually no changes in invertebrate abundance over time, while numbers fluctuated more widely downstream at “Birrah” where abundances were also higher. This pattern was mirrored by most of the dominant invertebrate groups, with chironomids the main exception. They were most variable at Brageen Crossing, with peak abundance towards autumn. Invertebrate taxa richness was variable in all Lower Gwydir River sites and highest in the summer months.

Ordinations of the benthic invertebrate community data showed that the overall community

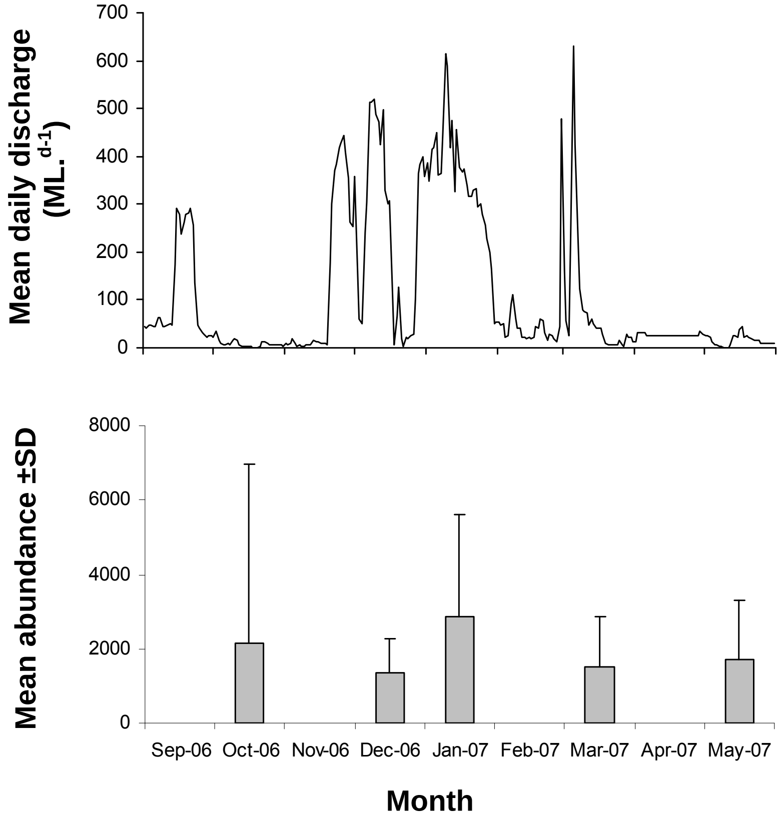

Figure 7.27. Temporal variation in microinvertebrate abundance and concomitant discharge variability within the Lower Gwydir River, September 2006 to May 2007. Invertebrate abundances were averaged over all samples analysed from each month.

composition was similar between the three waterways (Fig. 7.29). The Lower Gwydir River showed the widest spread between samples, although this may have been because samples from all seasons were processed for this river while only the spring samples were processed for the Gingham Watercourse and Mehi River.

At the smaller scale of the Gwydir River alone, there were only minor spatial differences in invertebrate communities between sites (Fig. 7.30), although there was a strong seasonal pattern. However, it seems unlikely, that flow events such as ECA releases were a major explanation of temporal variability at the temporal scale of our sampling (Fig. 7.31). All sites showed some kind of a seasonal cycle in their respective invertebrate communities, although, there was no consistent response to flow events.

7.4 Discussion

Overall water quality in Lower Gwydir floodplain waterways was poor. Measurements taken over the sample season show similar values to previous studies performed in the area with low water quality (Montgomery, 2002; Mawhinney, 2005). Furthermore, water quality further

