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M. P. Beentjes
D. J. Jellyman

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M. P. Beentjes[1]
D. J. Jellyman[2]

[1]NIWA
PO Box 6414
Dunedin

[2]NIWA
PO Box 8602
Riccarton
Christchurch

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EXECUTIVE SUMMARY

Beentjes M.P.; Jellyman, D.J. (2002). Evaluation of eel enhancement in Coopers Lagoon, South Canterbury.

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In 1997, Coopers Lagoon (Muriwai) in south Canterbury was stocked with 2009 juvenile eels (1984 shortfin, mean length 43.5 cm; 25 longfin, mean length 42.7 cm) sourced from Te Waihora (Lake Ellesmere) for the purpose of enhancing the lagoon as a site for Maori customary fishing. All transferred eels were tagged with coded wire tags. In 2001 the eel population in Coopers Lagoon was sampled and this report evaluates the effectiveness of this transfer.

A total of 60 shortfin and 8 longfin resident eels (eels without tags) were caught in Coopers Lagoon in 2001 (mean lengths: shortfin 74.4 cm, longfin 71.7 cm). Catch per unit effort (kg per net, no. eels per net) in 2001 was about half that of 1996–97. Nine shortfin and one longfin were recaptured with coded wire tags (tag–recaptures) and the mean days at liberty was 1451 (3.97 years) for shortfins and 1452 for the longfin. The tag return rate was 0.5% for shortfin and 4% for longfin. Tag–recaptures made up 12% of eels caught in Coopers Lagoon in 2001. All shortfin tag recaptures were female, but the sex of the longfin was unknown. Tag–recaptures were dispersed throughout the lagoon.

Mean length and weight of shortfin tag–recaptures were 73 cm and 933 g. During the four years at liberty shortfins grew, on average, about 33 cm and 812 g and both length and weight were significantly larger at recapture ($p < 0.001$). Mean annual length increment of shortfins was 3.4 $cm.yr^{-1}$ at release (from length at age) compared to 8.4 $cm.yr^{-1}$ at recapture (growth since release and recapture) and was significantly different ($p < 0.001$). Linear regression analysis of length at tagging and annual growth increment indicated that growth in length was linear. The one longfin tag–recapture had grown 5.3 $cm.yr^{-1}$. Shortfin condition (k) of tag–recaptures improved from a mean of 1.91 at release to 2.40 at recapture and the difference was statistically significant ($p < 0.001$). Condition of the one longfin tag–recapture improved from 2.12 to 2.44.

The recaptured eels experienced rapid and accelerated growth after transfer. The low number of tag–recaptures was ascribed to loss through migration of all shortfin males and some females. This may have been exacerbated by differentiation into males in response to initial high density after stocking. The success of the programme, in terms of restoring the Maori customary fishery in Coopers Lagoon, is difficult to evaluate given the potential loss of tagged and released eels through migration, and customary harvest. Future enhancement of Coopers Lagoon might consider transferring smaller quantities annually in tandem with more frequent sampling, as well as restricting transfer to shortfin eels over about 45 cm to ensure that only female shortfins are used for stocking and thus the loss of males to migration could be avoided. In addition, customary harvest should be monitored.

1. INTRODUCTION

Coopers Lagoon (Muriwai) was stocked with shortfin and longfin juvenile eels (*Anguilla australis, A. dieffenbachii*) in 1997 to enhance the lagoon for Maori customary fishing (Jellyman & Beentjes 1998) (MFish project INEE02). About 2000 predominantly shortfin eels were caught in Te Waihora (Lake Ellesmere), tagged with coded wire tags and transferred to Coopers Lagoon. Four years later in 2001, the eel population in Coopers Lagoon was sampled and this report examines the effectiveness of this transfer in terms of growth, survival, and movement.

Coopers Lagoon has been historically important to Maori as a customary fishery (Waihora Eel Management Committee, unpublished report), although the extent of the customary take is unknown. The lagoon has also been commercially fished in the past but no commercial fishing occurred since transfer of tagged eels in 1997. Before stocking in 1997, the eel population in Coopers Lagoon was sampled using electric fishing and fyke nets (Jellyman & Beentjes 1998). Shortfins were the predominant species (97%) and numbers were low compared to the 1970s (NIWA unpublished data). The decline in abundance is thought to have been a result of commercial fishing and intermittent recruitment due to modification to the natural drainage of the lagoon (Jellyman & Beentjes 1998). Relative abundance in Coopers Lagoon was low compared to that in Te Waihora (Jellyman et al. 1995) and growth rate was fast compared to that of the seed stock from Te Waihora. Eel growth has been shown to be density dependent (Horn 1996, Jellyman 1997) and eels transferred into Coopers Lagoon were expected to achieve enhanced growth because of the low eel density.

This research was carried out by NIWA under contract to the Ministry of Fisheries under Project Code EEL2000/02: *To measure the growth, survival and movement of juvenile eels transferred into Coopers Lagoon (1997) and Lake Hawea (1998).*

Lake Hawea will be covered in a separate report.

The tag and release of eels into Coopers Lagoon in 1997 was carried out under contract to the Ministry of Fisheries as part of Project Code INEE02.

1.1 Description of Coopers Lagoon

Coopers Lagoon is a small coastal lagoon in south Canterbury about 5 km west of Te Waihora. Its 45 ha (Irwin 1975) may vary up to five-fold during flood periods (Field-Dodgson 1975). For more details see Jellyman & Beentjes (1998). The lagoon comprises an elongate northern arm (mainly an expanded section of a central drainage ditch) and shorter western and eastern arms that are partially separated by a central drainage ditch and bank (Figure 1). The extent of the western arm is reasonably well defined by farm paddocks and willows (*Salix* sp.) lining a drainage ditch, but the eastern margin of the eastern arm is a swamp, and the boundary is ill-defined and dependent upon water level. The northern arm is supplied by a major ditch draining farmland near Lochvale, and the western arm receives water from a spring-fed stream that runs parallel to the sandhills/bar separating the lagoon from the sea, and enters the lagoon adjacent to the piped culvert.

