Enhancement of the eel stocks of Coopers Lagoon, Canterbury, by transfer of juvenile eels

D. J. Jellyman
M. P. Beentjes

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Cover: Tagging eels with an automatic injector.
(Photograph by Mike Beentjes)

Contents

Abstract

Jellyman, D. J. & Beentjes, M. P. 1998: Enhancement of the eel stocks of Coopers Lagoon, Canterbury, by transfer of juvenile eels.
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Experiments to determine whether coded wire tags could be used on eels proved successful. Of three tagging sites tested, the top of the head proved to be the most practical. A sample of 1919 commercially undersized eels (under 220 g) was supplied from Te Waihora (Lake Ellesmere) by commercial fishers, tagged, and released into Coopers Lagoon. These eels averaged 136 g and their current growth rate was about 40 $mm.yr^{-1}$. The density of resident eels in Coopers Lagoon was low and growth rates comparatively fast, averaging 63.5 $mm.yr^{-1}$ for their first 10 years. Almost all eels caught were females, with an average weight of 1316 g and average age of 18 years. The size distribution and the lack of juvenile eels indicated that recruitment is intermittent, and enhancement is a good option for increasing production of eels. It is estimated that the transferred eels will reach the commercial threshold size of 220 g within 2 years of introduction to Coopers Lagoon, and average 500 g within a further 7 years.

Introduction

This report is part of a Ministry of Fisheries contract (MFish Project No. INEE02) to further study enhancement opportunities: it focuses on enhancement from juvenile (sub-commercial sized) eels.

NIWA began evaluation and monitoring of eel enhancement from elver transfers in both the North and South Islands in 1995–96. Before this, elver transfer had been carried out on an *ad hoc* basis by the fishing industry, the Department of Conservation (DoC), and Maori groups, with involvement by the Electricity Corporation of New Zealand (ECNZ), the Ministry of Fisheries (MFish), and NIWA.

Maori wish to see selected eel fisheries restored to a state that satisfies their requirements for customary eel fisheries. A number of customary fisheries have been adversely affected by commercial fishing, exacerbated where recruitment is probably intermittent. Coopers Lagoon was chosen for a pilot study on shortfinned eels (*Anguilla australis*) as it is a small coastal lagoon close to the Taumutu pa, recruitment is likely to be adversely affected by the culvert drainage system, and eel stocks are reported to be low. Gold Creek, in the upper Mataura catchment, was nominated for enhancement with juvenile longfinned eels (*Anguilla dieffenbachii*), but there were concerns from local iwi that this was an inappropriate site, MFish were unable to nominate a suitable alternative, and so no transfers eventuated.

The programme objectives for 1996–97 were as follows.

1. To monitor elver transfer enhancement programmes to determine survival, growth, and potential yield of transferred eels.

2. To determine the effectiveness of transferring juvenile eels to productive environments to optimise growth and accelerate the recovery of customary fisheries.

The MFish contract project objective for 1996–97, dealing with juvenile enhancement was as follows:

To monitor juvenile enhancement programmes in lakes and rivers by determining size structure and growth of eels in customary areas to be enhanced and determining growth rates of seed juvenile eels to be transferred into these areas. A pilot programme will be undertaken in two of the following areas - Coopers Lagoon, Ngati Moki Creeks, the Selwyn River system, and Lake Ellesmere (for shortfinned eels); and the upper Mataura River, Lakes Hawea and Wanaka, and the Oreti River system (for longfinned eels).

Juvenile eels were defined within the contract as "eels within the size range 50–200 grams". Such eels may escape from commercial fyke nets through the mesh or escapement tubes. It was anticipated that juvenile eels transferred from an area of "low productivity" to an area of high productivity or low stocking, would exhibit accelerated growth and condition. Coopers Lagoon was sampled to determine growth rates, age and size composition, and reproductive status of the resident population before enhancement. The performance of recaptured transferred eels could then be measured against these parameters. Juvenile seed eels were to be caught in Lake Ellesmere (Te Waihora), and growth and condition recorded from a representative sample, before they were released into Coopers Lagoon. Tagging of juveniles was considered desirable so that recaptured individuals that had been transferred into the lagoon could be recognised. Tagging by either Floy (external streamer tags) or sequentially numbered coded wire tag was specified.

Study area

Coopers Lagoon is a small coastal lagoon about 5 km west of Te Waihora. The area is 45 ha (Irwin 1975), although this is said to vary up to 5-fold during flood periods (Field-Dodgson 1975). The area of 97 ha given by Jellyman (1993) and quoted in the MFish contract was taken from Timmins & King (1984), although this area probably includes adjacent wetland and the spit separating the lagoon from the sea. Thus, 45 ha is assumed to be the "normal" area.

The lagoon comprises an elongate western arm (about 600 m long) and a shorter eastern arm (about 300 m long), both arms being partially separated by a central drainage ditch and bank (Figure 1). The extent of the western arm is reasonably defined by farm paddocks and willows (*Salix* sp.) lining the drainage ditch, but the eastern margin of the eastern arm is a swamp, meaning that boundary is ill-defined and dependent upon water level. The upper eastern arm is supplied by a major ditch draining farmland near Lochvale, but also receives water from a spring-fed stream which runs parallel to the sandhills/bar separating the lagoon from the sea, and enters the lagoon adjacent to the piped culvert.

