Science Policy

NIWA

Taihoro Nukurangi

Enhancement of the eel stocks of Lake Hawea, by transfer of juvenile eels

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Final Research Report for
Ministry of Fisheries Research Project EEL9702

National Institute of Water and Atmospheric Research

September 1998

Final Research Report

Report Title: Enhancement of the eel stocks of Lake Hawea, by transfer of juvenile eels

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1. Date: 17 September 1998

2. Contractor: NIWA

3. Project Title: Evaluation and monitoring of the effects of the transfer of juvenile eels on eel populations in Maori customary fishing area

4. Project Code: EEL9702

5. Project Leader: Michael P. Beentjes

6. Duration of Project:

Start date 1 Oct 1997
Completion date 30 Sept 1998

7. Objective:

This report covers that part of Project EEL9702 objectives relating to the South Island: To evaluate and monitor the effects of the transfer of juvenile eels on eel populations.

8. Executive Summary

As part of a larger programme to enhance Maori customary eel fisheries, sub-commercial sized eels were transferred from the lower Clutha River to Lake Hawea. A total of 1630 kg juvenile eels (97.3% longfin) were caught by fyke net from the Moau and Koau Branches of the lower Clutha River between 2–6th February 1998. Of these eels, 2010 (21 %) were randomly selected, tagged with sequential coded wire tags, measured, and a size stratified sub-sample of otoliths taken for ageing. From the mean weight of 172 g, the total number of juvenile eels was estimated to be 9722. Ages ranged from 6 to 32 y and age corresponding to the mean weight was 16.2 y. Allowing for mortality (1.3 %) and other losses (1.8%) 9421 eels were estimated to be transferred into The Neck, Lake Hawea on February 12th 1998. The stocking rate of 8 kg ha $^{-1}$ for The Neck littoral area equated to 0.35 kg ha^{-1} for the entire lake littoral area. Lake Hawea eel resident population was sampled in February 1998 and only 3 longfinned female eels were caught. The results confirm that there are few eels left in Lake Hawea and those that remain are large slow-growing females. Assuming conservative survival and growth the biomass of the transferred eels should reach 7 t in 20 y, with eels averaging 1.5 kg. Before more transfers are undertaken it is recommended that the Neck be re-sampled in several years to determine growth, survival and movement.

9. Introduction

Background

Maori wish to see selected eel fisheries restored to a state that satisfies the requirements for customary eel fisheries. Such areas are generally depleted of eels due to past commercial exploitation and/or poor or limited recruitment resulting from some physical barrier to elver migration.

The key objectives of this research were transfer juvenile eels to Maori customary fishing areas, and to determine the status of eel populations in areas receiving transfers. This report presents results of a juvenile longfin eel transfer where eels were captured in the lower Clutha River, tagged, and then transferred to Lake Hawea. NIWA successfully tagged and transferred shortfin juvenile eels to Coopers Lagoon, a Maori customary fishing area, in 1997 (Jellyman & Beentjes 1997), and the Lake Hawea longfin eel transfer is an extension of this programme, utilising similar methods and techniques.

Juvenile longfin eels are generally considered by the eel industry to be in the size range 50–200 g, i.e., smaller than the minimum commercial size of 220 g. In the lower Clutha River these small eels are abundant, and optimal growth may be limited by high densities and poor habitat. Silt flushed from above Roxburgh and Clyde Dams, may be impacting the amount of available juvenile eel habitat by smothering weed beds (Brian Smith, eel fisher, pers. comm.). Longfin juvenile eels were caught from the lower Clutha River and transferred into Lake Hawea, one of three lakes at the head waters of the Clutha River. Access to Lake Hawea for eels has been restricted since the construction of Roxburgh Dam and Lake Hawea control gates in 1958. Lake Hawea currently has a remnant and declining eel population composed of very large and old females that recruited prior to hydro development (Beentjes *et al.* 1997). A survey of the lake (Beentjes *et al.* 1997) in 1995 indicated that eel abundance in Lake Hawea is very low and hence eels released into the lake should achieve enhanced growth due to the low eel density.