Historically, the lagoon was drained by a piped culvert which emerged from the sandhills as a boxed drain; this has been modified over time to a piped outfall as the sea has eroded the beachfront. Although it is occasionally opened manually, the pipe is generally blocked with gravel and is therefore non-functional in terms of controlling water level or allowing fish passage. Because of continuing problems in maintaining this outlet, the Selwyn District Council opted to control drainage of the lagoon by connecting it to McLachlan's Culvert, which is about 1.5 km east, and is open virtually all year. McLachlan's Culvert has an outfall level 0.41 m above MSL, and it should be negotiable to fish at some stage during the tidal cycle as waves are able to run up the outlet.

2. METHODS

2.1 Coopers Lagoon resident eel population (1996–97)

Coopers Lagoon was surveyed in November 1996 and March 1997 using electrofishing and unbaited fyke nets to determine the status of the resident eel population before stocking. Length and weight were recorded for all eels, and otoliths were removed for ageing and processed as below. Length and weight at age were used to estimate mean annual growth rate of resident eels in Coopers Lagoon. (For more details of methods used see Jellyman & Beentjes (1998).)

2.2 Catch of seed stock and transfer to Coopers Lagoon (1997)

An estimated 316 kg of juvenile eels (1894 shortfins and 25 longfins) was caught in Te Waihora and transferred into the southern end of Coopers Lagoon in February 1997 (Figure 1). Juvenile eels were defined as eels between 50 and 200 g (Jellyman & Beentjes 1998). Before transfer, all eels were tagged with sequentially coded wire tags inserted in the top of the head, and length and weight were recorded. Each stainless steel coded wire tag (1.25 x 0.25 mm) was etched with a unique 6-bit binary code. (For more details of methods used see Jellyman & Beentjes (1998).)

Length and weight at age were used to estimate mean annual growth rate of seed stock eels from Te Waihora. Otoliths from a representative sample of 54 juvenile shortfin eels were taken for ageing and prepared using the crack-and-burn method (Hu & Todd 1981). Otolith halves were mounted in silicone rubber sealant on microscope slides and observed under X10–100 magnification using a compound microscope with side illumination. The central area of oceanic larval growth was ignored (Jellyman 1979) and age was expressed as years spent in fresh water and was determined by the number of complete hyaline zones or winter rings in the otolith. Each otolith half was awarded a readability score of 1–5 (1 unreadable, 5 excellent)..

2.3 Re-sampling Coopers Lagoon after stocking (2001)

Coopers Lagoon was re-sampled in 2001 using the same type of fyke nets used in 1997. Electrofishing was not used as it was found to be unsatisfactory in 1996–97 because conductivity was too high in the lagoon. Sampling took place over five nights in 2001 (17–18 January, 8–9 February, and 23 March) (Table 1) and fyke nets were set by boat along the shore or in the main northern canal. Fifteen nets were used in January and February and 19 in March. Ten nets had leaders of 5 m and an overall mesh size of 15 mm (stretched diameter); the remaining nets had leaders ranging from 2 to 5 m and varied in mesh size from 20 to 30 mm. Apart from the northern canal, where V-wing fyke nets were set across the canal, all other nets were single or double-ended fykes set perpendicular to the lagoon shore or the island in the middle of the lagoon. Once positioned the nets were secured at each end by wooden poles. All the fyke nets were set in water over 0.4 m deep to maintain maximum catching efficiency. On 8 February, all nets were baited with beef liver to try and improve the previously low catch rate. Most of the more productive areas in the lagoon (Jellyman & Beentjes 1998) were fished except the western shore, which was too shallow to net effectively.

Nets were checked the following morning and all captured eels were taken ashore, anaesthetised with 2-phenoxyethanol, and measured for length and weight. Eels were also checked for the presence of coded wire tags using a hand-held tag detector wand (Northwest Marine Technology); eels found to have tags (tag–recaptures) were killed, and the heads removed for later dissection of the tags in the laboratory. All other eels were returned live to the water.

In the laboratory, tags were removed from heads and the unique binary code on the tag was read using a binocular microscope. It was then possible to match details of individual weight and length at recapture with that at release.

Because eel growth in length is linear (Jellyman 1995, 1997, Beentjes & Chisnall 1998), annual growth increments were expressed as centimeters per year ($cm.yr^{-1}$). Weight increases exponentially as larger eels accrue more weight annually than smaller eels, but annual weight increments were also estimated, as weight is the parameter of more importance to the eel industry.

For tag–recaptures:

annual length increment ($cm.yr^{-1}$) = (length at recapture–length at tagging)/years at liberty
annual weight increment ($g.yr^{-1}$) = (weight at recapture–weight at tagging)/years at liberty

For other eels:

annual length increment ($cm.yr^{-1}$) = (length-5 cm)/age, where 5 cm is length at recruitment into fresh water
annual weight increment ($g.yr^{-1}$) = weight/age

Eel condition (k) was calculated from $k = W*10^6/L^3$, where W = weight (g) and L = length (mm).

2.4 Relative abundance

Relative abundance was expressed as catch per unit effort (CPUE); catch per net (kg/net) or eels per net (no. eels/net).

