ISSN 0110-1765

Proceedings of the Salmon Symposium

Fisheries Research Division Occasional Publication No. 30

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Compiled by
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Fisheries Research Division
Occasional Publication No. 30
1981

Published by the New Zealand Ministry of Agriculture and Fisheries
Wellington
1981

ISSN 0110-1765

The symposium was held in Christchurch in August 1980.

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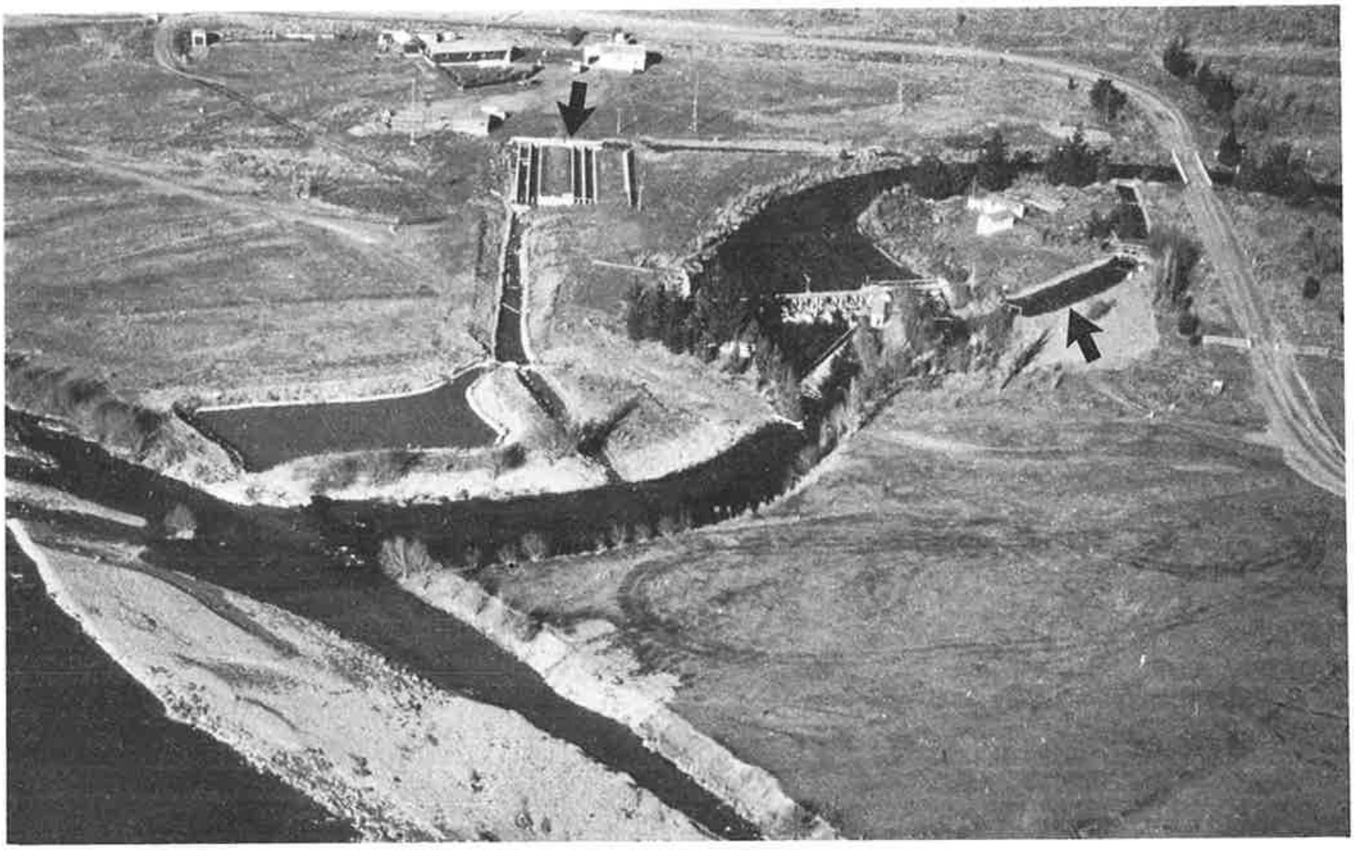

Glenariffe salmon trap, 1980. Main trap in centre, rearing raceways and holding pond for adults arrowed.

Opening address

by the Rt. Hon. Duncan MacIntyre
Minister of Fisheries

DURING the last few years we have witnessed in New Zealand an unprecedented level of interest and development in fisheries resources. This high level of activity is symptomatic of the general drive to diversify, as widely as possible, the base of our essentially primary industry oriented economy. As the process evolves, previously little-used or little-understood resources are being carefully evaluated for the contribution they can make to our nation's economic welfare. It is indicative of the times in which we live that such evaluation pays significant attention to environmental and ecological considerations. The name of the game is efficient utilisation, **not** exploitation.

New Zealand's unique reliance in primary industry on largely non-indigenous flora and fauna has been a source of interest to scientists in many disciplines. It may be fairly said that almost all the plant, animal, and fish species introduced to these islands have, in a truly biblical sense, gone forth and multiplied most mightily. Salmon provide a good example of this phenomenon and, as far as I am aware, New Zealand is still the only country in the Southern Hemisphere in which self-perpetuating stocks of salmon are firmly established.

Against such a background, this symposium has been mounted so that current problems facing the salmon fishery can be studied, information on what has already been done can be disseminated, and we may also have the opportunity of hearing from our overseas visitors about salmon management, enhancement, and commercial fisheries in their home countries.

Salmon ranching

The New Zealand Government strongly supports the concept of salmon ranching, and a policy for ocean ranching of quinnat salmon was approved by me in July. There seem to be no good reasons why such an industry should not prosper and we also believe that benefits will accrue to the recreational fishery. However, we appreciate that it will not happen overnight. For some years yet, salmon ranchers will have to obtain their ova from wild sources, since large annual fluctuations in the return of adult salmon make it nearly impossible to guarantee adequate ova supplies. You will be aware that this year, for example, no more than a token ova supply was available for the four farms already in operation.

Nonetheless, a firm policy was needed for future management of such a fishery. This has been evolved from discussions between my officers, the Department of Internal Affairs, the New Zealand Fishing Industry Board, and acclimatisation societies, and the draft has been finally prepared and recommended to me by the Freshwater Fisheries Advisory Council. The main objective of this policy is to encourage rational development of an ocean ranching quinnat salmon fishery. At the same time, activities which may damage existing freshwater recreational fisheries resources will be prevented or minimised. The policy will also ensure that existing resources remain available to anglers and that the long-term viability of trout and salmon fisheries will be maintained.

One of the difficulties the salmon farmer faces is that he has no control over the fish from the point of liberation until they return to the farm. However, it is intended that protected areas will be set up near hatcheries to prevent anglers from catching salmon which have returned to spawn. Anglers will have free access to fish outside such areas.

Restrictions are also to be imposed on non-angling fishing methods between January and April to safeguard the return of salmon to authorised capture sites. Methods will need to be devised to protect salmon at sea from deliberate capture. The Freshwater Fisheries Advisory Council has established a working party to examine and report on the problems. We are looking at the possibility that commercial hatcheries could be required to mark fish before releasing them.

Disease

There is absolutely no doubt that the need to control disease and its spread through the fishing industry will be a major consideration in marketing salmon. Considerable disappointment was created by the discovery of whirling disease in the Silverstream hatchery, but ministry staff, from Animal Health and Fisheries Research Divisions in particular, combined forces to deal with the problem and to determine the areas in which the disease might occur. Regrettably, we must accept that the disease is indigenous, at least in the South Island, and has been present since well before 1971. This emphasises the care that will have to be taken in the operation of any freshwater hatcheries, irrespective of whether they belong to government, societies, or private individuals. From now on, ministry livestock officers will have the additional responsibility of inspecting fish hatcheries in the same way as they inspect other land-based farming operations.

Conflicting interests

Where there is conflict of interest between commercial operators in development of a salmon industry, support will most positively be given to proposals which show the greatest benefit to the sports fishery. So far we have at least one application for each of the rivers in the Canterbury area which are most suitable for salmon ranching. You can appreciate that it will be necessary for my ministry to carefully assess the merits of each new proposal before approvals are granted. Efforts will be made to encourage more widespread distribution of salmon, and development will be encouraged for rivers as long as other sports fisheries are not endangered and ova supplies are available. We must consider that it may be necessary in the initial stages to limit the number of salmon ranching developments in any one catchment, and here we must decide whether we are dealing with a whole river system or just one river.

I know there is considerable concern about salmon being caught at sea as a by-catch, and many people hold that this is a covert rather than an accidental activity. Salmon have been caught for many years by commercial fishing boats off our coast, but recently it seems that the incidence of such catches has greatly increased. Whether this is due to more fish, different boat types, alternative fishing methods, or just the knowledge of the salmon's presence by commercial fishermen is, perhaps, immaterial. What must be considered is the resolution of conflicting interests: those of sports fisheries, including augmented natural runs, of commercial salmon farmers releasing fish to the sea, of commercial fishermen who unavoidably take fish, and of this ministry, which needs information from commercial fishermen as to where salmon are taken and requires that tags be returned. This was discussed at some length at the annual general meeting of the Freshwater Fisheries Advisory Council and written submissions were received from the South Island Council of Acclimatisation Societies and some individual South Island acclimatisation societies.

The advisory council has set up a working party to study the following objectives:

- To protect the recreational fishery at, or above, the current level;
- To permit salmon caught at sea by trawlers, as a by-catch, to be legally landed for use;
- To protect and promote the development of ocean-release salmon farms;
- To discourage target fishing for salmon by commercial interests;
- To discourage the present illegal sales of salmon and prevent the development of a more extensive black market;
- To provide protection from non-recreational fishing to salmon returning to their natal streams.

Legislative considerations

Originally, the salmon was introduced to become a commercial species. Rod and river netting licences and licences for trawling at sea were issued, and trapped fish were sold by the South Island council. These practices were stopped when natural stocks proved inadequate. Today, with an internal demand for salmon from the hotel and restaurant trade, high black market prices, modern fishing vessels, and the promise of greatly augmented natural salmon runs, it is obvious that current legal statutes provide inadequate control.

In Part I (Sea Fisheries) of the Fisheries Act 1908, "fish" is defined to include "every description both of fish and of shellfish" found in our waters, but it does not include salmon or trout. Therefore in those areas covered by just Part I of the act, no action may be taken regarding salmon; they could be transhipped for export, for example. Part II of the act does include salmon in the definition of fish, but the area of jurisdiction is limited to 500 m from shore where any stream enters the sea. Salmon may not be sold or landed, however, so that any fishing vessel bringing salmon ashore commits a violation.

Further confusion results from the type of information available. Some commercial fishermen claim that salmon mix with normal target species and that large-scale catches are unavoidable, recreational fishermen make unsupported statements about damage done, and so on. Obviously it is imperative that any system for control must be based on fact and that a complicated and expensive control mechanism should not be established on pure supposition.

Salmon caught by non-recreational means can be separated into three categories: off-shore catch by licensed foreign fishing boats, near-shore and river catch by both commercial and recreational set nets, and catches at sea by New Zealand based boats. Licensed vessels are not considered to be a real problem, as they are excluded, as far as we know, from sea areas populated by salmon. Joint venture and New Zealand registered overseas vessels could be a problem, except that there are provisions to exclude such ships from specific areas, or to limit them to specific gear, by conditions imposed on their permits. It is obvious that with an increase in salmon returning to rivers, uncontrolled river and near-shore gill netting, ostensibly for other fish, could severely damage a run or make a commercial salmon farm uneconomic. There is no suggestion that such practices be relicensed, but rather that certain restrictions be applied; for example, limiting the number of meshes allowable for a flounder net, limiting the number and placement of nets, or outright closure to any net fishing either permanently or for specified periods.

I have dealt at some length with our policy for a commercial salmon industry in New Zealand. I believe it was appropriate for me to do so in view of the symposium programme, which exhaustively covers the many other aspects of salmon and their environment in this country. I am sure that your deliberations will make a valuable contribution to our store of knowledge on this subject, and in wishing you a most successful meeting, I will take the opportunity of extending a very warm welcome to our overseas visitors. The benefit of their experience is a valuable input to this symposium. I have much pleasure in opening the meeting.

Discussion

Mr Waugh: Minister, one of your suggestions was that salmon farmers would have to mark all their fish. Because of a very heavy work load, I would hope that this is not made a requirement too early in the piece.

Mr MacIntyre: It depends on what type of marking you're doing: sheep ear tags, coded wire, or whatever. Yesterday while discussing the future of the snapper fishery in Auckland, I was advised they get a 10%–20% return from recreational fishermen; so we would expect everyone to send them in if we put them on salmon, wouldn't we?

Mr Henderson: Could we install observers on foreign and commercial fishing boats catching salmon at sea off the coast of New Zealand?

MacIntyre: It's a thought and obviously it could be done. However, manpower requirements would be such that possibly it would be more effective to examine the catch at the landing site.

Mr Dougherty: Will policing of black market salmon start as a national scheme rather than locally?

MacIntyre: Last year legislation was passed to allow fisheries inspectors and police to enter and inspect. This necessitates confiscation of salmon from the diners' plates, or else the evidence is consumed. If a complaint is laid it can be followed up.

Unknown: Are you starting to regard recreational fisheries as purely secondary to commercial fisheries?

MacIntyre: No, I hoped that my speech showed I considered the recreational fishery as paramount. Restrictions that may be imposed would be very limited in order to protect the resource. The recreational fishery has first priority.

The history of New Zealand's salmon fishery

by M. Flain

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NEW ZEALAND's early settlers formed local acclimatisation societies which continue to the present day, and most have a history of over a century of fish and wildlife management. Their councils are elected by the licence holders and they carry out day-to-day management. Initial government participation was by the Marine Department, which existed from 1887 to 1972.

The societies formed a research committee, which had its first meeting on 18 November 1929 and its last on 3 June 1937, by which time it had run out of money. Its functions were taken over by the Marine Department; early workers included such people as D. Hobbs, A. Parrott, M. Godby, and Professor E. Percival. On 1 September 1972 Fisheries Management and Research Divisions transferred from the Marine Department to the Ministry of Agriculture and Fisheries.

One other government department has freshwater fisheries responsibilities; this is the Department of Internal Affairs. Originally, the old Tourist Department had special interests in the Rotorua-Taupo area and the Southern Lakes district. These were taken over by the Department of Internal Affairs in 1930 and 1945 respectively.

The acclimatisation societies hold annual meetings of the North and South Island Councils, and elected representatives from these, with government representatives, meet as the Freshwater Fisheries Advisory Council, which conveys to government matters of concern. This body had its first meeting on 27 September 1946. An offshoot of this was the formation of the South Island Salmon Committee in 1952.

As a result of staff training difficulties, a scheme was introduced to give on-the-job training to field officers. This was known as the technical field service, and it began in 1957, carrying out short-term investigations. A further decision by the Freshwater Fisheries Advisory Council in 1964 to undertake long-term projects resulted in these officers becoming increasingly committed to the operation of the Glenariffe salmon trap on the Rakaia River. One other event was the formation of the New Zealand Salmon Anglers Association in April 1972; members of this association have been concerned with the various salmon enhancement schemes.

Introduction of salmon

The early acclimatisation societies, often acting independently, sought to introduce salmon into New Zealand, as the native species of freshwater fish were neither large nor very sporting.

Atlantic salmon, *Salmo salar* (Linnaeus)

Most of the settlers were European, and so their first choice was the Atlantic salmon. The Tasmanian Salmon Commissioner noted in 1862, "a contribution of £200 has been received from New Zealand", towards the cost of importing Atlantic salmon ova from Britain. This importation failed. A parliamentary resolution was passed on 23 September 1867 which read, "That in the opinion of this House, it is desirable that inquiries should be made by the Government with the view of ascertaining the best means to be adopted for introducing salmon into the Colony, the most favourable situation for carrying out any experiments in connection with the breeding of salmon, and the probable cost of such experiments."

The first successful importation was in 1868, and large numbers of fish were raised in subsequent years. The imported stocks originated from a variety of sources: from the rivers Tay, Firth, Severn, Tweed, and Ribble in Britain, from the Rhine in Germany, and from the Miramichi River in Canada. All of these stocks were anadromous. Although liberations were made throughout New Zealand, efforts were concentrated on the Aparima River in Southland between 1889 and 1893. These introductions appear to have been unsuccessful. In 1908 the government made further importations and concentrated on the Upukerora River, which feeds into Lake Te Anau. The government had a trap and a hatchery on this river until 1944.

Atlantic salmon became established and are still present in Lake Te Anau, though apparently in very small numbers. The Wildlife Service of the Department of Internal Affairs has recently tried to husband the resource. In addition, in 1960–65 the Southland Acclimatisation Society imported "Helmsdale salmon". These were "Baltic salmon", supposedly not inclined to travel far at sea.

It should be noted here that Donne (1927) refers to a consignment of "sebago" salmon to New Zealand from Green Lake Hatchery, Maine, and Rodd (1941) refers to 10 000 ova sent to New Zealand in 1905 from Chamcook Lakes, New Brunswick. It has been suggested that these small importations were the source of the present landlocked stocks in Lake Te Anau and that all other anadromous stocks got lost when they went to sea.

Sockeye salmon, *Oncorhynchus nerka* (Walbaum)

In 1900, 500 000 eggs were sent from the Fraser River hatchery in British Columbia to New Zealand. These all died in transit. One other importation, in 1902, succeeded. This was a gift from the Canadian Government to the New Zealand Government. These fish were from Shuswap Lake on the Fraser River and were from anadromous stocks. The result was unexpected. A landlocked variety established itself in the catchment of liberation, the Waitaki; there is virtually no evidence of a sea run. At present the stock is being investigated, but it is not being fished much. The construction of a compensatory trout spawning race at the Aviemore dam, which was used by large numbers of sockeye, revived interest in this species.

Chinook, quinnat, spring, king, or tyee salmon, *Oncorhynchus tshawytscha* (Walbaum)

From 1875 to 1880 acclimatisation societies tried, with government help, to introduce this fish, but apparently without success. Sir James Hector is credited with the foresight to see its potential for commercial development. In 1900 the government took on the task at its Hakataramea hatchery on the Waitaki River. From 1901 to 1907 five importations were made. These fish were from anadromous stocks from the Baird Station on the McCloud River, a tributary of the Sacramento River in California.

A run was established on the Waitaki River, and other rivers were stocked by stripping fish from this run. Some of these fish have developed into self-propagating, landlocked stocks, a feature most uncommon in North America. The success on the Waitaki was largely due to the perseverance of L. F. Ayson, Chief Inspector of Fisheries in the early part of this century.

As the runs increased, commercial exploitation was allowed. From 1922 to 1952 rod selling licences were issued, and netting licences were issued from 1925 to 1952. The societies objected, and the government discontinued the licences, but it maintained control of salmon. The societies were required to provide at least 750 salmon for sale. At this time there was a problem of salmon congregating at the tail race of the Highbank power station on the Rakaia River, and the societies used these as a source of fish for sale from 1951 to 1960. To administer this the South Island Salmon Committee was formed. Changes in operational procedures at Highbank caused the supply of salmon to lapse, but the committee remained and concerned itself with other matters of salmon management. The greatest number of fish obtained for sale was in 1956, when over 3000 were marketed and a further 400 unripe fish were transferred up stream.

Present work on salmon

Research on salmon in New Zealand has been limited. In 1925 Dr C. H. Gilbert made a private visit to New Zealand, and when he examined a small sample of scales, he suggested that there were marked differences in the age of the stocks compared with those of North America. This prompted the collection and analysis of larger samples by Dr H. J. Finlay of Otago University and, later, A. W. Parrott.

The construction of the Glenariffe salmon trap in February 1965 led to a range of investigations into the biology of the quinnat salmon and these are still being carried out.

Man-made problems faced by salmon in New Zealand are the same as those overseas; namely, hydro schemes, of which the first major ones were the Waitaki dam (1935) on the Waitaki River and the Roxburgh dam (1956) on the Clutha River, and water abstraction for irrigation, of which the first major scheme was the Rangitata Diversion Race (1945). All salmon rivers are in line to be affected by either or both of these threats. Pollution is also present to some extent in most rivers.

At present there is a major thrust by way of "ocean ranching" to increase salmon runs. The Ministry of Agriculture and Fisheries has raceways, lake impoundments, and spawning channels at Glenariffe and Silverstream. Private enterprise interests include: Pupu Springs Salmon Farm (C. Barker); Hurunui Salmon Co. (D. Lamont); Ashby Bros., South Branch Waimakariri (J. Ashby); Isaac Construction Co., South Branch Waimakariri (N. Isaac); South Pacific Salmon Co., Whisky Creek, Rakaia (A. Crowe); Blackford Stream, Rakaia River (E. R. Mee); ICI/Watties, Waitaki and Clutha Rivers (T. Beckett); Burnt Hill Salmon Ranch (Oregon), Owaka River, South Otago (A. Watson); Tasman Salmon Farm, Hokitika River (G. East); Orari Salmon Co. (D. Williams); and Rangitata (I. Maxwell).

Some effort in stream improvement has been undertaken by the Ministry of Agriculture and Fisheries with the acclimatisation societies and also by the New Zealand Salmon Anglers Association.

Comments on aspects of salmonid introductions

The introductions of Atlantic, sockeye, and quinnat salmon were from anadromous stocks. This was also true for rainbow trout, and from all of these some freshwater populations resulted. Freshwater populations of these species in the wild in other parts of the world are unusual for Atlantic and sockeye salmon and extremely rare for quinnat. There may have been small consignments of eggs from freshwater North American stocks of Atlantic salmon and rainbow trout, but not of quinnat or sockeye salmon. Why this freshwater residence should develop in New Zealand waters is unanswered.

Atlantic and sockeye salmon and rainbow trout have not developed anadromous runs in New Zealand. For the Atlantic salmon this can be explained by its known long migratory pattern, which does not fit New Zealand sea conditions, and the inference is that this must also be true for sockeye salmon and rainbow trout. Sampling of quinnat salmon at sea indicates that they do not range far off shore, the greatest distance so far known being 48 km off the east coast of the South Island. Perhaps because of this limited coastal distribution the quinnat have succeeded in creating anadromous spawning runs in New Zealand.

The main current running up the east coast of the South Island is the "warm" Southland Current; in North America the main current running down the west coast is the "cold" Californian Current. Despite these differences, quinnat salmon have succeeded in New Zealand, apparently in those areas which have in-shore waters of suitable temperature enclosed by the Southland Current.

Early introductions had varying success. Sockeye salmon and Great Lakes char (mackinaw) were each established from only one consignment. Major efforts with Atlantic salmon had limited success, and initial quinnat introductions seemed to be headed in the same way. However, concentrated efforts on one river system have established quinnat salmon in New Zealand. I suggest that part of the explanation for this success may be that the uncertainty of egg supplies resulted in the practice of retaining some fish in the river of liberation for extended periods of several years. These would have generated pheromones which may have helped returning adults to relocate their river of origin in a strange environment. The increased chance of survival of some of these larger fish, due to their size when released, may also have helped in establishing a spawning run. Some quinnat were released as yearling, 2-, 3-, and even 4-year-old fish, a practice most uncommon in those times.

Because of the instability of New Zealand rivers compared with those where our salmon stocks originated, and the major differences in physical conditions of the environment, New Zealanders may be considered fortunate in having salmon at all.

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Juvenile production and yield in quinnat salmon

by C. L. Hopkins

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THIS paper presents some of the results of studies made on juvenile quinnat salmon populations in the Glenariffe Stream, one of the major spawning streams in the Rakaia system. The Glenariffe is about 8–9 km long and with its tributaries makes about 10 ha of stream available to salmon.

Most adults enter the stream from March to June, with a peak in April. Fry emerge from the redds from July to early November, but most emerge from August to the end of October, with peak numbers in September. Nearly all young fish leave the Glenariffe very soon after emergence and most of the remainder leave as smolts from November to January. A few remain until the following spring.

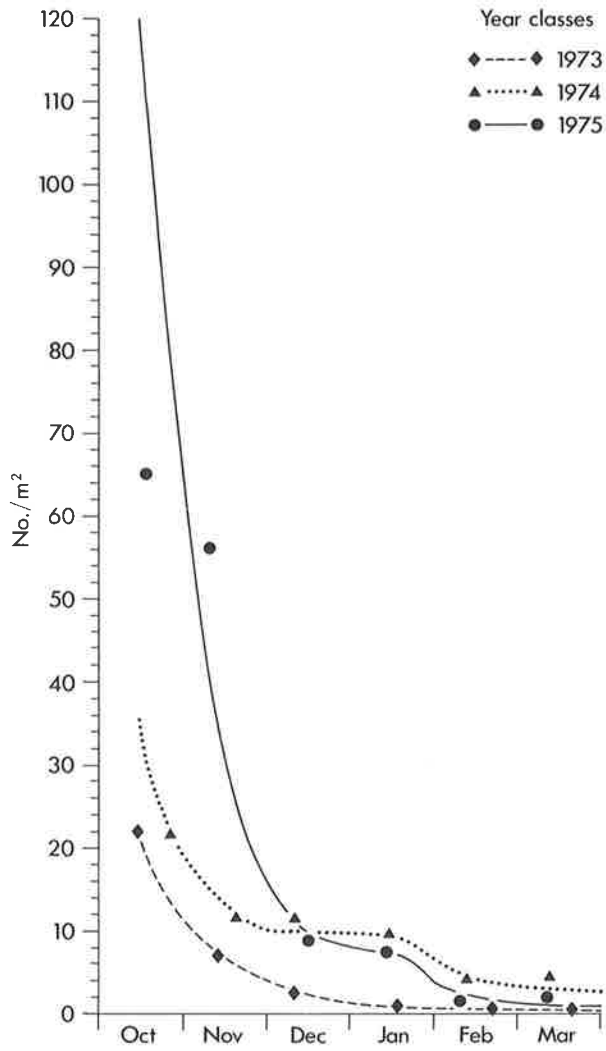

Fig. 1: Survival of young quinnat salmon in the Glenariffe Stream.

Fecundity studies on adult Rakaia salmon show a strong relationship between size of female and the number of eggs carried. Hence it is possible to estimate the total potential egg deposition of the annual run of salmon into the Glenariffe by counting and measuring the adults as they pass up through a fish trap which spans the stream near its confluence with the Rakaia River.

Examination of salmon carcasses over six spawning seasons has provided data on the degree of egg retention in spawned females and on the numbers of females that fail to spawn. This allows estimates of potential egg deposition to be converted into estimates of actual deposition in the redds.

We have no reliable data on survival in the redds up to the time when fry emerge into the stream. It appears from the work of Hobbs (1937) and Hawke (1978) that egg survival can be very high, above 95%. However, what happens to the alevins after hatching, and before emergence from the gravel, is unknown. In North America two unrelated pieces of experimental work in which eggs were artificially laid down in gravel, indicated that under good conditions survival to the alevin stage was 70%–95% (Bjornn 1969, Thomas 1975). My own calculated average of these experimental results is 85%. If losses at spawning and losses during development are combined, a survival of 80% of the potential egg deposition can be expected by the time fry emerge from the gravel, provided that there have been no damaging floods.

During spring and summer of 1973–74, 1974–75, and 1975–76 three consecutive year classes of young salmon were monitored by monthly sampling with electric fishing equipment at five different sites on the Glenariffe Stream. Sampling began in October and finished in March, by which time virtually all salmon smolts had left the stream. The original field work was planned and executed under Dr J. V. Woolland who left the Ministry of Agriculture and Fisheries in 1976.

Figure 1 shows survival curves for the three year classes of young salmon in the Glenariffe. The curves were drawn free-hand through the data points, each of which represents the average population density of five sampling sites. The curves cover only the last part of the fry recruitment period. An approximation of fry losses from the time of emergence from the redds to the end of the fry outmigration (end of October) can be obtained by extrapolating the October loss rate back to mid September, the mid point of the emergence period, and a time at which almost all of the estimated total emergence is assumed to be still present. The estimated total population surviving at 1 November is shown in Table 1, with estimates of the total fry emergence, the number of fry migrants through the Glenariffe fish trap, and the in-stream mortality during this time of fry migration.

From 1 November the survival curves obtained from electric fishing data were used to estimate population size at the beginning of each month to 1 April.

The massive outmigration of fry in early spring is of particular interest. Over 90% of all Glenariffe outmigrants leave the stream as fry. Population responses to density are probably most extreme during the period of fry emergence when fish numbers are highest. Fry migrants contribute virtually nothing to production in the Glenariffe population, since they migrate before much growth has taken place. But the growth of juveniles remaining may be enhanced by the reduction in population size resulting from loss of fry as migrants. Furthermore, if conditions are suitable, the dispersal of fry into the main river may allow more opportunity for growth and contribution to the total yield of smolts entering the sea.

Production as used here means the quantity of new material produced in the population over a given time. It is a synthesis of information on growth and population numbers, both of which change through the seasons as fish size usually increases and fish numbers decrease. Production is an aspect of growth in the population. When growth ceases, so does production.

The parameters needed to estimate production are population size and mean weight. Figure 2 shows mean weights of Glenariffe fish taken at monthly intervals. The free-hand curves drawn through the data points represent growth. Figure 3 shows fish numbers against mean weight, with an arbitrary starting point at 15 September in each year, when the total emergent fry recruits were assumed to be present. From measurements of newly emerged fry I took the starting weight of recruits as 0.27 g. The area under each curve gives an estimate of production by the population (Allen 1951). Since the early fry migrants leave the stream very soon after emergence, these were assumed not to contribute to production in the Glenariffe and their numbers are not included at the starting date of 15 September.

TABLE 1: Estimated total fry emergence in 1973, 1974, and 1975, population size at 1 November, and migration and mortality up to 1 November in the Glenariffe Stream

Year	Emergent fry	Population size	Fry migrants	Mortality
1973	506 800	67 900	248 000	190 900
1974	623 400	81 000	391 000	151 400
1975	2 684 900	283 000	1 900 000	501 900

Total production was 168 kg for the 1973 year class, 226 kg for the 1974 class, and 361 kg for the 1975 class. The overall difference in total production between the smallest and largest year classes was not as large as might be expected from the great disparity in their population sizes at the time of recruitment. The estimated recruitment in the three consecutive years bore the relation 1:1.2:5.3; the ratio for total production of each year class was 1:1.3:2.1. Compared

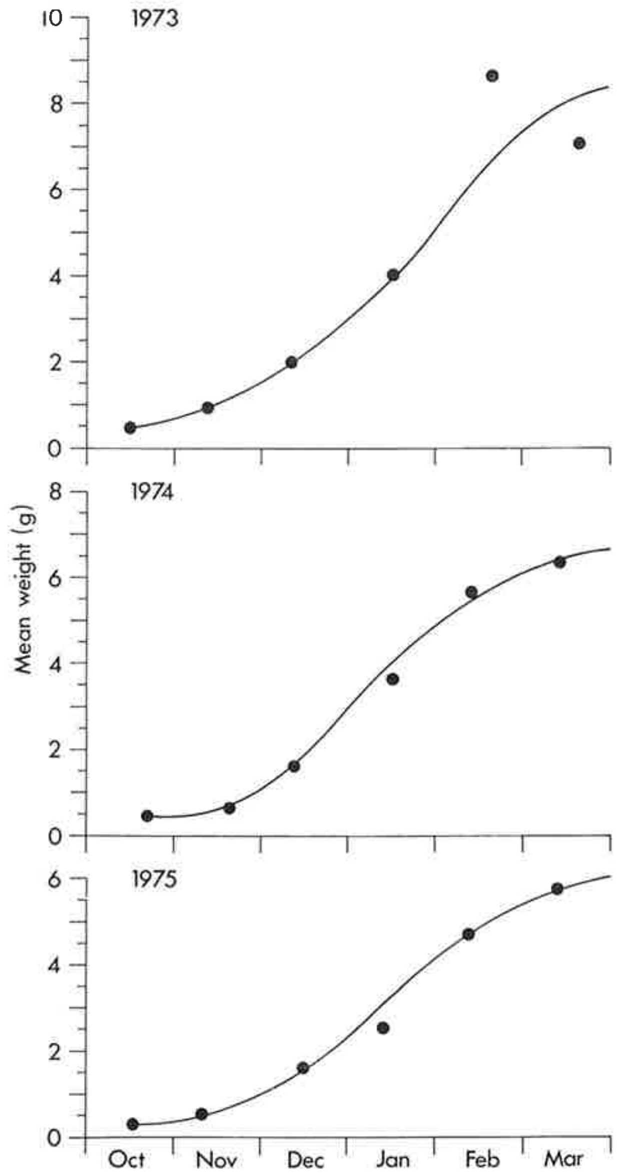

Fig. 2: Growth curves for three year classes of young quinnat salmon in the Glenariffe Stream.

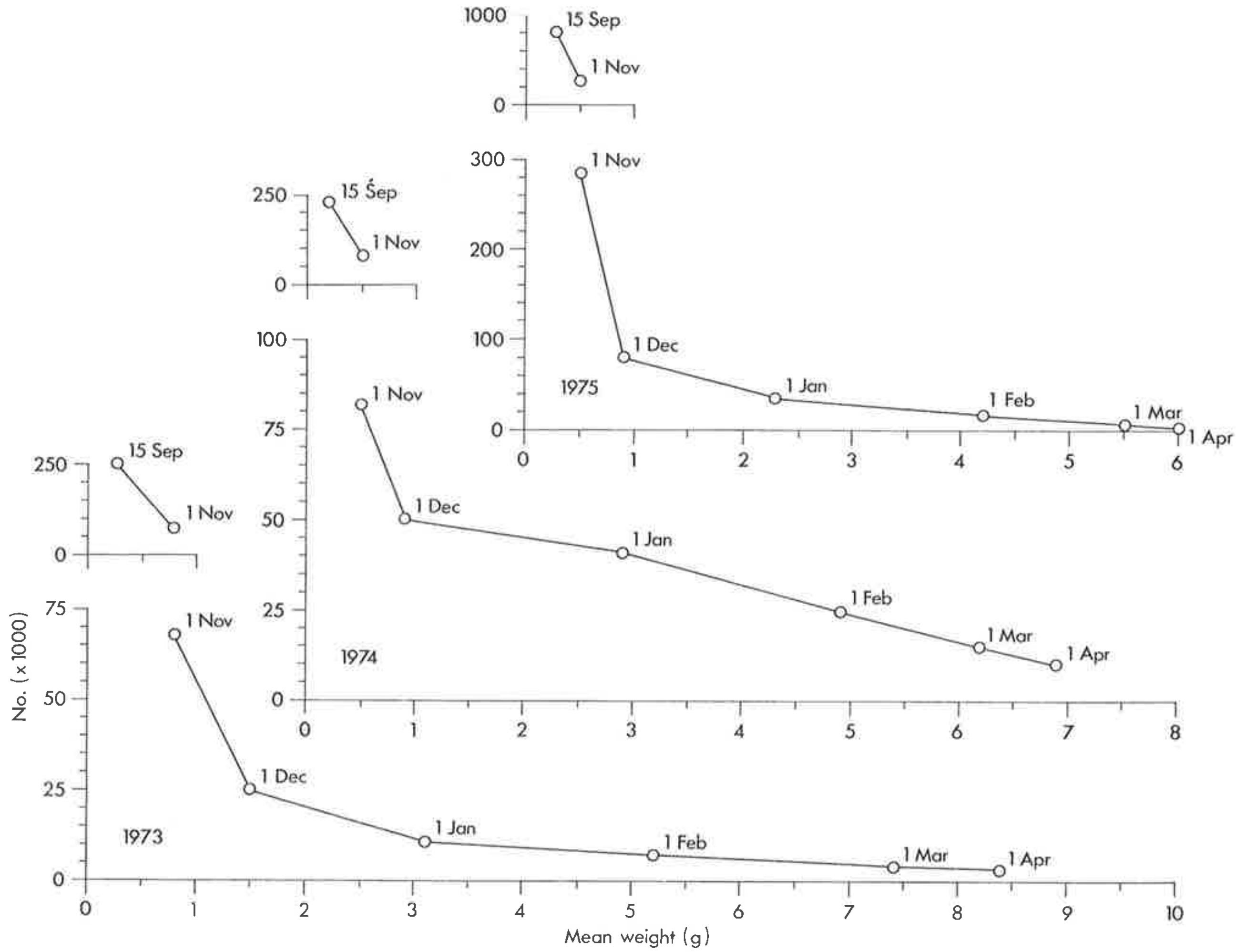

Fig. 3: Production curves for three year classes of young quinnat salmon in the Glenariffe Stream.

with the 1973 and 1974 year classes, production in the much larger year class of 1975 was disproportionately small. This seems to have been brought about by a combination of higher fry migration rate in 1975, higher overall loss rate due to death and migration, and lower growth rate during the first few months of life. These factors probably are to some extent density dependent and large initial fish numbers may not show commensurately high values of production.

Our major interest, as fishery managers, is in the yield of migrants leaving the stream for the sea. I measured yield as the total biomass of fry and smolts which passed down stream through the Glenariffe trap. The major part of the year class at this point in the seaward migration was early fry. The ratio of fry to smolts in the yield increased each year with increasing initial population, being in consecutive years about 1.5:2:6. For the 1975 year class fry migrants accounted for 86% of the total migrant biomass. Table 2 shows the yield of fry (August-October) and of smolts for 1973, 1974, and 1975.

TABLE 2: Yield of young migrant quinnat salmon in the Glenariffe Stream

	Yield (kg)	
Year	Fry	Smolts
1973	77.8	47.9
1974	130.3	59.1
1975	567.0	77.2

It is not known how many fry survive in the main river or how long they remain there before entering the sea. The Rakaia River is subject to frequent flooding in spring, the number and severity of floods varying from year to year. When floods are few and moderate, fry survival may be high; under adverse conditions it is probably low. In some, perhaps most, years the main contribution to the adult return probably comes from juveniles that rear for at least 3 months in the tributary streams before dispersing into the main river.

This has been the opinion of Fisheries Research Division's salmon team. We would like to see the loss represented by the mass migration of young fry conserved to appear as migrant yield later in the year.

The 1975 year class was by no means the largest brood to have appeared in the Glenariffe since studies began there in 1965. Unfortunately data such as I have just presented do not exist for the "fattest" years. However, it seems a strong possibility that little may be gained in yield of 3-month or older migrants after very large runs of adults have entered the spawning streams.

Any plans for trying to increase the output of downstream migrants should concentrate on provision of rearing space for young fry. Work along these lines has been in progress near Glenariffe since 1975, when an impoundment near the top of the stream was modified and 50 000 fry were transferred to it from the Glenariffe trap. The fish were released in late summer of 1976 and were trapped and marked as they left the lake. From that first release we have obtained an adult return of over 2%. A second small lake has subsequently been added to the first and experiments continue.

Another possibility would be to construct rearing channels fed from the Glenariffe Stream.

These ideas are based partly on what may be an incorrect assumption; that fry mortalities in the main river are so excessive that every effort should be made to try to retain as many fry as possible in the comparative shelter of the tributary streams. Studies are being done on the main Rakaia River to gather more information on the fate of juveniles as they move down towards the sea.

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Aspects of the juvenile quinnat salmon outmigration from the Glenariffe Stream

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SALMON research at the Glenariffe field station has been conducted, in one form or another, since 1965. Studies of the up-stream adult salmon spawning migrations were made regularly throughout this period, with less systematic work being done on down-stream migrating juveniles. Before 1973 several different down-stream trap designs were used, so that data comparison on an annual basis is generally not possible. In 1973 a detailed 4-year juvenile salmon monitoring programme was begun. It was aimed at obtaining consistent data both on the timing of the juvenile outmigration and on growth rates.

Although the pre-1973 data yielded few quantitative results, they nevertheless provided a wealth of background information which was used as a basis for the 1973–76 work. In particular, it was well established that during late winter and early spring (August-October) juvenile salmon less than a day old left the Glenariffe Stream in very large numbers and that this accounted for a large proportion of the total outmigration. The remainder were believed to stay in the Glenariffe for several months, after which they migrated as fingerlings.

The Rakaia River below Glenariffe, with its unstable bed, high turbidity, and liability to floods, appears at first sight to be a less hospitable environment than the Glenariffe Stream. Because of this, it was generally considered that survival of juvenile salmon in the Rakaia was low and that very little rearing took place there. Most returning adults were considered to have grown from juveniles which had reared in the Glenariffe (or other spawning streams) for at least 3 months and had then migrated directly to the ocean, with relatively little time spent in the Rakaia en route. Few of the early outmigrants, that is, those leaving before November, were thought to survive. This belief was reinforced by studies of scales taken from returning adult salmon, which indicated that less than 1% of these adults had entered the ocean within their first few days of life.

In this paper I shall summarise briefly those aspects of the 1973–76 work which relate to the timing of the down-stream juvenile migration and describe a simple mathematical model which can be used to interpret these results. I shall then look in some detail at the same results in terms of both juvenile and adult scale data. Finally, by comparing results from these three approaches, I shall draw some conclusions about the duration of juvenile salmon residence in the Rakaia River.

Outmigration from the Glenariffe Stream

One of the main aims of the 1973–76 programme was to examine the seasonal periodicity of the juvenile down-stream migration during each of the 4 years studied. A summary of these results is given in Table 1, which shows monthly estimates of the number of juveniles caught at the trap. Table 2 gives some details of each season's adult spawning run. Some of the figures are uncertain and may be revised later, though this will not affect any of the following discussion.

There has been a considerable range in adult numbers over the 4 years (Table 2), but the timing of each outmigration varies remarkably little from year

TABLE 1: Monthly trap catches of juveniles from the 1973 to 1976 seasons. Figures for 1973 and 1974 fish are actual catches; those for 1975 and 1976 fish are estimates only

Month	1973	1974	1975	1976
Aug	25 360	31 141	140 000	340 000
Sep	52 907	102 923	360 000	1 230 000
Oct	32 412	40 730	220 000	440 000
Nov	5 859	7 677	11 500	25 000
Dec	3 605	2 969	7 000	8 100
Jan	960	761	3 700	3 000
Feb	158	100	1 000	600
Mar	124	188	350	250
Apr	54	31	200	220
May	69	13	420	40
Jun	8	8	100	40
Jul	28	13	50	20
Aug	–*	12	560	80
Sep	–	5	150	130
Oct	–	5	50	50
	121 544	186 576	745 080	2 047 530

*No data available.

TABLE 2: Numbers of adult salmon and estimated egg deposition, Glenariffe spawning run, 1973–76

Year	No. of adults	No. of females	Est. egg deposition
1973	424	161	650 000
1974	447	172	700 000
1975	1 989	803	3 200 000
1976	2 588	1 522	6 100 000

to year. From August to October, roughly 3 to 6 months after spawning, juvenile catches at the trap account for between 90% and 98% of the total for each season. Daily migration figures during this period usually reach a peak in mid September, after which they decline steadily throughout October. From November onwards, the remaining juveniles leave the Glenariffe in a steadily decreasing trickle throughout the summer; few are caught after the end of January. In some seasons, notably 1975, significant numbers of yearling migrants were recorded 12 to 15 months after emergence.

To illustrate how the development of stream residence is reflected in the migration data, I will examine the 1973 figures in detail. Figure 1 shows the daily fry trap catches from August 1973 to January 1974, with juvenile mean lengths calculated at weekly intervals over the same period. Mean length increased from 33 mm on 12 August to 70 mm on 24 January, with individuals of up to 112 mm being recorded.

The important point here is that the size of juveniles passing through the trap did not begin to increase until November. Before this, mean size was almost constant over a period of 3 months, which corresponds exactly to the main flush of outmigrants from August to October and indicates the very high proportion of newly emergent fry migrating at this time. Some larger fish were caught (juveniles of up to 60 mm were recorded during October), but these accounted for less than 2% of the total over the 3 months.

The end of the fry migration in early November appears in Fig. 1 as an abrupt increase in mean length. Between 31 October and 7 November mean size increased from 37 to 49 mm. If a "fingerling" is defined as a juvenile salmon over 40 mm long (as distinct from fry less than 40 mm), it is evident that this transition in mean length corresponds to a sudden change in the relative proportion of fry and fingerlings. On 31 October fingerlings made up 17% of the sample, whereas a week later, on 7 November, the proportion was 88%.

