# Salmon Research at Glenariffe

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# SALMON RESEARCH AT GLENARIFFE

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HIGH in the foothills of the Southern Alps in Canterbury, on a tributary of the Rakaia River and about 60 miles from the sea, is the Glenariffe salmon trap, where staff of the Fisheries Research Division of the Ministry of Agriculture and Fisheries are investigating the behaviour and yearly spawning runs of quinnat salmon (*Onchorynchus tshawytscha*). Since it was built 11 years ago the trap has enabled thousands of fish to be tagged and their life cycle and growth rate to be studied. 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 flora and fauna and when the 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.

Successful introduction of trout led to attempts in the 1870s by the acclimatisation society movement to establish runs of quinnat salmon, but these efforts failed, mainly 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 and had a hatchery built on the Hakataramea River, a tributary of the Waitaki River. This river was selected on the basis of its similarity to known North American salmon rivers.

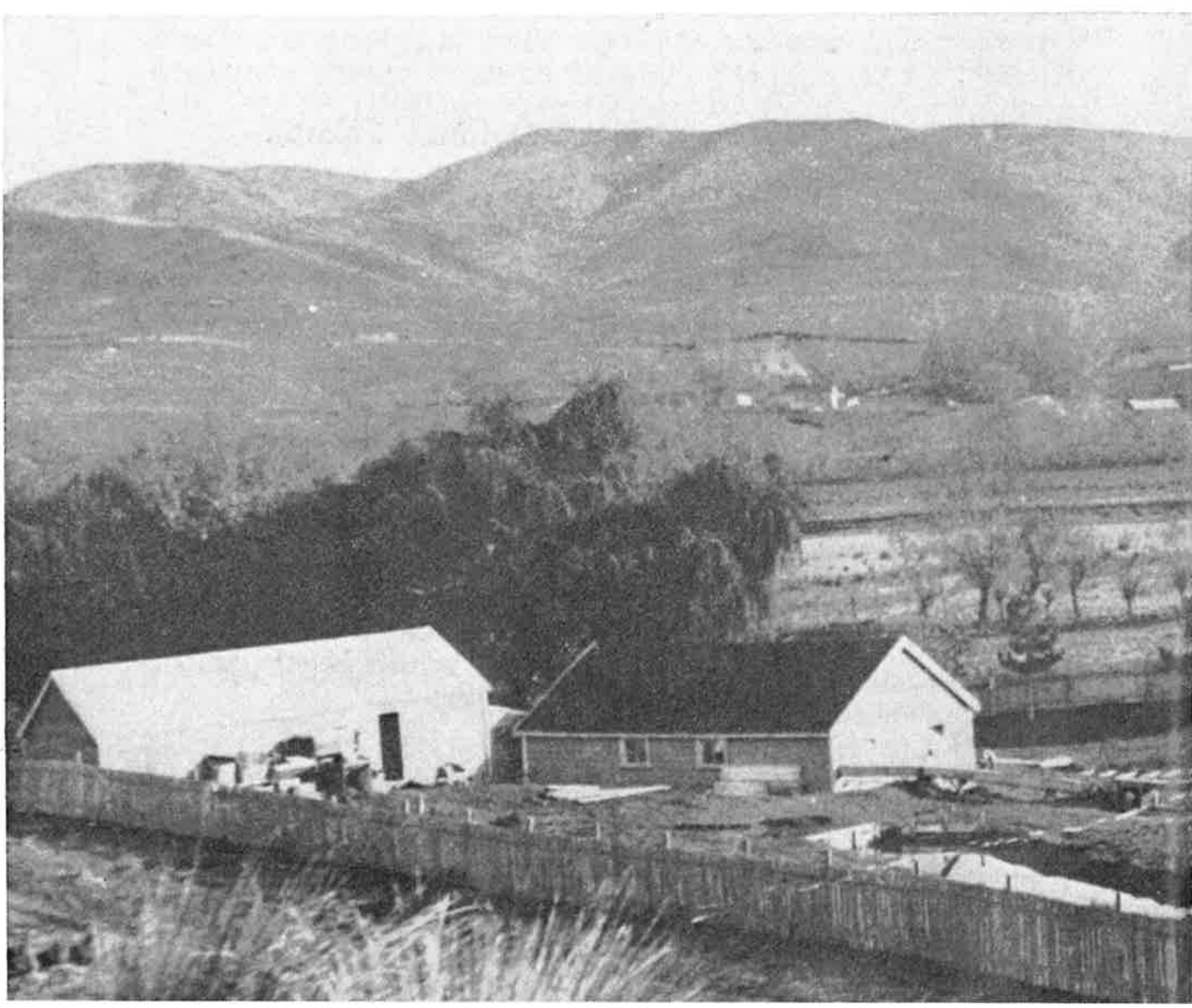
Ayson went to the United States to obtain ova and personally cared for them during their transhipment to New Zealand. This operation was repeated over several years, with the aim of establishing a run in the Waitaki River, which would become a source of ova from which to extend the stocking to other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

### First liberations

The first liberations from the hatchery were fry, released into tributaries of Lake Ohau in 1901. 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.

