# 3 Estimation of total abundance of fish populations: the calibration experiments

D. D. Reid and J. H. Harris

*Cooperative Research Centre for Freshwater Ecology, NSW Fisheries Research Institute, PO Box 21 Cronulla, New South Wales 2230*

***Summary***

In order to derive a measure of the proportion of the total population captured in routine NSW Rivers Survey samples, depletion experiments were carried out at seven of the 80 sites covered by the Survey. Estimates of absolute abundance were made for 10 species, with carp and bony herring the only species for which estimation of total abundance was possible for more than one site. It is concluded that in the cases of bony herring and carp, an order of magnitude estimate of absolute abundance is possible from routine surveys. For the other species, it would be necessary to obtain information from further depletion experiments before such estimates of absolute abundance could be made.

## *INTRODUCTION*

Catch-effort methods have been used in a relatively small number of studies to estimate total abundances of riverine fish (e.g. Johnson 1965, Mann 1971, Mahon *et. al*. 1979, Mahon 1980). In the present study depletion experiments were carried out at seven of the 80 sites covered by the NSW Rivers Survey. The objective was to estimate absolute abundance by species at a site, and hence enable the estimation of the proportion of the total population captured in routine Rivers Survey samples. No population estimates have been published for Australian native freshwater fish other than Australian bass (Harris 1988).

## METHODS

Sites represented both inland and coastal geographic regions, and lowland, slopes and montane river types, and were selected on the MacDonald, Darling, Little, Bogan, Gloucester, Coxs, and Clyde rivers (site numbers DM2, DUL8, DS14, DUL17, NCUL55, SCM64, SCUL76 respectively). Detailed descriptions of these sites are given in Chapter 2.

Fine-mesh stop-nets were placed at the upper and lower limits of the site (typically 200-500m apart). The first day's sampling involved the completion of the normal survey-sampling procedure (Chapter 1). Fish captured by electrofishing on day 1 were marked by clipping the left pectoral fin and were returned to the stop-netted section of river, so that fish captured in subsequent passive fishing operations on day 1 could be identified, and thus treated as equivalent to removals in the abundance estimation. Fish captured in the passive fishing operations on day 1 or in any of the operations on subsequent days, were returned to the water outside the closed-off section of the river.

Sampling continued for four days at all sites except the Gloucester and Clyde Rivers, which were sampled for five days. From day 2 onwards, the sampling intensity was either the same as for day 1 (Bogan, Little, Darling, Coxs and MacDonald rivers), or was twice the day 1 level (Gloucester and Clyde rivers). The higher sampling effort for the latter sites was required because of the larger scales of these sites. Details of the number of operations for each type of sampling gear, number of days fished and estimates of total effort by gear type are shown in Harris *et al.* (1996, see Tables 4.8.1 to 4.8.5). For the sites with constant sampling effort over the experiment, the depletion estimates were based on the data for all days sampled, while for the Gloucester and Clyde rivers, depletion estimates were based on data from day 2 to day 5.

Estimates of area sampled were obtained by measuring the length of the closed section of stream and the width at 10 approximately equally spaced points.

Seber (1986) recommended the generalised removal estimator of Otis *et al.* (1978) and the generalised jackknife estimator of Pollock and Otto (1983) as the best estimators of population size N. Both of these models allow for heterogeneity of capture probability between samples. The jackknife estimator generally gives more precise estimates than the generalised removal estimator when there are less than 10 samples (Pollock and Otto 1983). The July 1991 version of the program CAPTURE (Otis *et al.* 1978) was used to compute estimates of N based on the jackknife estimator.

For the Bogan River, the number of small carp and bony herring captured in the electrofishing operation was limited by the efficiency of scoop-netting, hence it was necessary to split the data for carp and bony herring into two size classes (≤100, >100mm). For the small carp

there was no fishdown effect, so the depletion method could not be used for abundance estimation. In this case the marking and release of all fish in the day 1 electrofishing operation, and the checking for marks in all subsequent samples, provided data for an estimate of abundance using the Chapman-Petersen estimator (Seber 1982). This estimator N* and an approximately unbiased estimate of the variance (v*) are given by :

$$N^* = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1, \qquad \text{....(1)}$$

$$v^* = \frac{(n_1 + 1)(n_2 + 1)(n_1 - m_2)(n_2 - m_2)}{(m_2 + 1)^2 (m_2 + 2)} \qquad \text{....(2)}$$

where $n_1$ is the number of fish originally marked and released, $n_2$ is the number of fish (marked and unmarked) in the second sample and $m_2$ is the number of marked fish in the second sample. In this case the second sample comprised the successive samples after day 1.

Use of a mark-recapture estimator was not possible for bony herring because this species suffers a high mortality on handling. For carp and bony herring larger than 100mm, N was estimated using the jackknife estimator for the removal method (Pollock and Otto 1983).

## *RESULTS*

Data were adequate for estimating absolute abundances for ten species, viz. carp, bony herring, Australian bass, Australian grayling, spangled perch, brown trout, golden perch, freshwater herring, striped mullet and long-finned eel. In the case of Murray cod, 30 fish were caught at site DUL14 (Little River), but no population estimate was possible, as there were a number of recaptures of marked fish (which had been returned to the water outside the stop-nets) within the closed-off area. The fish had apparently re-entered the area by burrowing under the leadline of the stop-nets.

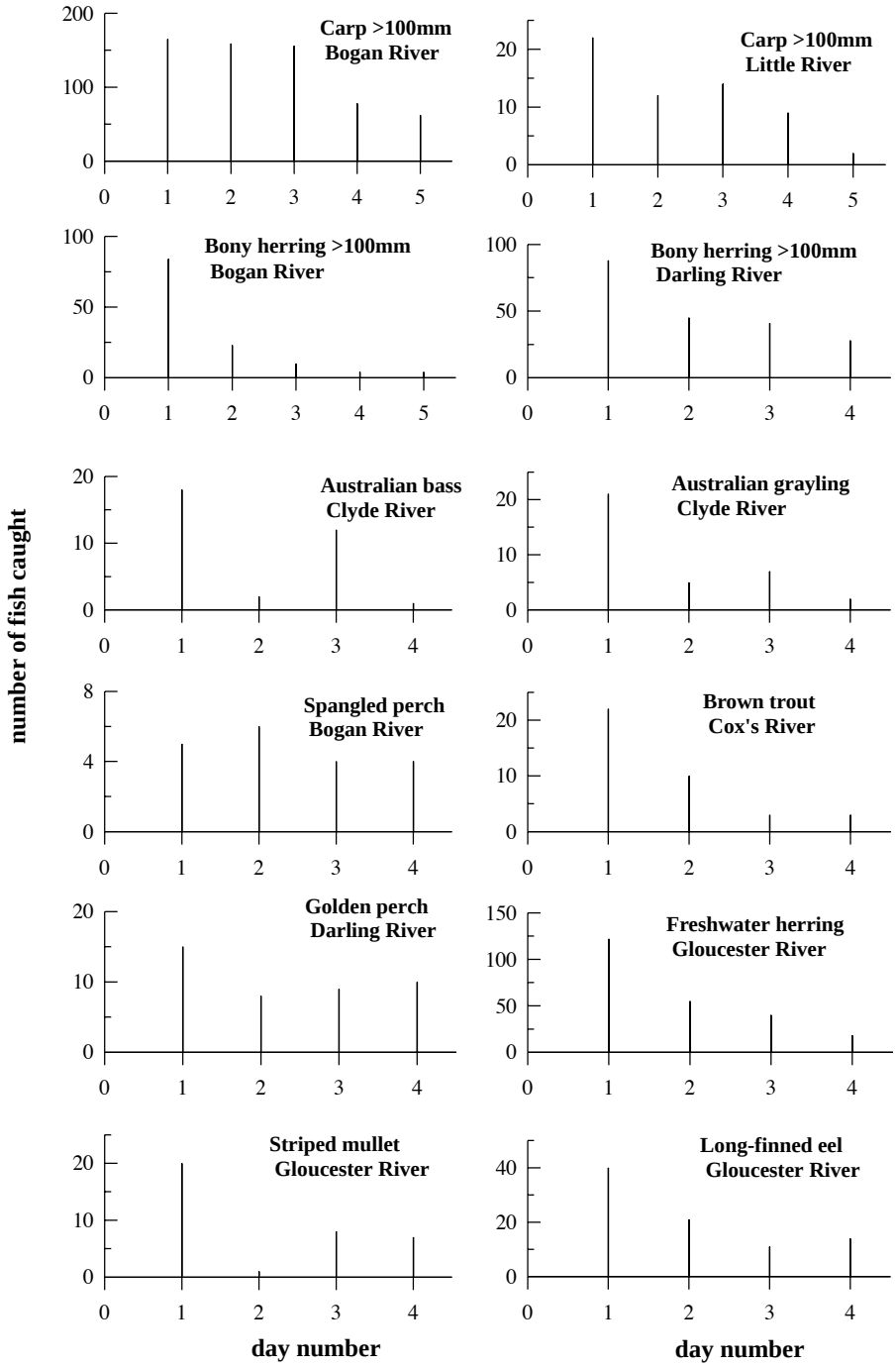


Figure 3.1 Catches on successive days of the successful depletion experiments.

Table 3.1 shows the estimates of N (and an approximate 95% confidence interval), the number of fish captured in the day 1 sample, the ratio of the population estimate ( $\hat{N}$ ) to the day 1 sample ($n_1$) and the estimate of density (number per Ha) for each of the site/species combinations for which estimation of the population size was possible.

Table 3.1 Estimates of abundances for ten species from depletion experiments

| Species | River | area Ha | Population estimate $\hat{N}$ (95% CI) | No. in day 1 sample ($n_1$) | $\hat{N}$ (95% CI) /$n_1$ | density (No./Ha) |
|---|---|---|---|---|---|---|
| Carp(≤100mm) | Bogan | 0.24 | 1848 (1181-2515)* | 140 | 13.20(8.4-18.0) | 7 700 |
| Carp(>100mm) | Bogan | 0.24 | 868 (808-947) | 165 | 5.26(4.9-5.7) | 3 616 |
| Carp(>100mm) | Little | 1.67 | 67 (61-90) | 22 | 3.05(2.8-4.1) | 40 |
| Bony herring (>100mm) | Bogan | 0.24 | 141 (130-169) | 84 | 1.68(1.5-2.0) | 584 |
| Bony herring (>100mm) | Darling | 1.93 | 286 (257-330) | 88 | 3.25(2.9-3.8) | 148 |
| Australian bass | Clyde | 1.00 | 45 (42-60) | 9 | 5.00(4.7-6.7) | 45 |
| Australian grayling | Clyde | 1.00 | 44 (39-62) | 3 | 14.67(13.0-20.7) | 44 |
| Spangled perch | Bogan | 0.24 | 21 (19-37) | 5 | 4.20(3.8-7.4) | 86 |
| Brown trout | Coxs | 0.43 | 47 (40-67) | 22 | 2.14(1.8-3.0) | 111 |
| Golden perch | Darling | 1.93 | 72 (56-102) | 15 | 4.80(3.7-6.8) | 37 |
| Freshwater herring | Gloucester | 3.90 | 309 (286-346) | 20 | 15.45(14.3-17.3) | 79 |
| Striped mullet | Gloucester | 3.90 | 61 (49-87) | 4 | 15.25(12.3-21.8) | 16 |
| Long-finned eel | Gloucester | 3.90 | 128 (114-166) | 5 | 25.60(22.8-33.2) | 33 |

* Note: This population estimate was obtained by Chapman-Petersen estimator ($N^*$).

## *DISCUSSION*

Abundance estimates are only available for six of the sites - in the MacDonald River goldfish and river blackfish were caught, but the fishdown effect was not sufficient to give reliable population estimates. For each of the other sites it was possible to provide a population estimate for at least one species. The ratio $\hat{N}/n_1$ may be considered as the factor by which the number from the normal sampling procedure (day 1 sample) must be multiplied to obtain the population estimate. This ratio varied between 1.68 and 25.60 over all site/species combinations, however only the estimates for bony herring and carp could be used for same-species comparisons across sites. Variation in the ratio between rivers was still substantial: for carp in the larger size class, the ratio was 5.26 for the Bogan River and 3.05 for the Little River. For bony herring, the ratios were 1.68 for the Bogan River and 3.25 for the Darling River. The largest values of $\hat{N}/n_1$ occurred for longfinned eel (25.6), reflecting either low catchability because of their escapement from fishing operations and/or re-entry of eels into the closed area by circumventing the stop-nets. Large

values of the ratio were also found for the strongly schooling species, being approximately 15 for grayling in the Clyde River and for freshwater herring and striped mullet in the Gloucester River.

The approximate 95% confidence intervals on the abundance estimates from the depletion experiments cover a range from 16% to 86% of the corresponding abundance estimate. Relatively tight confidence intervals apply to carp (>100mm) in the Bogan River (16% of $\hat{N}$), freshwater herring (19%) and bony herring (25% and 28% ). Relatively wide confidence intervals apply to the abundance estimates of spangled perch (86%), carp (≤100mm) in the Bogan River (72%), golden perch (64%) and striped mullet (63%). The estimate for carp ≤100mm in the Bogan River is based on the mark-recapture estimate, and in this case 566 fish were caught from an estimated population of 1848, ie 31% of the population. The size of the confidence interval is slightly less than that predicted for the depletion estimator of a population of this size, given in the table by Zippin (Seber 1982, p.313).

Mahon (1980) tested the accuracy of catch-effort methods by comparing catch-effort estimates from electrofishing at 11 localities with actual numbers of fish present, obtained by the use of rotenone after the fishings were completed. In this study, conducted in streams in Ontario and Poland, the time between successive fishings was generally only 25 to 30 min. Underestimation of population size by the removal method was estimated as 21.6% (average for the Leslie Method) by Mahon (1980) and 11 to 22% by Bohlin and Sundström (1977). Mahon noted that the electrofishing may have driven fishes into hiding, and that a longer interval between fishing episodes may have been necessary. In the present study, an interval of 24h between successive electrofishings was allowed, to lessen the carry over effect between successive electrofishing episodes.

The confidence intervals on population estimates for the present study cover a similar range (as a proportion of population estimate) to the 168 species/site cases in Mahon (1980).

Given the variability in the ratio $\hat{N}/n_1$ between species and for the same species between sites, the results of the depletion experiments highlight the intensive sampling which is required to obtain useable estimates of riverine fish populations. Although seven sites were each intensively fished for 4 or 5 days, same-species comparisons across sites were only possible for two cases (carp >100mm and bony herring >100mm). The larger ratio occurred for the lower-density case for bony herring and for the higher density case for carp. For the other species only a single estimate is available, hence we have no information about the spatio-temporal variability of the ratio.

