# ***Contents***

***Page***

# Table of contents

# *Overview and summary*

### *Introduction*

Rivers are a vital part of our natural heritage; irreplaceable, priceless assets which play a crucial role in our nation's social, spiritual and economic well-being. Our river systems give us amenable places to live, a focus for our spiritual ties with nature, and fresh water, one of the four basic elements of life. Rivers are fundamental to our productive land systems, standard of living, food, recreation and employment. River ecosystems support much of Australia's biodiversity as well as important fisheries resources. The scarcity of rivers in this dry continent makes them all the more precious.

But in New South Wales, as in other parts of Australia, troubling problems are emerging in our river systems. There are conflicts over the use of water, frequent signs of riverine environmental degradation, damaged catchments, declining natural resources and threatened biodiversity. In this context, the NSW Rivers Survey aimed to improve our understanding, to show how rivers and their aquatic life are faring in the 1990s, using freshwater fish communities as indicators, and to provide knowledge needed for better management. The project sought high-quality science as the best means of producing that knowledge.

The NSW Rivers Survey was a collaborative project between NSW Fisheries and the Cooperative Research Centre for Freshwater Ecology, with substantial support also provided by the NSW Resource and Conservation Assessment Council and the NSW Department of State Development. Five specific objectives were set for the Rivers Survey:

- Study the distribution, diversity and abundance of the native fish of New South Wales rivers.
- Determine the abundance, distribution and habitat use of carp and other alien species in New South Wales rivers
- Develop understanding of the ecological effects of river regulation and establish hypotheses for further study of environmental streamflows
- Establish and test a standardised predictive model for monitoring river health using fish community assessment
- Establish a standardised survey structure for use in other studies

### *Methods*

The basic method used was to study fish communities and habitats at a set of sites which represent the main freshwater ecological regions and river types of New South Wales. Four surveys were done over two years, intensively studying fish and their habitats in 80 sites chosen to represent five examples each of montane, slopes, regulated and unregulated lowland river reaches in four regions: the Murray, Darling, North Coast and South Coast. For the purposes of this study, unregulated rivers were defined as lowland rivers with flows that were either completely natural, or where tributary inflows created a minimally regulated flow regime despite the existence of a dam some distance upstream. Similarly, regulated rivers were defined as rivers with flows that were substantially modified from the natural condition by the operation of a dam upstream. To ensure that results were broadly representative and could be extrapolated to all New South Wales rivers, the sites were selected randomly, subject to constraints to ensure dispersal, detailed below. Intensive but minimally destructive sampling with five different fishing-gear types including electrofishing was designed to ensure that all fish species present at each site were represented in the samples. Fish were returned to the water except for small sub-samples of each species preserved for verification of their identity.

### *Results*

The Rivers Survey has resulted in a great quantity of new information, with extensive analyses supporting wide-ranging inference about our fish and rivers. These results and conclusions are presented in the report as ten separate chapters dealing with specific topics. The aims of the survey have been achieved. The survey design proved effective, the sampling methods collected comprehensive data from the 80 sites, and the sampling regime was completed on schedule, albeit with some difficult periods of intensive work for field sampling teams. Procedures were implemented to ensure high data quality.

Routine sampling in the Rivers Survey recorded a total of 50,438 fish (including both 'caught' and 'observed' data) belonging to 55 species. A total of 39 native freshwater species (*i.e.* those species recognised as regularly occurring above tidal limits for a significant part of their life-cycle) from 25 genera and 19 families were recorded, together with ten estuarine species. Six species of alien fish (*i.e.* those species introduced from overseas and now established in the wild) were caught and they comprised 18.4% of the total catch of fish. Despite the survey having spanned major climatic variations, beginning in drought then passing through a wet period, there was surprisingly little temporal variation in fish catches other than a marked seasonal increase in numbers in the two summer samples.

Data from the NSW Rivers Survey are available from each of the three main sponsoring agencies: NSW Fisheries, the Cooperative Research Centre for Freshwater Ecology and the NSW

Resource And Conservation Assessment Council, in either printed or electronic forms. Data have been archived on compact disc at the NSW Fisheries Research Institute.

