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The Glenariffe Salmon Research Station

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Cover: The Glenariffe Salmon Research Station on the banks of the Rakaia River, Canterbury, New Zealand.

The Glenariffe Salmon Research Station

by M. S. Field-Dodgson and J. R. Galloway
Fisheries Research Division,
Ministry of Agriculture and Fisheries,
Christchurch

High in the foothills of the Southern Alps in Canterbury, on a tributary of the Rakaia River 100 km from the sea and 500 m above sea level, is the Glenariffe Salmon Research Station, where staff of the Fisheries Research Division of the Ministry of Agriculture and Fisheries are carrying out research on quinnat salmon (*Oncorhynchus tshawytscha*).

The research station began as a simple fish trap on the Glenariffe Stream in 1965. Since then it has developed into an enhancement unit, with facilities for the artificial fertilisation and incubation of salmon eggs and the rearing of salmon fry up to yearling fish for release. It is the only salmon hatchery based on an established natural salmon run in the Southern Hemisphere.

This leaflet describes the events leading up to the installation of the Glenariffe salmon trap and the research work that has resulted from its establishment.

Introduction of quinnat salmon

Because of its isolation from other major land masses, New Zealand developed a distinctive native flora and fauna. When early European settlers arrived they found none of the plants and animals with which they had been familiar. Consequently, they tried to introduce many species, either to provide food or recreation or merely to enrich their surroundings.

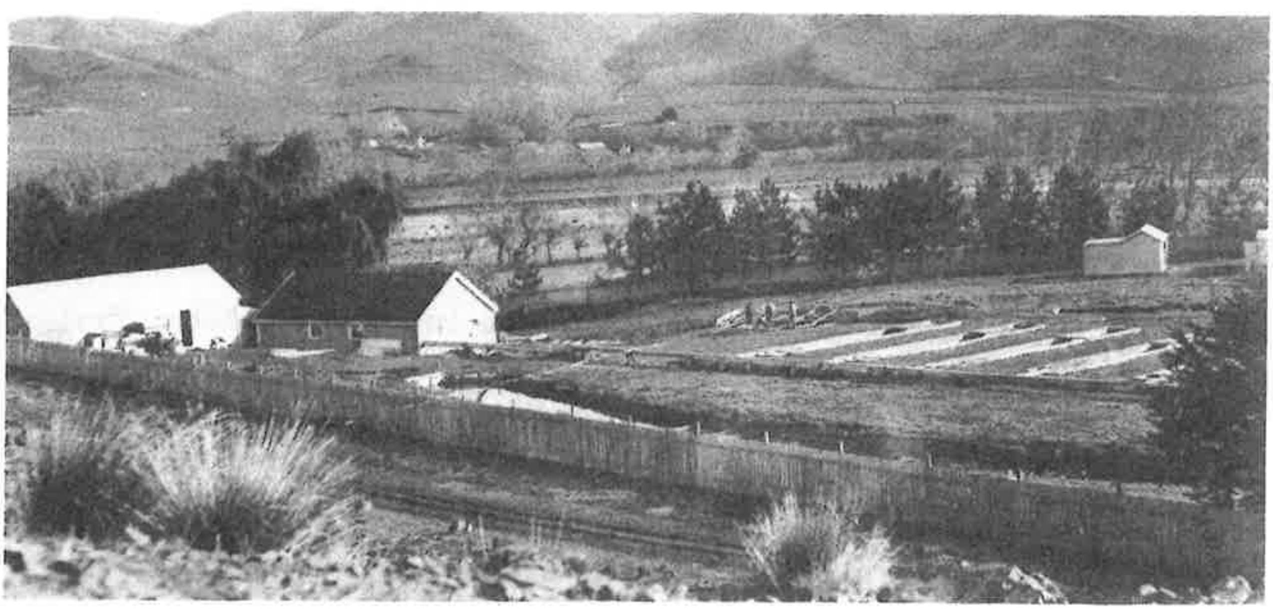
The successful introduction of trout led to attempts in the 1870s by the acclimatisation society movement to establish runs of quinnat salmon. These efforts failed, possibly because too few eggs were imported and the rivers chosen were unsuitable.

A more determined and calculated effort to establish salmon was made in 1901 by L. F. Ayson, Marine Department Chief Inspector of Fisheries, who obtained Government funds to have a hatchery built on the Hakataramea River, a tributary of the Waitaki River. This river system was selected because of its similarity to known North American salmon rivers.

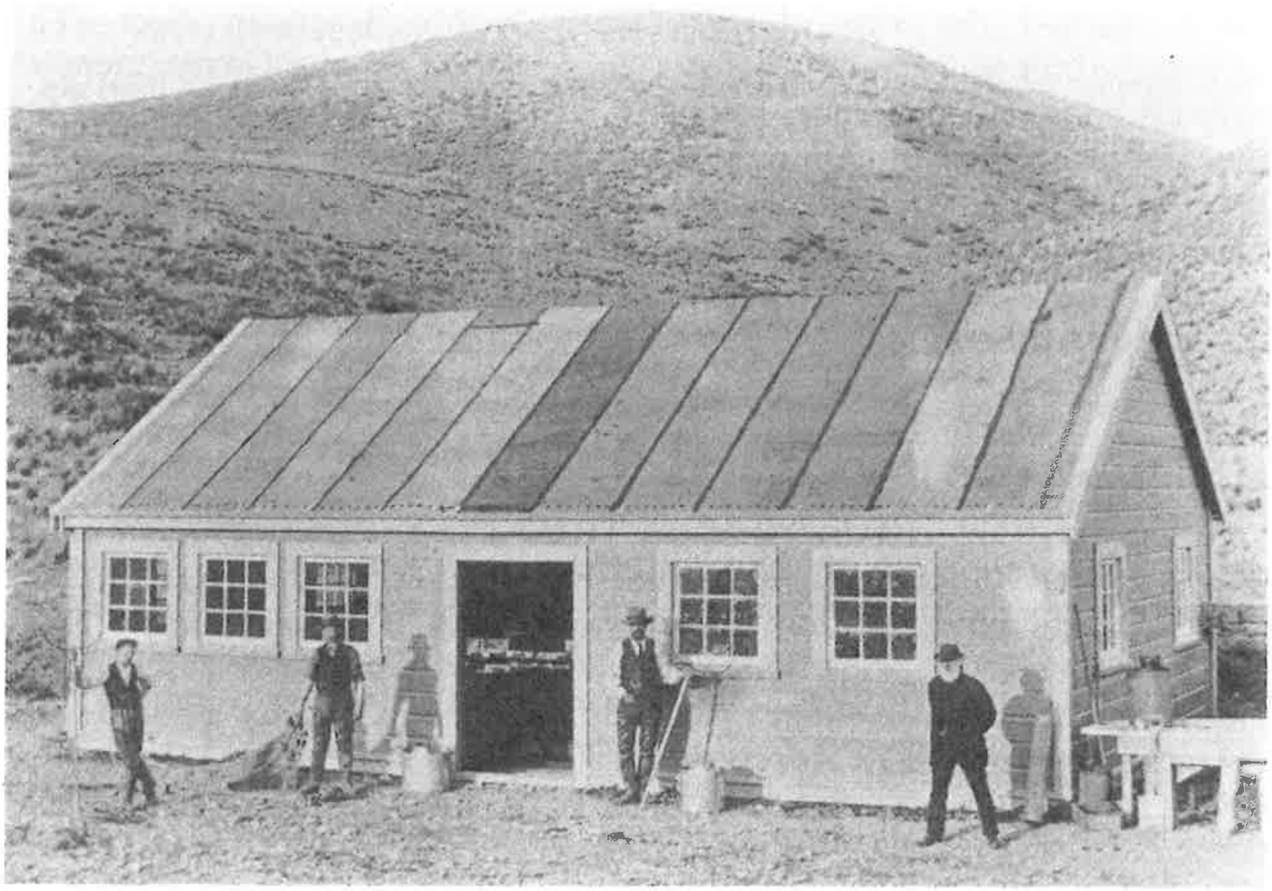
Ayson went to the United States to obtain ova and personally cared for them during their shipment to New Zealand. This operation was repeated over several years. Its aim was to establish a run in the Waitaki River, which would become a source of ova to enable extension of stocking to other rivers. It was intended that if runs were established, the fish would be harvested and marketed as in North America, and a renewable resource and a new industry would be created.

