1 Introduction and general methods

INTRODUCTION

There is widespread concern in the New South Wales community over the condition of our rivers. This concern arises from the frequent occurrence of blue-green algal blooms, fish kills, pollution incidents, water-allocation conflicts and declining fish stocks. Issues specifically affecting New South Wales fish resources include the status of native freshwater fish populations, the distribution and abundance of alien fish species, especially carp, the effects of carp on the riverine environment, the effects of river regulation by dams, weirs and streamflow modification, degradation of riverine habitats, and the need for better tools for assessing and monitoring river health.

Despite the unprecedented level of concern, there is a serious lack of factual information on the nature and status of riverine biological resources in New South Wales. In particular, our knowledge of the condition of the State's freshwater fish and fisheries has many deficiencies. Exposing these deficiencies has also made clear the currently limited ability of agencies to monitor the condition of rivers and to assess their responses to improved management. Better monitoring tools are required. Data are also urgently needed on the extent of the invasion of our rivers by the alien pest fish, carp, and on the effects of carp on rivers and their biota. This knowledge is needed to guide decisions on potential control programs. Better understanding of the environmental effects of river regulation, and how to reduce these effects, is also urgently needed to steer the water industry toward more ecologically sustainable practices.

Clearly, research is needed to fill these serious gaps in our knowledge of rivers. Research is also needed to provide a baseline for future monitoring, tested methods for application elsewhere, and a survey structure that can be adopted by other groups for consistent monitoring of different riverine fauna and water-quality characteristics. The survey can be repeated in the future following droughts or floods to test for the effects on fish of these forms of disturbance, or to show any large-scale trends. Such research would also generate data to develop and test a standardised, regional predictive model to provide a tool for assessing and monitoring New South Wales rivers.

Responding to these research needs, this co-operative survey project, *Study of the Fish Resources of NSW Rivers* (short working title: the *NSW Rivers Survey*) was established. Resources were provided by NSW Fisheries, the NSW Resource and Conservation Assessment Council and the Cooperative Research Centre for Freshwater Ecology.

Objectives of the NSW Rivers Survey

The project's objectives addressed a series of knowledge gaps identified below:

- To study the fish of New South Wales rivers to determine the health of these rivers and the status of their fish resources.
- To determine the distribution and ecological effects of carp and other alien fish species.
- To develop a better understanding of the ecological effects of river regulation.
- To establish and test a standardised predictive model for monitoring river health using fish-community assessments.
- To provide the basis for a standardised survey structure to be adopted by other agencies involved in monitoring New South Wales rivers.

No similar systematic, broad-scale surveys of riverine fish fauna have been completed in Australia. However, riverine fish-community research is in progress through the Tasmanian Inland Fisheries Commission; in Queensland through Griffith University and the Department of Natural Resources; in various parts of Victoria through the Victorian Marine and Freshwater Resources Institute (Koehn and O'Connor 1990); in the Northern Territory through the Environmental Research Institute of the Supervising Scientist and in several parts of this State through NSW Fisheries and the Cooperative Research Centre for Freshwater Ecology.

The survey can be repeated in the future, either partly or in its entirety, to test for the effects of natural disturbances such as droughts or floods, to measure the effects of altered river system management, or to detect any trends in the condition of rivers and fisheries.

GENERAL METHODS

Survey design

The guiding principles of the survey design were to ensure that sampling sites were representative of the main kinds of riverine habitats in New South Wales, that they were chosen at random to avoid subjective bias and to permit extrapolation of results, and to provide sufficient replication of sites to allow formal testing of hypotheses concerning fish distributions in New South Wales.

Stratifying the survey by geographic regions

Deficiencies in knowledge of the ecology of Australian rivers mean that ecological regions have not yet been well defined for riverine fauna. Therefore, to ensure adequate representation of the main river drainages of New South Wales in the survey, we divided the State into four geographic regions based on the main river-drainage divisions and on the main discontinuities in distribution patterns of fish species (McDowall 1996; Paxton *et al.* 1989). The four regions therefore constituted presumptive ecological regions to be validated during the course of the study:

- <u>DARLING REGION</u> - All New South Wales tributaries of the Darling River.
- <u>MURRAY REGION</u> - All New South Wales tributaries of the Murray River upstream of its confluence with the Darling River.
- <u>NORTH COAST REGION</u> - Eastern-flowing streams from the Wyong River northwards.
- <u>SOUTH COAST REGION</u> - Eastern-flowing streams from the Hawkesbury River southwards.

Stratifying the survey by river-reach types

The State of New South Wales possesses a great variety of rivers. These vary from small headwater creeks to expansive inland lowland reaches; from flow patterns generated by winter rainfall in the south, to summer-dominated flows of the north; and from wildly variable streams in the west of the state to (relatively) more predictable south-eastern alpine drainages.

Rivers can be classified according to their catchment size, their order in the drainage pattern, their gradients, flows, or a whole series of ecological classifications. Despite their enormous diversity, it was possible to represent broadly the main types of New South Wales river reaches within each of the four geographic regions in the following relatively simple classification:

- UNREGULATED LOWLAND - large* river reaches below 300 metres altitude (for the Murray and Darling regions), and between 40 metres altitude and the tidal limit (for coastal regions), and in which flows are either completely natural, or where tributary inflows create a minimally regulated flow regime despite the existence of a large dam upstream.
- REGULATED LOWLAND - as above, but with flows that are substantially modified from the natural condition by the operation of a dam upstream.
- SLOPES - (for the Murray and Darling regions) - river reaches between 300-700 metres altitude, either above or below waterfalls or large dams**
- SLOPES - (for coastal regions) - river reaches between 40-700 metres altitude, and not above waterfalls or large dams.**
- MONTANE - river reaches above 700 metres altitude

---

* 'Large' LOWLAND river reaches were identified as those listed as a 'waterway' by NSW Department of Land and Water Conservation (NSW Water Resources, undated), or which had a similar catchment area.
** Different criteria were needed for SLOPES reaches in the coastal and inland regions, and were established after studying a range of known representative sites. The steeper, younger topography of eastern slopes of the Great Dividing Range means that river channel morphology differs from inland SLOPES sites. Thus the stream gradient, sequence of pools and riffles, substrate character, sinuosity and other characteristics of SLOPES rivers are found at lower altitudes in coastal rivers than those inland. The fish fauna of coastal streams is dominated by diadromous species (*i.e.* migratory to and from the sea), so that the numerous high waterfalls of coastal rivers, and large dams, have a more profound impact on the fauna. This feature was therefore included in the criteria for SLOPES sites in the coastal regions.

The terminology adopted here for 'unregulated' and 'regulated' differs from the legislative definitions applied by the NSW Water Act, which define regulated rivers as those rivers where flows are regulated by dams owned or operated by the Department of Land and Water Conservation. Consequently, some sites designated as regulated in this study are identified as unregulated by NSW legislation. Similarly, the definitions adopted for this study pre-date the terminology of 'controlled' and 'uncontrolled' rivers used for the purpose of setting river flow objectives for the NSW Water Reform Package announced by the Government in August 1997.

None of these simple classifications adequately reflects the continuum of river-regulation intensity in New South Wales rivers. This continuum ranges from rivers reaches whose flows are totally unmodified from the natural condition, to reaches whose flows are completely determined by dam releases. However, neither the methods nor the data existed during the initial stages of this project to classify lowland rivers in New South Wales according to their degree of regulation. Consequently, lowland rivers were simply classified subjectively according to whether their flows were predominantly regulated or unregulated. For this reason, river reaches nominally classified as regulated represent a range of regulated flow regimes, and conversely, nominal unregulated rivers include reaches whose flows are not modified by dams as well as some whose flows may be altered by dam releases, extraction, or by impoundment in weirs from time to time. Comparisons between these river-reach types therefore indicate differences in fish communities between opposite ends of the continuum of flow regulation. For convenience throughout this report, minimally regulated rivers are referred to as unregulated, and are compared to other rivers which are, in comparison, heavily regulated.

Replicate river reaches

The need to compare different river reaches of the same type and in the same region, and to learn how representatives of river types varied from one another, required the sampling of multiple replicates. Five replicate reaches within each river type and region were therefore selected for study.

Different criteria were set for the length of river reaches to account for the widely varying total quantity of each river type in the State and to enable application of the procedure to ensure dispersion of survey sites. Thus the very extensive unregulated lowland reaches in the inland regions were defined as being 50 km long, whilst the more restricted regulated lowland reaches were set at 20 km. But, because lowland reaches of rivers are much shorter in coastal regions, both regulated and unregulated reaches in the North Coast and South Coast regions were set at 5 km long. It was difficult to find five replicate, truly unregulated lowland rivers in the two regions, and so the rivers selected represent a random selection of the least regulated rivers. All slopes and montane reaches were set at 10 km long.

A minimum-catchment-size criterion for river reaches was also set; this required a catchment size greater than 20 km^2, and that selected reaches were of stream order 3 or greater (Newbury and Gaboury 1988).

Exclusion and inclusion of research areas

NSW Fisheries Research Institute is involved in fish-community analyses in several other current research projects. Rather than risk duplication of effort and waste of scarce research resources, it was decided to exclude from the NSW Rivers Survey those catchments that were already being sampled. Areas excluded from the survey included parts of the Hawkesbury, Macintyre, Myall, Warrego and Paroo rivers. In contrast, it was also planned to maximise the value of the survey by coordinating sampling-site selection with a second project proposed to elucidate the effects of river regulation by large dams for irrigation using the same sampling methods. Eight particular reaches of the Murrumbidgee, Macquarie and Bogan rivers and Billabong Creek were therefore specifically included among the sites for the NSW Rivers Survey.

Random selection of river reaches for sampling

A fundamentally important decision at the outset was to determine how to select the reaches to be surveyed. The key principle was that any selection process that allowed biased site selection would destroy our capacity to extrapolate the results from survey sites to the rest of the State's rivers. Such a bias is unavoidable unless sites are selected at random. Bias would become evident as a tendency to choose supposedly undisturbed sites, sites that were convenient, attractive or well known, or sites that were believed, on some basis, to be 'representative'. The only way in which we could ensure the survey provided dependable results for the State's rivers as a whole, other than sampling a far greater number of sites, was to implement a method of random selection.

But unrestricted randomising of the selection of river reaches for survey sampling could potentially have resulted in a clumping of sites in one area, with an absence of sites from another. This outcome would have reduced the coverage and thus the benefits of the survey, so procedures were designed to ensure a reasonable degree of dispersal of randomly selected reaches. Rivers were grouped, on the basis of their approximate length within New South Wales, as *Large* (the Murray and Darling), *Medium* (the Richmond, Clarence, Macleay, Manning, Hunter, Shoalhaven, Tuross, Snowy, Murrumbidgee, Lachlan, Macintyre, Barwon, Gwydir, Namoi, Castlereagh, Macquarie, Bogan, Billabong, Great Anabranch) and *Small* (the remaining rivers). A selection rule was established whereby a maximum of three replicate reaches could be selected in total in each *Large* river, two from each *Medium* river and one from each *Small* river.

To further guarantee dispersion of selected reaches, a second rule required a minimum of three reach-lengths to separate all selected reaches, except for regulated reaches, for which a minimum one-reach separation was necessary because of the restricted total extent of this river-reach type, especially in coastal drainages. In addition to ensuring dispersion of selected sites, this rule also ensured that a practical level of independence was maintained between sites. Independence is a critical factor in site selection in enabling results of the survey to be extrapolated across New South Wales. Lack of independence among sites might result in one selected site being unduly influenced by conditions at a nearby upstream site, creating a bias in the results that is not representative of other rivers of that particular type.

A "modified-random" selection procedure was developed to select river reaches at random within the foregoing constraints. It was based on the New South Wales 1:100,000 topographic map series. A computer program was written to produce random latitude and longitude coordinates. Each of these coordinates was located on the relevant map sheet, then the slope and stream-drainage lines were followed downstream from that point until the designated type of river reach, as defined by the criteria above, was encountered. Subject to the two dispersion rules above, that reach was then selected as a replicate for that river type and region. Five replicate river reaches were selected within each region and river type. The stratified structure of the survey is shown in Figure 1.1.

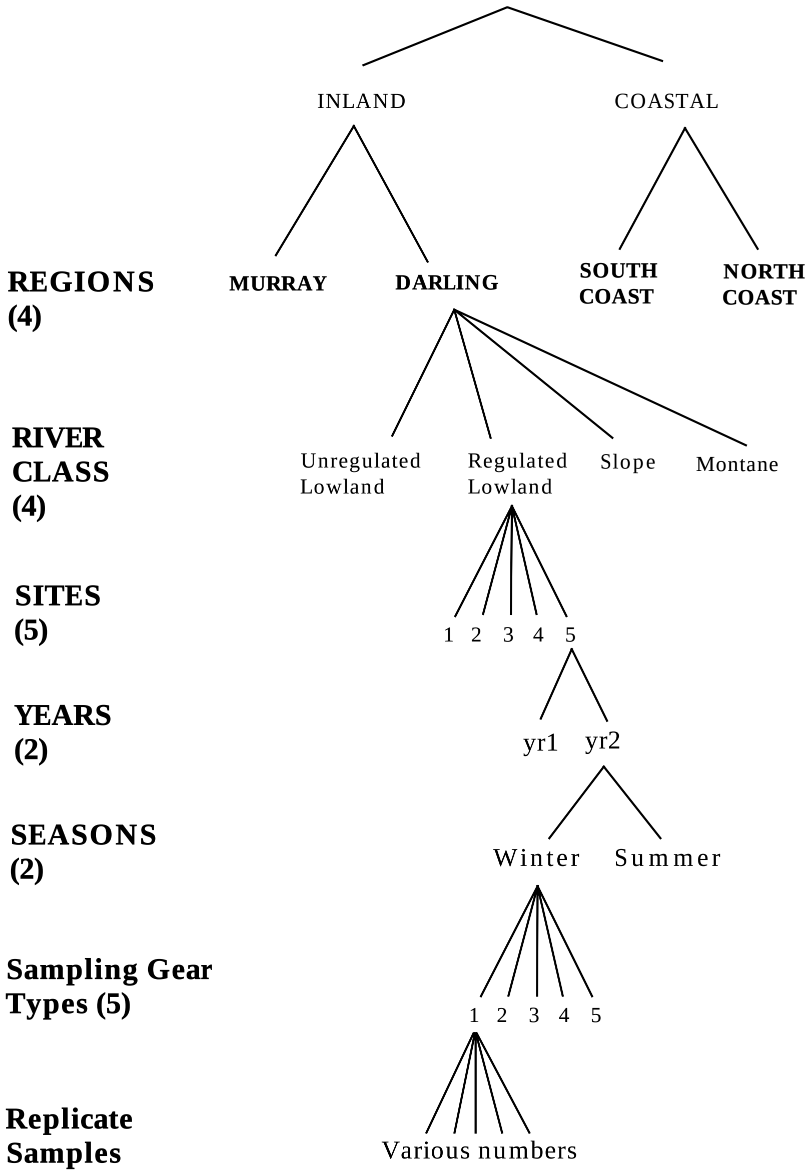

Figure 1.1 NSW Rivers Survey sampling design.

Selecting sampling sites within river reaches

Within each randomly selected river reach, a sampling site was chosen on practical considerations, chiefly access, provided that the site was representative of the river-habitat characteristics of the reach as a whole, and was not affected by exceptional influences, such as being within urban areas. Documentation of sites included precise location data using 1:100,000 maps and a Global Positioning System (GPS), plus habitat characteristics, and logistic information. These data were recorded in a *NSW Rivers Survey Sites Database* (Hartley *et al.* 1996).

Excluding sampling sites that were grossly degraded

In the process of choosing sites, it became clear that the modified-random selection process had chosen some reaches that were grossly degraded. These were parts of the Castlereagh River between Coonamble and Walgett, the Goulburn River at Sandy Hollow, and the Cockburn River near Moonbi, and they appeared so severely degraded that they were unlikely to support more than the smallest relict fish community. Rather than continue with the survey plan and expend sampling effort at these reaches, three alternative reaches were selected to replace them. But, since they had been identified as reaches to be sampled, these degraded rivers were classified separately and their fish communities were also assessed briefly and independently of other sites, using far less sampling resources.

Sampling frequency and random allocation of sampling times within seasons

Fish communities vary over daily, seasonal and annual time-scales. The sampling regime was designed to minimise sources of variation in the data arising from these differences. On a daily scale, sampling activities were planned at standard times, using the time of sunset as a base to avoid seasonal bias. The 80 sites were divided into "sampling runs" on the basis of their geographic location and river type. This breakdown resulted in a total of 15 sampling runs with an average of six sites to be sampled on each trip. A typical trip lasted six to eight days, and an estimated total of approximately 270 person-days was required for each full seasonal round of sampling. Before starting each sampling round, the order in which the runs were to be completed was selected at random to avoid any temporal bias. Each round of fieldwork was completed within a season of six months, on approximate ‘summer’ (October-March) and ‘winter’ (April-September) schedules.

Differences between summer and winter are a major source of variation, so the survey design required sampling in both of the major seasons. Since it is not possible to make a valid comparison between seasons without collecting samples more than once in each season, the survey plan extended over two full years to produce two winter and two summer samples, in addition to the five spatial replicates.

Survey sampling methods

Each fish species has different behaviour patterns and habitat preferences. Because of these differences, the catchability of each species in a particular type of fishing gear is likely to differ from that of other species. Since it was a primary requirement of the survey sampling methods to achieve a comprehensive record of the distribution of fish species, a suite of five fish-sampling methods was chosen, on the basis of past experience, to minimise the effects of these differences in catchability.

Fish sampling methods chosen for use in the survey were boat electrofishing, back-pack electrofishing, fyke nets, panel nets, and Gee-traps. These methods (detailed below) were chosen because they can be used in a variety of habitats and they complement each other so that all fish species, all habitat-preference groups of fish, and most sizes of fish other than larval and early juveniles are sampled. They are also minimally destructive methods, as we wished to avoid modifying the fish communities at survey sites. The project received Animal Care and Ethics certification.

The sampling design of the survey is outlined in Table 1.1 below, including the distribution and timing of use for the suite of gear types at the various kinds of river sites. Different numbers of sampling-gear replicates were used, to compensate for habitat-size differences among the montane, slopes and lowland river types. This helped to standardise sampling effort according to the amount of fish habitat available. Since the level of experience of the people involved with the sampling techniques varied, we conducted a Sampling Methods Workshop to familiarise all staff with the sampling techniques used in the survey and to ensure a suitable level of consistency in the application of sampling methods. The workshop was conducted at Warragamba Dam Conference Centre over 23-25 May 1994.

Table 1.1 Outline summary of the suite of sampling methods applied at sites in the different river types.

River Type(and approximate site length)	Sampling Gear	Timing, number, or size of samples
<u>Montane</u>	3 fyke nets,	3 h < sunset - 2 h > sunset
(~ 400 m)	9 Gee traps	3 h < sunset - 2 h > sunset
	2 panel nets	2 h < sunset - 1 h > sunset
	Back-pack electrofisher	2 x 50 m pool-edge habitats, 2 x 50 m riffle* habitats
<u>Slopes</u>	3 fyke nets	3 h < sunset - 2 h > sunset
(~1000 m)	9 Gee traps	3 h < sunset - 2 h > sunset
	3 panel nets	2 h < sunset - 1 h > sunset
	Boat Electrofisher	10 x 2 minute shots (weighted if site too small for 10 shots)
	Back-pack electrofisher	2 x 50 m riffle *
<u>Lowland</u>	3 fyke nets	3 h < sunset - 2 h > sunset
(~1000 m)	9 Gee traps	3 h < sunset - 2 h > sunset
	3 panel nets	2 h < sunset - 1 h > sunset

Boat electrofisher	10 x 2 minute shots (weighted if site too small for ten shots)

* Linear measurement, sampling band equal to the usual effective width of the back-pack electrofishing operation. Where riffles were difficult to identify due to low flow, predicted riffle area was sampled.

Boat electrofishing

Two 5m electrofishing boats, FRV Electricus and FRV AC/DC, were used in the survey. An on-board petrol-powered 7.5 kW Smith-Root generator produces an electric current which passes to a rectifier unit which produces a pulsed DC waveform and an electric field is produced in the water through large electrodes (Cowx 1990; Cowx and Lamarque 1990). Fish of all species and sizes are susceptible to the field, being attracted near the electrodes then immobilised, but there are variations in sensitivity (Growns et al. 1996).

The sampling procedure involved electrofishing all navigable habitats within the river channel, with one operator controlling the boat and two operators situated at the front of the boat controlling the fishing operations. Electrofishing was carried out in standardised two-minute replicates or "shots" during which immobilised fish were netted from the river and placed in a live-well in the boat to recover. Wherever possible 10 shots were made at each site. In a few cases where the habitat area was too small, fewer shots were made, and the catch data were subsequently adjusted to account for this. This technique is most efficient in areas of low turbidity (so dip netters can see the fish more easily) and mid-range conductivity (100-500 μ S cm^{-1}).

Back-pack electrofishing

Back-pack electrofishing uses the same principles as boat electrofishing, but on a smaller scale. This method is used in shallow, wadable pools and riffles (to a maximum depth of operator hip height) that are unsuitable for boating. Electricity is provided from batteries then transferred into the water, as a pulsed DC waveform, via a back-pack unit which is carried by the operator, with portable electrodes. Immobilised fish are dip-netted from the water by an assistant, and placed in a bucket of water for recovery. All species of freshwater fish can be caught using a back-pack electrofisher. Fishing effort was standardised by fishing set bank lengths of riffle and pool stream habitats (Table 1.1).