2.5 Statistical analyses

Statistical analyses were used to compare growth characteristics of juvenile shortfin eels at time of release into Coopers Lagoon with those at recapture (Statsoft 1999). Because there was only one longfin tag–recapture, statistical analyses were confined to shortfins. The following questions were addressed.

Did eels grow after release into Coopers Lagoon?
To determine if shortfin eels were significantly larger at recapture than at release, a t-test for dependent samples was used for shortfin tag–recaptures (N = 9).

Did eel annual growth and condition change after release into Coopers Lagoon?
To determine if shortfin growth rates at release were significantly different at recapture, a Mann-Whitney U non-parametric test was used to compare annual length increments ($cm.yr^{-1}$) of eels at release with eels at recapture. Length increments at release were determined from length at age (N = 54), and recaptures from growth over the four years at liberty (N = 9).

To determine if shortfin condition (k) at release and recapture were significantly different, a Mann-Whitney U non-parametric test was used to compare condition at release (N = 1894) with that at recapture for tag–recaptures (N = 9).

Was growth linear ?
Linear regression analysis was used to test the assumption of linear growth by plotting length at tagging (independent variable) against growth increment ($cm.yr^{-1}$) (dependent variable) for shortfin tag–recaptures (N = 9).

3. RESULTS

3.1 Coopers Lagoon resident eels (1996–97)

The surveys of Coopers Lagoon in November 1996 and March 1997 yielded 62 shortfin and 3 longfin eels (Jellyman & Beentjes 1998), and the data from both surveys were combined. There were no clear modes present, and the population was dominated by very large shortfin eels with few juveniles (Figure 2). The mean length and weight of shortfin was 77 cm and 1316 g, and longfin was 94 cm and 2353 g (Table 2). Of the shortfins, 50 were female, 11 were unsexed, and 1 was male; the 3 longfins were female. The mean age of resident shortfin eels was 17 years (range 4–48) and longfin 28 years (range 24–32). Mean annual growth rate was 4.9 $cm.yr^{-1}$ for shortfins and 3.28 $cm.yr^{-1}$ for longfins (Table 2). Mean condition of shortfins was 2.33 and longfins 2.83.

3.2 Juvenile eel seed stock (1997)

The stocking rate estimate for the lagoon (45 ha) was 7.0 $kg.ha^{-1}$. The length frequency distribution of juvenile eels was unimodal (Figure 3) and there was an overlap in size of eels present in Coopers Lagoon with seed stock at the time of transfer (see Figures 2 and 3). These eels were too small to determine sex (Beentjes & Chisnall 1998), but the size range (30–52 cm) indicated that males and females of both species were probably present as shortfin males migrate to sea at about 40 cm and longfin males at about 65 cm (Beentjes 1999). Mean lengths and weights were 43 cm and 164 g for shortfin, and 43 cm and 185 g for longfin (Table 3). Mean condition was 1.93 for shortfins and 2.27 for longfins (Table 3). The mean age of shortfin seed stock eels was 11 yr and mean annual growth rate was 3.4 $cm.yr^{-1}$ (Table 4).

3.3 Resident eels (2001)

All eels caught in Coopers Lagoon in 2001 without tags were deemed to be resident. Coded wire tag loss was insignificant for eels released and recaptured in Lake Hawea (authors' unpublished results) and we therefore assume tag retention was also high in eels released into Coopers Lagoon. A total of 60 shortfin and 8 longfin resident eels were caught in Coopers Lagoon in 2001 (Table 5, Figure 4). The length frequency distribution and mean size of shortfins are similar to those of resident eels present in Coopers Lagoon in 1997 (see Figures 2 and 4, Tables 2 and 5). There are no clear modes and the size range is wide with a high proportion of large eels. There were, however, proportionally more longfins present in 2001 than in 1997 (12% compared with 5% of total numbers). All resident eels were released after recording species, length, and weight; sex was not determined. However, based on size (Beentjes & Chisnall 1998, Beentjes 1999), nearly all shortfin and most longfin would be female. In addition, resident eels in Coopers Lagoon sexed in 1996–97 were almost exclusively female (Jellyman & Beentjes 1998).

CPUE in 1996–97 and 2001 is given in Table 6. The relative abundance of eels in 2001, post stocking, is considerably less than in 1996–97 by a factor of about three by weight and two by number.

3.4 Tag–recaptures (2001)

Nine tagged shortfins and one tagged longfin (tag–recaptures) were recaptured; the mean days at liberty were 1451 (3.97 years) for shortfins and 1452 for the one longfin (Table 7). This corresponds to a tag return rate of 0.5% for shortfin and 4% for longfin. Tag–recaptures comprised 12% of eels caught in Coopers Lagoon in 2001. Although sex was not determined, based on length, all shortfin were female and the longfin could have been either sex. Tag–recaptures were caught throughout the lagoon indicating that they had dispersed from the point of release.

Lengths at tagging and recapture are shown in Figure 5. Mean length and weight of shortfin tag recaptures (N = 9) were 73 cm and 933 g (Table 7). During the four years at liberty shortfins increased on average about 33 cm and 812 g and both length and weight were significantly larger at recapture ($p < 0.001$). The longfin tag–recapture increased 21 cm and 367 g.

Mean annual length increment of shortfins was 3.4 $cm.yr^{-1}$ at release (N = 54) (see Table 4) compared to 8.4 $cm.yr^{-1}$ at recapture (N = 9) (Table 7), and was significantly different ($p < 0.001$). Results of the linear regression analysis of length at tagging (independent variable) against annual growth increment ($cm.yr^{-1}$) (dependent variable) indicated that the slope was not significantly different from zero and therefore growth in length was linear. Therefore, the increase in annual length increment since transfer to Coopers Lagoon was the same for all eels regardless of tagged length. The one longfin tag–recapture had grown 5.3 $cm.yr^{-1}$.