First liberations

The first liberations from the hatchery were fry released into tributaries of Lake Ohau in 1901. Later, Ayson had a report from the Benmore Station manager, Mr. Sutherland, that large carcasses had been seen in the tributaries of Lake Ohau in April and May 1904, but he was too late to collect any specimens. These fish were likely to have been salmon, because the unusual appearance, the large carcass size, the time of year, and the time since the first liberation (3 years) all fit in with the known New Zealand life cycle pattern.



The first salmon hatchery in New Zealand, the Hakataramea hatchery, which was established in 1901 and continued to operate successfully until 1942.



The hatchery building at Hakataramea. The boy at the left is Charlie Ayson, son of L. F. Ayson, the man responsible for the Hakataramea hatchery.

Fry were liberated into the Hakataramea and Waitaki Rivers in 1903 and returning adult fish were first collected at the Hakataramea fish trap in 1906. The runs soon built up, and once they were of sufficient size additional importations of ova were discontinued. Fry raised from the stripping of fish from these runs were liberated into other river systems and helped to reinforce the populations which were already building up by a slow natural spread. Several fry-rearing substations were set up for this purpose and were financed by the Government. The Hakataramea hatchery continued operations until the Second World War and was closed down in 1942.

Establishment and spread of salmon

For a period, limited numbers of netting licences (1925–52) and rod selling licences (1922–52) were issued. During this time, the public could buy fresh or smoked New Zealand salmon from retailers. As well as the commercial fishery, an important sports fishery developed, but the runs never reached the size of the larger North American ones. The acclimatisation society movement then prevailed on the Government to have all commercial licences rescinded, because it was considered that the runs could not sustain commercial cropping. Government acceded to the request, but retained statutory control of the species and required the societies to provide a minimum of 750 salmon per season for the home market. The income from this was to be used to investigate, manage, and develop the fishery.

Highbank trap

When the Rangitata diversion race (RDR) was completed, water could flow from the Rangitata River to the Rakaia River and discharge through the Highbank power station. In the early 1950s large numbers of adult salmon congregated below the tail race of the hydro-electric scheme at Highbank. These fish either started life in the Rangitata River, were diverted down the RDR, survived the turbines, and finished their journey in the Rakaia River or were Rangitata River fish homing on the Rakaia-Rangitata water mixture and were attracted up the power station tail race, which contains pure Rangitata River water. This congregation of fish provided an opportunity for the acclimatisation societies to obtain supplies of salmon for the local market and thereby funds for the development of the salmon fishery.

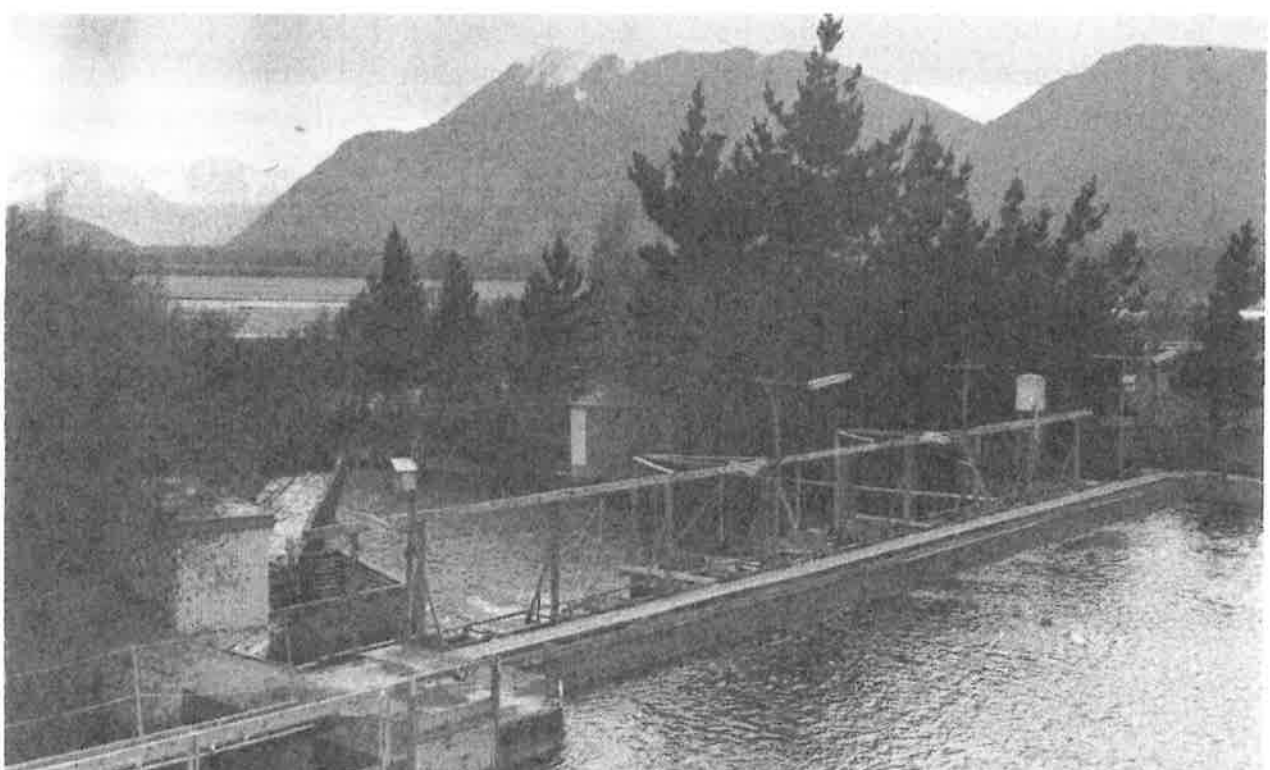
A trap was built with money lent by the Government, and the South Island Salmon Committee, a body of representatives from interested societies and government departments, was formed to administer the scheme. Fish were first marketed in 1953, when 718 were sold. Catches reached a peak of 3006 in 1956. However, after several years' use of the trap, changes in the operating procedure of the Highbank power station resulted in the number of fish trapped declining to the point where it was considered uneconomic to continue. The South Island Salmon Committee, however, broadened its membership with additional acclimatisation society representation and considered ways in which salmon research could be undertaken.

Recommendations from the committee and other interested parties resulted in the Freshwater Fisheries Advisory Council's suggestion that the South Island technical field service of the Marine Department should undertake projects of more extended duration than previous investigations. This led to the planning and building of the Glenariffe salmon trap in 1965.

Early salmon research and management

Factual information on quinnat salmon in New Zealand before the building of the Glenariffe trap was scarce. In 1928 Dr H. J. Finlay, of the University of Otago, received a Marine Department grant to investigate their biology. This he did from scale samples of 455 net-caught fish from the Waimakariri River. The results from his work were outstanding for the time — it was the first genuine attempt to analyse the age and growth structure of quinnat salmon from the Waimakariri River — but the significance of his findings was overlooked. Only after the Glenariffe trap had been in use for several years was his report on the subject found.

In 1937 D. F. Hobbs, a biologist with the Freshwater Research Committee of the New Zealand Acclimatisation Societies' Association, worked on redd structure and egg survival and found that natural spawning and reproduction were efficient up to the fry stage. In 1935 A. W. Parrott, also a biologist with the Freshwater Research Committee, confirmed many of Finlay's results from a larger number of scale samples and expanded on the early life history of the fish, but his results were not published until 1971. From 1934 to 1962 G. Stokell published work mainly on taxonomic features and on some of the freshwater stocks of quinnat salmon.



The Glenariffe salmon trap. The adult trap is by the shed at the left, the fry trap extends across the stream.

The first step in the management of the fishery was taken by Professor E. Percival, of the University of Canterbury, who in 1955 began ground party spawning surveys to determine the extent of the main spawning areas. This work was later taken over and expanded by the Marine Department, which set out to assess yearly abundance. In 1962 the work was allocated to the department's South Island technical field service, which had been formed to assist the societies in deciding their fisheries management policies.

