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Mixing pond for treated dairy-factory effluent at Te Rapa by Ben Chisnall

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Abstract

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There is currently a resurgence of interest in the farming and fattening of freshwater eels in New Zealand. In 2000–01, we undertook pilot scale pond trials to fatten shortfinned eels that were close to the commercial threshold size. The primary focus of the work was to minimise the costs of fattening eels by demonstrating practical synergies with existing pond systems, and by identifying inexpensive and locally available foods. We investigated whether it was possible to reliably select female shortfinned eels on the basis of size (as females achieve a larger size than males), and whether supplementary feeding was a viable means of increasing production from the wild fishery to improve supply for both commercial and Maori customary fisheries. Successful outcomes may lead to fattening on an intensive scale.

Results of fattening trials in farm ponds and in a pond of treated dairy processing wastes were encouraging. Female eels can be reliably selected for on-growing through grading of commercial threshold-sized eels; wild stocks in poor condition are not predisposed to poor growth; a proportion of these eels can be rapidly fattened in both farm ponds and treated effluent from dairy processing; and up to 50 times the natural growth rate can be achieved. However, individual growth rates may be highly variable in both farm and wastewater ponds, and so an initiating feed formulation to encourage rapid uniform feeding accompanied by regular grading will be crucial to the success of any form of wild eel-fattening enterprise, particularly in intensive culture.

Introduction

Eel farming trials began in New Zealand in the 1970s (Becket 1975, Jellyman 1976, Johnson 1980, Jones et al. 1983), but 10 years later only one of an initial six farms was still operational. Reasons for failure included uncertain supplies of glass eels, high overheads, persistent diseases, and fluctuating overseas prices. There were some trials on the fattening of eels in the mid 1970s (e.g., Sumner & Hopkirk 1976), but these also failed to achieve economic viability. Much has changed during the intervening 30 years, including better technologies, relatively cheaper foods and improved conversion rates, and better hygiene and husbandry techniques. In addition, the dramatic declines in stocks of Northern Hemisphere glass eels over the past decade have led to increased marketing opportunities for Southern Hemisphere species.

There is currently a resurgence of interest in the farming and fattening of freshwater eels in New Zealand. At present, there are no operational farms, but about nine permits have been issued for eel culture and at least four of these are intended to be used to pilot intensive fattening of eels. Thus the farming/fattening industry is in a re-establishment phase. For eel fattening (i.e., increasing the size of eels), the starting stock would be legal-sized eels over the minimum commercial size of 220 g, fed over 2–3m months to achieve economic viability. This would produce a product with an enhanced export market value through increased quality and size.

This study investigates selecting female shortfinned eels on the basis of size, and the use of density reduction accompanied by supplementary feeding as a means of increasing production from the wild fishery. It also sought to identify problems likely to be encountered in intensive fattening of captive wild-caught shortfinned eels. We stocked shortfinned eels into two dairy farm ponds and one dairy factory wastewater pond, in order to:

(a) see whether the commercial threshold sized (220 g) eels can be used as starting stock in fattening (i.e., whether they will adapt to such environments and grow in them);

(b) see whether the growth of stocked eels can be increased in farm ponds by reducing eel density and/ or by providing supplementary foods;

(c) establish maximum achievable growth rates in farm ponds at normal temperatures and in a dairy processing effluent pond at elevated temperatures for economic modelling;

(d) obtain preliminary information on supplementary feeds and feeding techniques for fattening in ponds.

Study sites

Reservoir farm ponds and a pond used for mixing treated dairy processing wastes were chosen, as both are common throughout New Zealand. Farm ponds already provide a substantial contribution to the wild fishery (Beentjes & Chisnall 1997). Previously, a range of farm and dairy waste ponds was assessed for physical characteristics, water quality, and invertebrate composition, to allow choice of suitable sites for eel fattening trials (Martin et al., unpublished results). Three of these sites were chosen for feasibility trials. One was a wastewater-mixing pond at the Te Rapa dairy factory (Anchor Products, Hamilton), and the other two were on pastoral farms in the South Waikato.

The two farm ponds were near Te Awamutu: one on Yarndley's horse ranch and one on Bourne's dairy farm. Trees and shrubs are scattered around the margins, and both drain large areas of pasture. Good access is available over existing farm tracks from SH3. Both ponds have surface areas of about 2000 m^2, and are on average 1.2 m deep. The physical characteristics of the two ponds were similar, as were the water temperatures, DO concentrations, macro-invertebrate diversity and abundance indices, water turbidity, and nitrogen concentrations. These features indicated that the two farm ponds had similar levels of primary production and natural invertebrate prey present. Temperature dataloggers in the ponds during 2000–01 showed that water temperatures were 21–26 °C between October and March, and dropped to below 14 °C in May. Both ponds have small residual outflows during summer, with larger flows likely in winter and spring.

The mixing pond for treated dairy-factory effluent from the Anchor Products factory at Te Rapa is used to mix and stabilise wastewater from the factory discharge to the Waikato River. Two separate wastewater streams from the factory flow into the pond. The northern stream contains stormwater, condensate, and washout from the factory. The southern stream contains effluent from factory processes that has been treated in an activated sludge system, and it has a more stable quality and flow than the northern stream. Discharge from the pond is controlled by a concrete flume and weir to a gravel bed filter, which drains 50 m through boulders to the Waikato River. The mixing pond has a surface area of 1200 m^2, is 1.5 m deep, has a DO concentration of 4–5 mg L^{-1}, a flow of $6–27*10^6$ L day^{-1} (mean about $18*10^6$ L day^{-1}), and a mean ambient temperature of 28 °C (maximum of 31 °C) (Martin et al., unpublished results). Over 3 years of operation, the ambient water temperature has remained above 20 °C between August and May, and has not exceeded 32 °C. Acidity (pH) has ranged from 7.57 to 8.36. Each parameter has therefore remained within the survivable range for shortfinned eels (Richardson et al. 1994, Richardson 1997; West et al. 1997).