Throughout most of the lake the average depth is 0.6–0.8 m, with shallower water along the western shoreline and the southern shoreline adjacent to the bar. Depth in the central drainage is 1.5–2.0 m. Substrate is stony along the southern margin, but mud elsewhere, with considerable production of hydrogen sulphide in shallow areas inshore of fringing rushes. The western shallows are firmer, and appear to be more recently inundated pasture. Macrophytes noted were *Myriophyllum, Elodea, Potamogeton*, and *Ruppia*; of these, *Myriophyllum* was by far the most abundant, but even that species had a discontinuous distribution, being confined to clumps at depths of 0.2–0.5 m. Much of the lagoon was surrounded with rushes (*Juncus* spp.), although there were also two large stands of raupo. The lagoon and surrounding wetland are a wildlife management reserve, and the lagoon is rated of national importance for its wildlife habitat (Taylor 1996).

Historically, the lagoon has been drained by a piped culvert which emerged through the sandhills as a boxed drain; this has been modified over time to a piped outfall as the sea has eroded the beachfront. At the time of the first visit (25–26 November 1996), the pipe was completely blocked with gravel and non-functional as a water level control, and therefore completely non-functional for fish passage. Because of continuing problems in maintaining this outlet, the Selwyn District Council has opted to control drainage of the lagoon by connecting it to McLachlans Culvert, which is about 1.5 km to the east. Discussions with Mr Ray Anderson, engineer with the Selwyn District Council, indicated that from an engineering viewpoint, this was a satisfactory solution, as McLachlans Culvert is open virtually all year round (a record of a single brief closure in 18 years); however, local ratepayers were understood to favour a lower lake level and there was some pressure to reopen the old culvert. Mr Anderson's opinion is that the lagoon is smaller than it was before completion of the present drainage system, although because drainage occurs year-round, there is less level fluctuation than previously. McLachlans Culvert has an outfall level 0.41 m above MSL, and Mr Anderson considered it should be negotiable to fish at some stage during the tidal cycle as waves are able to run up the outlet.

On the second visit (18–19 March 1997) the original culvert had been mechanically reopened for the first time in 3 years, apparently so that maintenance on McLachlans Culvert could be carried out. Although the culvert had been opened since 28 February (R. Anderson, pers. comm.) there was still a considerable outflow, with velocities estimated at 1.5 $m.s^{-1}$. The high tide appeared to cause occasional waves to flow back up the culvert and into the lagoon, but no salt water was detected (Table 1), indicating that these were not saltwater waves but wave refraction of the freshwater outflow. The presence of algae on exposed rocks within the lagoon implied some diel variation in level and this was observed overnight on 18 March when water level in the lagoon increased by 20 cm; as there was no saltwater intrusion, this must have been due to seawater levels impeding outflow from the lagoon.

An inspection of McLachlans Culvert on 18 March showed a strong outflow, although all this water came from a drain which ran east from Taumutu. The drain from Coopers Lagoon was not flowing: it enters the main drain through a flap floodgate. Portions of the Coopers Lagoon drain were electrofished to see whether there was any evidence that juvenile eels could gain entry to the lagoon via the culvert and drain.

Methods

Coded wire tagging

Coded wire tags (CWT) have long been used as a means of mass-marking juvenile salmon, e.g., Unwin *et al.* (1997). The stainless steel tags (1.25 x 0.25 mm) are etched with a 6-bit binary code. NIWA staff have tagged thousands of salmon in this way over 20 years. Batch codes have generally been used, that is, a batch of juvenile salmon from a specific location and of a specific size range will all be tagged with similar tags. However, sequentially numbered (individually identifiable) tags are also available.

Correspondence with the tag manufacturers (Northwest Marine Technologies Ltd) indicated that CWTs had not been used for eels, but they assumed that they could be. Their suggestions were that eels could be tagged in either the cheek muscle or in the webbing of the ventral fin. NIWA staff therefore undertook a series of tagging trials to ascertain an appropriate method for handling eels and the preferred tagging site.

Type of tagging applicator

Initially, a hand-held tagging gun was used — with difficulty as it required one hand to hold the eel, leaving the other to advance the tag, cut it, cock the gun, and implant the tag. Although this injector was suitable for trial tagging small numbers of eels, it was clearly unsuitable for tagging large numbers. Instead, a Mark IV Northwest Marine Technology automatic injector was used to tag the eels that were transferred to Coopers Lagoon.

Identification of suitable tagging site

Seven eels were initially tagged using the hand-held injector — two in the "cheek" (opercular) muscle, two at the base of the lower jaw, and three in the top of the head. The area suggested by the tag manufacturers, fin webbing, was disregarded as impractical. In practice, the base of the jaw provided a small target area which, while suitable when using the hand-held injector, proved difficult to locate precisely when using the automatic injector as the head of the injector partly obscured the fish. The cheek muscle provided a larger area, and was preferred to the jaw, but the top of the head provided the largest area of all, and was therefore the preferred site. Identifying successfully tagged specimens was achieved by using a hand-held "wand" which detected the presence of a tag.