Installation of the trap at Glenariffe

The Marine Department adopted the recommendation of the Freshwater Fisheries Advisory Council and arranged to build a salmon trap. Several sites were examined, including the Hakataramea River, Lake Stream (Lake Heron), Lambies Stream (Lake Clearwater), and Glenariffe Stream. Glenariffe was chosen for several reasons, the more important being:

- It was known to be a good spawning area and therefore could provide adequate material for investigative purposes.
- It was a stable area not subject to frequent violent flooding.
- It was reasonably accessible and close to the Marine Department's fisheries laboratory in Christchurch.

The installation of the first structure, a one-way adult trap, began in January 1965. It was made with a base of blue gum logs anchored into the stream bed by metal stakes.

This pilot trap was operational by 28 February 1965 and continued until 18 June of the same year. More than 2000 fish were handled, and the results indicated the suitability of the area for research into other aspects such as juvenile production. The site was accordingly surveyed with the help of the Department of Lands and Survey to determine if there was sufficient fall to install a workable fry trap. With the aid of the New Zealand Army's Southern District squadron of the Royal New Zealand Engineers, an adult trap and a horizontal screen fry trap were built into the stream. They were made at the Marine Department's Christchurch laboratory, and after each part had been labelled the two structures were dismantled and then reassembled on site at Glenariffe in January 1966.

1965

In the first year's operation of the adult trap the migrating adult fish were weighed, measured, and sexed. Aging was tried by examination of scales, but, because the scales of spawning salmon become overgrown by skin and their margins absorbed, they are hard to collect and were thought to be unreliable for aging. The next most easily collected structures for aging are the inner ear bones (otoliths). These were found to be much more reliable than the scales of spawning fish, and to obtain them 1 out of every 10 fish was marked with a numbered spaghetti tag. The tagged carcasses were recovered after spawning and the otoliths removed. It was thus possible to age already measured fish and to determine their growth rates. Length measurement of the carcass is made difficult because both the nose and tail are badly eroded and only rough estimates are possible.

In 1965 the acclimatisation societies were given permission to take 46 females for ova, but this permission was withdrawn soon afterwards — the salmon project's aim was to relate adult returns to juvenile production, and the removal of females introduced a complicating factor.

1966

The two-way trap was installed in January, and more than 1000 adult fish were put through it. As in 1965, 1 in every 10 of these was tagged with a numbered spaghetti tag, but the recoveries in both years were insufficient for reliable age and growth determination of the whole run.

Three adult salmon in the trap.

Tagging, weighing, measuring, and recording an adult female salmon at the trap.

1967

All fish were tagged, the spaghetti tags being replaced with sheep ear tags, which were passed through the operculum. Because these tags were less readily lost, there was a higher recovery rate (60%).

This year fork length was recorded as was a measurement from the front of the eye to the end of the vertebral column, so that a relationship between the two measurements could be established. Recovered carcasses of spent fish are usually damaged, but the skull and vertebral column tend to remain intact. Thus by use of this relationship it was possible to estimate from recoveries in other areas the true lengths of the fish which had spawned.

1968–75

The trap was operated until 1 November 1971 by the Fisheries Management Division of the Marine Department, after which the responsibility for it was transferred to Fisheries Research Division. (From 1 September 1972 the two fisheries divisions in the Marine Department joined with the Department of Agriculture to form the Ministry of Agriculture and Fisheries.)

Collection of data on adult fish was continued. During 1970 the run was very small. Examination of its age composition showed clearly that one year class was affected, and this could be directly related to a bad flood at Glenariffe in November 1967. Severe flooding can wash the juveniles out of the spawning streams and into the silt-laden Rakaia River, where many of them may perish. A further heavy flood in 1970 compounded the effect, so that, as forecast, the 1973 Glenariffe spawning run was the poorest recorded.

During 1973–76 the down-stream fry trap was operated for each full 12-month cycle and was calibrated to establish its catch efficiency. The project was undertaken to investigate juvenile production and the character of the fry migration from the Glenariffe Stream into the Rakaia.

Development of holding facilities

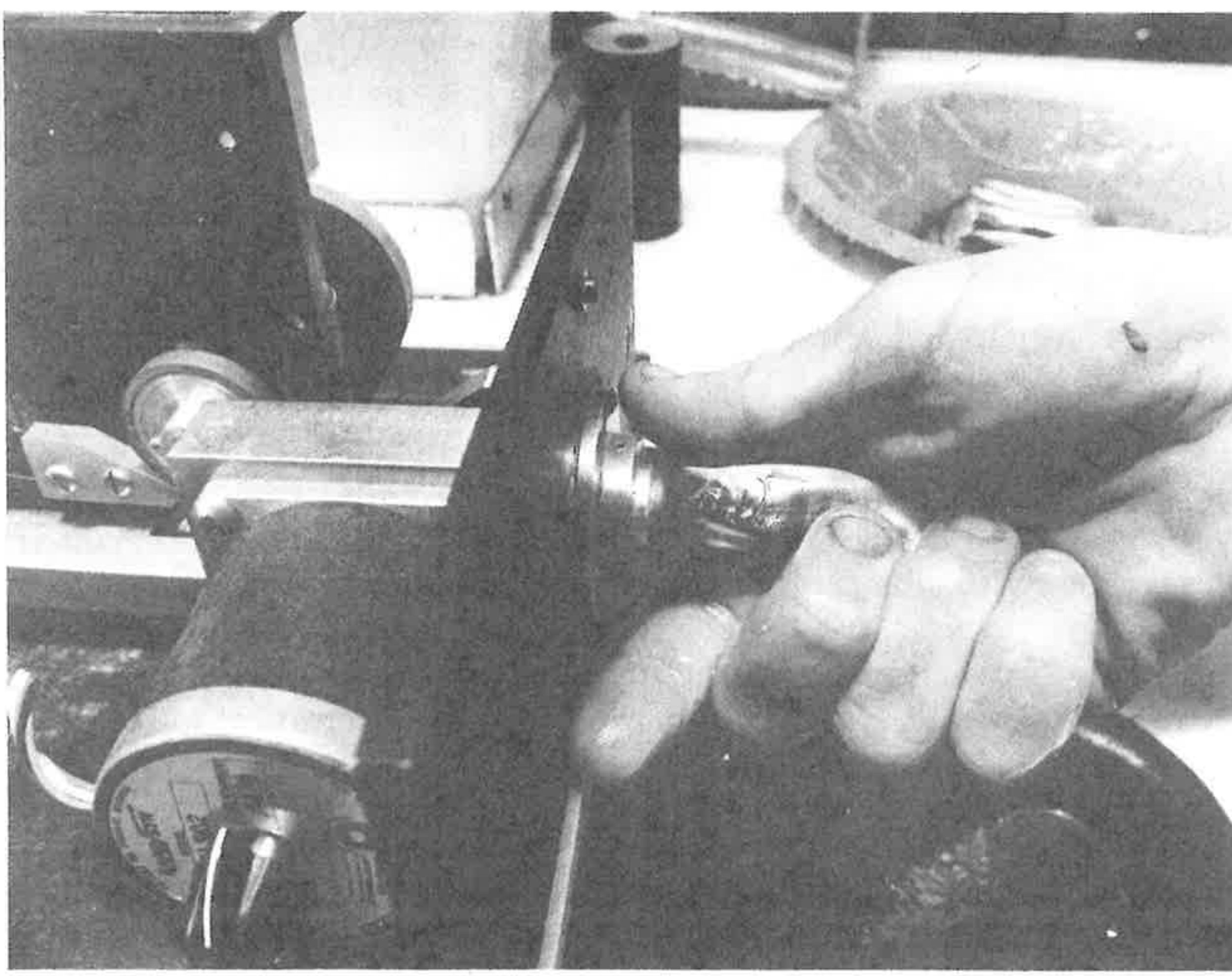
1976–80

When the migration patterns of the juvenile salmon had been investigated, the possibility of retaining some of the early outmigrant fry in portable swimming pools was examined. These fry are small (30–36 mm), and it was thought that their survival could be enhanced if they were grown to a larger size in artificial impoundments. This larger size might, in turn, increase their survival to adulthood and increase the size of the adult run.