The implication of these results is that in the cases of bony herring and carp, an order of magnitude estimate of absolute abundance is possible from routine surveys. For the other species, it would be necessary to obtain information from further depletion experiments before such estimates of absolute abundance could be made.

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# 4 Distribution and abundance of native fish in New South Wales rivers

C. B. Schiller[A], A.M. Bruce[A] and P. C. Gehrke[B]

[A] *Cooperative Research Centre for Freshwater Ecology, Narrandera Fisheries Centre, NSW Fisheries, PO Box 182 Narrandera, NSW 2700*

[B] *Cooperative Research Centre for Freshwater Ecology, NSW Fisheries Research Institute, P.O. Box 21, Cronulla, NSW 2230*

***Summary***

A total of 22,580 native freshwater fish representing 39 species, 25 genera and 19 families was recorded during sampling that was intensive (five gear-types) and repeated (four surveys) over two years at 80 stratified sites in the NSW Rivers Survey. Only 985 native fish were caught in the Murray ecological region, a mere 4.4% of the total catch. Fourteen species were found in each of the Murray and Darling regions, however the average number of native species per site was 2.6 in the Murray region compared to 4.6 at Darling sites. A total of 23 species was recorded from the North Coast region and 22 from the South Coast.

There was marked seasonal variation in total catch among river type groups for all regions, with more individuals captured during summer than winter. Seasonal variation in total catch was most pronounced in the Darling region and least evident for North Coast sites. Compared to total catch, seasonal variation in the number of species recorded in each region was much lower, and the regional was pattern reversed, with North Coast sites exhibiting the greatest variation and Darling sites the least. No Murray cod, *Maccullochella peelii*, or freshwater catfish, *Tandanus tandanus,* were caught in the entire Murray region, although more than 50 of each species were found at Darling sites. Only seven silver perch, *Bidyanus bidyanus,* were recorded from the Darling region, while two individuals of this species, which were probably the result of hatchery stockings, were recorded from the Murray region.

Other species reported to be widespread and relatively common across much of their range were either absent from one region, or restricted in distribution or abundance. These include olive perchlet, *Ambassis agassizii*, common jollytail, *Galaxias maculatus*, crimson-spotted rainbowfish, *Melanotaenia fluviatilis*, short-finned eels, *Anguilla australis* and flyspecked hardyhead, *Craterocephalus stercusmuscarum*. A total of 16 (29%) of the 55 native species predicted to occur in New South Wales rivers were not found at all, whereas nine of these (including at least four endangered and two vulnerable species) were previously recorded in a 1983 survey. Several species (including spangled perch, *Leiopotherapon unicolor* and shortheaded lampreys, *Mordacia praecox*) were found in areas outside their predicted range.

## *INTRODUCTION*

In New South Wales the decline in abundance of Australian freshwater fish has been of concern for over one hundred years, with the issue first being raised during the 1880 Royal Commission into the Fisheries of New South Wales (Faragher and Harris 1994). Since that time, many fish species have suffered continuing declines in abundance and distribution, some at alarming levels. This includes many of the smaller species as well as all of the species targeted by inland commercial and recreational fisheries, such as Murray cod, *Maccullochela peelii,* golden perch, *Macquaria ambigua*, silver perch, *Bidyanus bidyanus*, catfish, *Tandanus tandanus* and Macquarie perch, *Macquaria australasica* (Cadwallader and Backhouse 1983; Llewellyn 1983; Rowland 1989; Brown 1992; Mallen-Cooper 1992 & 1994; McDowall 1996).

These declines in abundance are commonly attributed to factors such as: general habitat degradation (Llewellyn 1983; Swales 1993), modified patterns of streamflow (Llewellyn 1983; Harris 1988; Pierce 1989; Koehn and O'Connor 1990; Gehrke *et al.* 1995), interrupted migratory pathways (Pierce 1989; Mallen-Cooper 1992, 1993; Mallen-Cooper *et al.* 1995), reduced water quality and pollution (Pierce 1989; Koehn and O'Connor 1990; Mallen-Cooper 1993), introduction of alien fish and diseases (Llewellyn 1983; Cadwallader and Lawrence 1990; Koehn and O'Connor 1990), illegal fishing and commercial overfishing (Pierce 1989; Rowland 1989; Cadwallader and Lawrence 1990; Brown 1992), changed energy fluxes (Harris 1996) and altered biotic interactions. Although these influences are crucial in determining the structure of riverine fish communities (Karr 1991), there is sparse evidence clearly linking them with declines in Australian native fish (Mallen-Cooper 1993). The main reasons for our poor understanding of causality stem from a lack of definitive information on the habitat associations and requirements of most native fish (Harris 1994), and inconclusive data on the impact of alien fish species on Australian freshwater native fish species.

A previous major work published more than a decade ago amalgamated several data sources into a synopsis of the distribution of freshwater fish in New South Wales at the time (Llewellyn 1983). However, no attempt was made to compare relative abundance in different regions by using a standard survey structure. The NSW Rivers Survey is the first study of its kind in Australia, attempting to determine the relative status of the riverine fish resources of the entire State in a consistent and repeatable manner. This baseline information is vital for effective conservation and management of native fish populations in New South Wales. It facilitates identification of populations and species under threat or suffering ongoing reductions in distribution or abundance, acts as an aid in identifying and understanding threatening processes, and its repeatability enables long term monitoring of populations to assess the effectiveness of management strategies. It was anticipated that by examining the fish community structure at all

sites it would be possible to characterise State-wide patterns in fish assemblages to enable prediction of the fish community structure at unsampled locations.

This chapter provides a descriptive account of the distribution and abundance of native fish in New South Wales rivers, as well as an assessment of the status of native fish resources in New South Wales.

## METHODS

Sites were selected from four ecological regions (North Coast, South Coast, Darling and Murray) in New South Wales, with four river types recognised in each region (Montane, Slopes, Regulated Lowland and Unregulated Lowland) as described in Chapter 1. Within each region five replicate sites were selected for each river type using a modified stratified-random selection process, this yielded a total of 80 survey sites across New South Wales (Chapter 1).

Fish were caught using a standard suite of quantitative passive (gill nets, fyke nets and Gee traps) and active (backpack or boat-mounted electrofishers) sampling gear to sample fish communities (Chapter 1). Sites were sampled during winter and summer over two years to provide an indication of variation in fish communities both within and between years. This survey regime resulted in four levels of sampling: regions, river type, years and times, with times of sampling corresponding to winter and summer.

### *Abundance and Distribution of Native Species*

As part of the interpretation of possible changes in distribution of native fish, a list of predicted New South Wales freshwater species and their distribution was compiled through a review of available literature. Where contradictions occurred, as was often the case, the most recent source was normally used. In most instances this source was McDowall (1996). Freshwater species are defined for the purposes of this study as those species regularly occurring above tidal limits for a significant part of their life cycle.

Species' names are constantly being revised as understanding of the relationships between species advances. Since the release of the NSW Rivers Survey Data Report - June 1996 (Harris *et al.* 1996), the nomenclature of freshwater fish species in New South Wales has been revised. To maintain consistency, species names used in this chapter follow those used in the earlier report. However, the following name changes are noted. The three glassfishes *Ambassis agassizii*,

*Ambassis castelnaui* and *Ambassis nigripinnis* have been synonymised as *Ambassis agassizii*, in the family Chandidae, which replaces the former family name Ambassidae (Allen 1996*a*). Distinctions between the carp gudgeon species *Hypseleotris klunzingeri*, *Hypseleotris* sp 4, and *Hypseleotris* sp 5 are unclear and these three species have been grouped into the species complex *Hypseleotris* spp..

## RESULTS

### *General Catch Summary*

A total of 22,580 Australian native freshwater fish representing 39 species, 25 genera and 19 families was collected during the NSW Rivers Survey (Table 4.1). Detailed results including catches at each of the 80 sites and four surveys are listed separately in the NSW Rivers Survey Database (Harris *et al*. 1996). The most abundant species was the western carp gudgeon complex, *Hypseleotris* spp. (17.5% of total catch of Australian native freshwater fish), followed by empire gudgeon, *Hypseleotris compressa* (12.8%), Australian smelt, *Retropinna semoni* (11.2%), bony herring, *Nematalosa erebi* (9.2%), Australian bass, *Macquaria novemaculeata* (4.8%), and striped gudgeon, *Gobiomorphus australis* (4.3%) (Table 4.1). The largest regional catch was recorded in the North Coast region, with 9,092 individuals (40.3%) and 23 species (59.0% of total Australian native freshwater fish species recorded), followed by the Darling with 7,033 individuals (31.1%) and 14 species (35.9%), the South Coast with 5,470 individuals (24.2%) and 22 species (56.4%), with the smallest catch by far recorded in the Murray region, 985 individuals (4.4%) and 14 species (35.9%) (Table 4.1 and Table 4.2).

There was marked seasonal variation in total catch among-river type groups for all regions, with more individuals captured during summer than winter (Figure 4.1). This variation was most pronounced in the Darling region, where winter catches for all river types were only 31% of those recorded in summer. Winter catches were 57% of summer catches for the Murray, 71% for the South Coast, and 81% for the North Coast regions. This pattern of greater catches during summer was reflected in catches at the river-type scale, except in the North Coast where montane and regulated lowland sites recorded greater catches in winter.

Table 4.1 Summary of catches of Australian native freshwater fish species from the four ecological regions of New South Wales sampled during the NSW Rivers Survey indicating all species recorded and the number of each caught.

| Family | Species | Common Name | Catchment | | | | |
|---|---|---|---|---|---|---|---|
| | | | Darling | Murray | North Coast | South Coast | Catch Totals |
| Ambassidae[1] | *Ambassis agassizii* [2] | Olive perchlet | 1 | 0 | 61 | 0 | 62 |
| | *Ambassis nigripinnis* [2] | Olive perchlet | 0 | 0 | 494 | 0 | 494 |
| Anguillidae | *Anguilla australis* | Short-finned eel | 0 | 0 | 1 | 48 | 49 |
| | *Anguilla reinhardtii* | Long-finned eel | 0 | 0 | 250 | 334 | 584 |
| Ariidae | *Arius graeffei* | Freshwater fork-tailed catfish | 0 | 0 | 59 | 0 | 59 |
| Atherinidae | *Craterocephalus fluviatilis**** | Murray hardyhead | 0 | 1 | 0 | 0 | 1 |
| | *Craterocephalus marjoriae* | Marjorie's hardyhead | 0 | 0 | 10 | 0 | 10 |
| | *Craterocephalus stercusmuscarum* | Flyspecked hardyhead | 208 | 14 | 0 | 0 | 222 |
| Bovichtidae | *Pseudaphritis urvillii* | Congolli | 0 | 0 | 0 | 29 | 29 |
| Clupeidae | *Nematalosa erebi* | Bony herring | 1982 | 100 | 0 | 0 | 2082 |
| | *Potamalosa richmondia* | Freshwater herring | 0 | 0 | 604 | 1 | 605 |
| Eleotridae [3] | *Gobiomorphus australis* | Striped gudgeon | 0 | 0 | 576 | 399 | 975 |
| | *Gobiomorphus coxii* | Cox's gudgeon | 0 | 0 | 31 | 817 | 849 |
| | *Hypseleotris compressa* | Empire gudgeon | 0 | 0 | 2616 | 271 | 2887 |
| | *Hypseleotris galii* | Firetailed gudgeon | 0 | 0 | 295 | 442 | 737 |
| | *Hypseleotris* spp.[4] | Carp gudgeon | 3717 | 111 | 115 | 0 | 3943 |
| | *Philypnodon grandiceps* | Flathead gudgeon | 4 | 42 | 309 | 334 | 689 |
| | *Philypnodon* sp.1 | Dwarf flathead gudgeon | 0 | 0 | 41 | 109 | 150 |
| Gadopsidae | *Gadopsis bispinosus* | Two-spined blackfish | 0 | 3 | 0 | 0 | 3 |
| | *Gadopsis marmoratus* | River blackfish | 21 | 0 | 0 | 1 | 22 |
| Galaxiidae | *Galaxias brevipinnis* | Climbing galaxias | 0 | 7 | 0 | 8 | 15 |
| | *Galaxias maculatus* | Common jollytail | 0 | 0 | 0 | 533 | 533 |
| | *Galaxias olidus* | Mountain galaxias | 162 | 289 | 260 | 5 | 716 |
| Melanotaeniidae | *Melanotaenia duboulayi* | Duboulay's rainbowfish | 0 | 0 | 314 | 0 | 314 |
| | *Melanotaenia fluviatilis* | Crimson-spotted rainbowfish | 99 | 2 | 0 | 0 | 101 |
| Mordaciidae | *Mordacia praecox*** | Nonparasitic lamprey | 0 | 0 | 0 | 33 | 33 |
| Mugilidae | *Mugil cephalus* | Striped mullet | 0 | 0 | 657 | 100 | 757 |
| | *Myxus petardi* | Freshwater mullet | 0 | 0 | 641 | 118 | 759 |
| Percichthyidae | *Maccullochella peelii* | Murray cod | 52 | 0 | 0 | 0 | 52 |
| | *Macquaria ambigua* | Golden perch | 191 | 37 | 0 | 0 | 228 |
| | *Macquaria australasica** | Macquarie perch | 0 | 22 | 0 | 0 | 22 |
| | *Macquaria novemaculeata* | Australian bass | 0 | 0 | 428 | 651 | 1079 |
| Plotosidae | *Tandanus tandanus* | Freshwater catfish | 58 | 0 | 488 | 1 | 547 |
| Prototroctidae | *Prototroctes maraena*** | Australian grayling | 0 | 0 | 0 | 64 | 64 |
| Pseudomugilidae | *Pseudomugil signifer* | Southern blue-eye | 0 | 0 | 193 | 0 | 193 |
| Retropinnidae | *Retropinna semoni* | Australian smelt | 424 | 354 | 586 | 1164 | 2527 |
| Scorpaenidae | *Notesthes robusta* | Bullrout | 0 | 0 | 63 | 8 | 71 |
| Terapontidae | *Bidyanus bidyanus*** | Silver perch | 7 | 2 | 0 | 0 | 9 |
| | *Leiopotherapon unicolor* | Spangled perch | 106 | 1 | 0 | 0 | 107 |
| **Total Species** | | | **14** | **14** | **23** | **22** | **39** |
| **Total Individuals** | | | **7033** | **985** | **9092** | **5470** | **22580** |

Note: The species names used in this table were current at the time of sampling. Subsequent to this period there have been a number of changes to the species' names and classifications as follows:

[1] The family "Ambassidae" (glassfishes, chanda perches) are now known as "Chandidae"

[2] The three glassfish *Ambassis agassizii*, *Ambassis castelnaui* and *Ambassis nigripinnis* have now been combined into the single species *Ambassis agassizii* (Allen 1996a).