For tagging, eels were initially placed in a purpose-made pipe which had a section removed to expose the top of the eel's head. The anaesthetised eel was slid into the pipe and could then be pressed against the injector which automatically inserted the tag. In practice, difficulties were experienced due to the considerable variation in size of eels handled, and the pipe was discarded in favour of holding eels by hand. The option of making a head mould was also discarded on the basis that at least five different sizes would have been needed; this method would have required a further grading of eels so that eels of a particular size range were tagged consecutively before the head mould was changed for the next size range of eel.

Tag retention trials

When coded wire tags are used on juvenile salmon, the tag is injected into an area of cartilage in the snout. This cartilage is relatively immobile, whereas muscle tissue contracts periodically and may "squeeze" the tag out. Hence a series of trials was carried out to determine tag retention. A sample of 31 sub-commercial sized eels (under 220 g) was collected from the Cust Main Drain on 10 December 1996. All eels were tagged in the top of the head and then checked by tagging wand to ensure that a tag was present. All eels were checked on 16 December 1996 when it was found that five (16%) had lost tags. Eels were checked again on 16 January 1997 and that no further tag loss had occurred. The percentage tag loss was greater than anticipated, and this was considered largely due to unfamiliarity with the species. Tag loss for chinook salmon using the same equipment is about 4 % (D. H. Lucas, NIWA, pers. comm.).

Tagging of eels for transfer into Coopers Lagoon

The contract suggested that up to 4850 eels be released into Coopers Lagoon based on a stocking rate of 5 $kg.ha^{-1}$, an (incorrect) lagoon area of 97 ha, and an average weight of 100 g. Using the actual area of 45 ha and a mean weight of 135 g (the mean weight of eels provided for transfer) equated to a stocking requirement of 1666 eels. Commercial eel fishers on Te Waihora, in cooperation with local iwi, were contracted to supply up to 2000 sub-commercially sized eels (50–

200 g) for tagging. Fyke net catches were initially sorted by the fishers and oversized and migratory eels released. Eels for tagging were delivered in perforated drums to an eel factory (Gould Aquafarm Ltd, Lakeside) where the drums were placed in flowing water. About 10 eels at a time were hand-netted from the drum, anaesthetised in a bucket with 2-phenoxyethanol, and again sorted to exclude oversized and migratory eels which were returned to Te Waihora. Eels for tagging were measured, and a subsample of 264 weighed to determine the length-weight relationship. About 70 eels were frozen for ageing later.

The injector was mounted on a bench and anaesthetised eels were held against it, with the operator's thumb pressed against the underside of the eel's head to provide stability. The needle insertion depth was adjusted to about 2 mm. The tag wire is pre-etched with the code, but small variations in tag length can mean that a tag may contain an incomplete sequence. The tag either side of that inserted into an eel was collected and stored for future reading so that the tag removed from any recaptured eel can be read and the matching tag sequence found from the retained tags. For this tag collection, the first tag ("start") was expressed from the machine, transferred to a data sheet and placed on a section of double-sided cellotape; the next tag was inserted into an eel, and the following tag ("finish") was collected and placed alongside the "start" tag.

After tagging eels were sent down a chute which checked whether the tag had been inserted in the eel. In a trial of tagging effectiveness on 234 eels, only 8 (3.4%) were recorded as having no tag, and these were retrieved and retagged. Once initial logistical problems had been sorted out, a tagging rate of 100 eels per hour was achieved, although it was felt that had all the eels been properly sorted before tagging, a rate of 120 an hour would be possible. Once tagged, eels were returned to perforated drums and placed in running water. Eels were not transferred to Coopers Lagoon for several days to allow them to recover from the stress of tagging.

In the laboratory, the species, length, and weight of tagged eels were entered onto a database. As it is expected that only a small proportion of tags will be recovered in subsequent years, only 1 in 50 of the retained reference tags were read: this will greatly facilitate locating the "true" sequence of tags from subsequent recaptures.

Otoliths were extracted in the laboratory from a size-stratified sample of the frozen eels, i.e. 5 eels per 1 cm group. Otoliths were prepared for reading using a modified version of the method of Hu & Todd (1981), and read using a binocular microscope and side illumination. Each otolith half was awarded a "readability score", based on an arbitrary 5 point scale (1 = excellent , 5 = unreadable), and freshwater age was recorded as the number of completed annuli in the otolith. For subsequent age-length analysis, live lengths were calculated by multiplying frozen lengths by 1.031 (E. Graynoth, NIWA, unpublished data).

Eel sampling methods

Electrofishing and unbaited fyke nets were used to survey the eel stock. For electrofishing, a portable battery-powered backpack machine was used. On 25 November 1996, high conductivity meant that the machine would not operate effectively along the shoreline of the eastern arm, which is the area where any saltwater intrusion occurs (Field-Dodgson 1975). Elsewhere, voltages of 100–200 were used. Eight sites covering about 650 m² were electrofished. During the March 1997 survey, water in much of the outflow drain to McLachlans Culvert was too conductive for electrofishing, as was water in the lagoon itself.