Fyke nets

Fyke nets are medium-sized traps which consist of two parts, a six-metre-long wing or wall of net to direct fish into the body of the trap itself, and three internal funnels which taper progressively towards the end of the trap and prevent the escape of fish. The nets were set obliquely to the stream bank, and facing downstream to catch fish moving against the direction of flow. Trapped fish were retained in the 'cod-end' at the base of the trap until being examined and released. Fyke nets were made of 30mm stretched-mesh netting.

Gee traps

Gee traps are small (350 mm long, 200 mm diameter) funnel traps of galvanised wire mesh (3 mm square mesh) and consist of two interlocking halves, each of which has a funnel entrance tapering to a 15 mm opening (Swales 1987). Traps were set un-baited on the stream bed and anchored to the bank or a snag. Large numbers of traps were used (nine per site) to sample a variety of habitats at each site. Gee traps sample small species of fish (i.e.<150 mm length).

Panel nets

Panel nets consist of a series of gill-nets made of nylon monofilament arranged in a wall of diamond-shaped mesh which entangles fish around the head or body. The panel nets used in the survey consist of three sections of different mesh (38 mm, 67 mm, and 100 mm, stretched mesh size), with a 5 m length of hung net for each mesh size. The panels were arranged in a randomly varying sequence to avoid any location bias. Nets had a drop of 2 m, were rigged to sink, and hung so they could be set in flowing water. Fish commonly caught in panel nets include highly mobile species (e.g. mullet), fish with many spines (e.g. Australian bass), and benthic fish like freshwater catfish. Panel nets are most efficient at sampling large and medium-sized fish, in deep and/or turbid water, and in this way they complement the catches from boat electrofishing (Growns *et al.* 1996).

Fish data recorded

As soon as possible after each fishing activity, all fish were identified to species (using standard reference texts, especially McDowall 1980 and Allen 1989), and counted. The catch or subsamples (see section on subsampling in this chapter) were then measured for length to the nearest 1 mm (fork length for fork-tailed species, total length for others). Each fish was also quickly examined on both sides for diseases, injuries, parasites, or other abnormalities before being returned alive to the water. Any fish which could not be identified with certainty was preserved in 70% ethanol and returned to the laboratory for identification. Due to the difficulty in differentiating between the three species of carp gudgeons *(Hypseleotris klunzingeri, H.* sp. 4 and *H.* sp. 5) and the fact that two of them are presently undescribed, all these species were pooled as *Hypseleotris* spp. During the electrofishing operations the presence of large numbers of small, schooling fish such as *Retropina semoni* and *Gambusia holbrooki* sometimes resulted in the need to estimate the abundance of these fish once they were definitely identified, rather than providing exact counts. These fish were recorded as 'observed'.

Due to the large number of eels at some sites and the difficulty in measuring and handling these fish, it was decided during early sampling that electrofished eels would not be netted or measured. Instead, their lengths were estimated and individuals were recorded as ‘observed’.

Subsampling procedure

At sites where catches of a species were large, subsampling was used to limit the numbers of fish to be measured in length and examined for abnormalities. For any single unit of gear (i.e. a particular trap or net, electrofishing shot, etc.), only ten fish, selected at random, of any particular species were measured. The nine Gee traps were treated as a single unit of gear, with the catches from all nine of them being combined. The first ten fish of each species from the total Gee trap catch were measured in length and examined. All fish caught in all gear units were counted and identified to species in the field, or occasionally preserved for later identification in the laboratory when field identification was difficult.

Habitat assessments

Habitat conditions were measured at each site on every visit as part of the standard data recording method established for NSW Fisheries’ *Freshwater Sampling Database* (Harris 1996). Habitat characteristics were assessed using measurements of variables which include dissolved oxygen (D.O.), pH, conductivity, turbidity and temperature. A subjective grading system was used for features including flow, depth, width, substrate, vegetation, cover, level, and turbidity.

Calibration

Fish catches in the routine survey samples indicate the relative abundance, or population density, of particular species at each site. These catches cannot show the total, or absolute, numbers of fish at any site. Despite the intensity and coverage of the sampling effort applied, only a proportion of any population will be caught and counted by practical sampling methods such as those used in this study. While this assessment of relative abundance is in itself very valuable information, it is possible, and more valuable, to estimate the absolute numbers of fish present. To achieve this objective, a calibration experiment was done during the fourth sampling round, in December 1995 - May 1996, to estimate the absolute abundance and biomass of fish populations and hence estimate the relationship between catches in standard survey sampling and total population size. Calibration was done in summer at seven sites, representing the inland and coastal geographic areas and lowland, slopes and montane river types.

Fine-mesh stop-nets at the upper and lower limits of the site were used to confine fish. The site was then fished repeatedly. After first completing the normal survey-sampling procedure, the optimum amount of sampling gear for the site was used consistently to sample for a further four 24-hour periods. Following the usual examinations and data-recording, the captured fish were released outside the stop-netted area.

Estimates of the absolute abundance of fish were derived statistically using population-depletion methods. The relationship between estimated total abundance and the catch from the normal survey sample was then calculated for each species to provide estimates of the ratio between absolute abundance and rivers survey catches for all represented species at all of the 80 sites.

The rejected river reaches

Three sites were initially selected using the modified-random site selection process, but were later rejected after a site inspection because they were grossly degraded, and unlikely to support a viable fish community. These sites were sampled only once during the survey, in October 1995, when it was thought the catchability of fish would be high. Back-pack electrofishing was the main technique used, and in the Cockburn River, where there was deep water, three panel nets were set to fish during the morning (Table 1.2). The habitat and fish found in these sites are described in detail in the NSW Rivers Survey Data Report (Harris *et al.* 1996).

Table 1.2 Sampling methods used for rejected sites.

Site	Sampling Gear	Sampling Effort
Cockburn River	3 panel nets	4 hours each net
	Back-pack electrofisher	4 x 50 m pool-edge habitats*
	2 x 50 m riffle**	
Goulburn River	Back-pack electrofisher	6 x 50 m riffle**
Castlereagh River	Back-pack electrofisher	6 x 50 m pool**

* Linear measurement, sampling band equal to the usual effective width of the back-pack electrofishing operation.

** Where riffles were difficult to identify due to low flow, predicted riffle area were sampled.

Data verification

After returning from the field, datasheets were photocopied and the originals put in a safe. Data were later stored on computer in the database management application, Advanced Revelation.

Double entry and cross-checks

Data were entered twice by independent operators and the two data sets compared using a computer program to identify differences in data entry. Discrepancies were checked on the originals or with the field staff concerned, and the necessary corrections were made in the computer data set.

The data-recording form was divided into three sub-components to record information on fish catches, other biological information, and habitat details. Because the catch and biological data are interlinked it was possible to cross-check part of the data recording by using a program which identified species that had occurred in the biological part of the data form but not the catch, and *vice versa*.

Range checks

Data were transferred into a spreadsheet in Microsoft Excel (Version 5) for further checking and analysis. Range checks were done on fish lengths, catch location, and the water-quality variables. To check fish length and catch location data, individual species were filtered out and sorted by either site number or length. Outliers or unusual recordings were checked on the original data forms or with the field staff concerned. Water-quality variables were divided into the different regions, river types and seasons, then individually sorted so the extremes could be checked and any errors identified.

Water-quality recording calibration

The water-quality variables of temperature, dissolved oxygen, conductivity, turbidity, and pH were collected during the survey using a Horiba U10 Water Quality Checker. Calibration of the Horiba was done either automatically or manually during the term of the survey. Manual calibration is the most accurate, but is more time consuming and was therefore only done in the periods between sampling seasons. Auto-calibration was quicker and simpler and was performed at the start of each trip.

REFERENCES

Allen G.R. (1989) *Freshwater Fishes of Australia.* T.F.H. Publications, Neptune City New Jersey.

Cowx, I.G. (1990) *Developments in Electric Fishing.* Fishing News Books, Oxford, UK.

Cowx, I.G. & Lamarque, P. (eds). (1990) *Fishing with Electricity; Applications in Freshwater Fisheries Management.* Fishing News Books, Oxford, UK.

Growns, I.O., Pollard, D.A, & Harris, J.H. (1996) A comparison of electric fishing and gillnetting to examine the effects of anthropogenic disturbance on riverine fish communities. *Fisheries Management and Ecology*, **3** (1), 13-24.

Harris J.H. (1995). The use of fish in ecological assessments. *Australian Journal of Ecology,* **20** (1), 65-80.

Harris J.H., & 25 others. (1996). The NSW Rivers Survey. Final report, Part 1 - Data, June 1996. NSW Resource and Conservation Assessment Council - Project G8. NSW Fisheries Research Institute & The Cooperative Research Centre for Freshwater Ecology.

Hartley S., Bruce A., Faragher R., Harris J., Marsden, T., Matthews J., Pethebridge R., Stuart I. and Thorncraft G. (1996). NSW Rivers Survey Sites Database. NSW Fisheries Research Institute and Cooperative Research Centre for Freshwater Ecology, Sydney.

McDowall, R.M. (ed) 1980. *Freshwater Fishes of South-eastern Australia*. Reed, Sydney.

Koehn, J.D. and O'Connor, W.G. (1990). *Biological information for the management of native freshwater fish in Victoria*. Government Printer, Melbourne.

Newbury, R. & Gaboury, M. (1988) The use of natural stream characteristics for stream rehabilitation works below Manitoba Escarpment. *Canadian Water Resources Journal*, **13** (4), 35-51.

Paxton J. R. , Hoese D.F., Allen G.R. and Hanley J.E. (1989). *Zoological Catalogue of Australia. Vol. 7, Pisces*. AGPS, Canberra.

Swales, S. (1987). The use of small wire-mesh traps in sampling juvenile salmonids. *Aquaculture & Fisheries Management* 18: 187-195.

2 General results

Summary

General results of the NSW Rivers Survey are provided in this section of the report as summary tables with a brief description in most cases. Survey sampling produced 50,438 fish belonging to 55 species. A total of 39 native freshwater species from 25 genera and 19 families were recorded, together with ten estuarine species. A review of all available sources indicated that 55 native freshwater species could be predicted in New South Wales, but 16 of these predicted species, included six classed as threatened, were not caught. Six species of alien fish from six genera were caught and they constituted 18.4% of the total catch of fish. Detailed results of these and other particular components of the work are presented in specific chapters. Survey results dealt with in this chapter include the following topics:

Page

Sites sampled in the NSW Rivers Survey

Eighty survey sites selected for sampling in the four presumptive ecological regions of New South Wales (South Coast, North Coast, Darling and Murray) are listed in Table 2.1 and illustrated in Figure 2.1. Sites are also classified according to the four principal river types (montane, slopes, regulated lowland and unregulated lowland). Brief summary details of the sites are given, full details are provided in the NSW Rivers Survey Sites Database (Hartley *et al.* 1996).

Table 2.1 List of sites sampled in the NSW Rivers Survey.

Site no.	Region	River type	Site code#	Waterway	Latitude	Longitude	Nearest town	Altitude (m)	Catchment area (km²)
1	Darling	Montane	DM1	Fish R	33° 31' 39"	149° 51' 50"	Tarana	760	928
2			DM2	MacDonald R	30° 37' 08"	151° 06' 18"	Bendemeer	740	1794
3			DM3	Gwydir R	30° 28' 04"	151° 21' 33"	Yarrowyck	760	861
4			DM4	Campbells R	33° 40' 45"	149° 37' 10"	Rockley	760	473
5			DM5	Duckmaloi R	33° 46' 39"	149° 54' 26"	Edith	1020	73
6		Regulated	DRL6	Namoi R	30° 45' 07"	150° 05' 04"	Boggabri	240	16740
7		Lowland	DRL7	Darling R	33° 22' 15"	142° 32' 18"	Pooncarie	60	437477
8			DRL8	Darling R	33° 50' 38"	142° 00' 42"	Wentworth	40	439687
9			DRL9	Gwydir R	29° 46' 40"	150° 25' 15"	Bingara	280	7807
10			DRL10	Macquarie R	32° 38' 14"	149° 04' 53"	Wellington	300	12374
11		Slopes	DS11	Peel R	30° 56' 51"	150° 49' 02"	Attunga	330	3994
12			DS12	Turon R	33° 04' 33"	149° 38' 53"	Sofala	590	1423
13			DS13	Talbragar R	32° 12' 57"	148° 51' 02"	Dunedoo	400	4050
14			DS14	Little R	32° 35' 45"	148° 41' 49"	Wellington	320	1924
15			DS15	Horton R	29° 54' 07"	150° 20' 26"	Upper Horton	360	1890
16		Unregulated	DUL16	Darling R	30° 24' 59"	145° 25' 03"	Bourke	100	218777
17		Lowland	DUL17	Bogan R	30° 00' 04"	146° 20' 51"	Bourke	120	30239
18			DUL18	Mehi R	29° 28' 16"	149° 54' 00"	Moree	200	10867
19			DUL19	Bogan R	31° 30' 43"	147° 10' 28"	Nyngan	180	16413
20			DUL20	Macquarie R	30° 13' 07"	147° 32' 51"	Carinda	125	15001
21	Murray	Montane	MM21	Belubula R	33° 34' 09"	149° 15' 12"	Blayney	860	248
22			MM22	Queanbeyan R	35° 36' 58"	149° 20' 52"	Queanbeyan	760	500
23			MM23	Bredbo R	35° 59' 46"	149° 12' 28"	Bredbo	740	686
24			MM24	Cooma Ck	36° 13' 38"	149° 07' 15"	Cooma	770	186
25			MM25	Retreat R	34° 03' 38"	149° 37' 57"	Black Springs	980	203
26		Regulated	MRL26	Bundidgerry Ck	34° 45' 39"	146° 36' 26"	Narrandera	160	21499
27		Lowland	MRL27	Murray R	36° 07' 29"	144° 48' 19"	Echuca	100	50269
28			MRL28	Tumut R	35° 17' 15"	148° 12' 51"	Tumut	260	2751
29			MRL29	Colombo Ck	35° 16' 26"	145° 57' 30"	Urana	120	22247
30			MRL30	Murrumbidgee R	34° 55' 00"	148° 32' 48"	Bookham	280	11025
31		Slopes	MS31	Lachlan R	34° 25' 14"	149° 03' 32"	Rugby	460	2025
32			MS32	Goodradigbee R	35° 09' 15"	148° 41' 40"	Wee Jasper	380	1035
33			MS33	Boorowa R	34° 15' 20"	148° 47' 17"	Boorowa	520	1294
34			MS34	Abercrombie R	33° 57' 24"	149° 19' 24"	Tuena	440	2616
35			MS35	Yass R	34° 53' 30"	148° 59' 53"	Yass	375	866
36		Unregulated	MUL36	Lachlan R	33° 39' 10"	145° 15' 11"	Hillston	100	55479
37		Lowland	MUL37	Murray R	36° 02' 50"	147° 55' 49"	Tintaldra	230	5378
38			MUL38	Murrumbidgee R	34° 43' 01"	143° 17' 49"	Balranald	60	86467
39			MUL39	Wakool R	34° 57' 29"	143° 28' 39"	Kyalite	60	34666
40			MUL40	Billabong Ck	35° 42' 00"	146° 43' 59"	Walbundrie	180	2812

(continued)

Site code consists of first letter(s) of region, first letter(s) of river type, then site number.

Table 2.1 (continued)

Site no.	Region	River type	Site code#	Waterway	Latitude	Longitude	Nearest town	Altitude (m)	Catchment area (km^2)
41	North	Montane	NCM41	Blicks R	30° 13' 19"	152° 30' 13"	Dundurrabin	700	152
42	Coast		NCM42	Nowlands Backwater	30° 11' 52"	152° 30' 13"	Guyra	1080	152
43			NCM43	Nowendoc R	31° 34' 06"	151° 44' 59"	Nowendoc	860	270
44			NCM44	Sara R	30° 11' 52"	152° 00' 19"	Guyra	1240	156
45			NCM45	Gara R	30° 26' 52"	151° 49' 19"	Guyra	1120	349
46		Regulated	NCRL46	Richmond R	28° 51' 29"	153° 00' 59"	Casino	20	1813
47		Lowland	NCRL47	Hunter R	32° 34' 01"	151° 08' 17"	Singleton	40	16324
48			NCRL48	Emigrant Ck	28° 47' 58"	153° 30' 38"	Tintenbar	15	23
49			NCRL49	Williams R	32° 25' 56"	151° 45' 41"	Dungog	40	658
50			NCRL50	Rocky Ck	28° 42' 32"	153° 23' 01"	Lismore	40	107
51		Slopes	NCS51	Ellenborough R	31° 26' 30"	152° 27' 28"	Ellenborough	160	1052
52			NCS52	Clarence R	28° 58' 49"	152° 33' 29"	Tabulam	120	6671
53			NCS53	Macleay R	30° 49' 18"	152° 31' 13"	Bellbrook	60	6271
54			NCS54	Hunter R	32° 14' 12"	150° 52' 26"	Muswellbrook	60	3848
55			NCS55	Gloucester R	31° 55' 12"	152° 03' 00"	Gloucester	100	1586
56		Unregulated	NCUL56	Wilsons R	31° 14' 19"	152° 36' 47"	Port Macquarie	40	146
57		Lowland	NCUL57	Orara R	29° 49' 23"	152° 53' 26"	Coutts Crossing	40	1305
58			NCUL58	Karuah R	32° 22' 48"	151° 57' 10"	Stroud	30	743
59			NCUL59	Clarence R	29° 33' 14"	152° 37' 54"	Gordon Brook	20	9884
60			NCUL60	Leycester Ck	28° 48' 17"	153° 15' 35"	Lismore	40	894
61	South	Montane	SCM61	Bombala R	36° 48' 23"	149° 17' 20"	Bombala	740	101
62	Coast		SCM62	Eucumbene R	35° 53' 30"	148° 30' 52"	Adaminaby	1340	73
63			SCM63	Wullwye Ck	36° 23' 30"	148° 54' 39"	Berridale	805	383
64			SCM64	Coxs R	33° 33' 03"	150° 07' 24"	Lithgow	700	500
65			SCM65	Delegate R	37° 01' 58"	148° 56' 57"	Delegate	750	325
66		Regulated	SCRL66	Shoalhaven R	34° 53' 59"	150° 25' 48"	Nowra	20	6660
67		Lowland	SCRL67	Mangrove Ck	33° 20' 06"	151° 07' 30"	Mangrove Mtn	10	214
68			SCRL68	Brogo R	36° 39' 44"	149° 50' 40"	Bega	10	771
69			SCRL69	Woronora R	34° 02' 52"	151° 00' 15"	Sydney	20	135
70			SCRL70	Nepean R	33° 52' 04"	150° 38' 07"	Wallacia	35	1789
71		Slopes	SCS71	Snowy R	36° 48' 08"	148° 24' 17"	Jindabyne	340	473
72			SCS72	Towamba R	37° 00' 09"	149° 37' 00"	Burragate	180	484
73			SCS73	Deua R	35° 45' 38"	149° 55' 18"	Moruya	60	866
74			SCS74	Tuross R	36° 11' 55"	149° 45' 31"	Bodalla	70	945
75			SCS75	Bemboka R	36° 39' 55"	149° 38' 43"	Bemboka	100	326
76		Uregulated	SCUL76	Clyde R	35° 26' 31"	150° 14' 23"	Brooman	30	838
77		Lowland	SCUL77	Wallagaraugh R	37° 21' 24"	149° 42' 06"	Eden	35	475
78			SCUL78	Tuross R	36° 07' 24"	149° 59' 57"	Bodalla	15	1614
79			SCUL79	Buckenbowra R	35° 44' 00"	150° 04' 00"	Mogo	20	242
80			SCUL80	Wonboyn R	37° 14' 45"	149° 49' 23"	Wonboyn Lake	10	169
81	Z Darling*	Slopes	DZS81	Cockburn R	31° 02' 17"	151° 09' 37"	Limbri	480	-
82	Z North Cst*	Slopes	NCZS82	Goulburn R	32° 20' 56"	150° 34' 25"	Denman	130	-
83	Z Darling*	Unregulated Lowland	DULZ83	Castlereagh R	30° 25' 06"	148° 09' 44"	Coonamble	180	-

Site code consists of first letter(s) of region, first letter(s) of river type, then site number.
* Degraded river sites which were rejected and sampled separately

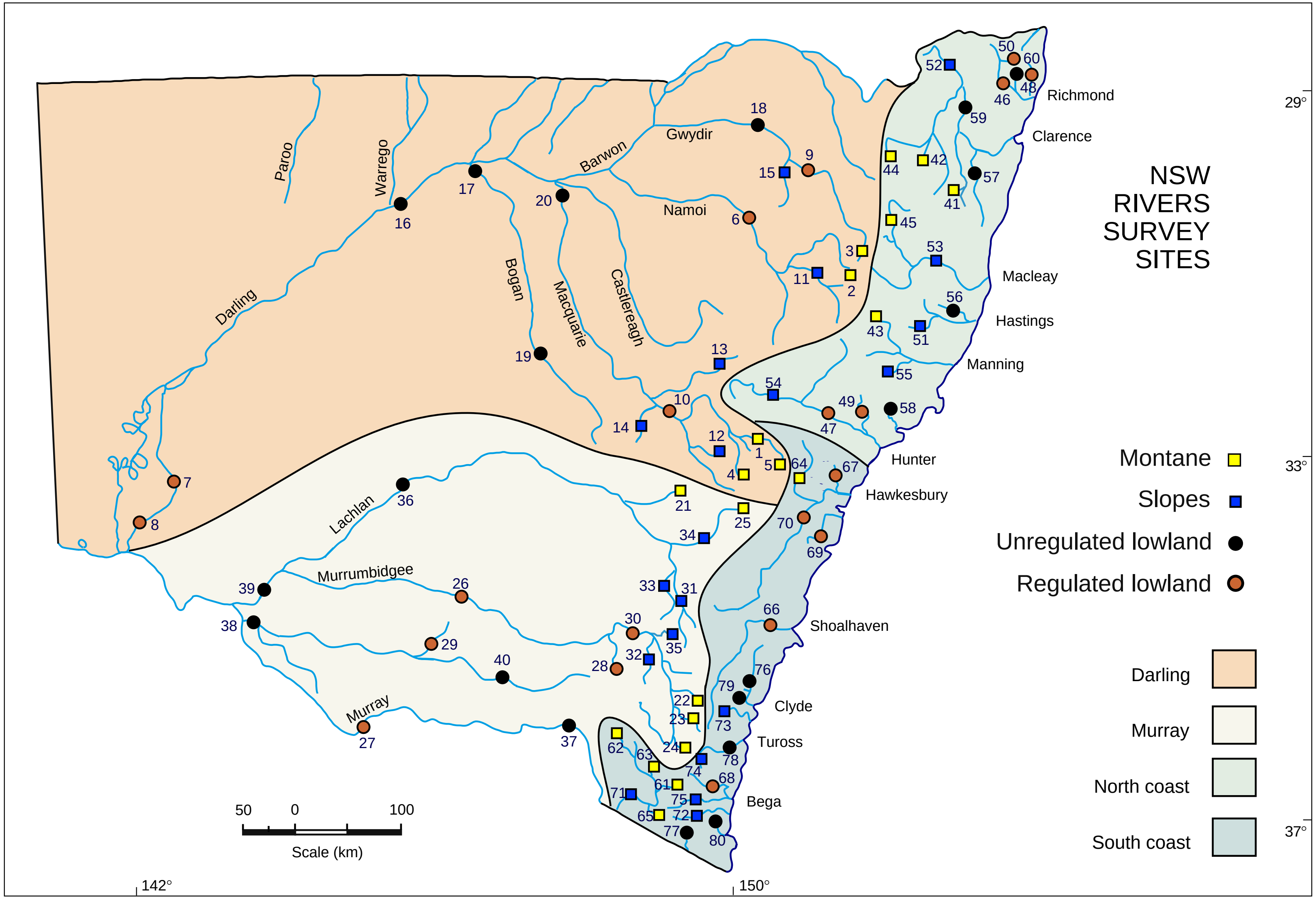

Figure 2.1 Map of New South Wales showing the location and river type of the 80 sampling sites used in the NSW Rivers Survey.