Fry were liberated into the Hakataramea and the Waitaki Rivers in 1903 and returning adult fish were first collected at the Hakataramea rack in 1906. Once these runs were of sufficient size, additional importations were discontinued. Fry raised from the stripping of these runs were liberated into other river systems and helped to reinforce the popula-

The Hakataramea hatchery, which was established in 1901 and continued to operate successfully until 1942.



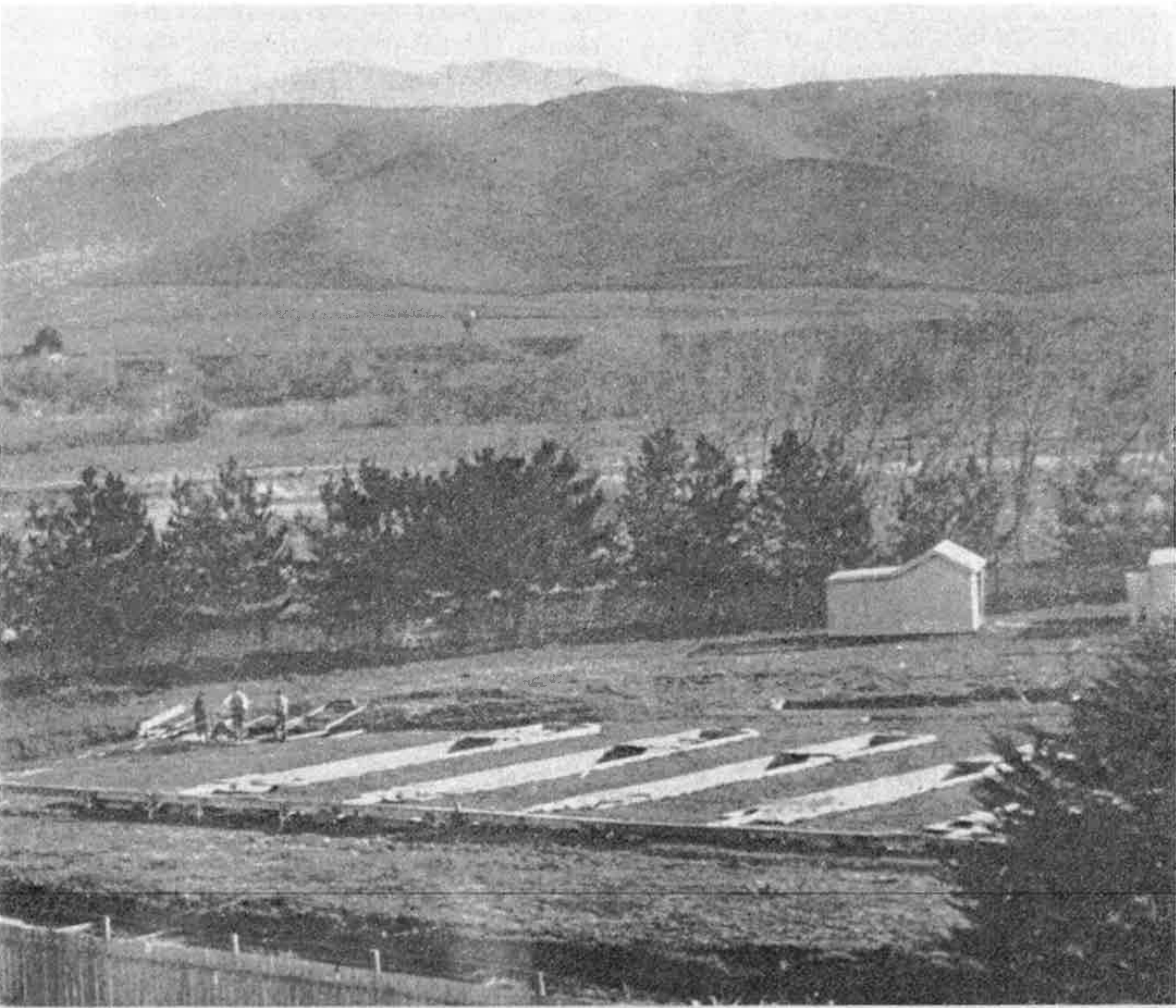
tions which were already building up by a slow natural spread. Several fry-rearing substations were set up for this purpose and were financed by the Government. The Hakataramea hatchery continued operations until the Second World War and was closed down in 1942.

For a period limited numbers of netting licences (1925–52) and rod selling licences (1922–52) were issued, and 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 members considered that the size of runs could not sustain commercial cropping.