For the November survey, a combination of seven single-wing, three double-wing, and two fine-meshed fyke nets was used. To increase the sample size of the March 1997 survey, a total of 16 single-wing and 1 double-wing fyke nets was used. Nets were set unbaited at right angles to the shore, around the edge of the lagoon where depth was over 0.4 m.

Eels caught were anaesthetised with 2-phenoxyethanol. As tagged eels had been introduced into the lake during February 1997, all eels caught during the March survey were screened for tags. All eels were measured (to 1 mm), weighed (to 1 g), and untagged eels had their sagittal otoliths removed. Sex of eels was recorded as "male" (gonad present as narrow lobed ribbon), "female" (gonad a wider lobed/pleated ribbon), or "unknown" (gonad undifferentiated). Tagged eels were released.

Otoliths were prepared for reading at the laboratory using a modified version of Hu & Todd's (1981) method. Otoliths were broken in half and, depending on size, heated for 15-22 s with a gas-powered miniature soldering torch. Both halves were then mounted on a microscope slide with silicone adhesive. Otoliths were read under x20 magnification using side illumination from a cold light source. Freshwater age was recorded as the number of complete dark (hyaline) rings external to the glass-eel portion of the otolith. The most readable half was given a readability score from 1 to 5 (1 = excellent, 5 = unreadable).

Condition (k) of eels was calculated from $k = w*10^6/L^3$

where w is weight (g) and L is length (mm).

Results

Coopers Lagoon

Catches

During the November 1996 survey, some apparently suitable habitats in the lagoon were electrofished, but only three eels were caught and no other eels were seen or disturbed. The three eels were a single migratory shortfinned male caught along the southern shoreline (despite the difficulties with conductivity referred to above), and two larger shortfinned eels caught in the lagoon, adjacent to the draglined canal. Despite intensive searching of shoreline habitats, no juvenile eels were seen.

The 12 fyke nets caught 23 eels, giving a low catch-per-unit-effort (CPUE) of 1.9 eels per net per night; as eels were relatively large, this equated to 2.09 kg per net per night.

Other fish species caught in the nets were upland bullies (*Gobiomorphus basalis*; maximum of about 40 in each of the fine-meshed nets), common bullies (*G. cotidianus*, including two extremely large individuals, 143 and 153 mm caught in the spring-fed stream), and two large and very well conditioned brown trout (*Salmo trutta*) from the same area (a female of 550 mm and a male of 610 mm).

In the March 1997 survey, no juvenile eels were seen or caught by electrofishing in ponded water (75 m^2) in the drain near McLachlans Culvert: conductivity was too high for electrofishing in much of the drain and in the lagoon itself.

From 18 fyke nets, a total of 2 longfinned eels and 40 shortfinned eels were captured, of which 2 shortfinned eels and 1 longfinned eel were tagged. Again this equated to a low CPUE of 2.3 eels per net per night, with a biomass of 3.38 kg per net per night.

Species and size distribution of eels

Of the 62 resident (untagged) eels caught by fyke netting, 60 (97%) were shortfinned eels. The size distribution of both species of eels is given in Table 2, and the total length-frequency for both species is shown in Figure 2. Relative to other waters (see Beentjes & Chisnall 1997), the average size of shortfinned eels (760 mm) was very large, with seven individuals of 1 m or more being caught.

The length-weight relationship for shortfinned eels was:

log weight = 3.134(log length) – 13.865 ($n = 64$, $R^2 = 0.98$, $p < 0.001$).

Condition (k) of shortfinned eels was:
($n = 62$), mean = 2.316, s.d. 0.334, range 1.447–3.311.

Age and growth

Otoliths were generally considered to be very readable (overall readability grade of 2.4). The growth rates of shortfinned eels were highly variable, but generally high, e.g., at 10 years of age, eels ranged from 386 to 840 mm in length. For age-length analysis, a 48 year old eel (769 mm) and a 41 year old eel (737 mm) were considered outliers and removed. The age range of the remaining eels was 4–30 years, with a mean of 15.8 years.

A von Bertalanffy growth curve was fitted to the data (Figure 3) and gave the following values : L_∞ = 1192 mm, t_0 = –3.37, K = 0.057. This relationship indicates that initial growth is reasonably fast, averaging 31 mm.yr^{-1} for a 10-year old eel, but reduces to 10 mm.yr^{-1} by age 30. As commercial catch data are expressed in terms of weight rather than length, growth in weight was calculated by transposing weight for a given length. Results indicate that eels reach the commercial threshold weight of 220 g in 5.3 years; they would average 578 g by age 10, and 1072 g by age 15. Of the 64 shortfinned eels, only the migrant male was recorded as a definite male, the sex of 12 was uncertain, and 51 were females.

Available food

The mysid *Tenagomysis chiltoni* was very common, with thousands caught in the fine-meshed nets, together with equivalent numbers of water boatmen (*Sigara* sp.). The snail, *Potamopyrgus antipodarum* was ubiquitous, and common wherever weed was present. Upland bullies were reasonably abundant, although nowhere as abundant as common bullies in nearby Te Waihora. Frogs were heard but not seen.