[3] The family "Eleotridae" (gudgeons) are now recognised as a sub-family (Eleotrinae) of the family Gobiidae (Larson and Hoese 1996).

[4] Due to uncertainty over the taxonomy and descriptions of the three carp gudgeons *Hypseleotris klunzingeri*, *Hypseleotris* sp. 4 and *Hypseleotris* sp. 5, all have been grouped under *Hypseleotris* spp.

IUCN (International Union for the Conservation of Nature) classification: * "data deficient", ** "vulnerable", *** "endangered"

Seasonal variation in the number of species recorded in each region was much lower than that observed for total catch (Figure 4.2). The pattern of regional variation in seasonal differences in species richness was the reverse of that observed for total catch, with the North Coast exhibiting the greatest variation and the Darling the least. In general, seasonal variation in the number of species recorded was greatest for unregulated lowland rivers, and least for montane rivers, although there was pronounced seasonal variation in North Coast montane sites where more species were recorded during winter than summer.

Table 4.2 Native fish species catch summary.

| Region | River Type | Native Fish | No. of Species | Av. Species pe Site |
|---|---|---|---|---|
| **Darling** | Montane | 247 | 3 | 1.2 |
| | Slope | 1374 | 10 | 4.6 |
| | Reg. Lowland | 1296 | 9 | 6.0 |
| | Unreg. Lowland | 4116 | 11 | 6.6 |
| | **Regional totals** | **7033** | **14** | **4.6** |
| **Murray** | Montane | 275 | 1 | 1.0 |
| | Slope | 188 | 7 | 3.0 |
| | Reg. Lowland | 250 | 6 | 3.0 |
| | Unreg. Lowland | 272 | 7 | 3.2 |
| | **Regional totals** | **985** | **14** | **2.6** |
| **North Coast** | Montane | 345 | 3 | 2.0 |
| | Slope | 2208 | 19 | 12.4 |
| | Reg. Lowland | 2742 | 19 | 12.8 |
| | Unreg. Lowland | 3797 | 19 | 14.4 |
| | **Regional totals** | **9092** | **23** | **10.4** |
| **South Coast** | Montane | 59 | 6 | 2.2 |
| | Slope | 1582 | 13 | 6.4 |
| | Reg. Lowland | 2252 | 19 | 10.6 |
| | Unreg. Lowland | 1577 | 16 | 10.6 |
| | **Regional totals** | **5470** | **22** | **7.5** |
| | **Totals** | **22580** | **39** | **6.3** |

No. of species = number of distinct species caught per river type, total distinct species per region and total distinct species for entire survey.
Av. species per site = average number of species caught from the five sites in each river type, average of all 20 regional sites and average of all 80 sites.

Species richness in the Darling and Murray regions was low when compared to the North Coast and South Coast regions (Table 4.2 and Figure 4.2 and Figure 4.3). In the Murray a maximum of five species was recorded at any site, with 50% of sites containing only 1-2 species. Species diversity was greater in the Darling region, with 30% of sites having 7-14 species, 45% 3-6 species and only 1-2 species at the remaining 25% of sites. This contrasts strongly with the North Coast and South Coast regions, where more than 15 native species were recorded at four North

Coast sites and one South Coast site. Between seven and 14 species were found at 60% of North Coast and 55% of South Coast sites (Figure 4.3).

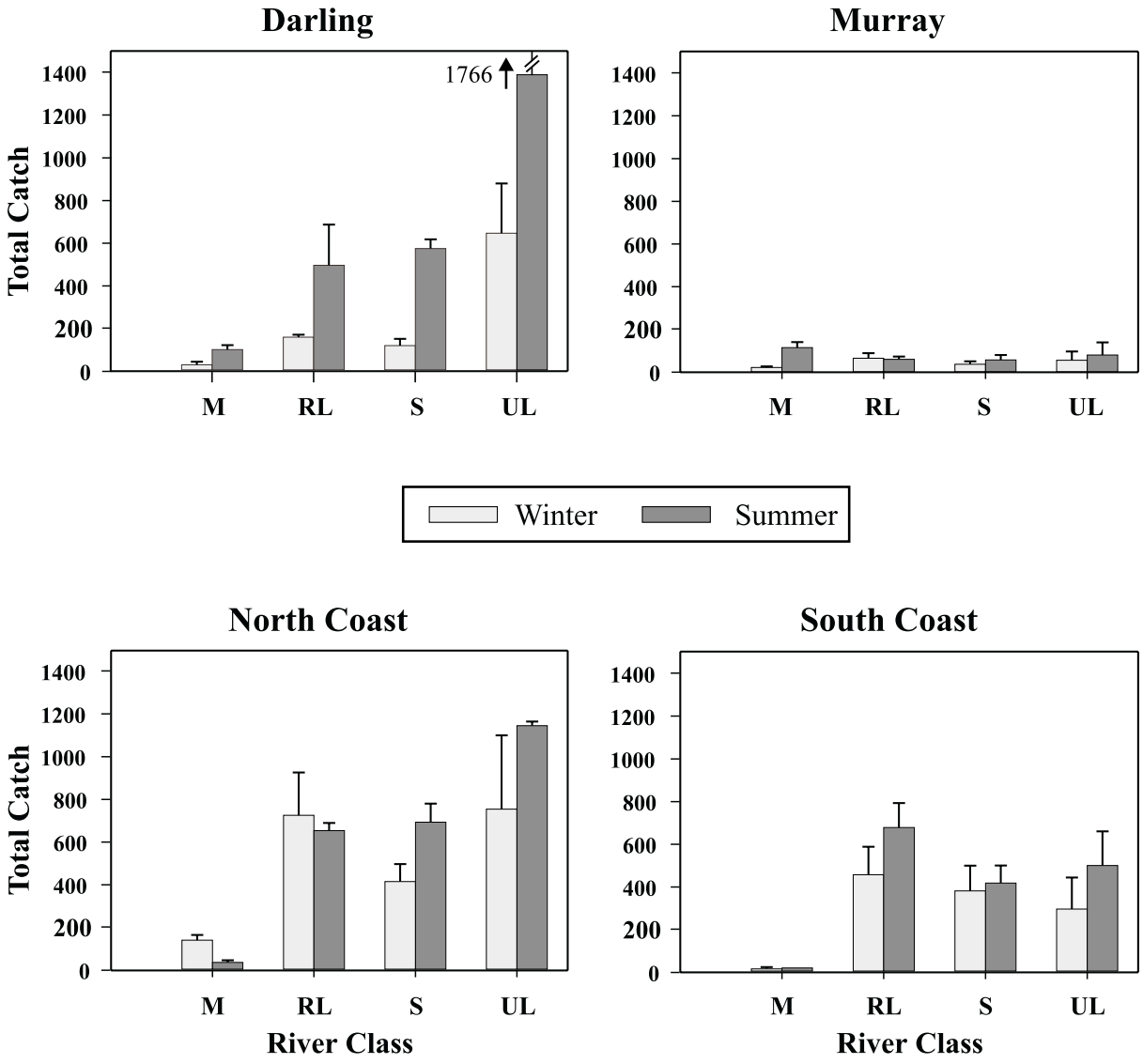


Figure 4.1 Mean total catch and standard error of species of Australian freshwater native fish recorded during winter and summer surveys in each of the four geographic regions of New South Wales sampled during the NSW Rivers Survey. Means and standard error based on two winter and summer samples at 5 replicate sites in each river type. River Types- M: Montane; RL: Regulated Lowland; S: Slope; UL: Unregulated Lowland

### *Abundance and Distribution of Native Species*

*Species recorded - State-wide*

Eighty one species of fish were predicted to occur in New South Wales rivers, consisting of 11 alien species, 15 estuarine species, and 55 freshwater species (Table 4.3). Of the 55 freshwater species, 39 were recorded by the NSW Rivers Survey (Table 4.1).

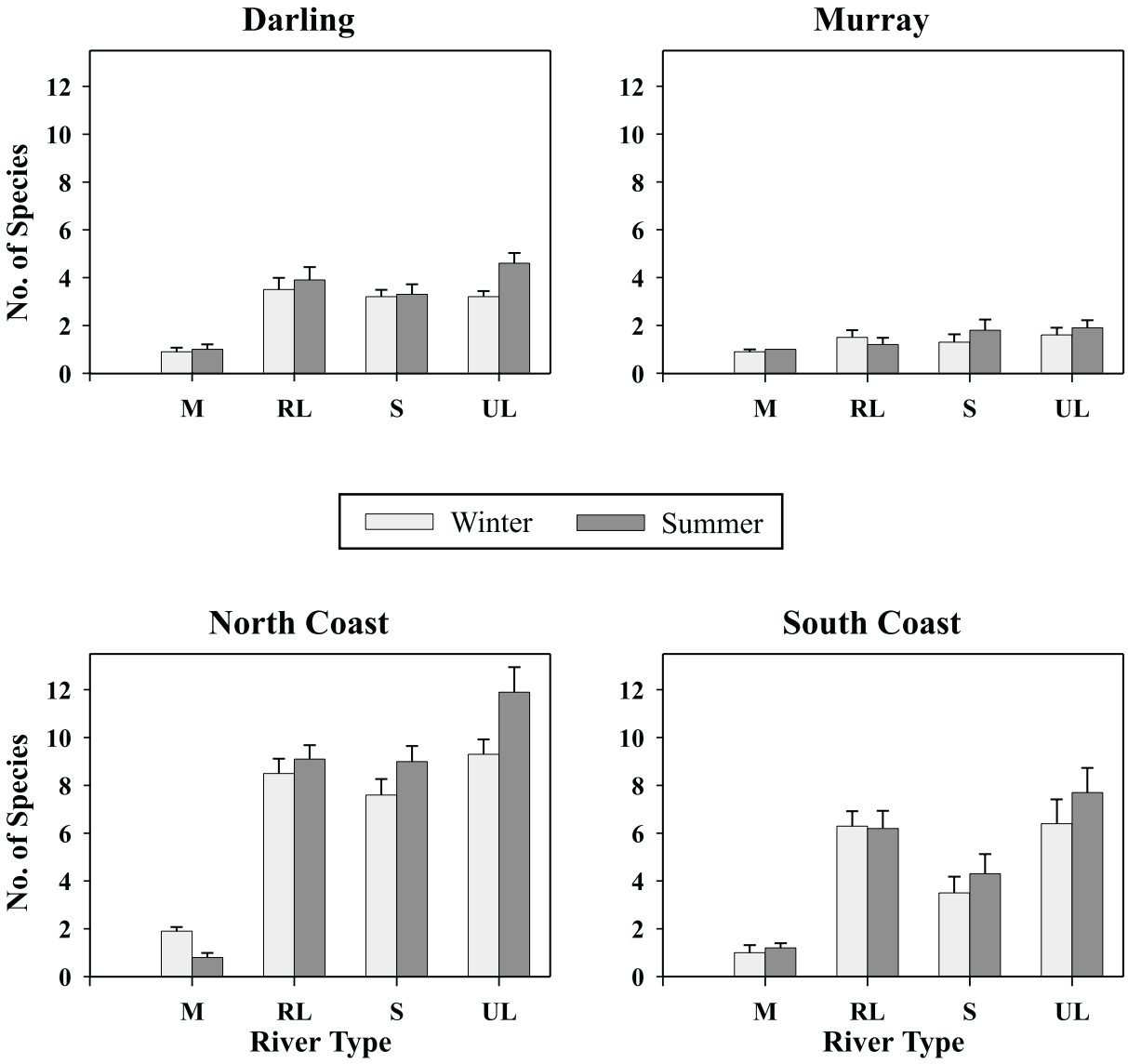


Figure 4.2 Mean number and standard error of species of Australian freshwater native fish recorded during winter and summer surveys in each of the four geographic regions of New South Wales sampled during the NSW Rivers Survey. Means and standard error based on two winter and summer samples at 5 replicate sites in each river type. River Types- M: Montane; RL: Regulated Lowland; S: Slope; UL: Unregulated Lowland

*Species recorded - By region*

A total of 14 species were recorded in both the Murray and Darling regions. However, the average number of species per site was much lower in the Murray than in the Darling, 2.6 compared to 4.6, indicating a much lower localised diversity (Table 4.2). With the exception of the Murray region, the lowest numbers of both individuals and species were recorded from montane sites in each region. In the Murray region only one native species, mountain galaxias, was recorded in montane sites, however it was present at all five of these sites and and was the second most abundant native species, after Australian smelt, from the Murray region.

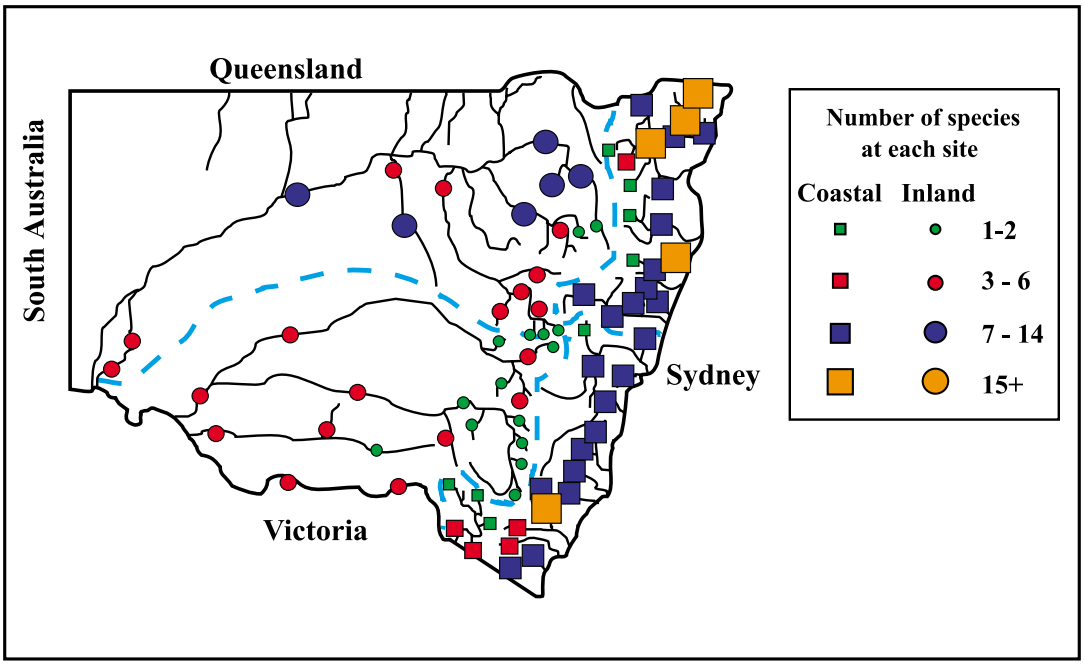


Figure 4.3 Species richness of native freshwater fish species at all survey sites.