Government acceded to the request, retaining the statutory control of the species and requiring 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

In the early 1950s large numbers of salmon congregated below the tail race of the hydro-electric scheme at Highbank on the Rakaia River. This was 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. After several years' use 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 trapping. 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 suggesting that the South Island technical field service of the Marine Department should undertake projects of more extended duration than previous investigations. This suggestion 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. His results for the time were outstanding, but the significance of his work and publication was overlooked. It was only after the Glenariffe trap had been in use for several years that his paper on the subject was 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 unpublished until 1971. From 1934 to 1952 G. Stokell published work mainly on taxonomic features and on some of the freshwater stocks of quinnat salmon.

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 Trap at Glenariffe

Adopting the recommendation of the Freshwater Fisheries Advisory Council, the Marine Department 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.

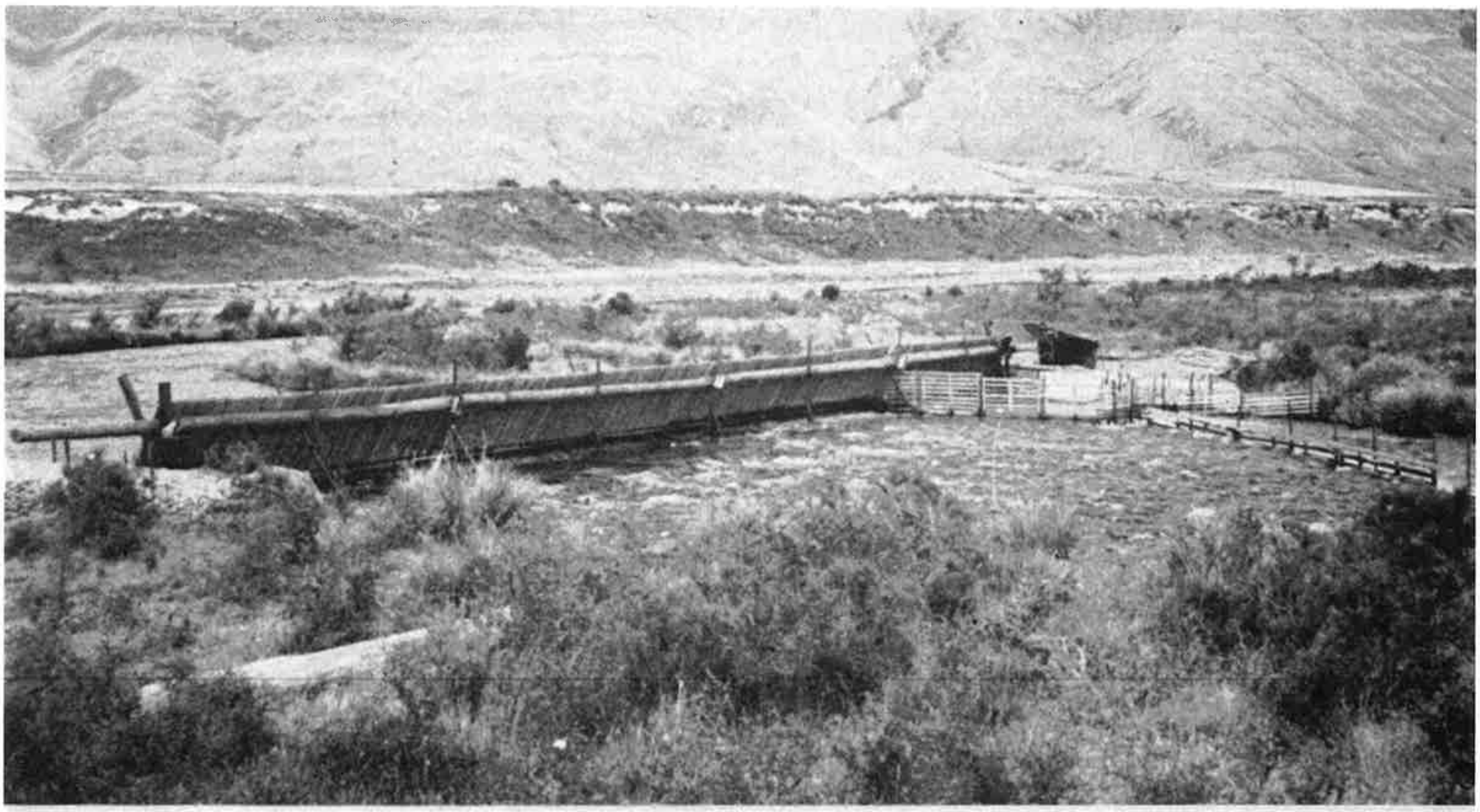
Glenariffe was chosen for several reasons, the more important being:

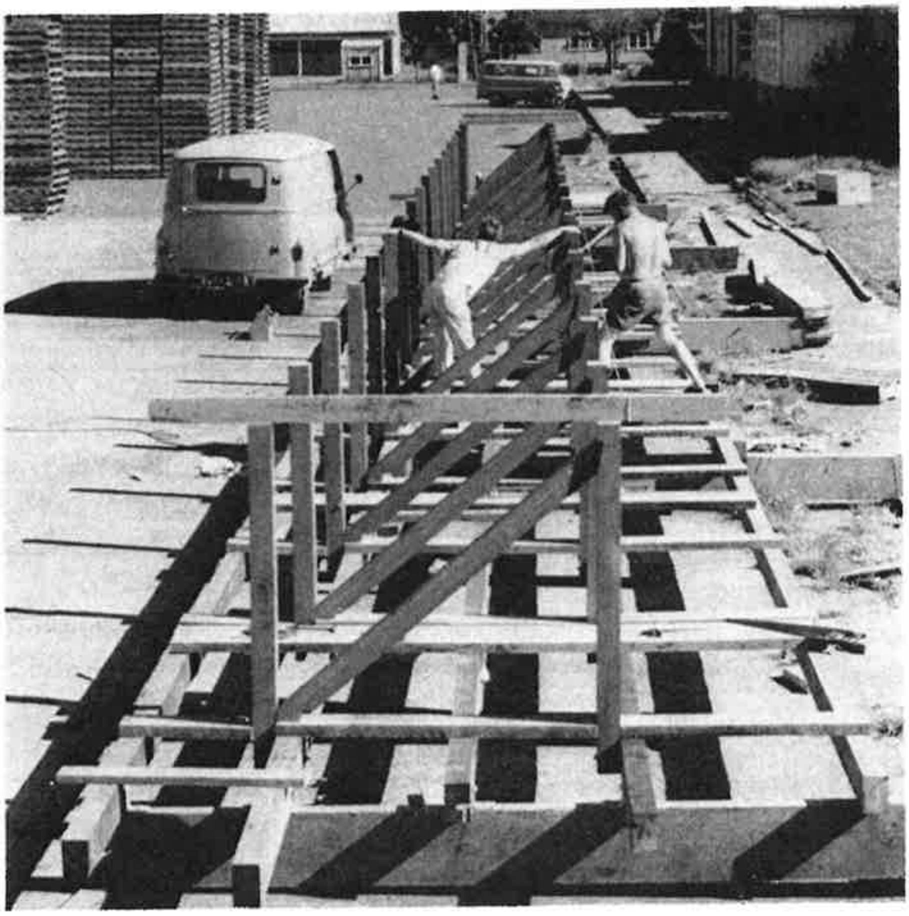
- It was known to be a good spawning area and therefore would provide adequate material for investigative purposes.
- It was a stable area not subject to frequent violent flooding.
- It was reasonably accessible and close to the Marine Department's fisheries laboratory in Christchurch.

The installation of the first structure, a one-way adult trap, was begun 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 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 Christchurch laboratory and after

The original "salmon rack", which was built in 1965 on the Glenariffe Stream, a tributary of the Rakaia River, in the South Island. The rack consisted of a lead into a holding pen with a narrow entrance and a "trash" barrier up stream to facilitate cleaning of accumulated floating debris from the holding pen and lead.





Prefabrication of the present trap at the Christchurch laboratory. The trap was subsequently dismantled and then reassembled at Glenariffe and replaced the original rack.

each part had been labelled the two structures were dismantled and then reassembled on site at Glenariffe.

**1965**

In the first year's operation of the adult trap the fish were weighed, measured, and sexed. Ageing 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 unreliable for ageing. The next most easily collected structures for ageing 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.