Te Waihora: tagged and transferred eels

Size distribution

A total of 1919 eels from Te Waihora was tagged and transferred to Coopers Lagoon during mid-late February 1997: 98.7% were shortfinned eels of which 75% were 400–500 mm long. The length and weight distributions are given in Table 3. The length-weight relationship for shortfinned eels was:

log weight = 3.134 (log length) – 13.969 ($n = 261$, $R^2 = 0.90$, $p < 0.001$).
Condition of shortfinned eels ($n = 261$) averaged 1.931 (SD 0.203, range 1.355–2.540).

As weight is the more widely used statistic in the fishery, the weight distribution of transferred shortfinned eels is shown in Figure 4.

Age and growth

The 54 undersized eels retained for ageing ranged from 338 to 535 mm long (mean 415 mm). Ages ranged from 5 to 16 years, with an average of 10.8 years; the modal age was 10, and three-quarters of the eels were between 9 and 13 years old. The age-length plot showed considerable scatter (Figure 5) and, because of the small size range represented, no attempt was made to generate an age-length relationship. Rather, growth was expressed in terms of individual eels. For this, the length of glass-eels (60 mm) was subtracted from the total length, and the resulting length divided by the age Individual growth ranged from 26 to 96 $mm.yr^{-1}$ with an average of 40.5 $mm.yr^{-1}$ (s.d., 11.9).

Discussion

The use of coded wire tags for eels is apparently a world first. The top of the head was the preferred site - were the eels to be commercially harvested, the suitability of this site would have to be checked with eel processors, though it seems unlikely that there would be serious objections as the head is usually regarded as waste. Unfortunately, it is not possible to apply an external mark to eels to indicate the presence of a tag, so retrieval of tagged eels will require entire catches to be screened with an electronic wand. Compared to the tagging of juvenile salmon, tagging of eels is slow, with a maximum rate of 120 per hour. If a programme required the transfer of tens of thousands of juvenile eels, then subsamples only could be tagged. Tagged eels, or just their heads, from Coopers Lagoon and any subsequent releases, will need to be returned to NIWA for tag removal and reading, and calculation of growth.

The average CPUE for Coopers Lagoon, 2.2 eels per net per night, was comparatively low; for instance, Jellyman & Bonnett (1996) recorded CPUE of 36–81 eels per net per night for a small North Island lake, while CPUE for nearby Te Waihora (1975–89) ranged from 2.5 to 8.0 (Jellyman *et al.* 1995). The large average size in the present study, 1309 g, "improved" the mean catch to 2.88 kg per net per night, although this was still lower than the 3.1–8.1 recorded for South Canterbury for 1983–84 to 1988–89 (Jellyman 1993).

Although the dominance of shortfinned eels in a coastal lake like Coopers Lagoon was expected, the size structure of the population was unusual, with a high proportion of very large eels and few juveniles. Growth rate was asymptotic and relatively rapid; for example, at 5 years, eels averaged 452 mm and 199 g, which corresponded to average growth of 90 $mm.yr^{-1}$ and 40 $g.yr^{-1}$.

Jellyman (1997) recorded growth rates for shortfinned eels from 17 locations throughout New Zealand ranging between 18 and 45 $mm.yr^{-1}$ (excluding hydro lakes where low densities lead to more rapid growth). Jellyman (1997) and Horn (1996) concluded that density was a major influence on growth rates, and the low density and rapid growth of eels in Coopers Lagoon are in agreement with this. At the time of transfer, the growth rates of eels transferred from Te Waihora were highly variable, but generally lower at 41 $mm.yr^{-1}$. Using the average weight of transferred eels of 135 g and assuming a similar growth rate to Coopers Lagoon eels, then the transferred eels will reach the commercial threshold size of 220 g in 2.1 years and 500 g in a further 7.0 years. The virtual absence of males agrees with the observation that, at low densities, most eels become females (e.g., Tesch 1977). Were excess small eels transferred to Coopers Lagoon, then it is likely that the proportion of males would increase, which would slightly depress average growth rates as males grow more slowly than females (Jellyman 1997). Of course, if numbers were such that growth became affected by density dependent factors, then growth rates would become further depressed.

There were few shortfinned eels under 10 years of age in Coopers Lagoon. Fyke nets are selective for eels over 35 cm and electric fishing effectively samples smaller eels. However, extensive electric fishing failed to find any small eels, and it was concluded that recruitment had been virtually nil for the past 10 years. Nearby Te Waihora experienced a large influx of glass-eels during 1996 (D. J. Jellyman, NIWA, unpublished data), so the lack of recruitment into Coopers Lagoon is more likely to be associated with conditions at the outlet rather than a lack of glass-eels. The engineer for the Selwyn District Council believed that the present opening to McLachlans Culvert was preferable to that at Coopers Lagoon itself, as it was open virtually year round. Despite this, no juvenile eels were found in the drain which now connects Coopers Lagoon to McLachlans Culvert, and it seems likely that the flap floodgate at the outlet of this drain restricts glass-eel elver access to the lagoon. However, if the Coopers Lagoon outlet as observed on 18 March 1997 had had similar operating conditions during the autumn glass-eel migration, glass-eels could have entered the lagoon.