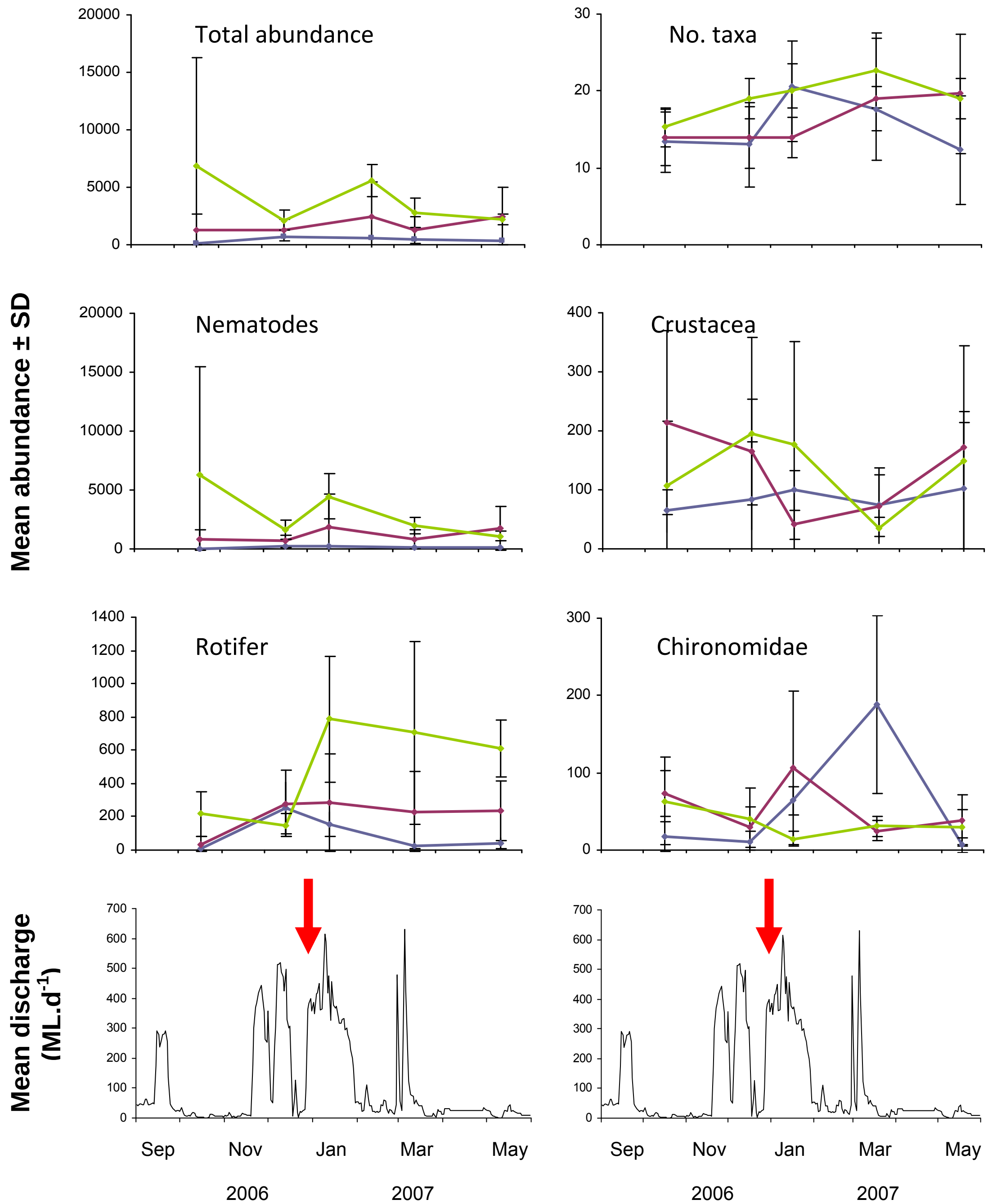

Fig. 7.28. Benthic microinvertebrate temporal variability for the three Gwydir River sites, October 2006 to May 2007. The upper six graphs show the change in mean abundance and number of taxa over the first field season. Red arrows indicate timing of an ECA release. Hydrographs in lower graphs show daily mean discharge at Brageen Crossing.

