Science Policy

NIWA

Taihoro Nukurangi

Final Report

Population Status of the Waihao Eel Fishery

Ministry of Fisheries Research Project INEE05

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Final Report

1.	**Programme Title**	Population status of the Waihou eel fishery
2.	**Project Code**	INEE05
3.	**Programme Leader**	Dr Don Jellyman
4.	**Duration of Project**	
	Start Date:	1 October 1996
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5. Executive Summary

The Waihao eel fishery (Wainono Lagoon, canal, and Waihao River) is an important traditional fishery to Ngai Tahu. Although the lagoon has been extensively fished by commercial eelers in the past, it is now recognised and managed as a traditional Maori eel fishery. The Ministry of Fisheries requested that an investigation of the current eel stock be carried out, to provide a benchmark for measuring any future changes resulting from stock augmentation. From sampling with fine-meshed fyke nets in the lagoon and canal, and electric fishing in the river, it was found that shortfins dominated all 3 areas, although there was a higher proportion of longfins in the Waihao River. The density of eels from the river was typical of that from other lowland rivers, while CPUE for the lagoon and canal were considered low. Perhaps as a consequence of low densities, growth was relatively fast, with eels in the lagoon reaching the commercial threshold size of 220 g in 10 years. Estimates of total mortality, Z, for the canal and river, were low (0.13 and 0.18 receptively) while the higher rate from the lagoon (0.25) is thought to reflect the commercial fishing which existed there until recently. There is some concern about the poor representation of early year classes within the catchment, and consideration should be given to ensuring that the Waihao Box is open to the sea for at least one period during the main glass-eel arrival time of October-November, each year.

6. Objectives

1. To assess the present status of the eel stocks in Wainono Lagoon and the Waihao catchment as a bench mark for future monitoring and restoration of the fishery.

Objectives and Report for 1996–97

1. To assess the present status of the eel stocks in Wainono Lagoon and the Waihao catchment as a bench mark for future monitoring and restoration of the fishery.

2. To report the results of the work to date to the Inshore 2 Fishery Assessment Working Group during the 1997 Working Group meetings.

3. To submit a progress report on the results of the research during 1996/97 to the Ministry of Fisheries by 30 September 1997.

7. Introduction

The Waihao eel fishery is a significant customary fishery to Ngai Tahu (Tau *et al.* 1990). Wainono Lagoon itself has always been of special importance to Ngai Tahu, being the equivalent to local iwi of Wairewa and Waihora (Lakes Forsyth and Ellesmere; Tau *et al.* 1990). The Waihao River was an important food producing area to Ngai Tahu from the Waimate, Waihao, and Waitaki districts, while the mouth – the Waihao box (so-called because of the box culvert) – had additional significance as the area which regulated river flow and mouth openings. The Waitangi Tribunal report on the Ngai Tahu claim (Waitangi Tribunal 1991) recommended that Wainono Lagoon, one of the original 1868 easements, should be restored as a non-commercial eel fishery (Te Waka a Maui me ona Toka Mahi Tuna 1996).

In their report, Tau *et al.* (1990) drew attention to the fact that drainage has reduced the area of the lake, and also detrimentally affected quality of both bird and fish habitat: "Today the bottom of Wainono is covered in a thick mud which, in some parts, is knee-deep. The area of Wainono has been reduced by drainage activities which have also caused the destruction of the fish and waterfowl habitat". Their recommendation "... that commercial fishing should be banned in the Waihao River and all of the connecting tributaries" (Tau *et al.* 1990) has since been recognised, and the lagoon and canal are now managed as an exclusive Ngai Tahu eel fishery.

The lagoon was described by Davis (1987) as " an important area for whitebait spawning and rearing, and the outlet channel is particularly important for spawning. It also supports populations of smelt, eels, and lamprey". Because of its importance for waterfowl, it is intended that the lagoon be gazetted as a Government Purpose (Wildlife Management) Reserve; its present status is that of a Conservation Area (Graeme Crump, Conservation Officer, Department of Conservation (DoC), Geraldine, *pers. comm.*). The Central South Island Fish and Game Council (CSIFGC) have purchased an area (164 ha) of low-lying land immediately south of the lagoon outlet, which becomes periodically flooded when water levels rise; the Council regard the lagoon as the most important waterfowl area within their district, and gamebird counts of over 8 000 birds are regularly recorded (J. Graybill, manager, Central South Island Fish and Game Council *pers. comm.*). Eels would also forage extensively in such an area.

A number of groups are interested in lagoon levels and opening times – these include local farmers (flood control), Maori (mahinga kai including eels and flatfish), Fish and Game Councils (mainly gamebird shooting), whitebaiters (wildlife values), and commercial eel fishers. Because of the variety of interests in the management of the lagoon, a Wainono Lagoon Conservation Area Working Party has been established, and is convened by DoC. The 12 members of this working party have agreed on all management policies, except for water levels – adjacent landowners were concerned that establishing a minimum water level via installation of a sill would result in more extensive flooding. To resolve this, DoC is currently investigating applying for Resource Consents. (Graeme Crump, Conservation Officer, DoC, Geraldine, *pers. comm.*). Until the water level issue is resolved, the Wainono Lagoon Conservation Area Management Statement cannot be published. However, the present draft includes a statement that effectively prohibits commercial eel fishing of the lagoon i.e. under section 3B of the 1987 Conservation Act, special permits are required for commercial eel fishers to operate on land administered by DoC, but, by agreement, none will be granted for the lagoon.

The Ministry of Fisheries (MFish) awarded a contract to NIWA to determine the population status of the Waihao eel fishery (Contract INEE05). The contract required the use of fine-meshed fyke nets (Chisnall and West 1996) to sample eels > 30 cm on the understanding that capture of eels of a wide size range would allow more accurate predictions of mortality than would be possible from using standard fyke nets (20 mm mesh) that capture few eels < 35 cm. The population data will be used as a benchmark to monitor the change in the numbers of eels contributing to the future customary take.