A sample of shortfinned eels from the lagoon was measured in November 1975 (NIWA, unpublished data): the mean length of the sample (n = 159) was 613 mm (s.d., 140 mm) and the range 275–931 mm; the length distribution was negatively skewed (Figure 6), with only 26% being 50 cm or less. Equivalent percentages for eels of 50 cm or less from Te Waihora length-frequencies at this time were 50–75% (Jellyman *et al.* 1995). The 1975 sample probably predated any extensive commercial fishing, and indicates that recruitment at that time was also probably intermittent.

Local farmers reported that the lagoon "used to be full of eels", a statement which was reiterated by a senior Ngai Tahu spokesman (Don Brown). However, the lagoon has been extensively commercially fished, and it is likely that the present low densities are the combined result of commercial fishing and intermittent recruitment. Certainly, low densities have resulted in rapid growth, and the lagoon seems capable of supporting a much higher biomass of eels. Should stock enhancement continue, monitoring of CPUE, condition, and growth rates will be important to evaluate the effect of stocking and ascertain when the optimal level has been achieved.

Observations during the glass-eel arrival season in autumn should indicate whether the floodgate at McLachlans Culvert is acting as a barrier to glass-eels. Failing some resolution of this, continued stocking is an option to improve the current population. The long-term best interests of the Coopers Lagoon eel population would seem to lie in ensuring natural recruitment, rather than the goodwill of locals to transfer juvenile eels, the present stock enhancement is likely to be successful in achieving modest returns from the eels transferred.

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***Table 1*: Water quality data, Coopers Lagoon. (Locations of sampling sites are shown in Figure 1.)**

	November 1996		March 1997		
Site	1	2	1	2	3
Temperature (°C)	20.3	14.7	16.9	13.1	17.1
Conductivity (mS/m)	245		272	123	267
Turbidity (NTU)			20	6	26
pH			9.1	8.75	9.0
Oxygen (mg/l)			8.6	9.1	8.6
Salinity (%)			0	0	0.01

***Table 2*: Length (mm) and weight (g) distributions of eels caught in Coopers Lagoon**

	Shortfinned eels		Longfinned eels	
	untagged	tagged	untagged	tagged
November 1996				
No.	24	0	2	0
Length: mean (range)	694 (356–1044)		843 (692–995)	
Weight: mean (range)	1057 (100–2958)		1935 (943–2926)	
March 1997				
No.	38	2	1	1
Length: mean (range)	819 (400–1032)	433 (380–487)	840	397
Weight: mean (range)	1479 (118–3103)	152 (88–216)	1950	129

***Table 3*: Length (mm) and weight (g) distributions of eels transferred from Te Waihora to Coopers Lagoon**

	Shortfinned eels	Longfinned eels
Length		
No.	1894	25
Mean (range)	435 (297–522)	427 (320–503)
Weight	261	3
No.	135 (46–246)	207 (168–244)
Mean (range)		