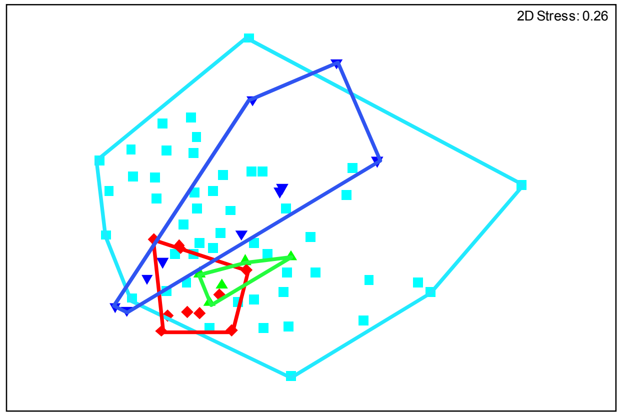

Fig. 7.29. Ordination (data fourth root transformed) of benthic microinvertebrate community data using all processed benthic samples from the three Lower Gwydir channels and the floodplain waterholes. There is strong overlap between the invertebrate communities of the four systems.

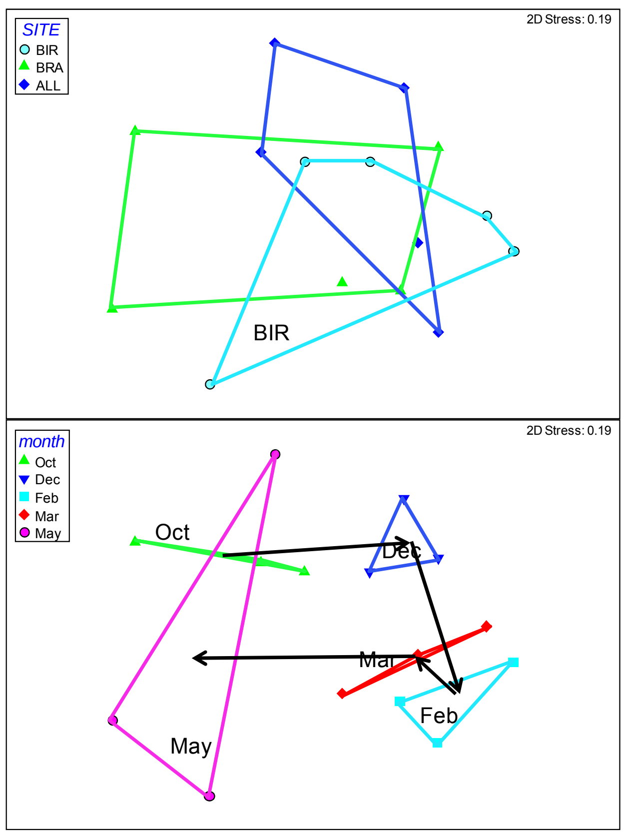

Fig. 7.30. Ordination of the Gwydir River benthic microinvertebrate community data. Each dot represent the invertebrate community in one site per month (averages over the three sub-samples). Different ways of colouring dots reveal spatial patterns (top graph) and temporal variability (bottom graph) of invertebrate communities collected in sites over the first season. Arrows in the lower figure indicate changes over the season.