Methods

Farm pond trials

Before stocking, most resident eels were removed from the two adjacent farm ponds (Yarndley's and Bourne's ponds) through depletion netting on 7, 13, and 15 December 2000 and 1 January 2001. We used the same fleet of fyke nets baited with ox heart. For Yarndley's this comprised five standard and five double-winged fyke nets (12 mm stretched mesh), and five fine meshed fyke nets (6 mm stretched mesh). For Bourne's pond, it comprised seven standard and one double winged fyke net (12 mm stretched mesh), and seven fine meshed fyke nets (6 mm stretched mesh). A random subsample of eels captured during these removals was killed (95 from Yarndley's and 82 from Bourne's) to obtain growth information from standard sagittal otolith preparations (Hu & Todd 1981).

The two farm ponds were stocked with shortfinned eels at the commercial threshold weight (220 g) obtained from waters immediately downstream of the two ponds. Shortfinned eels between 200 and 260 g were selected from commercial catches taken from Lake Ngaroto, Little Ngaroto, and Mangapiko River. Any eels exhibiting visual phenotypic features characteristic of maturing males (e.g., blackened fins, lateral line development) were rejected. As eels of this size are generally all females, we intended to stock mainly, if not exclusively, females. Total weights stocked into each pond were calculated as half that of the resident biomass estimated from the four removals (Armour et al. 1983). All eels were batch marked by ventral application of alcian blue dye with a panjet inoculator.

Codends of standard fyke nets were positioned over the outlets of the two ponds to determine any escapement or emigration during the study. These were checked fortnightly until August 2001.

In Yarndley's pond, eel stocks were left to feed naturally. Eels in Bourne's pond were given supplementary foods (mixes of various readily available foods such as heart, ox liver, maize starch, gelatine, fish meal, minced fish, and rendered fish concentrate) twice a week in the afternoon between 2 March and 18 April 2001. The weight fed ranged between 4 and 7 kg and consisted of 50–80% protein per feed (average of 5.4 kg or 12% of the total stock weight). Initially, food was given in three 1-m diameter trays, but it soon became evident that large concentrations of food were left uneaten and could contaminate the water despite residual food being removed within 2 days. Subsequently, multiple feed stations around the pond were used, resulting in a greater proportion eaten and less visible waste. Several changes to positions of food trays and food formulations were trialled during this period. Estimation of the proportion of food consumed by the following morning gave some indication of feeding response. Water samples were collected at one of the main feeding sites and at the outlet before feeding and were assessed for turbidity and ammonia in February 2001. This was repeated in April 2001 at the end of feeding.

The transplanted stocks were fished overnight on 2 May 2001, using the same fleet of nets, and the length and weight of each eel was recorded. A year later, a local fisher also fished the two farm ponds but used a fleet of 20 standard fyke nets. These nets had two or three pvc tubes fitted to each net that allowed escapement of small eels. All recaptured marked eels were measured and weighed.

Dairy factory pond trial

Before stocking, most eels were removed by depletion netting on 1 and 5 December 2000 and 16 January 2001. The nets used were 10 standard-meshed fyke nets (12 mm stretched mesh), 11 fine meshed fyke nets (6 mm stretched mesh), and 5 g-minnow traps (3 mm square mesh). All eels were killed to obtain growth information from standard sagittal otolith preparations (Hu & Todd 1981). The dairy factory pond was stocked at about twice the density estimated from the depletion netting (Armour et al. 1983).

Shortfinned eels of commercial threshold weight were obtained from Lake Whangape in the lower Waikato where growth and condition of eels is poor (Beentjes & Chisnall 1997, Chisnall 2000). Any obvious males were excluded. Eels retained weighed between 190 and 238 g and were batch marked by ventral application of alcian blue dye with a panjet inoculator. They were acclimated to ambient pond water temperatures (about 28 °C; Martin et al., unpublished results), in heated tanks over 4 days. They were then stocked into the treated effluent-mixing pond at the Te Rapa dairy factory.

Water quality parameters were assessed from regular analyses undertaken by the dairy factory in the outlet, and temperatures of the two effluent streams were collected during the study period using dataloggers.

Because ambient water temperatures were near the upper limit for freshwater eels (Richardson et al. 1994), a cool-water refuge tank was constructed in one arm of the pond. A purpose-built chicken-wire screen (20 mm mesh) was placed on the outlet canal to prevent escapes during the first 3 days. This screen had to be removed after that because it resulted in high turbidity through enhanced dispersal of algal flocs, with resultant effluent exceeding water rights conditions. Another chicken-wire screen was built beyond the discharge grill. However, many eels escaped and compromised the original aim of this experiment, so that only maximum growth rates could be calculated.

The remaining transplanted stocks were assessed on 2 May 2001, using the same fleet of nets. Eels were measured and weighed to determine maximum growth rates obtainable in a low-density, heated water environment.

Results

Farm pond trials

Resident stocks

Three longfinned and 353 shortfinned eels were removed from Bourne's pond, and 1 longfinned and 347 shortfinned eels were removed from Yarndley's pond. Wide size ranges of eels were taken and were similar for the two ponds (Table 1). Weight-length relationships were also similar for the two ponds:

Yarndley's, lnweight (g) = 3.364 (SE ± 0.043) lnlength (mm) – 15.297 (n = 112)

Bourne's, lnweight (g) = 3.268 (SE ± 0.044) lnlength (mm) = 14.750 (n = 136).

Catch rates (catch per fyke net per night) of the various nets used varied over the removal period, but average catch rates consistently declined over the four fishing efforts, and were similar for the two ponds (Figure 1). Most of the estimated eel biomass present in each pond was removed; Yarndley's 82% by number and 83% by weight; Bourne's 87% by number and 92% by weight.

