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Report to the Waiau River Working Party

WAIAU RIVER WORKING PARTY

SOUTHLAND REGIONAL COUNCIL

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FISH PASSAGE PROBLEMS AND OPTIONS FOR FISH PASSAGE AT MARAROA WEIR

REPORT PREPARED FOR THE ELECTRICITY CORPORATION OF NEW ZEALAND

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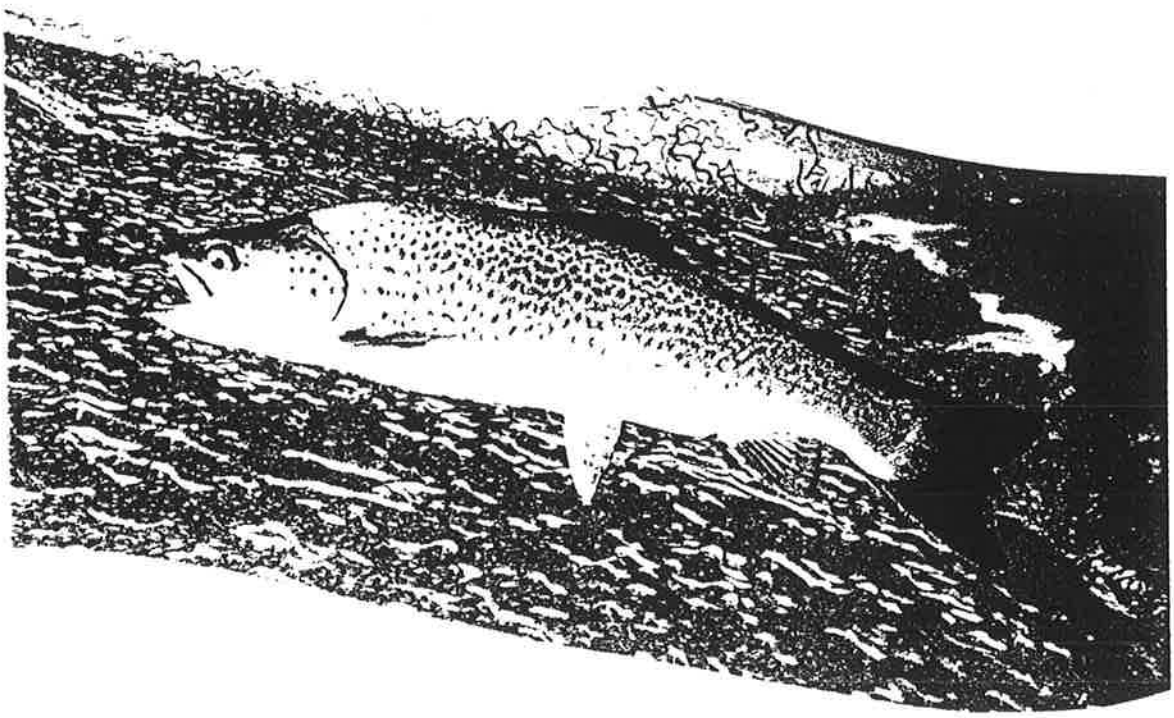

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August 1994

EXECUTIVE SUMMARY

This study examines options for maintaining fish passage over the Mararoa Weir.

The weir has the potential to control the upstream distribution of several species of native and introduced fish. It is generally conceded that fish passage must be provided over the weir. What is required is a low maintenance, highly effective fish pass. A further variable is that ECNZ may release a compensation flow down the Waiau River. It would be desirable to integrate both the fish pass and the compensation flow structures.

Siltation and the deposition of gravel, exacerbated by diversion of the Mararoa River directly toward the control gates. appears to have totally blocked up the existing fish pass. Desiltation and maintenance is made particularly difficult by the encased design. The interior is essentially inaccessible. Therefore the cost and logistics involved with keeping this fish pass working, are probably unreasonable under present day economic realities.