Mean annual weight increment of shortfins was 12.5 $g.yr^{-1}$ at release (N = 54) (see Table 4) compared to 204 $g.yr^{-1}$ at recapture (N = 9) (Table 7), and was significantly different ($p < 0.001$).

Shortfin condition (k) of tag–recaptures (N = 9) improved from a mean of 1.91 at release to 2.40 at recapture (Table 7), and the difference was statistically significant ($p < 0.001$). Condition at tagging and recapture is plotted in Figure 6. Condition of the one longfin tag–recapture improved from 2.12 to 2.44.

3.5 Additional data

Since this report was prepared, the heads of 19 eels captured in Coopers Lagoon (M. Wards, customary fisher) were made available. The heads came from 18 shortfins and 1 longfin captured during October-November 2000. Unfortunately, no lengths were available. The heads were scanned for coded wire tags, and 3 (16%) were found to contain tags. Using a head length/body length relationship for large *A. australis* (Ege 1939) the total lengths of the three tagged eels were estimated to be 54.6, 55.3, 66.0 cm, although some shrinkage of head length will have occurred during freezing.

4. DISCUSSION

This report presents the results of an enhancement programme in which juvenile shortfin and longfin eels caught in Te Waihora were released into Coopers Lagoon, a recruitment-limited lake that historically contained a healthy population of eels. The overall programme objective was to determine the effectiveness of transferring juvenile eels to facilitate recovery of customary fisheries. This provided a unique opportunity to study the effects of stocking in terms of growth, movement, and potential survival. In addition, the utility of deploying coded wire tags on eels was evaluated. The tag and transfer into Coopers Lagoon in 1997 and subsequent resampling in 2001 were undertaken under different programmes, the timing of which was determined by MFish contract milestones.

The shortfin recapture rate of 0.5% was very low. We have no reason to suspect that tag loss was high because coded wire tagged eels released and recaptured in Lake Hawea after three years showed negligible tag loss. Low overall densities, combined with the low numbers of tag–recaptures, suggest that most tagged eels have since left the lagoon. We would expect that any shortfin juveniles that differentiated into males would have migrated. In Te Waihora this occurs at about 40 cm and 120 g (Jellyman et al. 1995, Beentjes & Chisnall 1998, Beentjes 1999) and might account for half the eels released. Partial confirmation of outmigration of males was obtained in March 1998, when the old culvert had been opened and an observer saw many shortfin males leaving the lake (M. Wards, customary fisher, pers. comm.).

Some shortfin females may also have migrated because this takes place at between 50 and 100 cm (mean 74 cm) (Jellyman & Todd 1982), and all tag–recaptures would have been within this size range during the previous migration period in March-April 2000. Alternatively, it is possible that some shortfins released into Coopers Lagoon exhibited homing behaviour known to occur in shortfins (Jellyman et al. 1996) and *A. rostrata* (Lamothe et al. 2000). This is considered unlikely as the route back to Te Waihora could only have been via the sea and would need to coincide with a lake opening.

Several studies on *Anguilla anguilla* and *A. japonica* indicate that the expression of sex is partly dependent on the environment (Tesch 1977); eel populations of low density tend to be largely female and dense populations tend to be predominantly male. Before stocking, the low-density eel population in Coopers Lagoon was almost exclusively female which is consistent with this theory. The stocking rate of 7 kg.ha^{-1} would have dramatically increased density in the lagoon and in this environment transferred eels may have differentiated into males which have since migrated. This would also explain why so few tagged eels were recaptured and, together with the impacts of customary fishing, the low estimate of relative abundance in 2001.

It was not possible to quantify survival of tagged and transferred eels because the lagoon is not a closed system and shortfin males and some females would have migrated out of the lake to the sea. An unknown quantity will also have been harvested by customary fishers – for example, one fisher reported catching 150–180 large shortfins up to 2.5 kg in size, over a two-week period in late 2000 (M. Wards, customary fisher, pers. comm.). There are few estimates of long-term survival post stocking and most estimates of survival are based on elvers or glass eels as seed stock, and are not directly comparable. Pederson (2000), however, estimated survival using juvenile eels (*A. anguilla*, mean length 25 cm) as seed stock in a productive lake in Denmark at 55–75% over eight years. Survival using juvenile eels as seed stock is greater than that using elvers or glass eels. Mortality estimates (M) of unexploited populations of the New Zealand longfin are very low (0.04) (Jellyman 1994) and similar to that for *A. anguilla*. We therefore consider that the low number of tag–recaptures from the lagoon after four years is not due to mortality but to loss through migration.

Shortfin eels transferred into Coopers Lagoon experienced accelerated growth to the extent that the mean annual increment in length more than doubled from 3.4 cm.yr^{-1} at release to 8.4 cm.yr^{-1} at recapture. Longfin annual growth before transfer was not determined because of low numbers, but averages about 2.4 cm.yr^{-1} throughout the South Island (Beentjes & Chisnall 1998, Beentjes 1999). The value of 5.3 cm.yr^{-1}, although from only a single longfin tag–recapture, is more than double this growth rate. Statistical analyses showed that shortfin growth in length is linear and therefore regardless of length at transfer all eels grew at the same rate. This indicates that the increase in annual growth since transfer to Coopers Lagoon is not a function of length (i.e., larger eels growing faster than smaller eels), but is a result of the transfer to more favourable habitat. Density (= relative abundance) of eels in Coopers Lagoon in 1996–97 was low compared to the 1970s (NIWA unpublished data) and to Te Waihora (Jellyman et al. 1995), and this was attributed to the affects of commercial fishing and intermittent recruitment (Jellyman & Beentjes 1998). Density was even lower in 2001 (see Table 6). There may have been some differences in the types and specifications of nets used between surveys of Coopers Lagoon, but we assume that all nets used had equal catching ability and that CPUE is a reasonable indication of abundance. Growth in eels is often density dependent (Tesch 1977, Horn 1996, Jellyman 1997) and low eel density in Coopers Lagoon in 2001 may be the main factor contributing to the rapid growth of tag–recaptures that remained in Coopers Lagoon.