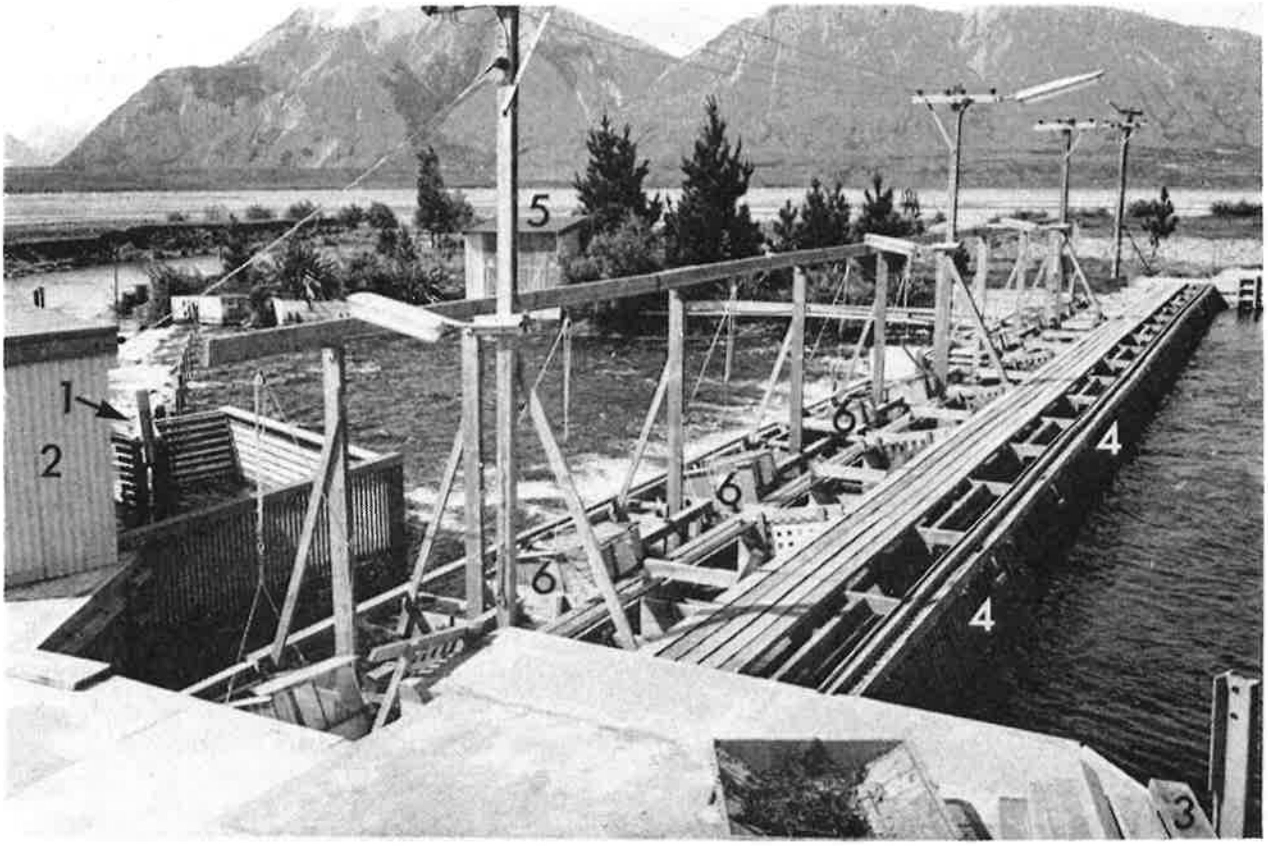
In this first year the acclimatisation societies were allowed to take 46 females for ova. But because the aim of the project was to relate adult returns to juvenile production, stripping for hatchery purposes, which introduced a complicating factor, was discontinued.

**1966**

A two-way trap was installed in January, and more than 1000 fish were put through it. One in every 10 of these was tagged with a numbered spaghetti tag, but the recoveries in 1965 and 1966 were insufficient for reliable age and growth determination.

**1967**

All fish were tagged, the spaghetti tags being replaced with sheep ear




The Glenariffe trap now incorporates a series of modifications and improvements, including lights, which facilitate night work. 1: Lead into the narrow entrance to the holding pen. 2: Covered measuring shed. 3: Pipe outlet. After measurement the adults are passed down a tube into a covered holding box to recover, from which they swim up a pipe which runs underground approximately in the position shown. 4: Trash barrier to prevent large pieces of debris clogging screens. 5: Fry or juvenile holding shed. 6: Fry cages. The flat stainless steel screens are out of sight in the wells, just in front of the pens.

tags, which were passed through the operculum. Because these tags were less easily lost, there was a higher recovery rate (60 percent).

This year fork length was recorded and also a measurement from the front of the eye to the end of the spine, so that a relationship between the two measurements could be established. Recovered carcasses of spent fish are usually damaged, but the skull and spine 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 fishes which had spawned.

**1968–75**

Collection of data on adult fish was continued. During 1970 the run was very small. Examination of its age composition showed clearly that only 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 perish. A further heavy flood in 1970 compounded the effect, so that, as forecast, the 1973 Glenariffe spawning run was the poorest recorded until then (Table 1).

**TABLE 1: Number of adults passing through the trap**

| Year | Males | Females | Combined |
|---|---|---|---|
| 1965 | 841 | 1279 | 2120 |
| 1966 | 560 | 572 | 1132 |
| 1967 | 1033 | 739 | 1772 |
| 1968 | 1492 | 1783 | 3275 |
| 1969 | 1204 | 1286 | 2490 |
| 1970 | 382 | 247 | 629 |
| 1971 | 1315 | 1091 | 2406 |
| 1972 | 1432 | 1613 | 3045 |
| 1973 | 263 | 161 | 424 |
| 1974 | 275 | 172 | 447 |
| 1975 | 1186 | 812 | 1998 |

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 the Fisheries Research Division. From 1 September 1972 the two fisheries divisions in the Marine Department amalgamated with the Department of Agriculture to form the Ministry of Agriculture and Fisheries.

## Life Cycle of Quinnat Salmon

A salmon spawning run consists of groups of fish 2, 3, 4, and 5 years old on their arrival in the river. Evidence indicates that these groups are further divided into groups originating from different spawning areas within the same river system. The members of these subgroups will have experienced a range of environmental conditions sufficiently varied to influence their rate of development. If data are collected over several years, it is possible to follow the progress of the various groups derived from a specific brood year and at the same time to obtain growth and mortality rates. This has been done in some parts of the United States for more than 60 years, a period covering 12 life cycles. In New Zealand adequate data have been collected for only the last 8 years, or one and a half life cycles.