Study Area

Wainono Lagoon (325 ha, Irwin 1975) is a moderately sized coastal lagoon, separated from the sea by a gravel bar up to 8 m high. It receives inflow from both the Waituna Stream to the west, and the Hook River from the north. When the water level increases from the normal 1.0 m above MSL to 1.5 m, the lagoon area increases to 420 ha (Graeme Crump, DoC. *pers. comm.*). The lagoon is drained by a 7 km canal which runs south to enter the estuary of the Waihao River. The river itself runs 64 km from its origins in the Campbell and Hunter Hills – the middle sections of it normally dry up during summer, although the lower 5 km continue to flow. Historically, the mouth of the river was often closed by an extensive gravel bar, causing flooding of adjacent low-lying land. To provide some control over this, a large breakwater, the "Waihao Box", was first constructed in the 1890's but was washed away in 1908. The present structure was installed in 1910, 1.5 km south of the original box. Costs of opening of the Waihao Box are borne by local farmers, and openings are at predetermined water levels. In addition to mechanical openings, conditions occasionally enable the lagoon to open by itself.

8. Methods

A reconnaissance trip was carried out in late February 1997, followed by the sampling trip from 3–10 March 1997. Ten unbaited fine-meshed fyke nets (0.72 mm mesh) were set overnight within the lagoon for 3 nights; as the fine-meshed nets require a minimum depth of 30 cm to fish, very shallow margins of the lake were ignored, and nets were set approximately equidistant where depth allowed. Nets were always set at right angles to the shore or bank, with the exception of 4 which were set offshore in the lagoon. To compare the size distribution of eels caught in the fine-meshed nets with that from standard fyke nets (20 mm mesh), a set of 5 standard fykes were set at the shoreline of the eastern lagoon. These were variously left for 2–3 nights before retrieval.

Although it has been suggested that the lagoon would be divided into 3 areas (eastern, western and northern), in practice the water level was lower than expected and the northern arm was too shallow for fyke nets to be set there. Following lagoon sampling, nets were set for 2 nights within the canal. Sampling locations are shown in Fig. 1. Although the Waihao Box had been closed for several weeks, it opened by itself on the first night that nets were set in the canal – thus the canal became tidal and this created some problems with setting and retrieval of nets.

All fine-meshed nets were retrieved the following morning, and catches processed at a central location. Eels from a particular net were emptied into a large drum containing anaesthetic. Larger eels were generally anaesthetised with Aqui-S (Crop and Food, New Zealand) and the carcasses given to the Waihao marae for consumption. Eels too small for consumption were normally anaesthetised with 2-phenoxyethanol, and the carcasses later disposed of. When unconscious, eels were identified by species, measured (to 1 mm), and weighed on an electronic balance (to 1 g). Eels from the standard fyke nets were measured and released. Catch-per-unit-effort (CPUE) was recorded as the number f eels caught per net per night.

For electric-fishing of the Waihao River, a battery-powered backpack machine was used. Sampling commenced 80 m downstream of Bradshaws Road bridge, being the area furthest downstream where water was shallow enough for fishing. Where possible, sampling took place across the whole river channel; in practice, depths > 0.75 m could not be fished successfully, resulting in some bias for shallow margins and hence smaller eels. Fishing proceeded upstream for 900 m, but extensive reaches were not sampled either because they were too deep or had a lack of cover. Low densities of eels meant that only single-pass fishing was carried out. A further reach of 250 m downstream of the Willowbridge Road ford was also sampled. Here extensive willow (*Salix* sp.) growth on the true right bank meant capture of larger eels was again difficult. However, apart from eels that escaped in such circumstances, all eels stunned were collected and aged to try and obtain a representative age distribution.

For the large samples of shortfin eels available from the lagoon, a stratified sampling regime was used to select eels for aging – the regime was designed to obtain maximum data on juvenile (sub-commercial sized) eels but minimise killing of larger eels; 10 cm size groups were used, and for eels < 40 cm, up to 30 eels per group were sampled, followed by 20 for the following group (40–50 cm) and 10 for each group thereafter. Eels were killed by prolonged exposure to the anaesthetic, and their sagittal otoliths removed and stored on double-sided Sellotape. Gonads of those eels killed were observed using a x2 magnifying glass and were classified as unknown (=undifferentiated), male, or female, according to the stages identified by Todd (1974). These stages were:

unknown	a narrow ribbon of tissue with no obvious lobes or folds
male	a wider ribbon with regular lobes
female	a slightly wider ribbon of tissue than males, with folds and pleats

Male shortfinned eels do not exceed 55 cm (Jellyman and Todd 1982), so any eels larger than this with unidifferentiated gonads, were recorded as females.

Otoliths were prepared for reading at the laboratory using a modified technique to that described by Hu and Todd (1981). For this, a single otolith from each pair was broken in half, heated for 15–22 sec (length of time depending upon size) using a gas-powered miniature soldering torch, and the halves mounted in a silicone adhesive. Reading of otoliths was carried out under x 20 magnification using side illumination provided by a cold light source. Freshwater age was recorded as the number of complete dark (hyaline) rings external to the glass-eel portion of the otolith. Readings of each otolith half were given a readability score from 1 (unreadable) to 5 (excellent). If readings from both halves were different, then the reading with the higher score was used; in the event of tied scores, the average age from both halves was recorded.

Condition (k) was calculated from:

$$k = w * 10^6 / l^3$$

where: w = weight (g)
l = length (mm)

Data from individual eels were recorded on a spreadsheet and analysed using Systat (Wilkinson 1990). An age-length key (Kimura 1977) was used to estimate total age class representation. Total mortality rates (Z) were calculated from least squares regressions of the log adjusted age class representations

9. Results

Water quality

Water quality parameters (Table 1) show slightly alkaline water, with moderately high conductivity in the lagoon, and high conductivity in the canal. The latter was probably due to a strong outflow, which resulted in suspension of much fine organic material. These conductivity values precluded electric fishing in the canal, and made it marginal in the lagoon. Dissolved oxygen was high, being 96%, 102%, and 106% saturation for the lagoon, canal and river respectively. Water clarity in the lagoon was restricted (0.35m) and would fluctuate considerably according to strength, duration, and direction of the wind.

