Fishes of the Nymboida, Mann and Orara Rivers of the Clarence River Drainage, New South Wales, Australia

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A six-month survey of fishes in the Nymboida, Mann and Orara Rivers in northeastern NSW was conducted from March–August, 1991. Forty collections at 12 sites yielded over 7000 specimens, representing 20 species and 15 families. Marjorie's hardyhead (*Craterocephalus marjoriae*) accounted for 41% of the total specimens. Other numerical dominants included Douboulay's rainbowfish (*Melanotaenia duboulayi*) 16%, firetailed gudgeon (*Hypseleotris galii*) 11%, western carp gudgeon (*H. klunzingeri*) 8%, Australian smelt (*Retropinna semoni*) and eastern mosquitofish (*Gambusia holbrooki*) with 6% each. Although not numerous in the sampling, the endangered eastern freshwater cod (*Maccullochella ikei*) was recorded from the Nymboida River and the Australian bass (*Macquaria novemaculeata*) from the three rivers sampled. Sampling also revealed the exotic species rainbow trout (*Oncorhynchus mykiss*) in the upper reaches of the Nymboida River and the goldfish (*Carassius auratus*) in the three rivers. The pattern of distribution includes longitudinal zonation in the upper reaches, where only five species were recorded; three of which were restricted to this region. This was followed by a rapid increase in species (11) beginning with the low gradient, less turbulent, middle section and then an addition of species (4) from the lower reaches of the system to the confluence with the Clarence River. Values for Jacard's (JI) and percent similarity (PSI) indices indicate the headwater fauna is highly dissimilar from the middle and lower reaches, while the three stations in the downstream section have similar faunas. The distribution pattern and results of the faunal similarity indices are corroborated by the results of detrended correspondence analysis (DCA).

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INTRODUCTION

Australia's freshwater fish fauna has been characterized as depauperate when compared to the richness of other continental assemblages (Allen 1989). The most recent compilations include only between 180–196 species of fishes living in Australian freshwater habitats (Merrick and Schmida 1984; Allen 1989), and the number of species completely restricted to freshwater is probably 20–25% less than the number usually reported (Allen 1989). However, the inventory of Australian freshwater fishes is far from completed. In the past several years populations of nominal species, such as Murray cod (*Maccullochella peeli*) (Rowland 1993), Macquarie perch (*Macquaria australasica*) (Dufty 1986), golden perch (*Macquaria ambigua*) (Musyl and Keenan 1992), blue-eyes (*Pseudomugil signifer*) (Ivantsoff et al. 1991), rainbowfish (*Melanotaenia fluviatilis*)