Nomenclature for freshwater fish species in New South Wales

Variations in the naming of fish can cause difficulty and confusion. Taxonomic revisions and local variations in common names both contribute to this confusion. During the NSW Rivers Survey, an effort has been made to ensure that scientific nomenclature is accurate and up to date. A review of common names has also been completed and the most suitable names have been accepted within NSW Fisheries. Table 2.2 gives full nomenclature for the 76 native and 11 alien fish species known to have been recorded from New South Wales freshwater environments at the end of June 1996. The same data are presented for each of the four ecological regions in Tables 2.3.1 - 2.3.4. Some taxonomic changes have been recorded in the literature since completion of the Rivers Survey. These changes are noted in Chapter 4.

Verifying fish species identification

Verification of the identity of fish species recorded in NSW Rivers Survey samples is continuing in conjunction with the Australian Museum. At the end of May 1997, a total of 85 collections, each with up to five individuals, had been examined by the museum. A total of 36 species were represented in the collections. All identifications by the Rivers Survey field teams were confirmed as correct. Specimens in these collections have been lodged with the Museum as voucher specimens, to answer any future questions about identifications, and to provide a resource for future taxonomic and other research.

Table 2.2 Fish species nomenclature; with specific names, common names accepted by NSW Fisheries, alternative common names previously used, family classification and origin of fish species.

Scientific name	Preferred common name	Alternative common name(s)	Family	Native or alien
Acanthogobius flavimanus	Yellowfin goby	Japanese goby, oriental goby	Gobiidae	Alien
Acanthopagrus australis	Yellowfin bream		Sparidae	Native
Afurcagobius tamarensis	Tamar River goby		Gobiidae	Native
Aldrichetta forsteri	Yelloweyed mullet	Sea mullet	Mugilidae	Native
Ambassis agassizii	Olive perchlet	Silver spray, doody, Agassiz's glassfish, western chanda perch	Ambassidae	Native
Ambassis castelnaui	Olive perchlet	Silver spray, doody, Agassiz's glassfish, western chanda perch	Ambassidae	Native
Ambassis marianus	Silver perchlet	Convex perchlet	Ambassidae	Native
Ambassis nigripinnis	Olive perchlet	Silver spray, doody, Agassiz's glassfish, western chanda perch	Ambassidae	Native
Anguilla australis	Short-finned eel	Silver eel	Anguillidae	Native
Anguilla reinhardtii	Long-finned eel	Spotted eel	Anguillidae	Native
Arenigobius bifrenatus	Bridled goby		Gobiidae	Native
Arius graeffei	Freshwater fork-tailed catfish	Blue salmon catfish	Ariidae	Native
Arrhamphus sclerolepis	Snub-nosed garfish		Hemirhamphidae	Native
Atherinosoma microstoma	Smallmouthed hardyhead	Greyback	Atherinidae	Native
Bidyanus bidyanus	Silver perch	Bidyan, black or silver bream, grunter	Terapontidae	Native
Butis butis	Bony-snouted gudgeon	Crimson-tipped gudgeon, nosy parker, crimson-tipped flathead gudgeon	Eleotridae	Native
Carassius auratus	Goldfish	Carp, crucian carp, Prussian carp	Cyprinidae	Alien
Carcharhinus leucas	Bull shark		Carcharhinidae	Native
Chanos chanos	Milkfish	Bangos	Chanidae	Native
Craterocephalus amniculus	Darling River hardyhead		Atherinidae	Native
Craterocephalus fluviatilis	Murray hardyhead		Atherinidae	Native
Craterocephalus marjoriae	Marjorie's hardyhead	Mary River hardyhead	Atherinidae	Native
Craterocephalus stercusmuscarum	Flyspecked hardyhead	Mitchellian hardyhead, western freshwater hardyhead, freshwater silver-side or line-eye	Atherinidae	Native
Cyprinus carpio	Common carp	Carp, European carp, koi carp	Cyprinidae	Alien
Gadopsis bispinosus	Two-spinned blackfish	Freshwater blackfish, slippery, slimy, marbled river cod	Gadopsidae	Native
Gadopsis marmoratus	River blackfish	Freshwater blackfish, slippery, slimy, marbled river cod	Gadopsidae	Native
Galaxias brevipinnis	Climbing galaxias	Cox's mountain galaxias, Pieman galaxias, koaro	Galaxiidae	Native
Galaxias maculatus	Common jollytail	Common galaxias, spotted minnow, inanga puyen	Galaxiidae	Native
Galaxias olidus	Mountain galaxias	Ornate mountain galaxias, inland galaxias	Galaxiidae	Native
Galaxias rostratus	Murray jollytail	Flathead galaxias, flathead jollytail	Galaxiidae	Native
Gambusia holbrooki	Gambusia	Mosquitofish	Poeciliidae	Alien
Geotria australis	Pouched lamprey		Geotriidae	Native
Glossamia aprion	Mouth almighty	Queensland mouth brooder, Gill's cardinalfish, flabby, stinker	Apogonidae	Native
Gnathanodon speciosus	Golden trevally		Carangidae	Native
Gobiomorphus australis	Striped gudgeon		Eleotridae	Native
Gobiomorphus coxii	Cox's gudgeon	Mulgoa gudgeon	Eleotridae	Native

(continued)

Table 2.2 (continued)

Scientific name	Preferred common name	Alternative common name(s)	Family	Native or alien
Herklotsichthys castelnaui	Sprat	Estuarine herring	Clupeidae	Native
Hypseleotris compressa	Empire gudgeon	Carp gudgeon, empirefish	Eleotridae	Native
Hypseleotris galii	Firetailed gudgeon	Gale's gudgeon	Eleotridae	Native
Hypseleotris spp	Gudgeon	Western carp gudgeon, Lakes's carp gudgeon, Midgley's carp gudgeon	Eleotridae	Native
Leiopotherapon unicolor	Spangled perch	Jewel perch, bobby perch or cod, spangled grunter	Terapontidae	Native
Liza argentea	Flat-tail mullet	Tiger mullet	Mugilidae	Native
Lutjanus argentimaculatus	Mangrove jack		Lutjanidae	Native
Maccullochella ikei	Eastern cod	Clarence River cod, cod, eastern freshwater cod	Percichthyidae	Native
Maccullochella macquariensis	Trout cod	Bluenose cod, blue cod	Percichthyidae	Native
Maccullochella peelii	Murray cod	Cod, codfish, goodoo	Percichthyidae	Native
Macquaria ambigua	Golden perch	Yellowbelly, callop, perch, Murray perch	Percichthyidae	Native
Macquaria australasica	Macquarie perch	Silver eye, white eye, mountain perch, bream, black bream	Percichthyidae	Native
Macquaria colonorum	Estuary perch	Perch	Percichthyidae	Native
Macquaria novemaculeata	Australian bass	Perch, freshwater perch	Percichthyidae	Native
Megalops cyprinoides	Oxeye herring	Tarpon	Elopidae	Native
Melanotaenia duboulayi	Duboulay's rainbowfish	Common or spotted sunfish, crimson-spotted rainbowfish, crimson-spotted jewelfish, pinkear, Australian rainbowfish	Melanotaeniidae	Native
Melanotaenia fluviatilis	Crimson-spotted rainbowfish	Murray River rainbow, inland rainbow	Melanotaeniidae	Native
Misgurnus anguillicaudatus	Oriental weatherloach	Japanese weatherloach, Japanese loach, Japanese weatherfish, loach, mud loach, weatherfish	Cobitidae	Alien
Mogurnda adspersa	Purple-spotted gudgeon	Purple-striped gudgeon, chequered gudgeon, trout gudgeon	Eleotridae	Native
Monodactylus argenteus	Silver batfish	Diamond fish	Monodactylidae	Native
Mordacia mordax	Shortheaded lamprey		Mordaciidae	Native
Mordacia praecox	Nonparasitic lamprey		Mordaciidae	Native
Mugil cephalus	Striped mullet	Sea mullet, bully mullet, grey mullet, hardgut mullet, river mullet	Mugilidae	Native
Myxus elongatus	Sand mullet	Tellegalene	Mugilidae	Native
Myxus petardi	Freshwater mullet	Pinkeye mullet	Mugilidae	Native
Nannoperca australis	Southern pygmy perch		Nannopercidae	Native
Nannoperca oxleyana	Oxleyan pygmy perch		Nannopercidae	Native
Nematalosa erebi	Bony herring	Bony bream, pyberry, melon fish, tukari	Clupeidae	Native
Neosilurus hyrtlii	Hyrtl's tandan	Mottled tandan, white tandan, yellowfin tandan, Glencoe tandan, silver moonfish	Plotosidae	Native
Notesthes robusta	Bullrout		Scorpaenidae	Native
Oncorhynchus mykiss	Rainbow trout	Steelhead	Salmonidae	Alien
Perca fluviatilis	Redfin perch	European or English perch	Percidae	Alien
Philypnodon grandiceps	Flathead gudgeon	Big-headed gudgeon, bullhead, Yarra gudgeon	Eleotridae	Native
Philypnodon sp1	Dwarf flathead gudgeon		Eleotridae	Native

(continued)

Table 2.2 (continued)

Scientific name	Preferred common name	Alternative common name(s)	Family	Native or alien
Platycephalus fuscus	Dusky flathead		Platycephalidae	Native
Potamalosa richmondia	Freshwater herring	Nepean herring	Clupeidae	Native
Prototroctes maraena	Australian grayling	Cucumber mullet, cucumber herring, Yarra herring	Prototroctidae	Native
Pseudaphritis urvillii	Congolli	Tupong, flathead, sandy, marble fish, sand trout	Bovichtidae	Native
Pseudogobius sp9	Swan River goby		Gobiidae	Native
Pseudomugil signifer	Southern blue-eye	Pacific blue-eye, common blue-eye	Pseudomugilidae	Native
Redigobius macrostoma	Largemouth goby		Gobiidae	Native
Retropinna semoni	Australian smelt		Retropinnidae	Native
Rhadinocentrus ornatus	Softspined rainbowfish	Ornate rainbowfish, southern softspined rainbowfish, sunfish or jewelfish, Fraser or Moreton Island sunfish, neon sunfish, porthole fish	Melanotaeniidae	Native
Salmo salar	Atlantic salmon		Salmonidae	Alien
Salmo trutta	Brown trout	Sea trout	Salmonidae	Alien
Salvelinus fontinalis	Brook char	Brook trout	Salmonidae	Alien
Strongylura krefftii	Freshwater long tom		Belonidae	Native
Tandanus tandanus	Freshwater catfish	Tandan, freshwater jewfish, dewfish, eeltail catfish	Plotosidae	Native
Tinca tinca	Tench		Cyprinidae	Alien
Valamugil georgii	Fantail mullet	Silver mullet	Mugilidae	Native

Table 2.3.1 Darling region fish species nomenclature: with specific names, common names accepted by NSW Fisheries, alternative common names previously used, family classification and origin of fish species.

Scientific name	Common name	Alternative common name(s)	Family	Native or alien
Ambassis agassizii	Olive perchlet	Silver spray, doody, Agassiz's glassfish, western chanda perch	Ambassidae	Native
Ambassis castelnaui	Olive perchlet	Silver spray, doody, Agassiz's glassfish, western chanda perch	Ambassidae	Native
Bidyanus bidyanus	Silver perch	Bidyan, black or silver bream, grunter	Terapontidae	Native
Carassius auratus	Goldfish	Carp, crucian carp, Prussian carp	Cyprinidae	Alien
Craterocephalus amniculus	Darling River hardyhead		Atherinidae	Native
Craterocephalus fluviatilis	Murray hardyhead		Atherinidae	Native
Craterocephalus stercusmuscarum	Flyspecked hardyhead	Mitchellian hardyhead, western freshwater hardyhead, freshwater silver-side or line-eye	Atherinidae	Native
Cyprinus carpio	Common carp	Carp, European carp, koi carp	Cyprinidae	Alien
Gadopsis marmoratus	River blackfish	Freshwater blackfish, slippery, slimy, marbled river cod	Gadopsidae	Native
Galaxias olidus	Mountain galaxias	Ornate mountain galaxias, inland galaxias	Galaxiidae	Native
Galaxias rostratus	Murray jollytail	Flathead galaxias, flathead jollytail	Galaxiidae	Native
Gambusia holbrooki	Gambusia	Mosquitofish	Poeciliidae	Alien
Hypseleotris spp	Gudgeon	Western carp gudgeon, Lakes's carp gudgeon, Midgley's carp gudgeon	Eleotridae	Native
Leiopotherapon unicolor	Spangled perch	Jewel perch, bobby perch or cod, spangled grunter	Terapontidae	Native
Maccullochella macauariensis	Trout cod	Bluenose cod, blue cod	Percichthyidae	Native
Maccullochella peelii	Murray cod	Cod, codfish, goodoo	Percichthyidae	Native
Macquaria ambigua	Golden perch	Yellowbelly, callop, perch, Murray perch	Percichthyidae	Native
Melanotaenia fluviatilis	Crimson-spotted rainbowfish	Murray River rainbow, inland rainbow	Melanotaeniidae	Native
Mogurnda adspersa	Purple-spotted gudgeon	Purple-striped gudgeon, chequered gudgeon, trout gudgeon	Eleotridae	Native
Nematalosa erebi	Bony herring	Bony bream, pyberry, melon fish, tukari	Clupeidae	Native
Neosilurus hyrtlii	Hyrtl's tandan	Mottled tandan, white tandan, yellowfin tandan, Glencoe tandan, silver moonfish	Plotosidae	Native
Oncorhynchus mykiss	Rainbow trout	Steelhead	Salmonidae	Alien
Perca fluviatilis	Redfin perch	European or English perch	Percidae	Alien
Philypnodon grandiceps	Flathead gudgeon	Big-headed gudgeon, bullhead, Yarra gudgeon	Eleotridae	Native
Philypnodon sp1	Dwarf flathead gudgeon		Eleotridae	Native
Retropinna semoni	Australian smelt		Retropinnidae	Native
Salmo trutta	Brown trout	Sea trout	Salmonidae	Alien
Salvelinus fontinalis	Brook char	Brook trout	Salmonidae	Alien
Tandanus tandanus	Freshwater catfish	Tandan, freshwater jewfish, dewfish, eeltail catfish	Plotosidae	Native
Tinca tinca	Tench		Cyprinidae	Alien

Table 2.3.2 Murray region fish species nomenclature: with specific names, common names accepted by NSW Fisheries, alternative common names previously used, family classification and origin of fish species.

Scientific name	Common name	Alternative common name(s)	Family	Native or alien
Ambassis agassizii	Olive perchlet	Silver spray, doody, Agassiz's glassfish, western chanda perch	Ambassidae	Native
Ambassis castelnaui	Olive perchlet	Silver spray, doody, Agassiz's glassfish, western chanda perch	Ambassidae	Native
Anguilla australis	Short-finned eel	Silver eel	Anguillidae	Native
Bidyanus bidyanus	Silver perch	Bidyan, black or silver bream, grunter	Terapontidae	Native
Carassius auratus	Goldfish	Carp, crucian carp, Prussian carp	Cyprinidae	Alien
Craterocephalus fluviatilis	Murray hardyhead		Atherinidae	Native
Craterocephalus stercusmuscarum	Flyspecked hardyhead	Mitchellian hardyhead, western freshwater hardyhead, freshwater silver-side or line-eye	Atherinidae	Native
Cyprinus carpio	Common carp	Carp, European carp, koi carp	Cyprinidae	Alien
Gadopsis bispinosus	Two-spinned blackfish	Freshwater blackfish, slippery, slimy, marbled river cod	Gadopsidae	Native
Gadopsis marmoratus	River blackfish	Freshwater blackfish, slippery, slimy, marbled river cod	Gadopsidae	Native
Galaxias brevipinnis	Climbing galaxias	Cox's mountain galaxias, Pieman galaxias, koaro	Galaxiidae	Native
Galaxias olidus	Mountain galaxias	Ornate mountain galaxias, inland galaxias	Galaxiidae	Native
Galaxias rostratus	Murray jollytail	Flathead galaxias, flathead jollytail	Galaxiidae	Native
Gambusia holbrooki	Gambusia	Mosquitofish	Poeciliidae	Alien
Geotria australis	Pouched lamprey		Geotriidae	Native
Hypseleotris spp	Gudgeon	Western carp gudgeon, Lakes's carp gudgeon, Midgley's carp gudgeon	Eleotridae	Native
Leiopotherapon unicolor	Spangled perch	Jewel perch, bobby perch or cod, spangled grunter	Terapontidae	Native
Maccullochella macquariensis	Trout cod	Bluenose cod, blue cod	Percichthyidae	Native
Maccullochella peelii	Murray cod	Cod, codfish, goodoo	Percichthyidae	Native
Macquaria ambigua	Golden perch	Yellowbelly, callop, perch, Murray perch	Percichthyidae	Native
Macquaria australasica	Macquarie perch	Silver eye, white eye, mountain perch, bream, black bream	Percichthyidae	Native
Melanotaenia fluviatilis	Crimson-spotted rainbowfish	Murray River rainbow, inland rainbow	Melanotaeniidae	Native
Misgurnus anguillicaudatus	Oriental weatherloach	Japanese weatherloach, Japanese loach, Japanese weatherfish, loach, mud loach, weatherfish	Cobitidae	Alien
Mogurnda adspersa	Purple-spotted gudgeon	Purple-striped gudgeon, chequered gudgeon, trout gudgeon	Eleotridae	Native
Mordacia mordax	Shortheaded lamprey		Mordaciidae	Native
Nannoperca australis	Southern pygmy perch		Nannopercidae	Native
Nematalosa erebi	Bony herring	Bony bream, pyberry, melon fish, tukari	Clupeidae	Native
Oncorhynchus mykiss	Rainbow trout	Steelhead	Salmonidae	Alien
Perca fluviatilis	Redfin perch	European or English perch	Percidae	Alien
Philypnodon grandiceps	Flathead gudgeon	Big-headed gudgeon, bullhead, Yarra gudgeon	Eleotridae	Native
Philypnodon sp1	Dwarf flathead gudgeon		Eleotridae	Native
Retropinna semoni	Australian smelt		Retropinnidae	Native
Salmo salar	Atlantic salmon		Salmonidae	Alien
Salmo trutta	Brown trout	Sea trout	Salmonidae	Alien
Salvelinus fontinalis	Brook char	Brook trout	Salmonidae	Alien
Tandanus tandanus	Freshwater catfish	Tandan, freshwater jewfish, dewfish, eeltail catfish	Plotosidae	Native
Tinca tinca	Tench		Cyprinidae	Alien

Table 2.3.3 North Coast region fish species nomenclature: with specific names, common names accepted by NSW Fisheries, alternative common names previously used, family classification and origin of fish species.