The growth of resident eels was assessed for two subsampled weight ranges: 240–259 g and 260–280 g (subsample n = 29). Shortfinned eels from each of these subsets were 11 years of age in both ponds. Mean incremental growth (not discounting size at entry to the ponds) was similar for the two size classes in each pond at 44–48 $mm.y^{-1}$ and 24–26 $g.y^{-1}$ (from individual length and weight divided by age).

Stocked eels

Graded shortfinned eels of the desired weight range (200–260 g) were marked and released into Bourne's and Yarndley's ponds in early February 2001 (Yarndley's, n = 215, length = 443–550 mm, weight = 200–260 g, total weight = 49.6 kg; Bourne's, n = 196, length = 454–562 mm, weight = 206–260 g, total weight = 45.2 kg). Mean weight of eels transferred into each pond was 231 g. Only 7% of graded eels were rejected as males before stocking. Only one marked eel was caught in the fyke net over the outlet pipe on Bourne's pond during the 3 months of the feeding trial, and no eels have been captured from either pond's outlet net during the autumn and winter (last check 17 August 2001). The outlet nets were dislodged during spring rains in 2001.

Supplementary feeding

The greatest feed consumption was in late March (65% of total fed) when trays were mounted on wire cages 0.5 m off the pond bottom. After two attempts at including fishmeal in the formulation, it was decided to use the most readily eaten foods (ox heart and liver) for the remainder of the season. Although up to 65% of the foods given were consumed, the proportion of the stock actively feeding remained unknown. Pond water-temperatures averaged about 24 °C during January–February, but declined from 21 °C to 14 °C during March.

Both before and after feeding, water turbidity ranged from 6.7 to about 13.1 NTU, and nitrogen (ammonia) levels ranged from 8 to 27 mg m^{-3}. Higher values occurred near the feed sites, and lowest values at the outlet discharge. Oxygen levels always remained above 6.4 ppm near the bottom of the pond.

Recaptures

The netting effort used previously was applied to both Yarndley's and Bourne's ponds on 2–3 May 2001. This recaptured 29% and 48% of the marked eels in the two ponds respectively (Table 2). Twelve unmarked shortfinned eels were captured in Yarndley's, and 2 in Bourne's. All recaptured eels retained a readily visible alcian blue mark and all were female.

Condition factors (CF) for the two stocks before release were negatively correlated with increasing size (larger fish in poorer condition), and there was a wide range in condition by May 2001 (Figure 2). Although the mean CF for Yarndley's recaptured eels was slightly lower in May than initially, some eels were in better condition. However, the mean CF for Bourne's recaptured eels was significantly higher than in initial stocks.

Yarndley's eels had not grown significantly, whereas Bourne's eels had a mean length gain of about 10 mm, and a mean weight gain of about 20 g during the 3 months in the pond (Figure 3). Some eels in Bourne's pond gained more than 60 g.

On 28 May 2002, a commercial fisher caught 20 shortfinned eels in Bourne's pond, and all were marked with alcian blue. These eels were 523–630 mm long (mean 584 mm, SE ± 6.7mm), and 289–503 g (mean 384 g; SE ± 15.6 g). The following day, the fisher caught 49 shortfinned eels in Yarndley's pond, of which 42 were marked. These eels were 470–650 mm long (mean 540 mm; SE ± 5.4 mm), and 234–607 g in weight (mean 327 g; SE ± 12.8 g). A severe drop in daily mean water temperature from 14 to 8 °C occurred during the overnight fishing of Bourne's pond, whereas water temperature remained at about 13 °C when Yarndley's pond was fished.

Dairy factory pond

Resident stocks

The first two removals of resident eels from the mixing pond showed a substantial decline in catch rates, but the third a slight rise (Figure 4). A total of 186 shortfinned eels were removed from the mixing pond. All residents were shortfinned eels and ranged from 122 to 854 mm in length and 1.7 to 1400 g (Table 3). The weight-length relationship for eels captured from the first two removals was lnweight (g) = 3.312 (SE ± 0.03) lnlength (mm) – 15.038 (n = 131).

Stocked eels

Shortfinned eels captured from Lake Whangape for stocking in the mixing pond initially weighed 190–238 g and were 452–544 mm long. They were in particularly poor condition (Figure 5). A condition index, defined as the weight of a 450 mm long eel calculated from the length-weight relationship for this stock, would be 160 g, which is at the very bottom of the lowest quartile of this index calculated for all North Island sites assessed in North Island wide stock surveys (Chisnall & Kemp 2000). Marked eels were released into the cool-water refuge on 24 January 2001. During the next few days, about 10 eels were found on the first screen, 4 of which were dead. Over the following 3 months, factory staff collected about 60 marked eels at the outlet grill and screen. Although 20 of these were dead, the rest were returned to the pond alive. During the first period of substantial rainfall in autumn (12–13 April), factory workers observed that a "large number of large marked eels" escaped through the breached screen.

Recaptures

Overnight sampling on 2 May 2001 recaptured only 17 marked eels along with 89 unmarked smaller eels that were probably newly recruited to the pond (Table 4). However, the recaptures showed that considerable growth had taken place (Figure 6). Recaptured eels showed a substantial increase in condition (see Figure 5). The maximum growth rate achieved was about 40 mm in length and 200 g in weight (Figure 6).

Water quality

During the 3-month trial, ambient water temperatures averaged 28 °C. Maxima were 30–31 °C on three days and 32 °C on one day. Turbidity averaged 18 NTU with a range of 3–136 NTU, and pH averaged 8.04 with a range of 6.8–8.5.

Discussion and Conclusions

Farm pond trials

The wild commercial fishery for shortfinned eels is based primarily on the harvest of immature females because males are known to mature and emigrate below the commercial size (e.g., Todd 1980, Chisnall & Kemp 2000). Females of both species grow to a large size before maturity, which takes a long time in the wild, with consequent long exposure to the fishery (Chisnall & Hayes 1991, Chisnall & Hicks 1993). In the present study, only 7% of the source stocks were rejected as males. Only females were recaptured, and no emigrant males were trapped at the farm pond outlets. These results indicate that using the threshold commercial size for selecting eels tends to select a high proportion of females. Larger (over 500 g) eels realise premium export prices, so selecting females for fattening is a useful strategy for aquaculture.