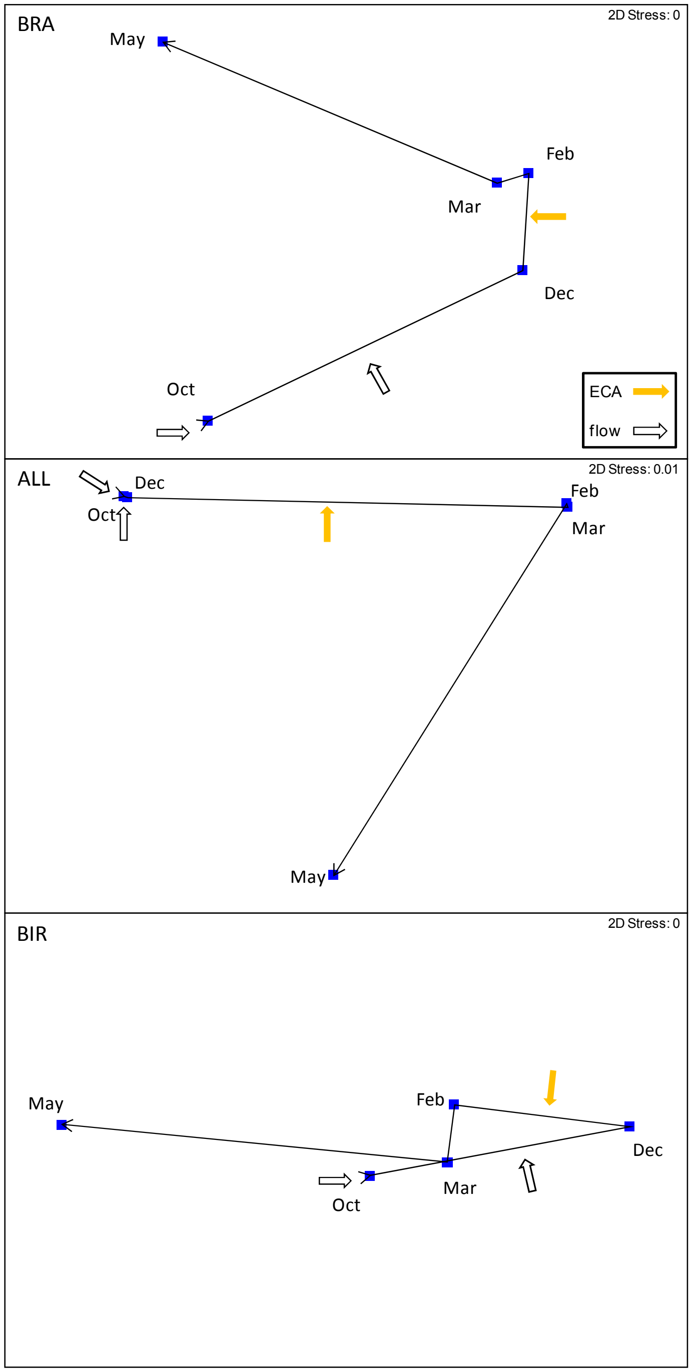

Fig. 7.31. Temporal variability in benthic microinvertebrate communities in the Gwydir River, October 2006 to May 2007. The trajectories indicate changes in invertebrate communities from beginning of the season (Oct) to the end (May). Orange arrows indicate the approximate timing of the ECA release, and white arrows show other flow events.

deteriorated longitudinally in all three water ways. Flow releases resulted in a temporary reduction in nutrient concentrations, turbidity and salinity, possibly due to a dilution effect.

However, due to the proportionally higher discharge, total nutrient, sediment and salt loads still appeared to increase during flow events. The high sediment load has the potential to alter habitat in the floodplain (e.g. filling pool habitat) and high nutrient concentration could lead to algal blooms in the future. The lower Murray-Darling has frequent blooms of blue green algae (Shiel, 1982) and the nutrient levels there are very similar to values found by us in Lower Gwydir watercourses.

The fish community sampled during this project was similar to that of previous surveys in the region. We found 12 fish taxa which is slightly higher than a recent estimate of nine species (Siebentritt, 1999). However, we did not catch silver perch, which were found in the system in previous studies, albeit in low numbers. The range of species detected in Lower Gwydir channels is typical for a lowland northern Murray-Darling catchment (Siebentritt, 1999; Lintermans, 2007). The fish communities were numerically dominated by a single native species in each of the study channels, with other species generally rare and infrequently encountered. Nevertheless, exotic fish species comprised around 25% of the total numerical catch. However, European carp was the dominant fish species in terms of biomass (~50%). The low abundance of some native fish species may indicate the patchy distribution of suitable habitat qualities in the study area, or that flow conditions have not been fully suitable to the maintenance or recruitment of their populations. Our use of a single sampling technique (fyke nets) may also have biased our samples away from several species, including Murray cod.