Total numbers of native freshwater fish recorded per site over the four sampling rounds were similar in North Coast and South Coast regions, with the majority of sites containing between 101 and 1000 individuals (Figure 4.4). Only one inland and one coastal site returned more than 1000 individuals, most of which were gudgeons of the *Hypseleotris* genus. In the Darling region 60% of sites returned total catches of 101-1000 individuals, however in the Murray region just one site had a total catch greater than 100. Between 11 and 100 fish were caught at 60% of sites in the Murray region, with a further four sites recording fewer than 10 individuals.

Species of Australian freshwater native fish recorded from each region were divided into three groups: (i) well-known recreational fishing and other large species (Figure 4.5, Figure 4.8 and Figure 4.11); (ii) small species with total recorded abundance greater than 200 individuals (Figure 4.6, Figure 4.9 and Figure 4.12); and (iii) other small species with total recorded abundance less than 200 individuals (Figure 4.7, Figure 4.10 and Figure 4.13).

Table 4.3 Species of native freshwater fish (those species regularly occurring above tidal limits for a significant part of their life cycle) predicted to occur in NSW rivers.

| Family | Species | Common name | Type |
|---|---|---|---|
| Ambassidae | *Ambassis agassizii* | Olive perchlet | Freshwater |
| | *Ambassis castelnaui* | Olive perchlet | Freshwater |
| | *Ambassis marianus* | Silver perchlet | Estuarine |
| | *Ambassis nigripinnis* | Olive perchlet | Freshwater |
| Anguillidae | *Anguilla australis* | Short-finned eel | Freshwater |
| | *Anguilla reinhardtii* | Long-finned eel | Freshwater |
| Apogonidae | *Glossamia aprion* | Mouth almighty | Freshwater |
| Ariidae | *Arius graeffei* | Freshwater fork-tailed catfish | Freshwater |
| Atherinidae | *Atherinosoma microstoma* | Smallmouthed hardyhead | Freshwater |
| | *Craterocephalus amniculus*** | Darling River hardyhead | Freshwater |
| | *Craterocephalus fluviatilis**** | Murray hardyhead | Freshwater |
| | *Craterocephalus marjoriae* | Marjorie's hardyhead | Freshwater |
| | *Craterocephalus stercusmuscarum* | Flyspecked hardyhead | Freshwater |
| Belonidae | *Strongylura krefftii* | Freshwater long tom | Estuarine |
| Bovichtidae | *Pseudaphritis urvillii* | Congolli | Freshwater |
| Chanidae | *Chanos chanos* | Milkfish | Estuarine |
| Clupeidae | *Nematalosa erebi* | Bony herring | Freshwater |
| | *Potamalosa richmondia* | Freshwater herring | Freshwater |
| Cobitidae | *Misgurnus anguillicaudatus* | Oriental weatherloach | Alien |
| Cyprinidae | *Carassius auratus* | Goldfish | Alien |
| | *Cyprinus carpio* | Common carp | Alien |
| | *Tinca tinca* | Tench | Alien |
| Eleotridae | *Butis butis* | Bony-snouted gudgeon | Freshwater |
| | *Gobiomorphus australis* | Striped gudgeon | Freshwater |
| | *Gobiomorphus coxii* | Cox's gudgeon | Freshwater |
| | *Hypseleotris compressa* | Empire gudgeon | Freshwater |
| | *Hypseleotris galii* | Firetailed gudgeon | Freshwater |
| | *Hypseleotris* spp. | Carp gudgeon | Freshwater |
| | *Mogurnda adspersa**** | Purple-spotted gudgeon | Freshwater |
| | *Philypnodon grandiceps* | Flathead gudgeon | Freshwater |
| | *Philypnodon* sp.1 | Dwarf flathead gudgeon | Freshwater |
| Elopidae | *Megalops cyprinoides* | Oxeye herring | Freshwater |
| Gadopsidae | *Gadopsis bispinosus* | Two-spined blackfish | Freshwater |
| | *Gadopsis marmoratus* | River blackfish | Freshwater |
| Galaxiidae | *Galaxias brevipinnis* | Climbing galaxias | Freshwater |
| | *Galaxias maculatus* | Common jollytail | Freshwater |
| | *Galaxias olidus* | Mountain galaxias | Freshwater |
| | *Galaxias rostratus*** | Murray jollytail | Freshwater |
| Geotriidae | *Geotria australis* | Pouched lamprey | Freshwater |
| Gobiidae | *Acanthogobius flavimanus* | Yellowfin goby | Alien |
| | *Afurcagobius tamarensis* | Tamar River goby | Estuarine |
| | *Arenigobius bifrenatus* | Bridled goby | Estuarine |
| | *Pseudogobius* sp.9 | Swan River goby | Estuarine |
| | *Redigobius macrostoma* | Largemouth goby | Estuarine |
| Hemirhamphidae | *Arrhamphus sclerolepis* | Snub-nosed garfish | Estuarine |
| Lutjanidae | *Lutjanus argentimaculatus* | Mangrove jack | Estuarine |

(continued)

Table 4.3 (continued).

| Family | Species | Common name | Type |
|---|---|---|---|
| Melanotaeniidae | *Melanotaenia duboulayi* | Duboulay's rainbowfish | Freshwater |
| | *Melanotaenia fluviatilis* | Crimson-spotted rainbowfish | Freshwater |
| | *Rhadinocentrus ornatus* | Softspined rainbowfish | Freshwater |
| Monodactylidae | *Monodactylus argenteus* | Silver batfish | Estuarine |
| Mordaciidae | *Mordacia mordax* | Shortheaded lamprey | Freshwater |
| | *Mordacia praecox*** | Nonparasitic lamprey | Freshwater |
| Mugilidae | *Aldrichetta forsteri* | Yelloweyed mullet | Estuarine |
| | *Liza argentea* | Flat-tail mullet | Estuarine |
| | *Mugil cephalus* | Striped mullet | Freshwater |
| | *Myxus elongatus* | Sand mullet | Estuarine |
| | *Myxus petardi* | Freshwater mullet | Freshwater |
| | *Valamugil georgii* | Fantail mullet | Estuarine |
| Nannopercidae | *Nannoperca australis* | Southern pygmy perch | Freshwater |
| | *Nannoperca oxleyana**** | Oxleyan pygmy perch | Freshwater |
| Percichthyidae | *Maccullochella ikei**** | Eastern cod | Freshwater |
| | *Maccullochella macquariensis**** | Trout cod | Freshwater |
| | *Maccullochella peelii* | Murray cod | Freshwater |
| | *Macquaria ambigua* | Golden perch | Freshwater |
| | *Macquaria australasica** | Macquarie perch | Freshwater |
| | *Macquaria colonorum* | Estuary perch | Estuarine |
| | *Macquaria novemaculeata* | Australian bass | Freshwater |
| Percidae | *Perca fluviatilis* | Redfin perch | Alien |
| Plotosidae | *Neosilurus hyrtlii* | Hyrtl's tandan | Freshwater |
| | *Tandanus tandanus* | Freshwater catfish | Freshwater |
| Poeciliidae | *Gambusia holbrooki* | Gambusia | Alien |
| Prototroctidae | *Prototroctes maraena*** | Australian grayling | Freshwater |
| Pseudomugilidae | *Pseudomugil signifer* | Southern blue-eye | Freshwater |
| Retropinnidae | *Retropinna semoni* | Australian smelt | Freshwater |
| Salmonidae | *Oncorhynchus mykiss* | Rainbow trout | Alien |
| | *Salmo salar* | Atlantic salmon | Alien |
| | *Salmo trutta* | Brown trout | Alien |
| | *Salvelinus fontinalis* | Brook char | Alien |
| Scorpaenidae | *Notesthes robusta* | Bullrout | Freshwater |
| Terapontidae | *Bidyanus bidyanus*** | Silver perch | Freshwater |
| | *Leiopotherapon unicolor* | Spangled perch | Freshwater |
| **Total species** | **81** | | |

IUCN (International Union for the Conservation of Nature) classification: * "data deficient", ** "vulnerable", *** "endangered"

***Darling and Murray regions:*** A total of seven recreational and other large species were recorded in the Darling and Murray regions, with five species common to both inland regions and two species, Murray Cod, *Maccullochella peelii*, and freshwater catfish, *Tandanus tandanus*, found only in the Darling region. There was pronounced disparity in the distribution and abundance of large species between the two inland regions (Figure 4.5). Bony herring, dominated lowland catches in the Darling region and north-western Murray sites. Golden perch, *Macquaria ambigua*,

was the most widespread large species, present at all lowland sites and one slopes site in the Darling region. In the Murray region golden perch were recorded at 11 sites, all of which had a low total catches of less than 10 fish, and it was the only large native species recorded at six of these sites. Silver perch, *Bidyanus bidyanus*, had a restricted distribution and were recorded in very low numbers at just three sites in the Darling region and one site in the Murray region. Macquarie perch, *Macquaria australasica*, were also rare, present in low numbers at only three sites in streams above lakes Wyangala and Burrinjuck. Both Murray cod, and freshwater catfish, were present at seven sites in the Darling region, with between 11 and 100 individuals recorded at three sites for Murray cod, and at two sites for catfish. At other sites in this region fewer than 11 specimens of either species were recorded. Neither species was captured in the Murray region.

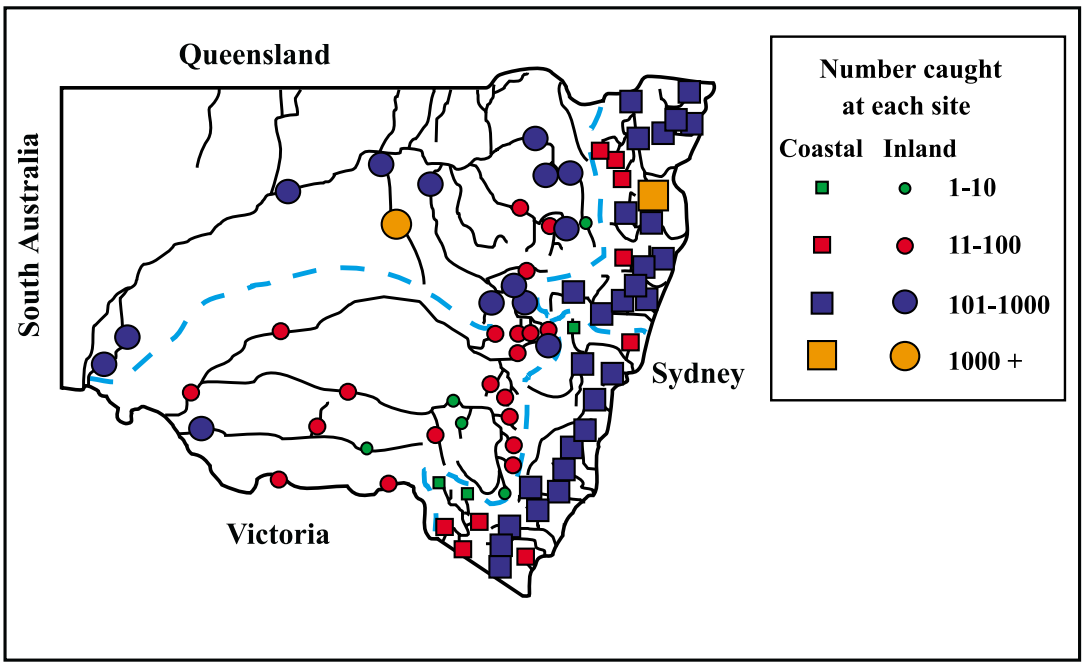


Figure 4.4 Total catch of native freshwater fish at each sample site. Dotted lines indicate divisions between Murray, Darling, North Coast and South Coast catchment regions.

The small species were dominated by carp gudgeons, *Hypseleotris* spp. and Australian smelt at slopes and lowland sites, and by mountain galaxias in the montane rivers (Figure 4.6). Eight additional species of small fish were also encountered at inland sites (Figure 4.7). Crimson-spotted rainbowfish, *Melanotaenia fluviatilis*, were the most widely distributed, being found at one Murray and eight Darling sites. Apart from *Melanotaenia fluviatilis*, the distributions of these small fishes were sparse and fragmented, with six of the eight species occurring at only one or two sites. Climbing galaxias, *Galaxias brevipinnis* are native to coastal regions and it is probable that populations found in the Murray River at Tintaldra have entered through the Snowy Mountains Hydro-Electric Scheme, which transfers water from the Snowy River into the Murray River (McDowall and Fulton 1996). Only one individual of both the olive perchlet, *Ambassis agassizii*, and the endangered Murray hardyhead, *Craterocephalus fluviatilis*, were found.