Scientific name	Common name	Alternative common name(s)	Family	Native or alien
Acanthopagrus australis	Yellowfin bream		Sparidae	Native
Afurcagobius tamarensis	Tamar River goby		Gobiidae	Native
Ambassis agassizii	Olive perchlet	Silver spray, doody, Agassiz's glassfish, western chanda perch	Ambassidae	Native
Ambassis marianus	Silver perchlet	Convex perchlet	Ambassidae	Native
Ambassis nigripinnis	Olive perchlet	Silver spray, doody, Agassiz's glassfish, western chanda perch	Ambassidae	Native
Anguilla australis	Short-finned eel	Silver eel	Anguillidae	Native
Anguilla reinhardtii	Long-finned eel	Spotted eel	Anguillidae	Native
Arenigobius bifrenatus	Bridled goby		Gobiidae	Native
Arius graeffei	Freshwater fork-tailed catfish	Blue salmon catfish	Ariidae	Native
Arrhamphus sclerolepis	Snub-nosed garfish		Hemirhamphidae	Native
Atherinosoma microstoma	Smallmouthed hardyhead	Greyback	Atherinidae	Native
Butis butis	Bony-snouted gudgeon	Crimson-tipped gudgeon, nosy parker, crimson-tipped flathead gudgeon	Eleotridae	Native
Carassius auratus	Goldfish	Carp, crucian carp, Prussian carp	Cyprinidae	Alien
Carcharhinus leucas	Bull shark		Carcharhinidae	Native
Chanos chanos	Milkfish	Bangos	Chanidae	Native
Craterocephalus fluviatilis	Murray hardyhead		Atherinidae	Native
Craterocephalus marjoriae	Marjorie's hardyhead	Mary River hardyhead	Atherinidae	Native
Cyprinus carpio	Common carp	Carp, European carp, koi carp	Cyprinidae	Alien
Galaxias maculatus	Common jollytail	Common galaxias, spotted minnow, inanga puyen	Galaxiidae	Native
Galaxias olidus	Mountain galaxias	Ornate mountain galaxias, inland galaxias	Galaxiidae	Native
Gambusia holbrooki	Gambusia	Mosquitofish	Poeciliidae	Alien
Glossamia aprion	Mouth almighty	Queensland mouth brooder, Gill's cardinalfish, flabby, stinker	Apogonidae	Native
Gnathanodon speciosus	Golden trevally		Carangidae	Native
Gobiomorphus australis	Striped gudgeon		Eleotridae	Native
Gobiomorphus coxii	Cox's gudgeon	Mulgoa gudgeon	Eleotridae	Native
Herklotsichthys castelnaui	Sprat	Estuarine herring	Clupeidae	Native
Hypseleotris compressa	Empire gudgeon	Carp gudgeon, empirefish	Eleotridae	Native
Hypseleotris galii	Firetailed gudgeon	Gale's gudgeon	Eleotridae	Native
Hypseleotris spp	Gudgeon	Western carp gudgeon, Lakes's carp gudgeon, Midgley's carp gudgeon	Eleotridae	Native
Leiopotherapon unicolor	Spangled perch	Jewel perch, bobby perch or cod, spangled grunter	Terapontidae	Native
Liza argentea	Flat-tail mullet	Tiger mullet	Mugilidae	Native
Lutjanus argentimaculatus	Mangrove jack		Lutjanidae	Native
Maccullochella ikei	Eastern cod	Clarence River cod, cod, eastern freshwater cod	Percichthyidae	Native
Macquaria colonorum	Estuary perch	Perch	Percichthyidae	Native
Macquaria novemaculeata	Australian bass	Perch, freshwater perch	Percichthyidae	Native
Megalops cyprinoides	Oxeye herring	Tarpon	Elopidae	Native
Melanotaenia duboulayi	Duboulay's rainbowfish	Common or spotted sunfish, crimson-spotted rainbowfish, crimson-spotted jewelfish, pinkear, Australian rainbowfish	Melanotaeniidae	Native

(continued)

Table 2.3.3 (continued)

Scientific name	Common name	Alternative common name(s)	Family	Native or alien
Mogurnda adspersa	Purple-spotted gudgeon	Purple-striped gudgeon, chequered gudgeon, trout gudgeon	Eleotridae	Native
Monodactylus argenteus	Silver batfish	Diamond fish	Monodactylidae	Native
Mugil cephalus	Striped mullet	Sea mullet, bully mullet, grey mullet, hardgut mullet, river mullet	Mugilidae	Native
Myxus elongatus	Sand mullet	Tellegalene	Mugilidae	Native
Myxus petardi	Freshwater mullet	Pinkeye mullet	Mugilidae	Native
Nannoperca oxleyana	Oxleyan pygmy perch		Nannopercidae	Native
Notesthes robusta	Bullrout		Scorpaenidae	Native
Oncorhynchus mykiss	Rainbow trout	Steelhead	Salmonidae	Alien
Perca fluviatilis	Redfin perch	European or English perch	Percidae	Alien
Philypnodon grandiceps	Flathead gudgeon	Big-headed gudgeon, bullhead, Yarra gudgeon	Eleotridae	Native
Philypnodon sp1	Dwarf flathead gudgeon		Eleotridae	Native
Platycephalus fuscus	Dusky flathead		Platycephalidae	Native
Potamalosa richmondia	Freshwater herring	Nepean herring	Clupeidae	Native
Pseudogobius sp9	Swan River goby		Gobiidae	Native
Pseudomugil signifer	Southern blue-eye	Pacific blue-eye, common blue-eye	Pseudomugilidae	Native
Redigobius macrostoma	Largemouth goby		Gobiidae	Native
Retropinna semoni	Australian smelt		Retropinnidae	Native
Rhadinocentrus ornatus	Softspined rainbowfish	Ornate rainbowfish, southern softspined rainbowfish, sunfish or jewelfish, Fraser or Moreton Island sunfish, neon sunfish, porthole fish	Melanotaeniidae	Native
Salmo trutta	Brown trout	Sea trout	Salmonidae	Alien
Salvelinus fontinalis	Brook char	Brook trout	Salmonidae	Alien
Strongylura krefftii	Freshwater long tom		Belonidae	Native
Tandanus tandanus	Freshwater catfish	Tandan, freshwater jewfish, dewfish, eeltail catfish	Plotosidae	Native
Valamugil georgii	Fantail mullet	Silver mullet	Mugilidae	Native

Table 2.3.4 South Coast region fish species nomenclature: with specific names, common names accepted by NSW Fisheries, alternative common names previously used, family classification and origin of fish species.

Scientific name	Common name	Alternative common name(s)	Family	Native or alien
Acanthogobius flavimanus	Yellowfin goby	Japanese goby, oriental goby	Gobiidae	Alien
Afurcagobius tamarensis	Tamar River goby		Gobiidae	Native
Aldrichetta forsteri	Yelloweyed mullet	Sea mullet	Mugilidae	Native
Ambassis marianus	Silver perchlet	Convex perchlet	Ambassidae	Native
Anguilla australis	Short-finned eel	Silver eel	Anguillidae	Native
Anguilla reinhardtii	Long-finned eel	Spotted eel	Anguillidae	Native
Arenigobius bifrenatus	Bridled goby		Gobiidae	Native
Atherinosoma microstoma	Smallmouthed hardyhead	Greyback	Atherinidae	Native
Carassius auratus	Goldfish	Carp, crucian carp, Prussian carp	Cyprinidae	Alien
Cyprinus carpio	Common carp	Carp, European carp, koi carp	Cyprinidae	Alien
Gadopsis marmoratus	River blackfish	Freshwater blackfish, slippery, slimy, marbled river cod	Gadopsidae	Native
Galaxias brevipinnis	Climbing galaxias	Cox's mountain galaxias, Pieman galaxias, koaro	Galaxiidae	Native
Galaxias maculatus	Common jollytail	Common galaxias, spotted minnow, inanga puyen	Galaxiidae	Native
Galaxias olidus	Mountain galaxias	Ornate mountain galaxias, inland galaxias	Galaxiidae	Native
Gambusia holbrooki	Gambusia	Mosquitofish	Poeciliidae	Alien
Gobiomorphus australis	Striped gudgeon		Eleotridae	Native
Gobiomorphus coxii	Cox's gudgeon	Mulgoa gudgeon	Eleotridae	Native
Hypseleotris compressa	Empire gudgeon	Carp gudgeon, empirefish	Eleotridae	Native
Hypseleotris galii	Firetailed gudgeon	Gale's gudgeon	Eleotridae	Native
Hypseleotris spp	Gudgeon	Western carp gudgeon, Lakes's carp gudgeon, Midgley's carp gudgeon	Eleotridae	Native
Liza argentea	Flat-tail mullet	Tiger mullet	Mugilidae	Native
Macquaria australasica	Macquarie perch	Silver eye, white eye, mountain perch, bream, black bream	Percichthyidae	Native
Macquaria colonorum	Estuary perch	Perch	Percichthyidae	Native
Macquaria novemaculeata	Australian bass	Perch, freshwater perch	Percichthyidae	Native
Misgurnus anguillicaudatus	Oriental weatherloach	Japanese weatherloach, Japanese loach, Japanese weatherfish, loach, mud loach, weatherfish	Cobitidae	Alien
Monodactylus argenteus	Silver batfish	Diamond fish	Monodactylidae	Native
Mordacia mordax	Shortheaded lamprey		Mordaciidae	Native
Mordacia praecox	Nonparasitic lamprey		Mordaciidae	Native
Mugil cephalus	Striped mullet	Sea mullet, bully mullet, grey mullet, hardgut mullet, river mullet	Mugilidae	Native
Myxus elongatus	Sand mullet	Tellegalene	Mugilidae	Native
Myxus petardi	Freshwater mullet	Pinkeye mullet	Mugilidae	Native
Notesthes robusta	Bullrout		Scorpaenidae	Native
Oncorhynchus mykiss	Rainbow trout	Steelhead	Salmonidae	Alien
Perca fluviatilis	Redfin perch	European or English perch	Percidae	Alien
Philypnodon grandiceps	Flathead gudgeon	Big-headed gudgeon, bullhead, Yarra gudgeon	Eleotridae	Native
Philypnodon sp1	Dwarf flathead gudgeon		Eleotridae	Native
Potamalosa richmondia	Freshwater herring	Nepean herring	Clupeidae	Native
Prototroctes maraena	Australian grayling	Cucumber mullet, cucumber herring, Yarra herring	Prototroctidae	Native
Pseudaphritis urvillii	Congolli	Tupong, flathead, sandy, marble fish, sand trout	Bovichtidae	Native
Pseudogobius sp9	Swan River goby		Gobiidae	Native
Pseudomugil signifer	Southern blue-eye	Pacific blue-eye, common blue-eye	Pseudomugilidae	Native
Redigobius macrostoma	Largemouth goby		Gobiidae	Native
Retropinna semoni	Australian smelt		Retropinnidae	Native
Salmo salar	Atlantic salmon		Salmonidae	Alien
Salmo trutta	Brown trout	Sea trout	Salmonidae	Alien
Salvelinus fontinalis	Brook char	Brook trout	Salmonidae	Alien
Tandanus tandanus	Freshwater catfish	Tandan, freshwater jewfish, dewfish, eeltail catfish	Plotosidae	Native
Valamugil georgii	Fantail mullet	Silver mullet	Mugilidae	Native

Threatened fish species

The threatened freshwater fish species of New South Wales are identified in Table 2.4, using the International Union for the Conservation of Nature's (IUCN) Red List classifications recommended by Jackson (1996). Of the total of 11 listed species (five 'endangered', five 'vulnerable', and one 'data deficient'), only five species were recorded in samples from the Rivers Survey. Only nine individual *Bidyanus bidyanus* were caught in the four survey rounds, and only one single *Craterocephalus fluviatilis*. Full details of locations and catches of these fish are provided in the NSW Rivers Survey Data List (Harris *et al.* 1996) and discrepancies in lists of native species captured *versus* those predicted are dealt with in detail in Chapter 4.

Table 2.4 Threatened freshwater fish species of New South Wales, with IUCN Red List classifications (Jackson 1996), habitat details, and preliminary data on threatening processes. Species not marked under 'Region caught' were not recorded in samples from the NSW Rivers Survey.

Species	Common name	IUCN status	Region caught*				River type	Threats
			D	M	NC	SC		
Bidyanus bidyanus	Silver perch	Vulnerable	**7**	**2**			Lowland	Habitat destruction / cold water pollution
Craterocephalus amniculus	Darling River hardyhead	Vulnerable					Lowland	Alien fish competition / habitat destruction
Craterocephalus fluviatilis	Murray hardyhead	Endangered		**1**			Lowland / slopes	Alien fish competition / habitat destruction
Galaxias rostratus	Murray galaxias	Vulnerable					Slopes / Montane	Alien fish competition
Maccullochella ikei	Eastern cod	Endangered					Lowland / slopes	Overfishing / habitat destruction
Maccullochella macquariensis	Trout cod	Endangered					Lowland / slopes / montane	Habitat destruction / overfishing
Macquaria australasica	Macquarie perch	Data deficient		**22**			Slopes / montane	Habitat destruction / alien fish / overfishing
Mogurnda adspersa	Purple-spotted gudgeon	Endangered					Lowland	Alien fish competition / habitat destruction
Mordacia praecox	Non-parasitic lamprey	Vulnerable				**33**	Lowland	Habitat destruction / migration barriers
Nannoperca oxleyana	Oxleyan pygmy perch	Endangered					Lowland	Habitat destruction / alien fish competition
Prototroctes maraena	Australian grayling	Vulnerable				**64**	Lowland / slopes	Habitat destruction

* Ecological regions: D- Darling, M-Murray, NC - North Coast, SC - South Coast. Numbers indicate total catch from all 20 sites and four surveys in each region.

Classification of fish by habitat guilds, trophic guilds and tolerance groups

Available knowledge on the habitat and trophic guilds (i.e. groups of fishes living in the same area and sharing broad feeding or habitat adaptations) of fishes occurring in fresh water in New South Wales (Harris 1995) is summarised in Table 2.5. Provisional classifications of fish species' tolerances to water-quality variables and migration barriers are also given. 'Freshwater' fish are defined as those species regularly occurring above tidal limits for a significant part of their life-cycle, as determined from published literature (McDowall 1996, Paxton *et al.* 1989, Allen 1989, Merrick and Schmida 1984, Llewellyn 1983) and records of NSW Fisheries.

Table 2.5 Classification of habitat and trophic guilds and tolerance groups of freshwater (see text) and estuarine fish species in New South Wales. 'Freshwater' refers to native freshwater fish, 'alien' species are those originating overseas and now established in the wild.

Species	Category	Habitat[1]	Trophic[2]	Tolerance[3]	Intolerance[4]
Acanthogobius flavimanus	Alien	2	2		
Acanthopagrus australis	Estuarine	3	5	T	
Afurcagobius tamarensis	Estuarine	2	2		
Aldrichetta forsteri	Estuarine	3	2		
Ambassis agassizii	Freshwater	3	4	I	wq
Ambassis castelnaui	Freshwater	2	4		
Ambassis marianus	Estuarine	2	4		
Ambassis nigripinnis	Freshwater	3	4	I	wq
Anguilla australis	Freshwater	2	5	T	
Anguilla reinhardtii	Freshwater	2	5	T	
Arenigobius bifrenatus	Estuarine	2	2		
Arius graeffei	Freshwater	2	3	I	migr
Arrhamphus sclerolepis	Estuarine	3	4	I	migr
Atherinosoma microstoma	Freshwater	3	4		
Bidyanus bidyanus	Freshwater	3	3	I	wq/migr
Butis butis	Freshwater	2	4		
Carassius auratus	Alien	3	2	T	
Carcharhinus leucas	Estuarine	3	5	I	wq/migr
Chanos chanos	Estuarine	3	2		
Craterocephalus amniculus	Freshwater	3	4		
Craterocephalus fluviatilis	Freshwater	3	4	I	wq
Craterocephalus marjoriae	Freshwater	3	4	I	wq
Craterocephalus stercusmuscarum	Freshwater	3	4	I	wq
Cyprinus carpio	Alien	3	3	T	
Gadopsis bispinosus	Freshwater	2	5	T	
Gadopsis marmoratus	Freshwater	2	4	T	
Galaxias brevipinnis	Freshwater	1	4	T	
Galaxias maculatus	Freshwater	3	4	I	migr
Galaxias olidus	Freshwater	1	4	T	
Galaxias rostratus	Freshwater	3	4		
Gambusia holbrooki	Alien	3	4	T	
Geotria australis	Freshwater	2	5		
Glossamia aprion	Freshwater	2	5		
Gnathanodon speciosus	Estuarine	3	5	I	migr
Gobiomorphus australis	Freshwater	1	4	T	
Gobiomorphus coxii	Freshwater	1	4	T	
Herklotsichthys castelnaui	Estuarine	3	4	I	migr
Hypseleotris compressa	Freshwater	3	2	T	
Hypseleotris galii	Freshwater	3	4	T	
Hypseleotris spp	Freshwater	3	4	T	
Leiopotherapon unicolor	Freshwater	3	4	T	
Liza argentea	Estuarine	3	2	I	migr
Lutjanus argentimaculatus	Estuarine	2	5		
Maccullochella ikei	Freshwater	2	5		

(continued)

Habitat[1]: 1 - Riffle-dwelling, 2 - benthic pool-dwelling, 3 - pelagic pool-dwelling.
Trophic[2]: 1 - herbivores/detritivores, 2 - microphagic omnivores, 3 - macrophagic omnivores, 4 - microphagic carnivores, 5 - macrophagic carnivores
Tolerance[3]: I - Intolerant, T - Tolerant
Intolerance[4]: Known intolerances, wq - water quality, migr - migration (after Harris 1995)

Table 2.5 (continued)

Species	Category	Habitat[1]	Trophic[2]	Tolerance[3]	Intolerance[4]
Maccullochella macquariensis	Freshwater	2	5		
Maccullochella peelii	Freshwater	3	5	I	migr
Macquaria ambigua	Freshwater	3	5	I	migr
Macquaria australasica	Freshwater	3	4	I	wq
Macquaria colonorum	Estuarine	3	5	I	migr
Macquaria novemaculeata	Freshwater	3	5	I	migr
Megalops cyprinoides	Freshwater	3	4		
Melanotaenia duboulayi	Freshwater	3	2	I	wq
Melanotaenia fluviatilis	Freshwater	3	2	I	wq
Misgurnus anguillicaudatus	Alien	2	2		
Mogurnda adspersa	Freshwater	2	4		
Monodactylus argenteus	Estuarine	3	2		
Mordacia mordax	Freshwater	2	5		
Mordacia praecox	Freshwater	2	1	T	
Mugil cephalus	Freshwater	3	2	I	migr
Myxus elongatus	Estuarine	3	2	I	migr
Myxus petardi	Freshwater	3	2	I	migr
Nannoperca australis	Freshwater	2	4		
Nannoperca oxleyana	Freshwater	2	2		
Nematalosa erebi	Freshwater	3	1	I	migr
Neosilurus hyrtlii	Freshwater	2	4		
Notesthes robusta	Freshwater	2	5	I	migr
Oncorhynchus mykiss	Alien	3	5	I	wq
Perca fluviatilis	Alien	3	5	T	
Philypnodon grandiceps	Freshwater	1	4	T	
Philypnodon sp1	Freshwater	1	4	T	
Platycephalus fuscus	Estuarine	2	5	I	migr
Potamalosa richmondia	Freshwater	3	4	I	migr
Prototroctes maraena	Freshwater	3	2	I	wq/migr
Pseudaphritis urvillii	Freshwater	2	4	I	
Pseudogobius sp9	Estuarine	2	4		
Pseudomugil signifer	Freshwater	3	4	I	wq
Redigobius macrostoma	Estuarine	2	2	I	migr
Retropinna semoni	Freshwater	1	4	T	
Rhadinocentrus ornatus	Freshwater	3	2		
Salmo salar	Alien	3	5		
Salmo trutta	Alien	3	5	I	wq
Salvelinus fontinalis	Alien	3	5		
Strongylura krefftii	Estuarine	3	2		
Tandanus tandanus	Freshwater	2	5	T	
Tinca tinca	Alien	2	4		
Valamugil georgii	Estuarine	3	2		

Habitat[1]: 1 - Riffle-dwelling, 2 - benthic pool-dwelling, 3 - pelagic pool-dwelling.

Trophic[2]: 1 - herbivores/detritivores, 2 - microphagic omnivores, 3 - macrophagic omnivores, 4 - microphagic carnivores, 5 - macrophagic carnivores

Tolerance[3]: I - Intolerant, T - Tolerant

Intolerance[4]: Known intolerances, wq - water quality, migr - migration (after Harris 1995)

Summary of fish species abundance

Fish species abundance in Rivers Survey samples is summarised in Table 2.6. During electrofishing operations the presence of large numbers of small, schooling fish such as *Retropinna semoni* and *Gambusia holbrooki* sometimes resulted in the need to estimate the abundance of these fish once they were definitely identified, rather than providing exact counts. These fish were recorded as 'observed'. Table 2.6 shows that a total of 50,438 fish of 55 species were recorded during the four routine survey rounds. Fish were most abundant in Darling region rivers, followed by the North Coast, South Coast and Murray region rivers. Table 2.7 records the abundance of fish species according to the river types in which they were caught.

Bias in data recording

Electrofishing is more efficient than other sampling methods, such as gill nets (Growns *et al.* 1996), catching a greater range of species and a larger size range for a given unit of effort. Like other sampling methods, however, it also possesses a number of biases. The most obvious of these is the limited ability of dip net operators to remove all fish from the water when large schools of fish are stunned, or with fish that are difficult to handle. For this reason, low abundances of fish are usually reflected accurately by catches from electrofishing. But the abundance of schooling species can be under-estimated in electrofishing catches. Similar under-estimation occurs in catches from gill nets or fyke nets, which may be saturated when large schools of fish are encountered. Bias in estimates of abundance obtained by electrofishing can be overcome to some extent by estimating the number of fish immobilised, but not caught, and recording numbers of fish both observed and caught. This approach introduces two qualitative levels of certainty in the data: landed catches that are accurately enumerated; and observed catches that vary from accurate enumerations of fish in low abundance, to subjective estimates of schooling species which may include large errors.