The wide range in growth achieved through the short period (7 weeks) of supplementary feeding in Bourne's pond indicated that only some of the stocked eels were consuming the food offered. However, the condition of most recaptured eels in Bourne's pond was improved (see Figure 2).

The mean weight gain achieved by stocked and fed eels over the 3 months (which did not include spring and summer growth) was equivalent to a year's growth in resident eels. However, this could reflect reduced (halved) density as well as supplementary feeding. The initial "fallow" period (about 1 month between removal of residents and stocking) may have provided additional invertebrate food for the new stocks, and the reduced biomass of the stock (50% of the total estimated biomass of resident stocks) may have also encouraged faster growth.

There was little evidence of substantial growth in length for eels in Yarndley's pond over the same period, but condition factor appeared to have improved for smaller individuals (Figure 2). The lower than natural density (50% of estimated resident biomass), combined with the fallow period, may account for this effect.

In both farm ponds, several eels recaptured in May 2002 weighed over 495 g, which was about 200 g more than the largest eel recaptured in May 2001 (Figure 3). It is clear that slow growth and poor condition of eels at the time of stocking had little bearing on growth after transfer, and indicated that stunted shortfinned eels are not predisposed to poor growth.

A more substantial weight gain (of about 200 g) was achieved by some of the stocks in both farm ponds between May 2001 and May 2002. Although the fishing effort by the commercial fisher was similar to our earlier sampling, escapement tubes fitted to commercial nets did not retain smaller fish, so the sample was inherently biased in favour of larger fish, and there can be no comparison of catch rates to quantify the population. This fishing was done in cold weather, which probably reduced catches. Nevertheless, the rapid growth indicates what can be achieved through density reduction in farm ponds, and provides a useful benchmark for intensive fattening ventures.

If a fisher were to adopt this management strategy of fattening wild eels in ponds, the scale would need to be increased to achieve a financial return. For example, based on 1 hour per day to feed 50 kg of eels twice weekly for 3 months, and spending nominally $50 on food, the return would barely cover costs (using a uniform maximum gain of 60 g achieved in this trial in late summer–autumn months). However, if the stocked eels were initially unmarketable but were marketable after 3 months, the eel fisher would receive a reasonable return for effort (62 kg produce to offset $50 feed costs and 24 hours labour). If a third party were to solely feed stocks once or twice a week, then perhaps 20–30 ponds could be pseudo-farmed given reasonable access and proximity. Twenty-five managed pastoral ponds should convert at least 1250 kg of poorly conditioned unmarketable stocks into 1550 kg saleable product in a similar late summer–autumn 3-month period. It is possible that summer and spring growth may also achieve greater returns, as indicated by the substantial increase in size of a few eels recaptured from both ponds in May 2002. A full cost-benefit analysis would need to be completed before commercialisation.

If supplementary feeds were more rapidly and widely accepted by wild stocks, then a more uniform gain in weight might be achieved, making the economics of the practice more attractive. It is, therefore, important to see whether wild-caught eels can be trained to accept supplementary feeding either before translocation or shortly afterwards. An "initiating feed" needs to be developed to suit this 220 g size class of wild eels. Trials to develop an initiator feed are under way.

Dairy factory pond trial

No estimate of survival can be made because of escapes. The fate of the bulk of stocked eels remains uncertain. The observations by factory staff of substantial numbers leaving the pond just before our assessment suggests that reasonable survival was achieved. However, despite the small number of recaptured eels, it is clear that growth and condition at the time of stocking had little bearing on growth after transfer, indicating that stunted shortfinned eels from Lake Whangape are not predisposed to poor growth. The wide size distribution of recaptured eels indicated that growth rates had been highly variable, and so the narrow size range at stocking did not result in uniform growth of transplanted eels.

High ambient water temperatures combined with a high density of aquatic invertebrates, primarily the mollusc *Physa* and chironomid larvae (Martin et al. unpublished results), were probably responsible for the exceptional growth and condition achieved by at least a small proportion of the stock. The minimum weight gain for the largest fish was about 200 g over 3 months (Figure 6). If this minimum rate is extrapolated over the 10 months a year when ambient water temperatures are above 20 °C, it equates to 50 times the natural growth rate (i.e., about 650 $g.y^{-1}$). This is in stark contrast to historic growth rates for shortfinned eels from Lake Whangape (23 $mm.y^{-1}$ and 14 $g.y^{-1}$, Chisnall & Hayes 1991).

Purpose-built tanks or canals to hold stocked eels in a through-flow of heated wastewater (possibly later returning the wastewater to the treatment systems) could achieve both retention of eel stocks and promote more uniform fast growth. Commercial development (in cooperation with the dairy factory) would need to assess ways of maximising production of natural foods, and could identify any potential dietary contribution from the dairy wastes in the treated effluent. The volume of waste heated water alone (average flow of $18*10^6$ L day^{-1}) with daily ambient water temperatures that drop below 20 °C only in June–July could prove attractive for eel fattening enterprises.

Summary of management implications

- Female shortfinned eels can be reliably selected by using the threshold market-size for eels. Females can achieve a greater potential size than males, so are more desirable for aquaculture ventures, such as fattening.

- Wild eel populations in poor condition are not predisposed to poor growth when transferred to farm ponds.

- Female shortfinned eels stocked into farm ponds do not immediately attempt to escape.

- Short-term minimal supplementary feeding of stocked farm ponds, in conjunction with reduced density, can achieve at least 4 times natural pond production rates for eels (or 14 times the production from source waters).

- Reduced biomass (or density) of eels along with a narrow size range at stocking allowed a proportion of stocks in both farm ponds to grow rapidly.

- Short-term rapid growth and increased condition can be achieved in heated dairy factory wastewater.