If the above definition of a fingerling is used as a guide-line, the main characteristics of Fig. 1 are readily described in terms of a combination of two distinct submigrations, each with its own characteristics. The first of these migrations represents emergent fry. Migration of fingerlings starts some time in October; the beginning of the migration tends to be obscured by the relatively large numbers of fry still present. Once the fry migration ceases, fingerlings rapidly become dominant, and they continue to leave the Glenariffe Stream throughout the summer. Growth is steady over this period; mean length increases from 52 to 70 mm over about 3 months.

Given this distinction between fry and fingerlings, it becomes apparent that any discussion of the migration figures must take into account two different sizes of juveniles. The mean length of fry is about 35 mm, regardless of the time of year, but for fingerlings the situation is more complex (Fig. 2). As the season advances, the migration consists of progressively decreasing numbers of larger and larger fish. A simple mathematical model is required to estimate the mean length of these juveniles.

Model of the Glenariffe fingerling migration

In determining the overall length distribution for fingerling migrants, several variables must be taken into account. There are three main considerations to be built in to the model:

- It must allow for a steady increase in growth as the season advances;
- It must allow for a steady decline in fingerling numbers;
- It must allow for a broad range of lengths at any particular date.

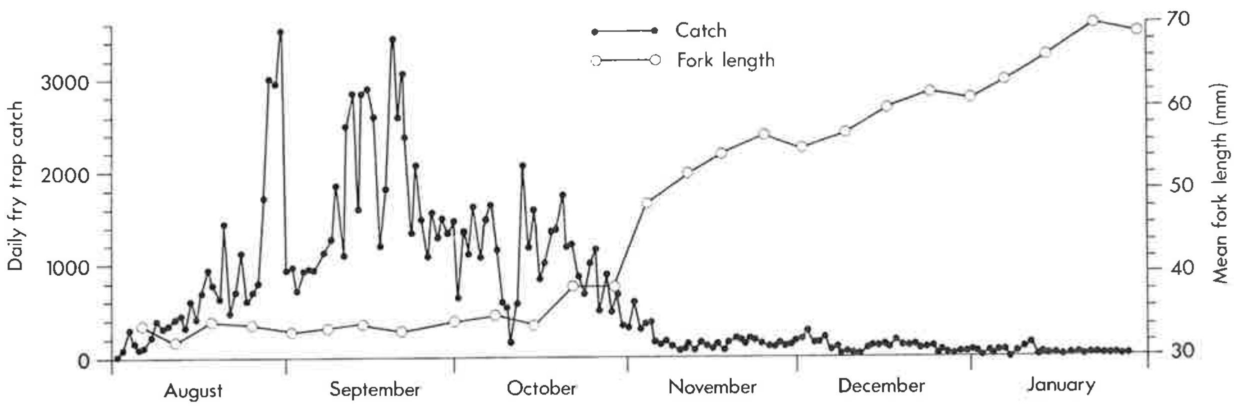

Fig. 1: Daily fry trap catch and mean fork length (at weekly intervals) for juvenile salmon leaving the Glenariffe Stream, August 1973 to January 1974.

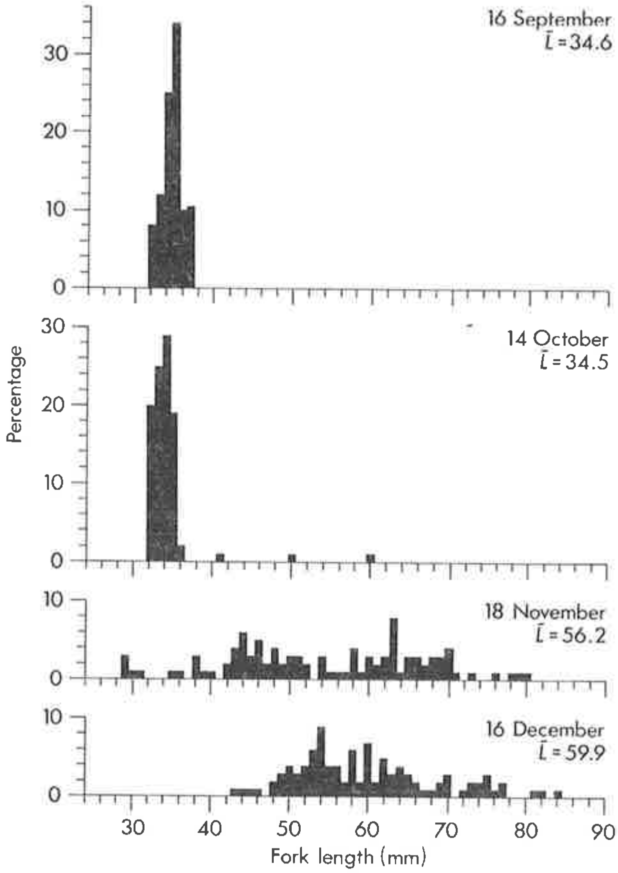

Fig. 2: Length-frequency distributions for Glenariffe outmigrant juvenile salmon, September 1973 to December 1973; $\bar{L}$= mean length.

Ideally, we would like to have length data recorded every day during the fingerling migration. Given the number of fish caught on any 1 day, one could estimate the overall length distribution for that day and then add the daily distributions together to obtain the distribution for the whole season. Since the change in length over 1 week is small, however, the use of weekly measurements does not introduce any significant error.

Figure 3 illustrates this process for the 1973 fingerling migration. Each week, the length distribution is replaced by a smooth curve with the appropriate mean and range, and this curve is weighted in proportion to the number of fingerlings trapped that week. Combining these curves results in an "envelope" which approximates the total length distribution over the November-January period.

The model gives a mean length of 58.1 mm, with about 75% of the fish ranging between 50 and 80 mm. A few larger fish are caught throughout autumn and winter, but in relatively small numbers which would make little difference to the above results. As it stands, the model accounts for over 98% of the fingerlings produced in the Glenariffe Stream over the 1973 season.

Analysis of juvenile salmon scales

The development of scales on juvenile salmon at Glenariffe has been examined to identify the scale characteristics of the fingerling migrants. The results given here are based on data gathered during the 1972 season, but comparison with more recent scale collections indicates that these results are representative of the general pattern for the Glenariffe.

Scales first appear as small platelets on juvenile salmon of about 40 mm in length. As the young fish grows, new material is added to the platelet edge so that the scales grow more or less uniformly out from the centre. However, this growth is not completely regular, but occurs instead as a series of ridges (or circuli) similar in appearance to annual growth rings on a tree. The number and size of these circuli are related to the length of the fish.

Figure 4 illustrates this relation for Glenariffe fingerlings caught between October 1972 and April 1973. Fitting a straight line to the data gives a mathematical approximation to the relation, which can then be used to estimate circuli numbers for fingerlings of any given length. In particular, we can

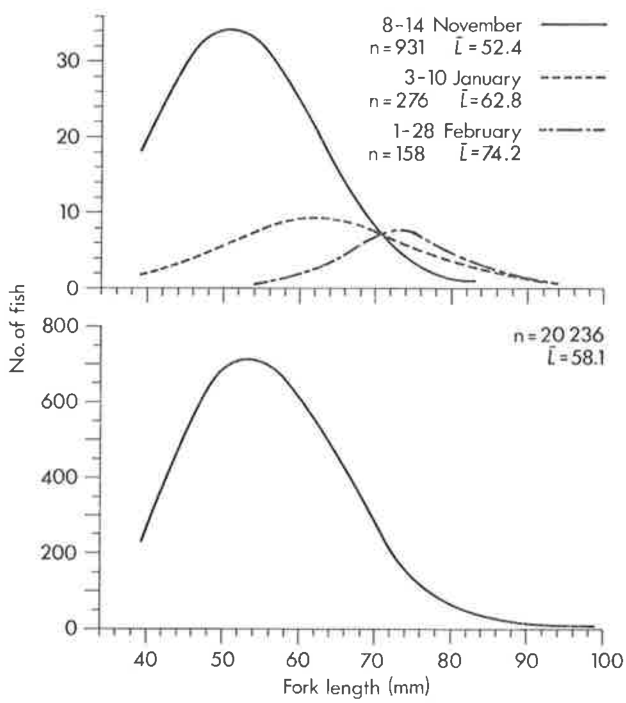

Fig. 3: Determination of overall length-frequency distribution for Glenariffe fingerling outmigrants. Lower curve is the sum of the upper three curves, plus other similar curves over the period October 1973 to May 1974; n = number of fish in sample, $\bar{L}$ = mean length.

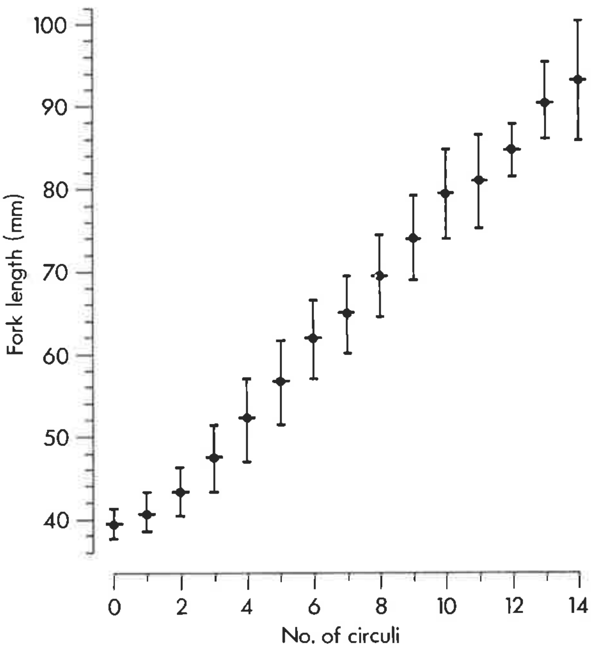

Fig. 4: Relation between mean fork length and number of scale circuli for juvenile salmon leaving the Glenariffe Stream between 12 October 1972 and 9 April 1973; vertical bars indicate one standard deviation.

use this relation to transform the model length distribution shown in Fig. 3 into an equivalent distribution representing the number of scale circuli to be expected on outmigrant Glenariffe fingerlings. For example, salmon in the 55- to 60-mm length range would have between four and six circuli.

Building this transformation into the model produces the result shown in Fig. 5 A. The distribution shows a broad peak at about five to six circuli, with over two-thirds of the fingerlings having between three and eight circuli. Larger fish are sometimes caught at the trap (some yearlings have over 20 circuli), but these have been excluded from the model for clarity. As it stands, Fig. 5 A represents over 98% of the fingerling migration. Analysis of data from the 1974, 1975, and 1976 seasons produces very similar results; though the total number of fingerlings ranges from 20 000 to 100 000, the mean number of circuli is constant to within plus or minus one.

Adult scale studies

The following discussion is a brief summary of the available data on the early juvenile migration as reflected in the scales of returning adults. It covers only those aspects of the adult scale work which can be compared directly with the fingerling migration as outlined above.

Throughout their stay in fresh water, migrating juvenile salmon maintain a constant but fairly slow rate of growth. This appears on the scales as a regular band of closely spaced circuli around the scale nucleus. On entering the ocean, the growth rate is greatly accelerated and the circuli become more widely spaced. A typical scale from an adult salmon thus shows two distinct regions within its nucleus, which correspond to the freshwater and ocean stages of its early life. Since other irregularities in the circuli spacing indicate the age of the fish, scale analysis provides a method of determining how much of an adult salmon's first year of life was spent in fresh water.

With this technique it is possible to identify several characteristic "life histories", each with its own distinctive scale nucleus. Although there is some debate as to how many of these scale types can be distinguished, three main types are generally accepted. I refer to these as:

1. Ocean: little or no freshwater residence;
2. Intermediate: part of the first year spent in fresh water;
3. Stream: over 1 year spent in fresh water.

Stream nuclei are found on about 20% of Rakaia salmon and represent fish which entered the ocean as yearlings. Intermediate nuclei are the most common and make up about 80% of the Rakaia run. Ocean nuclei account for less than 1% of the total (hence the belief that very few early outmigrant fry survived).

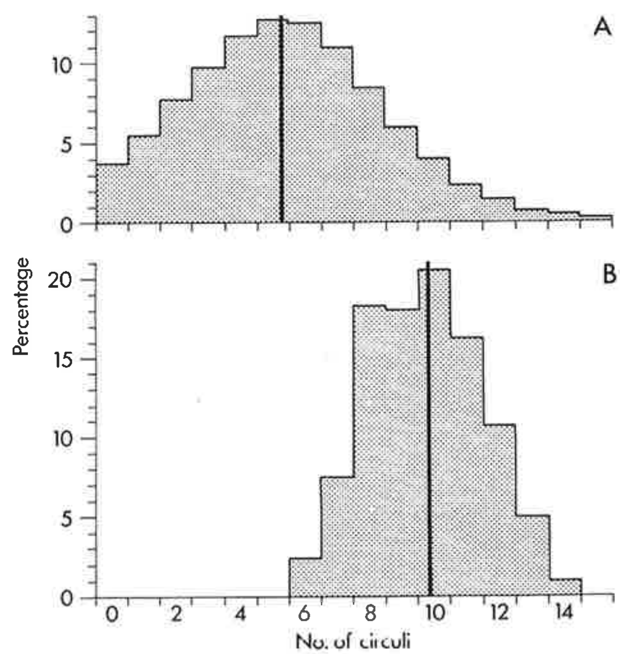

Fig. 5: Frequency distributions of circuli numbers within the nucleus for Glenariffe fingerlings, October 1973 to April 1974 (A) and angler-caught Rakaia salmon, 1973–74 and 1974–75 (B); vertical lines show position of the mean.

The following discussion concentrates on the intermediate nuclei, since they are the most readily identified with the main fingerling migration during the summer months.

The most direct way of comparing adult and juvenile scales is to look at the mean number of freshwater circuli. Although scales have only recently been taken from adult salmon within the Glenariffe system, there are extensive collections from angler-caught salmon from the Rakaia, and evidence obtained so far confirms that they have similar nuclear characteristics to scales taken from Glenariffe salmon. The sample described below was drawn from angler-caught salmon over the period 1973 to 1975.

For each set of scales an average (based on at least four scales) can be determined for the number of freshwater circuli. This average then becomes a relative measure of the amount of time spent in fresh water by each adult fish for which scales were collected. If the results for all the fish in the sample are combined (Fig. 5 B), we can determine the average extent of freshwater growth.

Comparison of this result with the corresponding juvenile data from Fig. 5 A shows a striking difference between the two samples. The adult scales show an average of 9.8 circuli, compared with 5.8 for the juveniles, and they are concentrated within a much narrower range. No intermediate nuclei were recorded with fewer than six circuli, though 64% of the juvenile scales fell into this category. On the other hand, fewer than 10% of the fingerlings had 10 or more circuli when they left the Glenariffe, compared with 54% of the returning adults. The impression gained from the figure is that the adult distribution is roughly equivalent to the juvenile distribution, but displaced sideways by about four circuli.

Discussion

If intermediate-type adult salmon are the survivors of juveniles which left the Glenariffe (or another spawning stream) as fingerlings, it is clear from the above results that the fingerling migration which leaves the Glenariffe is different in structure from that which enters the ocean at the Rakaia mouth. Regardless of exactly what happens, this change is quite incompatible with the idea that the Rakaia serves mainly as an arterial link between Glenariffe and the ocean and has little other effect on the salmon population. On the contrary, the Rakaia must be closely involved with whatever processes are taking place. One possibility is that mortality of the smaller fingerlings (less than about 60 mm) in the Rakaia is so high that none of them survive to reach the mouth. A second explanation, and the one I consider more likely, is that the down-stream journey is slow enough for a significant amount of growth to occur between Glenariffe and the Rakaia mouth.

Mortality cannot be ruled out as a contributing factor; there is ample evidence in the overseas literature to suggest that mortality of fingerlings decreases with increasing size. The problem is more one of magnitude. If mortality were the sole cause of the difference apparent between A and B in Fig. 5, there must be an exceptionally rapid decrease in mortality for fish with over six circuli, or over 60 mm in length. Although the above results do not rule out this possibility, it is difficult to imagine a biological process which could operate so selectively.

Allowing for some growth to take place in the Rakaia River provides a far more satisfying explanation. The difference between the mean number of circuli on the scales of Glenariffe fingerlings and on those of the returning adults—approximately four circuli—can be taken as indicating up to 2–3 months' growth, during which the fingerlings would increase in size to about 80 mm. If this explanation is correct, it is clear that the Rakaia River represents an important rearing area for juvenile salmon and accounts for a significant proportion of their freshwater development.

The detailed nature of the down-river migration remains, at this stage, a matter for speculation. The details of whatever biological processes are taking place in the Rakaia will be modified greatly from season to season by the presence or absence of major floods during the rearing period; it is conceivable that an unusually severe flood (such as occurred on 3 December 1979) could virtually exterminate an entire population of juveniles. Nevertheless, evidence from netting of juvenile salmon on the Rakaia, and from other aspects of the scale work, is consistent with the concept of a slow down-river rearing migration. Exploration of these ideas should provide a promising avenue for future work.

Discussion

Unknown: What is the effect of reared fish on your proportions of stream and intermediate nuclei?

Mr Unwin: This year we have returns from tagged reared fish and the nuclei appear to be characteristic, in that they have a larger centre, which indicates more rapid growth than in wild stocks. The tagging machine allows us to sample juvenile scales out of Glenariffe and examine the growth after release when scales are again taken from the tagged returning adults. This will enable us to examine them for evidence of growth in the river.

Mr Tonkin: Is any similar work being done at the Silverstream facility?

Unwin: No.

Unknown: Firstly, what proportion of the juvenile production remains in the stream and, secondly, what proportion of adult returns stems from the fish that remained in the stream?

Unwin: Between 2% and 10% remain in the stream; on average 95% leave as fry and 5% remain. In answer to your second question, we don't really know. We do know that the incidence of ocean nuclei is low; hence the fry, in the main, do not contribute directly to the run. What we don't know is how many fry rear in the main river. These can appear in the adult run as intermediate or stream nuclei, similar to those which stayed in the stream.

Dr Jellyman: From the scale patterns on the intermediate nuclei, is it reasonable to conclude that the fish move from fresh to salt water over a relatively brief time span?

Unwin: Yes, it would seem so. There would be differences in growth rates, but I guess about 6–12 rings would represent a 3-month period.

Jellyman: When would be the peak periods of movement?

Unwin: Most fingerlings leave the Glenariffe during November-December, at which time they show an average of 5–6 scale circuli. However, a typical intermediate scale with 9–10 circuli corresponds to a fingerling leaving the Glenariffe during February or March. The indication is therefore that peak movement from the Rakaia mouth also occurs at this time, 2–3 months after the fingerlings have left Glenariffe. The situation may of course be confused by differing growth rates in the Rakaia.

Improvement of spawning and rearing habitat for salmon

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SEVERAL options are available to managers attempting to increase the abundance and yield of salmon populations. Hatchery production is the most popular technique in use, but recent developments in habitat management give promise of another effective approach. Our aim is to review some of this promising work, mainly from the west coast of North America, and to suggest the techniques of habitat improvement that seem to have the greatest applicability to New Zealand conditions. We will emphasise approaches that would be particularly suited to the chinook (quinnat) salmon, *Oncorhynchus tshawytscha.*

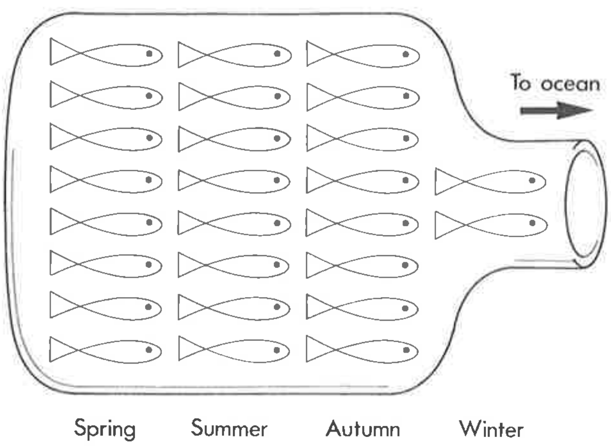

Fig. 1A: Example of a limiting factor bottle-neck occurring during the winter before migration to the ocean.

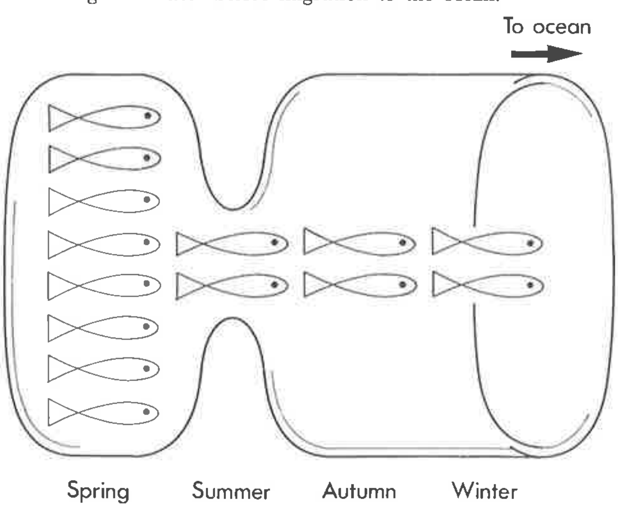

Fig. 1B: Numbers are affected by habitat conditions during summer, and the limitation carries through to smolt migration.

Habitat management has a long history in North America; it was first undertaken in the 1930s (Hubbs, Greeley, and Tarzwell 1932). However, much of the early work was somewhat haphazard. It was undertaken with little knowledge of limiting factors and with little evaluation. As a result, habitat management fell into disfavour among fishery agencies, and emphasis was placed on hatchery production as a means of enhancing salmonid populations.

More recent work has shown that abundant fish populations are predominantly associated with high quality habitat (Lewis 1969, Stewart 1970, Wesche 1976, Binns and Eiserman 1979). A few carefully designed evaluations of habitat improvement projects have shown that fish populations respond significantly to these improvements (for example, Boussu 1954, Hunt 1976, Ward and Slaney 1979). Such support has given renewed impetus to the concept of habitat management, and it appears likely that management effort of this sort will increase significantly in future. We are encouraged by the high level of interest and activity in stream improvement already displayed by several acclimatisation societies and the New Zealand Salmon Anglers Association.

It is important here to emphasise the rationale for habitat management: projects must be designed to increase the quantity or quality of an aspect of habitat that is limiting production. Usually it will be of little use to increase numbers in a population if a critical shortage in cover, or some other requirement, occurs at a later stage in the life cycle. An analogy to a bottle-neck is appropriate (Fig. 1A). In this example the capacity of the stream to produce salmon is limited by the winter habitat. It is worth noting that the neck may not necessarily be at the end of the bottle; limitation may occur early in the life history of the species (Fig. 1B). The limiting resource may differ from one catchment to the next, and occasionally from one year to another. Although the analogy is an oversimplification of complex ecological relationships, the concept has a useful place in planning. Attention to this facet of salmon ecology can avoid considerable wasted effort.

An example of the futility of enhancing populations before a limiting factor bottle-neck, is provided by an experiment from a coho salmon stream in British Columbia (Mason 1976). The juvenile coho population was provided with supplementary food during summer. As a result, the summer biomass was six to seven times the level recorded in previous years. However, by the time the fish migrated to the ocean as smolts in the next spring, their numbers had been reduced to the same level as that measured in other years. In this stream at least, the ultimate limitation to smolt abundance was some element of winter habitat (Fig. 1C).

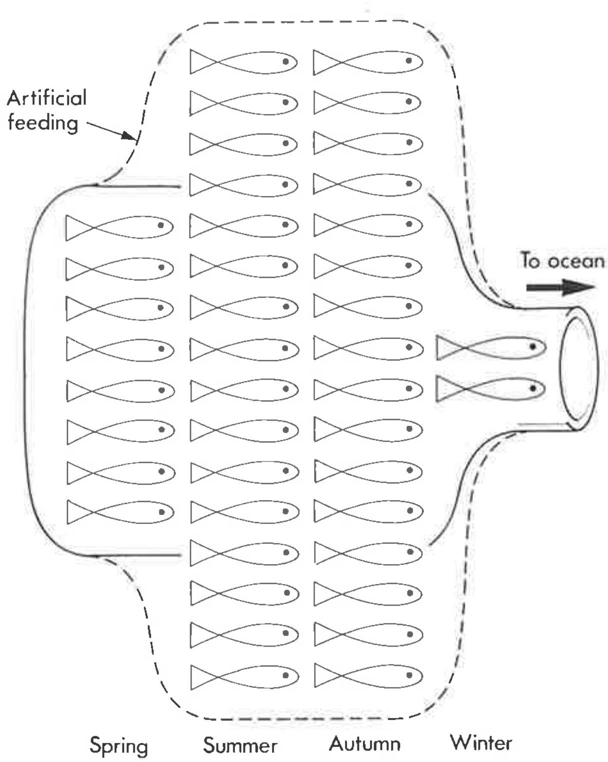

Fig. 1C: Result of attempts to increase abundance early in the life history, before operation of a limiting factor.

In the following text, techniques of habitat improvement are dealt with under three headings: spawning, rearing, and riparian. These categories represent a continuum in the environment and all must be considered in any one situation, even though improvement may be necessary in only one bottleneck category.

Spawning habitat

When spawning area is limited in extent or quality, improvement measures are possible. Spawning area can be increased by adding structures to hold either natural or introduced gravel. Quality of the gravel can be improved in several ways.

The particle size distribution in spawning gravel has an important influence on the success of hatching and emergence of salmon fry (Phillips, Lantz, Claire, and Moring 1975). Large proportions of fine sediment greatly reduce survival by reducing percolation of water through the gravel and by impeding emergence of fry. Recent studies suggest the use of geometric mean diameter as an effective measure of the suitability of spawning gravels (Shirazi and Seim 1979).

The optimum size distribution of gravel will vary with the species and size of fish. Large fish spawn in fast water that has a fairly high proportion of large gravel (Table 1). Gravel size should be adapted for the size of fish concerned. In remote places it will often be impractical to match the optimum size distribution of gravel, but this consideration should be incorporated where possible. It is also important to consider the stability of gravel if it is to be introduced to a new location. A diversity of gravel size will enhance the stability of spawning gravel (Anon. 1980). Formerly, gravel to be added to artificial spawning channels was screened to remove all fine particles (smaller than about 15 mm). More recently there has been a trend to include a small fraction of this grit material, down to a size of 1–2 mm, to improve stability of the spawning beds. The most suitable type of gravel is the smooth, rounded greywacke characteristic of the beds of many east coast rivers in New Zealand.

Wire mesh gabions placed across a stream can provide suitable basins for holding gravel. They should be filled with angular rather than rounded rock, as this provides more stability during flooding. They should have a low point in the middle to facilitate fish passage at low water. Lining the gabion with heavy, black plastic sheeting can direct water over rather than through the rock dam at low flow and

TABLE 1: Average size composition of gravel in natural redds of three species of Pacific salmon; approximate average weight of fish shown in brackets (from Anon. 1980)

Gravel size (diameter mm)	Fall-run chinook (9 kg) (%)	Coho (4 kg) (%)	Sockeye (1.5 kg) (%)
Fines	10	8	12
3–12	19	23	23
12–50	38	43	51
50–100	21	23	12
100–150	12	3	2

further aid fish passage. In large streams or in those of high gradient, a V-shaped configuration for gabions has been used effectively. With the V pointed down stream, these structures are more stable than those placed at right angles to the current. Placed in series they can dissipate much of the stream energy that would otherwise move the gravel bed load, and thus they can provide additional areas of stable spawning gravel (Reeves and Roelofs in press).

In large streams, placement of log sill dams has provided spawning areas where none previously existed. The cross log must be well anchored or keyed into the bank, which should be rip-rapped at that point to avoid bank erosion. When the log is anchored in place, boards are placed against it at an angle to the stream bed on the up-stream side and gravel placed against the log to complete the dam. "Cyclone" fencing is secured over the gravel to provide additional stability. A number of these structures placed in series produced good results in a chinook salmon stream in Oregon that previously had a limited spawning area. Before improvement about 50 chinook spawned in this reach of the stream. In the first winter after construction 350 spawners used the area, and an average of 200 fish have spawned there since (Hall and Baker in press).

A much simpler structure, known as a cedar-board dam, is suitable for small, more stable streams (Fig. 2). This consists of a cross log with two additional logs set in a V pattern and pointed down stream (Reeves and Roelofs in press). The two V logs are lined with heavy wooden shingles. (Cedar is used in the United States; totara or similar wood should be suitable in New Zealand.) The shingles provide a collection basin for gravel and also allow water to percolate through the retained gravel, an important consideration in the design of spawning areas. This type of structure should be useful for salmon in small streams.

Gravel cleaning may be useful when the quality of spawning gravel is poor, owing either to the natural occurrence of a high percentage of fine sediments or to induced erosion. One of the first major efforts to clean fine sediments from gravel on the west coast of the United States resulted in the design and construction of a complicated machine known as the "riffle sifter" (Anon. 1968). This large, amphibious tractor was designed to flush sediment from the gravel hydraulically and then pump the fines out on to the bank. Not all efforts in stream habitat improvement have been successful, and this one proved to be a very expensive failure. However, the principle of hydraulic cleaning appears to be sound, and experiments are being done at Washington State University to develop a suitable machine on a smaller scale (Mih 1978).

Where other stream values are not threatened, a bulldozer may be used to clean the fine sediment from spawning gravel. In one stream in Washington State where this was tried, the concentration of fine particles (smaller than 0.84 mm) in the gravel was reduced from about 18% to 10% and the survival of fry was substantially greater in the cleaned area than in the uncleaned control area (Hall and Baker in press). In small streams a fire hose can be an effective cleaning tool.

Fig. 2: Simple cedar-board dam, which provides a suitable catch basin to retain spawning gravel for fish such as this steelhead trout.

In all such sediment removal work it is important to consider the time of year and flow levels, to avoid improving one area at the expense of others down stream. This work should always be done with the advice of a biologist familiar with the area. Most gravel cleaning work in North America has been done in streams supporting species of salmon that do not spend much time as juveniles in the spawning areas.

Where spawning areas for chinook salmon also serve as rearing areas, extra precautions are necessary. Some preliminary work (Meehan 1971) has indicated that invertebrate populations were not significantly affected by the riffle sifter, but more evaluation of this procedure is needed. Recolonisation of benthos in a salmon rearing channel occurred within 3 weeks after gravel cleaning with a fire hose (Mundie and Mounce 1978).

Opening stream access to previously inaccessible spawning areas is often a cost-effective enhancement technique. Portable fish passages, such as the Alaska steep-pass, have helped in the establishment of some significant new runs of salmon. One in particular, the Frazer Lake run in Alaska, now numbers over 140 000 sockeye salmon and is expected to increase further to over 300 000 (Blackett 1979). Before access to new areas is contemplated, however, an assessment should be made of the possible effects on resident trout and native fishes of introducing salmon. Little specific information is available on competitive interaction of chinook salmon, but it is known that they are territorial and aggressive (Reimers 1968, Stein, Reimers, and Hall 1972).

Culverts, if constructed without planning or consultation with fishery agencies, can be a serious barrier to fish passage. The best solution to this problem is better education and liaison with those responsible for placing culverts. Where existing culverts constitute a block to migration, log or gabion sills can provide a series of jump pools that will allow access to the mouth of the culvert. Where velocity in the culvert is excessive owing to a steep gradient, baffles may be bolted to the bottom of the culvert to reduce velocity and provide for fish passage. Further suggestions are provided by Dane (1978).

Some spawning tributaries used by salmon in New Zealand are small streams that can easily be overgrown by riparian vegetation. Although this growth may provide cover for both adult and juvenile salmonids, it may hinder the up-stream progress of adult salmon. Gorse often does this. Some acclimatisation societies are already taking steps to remove these barriers (for example, North Canterbury Acclimatisation Society 1979). Severe obstacles should be removed, but it is important to allow some of the vegetation to remain to provide necessary cover.

Rearing habitat

Whereas the assessment of spawning habitat is generally straightforward, and improving it fairly easy, the same cannot be said for rearing habitat. The characteristics of good quality rearing habitat are not nearly as well known as those of spawning habitat. This is an important topic that needs much more research. Rearing habitat seems to be the critical limitation in most New Zealand salmon rivers.

Most of the early work on enhancement of rearing habitat was done in the mid-western United States, and some useful techniques have been suggested (Hubbs, Greeley, and Tarzwell 1932, White and Brynildson 1967). However, the stream-flow regime in that area is very stable (especially compared with that in New Zealand) and much of the early work does not apply to either western North America or New Zealand. A few techniques developed in western North America are now showing promise and may be of use here.

Boulder placement to increase cover has been an effective technique in Oregon and Idaho (Fig. 3). In one Idaho stream, boulder cover significantly increased over-winter residence of juvenile chinook

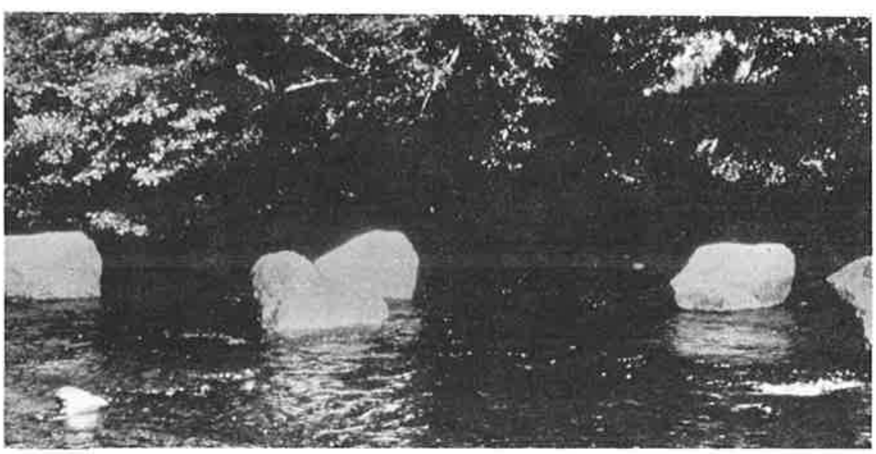

Fig. 3: Large boulders added to riffle areas can provide effective in-stream cover and increase numbers of juvenile salmon.

salmon and steelhead trout (Bjornn 1971). Boulder placement has also produced significant improvement in habitat for steelhead trout and coho salmon in some flood-prone streams in British Columbia. In one system the total salmonid abundance was increased threefold in areas where groups of large boulders were placed. Placing of boulders by helicopter was found to be cost effective. An early benefit-cost analysis of this project showed that boulder placement could compare favourably with stocking of hatchery smolts (Ward and Slaney 1979).

Rock structures can provide rehabilitation for fish habitat where it has been damaged by channelisation. One steelhead spawning stream in Oregon was extensively channelised for flood control after a large flood in 1964 (Fig. 4A). Salmonid habitat was almost totally destroyed. When another large flood did further extensive damage, a different approach was tried. Trenches were dug at intervals across the stream and back-filled with large angular rocks to form a series of pools and riffles (Fig. 4B). These structures have survived significant flooding and have protected the channel and banks. Use of the stream by steelhead trout has returned to significant levels (Reeves and Roelofs in press). In areas of stream subject to heavy use by livestock, fencing of the stream sides has been used in conjunction with rock structures to speed up the re-establishment of riparian vegetation. This plant cover stabilises the stream bank, moderates stream temperature, and provides cover for fish.

Fig. 4A: This section of stream in north-eastern Oregon was channelised as a flood control measure, and this destroyed virtually all salmonid habitat.

Fig. 4B: The same section, after rock-filled trenches provided a series of riffles and pools, which partially restored habitat for salmon and trout.

In some situations, properly designed rock groynes have been more effective than continuous rip-rapping for bank stabilisation. They provide an additional benefit to fish habitat enhancement by forming pools and providing cover, functions that rip-rapping does not do as well. This approach has been used at the Cass Hill Stream on the Waimakariri River system.

We emphasise the possibility for productive interaction between fish habitat interests and catchment boards during planning and construction of flood control measures. It is often possible to incorporate significant benefits to fish habitat in such schemes without sacrificing flood protection values. In the absence of such liaison some flood control projects have become unmitigated disasters from the point of view of salmonid habitat. One essential element for effective co-operation in such a partnership is mutual re-education. Fishery biologists and anglers need to learn to appreciate and understand the concerns of engineers, and vice versa. There is a particularly good example of such a co-operative effort on the Motueka River. We hope this project can provide guide-lines for further productive interaction.

Screening of irrigation diversions is a most important means of protecting rearing habitat. Screening has been used to some extent here, but there are important salmonid rearing areas in New Zealand that are not protected. As pressure for water abstraction increases, this effort will need to be intensified.

An exciting new development from the Canadian Salmonid Enhancement Program is a semi-natural rearing channel being developed for coho salmon in British Columbia (Mundie and Mounce 1978). Stream flow is controlled at an optimum level by a small headworks. Geometry of the channel was designed for optimum fish habitat. Fish in the channel have the advantage of natural food produced in the riffles (up to 25% of the total diet) and natural rearing habitat in pools with cover. Up to 500 000 coho salmon smolts, at about 15 g, can be produced in a channel 400 m long and 4.5 m wide with a flow of about 0.4 m^3/s. Returns of adult fish so far have been very promising. The cost of production has been below that for hatchery fish and the quality of smolts has been excellent. It appears that this approach has potential for use on quinnat salmon in New Zealand.

Riparian habitat

Protection of the riparian zone and the surrounding watershed is critical to preservation of fish habitat. Logging, grazing, mining, and flood control, among other activities, necessitate multiple use planning and management in the development of catchment resources. Close communication and co-operation among all users are necessary to minimise damage to individual resources and to provide for full use within resource limitations. For example, a few simple precautions during logging operations, such as simple log bridges for stream crossings instead of fords, can preserve major fish habitat values with little loss of forest productivity. Similarly, judicious fencing of stream areas heavily used by livestock can allow fishery and agricultural resources to co-exist.

In Oregon one watershed that had been heavily grazed for 70 years provides an example of the value of fencing streamside areas. Part of the stream was fenced in 1964, and within 10 years riparian vegetation provided cover over 75% of the stream inside the fence. Maximum stream temperature in the fenced section of stream was 19°C, compared with 25.5°C in the heavily grazed section. Populations of rainbow trout in the fenced section were about twice those in the grazed section. The cost of fencing was more than offset by the added value of the increased trout population (Hall and Baker in press). Where fencing is not possible, some benefit to riparian habitat and the fishery resource may be achieved by rotational grazing.

Where bank erosion is severe, more intensive measures may be needed to speed up stabilisation and revegetation. One technique that has proved effective is to secure cuttings of small trees against eroded banks. Tree species that retain their leaves or needles for some time provide the best results. As well as preventing further erosion, the cuttings can trap sediment and facilitate the establishment of stream bank vegetation (Reeves and Roelofs in press).

General considerations

Several considerations should be incorporated in the planning and execution of all of the above categories of habitat improvement. We will discuss aesthetics, hydraulics, and evaluation.

An important consideration in the design of all habitat improvement measures is that they fit harmoniously into the landscape. In one survey of angler motivation it was found that water quality and natural beauty were considered the most important factors of enjoyable fishing, well above the size and number of fish caught (Moeller and Engelken 1972). Ugly, artificial-looking structures could detract from the pleasure of angling even if they increased the number of fish available to be caught. A useful guideline is to use natural materials wherever possible. Concrete should never be used. If an artificial structure seems the only feasible alternative, some natural beautification may be added. For example, the portion of wire gabions out of water can be planted with grass or shrubs. Alternative designs should be considered; wire gabion groynes may be replaced by groynes made up of large angular boulders. Careful attention to the appearance as well as the effectiveness of enhancement structures will help to increase their acceptance by the angling public.

There is a need to incorporate the disciplines of hydrology, hydraulics, and geomorphology in the design and construction of in-stream structures. Well-meaning biologists can easily make things worse rather than better when they begin to tamper with the enormous energy of a large stream or river. Pertinent sources of information here are Leopold, Wolman, and Miller (1964) and Dunne and Leopold (1978).

Evaluation is an important component of improvement efforts. This is one of the most difficult areas to cover and its low priority is understandable. However, an enormous amount of effort has gone completely unevaluated in the United States. The meagre evaluation that has been done is often lost in a biologist's files. Hence, many mistakes are needlessly repeated, and many valuable approaches are not available to managers who could profitably make use of them. It is not easy to publish negative results, but brief mention of successes and failures could be a valuable service. An appropriate medium for this in New Zealand is *Freshwater Catch* (for example, Field-Dodgson 1980).

Conclusion

In this short review we have been able only to skim over some highlights of salmonid habitat management. We feel sure that habitat enhancement will play an increasing role in fishery management in the future. It is satisfying to note the high level of interest and the active work in stream improvement already being done in New Zealand.

The upsurge of interest in the topic has been accompanied by many recent publications, to which the reader is referred for further detail. Of most relevance are the excellent "Stream Enhancement Guide" from the Canadian Salmonid Enhancement Program (Anon. 1980) and two reviews sponsored by the Anadromous Fish Habitat Program of the United

States Forest Service (Hall and Baker in press, Reeves and Roelofs in press). An earlier publication also contains much useful information (Migel 1974). A recent bibliography on stream habitat improvement (Wydoski and Duff 1978) includes 390 items (though many of these references are not directly applicable to New Zealand streams). Two reviews of the habitat requirements of fishes have recently been published (Reiser and Bjornn 1979, Church, Davis, and Taylor 1979). These should provide useful information for the planning of habitat improvement measures.

Like all management techniques, habitat improvement has its limitations. It should not be seen as a panacea, nor does it apply in all situations. In particular, some of the large braided rivers in New Zealand, which can move enormous boulders when in flood, will be particularly intractable. However, the main streams of these rivers provide a large amount of the total freshwater area available for the rearing of juvenile salmon and we hope that some measures may be devised to allow more use of this potential resource. Some use of flow control in stable channels in conjunction with the development of hydro-electric generating capacity may help to turn a potential disaster for salmon populations to a less destructive end.

Finally, it must be recognised that protection of habitat is much simpler and less expensive than rehabilitation of damaged streams. In some instances rehabilitation is simply not feasible within a reasonable time. Much greater effort is needed to protect the unique and valuable resource that is the habitat of New Zealand's fish and wildlife. Recent action by the acclimatisation societies to take a more active role in pressing for habitat protection is an encouraging sign for the future.

Acknowledgments

We are indebted to Calvin Baker and Gordon Reeves for considerable background review that contributed to this paper. Their work was supported by the United States Forest Service, through the Anadromous Fish Habitat Program. This is Technical Paper No. 5729 from the Oregon Agricultural Experiment Station.

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Water resources development policy in New Zealand

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MOST people who tangle with water resources management get lost trying to sort out who is responsible for what and to whom. If you read the Water and Soil Conservation Act 1967, the principal legislation controlling water management in New Zealand, you may well conclude that messy legislation deserves a messy organisational structure. Having worked in counterpart water resources organisations overseas, I can assure you that New Zealand is not alone.

To enlighten the uninitiated, water management in this country is controlled by the National Water and Soil Conservation Organisation (NWASCO), which consists of three statutory bodies:

- The National Water and Soil Conservation Authority, the senior body which approves policy and prepares legislation;
- The Soil Conservation and Rivers Control Council, which is responsible for soil conservation, drainage, and river control;
- The Water Resources Council, responsible for water management.

The purposes of NWASCO are best summarised by the long title of the principal legislation, the Water and Soil Conservation Act 1967, which states:
"An Act to promote a national policy in respect of natural water, and to make better provision for the conservation, allocation, use, and quality of natural water, and for promoting soil conservation and preventing damage by flood and erosion, and for promoting and controlling multiple uses of natural water and the drainage of land, and for ensuring that adequate account is taken of the needs of primary and secondary industry, water supplies of local authorities, fisheries, wildlife habitats, and all recreational uses of natural water".

The Water and Soil Division of the Ministry of Works and Development provides NWASCO with administrative, technical, and research services and the 20 regional water boards are responsible for implementing water management legislation and policy at district level.