Species proportions and CPUE

Total catches by area, and CPUE are given in Table 2. Within the lagoon 99% of eels caught by fine-meshed fyke nets were shortfins, compared with 97% from standard fykes. A higher proportion of longfins was caught within the canal and Waihao River (16% and 12% respectively. The CPUE from the east and west sides of the lagoon were similar, but the larger average size of eel (323 g) from the west side (cf. 239 g from east side) meant that the average kg/net/night from the west side exceeded that from the east side.

An estimated 1000m² of the river was electric-fished, for a total catch of 122 eels. This equated to an approximate density of 0.12 eels.m^{-2}, or 20.6 g.m^{-2}. As mentioned previously, difficulties of capturing larger eels would have resulted in some sampling bias in favour of smaller fish. Overall though, eel densities in the river were considered low. Juvenile eels (say, < 12 cm), were surprisingly sparse, and 90% of these were collected from a single shallow braid (30 m², mean depth approximately 20 cm) where their density was estimated at 0.83 eels.m^{-2}.

In addition to both species of eel, other species of fish caught (and their relative abundance) were: common smelt *Retropinna retropinna* (common), yellow-eyed mullet *Aldrichetta* *forsteri* (common), common bully *Gobiomorphus cotidianus* (common), black flounder *Rhombosolea retiaria* (occasional) and brown trout *Salmo trutta* (occasional).

Sex distribution

The maximum size of male eels recorded from Wainono Lagoon was 495 mm (Table 3). For convenience, this was rounded up to 500 mm, and the sex distribution of eels less than this size established (Table 3). Of those eels able to be sexed, the majority were females i.e. 60% from Wainono Lagoon, and 73% from the canal. The sex of eels as small as 318 mm was able to be determined, which is well below the minimum size of male eels at migration i.e. 380 mm. However, a high proportion (52%) of eels from the lagoon were classed as "sex unknown" indicating that no obvious macroscopic differentiation into either males or females; the proportion was lower for the canal (21%).

By definition, all eels > 500 mm were females. Thus for the lagoon, 496 of the 600 shortfins caught (83%) were definitely females; some percentage of the "sex unknown" eels would also have become females, meaning that the proportion of males would have been somewhat less than 17%. Assuming that the sex proportions established for eels < 500 mm (n=104) were representative of the lagoon population (405 male, 60% female, Table 3), then the overall percentage of female eels in the lagoon was 93%. Similar calculations for the canal and river gave the percentage of females as 88% for both locations.

Size distribution

Length distributions of shortfin eels caught in fine-meshed nets from either side of the lagoon (Fig. 2) were significantly different ($t = -3.379$, DF = 577, $p<0.05$), with those from the east side averaging 461 mm (239 g) compared with 489 mm (324g) from the western side. The length-frequency of shortfins from the canal (Fig 2) was generally similar to those from the lagoon, and dominated by eels from 400–600 mm. The electric-fished sample from the river was quite different, with a mean size of 309 mm (range 89–980 mm), and being dominated by eels 100–150 mm.

Length-frequencies from the fine-meshed nets and standard fyke nets were also compared to see whether the size distributions from both types of nets were similar. Results (Fig. 3) showed that fine-meshed nets caught a substantial proportion of eels < 400 mm (28%) compared with 10 % for standard nets; a t-test of both samples showed they were significantly different ($t = -7.757$, DF = 545, $p<0.001$).

Length-weight relationships for both species (all sites combined) were:

shortfins: $\log w = 3.267(\log l) - 14.761$ n=524, $R^2 = 0.99$, $p<0.001$
longfins: $\log w = 3.277(\log l) - 14.640$ n=30, $R^2 = 0.99$, $p<0.001$

where: l = length in mm
w = weight in g

Age, growth, and condition

The age-length scatterplots for both margins of the lagoon (Fig. 4) appeared similar, with growth being reasonably uniform and slightly asymptotic. Least squared regression statistics for log-transformed values for the shortfins aged from both sides of the lagoon, the canal, and the Waihao River, are given in Table 4. Slopes of regressions of eels from either side of the lagoon were tested (ANCOVA, $p<0.05$) and were significantly different at the 5% level but not 1%.

Growth rates in the lagoon exceeded those from both the canal and river. Thus at age 10, shortfins from the eastern side averaged 468 mm, compared with 476 mm for the west side; comparable lengths for the canal and river respectively were 426 and 376 mm. By age 20, the sequence was similar except that eels from the river were growing slightly faster then those from the canal – lengths were: lagoon east 842 mm; lagoon west 745 mm; canal 627 mm; river 646 mm. On average, a lagoon eel would take 10 years to reach the minimum commercial size of 220 g compared with 12 and 13 years for canal and river eels respectively.

The influence of sex on growth rate was examined for males and females from the lagoon. For this, only eels < 500 mm (the upper size limit for males) were included. Least squares regressions indicated that initially females (n = 41) grew faster than males (n = 26), but growth rates were equal by a length of 478 mm (12 years old). Slopes of regressions were significantly different (ANCOVA $p<0.001$).

Average condition of longfins exceeded that for shortfins i.e. longfins mean = 2.31 (SD 0.44, n = 30); shortfins mean = 2.01 (SD 0.31, n=524). There was some variation in condition of eels between sites (Table 5), but no significant difference in condition for eels from either side of the lagoon. i.e. $t = -0.249$ DF = 363, $p>0.05$.

Mortality rate

The reconstructed age class representations for the lagoon, and river, are given in Fig. 5. The most significant estimates of total mortality, Z, (Table 6) indicate that mortality within the river and canal are relatively low (0.13 and 0.08 respectively). However, early age classes were not well represented from the river sample (only 24 of the 91 eels were < 6 years old), while overall numbers from the canal were low (n = 73). The estimate of Z from the lagoon was more robust, varying from 0.25–0.30, depending on the number of age classes included.