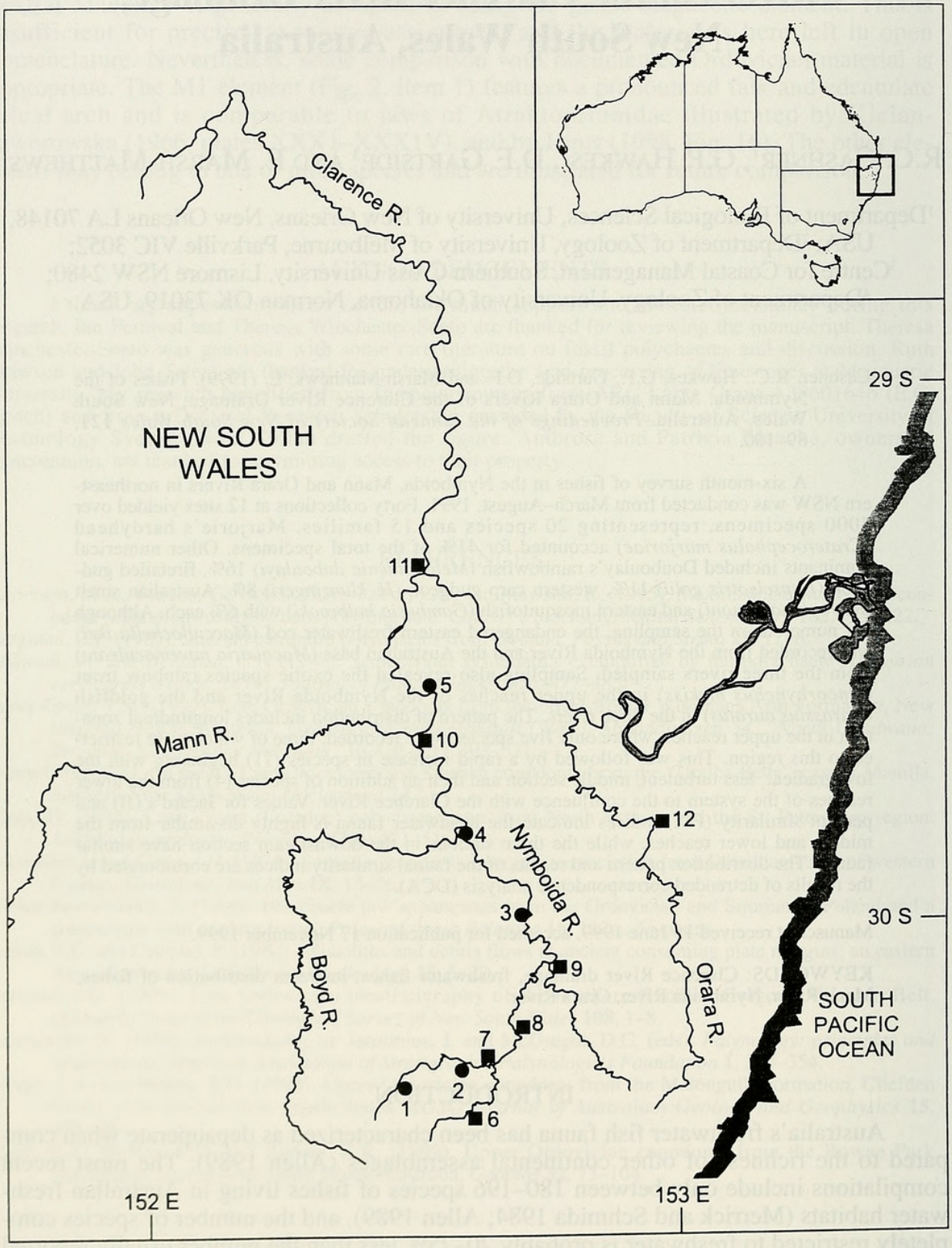

Figure 1. Map of Clarence River Drainage in northeastern NSW. Stations labeled 1–12 in the Nymboida, Mann and Orara Rivers were sampled during 1991. Closed circles, stations 1–5, were sites that were sampled monthly, March-August, 1991. Closed rectangles, stations 6–11, were sites that were sampled only once during the study and the closed rectangle on the Orara River, station 12, was sampled three times.

(Crowley et al. 1986), and freshwater catfish (*Tandanus tandanus*) (Musyl and Keenan 1996) have been identified as morphologically or genetically distinct and deserving of taxonomic recognition. It is also reasonable to expect the number of taxa of Australian freshwater fishes to increase as the faunas of individual rivers within major drainage divisions are better documented (e.g. Midgley et al. 1991). Stream surveys, as well as assessing genetic and morphological variation for wide ranging species, may reveal even more cryptic forms than listed above (Musyl and Keenan 1992). The Northern Rivers region in northeastern New South Wales (South-east Coast of Australian drainage division) includes four major basins, Tweed, Richmond, Clarence, and Bellinger rivers, that flow eastward into the South Pacific Ocean. Thus far 35 species of indigenous freshwater fishes have been reported from this area (Lake 1978; McDowall 1980; Merrick and Schmida 1984; Allen 1989), which gives it a greater overall species richness than 7 of the 12 commonly recognized drainage divisions in Australia (Lake 1978; Allen 1989). There is very little published material on the fishes of any of the individual rivers in the Northern Rivers region. Apparently the lower reaches or estuarine portions of these separate drainages have been well surveyed (D. Pollard, pers. comm.), but the fish communities in the upper, freshwater portions have only been studied sporadically (e.g., Llewellyn 1983; Bishop unpub. data). The objectives of this paper are to: a) document the fish species and their pattern of distribution over a six month period (March-August, 1991) in the Nymboida and Mann Rivers; b) prepare a preliminary list of fishes of the Orara River, another Clarence River tributary, based on three collections during 1991 and literature records; and c) compare community similarity and diversity among sites along the Nymboida and Mann Rivers and with one site in the Orara River.

MATERIALS AND METHODS

Description of Study Area

The Clarence River system, in northeastern NSW, is one of Australia's largest and most important coastal drainages with a catchment area of approximately 22,400 square kilometers (Bucher and Saenger 1989). The catchment is characterised by high average annual rainfall averaging around 1400 mm with a distinct seasonal peak during the summer months (December-April), and drier and cooler conditions during winter, resulting in highly variable river flows. Only about a quarter of the catchment has been cleared, mostly for agricultural use (Bucher and Saenger 1989).

The Nymboida and Mann Rivers constitute an important tributary of the Clarence. The Nymboida River originates on the Dorrigo Plateau near Hernani, NSW, and becomes a 3rd order stream within its first 5 km. The river flows in an easterly then northeasterly direction for approximately the next 100km. Major tributaries to the Nymboida in this stretch include Little Murray, Blicks and Little Nymboida Rivers. After the junction with the Little Nymboida, the Nymboida turns almost due north for 30 km and then northeastward along the remainder of its course. The Boyd River is the next major tributary before the Mann River joins the Nymboida. From its junction with the Mann on to its confluence with the Clarence River, the river is known as the Mann despite the fact that the Nymboida is the larger stream course. The Nymboida after its junction with the Mann is a 5th order river, has a drainage area of over 10,000 sq km, and flows over 200 km from its origin on the Dorrigo Plateau to the junction with the Clarence River (Fig. 1).

Collection Sites

Five stations (Fig. 1, 1–5), roughly coinciding with changes in stream order, were selected for monthly sampling of fishes in the Nymboida and Mann Rivers. Another six

sites (Fig. 1, 6–11) were sampled only once. One station on the Orara River (Fig. 1, 12) was sampled three times. All sites listed below were sampled between March-August, 1991, except the Nymboida River at the confluence of the Little Nymboida (Fig. 1, 9), which was sampled on 17 December 1991. A total of 40 collections was made during this survey. The collecting sites and localities were as follows:

NYMBOIDA AND MANN RIVERS

1. Nymboida River above the Dorrigo-Ebor road bridge and about 8 km east of the junction of the Dorrigo-Grafton road (Station 1).
2. Nymboida River at Riverview on the Dorrigo-Tyringham road, 7 km SW of Bostobrick (Station 2).
3. Nymboida River at the Nymboida Coaching Station (Station 3).
4. Nymboida River at its confluence with the Boyd River (Station 4).
5. Mann River near the bridge at Jackadgerry (Station 5).
6. Little Murray River on the Bostobrick-N. Dorrigo road, about 3 km northeast of N. Dorrigo.
7. Nymboida River on Moon Par road, 3 km northwest of the Dorrigo-Tyringham road.
8. Nymboida River at Platypus Flats
9. Nymboida River at its confluence with the Little Nymboida River (sampled on 17 Dec. 1991)
10. Mann River at New Zealand Falls
11. Clarence River 1 km above the mouth of Mann River