Most fish migrate up to the weir after a fresh, attracted by the volume of spilled water. Fish numbers build up below the weir when the gates finally close. Public concern over the fate of the trout and elvers which can be seen below the weir detracts from the image of ECNZ as a good corporate citizen. Past tagging studies indicated that brown trout did not migrate through the fish pass. Rainbow trout did use the fish pass. An examination of size-frequencies and ages of eels above the Mararoa Weir indicated that recruitment of these migratory fishes had been reduced since the weir was built. Eels still remain common above the weir, these long-lived fishes are well adapted to maintain populations in habitats where access may only be possible at intervals. But without an effective fishpass eels will eventually become greatly reduced in numbers in the upper catchment.

An effective fish pass structure faces the following constraints: It has to be built within a reasonable cost envelope and must conform to existing structures and their operation. Water velocities within the fish pass have to be low enough to allow elvers and other small native fishes upstream. The fish pass must be deep and wide enough to allow adult trout to swim upstream. The entrance of the fish pass must be located at or immediately below a point where a barrier to further upstream movement for fish is present. This barrier must remain an effective barrier over a wide range of flows.

There appear to be at least six options to allow fish passage across the Mararoa Weir:

1. Modify the downstream wing wall on the true right bank of the weir to prevent buildup of gravels in this area. Clean out the existing fishpass, lengthen and raise the intake to reduce the ingress of silt, add more baffles, floor roughening and widen the entrance area. These modifications could ensure eel and lamprey passage and may allow brown trout to make an easier passage.

2. Construct a wider, lower gradient fish pass from the head of the existing fishpass, out through the side of the weir and along the rockwall to the area where the existing fish pass used to discharge. This fish pass could be a Denil type fish pass or it could be an "artificial-natural" stream type, using cobbles imbedded into the bottom of the channel to brake water-flows and thus allow small fish to move upstream. or a combination of the two. This new exposed fish pass would be more accessible and therefore easier to maintain. It must allow adult trout plus a range of native fishes and small trout to move upstream. Denil fishways are a design which functions effectively over a wide range of flows.

3. Direct the compensation flow over the left bank of the overflow weir adjacent to the right bank abutment of the control gate structure. This flow would then be diverted around the tip of this structure to discharge into the lower end of the stilling basin pool. Fish attracted by this flow would enter a Denil-type fish pass built to zigzag up the right bank abutment to intersect with the resting-chamber of the existing fish pass.

4. Direct the compensation flow over the overflow weir on the right bank side. Abstraction of compensation water from this side of the weir would avoid the silt and gravel problems associated with the Mararoa River side. This compensation flow structure could also act as a water deflector to protect a Denil-type fish pass built up the side of the overflow weir. At low river levels, fish would swim in the compensation flow up the channel formed by the hydraulic jump, to the base of the compensation flow discharge. At this point they would encounter the fish pass entrance and could continue upstream. Diversion of the compensation flow around the tip of the right bank abutment of the control gate structure would allow fish to move up to the fish pass from the stilling basin pool, at all river levels.

5. Construct a dedicated channel on the true right bank of the Waiau River to take the full compensation flow over the weir. Use a velocity barrier (effective at flood flows?), below the bridge and divert fish up the channel at all times. It is considered that a compensation flow structure that can cope with the varying water levels above the weir and still allow fish passage, will have to be both complex and expensive.

6. Spills from the Mararoa weir are quite frequent. On average, water is spilled for 35% of the time. Sixty-six percent of the spills involve volumes less than 10 m^3/sec. Reports on fish movements supports the concept of targeting fish passage after flood events. Observation of flows beneath the control gates at Mararoa Weir, on the recession phase of a flood, showed there was then a clear space beneath the bottom of the gates and the water. The level differential between the upstream and downstream water surfaces was not great and it was considered that at such times, mature trout should be able to swim through the weir. If most trout migration is on the recession phase of a flood, then it may be possible to manipulate gate settings so that fish can get past the weir at these times. Water level differentials are of course much less. At the recession phase of a flood, a dirty Mararoa River may be left to flow down the Waiau for quite lengthy periods.

CONTENTS

FIGURES

FIGURES(cont.)

INTRODUCTION

Why is a fish pass needed at the Mararoa Weir ?.

It was accepted by the engineers designing this structure that a fish pass was to be an integral part of the design. The reasons behind this acceptance had to do with political pressure. The then Southland Acclimatisation Society campaigned effectively for provision of access from the Waiau River for the stocks of trout and Atlantic Salmon that spawned in the Mararoa River and the Whitestone River.