10. Discussion

As commercial eel fishing catch-effort landing data are not site-specific, it is not possible to establish quantities of eels taken from Wainono Lagoon over the past 20 years. Given that it is easily accessible and shallow, several tonnes are likely to have been taken annually. Since formation of the Wainono Lagoon Conservation Area Working Party in 1992, commercial eel fishing has ceased by agreement. The lagoon itself (excluding the Hook Swamp Drain) is now recognised as a non-commercial fishery (Te Waka a Maui me ona Toka Mahi Tuna 1996) managed by the local runanga, in recognition of the Waitangi Tribunal (1991) recommendation that the lagoon should be developed in partnership with Ngai Tahu as a fishery resource for the use of the tangata whenua found to be entitled to mahinga kai by the Maori Land Court. The present investigation was to establish baseline information on present stocks, and to see whether the eel stock required any augmentation to re-establish a suitable population structure.

Consistent with other lowland lakes and lagoons, the population of the lagoon was almost completely shortfins (99%). Being a species preferring flowing water, more longfins were found in both the canal and the Waihao River, although they still comprised only 13% of all eels from these areas.

Because of past changes to definitions of set-nets, the Ministry of Fisheries catch-effort landing returns do not provide accurate measures of CPUE; some historic data are available (Jellyman 1993) and give mean annual CPUE for South Canterbury from 1983/84 – 1988/89 ranging from 3.1 – 8.1 kg/net/night. Using the same fine-meshed fyke nets as the present study, Beentjes *et. al* (in press) obtained an average CPUE for 3 hydro lakes in the Waikato catchment of 8.6 eels/net/night. When comparing CPUE from fine-meshed fykes and standard fykes in Lake Waahi, Chisnall and West (1996) found that fine-meshed fykes averaged 69.0 eels/net/night compared with 14.7 for standard fykes, although when catches were expressed in terms of leader length, the differences virtually disappeared. In comparison, catches of 20.2 eels/net/night (5.9 kg) from Wainono Lagoon are well below those from Lake Waahi, but compare favourably with catches from the Waikato hydro lakes where recruitment has been affected by dams. Catches of 4.5 eels/net/night (2.2 kg) from the canal, are regarded as low.

Direct comparisons of CPUE are difficult as eel catches vary substantially according to such environmental factors as lunar phase, water temperature, water level, and barometric pressure (Jellyman 1991). The most relevant comparison with the above data appears to be with Lake Waahi, a lowland lake in the lower Waikato catchment with little or no impediment to recruitment of juvenile eels. On this basis, catches from Wainono Lagoon are approximately a third of those from Lake Waahi, indicating a relatively low density of eels in the lagoon.

The density of eels recorded from the Waihao River was considered low, with an average of 0.12 eels.m^{-2} (20.6 g.m^{-2}). As only single-pass electric-fishing was used, some adjustment of catches for sampling efficiency should be made. Jowett and Richardson (1996) calculated capture efficiencies of single-pass electric-fishing of 0.86 and 0.82 for shortfin and longfin eels respectively. Using these data, together with the number and species mix of eels caught from the Waihao River, adjusted estimates for density become 0.14 eels.m^{-2} or 24.6 g.m^{-2}. Jellyman (1997) summarised biomass estimates from a range of habitat types; averages from pastoral streams (n = 20) ranged from 31.5–96.5 g.m^{-2}, while lowland rivers (n = 13) ranged from 7.2–35.1 g.m^{-2}. The eel densities from the Waihao River fall within the range for other lowland rivers, and are consequently regarded as "average".

Females dominated overall catches from the lagoon and canal, but not the river. Of those eels which could be sexed and were less than the maximum length of 500 mm recorded for males, females again predominated in the lagoon , canal, and river. Prevailing wisdom is that the sex of eels is largely determined by environmental factors (e.g. Colombo *et al.* 1984), and low densities tend to favour the development of females. The findings from the present study are consistent with this.

A question that should be addressed is whether there is any evidence of separate stocks within the lagoon itself – hence, in hindsight, was it necessary to sample the east and west sides separately? Certainly there were differences in size distributions, growth rates and condition between both sides and although such differences were statistically significant, we do not regard them as very biologically meaningful. Studies of movements of tagged shortfins in Waihora (Lake Ellesmere) (Jellyman *et al.* 1996) showed that movements of eels were generally quite localised, although there was also a more mobile sector of the population that was capable of moving extensively – this latter group was not confined to any specific size-group and seemingly sedentary eels could become mobile for periods. On this basis, the stock of eels in Wainono Lagoon is best considered a single population, with individual eels generally being long-term residents at particular sites – hence some differences in growth and size between sites is not unexpected. The mobile sector of the population will have been important for repopulating areas where past commercial fishing may have reduced densities.

Compared with growth rates elsewhere in New Zealand (Jellyman 1997), growth from the lagoon, canal and, to a lesser extent, the Waihao River, were considered to be rapid. For example, at age 20, Wainono Lagoon eels were equivalent in size to eels from Pukepuke Lagoon (a small North Island eutrophic lake), and were only exceeded in size by eels from North Island hydro lakes where densities are low due to limited access for elvers. It would be of considerable interest to monitor growth over time as stocks build back up, to see whether the "equilibrium" growth rate is slower than at present.

Age distributions of eels from the 3 sites showed several trends. Lagoon eels were dominated by age class 9, which was also strongly represented at both other sites. Whereas a high proportion of lagoon eels (29%) were 8 years or less, only 7% of canal eels were in this age bracket, indicating that the lagoon was a preferred habitat for these juvenile eels. Youngest eels were encountered in the river, but this is probably because electric-fishing is less size-selective than fyke netting. Given that juvenile eels are able to migrate at least 130 km up the Waikato River within their first year in fresh water (Jellyman 1977), there is no reason to assume that significant numbers of juvenile eels will not be present in the canal and lagoon.

Of some concern was the relative lack of early year-classes from the river. Age-class 0 was considered to be poorly represented, as were classes 2–5 inclusive. Recruitment of glass-eels during autumn will be dependant upon their arrival coinciding with a mouth opening – the whitebait fishery has a similar dependency. The peak period for recruitment of shortfin glass-eels in Canterbury is October-November (NIWA unpublished data). Should there be no mouth opening over part of this time, then it is probable that whole year-classes will be poorly represented. However, shortfins from the lagoon of, say 220 g (the minimum commercial size) range from 6 to 16 years, meaning that partial or complete loss of a single year class may be of little consequence to the fishery as a whole.

