ISSN 0113-6984

Freshwater Fisheries Centre Annual Report for 1987

MAF Fish

New Zealand Ministry of Agriculture and Fisheries
1988

Freshwater Fisheries Centre Annual Report for 1987

New Zealand Ministry of
Agriculture and Fisheries
1988

Published by the New Zealand Ministry
of Agriculture and Fisheries
Wellington
1988

ISBN 0-477-08072-3

MAF Fish

MAFFish is the fisheries business group of the New Zealand Ministry of Agriculture and Fisheries. It was established on 1 April 1987 and combines the functions of the old Fisheries Research Division and Fisheries Management Division and the fisheries functions of the old Economics Division.

Edited by S. P. Townsend and G. G. Baird

Set in 9 on 10 English Times

Typesetting by Industrial Art and Communication Ltd.

Printed by Thames Publishing Co. Ltd.

Location directory

Christchurch	**Freshwater Fisheries Centre** **Kyle Street** **Christchurch**	**P.O. Box 8324** **Riccarton, Christchurch** **Tel. (03) 488 939**
Wellington	**Fisheries Research Centre** **Greta Point, Evans Bay Parade** **Wellington**	**P.O. Box 297** **Wellington** **Tel. (04) 861 029**
Rotorua	**Rotorua Fisheries Research Laboratory** **C/- Forest Research Institute** **Rotorua**	**P.O. Box 951** **Rotorua** **Tel. (073) 479 579**
Oamaru	**Oamaru Fisheries Research Laboratory** **Oamaru**	**P.O. Box 96, Oamaru** **Tel. 48 248**

Cover: Freshwater Fisheries Centre, Christchurch.

Introduction

As with all other government agencies, the Freshwater Research/Management group of MAFFish has recently been subject to extensive change.

The prevailing economic climate has resulted in reduced demand for consumptive uses of water for irrigation or electricity generation. This has meant that research staff have been able to catch up with work that has remained uncompleted owing to the pressures to solve pressing water-use problems. It has also meant that it has been possible to make progress with some long-term strategic research that would preferably have preceded the extensive studies relating to water exploitation problems. How long the relaxation of pressure on water resources (and therefore fisheries values) will last remains to be seen.

Changes in government administration in conservation areas have resulted in significant changes for research staff. Administration of freshwater fisheries has been transferred to the new Department of Conservation (DOC) with regard to:

- preservation of indigenous fish;
- preservation of fish habitats;
- protection of recreational fisheries.

As a consequence, research funding for these areas has been transferred to DOC, which contracts with the Ministry of Agriculture and Fisheries (MAF) to carry out research of its choosing. Statutory changes to bring this change of responsibilities into effect have yet to be promulgated.

The role of acclimatisation societies and their operational relationships with MAFFish and DOC are being considered as a part of the quango review.

Facilities at the Glenariffe Salmon Research Station expanded substantially during the year, funded largely by a grant from the Director-General's Venture Fund. This enabled the construction of more large raceways for smolt rearing, a hatchery building capable of incubating 15 million ova, and a bore water supply that provides pathogen-free water to the hatchery. This last item alleviates concerns about the presence of whirling disease in the raceway water supply from a tributary of the Glenariffe Stream. The station is seen as a major source of income to fund salmon research in the future through the sale of eyed ova to salmon farmers. Increased marketability of ova is generated by more rapid development in water of higher temperatures. This is possible at the Silverstream hatchery, near Kaiapoi, which is being kept open for this purpose and for some of the studies of all-female stock production.

All statutory responsibilities for administration of freshwater fisheries by MAF are now carried out from the Christchurch laboratory; Mr B. J. Swale has been appointed to carry out these responsibilities.

The electric fishing service of MAF is also based at Christchurch, and it has been restructured to facilitate annual certification of machines and ancillary equipment. The training course for machine operators has been revised.

A highlight of the past year for Christchurch staff has been the completion and occupation of new laboratories and offices, so that, for the first time, all staff are housed in a purpose-built complex.

R. M. McDowall
Manager, Freshwater Fisheries

Staff list
(at December 1987)

Manager: R. M. McDowall PhD

Christchurch

Salmon research

Leader: P. R. Todd PhD *salmon, eels, native fish*
M. S. Field-Dodgson MSc (Hons) *salmon culture*
M. Flain BSc *salmon and trout, rivers and lakes*
C. L. Hopkins MA *salmon, fish production*
M. J. Unwin MSc *salmon, fisheries resources, computing*
N. C. Boustead NZCS *salmon diseases*
R. A. Dougherty
L. Gledhill *resident technician, Glenariffe salmon research station*
T. Gough
L. J. Hawke
S. P. Hawke
D. H. Lucas *salmon tagging*
M. W. Tawa
T. J. Washbourne

Library
J. Potter BA (Hons)
Editorial
S. P. Townsend BA, BSc
Advisory officer
B. J. Swale BSc, MA *freshwater fisheries regulations*
Electric fishing
G. B. Smith
M. S. Weeks

Wellington

Freshwater resource assessment and research

Leader: L. D. Teirney BSc (Hons)
B. J. Hicks MSc (Hons) (on study leave)
J. Richardson BSc

Rotorua

Freshwater resource assessment and research

Leader: N. M. McCarter MSc *recreational fisheries*
S. M. Hanchet PhD
J. W. Hayes PhD *Waikato River and mining*
C. P. Mitchell MSc *native fish, grass carp*
D. K. Rowe MSc (Hons) *recreational fisheries* (on study leave)
B. Chisnall MSc
M. Rutledge BSc (Hons)
R. R. Strickland *effects of power development schemes*
Grass carp studies
C. M. Schipper

Freshwater resource assessment and research

Leader: E. Graynoth BSc *recreational fisheries, effects of power development schemes*
S. F. Davis BSc (Hons) *fisheries resources, effects of water abstraction*
G. J. Glova PhD *effects of water abstraction*
D. J. Jellyman PhD *eels, native fish, effects of water abstraction*
I. G. Jowett BE (Hons) *environmental simulation modelling, hydrology*
P. M. Sagar MSc *low flow effects, aquatic benthic fauna*
M. L. Bonnett BSc
C. R. Docherty
R. M. Eder
G. A. Eldon
C. J. Hardy
G. R. Kelly
M. J. Taylor BSc

Administration
D. K. Hide *administration officer*
J. M. Lamont
C. J. Murray
L. C. Taylor
N. E. Corcoran *senior typist*
C. M. Whaitiri *senior typist*

Oamaru

Freshwater resource assessment and research

Leader: G. D. James MSc (Distinction) *fisheries resources*
S. Bloomberg BSc (Hons) *hydro development and fisheries*
J Graybill MSc *salmonid ecology, regulated streams*
J. Kilpatrick BSc

Staff employed on consultants' projects

Hamilton

Leader: J. A. T. Boubee *impact assessment — thermal power station*
P. W. Empson BSc *eels and ichthyoplankton in the Waikato River*
A. S. Meredith PhD *ichthyoplankton in the Waikato River*
D. Palmer BSc (Hons) *eel migrations in the Waikato River*
A. G. Stancliff BSc (Hons) *whitebait fishery in the Waikato River*

Environmental studies

Indigenous freshwater fish bibliography

J. Richardson, R. M. McDowall

An updated and expanded version of McDowall's 1968 bibliography has been completed. The bibliography contains more than 2000 titles from 1788 to 1985. The references cover all aspects of indigenous fish biology and management, and each reference has been annotated for taxon and according to subject matter.

Freshwater fish survey data base

J. Richardson, M. J. Taylor

MAFFish maintains a computer-based store of information on the distribution of freshwater fish species. Nearly 500 new entries were added in 1987, bringing the total to 7500. More than 20 requests for information were received and processed for agencies other than MAFFish.