### *Principal conclusions*

Rivers sustain a large portion of the total biodiversity of New South Wales. But the State's degraded riverine ecosystems are rapidly losing their biodiversity. Evidence of degradation is especially clear in the Murray region, in rivers regulated for water supply, in inland lowland rivers, and in montane areas of coastal drainages. As indicators of river ecosystem condition, the fish are in severe decline, with the survey having found only 39 of the 55 species of native freshwater fish recognised from all sources of information as occurring in New South Wales waters, and thus 29% of the fish fauna were not detected. Rivers Survey data confirm the status of the 11 species classified nationally as threatened (five 'endangered', five 'vulnerable' and one 'data deficient'), and suggest that the conservation status of other, previously abundant fish such as freshwater catfish also needs to be carefully reviewed. There were high levels of visible abnormalities in many species, with up to 25% of fish showing evidence of parasites and other diseases.

The condition of rivers in the Murray River system gives cause for particular alarm. Only 4.4% of the total New South Wales catch of native fish came from the Murray region (including the Lachlan and Murrumbidgee systems). The Darling ecological region produced almost ten times as many native fish. There was an average of only 2.6 native fish species per site in the Murray region, compared with 4.6 species in the Darling sites. Native fish species constituted only 20% of the catch from regulated rivers in the Murray region. A telling indication of the condition of rivers in the Murray region was the fact that, despite intensive fishing with the most efficient types of sampling gear for a total of 220 person-days over a two-year period in 20 randomly chosen Murray-region sites, not a single Murray cod or freshwater catfish was caught, although more than 50 of each species were found at Darling-region sites. While it is well known that Murray cod do remain in some parts of the Murray region which were not sampled in the Rivers Survey, and even continue to support fisheries in some areas, the results emphasise that the populations of this keystone species are now fragmented and patchy, and their overall abundance is worryingly low. Relatively high catches of Murray cod are taken by anglers and commercial fishers targeting remnant populations in some key Murray-region habitats, but these fishery catches clearly do not reflect the true condition of the population overall.

The alien pest species, carp, are the dominant fish of the Murray and Darling river systems and are threatening a number of coastal systems. Carp are aided by various human modifications of rivers, especially flow regulation. At one site in the lowland reaches of the Bogan River, there was an average of one carp for every square metre of river surface area.

The Rivers Survey has provided knowledge for refining future survey designs. Analysis of the survey data, especially the performance and costs of the five fish-sampling methods which were used, has identified important ways to increase efficiency in future surveys without undue loss of sampling capacity. Streamlining of routine sampling for riverine fish (other than larvae and early juveniles) can be achieved through sole reliance on boat-mounted, high-power electrofishers, abandoning the passive trapping and gill-netting gear-types which are time-consuming, less efficient and require night work.

### *Specific conclusions*

#### *Estimating absolute abundance*

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

#### *Status of native fish*

A total of 22,580 native freshwater fish representing 39 species, 25 genera and 19 families was recorded. Only 985 native fish were caught in the Murray ecological region, a mere 4.4% of the total catch. Fourteen species were found in each of the Murray and Darling regions, however the average number of native species per site was 2.6 in the Murray region compared to 4.6 at Darling sites. A total of 23 species was recorded from the North Coast region and 22 from the South Coast.

There was marked seasonal variation in total native fish catch among river-type groups for all regions, with more individuals captured during summer than winter. Seasonal variation in total catch was most pronounced in the Darling region and least evident for North Coast sites. Compared to total catch, seasonal variation in the number of species recorded in each region was much lower, and the regional pattern was reversed, with North Coast sites exhibiting the greatest variation and Darling sites the least.

Low catches were recorded for fish other than Murray cod and freshwater catfish. Only seven silver perch were recorded from the Darling region, while two individuals of this species,

which were probably the result of hatchery stockings, were recorded from the Murray region. Other species reported to be widespread and relatively common across much of their range were either absent from one region, or restricted in distribution or abundance. These included olive perchlet, common jollytail, crimson-spotted rainbowfish, short-finned eels and flyspecked hardyhead. A total of 16 (29%) of the 55 native species predicted to occur in New South Wales rivers were not found at all, whereas nine of these (including at least four endangered and two vulnerable species) were previously recorded in a 1983 survey. Several species (including spangled perch and shortheaded lampreys were found in areas outside their predicted range.