- An initiating feed formulation to encourage rapid uniform feeding, accompanied by regular grading through harvesting (or promoting in tank culture), will probably be crucial to the success of such wild eel fattening enterprises.

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Table 1: **Number, size range, and maturity of shortfinned and longfinned eels caught and removed from two south Waikato farm ponds, November–January 2000.**

		Length (mm)		Weight (g)	
Location	Species	N	Range	N	Range
Yarndley's pond	Shortfinned eel (immature)	343	270–860	103	28–1 185
	Male	8	456–518	5	263–337
	Female	2	666–793	2	757–1 133
	Longfinned eel (immature)	3	342–450	2	87–200
Bourne's pond	Shortfinned eel (immature)	340	203–815	133	58–1 078
	Male	7	475–660	2	270–316
	Longfinned eel (immature)	1	315	1	58

Table 2: **Numbers and size ranges of recaptured marked shortfinned eels from Bourne's and Yarndley's farm ponds, May 2001.**

			Length (mm)		Weight (g)		
	Marked or not	N	Range	Mean ± SD	Range	Mean ± SD	Total weight recaptured
Yarndley's pond	Recaptures	62	474–535	507.6±14.8	186–273	229.4±18.9	14 223
	Not marked	13	351–698	517.9±93.7	–	–	–
Bourne's pond	Recaptures	94	460–560	512.9±18.0	189–305	249.7±26.7	23 469
	Not marked	2	472–850	–	–	–	–

Table 3: **Maturity, numbers, and size ranges of shortfinned eels removed from Anchor Products dairy factory effluent mixing pond, Te Rapa, November–December 2000 and January 2001.**

Removal date	Maturity	N	Length range (mm)	N	Weight range (g)
Nov–Dec 2000	Immature	129	122–570	117	1.7–393
	Male	6	429–493	5	154–232
	Female	9	570–854	9	410–1 400
Jan 2001	Immature	40	163–542	–	–
	Male	2	460–510	–	–
All dates	All eels	186	122–854	131	1.7–1 400

***Table 4*: Maturity, numbers, and size ranges of recaptured marked shortfinned eels from the effluent mixing pond Te Rapa dairy factory, 5 May 2001.**

		Length (mm)		Weight (g)		
	N	Range	Mean ± SD	Range	Mean ± SD	Total weight recaptured
Recaptures	17	474–58	521.5±30.1	226–447	308.4±72.8	5 242
Not marked immature	66	152–465	296.7±99.7	–	–	–
Not marked male	23	420–485	449.2±17.3	–	–	–

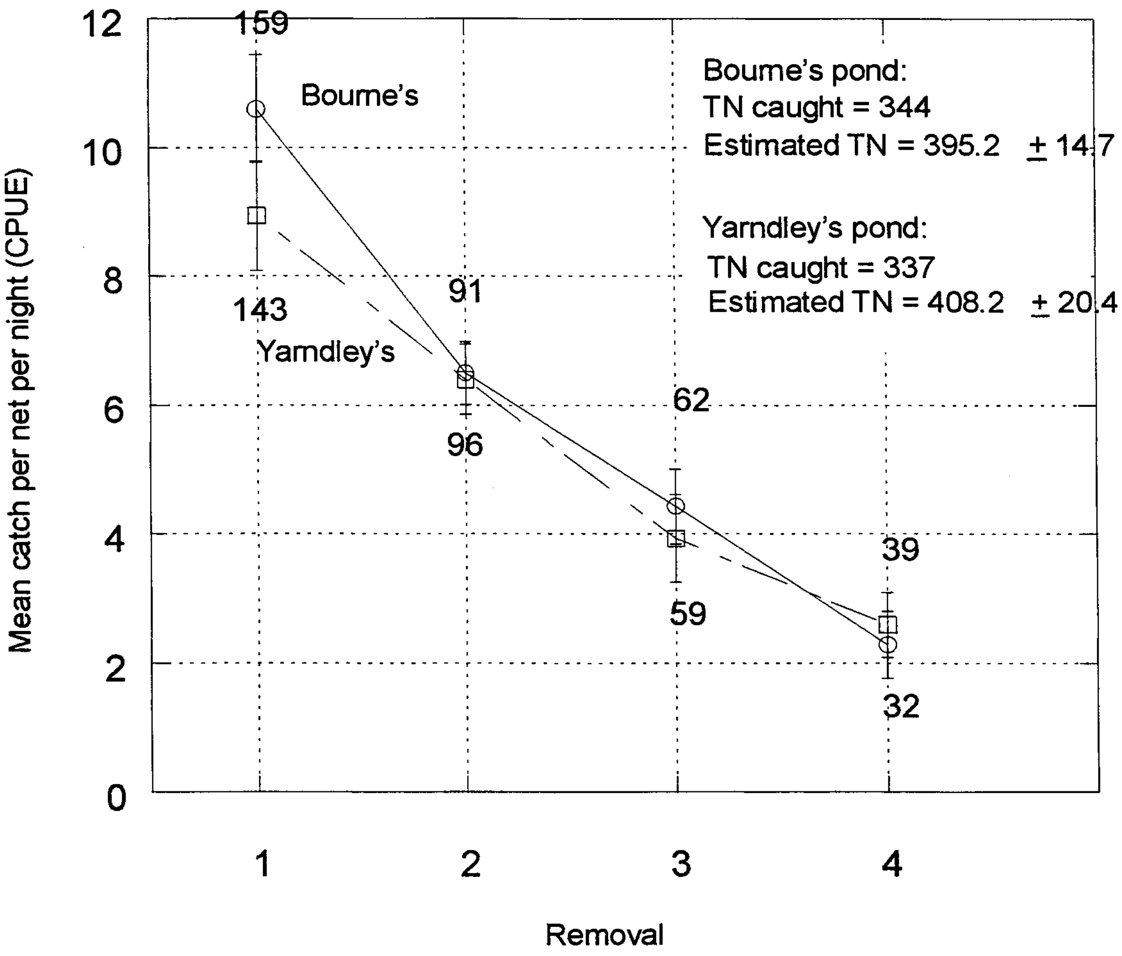

***Figure 1*: Catch rates of shortfinned eels during four removals from two south Waikato farm ponds between December 2000 and January 2001. Total numbers (TN) for each removal are given, along with the total number removed and number estimated.**