Total mortality estimates for eels from the canal were low (Z = 0.08), only slightly greater then estimates for unexploited shortfins from Lake Pounui (Z = 0.04: Annala and Sullivan 1996). Estimates from the lagoon (Z = 0.25–0.30) were relatively high compared with an estimate of 0.20 for the early years of the Waihora fishery, and a more recent estimate of 0.25 (Jellyman *et al.* 1995). This relatively high figure for the lagoon will reflect the extensive commercial fishing which has occurred there until recent years.

Overall, the Wainono Lagoon eels stocks are in a healthy state. This result is in general agreement with the opinion of Te Waka a Maui me ona Toka Mahi Tuna (1996) who considered that the status of shortfin stocks in the Pareora/Wainono catchment was "good", although they described the extent of the customary harvest as "excellent" in past years, but "poor" at present; presumably these comments mean that the present customary take is small, although the stock is regarded as "good". Numbers are probably considerably lower than prior to commercial fishing, but this is offset to some extent by rapid growth. The intermittent openings of the Waihao Box will affect recruitment and consideration should be given to providing one opening at some stage during the glass-eel season. Foraging in periodically flooded areas is important for shortfins (Jellyman 1989; Chisnall 1989), and lagoon eels will benefit from the extended foraging area provided by the CSIFGC's waterfowl area to the south of the lagoon – a weir to maintain minimum lake levels would facilitate eel access to this area.

11. Acknowledgments

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Table 1: Water quality parameters from Wainono Lagoon, Waihao Box and Waihao River

	Lagoon 1400 h 5.3.97	Waihao Box 1630 h 8.3.97	Waihao River 1500 h 9.3.97
Temperature (°C)	14.6	16.2	18.5
DO ($mg.l^{-1}$)	9.5	9.7	9.7
Conductivity ($\mu S\ cm^{-1}$)	373	682	102
pH	8.98	8.68	7.94
Salinity (%)	0.18	0.36	0.00
Turbidity (NTU)	60	50	10
secchi depth (m)	0.35		

Table 2: Summary of catch data, Wainono lagoon and canal, and Waihao River. S = shortfin; L = longfin.

	No. net	Eels caught		Eels aged		CPUE	
Site	nights	S	L	S	L	no/net/night	kg/net/night
Fine meshed fyke nets							
Lagoon east	16	338	2	115	0	21.3	5.19
Lagoon west	10	241	3	132	0	24.4	8.00
Lagoon centre	4	21	0	1	0	5.3	3.22
Canal north	10	21	12	19	11	2.1	2.29
Canal south	10	54	2	54	2	5.4	2.18
Standard fyke nets							
Lagoon east	11	209	6	0	0	19.5	7.87
Electric fishing							
Waihao River	–	108	14	91	0	–	–
Total eels		992	39	412	13		

Table 3: Distribution of the sex of shortfin eels <=500 mm from Wainono Lagoon, canal and Waihao River

	Sex					
	Male		Female		Unknown	
Site	no.	range (mm)	no.	range (mm)	no.	range (mm)
Lagoon	28	318–495	42	325–497	76	188–478
Canal	7	392–466	19	406–488	7	236–431
River	1	490	6	442–480	84	89–468

Table 4: Coefficients for the age-length relationships for shortfin eels, using log (length - 60 mm)

Site	n	Slope	Intercept	R^2	P
Lagoon east	115	0.938	3.852	0.81	<0.001
Lagoon west	132	0.719	4.375	0.78	<0.001
Canal	73	0.632	4.447	0.71	<0.001
Waihao River	87	0.890	3.707	0.87	<0.001

Table 5: Mean and standard deviation of condition (k) of shortfin eels

Site	n	k	SD
Lagoon east	227	2.004	0.332
Lagoon west	138	2.012	0.222
Canal	75	2.062	0.244
Waihao River	83	1.945	0.417

Table 6: Estimates of total mortality, Z, for shortfin eels from Waihao River, canal, and Wainono Lagoon. n^1 = no. of aged eels; n^2 = no. of age classes; * p = 0.05; ** p = 0.01; *** p = 0.001

Location	Age classes	n^1	n^2	Z	R^2
Waihao River	0–25	91	21	0.07	0.31**
	1–25	85	20	0.07	0.28*
	6–25	60	15	0.13	0.64***
Canal	6–35	73	21	0.04	0.14
	9–35	69	18	0.08	0.50***
Wainono Lagoon	6–27	241	17	0.25	0.85***
	9–27	165	14	0.30	0.90***