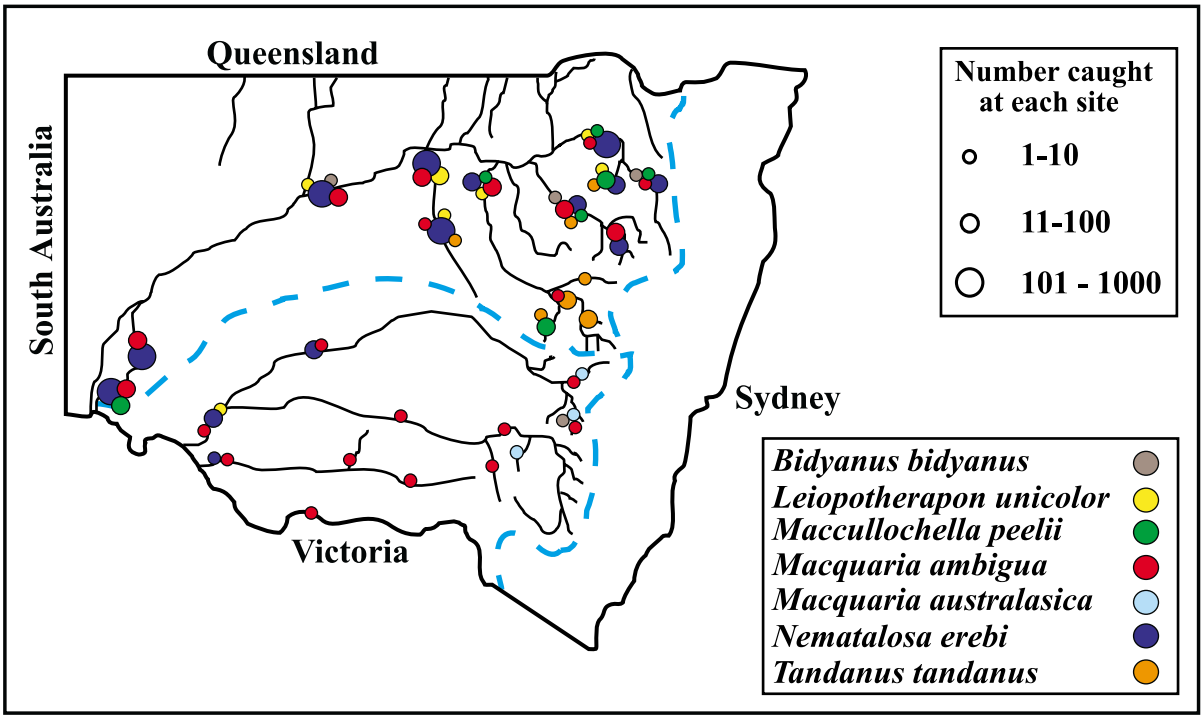


Figure 4.5 Total catch of native freshwater fish at inland sample sites: recreational and other large species.

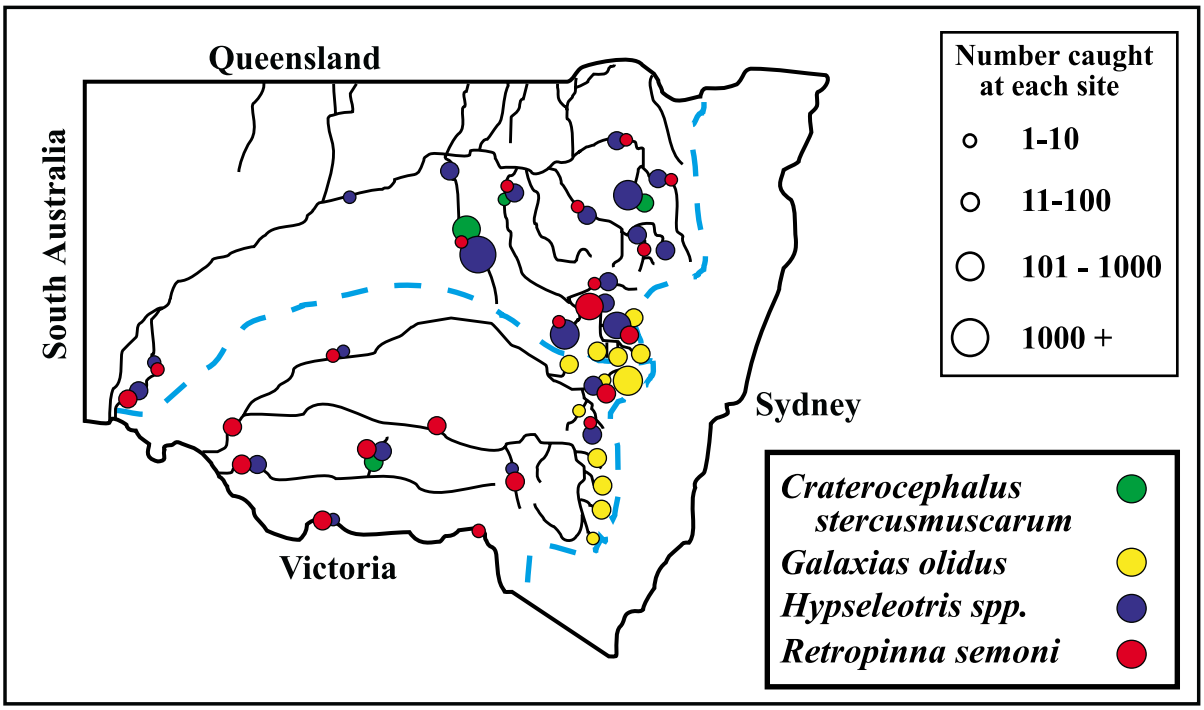


Figure 4.6 Total catch of native freshwater fish at inland sample sites: small species for which the total inland catch was > 200.

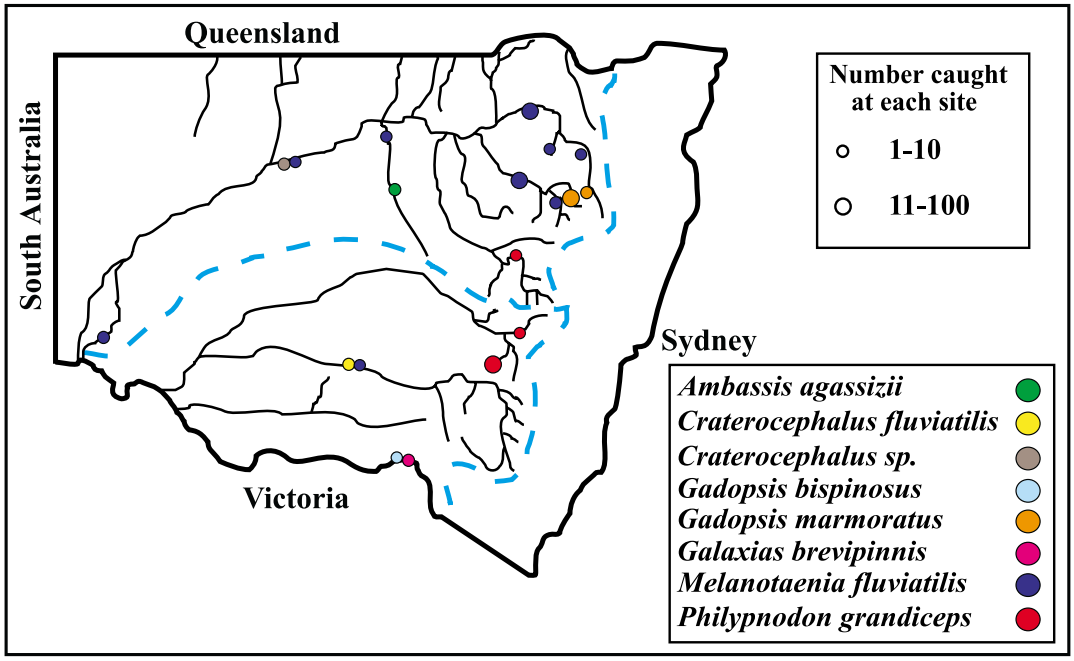


Figure 4.7 Total catch of native freshwater fish at inland sample sites: small species for which the total inland catch was < 200.

***North Coast region:*** A total of seven large or recreational native freshwater species were recorded in the North Coast region, all of which also occurred in the South Coast region. Of these, long-finned eels, *Anguilla reinhardtii* had the widest distribution and were the only species found at all 20 North Coast region sites (Figure 4.8). In contrast, short-finned eels, *Anguilla australis*, had a very restricted distribution and were only found at one site. The remaining five large or recreational native freshwater species, freshwater catfish, Australian bass, striped mullet, *Mugil cephalus*, freshwater mullet, *Myxus petardi*, and freshwater herring, *Potamalosa richmondia*, had relatively even distributions throughout the slopes and lowland rivers in the region, although each of the latter four species had a single occurrence of high catches of between 101 and 1000 individuals at a site.

Eight small species with total catches greater than 200 individuals were recorded in North Coast region rivers (Figure 4.9). Empire gudgeons, *Hypseleotris compressa*, were the most abundant with catches of between 101 and 1000 individuals at nine sites. Within the North Coast region mountain galaxias, were the only small species found at, and restricted to, montane sites.

A further eight small species with total catches for the region of less than 200 were recorded from North Coast streams (Figure 4.10). Marjorie's hardyhead, *Craterocephalus marjoriae*, were found at one site only, freshwater fork-tailed catfish, *Arius graeffei*, and carp gudgeon, *Hypseleotris* spp., at two sites, and olive perchlet, *Ambassis agassizii*, at three sites.

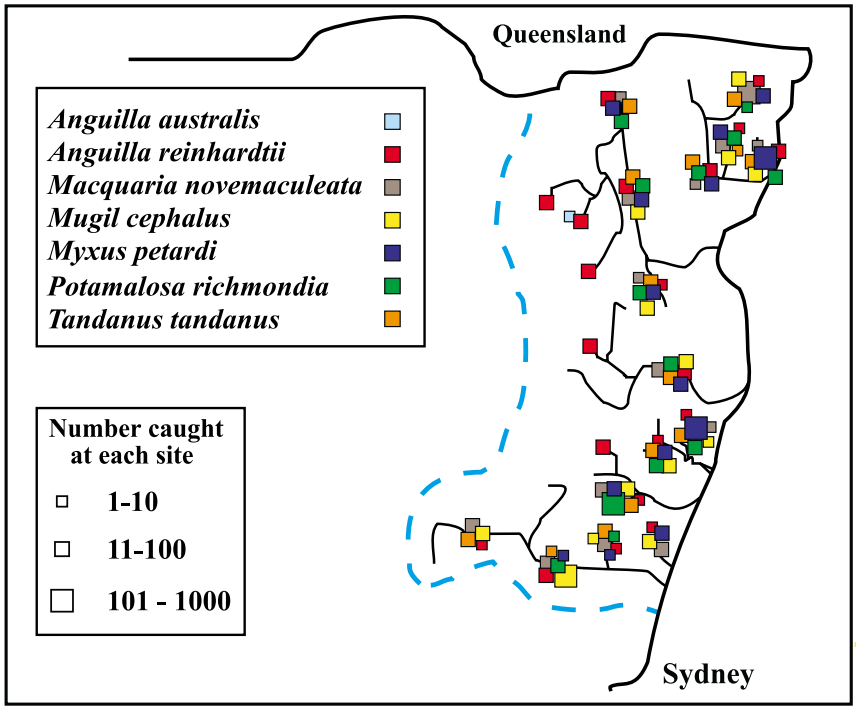


Figure 4.8 Total catch of native freshwater fish at North Coast sample sites: recreational and other large species.

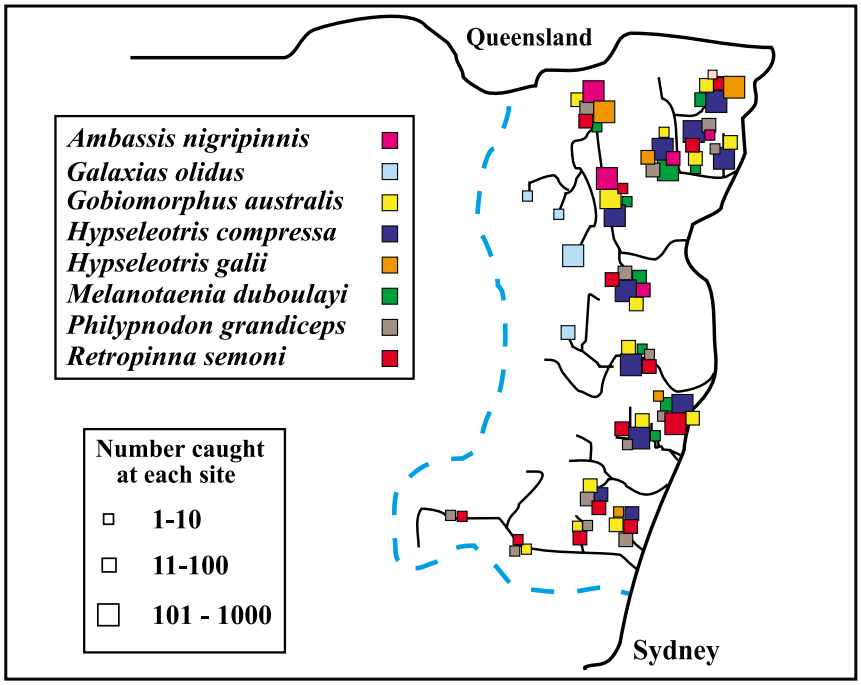


Figure 4.9 Total catch of native freshwater fish at North Coast sample sites: small species whose total catch for the region was > 200.

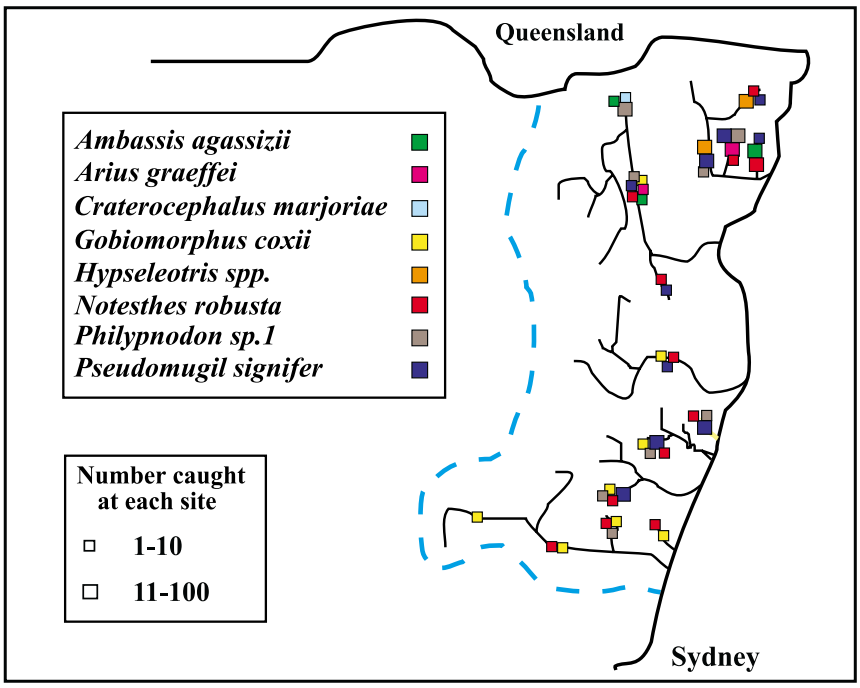


Figure 4.10 Total catch of native freshwater fish at North Coast sample sites: small species whose total catch for the region was < 200.