*General trends in freshwater fish communities*

Fish from the four river types and four regions were studied to identify fish communities on a large spatial scale within New South Wales, and to contrast their characteristics with fish communities elsewhere. Spatial differences among regions and river types were the major sources of variation in the composition of fish communities. In contrast, surprisingly little temporal variation was detected over two years. Each region showed a distinct character to its fish communities, which converged in montane reaches and diverged with increasing distance downstream. Thus rivers formed five groups based on fish distributions, identified as montane rivers, and the slopes and lowland rivers of the four geographic regions. Similarly, the fish fauna could be separated into four groups representing montane species, South Coast species, North Coast species, and a combined group of Murray-Darling species. Using catchment area and stream length upstream of each site as surrogates for habitat availability, species richness increased with increasing habitat availability in both North Coast and South Coast regions by both replacement and the addition of new species. In contrast, species richness in the Darling and Murray regions reached a maximum in the slopes reaches and then declined, reflecting a loss of species with increasing distance downstream in the lowland reaches. Dominant fish species display an increase in trophic diversity with increasing distance downstream, suggesting a downstream increase in diversity of available food types that is not reflected in species richness in inland rivers. The small number of species in the freshwater fish fauna of New South Wales is typical of the faunas of similar climatic regions world-wide. The New South Wales fish fauna can be classified into Montane, North Coast, South Coast and Murray-Darling units for fisheries management purposes, while there is some biological justification for managing the Darling River and its tributaries as separate entities from rivers in the Murray region. The decline in species richness with increasing distance downstream in lowland reaches of inland rivers is contrary to general longitudinal patterns of species richness in rivers, and suggests a need for remedial management of lowland rivers to increase habitat diversity. The fish communities identified in this study form logical entities for fisheries management, and provide an opportunity to manage fisheries to ensure the sustainability of riverine ecosystems rather than sustaining single species.

*The index of biotic integrity for assessing river health*

Rivers in Australia have suffered extensively from the effects of catchment degradation, regulation for water supply, pollution and alien species. Efforts to manage these factors and to restore riverine ecosystems need effective tools for assessing river condition and for adaptive management. Ways are needed to measure the 'health' of rivers. This implies a need for a comprehensive, sensitive and quantitative indicator for measuring the condition of the complex of variables which constitutes river health. To be effective, this indicator needs to be ecologically based, efficient and rapid. It needs to be applicable consistently in different ecological regions. It should also preserve information about the nature of any environmental changes which may alter the value of the indicator for a river reach in response to some environmental change.

The NSW Rivers Survey provided data for an assessment of the performance of the Index of Biotic Integrity (IBI) as a river-health indicator. The IBI predicts the fish-community attributes of a river reach of excellent environmental quality from regional and river-size data, using metrics of species richness, abundance, community structure, and the health of individual fish. Following a provisional index, IBI metrics were modified to suit the freshwater fish of south-eastern Australia. The IBI was able to discriminate relative environmental quality within a diverse set of stream systems and presumptive ecological regions. The 80 sites of the NSW Rivers Survey were spread through the full range of qualitative IBI rankings from 'Excellent' to 'Very poor' and 'No fish'. Results supported by habitat data show that the Murray region's rivers and a large proportion of montane rivers in New South Wales coastal regions are in a degraded condition compared to other regions and river types. The index's underlying assumptions were generally met and it performed satisfactorily with 12 metrics based on attributes of the fish fauna totalling 55 freshwater species. One metric, based on trophic guild, performed poorly and should be deleted from the index, leaving an 11-metric IBI. Six other recommendations are made to enhance the performance of the IBI as a rapid, efficient and sensitive ecological tool for monitoring river health. Results supported the designation of four ecological regions (Murray, Darling, South Coast and North Coast) for New South Wales freshwater fauna, and they provide a useful basis for management. Future work is recommended to complete validation of the IBI including comparisons with independent measures of river and catchment health, parallel assessments with other river-health indicators, studies of IBI responsiveness to known impacts, and tests of repeatability.

Because the IBI produces relative assessments, the present results do not permit an evaluation of the absolute condition of New South Wales rivers, but do give the capacity to assess spatial and temporal changes in the relative health of rivers within regions and river types. The main immediate values of the present IBI results lie in their capacity to provide a baseline for monitoring river health, and an efficient and sensitive means of checking the relative condition of any river site in New South Wales.