ORARA RIVER

12. Orara River at Coutt's Crossing, 17 km south of Grafton (sampled three times during the survey period).

Collection Methods

Specimens were collected during the day and at night by using 12 mm mesh seines, 75 mm and 112 mm mesh gill nets, eel lines, and traps. All types of collecting gear were employed during each sampling effort. Fish collections with seines and nets at each site were normally made for a period of 1.5 hrs. Traps and eel lines were set at dusk and checked every 4–6 hrs. All fishes collected were preserved in 10% formalin, returned to the University of New England-Northern Rivers (now Southern Cross University) for identification and then transferred to 50% isopropyl alcohol for permanent storage. Keys in Allen (1989) and Merrick and Schmida (1984) were used to identify specimens to species. Nomenclature in this paper follows Allen (1989).

All material collected was deposited in the Australian National Museum, Southern Cross University at Lismore, the University of New Orleans and Cornell University.

Physical-chemical Variables

Eleven physical and 19 chemical variables were measured at each of the permanent stations each time fish were collected. The methods used are given in Hawkes (1991) and are largely based on those of the American Public Health Association (1981) and Cole (1983). Ranges and means for 14 of the variables at stations 1–5 are presented in Table 1.

TABLE 1.

Ranges and means for 14 environmental variables recorded at stations 1–5 in the Nymboida and Mann Rivers; March–August 1991

Station	*1*		*2*		*3*		*4*		*5*	
Variable	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Temp. (C)	9.0–16.7	11.6	8.0–19.0	11.9	11.9–22.0	15.7	14.0–25.0	17.9	15.2–26.0	18.7
Cond. μS/cm	20.7–25.5	22.6	29.6–35.5	32.2	36.8–49.5	44.4	62.6–102.2	75.1	67.6–124.5	95.4
pH	6.3–7.5	6.8	6.3–7.4	7.0	5.7–7.2	6.6	6.7–9.8	7.5	7.0–8.8	7.6
DO (% Sat)	73.3–121.0	95.3	72.3–92.3	81.3	73.8–101.3	89.3	70.4–88.6	79.5	94.4–132.6	113.5
NO3 @pm)	0.1–0.3	0.2	0.0–0.7	0.2	0.0–0.3	0.1	0.0–0.1	0.1	0.0–0.2	0.1
PO4(ppm)	0.0–1.0	0.2	0.0–0.2	0.1	0.0–0.1	0.03	0.0–0.0	0.01	0.0–0.1	0.02
Chlor. a (@g/L)	0.0–20.5	9.3	0.04–3.3	15.3	1.0–28.1	10.1	0.0–0.5	0.2	0.1–0.4	0.1
Total Alk. (mg/L)	22.5–240.0	67.7	24.0–210.0	71.7	30.0–82.5	48.7	39.0–75.0	56.7	45.0–82.5	55.2
TDS (mg/L)	11.0–69.0	38.8	27.0–48.0	39.2	17.0–56.0	42.2	14.0–59.0	44.2	29.0–93.0	70.0
TSS (mg/L)	0.6–5.2	2.4	0.8–4.4	1.9	0.4–4.0	1.8	1.0–3.0	2.2	12–3.8	2.1
Current (m/sec)	0.1–0.2	0.2	0.1–0.3	0.2	0.3–0.6	0.4	0.0–0.1	0.1	0.1–0.12	0.2
Flow (ML/day)	25.9–69.1	55.3	103.7–570.2	343.9	1019.5–1840.3	1394.5	146.9–340.5	280.6	267.8–509.8	419.9
Depth(m)	0.3–0.5	0.4	0.8–1.1	1.0	1.4–2.1	1.6	0.6–0.9	0.7	0.3–0.5	0.4
Width (m)	8.6–12.2	10.3	16.3–17.8	17.2	21.6–28.0	25.3	67.0–86.0	76.9	84.0–105.0	90.0

Data analyses

Comparisons of fish assemblages based only on the 1991 survey data among stations along the Nymboida and Mann Rivers and between these stations and the one site on the Orara River were made qualitatively using Jaccard's Index (JI) (Ludwig and Reynolds 1988), and quantitatively by a percent similarity index (PSI) (Wolda 1981). Values for JI and PSI range from 0 (if no species are common to the two assemblages) to 1.00 (if all the species are identical between the two assemblages). Both indices have been used for fish community analysis and in studies of fish ecology (Lyons 1989; Cashner et al. 1994). Estimates of diversity were made using Shannon's Index (Ludwig and Reynolds 1988). Stations 1 and 2 and three other sites (6–8) were combined as a more inclusive headwaters region for comparison with downstream regions.

Principal components analysis (PCA) of species presence and 19 environmental variables was used to correlate changes in physico-chemical characters and fish assemblages at different stations along the Nymboida and Mann Rivers. Detrended correspondence analysis (DCA; Gauch 1982) was used to examine faunal similarity among stations based on abundance of species at each station. DCA is an indirect gradient analysis that simultaneously ordinates sites and species in multivariate space, with site placements reflecting the weighted average of species abundance at that site, and species placements representing the centroid of species distribution among all sites. The placement of sites along axes in multivariate space is biologically interpretable because DCA axes are scaled in standard deviations of species abundance curves (with 100 units representing one SD) such that sites separated by 100 units on an axis have, on average, a 50% similarity in composition. A difference of 400 units along an axis represents a complete faunal turnover on that axis (Gauch 1982). All DCAs were performed with PC-ORD Version 3.0 (McCune and Mefford 1997). For stations with multiple collections, all collections were pooled for this analysis.