All data have been transferred to the new data base system, and the amount of data stored has been considerably expanded. Progress on the new field sheet has been complicated by problems inherent in designing one form for a wide variety of data collection. However, a sample form has been circulated for comment and a new design should be finalised early in 1988.

Identification of rivers of national, regional, and local importance to recreational anglers

L. D. Teirney, J. Richardson, M. J. Unwin

Reports on the National River Angling Survey results have now been released for 18 acclimatisation societies and 2 wildlife conservancy districts. For each district, fishing rivers of national, regional, and local importance have been identified and classified as recreational (high use), scenic, or wilderness fisheries. Data on use, importance, various attributes, fishing reaches, fishing methods, and other recreational activities are presented for 313 rivers which attracted 15 or more respondents.

This information is being used widely by the regional fisheries managers to identify river fisheries which deserve protection under the 1981 Amendment to the Water and Soil Conservation Act 1967, by the regional water boards in water management planning and decisions, and by MAFFish to identify priorities and conduct related research. National trends from the survey are discussed in a recently compiled document, and angler characteristics will be the subject of a separate document.

Finally, a publication on the relationship between anglers' perception of catch rate, catch rate figures from creel census surveys, and drift diving counts of trout numbers in rivers throughout the country is being prepared. There are no plans to analyse the angling survey data base further than this.

Invertebrate habitat models

J. Richardson, I. G. Jowett

This project is complementary to the trout stocks computer modelling project. The primary objective is to develop habitat models for New Zealand benthic invertebrates, a major food source for both trout and indigenous fish. Invertebrate samples were collected from various habitats in two reaches of the Waingawa River in November 1986. Ministry of Works and Development hydrological staff measured features of the physical habitat at the same time.

Total invertebrate biomass ranged from 24 to 1463 $mg.m^{-2}$ over the 87 samples collected. The fauna was dominated by the mayflies *Deleatidium* spp., but another mayfly, *Nesameletus* spp., and Elmidae larvae and adults were occasionally abundant. Analysis is under way to determine the relationship between the physical habitat and invertebrate biomass.

Prediction of trout stocks in New Zealand rivers

I. G. Jowett

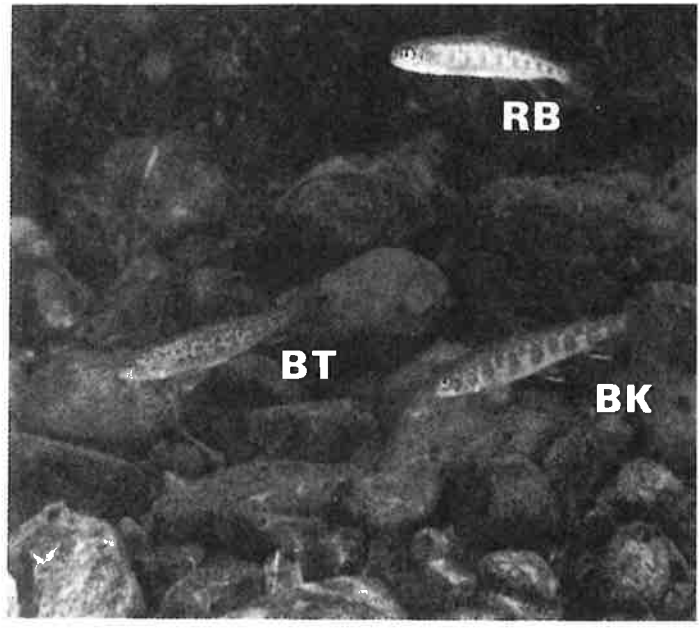
Drift-diving surveys of trout stocks have been made in about 150 rivers in New Zealand. In most of these rivers the physical habitat was described, and hydrological parameters were determined from the flow records. Preliminary analysis of the relationships between trout numbers seen during drift-diving surveys, the above factors, and detailed descriptions of the physical habitat and its variation with flow showed that most of the variation in the trout population could be explained by four variables: mean annual temperature, instream escape cover, percentage of stream area suitable for food production, and the co-efficient of variation in depth longitudinally.

As a joint project with the Water and Soil Directorate of the Ministry of Works and Development (MWD), detailed instream habitat surveys have continued on these rivers, and a computer system has been developed for simulation of river hydraulics and evaluation of instream habitat. In addition, the MWD have surveyed benthic invertebrates, periphyton, and water quality in each of these rivers to form a common data base with the information on trout stocks, hydrological characteristics, and physical habitat.

Interactive ecology of juvenile salmonids and native fish species

G. J. Glova

During the past 4 years, several field and stream simulator experiments were carried out to determine the extent of competitive interactions among four species of juvenile salmonids and three species of native fish. The studies included interactions within and between salmonids and native fish as these occur in nature. Data analyses are nearly complete.



Interaction between brook char (BK), brown trout (BT), and rainbow trout (RB) in the stream simulator.

Feeding of *Galaxias vulgaris* in a foothills stream

G. J. Glova, P. M. Sagar

Samples of *Galaxias vulgaris*, drift, and benthos were collected in the Hawkins River at specific times over a 24-hour period in summer to determine diel feeding periodicity and prey preferences. Feeding began at sunset, peaked by midnight, and virtually ceased by midday. Both drift and benthos were consumed by this nocturnally active, bottom-dwelling species. There was evidence that feeding on larval *Austrosimulium* spp., the larger *Deleatidium* nymphs, and the terrestrial coleopteran *Costelytra zealandica* was selective. In contrast, several aquatic and terrestrial prey taxa were distinctly avoided by the fish.

Adult *Galaxias vulgaris*.

Study area on the Hawkins River.

Patterns of age and growth of Selwyn River brown trout stocks, 1912–87

G. J. Glova, M. Flain, D. H. Lucas

The Selwyn River is the major spawning area for brown trout stocks of Lake Ellesmere, which are currently low. To investigate possible historical changes and trends in the age and growth of these stocks we analysed North Canterbury Acclimatisation Society data and scale samples from the Selwyn River spawning runs for selected years. A further data analysis will be required before the findings can be summarised and published.

Trapping operations on the Selwyn River.

Rakaia River: invertebrate drift and diet of juvenile salmon

P. M. Sagar, G. J. Glova

The diet of juvenile quinnat salmon and the invertebrate prey available to them were studied during spring and summer in the Rakaia River. In spring the feeding rate increased at dawn, when aquatic taxa made up most of the prey. Prey of terrestrial origin dominated the diet at dusk in summer, but formed only about 1% of the diet during spring, when few such prey were available.

During spring the fish fed selectively on larger nymphs of the mayfly *Deleatidium* spp. However, in summer, chironomids, other dipterans, and trichopterans were eaten instead of *Deleatidium*. Most of the chironomids and trichopterans taken were pupae or emerging adults, which suggests that these life history stages were particularly vulnerable.

The diel feeding periodicity and prey selection of juvenile salmon in the Rakaia River was studied further during November 1986. This study showed that food intake was greatest about dawn, when mayflies were the major prey. During the day, the young salmon fed selectively on chironomids and the larger mayflies, but at night, when feeding activity was very low, smaller mayflies were up to 50% of the prey.

The type and size of prey eaten by the salmon could not be explained in terms of the abundance and size of available prey. Rather, they were determined by selective feeding of the fish and diel activity of the prey.

Lower Waitaki River: effects of hydro development on fish and fisheries

J Graybill, G. D. James, S. Bloomberg, J. Kilpatrick

The first phase of fisheries investigations (funded by the Electricity Division of the Ministry of Energy, now Electricorp) to assess the effects of a proposed hydro-electric development scheme on the fish stocks and fisheries of the lower Waitaki River has been largely completed. A Residual River Report summarising the studies to date and making recommendations for a residual river has been submitted to Electricorp, and most individual study reports have been finished.