Given the very high growth rates of both shortfin and longfin eels released into Coopers Lagoon, the stocking rate of 7 kg.ha^{-1} appears conservative. However, although density was probably high in the first year or so after transfer, this would have declined after male shortfins migrated and the growth of remaining female eels was enhanced by low density. Maori customary fishing using fyke nets was observed on two of the five sampling nights. The extent of customary fishing over the four years since stocking cannot be quantified, but it is likely that this has contributed to the low eel numbers in the lagoon.

High growth rate is often a feature of eels stocked in hydro lakes where density is often very low because of barriers to recruitment. For example, eels released into Lake Arapuni had annual growth of 21 cm.yr^{-1} for longfin and 22 cm.yr^{-1} for shortfin; the exceptionally high growth was considered to be due to very low density and an abundant food source (Beentjes et al. 1997). Similarly, stocked longfin eels in Lake Hawea, where the resident eel population was negligible, had annual growth of 4.1 $cm.yr^{-1}$, one of the highest growth rates for longfin recorded in the South Island (authors' unpublished results). Examination of the literature on eel growth in New Zealand indicates that, apart from the extremely fast growth in North Island hydro lakes, growth rates of both species introduced into Coopers Lagoon were among the highest on record in New Zealand (Cairns 1941, Burnet 1969a, Chisnall 1989, Chisnall & Hicks 1993, Chisnall & Kalish 1993, Jellyman 1995, Beentjes et al. 1997, Jellyman 1997, Beentjes & Chisnall 1998, Beentjes 1999).

Longfins over 40 cm are piscivorous (Jellyman 1989), which would indicate that diet probably changed from exclusively invertebrates to include fish some time after transfer into Coopers Lagoon. Shortfins, however, do not become piscivorous until about 70 cm, just less than the mean size of tag–recaptures (74.4 cm) and therefore there may still be some shortfins that are not large enough to include fish in their diet. Fish provide a high energy diet (Ryan 1982) and the change to piscivory may partly explain the accelerated growth of eels after transfer.

Along with density and food, water temperature has been shown to be one of the most important variables affecting growth with warm temperatures enhancing growth (Jellyman 1991, Chisnall & Hicks 1993, Horn 1996, Jellyman 1997). The high growth rates of eels in Coopers Lagoon are consistent with the warm water temperatures of the lagoon which can exceed 20 °C during summer.

During the four years since release, eels dispersed throughout Coopers Lagoon, which given the small size of the lagoon (45 ha), was not unexpected. Tagging studies on eels in New Zealand have shown that movement of non-migratory eels is limited and tagged eels were often recaptured near or at the tagging site (Burnet 1969b, Chisnall & Kalish 1993, Jellyman et al. 1996). Tagging studies on the American eel (*A. rostrata*) also indicate that movement is restricted within a home range of about 1 ha (Bozeman et al. 1985) and 100 m (Ford & Mercer 1986), and *A. australis* in Australia to about 400 m (Beumer 1979). From this we can assume that adult eels establish territories or home ground ranges which are adequate to provide sufficient food resources. It seems likely that although eels have dispersed around the lagoon, they may have since adopted defined home ranges.

The success of the programme, in terms of restoring the Maori customary fishery in Coopers Lagoon, is difficult to evaluate given the small numbers of tag–recaptures. After four years since enhancement of Coopers Lagoon, biomass has declined relative to 1996–97 before the transfer. The period of four years between release and re-sampling, in retrospect, may have been too long since the size structure in 2001 is similar to that before transfer suggesting that enhancement has had little effect on the Coopers Lagoon eel population. Annual sampling would have been required to monitor the eel population dynamics of the lagoon after enhancement. Future transfers might consider smaller quantities transferred on an annual basis in tandem with a more frequent sampling programme. A second option would be to restrict transfer to shortfin eels over about 45 cm to ensure that only female shortfins are used for stocking and thus the loss of males to migration could be avoided. In addition, customary catches should be monitored.

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Table 1: Fishing dates, and types and numbers of fyke nets used to sample Coopers Lagoon in 2001.

Net type	Sampling date 17/01/01	18/01/01	8/02/01(baited)	9/02/01	23/3/01
Single wing fyke	13	13	13	13	16
V wing fyke	1	1	1	1	1
Double end fyke*	1	1	1	1	2

*two fyke nets joined by a single leader –counts as two nets

Table 2: Descriptive statistics for eels resident in Coopers Lagoon in 1996–1997. s.e., standard error.

Species	Variable	N	Mean	Minimum	Maximum	s.e.
Shortfin	Length (cm)	62	77.1	35.6	104.4	2.69
	Weight (g)	62	1316	100	3103	109.50
	Age (yr)	61	16.7	4	48	0.97
	Condition (k)	62	2.33	1.45	3.31	0.04
	Annual growth ($cm.yr^{-1}$)*	61	4.9	1.5	10.7	0.24
	Annual growth ($g.yr^{-1}$)*	61	79.2	6.7	203.9	5.95
Longfin	Length (cm)	3	93.9	84	99.5	4.98
	Weight (g)	3	2353	1850	2926	312.54
	Age (yr)	3	27.7	24	32	2.33
	Condition (k)	3	2.83	2.40	3.12	0.22
	Annual growth ($cm.yr^{-1}$)*	3	3.28	2.46	3.88	0.42
	Annual growth ($g.yr^{-1}$)*	3	87.1	57.8	108.4	15.13

*Determined from length and weight at age

Table 3: *Descriptive statistics for juvenile eels tagged and released into Coopers Lagoon in 1997.* Weight was recorded for only 261 eels and was calculated from length-weight coefficients for the remainder* (see Jellyman & Beentjes 1998). s.e., standard error.