The design was chosen on the recommendation of Mr R. Little of the Ministry of Agriculture and Fisheries. Successful fish passes are few and far between in New Zealand and there were few local precedents. This design was developed in Canada by the Quebec Department of Tourism, Fish and Game (Michel & Nadeau 1966). Discussions with overseas fish pass experts has since revealed that few, if any other of this design have been built elsewhere in the world (K. Bates, C. Katopodis, pers comm.).

Despite this lack of popularity , the Borda Orifice proved a good design. Velocities within the fish pass were low enough to allow small native fishes such as smelt and bullies through the pass (Field Dodgson 1981). The functional parts of the fish pass are a series of 16 borda orifices (Fig 1). There is a head loss of between 200-400 mm between each orifice owing to the resistance it provides to the water flow. Between each orifice the flow expands into chambers where fish can rest. The highest water velocities are at the mouthpiece of each orifice (Aspden 1972) where fish encounter velocities of 1.86 m/s (Jowett 1989). The fish pass required an average flow of 10 cusecs, an amount of water then considered sufficient to meet the energy needs of perhaps 6000 people (Field-Dodgson 1977).

Fig 1. shows the basic principles of the borda orifice design and the patterns of water flow which develop. Although the fish pass apparently functioned well, allowing even weak swimmers such as bullies, smelt, lampreys and elvers upstream, it was considered that brown trout appeared to find water velocities excessive at the entrance (S. Sutherland pers comm.). On the other hand, Jowett (1989) thought the water velocity of 0.12 m/s through the entrance was too low (?) to provide sufficient attraction for fish. Rainbow trout used the fish pass and were recaptured well upstream. Brown trout always seemed to be the species for which the fish pass presented the greatest difficulty (Field Dodgson 1981).

One of the major constraints on building a fish pass at this site was the requirement that it functioned over a range of water levels. At high water levels parts of the fish pass would become pressurised and accordingly the whole structure has been encased within a concrete tunnel. This step alone has made the fish pass impracticable. Maintenance is virtually impossible as the interior of the fish pass is almost inaccessible.