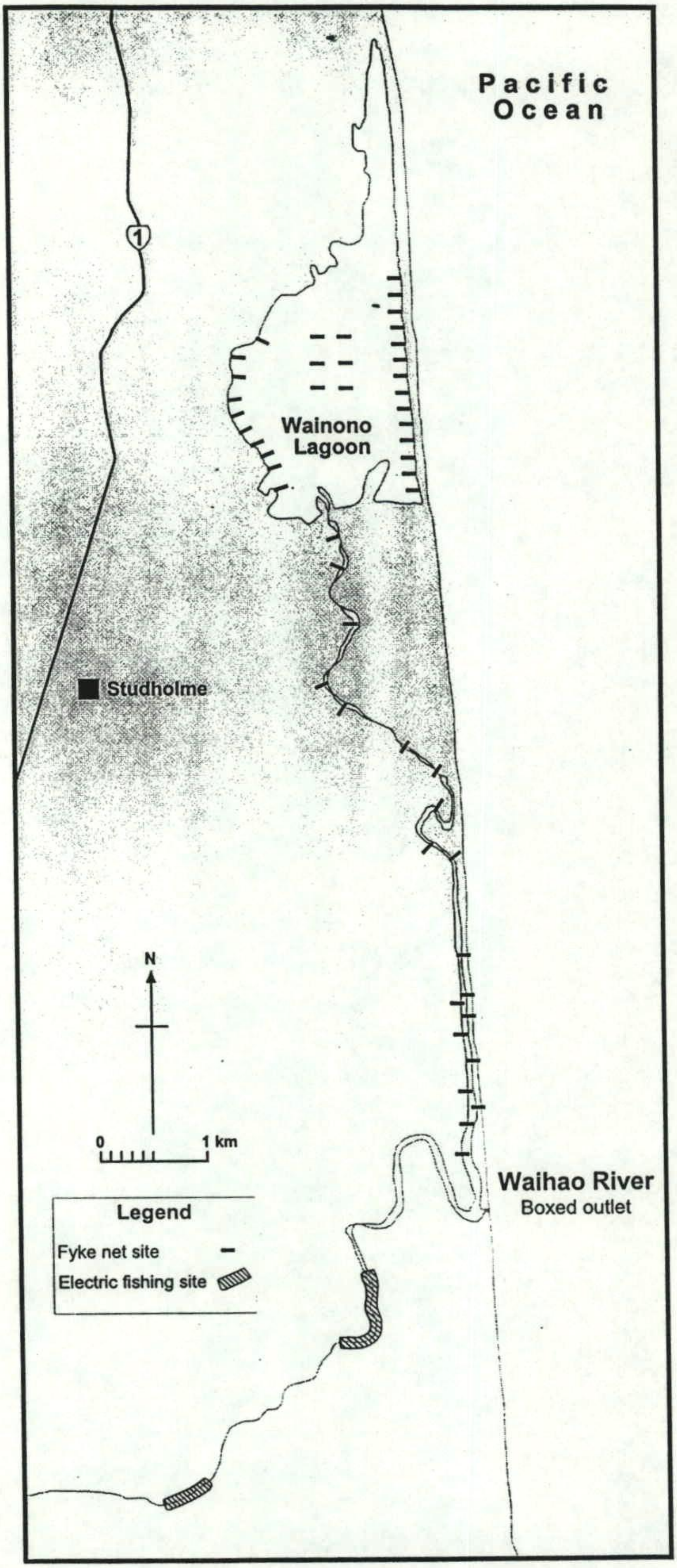

Figure 1: Map of Wainono Lagoon and canal, and the lower Waihao River showing fyke-net sites and electrofishing reaches.

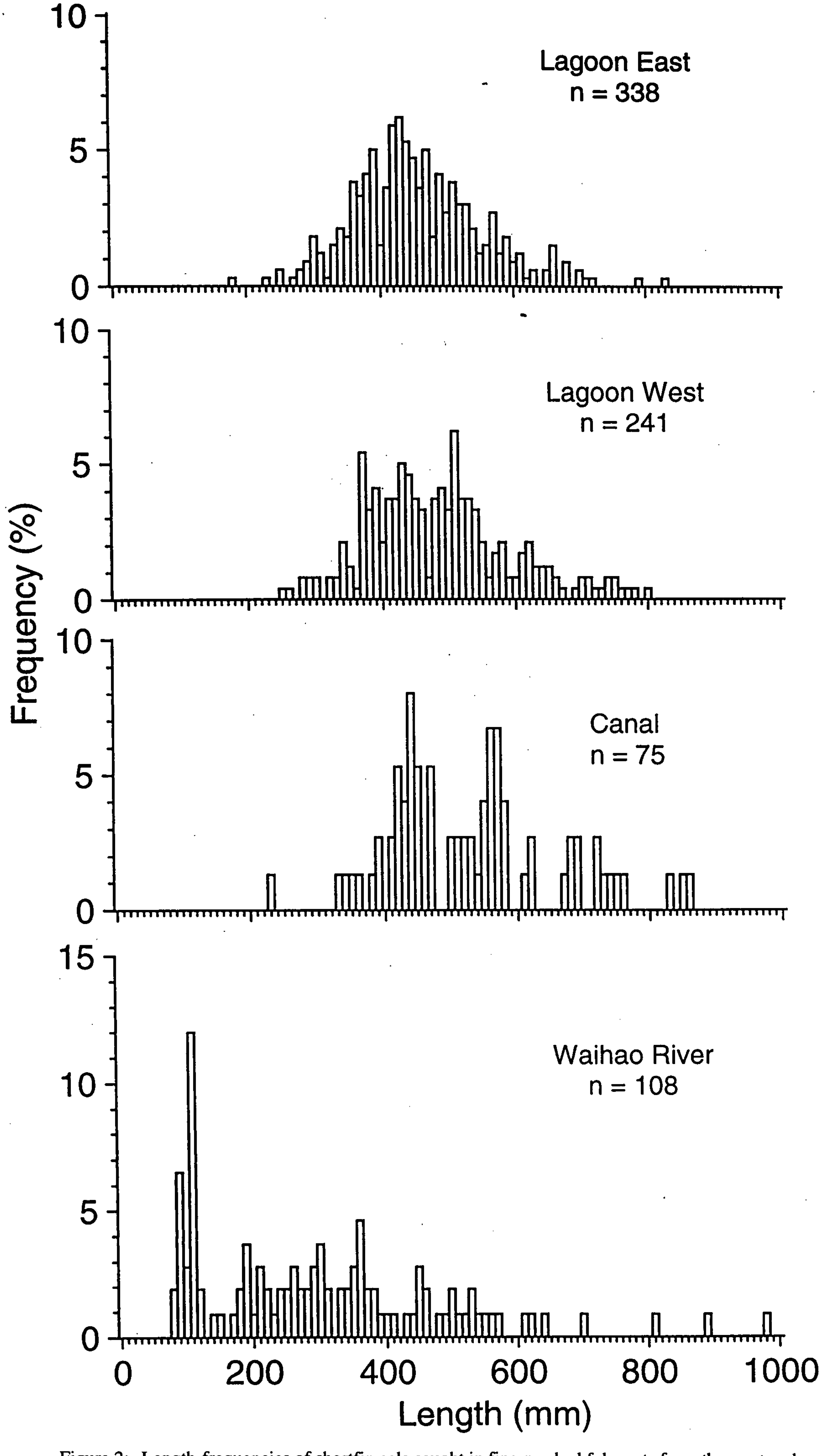

Figure 2: Length-frequencies of shortfin eels caught in fine-meshed fyke nets from the west and east sides of Wainono Lagoon and canal, and electrofished from the Waihao River.