10. Programme Objective

1. To evaluate and monitor the effects of the transfer of juvenile eels on eel populations.

<u>**Objectives for 1997/98**</u>

1. To transfer and record the species composition and numbers, and tag a representative sample, of juvenile eels transferred to two Maori customary fishing areas, appropriate for enhancement

2. To determine the size structure and growth rates of eels resident in the two Maori customary fishing areas identified above before the transfer of juvenile eels

This report only pertains to the South Island juvenile transfer programme and the results of the second juvenile transfer, which occurred in the North Island, are documented elsewhere.

Selection of juvenile eel capture site and enhancement site

The selection of Lake Hawea as the enhancement site was made by Ministry of Fisheries in consultation with Otago Southland (Arai Te Uru) Eel Management Committee, local Runanga, and NIWA. An area known as The Neck, was chosen as the release location on the lake as it is near to a proposed Nohoanga site, an area recognised by the Crown as being of historical customary importance to Maori for gathering Mahinga Kai. It is generally desirable to aim for a within catchment transfer which avoids any possibility of transferring diseases between catchments; the lower Clutha River was therefore the preferred location to provide the seed stock for transfer.

Consultation on the release of juvenile eels at Lake Hawea

NIWA consulted the following groups prior to the release of juvenile eels at Lake Hawea: MFish, Southland Otago Eel Management Committee, Ngai Tahu (Hokonui, Otakou, Moeraki and Kati Huirapi Runanga), Fish and Game Council, DoC, and Guardians of Lake Hawea. The actual release was attended by a single representative of Otakou Runanga who is also on the Arai Te Uru Eel Management Committee, several Guardians of Lake Hawea, a Fish and Game Officer, and interested members of the public. Journalists from the Otago Daily Times and Queenstown Mirror also attended and ran stories.

Description of Lake Hawea enhancement site

Lake Hawea is a glacial, oligotrophic lake, with a maximum water temperature of 14°C and a littoral area of 4654 ha (34 % of total lake area = 138 km^2). It lies at an altitude of 347 m, has a maximum depth of 384 m, a mean depth of 192 m (*see* Livingston *et al.* 1986, Viner *et al.* 1987 for more physical criteria). The catchment is largely tussock grassland growing on poor soils derived from schist (Flint 1975). The main water source is the Hunter River at the North end and the lake drains via the Hawea River at the South end. The Neck is a shallow bay at the isthmus of land that separates Lake Hawea from Lake Wanaka (Figure 1). The littoral zone of The Neck is about 190 ha at average lake level, constitutes 4% of the total lake littoral area, and the majority of the bay is < 20 m deep. Water temperature at The Neck in mid February 1998 was 16.5^{0}C.

Lake Hawea is subject to water level fluctuations of up to 10 m as a result of hydro storage. The submerged aquatic vegetation in Lake Hawea has been shown to be impoverished and has only two plant communities with the notable absence of vascular and other shallow water plants. By comparison, neighbouring Lake Wanaka undergoes a fluctuation of only 1.0 m and has five plant communities. The difference between these lakes appears to be a result of extreme water level fluctuations in lake Hawea (*see* Clayton *et al.* 1986). Because The Neck is a shallow bay its littoral area will be affected by even small water level changes, a drop in water level of 10 m would reduce this by about half.

Koaro (*Galaxias brevipinnus*), common bully (*Gobiomorphus cotidianus*), brown trout (*Salmo truta*) and rainbow trout (*Onchyrynchus mykiss*) are all common throughout Lake Hawea with upland bullies (*Gobiomorphus breviceps*) found only in a few isolated tributaries of the lake (Alibone 1997). No invertebrate studies have been carried out in Lake Hawea.

11. Methods

Capture of juvenile eels for transfer (lower Clutha River)

Two commercial fishers, sub-contracted and supervised by NIWA, were employed- to catch juvenile eels in the Matau and the Koau branches of the lower Clutha River (Figure 1). Commercial fyke nets designed to target longfin eels were baited and left overnight with escape tubes blocked to retain small sub-commercial eels. Where practical, catches were graded when nets were retrieved to remove eels > 220 g which were returned to the water. Eels retained for transfer were held in holding bags in the river for the capture period (1–6 February 1998) and then transported on 7 February to Mossburn Enterprises Ltd, Kennington in the processor's eel tanker. On arrival, large eels were removed and the total weight of the remaining eels was recorded. Eels were then transferred to large commercial holding tanks supplied with flowing water and aeration, where they were held for five nights.