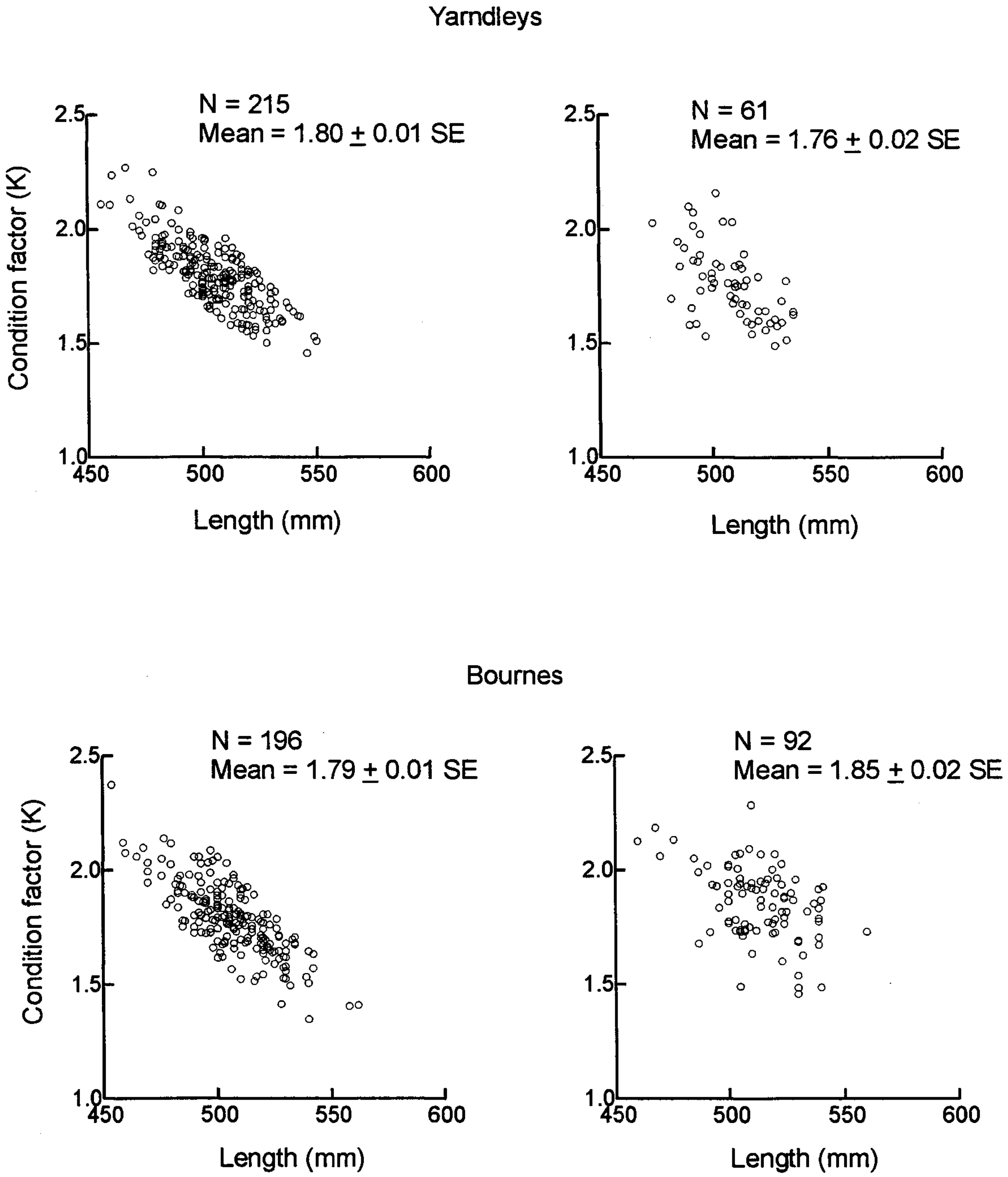

***Figure 2*: Distribution of condition factor (K) with length of stocked shortfinned eels at stocking in January-February 2001, and at recapture 3 May 2001, in two south Waikato farm ponds.**