Rarer native species appeared restricted to areas with better habitat conditions, including riparian cover and in-stream structure. In general, there was a trend of less native fish species at downstream sites, and a parallel increase in the abundance of exotic fishes. This may have been partially due to the reduction in flows at downstream sites and a decrease in water quality. It is possible that the habitat and water quality conditions primarily favour the recruitment of generalist and exotic species in this area.

Overall, it appeared that the conditions for spawning or recruitment were more favourable for a range of species during the second season of sampling. Peaks in the abundance of bony bream, spangled perch and especially European carp were observed in the Lower Gwydir River and Gingham Watercourse, but not the Mehi River. The total discharge volume was higher in the Gingham in this season, but was more similar between seasons in the Lower Gwydir River. Nevertheless, it appeared that the wetter 2007 season included higher base-flows which might have benefited fish recruitment. In the Mehi, where there was a reduction in total and median discharge, recruitment was far lower than in the other waterways. This is further supported by the fact that there was good recruitment in carp gudgeon in the Mehi in the first season, when flows were high, but greatly reduced juvenile abundances in the second year when overall discharge was lower.

Peaks in the abundance of new recruits during the second season were apparent in all months, both before and after the ECA release: November (bony bream, Gingham), January (European carp, Gwydir and Gingham; spangled perch, Gingham) and February (spangled perch, Gingham). In the first season, it is possible that bony bream were spawned during the Gingham ECA release, although similarly-sized fish were also present in May in the Gwydir and Mehi (no ECA release). Similarly, small spangled perch in the Gingham Watercourse in May appeared to have originated from the April ECA release, although a parallel response was less clear in the Gwydir following the late 2006 release in this channel. Nevertheless, size at age relationships will need to be generated for these species in the Lower Gwydir channels before accurate links between the appearance of juveniles and particular flow events can be established. This should be a priority for further work on fish-flow relationships in this system.

The variable flow conditions within and among the study channels made it difficult to assess the impact of specific flow releases on fish communities. We observed an increase in the more abundant fish species (spangled perch, bony bream, carp gudgeon) in summer, coinciding with recent flow releases, although this pattern was not always consistent between watercourses. For example, spangled perch appeared to respond to the early 2007 ECA release in the Gingham Watercourse but not in the Lower Gwydir River. It was also difficult to separate possible seasonal effects from flow responses over a shorter study of this nature. Most of the other fish species were not in high enough abundance for us to detect any marked response at all, with European carp being the main exception.

At the smaller scale of individual sites, fish communities overlapped between the rivers. However, fish communities varied along a longitudinal gradient, possibly reflecting changes in the availability and quality of downstream. Therefore, fish communities were organized according to differences in habitat (or its local modification of flow signals) on this smaller scale. The generalist species that can survive in degraded habitats (bony bream, spangled perch and European carp) were most common in downstream habitats, while the rarer native species were more common upstream. This further supported the idea that habitat requirements are a major factor in shaping fish communities.

Contrary to fish, the benthic invertebrate community structure was similar between the three waterways. However, there was a gradient with increasing invertebrate abundance towards the downstream sites. Reasons for this possibly relate to parallel patterns in the sediment structure along the river. The uppermost site had coarser sediment than the silty-sandy sediment matrix downstream. There was a seasonal cycle visible, both in invertebrate community composition and abundance patterns although, at the temporal scale of our sampling, flow conditions seemed to have been of only of minor importance in shaping invertebrate communities in the Lower Gwydir River. This may have been partially explained by the absence of major flood events in this channel during the study interval, which are known to have a significant disturbance effect on riverine sediments and to flush individuals from the floodplain egg-bank into channels.

Crustacean abundance varied considerably between seasons and river systems. For example, *Macrobrachium* abundances varied from very high abundance to a near absence over just a few months. There was no consistent seasonal response in abundances of shrimps and yabbies in the three rivers. Similar to fish, the response of crustaceans to flow releases was hard to pinpoint because of the inherent variability in the hydrographs and the complex distribution of crustaceans over the seasons and rivers. Furthermore, we did not detect any general pattern in crustacean distribution along a longitudinal gradient, suggesting that crustaceans may be less limited by habitat quality than fishes, and that other factors may be affecting their distribution.