In July 1977 two portable swimming pools were used to rear fry, and during September early outmigrant fry caught at the trap were placed in the pools. Twenty-eight thousand fry were artificially reared until January 1978 and released at a weight of 5 g. This pilot project showed that fry could be artificially reared, and it was to initiate a much broader approach to salmon research.

Tagging of juveniles is invaluable to answer such questions as: What is the relationship between age and size at release and age at return? Do the adults stray from their natal river? How accurate are the otolith readings? How do you identify different releases from other rivers? But tagging raises another question: How can you effectively tag a fish 70–100 mm long that stays in the sea for an average of 3 years (2–4 range) and returns 10 times larger? This problem was solved by using a new tagging machine developed in North America in the late 1960s. This machine inserts a miniature coded-wire tag into the nose cartilage of fish as small as 50 mm. The South Island Council of Acclimatisation Societies bought one and donated it to Fisheries Research Division for use on salmon projects. It is now being used extensively, along with a second machine bought by Fisheries Research Division.

Holding facilities, comprising two pairs of concrete raceways each 25 × 2 m wide × 1.25 m deep, were built and supplied with water from

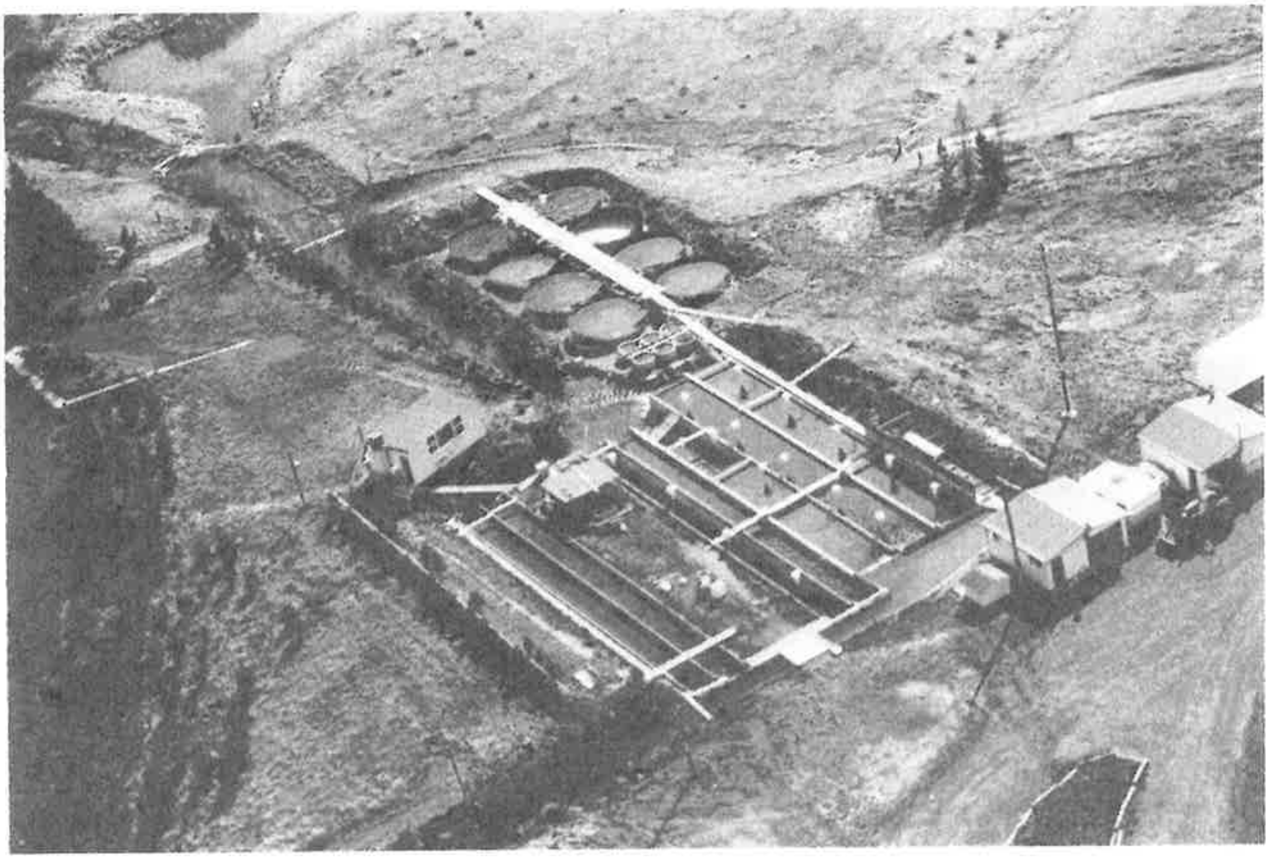


The tagging machine inserting a tag into the nose of a juvenile. [Photograph from *The Star*, Christchurch.]

the Glenariffe Stream. They were first used for the 1979 fry season, and up to 500 000 fry could be held and raised to taggable size. The raceways, therefore, not only enabled knowledge of both juvenile and adult fish to be extended, but also enhanced the total run in the Rakaia River.

Three more raceways were built at Glenariffe (each 30 × 3.3 m wide × 1.5 m deep). They more than doubled the holding capacity of the station.

As well as the three new standard raceways, eight circular ponds (6 m diameter × 1 m deep) were built in accordance with the designs of a Glenariffe staff member. They allowed for greater flexibility in rearing different batches of fish for release and provided space for holding brood stock of other salmon species. They could also be used for feeding and growth trials and for other research that required replication of conditions with small batches of fish.



The holding facility; from the bottom, anticlockwise — header race, four original (smaller) raceways, three later (longer) raceways, small egg hatching and fry rearing circular tanks, eight large circular ponds. The settling pond is top left and the building in the left centre is the shed where small fish are tagged.

Various methods have been tried to increase the production of juveniles by semi-natural means. Between 1975 and 1981 two man-made lakes were stocked with fry caught at the Glenariffe trap. The fish fed on naturally occurring organisms and were tagged before release. Poor survival from these releases suggested that supplementary feeding with automatically dispensed artificial diets would be necessary to get a good survival rate in such impoundments.

A small spawning channel was built in 1980, and 140 adults of hatchery origin were placed in controlled sections and allowed to spawn naturally. Siltation and lack of ground water reduced egg survival and fry productivity, but the quality of the surviving fingerlings was high. Refinements will be made to the channel to increase ground-water flow and juvenile habitat.

1981–85

Expansion of fish holding facilities at the Glenariffe Salmon Research Station was planned because of developments initiated in 1975. At this time, salmon farming was being undertaken in many parts of the world and the curiosity of some people in New Zealand was aroused.