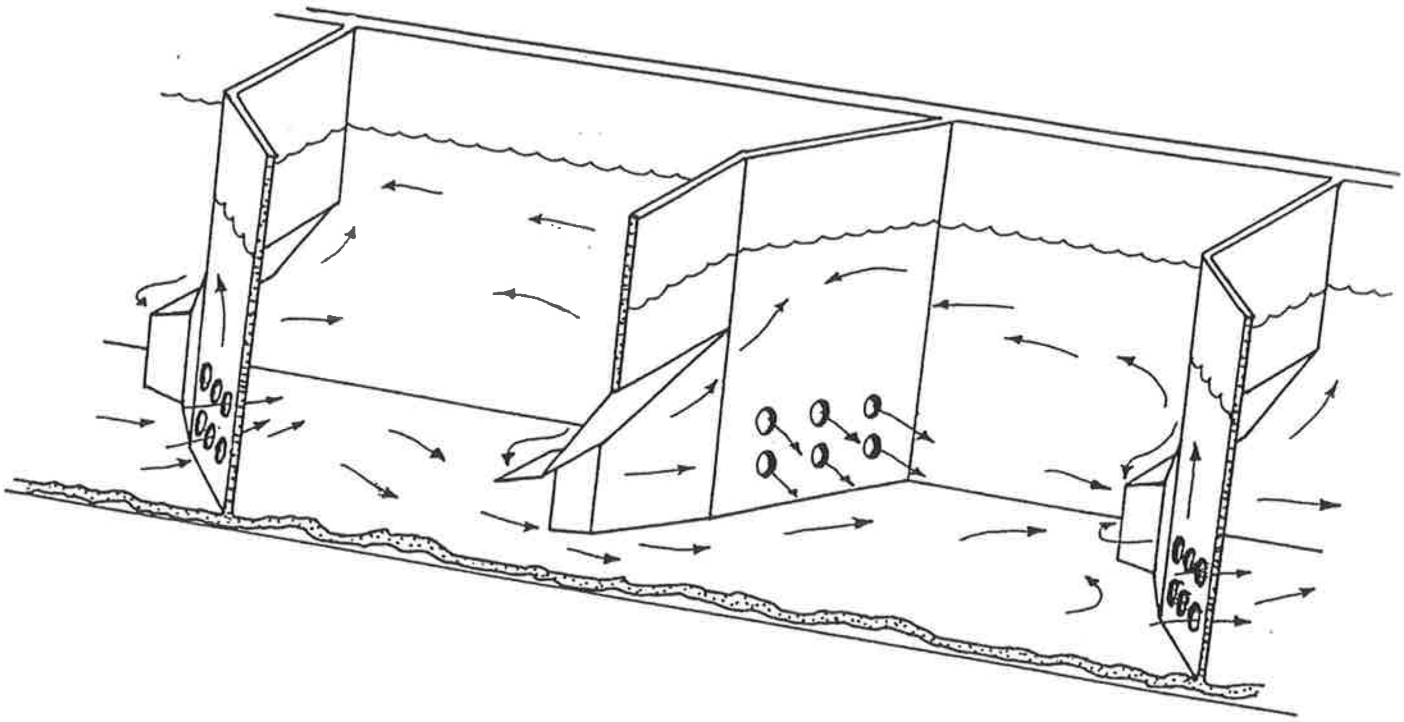

Fig 1. Borda orifice pass, showing baffle design and water flow patterns.

The manual for operation of the fishpass (M.L.C. fishpass operation, ECNZ files), discusses cleaning the fish pass;

"4.1 Cleaning of the fish pass
Most of the silt and some floating debris will collect in the silt trap. This should be flushed out by the removal of the cover plates on the silt trap. (the downstream channel will have to be pumped out [!] to do this)".

This hopeful approach is encountered again in;

"4.3 Upstream approach
Check the silt level and determine if any extensive silt removal is required to ensure the continued operation of the fishpass. Silt removal could [my underlining] be achieved by a number of methods apart from mechanical means. One possibility [my underlining] is to jet the silt during the shutdown period while opening the fishpass gate and allowing flow along the approach pipe into the silt chamber and out into the stilling basin.

4.4 Downstream channel and fish entrance chamber
Clean out silt from the fish entrance chamber. Check the bypass pipe exit.

The downstream channel may need some maintenance"[!]-[at present this channel no longer exists at all, being buried beneath an accumulation of gravels].

The reality of course was that the amount of silt coming down the Mararoa River was always sufficient to badly obstruct flows down the fish pass (S. Sutherland pers comm.). This problem with fine silt was present even before diversion of the Mararoa River. Then, when the Mararoa River was diverted directly toward the radial gates of the control structure, large quantities of river shingle began to arrive on every flood. The bed load of the Mararoa River is now passed through the control structure. Shingle swept into the stilling basin in front of the gates blocked up the entrance to the fish pass and covered the downstream channel. Various attempts were made to modify water flows around the entrance but the problem of shingle buildup has continued to the extent that only a weak flow now issues from the fish pass (Fig 2). It is considered that the fish pass interior is probably almost totally clogged with silt (S. Sutherland pers comm.).

This structure was designed in the halcyon days when financial management was less of a pressing problem and when staff numbers were far higher. Nowadays the facts are that maintenance costs of keeping the fish pass in operation in its present form are likely to greatly exceed what any reasonable person would consider worthwhile.

Although the fish pass was originally intended to allow rainbow trout upstream, the target species for fish passage over the Mararoa Weir at present appear to be brown trout and juvenile eels (elvers). Passage for lampreys also needs to be considered.