Tagging and transfer

Eels were removed from the holding tanks in batches of 100–200 and anaesthetised with AQUI-S to facilitate handling. Any shortfin eels were, returned to the holding tanks, and were not tagged. As the contract called for between 10–20% of transferred eels to be tagged, a target of 2000 eels was set. Length down to the nearest cm, and weight (± 5 g) were recorded for each eel and then sequential coded wire tags (CWT) were inserted in the top of the head to a depth of 2 mm using the Mark IV Automatic Coded Wire Tagging Injector, (*see* Appendix 1 for details of the CWT method). Small variations in tag length can mean that a tag may contain an incomplete coding sequence and therefore the tag either side of the injected tag was collected and stored. The tag removed from any recaptured eel can be read by matching the tagging sequence to that of the retained tags. After tagging, the eel was passed down a chute which verified if the tag had been successfully inserted. Tagged eels were immediately returned to running water tanks to recover. Any dead eels were removed from holding tanks and/or the tanker and numbers recorded to estimate mortality due to tagging and transfer. On 12 February 1998, both tagged and untagged eels were transported in a single consignment to Lake Hawea and released into The Neck.

Age and growth

Otoliths were removed for ageing from a length stratified sub-sample of transferred eels (4 otoliths per cm length class). Otoliths were 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. Ignoring the central area of oceanic larval growth (Jellyman 1979), 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 = excellent, 5 = unreadable).

Growth was described by least-squares linear regression of weight-at-length, length-at-age and weight-at-age using Statistica (Statsoft 1995). Mean annual length and weight increments were also derived by dividing the length (minus 50 mm; length at recruitment into fresh water) or weight by age for each aged eel (*see* Beentjes *et al.* 1997).

<u>Sampling of Lake Hawea eel stocks</u>

The Lake Hawea enhancement site was sampled on between 17 and 18 February 1998 to determine the population status of resident eels. Commercial fyke nets were again used but escape tubes were left open in this case as there are no small eels present in Lake Hawea (Beentjes *et al.* 1997, Dave Richardson, eel fisher, pers. Comm.). Thirty three nets were set in and around The Neck by boat on each of two nights and were checked each morning. Captured eels were taken ashore and subjected to a lethal dose of 2-phenoxyethanol prior to recording length, weight and removing both sagittal otoliths for ageing. Reproductive status was determined from external morphology and by examination of gonads.

Lake Hawea eel population had previously been sampled in December 1995 (Beentjes *et al.* 1997) and data from this study are included in this report.

12. Results

Juvenile eels (lower Clutha River)

<u>Catch and relative abundance</u>

The total weight of juvenile longfinned eels (excluding any graded oversize eels) caught from the lower Clutha River was 1682 kg. 380 nets-nights were used to catch these eels which equates to a catch per unit effort (CPUE) for juvenile eels of 4.4 $kg.net^{-1}.night^{-1}$. This is a conservative estimate since some blocked escape tubes had opened, resulting in the loss of almost the entire catch from several nets. Based on the mean eel weight of 173 g (Table 1), the total catch was estimated at 9722 eels. Of these, 126 died, (1.3%) and a further 30 kg (1.8%) escaped through the coarse grating (designed for commercial sized eels), into nearby eel tanks and were inadvertently processed; therefore the total transferred quantity was around 1630 kg or 9421 eels. The stocking rates were 8 kg ha^{-1} for the littoral area of The Neck and 0.35 kg ha^{-1} for the entire littoral area of Lake Hawea.

<u>Tagging</u>

A total of 2010 longfinned eels were tagged with sequentially coded wire tags at an average rate of around 670 eels/day. The percentage of the total transferred eels that were tagged was 2010/9421 = 21.3 %, assuming negligible deaths due to tagging. Only 2 shortfin eels were found during tagging and therefore the total number of shortfin eels transferred into Lake Hawea is estimated at seven (0.07%).

Size distribution

The length and weight distributions of tagged eels are shown in Figures 2 and 3, and the summary statistics in Table 1. The length distribution was uni-modal ranging from 30 to 55 cm, with a mean length of 41.9 cm. Weight distribution was also uni-modal but skewed slightly to the right. Around 33 % of transferred eels were greater than 200 g and 23 % were greater than the Minimum Legal Size (220 g). As it was impractical to separate these larger eels from those < 200 g, all eels were transferred.