Further information was required on rainbow trout and salmon angling to better assess the effectiveness of the proposed residual river, and additional funds have been made available by Electricorp for studies which will concentrate on understanding the recruitment processes and requirements of juvenile and adult rainbow trout in the present lower Waitaki system and in other rivers that may be similar to the proposed residual river.

Distribution and abundance of juvenile salmonids and native fish in the lower Waitaki River

S. Bloomberg

Nineteen sites on the lower Waitaki River and its tributaries were electric fished from 1977 to 1982 to establish the distribution and abundance of juvenile salmonids and native fish.

Juvenile brown trout were found throughout the river and were clearly the most abundant and widespread salmonid. Juvenile quinnat salmon were also common, though they were absent from the upper reaches of the Maerewhenua River and several smaller tributaries. Juvenile rainbow trout were found predominantly in the Maerewhenua, Hakataramea, and Awakino Rivers, and brook char were limited to Dalgety Stream, a tributary of the Hakataramea River. The distribution of juvenile rainbow trout is consistent with redd counts and trapping data, which show that adult rainbow trout resident in the Waitaki mainstem migrate into these tributaries to spawn.

Upland bullies were the only native species common throughout the lower Waitaki. Blue-gilled bullies and

common river galaxias were abundant in the lower reaches of the Waitaki and in the tributary streams respectively, whereas common bullies, koaro, torrentfish, long-finned eels, short-finned eels, and lampreys were all relatively scarce. Black flounders, inanga, common smelt, and Stokell's smelt are also present in the lower Waitaki River, but were not found in this study.

Mean length data showed that juvenile brown and rainbow trout emerge from redds at about 23–28 mm fork length and reach lengths of up to 149 mm at 1 year of age.

Lower Waitaki River: salmon surveys

G. D. James

Surveys were conducted again this year with the Waitaki Valley Acclimatisation Society to estimate the size of the salmon run. Unlike the two previous record years, the runs in 1987 were very low. A helicopter survey in May showed that about 4000 spawning salmon were present, only one-quarter to one-third of the numbers in each of the previous 2 years. Results from a postal survey of anglers confirmed that catches were also much lower. It is likely that several factors are jointly responsible for the small run: a poor year-class, because there were low runs 3 and 6 years ago and most fish return as 3-year-olds; poor food supplies at sea; and greater catches by commercial fishing vessels.

Sockeye salmon: fishing potential and protection from the effects of the upper Waitaki power development scheme

E. Graynoth

Annual trapping of the spawning runs of sockeye salmon which migrate from Lake Ohau into Larch Stream finished in 1985. Since then, the runs have been monitored by visual spawning surveys and by the collection of fish by use of seine nets.

In 1986 and 1987 it was difficult to count spawning fish because flood waters overflowed into Larch Stream from the adjacent Hopkins River. In 1986 many spawning fish were seen in clear tributaries of Larch Stream.

Recent sockeye salmon spawning runs into Larch Stream

Year	No.	% females	Length (cm)
1982	3 700	25	23
1983	400	24	29
1984	400	20	26
1985	2 700	41	29
1986	2 100	43	30
1987	<100?	-*	-

* No data.

In 1987 no adult salmon were seen in spawning surveys in March, and no fry were found during electric fishing surveys in July.

The numbers of fish counted in recent years is given below. A single, dominant, 3-year cycle of abundance has existed since about 1970. Large runs of 3-year-old fish occurred in 1970, 1973, 1976, 1979, 1982, and 1985. Thus, a large run may occur in 1988.

As a result of the upper Waitaki power scheme there has been a dramatic decline in the abundance of sockeye salmon in New Zealand. Attempts to increase the stock of sockeye salmon by transfer of mature fish to tributaries of Lake Benmore and by the release of hatchery-reared fry and juvenile fish into Larch Stream, Diadem Stream, and Lakes Benmore, Aviemore, and Poerua all seem to have failed. The causes for these failures are unknown, because no substantial follow-up and research studies have been undertaken.

Upper Waitaki River: effects of hydro development on fish stocks and fisheries

S. Bloomberg, N. H. McCarter, E. Graynoth

The effects of hydro-electric power development on fish stocks and fisheries of the upper Waitaki catchment were studied from 1980 to 1985. The results of five studies have been published in Fisheries Environmental Reports (No. 13, 15, 18, 38, and 83), and the rest are nearly complete. A summary is given below:

- The Ahuriri Arm of Lake Benmore is the most popular trout fishery in the upper Waitaki catchment.
- Brown trout stocks of the Haldon and Ahuriri Arms of Lake Benmore appear to be stable, whereas rainbow trout stocks declined between 1975 and 1985.
- Up to 1246 brown trout and 446 rainbow trout migrate from the Haldon Arm of Lake Benmore into the Tekapo River to spawn each year.
- The Tekapo River is the most important spawning tributary of the Haldon Arm.
- Lake Ruataniwha supports good stocks of brown and rainbow trout.
- Growth rates of trout in Lake Ruataniwha are faster than in many other upper Waitaki lakes.
- The residual Ohau River is the only spawning tributary of Lake Ruataniwha.
- The Pukaki and Ohau canals support only moderate numbers of poor condition trout and do not compensate for the loss of the Ohau River fishery.
- Lake Pukaki is a relatively poor fishery. There are few trout, though there are some large fish at stream mouths and at the outflow of the Tekapo B power station.

Lower Clutha River: effects of possible hydro development

D. J. Jellyman

Summaries of the results of fisheries studies have been included in the comprehensive report of the scheme published by the Ministry of Works and Development. These studies indicated that the scheme option which produced the largest shallow littoral area and the smallest lake level fluctuations was the preferred scheme from a fisheries viewpoint.

All schemes would further impede fish passage; no fish passes were recommended for quinnat salmon, though passes were recommended for small eels. At present, brown trout are the most abundant fish in the study area (Roxburgh Dam to Tuapeka Mouth), and, though the population is not large compared with other South Island rivers, the growth rates are comparable. Trout fisheries that would develop in any new reservoirs would be more productive than the present river fishery for trout, but the summer fishery for anadromous quinnat salmon would be a substantial loss. Furthermore, because new lakes would cause the number of juvenile salmon recruits from Lakes Wakatipu, Hawea, and Wanaka to fall, the fishery for wild salmon in the lower Clutha River would also be correspondingly reduced.

Effects of power development on Lake Coleridge

E. Graynoth, C. J. Hardy

In 1985 the Electricity Division of the Ministry of Energy (now Electricorp) applied for a 10-year renewal of water rights to divert the Wilberforce River into Lake Coleridge. After a series of meetings with local interests, it was agreed that the effects of this diversion on the fish stocks and fisheries should be monitored, and this was made a condition of the water rights. A research proposal was developed by the Freshwater Fisheries Centre in Christchurch, and it has recently been approved by the North Canterbury Acclimatisation Society and Electricorp. Studies will be financed by Electricorp and will start early in 1988.

The overall aim is to determine the extent of changes since the Wilberforce was diverted and the direction and likelihood of future changes. Specific objectives are:

- to monitor the quinnat salmon stocks and fishery;
- to study the potential impact of changes in water clarity and siltation on the benthic fauna and fish stocks;
- to collect benthic and plankton samples for comparison with samples collected in the late 1960s;
- to reassess the overall impact of hydro-electric development on the fish stocks and fishery, and to suggest improvements to fisheries management and hydro-electric operations.