To maintain accuracy for quantitative analyses in this study, observed catches were not included, except for eels, which were recorded as observed because they were difficult to handle. The potentially large sampling errors created by including observed data were considered to be inappropriate for most quantitative analyses in this study. While this decision ensures that only quantitative data with relatively small sampling errors are used for most species, the bias created by omitting observed data can lead to serious under-representation of highly abundant species. To address these problems of data quality, the magnitude of bias created by using landed catches only was estimated by expressing the numbers of observed fish as a percentage of the total number observed and caught (Table 2.8 and Table 2.9). A subjective assessment was then made as to whether the estimates of bias were likely to have high or low reliability, depending upon the predominant occurrence of observed fish as solitary individuals or as members of large schools.

Table 2.6 Abundance of fish species caught and observed in the four different ecological regions of the NSW Rivers Survey.

Species	Darling		Murray		North Coast		South Coast		Total	
	Caught	Observed#	Caught	Observed	Caught	Observed	Caught	Observed	Caught	Observed
Acanthopagrus australis	0	0	0	0	8	3	0	0	8	3
Ambassis agassizii	1	0	0	0	61	136	0	0	62	136
Ambassis nigripinnis	0	0	0	0	494	1	0	0	494	1
Anguilla australis	0	0	0	0	1	0	48	30	49	30
Anguilla reinhardtii	0	0	0	0	250	1068	334	950	584	2019
Arius graeffei	0	0	0	0	59	0	0	0	59	0
Arrhamphus sclerolepis	0	0	0	0	4	2	0	0	4	2
Bidyanus bidyanus	7	0	2	1	0	0	0	0	9	1
Carassius auratus	271	98	97	28	138	12	15	1	521	139
Carcharhinus leucas	0	0	0	0	1	0	0	0	1	0
Craterocephalus fluviatilis	0	0	1	0	0	0	0	0	1	0
Craterocephalus marjoriae	0	0	0	0	10	0	0	0	10	0
Craterocephalus stercusmuscarum	208	286	14	10	0	0	0	0	222	296
Cyprinus carpio	1067	425	925	358	83	53	37	4	2111	840
Gadopsis bispinosus	0	0	3	0	0	0	0	0	3	0
Gadopsis marmoratus	21	5	0	0	0	0	1	1	22	6
Galaxias brevipinnis	0	0	7	5	0	0	8	0	15	5
Galaxias maculatus	0	0	0	0	0	0	533	202	533	202
Galaxias olidus	162	14	289	159	260	15	5	0	716	188
Gambusia holbrooki	633	2531	30	52	648	194	360	590	1671	3367
Gnathanodon speciosus	0	0	0	0	3	0	0	0	3	0
Gobiomorphus australis	0	0	0	0	576	55	399	27	975	82
Gobiomorphus coxii	0	0	0	0	31	20	817	276	849	296
Herklotsichthys castelnaui	0	0	0	0	7	0	0	0	7	0
Hypseleotris compressa	0	0	0	0	2616	215	271	0	2887	215
Hypseleotris galii	0	0	0	0	295	291	442	0	737	291
Hypseleotris spp	3717	287	111	2	115	80	0	0	3943	369
Leiopotherapon unicolor	106	0	1	0	0	0	0	0	107	0
Liza argentea	0	0	0	0	22	10	0	0	22	10
Maccullochella peelii	52	17	0	0	0	0	0	0	52	17
Macquaria ambigua	191	24	37	5	0	0	0	0	228	29
Macquaria australasica	0	0	22	1	0	0	0	0	22	1
Macquaria colonorum	0	0	0	0	8	0	1	0	9	0
Macquaria novemaculeata	0	0	0	0	428	33	651	47	1079	80
Melanotaenia duboulayi	0	0	0	0	314	69	0	0	314	69
Melanotaenia fluviatilis	99	18	2	0	0	0	0	0	101	18
Mordacia praecox	0	0	0	0	0	0	33	185	33	185
Mugil cephalus	0	0	0	0	657	189	100	71	757	260
Myxus elongatus	0	0	0	0	0	0	2	0	2	0
Myxus petardi	0	0	0	0	641	57	118	1	759	58
Nematalosa erebi	1982	947	100	38	0	0	0	0	2082	985
Notesthes robusta	0	0	0	0	63	24	8	1	71	25
Oncorhynchus mykiss	7	0	77	8	1	0	11	4	96	12
Perca fluviatilis	263	87	131	15	0	0	26	1	421	103
Philypnodon grandiceps	4	0	42	1	309	31	334	10	689	42
Philypnodon sp1	0	0	0	0	41	0	109	25	150	25
Platycephalus fuscus	0	0	0	0	1	0	0	0	1	0
Potamalosa richmondia	0	0	0	0	604	94	1	0	605	94
Prototroctes maraena	0	0	0	0	0	0	64	4	64	4
Pseudaphritis urvillii	0	0	0	0	0	0	29	5	29	5
Pseudomugil signifer	0	0	0	0	193	2	0	0	193	2
Redigobius macrostoma	0	0	0	0	0	0	1	0	1	0
Retropinna semoni	424	5117	354	124	586	4303	1164	2562	2527	12105
Salmo trutta	116	3	70	26	0	0	97	14	283	43
Tandanus tandanus	58	10	0	0	488	26	1	0	547	36
Grand Total	**9390**	**9868**	**2315**	**833**	**10017**	**6983**	**6020**	**5011**	**27742**	**22696**

Observed and identified but not caught. Abundance estimates only.

Table 2.7 Abundance of fish caught and observed in the four different river types of the NSW Rivers Survey over all four ecological regions.

Species	Montane		Slopes		Unregulated Lowland		Regulated Lowland		Total	
	Caught	Observed#	Caught	Observed	Caught	Observed	Caught	Observed	Caught	Observed
Acanthopagrus australis	0	0	0	0	3	0	5	3	8	3
Ambassis agassizii	0	0	9	36	8	0	45	100	62	136
Ambassis nigripinnis	0	0	240	1	212	0	42	0	494	1
Anguilla australis	39	13	8	17	1	0	1	0	49	30
Anguilla reinhardtii	86	40	277	1179	87	370	134	430	584	2019
Arius graeffei	0	0	0	0	59	0	0	0	59	0
Arrhamphus sclerolepis	0	0	0	0	4	2	0	0	4	2
Bidyanus bidyanus	0	0	2	0	1	1	6	0	9	1
Carassius auratus	54	22	271	105	105	5	91	7	521	139
Carcharhinus leucas	0	0	0	0	1	0	0	0	1	0
Craterocephalus fluviatilis	0	0	0	0	0	0	1	0	1	0
Craterocephalus marjoriae	0	0	10	0	0	0	0	0	10	0
Craterocephalus stercusmuscarum	0	0	13	15	195	271	14	10	222	296
Cyprinus carpio	0	0	735	204	771	314	606	322	2111	840
Gadopsis bispinosus	0	0	0	0	3	0	0	0	3	0
Gadopsis marmoratus	22	6	0	0	0	0	0	0	22	6
Galaxias brevipinnis	8	0	0	0	7	5	0	0	15	5
Galaxias maculatus	0	0	77	13	355	38	101	151	533	202
Galaxias olidus	679	180	37	8	0	0	0	0	716	188
Gambusia holbrooki	1141	2685	385	652	132	30	13	0	1671	3367
Gnathanodon speciosus	0	0	2	0	0	0	1	0	3	0
Gobiomorphus australis	0	0	87	2	604	44	283	36	975	82
Gobiomorphus coxii	0	0	760	289	77	6	12	1	849	296
Herklotsichthys castelnaui	0	0	0	0	6	0	1	0	7	0
Hypseleotris compressa	0	0	374	1	1582	98	931	116	2887	215
Hypseleotris galii	0	0	112	241	9	0	616	50	737	291
Hypseleotris spp	87	0	1196	115	2303	174	357	80	3943	369
Leiopotherapon unicolor	0	0	2	0	105	0	0	0	107	0
Liza argentea	0	0	0	0	17	10	5	0	22	10
Maccullochella peelii	0	0	31	13	7	1	14	3	52	17
Macquaria ambigua	0	0	18	14	112	5	98	10	228	29
Macquaria australasica	0	0	22	1	0	0	0	0	22	1
Macquaria colonorum	0	0	0	0	0	0	9	0	9	0
Macquaria novemaculeata	0	0	79	5	306	28	695	47	1079	80
Melanotaenia duboulayi	0	0	17	0	95	25	202	44	314	69
Melanotaenia fluviatilis	0	0	11	2	58	4	32	12	101	18
Mordacia praecox	0	0	4	6	28	177	1	2	33	185
Mugil cephalus	0	0	135	32	258	108	365	121	757	260
Myxus elongatus	0	0	0	0	0	0	2	0	2	0
Myxus petardi	0	0	125	5	339	21	295	32	759	58
Nematalosa erebi	0	0	53	1	1469	512	560	472	2082	985
Notesthes robusta	0	0	17	10	28	8	26	7	71	25
Oncorhynchus mykiss	49	5	23	4	9	1	15	2	96	12
Perca fluviatilis	87	9	116	40	21	6	196	48	421	103
Philypnodon grandiceps	5	0	102	1	247	40	335	1	689	42
Philypnodon sp1	0	0	36	0	79	24	35	1	150	25
Platycephalus fuscus	0	0	0	0	1	0	0	0	1	0
Potamalosa richmondia	0	0	257	40	145	44	203	10	605	94
Prototroctes maraena	0	0	29	3	32	1	3	0	64	4
Pseudaphritis urvillii	0	0	10	1	16	4	3	0	29	5
Pseudomugil signifer	0	0	97	0	64	2	32	0	193	2
Redigobius macrostoma	0	0	0	0	0	0	1	0	1	0
Retropinna semoni	0	0	849	7507	751	4003	927	596	2527	12105
Salmo trutta	215	14	20	6	14	20	34	3	283	43
Tandanus tandanus	0	0	257	22	118	4	172	10	547	36
Grand Total	**2473**	**2974**	**6905**	**10591**	**10845**	**6405**	**7520**	**2726**	**27742**	**22696**

Observed and identified but not caught. Abundance estimates only.

Table 2.8 Percentage of total number of individuals recorded as observed during electrofishing in the four different regions. The contributions of abundant species (>1000 individuals) with large percentages (>30%) of observed individuals may be under-estimated in quantitative analyses.

Species	Darling	Murray	North Coast	South Coast	Total	Likely under-estimation
Acanthopagrus australis	-	-	27.3	-	27.3	Low
Ambassis agassizii	0.0	-	69.0	-	68.7	Low
Ambassis nigripinnis	-	-	0.2	-	0.2	Low
Anguilla australis	*a*	*a*	*a*	*a*	*a*	
Anguilla reinhardtii	*a*	*a*	*a*	*a*	*a*	
Arius graeffei	-	-	0.0	-	0.0	Low
Arrhamphus sclerolepis	-	-	33.3	-	33.3	Low
Bidyanus bidyanus	0.0	33.3	-	-	10.0	Low
Carassius auratus	26.5	22.4	8.0	6.3	21.0	Low
Carcharhinus leucas	-	-	0.0	-	0.0	Low
Craterocephalus fluviatilis	-	0.0	-	-	0.0	Low
Craterocephalus marjoriae	-	-	0.0	-	0.0	Low
Craterocephalus stercusmuscarum	57.9	41.7	-	-	57.1	Low
Cyprinus carpio	28.5	27.9	39.0	9.8	28.5	Low
Gadopsis bispinosus	-	0.0	-	-	0.0	Low
Gadopsis marmoratus	19.2	-	-	50.0	21.4	Low
Galaxias brevipinnis	-	41.7	-	0.0	25.0	Low
Galaxias maculatus	-	-	-	27.5	27.5	Low
Galaxias olidus	7.9	35.5	5.5	0.0	20.8	Low
Gambusia holbrooki	80.0	63.4	23.0	62.1	66.8	High
Gnathanodon speciosus	-	-	0.0	-	0.0	Low
Gobiomorphus australis	-	-	8.7	6.2	7.7	Low
Gobiomorphus coxii	-	-	38.9	25.3	25.9	Low
Herklotsichthys castelnaui	-	-	0.0	-	0.0	Low
Hypseleotris compressa	-	-	7.6	0.0	6.9	Low
Hypseleotris galii	-	-	49.7	0.0	28.3	High
Hypseleotris spp	7.2	1.8	41.0	-	8.6	Low
Leiopotherapon unicolor	0.0	0.0	-	-	0.0	Low
Liza argentea	-	-	31.3	-	31.3	Low
Maccullochella peelii	24.8	-	-	-	24.8	Low
Macquaria ambigua	11.1	11.9	-	-	11.3	Low
Macquaria australasica	-	4.3	-	-	4.3	Low
Macquaria colonorum	-	-	0.0	0.0	0.0	Low
Macquaria novemaculeata	-	-	7.1	6.8	6.9	Low
Melanotaenia duboulayi	-	-	18.0	-	18.0	Low
Melanotaenia fluviatilis	15.4	0.0	-	-	15.1	Low
Mordacia praecox	-	-	-	84.9	84.9	Low
Mugil cephalus	-	-	22.4	41.5	25.6	Low
Myxus elongatus	-	-	-	0.0	0.0	Low
Myxus petardi	-	-	8.2	0.8	7.1	Low
Nematalosa erebi	32.3	27.5	-	-	32.1	High
Notesthes robusta	-	-	27.6	11.1	26.0	Low
Oncorhynchus mykiss	0.0	9.4	0.0	26.7	11.1	Low
Perca fluviatilis	24.8	10.5	-	3.7	19.7	Low
Philypnodon grandiceps	0.0	2.3	9.1	2.9	5.7	Low
Philypnodon sp1	-	-	0.0	18.7	14.3	Low
Platycephalus fuscus	-	-	0.0	-	0.0	Low
Potamalosa richmondia	-	-	13.5	0.0	13.4	Low
Prototroctes maraena	-	-	-	5.4	5.4	Low
Pseudaphritis urvillii	-	-	-	14.7	14.7	Low
Pseudomugil signifer	-	-	1.0	-	1.0	Low
Redigobius macrostoma	-	-	-	0.0	0.0	Low
Retropinna semoni	92.3	25.9	88.0	68.8	82.7	High
Salmo trutta	2.5	27.1	-	12.6	13.2	Low
Tandanus tandanus	14.6	-	5.1	0.0	6.2	Low
Grand Total	51.2	26.5	41.1	45.4	45.0	

a Percentages were not calculated for eels because these species were routinely recorded as observed.
Species not occurring within a region are shown as - . Species occurring within a region, but with no observed individuals, are shown with a percentage of zero.

Table 2.9 Percentage of total number of individuals recorded as observed during electrofishing in the four different river types. The contributions of abundant species (>1000 individuals) with large percentages (>30%) of observed individuals may be under-estimated in quantitative analyses.

Species	Montane	Slopes	Unregulated lowland	Regulated lowland	Total	Likely under-estimation
Acanthopagrus australis	-	-	0.0	37.5	27.3	Low
Ambassis agassizii	-	80.0	0.0	69.0	68.7	Low
Ambassis nigripinnis	-	0.4	0.0	0.0	0.2	Low
Anguilla australis	*a*	*a*	*a*	*a*	*a*	
Anguilla reinhardtii	*a*	*a*	*a*	*a*	*a*	
Arius graeffei	-	-	0.0	-	0.0	Low
Arrhamphus sclerolepis	-	-	33.3	-	33.3	Low
Bidyanus bidyanus	-	0.0	50.0	0.0	10.0	Low
Carassius auratus	28.8	27.9	4.3	7.1	21.0	Low
Carcharhinus leucas	-	-	0.0	-	0.0	Low
Craterocephalus fluviatilis	-	-	-	0.0	0.0	Low
Craterocephalus marjoriae	-	0.0	-	-	0.0	Low
Craterocephalus stercusmuscarum	-	53.6	58.2	41.7	57.1	Low
Cyprinus carpio	-	21.7	28.9	34.7	28.5	Low
Gadopsis bispinosus	-	-	0.0	-	0.0	Low
Gadopsis marmoratus	21.4	-	-	-	21.4	Low
Galaxias brevipinnis	0.0	-	41.7	-	25.0	Low
Galaxias maculatus	-	14.4	9.7	59.9	27.5	Low
Galaxias olidus	21.0	17.7	-	-	20.8	Low
Gambusia holbrooki	70.2	62.9	18.5	0.0	66.8	High
Gnathanodon speciosus	-	0.0	-	0.0	0.0	Low
Gobiomorphus australis	-	2.2	6.7	11.3	7.7	Low
Gobiomorphus coxii	-	27.6	7.2	7.8	25.9	Low
Herklotsichthys castelnaui	-	-	0.0	0.0	0.0	Low
Hypseleotris compressa	-	0.3	5.8	11.1	6.9	Low
Hypseleotris galii	-	68.3	0.0	7.5	28.3	High
Hypseleotris spp	0.0	8.8	7.0	18.3	8.6	Low
Leiopotherapon unicolor	-	0.0	0.0	-	0.0	Low
Liza argentea	-	-	37.0	0.0	31.3	Low
Maccullochella peelii	-	29.5	13.2	17.6	24.8	Low
Macquaria ambigua	-	43.8	4.3	9.3	11.3	Low
Macquaria australasica	-	4.3	-	-	4.3	Low
Macquaria colonorum	-	-	-	0.0	0.0	Low
Macquaria novemaculeata	-	5.9	8.4	6.3	6.9	Low
Melanotaenia duboulayi	-	0.0	20.8	17.9	18.0	Low
Melanotaenia fluviatilis	-	15.4	6.5	27.3	15.1	Low
Mordacia praecox	-	60.0	86.3	66.7	84.9	Low
Mugil cephalus	-	19.1	29.4	24.9	25.6	Low
Myxus elongatus	-	-	-	0.0	0.0	Low
Myxus petardi	-	3.8	5.8	9.8	7.1	Low
Nematalosa erebi	-	1.9	25.8	45.7	32.1	High
Notesthes robusta	-	37.8	21.2	21.5	26.0	Low
Oncorhynchus mykiss	9.3	14.8	10.0	11.8	11.1	Low
Perca fluviatilis	9.3	25.6	23.1	19.7	19.7	Low
Philypnodon grandiceps	0.0	1.0	13.9	0.3	5.7	Low
Philypnodon sp1	-	0.0	23.3	2.8	14.3	Low
Platycephalus fuscus	-	-	0.0	-	0.0	Low
Potamalosa richmondia	-	13.5	23.3	4.7	13.4	Low
Prototroctes maraena	-	8.4	3.0	0.0	5.4	Low
Pseudaphritis urvillii	-	9.1	20.0	0.0	14.7	Low
Pseudomugil signifer	-	0.0	3.0	0.0	1.0	Low
Redigobius macrostoma	-	-	-	0.0	0.0	Low
Retropinna semoni	-	89.8	84.2	39.1	82.7	High
Salmo trutta	6.1	23.1	58.8	8.1	13.2	Low
Tandanus tandanus	-	7.9	3.3	5.6	6.2	Low
Grand Total	54.6	60.5	37.1	26.6	45.0	

a Percentages were not calculated for eels because these species were routinely recorded as observed.
Species not occurring within a river type are shown as - . Species occurring within a river type, but with no observed individuals, are shown with a percentage of zero.

Fish species occurrence and richness

Survey sampling collected 55 fish species. These comprised 39 native freshwater species from 25 genera and 19 families, together with ten estuarine species and six alien fish species. Fish species richness data from the survey for the 26 river drainage basins and four freshwater ecological regions of New South Wales are summarised in Table 2.10, together with a comparison of results from a 1983 survey. Classifications of species by habitat and origin were given in Table 2.5. Appendix 1 provides fish species occurrence data from the Rivers Survey for the 25 river-drainage basins identified by New South Wales Department of Water Resources (undated). Full details of the site, location and timing of particular records are given in the NSW Rivers Survey Data Report (Harris *et al.* 1996).

Table 2.10 Numbers of fish species recorded in river drainage basins in the NSW Rivers Survey ("1996 survey") and a previous study (Llewellyn 1983)("1983 survey"), with the discrepancies (1996 total, minus 1983 total) between results from the two surveys.

		No. of species caught		
Catchment name	**Ecological region**	**1996**	**1983**	**Discrepancy**
Richmond River	North coast	28	14	14
Clarence River	North coast	24	26	-2
Macleay River	North coast	18	14	4
Hastings River	North coast	18	15	3
Manning	North coast	17	2	15
Karuah River	North coast	11	6	5
Hunter River	North coast	16	10	6
Hawkesbury River	South coast	17	21	-4
Sydney Coast - Georges River	South coast	13	11	2
Shoalhaven River	South coast	16	16	0
Clyde River	South coast	13	8	5
Moruya River	South coast	11	13	-2
Tuross River	South coast	14	7	7
Bega River	South coast	16	6	10
Towamba River	South coast	8	2	6
East Gippsland	South coast	10	10	0
Snowy River	South coast	11	8	3
Upper Murray	Murray	7	4	3
Murray River	Murray	8	12	-4
Murrumbidgee River	Murray	15	25	-10
Lachlan River	Murray	14	17	-3
Gwydir River Basin	Darling	14	12	2
Namoi River Basin	Darling	12	14	-2
Castlereagh River Basin	Darling	3	6	-3
Macquarie River Basin	Darling	17	18	-1
Darling River Basin	Darling	11	9	2

A comparison of the fish species predicted and those actually caught

A review of all available sources indicated that 55 native freshwater species could be predicted in New South Wales, but 16 (29%) of these predicted species, including six classed as threatened, were not caught in the NSW Rivers Survey. Table 2.11 summarises these data by ecological regions. Details of the species caught and those predicted from various sources are presented in Table 2.12. Only 50 out of an overall total of 81 fish species (listing freshwater, estuarine and alien groups) which were predicted to occur in fresh water were actually collected in the Rivers Survey, and five additional species were collected which were not predicted. Other than the 16 native freshwater fish noted above, the discrepancy of 31 species includes 11 estuarine and five alien fish species. The discrepancy also includes five freshwater species *(Aldrichetta forsteri, Butis butis, Chanos chanos, Glossamia aprion and Megalops cyprinoides)* which are at the limits of their distribution in New South Wales waters. The status and distributions of these different groups of fish is discussed in detail in Chapters 4 and 8. During the modified-random selection process to choose sites for the Rivers Survey, four river catchments were excluded because NSW Fisheries was already sampling fish in other projects in these rivers. They were the Paroo, Macintyre, Myall/Crawford and parts of the Hawkesbury river systems. Analysis of results from these various studies (Table 2.13) show that only two additional predicted species were caught, *Neosilurus hyrtlii* and *Mordacia mordax*. The five species which were collected but not predicted were *Acanthopagrus australis, Carcharhinus leucas, Gnathanodon speciosus, Herklotsichthys castelnaui* and *Platycephalus fuscus*. All five of these are estuarine species rather than freshwater fish.