The general life cycle pattern outlined below is true of sea-run and

**TABLE 2: Age-frequency distribution, mean lengths, and mean weights of sea-run, angler-caught spawning quinnat salmon**

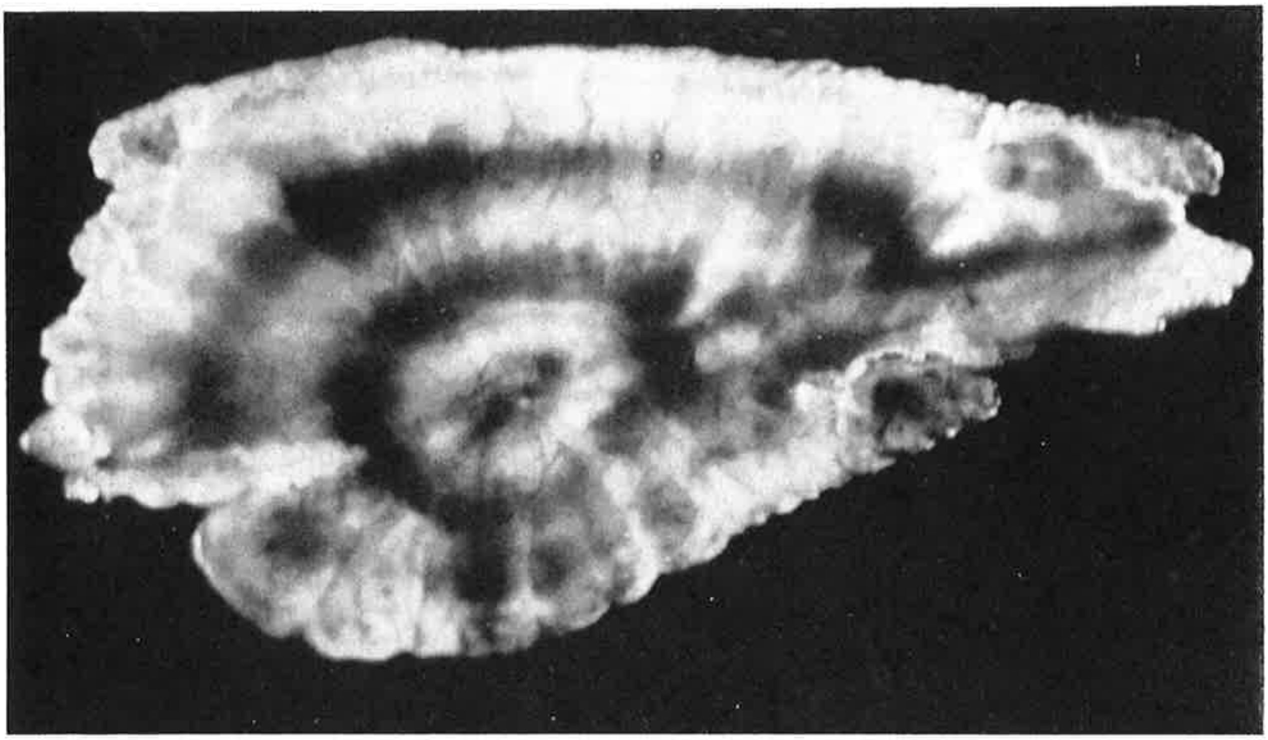
| Age-frequency distribution | | Mean lengths | | Mean weights | |
|---|---|---|---|---|---|
| Age | % | (in.) | (cm) | (lb) | (kg) |
| 2 | 9.0 | 23 | 58 | 5 | 2.3 |
| 3 | 70.0 | 30 | 76 | 11 | 5.0 |
| 4 | 21.0 | 35 | 89 | 15 | 6.8 |
| 5 | 0.1 | 40 | 102 | 22 | 10.0 |

A sheep's ear tag (arrowed) is now used to identify an adult fish. It is passed through the operculum at the time the fish is measured and weighed. This enables the recovery of identifiable carcasses after the fish have spawned.

freshwater quinnat salmon throughout New Zealand. Length-frequency data before 1920 and age readings since show that this pattern has not basically altered over the years.

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. Very few 5-year-old fish occur. Statistics of an average sea run of New Zealand salmon are shown in Table 2.

The adult fish probably re-enter their river of origin between late December and late June, most of them passing through the river



Once a carcass is recovered the head is split open and the "ear bones" (otoliths) are removed. These are very durable and show light and dark bands, which are related to the age of the fish. The otolith above, which is about 1 cm long, is from a fish returning at the end of its third year of growth.

mouth at mid March and on to the spawning grounds in mid April. During this period feeding has stopped and the quality of the flesh progressively deteriorates.

The females select sites in the upper reaches of a river and dig nests known as redds in the gravel of the stream bed; the males wait in close attendance and fight off challengers. The male fertilises the eggs as they are laid in the depression created by the female, which then moves up stream and repeats the process of gravel excavation. The gravel moves down stream with the current and settles, filling in the depression and covering the eggs. This process is repeated several times, the collective excavated area with egg pockets being known as a redd.