***South Coast region:*** All of the large or recreational native freshwater species recorded in the North Coast region (eight species) also occurred in the South Coast region. Australian bass was the most abundant large species in the this region, with catches of 101 to 1000 recorded at three sites close to Sydney, and lower numbers at seven other sites (Figure 4.11). Only a single specimen of both freshwater catfish and freshwater herring were caught in this region. There were distinct differences in the distribution of both eel species within the region. Short-finned eels were more common in upper reaches, while long-finned eels were more often found at lower elevation sites. Australian grayling, *Prototroctes maraena*, a species classified as 'vulnerable', were found at eight sites from the Clyde River south.

Seven small species with total catches greater than 200 individuals were recorded in South Coast region rivers (Figure 4.12). Five of these species had localised areas of high abundance with catches of between 101 and 1000 individuals at one site only. Cox's gudgeons, *Gobiomorphus coxii*, were found at this density in three rivers in the southern half of the region, and Australian smelt at six sites.

A further seven small species, with total catches less than 200 individuals, were encountered in South Coast rivers (Figure 4.13). River blackfish, *Gadopsis marmoratus* and mountain galaxias, *Galaxias olidus*, were restricted to the Delegate River, while climbing galaxias, which was also present in the Delegate River, was recorded at the survey's highest-altitude site, on the Eucumbene River above the Jindabyne and Eucumbene Dams. Non parasitic lamprey, *Mordacia praecox,* were found at five sites, the two southern-most of which were outside the species' predicted range (Potter 1996a).

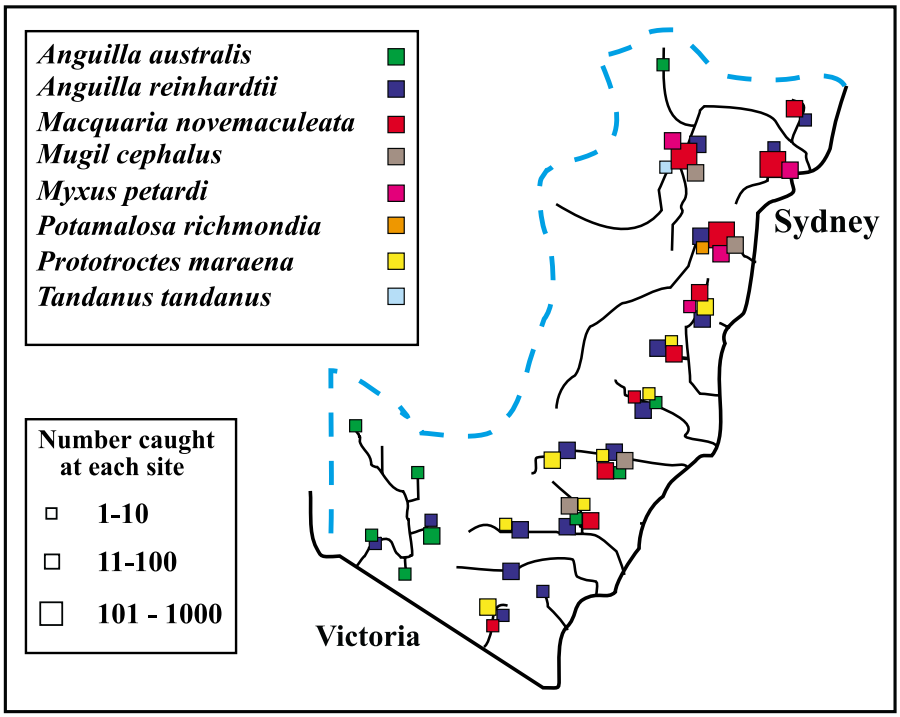


Figure 4.11 Total catch of native freshwater fish at South Coast sample sites: recreational and other large species.

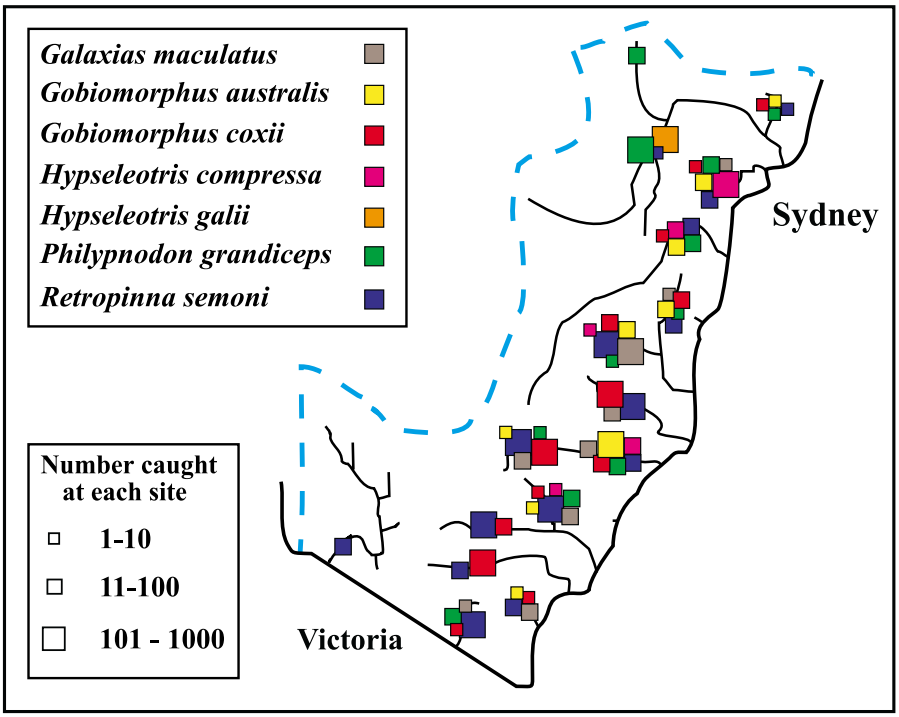


Figure 4.12 Total catch of native freshwater fish at South Coast sample sites: small species whose total catch for the region was > 200.

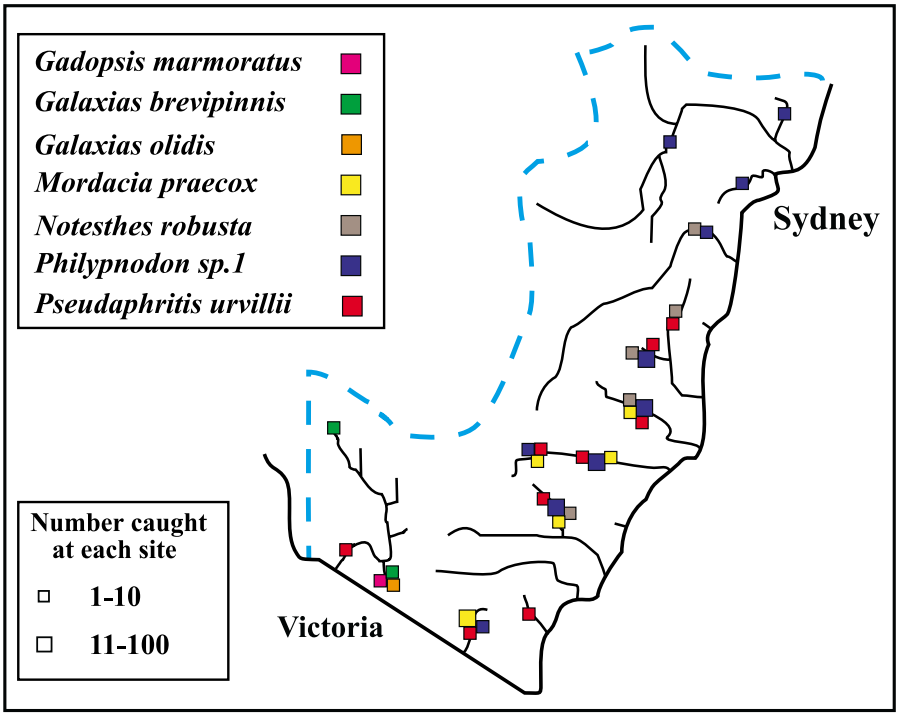


Figure 4.13 Total catch of native freshwater fish at South Coast sample sites: small species whose total catch for the region was < 200.

*Species recorded with restricted distribution and /or low abundance*

Rare species ( i.e. those caught at only one or two sites, or with total catches of ten individuals or less) were recorded in all four regions (Table 4.4). Eight rare species were recorded in the Murray region, seven in the South Coast region, four in the Darling, and two in the North Coast region. Seven silver perch, a species classified as 'vulnerable', were found in three rivers in the Darling region, two of which are often stocked by angling clubs with hatchery-bred fingerlings. The one site in the Murray region where two silver perch were caught is above Wyangala Dam, which is regularly stocked with silver perch and other native species by NSW Fisheries. Olive perchlet were reported to be relatively common in western rivers of the Murray-Darling system among log snags and aquatic vegetation, and their eggs are reportedly scattered among vegetation (Allen 1996*a*). However the NSW Rivers Survey found only one specimen in the Darling region, and none in the Murray region. Aquatic vegetation was recorded as rare or absent from most sites in the Darling and Murray regions, suggesting that the absence of vegetation may be associated with the species' decline. In New South Wales, river blackfish are restricted to higher-altitude streams in inland catchments, as well as the Snowy River system. This species appears susceptible to increased stream sediment load because of its dependence on stream-bed cover (Jackson *et al.* 1996). Flathead gudgeon, *Philypnodon grandiceps*, were considered abundant through most of the Murray-Darling system (Larson and Hoese 1996), preferring quiet waters, particularly lakes and dams. During this study only 46 individuals of this

species were recorded, four from one site in the Darling region and 42 from two sites in the Murray region.

Table 4.4 Native species of fish recorded by NSW Rivers Survey within a region but with less than 10 individuals or occurring at 2 or less sites.

| Catchment | Species | Common name | No. caught | No. sites |
|---|---|---|---|---|
| **Darling** | *Ambassis agassizii* | Olive perchlet | 1 | 1 |
| | *Bidyanus bidyanus*** | Silver perch | 7 | 3 |
| | *Gadopsis marmoratus* | River blackfish | 21 | 2 |
| | *Philypnodon grandiceps* | Flathead gudgeon | 4 | 1 |
| **Murray** | *Bidyanus bidyanus*** | Silver perch | 2 | 1 |
| | *Craterocephalus fluviatilis**** | Murray hardyhead | 1 | 1 |
| | *Craterocephalus stercusmuscarum* | Flyspecked hardyhead | 14 | 1 |
| | *Gadopsis bispinosus* | Two-spined blackfish | 3 | 1 |
| | *Galaxias brevipinnis* | Climbing galaxias | 7 | 1 |
| | *Leiopotherapon unicolor* | Spangled perch | 1 | 1 |
| | *Melanotaenia fluviatilis* | Crimson-spotted rainbowfish | 2 | 1 |
| | *Philypnodon grandiceps* | Flathead gudgeon | 42 | 2 |
| **North Coast** | *Anguilla australis* | Short-finned eel | 1 | 1 |
| | *Craterocephalus marjoriae* | Marjorie's hardyhead | 10 | 1 |
| **South Coast** | *Gadopsis marmoratus* | River blackfish | 1 | 1 |
| | *Galaxias brevipinnis* | Climbing galaxias | 8 | 2 |
| | *Galaxias olidus* | Mountain galaxias | 5 | 1 |
| | *Hypseleotris galii* | Firetailed gudgeon | 442 | 1 |
| | *Notesthes robusta* | Bullrout | 8 | 5 |
| | *Potamalosa richmondia* | Freshwater herring | 1 | 1 |
| | *Tandanus tandanus* | Freshwater catfish | 1 | 1 |

IUCN (International Union for the Conservation of Nature) classification: ** "vulnerable", *** "endangered"

Ivantsoff and Crowley (1996) reported that flyspecked hardyhead, *Craterocephalus stercusmuscarum*, are rare, if present at all, in southern Murray and Darling regions, but remain abundant in the northern Darling system. During this study most (94%) of the catch of this species in the Darling region was collected from the Bogan River, near vegetation in a weir pool. Similar habitat conditions existed where this species was caught in the Murray region. Two-spined blackfish, *Gadopsis bispinosus*, are only known to occur in streams near three or four Rivers Survey sites (Jackson *et al.* 1996). Although spangled perch, *Leiopotherapon unicolor*, are a hardy species with a wide temperature tolerance, they have only been positively recorded from the Lachlan River in the Murray catchment (Llewellyn 1973). Therefore, while this species was predicted to occur in the Murray region, the single specimen caught in the Murrumbidgee River below Balranald during the Rivers Survey is a significant new record for the species' southern limit. Of the 99 crimson-spotted rainbowfish captured in inland rivers, only two were recorded in the Murray region, both at the same site. The species is reported as being relatively common throughout the Murray-Darling system, although limited, like spangled perch, by cold winter temperatures (Allen 1996*b*).

Although essentially a still-water species, short-finned eels are predicted to be abundant in all New South Wales coastal rivers (Beumer 1996). However, only 49 specimens were recorded during this survey and their distribution was essentially limited to the South Coast region as all but one individual was caught in South Coast rivers. Commercial fishing of short-finned eels is considered to be an important contributing factor in the decline of the species (Beumer 1996). In contrast, long-finned eels were more abundant, with a total catch of 584, and were recorded in similar numbers in both the North and South Coast regions. Marjorie's hardyhead is reported as being restricted to the Clarence River in New South Wales, where it is locally abundant (Ivantsoff and Crowley 1996), however only ten fish were found in this survey.

Firetailed gudgeon, *Hypseleotris galii*, were only found at one site in the Nepean River in the South Coast region, but in great abundance. Larson and Hoese (1996) indicate that this species is rarely found with empire gudgeons, a finding supported for this region by this study as empire gudgeons were absent from the Nepean site, but occurred at five other South Coast sites. In contrast, on the North Coast empire gudgeons were collected in high numbers at all sites where firetailed gudgeons occurred. Only eight bullrouts, *Notesthes robusta*, and one freshwater herring (*Potamalosa richmondia*) were found in South Coast rivers. Neither species is considered common in the South Coast region, but are not under threat (Pollard and Parker 1996; Briggs and McDowall 1996). Populations of the freshwater catfish in eastern-drainage rivers near Sydney have probably been introduced from inland regions (Pollard *et al.* 1996; Gehrke 1996). Mountain galaxias were reasonably abundant in montane rivers in the Darling, Murray and North Coast regions, but only five individuals were caught, from one site, in the South Coast region. McDowall and Fulton (1996) indicated that this species is often found only where trout have not become established, however this study found trout at 12 of the 17 sites where mountain galaxias occurred (Table 4.5), suggesting that other factors, such as the amount of vegetation and other cover, may be equally significant in determining their distributions.