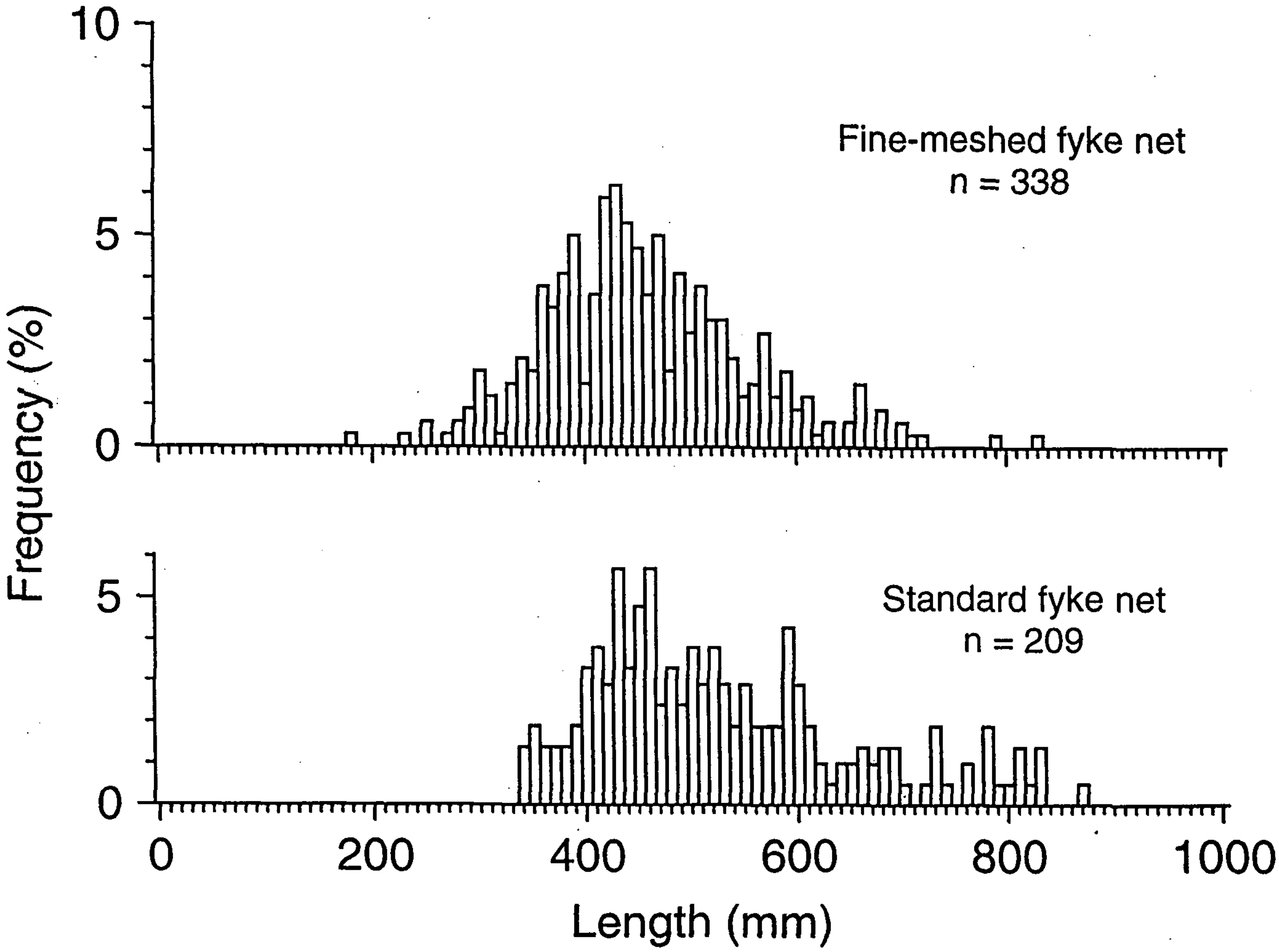

Figure 3: Length-frequencies of shortfin eels from the east side of Wainono Lagoon caught in fine-meshed and standard fyke nets.