Female fish may dig several redds. After the spawning act, all the sea-run fish die. Small yearling smolts which have remained in fresh water also participate in the spawning act; these are all males, some of which have been shown in North American runs to survive to return later as sea-run adults.

The young fry emerge from the gravel 2 to 3 months later, depending on water temperature. Most of them move out of the spawning streams at a very immature stage, but a few remain in fresh water from 3 to 15 months.

Very little is known about the movements of salmon once they enter the sea; most samples have been small fish caught in harbours on the east coast of the South Island.

## Objectives of Research at Glenariffe

Like the trap itself, the objectives of research at Glenariffe have evolved over the years and as insight has been gained from experience and knowledge, so the use of the trap has expanded. The initial objective, which was to establish the basic life cycle and growth rates of quinnat salmon in New Zealand, has been achieved. At the same time this has allowed comparisons to be made with North American stocks at equivalent latitudes. These show that the New Zealand growth rates are similar to North American for similar year classes. Data from early samples also show that there has been no fundamental change in growth rate since shortly after the salmon were introduced.

The next objective was to examine the relationship between the number of spawning adults and the production of juveniles. Because of the very large numbers of juveniles to be handled and the small staff available this work was most difficult. Accurate results are now available from 1972. Broadly these show that about 95 percent of the fry move down stream into the main river and out to sea at a size too small to survive the change from fresh to salt water. (Scale studies have shown that very few of the fish which have spent less than 3 months in fresh water ever return as adults.) However, those that remain and grow to smolt size in the streams before migrating to sea have a high survival rate.

To provide more holding water in which fry can linger and grow, a small lake above the Glenariffe trap has been modified and control gates have been put in. Fry which would otherwise have been lost as they passed through the trap were caught and transferred to the lake for the first time in 1975.

A floating fry trap below the main Glenariffe trap. The fry trap has been used to estimate losses of fry and juveniles from the system as well as to provide additional information on migration of smolts.

Unlike those of North America, New Zealand rivers are unstable and lack suitable pools in the headwaters where young salmon may linger and grow. This is probably the main reason why no large local runs have developed.

To test this possibility the headwaters of the Glenariffe Stream were modified in 1975 so that large numbers of outmigrant fry caught at the trap could be held in a man-made lake until they reached sufficient size to be able to make the transition from fresh to salt water safely. They have since been released and observations will be made on future adult runs to see if these runs have increased. If the work is successful, the potential gain for anglers is obvious, and the possibility of modifying the headwaters of other rivers will merit consideration.

To relate the Glenariffe run to that of the whole of the Rakaia River, aerial surveys have been made since 1971, at first from fixed-wing aircraft and later from helicopters. This method is more comprehensive than the ground surveys which it replaced. From these counts the relative importance of the major spawning areas has been determined, and estimates of total runs throughout the Rakaia have been obtained. At the same time postal questionnaires have produced estimates of angler cropping of runs.

All of these investigations are aimed at obtaining information on the more significant factors affecting sound management. They also provide information from which fisheries research workers can develop a mathematical model of the fishery; such a model allows prediction of future runs and identification of critical stages in the life cycle. Despite the limited data available, reasonable forecasts of the sizes of future runs can now be made.

## Techniques and Methods

In addition to the principal research, other related investigations have been made and various techniques have been evaluated.

Methods developed at Glenariffe to monitor adult runs now enable other organisations to monitor the runs in other rivers and lakes with relatively little effort. This has been done, for example, in conjunction with the Waitaki Valley, Ashburton, Westland, and North Canterbury Acclimatisation Societies and the Southern Lakes Acclimatisation District of the Department of Internal Affairs.