Fiordland: freshwater fish survey of Preservation and Chalky Inlets

G. D. James, M. L. Bonnett

A survey of freshwater fish was conducted in this remote area of Fiordland in late 1986 as part of the Operation Raleigh programme. Although there were no previous records of freshwater fish from this area, the species composition and abundance were found to be generally similar to the Dusky Sound area to the north. Nine species were found, including two new to the Fiordland National Park freshwater fish fauna (common smelt and short-jawed kokopu). Except for red-finned bullies, which were often abundant, fish were present only in low to moderate numbers. No introduced species were found. Acknowledgment is made of the co-operation and support of the Operation Raleigh organisation.

Freshwater eel studies

D. J. Jellyman

Fyke net captures of both species of eel in Lake Pounui, Wairarapa, over a 4-year period, have been analysed by multiple regression techniques. Catch per unit of effort was correlated with 11 environmental parameters. Water temperature was a significant factor for both species, though increased water level was more important than temperature for shortfinned eels. Catches were also affected by changes in barometric pressure, but the amount of light at night had no effect.

Canterbury mudfish

G. A. Eldon

A population of Canterbury mudfish was established in 1982 at a farm dam near Taiko, South Canterbury, and it has spread widely. In spring 1987, fish were found up to 3 km down stream from the dam, and they have also been reported from tributary gullies.

The mudfish sanctuary at Peacock Springs was successful. A lowering of the water table meant that the pond was not as large as it was originally, but a second pond has now been stocked.

Attempts are being made to establish a population in a covenanted wetland of Steventon in the North Canterbury foothills. Fish liberated late in winter 1986 apparently did not breed in spring, but a second liberation was made in December and high hopes are held for this project.

The reorganisation of some environmental agencies has hindered attempts to have a natural mudfish habitat near Hororata declared a reserve.

Distribution and habitats of fish in South Westland

G. A. Eldon

This project finished when the South Westland Management Evaluation Programme funding ceased, and final environmental reports on all phases of the fisheries exploratory work have been published.

Stream rehabilitation

G. A. Eldon

A study has begun on the possibilities for rehabilitation of West Coast streams diverted for gold mining operations.

Fish and invertebrate population estimates were made from a reach of the Big Hohonu or Greenstone River before it was diverted by Thames Minerals in 1987. The new channel was divided into two reaches; the upper was designed to normal catchment board specifications and the lower was provided with a more varied profile and substrate.

Recolonisation times by fish and invertebrates are being studied. Although floods have already reshaped the new channel and levelled the boulder falls, there may still be sufficient contrast between the two sections to indicate whether the provision of more varied channels in small, flood-prone, gold-bearing rivers is justified.

Upland galaxiid studies

M. L. Bonnett, S. F. Davis

The two species of galaxiid being studied (*Galaxias prognathus* and *G. paucispondylus*) are often found together in some high country streams of the South Island. Both species spend their entire life cycle in fresh water, unlike most other galaxiid species, which have a marine juvenile life stage.

Since 1986, samples have been collected, mostly from a spring-fed tributary of the Rangitata River. The samples are providing information on the age, diet, and breeding cycle of both species, and surveys within various other catchments are helping to define distribution and habitat requirements.

Native fish habitat models

S. M. Hanchet

The effect of land use and other habitat variables on the relative density of banded kokopu is being investigated. Electric fishing was carried out at 55 sites in streams draining the Hakarimata Range into the Waikato River. Many habitat variables were measured at each site.

Thames Minerals cutting the diversion channel on the Greenstone River in such a way that residual water in the old channel remained clear to facilitate fish salvage.

Banded kokopu were caught at 26 sites, but were significantly more abundant in streams with a bush-covered catchment than in streams with pastured or exotic catchment. Regression and discriminant function analyses were used to predict the relative abundance of banded kokopu. A model combining five variables, including percentage of native bush, instream cover, substrate diversity, and density of eels, classified 80% of the sites correctly.

Structure of fish communities in shallow Waikato lakes and their relationship to aquatic macrophytes and water quality

J. W. Hayes

A methodology for sampling fish communities in shallow lakes in New Zealand was developed. In particular, fine-mesh trap nets in conjunction with gill nets appeared to be effective at representatively sampling these fish communities. This methodology allowed an investigation into the impact on fish of a major environmental change which has occurred in some of the lower Waikato lakes in the past decade. This change has involved increased water turbidity and collapse in aquatic macrophyte beds. The investigation showed that these lakes are very productive in terms of fish biomass and the major invertebrate prey item, the mysid shrimp *Tenagomysid chiltoni*. Low water clarity and absence of aquatic macrophytes did not appear to be detrimental to the fish communities. In fact, these conditions were associated with high biomass of two species, short-finned eels and common bullies. These shallow lake fish communities appear to be more detrimentally affected by access restrictions on migratory species than by the above-mentioned environmental change.

Studies on fish from Lakes Waahi and Whangape

M. Rutledge, B. Chisnall

Quarterly samples of fish were taken from the lakes for analysis of diet and age. The preliminary results show that the most important items in the diet of eels from both lakes are bullies and mysids. The lake eels grow faster than those in the Waikato River.

Spawning requirements of inanga

C. P. Mitchell

An initial study (1986) in two small streams in Ohiwa Harbour led to the suggestion that both tidal fluctuations and the saltwater wedge were responsible for delineating the spawning sites of inanga (*Galaxias maculatus*). By use of these descriptors, a further 14 sites were located on Bay of Plenty and North Island west coast rivers in 1987. Inanga were also found to prefer indigenous vegetation (flax and carex) to grazed exotic pasture. These results and their obvious management implications were presented as a 15-minute video ("More Whitebait") which has been screened widely.

Effect of ration size on growth and fecundity of inanga

C. P. Mitchell

Earlier research has shown that the growth and fecundity of inanga are highly variable, and it suggested that environmental quality may be the controlling factor.

Fish held under identical conditions were tested at four different feeding rates. Growth and fecundity were directly correlated with feeding rate. The data are being prepared for publication. It is suggested that fecundity per unit length be used as an estimator for habitat suitability.

Laboratory spawning of inanga

C. P. Mitchell

This study aims to define the precise factors which control ovulation, spawning site selection, and spawning in inanga. Inanga maintained under a lunar cycle of water level fluctuations combined with a water current and regular salt water intrusion showed a far higher occurrence of ovulation than control fish. However, natural spawning did not occur, despite the provision of a range of vegetation types.

Responses of native fish and invertebrates to current velocities

C. P. Mitchell

A short series of flume experiments to measure the swimming performance of some migrating native fish showed that the water velocities which block upstream movement were far lower than those used in designing fish passes for salmonids. These data have been prepared for publication.

Production of triploid grass carp

N. H. McCarter

Grass carp eggs were pressure shocked to produce triploid fish in the summer of 1986–87. A few fingerlings were produced, but survival was low. Triploidy was confirmed by cell measurements, chromosome counts, and the direct measurement of DNA concentration in red blood cells. Better husbandry and production methods will be required to produce many triploid fish for aquatic plant management.

Otolith aging in galaxiids

C. P. Mitchell

Regular growth rings were found on otoliths of galaxiid fish. Otoliths collected from laboratory-raised fish showed that the rings represent daily growth. Age and relative daily growth rates were estimated for laboratory-raised fish and for fish collected from Ohiwa Harbour.

Aquaculture development

N. H. McCarter

There was an increased number of inquiries about aquaculture. Written reports and technical assessments were provided for aquaculture proposals in New Zealand and overseas, and assistance was given in the establishment of the first freshwater prawn farm in New Zealand. Carp polyculture, freshwater prawns, and pond culture of salmon are the most promising candidates for development.

Twelve silver carp were captured from Lake Oraki (Hawke's Bay) and transferred to Rotorua. If fish are in reasonable condition, fry may be produced in 1988.