The size distribution of eels sampled from the lower Clutha River during 1996–97 commercial catch sampling programme is shown for comparison (Figure 2) (Beentjes & Chisnall *in press*). These eels were caught using the same type of commercial fyke net but with escape tubes operating to allow escapement of sub-legal eels. The combined distribution represents the overall size distribution of longfin eels from lower Clutha River vulnerable to capture in commercial fyke nets, and demonstrates that escape tubes are effective in excluding smaller eels from commercial catches.

Age and growth

Ages were determined for 96 of the 100 longfin eels that had otoliths removed and the average readability score was 2.1. Size and age ranged from 29 to 57 cm, and 6 to 32 y respectively, and age at mean weight was 16.2 y. A linear regression model was fitted to the data because length at age appeared linear (Figure 3). The considerable variability in length at age and weight at age is reflected in the low r^2 values.

The regressions of length and weight on age were:

$$length = 1.1852\,(age) + 23.038 \qquad (N = 96,\ r^2 = 0.45,\ P < 0.001)$$

$$log\ weight = 0.0909\,(age) + 3.595 \qquad (N = 96,\ r^2 = 0.43,\ P < 0.001)$$

The regression of age on weight was:

$$age = 4.7851\,(log\ weight) - 8.493 \qquad (N=96,\ r^2 = 0.43,\ p < 0.001)$$

From this relationship it was calculated that on average it takes 17.3 years to reach 220 g (minimum legal size), 21 y to reach 500 g, 24 y to reach 1000 g, 26 y to reach 1500 g, and 28 y to reach 2000 g. Weight gain is initially slow with 17 years required for these eels to recruit to the commercial fishery, but thereafter as weight increases exponentially relative to length, eels have doubled their weight within a few years.

The average annual length and weight increments were 2.45 cm/y (mean length = 41.3 cm, N = 96, s.e. = 0.05) and 10.9 g/y (mean weight = 172 g, N=96, s.e. = 0.48). Annual length and weight increments provide an indication of average growth achieved to reach this age. The latter are strongly correlated with size as larger eels accrue more weight annually than smaller eels. Comparisons of annual weight increments are therefore only valid between eels of the same size or average size.

The length weight relationship was:

$log\ (weight) = 3.1926\ (log\ length) - 6.8241 \quad (N = 2010, r^2 = 0.93, P < 0.001)$

Lake Hawea eel population

Catch and relative abundance

Only three longfinned eels were caught on the survey of The Neck in February 1998 (Table 2), with a resulting low CPUE of 0.04 eels.net^{-1}.night^{-1}. This data was combined with that collected from the 1995 eel population survey of Lake Hawea when a greater part of the lake was surveyed. Three longfinned eels were also caught in the 1995 survey and the CPUE value was also 0.04 eels.net^{-1}.night^{-1}. Mean length of eels from both surveys combined was 112 cm and mean weight 4880 g (Table 2). The gonad development and external morphology of these eels indicated that they were preparing for migration.

Age and growth

The mean age of eels caught in Lake Hawea was 56 years (Table 2) although most otoliths were difficult to read and the degree of confidence in these ages is low. The relative width between annuli did not indicate accelerated growth in recent years despite the low eel density in the lake. The data are too few to estimate growth rates, however by comparison, eels from the lower Clutha River would take only 32 y to reach the average weight of Lake Hawea eels (mean = 4880 g) compared with 46 y for eels from Lake Wanaka (Beentjes *et al.* 1997). Growth rate in Lake Wanaka therefore appears to be mid way between that in the lower Clutha River and Lake Hawea. Although growth is slower in eels from these headwater lakes, their condition is better than those of their downstream counterparts. For example, eels of 112 cm length (mean length of Lake Hawea eels) would weigh 3790 g in the lower Clutha River, compared to 4862 g in Lake Wanaka and 4880 g in Lake Hawea.

13. Discussion

The Ministry of Fisheries contract called for a minimum of 5000 juvenile eels to be transferred into an area of customary importance to Maori and for 10–20% of these eels be tagged. This programme successfully transferred about 9400 eels of which 21% were tagged. Eels were caught in the lower Clutha River and released into The Neck, one of the most productive areas of habitat within Lake Hawea.