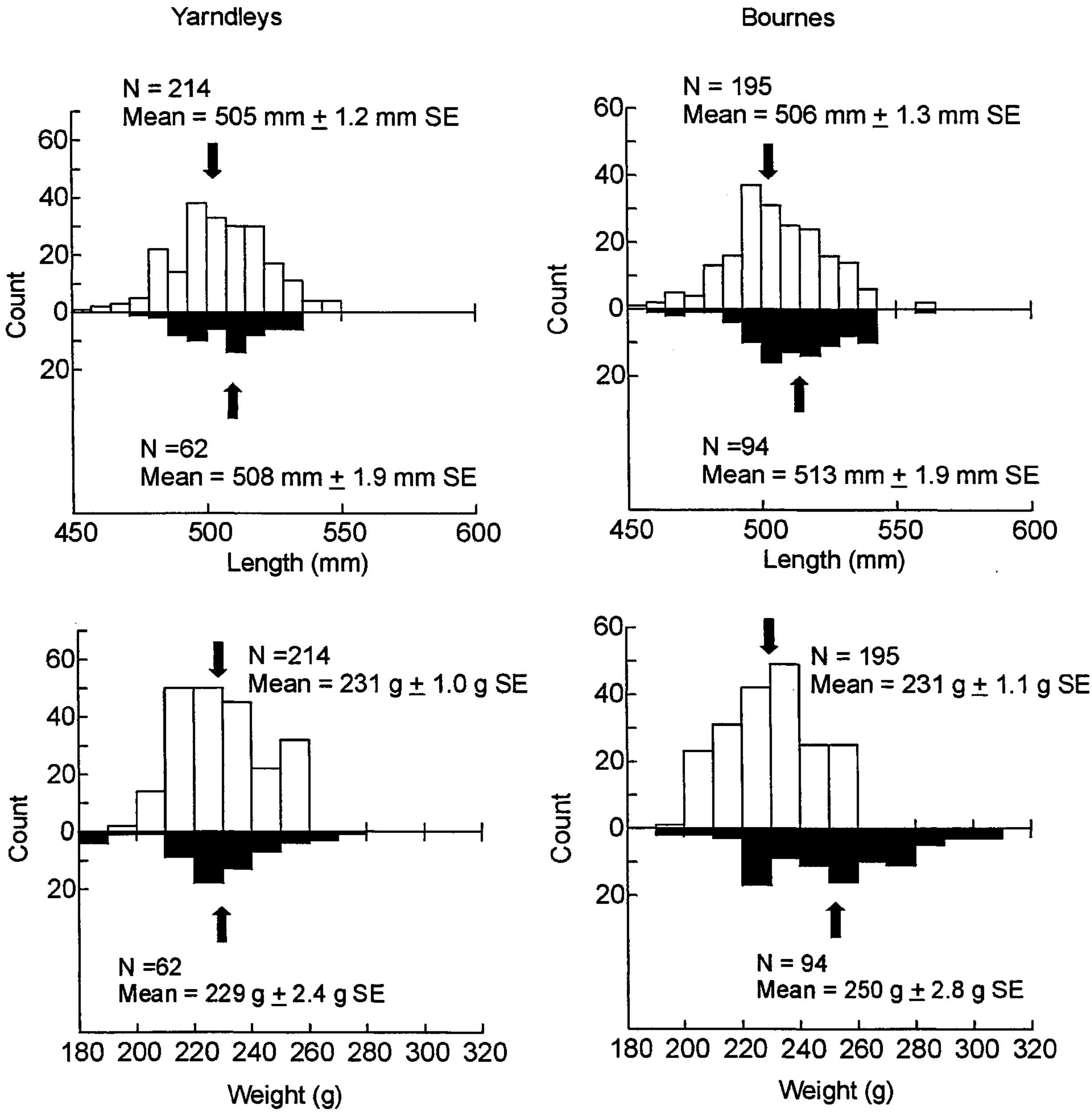

Figure 3: **Length and weight distributions of stocked and recaptured shortfinned eels at stocking in January-February 2001, and at recapture 3 May 2001, in two south Waikato farm ponds. Arrows indicate means; shading indicates recaptured eels.**

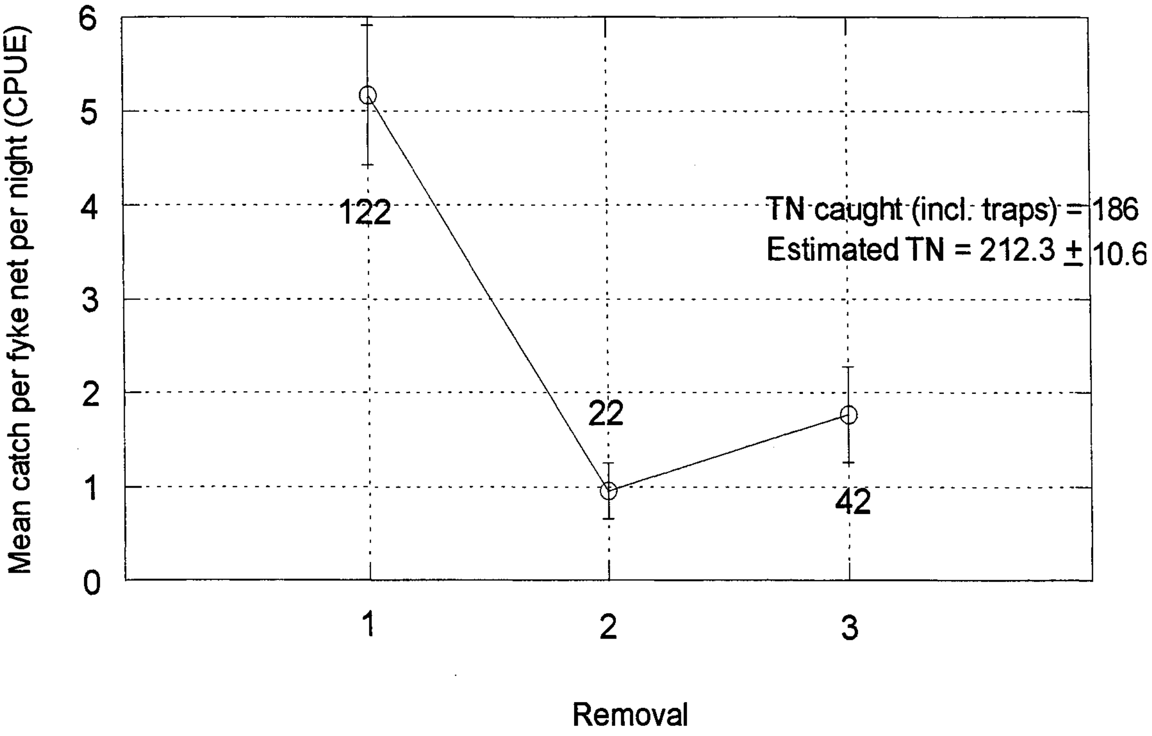

***Figure 4*: Catch rates of shortfinned eels during three removals from Te Rapa wastewater mixing pond between November 2000 and January 2001. Total numbers (TN) for each removal are given, and total number removed and predicted.**