Lower Waikato fisheries studies

C. P. Mitchell, J. A. T. Boubee, A. S. Meredith, A. G. Stancliff, P. W. Empson, D. Palmer

The lower Waikato fisheries group is fully funded by Electricorp. The studies concentrated on both the fisheries resources of the lower Waikato River and how these are affected by present and proposed thermal power developments. Many of the projects are nearly complete and several reports are being produced. Environmental impact statements are being prepared for the Huntly, Meremere, and Clune Road power developments.

Fish and shrimp migration past Huntly thermal power station

A. G. Stancliff, J. A. T. Boubee

Upstream migrations of fish and shrimps past Huntly thermal power station have been studied to assess the effects of the outfall discharge. Thermal, velocity, and pollutant barrier effects were noted. The ability of fish to negotiate these barriers by crossing the river was studied by use of immersion staining techniques and trapping from fixed stands. Galaxiids that moved up stream past the station did so by crossing to the unaffected margin. Disruption of recruitment to populations in the tributaries up stream and on the station side of the river has yet to be determined. Common bullies and shrimps negotiated the barriers by moving along the river bottom.

Ichthyoplankton studies

A. S. Meredith, P. W. Empson

The composition, abundance, and distribution of larval fish in the Waikato River at Huntly, Meremere, and Tuakau have been described. Larval fish are abundant throughout the length of the river, and annual production of the middle reaches was estimated at more than 5 billion individuals. Most spawning occurs in mid river or on the margins, whereas migration occurs predominantly in mid river. The main migrations occur in autumn and spring, and most movement is during darkness. These distribution patterns are being related to the operation of power station intake and outfall systems and to the design and siting criteria for structures at new sites.

Elver migrations

D. Palmer, A. G. Stancliff, J. A. T. Boubee

The patterns of migration of elvers past Huntly thermal power station and their ability to negotiate the thermal plume were described. Signficant numbers of elvers migrated across the river bottom and could, therefore, pass the outfall plume safely. In view of this, and because it caused entrapment of other fish species, it was recommended that the elver bypass be closed.

Whitebait studies

A. G. Stancliff

The historical and present states of the whitebait fishery of the Waikato River have been documented, and factors influencing the whitebait migration were discussed. The fishery has declined since the early 1950s from 44 to 14 t. The catch of galaxiid species has since stabilised, but the smelt fishery is continuing to decline. The upstream movement of whitebait was also studied to describe the main pathways, timing, and speed of migrations. At sites up stream from the estuary, migrations occurred from July to late January along both river margins. The rate of upstream migration increased as river temperatures rose in early summer.

Adult eel migrations

D. Palmer, J. A. T. Boubee

The downstream migrations of adult eels have been studied from the impingement of eels on the intake screens at Huntly thermal power station. As well as noting migration timing of eels, downstream migrations of ripe inanga and several other fish species were recorded. Recommendations were made to alleviate the impingement problem.

Temperature responses of fish and crustacea

J. A. T. Boubee

The responses of native fish and shrimps to differing temperatures and water velocities were studied in experimental channels at Huntly thermal power station. Shrimps, elvers, and inanga avoided faster flows; smelt preferred faster flows; and bullies showed no velocity preference. Elvers were attracted to the warmer channel, whereas the other species avoided the warm channel from 23 °C. This work has allowed the behaviour of different fish species to be predicted in relation to thermal power station discharges.

Salmon feeding trials

M. S. Field-Dodgson

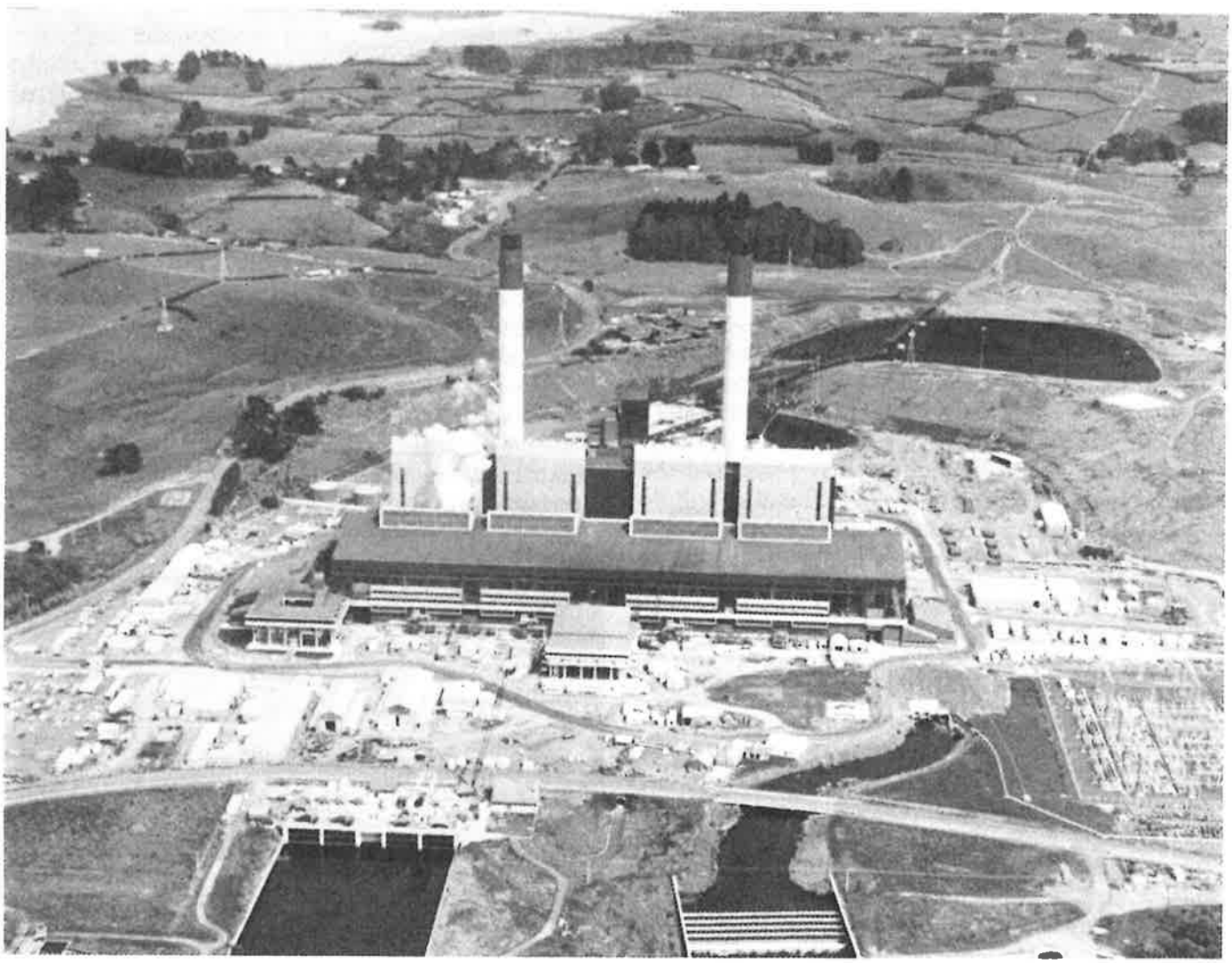
Plans are under way for a project to investigate aspects of artificial salmon diets such as quality, efficiency, feeding regimes, and fat-protein ratios. Some industry participation is planned, and discussions are under way.

Advice and technical information is given to salmon farmers on all aspects of salmon husbandry.