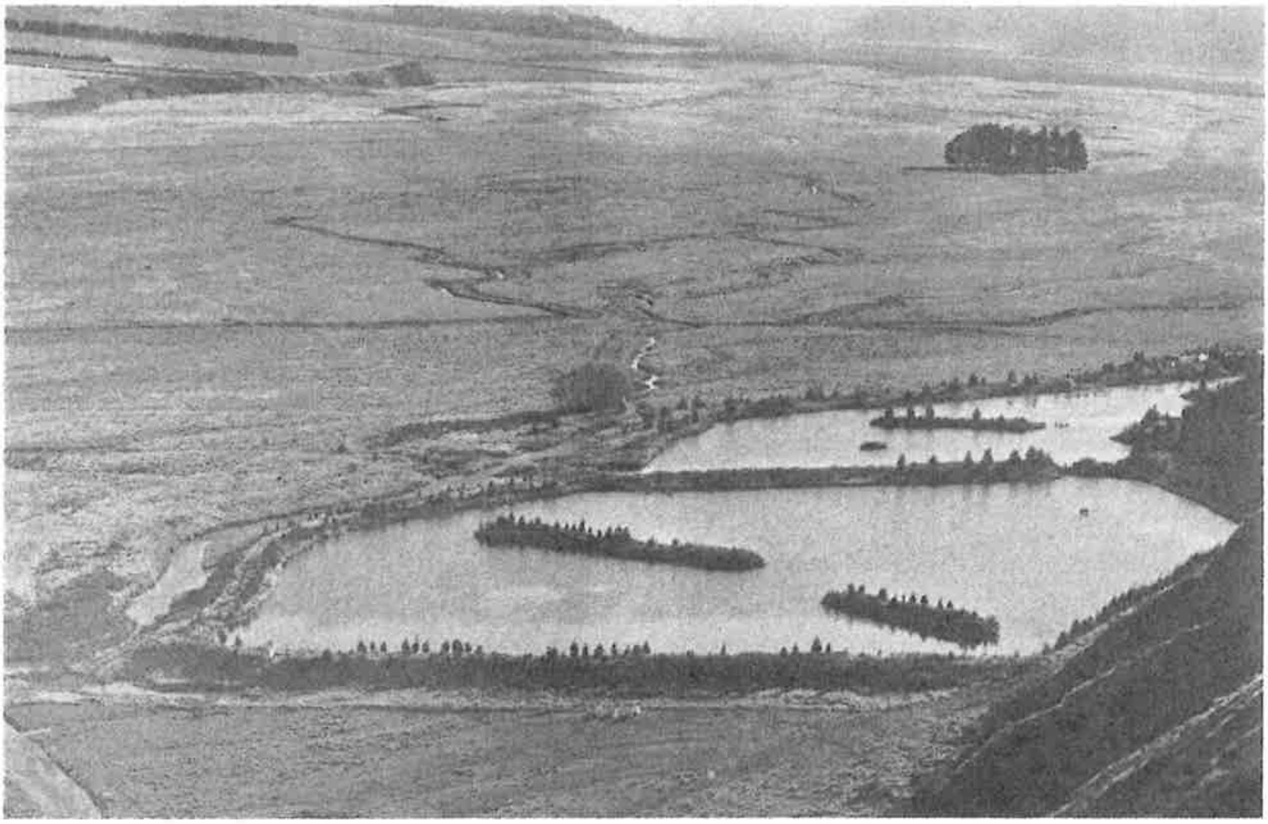
The first method tried was ocean ranching. Small fish are raised on artificial diets in concrete raceways and then released into an adjacent river, usually one that has an established salmon run. The farmer then awaits their return to the point of release as much larger adults (500 times heavier) which he can harvest, some for flesh and others for eggs and milt.

A more recent method uses either fresh or salt water, and the small fish are not released, but grown on to 1.5–2 kg and then harvested. This is called pond or net-pen rearing.

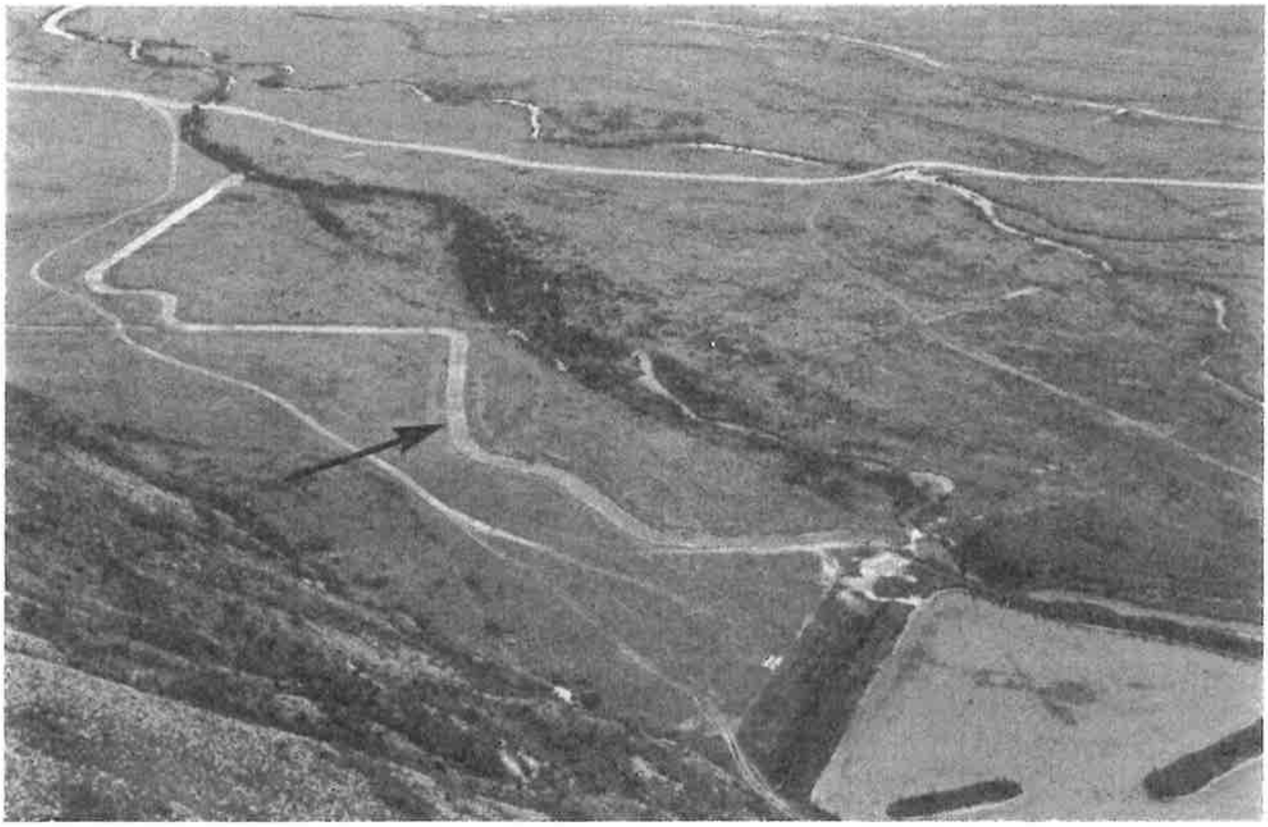
So far there are 10 farms, some ocean ranching and some pond rearing. Research at Glenariffe is aimed at providing support and advice for the salmon farmers.

Initially the original rectangular raceways were stocked with wild fry caught in the fry trap during August, September, and October. However, to investigate the possibility of artificially fertilising salmon eggs, some ripe adults that entered the trap were held for stripping. It was found that 90% fertilisation could be achieved, and the resulting fry were all of similar size and less prone to gill disease than wild fish.

A series of sorting pens leading to an enclosed stripping shed were built, so that the husbandry operations could be carried out with a

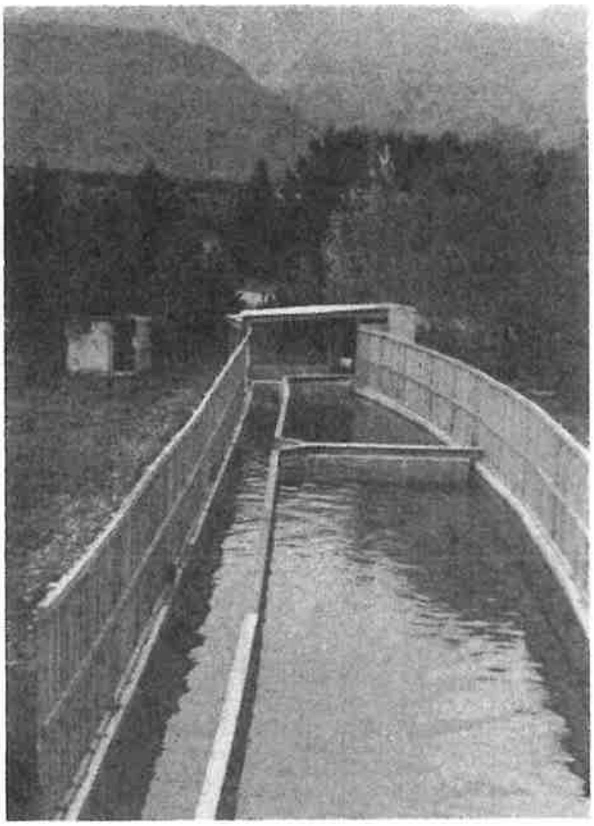


Hydro lakes used for enhancement. The upper Rakaia River is in the background.



The artificial spawning channel (arrowed) used for enhancement is supplied by water from Glenariffe.

A fry trap (one of nine across the Glenariffe) with its catch.