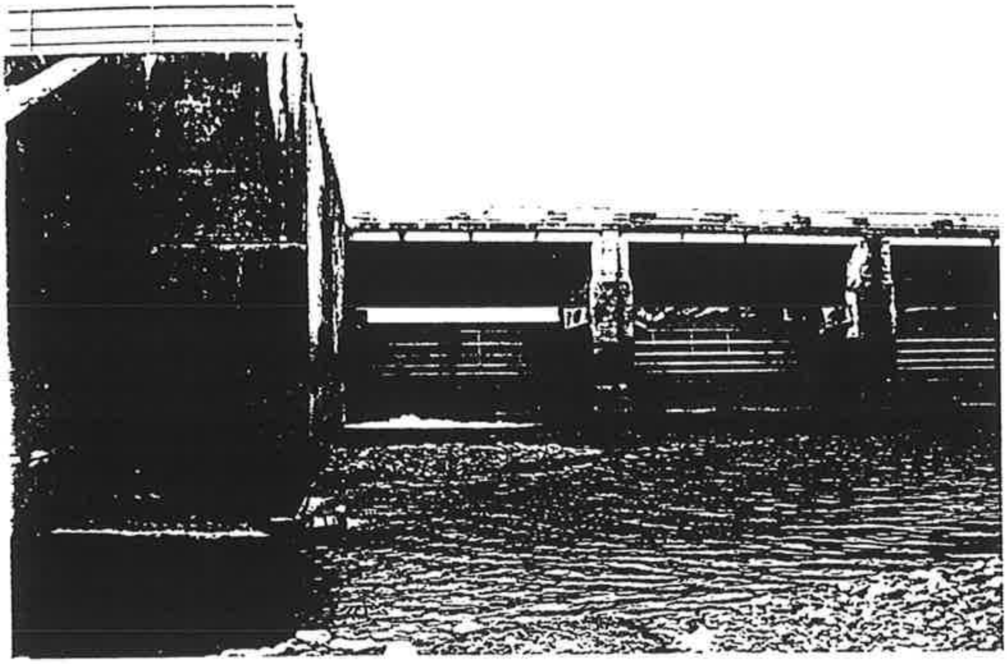

Fig 2: Fish pass entrance (left) at Mararoa Weir. Discharge into the stilling basin from wingwall is from a broken window in the fish pass. Note gravel deposition in the fish pass entrance area.

Elvers migrate upstream from the sea to find living places in the upper Waiau Catchment. Lampreys seek spawning sites in small tributaries upstream of the weir. All other fish in the upper catchment (including brown and rainbow trout), appear capable of forming landlocked populations, passage to and from the lower river or to the sea is not obligatory. However trout from the lower Waiau river formerly migrated upstream to the Mararoa and Whitestone Rivers to spawn (M. Rodway pers comm.).

The fish pass was trapped over 1978, 1979 and 1980. A quite remarkable trap was prefabricated and built within the fish pass by NZED engineers. Six species of fish, ranging from bullies to adult brown trout were caught in the trap. Tagging both rainbow and brown trout in the trap produced the disquieting information that all later recaptures of brown trout were caught from the Waiau River below the trap (Field Dodgson 1981). On the other hand, tagged rainbow trout were caught well up the Mararoa River.

There is evidence from other studies that brown trout within a river system can easily become sectioned into a series of populations by hydroelectricity development, despite installation of fish passes (Linløkken 1993). In that study it was estimated that less than 2% of the estimated stock of brown trout had used the fish passes provided. Lonnebjerg (1990) reported on a fish pass in Denmark successfully used by a range of weak swimming fish, that brown trout failed to use, apparently simply because of poor entrance siting.

Brown trout stocks in the Waiau river have evidently adjusted to construction of the weir. They are certainly common in the lower river and lagoon (C. Mitchell pers obs). Recent fisheries investigation in the lower Waiau River catchment have shown that brown trout fry and fingerlings can be very abundant in some areas, particularly the Orauea catchment (Mitchell & Davis-Te Maire 1994). Field-Dodgson(1981) reported that brown trout were observed spawning below the weir. If the fish pass was reinstated, would they in fact use it ?. Tilzey (1977) showed that brown trout were very accurate at homing back to the same tributary streams in which they had spawned previously. Brown trout stocks can be complex. Skaala (1989) showed that there was comparatively little gene flow even between seagoing and river resident stocks within the same river system.

It has to be accepted that, despite the best intentions, brown trout may not use any fish pass structure that may be provided for them. The risk of failure with this versatile and adaptable species appears to be particularly high.

METHODS

Discussions were held with M. Rodway, Manager of the Southland Fish and Game Council. He conveyed the concerns of the Council about the weir structure and the performance of the fish pass.