Salmonids: diet and feeding of juvenile salmon

M. S. Field-Dodgson

The work on the diel feeding of juvenile salmon in "Double Hill Flats Stream" is being written up for publication. From the analysis, it appeared that the salmon fed on invertebrates drifting in mid water, mainly *Deleatidium* spp. nymphs. However, during the late evening there was a major diet shift to adult caddis, and some fish had up to 20 caddis in their stomachs. Average stomach fullness remained high well into the night, and levels started to decrease at 0130 hours. Larger, probably dominant, fish always had significantly more food in their stomachs than smaller fish, except between the sampling periods of 2130 hours and 0130 hours, when feeding intensity was greatest. This shows a possible relationship between territorial interaction, feeding behaviour, and light levels.



Huntly thermal power station on the left bank of the lower Waikato River. [Ministry of Energy photograph.]

Salmon

Genetic manipulation and sex control in quinnat and sockeye salmon

C. L. Hopkins, P. R. Todd

In an attempt to produce an all-female stock of quinnat salmon, eggs of the 1986 returns to Glenariffe had been inseminated with sperm gamma irradiated to make them genetically inert. The activated eggs were then pressure shocked to diploidise them. Only about 300 fry were obtained by this method, and almost all of them died before they were old enough to allow a sex check of the developing gonads. By the time it was possible to carry out this check, in early 1987, only nine juveniles were left. All of these were sacrificed and found to be females. To this extent the experiment was successful, but the low viability of such gynogenetic fish poses a problem for further work. Trials are now being carried out using "foreign" sperm (in this instance, from sockeye salmon and brown trout) instead of irradiated quinnat sperm to inseminate quinnat eggs.

Another method for producing an all-female stock is being tried this year. In 1985, a group of quinnat salmon fry were treated with testosterone to masculinise the females. In autumn 1987, ripe males from this stock were mated to wild, returning females. It was assumed that the male population consisted of approximately 50% normal (XY) males and 50% masculinised (XX) females, the latter capable of fathering only females. However, there were no physical differences between the two types of male. Therefore, egg lots were divided into 20 families, each fertilised by one of the males. At hatching, each family was divided again, one part being treated with testosterone, the other remaining untreated for eventual progeny testing to find which families were all-female (i.e., which had an XX paternal parent). Progeny testing will be done in early 1988, and the testosterone-treated members of XX families will be amalgamated and reared on at Glenariffe. At maturity, these fish will be XX males and could be used to inseminate eggs which would be female zygotes.

Cyclic production of thyroxine in juvenile quinnat salmon

C. L. Hopkins

In autumn 1986, tagged quinnat salmon juveniles were released from Glenariffe at 6-day intervals throughout a lunar month. A few males from these releases returned in 1987 as 2-year-olds. There should be further returns in 1988, after which it should be possible to comment on the results of the project. However, the returns will not be completed until 1989.

Sea distribution of salmon from commercial catch data

M. Flain

This work was largely transferred to M. Unwin and R. Dougherty, as coded-wire tag recoveries allowed more intensive investigations to be carried out. However, D. Lucas and M. Flain became involved again because of marked discrepancies in the results of scale readings and coded-wire tag results with respect to by-catch estimates. The evidence presently suggests the scale reading gives much more reliable results.

Weight loss of spawning migrant adult chinook salmon

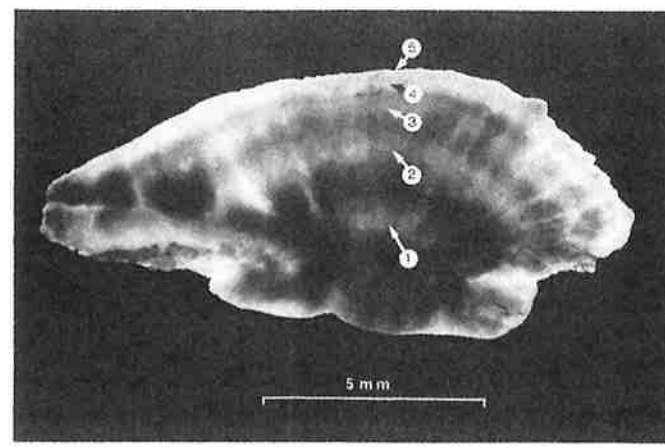
M. Flain

Sampling problems have caused delays to this project, and a reduced investigation is being written up.

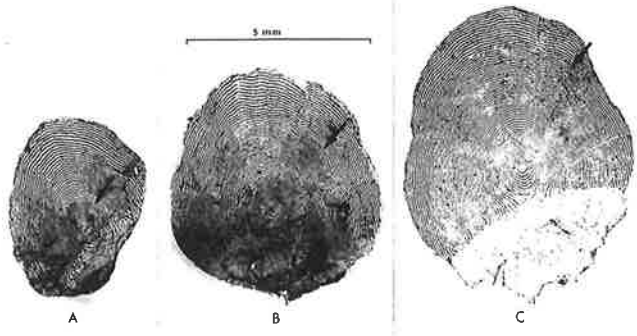
Reliability of chinook salmon aging

M. Flain, G. J. Glova

The reliability of otolith and scale readings of Rakaia River chinook salmon was tested. One experienced reader aged samples of adult fish of known age, 405 from otoliths and 508 from scales, almost 100% correctly. Ages estimated from scales from 402 adult fish of unknown age, in triplicate, were in complete agreement 92.5% of the time. The freshwater life history type was consistently identified for 90.6% of the fish on the basis of the pattern of scale circuli in the first year's growth. A comparison of these results with those in the literature indicates that fish aging by a single experienced reader was more precise and more accurate than by the combined efforts of several readers. This work is complete, and the results are in press.



Otolith of a 5-year-old Rakaia River chinook salmon.



Scales of 2-year-old Rakaia River chinook salmon of the stream (A), intermediate (B), and ocean (C) life history types. Arrows show the first annulus.

Incidence of precocious male chinook salmon

M. Flain

It was proposed to use data from various salmon farming schemes to compare the incidence of precocious males on farms with that in wild populations. Farm operating procedures do not provide adequate unbiased data for this, and so the project has been reduced to examine wild stocks only. Results are being written up.

Disease studies

N. C. Boustead

Ninety-six submissions or inquiries about fish health problems were investigated during the year to 1 November. The advent of user pays for these services and the clients' wish for complete confidentiality prevents the publication of some cases. Fish health problems encountered in salmon include bacterial gill disease, whitespot, skeletal deformities, cutaneous ulcerations, chilodonella, sockeye syndrome, and tail rot. In addition to diseases of salmon, fish health investigations were conducted on cases involving eels, trout, native fish, ribaldos, and grass carp. Most of the submissions were from companies involved with aquaculture. Others were received from acclimatisation societies, anglers, and other agencies of MAFFish. A notable visitor during the year was Professor Ron Roberts, Director of the Aquaculture Unit at Stirling University in Scotland. In February, a paper on diseases of salmon in New Zealand was presented at the Fourth Australasian Association of Animal Production Conference.

In addition to disease diagnostic work, comprehensive submissions were made on the continuing saga of salmon importations. A newsletter (the Aquaculture Information Leaflet) directed at the salmon industry has been produced and has met with a favourable response.

The parasite commonly known as whitespot (*Ichthyophthirius multifiliis*), shown here infecting a wild native bully (top). This parasite has also been found on salmon farms. The lower figure shows the parasite enlarged to reveal the U-shaped nucleus.

Whirling disease survey work continued on a limited basis. Rainbow trout from two east coast South Island rivers were found to be infected. This was not surprising and confirmed the belief that this disease exists at low levels in several river systems. The rainbow trout examined showed no outward signs of disease and were apparently unaffected by the infection. Limited sampling of salmon at the Glenariffe Salmon Research Station by MAFQual found no whirling disease.

Published papers and articles and unpublished reports

Bloomberg, S.: Rainbow trout spawning in the Awakino River. *Waitaki Valley Acclimatisation Society Annual Report 1987.* [Unpaged.]