Species	Variable	N	Mean	Minimum	Maximum	s.e.
Shortfin	Length (cm)	1894	43.5	29.7	52.2	0.09
	Weight (g)	1894	164	46	282	1.04
	Condition (k)	1894	1.93	1.35	2.43	0.00
Longfin	Length (cm)	25	42.7	32	50.3	0.93
	Weight (g)	25	185	65.0	313.7	13.29
	Condition (k)	25	2.27	1.98	2.54	0.03

*Shortfin: Weight=$0.000000857(L)^{3.134}$
*Longfin: Weight=$0.00000012508(L)^{3.4792}$

Table 4: Length, weight, age, and annual growth for shortfin eels released into Coopers Lagoon in 1997. s.e., standard error.

	N	Mean	Minimum	Maximum	s.e.
Length (cm)	54	40.3	32.8	51.9	0.64
Weight (g)	54	130.5	65.7	276.9	6.49
Age (yr)	54	10.8	5	16	0.34
Annual growth ($cm.yr^{-1}$)*	54	3.4	2.1	8.2	0.14
Annual growth ($g.yr^{-1}$)*	54	12.5	5.1	39.0	0.73

*Determined from length and weight at age

Table 5: Descriptive statistics for eels resident in Coopers Lagoon in 2001. s.e., standard error.

Species	Variable	N	Mean	Minimum	Maximum	s.e.
Shortfin	Length (cm)	60	74.4	39.5	105.7	2.12
	Weight (g)	55	1136	89	2777	93.51
	Condition (k)	55	2.26	1.34	3.04	0.04
Longfin	Length (cm)	8	71.7	40.6	102.2	7.39
	Weight (g)	8	1195	127	3172	353.09
	Condition (k)	8	2.51	1.90	2.97	0.14

Table 6: Catch per unit effort (CPUE) for Coopers Lagoon in 1996–97 and 2001.

				CPUE	
Sampling date	Nets	Catch (kg)	No. eels	kg/net	No. eels/net
Nov 1996 & Mar 1997	30	88.6	65	2.95	2.16
Jan, Feb & Mar 2001	79	83.4	78	1.06	0.99

Table 7: Descriptive statistics for tag-recaptures in Coopers Lagoon in 2001. s.e., standard error.

Species	Variable	N	Mean	Minimum	Maximum	s.e.
Shortfin	Tagged length (cm)	9	39.4	32.6	45.3	1.47
	Recaptured length (cm)	9	72.7	67.2	79.9	1.35
	Length increment (cm)	9	33.3	27.4	39	1.31
	Annual growth ($cm.yr^{-1}$)	9	8.4	7.0	9.9	0.32
	Tagged weight (g)	9	121	64	181	13.59
	Recaptured weight (g)	9	933	725	1315	60.95
	Weight increment (g)	9	812	599	1134	57.77
	Annual growth ($g.yr^{-1}$)	9	204	152	289	14.90
	Tagging condition (k)	9	1.91	1.86	1.94	0.01
	Recapture condition (k)	9	2.40	2.13	2.69	0.06
	Days at liberty	9	1451	1434	1516	8.86
Longfin	Tagged length (cm)	1	36.6	–	–	–
	Recaptured length (cm)	1	57.8	–	–	–
	Length increment (cm)	1	21.2	–	–	–
	Annual growth ($cm.yr^{-1}$)	1	5.3	–	–	–
	Tagged weight (g)	1	104	–	–	–
	Recaptured weight (g)	1	471	–	–	–
	Weight increment (g)	1	367	–	–	–
	Annual growth ($g.yr^{-1}$)	1	92	–	–	–
	Tagging condition (k)	1	2.12	–	–	–
	Recaptured condition (k)	1	2.44	–	–	–
	Days at liberty	1	1452	–	–	–