The adult holding pen. Females are in the top pen, males are in the bottom pen. The stripping shed is at the top end of the pen.

20-g juvenile tagged salmon in the raceways. (Note the white mark just above the tail fin of the fish in the top right of the photograph — its adipose fin has been removed.)

minimum of stress to the adult fish. Fish to be used for stripping are held in the pens until required.

The raceways are now stocked entirely with fry from stripped adults. However, careful consideration is given to the number of fish held for stripping, so that adequate stocks are let through the salmon trap to spawn naturally and maintain the wild run. Also, fish are taken for stripping throughout the run and are selected for ripeness, not size. This avoids genetic selection, so that changes in the gene pool of the Glenariffe run are kept to a minimum.

With increased dependence on artificially fertilised and hatched fry, a better quality of raceway water supply was required: silt can smother and suffocate eggs when it settles out. The sediment load of the Glenariffe main stream has increased since 1979, when swamp drainage was carried out at its source and there was a large slip at the head of one of its tributaries. The east branch of the Glenariffe has high water quality and rarely discolours, and so it was diverted to become a new water source for the raceways.

Eggs being put in the raceways in Washington pond trays for development.

Quinnat salmon life history

In an average run of spawning fish most are returning at the end of their third year of life, with fairly large numbers in their fourth and second years (the 2-year-olds are mostly males). There are very few 5-year-olds. Statistics of an average sea run of Rakaia salmon are shown in Table 1.

The quinnat salmon is anadromous; it migrates from salt water to fresh water to spawn. In New Zealand, salmon first appear at the river mouths in November, and numbers in the lower river increase to reach a peak during February. After travelling up river, most salmon enter the high country spawning tributaries towards the end of April. Consequently, our stocks are termed autumn-run fish.

Adult salmon reach the Glenariffe Stream to spawn from late February to mid June. Once in fresh water, they cease feeding and their condition and impressive silvery coloration deteriorate. By the time they reach the spawning grounds, they are dull and in relatively poor condition.

The eggs are laid in the gravel of the stream bed in a nest called a redd. The female digs a depression in the gravel by turning on her side and, with pronounced flexions of her tail, dislodging the gravel, which is transported a short distance down stream by the stream current. The female then lays some eggs, an attendant male fertilises them, and the digging process is repeated slightly up stream of the eggs to cover them. Several egg pockets make up the redd, the second pocket being slightly in front of the first and so on up stream. The average number of eggs per redd is 4500. When spawning is completed the female lingers on the redd and eventually dies. The male may move on to find another unspawned female, but he too eventually dies.

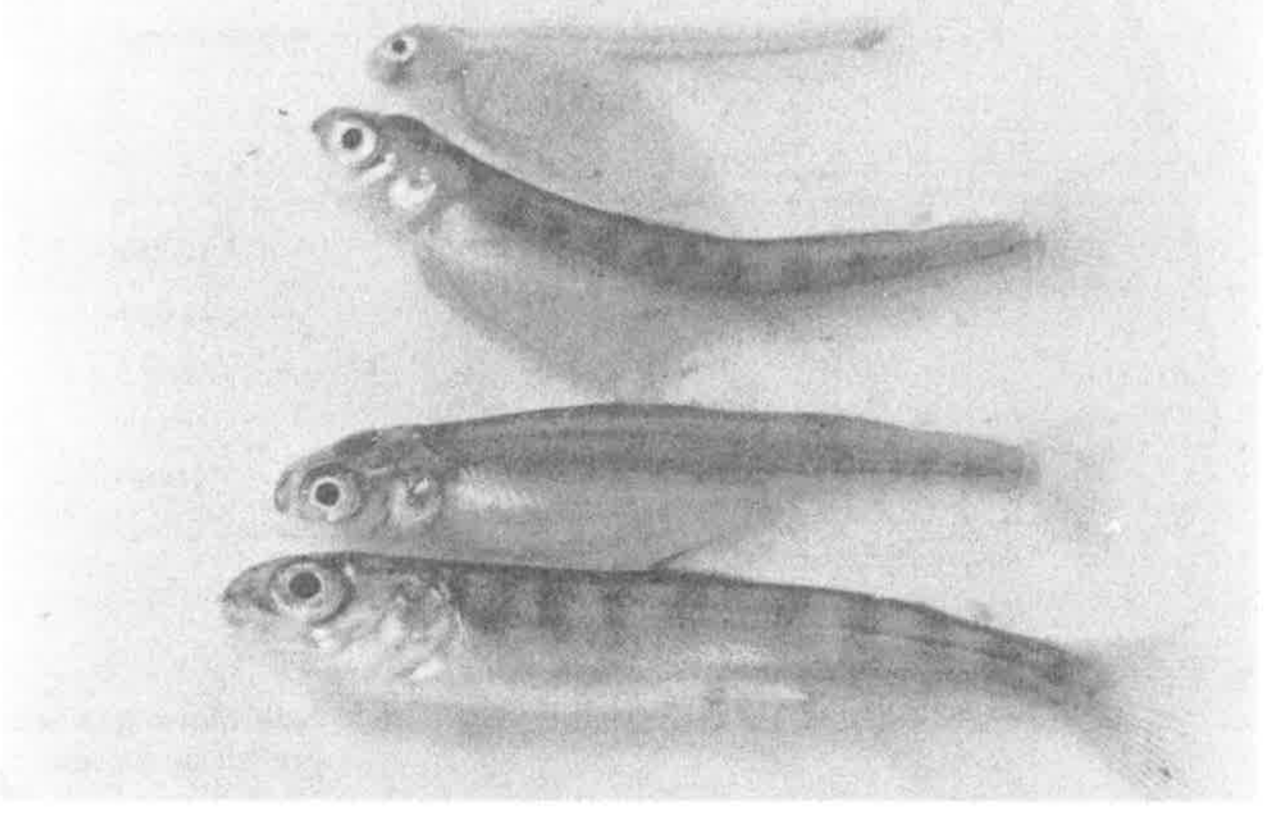
TABLE 1: Age-frequency distribution and mean lengths and weights of angler-caught adult salmon from the Rakaia River, 1975; figures in brackets show the age composition of the 1973 run

Age	% composition	Mean length (cm)	Mean weight (kg)
2	12.8 (18)	58	2.3
3	79.7 (45*)	76	5.0
4	7.4 (36.6)	89	6.8
5	0.1 (0.4)	100	10.0

* The 3-year class was affected by floods in 1970.

The eggs remain in the gravel for about 4-5 months. During this time they hatch into alevins (6–8 weeks) and absorb their yolk sacs to become "buttoned up" fry (8–10 weeks). The first fry emerge from the redd gravels at the end of July, but the peak of emergence is mid September. A large proportion of the fry population (95–99%) emerge during August and September and are termed "early outmigrants"; their mean length is 34 mm and some still have visible yolk sacs. Most of the remaining fry grow and develop in the spawning streams and emigrate during the period February to April as "smolts", mean length 65–85 mm. A very small percentage remain in the spawning stream for a year, until the following August, and migrate as yearling smolts, 100–150 mm long.

It has been thought that because of their small size fry outmigrants either did not survive in the main river or were swept straight to sea and did not add significantly to the adult returns. But we now know that fry do grow in the Rakaia mainstem and a good proportion of the early outmigrant fry may continue rearing in the river. Smolts capable of surviving in the sea probably have to be at least 65–70 mm long. At this size they are good swimmers and can cope with the rigours of the marine environment.