Files that dealt with the original decisions to build the fish pass were examined. Some of the original plans still available were studied. A range of reports and publications dealing with the fish pass were read. The concepts involved with reinstating fish passage were discussed with ECNZ staff and an impression was gained on the likely actions of ECNZ.

Mr S. Sutherland, Field Officer of the Southland Fish and Game Council opened up the fish trap facility of the fish pass. He also provided information on his experience of monitoring the trap.

The fish pass was inspected on four occasions. In March 1993 when the weir gates were fully closed and over a series of visits in February 1994. when the Mararoa River was in flood. At this time the radial gates were fully opened and large volumes of highly discoloured water were flowing down the Waiau River. Fine mesh fyke nets (3 mm. mesh) were set overnight below the fish pass entrance. Others were set upstream of the weir and left overnight. Concrete faces of the weir structure close to water level, downstream of the radial gates, were inspected at night by using 55 watt handheld spotlights.

Otoliths from a sample of 158 longfinned eels (*Anguilla dieffenbachii*) and 22 shortfinned eels (*Anguilla australis*) caught from known locations throughout the Waiau River Catchment were used to compare both minimum ages and the age structure of eel populations above and below the weir.

Otoliths were dissected from larger eels after the spinal cord had been severed and the muscles had relaxed. Dissection of otoliths from elvers was done under a binocular microscope using heads preserved in isopropyl alcohol. After a period of drying, all otoliths were broken in two and the broken face ground smooth using wetted 120 grit carborundum paper. Otoliths were then burned for approx 50 seconds to enhance the banding zones and then embedded, ground face down in clear silicone adhesive, on microscope slides. Viewing through the slide, contrasting light and dark zones were then counted across the otoliths at 100x magnification.

It proved impossible to handle elver otoliths in this fashion. Working under a binocular microscope, otoliths were broken underwater by pressure with a scalpel blade and after burning, embedded broken surface exposed, in silicone adhesive. These very small otoliths were then covered with a light vegetable oil to enhance the contrast between dark and light zones.

For all otoliths, the number of light, wide zones were then assumed to represent summers. Readings were made along as many strips across the otolith where the banding zones could be resolved. The total counts possible for all otolith preparations from an individual fish were then summed. The mean of this figure was defined as the age estimate.

RESULTS

When first visited in 15/3/93, there was no sign of any fish life anywhere, either around the fish pass nor in the clear pool formed in the stilling basin. Nighttime observations were made on 24/1/94. At this time the Mararoa River was in flood and the control gates were fully open. A large volume of turbulent and discoloured water was flowing downstream from the control gates. Small accumulations of elvers attempting to climb the furthermost downstream concrete walls of the stilling basin were observed. These fish had managed to progress upstream through the rock rip-rap lining the downstream margins of the river channel, only to be blocked by water velocities past the returns on the smooth concrete walls of the stilling basin.

Six fine mesh fyke nets (3mm. & 6mm. stretched mesh) were set overnight at the base of the weir. A catch of 27 elvers and small eels (plus three large common bullies) were taken at the site of the exit from the fish pass, although the exit was buried by large quantities of shingle. The only species of eel caught was *Anguilla dieffenbachii*, which was to be expected, considering the dominance of this species in the upper Waiau system (Mitchell & Davis-Te Maire 1994). Eels from 11-56 cm. long were caught. Most were in the size range 11-21 cm. (Fig 3) and could be called elvers. It was interesting that all these eels had empty guts. It could be expected that the larger eels had been attracted into the nets to feed upon the smaller ones, but this was not the case. This lack of feeding may be common for upstream migrating eels, or perhaps it is a result of crowding below the weir and the general stress faced by these eels. Perhaps they were concentrated within an area that was inherently unfavorable for eels to live in. Analysis of growth rates of eels from the Waiau River found the growth rates of this sample to be the poorest in the catchment (Mitchell & Davis-Te Maire 1994).

Otolith aging of these eels showed that the elvers ranged in age from 2 to 8 years. Larger eels were from 15 to 28 years old (Fig 4).

The size frequency of 305 eels caught from throughout the Waiau Catchment was divided into the catch from above and below the weir (Fig 5). It can be seen that there is a relative lack of smaller eels in the upper catchment. This lack of smaller eels could be due either to the obstacle posed by the weir for upstream migrants over the past 17 years, or perhaps to the time taken for eels to migrate long distances upstream.