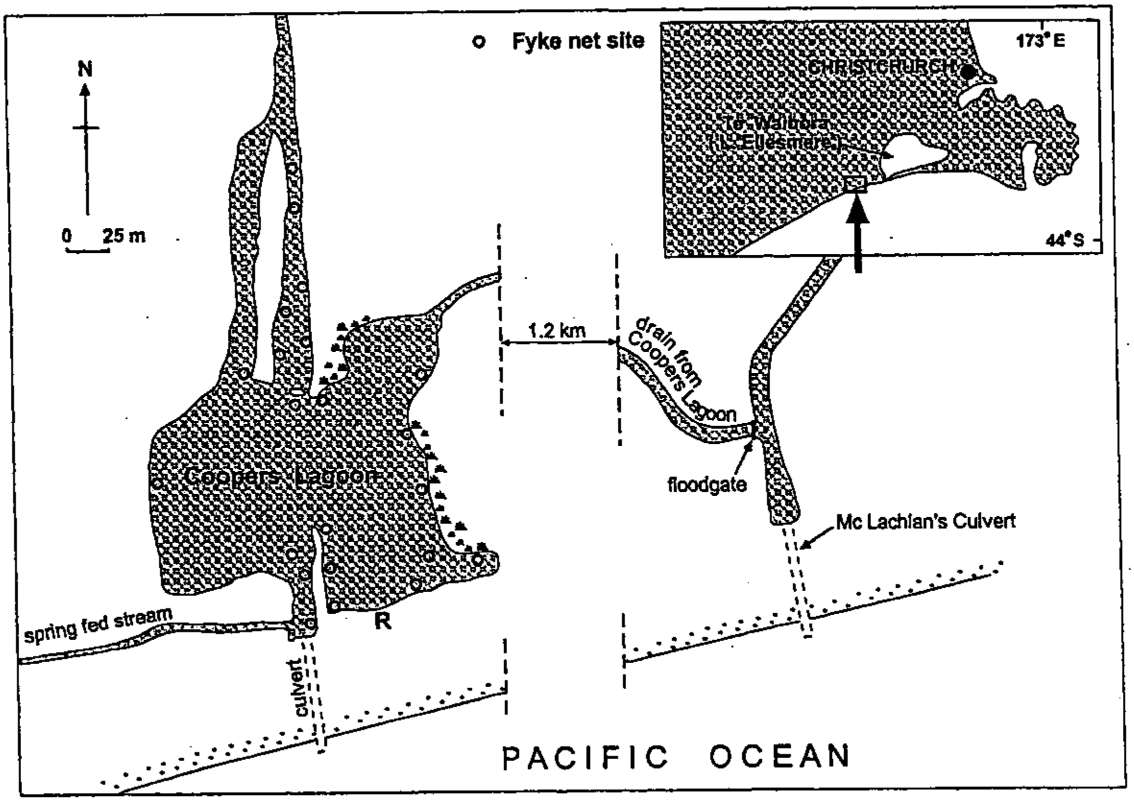

Figure 1. Map of Coopers Lagoon showing fishing locations in 2001. R, release point of juvenile eels in 1997.

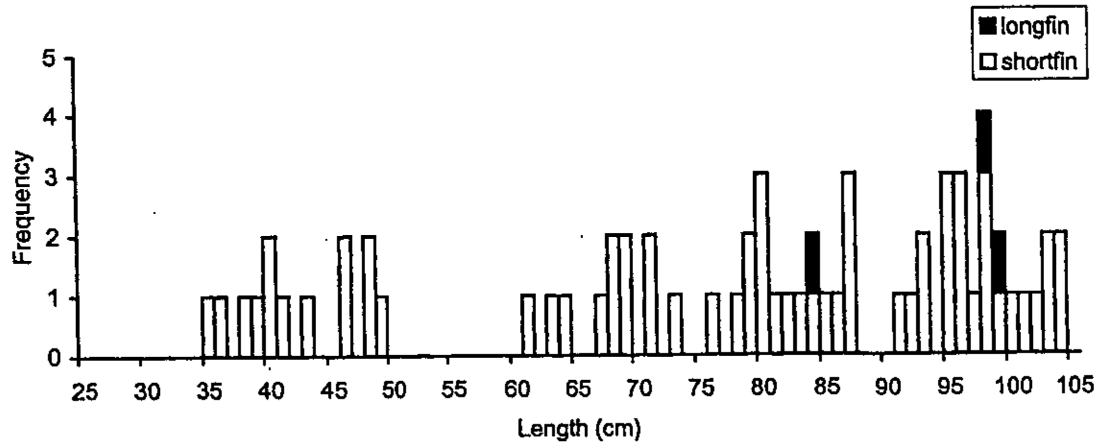

Figure 2: Length frequency of resident eels caught in Coopers Lagoon in 1996–97. N = 65.

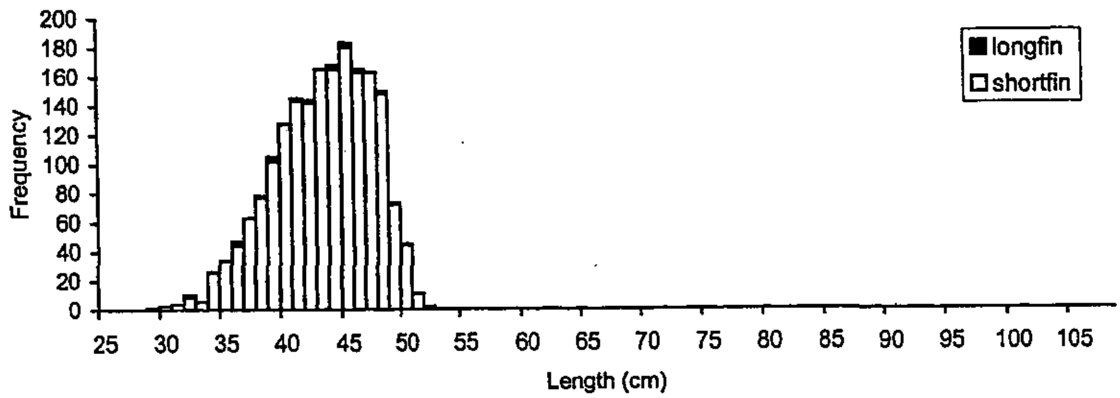

Figure 3: Length frequency of eels tagged and released into Coopers Lagoon in 1997. N = 1894 shortfin and 25 longfin.