RESULTS AND DISCUSSION

Prior to 1991, there had been scant published information on the fishes of the freshwater portions of the Clarence River, and the upper Clarence, Nymboida and Mann Rivers had not been intensively sampled. Even Llewellyn's (1983) comprehensive survey of the New South Wales freshwater fishes included only five localities (two of which overlapped with our sites) and recorded just six species from the Nymboida and Mann Rivers. In the study reported herein, over 7,000 specimens were collected during the 1991 survey of the Nymboida and Mann Rivers, which included 20 species, representing 15 families (Table 2). The numerically dominant species was Marjorie's hardyhead (*Craterocephalus marjoriae*), which accounted for 41% of all the specimens taken. Other species with relatively high abundance were Duboulay's rainbowfish (*Melanotaenia duboulayi*) 16%, firetailed gudgeon (*Hypseleotris galii*) 11%, western carp gudgeon (*H. klunzingeri*) 8%, Australian smelt (*Retropinna semoni*) and eastern mosquitofish (*Gambusia holbrooki*) 6% each. The other 14 species were relatively rare (<1%-2%), and one species, the shortfinned eel (*Anguilla australis*), was represented by only a single specimen. Four additional species have been documented from other sources (Llewellyn 1981; Harris unpub. data; Bishop unpub. data); the introduced brown trout (*Salmo trutta*), ornate rainbowfish (*Rhadinocentrus ornatus*), striped gudgeon (*Gobiomorphus australis*) and Cox's gudgeon (*G. coxii*), which brings the total to 24 species for Nymboida and Mann Rivers.

Thirteen species were represented from over 750 specimens taken during three collections at a single site in the Orara River (Table 2). Australian smelt (*Retropinna semoni*), empire gudgeon (*Hypseleotris compressa*), and eastern mosquitofish (*Gambusia holbrooki*) were the most abundant. Seven more species were added based on earlier collections (Llewellyn 1981; Harris unpub. data; Bishop unpub. data). These included the non-native goldfish (*Carassius auratus*), fork-tailed catfish (*Arius graeffei*), ornate rain-

TABLE 2.

List of fish species for the Nymboida, Mann and Orara rivers collected during March-August, 1991. Numbers are sample sizes for each species. Records for other species are based on field data sheets of John Harris 6:XII:90 (JH); and unpublished reports by Llewellyn 1983 (LL) and Bishop 1991 (KB). Mnemonics used in Figure 4 are given next to each species name.

NYMBOIDA AND MANN RIVERS		ORARA RIVER	
Anguilla australis (AAUS)		*Anguilla reinhardtii*	
Anguilla reinhardtii (AREI)	34	*Potamalosa richmondia*	3
Potamalosa richmondia (PRIC)	144	*Retropinna semoni*	235
Retropinna semoni (RSEM)	399	*Carassius auratus* JH	
Galaxias olidus (GOLI)	149	*Arius graeffei* LL	
Oncorhynchus mykiss (OMYK)	11	*Tandanus tandanus*	2
Salmo trutta LL,KB		*Gambusia holbrooki*	109
Carassius auratus (CAUR)	3	*Craterocephalus marjoriae*	86
Tandanus tandanus (TTAN)	191	*Melanotaenia duboulayi*	60
Gambusia holbrooki (GHOL)	536	*Rhadinocentris ornatus* LL	
Craterocephalus marjoriae (CMAR)	2887	*Pseudomugil signifer* LL	
Melanotaenia duboulayi (MDUB)	1121	*Macquaria novemaculeata* JH	
Rhadinocentris ornatus LL,KB		*Mugil cephalus* JH	
Ambassis agassizi (AAGA)	142	*Myxus petardi* JH	
Maccullochella ikei (MIKE)	6	*Notesthes robusta* (NROB)	2
Macquaria novemaculeata (MNOV)	29	*Gobiomorphus australis* (GAUS)	8
Bidyanus bidyanus (BBID)	1	*Gobiomorphus coxii* (GCOX)	2
Myxus petardi (MPET)	7	*Hypseleotris compressa* (HCOM)	234
Gobiomorphus australis LL,KB		*Hypseleotris galii*	6
Gobiomorphus coxii LL, KB		*Hypseleotris klunzingeri*	5
Hypseleotris galii (HGAL)	740		
Hypsleotris klunzingeri (HKLU)	578		
Philypnodon grandiceps (PGRA)	18		
Philypnodon sp. (PSP)	60		

TABLE 3.

Number of species (n) captured and Shannon diversity index (H) for each site in parentheses. Headwater sites (Stations 1, 2, 6–8) combined for comparison. Jacard's index of similarity followed by percent similarity index for fish assemblages at headwater sites and stations 3-4 in the Nymboida, station 5 in the Mann River and one locality on the Orara River, based on collections made in 1991.

	n	H				
Headwaters	5	0.943				
Nymboida 3	12	2.302	0.13, 0.07			
Nymboida 4	13	2.186	0.13, 0.04	0.77, 0.58		
Nymboida 5	13	2.820	0.13, 0.06	0.69, 0.57	0.79, 0.66	
Orara R.	13	2.279	0.13, 0.06	0.45, 0.41	0.53, 0.23	0.61, 0.32

bowfish (*Rhadinocentris ornatus*), Pacific blue-eye (*Pseudomugil signifer*), Australian bass (*Macquaria novemaculeata*) and two mullets, the sea mullet (*Mugil cephalus*) and the freshwater mullet (*Myxus petardi*), raising the total documented for the Orara to 20 species. The relative species richness for the Orara River is surprising considering the limited effort and the single site sampled.