The age frequency of 76 longfinned eels caught from the Waiau Catchment above the weir was plotted (Fig 6). Only 5 of the eels appeared to be younger than the time the weir was built (17 years). The youngest eel was 14 years old. These 5 eels could even be errors in otolith reading, underestimates of age are the most likely error with this technique. But from this data only 7% of the population postdates the weir. In contrast 43% of 77 longfinned eels aged from below the weir were 17 years or younger. This pattern of longfinned eel age gives little support to any assertions that the fish pass has allowed significant numbers of this species into the upper Waiau Catchment.

Surprisingly, no young eels were found among 18 eels caught from Deep Cove (Fig 6). Migrations of elvers should be expected at this new outlet from the upper catchment. Only one night was fished and so the fishing effort was limited. But this result may also perhaps reflect the small amount of eel habitat available at the head of the fiord. Old resident eels may be well entrenched, occupying all available territory.

A different impression of the impact of the fish pass was gained from an examination of the age frequency of 6 shortfinned eels (*Anguilla australis*) aged from above and 17 from below the weir. Although fewer of this generally lowland species were caught above the weir, their age frequency (7-29 years), was similar to the age frequency below the weir (6-31) (Fig 7). There is no evidence for a reduction in numbers of shortfinned eels after 1976.

A further issue is the behavior of eels once they move over the weir. Do they instinctively carry on up the Mararoa, ignoring the downstream route that leads to the vast habitats of the lakes and the inland Waiau ?. Fig 8 shows the ages of eels caught on the Mararoa side of the weir, including the Mavora Lakes, compared with the "Manapouri" side of the catchment. There is no evidence that younger longfinned eels were confined to the Mararoa side. In addition, shortfinned eels caught from Manapouri and the Balloon Loop area of the upper Waiau River were aged at 7,13 and 17 years.