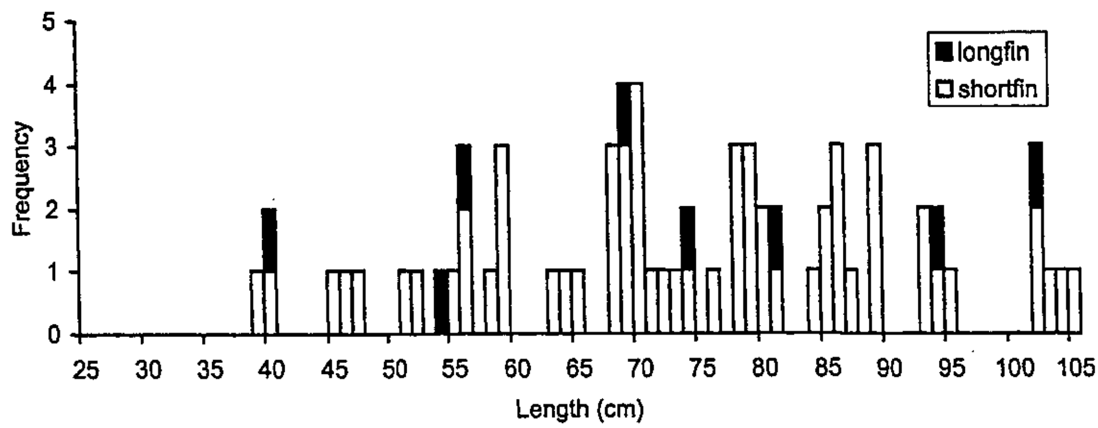

Figure 4: Length frequency of resident eels caught in Coopers Lagoon in 2001. N = 68.

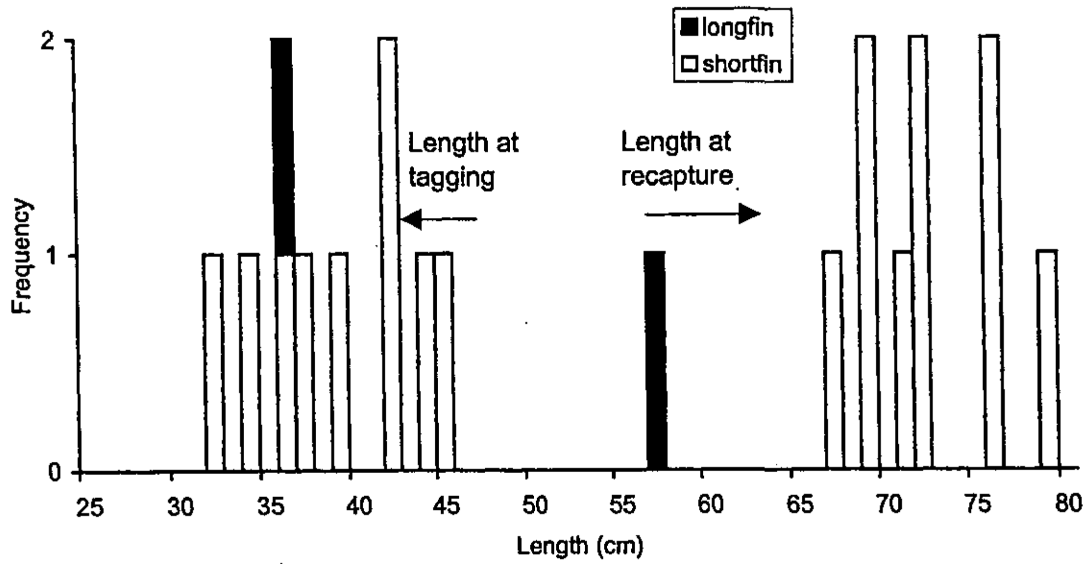

Figure 5: Length frequency of tag-recaptures at tagging and recapture. N = 10.

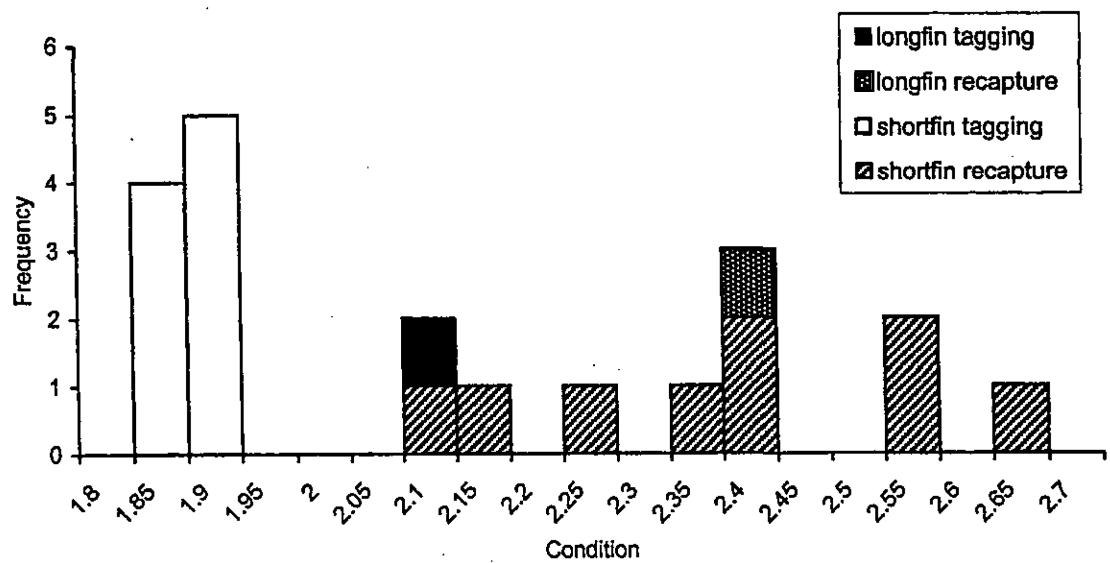

Figure 6: Condition frequency of tag-recaptures at tagging and recapture. N = 10. Ranges:1.8 = 1.81–1.85, 1.85 = 1.86–1.9 etc.