Movement of transferred eels

Tagging studies on eels have shown that movement of non-migratory eels is limited and tagged eels were often recaptured near or at the tagging site (Beumer 1979, Chisnall & Kalish 1993, Jellyman *et al.* 1996). Additionally, results of stocking of Danish rivers found that eels released into one site (spot stocking) did not disperse far (< 1km) (*see* Knights & White 1997). Therefore in the short term, movement of eels out of the Neck may be limited but high densities compounded by increasing size may encourage eels to disperse around the lake over time. Movement may also be affected by water level fluctuations which may act to force eels into deeper water or out of the neck along the littoral zone. Future sampling will determine the extent of any movement.

Lower Clutha River eels

Relative abundance (CPUE) for juvenile eels in the lower Clutha River was conservatively estimated at 4.4 $kg.net^{-1}.night^{-1}$ and is substantially greater than both commercially caught eels from the same area (1.57 $kg.net^{-1}.night^{-1}$) and the average CPUE for Southland and Otago, (2.7 $kg.net^{-1}.night^{-1}$) (Beentjes 1997). Assuming that vulnerability to capture is the same, the difference in CPUE indicates that juvenile eels have a greater density than commercially sized eels in this area.

The contrasting size distributions of juvenile and commercially caught eels shown in Figure 1 demonstrate the effectiveness of escapement tubes in allowing undersize eels to escape. Some smaller eels were observed in nets but escaped capture when nets were lifted, as below a certain size (< 30 cm, 55 g) eels are able to pass through the 12 mm mesh.

The growth attained by juvenile eels in the lower Clutha River (17.3 y at 220 g) was similar to that of commercially caught longfin eels from the same area (18 y at 220 g) and to the mean growth rate of South Island rivers (17.5 y at 220 g) (Beentjes and Chisnall *in press*). The highly variable growth, was typical of that for longfin eels from other South Island rivers (Beentjes and Chisnall *in press).* While the density of juvenile eels is greater than that of commercial eels in the lower Clutha River, growth rate is only marginally slower than that of commercial eels. Growth in eels is often density dependent (Horn 1996, Tesch 1977) and high density is probably a constraint on growth of eels of all sizes in the lower Clutha River.

Sex

Although the sex of eels transferred was not determined, based on the results of the eel catch sampling programme (Beentjes and Chisnall *in press)*, the majority of these eels are likely to be immature or undifferentiated. There have been several studies that have shown that *Anguilla anguilla* and *A. japonica* are able to change sex and that this is partly dependent on the environment (Tesch 1977). Eel populations of low density tend to be largely female while dense populations tend to be predominantly male. While it is unknown whether *A. dieffenbachii* display this tendency it will be interesting to examine sex ratios of these eels that were transferred to Lake Hawea in several years time to see if these eels develop predominantly into females.

Lake Hawea resident eels

Sampling of Lake Hawea indicates that there are few eels left in this lake and that those that remain are large slow growing longfinned females. The decline in the population has been due to a combination of commercial fishing and spawning migration in the absence of recruitment. Despite the very low density of eels in Lake Hawea, growth as determined from the relative width between annual growth rings of otoliths, has not increased as might be expected. However these eels may have evaded capture by residing in tributaries of the lake where growth would be limited by food and water temperature. If eels remain in or near The Neck, the expectation is that these eels will experience reasonable growth, possibly better than in the lower Clutha River.

Stocking

Stocking is a widespread eel management practise in European lakes (Moriarty 1990, Moriarty *et al.* 1990) and stocking densities are often based on these studies. In a recent review Knights and White (1997) recommend that optimal stocking rates should be around 0.1 $kg.ha^{-1}$ (300 glass eels/elver ha^{-1} or an equivalent weight of juveniles) for warmer productive waters and in cooler waters stocking should be reduced by a half to a third. Given the approximate littoral area of The Neck (190 ha), the stocking rate was 8 kg ha^{-1} which is considerably more than 0.1 kg ha^{-1} recommended by Knights and White (1997). Stocking rate for the entire Lake Hawea littoral area equated to 0.35 kg ha^{-1}, and is still greater than that recommended. Although not explicitly stated, these recommended stocking rates are probably annual stocking figures for exploited stocks.