Bloomberg, S.: Waitaki River salmon angling competition. *Waitaki Valley Acclimatisation Society Annual Report 1987.* [Unpaged.]

Bonnett, M. L.: Fish of the Rangitata River. *Freshwater Catch No. 30*: 23.

Bonnett, M. L., and Minns, C. K.: Colour co-ordinated catchments. *Freshwater Catch No. 30*: 24.

Boubee, J. A. T., Palmer, D., and Stancliff, A. G.: Response of migratory fish and shrimps to thermal discharges. [Internal report to Electricorp.] 17 p.

Boubee, J. A. T., Stancliff, A. G., and Mitchell, C. P. [1986]: Fish and fish communities in the lower Waikato River. Part I. Impacts of thermal power station development on migrant and resident fish. [Internal report to Electricorp.] 80 p.

Davis, S. F. [1986]: Protection sought for South Island lake. *Freshwater Catch No. 30*: 3.

Davis, S. F.: Rakaia High Court decision released. *Freshwater Catch No. 31*: 17–18.

Davis, S. F.: Schedule of protected waters. *Freshwater Catch No. 31*: 24.

Davis, S. F.: Wetlands management. *Freshwater Catch No. 33*: 16–17.

Davis, S. F.: Lignite mining deferred. *Freshwater Catch No. 33*: 18–19.

Davis, S. F.: Wetlands of national importance to fisheries. *N.Z. Freshwater Fisheries Report No. 90.* 48 p.

Davis, S. F., and Scott, D.: Mataura NCO announced — and objected to. *Freshwater Catch No. 30*: 3–4.

Davis, S. F., and Teirney, L. D.: Fish and fisheries. *In* Henriques, P. R. (Ed.), "Aquatic Biology and Hydroelectric Power Development in New Zealand", pp. 237–263. Oxford University Press. 280 p.

Davis, S. F., Unwin, M. J., Zeldis, J. R., and Hayes, J. W.: Angler use of the Rangitata River salmon and trout fisheries. *N.Z. Freshwater Fisheries Report No. 85.* 109 p.

Eldon, G. A.: Freshwater fishes in the Haast River to Cascade River area, South Westland. *Fisheries Environmental Report No. 84.* 27 p.

Eldon, G. A.: Regional modifications to waterways: Part X — Westland. *Freshwater Catch No. 31*: 19–23.

Field-Dodgson, M. S.: Determining head capsule widths of *Deleatidium* spp. from labrum length. *N.Z. Journal of Marine and Freshwater Research 21*: 151–152.

Field-Dodgson, M. S.: The effect of salmon redd excavation on stream substrate and benthic community of two salmon spawning streams in Canterbury, New Zealand. *Hydrobiologia 154*: 3–11.

Field-Dodgson, M. S.: Size characteristics and diet of emergent chinook salmon in a small, stable, New Zealand stream. *Journal of Fish Biology 32*: 17–27.

Field-Dodgson, M. S.: Glenariffe: what the public saw. *Freshwater Catch No. 33*: 7–8.

Field-Dodgson, M. S.: Obituary: Sir Neil Isaac. *Freshwater Catch No. 33*: 9–10.

Field-Dodgson, M. S.: Rise and fall of the fish of kings. *N.Z. Financial Review 7 (2)*: 57–60.

Field-Dodgson, M. S.: The technology and husbandry of farming salmon. Proceedings of the 4th AAAP Animal Science Congress. 501 p.

Field-Dodgson, M. S.: Overseas travel report: First Annual Tasmanian Aquaculture Conference, 17–25 July 1987. *Fisheries Research Centre Internal Report No. 78.* 104 p.

Flain, M.: The charming char. *Freshwater Catch No. 31*: 10–11.

Flain, M.: Meeting at Kakaho Channel. *Dive and Watersport 10 (1)*: 41.

Glova, G. J.: Comparison of allopatric cutthroat trout stocks with those sympatric with coho salmon and sculpins in small streams. *Environmental Biology of Fishes 20*: 275–285.

Glova, G. J.: Co-occurrence of brooks, browns, and rainbows. *Freshwater Catch No. 31*: 5–6.

Glova, G. J.: Rakaia salmon fishing — a further look at the problem. *Freshwater Catch No. 33*: 3–4.

Glova, G. J., Sagar, P. M., and Docherty, C. R.: Diel feeding periodicity of torrentfish (*Cheimarrichthys fosteri*) in two braided rivers of Canterbury, New Zealand. *N.Z. Journal of Marine and Freshwater Research 21*: 555–561.

Graynoth, E.: Growth of landlocked sockeye salmon (*Oncorhynchus nerka*) in New Zealand. *N.Z. Journal of Marine and Freshwater Research 21*: 15–30.

Graynoth, E.: Effects of hydro-electric development on the fish stocks and fisheries of Lake Coleridge. [Unpublished research proposal to Electricorp.] 29 p.

Graynoth, E., and James, G. D.: Review of the lower Waitaki River fisheries studies, 1980–86. *Fisheries Research Division Internal Report No. 64*. 71 p.

Hanchet, S. M.: Fisheries values of the Mokauiti Stream. *Freshwater Catch No. 31*: 6.

Hanchet, S. M., and Hayes, J. W. [1986]: Fish and fisheries resource values of the Mokau River and pre-impact assessment of tributaries draining into the Mokau Coal Field. [Unpublished report to N.Z. State Coal.] 54 p.

Hanchet, S. M., and Hayes, J. W. [1986]: Fisheries resources of the Rotowaro area, a preliminary report. [Unpublished report to N.Z. State Coal.] 16 p.

Hanchet, S. M., and Hayes, J. W.: Summary of results of the 1986–87 fisheries survey of the Rotowaro catchment and fisheries issues relevant to coal mining. [Unpublished report to N.Z. State Coal.] 9 p.

Hardy, C. J.: Dr Livingston Stone. *Freshwater Catch No. 31*: 3–4.

Harvey, M. J., and Jellyman, D. J. [1986]: Background to fisheries studies of the lower Clutha River. *Fisheries Environmental Report No. 76*. 101 p.

Hawke, S. P., and Field-Dodgson, M. S.: Simple low-cost circular ponds. *Progressive Fish-Culturist 49*: 75–76.

Hayes, J. W.: Competition for spawning space between brown (*Salmo trutta*) and rainbow trout (*S. gairdneri*) in a lake inlet tributary, New Zealand. *Canadian Journal of Fisheries and Aquatic Sciences 44*: 40–47.

Hayes, J. W.: Spawning and juvenile mortality. *Limnological Society Newsletter No. 23*: 18.

Hayes, J. W., and Hanchet, S. M.: Fish survey of the Rotowaro catchment and fisheries issues relevant to coal mining. [Unpublished report to N.Z. State Coal.] 20 p.

Hopkins, C. L., and Sadler, W. A.: Rhythmic changes in plasma thyroxine concentration in hatchery-reared chinook salmon, *Oncorhynchus tshawytscha*. *N.Z. Journal of Marine and Freshwater Research 21*: 31–34.

Hopkins, C. L., and Unwin, M. J.: River residence of juvenile chinook salmon (*Oncorhynchus tshawytscha*) in the Rakaia River, South Island, New Zealand. *N.Z. Journal of Marine and Freshwater Research 21*: 163–174.

James, G. D.: The 1987 salmon run. *Waitaki Valley Acclimatisation Society Annual Report 1987*. [Unpaged.]

James, G. D., and Ward, M. E. [1986]: The 1986 salmon run (survey results). *Waitaki Valley Acclimatisation Society Annual Report 1986*: 8–9.

Jellyman, D. J. [1986]: New world record quinnat salmon. *Freshwater Catch No. 30*: 14.