*Absent species - State-wide*

Sixteen species of native freshwater fish predicted to occur in New South Wales rivers were not recorded by the NSW Rivers Survey (Table 4.6), although nine of these species were recorded by Llewellyn (1983). Of the sixteen absent species, four are classified as 'endangered' (*Maccullochella ikei, Maccullochella macquariensis, Mogurnda adspersa, Nannoperca oxleyana*) and two as 'vulnerable' (*Craterocephalus amniculus* and *Galaxias rostratus*). Six other species (*Glossamia aprion, Atherinosoma microstoma, Butis butis, Megalops cyprinoides, Rhadinocentrus ornatus*, and *Nannoperca australis*) have restricted distributions. At least one Rivers Survey site occurred within the predicted range of each of these species, so that their absence from this study cannot be attributed to sampling outside previously recognised distributions. The shortheaded lamprey, *Mordacia mordax*, spends a large proportion of its life cycle at sea, the pouched lamprey, *Geotria australis*, has an unknown distribution in New South Wales rivers, and Hyrtl's tandan,

*Neosilurus hyrtlii*, only occurs outside the range of Rivers Survey sites (McDowall 1996), in the Paroo and, possibly, Warrego Rivers which were excluded from selection of Rivers Survey sites (Chapters 1 and 2).

Table 4.5 *Galaxias olidus* catch summary, and comparisons with catches of rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) from the same sites.

| Site No. | *Galaxias olidus* | *Oncorhynchus mykiss* | *Salmo trutta* |
|---|---|---|---|
| 1 | 20 | 5 | 46 |
| 4 | 60 | | 39 |
| 5 | 59 | | 26 |
| 12 | 23 | 2 | 2 |
| 21 | 29 | | |
| 22 | 33 | 8 | 5 |
| 23 | 95 | 16 | |
| 24 | 5 | 1 | |
| 25 | 113 | 8 | 13 |
| 33 | 2 | 3 | |
| 34 | 1 | 7 | 3 |
| 35 | 11 | 1 | |
| 41 | 176 | | |
| 42 | 2 | | |
| 44 | 2 | | |
| 45 | 80 | | |
| 65 | 5 | | 9 |
| **Totals** | **716** | **51** | **143** |

The final species, *Ambassis castelnaui*, which has undergone a taxonomic review and is now synonymised with *A. agassizii* and *A. nigripinnis* as *A. agassizii* (Allen 1996a), was recorded from the Darling and North Coast regions during the Rivers Survey. *Ambassis nigripinnis* was recorded from the North Coast region, while Llewellyn (1983) recorded *A. castelnaui* in the Darling region and *A. nigripinnis* in the North Coast region.

*Absent species - By region*

Comparison of data from the NSW Rivers Survey with the predicted species list on a region-by-region basis identifies further absent species. Most such absences can be attributed to individual species having a restricted distribution and/or specific habitat preferences (Table 4.7).

***Darling region:*** Seven species were predicted but not recorded by the survey of rivers in the Darling region. Three of these species are classified as 'endangered' and two as 'vulnerable' (Table 4.7). Within New South Wales *Neosilurus hyrtlii* only occurs in the Paroo and, possibly, Warrego Rivers, which are outside the range of Rivers Survey sites (Pollard *et al.* 1996), and

*Philypnodon* sp.1 is known from only one location in this region, near Bathurst (Larson and Hoese 1996).

Table 4.6 Predicted freshwater native species not recorded by NSW Rivers Survey.

| | | Predicted catchments | | | | |
|---|---|---|---|---|---|---|
| **Species** | **Common name** | **Darling** | **Murray** | **North Coast** | **South Coast** | **NSW 83** |
| *Ambassis castelnaui* [1] | Olive perchlet | • | • | | | • |
| *Glossamia aprion* | Mouth almighty | | | • | | |
| *Atherinosoma microstoma* | Smallmouthed hardyhead | | | • | • | |
| *Craterocephalus amniculus*** | Darling River hardyhead | • | | | | |
| *Butis butis* | Bony-snouted gudgeon | | | • | | |
| *Mogurnda adspersa**** | Purple-spotted gudgeon | • | • | • | | • |
| *Megalops cyprinoides* | Oxeye herring | | | • | | |
| *Galaxias rostratus*** | Murray jollytail | • | • | | | • |
| *Geotria australis* | Pouched lamprey | | • | | | |
| *Rhadinocentrus ornatus* | Softspined rainbowfish | | | • | | • |
| *Mordacia mordax* | Shortheaded lamprey | | • | | • | • |
| *Nannoperca australis* | Southern pygmy perch | | • | | | • |
| *Nannoperca oxleyana**** | Oxleyan pygmy perch | | | • | | • |
| *Maccullochella ikei**** | Eastern cod | | | • | | • |
| *Maccullochella macquariensis**** | Trout cod | • | • | | | • |
| *Neosilurus hyrtlii* | Hyrtl's tandan | • | | | | |
| **Total species** | **16** | **6** | **7** | **8** | **2** | **9** |

Note: The species names used in this table were current at the time of sampling. Subsequent to this period there have been a number of changes to the species' names and classifications as follows:
[1] The three glassfish *Ambassis agassizii*, *Ambassis castelnaui* and *Ambassis nigripinnis* have now been combined into the single species *Ambassis agassizii*. During the Rivers Survey *Ambassis agassizii* was recorded from the Darling and North Coast regions and *Ambassis nigripinnis* from the North Coast region. Llewellyn recorded *Ambassis castelnaui* in the Darling and *Ambassis nigripinnis* in the North Coast region.
[2] Llewellyn, L.C. (1983). The Distribution of Fish in New South Wales. Australian Society for Limnology, Special Publication No.7.
IUCN (International Union for the Conservation of Nature) classification:** "vulnerable", *** "endangered"

***Murray region:*** Of the twelve species predicted but not recorded by the Rivers Survey in rivers in the Murray region, ten have restricted distributions or habitat preferences (Table 4.7). Of these, two are classified as 'endangered' and one as 'vulnerable'. The pouched lamprey, *Geotria australis*, has an unknown distribution in New South Wales (Potter 1996b), and four other species (*Anguilla australis, Mordacia mordax, Nannoperca australis* and *Philypnodon* sp.1) have restricted distributions or habitat preferences (Table 4.7), although at least one Rivers Survey site occurred in the predicted distribution of each species (Mallen-Cooper *et al.* 1995; McDowall 1996).

River blackfish is a species that has undergone a considerable reduction in range and abundance (Jackson *et al.* 1996), although it remains locally abundant in many areas. Habitat degradation and increased siltation are the main factors implicated in its decline.

Table 4.7 Native species of freshwater fish predicted to occur in NSW but not recorded by the NSW Rivers Survey: Species with known restricted distribution or habitat preference outlined per region.

| Catchment | Species | Common name | Sites within range[1] | Species distribution and habitat restrictions[2] |
|---|---|---|---|---|
| Darling | *Craterocephalus amniculus* | Darling River hardyhead | Y | Classified as 'vulnerable'. Usually found in gently flowing, shallow, clear water, or in the weed at the edges of such waters. |
| | *Craterocephalus fluviatilis* | Murray hardyhead | Y | Classified as 'endangered'. Only known distribution in the Darling catchment is possibly near the junction with the Murray R. |
| | *Galaxias rostratus* | Murray jollytail | Y | Classified as 'vulnerable'. Found mostly in still and gently flowing waters in lakes, lagoons, billabongs and backwaters. Distribution appears rather local and intermittent. |
| | *Maccullochella macquariensis* | Trout cod | Y | Classified as 'endangered', and wild fish now presumed absent from Darling system. Sampling sites were within range of hatchery stocked fish. |
| | *Mogurnda adspersa* | Purple-spotted gudgeon | Y | Classified as 'endangered'. Possibly declined as a result of interactions with introduced gambusia. |
| | *Neosilurus hyrtlii* | Hyrtl's tandan | N | In NSW found in the Paroo, and also possibly in the Condamine and Warrego systems. |
| | *Philypnodon* sp.1 | Dwarf flathead gudgeon | Y | Only known occurance in Darling catchment is possibly near Bathurst |
| Murray | *Anguilla australis* | Short-finned eel | Y | Rarely recorded as far upstream as the Murray in NSW |
| | *Gadopsis marmoratus* | River blackfish | Y | Restricted to altitudes above 150m in Murray region. Appears susceptible to increased sediment load. |
| | *Galaxias rostratus* | Murray jollytail | Y | Classified as 'vulnerable'. Found mostly in still and gently flowing waters in lakes, lagoons, billabongs and backwaters. Distribution appears rather local and intermittent. |
| | *Geotria australis* | Pouched lamprey | ? | Unknown whether they migrate up the Murray as far as NSW |
| | *Maccullochella macquariensis* | Trout cod | Y | Classified as 'endangered'. Only known wild population in NSW is in the Murray R below Yarrawonga. Sampling sites were within range of hatchery stocked fish. |
| | *Maccullochella peelii* | Murray cod | Y | Originally present throughout Murray-Darling system except upper reaches of some tributaries. Declined dramatically in range and abundance, now relatively uncommon in most areas. |
| | *Mogurnda adspersa* | Purple-spotted gudgeon | Y | Classified as 'endangered'. Possibly declined as a result of interactions with introduced gambusia. |
| | *Mordacia mordax* | Shortheaded lamprey | Y | Rarely recorded in the Murray in NSW |
| | *Nannoperca australis* | Southern pygmy perch | Y | Large scale reductions in range since European settlement in Murray-Darling, due to habitat loss and predation. Prefers lakes and billabongs to flowing waters. |
| | *Philypnodon* sp.1 | Dwarf flathead gudgeon | Y | Prefers calm waters and lives over mud or rocks or in weedy areas. |
| North Coast | *Atherinosoma microstoma* | Smallmouthed hardyhead | Y | Uncommon in freshwater, prefers coastal lakes and lagoons |
| | *Butis butis* | Bony-snouted gudgeon | Y | Uncommon in freshwater, and only in far north coast of NSW |
| | *Glossamia aprion* | Mouth almighty | Y | Rare in NSW northern coastal streams |
| | *Leiopotherapon unicolor* | Spangled perch | Y | The Clarence River system is the southern most limit on the eastern drainage. Prefers turbid, still flowing waters. |
| | *Maccullochella ikei* | Eastern cod | Y | Classified as 'endangered'. Hatchery bred fish have been stocked into the Clarence and Richmond rivers. |
| | *Megalops cyprinoides* | Oxeye herring | Y | Only juveniles usually found in freshwater, and only in far north coastal rivers in NSW. |
| | *Mogurnda adspersa* | Purple-spotted gudgeon | Y | Classified as 'endangered'. Coastal distribution in NSW is limited to far north streams. |
| | *Nannoperca oxleyana* | Oxleyan pygmy perch | Y | Classified as 'endangered'. |
| | *Rhadinocentrus ornatus* | Softspined rainbowfish | Y | Patchy, localised distribution in some northern NSW coastal streams. |
| South Coast | *Atherinosoma microstoma* | Smallmouthed hardyhead | Y | Uncommon in freshwater, prefers coastal lakes and lagoons |
| | *Macquaria australasica* | Macquarie perch | Y | Status classified as 'data deficient' due to lack of knowledge. Only occurs in upstream waters of the Shoalhaven and Hawkesbury river systems in south coast drainages. |
| | *Mordacia mordax* [3] | Shortheaded lamprey | Y | Spends a large portion of its lifecycle at sea. |
| | *Pseudomugil signifer* | Southern blue-eye | Y | Does not penetrate far upstream of estuaries, only found north of Narooma. |

[1] Were Rivers Survey sites within the predicted range of the species? (Y=Yes, N=No)
[2] From McDowall, R.M. (1996). Freshwater Fishes of Southeastern Australia. Reed, Sydney.
[3] Although *Mordacia mordax* is reported as having a wider distribution in south coast streams than *Mordacia praecox*, all specimens retained for verification were identified as *Mordacia praecox* and so it is likely that all *M. praecox* identifications were correct, and that the distribution of this species is wider than previously considered.

Historically Murray cod occurred throughout most of the Murray-Darling river system, with the exception of the upper reaches of some tributaries. This species, which is exploited by both recreational and commercial fisheries, has undergone a dramatic reduction in range and abundance and is now relatively uncommon in many areas (Harris and Rowland 1996). Fifty-two Murray cod were caught at seven sites in the Darling region during the Rivers Survey, but none

were recorded from rivers in the Murray region. Although the species is still regularly caught by commercial and recreational fishermen in some areas of the Murray region, its absence from Rivers Survey catches indicates that the species' distribution in the Murray system is even more reduced and fragmented than has previously been considered.

Aside from the fact that the findings of this study are applicable at the large scale of region and river type, and not at the smaller, more specific, scale of individual rivers or river regions, the catch of Murray cod at a particular site will be influenced by several factors. Murray cod exhibit high site fidelity and will only be caught at a site if it is part of their daily home range/territory at the time of sampling. With passive types of sampling apparatus the catchability of cod is strongly linked to flow, with resident fish having low catchability in low flows. However this confounding factor is avoided by sampling with electrofishers, and species-accretion curves indicate a high level of certainty that virtually all species at sites were identified by the end of the survey (refer Chapter 7). Cod may also be caught at a site if sampling happens to coincide with their movement through it during the seasonal spawning migration. However fish recorded in this manner do not reflect the true nature of the fish community at the sampled site, as they are not residents of the area sampled but are simply passing through to some other habitat.

The remaining two species predicted for the Murray region but not recorded by the Rivers Survey are reported as being widespread and relatively common over much of their range, and therefore may have recently undergone a major reduction in distribution and abundance (Table 4.8). Although *Ambassis agassizii* is restricted to western areas in the Murray system, this species is reported to be relatively common throughout most of its range, with aggregations common among log snags and aquatic vegetation. Eggs are reported to be scattered among vegetation in the spawning period (Allen 1996*a*). Habitat assessments by field teams during the Rivers Survey (Harris *et al.* 1996) found aquatic vegetation to be rare or absent from most Darling and Murray sites, which may be a contributing factor in the species' decline. The second species, freshwater catfish, prefer lakes and slow-flowing rivers and although they are said to remain widely abundant throughout the Murray-Darling river system, they are becoming scarce in many inland riverine habitats (Pollard *et al.* 1996). It has been suggested that cold-water discharge from dams may be partly responsible for the reduction in range of the species, however during the Rivers Survey the two highest catches in inland regions were from cool or cold habitat areas in the Turon River (20 fish) near Sofala (altitude 590m, cool water stream), and the Macquarie River site (17 fish) which is one kilometre below Burrendong Dam and receives cold water discharged from the base of the dam. It seems more likely that interactions with carp are associated with the radical decline in freshwater catfish, although carp were found in varying numbers, up to 121 individuals, at all of the seven Darling region sites where catfish occurred.