*Differences in fish communities associated with river regulation*

Lowland reaches of forty rivers in New South Wales were designated as 'regulated', where flows were substantially modified from the natural condition by the operation of a dam upstream, or 'unregulated', where flows were either completely natural, or where tributary inflows created a minimally regulated flow regime despite the existence of a dam some distance upstream. Significant differences occurred in the composition of fish communities between river types, although communities in each region retained a unique regional character. The proportion of native species in the total catch was greater in unregulated rivers in all regions, ranging from 27% in the Murray region to 100% in South Coast rivers. In regulated rivers, native species made up 20% of the catch in the Murray region compared with a maximum of 99% in the North Coast. Carp were the main alien species contributing to the changes in the proportional abundance of native species. Native species whose abundances river regulation reduced most were western carp gudgeons, bony herring, and striped gudgeons. Fifteen native species showed some effect of river regulation on the size structure of their populations. Individual species showed positive, negative, or mixed positive and negative effects of regulation, measured by their contribution to the fish community, species abundance, and population size structure. Three abundant alien species and seven native species showed only positive or mixed responses, whereas thirteen native species exhibited only negative effects of river regulation. Consequently, flow regulation has reduced the resilience of New South Wales' rivers and native fish communities to invasion by alien fish species. Experience in other regulated rivers shows that modifying the regulated flow regime can successfully rehabilitate fish communities, suggesting that similar benefits can be expected from implementing enhanced river flow objectives in New South Wales. To demonstrate more fully the ecological and economic benefits of new river flow objectives, investigations to assess the responses of fish to modified flows need to include individual, population, and community levels of organisation. Better tools are also required to measure the degree of flow regulation at individual sites.

*Alien fish species*

Alien species are defined as those species introduced from overseas and now established in the wild. Of the 11 species which have been recorded from New South Wales rivers, six were captured during the NSW Rivers Survey for a total of 5,103 individuals, or 18.4% of the total fish catch. The species captured were redfin perch, gambusia, goldfish, brown trout, rainbow trout, and common carp. (Carp are considered in a separate section.) Alien fish showed significant differences in abundance among regions and among river types, with a highly significant region*river type interaction. Catches were lower in winter months than in summer. Rivers in the Darling region contained the highest number of alien species but the Murray region had the highest proportion of individuals belonging to alien species (57.5%). In comparison the Darling (25.1%), North Coast (8.7%) and South Coast (9.1%) had lower proportions of alien species in the

total catch. Distributions of each of the alien species captured during the survey could be explained by their temperature tolerances and by attributes of the habitats.

*Carp and environmental factors*

Environmental factors associated with the biomass density (kg site$^{-1}$) of common carp in rivers of New South Wales were explored. Carp were not found in any of the 20 montane sites. In the inland rivers, carp were present in all sites below an altitude of ca. 500 m ASL. In the coastal sites, the distribution of carp was restricted to only six sites in an altitudinal range of 0-60 m ASL within regulated lowland rivers. All inland rivers had higher carp biomass densities than the coastal rivers. Carp biomass densities in the inland rivers were found to increase slightly with altitude, for altitudes up 500 m ASL. These slightly higher carp biomass densities in the inland rivers were associated with an abundance of riffle habitat and coarse particles in the substratum. This unexpected association was probably the result of upstream migration of adult carp from spawning habitats, and the presence of barriers to fish dispersal including dams and natural river features. The likely spawning habitats from which adult carp migrated were lowland sites (below 200 m ASL) and water storages in mid-altitudes (200-500 m ASL).

Across New South Wales, higher carp biomass densities were associated with variables indicating human impacts, in particular the effects of dams and agriculture. Alteration of flows and water temperatures, physical barriers to fish migration, carp spawning habitat created in artificial lakes, and agricultural effects on water quality and habitat are all factors suggested as leading to higher carp biomass densities. These results suggest that river management focused on carp spawning habitat, adult migration from these spawning areas and the effects of agriculture and river regulation would be effective in reducing carp biomass densities, improving water quality and increasing native fish stocks.

*Sampling-gear performance*

Better knowledge of sampling-gear performance is needed to improve the design and benefit/cost of freshwater fish surveys. Aspects needing clarification include: ability to sample representatively from the full range of fish species and sizes; capacity to collect an abundant sample quickly; cost; and ability to sample non-destructively. Five fish-sampling methods were used during the NSW Rivers Survey: boat electrofishing, back-pack electrofishing, fyke netting, panel netting and Gee trapping. The sampling regime was varied to suit river type (montane, slopes, and lowland).