Jellyman, D. J. [1986]: Review of the marine life history of Australasian temperate species of *Anguilla*. *American Fisheries Society Symposium 1*: 276–285.

Jellyman, D. J.: Factors affecting trout abundance in rivers: proceedings of a workshop held in May 1987. *Fisheries Research Centre Internal Report No. 76*. 44 p.

Jellyman, D. J.: Freshwater fisheries and impact assessment. *Freshwater Catch No. 32*: 22–24.

Jellyman, D. J.: Wairau River conservation notice appealed. *Freshwater Catch No. 31*: 18–19.

Jellyman, D. J., Eder, R. M., and Hardy, C. J.: Recreational and angling surveys of the Waimakariri River. *Fisheries Environmental Report No. 86*. 55 p.

McCarter, N. H.: Update on the use of grass carp for weed control in New Zealand. *In* McAuliffe, K. W., and Boag, J. M. C. (Eds.), Proceedings of the Third National Land Drainage Seminar, pp. 147–151. *Massey University Occasional Report No. 7*.

McCarter, N. H.: Time for triploids. *Freshwater Catch No. 32*: 10–11.

McCarter, N. H.: Testing for triploids. *Freshwater Catch No. 33*: 11–12.

McCarter, N. H.: Growth rates. *Limnological Society Newsletter No. 23*: 19.

McCarter, N. H.: Brown and rainbow trout in Lake Benmore. *Fisheries Environmental Report No. 83*. 67 p.

McCarter, N. H.: Background notes on freshwater aquaculture in New Zealand. [Unpublished report.] 23 p.

McCarter, N. H.: Carp and prawn aquaculture in Wuxi and Hong Kong. Overseas travel report. [Unpublished report.] 12 p.

McDowall, R. M.: The native fish. *In* Viner, A. B. (Ed.), Inland waters of New Zealand, pp. 291–306. *DSIR Bulletin No. 241*.

McDowall, R. M.: Impacts of exotic fishes on the native fauna. *In* Viner, A. B. (Ed.), New Zealand inland waters, pp. 333–347. *DSIR Bulletin No. 241*.

McDowall, R. M.: River estuaries in the life cycles of New Zealand fish species. *In* Yáñez-Arancibia, A. (Ed.), "Fish Community Ecology in Estuaries and Coastal Lagoons: Towards an Ecosystem Integration", pp. 557–570. Unam Press, Mexico City.

McDowall, R. M.: The occurrence and distribution of diadromy in fishes. *American Fisheries Society Symposium 1*: 1–13.

McDowall, R. M.: Fresh and brackish water fisheries in New Zealand. *In* Petr, T. (Ed.), Reports and papers presented at the expert consultation on inland fisheries of the larger Indo-Pacific Islands, Bangkok, Thailand, 4–9 August 1986, pp. 110–118. *FAO Fisheries Report 371, Supplement.*

McDowall, R. M.: Fish stocks for cool freshwaters. *In* Petr, T. (Ed.), Reports and papers presented at the expert consultation on inland fisheries of the larger Indo-Pacific Islands, Bangkok, Thailand, 4–9 August 1986, pp. 210–223. *FAO Fisheries Report 371, Supplement.*

McDowall, R. M.: Minimising the risks, protocols, controls and quarantine in fish introductions. *In* Petr, T. (Ed.), Reports and papers presented at the expert consultation on inland fisheries of the larger Indo-Pacific Islands, Bangkok, Thailand, 4–9 August 1986, pp. 233–238. *FAO Fisheries Report 371, Supplement.*

McDowall, R. M.: Spotting the difference. *Flyfisher 24*: 21.

McDowall, R. M.: Towards a conservation ethic for rivers. *N.Z. Salmon Angler 14 (1)*: 19–22.

McDowall, R. M., James, G. D., Field-Dodgson, M. S., and Brown, J. L.: Charging for services and products/cost recovery. [Freshwater section, Fisheries Research Division. Discussion papers.] 20 p. and 2 appendices.

Meredith, A. S., Empson, P. W., Boubee, J. A. T., and Mitchell, C. P.: Ichthyoplankton studies on the lower Waikato River. I. Entrainment at Huntly thermal power station. *N.Z. Freshwater Fisheries Report No. 88.* 22 p.

Meredith, A. S., Empson, P. W., Boubee, J. A. T., and Mitchell, C. P.: Ichthyoplankton studies on the lower Waikato River. II. Larval distribution at Huntly. [Internal report to Electricorp.] 74 p.

Palmer, D., Boubee, J. A. T., and Mitchell, C. P.: Impingement of fish and crustacea at Huntly thermal power station. *N.Z. Freshwater Fisheries Report No. 91.* 40 p.

Palmer, K. L.: Adult trout in the demonstration channels, lower Waitaki River, 1982–85. *Fisheries Environmental Report No. 81.* 61 p.

Pierce, L. A.: Non-salmonid fisheries of the lower Waitaki River. *Fisheries Environmental Report No. 82.* 46 p.

Richardson, J. [1986]: Brown mudfish population protected. *Freshwater Catch No. 31*: 10.

Richardson, J. [1986]: Angling survey results. *Freshwater Catch No. 32*: 3–5.

Richardson, J., and McDowall, R. M.: An annotated bibliography of the indigenous New Zealand freshwater fish. *N.Z. Fisheries Occasional Publication No. 1.* 138 p.

Richardson, J., Teirney, L. D., and Unwin, M. J.: The relative value of Central North Island Wildlife Conservancy and Wanganui rivers to New Zealand anglers. *N.Z. Freshwater Fisheries Report No. 87.* 125 p.

Rutledge, M.: Benthic invertebrates of the lower Waitaki River and tributaries. *Fisheries Environmental Report No. 80.* 60 p.

Sagar, P. M.: Salmonids in the southern ocean. *Freshwater Catch No. 30*: 11–13.

Sagar, P. M., and Glova, G. J.: Prey preferences of a riverine population of juvenile chinook salmon, *Oncorhynchus tshawytscha*. *Journal of Fish Biology 31*: 661–673.

Saxton, B. A., Rowe, D. K., and Stancliff, A. G.: Species composition and relative importance of whitebait fisheries in 13 Bay of Plenty rivers. *Fisheries Environmental Report No. 79.* 63 p.

Stancliff, A. G., Boubee, J. A. T., Palmer, D., and Mitchell, C. P.: Cross channel movement of migratory fish and shrimp in the Waikato River near Huntly thermal power station. [Internal report to Electricorp.] 19 p.

Strickland, R.: Nga tini a tangaroa, a collection of Maori names for fish (Maori to English and English to Maori). [Unpublished report.] 63 p.

Taylor, M. J., and Main, M. R.: Distribution of freshwater fishes in the Whakapohai River to Waita River area, South Westland. *Fisheries Environmental Report No. 77.* 85 p.

Teirney, L. D.: River protection and flow requirements for fish: the New Zealand experience. *In* Campbell, I. C. (Ed.), Stream protection: the management of rivers for instream uses, pp. 169–198. Water Studies Centre, Chisholm Institute of Technology, East Caulfield, Australia.

Teirney, L. D.: Round three for the Manganuioteao River. *Freshwater Catch No. 32*: 12.

Teirney, L. D., Richardson, J., and Unwin, M. J.: The relative value of Ashburton rivers to New Zealand anglers. *Fisheries Environmental Report No. 78.* 70 p.

Teirney, L. D., Richardson, J., and Unwin, M. J.: The relative value of North Canterbury rivers to New Zealand anglers. *N.Z. Freshwater Fisheries Report No. 89.* 113 p.

Printed by Thames Publishing Co. Ltd. under the authority of
V. R. WARD, GOVERNMENT PRINTER, WELLINGTON, NEW ZEALAND—1988