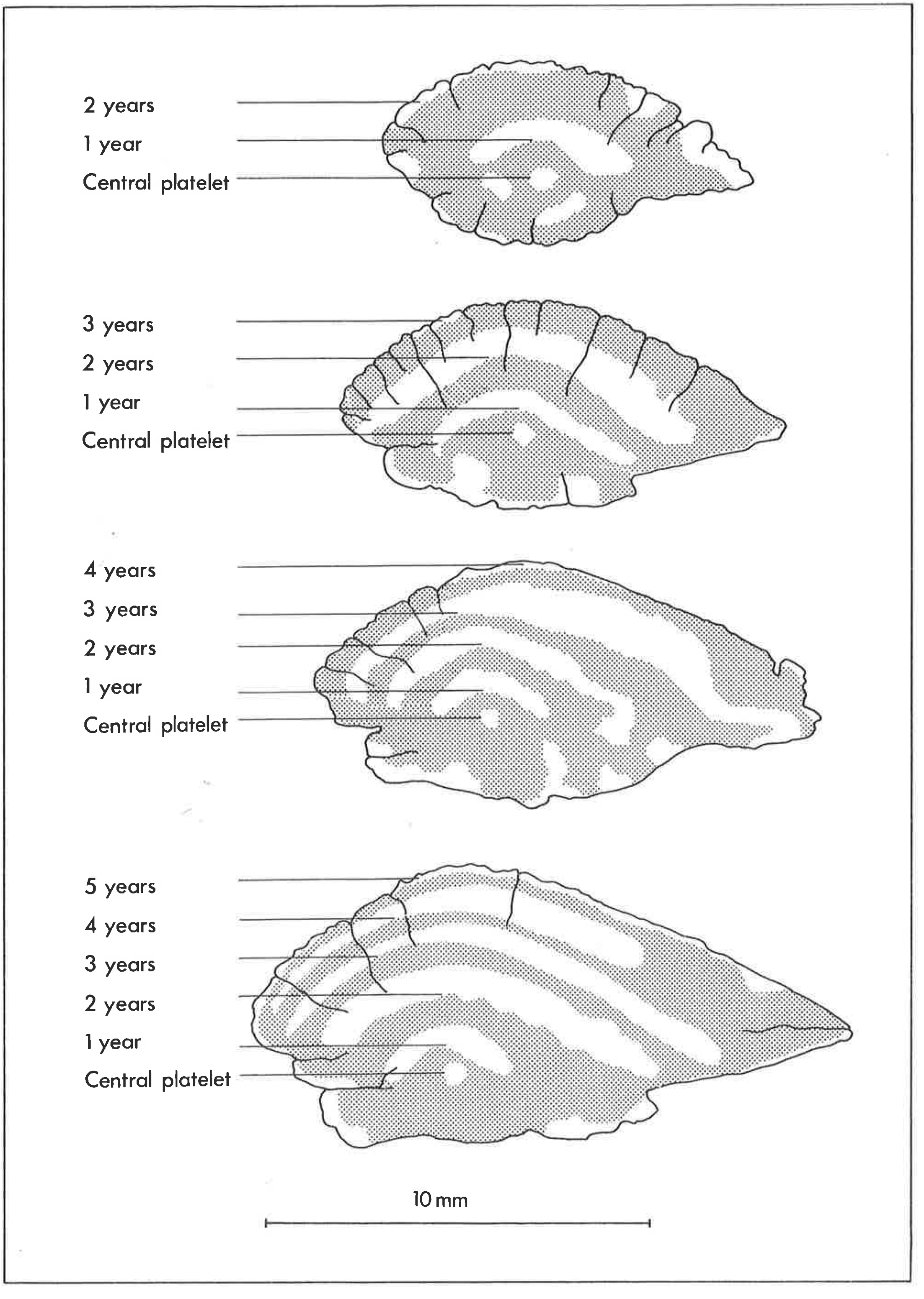
Stages of development after hatching: alevin just hatched, alevin 2 weeks advanced, fry almost "buttoned up" (very little yolk sac), buttoned up fry.

Aging

The initial method of aging salmon was by examination of annual rings on the otoliths (see opposite page). Each year alternate opaque and translucent layers are formed in the otolith. By counting the translucent layers or rings the age of the fish can be determined.

Another method is to examine the scales. Unlike the otolith (which has only one annual ring), scale rings (or circuli) are produced at regular intervals as the fish grows (see below). The distance between adjacent rings increases with increasing growth rates: in winter, when growth is slowest, the rings are close together (a growth check); in summer, when the fish grows more rapidly, the rings are more widely spaced. The number of seasons a fish has lived through (and hence its age) can thus be determined by examining the scales and counting the growth checks on the scale.

Scale showing annual growth increments (A–A', 1 year; A'–B, 2 year; B–C, 3 year; C–, 4 year.)



Otoliths of the four representative age classes.

As well as giving the age, scales taken from adult salmon also provide information on their early life in fresh water. Because growth in fresh water is slower than in salt water, the spacing between adjacent rings increases abruptly when a young salmon enters the ocean. By examining the central portion (or nucleus) of an adult scale, corresponding to the first 6–12 months of the fish's life, it is possible to determine approximately how long that fish lived in fresh water before it migrated to sea. Because of the additional information we can gain from scales, they are now used for most of our aging work.

Two main types of scale nucleus are recognised, stream and intermediate (Table 2). Stream nuclei are found on fish which spent all of their first year of life in fresh water; intermediate nuclei show that an adult salmon spent 3–6 months in fresh water before migrating to the ocean. A third type, the ocean nucleus, is very rare and characterises a fish that went straight to sea as a fry and had no growth phase in fresh water. Most 4-year-old returning fish have stream nuclei, whereas most 2- and 3-year-old returning fish have intermediate nuclei. Hence, the longer the juvenile fish stay in fresh water (up to a year) the older they are when they return.

The number of adult salmon returning to Glenariffe varies from year to year owing to the multitude of known and unknown variables that affect the fish throughout their life history (Table 3). One harmful variable that has been identified is flooding in the main river. If a large flood occurs in the Rakaia during spring, fry mortalities increase, which results, 3 years later, in a reduced 3-year age class returning from the sea. For example, in 1970 and 1971 there were major floods and in 1973 and 1974

TABLE 2: The relationship between scale nucleus type and age at return to the Glenariffe salmon trap*

	Age			
Nucleus type	2	3	4	Total
Stream†	9 (15%)	127 (22%)	52 (70%)	188 (27%)
Intermediate‡	50 (85%)	437 (78%)	22 (30%)	509 (73%)
Total	59 (8%)	564 (81%)	74 (11%)	697 (100%)

* Data are from scale samples from adult salmon.
† First year in fresh water.
‡ Less than 1 year in fresh water.

the numbers of returning adults were heavily reduced. Comparison of the 1973 age structure with that of a normal year shows the 3-year-old class to be reduced by 35% (Table 1).

Estimates of the total fry production from the Glenariffe Stream were made between 1973 and 1976. As it is known that an average sized female contains 4500 eggs, the total number of eggs laid and subsequent fry production and migration can be related to the total run. The numbers of adults returning from each brood year can also be calculated (Table 4).

The egg to adult survival is highly variable, but if good rearing conditions prevail, a small number of adults can produce a high brood-year return. For example, the 1973 adult run of only 160 females produced a return of 3218 adults over the next 4 years (egg to adult survival 0.5%).

TABLE 3: Number of adults passing through the Glenariffe trap (figures in brackets are returns of hatchery salmon)

Year	Male	Female	Total	
1965*	841	1 279	2 120	
1966*	560	572	1 132	
1967	1 023	746	1 769	
1968	1 483	1 782	3 265	
1969	1 210	1 297	2 507	
1970	381	248	629	
1971	1 313	1 084	2 397	
1972	1 427	1 621	3 048	
1973	264	160	424	
1974	280	175	455	
1975	1 190	799	1 989	
1976	1 063	1 524	2 588†	
1977	1 011	778	1 789	
1978	895	888	1 783	
1979	1 351	1 540	2 891	(4)
1980	938	595	1 533	(152)
1981	1 151	1 279	2 430	(611)
1982	633	425	1 058	(536)
1983	1 048	518	1 566	(853)
1984*	1 531	1 092	2 623	(1 727)
1985*	3 876	3 292	7 168	(4 346)

* Provisional figures.