Water management planning

Most regional water boards view water management planning as something of an enigma—aesthetically beautiful, but difficult to achieve in practice because of the complexity of interrelated sciences and the conflicting interests involved. Certainly the current policy and legislation do little to assist water boards in the preparation of these all-important documents. Water managers have often been accused by the public of being theoretical geniuses and practical idiots, and it is little wonder when one considers the complexity of water management problems.

Principal components of water management planning are water quality classification and water allocation. Although water boards have in the past tended to approach these subjects independently, they are very much interrelated. For this symposium I prefer not to discuss the problems associated with water classification, but instead to concentrate on water allocation plans.

For some years, water allocation plans have been promoted as the most satisfactory method to control management of the water resources within a catchment. The limited staff and financial resources available to regional water boards have, however, restricted preparation of water allocation plans to those catchments where there already is, or is likely to be, a conflict of interests in the sharing of the available water. The success or otherwise of existing water allocation plans is debatable. However, if nothing else, such plans have tried to reserve resources for recreational purposes (some would claim too little) and to provide at least some rational basis for future allocation and management. In preparing water allocation plans, the procedure adopted by both the North and South Canterbury Regional Water Boards is as follows:

1. Field work is undertaken and all existing data are collated and analysed to produce a water resources report. This report summarises what is known about the magnitude and variability of flows, the existing water quality, and the existing and predicted future use of the resource.

2. The water resources report is then published and circulated to interested parties and the public for comment.

3. The public and interested parties are invited to make submissions on aspects which they consider should be incorporated within the water allocation plan.

4. A draft allocation plan is prepared and submitted to the board for approval as a working document.

5. The draft is discussed with the public and interested parties who presented submissions.

6. The draft is amended if necessary and presented at a public hearing before its adoption by the board.

Fundamental to most water allocation plans, and undoubtedly the most controversial aspect, is the setting of "minimum flows". It is perhaps unfortunate that this is the only part of an allocation plan which has so far been given any statutory recognition. It is, I consider, a rather misleading term, which has caused much confusion among the public and even among water managers. By minimum flow, do we mean a 1-in-10-year low flow, average annual low flow, the minimum flow necessary to sustain a particular recreational activity, or the minimum flow required to meet water classification standards for waste discharge industries?

It is important, therefore, that where possible there is some uniformity in the criteria used to determine the minimum flow and also that those concerned in water management understand the minimum flow requirements of various recreational groups and industry.

Generally, the approach adopted by the two local water boards is as follows:

1. Define the sites of existing or future water abstraction or waste discharge and assess their effect both on the timing and magnitude of flow and on water quality changes on the river down stream of the sites.

2. Determine the alteration to the flow regime that these demands will make.

3. Assess the possible effects the altered flow regime will have on all river users.

4. Assess the minimum flow required in the river to maintain it as a fishery and to provide for recreational and wildlife interests.

Of these, criterion 4 is the most difficult to establish and must, of necessity, be a value judgment. If you ask a fisheries manager how much water is required to retain an optimum fishery habitat, he is unable to give a definitive answer. He can expound at length on the importance of flood freshes and the harmful effects associated with extreme low flows, but in my experience, fisheries interest submissions for water allocation planning tend to be loaded with generalisations. With respect, I sometimes wonder if fisheries interests have any concept of the optimum flow conditions necessary to their particular recreation. I have found that other recreational groups are far more definitive in describing their minimum flow requirements. You may well contend that water managers have an obsession with placing numbers on everything and that it is not possible to be mathematically precise in a science as complex as freshwater fisheries. However, though it may not be possible to meet the degree of precision that water managers unreasonably expect, it is far better to impart into the allocation plan the value judgment of a fisheries expert than to have an engineer, who has neither the expertise nor the data, make the necessary decision on the minimum flow requirements for fisheries.

It is important that all groups recognise the diversity and conflict of interests involved in

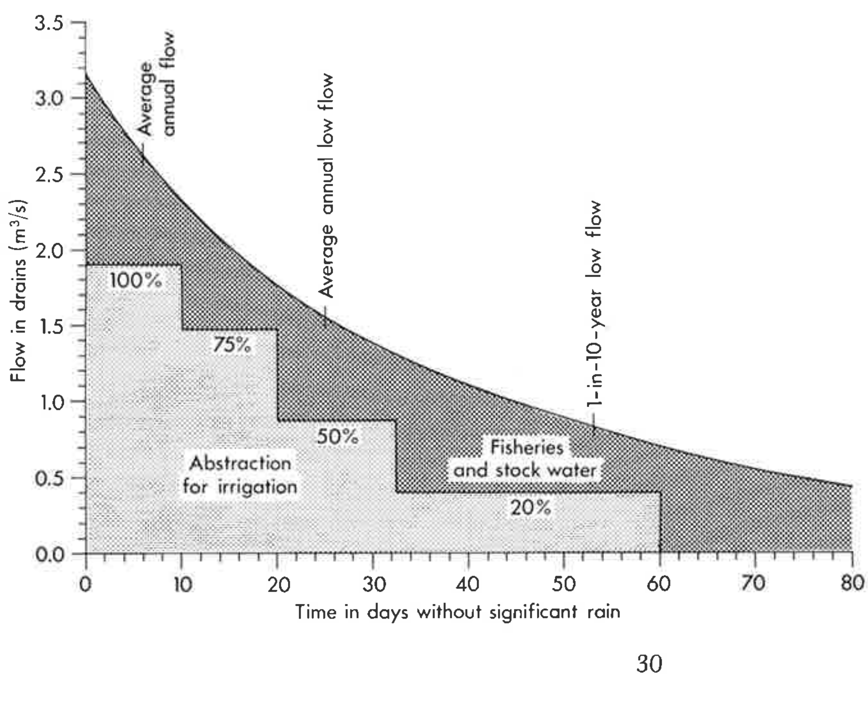

Fig. 1: Ashburton-Hinds drains preliminary water allocation plan.

preparing a water allocation plan. For example, the following is a list of organisations concerned in submissions with the Rangitata River water allocation plan: Ministry of Works and Development, Ashburton County Council, Strathallan County Council, New Zealand Electricity, Department of Lands and Survey, Ministry of Agriculture and Fisheries, Ashburton Power Board, Ashburton Acclimatisation Society, South Canterbury Acclimatisation Society, New Zealand Salmon Anglers Association, New Zealand Jet Boat Association, and South Canterbury Canoe Association.

Allocation planning is, I believe, now in the same state as the water right system was in the early 1970s, when people applying for a right usually applied for twice as much as they needed because they thought they might miss out. The same sort of thinking is apparent when one studies submissions presented for consideration in a water allocation plan.

I should like now to examine some of the allocation plans that have so far been published. First, I must point out that there is no national policy for the presentation of water allocation plans, and regional water boards have had to develop their own techniques. To some extent, their efforts have been subject to some unjust criticism.

The selection of the minimum flow is not the major problem, but rather the task of communicating to the public the likely changes in the flow regime as a result of the water allocation plan. Water resources in a river system increase as you proceed down stream and so, like the flow regime, a water allocation varies in time and space, and to describe this to the public presents a major difficulty.

Figure 1 shows the water allocation plan for the Ashburton-Hinds drains, a series of nine drains between the Ashburton and Hinds Rivers, from which water is abstracted from October to March for spray irrigation of crops and pastures. This illustration tells me how the resource is to be managed, but it is incomprehensible to the average farmer, who has no concept of average annual low flow, much less a 1-in-10-year low flow. Such an illustration is essential to the water manager, since it tells him when and what restrictions to water abstraction should be applied. For example, when the flow in the drains falls to 2.5 m^3/s, all water abstractions for irrigation are reduced to 75% of that stated in the water right, and if there is no further rain for 10 days, the water manager can expect to increase restrictions to 50%. This technique is widely used by a number of water boards and from the water manager's viewpoint it is one of the better techniques for controlling abstraction from small streams and drains.

In contrast, Fig. 2 shows part of the water allocation plan for the Rangitata River. It shows the limit of abstraction permitted in November each year and the flow reserved for recreational purposes, for various flow rates observed at the Klondyke recorder. For example, for a flow at Klondyke recorder of 50 m^3/s, 31 m^3/s is allocated for abstraction, principally for irrigation, and 19 m^3/s is reserved for recreation and fisheries. A flow of 50 m^3/s in November at Klondyke occurs on average only 1% of the time. Similar graphs for the remaining months are also included in the allocation plan publication. This type of allocation has been widely used by both the North Canterbury and South Canterbury boards for large rivers, including the Rangitata, Rakaia, Waiau, and Hurunui.

There is, I feel, little public acceptance of hydrology, and the statistics and mathematical models which delight the hydrologist are meaningless to the public at large. To convey to the public the magnitude of restrictions they will face under a particular plan is best achieved by simple diagrams. The best method in my experience is to feed the plan and the available flow record into a computer and produce a time sequential plot which shows the portions of flow allocated and retained (Fig. 3). The public recognise that 1973 was a drought year and from the plot they are able to assess for themselves the consequences of the proposed allocation plan. This does much to allay their concerns.

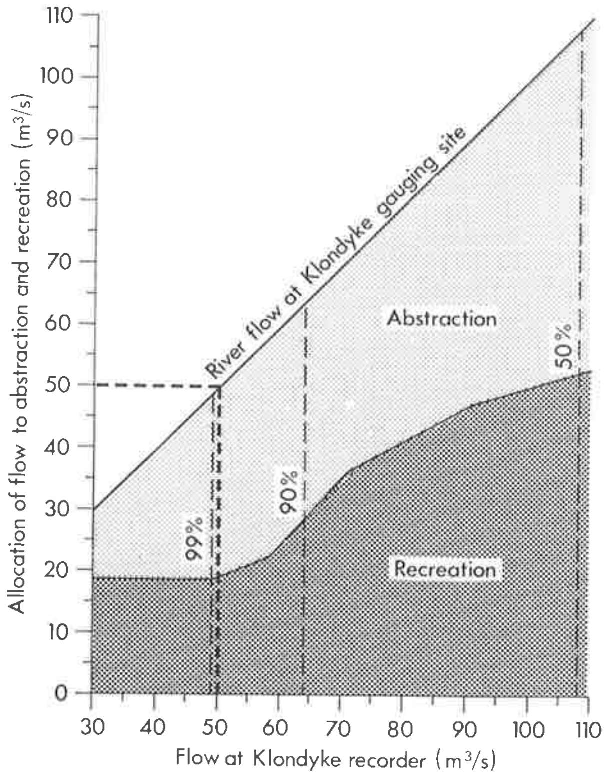

Fig. 2: Rangitata River water allocation plan for November.

The examples so far presented are of plans relating to a specific site on the river system. What are the consequences of the allocation plan at other sites on that same river system? Figure 4 shows an example of a technique used by some boards to present the special effects of a water allocation plan. The plan is based on allocating a maximum of 50% of the average low flow occurring at any point, and this flow is plotted against the distance up stream from the river mouth. This type of presentation has the following advantages:

- it shows the relative location of abstraction points;
- it assures the water manager that he has not exceeded the planned allocation levels at any point of the river system;
- it shows the location and magnitude of any allocation reserve.

Unlike the Rangitata River, where much of the abstraction is centred on the Rangitata Diversion Race, most rivers are subject to point abstractions throughout the whole length of the river system. Because of this, I believe that this type of presentation for water allocation plans will be used much more in the future.

Problems facing freshwater fisheries with regard to water rights and allocation plans

The acclimatisation societies have a statutory obligation to manage New Zealand's freshwater fisheries and, with it, a responsibility to one of the largest and most diverse recreational groups. The ever-increasing pressure on rivers for irrigation abstraction and hydro power development means that fisheries managers must be much more definitive about the magnitude of the fisheries resources and the harmful consequences of such developments. Under the current legislation, the applicant for a water right is not required to prove that the abstraction will not be harmful to fisheries interests. As an objector to a water right application, the fisheries manager assumes the added injustice of having to carry the burden of proof.

Naturally, fisheries managers are becoming increasingly concerned about the continual threat of abstraction to the fisheries resource. In October 1979, however, an important precedent was established when the Manawatu Regional Water Board granted to the Wellington Acclimatisation Society a water right "to use the water of the Manawatu Catchment

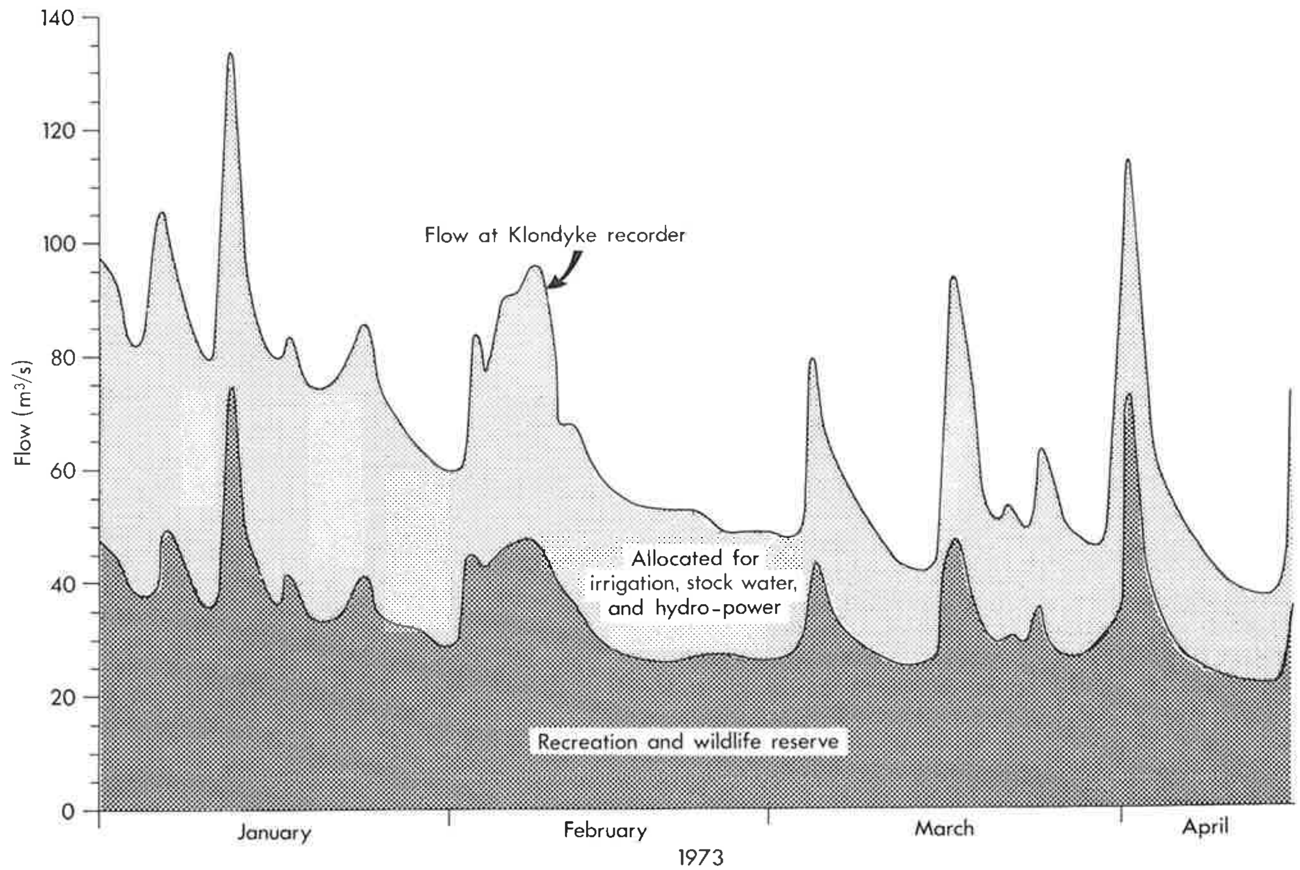

Fig. 3: Rangitata River water allocation plan for 1973 low flow period.

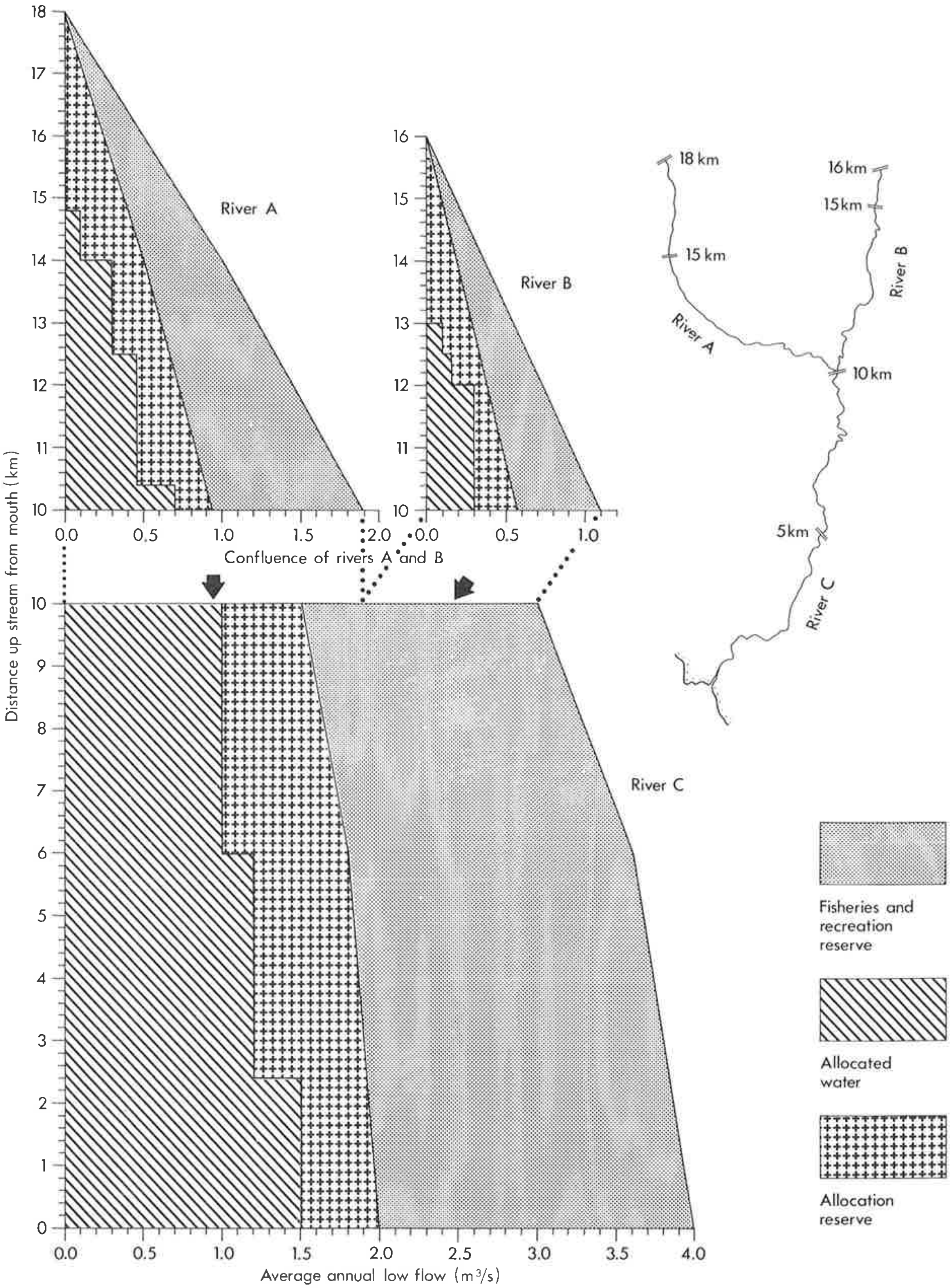

Fig. 4: A recommended technique for water allocation planning.

District to maintain a trout fishery". In explanation of the water right, the board emphasised that:

1. The right authorises the use of water for maintaining a trout fishery. Any other specific actions (for example, taking water for hatchery purposes) should be the subject of specific water rights.

2. The right does not imply authority to alter or interfere with the water concerned (for example, altering or diverting flows or constructing weirs).

3. The board does not guarantee that the water will be available or suitable for this use, that is, maintaining a trout fishery.

4. The right does not imply any priority or power over other users of the water, whether those uses are subject to water rights or not.

The granting of the right secures for the Wellington Acclimatisation Society a firmer legal foundation for fisheries management in the Manawatu district. The status of a registered water user may be particularly important where disputes over a water right application are taken to appeal and the legal standing of an objector may be called to question. Furthermore, this water right shows that the current legislation does provide for recognition of specific fisheries usage and it has pinpointed the need for clarification and improved legislation in this regard.

Water management in this country is still very much in its infancy. To quote from a paper* by Dr Gordon Glova: "Water resource policy is a continual process of successive compromise toward some desired objectives that continues to change with evolving social goals. Likewise, water management is a political/decision-making process which must allocate a finite resource among an ever growing number of uses. This intense competition for the allocation of water, coupled with the public's concern for environmental amenities, is the impetus behind the need for a greater understanding of instream flow uses in water resource administration. Instream flow advocates need to be much better informed about decision-making and administrative processes, and the legal means available to protect stream flows.

"The instream flow manager needs credible techniques which provide quantified results consistent with administrative procedures. Because water management is such a sensitive subject the water administrator operates very largely by negotiation and will frequently place less emphasis on a poorly quantified or poorly conceived instream flow request in order to make water available for other, more firmly quantified traditional uses. Ideally, water management must recognize the dynamic nature of instream uses and develop contingency plans for various water supply conditions which equitably distribute the losses among all uses, both instream and out-of-stream during low water years."

Improvements to the current legislation are sorely needed, and it is to be hoped that the proposed new water management legislation, with the new freshwater fisheries legislation, will provide a more consistent basis for water resources management.

*The full paper is published in *Freshwater Catch No. 7*, 1980.

Discussion

Mr Sutton: The Water and Soil Conservation Act 1967, I think Section 20, says that when a regional water board is considering any scheme or plans it must consider the interests of freshwater fisheries and wildlife and recreational users and consult the appropriate authority. You just said that the legislation is up for amendment. We don't know what the amendments are, but there is a feeling in some quarters that this rather indifferent clause which gives some protection to fisheries and wildlife and recreation will perhaps be further weakened. Now, in view of the important things Dr Hall said this morning about stream bank protection, do you think there is a need for us as a group to take steps to ensure that this aspect of legislation is strengthened rather than weakened?

Mr Scarf: From what I have seen of the new water and soil legislation I feel that the fisheries interests will be centred essentially on the flow aspects, not on the sort of channel. We were expecting the new fisheries legislation to cover this aspect. The water and soil legislation appears to cover only the water part for fisheries.

Sutton: So your answer is that, in consideration of what Dr Hall said this morning, the legislation is likely to be inadequate.

Scarf: I am sorry I was not here this morning for Dr Hall's speech.

Mr Hamblett: Perhaps I can make comments here because I did hear Dr Hall this morning and I think that those issues are not directly related to water right issues; they are more related to the way the catchment boards, which are the authorities concerned, go about their projects. I would think that the way to make sure that those things are looked after is to keep in very close contact with the catchment boards.

Dr McDowall: I would like Mr Scarf to comment on the need for a national plan for the future use and deployment of New Zealand's water resource, as opposed to what I see as the piecemeal picking away of that resource by relatively isolated water boards in different parts of the country who are responsible for their own water and generally speaking have no concern for the national water resource. What is going to be the picture of New Zealand's water resource in 20 years' time if we continue to have each individual water board or catchment board managing its water and having no concern for the national resource and its future?

Scarf: Certainly we need some sort of organised policy. At the moment each catchment board has its own priorities and its own standards for water allocation plans. The boards recognise the need for an overall plan and I am sure fisheries interests do too. It is the only way you can get co-ordination at a regional level. I am hopeful that under the new legislation the policy will become more definite. The only policy we have at the moment is a little booklet called "A practical guide to the preparation of water allocation plans". It was adequate when it was written, about 5 years ago, but we have come a long way since then. It should now be updated so that we have a national policy for water allocation plans in the future. This is the only way in which we can get consistency throughout the country.

Mr Flain: You mentioned that the societies have the burden of putting an objection forward and then proving the objection. That seems to me to be opposed to the principle that the user pays. And you went on to say that hydro and irrigation interests would nevertheless still have priority in respect of the common water resource. Is that to continue?

Scarf: That was not what I implied. Certainly fisheries interests at the catchment board level have as much right to the water as anyone else. What I was trying to say is that the hydro interests, because of their engineering orientation, are far more definitive in their exact water requirements than fisheries interests are. All too often, you tend to opt in favour of them because of their definitive approach. I am not suggesting that they have any better or higher rights.

Recreational evaluation and protection of salmon-fishing rivers

by L. D. Teirney

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IN the proceedings of the 1971 salmon symposium there is a particularly pertinent comment about the likely loss of salmon habitat within the next 10 years as a result of developmental pressures on the major salmon rivers. Now, 9 years later, I would like to consider what has happened to these rivers and what is likely to happen to them in the future.

Hurunui

At present abstractions of water from the river for irrigation and water supply amount to 1 m^3/s. Water right applications for the abstraction of 5 m^3/s have been lodged in association with the Balmoral community irrigation scheme.

When water resources are limited and subject to conflicting demands, as in all of the braided shingle rivers on the east coast of the South Island, the regional water boards are encouraged to produce Water Allocation Plans (WAP) for each catchment. These plans specify how the water resources are to be allocated and how much water must remain in the river to satisfy the in-stream uses and protect the aquatic habitat.

Recently the North Canterbury Regional Water Board produced a WAP for the Hurunui River which featured a minimum flow of 7 m^3/s, lower than the 8 m^3/s lowest flow ever recorded. Fisheries investigations have shown that adult salmon migrations into the river during summer are adversely affected at a flow of 16 m^3/s. As a result of submissions by the fisheries interest, the minimum flow was raised to 10 m^3/s, but whether this flow will protect the salmon runs remains open to question.

Future proposals include five additional community irrigation schemes with a combined water requirement of 15 m^3/s and a 40-MW local authority hydro-electric power scheme. There is little doubt that the development of small hydro schemes would be accelerated should Government encourage the growth of energy-intensive industries.

Waimakariri

The abstraction of water for irrigation, water supply, and industrial use has been limited to about 5 m^3/s because of a dilution requirement in the lower river. Effluent disposal from three freezing works, treated sewage effluent, and wastes from a fellmongery and woollen mill which have since closed, caused the regional water board to impose a 57-m^3/s dilution flow in 1971. Efforts are being made to persuade the freezing companies to improve their effluent standards, but these have met considerable resistance.

Rakaia

All but 3 m^3/s of water has recently been diverted from the Wilberforce River into Lake Coleridge for power generation. Below the gorge the Highbank power station discharges water from the Rangitata Diversion Race (RDR) into the Rakaia River. Abstractions for irrigation and water supply total 3 m^3/s between the gorge and the sea. However, water right applications for a 20-m^3/s abstraction to satisfy the lower Rakaia community irrigation scheme are imminent. Future proposals include the Central Plains irrigation scheme, which has a water requirement of 50 m^3/s, and a 47-MW local authority hydro-electric power scheme which plans to abstract 179 m^3/s from just below the gorge. Although the lowest flow ever recorded is approximately 80 m^3/s, the minimum flow associated with the 1974 WAP is 42 m^3/s. This WAP is now under revision.

Ashburton

The Greenstreet community irrigation scheme has rights to abstract 1.5 m^3/s from the North Branch of the Ashburton River. Up to 7 m^3/s can be abstracted from the South Branch to augment the flow in the RDR. Water rights may be restricted to ensure a flow of 2.8 m^3/s at the State Highway 1 bridge. The continuing problem of low summer flows may lead to storage proposals in the catchment to satisfy future irrigation requirements.

Rangitata

At present, abstraction for irrigation and water supply amounts to 1.3 m^3/s. The RDR, which diverts more than 28 m^3/s (or up to 33% of the Rangitata River flow), supplies several community irrigation schemes and the Highbank power station. In 1979 a WAP featuring a minimum flow of 17 m^3/s was adopted by the National Water and Soil Conservation Authority (NWASCA). Three additional irrigation schemes with a water requirement of 27.5 m^3/s are proposed; however, the water will not be available from the Rangitata, where the lowest flow ever recorded is 31.3 m^3/s.

Opihi

Currently 4.6 m^3/s is abstracted for water supply, private irrigation, and the Levels Plains community scheme. Since the Levels Plains scheme has been operational, the river has at times completely dried up in the lower reaches. As a result, the regional water board produced a WAP in 1973 which allowed restrictions to be placed on water abstractions to maintain a minimum flow of 1.98 m^3/s. Irrigation requirements are not fully satisfied in the catchment, and this may result in the construction of storage facilities in the future.

Waitaki

Community irrigation schemes abstract 30 m^3/s from the river below the Waitaki dam. A further 3 m^3/s is abstracted for domestic stock and industrial water supply. As power developments in the upper Waitaki valley near completion, New Zealand Electricity has a much greater control over the flow regime below the Waitaki dam. A fluctuating flow now characterises the lower river and as a result major river control works have been necessary.

Future proposals include additional community irrigation schemes with a flow requirement of 20 m^3/s. More significant, however, are several hydro development options, the most likely of which incorporates a canal with up to 10 power houses along its length, a floodway, and a residual river, all within the confines of the existing river bed.

This résumé would suggest that multiple developments have caused major modifications to the salmon rivers over the past 10 years and will continue to do so at an accelerated rate in the future.

River protection

Those wishing to protect a valuable salmon-angling river search the Water and Soil Conservation Act 1967 for provisions which may be of use when putting forward their case. Two difficulties inherent in the act immediately become apparent. Firstly, water rights can be granted only to those who wish to dam, divert, or discharge; in other words, those people wishing to protect in-stream values are not legitimate water users. Secondly, water right applications are considered in isolation from the need for the development and what is happening to other rivers locally, regionally, or nationally. As a result, consideration is not given to the fact that a river may be one of the few remaining characterised by a particularly unusual combination of features. Adherence to a multiple use concept on an individual river basis means that developments are promoted at the expense of existing river habitat and fisheries. Often there is no such thing as a compromise and, as a result, the fisheries interest has been observing a cumulative loss of fisheries habitat in valuable recreational angling waters. Provisions within the act which can be used by recreational anglers to protect their interests are remarkably few and fall into the following categories:

- **Objecting to water right applications.** Although conditions have been imposed on water rights which may alleviate the more serious damage possible to river habitats as a result of a development, the fisheries interest has never prevented a development from taking place by use of this provision. The problem lies in the judgment which must be made between an economic use of water and a recreational use, which cannot be valued in economic terms alone. As a result, the economic use has always been favoured.
- **Applying for water rights.** Although recreational users are not regarded as legitimate water users, the Wellington Acclimatisation Society recently applied for, and was granted, rights for fisheries in the waters of the Manawatu catchment district. However, these rights do not ensure the continuing existence of the present fishery; nor do they preclude other developments from taking place. To provide some measure of protection, a particular flow regime must be guaranteed. Such specific rights will not be granted until the criteria defining legitimate water users are expanded. At the earliest, this possibility is still 2–3 years away when the act is finally revised.
- **Making submissions on a WAP and minimum flow.** From experience on the salmon rivers, the minimum flow can be set well below the lowest flow ever recorded. Should this single low flow become the only flow for long periods, as is possible where water is abstracted for irrigation, it may result in loss rather than protection of fish habitat.
- **Requesting that a minimum flow be legally fixed by NWASCA.** In 1978 the Ministry of Works and Development challenged the anglers to use this provision, as once the flow is legally fixed it cannot be further reduced when a WAP is revised. The minimum flow associated with the Rangitata WAP would be an ideal test case, and I am surprised that neither the Ashburton nor South Canterbury Acclimatisation Society has made such a request to NWASCA. While the provision remains untested it appears that better protective legislative provisions are not really desired by the anglers.

In attempting to make use of any of the above provisions the fisheries interest is generally seriously disadvantaged by the lack of quantitative and comparative information about the river fisheries it wishes to protect.

The only other possible mechanism for protecting rivers of exceptional scenic and recreational value is still under consideration. Recently, Government adopted a Wild and Scenic Rivers Policy, but as yet there is no legislative mechanism for its implementation. In the meantime, however, recreational groups are identifying their most valued rivers so that they can submit them for consideration and eventual protection when relevant provisions are included in the legislation. Therefore it is essential that highly valued salmon and trout rivers be identified and submitted for protected status, or it is obvious that even these rivers will be further downgraded.

Angler survey

In response to the need for quantitative and comparative information on our recreational angling rivers, Fisheries Research Division has implemented a national survey in conjunction with the acclimatisation societies. The survey, which takes the form of a postal questionnaire, aims to assess the relative importance of New Zealand rivers to the recreational angler. Anglers selected from each acclimatisation society are asked to evaluate the reasons why a particular river is selected for fishing. The results therefore reflect the attitudes of anglers rather than providing creel census type of information on such features as actual catch rates.

Survey booklets have been mailed to a randomly selected sample of anglers from each of seven societies—Nelson, Marlborough, North Canterbury, Ashburton, South Canterbury, Waitaki, and Otago. A 10% sample of full-season licence holders from each society resulted in a combined total sample of 3000 anglers. The data presented here are based on responses from 1700 anglers, a response rate of between 50% and 60% for each society. However, booklets are still being returned and, for this reason the results must be regarded as provisional at this stage. Estimates of the number of anglers fishing each river and the number of visits made represent an absolute minimum effort. More realistic estimates will be possible when more of the questionnaires have been returned.

Each society has its own booklet, which includes a covering letter from the president explaining the need for the information, instructions on how to fill in the survey, and contacts who can answer queries about the survey. A certain amount of angler information is required with the average number of fish landed from rivers each year. To dissociate the survey from a particular fishing season, anglers are asked to base their responses on their last 3–5 years' angling experience. For each river fished, the angler is asked to fill in the following information:

Importance of the river on a 1–5 scale (5 = highest).
Average number of visits per year (a visit being any time up to 1 day).
Reach fished: headwaters, middle reaches, and lower reaches.
Close to home (5 = closest).
Easy access (5 = easiest).
Large area fishable (5 = largest).
Scenic beauty (5 = highest).
Feelings of peace and solitude (5 = highest).
Catch rate (5 = highest).
Size of fish (1–5, tied to actual size classes).

Techniques used and other recreational activities complete the information. Each angler is also asked to fill in the same information for rivers fished outside the acclimatisation society district. Five measures of relative importance result from the survey information for each river: the number of anglers visiting the river, the number of visits made, the number of visits per angler, the number of anglers from other society districts travelling to fish the river, and the importance rating assigned to the river by those anglers who fish it.

The Rakaia and Waimakariri are the most fished of the seven major salmon rivers (Table 1). The Waitaki attracts the most anglers from other districts (Table 2). When these results are added to those in Table 1, both the Waitaki and Rangitata move closer to the Rakaia and Waimakariri, but the relative positions do not alter. The importance ratings assigned by the anglers have been presented as percentage frequencies in Fig. 1, to make comparisons between rivers. The Waitaki, Rakaia, and Waimakariri are rated very highly by the anglers; the Hurunui is not as highly rated, but it is still important. Anglers who fish the

TABLE 1: Importance ratings of salmon rivers for salmon fishing

Rank	No. of anglers		No. of visits		Visits per angler	
1	Rakaia	3 177	Waimakariri	42 280	Waitaki	17
2	Waimakariri	3 000	Rakaia	32 140	Ashburton	16
3	Rangitata	1 850	Rangitata	27 017	Rangitata	16SC*,12A†
4	Waitaki	1 130	Waitaki	19 080	Waimakariri	14
5	Opihi	1 050	Opihi	13 460	Opihi	13
6	Hurunui	950	Ashburton	9 640	Rakaia	11A,10NC‡
7	Ashburton	620	Hurunui	5 470	Hurunui	6

* South Canterbury.
† Ashburton.
‡ North Canterbury.

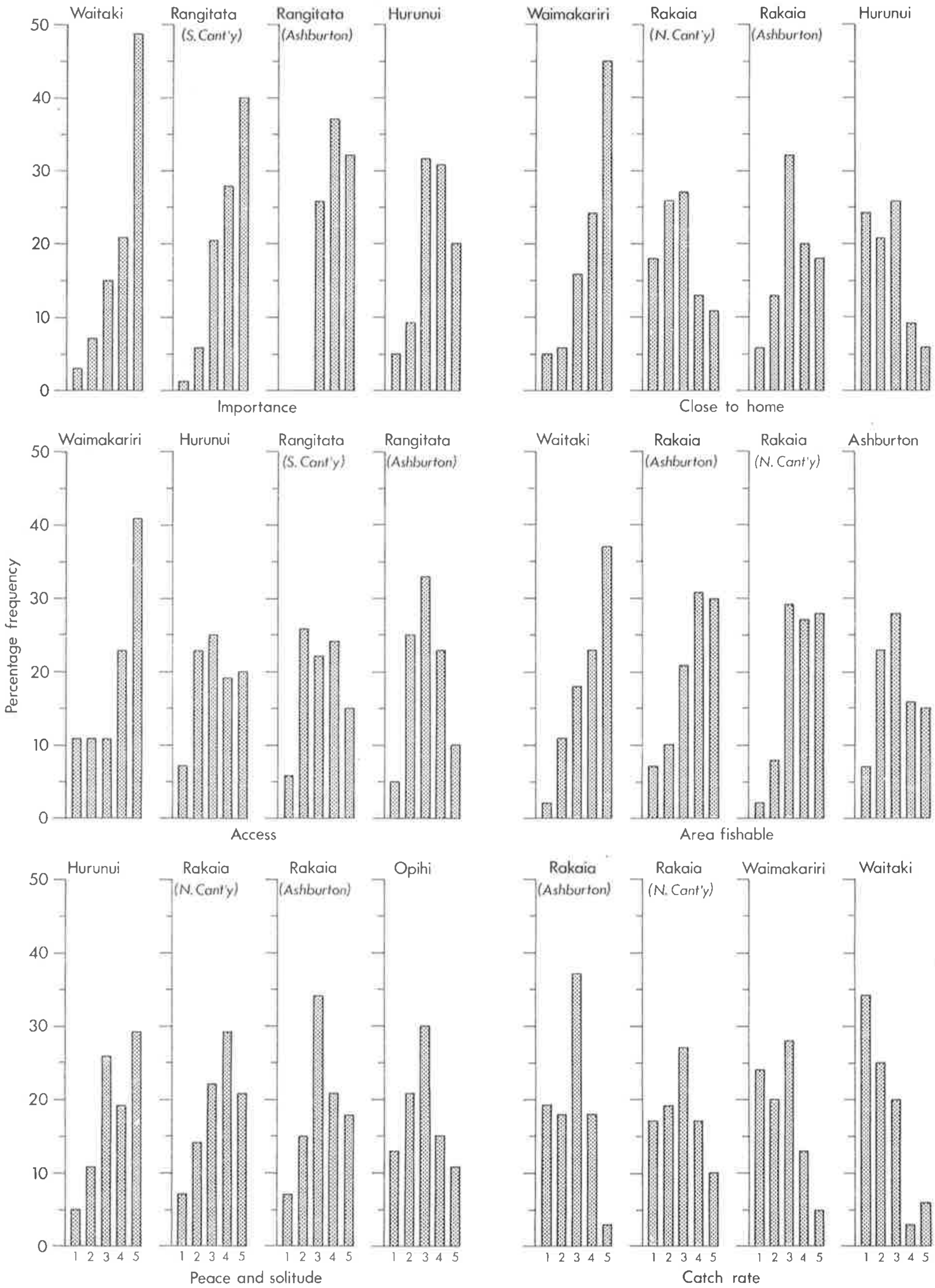

Fig. 1: Assessment of salmon river characteristics by the anglers.

TABLE 2: Importance rating of salmon rivers according to anglers visiting from other South Island societies

Rank	River	No. of anglers	Visits per angler
1	Waitaki	1 219	7 072
2	Rangitata	713	3 677
3	Opihi	306	1 767
4	Ashburton	242	1 708
5	Waimakariri	109	877
6	Rakaia	102	428
7	Hurunui	43	162

In summary, if our aim is to protect valuable salmon angling opportunities, it is important that we understand what aspects of the fishing experience on each river stimulate anglers to expend considerable time, energy, and money to pursue the sport. The last word should therefore go to one Waitaki angler, who wrote, "I have farmed on the banks of the Waitaki and fished the river since 1927. The river is my way of life. Take it away and my life won't be worth living."

TABLE 3: Importance ratings of salmon rivers for trout fishing

Rank	No. of anglers		No. of visits		Visits per angler	
1	Waimakariri	1 520	Waitaki	26 110	Waitaki	19
2	Waitaki	1 370	Waimakariri	14 950	Opihi	12
3	Opihi	1 130	Opihi	12 840	Ashburton	11
4	Rakaia	1 087	Hurunui	8 220	Waimakariri	10
5	Rangitata	1 000	Rangitata	7 723	Rangitata	10A*,8SC†
6	Hurunui	950	Rakaia	6 917	Hurunui	9
7	Ashburton	433	Ashburton	4 787	Rakaia	7

* Ashburton.
† South Canterbury.

Waimakariri, Ashburton, and Opihi live close by and therefore do not have to travel far. In comparison, anglers must expend effort, time, and money to fish the Rakaia and Rangitata and particularly the Hurunui, which is remote from any population centre.

When these same rivers are considered as trout fisheries a different picture emerges. The Waitaki is more important in relation to the Rakaia and Rangitata, which have become less important (Table 3). The relative importance of the seven rivers for salmon and trout angling is presented in Table 4. The numbers of anglers visiting each river to fish for salmon and for trout are compared in Fig. 2. Although the Waitaki is regarded as one of the most important salmon rivers, it is actually fished by more trout anglers.

Apart from the Rakaia, most salmon angling takes place in the lower reaches of a river. In comparison there is a shift up stream by anglers fishing for trout (Fig. 3). An improved scenic beauty rating is associated with this movement into the headwaters, particularly in the Hurunui.

Many anglers attached letters and comments to their replies and these provided much additional information. Often the anglers' real feelings about the rivers were made clear. The Hurunui is highly valued for its remoteness and the wide range of recreational opportunities afforded in such a peaceful setting. Some anglers would not feed the fish caught from the lower Waimakariri to the cat because of the terrible taste. Every comment on the Ashburton referred to the low summer flows, and catchment board activities in the Opihi during summer attracted much criticism. The attributes of the lower Waitaki were praised by many, whereas the activities of developers stimulated the expression of a range of inventive but unprintable new adjectives.

TABLE 4: Overall importance of salmon rivers for salmon and trout fishing

Rank	Salmon	Trout
1	Waimakariri = Rakaia	Waitaki
2	Rangitata	Waimakariri
3	Waitaki	Opihi
4	Opihi	Rangitata = Rakaia = Hurunui
5	Ashburton = Hurunui	Ashburton

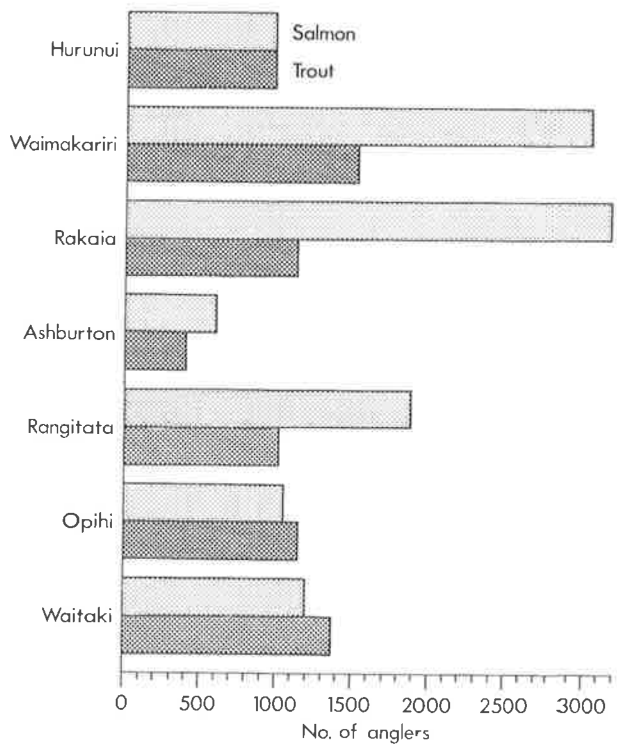

Fig. 2: Comparative importance of salmon rivers as salmon and trout fisheries.