The uppermost sites in the Nymboida River, stations 1 and 2 and 6–8 (Fig. 1), yielded only 1 shortfinned eel, 6 longfinned eels (*Anguilla reinhardii*), 149 marbled galaxias (*Galaxias olidus*), 11 specimens of rainbow trout and 10 eastern mosquitofish during the survey. Jacard's index of similarity (JI) and percent similarity index (PSI) were used to provide an estimate of community relatedness between adjacent sites in the Nymboida and Mann Rivers. Fish collection data for the two sites labeled as headwaters for the Nymboida River (sites 1–2) were pooled. Data for each of the three downstream stations (3–5) were treated separately, but data at each station were aggregated for the six month period. JIs ranged from 0.13–0.79 and PSI values were 0.04–0.66 (Table 3). These indices have been widely used to compare faunal similarities of different sites within and between streams. Values of 0.70 and higher for JI and $\geq$ 0.65 for PSI have been considered indicative of faunal similarity (Matthews et al. 1988; Cashner et al.1994). Both JI and PSI indicate that the uppermost or headwaters region is highly dissimilar from the middle and lower reaches and that stations 3–5 have similar faunas. In this region, the values for PSI are generally lower than the values for JI, but do not reach the level of $\leq$ 0.40, which is generally accepted as low or dissimilar (Matthews et al. 1988).

The comparison of the three lower stations on the Nymboida and Mann Rivers with the single site on the lower Orara River clearly indicates that reaches at similar positions of different Clarence River tributaries are not faunisitically identical (Table 3), because JI values ranged from 0.45–0.61 and PSI values were much lower at 0.22–0.41. The Shannon index of diversity was calculated for Nymboida River headwaters, stations 3–5, and the site on the Orara River. There was a sharp increase in species richness and diversity downstream between the headwater sites and station 3 on the Nymboida River, a pattern sometimes observed in North American streams, rather than a gradual downstream increase (Matthews 1997). The lower Orara River was similar in species number (though not composition) and diversity to the three lower Nymboida River sites (Table 3).

The pattern of longitudinal distribution of fishes within the Nymboida is one of apparent zonation in the upper reaches, where three species, *A. australis, O. mykiss,* and *G. olidus*, are restricted and only five species have been recorded (Fig. 2). The pattern does not persist, rather there is an abrupt increase in species (5 to 12), starting in the more placid waters of station 3. Thirteen species were recorded from stations 4 and 5, although not exactly the same ones. The restriction of *C. auratus, M. petardi* and *B. bidyanus* to the lower reaches probably does not reflect their true distribution in the Nymboida and Mann Rivers. All three likely extend upstream at least as far as station 3 which still has relatively placid waters. There may be replacement of upland forms in the middle and lower reaches, but basically, from station 3–5, there is an addition of deeper-bodied forms, benthic species and those preferring the conditions in the middle and lower reaches of lotic habitats.

Detrended correspondence analysis of stations, with the Orara River (station 12) included, confirmed the longitudinal pattern revealed from presence-absence of species. The DCA, which is based on abundance, produced a long gradient (>500 units) on the first axis, indicating a complete faunal turnover from upstream station 1 to downstream stations (3, 4, 5, 10, 11), with stations 2, 6, 8 intermediate (Fig.3). The gradient on Axis 1 reflects longitudinal distribution of species in the Nymboida and Mann Rivers, and the gradient on Axis 2 reflects not only the downstream position of station 12 within the Orara river, but also the presence of four species in the Orara not found in the Nymboida (Fig. 4). Orara station 12 was aligned with downstream stations of the Nymboida on DCA Axis 1, but was distinctive on DCA Axis 2.