Survival of glass eels to harvest has been estimated to be around 20–30% in Europe (Moriarty and Dekker 1997) while Tesch (1977) gives a figure of 40 % survival for larger eels. Since the eels transferred into Lake Hawea averaged 16 y of age, we might assume a higher survival of say 50%. And if these eels are not exploited until such time as they are of size suitable for customary harvest (say 1.5 kg), then we can expect the enhancement to yield a biomass of around 7066 kg. Based on the average age of eels that were transferred (16.2 y), and the growth rate expected in Lake Hawea, these eels should reach this target weight in a further 20 y. It is possible that low density may result in faster growth than this, although as stated there was no evidence of this from otolith annuli widths of resident eels.

This predicted biomass is small compared to the estimate of 200 t of eels that have been commercially harvested from Lake Hawea. (Dave Richardson pers com). To maintain a biomass of 200 t would require extensive annual or regular stocking with elvers or juvenile eels. There are many inconsistencies in the literature on stocking and potential yields and all of this work is based on the European eel *A. anguilla*. Additionally, eel populations and yields are higher in New Zealand waters than in Europe (Tesch 1977) and so we could expect stocking rates to be higher. While we should not ignore overseas studies we need to determine stocking regimes appropriate for New Zealand eel species, conditions and habitats.

Future sampling

A key element of this programme was to *evaluate* and *monitor* the transfer of juvenile eels. The first phase of this project has been successfully carried out and the juvenile eels have been transferred. Some time in the future it will be necessary to monitor and evaluate how successful the transfer has been in terms of growth, survival, and movement. This could be achieved by sampling the transferred population in several years to assess whether eels have remained in and around The Neck and the growth that eels have achieved since release. Since the resident population in Lake Hawea is composed of very large female eels the transferred eels should be easily distinguished.

14. Acknowledgments

This research was carried out by NIWA under contract to the Ministry of Fisheries as part of Evaluation and monitoring of the effects of the transfer of juvenile eel populations in Maori customary fishing areas (MFish Project No. EEL9702). NIWA acknowledges and thanks Mossburn Enterprises Ltd for making their facilities available to NIWA. Thanks also to the following persons and/or groups: Arai Te Uru Eel Management Committee, Ron Caughy, Stuart Harrington, Dave Richardson, Brian Smith, Bruce Thompson and Victor Thompson. Thanks to NIWA staff Andrew Willsman and Tom Gough for tagging assistance and Jill Parkyn for preparing and reading otoliths. Thanks also to Don Jellyman for reviewing the manuscript and to Larry Paul for general comments.

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16. Publications

This report is in press as a NIWA Technical Report.

17. Data Storage

Electronic data are archived at NIWA Greta Point in the appropriate research databases to the standards and specifications of fisheries data managers. Otoliths have been catalogued and are stored at NIWA Greta Point. Reference coded wire tags are held at NIWA Christchurch.

Appendix 1: Coded wire tagging technique

Tagging using coded wire tags (CWT) involves implanting a small stainless steel tag (0.5–2.0 x 0.25 mm diameter) into cartilage, connective or muscle tissue using a hand-held or automatic injector (Northwest Marine Technology Inc). NIWA has used batch coded CWTs extensively for tagging juvenile salmon. The tags are encoded with a 6-bit binary code etched into the metal. Identifying tagged specimens is achieved by using a hand-held 'wand' which detects the presence of the tag and locates it to within one centimetre. To retrieve the tag the eel is administered a lethal dose of anaesthetic and the tag removed and read under a stereoscopic microscope. In this programme, sequential CWTs (unique) were used to enable tagged length and weight to be determined at recapture.

Tagging trials using CWT on eels were conducted prior to the enhancement of Coopers Lagoon in 1996–97 (Jellyman & Beentjes 1998). The trial indicated that best results were obtained using an automatic CWT injector and that the preferred tagging site was the top of the head. While 16% tag loss was determined in trials, this was achieved using the hand-held CWT injector gun which tends to be less consistent than an automatic CWT injector in its delivery of the tag. With experience gained from tagging hundreds of eels, and the use of the automatic CWT injector, tag loss would probably be considerably less than 16 %.