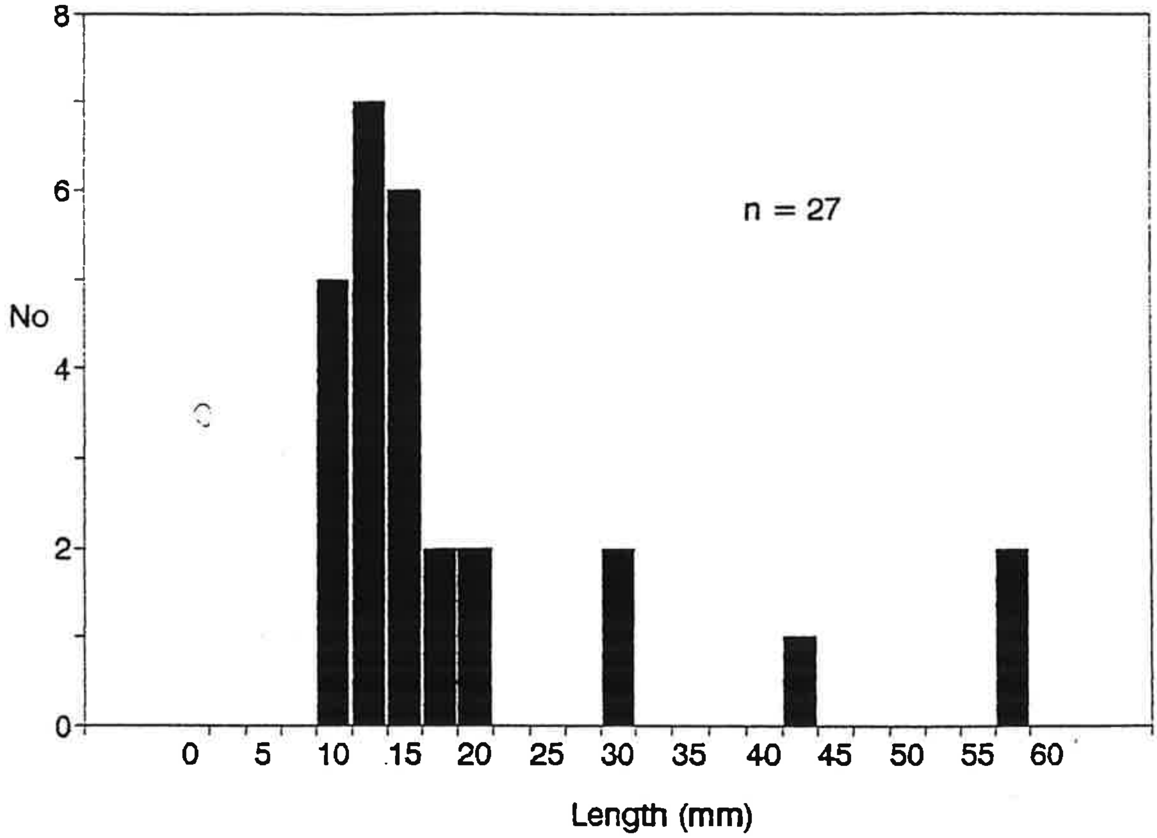

Fig 3. Size frequency of longfinned eels (*Anguilla dieffenbachii*) caught immediately below the Mararoa Weir (26/1/94).

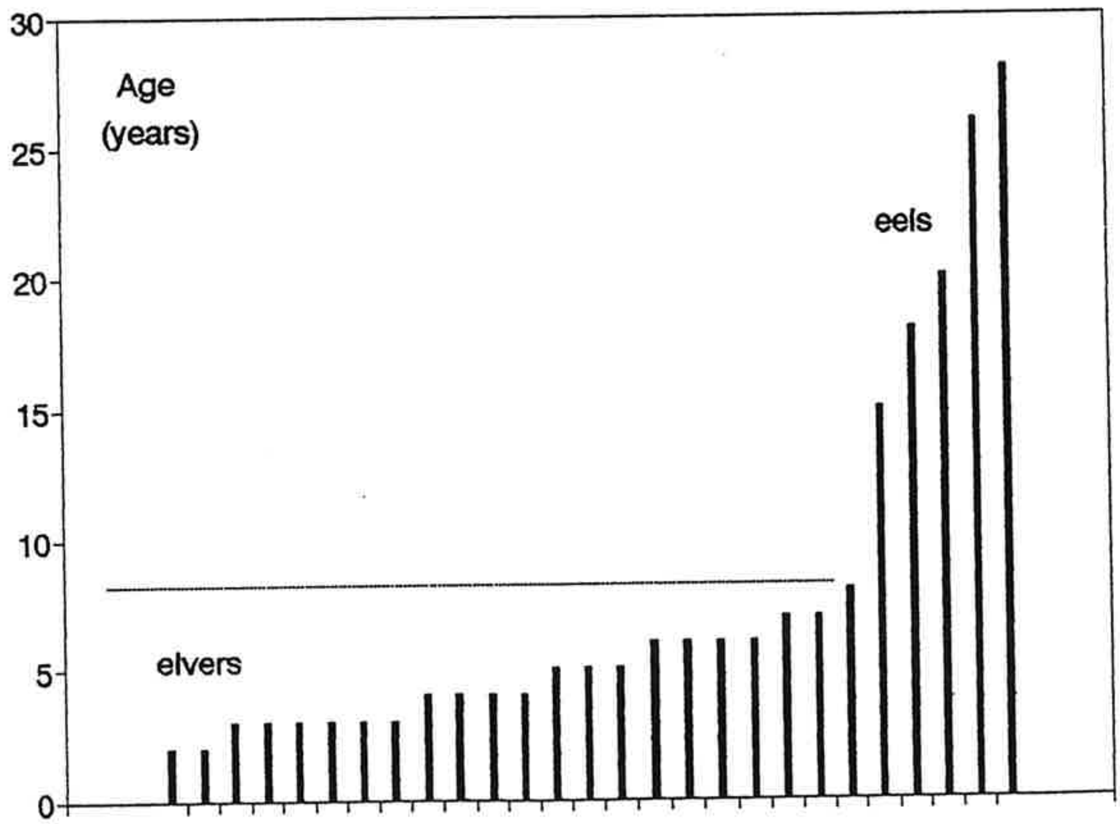

Fig 4. Ages of longfinned eels (*Anguilla dieffenbachii*) caught immediately below Mararoa Weir (26/1/94).