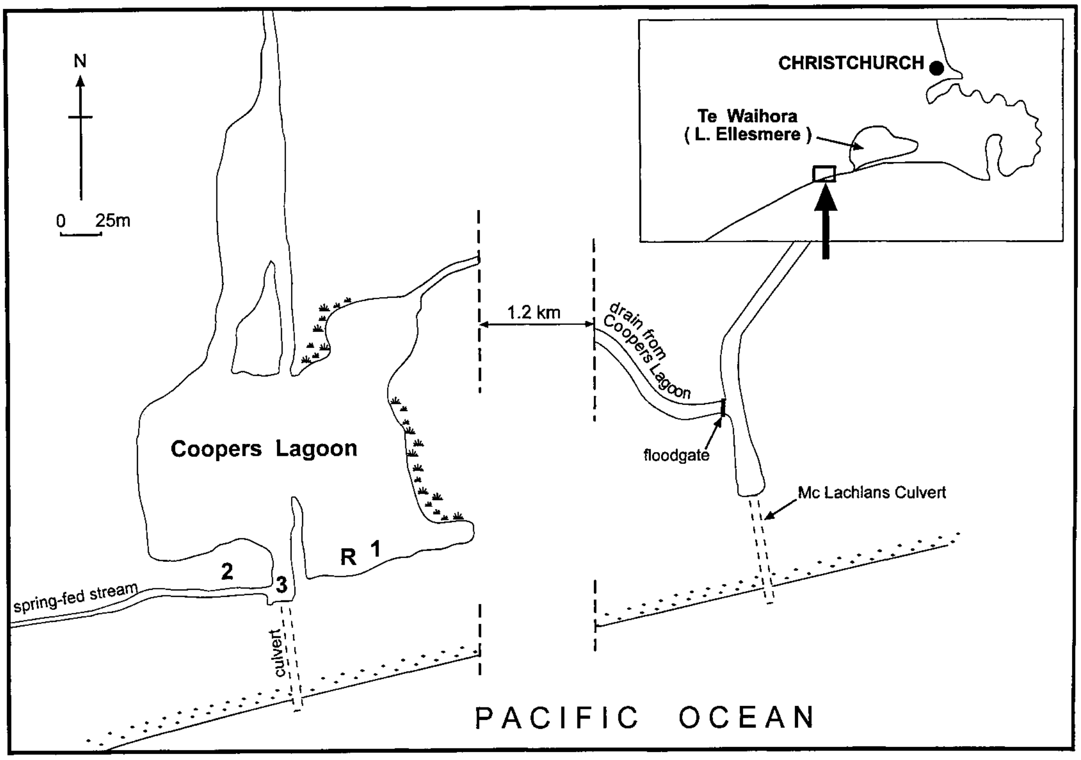

Figure 1: **Coopers Lagoon and McLachlans Culvert showing the drain which now links them: both ocean outfalls are shown, together with water quality sampling sites (1–3) and the release point for tagged and transferred eels (R).**

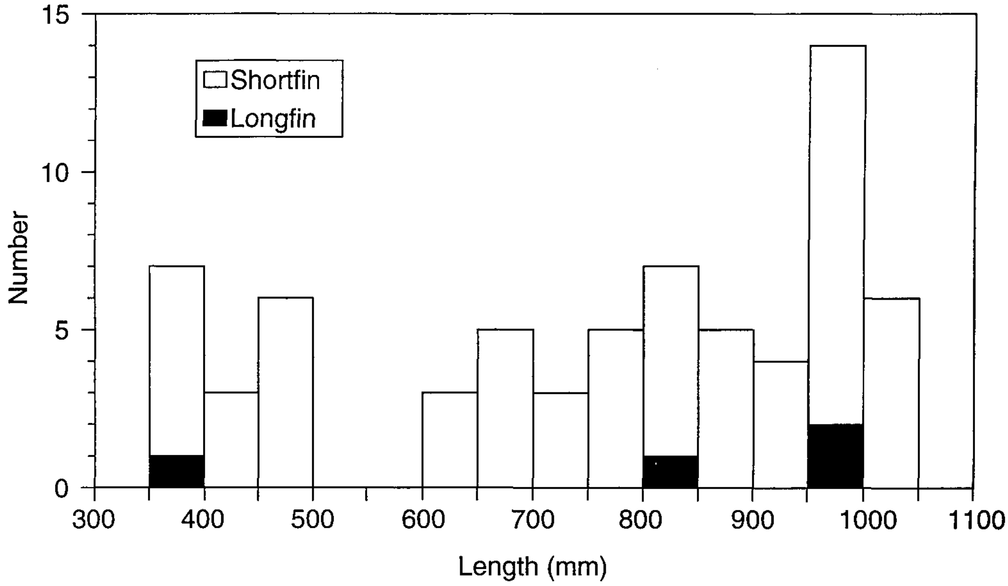

Figure 2: **Length-frequency of shortfinned and longfinned eels from Coopers Lagoon.**