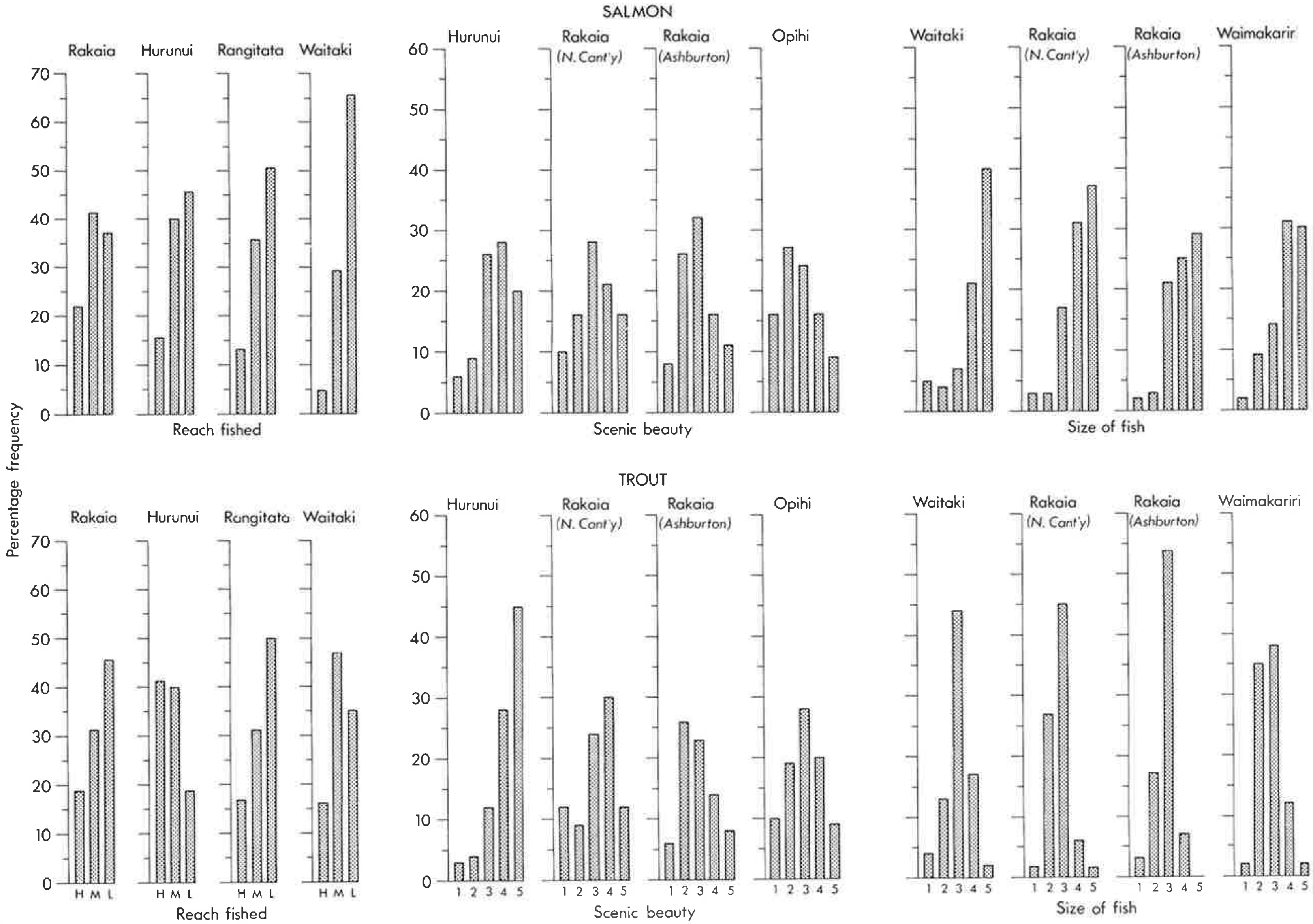

Fig. 3: Comparison between features of the salmon and trout fisheries supported by the salmon rivers.

Power generation and the fishery of the lower Waitaki River

by E. Graynoth

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THIS paper briefly describes the fish stocks and fisheries of the lower Waitaki River and then discusses three alternative hydro-electric power development schemes. A decision on a particular development option may be made late this year or early in 1981, and it is important that anglers and the public are advised of the alternatives. Therefore, I would like you to consider these options and advise me of your preferences.

The river, fish stocks, and fisheries

The Waitaki is a large, braided river with a flow rate of about 350 m^3/s. It enters the sea 200 km south-west of Christchurch on the east coast of the South Island. The river has six large lakes and hydro-electric reservoirs in its headwaters, and these control and regulate its flow. This paper is solely concerned with the lower 65 km of river from the Waitaki dam to the sea. Typically the lower Waitaki has about seven channels in a 1- to 2-km-wide flood plain.

The river and its tributaries have a diverse fish fauna, with 20 of the 33 species of native fish and 5 of the 7 species of salmonids in New Zealand. The salmon and trout fisheries are of national importance and there are local fisheries for flounders, mullet, eels, kahawai, and whitebait.

Before the Waitaki dam was built in 1935 there may have been as many as 100 000 fish in the quinnat salmon run. Now the run is only 10 000 to possibly 20 000 fish in a good year. Salmon angling is most popular in the lowest 10 km of river, because the fish are often in poor condition up stream. About 30% of the New Zealand salmon catch comes from this river. Catches range from about 1000 to possibly 5000 salmon per year, depending on the size of the runs and on angling conditions.

The Waitaki River is exceptional among salmon rivers in that it also supports good stocks of both brown and rainbow trout and a high quality trout fishery. We estimate that anglers catch about 10 000 brown trout and 3000 to 5000 rainbow trout every year. The trout are larger than average and usually 35–50 cm long.

Power planning

Although power planners in New Zealand Electricity (NZE) and the Ministry of Works and Development (MWD) have been considering developing the lower Waitaki for about 20 years, the pace of investigations has recently accelerated. In 1964 an initial study was completed, and reports were published in 1974, 1978, and 1979. Earlier this year MWD released a provisional timetable for power development. The plan is that later this year, or in early 1981, a decision will be made to concentrate on one development option. After environmental studies and public comment, an environmental impact report will be prepared, and water rights will be applied for in 1985–86. Construction could begin in 10 years, and the first power could be produced in 1995. The entire scheme could be completed in 35 years, in 2015.

The scheme will produce an estimated 3000–3800 gWh per year, at a cost, in 1978 figures, of about \$800–1000 million. The electricity produced would be insufficient to supply a fully developed second aluminium smelter, which would require about 5100 gWh per year.

Three-channel option

The first power development option is to have three channels. A power canal, with a series of 10 power stations along it, would probably be situated on the south bank of the river. North of the canal would be a 400-m-wide floodway and then a 400- to 800-m-wide residual river and wildlife area (Fig. 1). All the channels would flow from a diversion structure up stream at Kurow down to the lowest power station, just up stream of the State Highway 1 bridge and about 4 km from the sea.

The power canal would have a capacity of 525 m^3/s, which is well above the mean flow of the present river and tributaries. The canal would be 80 m wide, up to 11 m deep, and would contain water flowing at up to 1 m/s. From our studies in the Wilberforce and Rangitata Diversion Races we think that these canals would contain a sparse trout stock and support only a limited fishery. We plan to study canals constructed in the upper Waitaki power development scheme to determine ways of developing the fish stocks and fisheries. It may be possible to make small design modifications and provide food for trout and attract fish to areas where they can be caught by anglers. At the moment we do not think it worth while to build fish passes at the power stations.

The floodway north of the power canal is designed to carry floods originating from the upper Waitaki

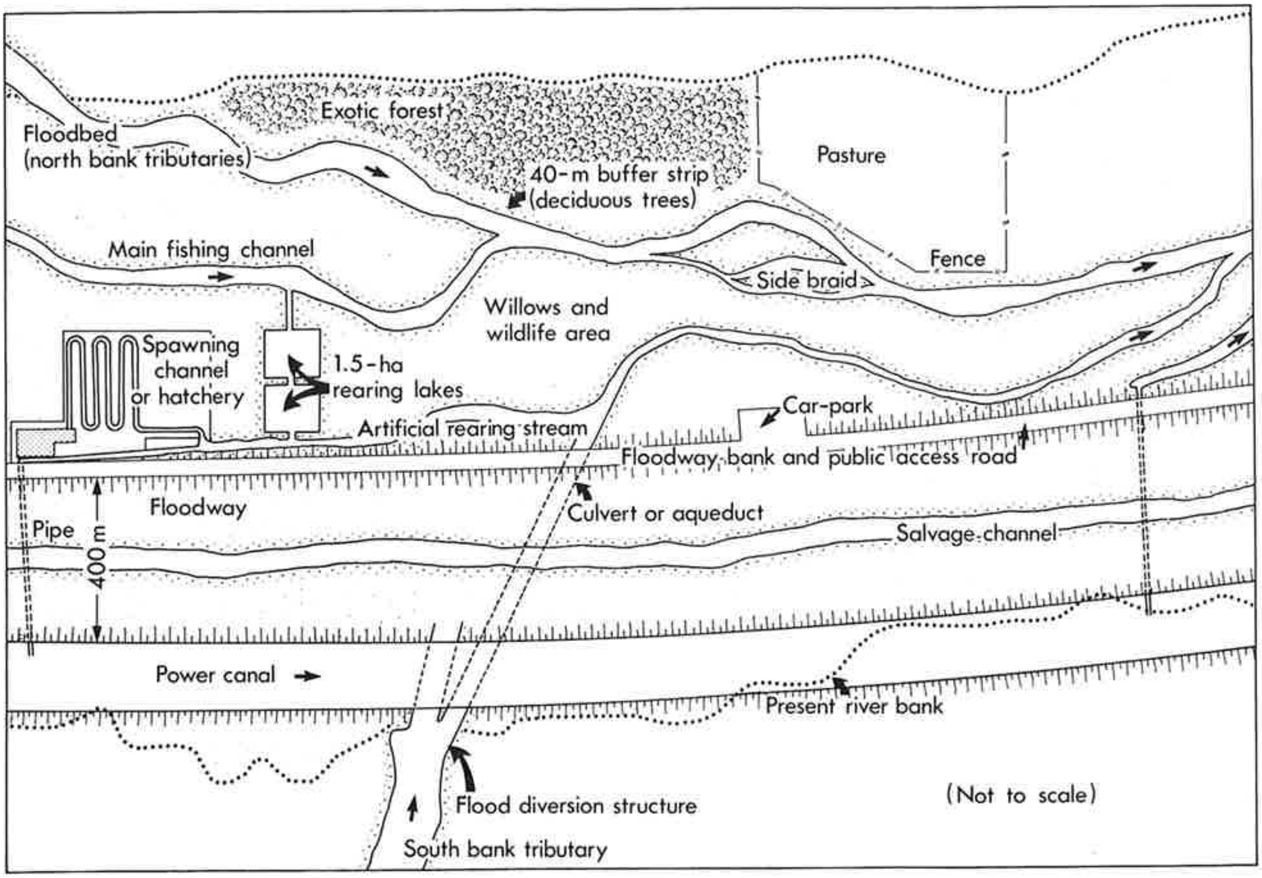

Fig. 1: Three-channel option. Proposed layout of channels and fisheries facilities.

catchment and also from the Hakataramea River and other major tributaries. Diversion weirs would need to be constructed at the mouths of these tributaries to direct floods into the floodway and so protect the residual river.

The design of the residual river area is being studied, and it seems that there should be channels of various sizes. Down the centre would be one or two large main channels (containing possibly 20–40 m^3/s) which could support resident trout stocks, native fish, and trout and salmon angling. Parallel to these channels would be a series of smaller side streams and backwaters designed for trout and salmon spawning and for rearing juvenile salmonids. The production of juvenile fish may need to be supplemented by the provision of artificial rearing channels and possibly a hatchery and rearing complex.

One of the main difficulties with this option is the design of the large centre channels. These channels need to support stocks of fish and fisheries equivalent to those in the present river and yet use only a small amount of the present river's flow. For example, we estimate that to support the present trout fishery the river should contain about 250 large takable trout per kilometre. However, studies made in single-channel North Island rivers show that numbers of takable trout rarely exceed 60 per kilometre. By carrying out intensive research into the requirements of trout in large rivers, and by careful flow manipulations and the protection of the residual river from flood damage, we think it may be possible to reach this design target without using excessive amounts of water.

In all the options we think it is crucial that the lower reaches of the river (from the State Highway 1 bridge to the sea) be left more or less unmodified. Studies have shown that this region supports dense and diverse stocks of native fish and also most of the salmon angling.

Two-channel option

The second development option is similar to the first, but is to have only two channels—a power canal to the south and a combined floodway and residual river to the north. Floods originating from the upper catchment would flow down the residual river from January to early May, whereas floods from the tributaries would occur later, from June to September. Figure 2 shows the floods that would have occurred if this option had been in operation in 1967, and if the residual river contained a base flow of 40 m^3/s. We estimated that there would be a mean daily flood of 1000 m^3/s once every 25 years, a flood of 700 m^3/s every 10 years, and a flood of 250 m^3/s every year.

These figures were based on historical flow records and computer simulations and were rather upset by the floods of 5 June 1980, when flows from the tributaries of the lower Waitaki measured 1400 m^3/s. Flows in the Maerewhenua River (which almost dries up in summer) were estimated at 700 m^3/s.

We are therefore dealing with very large floods, and if this option is taken, we will have to determine their impact on the fish stocks and fisheries in the residual river and find ways to mitigate their adverse effects. However, there is little quantitative information on what happens to braided rivers and their faunas when floods of this magnitude occur. One particular problem is the unusually long duration of the floods from the upper Waitaki; they may last 2–3 weeks. The tributary floods are very different; they last only a few days and have high silt and bed loads.

This option is still being studied and it seems that the flood damage could be reduced by careful channel design and river training work. For example, there would be a relatively smaller increase in water depths, and hence water velocities, in a wide flood plain than in a narrow flood plain. Therefore, it is thought that the impact on fish stocks would also be less with a wide flood plain. Nevertheless, it seems fairly conclusive that fish stocks would be harmed by these floods and fish production would never be as high as it would be in the first option. Therefore, more residual water would be needed in this option to maintain the present fish stocks and fisheries.

One-channel option

The third option is to slightly enlarge the power canal and build a series of possibly 10 narrow hydro-electric reservoirs down the river valley (Fig. 3). In favourable sites, such as below Kurow, larger reservoirs, which extend across the entire plain, could be formed.

Small salmonid spawning and rearing streams could be left beside the reservoirs and these could also support some fishing. Floods would be contained within the reservoirs and be passed down stream over spillways next to the power stations. In this scheme, fishways would allow fish to move between the reservoirs where most of the fishing would take place. We think that the reservoirs would be similar to the lower reaches of Lake Waitaki.

Depending on the design of these reservoirs, it should be possible to develop some fish stocks and fisheries. Much would depend on the extent of the shallow slow-flowing areas, on water level fluctuations, and on the effectiveness of fish passes. If this option was taken it would destroy the natural river, its fauna, and the river-based fisheries. Although salmon angling could take place below the final power house, we think it could be quite difficult to catch salmon in the reservoirs themselves. We are also concerned about the possibility of gas bubble disease, which is caused by air entrainment at spillways during floods. In the Columbia River in the United States this disease has seriously damaged the salmon run and fishery.

No power development

The final option is that of no hydro-electric power development on the lower Waitaki River. River training works will no doubt be continued, as will the abstraction of water for irrigation. Changes in power generation will still cause daily fluctuations in water

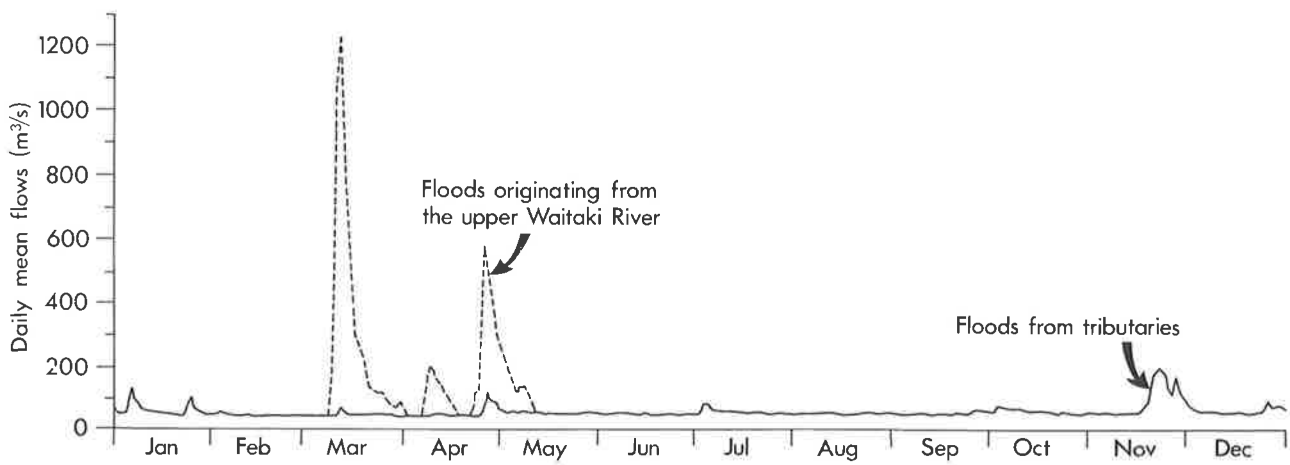

Fig. 2: Two-channel option. Simulated flows in the combined floodway and residual river during 1967.

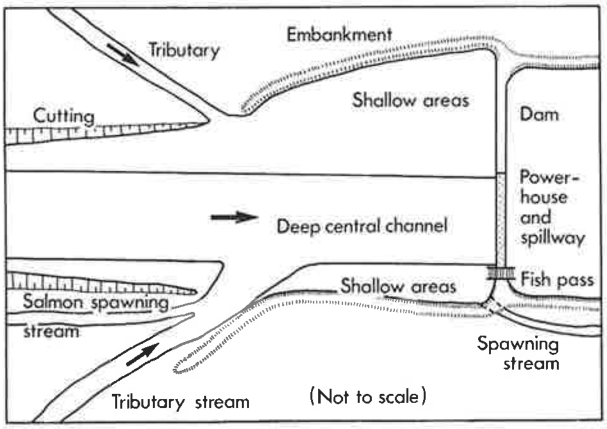

Fig. 3: One-channel option. Possible design of combined power channel and floodway.

levels and floods will continue periodically to destroy salmon spawning grounds. In addition, unless there is some control over the excessive growth of willows and gorse and other exotic weeds in the flood plain, access for anglers and other river users could become quite difficult.

On the positive side, we could be reasonably certain that the present fish stocks and fisheries would be maintained, and there is always the possibility that the fishery could be developed by the release of hatchery-reared fish or by other means.

Fisheries Research Division investigations

The FRD investigations of this power development scheme started in 1965–66, when an intensive creel census was undertaken in the lower river. In 1975 a small laboratory and research team was established at Oamaru and we have completed our preliminary studies into the fisheries and distribution and abundance of fish in the lower river. After recent negotiations with NZE a new phase of studies was started as it became clear that a greatly increased effort and expenditure was required.

Over the past year we have prepared a report on the fisheries aspects and requirements of the scheme. The report describes the options in more detail and will be completed and distributed in the near future to acclimatisation societies and other interested organisations.

In addition, using funds supplied by NZE, we have recently appointed four fisheries consultants to work on particular aspects of the scheme. Three post-graduates from the University of Otago are studying the biology and water requirements of trout and juvenile salmon, and a post-graduate from the University of Canterbury will be studying anglers' effort, catch, and future requirements. Dr Scott of the University of Otago is organising studies into the effects of flow reductions and fluctuating flows on juvenile salmon and trout at a replicate channel facility that has been constructed by NZE near Duntroon.

If all goes to plan, we expect to increase the fisheries team considerably to 10 to 15 researchers over the next few years. Our aim is to provide factual material on the options for documents such as environmental impact reports and to determine whether the fish stocks and fisheries can be maintained if the power scheme proceeds.

Demonstration channels

The three-channel option is now receiving the most study and we are considering constructing flow regulating headworks on certain channels near Duntroon to more accurately simulate the physical and biological characteristics of a future residual river. We propose to modify certain channels so that they contain stable residual flows of 5, 10, 20, and 40 m^3/s. These channels would be intensively studied over the next 5 years to determine the maximum stocks of fish they could produce and whether or not anglers are satisfied with their size and other features.

These studies will be expensive, but we think they are justified because of the importance of the fishery and the high economic value of water left in the residual river. Economists from NZE say that a residual flow of 30 m^3/s would be worth about $5 million per year. This is what it would cost to replace the lost electricity by electricity generated in thermal power stations. Therefore, NZE are keen to determine what is a reasonable minimum residual flow.

Finally, I think it is fairly obvious that anglers, acclimatisation societies, and FRD will have to consider carefully what type of river and fishery they would like to see in the future. Therefore, I would greatly appreciate your comments on the options I have described.

The NZE Waitaki hydrobiological research station

by D. Scott

Zoology Department, University of Otago, Dunedin

IT is becoming increasingly obvious that the major threat to salmon fisheries is the development of hydro electricity. At the 1971 salmon symposium, Hardy (1972) discussed some of the problems associated with dams and suggested that the salmon populations are rarely better off than they were before construction. The substantial interference with the salmon runs in the Waitaki and Clutha River systems is undocumented, but nevertheless real, and Scott (1978) has illustrated the effects of hydro schemes on freshwater fisheries.

With these considerations in mind, and with the prospect of further substantial power developments in the near future, fisheries interests have tended to communicate at various levels with development agencies. This has allowed fisheries people to form a clearer view of future problems and has equally afforded the development agencies indications of possible losses in recreational assets.

The present development is the outcome of such interactions concerning the Waitaki River.

Development of the proposal

The future of the lower Waitaki salmon fishery has been a matter of concern since 1974, when proposals for power development were released. I was particularly interested in the effects of reduced flows and varying flows on the rearing of young salmonids and discussed the possibilities of research related to future developments on the Waitaki River with interested parties, namely the Waitaki Valley Acclimatisation Society, Fisheries Research Division of the Ministry of Agriculture and Fisheries, and New Zealand Electricity Division (NZE) of the Ministry of Energy. It soon became clear that the most useful approach was to develop experimental channels where some of the effects of development could be simulated under controlled conditions. Negotiations for such a facility started in 1978, and in May 1979 a formal approach was made to NZE with detailed suggestions for research. This was referred to Fisheries Research Division in Christchurch, as fisheries advisers to government.

A definitive meeting took place in Kurow in January 1980 between the Waitaki Catchment Commission, Waitaki Valley Acclimatisation Society, Ministry of Works and Development, NZE, Fisheries Research Division, and University of Otago. Fisheries research was discussed in a fairly wide context, and agreement was reached in principle on the present proposals.

The Ministry of Works and Development agreed to carry out the initial works on behalf of NZE, who would run the facility. The research was to be carried out by workers from the university with assistance and co-operation of staff from NZE and the Ministry of Agriculture and Fisheries.

Although these details may appear of marginal interest, it should be emphasised that major research undertakings can hardly proceed satisfactorily without the co-operation of interested parties.

The experimental channels

The site proposed had distinct advantages, as it was adjacent to the irrigation headpond of the Waitaki irrigation scheme. An assured water supply could be drawn from this headpond and flood protection was satisfactory. Work started on the site in March and five channels were constructed, each 100 m long and 3 m wide at the base. Each channel has a separate control gate in a constant-level pond and the usual operating range of the channels is:

Discharge (m^3/s)	Velocity (m/s)	Depth (m)
0.19	0.30	0.18
0.25	0.40	0.20
0.32	0.50	0.23

Discharge outside these values could also be used. There are three deepenings to simulate pools in each channel, and down-stream traps to catch outmigrants are being developed. The control gates can be operated manually and automatic control is planned for two of them to allow fluctuating discharges.

Since the original proposal NZE has added a biologist (Dr Paul Henriques) to the Dunedin staff and at his suggestion ponds have been constructed on site to allow a study of aquatic plants with reference to hydro lakes.

Objectives

With the development of the lower Waitaki, a vital question is how much water could be left in the river. This will in turn affect the distribution of water in the side braids which, in my experience, are of considerable importance for the rearing of salmon and trout in their first year. One set of experiments is aimed at the effects of reduced flows on the distribution, behaviour, and production of young fish during the first year of life. This will be done by setting one channel as an optimum (control) and comparing the effects of differing levels of reduction in other channels. The application to the Waitaki is that in attempting to set a residual flow, specifications for side braids as preferred rearing areas would be made available.

It has been suggested that flows in the residual Waitaki might not vary much after development. Nevertheless, the effects of varying flows are clearly of general importance when hydro development is being considered, and both juvenile and adult fish are likely to be affected. A second set of experiments will compare the effects on production and behaviour of varying flows, the flows being controlled automatically according to a programme simulating possible changes below a power station. Results from this set of experiments would go some way towards a much needed quantification of the effects of varying flows on small streams. Although it is generally accepted that varying flows are adverse, I have been unable to find useful quantitative information on this subject.

Progress

Water is now running in the channels and it is proposed to stock them with rainbow trout eggs or fry this month. Two research workers are now installed at the university, a post-doctoral research fellow (Dr David Rimmer) and a Ph.D. student (Mr Jim Irvine). Both are from Canada, and both have a background in salmon; so I am optimistic that their stay here will be fruitful.

We have had some difficulties in developing the channels, but these should not be lasting. I have been impressed with the speed with which the job has been completed, given an agreement in principle in January of this year, and I would like to thank personally the staff of NZE and the Ministries of Works and Development and Agriculture and Fisheries, who have been both realistic and encouraging in their attitude to this research.

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Discussion

Unknown: Are the channels hydraulically realistic? In other words, should they be straight?

Dr Scott: If we had simulated natural streams, we would have increased the difficulties of statistical analysis. If curves were introduced, replication would be almost impossible, and by making the channels straight we have reduced this difficulty. We've had to compromise, but having discussed this aspect at length, we decided that a reasonable level of confidence in replication was of more value than having bends.

Mr Flain: Of all the things outlined in the last few papers, there has been no reference to lakes with respect to water abstraction and hydro-electric development. Their key attribute is storage capacity, and though a lot of the schemes concern the major rivers, they will have a definite impact on the lakes as well. For example, the development of the Rakaia River will have a marked influence on Lake Coleridge, a major fishery in itself.

Scott: Yes, but in the future we are going to have more lakes than rivers.

Flain: But if the levels fluctuate, are they good lakes?

Scott: Where there are lakes, people will fish in them. The thing that is going to be valuable in the future will be the river. This is why I am concerned now; there are fewer of them.

Mr Beckett: What will be the applicability of this experiment compared with what happens in the real sense as far as turbidity is concerned? You increase the flow in your channels, to simulate a fresh, but the turbidity will not necessarily increase as it may in the main river.

Scott: Are you suggesting that we should have experiments directly related to turbidity?

Beckett: I'm suggesting that turbidity may be an important factor in assessing the effect of increased flow, because it often accompanies increased flow.

Scott: It depends on the history of the channel. If you have a channel that is wide and braided like the Waitaki, and the river occupies a small part of it, with regular fluctuations, when it rises I suggest that you won't get a great increase in turbidity because the river bed will be clean from the regular fluctuations. If you're talking about a river not like the Waitaki, that has a reasonably confined channel, and its level increases beyond this channel, you will have soil erosion and turbidity. Therefore, applicability will depend on the type of river you're concerned with.

Quinnat salmon management in the Southern Lakes Conservancy

by R. T. Hutchinson

Senior Wildlife Officer, Wildife Service,
Department of Internal Affairs, Queenstown

MANAGEMENT of quinnat salmon in the Southern Lakes Conservancy is set up as two separate programmes: one applies to the anadromous stocks established in South Westland waters and the other to the landlocked, or lake limited, stocks of the three Clutha source lakes (Hawea, Wanaka, and Wakatipu). Both programmes began in the early 1960s, but detailed monitoring of selected spawning runs and hatchery inputs did not begin until the early 1970s.

Anadromous salmon

Background

Anadromous runs of quinnat salmon in South Westland waters were first confirmed in 1964, when spawning fish were observed in the Moeraki and Paringa catchments, which drain into the Tasman Sea 23 and 39 km respectively north-east of the Haast River mouth. Fishing of these stocks was permitted under existing legislation and soon attracted widespread interest from anglers. Most fishing pressure was directed at the fish after they entered Lakes Moeraki or Paringa and began to concentrate near the mouths of the upper Moeraki River and The Windbag. The collection of angling data and visual monitoring of spawning runs began in 1966. As a precautionary measure immediate steps were taken to close the upper Moeraki River and The Windbag to fishing and to institute a daily bag limit of four fish.

Angling data from the three seasons up to 1969 showed a significant decline in the total number of salmon entering the two lakes each season. Catch rate, total numbers caught by anglers, and numbers observed on the spawning grounds in The Windbag also indicated a declining population. In an attempt to halt this, the taking of quinnat salmon from West Coast waters of the conservancy was prohibited from 1 September 1970.

Trapping

During the next 4 years staffing limitations in the conservancy prevented any more than opportunity inspection of The Windbag spawning runs. However, staffing improved in 1974 and management involvement, with some redirection of the programme, recommenced in 1975. With the ultimate objective of assisting the build-up of salmon runs and their extension into other suitable catchments, a temporary trap was installed in The Windbag during April 1975 to check the feasibility of trapping this flood-prone stream. This trial was to help determine whether trapping was the best means of consistently monitoring qualitative and quantitative parameters of the annual spawning run, and of securing a reasonably reliable source of ova. The ova were needed to investigate (via hatchery culture) the possibility of increasing recruitment to The Windbag run and the establishment of runs elsewhere in South Westland.

Although trapping of The Windbag was more difficult than usual, effective operation of a trap was feasible and in April 1976 a permanent and considerably stronger capstan-type trap was installed. This incorporates a hinged barrier which can be quickly collapsed, to allow passage of flood flows, and raised again as water levels return to normal. The trap has been operated annually for an average of 36 days from mid April to mid May. It does not provide a complete count of spawning migrants, but trap figures, combined with observations of fish and redds over the entire length of the stream, are thought to provide a reliable estimate of the total spawning run.

Possibly the largest spawning run of salmon to enter The Windbag during the past decade was observed during May 1974, when 156 salmon were counted in the section of stream above the State Highway 6 bridge. This count was made on 19 May, rather late in the spawning period, and according to local opinion the run was the largest in memory. The following year the estimated run declined to 70–80 spawners. It remained at a similar level in 1976, began a steady increase to a peak of 380–420 fish in 1979, and then declined to 80–100 in 1980 (Table 1).

Annual trapping figures have shown a similar trend, starting at 30 fish in 1975, increasing progressively to a total of 132 in 1978, almost doubling to 209 the following season, and then declining to 31 in 1980.

Sex ratios, expressed as number of males per female, have ranged from a 1976 peak of 3.5:1 to a low of 1.38:1, in 1980.

Qualitative data of the salmon handled at the trap during the past 5 years also show a trend towards

TABLE 1: **The Windbag salmon spawning run data: estimated total run (from spawning surveys), total salmon trapped, and sex ratio (from trapping data), 1975–80**

Year	Estimated run	Number trapped	Sex ratio (male to female)
1975	70–80	30	2.33:1
1976	75–85	41	3.50:1
1977	110–120	60	1.86:1
1978	250–260	132	1.59:1
1979	380–420	209	2.17:1
1980	80–100	31	1.38:1

improvement in the size and quality of fish. From 1976 the average length, of almost 59 cm, increased to almost 66 cm in 1977, remained close to this for the next 2 years, and then declined to 60 cm in 1980. Maximum length increased from 72 cm in 1976 to 82 cm in 1978, and minimum length has ranged from 40 cm in 1979 to 48 cm in 1977. Any trend in minimum length may to some extent be confused by the inclusion of landlocked fish in the 1979 and 1980 trapping records. Average weight increased from 2.83 kg to 4.02 kg in 1978, dropped to 3.63 kg the following year, and dropped further to 2.93 kg in 1980. Maximum weight reached 7.05 kg in 1978 and was 6.3 kg in 1980; minimum weight declined from 1.2 kg in 1978 to 0.9 kg this season. Condition factors over the past 5 years have ranged between 72.44 and 28.31, both recorded in 1978; the seasonal average has remained above 40.00 (Fig. 1).

Since 1977 representative samples of scales and/or otoliths from spawning fish have been aged by Mr M. Flain of Fisheries Research Division in Christchurch. Age data have shown a strong dominance of 3- and 4-year-old fish in each yearly run, with 2-year-olds contributing in only 1 of the 4 years (1977). The scales and otoliths have also revealed an unusual mixture of fish in the run: some had migrated to sea as fingerlings, some had remained in fresh water for up to 3 years before going to sea, and some had remained in fresh water entirely.

Hatchery returns

As a precautionary measure, the collection of ova from The Windbag run for onward incubation and rearing at the Wanaka hatchery is limited to about 50% of the females trapped. Ideally, several strippings are made at intervals through the spawning period. Under this limitation total quantities of ova collected annually have been small, exceeding 100 000 only once in the 6-year period to 1980 (Table 2). Most of the fish hatched from these ova have been returned to The Windbag either as fin-clipped smolts at approximately 90 days old, or as tagged or fin-clipped age 1+ fingerlings.

Adult returns from liberations of hatchery fish began to appear in the 1978 spawning run when nine 3-year-old fish from the 1975 liberation of 3500 fin-clipped smolts were recorded. These fish represented 6.82% of the total fish trapped and 0.26% of the number liberated. In the next year there was a notable increase in the numbers of hatchery fish returning. Forty-four salmon from two year classes were recorded among the fish trapped; these represented 21.05% of the total and 0.3% of the number of fish liberated up to 1977. In the appreciably smaller 1980 spawning run there were six marked fish comprising 19.0% of the total trapped and 0.02% of the hatchery releases, including liberations carried out during 1977. It should be noted that the data relating to return of hatchery fish are conservative as a result of the incomplete nature of the trapping results.

Future objectives

In the 15 years since the Moeraki and Paringa runs were confirmed, salmon have been caught or observed in a number of other catchments north and south of these two systems. Sightings have been confirmed at least once in the Arawata (1964), Hollyford (1968),

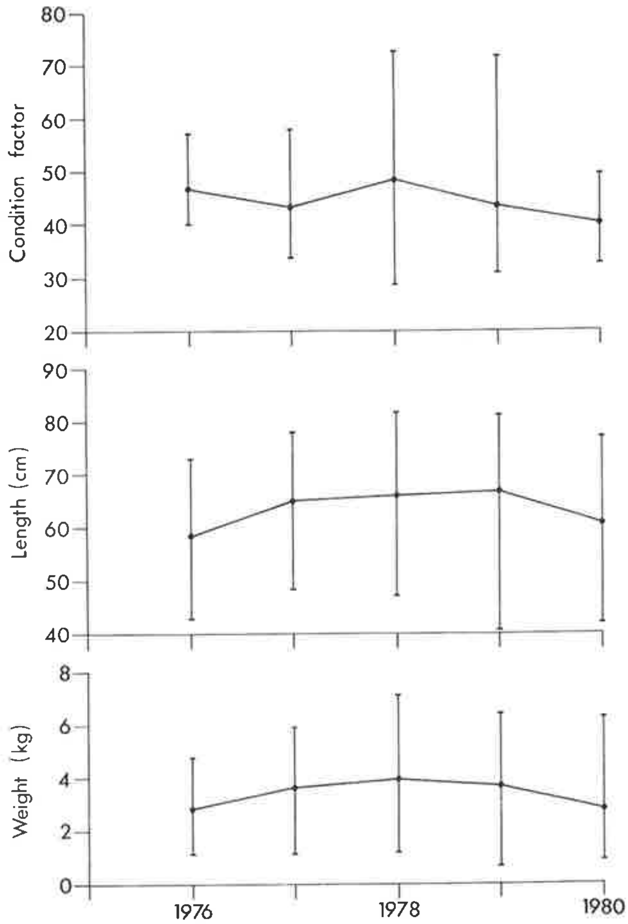

Fig. 1: Weight, length, and condition factor of salmon trapped in The Windbag, 1976–80.

TABLE 2: Ova collected, hatchery liberations, and adult returns of salmon, The Windbag, 1975–80

Year	Ova collected	Liberations: Smolts	Liberations: Fingerlings	Returns (% of trap total)
1975	20 000	3 500	–*	–
1976	11 000	10 700	890	–
1977	29 300	18 800	1 827	–
1978	99 000	55 300	7 000	6.82
1979	106 000	49 000	7 302	21.05
1980	24 800	–	–	19.00

*No fish.

Turnbull (1969), Haast (1975), Waiatoto (1977), and Ohinemaka (1979) Rivers, and in Lake Ellery (1970). Salmon have also been caught in the sea off the mouth of the Mahitahi River, in Jackson Bay, and Smoothwater Bay, and there have been as yet unconfirmed observations of salmon in catchments draining into Caswell and Dusky Sounds in Fiordland. These observations indicate that anadromous runs of quinnat salmon can be supported by many river catchments of South Westland and marine conditions off the coast. If The Windbag run is successful in future years, the Wildlife Service intends to try establishing other runs in waters south of the Moeraki and Paringa Rivers. A full survey of the Haast River and its tributaries, carried out between 1965 and 1968, identified suitable spawning and rearing areas for salmon in several parts of the catchment, and a trial release programme has been recommended subject to the uninterrupted availability of ova for a minimum 4-year period.

The Okuru and Turnbull Rivers are other prospects and, because spawning areas in the main tributary stream entering Lake Ellery are rather limited, the small run in this lake might well be increased by hatchery liberations.

Another prime objective is to lift the restrictions on fishing for quinnat salmon in South Westland waters of the conservancy; however, this is unlikely to occur in the next 4–6 years unless there is a substantial increase in the size of The Windbag spawning run.

Landlocked salmon

Background

All three of the Clutha source lakes support populations of landlocked quinnat salmon and though this resulted from completion of the Roxburgh hydro-electric dam in 1956, non-anadromous stocks were known to exist in all three lakes before that date. The interest of the Wildlife Service in managing the fish was stimulated by a spectacular increase in numbers of salmon caught from Lake Hawea immediately after the raising of that lake's level in 1958. Until 1979 there was no daily bag limit for landlocked salmon. In response to criticism of the unusually large catches from Hawea after completion of the Hawea control structure, a creel census was conducted during two angling seasons. Two unexpected indications of the potential of the fish were revealed by the census: firstly, it could account for as much as 60% of the anglers' catch from the lake and secondly, it could be responsible for average catch rates as high as 0.8 fish per hour.

Continuing on from the Lake Hawea angling census, field inspections were started to try and locate the spawning areas used by salmon in the catchments of all three lakes. In 1969 these inspections confirmed that Diamond Creek, at the head of Lake Wakatipu, was an important spawning area and preparations were made to begin the trapping of spawning migrants the following autumn. The main aim of the Hawea work was to develop the knowledge and techniques necessary to propagate fish under hatchery conditions and so boost wild stocks.

Trapping

For the first 2 years a 2.4-m diameter rigid fyke trap was used to catch migrant adult salmon, but its successful operation required an unacceptable level of maintenance to overcome a problem of weed drift. In 1972 it was replaced by a conventional fixed-barrier trap, able to withstand flood levels 70 cm above normal flows. Starting in the same year, the extensive beds of aquatic plants in the creek have been reduced and controlled by applying Paraquat during late summer each year.

The duration of trapping over the April-May spawning period has averaged 38 days, but it was extended to 49 days in some years and reduced by flooding to as low as 28 days in others. Although the trap effectively screens all but extreme flood flows, removal of barriers for varying periods has been necessary in some years, and in most seasons some spawning has occurred below the trap site. The annual count of migrant salmon is therefore not absolute.

Numbers of migrant salmon recorded have never been very high, exceeding 200 fish only once during 11 years of trapping, though the indicated trend is towards an increase in numbers after 1972, followed by some stabilisation. There is also a cycle apparent in the trapping figures, with peaks and troughs in alternate years (Table 3).

TABLE 3: Total salmon trapped and sex ratio, Diamond Creek, 1970–80

Year	Salmon recorded	Sex ratio (male to female)
1970	72	2.8:1
1971	15	–*
1972	57	2.4:1
1973	25	–
1974	126	3.8:1
1975	49	3.3:1
1976	222	2.1:1
1977	169	1.5:1
1978	133	2.0:1
1979	144	1.9:1
1980	44	2.5:1

*Not calculated.

These salmon are appreciably smaller than the anadromous form and do not often exceed 1 kg in Lake Wakatipu. The heaviest salmon recorded so far was a 2-kg female in the 1979 spawning run. Average length and weight peaked at 44.54 cm and 0.81 kg in the 1973 spawning season, declined during the next 2 years to a low of 37.36 cm and 0.42 kg in 1975, and then improved again to 42.20 cm and 0.86 kg in 1977. Since that date, both length and weight have steadily declined to an average of 33.35 cm and 0.38 kg in 1980. Average condition of the salmon has fluctuated throughout the trapping period, with a decline since 1976 (Fig. 2).

Aging of a representative sample from the recorded run has been carried out since 1970 by Mr Flain and the results have revealed an age structure quite different from that of the anadromous run in The

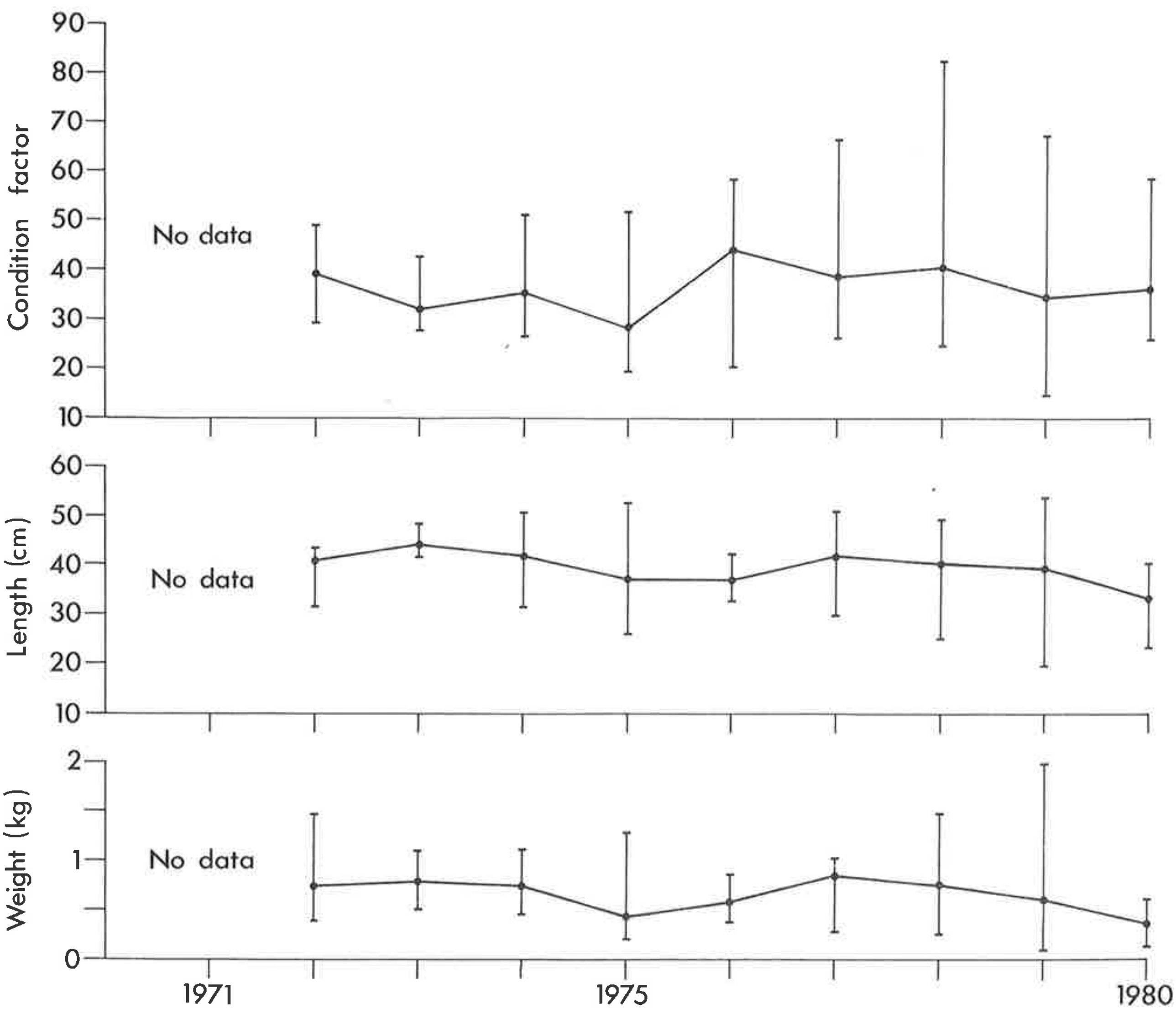

Fig. 2: Weight, length, and condition factor of salmon trapped in Diamond Creek, 1972–80.