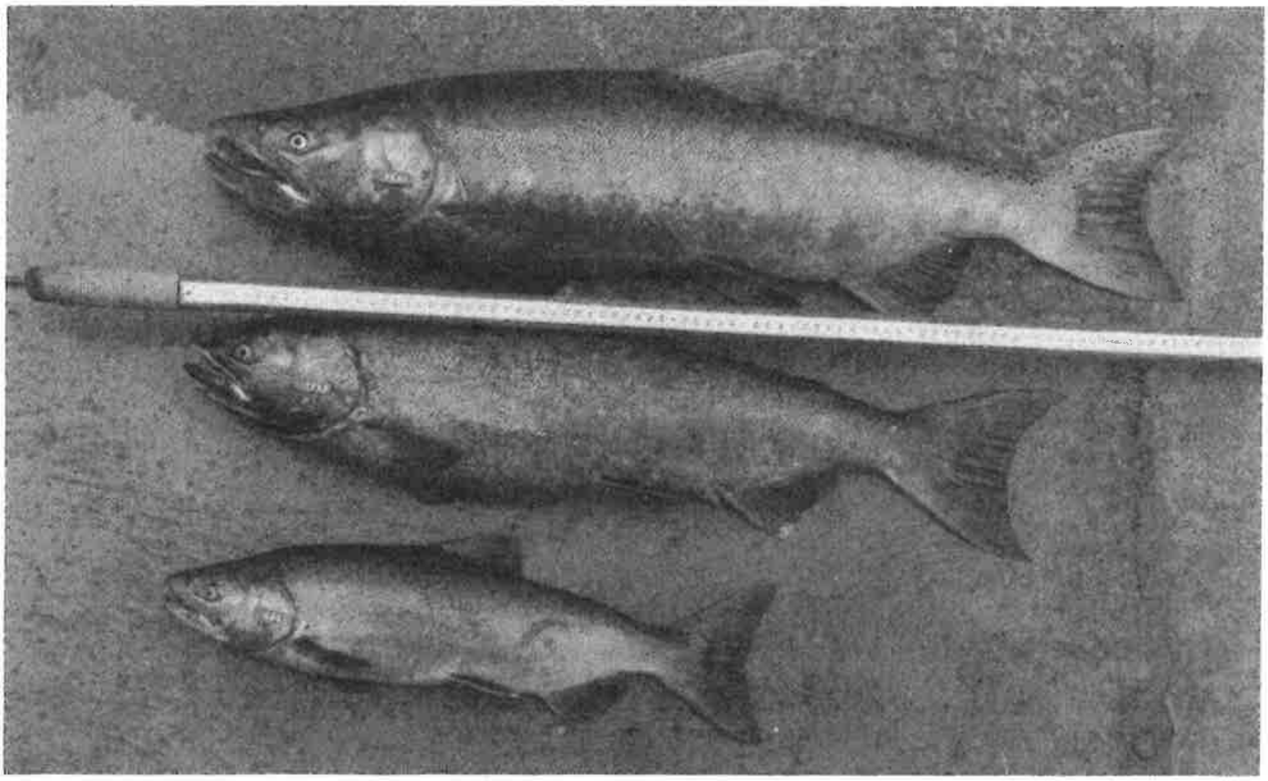
† Includes one fish not sexed.

This is probably related to a flood-free spring in 1973, which allowed high fry survival. In contrast, the lowest egg to adult survival was 0.06% for the 1971 brood, when major flooding occurred. The mean egg to adult survival for the Glenariffe Stream is 0.1%.

TABLE 4: The brood success of four adult runs to the Glenariffe trap

Year	No. of males	No. of females	Potential egg deposition	% unspawned	Juvenile migration	Egg to juvenile survival (%)	Egg to adult survival (%)
1973	264	160	685 000	3.6	275 000	40.1	0.47 (3 218)*
1974	275	172	825 000	4.1	426 000	51.6	0.16 (1 294)*
1975	1 186	803	3 560 000	6.0	1 885 000	52.9	0.06 (2 020)*
1976	1 066	1 522	6 700 000	4.1	3 732 000	55.7	0.04 (2 956)*

* No. of adults from brood year.



A day's catch of 2-, 3-, and 4-year-old hatchery reared fish. (Note the absence of the adipose fin — between the dorsal and caudal fins.)

Research aims at Glenariffe

Early research at Glenariffe was into the basic biology of the fish and the character of its life history. Growth rates, age structure, and fry production were determined. Three recent developments — the construction of the raceways, the use of the coded-wire tagging machine, and the development of ocean ranching and pan-size rearing — have broadened the research functions of the Glenariffe station. Currently, the main research aim is to determine how to obtain the maximum adult return from the number of juveniles released, which will benefit both the angler and salmon farmer. The best return achieved at Glenariffe so far is 5% (50 times the average survival in the wild) from a release in August 1981. However, because of the 1981-83 releases of tagged fish, the 5% return may be surpassed.

The present series of experiments is thus intended to determine the time and size at which to release hatchery reared juveniles to maximise the return of adults. From April to August 1983 there was a monthly release of 90 000 tagged fish from three different size groups. These releases (totalling 450 000 fish) were made at a time of the year when few juvenile salmon occur naturally in the river. Similar sized releases were made in 1984 and 1985, when the programme was stopped. Analysis of the adult return data from these experiments will indicate which release size and time combination produces the best return. Commercial ocean ranchers will then be able to determine the time and size that will suit them.

The salmon farmer who is pond rearing or sea-pen rearing is being assisted by research into the production of sterile fish. When male fish mature, their appearance and flesh quality deteriorates and the farmer's salable production is reduced. If maturation could be avoided, the farmer could raise fish which did not deteriorate and, therefore, he could increase his production efficiency.

Studies on the basic biology of salmon are continuing, with detailed investigations into the use adults and juveniles make of the spawning streams. The adult female's choice of redd site, the early survival of fry, and the habitat requirements and diet of juveniles are being examined.

Research is also being conducted on habitat requirements, growth, and survival of wild juveniles in the Rakaia River. Once in the Rakaia they continue to feed and grow. As they migrate down stream smaller fish (less than 60 mm) inhabit side pools and larger ones use the margins of the minor braids.

Other freshwater biological research is undertaken at the research station. This includes studies of fish food living in the stream beds and aspects of the behaviour of both native and salmonid fishes. The siting of Glenariffe is ideal for these studies because of the number of streams nearby and the stable nature of most of them. The accommodation available is another obvious asset.

Enhancement works

In addition to the lakes and spawning race, stretches of natural spawning tributaries of the Rakaia are being improved (with the help of the North Canterbury Acclimatisation Society and the New Zealand Salmon Anglers' Association) to increase the spawning area and habitat for adult and juvenile salmon respectively. The most recent work was undertaken at Manuka Point stream. One stream was diverted into another and protected with willow plantings to produce an extra 3 km of spawning bed. A subsequent survey of this area in 1982, when the adults arrived to spawn, recorded 420 fish.

Manuka Point stream improvement. (Note the willow poles at the edge of the new stream.)

In addition to rearing quinnat salmon, Glenariffe is being used to raise brood stock of other salmon species. Five thousand sockeye salmon (*Oncorhynchus nerka*) have been reared and stripped of eggs and milt for a brood stock and to sell to salmon farmers. These fish originated from adults salvaged from the Ohau River, where the naturally occurring landlocked population has had its spawning migration from Lake Benmore to Lake Ohau stopped by the Ruataniwha dam.

The future

Salmon fishing is a very popular pursuit; for example, the Rakaia River supports 8000 anglers in a season. Natural salmon runs are restricted to the east coast of the South Island and major changes in the rivers of this area can have a bad effect on salmon numbers. Several salmon rivers have been modified, to the detriment of the salmon population. Examples are the Clutha and Waitaki Rivers, on which construction of hydro-electric dams has blocked up-stream migration to the spawning grounds. Irrigation development can change the flow regime of a river to the extent that salmon are no longer able to use it. However, with careful planning and honest debate this need not arise. Water can be a multiple use resource and as such should be shared. There must be compromise between those who use the water out of the river and those who use the river.

The salmon is now part of New Zealand's heritage and in only one other area in the Southern Hemisphere, Chile, is a sea-run stock of quinnat salmon being developed. Research on salmon at Glenariffe and elsewhere will help us to understand this fish and allow resource management decisions to be made with the conservation of the species in mind, so that there will be salmon for subsequent generations to enjoy.

A "picket fence" of salmon anglers at the mouth of the Rakaia River.

A resource we are protecting for future generations.

Inquiries about this leaflet should be addressed to:
The Director, Fisheries Research Division,
P.O. Box 297, Wellington, New Zealand.

Copies are obtainable from the Editor, at the same address.

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