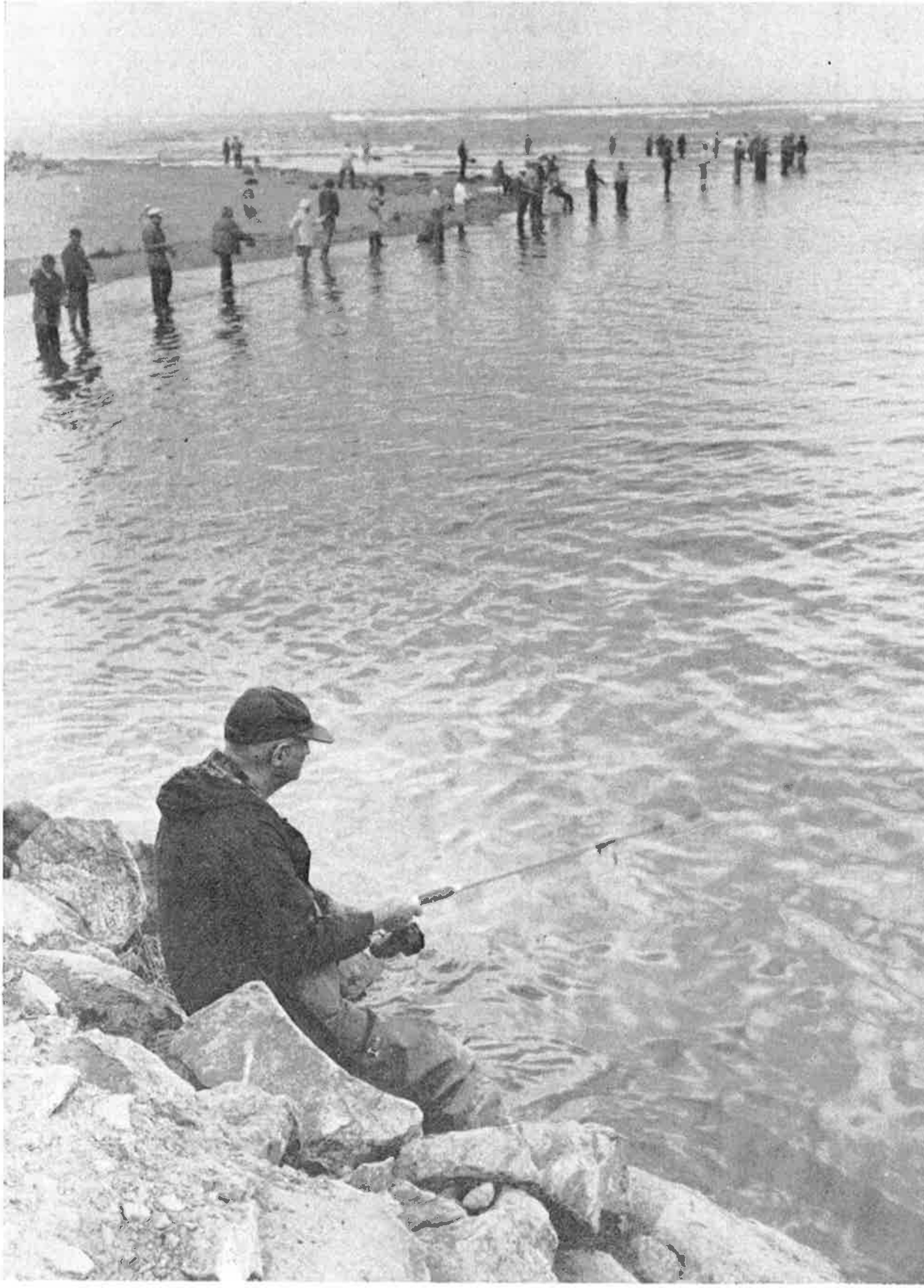
Drift diving techniques for counting fish in the river have been tested. Data from anglers have been examined to determine whether their catches and catch rates are truly representative of the run.

Limited information has been obtained on the distribution of salmon in the sea, but this is an area for separate study, as no sea fishing for salmon is permitted.

Other studies on juveniles include investigation of movements of the fish in the nursery streams and the testing of various marking techniques such as freeze branding, fin clipping, fluorescent staining, pigment injection, and dyeing. These are used for various purposes, including the understanding of fish behaviour and estimation of numbers. For example, release of known numbers of dyed fish above the trap, then analysis of proportions of these fish in the subsequent catch, has made it possible to determine the efficiency of the trap. Thus sample counts of outmigrants can now be used to estimate the total downstream run without the need to trap all the stream or count all the fish.

Investigations of redds have dealt with their structure and the effects of jet boats on them and water flow patterns over them. There is a possibility that the age of the fish can be determined from fin rays. If their fins could be clipped and rays removed for subsequent ageing as the fish passed through the trap, the age and size relationships of individual fish could be determined more directly; at the same time the need for tagging and carcass recovery would be eliminated.

As part of the work continuous records have been kept of barometric pressure, day and night light intensity, wind, air temperature, and rainfall. The stream bottom fauna has been analysed and water levels, turbidity, and temperature have been recorded. Records of brown and rainbow trout runs which also occur in the Glenariffe system are being analysed. To minimise the work of dealing with so many data the information is being progressively computerised.



A "picket fence" of salmon anglers at the mouth of the Waimakariri River, North Canterbury, during the period of the adult quinnat (chinook) salmon run, which extends from late December to early June.

## Outlook for the Future

For most populations of brown and rainbow trout in New Zealand the angling pressure is light, and as the fish are widespread, they require little management. But because salmon are mainly restricted to the east coast rivers of the southern half of the South Island, any change in the condition of those rivers can have a deleterious effect on salmon population. Proposals to use these rivers for irrigation and hydro-electric development, and their increasing use for effluent disposal, therefore threaten the abundance of this prime sporting and food fish in New Zealand.

Because it spends most of its growing period in the sea, the salmon lends itself to harvesting the sea's productivity, especially of the large amounts of Crustacea or krill, on which it feeds. The adults returning to the rivers to spawn can readily be managed and cropped. Provided their numbers are adequate, they can, of themselves, furnish a sound economic argument for maintaining rivers in good condition, with copious flows of good-quality water.

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