***North Coast region:*** Ten native freshwater species were predicted but not recorded for North Coast rivers. Of these, nine are restricted in distribution or habitat (Table 4.7), three are classified as 'endangered' and six (*Atherinosoma microstoma, Butis butis, Glossamia aprion,*

*Leiopotherapon unicolor, Megalops cyprinoides* and *Rhadinocentrus ornatus*) have restricted distributions or habitat preference, although at least one Rivers Survey site occurred in the predicted range of each of these species (McDowall 1996). The remaining species, common jollytail, is reported to be widespread and abundant throughout coastal streams from southern Queensland to Adelaide (McDowall and Fulton 1996). Although 533 were caught at nine South Coast sites during the Rivers Survey, none were found in North Coast streams (Table 4.8). This observation parallels a recent study in the Hawkesbury River basin, in which this species was represented by only a single specimen (Gehrke 1996).

Table 4.8 Native species of freshwater fish predicted to occur in NSW but not recorded by the NSW Rivers Survey: Species presumed to have widespread distribution and reasonable abundance outlined per region.

| Catchment | Species | Common name | Sites within range[1] |
|---|---|---|---|
| **Murray** | *Ambassis agassizii* | Olive perchlet | Yes |
| | *Tandanus tandanus* | Freshwater catfish | Yes |
| **North Coast** | *Galaxias maculatus* | Common jollytail | Yes |

[1] Were Rivers Survey sites within the predicted range of the species? (Yes, No)

***South Coast region:*** Of the four species predicted but not recorded from the South Coast region (Table 4.7), the shortheaded lamprey spends a large proportion of its life cycle at sea, and small-mouthed hardyhead, *Atherinosoma microstoma*, and southern blue-eye, *Pseudomugil signifer*, have restricted distributions or habitat preference. Macquarie perch are a threatened species, and classified as 'data deficient' (Jackson 1996). In this region, Macquarie perch are restricted to the Shoalhaven and Hawkesbury-Nepean river systems. Fish were translocated from the Murrumbidgee River into the Nepean River in 1915, although it is believed that natural populations of the species could have existed in the region prior to this stocking (McDonald 1976; Dufty 1986; Gehrke 1996).

*Survey comparisons*

The list of fish species occurring in New South Wales produced by Llewellyn (1983), who amalgamated findings from extensive unstructured surveys in 1975/76, a review of Australian Museum records from 1960 to 1976, and personal unpublished data, includes species from each region that were not recorded by the NSW Rivers Survey (Table 4.9). At least four of these unrecorded species are classed as endangered: the purple-spotted gudgeon, *Mogurnda adspersa*, in both the Darling and Murray regions; trout cod, *Maccullochella macquariensis*, in the Murray system; eastern cod, *Maccullochella ikei*, and oxleyan pygmy perch, *Nannoperca oxleyana*, in northern coastal streams.

The endangered Murray hardyhead was also reported by Llewellyn (1983) from the Murray, Murrumbidgee and Lachlan Rivers; from four upper tributaries of the Darling River; and from the Clarence River in the North Coast region. The genus has undergone reclassification in recent years, and specimens recorded by Llewellyn (1983) from the Darling tributaries were probably the flyspecked hardyhead, or Darling River hardyhead, *Craterocephalus amniculus*, while North Coast individuals were more than likely examples of Marjorie's hardyhead (Ivantsoff and Crowley 1996).

Table 4.9 Survey comparisons (native freshwater species only).

| **Species recorded within each region by Llewellyn[1] (1983) not caught during NSW Rivers Survey** | | **Species caught within each region during NSW Rivers Survey not recorded by Llewellyn (1983)** | |
|---|---|---|---|
| **Species** | **Common name** | **Species** | **Common name** |
| **Darling** | | **Darling** | |
| *Ambassis castelnaui* [2] | Western chanda perch | *Ambassis agassizii* [2] | Olive perchlet |
| *Craterocephalus fluviatilis* [4] *** | Murray hardyhead | *Philypnodon grandiceps* | Flathead gudgeon |
| *Mogurnda adspersa* *** | Purple-spotted gudgeon | | |
| **Murray** | | **Murray** | |
| *Ambassis agassizii* [2] | Olive perchlet | *Craterocephalus stercusmuscarum* | Flyspecked hardyhead |
| *Anguilla australis* | Short-finned eel | *Gadopsis bispinosus* [3] | Two-spinned blackfish |
| *Galaxias rostratus* ** | Murray jollytail | *Galaxias brevipinnis* | Climbing galaxias |
| *Maccullochella macquariensis* *** | Trout cod | *Leiopotherapon unicolor* | Spangled perch |
| *Maccullochella peelii* | Murray cod | *Melanotaenia fluviatilis* | Crimson-spotted rainbowfish |
| *Mogurnda adspersa* *** | Purple-spotted gudgeon | | |
| *Mordacia mordax* | Shortheaded lamprey | | |
| *Nannoperca australis* | Southern pygmy perch | | |
| *Tandanus tandanus* | Freshwater catfish | | |
| **North Coast** | | **North Coast** | |
| *Craterocephalus fluviatilis* [4] *** | Murray hardyhead | *Ambassis agassizii* [2] | Olive perchlet |
| *Galaxias maculatus* | Common jollytail | | |
| *Leiopotherapon unicolor* | Spangled perch | | |
| *Maccullochella ikei* *** | Eastern cod | | |
| *Nannoperca oxleyana* *** | Oxleyan pygmy perch | | |
| *Rhadinocentrus ornatus* | Softspined rainbowfish | | |
| **South Coast** | | **South Coast** | |
| *Hypseleotris* spp. | Carp gudgeon | *Pseudaphritis urvillii* | Congolli |
| *Macquaria australasica* | Macquarie perch | | |
| *Mordacia mordax* | Shortheaded lamprey | | |
| *Pseudomugil signifer* | Southern blue-eye | | |

[1] Llewellyn, L.C. (1983). The Distribution of Fish in New South Wales. Australian Society for Limnology, Special Publication No.7.

[2] The three glassfish *Ambassis agassizii*, *Ambassis castelnaui* and *Ambassis nigripinnis* have now been combined into the single species *Ambassis agassizii*. During the Rivers Survey *Ambassis agassizii* was recorded from the Darling and North Coast regions and *Ambassis nigripinnis* from the North Coast region. Llewellyn recorded *Ambassis castelnaui* in the Darling and *Ambassis nigripinnis* in the North Coast region.

[3] not identified as a distinct species in 1983.

[4] probably *Craterocephalus stercusmuscarum* in the Darling and *C. Marjoriae* in the North Coast

IUCN (International Union for the Conservation of Nature) classification: ** "vulnerable", *** "endangered"

The results of this distributional analysis indicate that 16 out of 55 native freshwater species (29% of the fauna) predicted to occur within sites surveyed are now either absent from New South Wales rivers, or occur in only low numbers so that the likelihood of capture is very low. A further 18 species currently have restricted distributions within specific regions or occur in only low abundances, making a total of 62% of all species whose conservation status appears to be at risk. While this percentage is alarming in itself, the rate of decline in some of these species since the last survey in 1983 is also a major concern. While the earlier survey was not quantitative, and the results of the two investigations cannot be compared in a formal statistical manner, the extent and rate of decline in native fish populations provides a grave warning on the condition of fish stocks in New South Wales rivers.

The implications of this finding are equally concerning. It is clear that efforts over the last decade by environmental agencies and fisheries managers have not been effective in arresting degradation of fish habitats and declines in their populations. It is also clear that continuation of the same management practices will be no more effective at protecting aquatic resources than in the past. To genuinely conserve and protect these resources so that they can be used in a sustainable manner, rather than merely accepting management strategies that preside over a continuing decline, will require new approaches to managing fish and the rivers in which they live.

Such approaches are achievable, and far from fanciful. For instance, within New South Wales a new approach to setting objectives for river flows and water quality is being developed and is scheduled for implementation during 1997 and 1998. From the perspective of fisheries management, the required approach is not so clear. Fisheries management strategies almost exclusively focus on single species fisheries, without considering or attempting to manage the flow-on effects that harvesting single species must have on other ecosystem components. In relatively undisturbed ecosystems with a large number of species, impacts from harvesting tend to be buffered to some extent by alternative trophic pathways that confer a degree of resilience on exploited ecosystems. However, when such systems are disturbed, they may become unstable, so that they lose some of their ability to sustain or recover from the impacts of harvesting.

In freshwater ecosystems in New South Wales, the ability of rivers to sustain harvesting appears to be very limited. The fish fauna of Australian rivers, especially in temperate regions, contains only a small number of species. Thus few alternative trophic pathways exist to buffer the impacts of selective harvesting of large predatory fish. In addition, rivers themselves have been subjected to many forms of disturbance for some time, so that the resilience of systems is low. It should come as no surprise under these circumstances that populations and distributions of native fish are shrinking. So then, while river flows and water quality are being addressed at an unprecedented level at both state and national levels, management of river fisheries has yet to develop a course which has potential to reverse the current decline.

## *DISCUSSION*

The NSW Rivers Survey recorded 22,580 Australian native freshwater fish representing a total of 39 species, 25 genera and 19 families. Of the 55 native freshwater fish species predicted to occur in New South Wales rivers, 16 (29%) were not encountered. The survey focused on river-channel habitats, and a number of species which prefer still-water habitats were either not encountered at all or were only recorded in low numbers.

Total numbers of native fish caught were lowest in the Murray region (985 individuals, 4.4% of the total). Although the same total number of species (14) was found in both the Murray and Darling inland regions, the average number of native species per site was much lower in the Murray region (2.6) than in the Darling region (4.6). These findings indicate that compared to other regions sampled in New South Wales, fish communities in the Murray region are impoverished in terms of both total abundance and species diversity. In particular, the four major inland commercial and/or recreational angling species all appear to be declining in the Murray region. Murray cod and freshwater catfish were not caught at all, while just two silver perch were recorded (both from the same location) and only 37 golden perch were recorded from eleven sites.

The findings for Murray cod are not in conflict with the fact that this species is still regularly caught by commercial and recreational fishers in some areas of the Murray region. This study was not a detailed survey or stock assessment of fish populations in rivers of New South Wales, rather it was a broad-scale study of fish communities and habitats at a set of sites representing the main freshwater ecological regions and river types in the state. As such, the findings of the study are applicable at the large spatial-scale of regions and river types as an indication of overall large-scale patterns in fish distribution and abundance. As the spatial scale of interest becomes smaller and more specific, for example focusing on individual species in specific rivers or river sections, it would not be unexpected that the occurrence and distribution of individual species would differ from that found at the larger spatial scale of region and river type. In the context of regional findings that a particular species is absent or has low abundance, the presence of discrete areas where that species is locally abundant, such as Murray cod in the River Murray, serves to highlight that the distribution of the species is highly fragmented.

Coastal streams proved to be more productive than inland rivers, in terms of both total numbers of fish caught and numbers of species recorded. Catches from slopes and lowland rivers were more homogeneous in coastal regions than in inland regions, with most species occurring relatively evenly across the river types. This finding may be a result of the different elevations used in this study to define the transition from lowland to slopes river types in the coastal and inland regions. In the Murray and Darling regions, an elevation of 300 m was used to mark the

boundary between lowland and slopes river types, but in the North Coast and South Coast regions, an elevation of 40 m was adopted because of the different topography of the coastal river plain and the different altitudinal distribution of geomorphic river types. However, it is apparent from this study (and from the analyses in Chapter 5) that there is little difference between broad-scale fish assemblages encountered above and below these broad boundaries.

Lowest numbers of individuals and species tended to occur in montane sites, which is not unexpected, given that habitat diversity and availability in montane rivers is lowest of the four habitat types sampled (Harris *et al.* 1996, Chapter 5). Montane sites in the Murray region were an exception to this, in that although only one native species was recorded (*Galaxias olidus*), it was present in large numbers. This result is consistent with other studies which have found that rivers with a low diversity of available habitats tend to contain fish communities with low species diversity (Lake 1982; Karr *et al.* 1986; Karr 1991).

Previously it has been reported that trout (rainbow trout, *Oncorhynchus mykiss* and brown trout, *Salmo trutta*) and mountain galaxias do not occur as sympatric species (McDowall and Fulton 1996). This study recorded trout at 12 of the 17 sites at which mountain galaxias were recorded, indicating that the presence of trout does not completely preclude the occurrence of mountain galaxias. Additional factors, including the availability of habitats which provide refuge from trout predation, are likely to limit the distribution and abundance of galaxiid species in montane rivers.

The apparent failure of native fish species to distinguish between riverine habitats in lowland and slopes reaches may reflect a lack of specialisation for particular habitat types within the Australian native fish fauna. It has been suggested that the unpredictability of the Australian climate, compared with other continents, has resulted in an aquatic fauna that is highly opportunistic in the way that individual species respond to favourable conditions (McDowall 1996; Harris and Gehrke 1994). At a much finer habitat scale, Australian native fish species still display preferences for specific habitats such as snags, pools and riffles (Chapter 6) which occur in both slopes and lowland rivers.

The large percentage of native fish species (62%) which have undergone reductions in range or abundance, or which have restricted distributions that make them particularly vulnerable to disturbance, is far higher than was previously thought to be the case in New South Wales. It is evident that practices in managing rivers and fisheries resources over the last ten years have been ineffective in protecting fish and their habitats. As a result, new approaches are required to managing fish and the rivers in which they live. One such approach is being developed in New South Wales to set environmental objectives for river flows and water quality (Harris *et al.* (in prep.)). However, current fisheries management strategies for native species in New South Wales focus on single species management and minimising destruction of fish habitats. Because single-species management does not take into account interactions with other species, it is difficult to see

how this approach can enhance the conservation of fisheries resources on a broad scale within New South Wales rivers, and elsewhere throughout Australia.

A change in focus from managing exploitation of individual species, to managing fish communities (Evans *et al.* 1987), is inherently attractive because of the complex interactions involved that predicate a broader perspective than is customary in managing freshwater fisheries. Furthermore, community-based management is likely to be more receptive to the condition of river environments, and thereby provide a far more robust assessment of ecological sustainability than stock assessments for individual species. One of the underpinning requirements of managing fish communities is that communities actually exist on a defined scale, and that they can be identified. This approach is examined in more detail in Chapter 5.

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