Of the gear used, boat electrofishing captured the greatest number of fish (11,255). Boat electrofishing also captured 50 of the 55 species sampled during the survey. The missing species were all classified as ‘rare’ (<1% of total regional sample) and four were predominantly estuarine. The number of species (and number of fish) captured by the other methods were: back-pack

electrofishing in pools, 13 spp. (724); back-pack electrofishing in riffles, 29 spp. (2,324); fyke netting, 27 spp. (760); Gee trapping, 30 spp. (8,936); and panel netting, 27 spp. (3,325). Electrofishing with both back-pack and boat units captured the majority of the fish by number in all river types and regions. A comparison of panel-net catches with those from the boat electrofisher, *FRV Electricus*, at sites where turbidity was estimated showed that the relative catches by boat electrofisher at high turbidity was not significantly different from those at lower turbidities. The most effective method for collecting riverine fish to discern the effects of disturbance on a community are those which collect the most species, as the chance of capturing species which are sensitive to the change are increased. Electrofishing has benefit/cost advantages over passive gear types, it is rapid, relatively less selective of size and species, and can be applied among threatened species, so it is the method of choice for sampling south-eastern Australian freshwater fish communities.

### *Six recommendations*

*1. Recognise that river heritage is degraded*

The primary recommendation from the Rivers Survey is to accept that our riverine heritage in New South Wales is in a generally degraded condition and in urgent need of restoration. River biota is reflecting the problems of river habitats: aquatic biodiversity is rapidly being lost; productivity of natural resources is seriously declining, especially recreational and commercial fisheries; and the values and supply of the basic resource, fresh water, have been damaged. Restoration of river-ecosystem components is needed, especially flow regimes, thermal regimes and river catchments, particularly in the riparian zones. There is an urgent need to control carp and to restore fish passage at barriers such as dams and weirs.

*2. Fill knowledge gaps*

Some important research issues and gaps in the knowledge required to manage New South Wales rivers effectively should be addressed through high-quality applied research to:

2.1 Design flow regimes in rivers regulated for water supply (*i.e.,* most rivers) so that river ecosystems can be sustained.

2.2 Develop better tools to measure water-regime changes in New South Wales rivers for further study of river regulation and to aid implementation of enhanced river flows.

2.3 Implement programs to protect and rehabilitate populations of each of the 11 freshwater fish species recognised nationally as being threatened with extinction, and review of the status of other species of concern.

2.4 Design effective ways to control the invasion of freshwater environments by carp and other alien pest fish.

2.5 Study the techniques, and benefits, of alleviating thermal pollution below dams; of restoration programs for floodplains and their wetlands; of restoring fish passage at the 3,000 - 4,000 artificial barriers in New South Wales streams; of re-establishing instream habitat structure; and of rehabilitating stream riparian zones.

2.6 Develop knowledge to prevent or manage the range of parasitic, viral and other diseases threatening native freshwater fish.

*3. Recognise that fish stocks are threatened*

Much of the Rivers Survey data supports conclusions from independent studies that New South Wales fish stocks exploited for recreational and commercial fisheries have suffered long-term damage and are threatened by habitat degradation, fishing pressure, disease, alien species and fragmentation of populations. Eleven New South Wales freshwater fishes are already listed nationally as threatened. These include five exploited species (silver perch, Macquarie perch, Australian grayling, trout cod and eastern cod) which are protected in various ways under the NSW Fisheries Management Act (1994). Other exploited species of particular concern should now include freshwater catfish. Stocks of Murray cod and short-finned eel also need to be closely monitored.

*4. Continue the NSW Rivers Survey*

The Rivers Survey has proved to be a potent source of knowledge about the condition of rivers and their biota. The results also show how substantial streamlining of survey procedures can now be achieved, and cost-savings realised, without compromising the value of the survey. As remedial river-management and restoration programs are implemented and become an increasing focus of public attention, the need to monitor river condition will expand. The established structure, methods and knowledge base of the Rivers Survey provide a major asset ideally suited to continued servicing of that need.

*5. Extend the use of the Index of Biotic Integrity to assess river health*

The Index of Biotic Integrity using fish has been assessed and shown to be a sensitive, rapid and efficient way of evaluating the health of any New South Wales river reach. While the validation of this index needs to be completed, it can now be applied for practical river-assessment and monitoring, along with other methods, such as the AUSRIVAS biological indicator of water quality.

### *6. Science in natural-resource management*

Decisions in the management of natural resources can arise from two different processes. They can result from the judgement of decision-makers, in the absence of adequate information, by applying past experience, trial-and-error, consultation and consensus, or even guesswork. Alternatively, management can be based on good information and high-quality science as a way of knowing the best decisions. The NSW Rivers Survey has provided another example to emphasise the practicality and value of aiming for good scientific standards. It is recommended that natural-resources agencies should strengthen policies to ensure that river management continues to be based on high-quality science.