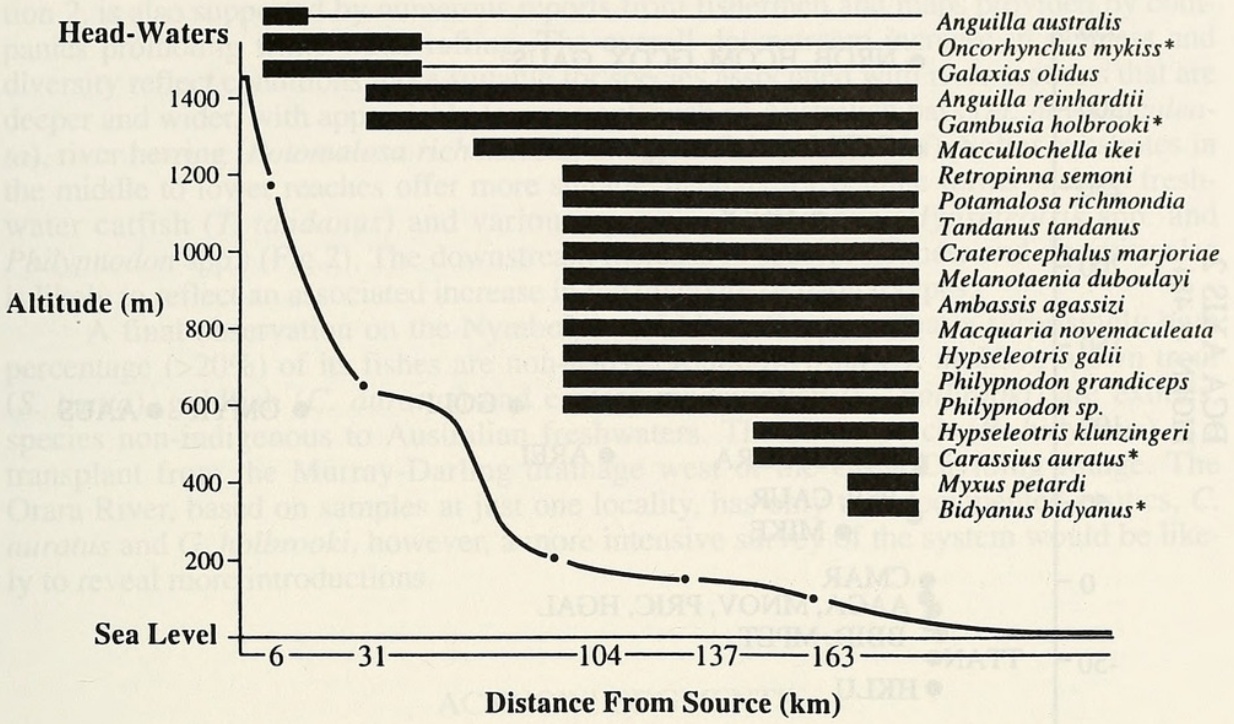

Figure 2. Longitudinal distribution of fishes collected in the Nymboida and Mann Rivers in 1991. Exotic species are marked with an asterix.

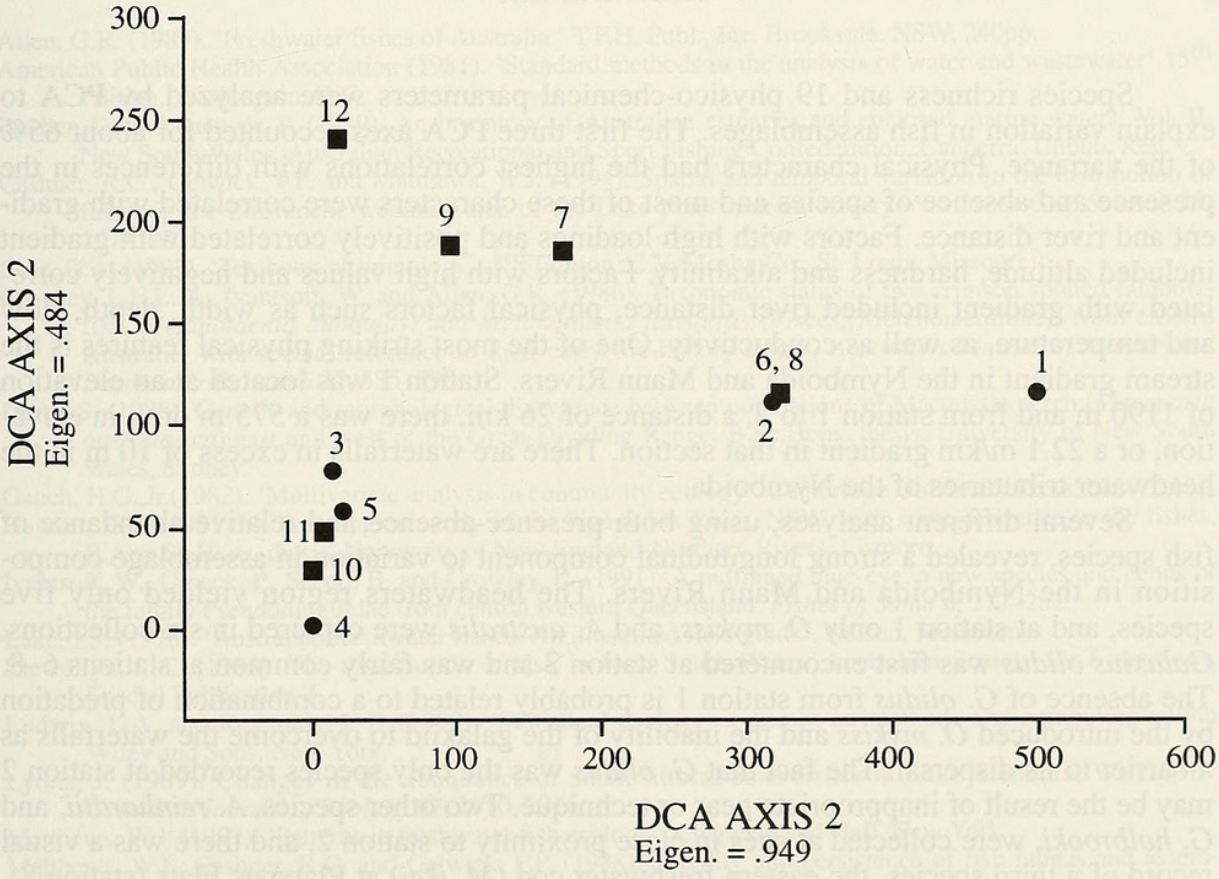

Figure 3. Station plot of Nymboida and Orara DCA. (Station identifications given in Fig. 1).