The survey reported by Llewellyn (1983) was less structured than the NSW Rivers Survey and involved substantially less sampling effort. Not surprisingly therefore, the species-richness discrepancies between results of the two surveys for individual river basins which are listed in Appendix 1 mostly resulted from increased numbers of species recorded in 1996, with 35% of the drainages recording more species. The distribution of negative discrepancies is important however; in the North Coast region one drainage of the seven (14%) had fewer species in 1996. Of the ten South Coast drainages, two (20%) had fewer species. But results were sharply different in the inland regions; in the five Darling region drainages three (60%) had fewer species, while the Murray region was worst in this comparison, with three out of four (75%) river drainages recording fewer species in the 1996 Rivers Survey than they had in the less-intensive survey of 1983. Eleven species collected in 1983 were not found in 1996. These were *Ambassis castelnaui, Galaxias rostratus, Maccullochella ikei, Maccullochella macquariensis, Mogurnda adspersa, Mordacia mordax, Nannoperca australis, Nannoperca oxleyana, Rhadinocentrus ornatus, Salvelinus fontinalis* and *Tinca tinca.* The twelve species collected in 1996 but not in the 1983 survey were *Acanthopagrus australis, Ambassis agassizii, Arrhamphus sclerolepis, Carcharhinus* *leucas, Gadopsis bispinosus, Gnathanodon speciosus, Herklotsichthys castelnaui, Liza argentea, Myxus elongatus, Platycephalus fuscus, Pseudaphritis urvillii,* and *Redigobius macrostoma*.

Table 2.11 Comparison of the numbers of freshwater native and alien fish species caught in the Rivers Survey, and those predicted from all available information in each of the four ecological regions, and for New South Wales as a whole.

	Native species		**Percent native spp. caught**	**Alien species**	
	Predicted	Caught		Predicted	Caught
Darling	21	14	67	7	6
Murray	27	14	52	10	6
North Coast	33	23	70	7	4
South Coast	26	22	85	10	4
NSW total	**55**	**39**	**71**	**11**	**6**

Table 2.12 Comparison of the 55 fish species caught in the NSW Rivers Survey with those predicted from all available information (81 species), together with the results of the 1975-76 survey by Llewellyn (1983).

Species	**NSW Pred**[1]	**NSW 96**[2]	**NSW 83**[3]	**Darl. Pred.**	**Darl. 96**	**Darl. 83**	**Murr. Pred.**	**Murr. 96**	**Murr. 83**	**NC Pred.**	**NC 96**	**NC 83**	**SC Pred.**	**SC 96**	**SC 83**	**Pred. Tot.**	**96 Tot.**	**83 Tot**
Acanthogobius flavimanus	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**1**	**0**	**0**
Acanthopagrus australis	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	**0**	**1**	**0**
Afurcagobius tamarensis	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	**2**	**0**	**0**
Aldrichetta forsteri	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**1**	**0**	**0**
Ambassis agassizii	1	1	0	0	1	0	1	0	0	1	1	0	0	0	0	**2**	**2**	**0**
Ambassis castelnaui	1	0	1	1	0	1	1	0	1	0	0	0	0	0	0	**2**	**0**	**2**
Ambassis marianus	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	**2**	**0**	**0**
Ambassis nigripinnis	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	**1**	**1**	**1**
Anguilla australis	1	1	1	0	0	0	1	0	1	1	1	1	1	1	1	**3**	**2**	**3**
Anguilla reinhardtii	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	**2**	**2**	**2**
Arenigobius bifrenatus	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	**2**	**0**	**0**
Arius graeffei	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	**1**	**1**	**1**
Arrhamphus sclerolepis	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	**1**	**1**	**0**
Atherinosoma microstoma	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	**2**	**0**	**0**
Bidyanus bidyanus	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	**2**	**2**	**2**
Butis butis	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**	**0**	**0**
Carassius auratus	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**4**	**4**	**4**
Carcharhinus leucas	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	**0**	**1**	**0**
Chanos chanos	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**	**0**	**0**
Craterocephalus amniculus	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**	**0**	**0**
Craterocephalus fluviatilis	1	1	1	1	0	1	1	1	1	0	0	1	0	0	0	**2**	**1**	**3**
Craterocephalus marjoriae	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	**1**	**1**	**1**
Craterocephalus stercusmuscarum	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	**2**	**2**	**1**
Cyprinus carpio	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	**4**	**4**	**3**
Gadopsis bispinosus	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	**1**	**1**	**0**
Gadopsis marmoratus	1	1	1	1	1	1	1	0	1	0	0	0	1	1	1	**3**	**2**	**3**
Galaxias brevipinnis	1	1	1	0	0	0	1	1	0	0	0	0	1	1	1	**2**	**2**	**1**
Galaxias maculatus	1	1	1	0	0	0	0	0	0	1	0	1	1	1	1	**2**	**1**	**2**
Galaxias olidus	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**4**	**4**	**4**

(continued)

NSW Pred[1] - Fish species predicted in New South Wales freshwater environments, 1994 (see text). '1' = species predicted, '0' = species not predicted.
NSW 96[2] - Fish species caught in the Rivers Survey, all regions. Darl - Darling, Murr - Murray, NC - North Coast, SC - South Coast. '1' = species caught, '0' = species not caught.
NSW 83[3] - Records of Llewellyn (1983).

Table 2.12 (continued)

Species	NSW Pred[1]	NSW 96[2]	NSW 83[3]	Darl. Pred.	Darl. 96	Darl. 83	Murr. Pred.	Murr. 96	Murr. 83	NC Pred.	NC 96	NC 83	SC Pred.	SC 96	SC 83	Tot. Pred.	Tot. 96	Tot. 83
Galaxias rostratus	1	0	1	1	0	0	1	0	1	0	0	0	0	0	0	**2**	**0**	**1**
Gambusia holbrooki	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**4**	**4**	**4**
Geotria australis	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	**1**	**0**	**0**
Glossamia aprion	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**	**0**	**0**
Gnathanodon speciosus	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	**0**	**1**	**0**
Gobiomorphus australis	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	**2**	**2**	**2**
Gobiomorphus coxii	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	**2**	**2**	**2**
Herklotsichthys castelnaui	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	**0**	**1**	**0**
Hypseleotris compressa	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	**2**	**2**	**2**
Hypseleotris galii	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	**2**	**2**	**2**
Hypseleotris spp	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	**3**	**3**	**4**
Leiopotherapon unicolor	1	1	1	1	1	1	1	1	0	1	0	1	0	0	0	**2**	**2**	**2**
Liza argentea	1	1	0	0	0	0	0	0	0	1	1	0	1	0	0	**2**	**1**	**0**
Lutjanus argentimaculatus	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**	**0**	**0**
Maccullochella ikei	1	0	1	0	0	0	0	0	0	1	0	1	0	0	0	**1**	**0**	**1**
Maccullochella macquariensis	1	0	1	1	0	0	1	0	1	0	0	0	0	0	0	**2**	**0**	**1**
Maccullochella peelii	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	**2**	**1**	**2**
Macquaria ambigua	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	**2**	**2**	**2**
Macquaria australasica	1	1	1	0	0	0	1	1	1	0	0	0	1	0	1	**2**	**1**	**2**
Macquaria colonorum	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	**2**	**2**	**2**
Macquaria novemaculeata	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	**2**	**2**	**2**
Megalops cyprinoides	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**	**0**	**0**
Melanotaenia duboulayi	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	**1**	**1**	**1**
Melanotaenia fluviatilis	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	**2**	**2**	**1**
Misgurnus anguillicaudatus	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	**2**	**0**	**0**
Mogurnda adspersa	1	0	1	1	0	1	1	0	1	1	0	0	0	0	0	**3**	**0**	**2**
Monodactylus argenteus	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	**2**	**0**	**0**
Mordacia mordax	1	0	1	0	0	0	1	0	1	0	0	0	1	0	1	**2**	**0**	**2**
Mordacia praecox	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	**1**	**1**	**1**
Mugil cephalus	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	**2**	**2**	**2**

(continued)

NSW Pred[1] - Fish species predicted in New South Wales freshwater environments, 1994 (see text). '1' = species predicted, '0' = species not predicted.
NSW 96[2] - Fish species caught in the Rivers Survey, all regions. Darl - Darling, Murr - Murray, NC - North Coast, SC - South Coast. '1' = species caught, '0' = species not caught.
NSW 83[3] - Records of Llewellyn (1983).

Table 2.12 (continued)

Species	NSW Pred[1]	NSW 96[2]	NSW 83[3]	Darl. Pred.	Darl. 96	Darl. 83	Murr. Pred.	Murr. 96	Murr. 83	NC Pred.	NC 96	NC 83	SC Pred.	SC 96	SC 83	Pred. Tot.	96 Tot.	83 Tot
Myxus elongatus	1	1	0	0	0	0	0	0	0	1	0	0	1	1	0	**2**	**1**	**0**
Myxus petardi	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	**2**	**2**	**2**
Nannoperca australis	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	**1**	**0**	**1**
Nannoperca oxleyana	1	0	1	0	0	0	0	0	0	1	0	1	0	0	0	**1**	**0**	**1**
Nematalosa erebi	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	**2**	**2**	**2**
Neosilurus hyrtlii	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**	**0**	**0**
Notesthes robusta	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	**2**	**2**	**2**
Oncorhynchus mykiss	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	**4**	**4**	**3**
Perca fluviatilis	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	**4**	**3**	**3**
Philypnodon grandiceps	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	**4**	**4**	**3**
Philypnodon sp1	1	1	1	1	0	0	1	0	0	1	1	1	1	1	1	**4**	**2**	**2**
Platycephalus fuscus	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	**0**	**1**	**0**
Potamalosa richmondia	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	**2**	**2**	**2**
Prototroctes maraena	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	**1**	**1**	**1**
Pseudaphritis urvillii	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0	**1**	**1**	**0**
Pseudogobius sp9	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	**2**	**0**	**0**
Pseudomugil signifer	1	1	1	0	0	0	0	0	0	1	1	1	1	0	1	**2**	**1**	**2**
Redigobius macrostoma	1	1	0	0	0	0	0	0	0	1	0	0	1	1	0	**2**	**1**	**0**
Retropinna semoni	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**4**	**4**	**4**
Rhadinocentrus ornatus	1	0	1	0	0	0	0	0	0	1	0	1	0	0	0	**1**	**0**	**1**
Salmo salar	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	**2**	**0**	**0**
Salmo trutta	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	**4**	**3**	**3**
Salvelinus fontinalis	1	0	1	0	0	1	1	0	0	1	0	0	1	0	1	**3**	**0**	**2**
Strongylura krefftii	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**	**0**	**0**
Tandanus tandanus	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	**4**	**3**	**4**
Tinca tinca	1	0	1	1	0	0	1	0	1	0	0	0	0	0	0	**2**	**0**	**1**
Valamugil georgii	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	**2**	**0**	**0**
Total	**81**	**55**	**54**	**28**	**20**	**22**	**37**	**20**	**26**	**54**	**35**	**31**	**47**	**31**	**33**			

NSW Pred[1] - Fish species predicted in New South Wales freshwater environments, 1994 (see text). '1' = species predicted, '0' = species not predicted.
NSW 96[2] - Fish species caught in the Rivers Survey, all regions. Darl - Darling, Murr - Murray, NC - North Coast, SC - South Coast. '1' = species caught, '0' = species not caught.
NSW 83[3] - Records of Llewellyn (1983).

Table 2.13 List of species caught from river drainage basins that were excluded (completely or partially) from site selection for the NSW Rivers Survey because other NSW Fisheries research projects were already sampling in those catchments.

Species	**River drainage basin**			
	Macintyre (D)	**Paroo (D)**	**Myall/Crawford (NC)**	**Hawkesbury (SC**
Acanthogobius flavimanus	0	0	0	1
Acanthopagrus australis	0	0	1	1
Anguilla australis	0	0	0	1
Anguilla reinhardtii	0	0	1	1
Arrhamphus sclerolepis	0	0	0	1
Bidyanus bidyanus	1	1	0	1
Carassius auratus	1	1	0	1
Craterocephalus stercusmuscarum	1	0	0	0
Cyprinus carpio	1	1	0	1
Galaxias brevipinnis	0	0	0	1
Galaxias maculatus	0	0	1	1
Galaxias olidus	0	0	0	1
Gambusia holbrooki	1	1	1	1
Gobiomorphus australis	0	0	1	1
Gobiomorphus coxii	0	0	0	1
Herklotsichthys castelnaui	0	0	1	1
Hypseleotris compressa	0	0	1	1
Hypseleotris galii	0	0	1	1
Hypseleotris spp	1	1	0	1
Leiopotherapon unicolor	0	1	0	0
Liza argentea	0	0	1	1
Lutjanus argentimaculatus	0	0	0	1
Maccullochella peelii	1	0	0	1
Macquaria ambigua	1	1	0	1
Macquaria australasica	0	0	0	1
Macquaria colonorum	0	0	0	1
Macquaria novemaculeata	0	0	1	1
Melanotaenia fluviatilis	1	1	0	0
Misgurnus anguillicaudatus	0	0	0	1
Monodactylus argenteus	0	0	0	1
Mordacia mordax	0	0	0	1
Mugil cephalus	0	0	1	1
Myxus elongatus	0	0	1	1
Myxus petardi	0	0	1	1
Nematalosa erebi	1	1	0	0
Neosilurus hyrtlii	0	1	0	0
Notesthes robusta	0	0	1	1
Oncorhynchus mykiss	0	0	0	1
Perca fluviatilis	1	0	0	1
Philypnodon grandiceps	0	0	1	1
Philypnodon sp1	0	0	1	1
Platycephalus fuscus	0	0	0	1
Potamalosa richmondia	0	0	0	1
Pseudomugil signifer	0	0	1	1
Redigobius macrostoma	0	0	0	1
Retropinna semoni	1	1	1	1
Salmo trutta	0	0	0	1
Tandanus tandanus	1	0	1	1
Total	**13**	**11**	**19**	**43**

‘1’ - indicates species caught, ‘0’ - indicates species not caught. D,M,NC,SC - region codes.

Abnormalities and diseases of fish

Each individual fish measured in Rivers Survey samples was examined for external lesions and visible evidence of injuries, diseases or other abnormalities. Table 2.14 and Figure 2.2 show, by ecological region and river type, the proportions of the catch with abnormalities including infestation with the copepod parasite *Lernaea*, wounds, ulcers, cysts, and a composite group of other less-common abnormalities. Only 22 of the 80 sites recorded no abnormalities among fish (Table 2.15). Up to 100% of fish from the remaining sites suffered abnormalities. More sites in the Murray and Darling regions experienced high proportions of abnormalities among fish, but little other pattern was evident in the distribution of high-abnormalities sites (Figure 2.3). No consistent pattern was evident in the distribution of abnormalities according to river type (Table 2.14), although montane sites were strongly affected in the Darling and Murray regions. Unregulated lowlands sites in the Murray and South Coast regions also had relatively high proportions of fish with abnormalities. The incidence of abnormalities recorded at individual sites progressively increased during the survey (Table 2.15), six sites suffered their highest proportion of abnormalities during the first survey, 12 during the second, 19 during the third and 21 sites experienced their highest proportion of abnormalities in the final survey round.

Table 2.16 shows the incidence of abnormalities by species. Murray cod (27.7%) and golden perch (24.3%) suffered the highest abnormality rates. Only 25 of the 55 species caught were free of visible abnormalities over all samples. Some bias appears to be present in these results as, apart from rare species and the venomous bullrout, which was difficult to examine, the species recorded with low incidences are predominantly small-bodied fish on which abnormalities would be more difficult to detect than on the generally larger fish nearer the top of the occurrence table.

The presence of increasing densities of carp among the catch was associated with increasing incidence of visible abnormalities, particularly *Lernaea* infestation, in other fish species. Regression analysis showed a significant relationship ($P = 0.0036$) between the incidence of abnormalities on fish other than carp, and the proportion of carp in the population and showed that 10.3% of the total variation in abnormalities was explained by the proportion of carp in the catch. Figure 2.4 illustrates this trend for high carp density to be associated with abnormality in other fish.

Table 2.14 Proportion (%) of the measured fish population with specified abnormalities, by region, river type and overall.

Region	River type	Lernaea	Wounds	Ulcers	Cysts	Other*	All
Darling	Montane	0.00	0.19	0.00	3.60	0.19	3.98
	Slopes	2.82	0.45	0.64	1.82	0.09	5.63
	Reg. low.	3.20	0.25	0.25	0.34	0.84	4.71
	Unreg. low	2.46	0.16	1.69	0.44	0.38	4.76
	Total	2.74	0.26	0.88	1.10	0.41	4.86
Murray	Montane	0.34	0.00	0.00	8.50	0.00	8.84
	Slopes	1.17	0.39	0.19	0.39	0.00	2.14
	Reg. low.	5.11	0.32	1.12	0.00	0.32	6.55
	Unreg. low	8.62	0.54	0.36	0.00	0.25	10.05
	Total	4.37	0.35	0.50	1.36	0.25	6.73
North Coast	Montane	0.00	0.00	0.00	9.11	0.00	9.11
	Slopes	0.18	0.42	0.06	0.36	0.60	1.44
	Reg. low.	1.41	0.49	0.05	0.70	1.30	3.57
	Unreg. low	0.08	0.17	0.00	0.51	0.17	0.93
	Total	0.50	0.32	0.03	1.07	0.61	2.37
South Coast	Montane	0.00	0.00	0.00	0.00	0.00	0.00
	Slopes	0.00	0.23	0.00	0.00	0.00	0.23
	Reg. low.	0.83	0.76	0.69	0.07	0.35	2.50
	Unreg. low	0.18	0.44	0.35	0.18	2.48	3.63
	Total	0.34	0.46	0.34	0.07	0.79	1.92
All	Montane	0.07	0.07	0.00	5.38	0.07	5.58
	Slopes	0.87	0.37	0.20	0.61	0.24	2.18
	Reg. low.	2.12	0.49	0.41	0.35	0.80	3.90
	Unreg. low	1.65	0.26	0.63	0.37	0.71	3.50
	Total	1.44	0.34	0.39	0.87	0.56	3.45

* Refers to other externally visible abnormalitites such as malformations, tumours, scars, red-spot disease lesions, fin rot, and parasites other than Lernaea.

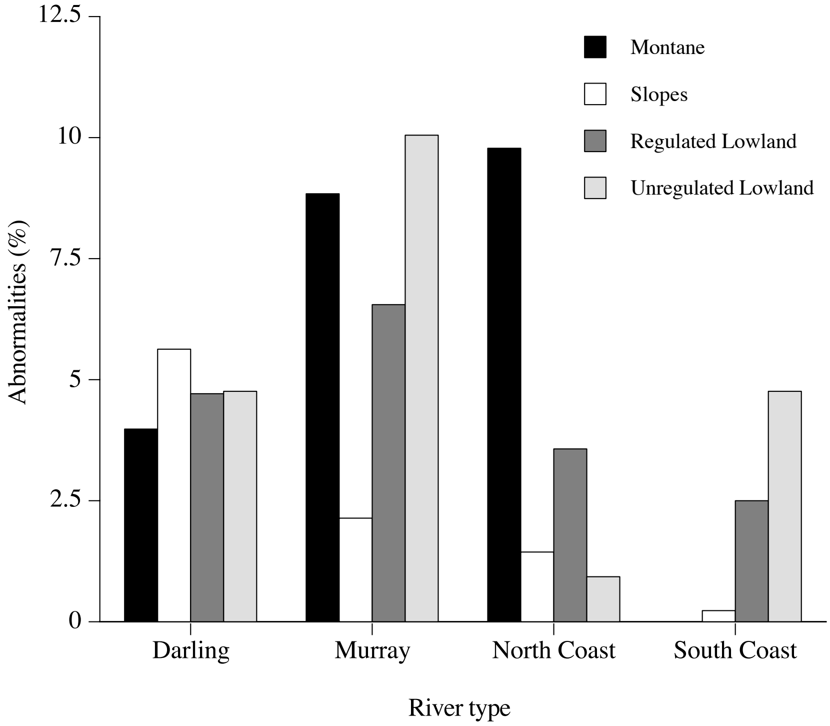

Figure 2.2 Proportions (%) of the measured fish population having visible abnormalities, averaged over all four surveys, by region and river type. (∑N=17047).

Table 2.15 Proportions of the measured fish populations having some form of abnormality at the 80 Rivers Survey sites. The table is sorted by sites having the highest incidence of abnormality at any one survey.