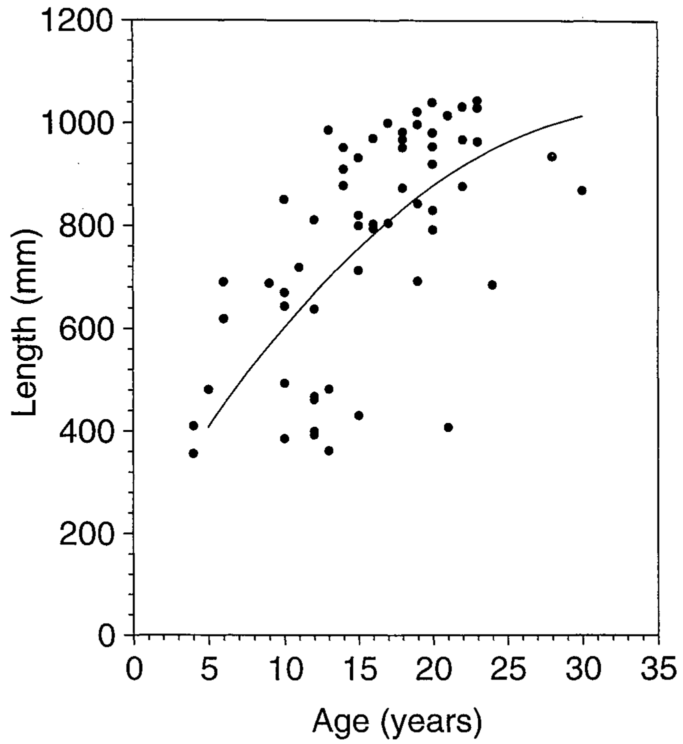

***Figure 3*: Age-length relationship for shortfinned eels from Coopers Lagoon and the von Bertalanffy curve.**

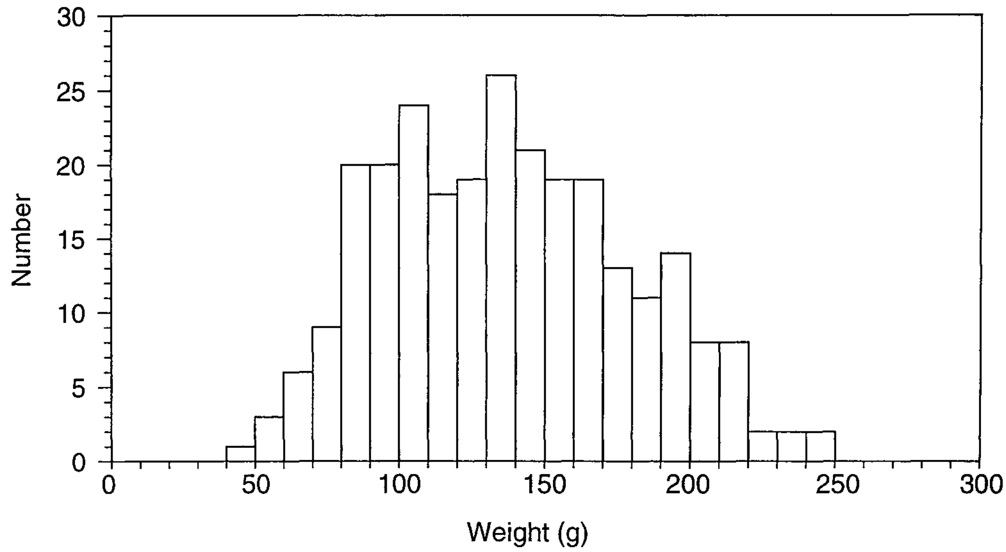

***Figure 4*: Weight distribution of shortfinned eels tagged and transferred to Coopers Lagoon.**

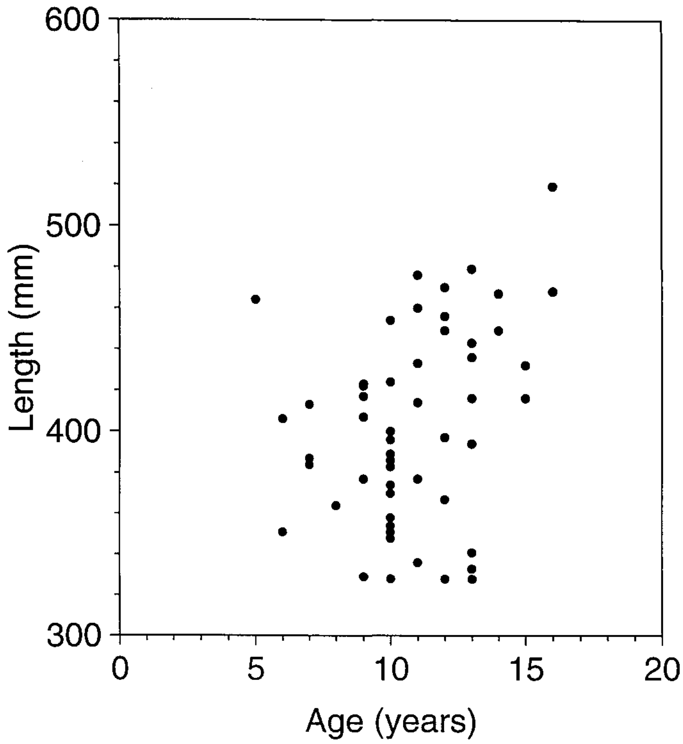

Figure 5: **Age-length relationship for a sample of undersized eels from Te Waihora.**

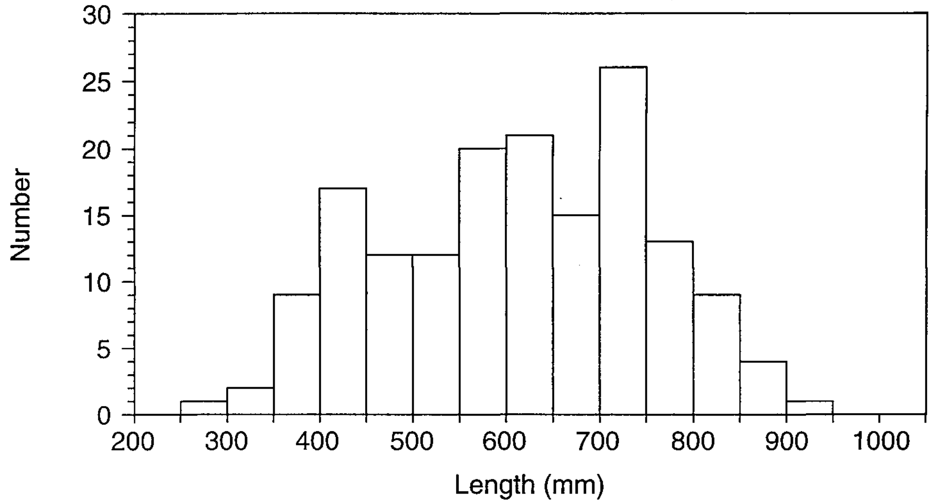

Figure 6: **Length-frequency of a sample of shortfinned eels from Coopers Lagoon, November 1975.**