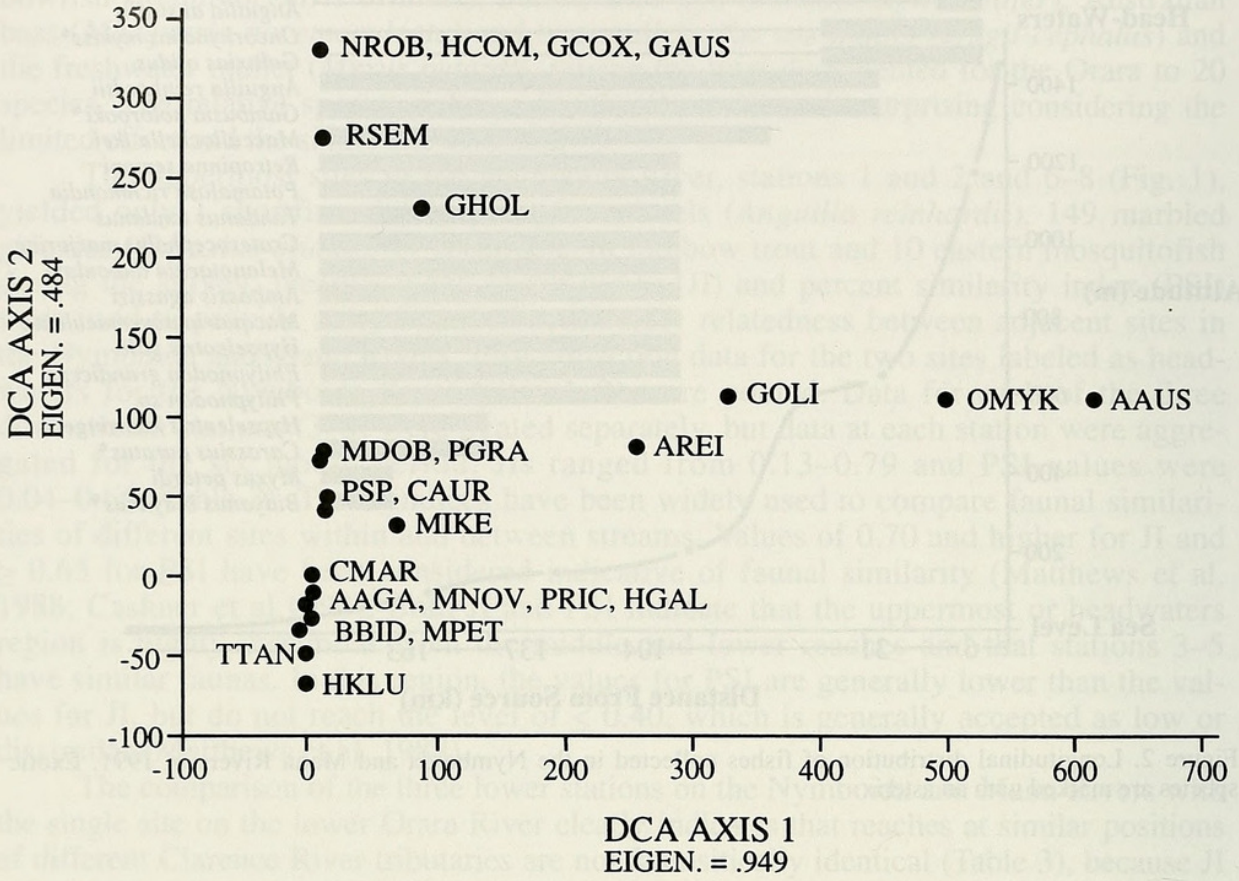

Figure 4. Species plot of Nymboida and Orara DCA. (Species mnemonics given in Table 2).

Species richness and 19 physico-chemical parameters were analyzed by PCA to explain variation in fish assemblages. The first three PCA axes accounted for about 65% of the variance. Physical characters had the highest correlations with differences in the presence and absence of species and most of these characters were correlated with gradient and river distance. Factors with high loadings and positively correlated with gradient included altitude, hardness and alkalinity. Factors with high values and negatively correlated with gradient included river distance, physical factors such as width, depth, flow and temperature, as well as conductivity. One of the most striking physical features is the stream gradient in the Nymboida and Mann Rivers. Station 1 was located at an elevation of 1190 m and from station 1 to 2, a distance of 26 km, there was a 575 m drop in elevation, or a 22.1 m/km gradient in that section. There are waterfalls in excess of 10 m in the headwater tributaries of the Nymboida.

Several different analyses, using both presence-absence and relative abundance of fish species, revealed a strong longitudinal component to variation in assemblage composition in the Nymboida and Mann Rivers. The headwaters region yielded only five species, and at station 1 only *O. mykiss,* and *A. australis* were captured in six collections. *Galaxius olidus* was first encountered at station 2 and was fairly common at stations 6–8. The absence of *G. olidus* from station 1 is probably related to a combination of predation by the introduced *O. mykiss* and the inability of the galaxiid to overcome the waterfalls as a barrier to its dispersal. The fact that *G. olidus* was the only species recorded at station 2 may be the result of inappropriate gear or technique. Two other species, *A. reinhardtii,* and *G. holbrooki*, were collected at sites in close proximity to station 2, and there was a visual record of a third species, the eastern freshwater cod (*M. ikei*) at Platypus Flats (station 8). The occurrence of *M. ikei* at least as far upstream at Platypus Flats, if not actually at sta-

tion 2, is also supported by numerous reports from fishermen and maps provided by companies promoting white-water rafting. The overall downstream increase in richness and diversity reflect conditions more suitable for species associated with river sections that are deeper and wider, with appreciably less current, such as Australian bass (*M. novemaculeata*), river herring (*Potomalosa richmondia*) and glassfish (*A. agassizi*). Softer substrates in the middle to lower reaches offer more suitable habitats for benthic forms such as freshwater catfish (*T. tandanus*) and various species of gudgeons (*Hypseleotris* spp. and *Philypnodon* spp.) (Fig.2). The downstream increase in species richness and diversity also is likely to reflect an associated increase in the diversity of habitat types.