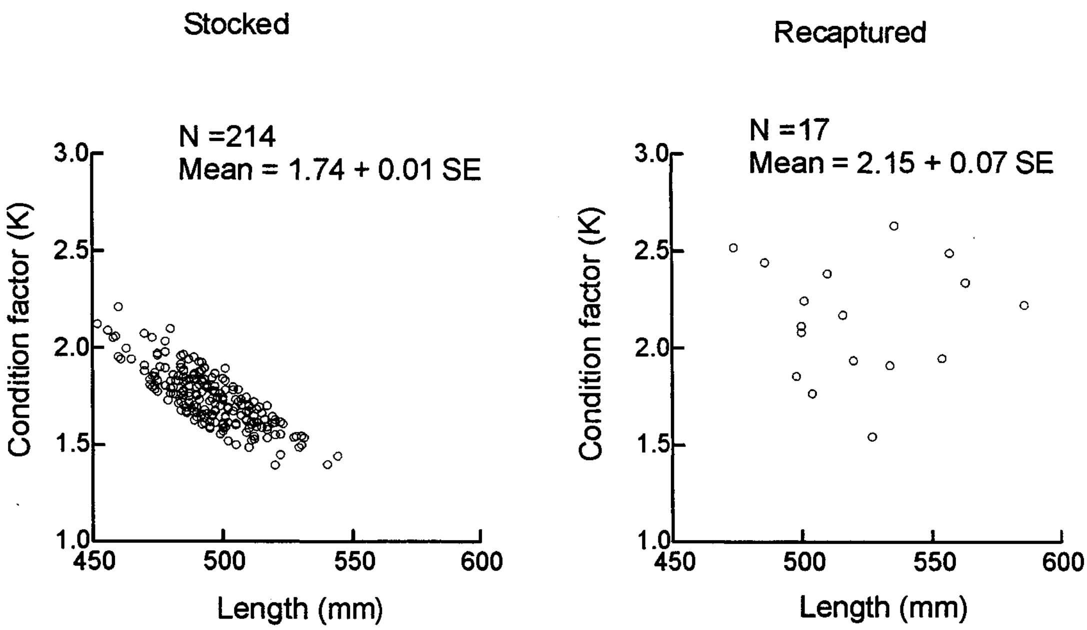

***Figure 5*: Distribution of condition factor (K) with length of stocked shortfinned eels at stocking on 26 January 2001, and at recapture on 2 May 2001.**

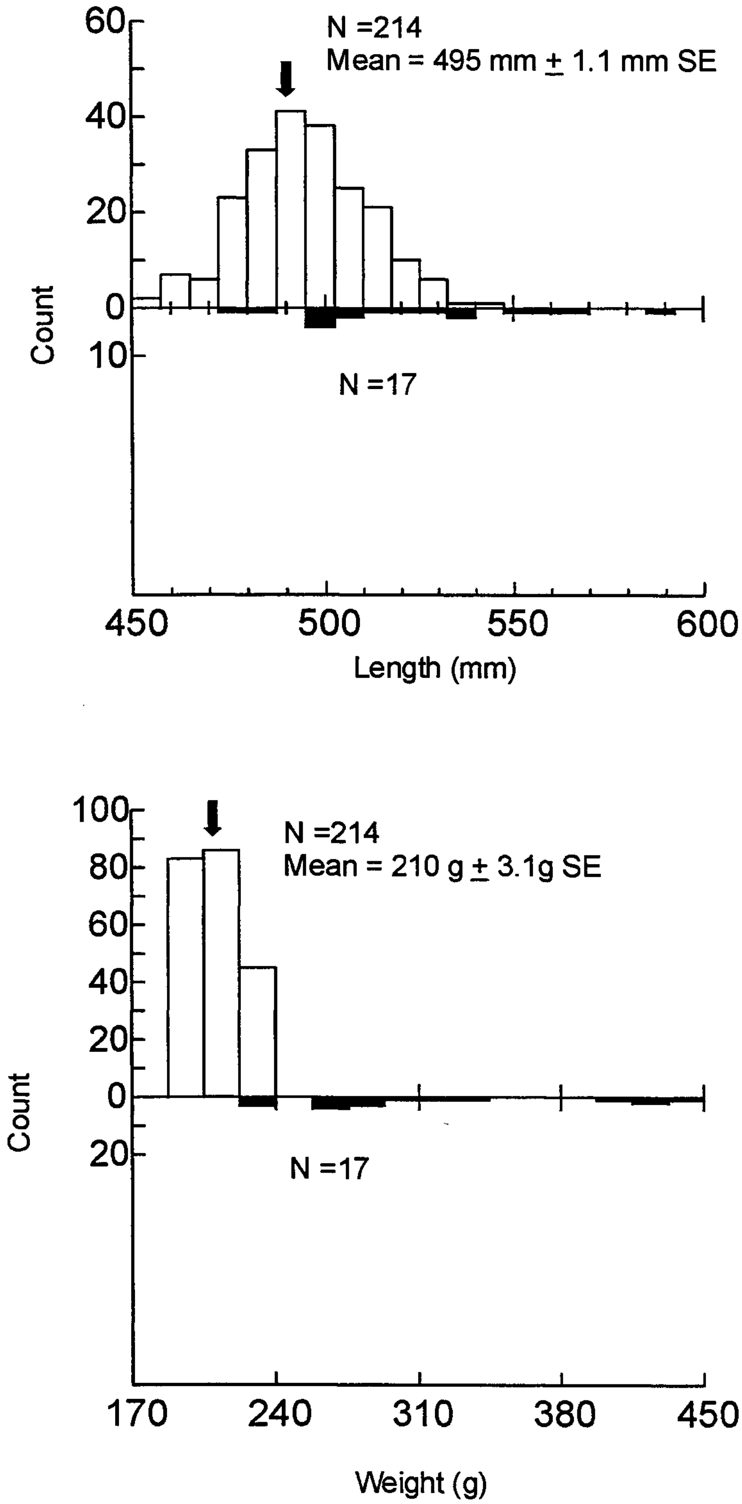

***Figure 6*: Length and weight distributions of stocked and recaptured shortfinned eels at Te Rapa wastewater mixing pond. Arrows indicate means and shading indicates recaptured eels.**

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