TABLE 4: Ova collected, hatchery liberations, and adult returns of salmon, Diamond Creek, 1970–80

Year	Ova collected	Liberations: Smolts	Liberations: Fingerlings	Liberations: Origin	Returns (% of trap total)
1970	5 500	–*	–	–	–
1974	8 000	2 350	–	L†	–
1976	–	–	1 600	A‡	–
1976	18 000	7 500	–	L	–
1977	25 000	–	3 000	L	–
1977	–	10 000	–	M§	1.78
1978	19 000	–	7 350	M	2.26
1979	3 600	–	7 240	L	–
1979	–	10 000	–	A	3.47
1980	–	–	–	–	22.55

* No fish.
† Landlocked stock.
‡ Anadromous stock.
§ Mixed stock.

Windbag. Two-year-old fish, exclusively precocious males, are absent from only 2 years' data and comprise a substantial percentage of the sample in 6 of the 11 years, 4-year-olds exceed 20% in only 2 years, and 5-year-olds appear once during the trapping period.

Hatchery returns

The amount of ova collected from such a limited number of spawning salmon, of which usually less than one-third are female, has not been large. Ova counts from 25 females from 3 years have ranged between 510 and 850 eggs per female, and there have been recurrent difficulties with attempts to hold "green" females for later collection of their ova. The quantity of ova collected has varied from nil in some years to a maximum of 23 000 in 1977. In trying to further increase stocks, the liberation of smolts or fingerlings has been augmented with anadromous fish (Table 4).

Liberated smolts or fingerlings have been marked either by removal of the left or right pelvic fin or by attachment of an external tag on a wire loop, immediately forward of the dorsal fin.

Returns from these liberations were first identified in the 1977 spawning run when three salmon, 1.78% of the total recorded, entered the trap. In 1978 another three fish, 2.26% of the total, entered the trap and the following year five, comprising 3.47% of the total, were recorded. Although the 1980 trapping figures are less reliable than in earlier years, because of a change of trap site and facility, 13 hatchery salmon were identified, representing 29.55% of the total recorded. These hatchery fish were exclusively 2-year-old males in 1977 and 1978, four 2-year-old males and one 3-year-old female in 1979, and ten 2-year-old males and three 3-year-old females in 1980.

Future objectives

It is the opinion of many resident anglers that landlocked salmon in Lake Wakatipu provided an appreciably higher level of sport in the past than in recent years, and field observations of anglers' catches tend to support this. This fish apparently concentrates in schools for much of its life in the lake, travels extensively in its feeding forays, and is easily taken by inexperienced threadline fishermen who in many cases are holiday visitors to Central Otago and are unfamiliar with the more productive fishing locations and times.

Figure 3 shows a quite regular cycle in the salmon contribution to the anglers' catch, but an overall

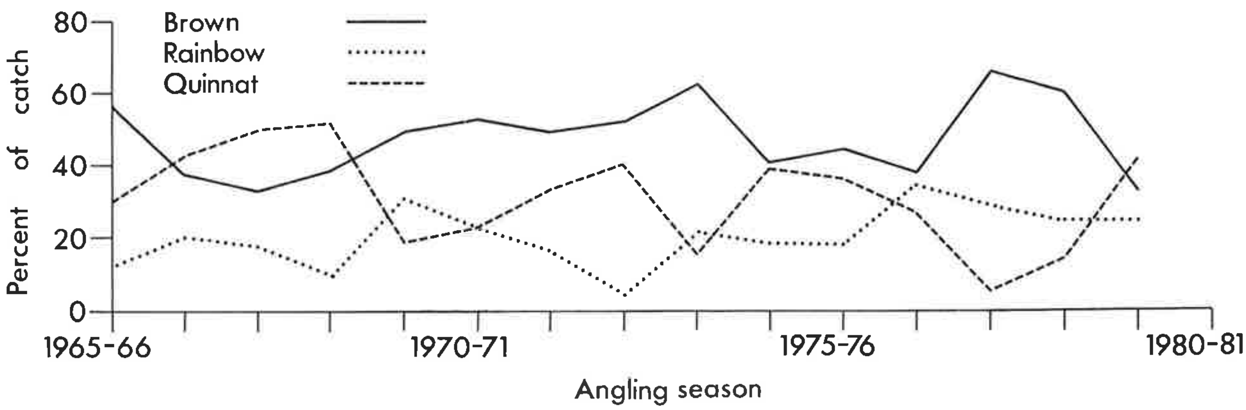

Fig. 3: Anglers' catch of brown and rainbow trout and quinnat salmon in Lake Wakatipu, 1965–80.

declining trend with both peaks and troughs reaching progressively lower levels over the period covered by the data.

The primary objective of the Wildlife Service work on this fish is to return stocks to their former abundance in the anglers' catch, and if possible, to maintain their position at this level. To help achieve this, the long popular and rewarding practice of fishing the spawning runs into Diamond Creek has been prohibited since 1976, and attempts to collect ova for hatchery propagation have ceased.

Diamond Creek was used as a spawning area by migrant anadromous salmon before completion of the Roxburgh dam and, in many respects, it is physically similar to other important spawning waters such as the Glenariffe Stream, Hydra Waters, and Deep Stream in the Rakaia and Rangitata catchments. It has, however, suffered modification as a result of progressive farm development in its catchment. This has eliminated the valuable stream bank cover of native plants and shrubs and caused a loss of spawning gravels through progressive invasion by aquatic plants and subsequent siltation. Although benefiting from the smoothing effect that Lakes Diamond and Reid have had on flood discharges, Diamond Creek is a relatively large waterway and does not offer juvenile salmon habitat of high quality. Consideration has recently been given to improving the habitat for salmon fry, both in stream and along the stream banks, but flood-induced changes to the creek channel at its confluence with the Rees River have recently raised doubts about our ability to carry on effective monitoring of the annual spawning run.

Landlocked salmon stocks of the Clutha lakes will not be increased quickly by the collection of a proportion of their ova for hatchery incubation and cultivation, at least while the spawning runs remain so small. Supplementary releases of smolts and yearlings from anadromous sources, however, may well be justified.

Discussion

Dr McDowall: Do you have any idea of the proportion of the fish returning to The Windbag that are landlocked or partially landlocked, and of those that are sea run?

Mr Hutchinson: On scale character? Mr Flain has published a table in *Freshwater Catch* which shows the length of time spent in fresh water.

Mr Waugh: I seem to recall a variation in the average size of the fish that came back. Is there any link between this and the fish that have spent 2–3 years in fresh water before migrating to the sea?

Hutchinson: The landlocked fish are included in the data that will be published.

Waugh: So you can tell that if you get small fish back, they've been in fresh water for a long time. Have you linked this up so that when you have a run of small fish back, you can tell if a large percentage of them spent a long time in fresh water?

Mr Flain: There are insufficient data. The data have only been supplied for the last 3 years.

Hutchinson: We're relying on carcass recovery, and the flood-prone nature of the catchment often precludes 100% recovery. If The Windbag floods and we have to lower the trap, many carcasses will be lost down stream.

Mr Tonkin: Why bother with Atlantic salmon when you could concentrate on brown trout?

Hutchinson: Atlantic salmon are easily caught by anglers, and the uneducated angler, if we can use that term, benefits greatly by having these fish in his region. The brown trout could never match this.

A review of Atlantic salmon in New Zealand, with notes on current status and management

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THIS paper reviews the introduction and establishment of Atlantic salmon (*Salmo salar*) in New Zealand. The life history and past and present population management of this now rare species are also discussed.

Summary of introductions

1868 to 1907. In the 40 years up to 1907 at least 23 different importations, totalling nearly 3 million Atlantic salmon ova, were made to New Zealand (Thomson 1922). Most of these eggs came from anadromous salmon entering British rivers. Others came from Germany and Canada. Fry were released throughout much of the country, though most were put out in Southland and Otago. These releases were all unsuccessful, though various reports suggested that the fry grew in fresh water and migrated seawards.

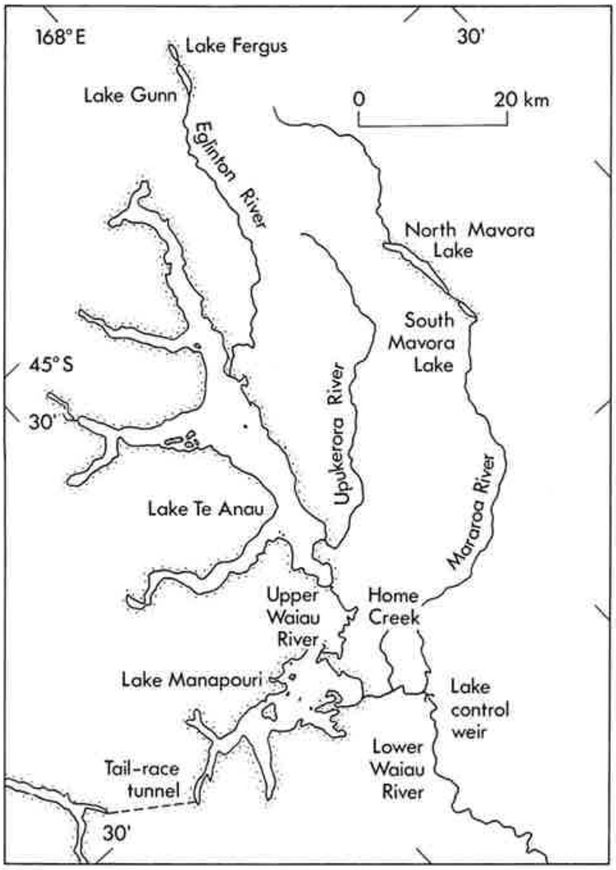

Fig. 1: The upper Waiau River catchment.

The only recorded importation of landlocked salmon was 10 000 ova from Green Lake, Maine, United States in 1905 (Donne 1927). These fish were originally destined for Lake Te Anau, but most were lost into the Makarewa River when the Wallacetown hatchery was flooded. Some reports claim that about 100 surviving fry may have been released in Lake Te Anau (Thomson 1922, Godby 1925); others assert that no fry ever reached the lake (Southland Anglers' Club 1929) or that the fate of the remaining fry is unknown (Stock 1928, Stokell 1955). Ayson (1910) brought these eggs to New Zealand, and his account differs substantially from the others. He states on page 973 that "A number of the young fish have been planted in one of our lakes, and some are now being reared at two hatcheries for the purpose of procuring eggs from them when they mature." This is not substantiated by any other authority and there are no records of the hatchery operations to which he refers.

1908 to 1911. The early attempts had failed and so the New Zealand Marine Department embarked on a programme to import large numbers of anadromous-stock ova and concentrate the releases of fry in the upper Waiau River catchment, which had previously not been stocked (Fig. 1). Between 1908 and 1911, 150 000 ova came from Canada, 940 000 from Germany, and 1 075 000 from Britain. From these ova about 1 872 000 fry were stocked in the Upukerora River and Lake Te Anau (Ayson 1908, 1909, Thomson 1922, Hefford 1927b, and *Marine Department Annual Report for 1910–11*). Survivors of some of these fish were undoubtedly the ancestors of today's population.

Establishment

There is little information on the period from 1912 to 1921. However, a spent male salmon was caught in the lower Waiau River in October 1916. It was 68.5 cm long and had spawned three times; so it must have been at least 6 years old, and was possibly 7 or 8 years old (Godby 1925, Regan 1927, Stock 1928). In 1922 some 50–100 salmon were caught in Lake Te Anau and in the Upukerora and Eglinton Rivers

(Calderwood 1927, and *Marine Department Annual Report for 1922–23*). The Marine Department first trapped in the Upukerora River in 1923 and caught 160 salmon. By the 1930s the species was considered well established in Lakes Manapouri and Te Anau, and in the Waiau, Upukerora, and Eglinton Rivers (Pearce 1928, Southland Anglers' Club 1929, Hefford 1930, Hobbs c. 1950, and *Marine Department Annual Report for 1923–24*).

Because of their unusual appearance, freshwater feeding habits, and indefinite scale structure, there was much controversy over the origin and identity of the salmon in the Waiau system. Some authors claimed the fish were normal sea-run salmon (Whitney 1927a); others contended that they were hybrids between salmon and brown trout (Godby 1925). However, the evidence clearly showed that, whatever their origin, the fish were true *Salmo salar* that had adopted a wholly freshwater existence and migrated from the lakes to the tributary rivers to spawn (Regan 1927, Calderwood 1927, Hefford 1927a, Parrott 1932, Stokell 1934, 1955, 1959).

Stokell (1959) compared morphological and meristic characters and argued that the Atlantic salmon in New Zealand are descended from anadromous stock, not from American or Canadian landlocked fish. His view was shared by Calderwood (1927). It is not known which of the anadromous stocks (British, German, or Canadian), or indeed any combination of them, actually produced the New Zealand population. In the 1960s there was an attempt to identify the origin of the Te Anau fish by determining their chromosome number. The attempt was unsuccessful because of technical problems (D. Scott pers. comm.). It has been stated that North American salmon are more likely to produce lake-resident populations than are European stock. Therefore, the 1908 importation of Canadian eggs may have been the progenitor of the salmon in the Waiau catchment (Godby 1925, D. Scott pers. comm.).

It is not known why Atlantic salmon failed to develop anadromous runs in New Zealand, yet voluntarily assumed the much less common land-locked habit. It appears that some fish did at least reach tidal waters and there is one report of a salmon caught in the Wairaurahiri River which enters the sea 30 km south-west of the Waiau River mouth (Hefford 1927a, 1927b).

Whitney (1927b) proposed that excessive predation by marine fish and mammals led to the landlocked life history. Stokell's (1955) theory was that factors inherited from the original landlocked stock prevented successful adaptation to marine life. The more tenable hypotheses relate to physical and morphological oceanic features which, singly or in combination, may minimise the chances of salmon surviving and finding their way back to the southern New Zealand coastline. Several authors argued that because of the relatively low latitude of New Zealand, winter ocean temperatures are too high, or at least borderline, compared with those found in the natural range of salmon in the Northern Hemisphere (Rutherfurd 1900, Regan 1927, Anon. 1929, Stokell 1955). However, Thomson (1922) claimed that in all seasons the sea temperature off the east and south coasts of the South Island is lower than that round Britain or the west coast of Norway.

Scott (1959, 1960) proposed that because young salmon from British rivers make long off-shore migrations, and the mechanism controlling their return to the natal waters evolved in the Northern Hemisphere, it is likely that fish imported into New Zealand would become disoriented in the open ocean and be unable to find their way back to this country. He contrasted this with the success in New Zealand of sea-run brown trout, which are believed to confine their marine life largely to coastal waters.

This idea was developed further by Stewart (1977), who described the failure to establish Atlantic salmon in the Falkland Islands. These islands are in a more suitable latitude than New Zealand and also have successfully established sea-run brown trout. Stewart argued that long-distance marine migrations of salmon are fairly passive and are controlled by rotational oceanic currents, or gyres, which result from the presence of large integrated land masses. A salmon smolt entering a gyre off its home coast eventually circulates back to that coast when physiological changes induced by the onset of maturity activate the mechanism to recognise its imprinted home-river odour. Straying or loss occurs when a fish leaves or transfers to another gyre and either arrives at a foreign coast or is transported to a lethal temperature regime. Stewart proposed that suitable gyres do not develop close to the small land masses of New Zealand or the Falkland Islands, and thus the salmon are lost at sea.

Biology and life history

The life history of Atlantic salmon in New Zealand is poorly documented and imperfectly understood. Various fragmentary accounts cover some details, but much remains to be determined. I have summarised the main details below.

Spawning. The general form of mature salmon in the Te Anau population is similar to that of grilse from sea-run populations. The body is slender and somewhat cylindrical with an elongated caudal peduncle and a moderately forked tail. Females become darker than in their lake-dwelling stages and males develop a bronze tinge and a kype on the lower

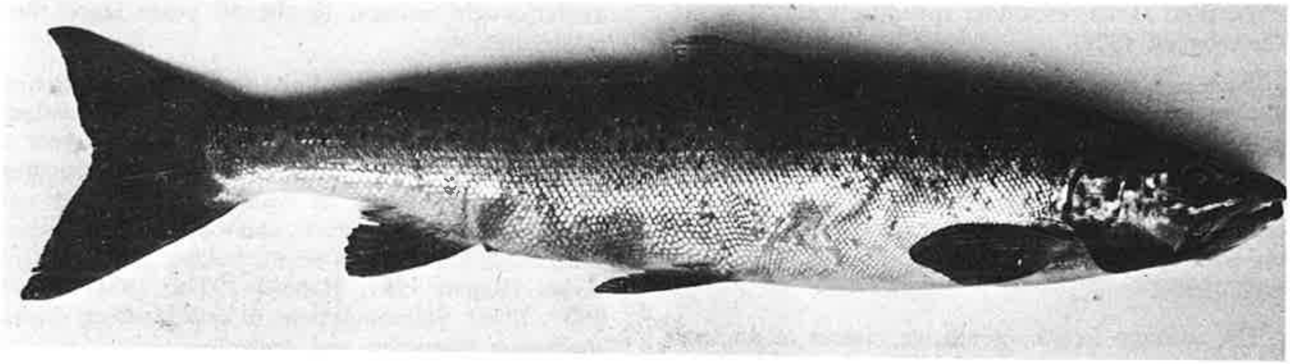

Fig. 2: A mature hatchery-reared (released at 16 months) male Atlantic salmon, 4 years old, 525 mm fork length.

jaw (Fig. 2). The dark red coloration that is typical of mature sea-run males has only rarely been observed in New Zealand salmon (Hefford 1938).

Redds are similar in site, size, and construction to those of brown trout (*Marine Department Annual Report for 1938–39*, and my unpublished data).

The peak spawning runs in the Upukerora River between 1932 and 1944 (Table 1) occurred in May and June, and rarely in April (McIvor 1950a, and *Marine Department Annual Reports*). In recent years (1976–80) I have seen salmon occupying redds in the outlets of Lakes Gunn and Fergus from 22 June to 14 July.

The male to female ratio of 5226 adult salmon recorded from the Upukerora trap between 1923 and 1944 was 1:1.16 (*Marine Department Annual Reports*). The sex ratio of 14 fish I caught in 1979 and 1980 at Lake Gunn was 1:1.

Stripped eggs, incubated at 9.5°C, were eyed at 31 days and hatched between 39 and 44 days after fertilisation (D. J. Murphy pers. comm.).

Of 21 mature fish examined in the 1920s, 30%–40% had first spawned at 4 years of age and about 20%–25% each at 3 and 5 years (Calderwood 1927). Thirteen salmon of known age were caught at Lake Gunn in 1979 and 1980. These fish were spawning for the first time. Three were 3 years old and 10 were 4 years old (my unpublished data).

Multiple spawning by Atlantic salmon is not uncommon. In the 1920s and 1930s scales were examined from 49 previously spawned fish caught by anglers. Of these, 57% had spawned once, 31% twice, 8% three times, and 4% showed evidence of five spawnings (Calderwood 1927, Parrott 1932).

Rearing and growth. After emergence, salmon fry spend varying periods as parr in the river before migrating to the lake where they undergo further growth before maturity. A summary of data from Calderwood (1927) and Parrott (1932) is shown in Table 2. Two-year-old smolts predominate, followed by 1- and 3-year-olds, with small numbers of 4- and 5-year-olds. Stokell (1934) suggests that some fish may enter the lake at about 6 months old. The largest parr migrate earliest, though the average length at migration increases with smolt age. One-year-old smolts averaged 130 mm in length, 2-year-olds were 175 mm, and 3-year-olds were 300 mm. The youngest smolts grow fastest during their first year in the lake and they appear to maintain this length advantage throughout their life (Parrott 1932). Regardless of smolt age, about 75% of salmon spend 2 years in the lake before their first spawning, with equal

TABLE 1: Monthly runs of Atlantic salmon recorded in the Upukerora trap, 1932–44; (data from Annual Reports, N.Z. Marine Department and McIvor 1950a)

Year	Period trapped	Month							Total
		Mar	Apr	May	Jun	Jul	Aug	Sep	
1932	Apr–Aug		6	45	100	22	23		196
1934	29 Apr–end Jul		7	4	28	5			44
1935	Mar–Aug	4	29	175	45	48	6		307
1936	10 Mar–2 Sep	37	117	158	102	81	12	1	508
1937	20 Mar–30 Jul	9	62	75	15	13			174
1939	13 Apr–31 Jul		180	50	60	65			355
1940	16 Apr–Jun		87	173	35				295
1941	early May–27 Aug			114	6	2	7		129
1942	May–Aug			108	52	62	43		265
1943	late Apr–Aug		0	67	42	5	5		119
1944	24 Apr–Aug		9	65	137	25	11		247
Monthly total		50	497	1 034	622	328	107	1	2 639
Percent of total		2	19	39	23	12	4	0.03	

proportions of the remainder spending 1 and 3 years (Calderwood 1927).

There are many estimates of the average size of salmon caught by anglers in the early years after establishment, but few have sufficient detail or precision to be accepted as representative samples of the exploited populations at the time (Table 3). The two heaviest salmon recorded from the Upukerora trap were 6.81 kg in 1932 and 6.13 kg in 1935 (Hefford 1933, 1936).

The average length of all age classes of angler-caught salmon recorded in the 1920s and 1930s was 60.4 cm (Calderwood 1927, Parrott 1932). Between 1947 and 1962 the average length was 52.8 cm (Graynoth 1971). An examination of age classes assigned by Calderwood and Parrott (Table 4) shows that though there was a trend towards increasing length with age, the average lengths suggest considerable overlap in size between different age classes. A sample of twenty-nine 4-year-old salmon from the 1920s–1930s group had an average length of 59.4 cm. Four 4-year-old fish from Lake Gunn in 1974 had an average length of 47.8 cm, and in 1980, ten 4-year-old fish from this same water averaged 49.25 cm (Wildlife Service unpublished data). In general, there appears to have been a gradual reduction in the size of angler-caught salmon in the 60 years since their establishment.

Food and feeding. I can find no information on the food of salmon parr and smolts in local waters. Published descriptions of the stomach contents of angler-caught salmon in the 1920s and 1930s suggest that they fed mainly on aquatic insect larvae and adults, some terrestrial arthropods, and small indigenous fish such as smelt, bullies, galaxiids, and elvers (Regan 1927, Hefford 1927a, 1931, Stokell 1934, 1955). Salmon appear to cease feeding during up-stream migration and spawning.

Competition and predation. There are many opinions on the effects of competition and predation on Atlantic salmon by other fish species such as brown trout, rainbow trout, and eels (Youl quoted by Thomson 1922, Calderwood 1927, Hefford 1935, 1939, Hobbs c.1950, McIvor 1950a, 1950b, Stokell 1955, Scott 1960, 1961a). Most authors have expressed fears of the competitive advantage of brown trout over salmon, though the establishment of late-spawning rainbow trout in Lake Te Anau in the 1930s has been cited as a possible cause in the decline of salmon by the superimposition of redds. It should be noted that salmon were acclimatised in the presence of an existing brown trout population, whereas

TABLE 2: Age at lakeward migration (smolting) of angler- caught Atlantic salmon from the upper Waiau River system (determined from scale readings)

	Age at smolting (years)						
	1	2	3	4	5	Total	Source
No. of fish	9	19	9	5	1	43	Calderwood (1927)
No. of fish	15	23	4	0	0	42	Parrott (1932)
Total	28	42	13	51	85		
Percent of total	28	49	15	6	1		

TABLE 3: Maximum and average sizes of angler-caught Atlantic salmon from the upper Waiau River catchment, 1923–80

Period	No. of fish	Comments	Average length (cm)	Average weight (kg)	Maximum weight (kg)	Source
1923	–*		–	3.63†	6.36	Calderwood (1927)
1925–26	316		–	2.54	–	Stokell (1959)
about 1926	49		–	2.95	4.99	Calderwood (1927)
about 1927	–		–	–	7.72	Pearce (1928)
1927	–		–	2.27–3.63†	–	SAS‡ (1928)
1934	70	immature	–	1.63	–	Stokell (1934, 1959)
1934	44	mature	–	2.45	–	Stokell (1934, 1959)
1934	114	combined	–	1.91	–	Stokell (1934, 1959)
1935	–		–	1.59–2.27†	–	SAS (1936)
1940	29	selected sample	–	2.25	5.45	MD§ (1941)
1940	–	season average	–	1.82†	–	MD (1941)
1951–53	10	Lake Manapouri	–	1.36	–	Stokell (1955, 1959)
1947–62	76	Lake Te Anau	52.8	1.77	–	Graynoth (1971)
1962–63	10	Lake Manapouri	50.8	1.02	–	WS‖ (1965)
1974	5	Lake Gunn	49.6	1.21	1.70	WS (1974)
1976–80	7	all waters	43.9	0.70 (n=6)	0.95	WS (1976–80)

*No data available.
†Estimated.
‡Annual Reports, Southland Acclimatisation Society.
§Annual Reports, N.Z. Marine Department.
‖Wildlife Service unpublished data.

TABLE 4: Average length of angler-caught Atlantic salmon in each age class from the upper Waiau River catchment (data calculated from Calderwood (1927) and Parrott (1932))

	Source					
	Calderwood		Parrott		Combined	
Age (years)	No. of fish	Average length (cm)	No. of fish	Average length (cm)	No. of fish	Average length (cm)
2	1	61.0	2	50.5	3	54.0
3	5	70.1	17	52.6	22	56.6
4	11	64.6	18	56.3	29	59.4
5	11	66.0	4	61.9	15	64.9
6	4	64.0	0		4	64.0
7	3	72.8	0		3	72.8
8	1	70.0	0		1	70.0
	36	66.5	41	55.0	77	60.4

rainbow trout did not appear until some 15 or 20 years later. Rainbow trout apparently showed an early upsurge in the catchment, at one time reputedly dominating spawning runs in the Upukerora River (Hobbs c.1950), but this is not so now (see below).

Interpretation of the relationships between the three salmonid species is further complicated because brown trout and salmon were heavily exploited for ova collection until 1944, and it is apparent that this greatly affected their numbers.

There is no published information on the effects of eels on salmon, but my limited observations suggest that up to 20% of adult salmon in Lake Gunn have scars from eel attacks.

Management and exploitation

Ova collection. When the existence of a salmon run in the Upukerora River was confirmed the fish were exploited for ova collection. A trap was established by the Marine Department, and between 1923 and 1944 (when trapping was discontinued) 5226 salmon were caught. These fish, with a few from the Eglinton River, produced about 8 124 000 ova, of which 46% (3 724 200) were "exported" from the catchment, 3.5% were used to stock down-stream tributaries, and 48% were stocked, mainly as fry, in the Te Anau catchment. However, over half the total ova collected was taken before 1930, and 94% of this was stocked outside Te Anau (*Marine Department Annual Reports* from 1924 to 1945, and *Southland Acclimatisation Society Annual Reports* from 1927 to 1940). (See Appendixes 1 and 2.)

The Upukerora trap was not an efficient structure because of its design and the proneness of the river to flooding and so varying numbers of trout and salmon escaped past it in most years, or spawned down stream (Hefford 1935, and *Marine Department Annual Report for 1938–39*). Therefore some natural recruitment to the salmon population probably always occurred. In addition, smaller numbers of salmon spawned virtually unimpeded by man in the upper Waiau and Eglinton Rivers, though limited and sporadic ova collection (totalling about 171 000 eggs) took place in the Eglinton.

Perhaps of greatest importance, though, was that, concurrent with salmon trapping, many millions of brown trout ova were taken from the Upukerora River run to stock other Southland waters. This had a significant effect in reducing the runs of brown trout and was recognised by affected agencies (Hobbs c.1950, McIvor 1950a, 1950b, and *Southland Acclimatisation Society Annual Report* for 1940). Further evidence of this effect can be seen from the trapping results for the period 1962 to 1969, which followed some 17 years without abstraction of trout or salmon ova (Fig. 3). The average annual run of brown trout recorded in

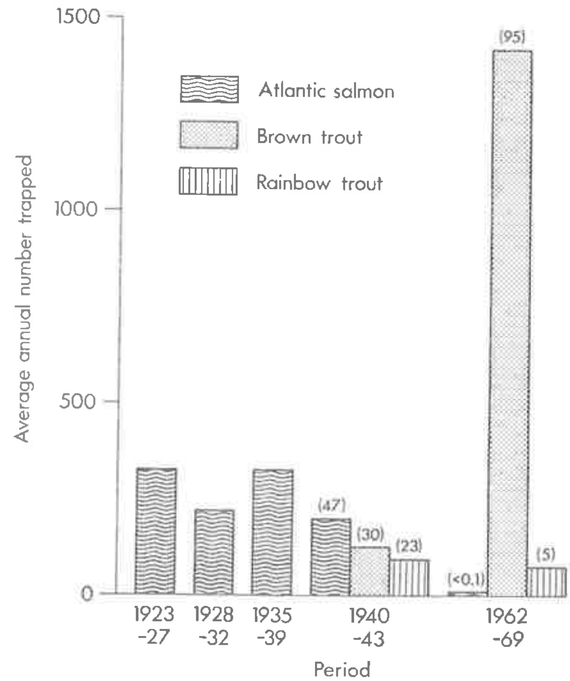

Fig. 3: Numbers and proportions of salmonids recorded from the Upukerora trap, 1923–69. Numbers in parentheses are the percentages of each species in the run for the period. (Data from McIvor (1950a), *Marine Department Annual Reports*, and Wildlife Service (unpublished).)

the trap from 1940 to 1943 (April to August) was 132, whereas between 1962 and 1969 it was 1447. Between the same two periods the average runs of rainbow trout dropped from 98 to 70 and the salmon declined from an average of 202 to 1 fish per year (McIvor 1950a, Wildlife Service unpublished data). Note that in Fig. 3 there are no data for trout numbers before 1940. Data for all species for 1933, 1934, 1938, and 1963 are not included because of inadequate or nil trapping effort. Significant stocking of salmon fry began in 1929 and continued until 1944.

Angling. Atlantic salmon are generally regarded as fairly easy to catch by conventional angling techniques, and overexploitation by anglers may have been a contributing factor in the decline of the species (Hefford 1930, 1931, Hobbs c.1950). Therefore restrictive regulations were imposed in the early 1930s to control daily catch, methods, and fishing areas. The effect of these restrictions on total salmon numbers is not documented.

Estimates (of unknown reliability) of the annual anglers' catch of salmon are available for most years between 1922 and 1935 (Table 5). The average catch is about 300–800 fish, with a peak of 1000–1200 in 1929 (*Marine Department Annual Reports*). Comments on angling success between 1937 and 1944 (*Marine Department Annual Reports*) suggest little overall change during that period. Graynoth (1971) analysed anglers' diaries and rangers' creel checks for 11 seasons from 1947 to 1967 and estimated the annual average catch to be 1500 salmon. However, he notes (page 10) that "Few Atlantic salmon have been recorded in recent years". Over this period his data show that salmon accounted for 12% of the total catch in Lake Te Anau and the Waiau River. The only recent comparable records, covering six seasons between 1972 and 1980, show that salmon now account for about 1% of the catch in these two waters (Wildlife Service unpublished data).

TABLE 5: Estimated annual numbers of Atlantic salmon caught by anglers from the upper Waiau River catchment, 1922–67

Period	Estimated annual catch	Source
1922–23	56	Marine Department*
1923–24	300	Marine Department*
1924–25	considerable increase	Marine Department*
1925–26	700	Marine Department*
1926–27	700–800	Hefford (1927b)
1927–28	700–800	Marine Department*
1928–29	1000	Marine Department*
1929–30	1000–1200	Hefford (1930)
1930–31	300–400	Hefford (1931)
1931–32	300–400	Hefford (1932)
1932–33	300–400	Southland Acclimatisation Society*
1933–34	disappointing	Marine Department*
1934–35	150	Hefford (1935)
1935–36	300–400	Southland Acclimatisation Society*
1937–38	fair	Hefford (1938)
1938–39	improved	Hefford (1939)
1939–40	good	Marine Department*
1940–41	fair, at least 184	Marine Department*
1941–42	improved	Marine Department*
1942–43	better than average	Marine Department*
1943–44	fair	Marine Department*
1944–45	poor	Marine Department*
1947–67	1500	Graynoth (1971)

*Data from annual reports for the years concerned.

Management before 1965. Apart from the extensive ova collection and distribution before 1930, there have been several attempts to transplant salmon stocks from Te Anau to other waters or to import further ova from Europe.

In 1927 and 1928, some 30 000 fry were released in South Mavora Lake in the upper Mararoa River (*Southland Acclimatisation Society Annual Reports* for 1928 and 1929). Several hundred thousand fry and ova were stocked in this river between 1924 and at least 1930. Two releases, each of 40 000 fry, were made in Lake Coleridge in 1928 and 1931. Salmon from the first release were caught until the end of 1932, and though the scales provided some evidence of spawning, the species did not establish (Hefford 1931, 1932, Stokell 1934). A release of 6700 fry into the tributaries of Lake Wakatipu in 1931 was not successful (*Southland Acclimatisation Society Annual Report* for 1932).

In an attempt to establish a strain of sea-run salmon that did not migrate far from the coast, a few ova were imported from Scotland (1960), Sweden (1961), and Poland (1965) by the Southland Acclimatisation Society and stocked in the Waiau and upper Oreti catchments. It was intended to do cross breeding experiments between these strains and Te Anau fish, but because of various difficulties the project was abandoned (Scott 1959, 1960, 1961b, *Southland Acclimatisation Society Annual Reports* for 1960 and 1965).

Management after 1965. The Wildlife Service, which had taken over management of the Southern Lakes district in 1945, became increasingly concerned at the continuing drastic decline in the salmon stocks which was apparent from the early 1960s. The species has value as a potential angling resource, as it is not particularly difficult to catch by traditional methods and is highly regarded as a game fish. It had comprised a significant proportion of the anglers' catch for almost 40 years. With the restriction on further importations of salmonids because of disease risks, it is most unlikely that fresh supplies of salmon could be brought into the country. Even if this debatable move were taken, there would be no assurance of a repetition of the combination of factors which caused the unusual, entirely freshwater-dwelling population that we now have. We believe that we have a responsibility to do all we can to prevent the extinction of the species in New Zealand

and, if possible, to expand and enhance the existing stock for further use.

With the resurgence of brown trout after the cessation of trapping came the almost complete failure of the main salmon spawning run in the Upukerora River (McIvor 1950b, Hutchinson 1975). Significant, but also diminishing, numbers spawned in the upper Waiau River, but it is likely that this source of recruitment to Lake Te Anau has been eliminated by the up-stream migration barrier of the control structure installed at the lake outlet as part of the Manapouri power development scheme. The altered rates and seasonal patterns of flow that resulted from the operation of the control gates have, at times, seriously affected trout and salmon spawning beds in the river. In one recent season, an estimated 80% of redds in the river were lost because of low winter flows (my unpublished data). The Lake Manapouri control structure on the lower Waiau River has almost certainly precluded the very unlikely future establishment of a sea-run population of salmon in the Waiau system.

The earliest efforts in this period were directed at establishing Atlantic salmon in an otherwise salmonid-free lake to maintain an additional population for future stocking purposes if the species was eliminated from the Waiau catchment. A few ova were obtained from the Upukerora in July 1965, and in October 1966, 400 yearlings were released in Lake Douglas, a small upland lake in the Okuru catchment of South Westland. Later checks, up to 1974, produced no evidence of survival from this release. On two other occasions in the late 1960s a few ova were stripped from salmon at Te Anau. However, these were all of poor quality and produced few fish (Hutchinson 1975, Wildlife Service unpublished data).

Attention then turned to Lakes Gunn (1.67 km^2) and Fergus (0.42 km^2) in the upper Eglinton valley. These two lakes apparently provided a more suitable habitat than either Te Anau or Manapouri, and despite some evidence of a drop in numbers, more salmon had lasted in these lakes than elsewhere in the system. Lake Fergus is connected to Lake Gunn by a short outflow about 500 m long. This is the only stream spawning area for salmon and brown and rainbow trout from Lake Fergus, though some may spawn on shingle slides and in small stream mouths round the shore line. The maximum recorded outflow is about 600 l per second, though the stream often dries up in late winter as the lake level falls. Consequently, spawning success may be very limited or restricted to wet years. As well as the outlet from Lake Fergus, Lake Gunn has one other major tributary, the Melita Stream. This is accessible to trout and salmon for about 200 m, though it is an unstable stream of limited spawning value. The Eglinton River is the permanent outflow of Lake Gunn (Fig. 4) and has an average flow of about 2500 l per second and a maximum flow of over 5500 l per second. The upper 800 m of this stream is stable and provides good spawning facilities which are used by brown trout, rainbow trout, and salmon. Large eels are common in this stretch.

In 1974 adult salmon were taken from Lake Gunn in an attempt to provide brood-stock. Twenty-nine salmon were caught by netting and trolling, but the fish were extremely susceptible to injury during handling and transporting, and only 10 reached Wanaka hatchery alive (Hutchinson 1975). Efforts to obtain fertile ova from these fish have been unsuccessful, and in 1976 further attempts were made to find a source of ova from wild spawning fish in the upper Eglinton River. In August of that year some 1200 eyed eggs were removed from a salmon redd in the outlet of Lake Fergus and hatched at Wanaka. These fish have grown well, and from those retained for brood-stock, 95 000 eggs were taken in 1979 and

Fig. 4: A typical spawning habitat in the Eglinton River 300 m below Lake Gunn. Flow rate about 2000 l per second.

94 000 in 1980. Eight hundred 16-month-old fin-clipped salmon, reared from the 1976 eggs, were released in Lakes Gunn and Fergus in January 1978. Three of these were recaught while spawning in 1979, and 10 more were recaught in 1980. This shows a minimum of 1.6% survival to maturity for the release. It is possible that other fish may have spawned undetected, and that others may mature in 1981 or later.

The outlets of Lakes Gunn and Fergus are the only areas where salmon spawning is known to still occur. Numbers of wild spawning salmon seen in these two streams in the last 5 years have varied from five to none, and it is probable that the population has fallen below the compensation level and recruitment no longer exceeds mortality.

Over this same 5-year period, there were proposals to reduce the effects of competition and predation on the juvenile stages of salmon. Attempts were made to remove brown and rainbow trout from Lake Gunn by use of live-trap nets, but the steep shore line limited success. In 1976 there was a trial removal of large eels from the main spawning area in the outlet. However, approval to continue this relocation was refused by the National Parks Authority, who administer most of the Te Anau - Manapouri catchment through the Fiordland National Park Board. It was hoped that a long-term reduction in trout numbers could be achieved by installing a velocity barrier in the river below Lake Gunn, followed by intensive netting of the trout population in the lakes. Unfortunately the National Parks Authority also declined our request to build this structure. It was obviously impractical to continue to remove trout from the lake when both adults and juveniles could be readily recruited from down stream, and so this approach has been virtually abandoned.

There has been some criticism of the assumption that the most vulnerable stage of a salmon's life occurs in its first year, and also of our resulting proposals and attempts to minimise competition and predation in the stream rearing habitats. However, the success of the limited release of yearlings in 1978 suggests that the assumption may be correct, and that if survival can be assured for the first year of life, the fish has a good chance of reaching maturity unaided. This implies that hatchery rearing and release may be the most suitable management technique.

The National Parks Authority and the Fiordland National Park Board were reluctant to support any "long-term manipulation" of Lakes Gunn and Fergus for the protection of Atlantic salmon and it became obvious that a change of emphasis was required in our management policy. We now intend to build up the population in these two lakes in the short term by intensive stocking. This will provide a recreational angling resource and a reasonably assured supply of wild-reared fish for the future. Efforts will be directed at obtaining further wild fish to supplement the genetic material of the existing brood-stock. As larger supplies of young fish become available it is intended to begin releases in the Upukerora River and Home Creek (a lower Waiau River tributary) to increase the seriously depleted populations in Lakes Te Anau and Manapouri.

In the long term, we envisage establishing salmon outside the national park, both to avoid some of the management problems currently experienced and, by spreading the stock, to minimise the possibility of the species becoming extinct in this country.

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Appendix 1

Records of Atlantic salmon trapping and ova collection in Upukerora and Eglinton Rivers, 1923–44; (data from McIvor 1950a, and annual reports of the Marine Department and the Southland Acclimatisation Society).

Year	Trapping period		No. of salmon trapped			No. of ova collected	Comments
	Start	Stop	Male	Female	Total		
Upukerora River							
1923	–*	–	83	77	160	637 000	
1924	–	18 Sep	53	76	129	454 000	many floods
1925	13 Apr	21 Aug	244	283	527	936 500	good weather
1926	–	–	204	224	428	612 000	several floods
1927	–	–	200	211	411	659 000	many floods
1928	13 Apr	–	75	136	211	396 000	many floods
1929	23 Mar	7 Aug	58	171	229	374 000	about 300 fish bypassed trap
1930	10 Apr	22 Aug	169	86	255	240 000	dry winter
1931	24 Mar	10 Aug	82	145	227	330 500	5 floods
1932	Apr	Aug	106	90	196	325 000	no floods after April
1933	31 May	Jun	4	9	13	13 000	many floods, trapping abandoned
1933	–	Aug	–	–	–	165 000	Southland Acclimatisation Society trap
1934	29 Apr	Jul	19	25	44	44 000	severe floods, trap out 15–31 May
1935	–	–	170	137	307	271 000	3 floods, many fish lost
1936	11 Mar	2 Sep	219	289	508	422 000	many females not stripped
1937	20 Mar	30 Jul	65	109	174	208 000	
1938	–	–	0	0	0	3 500	no trapping
1939	13 Apr	31 Jul	113	242	355	707 500	good season
1940	16 Apr	Jun	149	146	295	401 500	
1941	Apr	27 Aug	63	68	131	144 000	many fish bypassed trap
1942	May	Aug	151	114	265	210 000	early fish bypassed trap
1943†	Apr	Jul	72	42	114	101 000	some spawning below trap
1944	24 Apr	Aug	115	132	247	299 250	
			2 414	2 812	5 226	7 953 750	
Eglinton River							
1927	Jul	–	–	–	–	45 000	
1931	–	–	–	–	about 100	67 000	
1933	–	Aug	–	–	–	55 000	
1935	–	–	–	–	–	4 000	
					171 000		

* Data not available.
† McIvor (1950a) records 119 salmon for this season.

Appendix 2

Stocking records of Atlantic salmon, 1923–44 (blank spaces denote no fish or ova stocked).