Site code•	Site Name	No. fish measured	% fish with abnormality#	Highest incidence of abnormality*	Relevant survey
MM25	Arkstone	128	18.8	100.0	3
DM5	Burrough Crossing	84	22.6	75.0	3
DRL9	Benbraggie	134	3.0	40.0	2
MUL36	Wheelba Bridge	175	8.0	36.0	4
DUL20	Brewon	215	20.5	35.4	4
MRL26	Narrandera	143	8.4	33.3	4
NCM45	Herbert Park	184	14.7	32.5	3
MUL39	Kyalite	177	15.3	27.3	4
MUL40	Walbundrie	59	10.2	27.3	3
DS12	Sofala	333	5.1	26.6	1
DRL7	Pooncarie	236	7.2	26.5	4
NCS54	Pecan Nut Farm	151	7.3	25.0	2
SCRL67	Mangrove Mountain	71	15.5	25.0	4
NCRL47	Elderslie	389	12.6	22.5	3
DS15	Reata	235	5.5	20.0	4
DS14	Weonga	139	7.9	19.0	4
DRL8	Downham Farm	428	6.1	16.9	4
SCUL77	Timbilica	208	2.9	16.7	4
MRL29	Bindawalla	174	12.1	16.4	4
NCM41	Dundurrabin	155	3.9	16.1	3
DS11	Pontibah	185	4.9	15.8	3
SCS72	Burragate	181	1.7	15.8	3
DS13	Dunedoo	209	5.7	15.0	4
DUL19	Koomora	574	3.5	15.0	4
MUL38	Willow Isles	91	9.9	14.7	3
DM2	Comara	176	0.6	14.3	1
MRL27	Echuca	138	5.8	14.0	4
SCUL79	Batemans Bay	288	6.9	13.5	4
NCM42	Spring Ridge	19	10.5	12.5	3
MS31	Little Narraway	123	6.5	11.4	4
MM23	Cappawidgee	70	2.9	11.1	4
DRL6	Vickery Bridge	117	6.0	10.0	4
DRL10	Burrendong	273	0.7	10.0	1
SCUL78	Bodalla	373	3.8	9.7	2
NCUL58	Stroud	290	1.7	9.4	3
NCM44	Rozelle	20	5.0	9.1	3
SCRL70	Wallacia	303	4.6	8.6	4
NCRL49	Dungog	126	2.4	7.1	2
DUL16	East Toorale	292	2.1	6.8	2
NCS51	Ellenborough	339	2.4	6.7	2

(continued)

• Site code consists of first letter(s) of region, first letter(s) of river type, then site number
Totalled over all four surveys
* Maximum incidence of abnormalities at any survey

Table 2.15 (continued)

Site code•	Site Name	No. fish measured	% fish with abnormality#	Highest incidence of abnormality*	Relevant survey
DUL18	Moree	296	3.0	5.4	4
SCRL69	Sutherland	428	1.4	5.3	3
NCS55	Carinya	361	0.8	5.0	1
SCRL68	Yarranung	257	0.4	4.8	3
DM4	Charlton	91	1.1	4.5	1
MS34	Tuena	140	0.7	4.5	1
NCRL50	Dunoon	521	1.9	4.5	3
MS35	Buckmasters Bridge	81	2.5	3.9	2
SCRL66	Burrier Pump Station	380	1.1	3.8	2
NCUL56	Eugowra	381	1.6	3.5	2
NCRL48	Tintenbar	498	0.6	3.3	2
NCUL59	Gordon Brook	500	1.2	3.1	3
DUL17	Bogan Bridge	452	1.8	2.7	2
SCUL76	Tumble Bar Farm	209	0.5	2.0	3
NCUL57	Coutts Crossing	515	0.6	1.7	2
NCS52	Timbarra	473	0.4	1.2	3
NCRL46	Casino	313	0.3	1.0	4
NCUL60	Lismore	651	0.3	0.5	3
DM1	Riverlee	68	0.0	0.0	-
DM3	Riverview	109	0.0	0.0	-
MM21	Allonby	44	0.0	0.0	-
MM22	Benbullen	46	0.0	0.0	-
MM24	Cooma	6	0.0	0.0	-
MRL28	Readymix	103	0.0	0.0	-
MRL30	Glendale	68	0.0	0.0	-
MS32	Coodravale	126	0.0	0.0	-
MS33	Balbardie	43	0.0	0.0	-
MUL37	Tintaldra	55	0.0	0.0	-
NCM43	Linda Downs	17	0.0	0.0	-
NCS53	Bellbrook	348	0.0	0.0	-
SCM61	Bibbenluke	51	0.0	0.0	-
SCM62	Adaminaby	42	0.0	0.0	-
SCM63	Arable	7	0.0	0.0	-
SCM64	Lithgow	165	0.0	0.0	-
SCM65	Bill Jeffery Memorial	32	0.0	0.0	-
SCS71	No Name Reserve	45	0.0	0.0	-
SCS73	Duea National Park	515	0.0	0.0	-
SCS74	Tuross	451	0.0	0.0	-
SCS75	Morans Crossing	103	0.0	0.0	-
SCUL80	Narrabarba	51	0.0	0.0	-

• Site code consists of first letter(s) of region, first letter(s) of river type, then site number
Totalled over all four surveys
* Maximum incidence of abnormalities at any survey

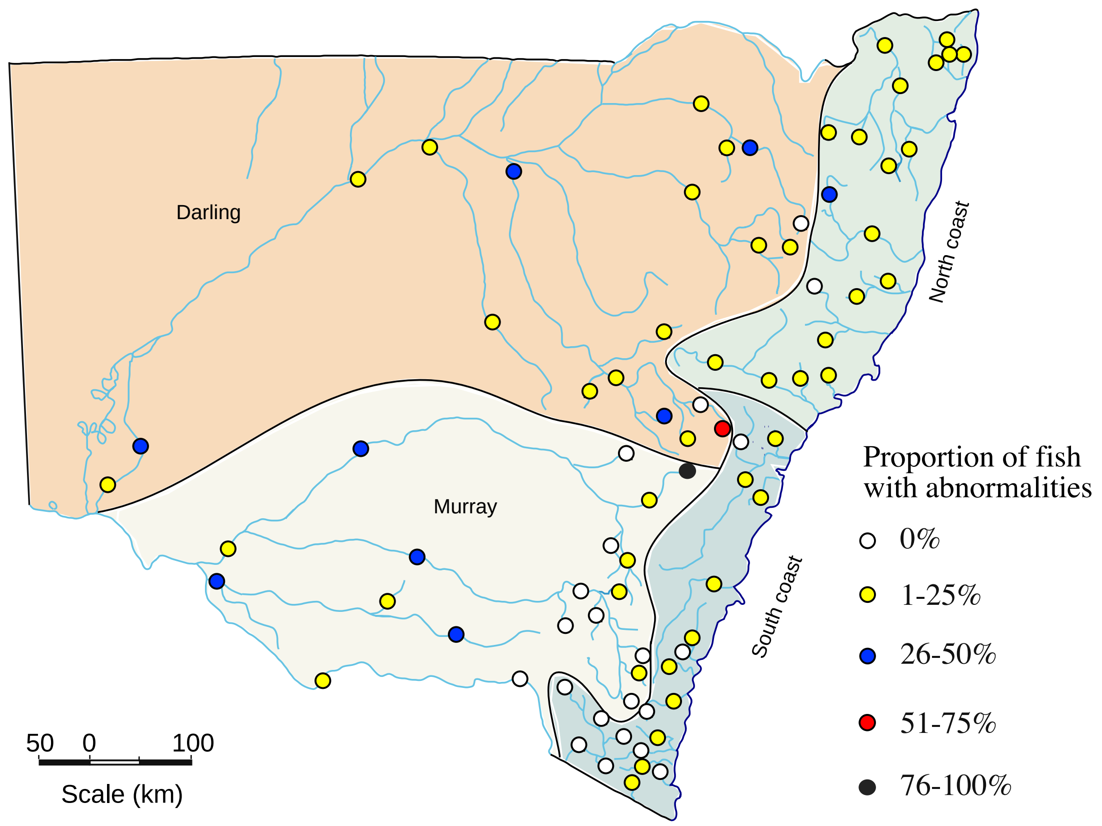

Figure 2.3 Distribution of sites showing various levels of visible abnormalities on fish, over all four Rivers Survey samples.

Table 2.16 Occurrence of visible abnormalities in fish species. The table is sorted by species with the highest incidence of visible abnormalities.

Species	**Total fish measured**	**No. abnormal fish**	**% fish with abnormalities**
Maccullochella peelii	47	13	27.7
Macquaria ambigua	218	53	24.3
Philypnodon sp1	145	19	13.1
Acanthopagrus australis	8	1	12.5
Galaxias olidus	567	66	11.6
Macquaria colonorum	9	1	11.1
Carassius auratus	440	44	10.0
Macquaria australasica	23	2	8.7
Cyprinus carpio	1871	155	8.3
Mugil cephalus	687	34	4.9
Gambusia holbrooki	682	33	4.8
Leiopotherapon unicolor	84	4	4.8
Macquaria novemaculeata	1016	42	4.1
Hypseleotris galii	242	10	4.1
Gadopsis marmoratus	25	1	4.0
Tandanus tandanus	535	20	3.7
Melanotaenia fluviatilis	99	2	2.0
Gobiomorphus australis	817	14	1.7
Nematalosa erebi	1347	23	1.7
Prototroctes maraena	61	1	1.6
Myxus petardi	670	8	1.2
Hypseleotris spp	780	9	1.2
Oncorhynchus mykiss	89	1	1.1
Perca fluviatilis	302	3	1.0
Philypnodon grandiceps	535	5	0.9
Retropinna semoni	1637	14	0.9
Gobiomorphus coxii	737	4	0.5
Galaxias maculatus	202	1	0.5
Hypseleotris compressa	1000	4	0.4
Salmo trutta	282	1	0.4
Ambassis agassizii	34	0	0.0
Ambassis nigripinnis	93	0	0.0
Anguilla australis	46	0	0.0
Anguilla reinhardtii	468	0	0.0
Arius graeffei	46	0	0.0
Arrhamphus sclerolepis	4	0	0.0
Bidyanus bidyanus	9	0	0.0
Carcharhinus leucas	1	0	0.0
Craterocephalus fluviatilis	1	0	0.0
Craterocephalus marjoriae	10	0	0.0
Craterocephalus stercusmuscarum	135	0	0.0
Gadopsis bispinosus	3	0	0.0
Galaxias brevipinnis	15	0	0.0
Gnathanodon speciosus	3	0	0.0
Herklotsichthys castelnaui	7	0	0.0
Liza argentea	16	0	0.0
Melanotaenia duboulayi	221	0	0.0
Mordacia praecox	34	0	0.0
Myxus elongatus	2	0	0.0
Notesthes robusta	60	0	0.0
Platycephalus fuscus	1	0	0.0
Potamalosa richmondia	490	0	0.0
Pseudaphritis urvillii	29	0	0.0
Pseudomugil signifer	164	0	0.0
Redigobius macrostoma	1	0	0.0

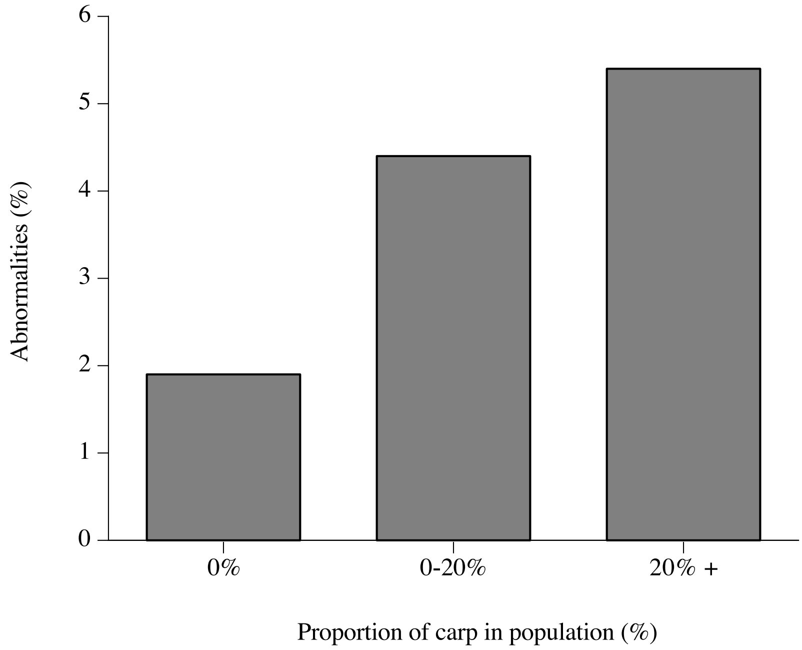

Figure 2.4 The relationship between the proportion of carp in fish populations and the incidence of visible abnormalities on fish other than carp.

Fish in degraded sites

Three sites (DS81, DUL83 and NCS82) were selected in the modified-random process for choosing river reaches to be sampled in the Rivers Survey, but rejected from routine sampling because they were severely degraded (Chapter 1). These sites, in the Cockburn, Castlereagh and Goulburn rivers, were sampled once only, in survey 4, using backpack electrofishing gear because of their shallow, silted habitats. Only four, three and two species, respectively, were recorded from each site (Table 2.17).

Table 2.17 List of species caught and observed at the degraded river sites, which were sampled once only, in survey 4.

Site code	Stream name	Site name	Nearest town	Species	No. caught	No. observed
DS81	Cockburn River	Moonbi	Limbri	*Cyprinus carpio*	1	0
				Gambusia holbrooki	27	2100
				Tandanus tandanus	2	0
				Hypseleotris spp	23	10
				DS81 total	**53**	**2110**
NCS82	Goulburn River	Denman	Denman	*Anguilla reinhardtii*	0	1
				Gambusia holbrooki	27	400
				NCS82 total	**27**	**401**
DUL83	Castlereagh River	Combogolong	Walgett	*Cyprinus carpio*	11	0
				Leiopotherapon unicolor	1	0
				Retropinna semoni	1	0
				DUL83 total	**13**	**0**

Length-weight relationships

To obtain estimates of total fish biomass per unit area sampled and to improve biological knowledge for future studies, lengths and weights of all fish sampled in the calibration experiments were measured (Chapter 3). For routine Rivers Survey samples, only fish lengths were measured, so a length-weight relationship was required to convert the survey data to estimated biomass.

Calibration experiments provided data for the estimation of length-weight relationships for ten fish species: Australian bass *Macquaria novemaculeata*, Australian grayling *Prototroctes maraena*, bony herring *Nematalosa erebi*, bullrout *Notesthes robusta*, carp *Cyprinus carpio*, freshwater catfish *Tandanus tandanus*, freshwater herring *Potamalosa richmondia*, goldfish *Carassius auratus*, longfinned eel *Anguilla reinhardtii*, and river blackfish *Gadopsis marmoratus.* Lengths were measured to the nearest millimetre, as total length, for bullrout, freshwater catfish and long-finned eel, and as caudal fork length for the other seven species. Weights were measured to the nearest gram.

Two models were fitted to the data for each species:

(A) A nonlinear model of the form

$\text{weight} = a.\ (\text{length})^{b} + \varepsilon$

where a and b are fitted parameters and ε is the error term.

(B) A linearised model of the form

$\log_{10}(\text{weight}) = a' + b' \log_{10}(\text{length}) + \varepsilon'$.

Taking antilogs to obtain estimates in the original units gives

weight = a''. $(\text{length})^{b'}$. ε'', where $a''=10^{a'}$ and $\varepsilon''=10^{\varepsilon'}$.

Model B is based on a logarithmic transformation which tends to stabilise the variance over the range of the data, but expression of the results in the original units by taking antilogs introduces a bias: the compressing effect of the log transformation on the large values gives rise to less leverage of these large values. Beauchamp and Olson (1973) proposed a number of alternative exact and approximate estimators to correct for this bias. The exact correction factor needs to be computed for each datum point and involves the calculation of a modified Bessel function. A single approximation for each dataset (Beauchamp and Olson 1973; Sprugel 1983) gives results which are very similar to those based on the exact estimator. The exact correction and the approximation were computed for the present study, but only the approximation is quoted in the results. The latter has the form $\exp(\log_e 10 \ . \ SEE^2/2)$, where SEE is the standard error of estimate of the regression based on data in base-10 logarithms.

The results of fitting the alternative models A and B were compared by analysing the residual patterns from fitting of the models. The results for Model B showed generally more acceptable residual patterns than the nonlinear fit (model A) although the differences between models were quite small. Table 2.18 shows parameter estimates (and approximate standard errors) from the fitting of Model B to the data for each species. Figure 2.5 shows the length-frequency distributions for carp caught in the calibration experiments in the Bogan River, Darling River and Little River, and for the combined data from these three sites. Figure 2.6 shows the observed values and fitted relationships for length and weight of carp from these rivers. Figure 2.7 (a)-(i) shows the fitted weight-length relationships for species as indicated.

Table 2.18 Estimates from (log-log) length-weight regressions.

	a(se)	b(se)	adj. R^2	rss	N	CF*	length range (mm)
carp (site 8)	-4.0948(.0920)	2.7402(.0370)	0.9884	0.0807	66	1.0033	164-640
carp (site 14)	-4.0745(.1242)	2.7423(.0470)	0.9835	0.0308	59	1.0014	285-558
carp (site 17)	-4.5854(.0254)	2.9533(.0123)	0.9830	5.763	1006	1.0153	44-610
carp (sites 8,14,17)	-4.5085(.0189)	2.9148(.0089)	0.9896	6.0246	1131	1.0143	44-640
Australian bass	-4.8244(.0558)	3.0449(.0243)	0.9940	0.1773	96	1.0050	105-455
Australian grayling	-4.2991(.6000)	2.7133(.2564)	0.7208	0.0677	44	1.0042	195-258
bony herring	-5.0641(.1129)	3.1227(.0574)	0.9597	0.8497	125	1.0183	39-172
bullrout	-5.5280(.2446)	3.3632(.1070)	0.9850	0.0361	16	1.0064	125-284
freshwater catfish	-5.1828(.2317)	3.1017(.0877)	0.9564	0.0909	58	1.0042	221-506
freshwater herring	-5.3662(.1864)	3.2102(.0824)	0.8914	0.2417	186	1.0035	155-233
goldfish	-5.4128(.1304)	3.3796(.0655)	0.9780	0.1971	61	1.0087	43-149
longfinned eel	-4.6326(.4097)	2.7246(.1495)	0.7628	3.3027	104	1.0887	240-1400
river blackfish	-4.7346(.0652)	2.8147(.0301)	0.9917	0.1737	74	1.0063	65-247

*Correction factor: CF =exp($\log_e 10 * SEE^2 / 2$) where SEE is the standard error of estimate from the regression.

The length distributions of carp caught in the Bogan River (site DUL17), Darling River (site DUL8) and Little River (site DS14) are obviously quite different from each other, with relatively little overlap in sizes of carp between the three sites. The comparison of regression lines (log weight on log length) between sites DUL8 and DS14 showed no statistically significant differences between the two sites (analysis of covariance with site as the covariate, $F_{1,121}$ = .0000009, P= .98). A formal statistical comparison of the regression for site DUL17 against sites DUL8 and DS14 is not very informative, as there is very little overlap in the length distributions for sites DS14 and DUL17. The fit of the model for the combined data does not show any problem with the residuals for any of the three sites: the data for sites DUL8 and DUL17, which have a relatively small contribution to the total sample, are spread reasonably evenly about the fitted curve.

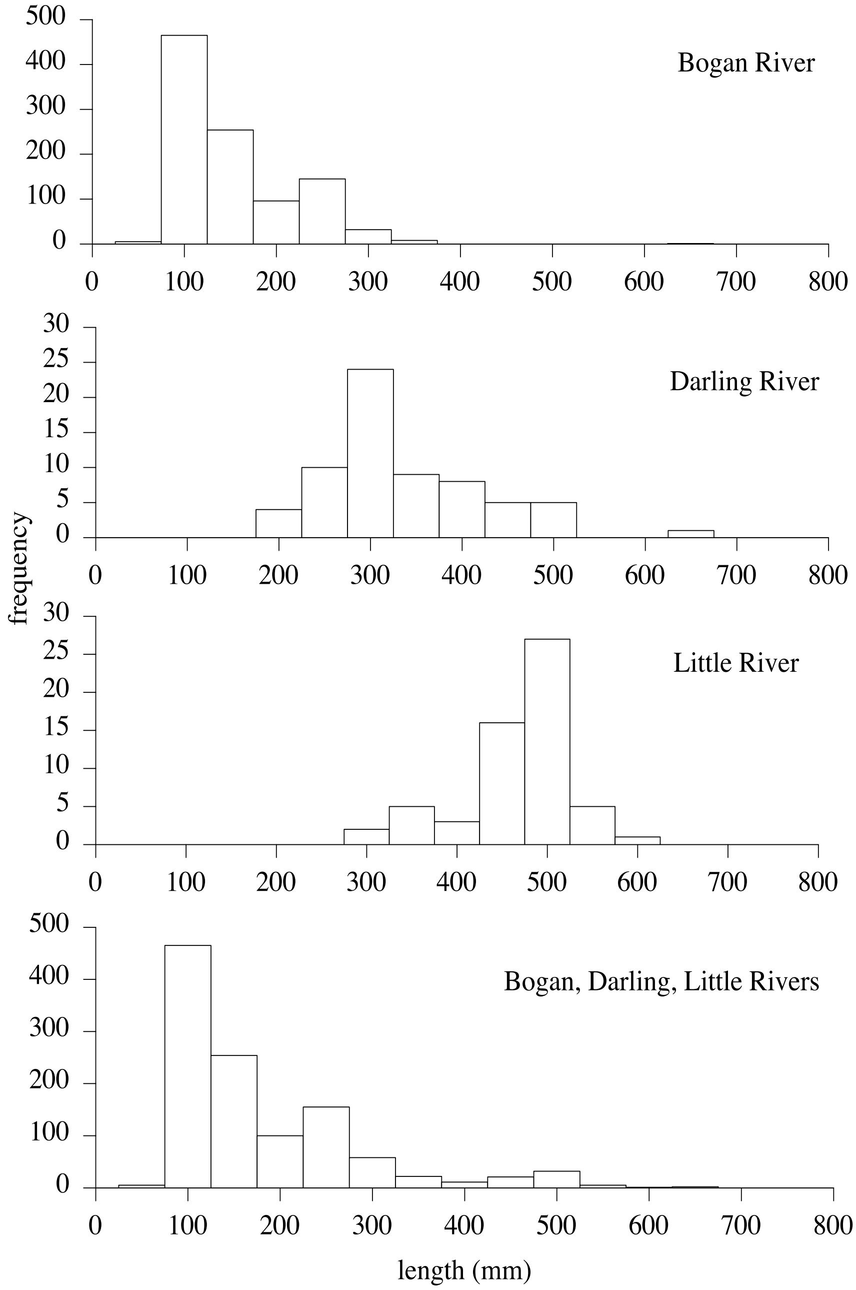

Figure 2.5 Length frequency distributions for carp caught in the calibration experiments in the Bogan, Darling and Little rivers, and for the combined data from the three sites.