A final observation on the Nymboida and Mann Rivers is that a surprisingly high percentage (>20%) of its fishes are non-native. Rainbow trout (*O. mykiss*), brown trout (*S. trutta*), goldfish (*C. auratus*) and eastern mosquiofish (*G. holbrooki*) are exotics, species non-indigenous to Australian freshwaters. The silver perch (*B. bidyanus*) is a transplant from the Murray-Darling drainage west of the Great Dividing Range. The Orara River, based on samples at just one locality, has only two documented exotics, *C. auratus* and *G. holbrooki*, however, a more intensive survey of the system would be likely to reveal more introductions.

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REFERENCES

Allen, G.R. (1989). 'Freshwater fishes of Australia.' T.F.H. Publ., Inc. Brookvale, NSW, 240pp.

American Public Health Association (1981). 'Standard methods in the analysis of water and wastewater' 15th Edition, Washington, D.C.

Bucher, D. and Saenger, P. (1989). An inventory of Australian estuaries and enclosed marine waters. Vol. II. New South Wales. Australian Recreational and Sport Fishing Confederation, Canberra. Unpub. Rep.

Cashner, R.C., Gelwick, F.P. and Matthews, W.J. (1994). Spatial and temporal variation in the distribution of fishes in the LaBranche wetlands area of the Lake Pontchartrain estuary. *Northeast Gulf Science* **13**, 107–120.

Cole, G.A. (1983). 'Textbook of limnology', 3rd Edition, C.V. Mosby Co., St. Louis, Missouri.

Crowley, L.E.L.M., Ivantsoff, W. and Allen, G.R. (1986). Taxonomic status of two crimson spotted rainbowfish, *Melanotaenia duboulayi* and *Melanotaenia fluviatilis* (Pisces: Melanotaeniidae), from eastern Australia, with special reference to their early life-history stages. *Australian Journal of Marine and Freshwater Research* **37**, 385–398.

Dufty, S. (1986). Genetic and morphological divergence between populations of Macquarie perch (*Macquaria australasica*) east and west of the Great Dividing Range. B.Sc.Hons. thesis, University of New South Wales, Sydney.

Gauch, H.G.,Jr.(1982). 'Multivariate analysis in community ecology'. Cambridge University Press, New York.

Hawkes, G.P. (1991). A limnological study of the Nymboida River, NSW, with some reference to the fishes. B.App.Sc.Hons. thesis, University of New England-Northern Rivers, Lismore.

Ivantsoff, W., Umack, P., Saedd, B. and Crowley, L. (1991). A redfinned blue-eye, a new species and genus of the family Pseudomugilidae from central western Queensland. *Fishes of Sahul* **6**, 277–282.

Lake, J.S. (1978). 'Australian freshwater fishes. An illustrated field guide'. Nelson, Melbourne.

Llewellyn, L.C. (1983). The distribution of fish in New South Wales. Australian Society for Limnology, Special Publication 7.

Ludwig, L.A. and Reynolds, J. F. (1988). 'Statistical ecology: a primer on methods and computing'. John Wiley and Sons, New York.

Lyons, J. (1989). Changes in the abundance of small littoral-zone fishes in Lake Mendota, Wisconsin. *Canadian Journal of Zoology* **67**, 2910–2916.

Matthews, W.J. (1997). 'Patterns in freshwater fish ecology'. Chapman and Hall, New York.

Matthews, W.J., Cashner, R.C. and Gelwick, F.P. (1988). Stability and persistence of fish faunas and assemblages in three midwestern streams. *Copeia* **1988**, 945–955.

McCune, B. and M.J. Mefford. (1997). 'PC-ORD. Multivariate Analysis of Ecological Data, Version 3.0'. (MJM Software Design, Glenenden Beach, Oregon, USA).

McDowall, R.M., ed. (1980). 'Freshwater fishes of south-eastern Australia' Reed, Sydney.

Merrick, J.R. and Schmida, G.E. (1984). 'Australian freshwater fishes. Biology and Management'. J.R. Merrick, Sydney.

Midgley, S.H., Midgley, M., and Rowland, S.J. (1991). Fishes of the Bulloo-Buncannia drainage division. *Memoirs of the Queensland Museum* **30**, 505–508.

Musyl, M.A. and Kennan, C.P. (1992). Population genetics and zoogeography of Australian freshwater golden perch, *Macquaria ambigua* (Richardson 1845) (Teleostei: Percichthyidae), and electrophoretic identification of a new species from the Lake Eyre Basin. *Australian Journal* of *Marine and Freshwater Research* **43**, 1585–1601.

Musyl, M.A. and Kennan, C.P. (1996). Evidence for cryptic speciation in Australian freshwater eel-tailed catfish, *Tandanus tandanus* (Teleostei: Plotosidae). *Copeia* **1996**, 526–534.

Rowland, S.J. (1993). *Maccullochella ikei*, an endangered species of freshwater cod (Pisces: Percichthyidae) from the Clarence River system, New South Wales and *M. peeli mariensis*, a new subspecies from the Mary River system, Queensland. *Records of the Australian Museum* **45**, 121–145.

Wolda, H. (1981). Similarity indices, sample size and diversity. *Oecologia (Ber.)* **50**, 296–302.