	Waters stocked				
	Te Anau tributaries		Down-stream Waiau tributaries		Outside Waiau system
Year	Fry	Yearlings	Ova	Fry	Ova
1923					637 000
1924			8 000		454 000
1925	62 500		100 000		774 000
1926	30 000				580 000
1927			15 000	42 000	632 000
1928				15 000	367 000
1929	145 000				210 000
1930	101 000			90 500	
1931	342 300				48 700
1932	311 500				
1933	193 000				
1934	10 000				21 500
1935	275 000				
1936	422 000				
1937	208 000				
1939	700 000	3 222			
1940	401 000	5 393			
1941	139 000				
1942	180 000				
1943	93 000	7 000			
1944	299 000	7 149			
Sub-totals	3 912 300	22 764	123 000	147 500	3 724 200
			270 500		
Totals	3 935 064		3 994 700		

Discussion

Unknown: The river gravel shown in one of your slides looks very fine. The area may be all right for spawning and for rearing under-yearlings and yearlings, but it represents a bad wintering habitat.

Mr Gibbs: In that particular stretch the gravel is very fine because it is the protected outlet of Lake Gunn and is free from the effects of flooding. However, further down stream the nature of the river changes quite rapidly as more of its tributaries feed into it. It then becomes a more typical surface run-off type of river, with larger stones and some boulders.

Mr Graynoth: I did some work on the diet of landlocked Atlantic salmon in the upper Clutha lakes and I noticed in the literature of overseas works that the adult fish seem to feed almost exclusively on smelt. You mention their food type from previous studies, but do you think their reduced numbers could be due to a decline of smelt?

Gibbs: There is no real evidence that there has been a decline of smelt in the Te Anau area. In dietary studies on local salmon there has been no distinction of capture sites, or where the samples were taken from. Some of the fish could have come from the upper Waiau River, which may account for the high percentage of benthic insect larvae and adults. Stokell's study of gut contents is the origin of a lot of the data, but again, with no idea of where the fish came from, quantification of the results is impossible. But certainly they do feed on smelts, bullies, galaxiids, and, at least in one case, elvers.

Swimming behaviour of adult *Oncorhynchus* from growing ground to spawning ground

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IN the genus *Oncorhynchus* there are several well-known species such as cherry salmon (*Oncorhynchus masou*), red salmon (*O. nerka*), quinnat salmon (*O. tshawytscha*), silver salmon (*O. kisutch*), dog salmon (*O. keta*), and pink salmon (*O. gorbuscha*). There are also Amago salmon (*O. rhodurus*) and Biwa salmon (*O. rhodurus* var.), which may be considered as one species or as two individual species. Amago salmon is found only in Honshu, the main island of Japan, and Biwa salmon is a special breed from Lake Biwa near Kyoto, Japan.

Now we will describe, mainly from the ecological point of view, the findings of our investigation into these seven species. This will concern the swimming behaviour of the adult salmon from the growing ground to the spawning ground.

Swimming distance

Having investigated the distances between the spawning grounds and growing grounds of the seven species, we found the following:

- For Amago salmon, the growing ground and spawning ground are either the same or very near;
- For cherry salmon, some have growing and spawning grounds which are near, but others are more distant. The range of distance is large;
- For silver and quinnat salmon, the growing and spawning grounds are distant, but not as widely separated as those of red salmon, dog salmon, and pink salmon;
- For red, dog, and pink salmon, the distance between their growing and spawning grounds is the greatest of all.

Homing of *Oncorhynchus*

It is generally accepted that salmon home on their spawning ground, but some, like Amago, spawn where they were spawned or very near by. In the strict sense, they cannot be said to have a homing migration. Landlocked salmon are similar to Amago salmon in this respect. We consider they have a potential inherent tendency towards homing, which can adapt itself to the environment.

Homing of adult fish on their spawning ground is not peculiar to *Oncorhynchus*, but is also seen in many other fish. Many species of littoral fish spawn and grow on the same ground. We think that, originally, fish hatched and grew on the same ground, but to cope with the diversity and peculiarity of the ocean, their hatching ground and growing ground became separated. To adapt to this, the behaviour of homing migration was formed. We think it quite natural that there are some species that still observe the old behaviour, but they have the homing migration instinct.

Homing motivation theory

Homing, especially a very long-distance homing migration, can be regarded as one of the highest grades of differentiation in fish. When salmon swim from the growing ground to the spawning ground, they have vast areas of ocean to cross. What do salmon use as their compass in swimming across these seas? One explanation of homing is the theory of the mystic element, but we do not accept this. There is also the theory of the olfactory sense, which suggests that salmon swim from distant seas to the spawning grounds by use of a keen sense of smell. Many experiments have proved that salmon swim from the sea at the river mouths to the spawning grounds by use of their olfactory sense, but we have no evidence that they use this sense to get from the open sea to the river mouths. Another theory suggests that salmon perceive the position of the sun and use this as a compass while homing. Again, there is no proof of the relationship between the light of the sun and the swimming behaviour of salmon in the ocean.

Migration under the control of currents

We have a different theory from those above. The general behaviour of salmon in the sea is greatly affected by the sea's physical structure; that is, the ocean currents and their resultant fronts and convergences. In short, our theory is that the swimming behaviour of salmon in the sea is controlled by the currents.

A current is made up of water masses, and water masses stream in vortices. It may be difficult for salmon to know the direction of the vortices themselves because there are many turbulent flows within them, but the salmon can take their orientation parallel to the general trend of these turbulent flows. The organs used in doing this are Mauthner's cell of the medulla and the acoustico-lateral organ. In an experiment in a water tank, fish which had their eyesight removed drifted about like plankton. However, when they were engulfed in man-made turbulent flows, the blind fish orientated themselves horizontally parallel to the main stream. Mauthner's cell plays a part in this type of orientation (Dr K. Uchihashi's work in 1960).

It is fairly well known that when two water masses form a front the distribution of the temperature in this region controls the behaviour of salmon. Because of this, we believe that if there was no relationship between the currents at two distant points, there could not be any homing migration between these points. Another important fact is that when salmon live on the bottom of the continental shelf, they take their orientation from the ridge of the sea bottom. It is also assumed that they take their orientation alongside the main trend of water, which is also controlled by ridges.

With respect to what we have just mentioned, we have recently found an interesting fact. Since 1973 the Chileans have been stocking the rivers of latitude 45° S every year with 100 to 200 million dog salmon (*Oncorhynchus keta*) fry spawned in Japan. No fish are said to have homed yet.* When we compare this with the acclimatisation of salmon in New Zealand, there are important differences between them. Firstly, dog salmon is of a higher grade of ecological differentiation than quinnat salmon and is never found in a landlocked form. It is a typical pelagic fish in the open sea and its homing distance is very long. Secondly, the Humboldt Current flows north along the west coast of Chile and nearly reaches the Galapagos Islands. From there it flows west, becomes the South Equatorial Current, and then is finally scattered (Fig. 1). It cannot possibly be expected that homing dog salmon will be orientated and carried by this scattered remnant of current back to the coast of Chile.

On the other hand, the quinnat salmon of New Zealand is a fish whose ecological differentiation is of a medium grade. It is thought to live quite near, or on, the bottom of the sea, and the oceanographic structure of off-shore New Zealand differs from that of Chile. Off the New Zealand coast there is the Southland Current, the Southland Front, and, in the north, the Subtropical Surface Water (Fig. 2). This oceanographic structure exists far to the east off the Canterbury Bight and forms a type of fence. As a result, the homing migration of New Zealand salmon seems to have been kept, and the salmon resources have been maintained even though on a small scale. This is probably because the homing behaviour and the actual conditions of the off-shore current, which we think may seldom be found, are well harmonised with each other.

Aims of our research

We now think that there are several reasons for the acclimatising success of quinnat salmon in New Zealand. Quinnat salmon has a low ecological differentiation, and from the beginning of naturalisation in the lakes of New Zealand its seasonal periodicity adjusted fully to the conditions in the Southern Hemisphere. Besides this, it has the habit of living on the sea bottom and around the east coast of the South Island. It is thought that the oceanographic features there (mentioned above) produce a water mass different from that in the open sea. This is based on supposition and so there is a need for more research. We understand that the Fisheries Research Division of the New Zealand Ministry of Agriculture and Fisheries is doing such research at present.

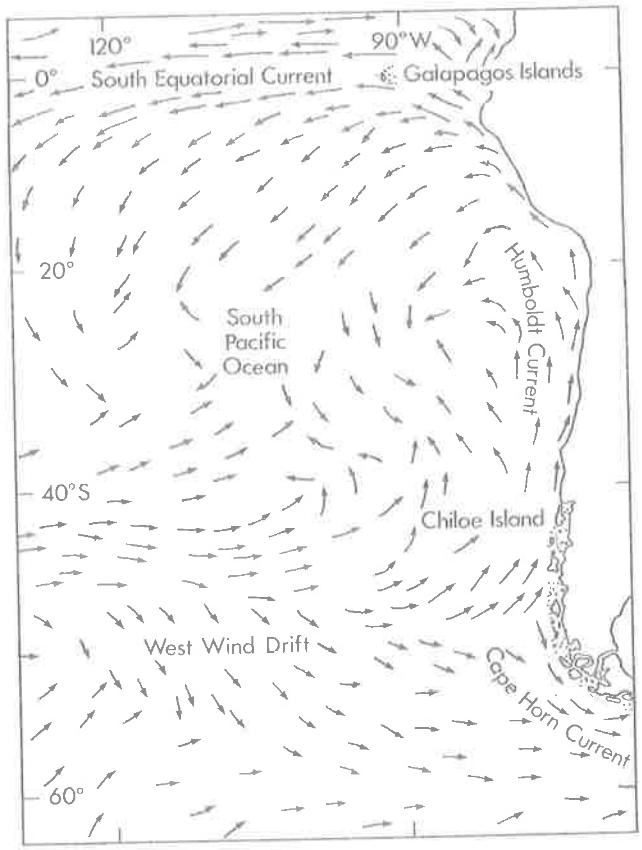

Fig. 1: Pattern of surface currents off the west coast of South America (Gorshkov 1976).

*In the February 1980 issue of *Fishing News International*, an American firm was reported to have made a delayed release of 260 000 chinook (quinnat) salmon and 35 000 coho (silver) salmon smolts near Chiloe Island, Chile. After the release, quinnat salmon began to home from the end of 1979. It was reported that 150 salmon came home during December 1979. This was their first return to Chile, and it may be explained by the fact that quinnat salmon belong to a species of ecologically low differentiation. Their littoral behaviour probably appeared and they did not swim far enough to be engulfed by the Humboldt Current.

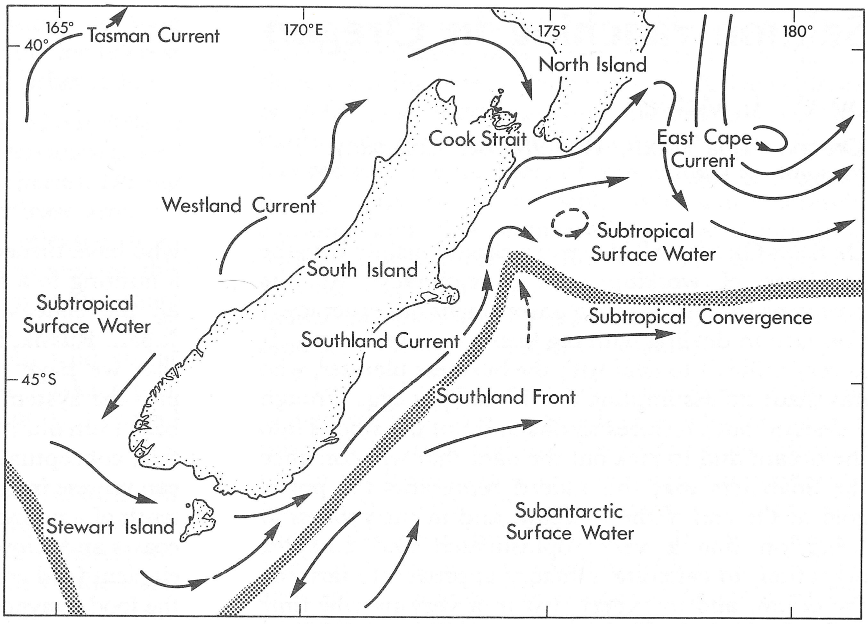

Fig. 2: Pattern of currents and zones of convergence round the South Island of New Zealand (Heath 1973).

The following are subjects which we are investigating;

- We are trying to analyse mathematically the swimming behaviour of the fry and smolts of quinnat salmon and other species of *Oncorhynchus*;
- We are trying to establish the relationship between the salmon's behaviour and artificial lesion of each part of its brain. This is done by laser rays;
- We are researching bottom living behaviour and swimming behaviour from the viewpoint of the morphology of the central nervous system;
- We are investigating the relationship between the salmon's ecological movements and the microchemical substances in its living conditions.

In 1958 a Canadian biologist, Dr F. Neave, advanced a new theory that *Oncorhynchus* had evolved from *Salmo* as a result of the topographical changes in the Japan Sea. But we have already mentioned several species that have not yet been differentiated ecologically and are distributed around the Japan Sea. It was a salmon of medium ecological differentiation that was successfully acclimatised in New Zealand. Dog salmon, on the other hand, is a species with a high grade of ecological differentiation which has not been successfully acclimatised in Chile. We think that the homing migration of salmon is a specialised, high grade behaviour which has been formed by adapting to the peculiar character of the ocean and that it may be difficult for salmon to conform to an oceanographic structure of a different type. However, for salmon with non-differentiated behaviour, it is easy to conform, but difficult to produce huge resources.

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Salmon ranching in Oregon

by W. J. McNeil

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DR KEES GROOT will give you a candid insight into the problems of working with bureaucracy. All the problems that he has with government bureaucracy, I also face in dealing with big business bureaucracy. It is very difficult to deal with the business planner, who has made an assumption that he can put eggs through a system that produces smolts and put the smolts into the ocean; and to pick out the data that will convince the financiers that this indeed represents the pot of gold at the end of the rainbow; and in the process to bring on line a very sophisticated and complex operation, to generate a factory approach to farming the ocean, and to expect that in a very narrow time frame it is going to be profitable. Then a biologist comes along and suggests that we face one minor problem that we have not yet solved: we haven't yet learned how to make paper eggs hatch. The bureaucrats tend to disregard your advice and move ahead anyway and so you are placed in the position of trying to make the system work.

I want to take a few moments to comment on what I think I see developing here in New Zealand. At this symposium you are coping with change. How do you allocate the water resource among various economic demands? There is also change occurring in the marine environment, not necessarily of an ecological nature, but from a political standpoint the great changes have occurred in the marine food-producing system. After the Second World War there was a great deal of interest in expanding the animal protein food base of humanity by turning to the ocean. Many speculative estimates were made that we could solve our food shortage by turning to the ocean. Some countries have succeeded in some measure in doing this. In the United States we went through a period of rapid expansion of ocean fisheries. About 1969 we hit a level of about 70 million metric tons of animal protein being harvested. In 1980 we are still at that level, with no appreciable increase over the decade. A natural response is to reallocate the fishing effort. We have been through that now, and presumably it has also happened in New Zealand. Many countries have a 200-mile conservation limit around their coastlines. But just because we reallocate our harvesting does not necessarily mean we are increasing the ocean's productivity.

We are on the threshold of another major change. We see good evidence of this in countries like Japan, who have turned to aquaculture. We are shifting from a hunting to a farming philosophy. With the salmon, all the endeavour that we see in Alaska, Canada, Japan, Russia, and elsewhere relates to a recognition that we have to bring more intensive management into the system, if we are going to increase our food base from our marine waters. The salmon are ideal for this, conceptually. We have several species which we can release from a thousandth of a pound (0.45 g) to a tenth of a pound (45 g) at a particular point along our coasts and allow them to range at sea. They are fairly efficient food converters, and when they have finished the food conversion, we don't even have to chase them home; they swim right back to the point of harvest. This is the dream that drives us, as we attempt to bring these technologies on line.

I would like to mention a publication that will be coming out shortly from the Oregon State University Press. We really don't have a full understanding of salmon. Two years ago we held a symposium in Oregon, called "Salmonid Ecosystems of the North Pacific" and the results of that symposium are just now being published.

I'll turn now to the Oregon situation. At Weyerhauser we have many years ahead of us before we can refine our programme and make it economically viable. A number of problems have faced us early on. One is that we had a prespawning mortality that was unacceptably high, and we have not yet learned how to solve that problem completely. Another is that with the fish that we have matured and spawned in salt water, the egg viability has not been acceptable. We are now trucking the adults to our freshwater site at Springfield for maturation.

In 1971 the Oregon legislature passed a law allowing salmon ranchers to release chum salmon to sea. An amendment in 1973 added coho and quinnat. The number of smolts authorised for release by private salmon ranching firms includes 100 million chum, 38 million coho, and 42 million quinnat. Actual numbers so far released are below these figures and will probably remain so for some years because of scarcity of brood-stock. In time, if salmon ranchers can achieve the authorised levels, about two-thirds of salmon smolts from Oregon hatcheries will probably come from the private sector.

Private salmon hatcheries are required by law to release fish directly into the sea or into estuaries, and so returning fish make little contribution to river fisheries. However, they are all available for harvest by both recreational and commercial fishermen.

From unpublished data it seems that about 80% of coho salmon caught by American recreational and commercial fishermen come from hatcheries. During the period 1960–77 there was an increase from 14 million to 88 million coho smolts released from hatcheries on the Pacific coast. The harvest of this species also increased substantially over the same period, and the commercial harvest now is 50% higher than it was in the 1930s when wild stocks contributed most of the fish caught. In Alaska, where the fishery is still supported by wild stocks, the trend is downward.

On the Pacific north-west coast, from California to Alaska, public hatcheries released 217 million quinnat salmon in 1977. Because of such large releases, the commercial catch is higher today than in the past. Attainment of authorised levels of release by private hatcheries in Oregon would increase releases of quinnat smolts by about 20% of the number released in 1977 by the United States and Canada.

In 1978 public hatcheries in Oregon released 72 million smolts. A small increase is expected over the next few years, but the private hatchery programme could release 180 million smolts, a 358% increase (with the public sector) over 1978 numbers. This raises the question of whether the ocean can support these great increases. There is no conclusive evidence of density-dependent growth and mortality in the marine environment. On top of this, intensive fishing has reduced the numbers of competitors, and ocean-rearing capacity is probably well above present stocking rates. The biomass of potential competition with salmon is probably 10+ times greater than the biomass of salmon and it is unlikely that the increased salmon numbers will have a measurable effect on the production of other finfish competitors.

There are some problems concerned with the management of salmon populations which contain a mix of wild stock and hatchery-based stock. Because egg to smolt survival is so much higher in hatcheries than in the wild, wild populations are much more easily damaged by overfishing. If the manager attempts to conserve a dwindling wild stock, surpluses arise in populations returning to hatcheries. The public hatcheries then face the problem of disposing of this surplus, perhaps by selling the fish. Private salmon ranching offers the opportunity of utilising hatchery fish without the public sector entering the market. At the same time they contribute to a commercial and recreational fishery, and so reduce the requirement for large-scale release of salmon smolts by state-owned hatcheries.

Discussion

Unknown: I have two questions. Of the fingerlings or smolts that you release, what percentage do you get back and what do you expect to get back? The second question is, if you had been able to raise them right from fry at one site and release them, what would be the differential in terms of what you might have got back?

Dr McNeil: In reply to your first question, with coho we have achieved about 0.5% return back to the facilities. Within this average, we have had as high as 2% return and as low as zero. What we need for profitability is something like 2% return in coho on the assumption that we are a coho orientated programme. Once we are successful in bringing quinnat into the picture, I think the overall rate of return can be reduced, because the quinnat is a much more valuable fish. I expect we could be profitable with quinnat at 0.5% return. There is some suggestion that we are approaching that with the limited quantity of quinnat we have put into the sea. For chum salmon, I would expect that even less than 0.5% return from the ocean would be profitable. The question of whether we would achieve better productivity by putting the system on the coast is academic, because we don't have fresh water on the coast which could support our programme. We had to go inland to find a stream that would provide enough fresh water.

Mr Flain: Could we look in more detail at your mechanics of imprinting?

McNeil: All I can say is that it appears to be working in the case of coho and quinnat salmon. We just put the fish in the saltwater ponds and hold them for 10 days and they appear to be homing quite precisely.

Flain: At what stage do you put the fish in the ponds?

McNeil: As smolts, physiologically competent to go to salt water. The coho are roughly 20–25 g, the quinnat 30–40 g.

Mr Waugh: You showed the percentages of the returns in relation to the distance from your facility. Can you tell us what percentage of those returns was represented by recaptures? Do you think you contributed to the commercial fishery?

McNeil: It varies. Last year it appears that for every fish we got back, one went to the existing fishery. In other years the ratio has gone as high as three to four fish in the fishery for one back to us.

Unknown: Of the fish that you took to the coastal release site, did many of them go back up the original river?

McNeil: We've not seen any of them back up the original river and I don't expect to. The state has been looking rather carefully for evidence of straying.

Unknown: Is the 10-day period when you have them in the saltwater ponds scientifically accepted as an adequate method of giving them the proper homing instinct?

McNeil: The evidence I've seen would suggest that the imprinting probably occurs in a matter of hours. The reason we hold them for 10 days is that they go through a lot of stress and it takes them about 5 days to overcome the symptoms of this stress. Then we hold them another 5 days to get a little extra size on them. We have tested fish by holding for 2 days versus 21 days, and we can't see any real difference in homing response.

Mr Lightfoot: Have you any indication from your returns as to how they are affected by commercial sea fishermen?

McNeil: I think the returns are going to be of great benefit to them, but our greatest critics are the commercial fishermen. They feel threatened. We are farmers and they believe we represent the first major step to do them out of their livelihood.

Methods of commercial salmon propagation in the United States

by R. E. Burrows

Salmon culturist,
Washington State, U.S.A.

THE objectives of commercial salmon hatcheries differ significantly from those of public hatcheries. Publicly operated hatcheries are trying to make as many fish as possible available to the sports and commercial fisherman, with only enough escaping to maintain the adult run. The commercial operator, on the other hand, desires as great a return to the release site as possible, retaining only enough adults to ensure an adequate egg supply and harvesting the remainder. It is the harvest that makes commercial operations feasible and profitable.

Because of the different objectives, commercial and public hatcheries are sited differently. To secure prime fish for market, the commercial hatchery return site is on or near salt water and as inaccessible to the commercial and sports fishery as possible.

Oregon, the only state in the United States that allows private hatcheries to market returning adults for profit, requires that all releases of smolts be made in salt water. Two methods are used to meet this requirement: in the first, the fish are reared and released at the same site; in the second, they are reared at an inland site, where adequate freshwater is available, and trucked to a release and recovery site.

Problems of rearing methods

In the first method, where the fish are reared and released at and return to the same site, the problem is to find adequate fresh water for early rearing and, at the same site, salt water which will not be overexploited by commercial and sports fishermen. It has been demonstrated that fishermen in the United States take at least 50% of the adult salmon populations in the ocean and an additional 40% in the bays, estuaries, and rivers, which leaves only 10% to escape up stream to hatcheries. The ideal site is on a cove into which a small stream empties; less desirable would be a large bay or estuary to which fishermen have easy access. The use of rivers is precluded by Oregon law.

The second method, where the fish are reared at one site with adequate fresh water and trucked as smolts to a release and recovery site, presents additional problems. The location of the release-recovery site should be similar to that of the single-site hatchery with, preferably, a freshwater supply sufficient to support the adult brood-stock during maturation. The distance between the freshwater and saltwater sites should be short enough to make transport practicable. The freshwater hatchery should have adequate water temperatures to induce rapid growth and the water supply should have a low disease incidence.

Both of these methods are used by private hatcheries in Oregon.

Single-site hatcheries

There is only one single-site hatchery, which is on a small saltwater cove into which a small freshwater creek flows. Both fresh and salt water are available for rearing. During autumn, winter, and spring from 500 to 8000 gallons per minute (0.03 to 0.5 m^3/s) of fresh water are available for incubation and rearing. The hatchery has a capacity of 7 million eggs and the ten 75- by 17-ft (23- by 5-m) ponds and four 200- by 25-ft (61- by 7.5-m) ponds provide a release capacity of 5 million smolts. The hatchery and small ponds have a recycling system for reconditioning both salt and fresh water, either separately or in combination. The four large ponds are supplied with either fresh or salt water or a combination of both. The saltwater pumps have a capacity of 50 ft^3/s (1.4 m^3/s), supplying each of the large ponds with 12.5 ft^3/s (0.35 m^3/s).

The large ponds are both fingerling rearing and adult holding ponds. The fish ladder has a trap for the capture of harvest fish and the sorting of adults for brood-stock. During adult holding, the large ponds may be supplied with fresh water while salt water as attraction may be discharged through the ladder. The freshwater supply to the recycling system used for early rearing is equipped with ultraviolet disinfection and filtration.

The adult chinook salmon trapped at the head of the fish ladder are either harvested or held for brood-stock. The brood-stock are retained in a large holding pond with a diffused water inlet and pens for sorting and holding mature fish. Spawning occurs in November and December. The eggs and fry are incubated in vertical incubators and placed in the small rearing ponds as first-feeding fingerlings. Early rearing is in fresh water which is gradually changed to one-third salt water. When the fish reach a weight of 1 g (450 fish per pound) the large ponds are stocked with 4 million of them. As they grow the percentage of salt water is increased until at 90 fish per pound almost the entire flow is salt water. As pond capacities are reached fish are released, with a final release of 2.7 million, at 10 fish per pound, in the middle of September.

Double-site hatcheries

Several companies are running double-site hatcheries. The largest has built a 40-million-capacity inland hatchery for the release of coho and chinook salmon at two release and recovery sites on saltwater bays. At present the work is confined principally to coho salmon.

The freshwater hatchery is supplied by river water which has been heated and disinfected and is used as a single-pass system. The eggs and fry are incubated in pond incubators of the Washington type and the fish are reared in 100- by 20-ft (30.5- by 6-m) ponds. Growth is accelerated by warm water until the coho are smolt size at 6 months instead of 18 months. At 20 to 30 per pound the fish are trucked to the release-recovery sites and placed in saltwater ponds. They are held for 10 days to 2 weeks for imprinting and then released into the large bay. Adults return to the bay and ascend the fish ladder, which is discharging straight salt water, and are sorted for harvest or brood-stock retention. Experience has demonstrated that the coho salmon do not mature normally in salt water and a high mortality develops in the eggs and fry. To circumvent this, the adults reserved for brood-stock are trucked to another freshwater holding site for maturation and spawning.

Hatchery site requirements

Both single-site and double-site methods have advantages. Once built, the single-site hatchery is cheaper to run, but single sites suitable for optimum operation are difficult to find. The requirements for an ideal site are as follows:

- The saltwater intake should preferably be on an ocean cove with no extensive saltwater estuary. Salmon are subject to a bacterial infection (*Vibrio anguillarum*) which is particularly virulent in brackish water at 10‰–15‰ salinity. Straight salt water at 30‰ is not conducive to the development of vibriosis. A vaccine has been developed to immunise smolts before saltwater release, but this treatment is expensive at about $10 per thousand fish. Our experience has been that chinook salmon held at 30‰ salinity in rapid interchange ponds do not develop vibriosis.
- The freshwater supply should be adequate to meet incubation and early rearing requirements. During later stages or rearing, chinook salmon may be converted to straight salt water. A recycling system may be developed to augment the freshwater flow during early rearing if necessary.
- The freshwater supply should be sufficient to maintain adult brood-stock during incubation.
- The hatchery site should be reasonably flat so that pond and hatchery layout can be developed at minimum expense.
- The hatchery site should be within normal ocean range of adult salmon.

The size of the hatchery is determined by the quantity and quality of the water supply, the area available, the capital investment, and the number and size of the fish to be produced. The private hatchery is not judged by the number of fish released, but by the number of returning adults. Generally, the larger the fish at time of release, the greater the number of adult returns. Fish averaging 90 per pound (5 g) at release produce a minimum return. Increases in fish size result in increases in the survival rate. For example, comparable chinook fingerlings released at the same time at 25 per pound (18 g) and 90 per pound (5 g) returned 17 times as many adults from the larger size. With chinook salmon, the aim is to produce as many 10-per-pound (45-g) migrants as the hatchery will support. Increased efficiency may be obtained by stocking for a 50-per-pound (9-g) capacity and releasing at 50 per pound and 25 per pound as the capacity is exceeded.

Some compromises may be necessary if all requirements for an ideal hatchery location cannot be met at any particular site. Such compromises have resulted in double-site hatcheries, estuary locations, and increased operating costs. Generally, increased construction costs to exploit an optimum location will result in reduced operating costs and increased adult returns.

Diseases in salmon hatcheries

by N. C. Boustead

Technician, Fisheries Research Division, Ministry of Agriculture and Fisheries, Wellington

MUCH attention has been focused on whirling disease lately, and so I propose to tell you about several other diseases that we have seen in salmon in New Zealand. I shall also discuss some diseases that may affect salmon, but are not known in New Zealand, and some concepts that are being applied to managing diseases.

Fisheries Research Division has been operating a disease diagnostic service since 1973. From then until now we have received over 400 submissions and enquiries from individuals, societies, and government and private hatcheries. As well as salmon and trout, these submissions have included eels, freshwater crayfish, and marine fish. They include both wild and hatchery fish and we make no distinction between whether the fish are from private hatcheries or sports fishing hatcheries. We do place more emphasis on hatchery fish because this is where we can do the most good. We can also obtain samples of moribund or dying fish from hatcheries and these are the best for examination. Fish from the wild are often preserved in a manner unsuitable for further examination or have suffered some post-mortem changes that make determination of the cause of death difficult. This diagnostic service and some of the research at Fisheries Research Division have provided us with a fairly good idea of what diseases of salmon we have and what we can expect.

When we receive samples for examination the behaviour and appearance of the fish only give us some idea of what to look for. To identify a particular fish disease it is almost always necessary to get a firm identification of the organism causing the disease. For example, we have received from both the North and South Islands a number of salmon and trout with skeletal deformities, which could be caused by any of the following: vitamin deficiency, congenital defects, physical damage, electric fishing, infection with tail rot, or whirling disease. Clearly, therefore, any fish with skeletal defects does not necessarily have whirling disease. It is also important to realise that a fish can have a disease with no outward sign of a problem until it dies.

The point I am stressing here is the importance of identifying the disease organism causing the problem. It is not possible merely to look at fish in a hatchery and declare that they have not got, or are not carrying, certain diseases.

Diseases identified in New Zealand salmon

The most common disease we have seen in quinnat salmon is **bacterial gill disease.** We have also seen this in trout culture, but quinnat are much more susceptible. The disease has appeared each year over the last few years in government, society, and private hatcheries. It is also quite common in salmon culture in the United States.

Bacterial gill disease is characterised by a build-up of large numbers of bacteria on the gill surfaces. These bacteria were formerly called Myxobacteria and are now referred to as Cytophaga. The overwhelming numbers, combined with the hyperplasia they cause, lead to smothering of the gills.

The name bacterial gill disease is something of a misnomer, as these bacteria are considered a symptom or consequence of the true cause. Experiments with the bacteria alone have not been able to reproduce the disease. Crowding and physical or chemical irritation of the gills are believed to be the real causes of the problem. Particularly dusty feed or dirty water with a lot of particulate matter can predispose the fish to infection.

How large are the losses from bacterial gill disease? The documented cases we have put losses at less than 4% in a raceway culture. Without treatment it may have caused more severe losses. Treatment can be carried out with Diquat, Cetrimide, or the drug Furanace. Keeping fish at lower stocking densities can help prevent the disease and an experienced person can recognise the onset of the disease by changes in the behaviour of the fish. Prompt treatment at this time can keep losses to a minimum. Some facilities in the United States and Canada are using potassium permanganate, but the margin for error is small with this chemical.

Another problem in salmon hatcheries is **sunburn** or **backpeel** (Fig. 1). This occurred when fish were held over summer and in some instances the tissue damage allowed the fungus *Saprolegnia* to invade the wound. Salmon can be predisposed towards sunburn if the diet is deficient in the vitamin niacin or contaminated with phenothiazine. In the case quoted above the sunburn was due to photosensitivity of the fish and prolonged fine weather in the area.

Sunburn can be prevented by providing shade. At the Idaho Department of Fish and Game Hatchery at McCall this has been done by building an entire roof

Fig. 1: A quinnat salmon severely affected by sunburn. Skin and scale layers have eroded away to expose the underlying tissue.

over the rearing ponds. At Rapid River floating wooden rafts offer shade. Garden water sprinklers are used extensively above raceways to break up the light and protect the fish from being disturbed (Fig. 2). These devices are primarily to provide shade and shelter for adult salmon which are being held for long periods before egg take. They do increase adult survival and could also be effective against sunburn.

Another disease we have seen is **coagulated yolk.** This is a disease of yolk-sac fry. It is characterised by the presence of white coagulation within the yolk and can lead to the death of the fry. The cause has been attributed to a variety of different characteristics, including water quality and temperature changes, but has not been satisfactorily explained.

Some recent work by Joe Banks at the Abernathy Salmon Culture Development Center in the United States has shown that losses from coagulated yolk have been reduced substantially (70%–80% reduction) by use of an artificial substrate such as a $\frac{3}{4}$-inch (2-cm) plastic netting which is inserted into the Heath trays. This method is under further evaluation at other hatcheries in North America.

Our records of diseases in salmon show only one other problem. This was in 1973 and caused losses of 16% of salmon being raised. It was attributed to a deficiency of the vitamin thiamine. No similar losses have been seen since.

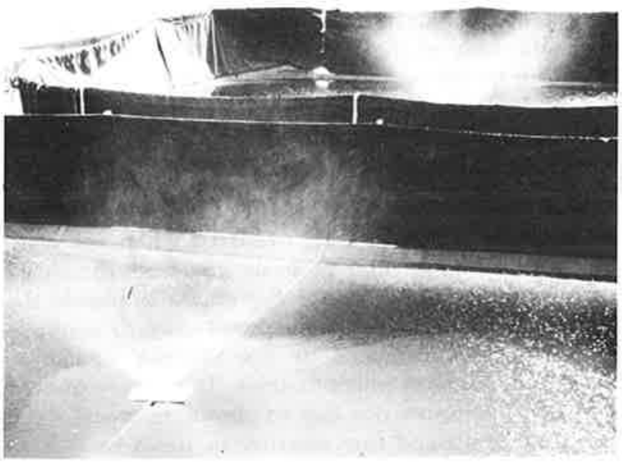

Fig. 2: Domestic garden water sprinklers being used to provide shade and shelter for salmon brood-stock held over summer in ponds.

These are the only diseases we have found in salmon culture. Only one (bacterial gill disease) is infectious, and total losses have been minimal; flooding has caused much greater damage.

Potential diseases

There are organisms in other species of fish in New Zealand which have the potential to produce disease in salmon. One example is **whirling disease**, though the only occasion of which I am aware where salmon have been infected with whirling disease is in some experiments done in Pennsylvania by Joseph O'Grodnick. He has found that Atlantic, sockeye, and quinnat salmon were infected with whirling disease when exposed under certain conditions; that is, when exposed to the disease as 30-day-old fry. As fish become older they become more resistant to the disease. Salmon appear to have a greater natural resistance than rainbow trout.

Another potential disease is **columnaris**, which is related to bacterial gill disease, but causes gill erosion. It occurs here in eels, but it is known to affect salmon in the United States. It does not cause major problems in hatcheries.

Ich or **white spot** is also found on eels and on a wide range of other fish, including salmon and trout. Other external parasites, including *Trichodina, Chilodonella,* and monogenean flukes, have been seen in New Zealand on various fish. In a flow-through raceway they are unlikely to cause problems, but in recirculating ponds or where water is reused, and in warmer waters, their numbers can build up and kill fish. There should be no major problems in well-managed and well-designed fish culture facilities.

A quinnat salmon caught at sea off Wanganui showed a large lesion (12 by 7 cm) behind the vent. It had other similar lesions about the fins, vertebrae, and operculum. This salmon was gutted and had been frozen and thawed several times before we received it and so it was not suitable for further examination. I would emphasise that this has been seen only once in one fish.

Diseases known in the United States

I must emphasise that we have not seen any of the following diseases in New Zealand.

Bacterial kidney disease (BKD) affects smolts and also returning adults and their progeny (Fig. 3). It is not present in all hatcheries, but can cause significant losses.

Dr G. W. Klontz has recently found that injection of adults with the drug Erythromycin 200 has

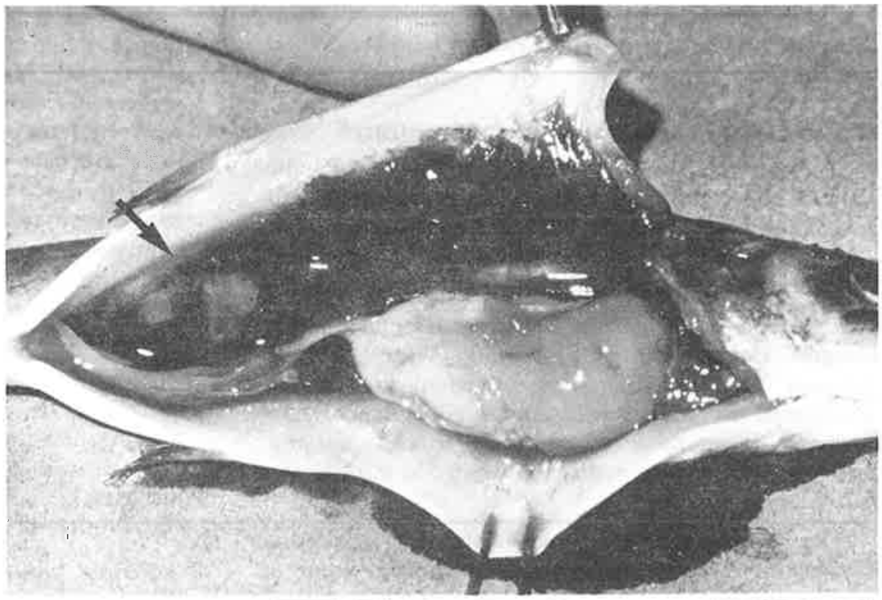

Fig. 3: A juvenile coho salmon showing gross signs of bacterial kidney disease. The arrow indicates the enlarged grey lesion in the kidney.

eliminated gross signs of BKD in adults and progeny. The drug is injected into a particular cavity in the muscle next to the dorsal fin (Fig. 4) and appears to be successful in treating BKD. However, the fish can be damaged by handling or if the injection is not in the correct place.

Furunculosis, another bacterial disease, is not known in New Zealand. It can cause ulceration and haemorrhaging on the skin surface of salmon, but it can also cause death with no outward signs of the disease.

One of the papers given at the American Fisheries Society Fish Health Meeting in 1980 by T. Trust described an atypical form of furunculosis in goldfish in Australia. It was believed to have been imported on ornamental fish from Japan. Though the disease was similar to furunculosis, it was not identical.

Another group of fish diseases is caused by the **fish viruses.** There have been no substantiated cases of viral diseases from New Zealand fish. However, nobody has really gone out and looked for them. Many fish diseases, including those caused by the fish viruses, can be present in fish populations without causing mortality.

With the amount of fish culture done in New Zealand by government and acclimatisation societies, I believe that if some of the more common viral diseases of salmon and trout were present, we would be aware of them. We can say now that we have not seen any of the fish viral diseases. We need to keep in mind that there has been a rapid growth in fish virology internationally and there are at least 17 different fish viruses isolated and 15 others known. New viruses are still being found; for example, Dr Kimura has recently isolated a new herpes virus from cherry salmon in Japan.

Fig. 4: Injection of quinnat salmon brood-stock at McKenzie Hatchery in Oregon.

I have summarised a few of the more significant diseases. Further information can be found in Wood (1979).

Effect of fish diseases on salmon culture

Diseases are present in hatcheries along the Pacific coast of North America, and yet salmon culture is still successfully practised. In 1976 a total of 294 million salmon and steelhead was raised in federal, state, and private hatcheries.

A specific example is the Elk River Hatchery of the Oregon Department of Fish and Wildlife, where diseases such as ich, IHN, furunculosis, enteric redmouth, coagulated yolk, and a gill amoeba have occurred. That hatchery continues to raise salmon and has been getting returns of up to 5% back to the Elk River.

The emphasis is on good husbandry and good management to keep losses to a minimum. Some of these concepts have already been discussed (Boustead 1980) and they are becoming increasingly refined and understood all the time. An example is at Dworshak Hatchery in Idaho, which has had fewer disease problems by lowering the temperature at which the fish are raised. Other salmon hatcheries obtain water from deep in lakes where it is cooler than surface or river water. As a result of work done in Canada by Sandercock and Stone many hatcheries are cutting back on stocking densities and this reduces disease problems.

Management practices used in the United States to deal with particularly serious fish diseases vary between different states and between federal and state governments. There is also some variation between past and present practices. For example, in Michigan fisheries authorities tried to eliminate whirling disease by destruction of fish and there was even an attempt to treat a small river. These efforts were unsuccessful and they have now a policy of living with the disease and ensuring that they do not knowingly increase its distribution.

In Pennsylvania the Fish Commission is continuing to use some facilities which have had outbreaks of whirling disease. Where the water supply was a protected, clean spring source the ponds were converted to concrete raceways and restocked and their use was continued. Another facility at Cedar Springs that is contaminated with whirling disease continues to raise fish for the sports fishery. They have changed from rainbow trout to brown trout, which are more resistant to the disease, in the same ponds. These brown trout are then stocked into streams for the sports fishery.

Many hatcheries that have fish viruses such as IPN and IHN are tending to live with the problem and accept some losses. Federal and state governments have disease specialists who monitor hatcheries for diseases, and the emphasis is on not increasing distribution of disease.

People concerned with salmon culture in New Zealand are fortunate that this country has few of the more serious diseases of salmon. This is possibly because we have no native salmon or trout and most of those that were introduced entered the country by sea voyage, which acted as an effective quarantine period. We now have legislation controlling the imports of further salmon and trout.

The recent incidence of whirling disease has resulted in seven fish diseases being included under the Animals Act of 1967. This means the livestock officers of the Animal Health Division of the Ministry of Agriculture and Fisheries are empowered to inspect fish in hatcheries and if disease is suspected, to take samples. These officers will make arrangements before visiting, and they have undergone a training course to enable them to carry out this work.

The gazetting of these diseases means that the quite considerable resources of the Animal Health Division, including quarantine, can be implemented under provision of this act. I can only hope that we do not have to use these provisions.

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Discussion

Dr Jellyman: The emphasis of the previous three speakers was on maximum output of fish and yet, if I read you rightly, you are saying that we need to be more aware of stress-related problems, especially those brought on by density. Can you see some conflict here, and in the emphasis in the United States on decreased density of fry?

Mr Boustead: I don't know if Dr Groot would like to comment on some of the work that was done in Capilano Hatchery. Experiments there suggested that lower stocking density gave increasingly bigger returns. Just why this is, and whether it is a function of density or other factors, is still being investigated. These experiments are now being repeated in many hatcheries in the United States. It was pointed out this morning that it takes 3 years for the experiments, 5 years for the fish to come back, and another 2 years for evaluation. There is a general consensus that many different factors come into play. Keeping stress down, nutrition, stocking, water quality, food, management—all are interrelated. Researchers at the University of Idaho say that they have 56 different parameters and there is a lot of work in getting these all together and putting them at their optimum to get best fish production. The emphasis is on producing a quality smolt.

Mr Beckett: Could you comment on the likely status of vibrio in the marine environment of New Zealand?

Boustead: In about 1973 or 1974 we looked for it and found it in Lake Ellesmere. A culture was deposited with Animal Health Division. Since that time there has been no further work. If we continue to do a little work in the marine environment, I dare say we will be able to give you more information. It is considered virtually ubiquitous.

The Australian chinook salmon fishery

by P. L. Rogan

Sport Fisheries Section, Fisheries and Wildlife Division, Ministry for Conservation, Victoria, Australia

APART from some early unsuccessful attempts to establish sea runs of chinook salmon (*Oncorhynchus tshawytscha*) in Victoria and Tasmania, the fishery in Australia has been based entirely on the release of hatchery-reared fish into landlocked lakes. Initially this programme depended on the regular importation of eyed ova from New Zealand or the United States and it continued from 1936 until 1966. Originally some 15 lakes throughout Victoria were stocked, but in only 2 lakes was sufficient growth potential demonstrated to warrant continued stocking. These were Lakes Purrumbete and Bullen Merri.