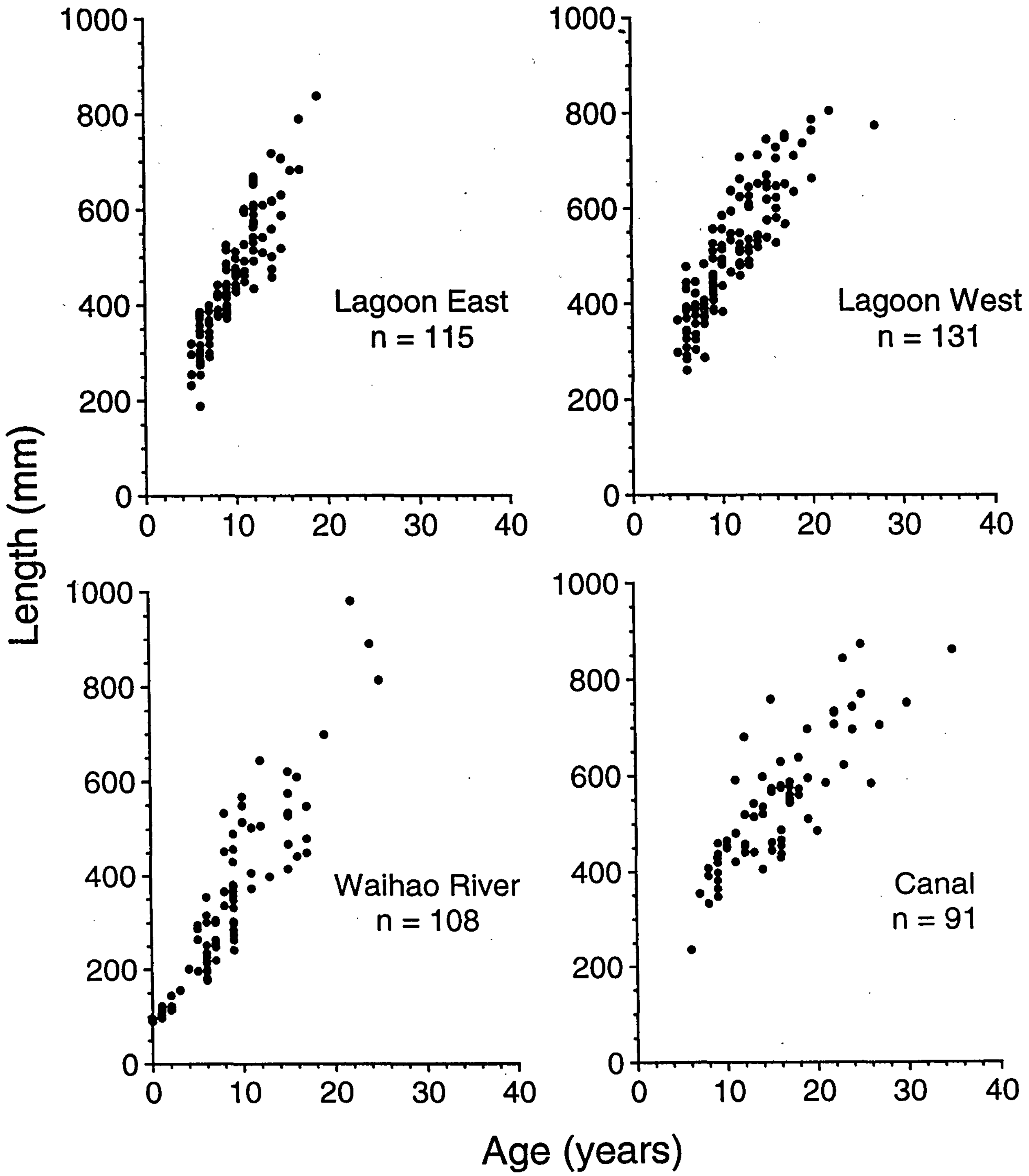

Figure 4: Age-length distributions of shortfin eels from Wainono Lagoon and canal, and the Waihao River.

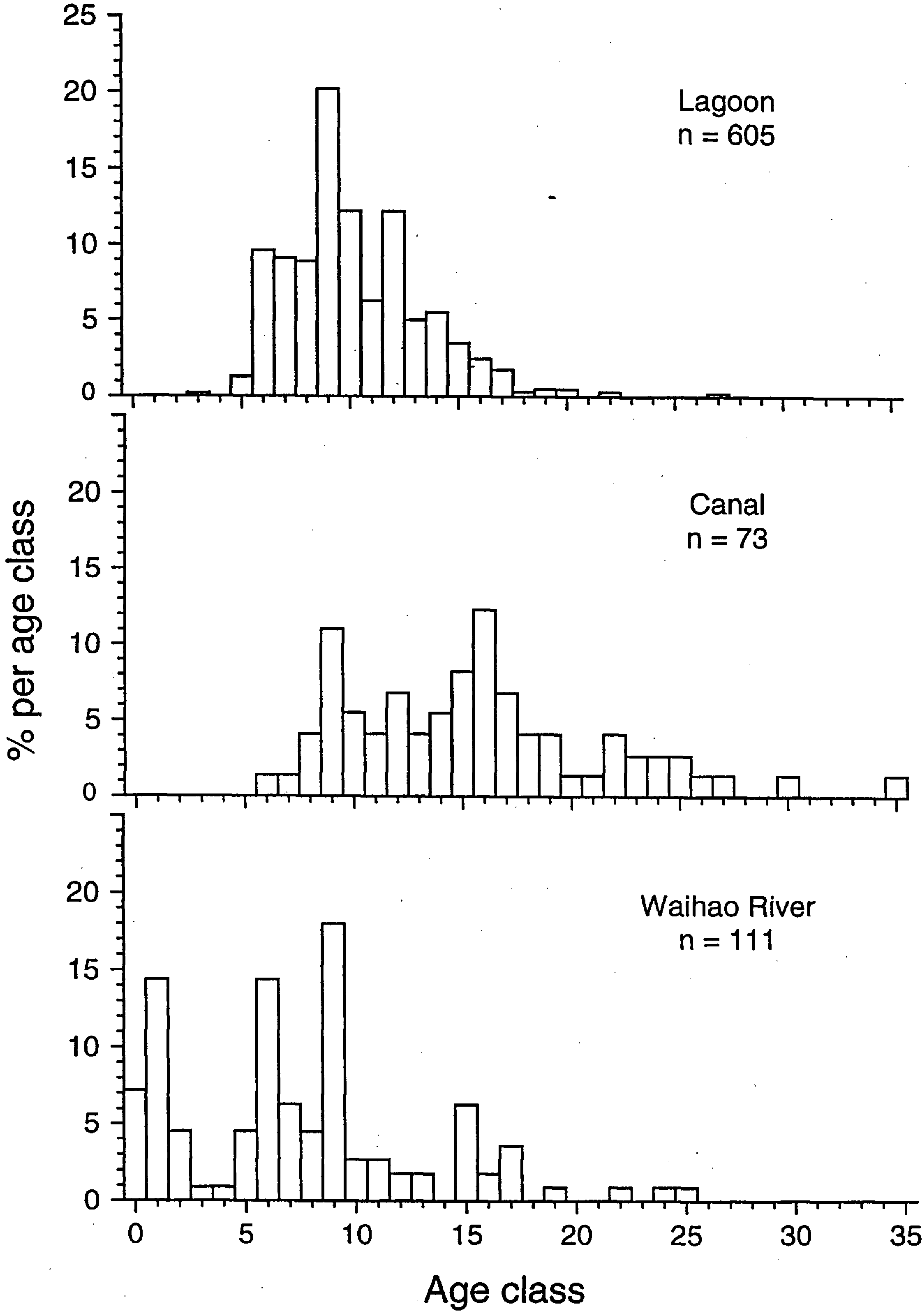

Figure 5: Age-class distributions for shortfin eels from Wainono Lagoon and canal, and the Waihao River.