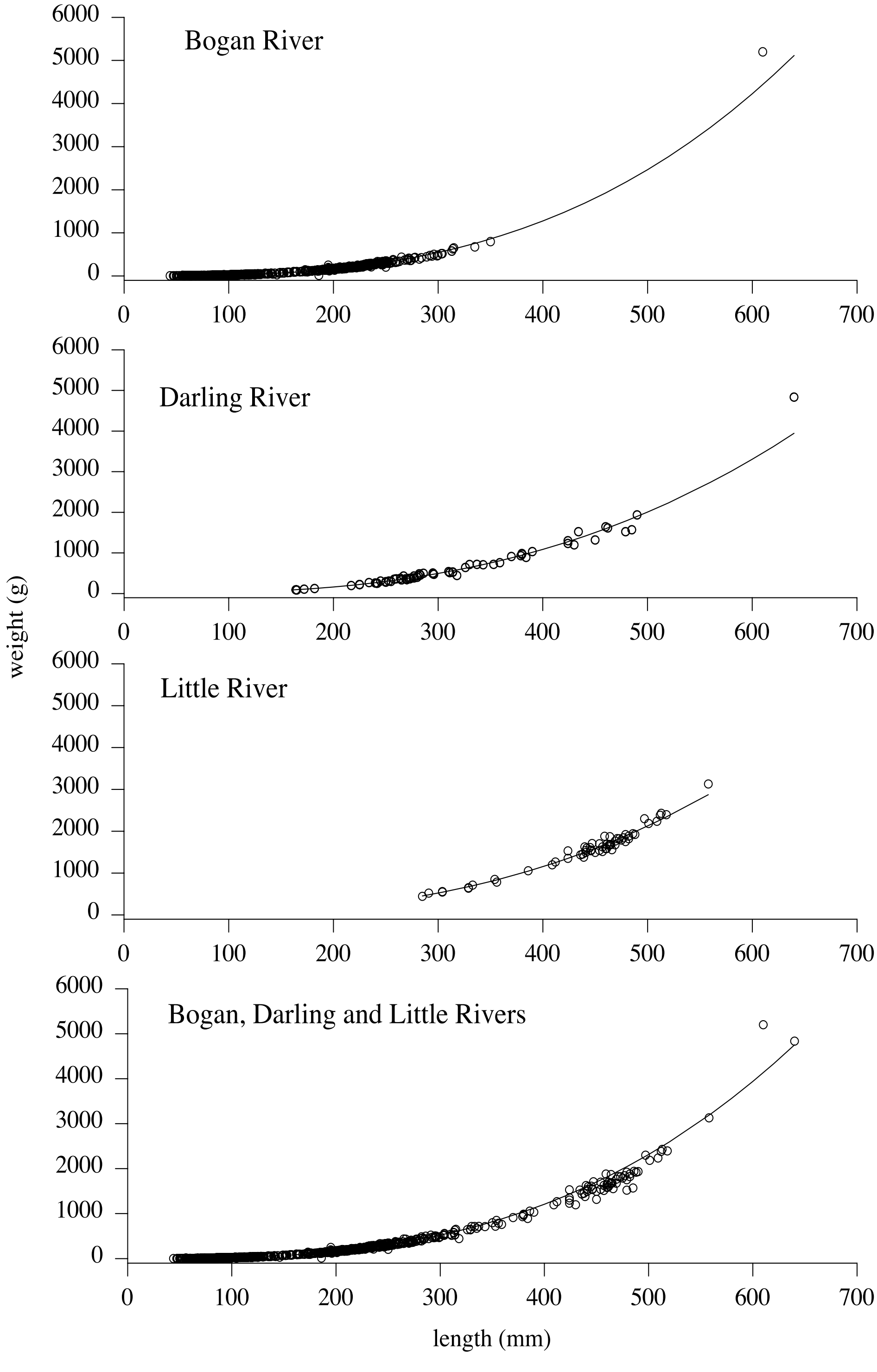

Figure 2.6 Observed values and fitted relationships for length and weight of carp.

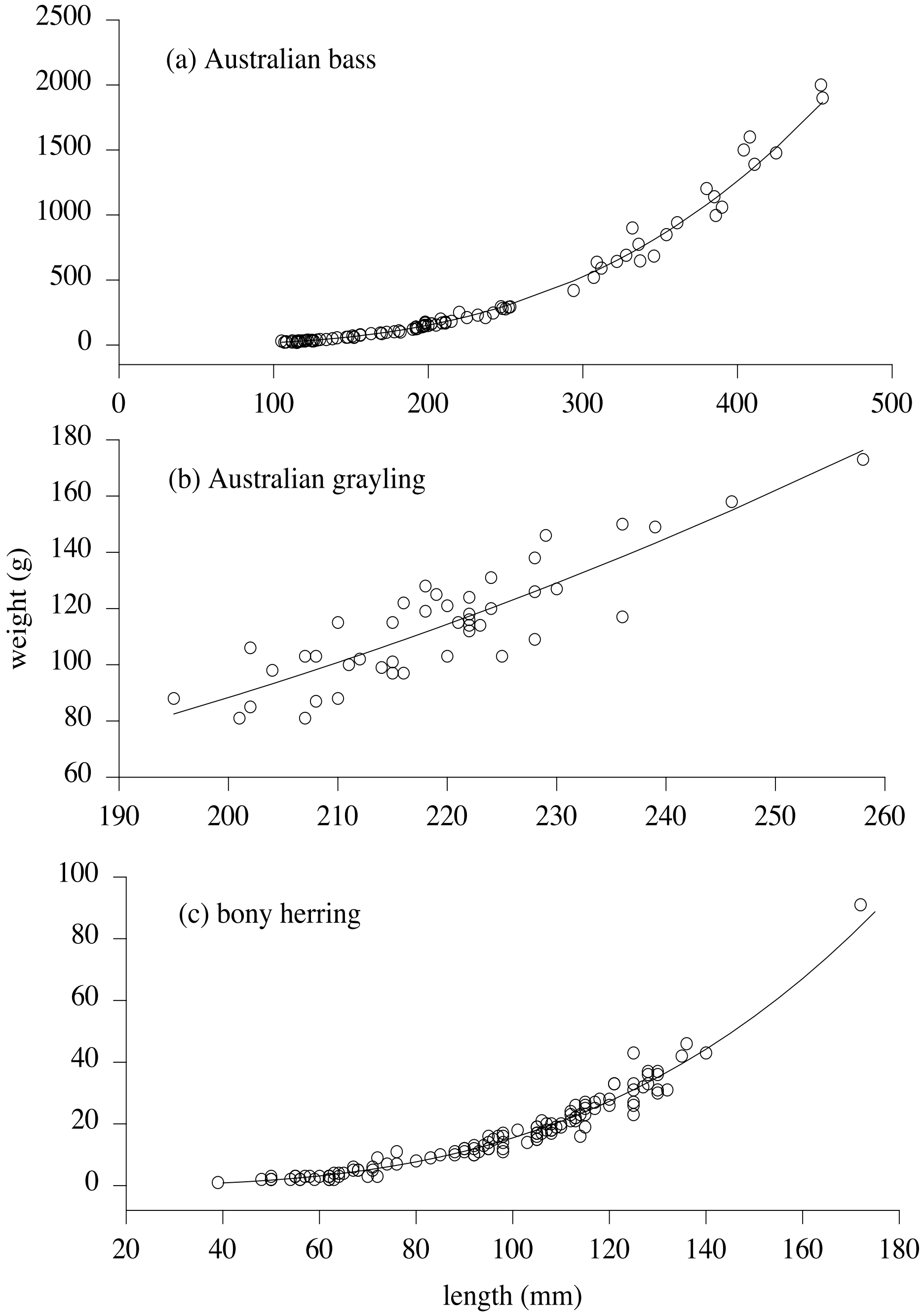

Figure 2.7 (a)-(i) Weight-length relationships for species as indicated. Observed values are shown by open circles, the fitted relationship by a solid line.

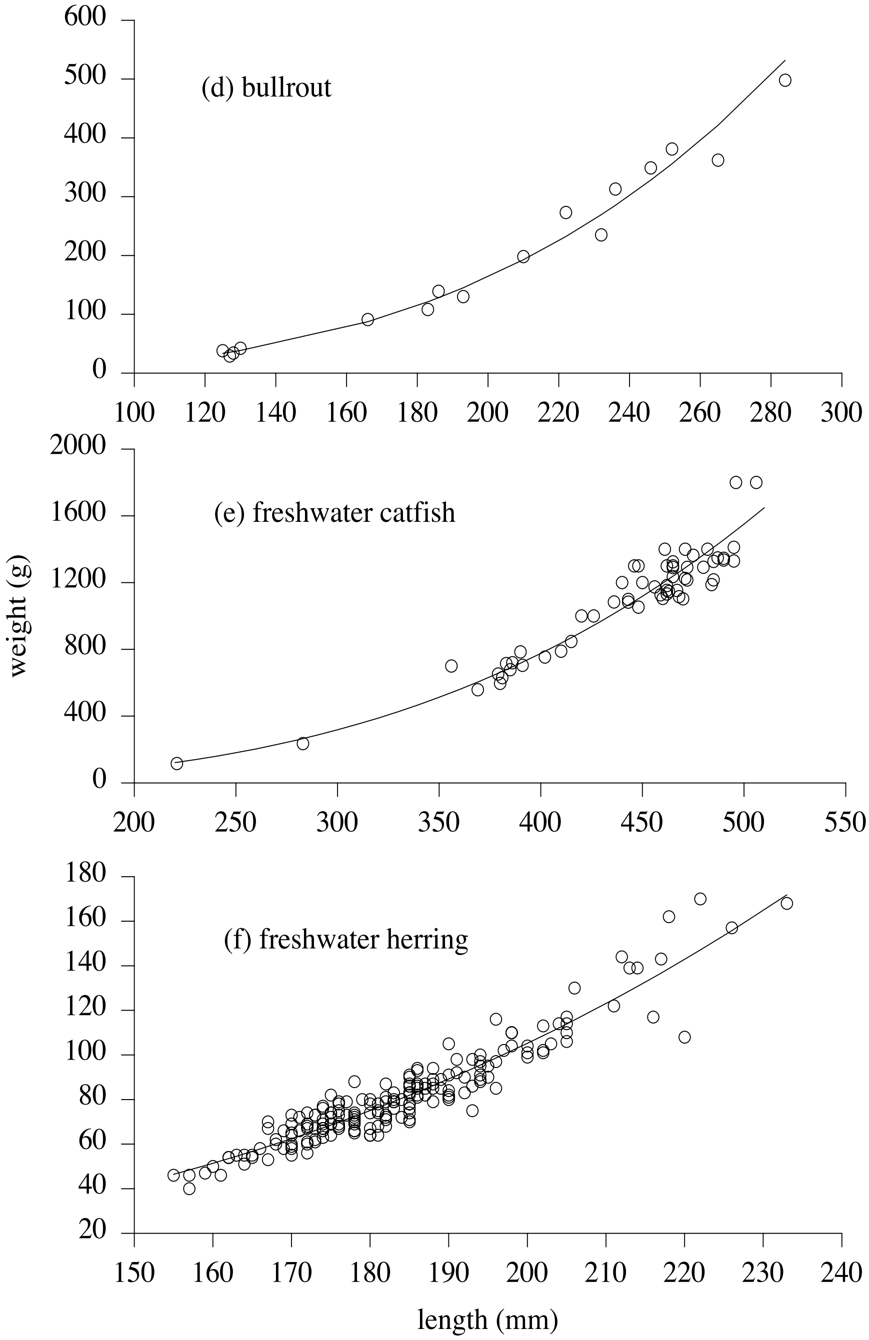

Figure 2.7 (continued)

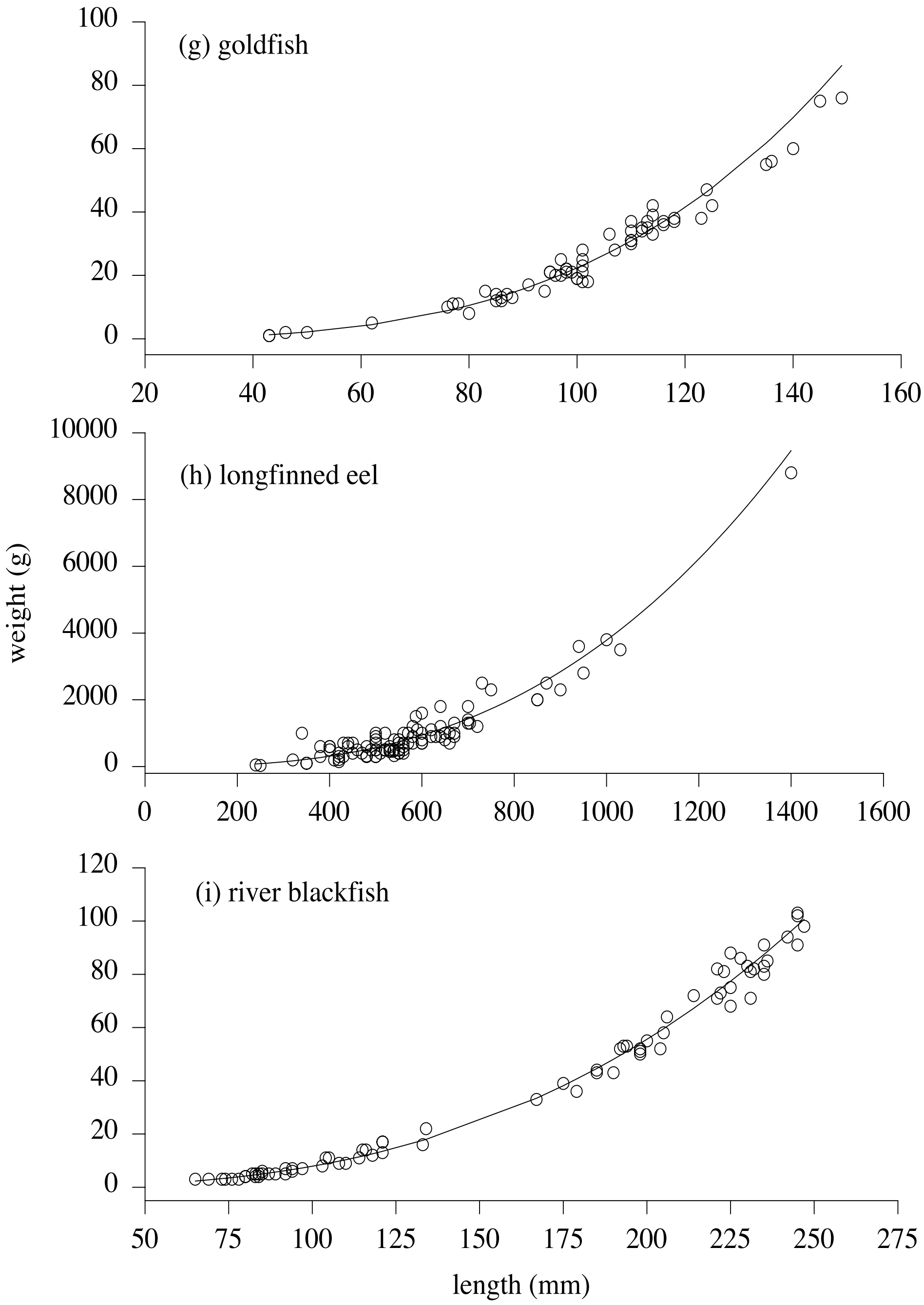

Figure 2.7 (continued)

Analysis of sampling costs

An analysis was carried out to determine the costs of fish sampling in the NSW Rivers Survey and to assess the relative costs of electrofishing compared with passive sampling methods. The initial costs of expendable gear such as nets and traps were included in the analysis, but capital items such as boats and electrofishers were excluded. Cost categories including staffing, travel, electrofishing and passive-method sampling are noted below.

Staffing costs

During the 24-month survey period there were 509 days spent by teams in field sampling work. Sixty days of this effort was spent on the calibration experiments (Chapter 3), which generally required four people. Three-quarters of the remaining sampling effort (*i.e.* 337 days) involved three-person teams. The total staff effort for all components of the field sampling work was 1,235 person-days. This figure included an unknown but considerable proportion of voluntary labour from summer students, *etc*. Staff in field-sampling teams usually comprised two technicians and a scientist for lowlands and slopes sites, and one technician and a scientist for montane sites. The approximate average cost per person per day for salaries and on-costs (30%) was $101.00. There were also overtime payments of $30,000 over the two years. Therefore staffing for the four rounds of field sampling over two years, which was one of the largest expenses for the Rivers Survey, cost an approximate total of $155,000.

Travel costs

Travelling allowance added a further $109.00 per person per day for field sampling work. This expense therefore totalled approximately $135,000. Vehicle lease and other transport costs reached a total of $51,000, including $31,000 for fuel.

Relative costs of sampling methods

Chapter 1 describes the Rivers Survey sampling methods. Chapter 10 details the relative efficiencies of the passive sampling gear types and electrofishing, including both back-pack gear for shallow habitats and boat electrofishers for larger waters. Data on the cost-efficiency of these two basic approaches to fish sampling are needed to plan future work. Electrofishing catches more species and more individual fish than the other gear types (Chapter 10), so that the cost-per-fish aspect favours electrofishing gear as the most cost-effective approach to sampling. With certain averaging assumptions on the times required to collect samples with the various gear types, based on field experience and gear-setting times, the average staff cost of sampling (including travel allowances) with the suite of passive fishing gear was about $780 per site. Each passive-gear sample needs a day's work by two people, and involves overtime payments because of the requirement to work into the night. Using the electrofishing gear, average cost for a site was greatly reduced because, although three people are needed, two sites can be sampled in one day, without overtime. The estimated cost per site for electrofishing was about $400, approximately half the cost of using passive gear.

Public availability of the NSW Rivers Survey data, and archives

All material from the NSW Rivers Survey is available through each of the sponsoring agencies: NSW Fisheries (Sydney), the Cooperative Research Centre for Freshwater Ecology (Canberra) and the NSW Resources and Conservation Assessment Council (Sydney). Printed reports include the final report (Harris and Gehrke 1997), the sites database (Hartley *et al.* 1996) and the full data set (Harris *et al.* 1996). These reports are also available through the relevant Home Pages of agencies through the World-Wide Web: http://www.nsw.fisheries.gov.au (NSW Fisheries), http://lake.canberra.edu.au/crcfe/ (Cooperative Research Centre for Freshwater Ecology). The survey data and reports are also stored as archives on compact disc at each of the sponsoring agencies.

REFERENCES

Allen G.R. (1989) *Freshwater Fishes of Australia.* T.F.H. Publications, Neptune City New Jersey.

Beauchamp J.J and Olson J.S. (1973). Corrections for bias in regression estimates after logarithmic transformation. *Ecology* **54**, 1403-1407.

Harris J.H and Gehrke P.C. (1997). Fish and Rivers in Stress. The NSW Rivers Survey. NSW Fisheries Research Institute & the Cooperative Research Centre for Freshwater Ecology. Sydney.

Harris J.H., et. al. (1996). The NSW Rivers Survey. Final report, Part 1 - Data, June 1996. NSW Resource and Conservation Assessment Council - Project G8. NSW Fisheries Research Institute and The Cooperative Research Centre for Freshwater Ecology (unpublished).

Harris J.H. (1995). The use of fish in ecological assessments. *Australian Journal of Ecology,* **20** (1), 65-80.

Hartley S., Bruce A., Faragher R., Harris J., Marsden, T., Matthews J., Pethebridge R., Stuart I. and Thorncraft G. (1996). NSW Rivers Survey Sites Database. NSW Fisheries Research Institute and Cooperative Research Centre for Freshwater Ecology, Sydney.

Jackson P.D., (1996) Australian Threatened Fishes - 1995 Supplement. *Australian Society for Fish Biology Newsletter*, **26**. No. 1.

Llewellyn, L.C. (1983). The Distribution of Fish in New South Wales. *Australian Society for Limnology, Special Publication No.7*, 23 pp.

McDowall R.M. (Ed.) (1996). *Freshwater fishes of south-eastern Australia*. (Second Edition) Reed Books, Sydney Australia.

Merrick J.R. & Schmida G.E. (1984) *Australian Freshwater Fishes.* Griffin Press, Netley, South Australia.

New South Wales Department of Water Resources. (undated) PINEENA - New South Wales River Basin Maps.

Paxton J. R. , Hoese D.F., Allen G.R. and Hanley J.E. (1989). *Zoological Catalogue of Australia. Vol. 7, Pisces*. AGPS, Canberra.

Sprugel D.G. (1983). Correcting for bias in log-transformed allometric equations. *Ecology* 64, 209-21