In 1966 a voluntary ban was instituted by the various state fisheries departments on the importation of live salmonids. This was to prevent the introduction of fish diseases into Australia. The ban was later ratified as a Commonwealth law, and it cut off the traditional sources of salmon.

However, just before the ban came into effect, the Fisheries and Wildlife Division (which was then the Victorian Fisheries and Wildlife Department) had imported 20 000 fall-run Tulle stock chinooks from the Columbia River in Oregon. About 1000 of these fish were retained at the division's Snobs Creek Hatchery to see whether they could be reared to maturity. Progress was slow and difficult, particularly in the early years, when at one stage only one ripe male was available to serve an entire year class of females. However, the stock became progressively domesticated and acclimatised to the artificial regime and by 1976 we had sufficient fish to recommence a stocking programme. These fish had been convinced that they did not need to run to sea and that they could survive on a dry diet and produce viable ova at temperatures of 20°–22°c.

Hatchery-stocked lakes

Before describing the fishery it is necessary to consider some of the characteristics of the two lakes into which the fish are released.

Lakes Purrumbete and Bullen Merri are some 7 km apart in south-west Victoria near Camperdown. They are volcanic in origin and of comparable size (552 ha and 488 ha). In comparison with most mainland Australian lakes they are very deep (45 m and 66 m) and their water temperatures vary from 9.6° to 20.7°c. During October-April a thermocline forms at a depth of 12–40 m, but most commonly at about 20 m. Both lakes are distinctly alkaline with mean pH values of 8.4 and 9.1.

They are extremely productive and support abundant populations of common galaxias (*Galaxias maculatus*) as well as big-headed gudgeon (*Philypnodon grandiceps*).

Lake Purrumbete also has a large population of short-finned eels (*Anguilla australis*) as well as pigmy perch *Nannoperca australis*, two other galaxiids, and the introduced species rainbow trout (*Salmo gairdnerii*), European perch or redfin (*Perca fluviatilis*), goldfish (*Carassius auratus*), tench (*Tinca tinca*), and roach (*Rutilus rutilus*).

The salmonids do not breed in either lake and the populations are maintained by the release of hatchery-reared fish.

Lake Purrumbete

The 15 000 advanced yearling salmon released into Lake Purrumbete in May 1976 at an average weight of 70 g had grown to a mean weight of 600 g by November, when the lake was opened to fishing.

The salmon proved exceptionally easy to catch; some 3000 were landed during the opening weekend, compared with 600 rainbow trout. At that stage rainbow trout outnumbered salmon in the lake by about 5 to 1; so the salmon were about 25 times more catchable. The overall catch rate was 1.5 fish per angler per day. About 80% of anglers caught at least one fish and some caught their daily bag limit of five fish within 2 hours.

The popularity of these opening weekends has grown in subsequent years as the division has continued to stock this lake annually with 15 000–20 000 salmon. Attendances have been as high as 5000 people, with up to 1000 boats on the water at once (Fig. 1).

Catches for the opening weekend have been as high as 6800 salmon and catch rates of 2 fish per angler per day have been achieved. This extremely high level of exploitation has greatly influenced our management of this lake. Most of the traditional restrictions (bag limit, closed season, and size limit) on most species of freshwater fish in Victoria have been removed during the past 10 years. However, in this instance it was felt that because the numbers of fish were so limited, and

Fig. 1: Opening weekend at Lake Purrumbete.

the catch rates so high, a bag limit would for once achieve its intended purpose of conserving the stock and sharing the catch.

The closed season on Lake Purrumbete was originally instituted to protect the fish for the few months when they are large enough to take a lure, but still too small to be worth keeping. Although we can now produce sufficient fish to stock heavily enough to counteract any loss of small fish, two factors which emerge from the first three openings have caused us to retain the closed season. One is that the openings have become important social events and attract many people. The other is that, in response to not being exposed to fishing pressure for several months, the fish are much easier to catch for the first few weeks after the lake is opened. The combined effect of these factors probably results in a higher overall catch per year than if there was no closed season.

One other modification to the management of this lake was made necessary by its reputation as a rainbow trout water that consistently produced good numbers of 3–9.5-kg trout. One of the most productive periods for catching these larger trout is during June, July, and August, when they consistently move closer to shore to look for spawning sites or an exit from the lake. Whenever a salmon closed season conflicts with this period, fishing is permitted from the bank to give anglers access to the trout. The prohibition of fishing from boats appears to reduce fishing for salmon sufficiently to retain the high catch rates at opening weekends.

Consistent dates have not yet been set for the closed season. Netting surveys are made regularly to monitor growth rates of the salmon, and regulations are implemented each year on the basis of this information.

The netting surveys have shown that since 1976, salmon released as 70–100-g fish in April-June are, on average, 2.5 kg as 2-year-olds and 5 kg as 3-year-olds. The most recent release of fish took place in November 1979 with salmon of only 7–9 g. These fish have responded well to the longer time in the lake and were, on average, just over 1 kg by mid July—less than 7 months after release.

Most male salmon in the lake mature as 2-year-olds. The remainder of the males, and most of the females, mature as 3-year-olds. This means that there are only two year classes of fish to catch. Fish in the 1+ year class usually constitute 70% of the total catch, and though they are only 600–1200 g, these are the fish on which the popularity of the salmon openings depends.

Lake Bullen Merri

Lake Bullen Merri has many characteristics in common with Lake Purrumbete, but also has some significant differences. Although Lake Purrumbete is landlocked at some times of the year, it does have regular inflows and outflows and contains fresh water with a mean total dissolved solids level of 430 ppm. Lake Bullen Merri is a crater lake with no outlet and a relatively small catchment. Consequently it is extremely sensitive to long-term variations in precipitation, run-off, and evaporation.

Since the lake was first seen by European man in 1841, the lake level has been receding by an average of 23 cm per year—a total of more than 30 m. The stumps of trees which must have taken hundreds of years to grow are still *in situ* up to 20 m below the present water level, which indicates that water levels in the past were much lower and were low for long periods. During the past 139 years, commensurate with the decrease in volume of the lake, there has been an increase in salinity from 3400 ppm to 8500 ppm. Over the last 15 years the mean pH has increased from 8.7 to 9.1.

During most of the last 40 years this lake produced rainbow trout of the same quality as those from Lake Purrumbete, but it became subject to increasingly frequent, and as yet unexplained, fish kills. By 1976 the frequency of mortality was so high that stocking of the lake with trout was discontinued.

In 1978, for the first time, we were able to produce salmon surplus to the requirements for Lake Purrumbete and 20 000 advanced yearling salmon were released into Lake Bullen Merri in May of that year in the hope that they might better withstand whatever was responsible for the trout mortalities. The growth rate of these salmon has been little short of remarkable for a landlocked stock. As 2-year-olds in April 1979, the mean weight of a sample of 91 fish was 2.73 kg and the biggest fish in the group weighed 4.3 kg. This was only 10 months after release as 109-g fish. By February 1980, the mean weight of a sample of 37 fish was 8.64 kg and this included 3 fish at 11.4 kg. These fish were 34 months old and had been in the lake for 21 months.

This population of fish provided very little fishing. The lake was not opened until the salmon were more than 2 years old and, compared with salmon in Lake Purrumbete, these fish were extremely difficult to hook. We believe that this was mainly because the galaxiid populations were exceptionally high. The stocking rate of the lake has now been increased to give a more acceptable predator-prey balance. Considerable problems were also caused as most anglers lacked experience in handling fish of this size and strength and often used inappropriate gear.

The catch rate for this year class reached reasonable levels only during March and April of this year, when the large, mature 3-year-olds were persistently cruising the shallows from dusk to dawn. As anglers experimented with baits, lures, and methods of presentation, some made quite good catches, and in one instance a bag limit was caught.

Trapping trials

During March-April we attempted to develop methods of selectively catching live mature salmon from both lakes, with the aim of using these fish as a potential brood-stock. There were two reasons for these trials. Firstly, our salmon fishery at present depends on the small stock held at the hatchery. In case anything happened to this stock we thought we should know if it was possible to replenish the hatchery from the lake populations. Secondly, rearing fish to maturity (which can take up to 5 years at the hatchery) is very expensive, whereas stripping wild fish may be more economical.

As both lakes are completely landlocked during March and April, we thought the creation of a small current by use of a pump might provide a stimulus to attract mature salmon seeking a spawning site.

Pens of about 32 m^2 were constructed near the shore of both lakes in 1–1.8 m of water. The off-shore wall of each pen was clad with steel decking which extended from the lake bed to about 20 cm above water level. The other three sides were enclosed by a plastic trellis material with a mesh size of 4 by 2 cm.

Two 50-mm pumps, with a combined output of about 500 l per minute, were installed so that the flow was directed over the off-shore wall. A venturi was fitted on the suction line of each pump to allow water from some outside source to be bled into the pump stream and provide an olfactory stimulus for the salmon.

We hoped that the stream of water over the solid wall would function as a fish ladder, and that salmon attracted to the area by the current, turbulence, or smell of the water would leap into the pen and be trapped. The trials were initially done on Lake Bullen Merri, as it contained many more salmon than Lake Purrumbete and had no other species of fish which might be needlessly destroyed by the trapping operation.

Limited mesh netting was also carried out round the lake to check on the state of maturity of the fish and to determine patterns of fish movement. Two peaks of fish movement were found: one immediately after dusk and the other shortly before dawn. There was some activity right through the night and none during the day. The fish generally tended to move in the opposite direction to any wind-induced current in the lake.

Pumping was carried out from mid afternoon until mid morning for 10 days, and though fish could be observed outside the pen, none would enter. To facilitate entry, an underwater opening about 60 cm square was cut into the steel wall and fitted with a cone to prevent fish escaping. The flow from one of the pumps was then directed through this entrance. Pumping continued for a further 4 days, but fish still could not be induced to enter the pen.

To check whether fish were being attracted to the water flow, we set two 23-m nets immediately outside the pen in the area where the flow from the pumps was directed. These nets were cleared every 1–2 hours and had a catch rate of 1.6 fish per hour. By comparison, nets set away from the pumped flow and cleared at the same frequency, caught 0.16 fish per hour, whereas those left overnight away from the pumps caught 0.02 fish per hour.

Provided that the nets were cleared frequently and the weather did not get rough, survival of the netted fish was as high as 90% and averaged almost 70% (Fig. 2).

To test the selectivity of this catch method for mature salmon, we repeated the test in Lake Purrumbete for 4 nights. In this lake the pumping site was some 500–600 m away from deep water, and was probably well away from the normal paths of fish movement, as on most occasions the pumps needed to run for about 6 hours before fish were caught. One night was very clear and completely calm and there was no wind-induced current to carry the pumped stream out to the deeper water, and no fish were taken. On 3 other nights, 45 fish were taken at a catch rate of 1.3 per hour. One of the salmon was immature and the only other fishes taken were two rainbow trout. The selectivity of the method for mature salmon was therefore 93.6%.

By comparison, a normal netting survey made immediately after the trapping operation yielded 18 salmon, 18 rainbow trout, and 11 redfin from 21 nets in 18 hours. The catch rate of salmon was therefore 0.01 per net per hour and the selectivity for mature salmon was 38%.

The average weight of the salmon caught was 7.11 kg in Bullen Merri and 5.01 kg in Purrumbete, and, particularly in the former, the condition factor, flesh colour, and quality were exceptionally good for mature fish.

Some problems were caused by high temperatures while transporting ova, stripped from fish at the lake, to the hatchery, and most died within several hours of fertilisation. Live ripe fish taken direct to the hatchery and stripped there yielded a slightly higher percentage of viable eggs (34%) than the hatchery stock (30%).

Viability of the hatchery stock has been consistently low and has varied from 4% to 44%. Only during the last 2 years have we had enough fish to be able to select potential brood fish solely from the progeny of highly fertile parents. The parents of fish selected as potential breeders from the 1979 and 1980 crops had mean egg viabilities of 78.7% and 71.2% respectively, and their progeny should produce even better performances.

Future expansion

Earlier experience has indicated that productive salmon waters need to be landlocked to prevent escape of the salmon, and they must also contain large populations of forage fish if the growth potential of the salmon is to be realised. No lakes in Victoria are comparable to Lakes Purrumbete and Bullen Merri, but there are some predominantly shallow lakes containing large numbers of European perch or redfin. These fish breed prolifically and many of the lakes carry huge numbers of stunted individuals. When this occurs, fishing for the redfin (a popular angling species in many parts of Victoria) becomes very poor.

This year, as a trial, salmon were released into Lake Burrumbete in west-central Victoria. This large (2000 ha) shallow lake supports a huge population of redfin. The idea was to use salmon as an efficient non-breeding predator to remove a large percentage of the small fish and produce a population balance which is more conducive to good fishing. If the trial succeeds, other suitable lakes will be stocked in rotation every 5 or 6 years. Salmon will provide the fishing during the first 2 years. In the next few years there will be

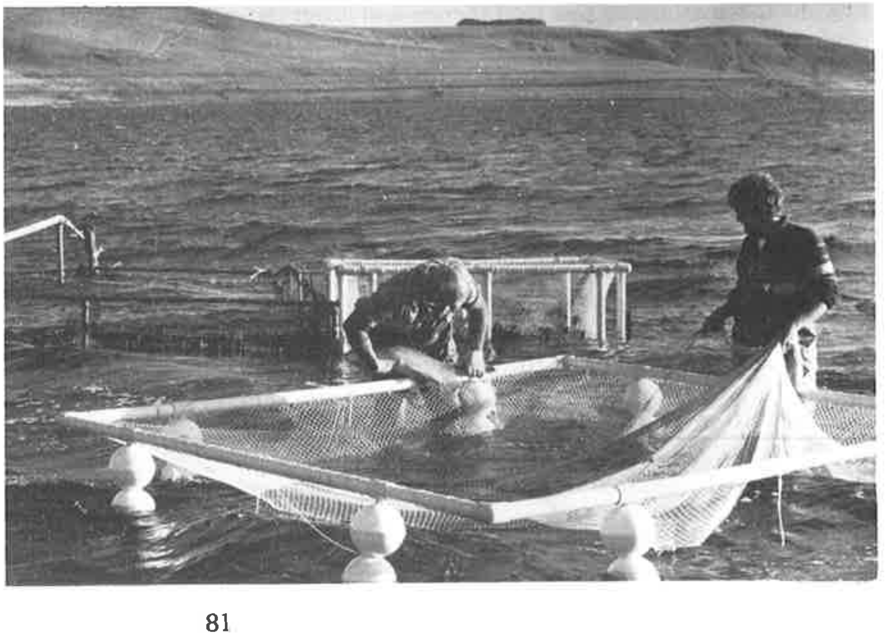

Fig. 2: Three-year-old female fish being removed from a floating pen.

improved redfin or perch fishing from a population containing a much larger percentage of big fish. In the final phase the redfin population will again become unbalanced and there will be large numbers of small redfin to provide food for the next salmon released.

One other proposal we are considering is to establish a non-breeding population of chinook salmon in Port Phillip Bay close to Melbourne. This is a very large (almost 2000 km^2) estuary which is fished by more than 300 000 anglers per year. The proposal is to hold morpholine-imprinted fish in temporary races or ponds immediately beside the main tributary to the bay, the Yarra River. The fish would be held for several months and be released as smolts to migrate down river to the bay. Because of the bay's large size and fairly small exit, we expect that most of the salmon would remain there for most of their lives rather than run into Bass Strait. When the fish matured they would be attracted back to a trap in the lower reaches of the river by a controlled release of morpholine.

The introduction of an exotic species to a new environment cannot be undertaken lightly. The environmental impact of this programme will be fully investigated and unless there is full approval and general public acceptance it will not even reach the stage of a trial release.

We believe, however, that adequate steps can be taken to minimise the environmental impact of the salmon and maintain full control of the population, and that chinook salmon would prove a valuable addition to the state's most heavily fished water.

Discussion

Dr Glova: Your lakes are unique in that they have a number of species of forage fish for the quinnat salmon. With such a high stocking density, I would expect that eventually the level of the food supply would decline. What is probably happening now is that the fish may utilise one food species and lower its availability, and then shift to another food species. Do you see the possibility of this occurring?

Mr Rogan: No. These lakes have been stocked with rainbow trout for 30–40 years. The fact that there is no breeding and we have full control over numbers and predation pressure has, I think, let them retain their productivity. A few years ago we were piling 70 000 trout a year into Lake Purrumbete. We reduced it to 50 000 trout and 15 000 salmon; then the lake was closed. There were no fish being taken out and we did push it too hard, and the growth rate decreased. It was interesting that salmon growth rate suffered far more than that of trout. The trout diversified their feeding into insects, but where there were no forage fish, salmon growth rate dropped right off. Within 2 years we improved the growth rate. It is also interesting that previously we had been stocking yearling fish in these lakes. Just recently—in November last year—we put in fish of about 9 g. A month ago, in both lakes, they were averaging 1 kg. The longer period of residence in the lake has really pushed them on.

Unknown: You said you had a problem with rearing eggs. I would imagine that was because of the high temperature.

Rogan: Yes. But the figures are improving all the time. We are selecting a fairly tough fish.

ICI/Wattie Salmon Development Project

by T. W. Beckett

Chairman, ICI/Wattie Salmon Development Project, Wattie Industries Limited, Auckland

THE concept of ocean ranching has considerable commercial appeal, especially in New Zealand with the chinook, an introduced Pacific salmon of established commercial importance which has no sea fishery based on it.

In 1972 Wattie Industries Limited began investigating the potential of a chinook fishery. This was a result of the interest of an employee (Tim Rait, who was a keen salmon angler) of our poultry company in Christchurch. We obtained samples of home-canned New Zealand chinook salmon, which did little to heighten our enthusiasm, but at least we didn't get botulism. At that time we got little encouragement from the government officials whose responsibility it was to advise on managing the salmon resource, and we therefore decided to monitor the developments.

In 1975 the New Zealand Fishing Industry Board (FIB) suggested that we contact ICI New Zealand Limited who were independently looking at a sea-ranching proposal; and the present arrangement was formalised in August 1975. We agreed to proceed together on a preliminary feasibility study to investigate the potential of ocean ranching chinook in New Zealand.

Feasibility study

The first task was to look at the world-wide market for chinook. Our initial evaluation, made with the help of trade commissioners and industry contacts, indicated that there was a market for chinook salmon; especially fresh, chilled, frozen, or smoked. Total salmon demand in an unlimited world supply situation was assessed at 600 000–700 000 t per year. The United States market was expected to account for 200 000 t per year. World demand was also expected to increase, possibly by 40%–50% by the year 2000. Present world supply is about 400 000 t. A recent paper lists consumption of salmon as: United States, 28%; Japan, 25%; USSR, 17%; Canada, 7%; and Europe and others, 23%.

While this study was taking place, an attempt was made to gather as much information as possible on the biology of chinook in New Zealand and overseas. The Ministry of Agriculture and Fisheries (MAF), FIB, acclimatisation societies, universities, libraries, and anglers all provided information.

The next stage was to send some New Zealand chinook overseas for market evaluation. By this time, preliminary site investigations had been narrowed down to the Waitaki and Clutha Rivers, and a major exercise was mounted in February and March 1976 to obtain samples from these rivers. This was co-ordinated by MAF and involved the Waitaki Valley Acclimatisation Society and the Otago Acclimatisation Society. Although few fish were caught, the efforts to net the Waitaki and the Clutha taught us a lot about the characters of these rivers. The catching exercise was designed to obtain a range of qualities of fish to evaluate the market potential of fish caught in New Zealand rivers. The fish were divided into three grades:

1st grade—light green dorsally, white ventrally;
2nd grade—dark green dorsally, white-grey ventrally;
3rd grade—dark ventrally, often reddish over all.

By good fortune, sea-caught fish were taken by sports fishermen off the rocks at Moeraki. These fish were graded as 1st+ because they were steel grey-blue dorsally and white ventrally. Total fish taken are shown below:

Grade	Where caught	No. of fish
1st+	sea	10
1st	river	43
2nd	river	16
3rd	river	15
		84

Most of the 1st, 2nd, and 3rd grade fish were rod caught. Some of the 3rd grade fish were "black" males netted at Highbank by MAF on a particularly cold night in late April.

The fish were gutted and transported on flake ice in polystyrene boxes to J. Wattie Canneries Limited, Christchurch, where they were frozen. Each fish was graded and individually numbered with a sheep ear tag through the operculum. A questionnaire was designed and in mid May a selection of grades of frozen fish was air freighted to salmon wholesalers in Japan, United Kingdom, United States, Canada, and West Germany. The wholesalers were asked to fill out a separate sheet for each sample, and to supply information on quality, price, etc.

The results showed that New Zealand 1st+, 1st, and 2nd grade chinook were identical to North Pacific chinook and would find a similar market at an acceptable price. More sophisticated markets, such as Japan and West Germany, considered that 3rd grade fish were not marketable. A full report was written and copies were distributed to MAF, the South Island Salmon Committee, the Waitaki Valley Acclimatisation Society, and the Otago Acclimatisation Society.

The results of this market survey were sufficiently encouraging for us to proceed to the design of an experimental and research programme on the release of marked smolts and the evaluation of the numbers that return and the quality of any returning fish.

Experimental programme

In mid 1976 the two companies agreed to an experimental programme which was intended to run for at least 5 years. The original programme has altered only slightly. No income was expected from this developmental phase.

I propose to review the criteria, methods, and assumptions used in the design of our developmental programme in view of our present knowledge.

It was considered that a commercial sea-ranching operation in New Zealand should generate export income of about $10 million per year. The experimental programme was then designed to give answers applicable to an operation of this scale.

A second thorough review was made of overseas and local information about chinook, especially in relation to environmental and physical factors to further select potential sites. Much of the information was contradictory; so a number of criteria and assumptions were arbitrarily made. These included the following:

1. Adult fish would have to be caught in fresh water in New Zealand to give the anglers first access to these fish. Therefore, return sites should be far enough up stream to give sport anglers access, but close enough to the sea to enable fish of marketable quality to be harvested.
2. The Waitaki and Clutha Rivers, as large South Island east coast rivers within what was believed to be suitable sea surface temperature areas, were reconfirmed as first choices for release sites.
3. A known percentage of all releases would be tagged or marked to enable subsequent identification.
4. No fish would be released until they had been fed for 90 days and weighed on average at least 5 g. Fish would be released before the longest day (say Christmas Day) in New Zealand. The aim was to have released all fish in the last week of October or the first 2 weeks of November; before river water temperatures exceeded 15°C.
5. To ensure that they returned to a particular release site, "foreign" ova or smolts could be imprinted by short-term (5–14 days) residence before release. No chemical imprinting (for example, morpholine) would be used until it was found necessary.
6. No minimum number of fish would be required for a successful release. An optimum minimum for separate releases was arbitrarily set at 50 000–100 000 5-g smolts.

Staff and organisation

It has always been the belief of both companies that technically qualified people are important because they have background knowledge and some experience in evaluating options and developing ideas. This project has been fortunate in that three or four science graduates have been associated with it at all times. Technical expertise in aquaculture has been provided by two qualified biologists at any one time. One of these biologists has travelled extensively overseas to visit fish farming establishments and has been practically involved in aquaculture in New Zealand for 10 years.

The project is run by a joint venture committee comprising two representatives of each company, with the chairmanship alternating between the companies annually. This committee determines the project policy, which is implemented by the field manager, who is directly responsible for the daily management and also attends joint venture committee meetings. The present field manager, Mark Gillard, is a graduate biologist who has been practically involved in commercial freshwater fisheries work for the past 5 years.

Waitaki River site

The Waitaki River is an established major New Zealand salmon river. It is also the first river where chinook were established in New Zealand. It was thought that, compared with the rivers further north, the Waitaki had been relatively stabilised by dams. However, experience on the Waitaki has modified this opinion. A gravel race was built in 1976 and replaced by a concrete race in 1977. The major difficulties with this site are the fluctuating river levels and the high water temperatures in spring and summer. A gravity-fed water supply gives 0.10–0.17 m^3/s (Fig. 1).

So far 481 000 fish have been released from the Waitaki site (Table 1). This site is permanently staffed only when fish are there.

Clutha River site

The Clutha River is very different from the other major east coast South Island rivers. It has a stable bed and fairly even and moderate temperatures throughout the year. Below Balclutha the river meanders to the sea with little fall. The estuarine conditions are stable and tidal fluctuations of up to 1 m occur at the site. The site was developed in 1977 and consists of a pumped water supply (two 0.10-m^3/s Flygt submersible pumps), a standard concrete

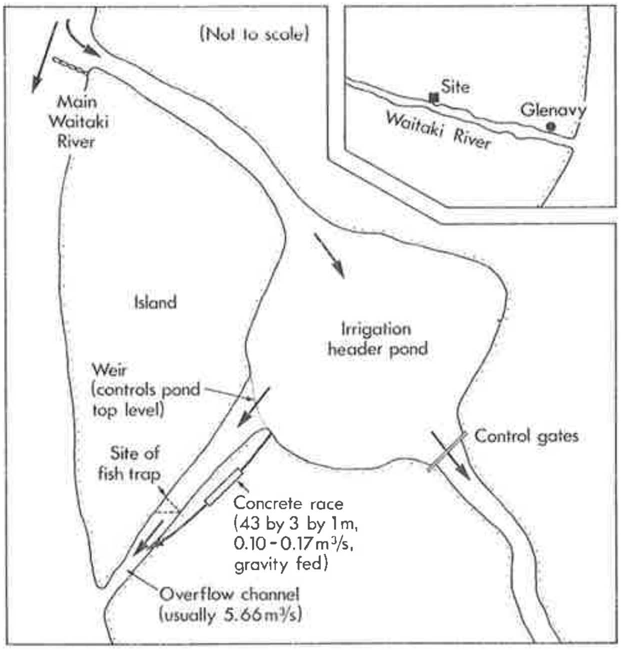

Fig. 1: The Waitaki River site of the ICI/Wattie Salmon Development Project.

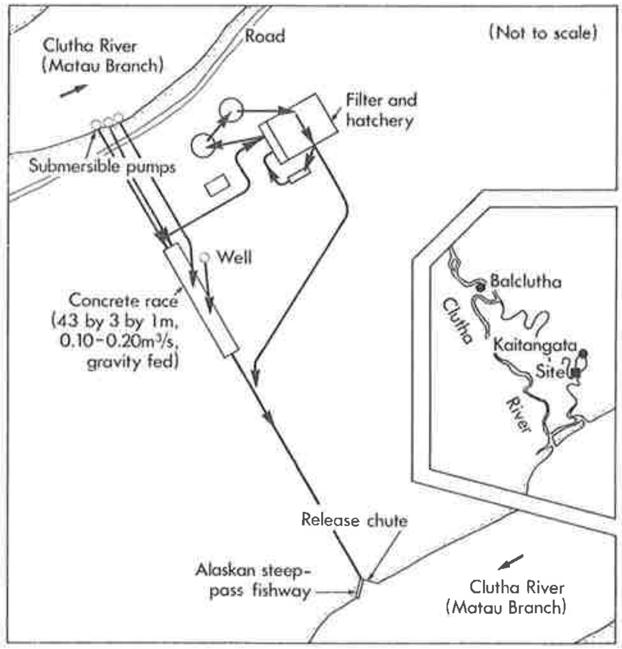

Fig. 2: The Clutha River site of the ICI/Wattie Salmon Development Project.

raceway (43 by 3 by 1 m), a small hatchery with 5-m troughs supplied by a diatomaceous earth filter capable of delivering 227 l per minute, and an Alaskan steep-pass fishway at the exit into the river (Fig. 2). A ground well supplies distinctive water to the raceway while fish are there. This is done in an attempt to imprint the smolts.

Since 1977, releases from the Clutha site total 397 904 fish (Table 2). Staff are permanently on site here.

TABLE 1: Releases from the Waitaki River site

Year	Time at site	No. of days at site	Origin of fish	Size at release (g)	No. released	% tagged
1976	27 Oct to 10 Nov	15	Unknown	5.6	100 481	16.7
1977	26 Oct to 2 Nov	8	Unknown	4.3	99 833	8.7
	17 Nov to 21 Dec	36	Unknown	11.2	49 766	9.4
1978	25 Oct to 29 Oct	5	Unknown	7.0	82 671	11.7
	13 Nov to 21 Nov	9	Unknown	10.0	50 145	9.6
1979	6 Aug to 16 Nov	93	Waitaki	6.0	47 477	21.7
	6 Aug to 16 Nov	93	Rakaia	5.0	50 650	20.6
1980	11 Dec and 13 Dec to 16 Dec	5–7	Waitaki	6.0	25 442	49.1
					506 465	

TABLE 2: Releases from the Clutha River site

Year	Time at site	No. of days at site	Origin of fish	Size at release (g)	No. released	% tagged
1977	8 Nov to 12 Nov	5	Unknown	4.0	63 512	11.6
	15 Dec to 19 Dec	5	Unknown	7.5	12 838	75.0
1978	28 Oct to 1 Nov	5	Unknown	7.2	92 967	10.5*
	15 Nov to 19 Nov	5	Unknown	11.2	43 158	10.3
1979	17 Oct to 23 Oct	7	Rakaia	6.2	92 704	10.8
	24 Oct to 30 Oct	7	Deep Stream	8.1	92 725	11.4
1980	Up to 17 Dec	150+	Winding Creek	5.4	71 026	43.6
					468 930	

*From the first 1978 release, fish were graded in September into three size classes (about 3000 fish were tagged from each of the largest, average, and smallest classes).

Special projects

Several special studies have been carried out over the last 4 years to try to build up our own information on aspects of chinook in New Zealand. Detailed reports on this work have been completed. Some examples of these studies are outlined below:

1. In 1976 there was no factual information available to assist us in determining when New Zealand chinook were capable of surviving in the sea. A simple experiment on saltwater adaptation was carried out on the Waitaki in 1976. Direct seawater challenge tests were made by use of buckets of freshly collected sea water. All fish survived direct transfer into the sea water for 24–48 hours.

In winter and spring of 1978, a detailed study of sodium plasma concentrations began on a sample of 109 salmon of different sizes and ages from different areas. Small fish were subjected to a direct seawater challenge test by the methods of Clarke and Blackburn (1977). Analysis of sodium plasma was done at the University of Canterbury. Originally it had been hoped to analyse gill ATPase, but there were difficulties in setting up the experiment in New Zealand.

2. The external appearance of returning sea-run adult fish was monitored at the Glenariffe trap and the Silverstream hatchery in 1977.

3. Several specific experimental releases were instituted, and all were based on assumptions outlined above. An example was the grading of the first 1978 Clutha release into three sizes; each group was tagged separately before release. Fish have been retained at release sites for periods from as short as 5 days, up to 93 days. Fish size at release has varied from 4.0 g to 11.2 g. Basic biological and water quality details have been recorded for all holding, release, and return periods. We have done no work on diet formulation ourselves, but have used the Silverstream diet formulation exclusively. This gives us the opportunity to compare any of our results with those from Silverstream.

Detailed reports were also completed on hatchery practices, scale and otolith sampling, and analysis of New Zealand results each year.

Results

The results for recovered tagged fish are very disappointing. The 1976 Waitaki release used left pelvic fin clips; so the results are less accurate than the results from nose-tagged returning fish. Twelve left-pelvic-clipped fish have been recovered. Scale analysis from some of these recoveries showed the fish were of the correct age and had either intermediate or stream nuclei. Unfortunately, four of these fish were in the wrong river; two were in the Waimakariri River and two in the Rakaia River. Ten fish recorded in 1979 were 3-year-olds, and two in 1980 (both in the Waitaki) were 4-year-olds. Only one nose-tagged sea-run consortium fish has been recovered; it was a 2-year-old female from the 1977 Clutha release. This fish was caught by an angler at the Roxburgh dam; well up stream from the release site, but at least it was in the "correct" river. Salmon were seen trying to enter the Clutha return facility in 1979; so a fishway was installed in late 1979 for the 1980 return.

Although we have little factual evidence we suspect the following:

- New Zealand wild chinook have a considerable stray factor which is possibly a legacy of their recent introduction;
- The release of returning adults' progeny will increase return rates;
- New Zealand sea-run fish (at a weight of 6–7 kg or more for premium overseas markets) will give consistently low returns because of local oceanographic factors.

If we could afford to develop a home run, the project would probably be worth pursuing. However, it is a long-term developmental project and is not recommended for get-rich-quick entrepreneurs.

We would like to thank MAF for the considerable assistance it has offered at all stages. In particular, Chas Hardy has been of great practical assistance to the project from the beginning. The help with hatchery techniques and the transportation of small chinook is especially gratefully acknowledged. I feel that the Silverstream programme has yielded extremely useful results with the establishment of a home run back to the hatchery; and I hope this work is continued.

I would like to see the future work by MAF concentrate on trying to find out the sea range of New Zealand chinook. The translocation of tagged Silverstream progeny with Glenariffe fish, or vice versa, could possibly give valuable information on the significance of home runs in New Zealand.

Finally, I would like to thank the Waitaki Valley and Otago Acclimatisation Societies; both have given us much assistance and whole-hearted co-operation over the last 5 years.

Reference

CLARKE, W. C., and BLACKBURN, J. 1977: A seawater challenge test to measure smolting of juvenile salmon. *Technical Report, Fisheries and Marine Service, Department of Environment, Canada, No. 705.* 11 pp.

Discussion

Mr Flain: With reference to the Waitaki facility, can you imprint the fish in this situation?

Mr Beckett: Possibly not. The hope is that the fish will remember by getting something out of the concrete raceways and concrete pipes.

Flain: Doesn't that work against you? You have such a little variation between the water which you are piping and the river to expect them to return.

Beckett: I don't know. I'd prefer to put that question on to the experts. We have concrete ponds, concrete pipes, and concrete structures. Some people would tell you that is sufficient for the fish to come back again.

Conflicts in salmon harvest

by J. R. Galat

President, Burnt Hill Salmon Ranch Ltd., Oregon, U.S.A.

PROBLEMS related to the harvest of salmon in New Zealand are at present minor. However, as salmon runs increase, pressures could develop from different groups, each claiming a "right" to the fish. This is understandable, since salmon is one of the most valuable food products of the oceans. The larger sizes of chinook salmon (called quinnat in New Zealand) are at present bringing about US$5 per kilogram to the fishermen in the United States. Prices paid to exporters in recent years have been as much as US$10 per kilogram.

In the United States commercial fishermen alone harvest about 150 million kg of salmon annually, of which about 10% are chinook. The sports fishermen and tribal Indians also harvest a substantial number of fish. In some areas the sports harvest exceeds the commercial harvest for a particular species. In addition, salmon ranching ventures depend on what is left after other groups complete their harvest. With all of these demands on the salmon runs it is understandable that management of the resource is difficult in the United States.

The conflicts in salmon harvest that exist in the United States need not occur in New Zealand, but measures must be taken now to prevent potential conflicts before the resource is developed to a large scale and before various groups "lay claim" to the salmon. Investors in salmon ranching ventures must be particularly aware of the potential for losing control of their business.

History of salmon harvest

In contrast to the New Zealand situation, when the United States was originally settled by Europeans, rivers were generally teeming with salmon. Indian tribes living along the rivers used crude means to harvest the fish. Since the runs were so large, adequate numbers of fish escaped to spawn. The new settlers were much more efficient, however: gill nets, traps, salmon harvest wheels, and other devices soon threatened to take enough of the fish so that there would be insufficient spawners to sustain the runs. At this point conservationists were able to exert enough influence to outlaw the salmon wheel and other of the more efficient means for harvest in the rivers.

It should also be mentioned that the salmon resource was treated at this time as a fairly low valued commodity. With a light population in the north-western United States there were few sports fishermen. Large businesses dominated the salmon harvest, which was generally canned for shipment to other United States cities.

The development of dams on the major salmon rivers further depleted the runs, even though fish passage facilities were generally constructed with each project.

Internal combustion engine-driven salmon trollers and seiners began to intercept larger numbers of the fish in the ocean both while feeding and on their return migrations to the rivers.

Populations grew in the north-west and this caused a greater demand for sports fishing. The value of salmon increased substantially at the same time. The tribal Indians, who had so far not pressed for their treaty rights to the resource, began to insist on their share. In addition, since the potential for profit had increased, the number of commercial salmon fishermen also grew dramatically.

At the present time, through major efforts by the federal and state regulatory agencies, the salmon resource is being maintained, but it seems that no one is happy. The regulators are besieged by complaints from the Indians, commercial fishermen, sports fishing groups, and conservationists that one or more of the others are getting more than their share of the resource. Another problem is that the courts have been used more and more in recent times to overturn decisions made by the regulators.

All of these problems are due to the fact that there are too many people with a vested right in a limited resource which has become very valuable; a resource which, because of its characteristic of returning to its spawning area, should be easy to regulate.

Potential for avoiding management problems in New Zealand

Because New Zealand had no salmon runs before the fish were introduced during the early part of this century, future regulation of the resource can be simplified. The conditions that developed in the United States and the conflicts between various claimant groups need not become part of the regulatory process here.

The present situation with salmon in New Zealand is similar in many respects to the development of the great cattle ranches in the south-western United States during the 1800s. Many early ranching pioneers laid claim to large land areas and gathered and branded wild longhorn cattle that had been introduced many years before and were then claimed by no one. Through much struggle and effort, large cattle ranches were developed and the breed was gradually improved. Today there is a highly controlled cattle ranching industry which depends, to a large extent, on the use of government owned land for grazing. Similarly, salmon ranching in New Zealand requires the development of wild stock that has previously been introduced by others. It also depends on the use of government owned grazing areas, that is, the ocean. One big difference, however, is that cattle ranching requires an annual round-up for branding and selection for sale, but salmon return of their own accord to their place of release.

The current salmon harvest regulations in the United States could be improved by eliminating all salmon fishing in the ocean. By doing this, the regulators could then control the harvest on each river and stream independently. Such a terminal harvest is efficient and highly controllable. Proper allocations between various groups would be simplified.

Commercial fishing for salmon in the ocean is not at present authorised in New Zealand, but incidental catches are being made in the harvest of other fish.

The salmon in New Zealand is a game fish. There is understandable concern from some of the acclimatisation societies and others that once salmon is commercialised the past benefits enjoyed by sportsmen may be degraded. In the absence of regulation, such could be the case. The following are some of the areas where close regulation is required:

- **Harvest.** There should be no (or minimal) harvest in the ocean. Salmon ranching ventures should not be entitled to rack or trap an entire river or stream if the watercourse also serves an up-stream sports fishery or spawning area.
- **Rearing and release.** Rearing methods and fish condition should be certified by the regulating authority before releases are made.
- **Seed-stock.** Smolt replacements should be made where ova are taken from wild stock or fry are removed from streams, unless the ova or fry are surplus to natural spawning. Smolt replacements should normally be about 5% of the number of ova and about 10% of the number of fry taken from the stream.

Conclusion

With proper regulation, there is no reason that commercial salmon ranching ventures, with a terminal harvest, and a salmon sports fishery could not co-exist in New Zealand.

The physical characteristics of the New Zealand salmon rivers are not generally conducive to natural propagation. Flooding and sudden changes in the river channels of many of the major rivers create a difficult spawning and nursery environment. However, judicious placement of salmon ranching operations should enhance the existing runs in all the New Zealand rivers through the natural straying that occurs on the return migration.

Discussion

Unknown: In response to your suggestion that all marine harvesting of salmon should cease in North America, how do you propose to catch the fish from large, wild runs which obviously will not be able to be taken in the manner that you propose under a ranching system?

Mr Galat: Once the ocean catch is brought to zero, the regulations would then be able to regulate each terminal harvest. The fish will be returning to some river or stream or estuary, and it is there that authorities will be able to open and close the seasons and allow enough escape for either natural spawning or return to the hatchery.

Unknown: Do you think that the fish could be taken in sufficient numbers down stream to be of suitable quality for marketing?

Galat: They should be taken at the river mouth in the ocean, preferably.

Mr Campbell: This would be all right if you were talking about coho or chinook, but there are some other breeds which are fairly well deteriorated by the time they enter the mouth of the river. If you cut out all commercial harvesting at that time, what are you going to do with them?

Galat: That is a problem, and you are not faced with it here because you don't have these runs. In the United States that type of control is being used now in Bristol Bay. The fishing season is opened as the fish are returning; these fish have to be schooling for return before it is efficient to catch them.

Campbell: I appreciate that you allow a certain amount of escape for spawning. But you have a big commercial fishery and a tremendous investment. What happens to it? Shouldn't it be utilised commercially for the benefits of all those people who couldn't catch it as sportsmen?

Galat: In past years we have seen the United States fishing regulations become more and more severe. We have seen more salmon trollers being converted to other uses; for instance, shrimping and other fishing.

Canada's west coast Salmonid Enhancement Program—potential and concern

by C. Groot

Department of Fisheries and Oceans Resource Services Branch, Pacific Biological Station, Nanaimo, British Columbia, Canada

THE purpose of my presentation is to explain briefly the scope of the Salmonid Enhancement Program (SEP) in British Columbia, and then to give a scientist's point of view of the programme and share with you some of my concerns with such a scheme.

British Columbia has about 1800 coastal rivers and streams that contain sea-run stocks of five species of Pacific salmon and steelhead trout. At the beginning of this century the estimated potential harvest was about 300–360 million pounds per year. By the early 1930s most stocks had declined substantially to an annual catch of about 180 million pounds. This decline continued and the 10-year average in the 1940s was 164 million pounds, in the 1950s, 155 million, and in the 1960s, 137 million—an all-time low. By this time fisheries biologists of the Pacific region of Canada became seriously concerned about the Pacific salmon stocks and started a number of salmonid enhancement schemes, which temporarily halted the decline.

Both the United States and Canada have had extensive hatchery programmes since the late 1800s. However, in western Canada all Pacific salmon hatcheries were closed in 1929, since it became evident that the production results obtained by these hatcheries were poor.

New hope for increasing salmon production by artificial enhancement was offered by new experience gained in hatchery technology during the 1960s in the United States for coho and chinook salmon and in Japan for chum salmon, and by the development in Canada of gravel incubation boxes, man-made spawning channels, and lake fertilisation methods for pink, chum, and sockeye salmon. Plans were made not only to halt the continuing decline in salmon stocks, but to return salmon production to approximately the level during the early 1900s.

In 1977 a Cabinet Submission was presented to the Federal and Provincial Governments. It outlined a plan to increase salmonid production by 190 million pounds to its assumed historic annual harvest potential of 335 million pounds in about 20 years. The Federal Cabinet accepted in principle an enhancement proposal in two phases. For Phase I, covering the years 1 to 7 (1977–84), Cabinet committed an investment of $150 million. This is expected to increase salmonid production by 50 million pounds annually. A further commitment for Phase II for years 8 to 20, for the additional 140 million pounds, can be expected only if the programme demonstrates substantial progress during Phase I. The Phase I programme is now in its 4th year.

Besides benefiting the salmonid resource directly, the SEP plan will also have an indirect effect. It forces developers of other resources, such as provincial and municipal governments, and hydro-electric, forestry, and mining industries, to negotiate well in advance how to integrate their future plans for specific drainage systems with the salmonid enhancement plans. This will relieve fisheries from being on the defence all the time against development plans of other groups, since it now has its own long-term plans clearly spelled out and accepted by Federal and Provincial Cabinets.

Returning the British Columbia salmonids to their historic levels of abundance by adding 190 million pounds or 25–40 million fish to the annual harvest is a resource manipulation on a grand scale. For such a programme to be successful, it is fundamentally important to keep two biological characteristics of salmonids clearly in mind. Firstly, all five species of Pacific salmon and the steelhead trout are anadromous; that is, they spawn in streams and lakes and the juveniles then migrate after an early freshwater life of 0–3 years to the ocean. After maturing in the ocean for one or more years, the different species return to fresh water to spawn. The major implications arising from this anadromous behaviour are:

1. These fish are available for direct manipulation only during their freshwater phases as egg, alevin, fry, smolt, and maturing adult. During a major part of their life cycle in the ocean they are out of reach.
2. Whatever enhancement or management technique is employed to increase production, it must not interfere with the physiological changes required for the freshwater-saltwater transition and with the long-distance migrations in the ocean and homing abilities to return to the ancestral spawning grounds.
3. Since man and fish are often in direct competition for the available fresh water, human development schemes can have a dramatic, often devastating effect on the salmonids. We have only to look at Europe, eastern Canada, and eastern and

western United States to realise what can happen to salmon stocks when they are in conflict with man.

Secondly, a very important biological characteristic of salmonids is that they return to their home stream to spawn. Populations of one species migrating to different streams are to a great extent reproductively isolated from each other and are referred to as stocks. In addition, members of one stock returning to the same spawning grounds in different years as separate year classes can be reproductively isolated from each other. This is especially so when all maturing fish return at the same age, as in pink salmon and some sockeye salmon. There is mounting evidence to conclude that stocks differ genetically and that each is finely tuned and adapted to the characteristics of the specific habitats occupied during the life cycle. In the Fraser River, one of the most important Pacific salmon rivers in the world, there are about 40 to 50 sockeye, 100 to 200 coho and chinook, and a multitude of chum, pink, and steelhead stocks, all with their own life history strategies. The strong homing tendency and the resulting separation in stocks have to be considered seriously in any salmonid enhancement scheme to safeguard against changes in genetic composition or loss of genetic variability in the salmonid resource.

To enhance salmonid production, we have three options:

- manipulating the **environment**, which involves both natural (habitats) and man-made (incubation and rearing facilities) environments;
- changing characteristics of the **organism**, physiologically, genetically, or behaviourally;
- managing the **population** as it passes through the fishery to assure sufficient escapement.

All three options generally apply in any enhancement scheme. For example, by raising salmon in a hatchery in a controlled environment, we are affecting the organism in ways which are still poorly understood, and when the progeny return from the ocean, the harvesting techniques used induce a definite selection. In addition, artificial propagation projects often affect conditions in the habitats and therefore modify the natural environment.

All resource manipulations by man, planned or unplanned, create changes in existing situations and will continuously require new solutions to resolve them. We can conveniently recognise five major areas of concern where new problems can be expected to occur and reoccur.

1. **Incubation units**. Problems here are in the operation of hatchery, incubation box, and spawning channel facilities. They are the most visible and most direct ones. When eggs start to die off, get diseased, are not fertilised, or do not develop properly, the facility manager realises that he has a problem. Causes of the problems are generally related to poor water quality, disease, stress, feeding and diet difficulties, maturation state of adults, and gamete manipulation.

2. **Juvenile production units**. Problems here relate to time and size of release, smoltification (saltwater readiness), stress due to crowding, and growth in coho, chinook, and Japanese-style chum hatcheries. Also included are questions resulting from lake and stream enrichment projects to promote growth and survival in sockeye, coho, and steelhead in natural and semi-natural situations.

3. **Migrant and marine salmon**. During their life cycle, salmonids perform several major habitat changes: from gravel beds in streams and lakes as eggs and alevins, to streams, lakes, and estuaries as fry and/or juveniles, to open ocean as immatures and maturing adults, and to rivers, lakes, and streams as mature, spawning adults. The major concerns here are the possible changes that might occur in the timing and routes of migration, the distribution in fresh and salt water, and the accurate long-distance direction finding and homing mechanisms that form the basis of the habitat shifts.

4. **Genetics and transplants.** The problems in this area relate to the genetic specificity and diversity of stocks and the effect of enhancement and management practices on the genetic make-up of the fish. Many streams are barren or have missing year classes. How do we establish new stocks and improve ailing ones without interfering with or destroying the delicate adaptations of the organism to its environment?

5. **Systems units**. Salmonids do not live in isolation in rivers, lakes, estuaries, and the ocean. They co-exist in a system with members of other stocks of the same species, with species of the same genus, and with a varying multitude of other living organisms (including man), and non-living objects. During evolution a particular balance has developed between organism and environment that optimises survival. Many problems are developing daily as a result of our poor understanding of the effect of the pressures exerted on the living resources by industrial and urban development. It is becoming crucial that strategies for enhancement and management be developed on a systems basis, to maintain a certain balance in the total composition of salmonid stocks of all species in relation to their changing environment.

Research and development with respect to salmonid enhancement have so far primarily concentrated on the first two areas, incubation and juvenile production units, since the main thrust of the SEP is increased production. Our expertise and knowledge are also strongest in these areas. However, as manipulation of the resource increases, the problems will shift to the last three areas, migrant and marine salmon, genetics and transplants, and systems units. Special attention will have to be given to the systems area, because it is here that we can expect the major and most perplexing issues to arise in the next 10 to 20 years.

From a research point of view, it is difficult, if not impossible, to determine what systems problems will emerge with certain enhancement approaches. However, we must enhance the salmonids and cannot wait until more knowledge is available, since habitat deterioration and human development schemes are proceeding at a rapid pace and are continuously challenging the salmonid's living conditions. We must therefore move on and learn as we play. The key factor is proper evaluation of what is happening. Our problem as salmon biologists is to convince the Federal and Provincial Governments, as developers of the salmonid resource, that it is important and crucial to invest time, effort, money, and expertise in learning more about the intricacies of the salmonid living systems. So far we have been only moderately successful in Canada.

Panel discussion
Problems of salmon management in New Zealand

Chairman: Mr D. P. O'Connor

Panel: Dr R. M. McDowall (Fisheries Research Division, Ministry of Agriculture and Fisheries)
Mr B. T. Cunningham (Director, Fisheries Management Division, Ministry of Agriculture and Fisheries)
Mr C. R. Anderson (Chairman, Salmon Committee, Council of South Island Acclimatisation Socictics)
Mr R. Lightfoot (President, N.Z. Salmon Anglers Association)
Mr J. D. Wisker (Secretary, Salmon Ranchers Association)

Discussion

Mr D. Anderson: I would like to ask the panel how the starting of so many salmon ranching projects can be justified when there is a shortage of ova, there is no management policy and no regulations, and research into salmon resources in New Zealand is incomplete.

Mr B. T. Cunningham: The first point is that it is governmental policy to have salmon ranching. The policy has been in action for some years; therefore the authorisation procedure has been operating through Fisheries Management Division. The policy has been codified through the Freshwater Fisheries Advisory Council over the past couple of years or so; it came to fruition at the council's last meeting and was presented to Government, and Government adopted a salmon ranching policy. It is fully admitted that while the policy was being developed there were discussions going on between the various participants, with different points of view being put forward and having to be fully discussed and agreed. All this takes time. The next step is to work from the policy and draft a proposal for the regulations, and further discussions will take place before final recommendations go to Government. Another question was, why did we start before full knowledge of salmon and the resource was available. If we waited for all the knowledge to be accumulated, we wouldn't get anywhere.

Mr R. Lightfoot: We, the anglers, are very concerned by the lack of regulations because there are too many ocean ranchers starting with little or no expertise. We feel the regulations should be promulgated as soon as possible now that a policy has been adopted.

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Sir Malcolm Burns: Would members of the panel comment on Mr Galat's proposal, or suggestion, that it would be desirable to withdraw a proportion of breeding stock to ensure that the normal run would be maintained and that surplus fish would add to the wild run. This seems to me to be a very reasonable and practicable proposal.

Dr R. M. McDowall: In a sense this is already being done at Glenariffe. We are withdrawing a proportion of the Glenariffe run and converting it to hatchery raising and releasing. So our practice supports the proposal.

Burns: But that refers only to Glenariffe. There are now established centres on the Hurunui and Rakaia Rivers, and doubtless there will be on the Waitaki.

Cunningham: Our situation is different from that mentioned by earlier speakers, which could be put into practice tomorrow if somebody had the right sort of cheque book. In discussions of the regulations framework there was a divergence of opinion on whether the farmer was allowed to release part of his extra ova supply back into the stream. The question still has not been resolved: Should some go back?

Burns: I would like to hear from Mr Anderson, who is chairman of the committee which allocates or recommends allocation of ova. He should have some comment to make on this kind of proposal.

Mr C. R. Anderson: The only proposal anywhere near this suggestion has been that of Fisheries Research Division at Glenariffe. I would be interested to hear the general reaction of the salmon committee to the proposition.

Mr M. Flain: The original concept of the Silverstream hatchery was to provide fish for enhancement. If the societies, who are responsible for fisheries management, like the idea of salmon enhancement, they are capable, by a variety of means, of going ahead and doing it, without reference to anybody else, in their own particular waters.

Mr G. D. Waugh: Mr Burns is picking up Mr Galat's comments that we should have an insurance policy for each river. The idea would be to withdraw a certain number of ova, rear them at some scparatc, safc facility, and release them in the river of origin. This could be done in one of two ways: by acclimatisation societies with the right facilities or by MAF, if we had the facilities. But we would have to retain at, say, Silverstream, at least eight separate river stocks if we were to be sure that we were returning to those rivers the same stock that we had previously withdrawn.

McDowall: There is another alternative. Some people might say that some of these rivers have rearing facilities that are not being utilised, and that the commercial operators should be making use of the resources in this way.

Mr J. S. Campbell: This is where ocean ranching comes in. If ocean ranching companies took up what the government does not have the money to do, they would be practising enhancement.

Mr J. D. Wisker: I would like to endorse Mr Galat's suggestion. If approval were given to trap on other rivers, private enterprise would do it.

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Mr R. A. Dougherty: In a previous salmon symposium there was considerable discussion of protection of the existing salmon spawning areas. In the last 10 years, Rakaia spawning areas have been lost, some probably for ever. Much of the Hydra Waters, for example, is now in the Rakaia—a loss of some 3 miles of spawning and nursery water. Is anything to be done about this sort of thing, and who is going to do it?

Anderson: I wouldn't like to comment on the Hydra Waters. Money and effort are being spent on protecting the Glenariffe area and on Deep Stream (Mesopotamia); those two in particular. There are probably other smaller ones which don't come to my mind at the moment.

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Mr J. Lockley: All salmon ranching so far has initially depended on supplies of ova or fry from government sources, with the blessing of the salmon committee. We have among us some potential salmon ranchers who are assessing the situation. Is it true that they are unlikely to be able to get supplies from this source? Certainly the Freshwater Fisheries Advisory Council does not see any prospects for allocating ova for any new ventures.

Cunningham: It is easy to say there is a policy coming in which will facilitate ocean ranching, but there is the difficulty of how you get it started. Some time in the future, each ranch must be self sufficient in regard to its ova supply. Part of the initial policy is that from the Crown's resources some stock has to be made available to ranchers.

McDowall: There's another important problem that needs to be looked at here; that of technology. At the moment we have five farms trying to develop a technology for ocean ranching of salmon. They are doing all sorts of different things. I have some questions in my mind as to whether the resources are being wisely used in all cases. Are we going to see this develop until we have 20 different organisations doing 20 different things, wasting a valuable resource, and receiving a minimal allocation of ova because we are unable to supply reasonable numbers? In 1979 we supplied over 3 million stock units (ova, fry, and smolts), after a great deal of work. The next year we allocated about the same number, but we had a slightly below average year at Glenariffe and were unable to supply any significant number to anyone. To talk of expansion under those circumstances is absolute lunacy.

Mr K. Fitzgerald: The salmon ranchers have been getting ova from MAF and largely from one river system. This may be where they make a mistake. So far I haven't heard any proposal for these people to trap in their own rivers, to get their own supplies.

Mr T. W. Beckett: We have trapped Waitaki adults for the last 2 years and released Waitaki fish in the Waitaki River. We would like someone to show us how we could trap Clutha adults.

Dr D. Scott: I think Mr Beckett would be wasting his time trying to trap Clutha adults.

Mr C. L. Hopkins: There are two salmon ranches which are not on salmon rivers and cannot therefore initially trap their own adults for stripping.

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Mr R. Sutton: Mr Galat, in his talk, raised the important question of the freshwater aspect of the migratory cycle of salmonids. We don't have too many worries as far as the sea is concerned, but it is what happens in rivers which is so important. Dr Hall stressed the importance of the nursery areas. Water and soil legislation is unlikely to give the sort of habitat protection we really need. Acclimatisation societies have been trying hard through their own legislative back-up to protect habitat. What is MAF doing; what is the Salmon Anglers Association doing; what is the Salmon Ranchers Association doing?

McDowall: That is a strange question after listening to Laurel Teirney yesterday telling you what we are doing in this line. Our ministry has made submissions to the Ministry of Works and Development on what we regard as important features in the proposed changes to water and soil legislation. But our involvement in environmental problems does not end there. We have a fairly large team working on problems on the Hurunui, Rakaia, and Ashburton Rivers, and we will be looking at the Rangitata. We are trying to come to grips with the problems generated by impoundment and abstraction. There is a need for the acclimatisation societies to become aware of the threat to their waters, instead of diverting their attention to other areas of conflict. The real conflict in future will be the fact that in 20 years we may have no rivers left at all. The ministry is very much concerned with identifying those rivers which have high recreational values. Having identified them, we then attend to those values which need retaining.

Lightfoot: Our association makes submissions on all projects which affect salmon rivers. We are doing a survey on anglers and the information we get will assist us in future submissions on water rights related to abstraction. We also do a considerable amount of stream improvement work. We have applied this year for $3,600 from the Ministry of Recreation and Sport for stream improvement work.

Wisker: The Salmon Ranchers Association has worked in co-operation with FRD and with the salmon anglers. Give us the chance to generate a good return of fish and then people will be less likely to ruin the river.

Ms L. D. Teirney: I have seen the draft of the new Water and Soil Act, and we are not going to get much more protection than we have now. Water rights and river allocation plans will virtually not change. We have a government policy on wild and scenic rivers, and that will eventually appear as legislation. I am part of a group which is looking at whether this should go with water and soil legislation or with other acts. We need the backing of acclimatisation societies here to put that policy into legislation so that we can use it. If we can show we have a massive fishery on some rivers, we can put these rivers forward for protection. But I suspect that Government will not accept more than a few rivers.

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Mr I. Maxwell: What are the acclimatisation societies' intentions over the dramatic loss of salmon fry down the Rangitata Diversion Race? I understand that some qualified people consider that possibly one-third of the Rangitata fry migrants go down the diversion race.

Anderson: The loss is not completely quantified. The Rangitata Diversion Race takes salmon from two rivers, as it takes about half the water of the Ashburton River also. In some years salvage operations have taken up to tens of thousands of juveniles. There are reports of fry and smolts going out on to the paddocks. The Ministry of Works and Development tells us that it would now be very difficult to screen the Klondyke intake. Some Rangitata juveniles get into the Hinds, Ashburton, and Rakaia Rivers. There are plans to reassess the irrigation scheme and this is supposed to happen within the next several years. Then there will probably be some kind of protection incorporated into the Klondyke intakes.

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Dr F. Michaelis: In regard to the Bubbling Springs Salmon Farm, I have been asked about the impact of releasing perhaps 21 million small fish into a river system. The fish would feed extensively on their way down to the estuary. As far as I know, there is no information on the feeding of small salmon in New Zealand. Is FRD going to look into this, and would it raise any problems of management if the young salmon had an impact on the nursery areas in the estuary for some of our marine species?

McDowall: We have some data on the feeding of young fry and smolts. We expect to do some work on the interactions between different species of salmonids, including quinnat, in freshwater systems. Beyond that, I cannot answer your question. I don't want to get involved in a clairvoyant argument on the impact of some hypothetical large number of smolts released in the Takaka or any other river.

Michaelis: I cannot answer it either, but do you think it is a significant point that should be looked at?

McDowall: It's one of a multitude of things we should be looking at.

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Mr D. P. O'Connor: How do you react to a suggestion that salmon caught at sea should be sold through approved agencies, the value of the sales being paid to the acclimatisation societies? Would it work?

Cunningham: Through the Freshwater Fisheries Advisory Council there is a working party appointed (which hasn't yet started work) to look at this problem. It would be premature for me to say what the decision will be.

Anderson: The final words of the question were, "Would it work?" Well, I think it will work, but we don't want it. If it won't work, it is no good to us.

Lightfoot: From an angler's point of view, I don't take to the idea at all. The ministry will somehow have to resolve this question of catching salmon at sea as a by-catch; certainly not as a target fish, or there won't be any salmon left in New Zealand. If we have to make it legal, we should try to stop netting of fish within several kilometres' range of the salmon rivers during the salmon season, October to May.

Wisker: We are totally in agreement with the anglers.

Cunningham: There are certain things in current law which the ministry could do. We are faced with the problem, though, that there are changing fishing practices which we cannot control. We cannot tell the trawler owners not to modernise their gear because they might start catching more salmon. Previously, when the gear was less efficient, the quantity of salmon taken as a by-catch was less.

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Mr M. Hall: There has been a change in fishing methods over the last year or two. This year, outside the Rangitata River mouth and within half a mile of the mouth, a set net was placed which was at least a mile long. Over a period of months several nets were placed in that area and the months happened to coincide with the time of the adult migration of salmon into the rivers. Does the panel think that commercial catches of salmon are being sufficiently monitored, and if not, what should be done?

Cunningham: The short answer is no. Perhaps you can give us assistance to improve that towards a "yes", though we'll never get an absolute answer. We are here to accept your advice, information, or knowledge.

McDowall: An example of the sort of things that happen: I spoke to one of the acclimatisation societies in the salmon district some time last year, and someone asked who was responsible for oversight of the catching of salmon at sea. I said, "The ministry". He then said he'd seen someone raffling salmon in a pub and now wanted to know what the ministry was going to do about it. I asked him what he had done about it, and he said, "Nothing". So I said that our fisheries inspectors were not clairvoyant. Until our people are made aware of what is happening, there is nothing we can do about it at all.

Cunningham: The setting of a net in a particular situation does not necessarily mean that any quinnat salmon are caught. I, personally, am aware of our fisheries officers being sent to inspect netsmen and they have found the catches not to be salmon. Naturally, this doesn't mean there are never any salmon caught, but certainly it is not always the case.

Hall: Next year, if this fishing boat does the same thing, I would hope to find someone I can contact, tell him the net is there, tell him the name of the boat, and ask him to inspect the catch.

Cunningham: The names of all regional fisheries officers are in the public telephone directories.

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Dougherty: In the proposal I saw for the Montalto power scheme on the Rangitata Diversion Race there is provision for a fish screen. At this stage, could someone make application for a fish trap? A screen without a trap will serve no purpose at all.

Anderson: There's no provision for a fish screen at Montalto. Do you mean a fish pass?

Dougherty: The proposal I saw said it was to be screened. This will only hold fish at the head of the screen. If they could be diverted into some sort of trap it would be better.

Anderson: There is no provision for a screen as far as I'm aware. In discussions between the parties concerned, it was found very difficult to justify a screen.

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O'Connor: Yesterday we heard that only about 5% of fry at Glenariffe remained in the breeding stream to fingerling stage. In North America do chinook salmon fry escaping from the breeding streams contribute significantly to adult returns? Of what order of magnitude are the adult returns represented by fry maturing to smolts in the breeding streams, and is it likely that a similar relationship is found in New Zealand?

Dr C. Groot: In some of our Canadian rivers we have three types of chinook. One that goes out as a fry, another that goes out after about 3 months, and another that goes out after a year. There are strong indications that these three groups are distinctly different from each other. They are probably of different races or stocks. Circumstantial evidence at the moment is that probably the group that goes out after 3 months contributes most to the return. It will be another few years before we have some answers. On the other hand, there is no question that the chinook that go out as fry do contribute to the total runs. I think that the most advantageous route for the future will be to hold chinook for a year.

Waugh: Dr Groot's reply to the question applies to what happens in North America. In the unstable New Zealand rivers, which have short estuaries, it has been hypothesised that very few fry remain to rear in the river.

McDowall: We must look at the river systems as we know them. The Glenariffe Stream runs into the Rakaia River. As Martin Unwin explained yesterday, smolts go out with six to seven circuli on the scales.

The fish that come back have about 11 circuli in the scale nucleus. Some time between leaving the Glenariffe with six circuli and going to sea they have put on more freshwater circuli. So there is a certain amount of rearing in the main river. That applies to smolts. What happens to fry that leave the Glenariffe? We have no idea.

Flain: There are absolute data showing that 95% of juvenile salmon in the spawning tributaries leave those tributaries as fry. There is some evidence that what remains behind does not contribute all of the adult return run. That is, some of the fry survive in the river to contribute to returns. But only a small proportion of the fry outmigration needs to survive in the main river to make a significant contribution to the adult return. Fry have little capacity for rearing in our short, flashy rivers. On the other hand, the larger fingerlings have learned to compete and to find the best cover, and they are big enough, probably, to survive in the main river—even to withstand floods. Furthermore, most work done overseas indicates that salmon have to reach a certain size before they can make the transition from fresh to salt water. Since our fry would pass down river in a matter of a few days, they would not have reached a physiological state in which they could make the transition by the time they reached the sea.

Groot: Chinook fry have two stages at which they can cope with salt water. There is an initial, short period and then they revert to the freshwater phase until about 3 months later, when there is a longer period in which they can make the transition. They survive better if they get to sea at this later stage. In North America fry usually hold in the estuaries, but there are no extensive estuaries in New Zealand salmon rivers where fry could grow.

Wisker: There is concern about getting the salmon farming industry started. Now we have heard that 95% of outmigrants are wasted. So we should be allowed to use this waste in the industry.

D. Anderson: What you call waste may be supplying a valuable food supply to other, larger salmonids.

Waugh: Whatever happens to the so-called waste, I would far sooner see it converted into salmon than into food for barracouta.

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Unknown: What evidence do we have on the return rates of adult fish from different sizes of releases in New Zealand?

McDowall: There is not enough information yet to be definitive. We are only just beginning to come to grips with this question of different release sizes and relative return rates. We can say that the release of large smolts last year gave us the best return we have ever had, about 1% at the 2-year-old stage.

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Mr J. Tonkin: Yesterday Dr Hall spoke about bottlenecks. The question I would like to ask follows on from the fact that quite obviously there is a bottleneck in fry production. Does the bottle-neck lie in the very numbers that are produced, is it within the river, or is it at sea?

McDowall: Our guess would be that the real bottleneck is in the capacity of suitable rearing waters to rear fish to a size at which they are capable of going to sea. That is why so many fry are getting washed out, because there is nowhere for them to rear. Some recent work we have done in the Rakaia lagoon has been turning up yearling salmon smolts, but we don't know whether they reared in the lagoon or further up stream. Certainly, it seems that the lagoon at some periods holds large salmon smolts.

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O'Connor: On behalf of the audience, may I thank the panel for performing their difficult task this afternoon. Thank you very much.

P. D. HASSELBERG, GOVERNMENT PRINTER, WELLINGTON, NEW ZEALAND—1981

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The Swimming Behaviour of the Adult Oncorhynchus from the Growing Ground to the Spawning Ground.

Kiyoshi Uchihashi,
Yunosuke Iitaka,
Tsutomu Morinaga.

Among Oncorhynchus there are several very well-known species such as Cherry Salmon (Oncorhynchus masou), Red Salmon (O. nerk), Quinnat Salmon (O. tschwytcha), Silver Salmon (O. kisutch), Dog Salmon (O. keta) and Pink Salmon (O. gorbusha). Also, there is Amago Salmon (O. rhodurus) and Biwa Salmon (O. rhodurus var.) which may be considered as one separate species or as two individual species. Amago Salmon is only found in Honshu, the main island of Japan, and Biwa Salmon is a special breed of Lake Biwa near Kyoto, Japan. So, we have seven species, unless we regard Biwa Salmon separately, then we have eight species in all.

Now we are going to tell you, mainly from the ecological point of view, about the findings of our investigation into the seven species we have just mentioned. This will concern the swimming behaviour of the adult salmon from the growing ground to the spawning ground.

(1) The Swimming Area.

Having made the investigation into the home-range expanse of seven species of Oncorhynchus, we found that the grade of the ecological differentiation from the smallest to the largest is as follows : Amago

Salmon to Cherry Salmon to Silver Salmon and Quinnat Salmon to Red Salmon, Dog Salmon and Pink Salmon. From the fact that we have just mentioned, we notice the difference in the home-range expanse according to the species. When we go on examining the distance between the spawning ground and the growing ground of these species, we find the following differences :

Amago Salmon	- It's growing ground and spawning ground are either the same or very near.
Cherry Salmon	- There are some whose growing and spawning grounds are very near, while those of others are rather distant. The range of distance between these grounds is large.
Silver Salmon and Quinnat Salmon	- Their growing and spawning grounds are rather distant but not as extensive as those of Red Salmon, Dog Salmon and Pink Salmon.
Red Salmon, Dog Salmon and Pink Salmon	- The distance between their growing and spawning grounds is the greatest of all.

Judging from this data we can see that there are two types of salmon. Some have almost no distance to cover between the growing and spawning grounds, while others have an extremely long distance to go.

(2) The Homing of Oncorhynchus.

It is generally accepted that salmon home on their spawning ground. But some salmon, like Amago, spawn where they were spawned or in close

proximity. So, in the strict sense we cannot call this a homing migration. Next, let us examine salmon of land-locked form. They are all similar to Amago salmon in homing. It is a superficial view that the narrow, closed area forces these salmon to apparently home. We consider they have a potential inherent tendency towards homing which can adapt itself to the environment and appear as it is. We would like to tell you some things about this.

(3) Is the Homing Migration Peculiar to Oncorhynchus ?

The behaviour of fish to home on their spawning ground on reaching the adult stage is not peculiar to Oncorhynchus but is also seen in many migratory fish. Many species among littoral fish spawn and grow on the same ground. We view the matter in this way. Originally, fish hatched and grew on the same ground. In coping with the diversity and peculiarity of the ocean, their hatching ground and growing ground became separate. To adapt to these two separate grounds the behaviour of homing migration was formed. We think it quite natural that there are some species that are still observing the old behaviour but they have the homing migration instinct. They are trying hard, but almost in vain, to maintain their species.

(4) Homing Motivation Theory.

Homing, especially a very long-distance homing migration, can be regarded as one of the highest grades of differentiation. When salmon swim from the growing ground to the spawning ground, they have vast, deep and dynamic seas and oceans before them to cross. What do salmon use as their compass in swimming across these seas ? One explanation of homing is the theory of the mystic element, but we do not accept this. We still have the theory of the Olfactory Sense. This theory tries to prove that salmon swim from distant seas to the spawning grounds by means of a keen sense of smell. Through many experiments, which have been made up to now, it has been proven that salmon swim from the sea at the river mouths to the spawning grounds using their olfactory sense. But we have no supporting evidence for it from the open seas to the river mouths. Another theory explains that salmon perceive the position of the sun which they use as a compass while homing. Again no actual proof has ever been shown concerning the relationship between the light of the sun and the swimming behaviour of salmon in the ocean.

We think differently from each of these theories. The general behaviour of salmon in the sea is greatly affected by the seas physical structure, i. e., the ocean currents and their resultant fronts and convergence. On the other hand, after they reach the sea near the river mouths, they swim to the spawning ground by means of their olfactory sense. In short, our theory is that the general swimming behaviour of salmon in the sea is controlled by the currents.

(5) Migration Under the Control of Currents.

A current is made up of water masses, and water masses stream in vortices. It may be difficult for salmon in such a sea to know the direction of the vortices themselves ~~because there are~~ many turbulent flows in the vortices, but the salmon can take their orientation parallel to the general trend of these turbulent flows. The organs used in doing this are Mauthner's cell of the medulla and the acoustico-lateral organ.

In an experiment made in a water tank, the fish which had their eyesight removed drifted about like plankton. However, when they were engulfed in man-made turbulent flows, the blind fish orientated themselves horizontally parallel to the main stream. Mauthner's cell, the acoustico-lateral organ which we have just mentioned, plays a part in this orientation phenomenon (Dr K. Uchihashi's work in 1960).

We do not think that the orientation always occurs in this way but it does mostly. When a water mass forms a front in between another water mass, it is a fairly well-known fact that the distribution of the temperature in these conditions controls the behaviour of salmon. In short, the behaviour of salmon has a close relationship with ocean currents, which depend upon the oceanographic structure. Because of this fact we belive that if there was no relationship between the currents at point A and at point B, which are distant to each other, there could not occur any homing migration between these points. There is another important point to mention here. When salmon live on the bottom of the continental shelf, they take their orientation from the ridge of the sea-bottom. It is also assumed that they take their orientation alongside the main trend of water, which is also controlled by ridges.

With respect to what we have just mentioned we have recently found a very interesting fact. Since 1973 the Chilians have been stocking the rivers of Latitude 45° South in Chile with 100 to 200 million Dog Salmon (Oncorhynchus keta) fry spawned in Japan every year. No fish are said to have homed yet.* When we compare this fact with the acclimatization of salmon in New Zealand, there are very important differences between them. Firstly, Dog Salmon compared to Quinnat Salmon is a fish of a higher grade of ecological differentation and is of never forming a land-locked. They are typical pelagic fish in the open sea and their homing distance is very long. Secondly, the Humboldt Current flows north along the west coast of Chile and nearly reaches the Galapagos Islands. From there it flows west, becoming the South Equatorial Current, and then it is finally scattered. It cannot possibly be expected that homing Dog Salmon will be orientated and carried by this scattered remnant of current back to the coast of Chile. On the other hand, the Quinnat Salmon of New Zealand is a fish whose ecological differentiation is of a medium grade. It is thought that they live quite near, or on, the bottom of the sea, and that the oceanographic structure of off-shore New Zealand differs from that of Chile. Off the New Zealand coast, there is the Southland Current, the Southland Front, and in the north, the Sub tropical Surface Water. This oceanographic structure exists far to the east off the Canterbury Bight forming a type of fence. In short, the homing migration of New Zealand Salmon seems to have been kept, and the salmon resources have been maintained even though on a small scale. This is probably because the homing behaviour and the actual conditions of the off-shore current, which we think may seldom be found, are well harmonized with each other. This phenomenon is precious as a biological monument.

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* According to the Fishing News of the 15th February, 1980, it was reported that an American firm had made a delayed release of two hundred and sixty thousand (260,000) Quinnat Salmon and thirty-five thousand (35,000) Coho Salmon [in this paper referred to as Silver Salmon], both of which were in the smolt stage. They were released from the hatchery of Acoho in Chiloe Island, Chile. After the release, Quinnat Salmon began to home from the end of 1979. It was reported that one hundred and fifty (150) salmon came home during the month of December, 1979. This was their first return to Chile. Their return may be explained by the fact that Quinnat Salmon belong to a species of ecologically low differentation. Their littoral behaviour may have appeared and they did not swim far enough to be engulfed by the Humboldt Current.

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(6) The Aims of Our Research.

We now think that there are several reasons for the acclimatizing success of Quinnat Salmon in New Zealand. Quinnat Salmon is a species with a low ecological differentation. From the beginning of naturalization in the lakes of New Zealand it's seasonal periodicity was able to be regulated and adjusted fully to the conditions of the Southern Hemisphere. Besides this, Quinnat Salmon has the habit of living on the sea-bottom and arround the east coast of the South Island. It is thought that there is the oceanographic construction, which we have already mentioned, which produces a water mass different from that in the open sea. What we have just said is based on supposition, it has not been proven yet. So for research in the future there is a need to establish first of all, the homing ability according to each of the grades of growth and of the sea area separetely. We understand that this investigation is now being made by the Fisheries Research Division of the New Zealand Government, to whose results we are looking forward.

Next we would like to tell you about our investigation plan, a part of which we are currently executing ;

I We are now trying to analyse mathematically the swimming behaviour of the fry and smolt of Quinnat Salmon and other species which also belong to the genus Oncorhynchus,

II We are attempting to establish the relationship between salmon's behaviour and the artifical lesion of each part of its brain. This is done by laser rays,

III We are also researching bottom living behaviour and swimming behaviour from the viewpoint of the morphology of the central nervous system,

IV We are investigating the relationship between the salmon's ecological movements and the micro-chemical substances in it's living conditions.

From this you can see that it is impossible for us to carry out these investigations without having the cooperation of New Zealand and her people.

In 1958, a Canadian biologist, Dr F. Neave advanced a new theory that Oncorhynchus had evolved from Salmo due to the topographical changes in the Japan Sea. But we have already mentioned several species that have not yet been differentiated ecologically that are distributed around the Japan Sea. It was the salmon of the medium grade in ecological differentiation that they succeeded in acclimatizing to New Zealand. Dog Salmon, on the other hand, is a species with a high grade in ecological differentiation with which they were not successful in acclimatizing in Chile. We think that the homing migration of salmon is a specialized, high grade behaviour which has been formed by conforming to the peculiar character of the ocean, and that it may be difficult for salmon to conform to the oceanographic structure of a different type. On the other hand,

it must be added that for Salmon with a non-differentiated behaviour, it is easy to conform but it is difficult to produce huge resources.

Acknowledgements

We are grateful to the New Zealand Government and to the scholars in this country for their extensive cooperation and support which they gave us while we were doing our Salmon research. Now, we would like to express our hearty thanks for being invited to attend this Symposium.

taking off ~~We would now like to give you an opportunity to make your comments and learned advices.~~ (Our discussion will be aided by Dr Yosuke Kawachi from Otago University who will act as our interpreter.)

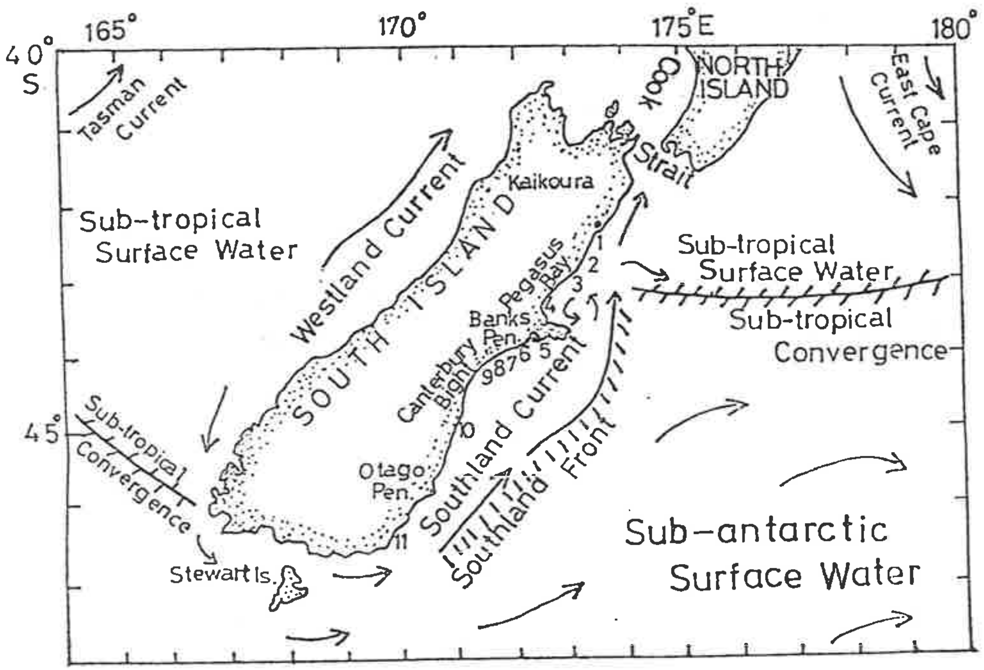

Fig. 1 A map showing pattern of currents and zones of convergence around the South Island of New Zealand (from Dr R.A. Heath in 1973).

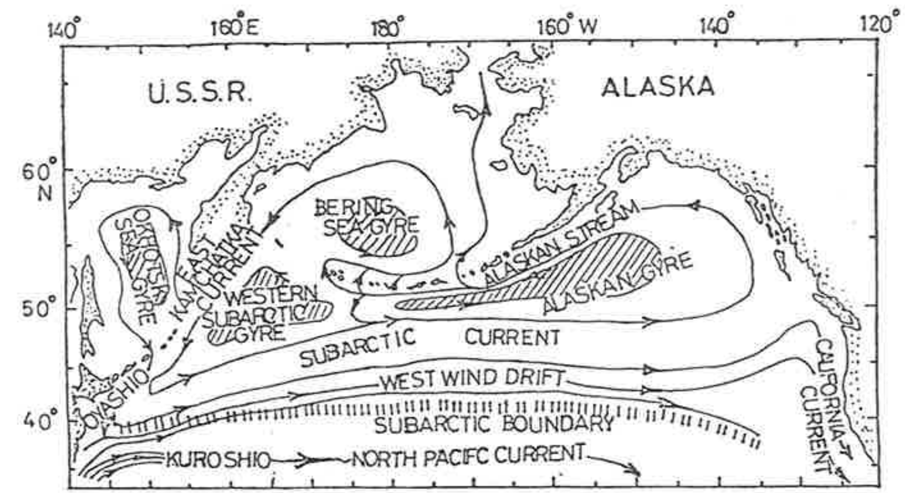

Fig. 2 A map showing pattern of surface currents of the North Pacific Ocean (from Drs Dodimead, Favorite and Hirano : Review of Oceanography of the Subarctic Pacific Region - 1, NPFC Bull., No. 13, 1962).

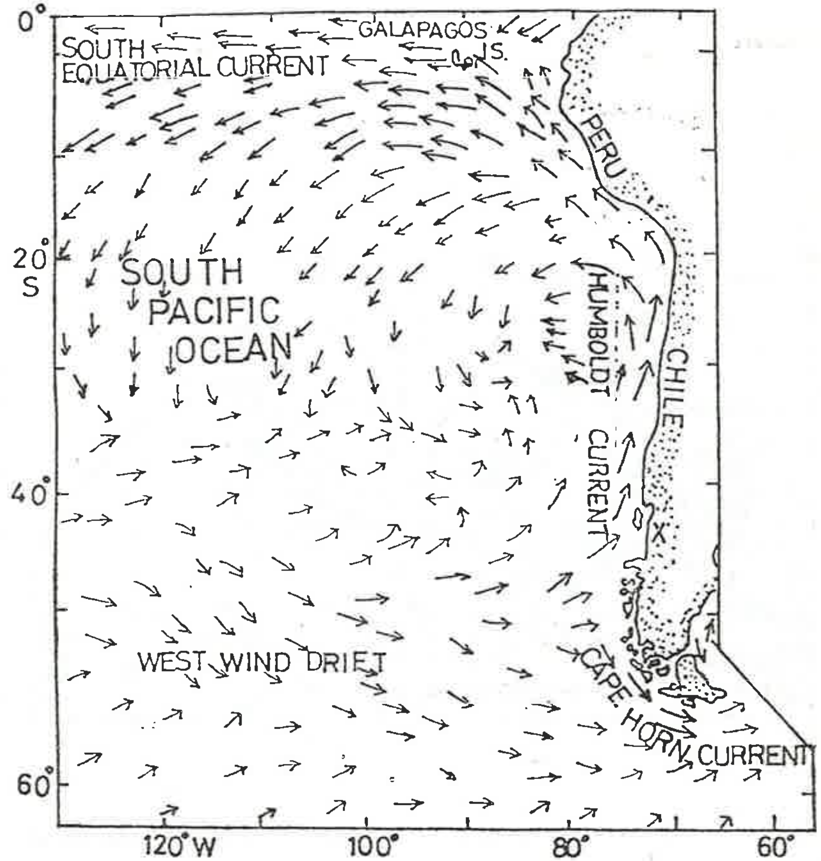

Fig. 3 A map showing pattern of surface currents of the South Pacific Ocean (from Pacific Ocean Atlas Vol. 1, USSR Navy in 1974).

Salmon Symposium at University of Canterbury Christchurch, New Zealand 30-31 August, 1980

sponsored by

THE MINISTRY OF AGRICULTURE AND FISHERIES

FISHERIES RESEARCH DIVISION

Programme

Saturday August 30

8.30 a.m.	REGISTRATION
9.30 a.m.	TEA
10.00 a.m.	INAUGURATION. The Honourable Duncan McIntyre, Minister for Agriculture and Fisheries

SESSION 1 - Chairman, Mr G.D. Waugh (Director, Fisheries Research Division, M.A.F.)

10.30 a.m.	The history of New Zealand's salmon fishery. M. Flain (Fisheries Research Division, Christchurch)
11.00 a.m.	Juvenile production and yield in chinook salmon. C.L. Hopkins (Fisheries Research Division, Christchurch)
11.30 a.m.	Aspects of the juvenile chinook salmon migration. M.J. Unwin (Fisheries Research Division, Christchurch)
12.00 noon	Improvement of salmon spawning and rearing habitat. Dr J.D. Hall (Oregon State University, Corvallis) and M.S. Field-Dodgson (Fisheries Research Division, Christchurch)
12.30 p.m.	LUNCH

SESSION 2 - Chairman, Mr S.G. Hamblett (Consultant to Water and Soil Division, M.W.D.)

1.30 p.m.	Water resources development policy in New Zealand. F. Scarf (South Canterbury Catchment Board, Timaru)
2.00 p.m.	Recreational evaluation and protection of salmon fishing rivers. L.D. Teirney (Fisheries Research Division, Wellington)
2.30 p.m.	Power Generation and the fishery of the lower Waitaki River. E. Graynoth (Fisheries Research Division, Christchurch)
3.00 p.m.	TEA

SESSION 3 - Chairman, Mr M.S. Field-Dodgson (Fisheries Research Division, M.A.F.)

3.30 p.m.	Otago University's experimental programme on the Waitaki River. Dr D. Scott (University of Otago, Dunedin)
4.00 p.m.	The Southern Lakes Conservancy salmon management programme. R.T. Hutchinson (Southern Lakes Conservancy, Queenstown)
4.30 p.m.	The Atlantic salmon in New Zealand. J. Gibbs (Southern Lakes Conservancy, Queenstown)
5.00 p.m.	EVENING DRINKS AND DINNER

SESSION 4 - Chairman, C.L. Hopkins (Fisheries Research Division, M.A.F.)

7.30 p.m.	The migratory movement of adult salmon from their feeding grounds to their spawning grounds. Dr K. Uchihashi, Dr Y. Iitaka and Dr T. Morinaga (University of Kinki, Osaka)
8.00 p.m.	Films: The Big Qualicum River Project (with sound track)
	Spawning Behaviour of Pacific Salmon (no sound track: commentary by Dr K. Groot)

Sunday August 31

SESSION 5 - Chairman, Dr G.J. Glova (Fisheries Research Division, M.A.F.)

8.30 a.m.	Canada's West Coast salmonid enhancement programme. Dr K. Groot (Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo)
9.20 a.m.	The Weyerhauser salmon project. Dr W.J. McNeil (Springfield, Oregon)
10.00 a.m.	TEA

SESSION 6 - Chairman, Mr C.J. Hardy (Fisheries Research Division, M.A.F.)

10.30 a.m.	Salmon culture. Dr R.E. Burrows (Salmon culturist, Washington State)
11.00 a.m.	Diseases in salmon hatcheries. N.C. Boustead (Fisheries Research Division, Wellington)
11.30 a.m.	The Australian quinnat salmon fishery. Dr P. Rogan (Arthur Rylah Institute for Environmental Research, Heidelberg, Victoria)
12.00 noon	The Wattie/ICI salmon ranching programme. T.W. Beckett (Wattie Industries, Auckland)
12.30 p.m.	LUNCH

SESSION 7 - Chairman, C.L. Hopkins (Fisheries Research Division, M.A.F.)

1.30 p.m.	The relationship of commercial to sports fishing in the U.S.A. J.R. Galat (President, Burnt Hill Salmon Ranch Ltd, Oregon)
2.00 p.m.	Panel discussion: Problems of salmon management in New Zealand. Chairman: Mr D.P. O'Connor. Panel: Dr R.M. McDowall (Fisheries Research Division, M.A.F.), Mr B.T. Cunningham (Director, Fisheries Management Division, M.A.F.), Mr C.R. Anderson (Chairman, Salmon Committee, Council of South Island Acclimatisation Societies), Mr R. Lightfoot (President, New Zealand Salmon Angling Association), Mr J.D. Wisker (Secretary, Salmon Ranchers Association)
3.00 p.m.	TEA
3.30 p.m.	Panel discussion (continued)
4.30 p.m.	Summary. Dr D. Scott (University of Otago, Dunedin)
	Closure: C.L. Hopkins (Fisheries Research Division, M.A.F.)

Venue

The meeting will be held in Lecture Theatre A2 on the Ilam campus, near the main Library block. Easiest access is via University Drive from Ilam Road or Clyde Road.

Lunches, morning and afternoon tea and dinner will be served in the Students Union.