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Taihoro Nukurangi

Longfinned eel female spawning escapement

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7. **Executive Summary**

There are concerns about the status of longfin eels *Anguilla dieffenbachii* in New Zealand as the species is endemic, long-lived, and subject to extensive commercial and customary harvest. The present report is one of a series of investigations on this species that include recruitment, and a general review of their well-being. The objective of the present report was to estimate the potential spawning escapement of longfin female eels from a selected river system subject to commercial fishing, and it was carried out in conjunction with a NIWA survey of juvenile longfinned eels in the Aparima River, Southland.

From the macroscopic determination of sex of 738 longfins, only five eels were identified as females; of these, four were caught in tributaries, and only one in the mainstem. The length frequency of fyke-netted eels, showed a skewed distribution, typical of that of commercially fished populations. While commercial fishing alters the size structure of eel population, it does not account for the lack of immature females below the legal size of 220 g. Possible reasons for the lack of females are discussed. Males dominated the eels available to the commercial fishery, and were distributed throughout the catchment. In the absence of substantial numbers of females, a maturation model was derived using data from other catchments. The estimated total population of eels > 700 mm (assumed to be female) in the Aparima catchment was 7500 (± 50%), of which an average of 240 (3.2%) would migrate to sea each year. Of these eels are, an estimated 22% would be protected by the current maximum size limit of 4 kg. Prior to commercial fishing, female longfins were much more abundant in the Aparima River, and a conservative estimate would be 20 000, and possibly 40 000; these figures equate to an annual spawning escapement 3-5 times greater than at present.

8. Introduction and Objectives

Freshwater eels constitute an important commercial fishery (1998-99 landings of approximately 1218 tonnes), and a customary fishery of considerable importance to Maori. The longfin, *Anguilla dieffenbachii*, is an endemic species that comprises the majority of the South Island catch. As with all species of freshwater eel, the commercial fishery is based on capture of immature eels. At migration, females may be of considerable age; an average age of 34 years was given by Jellyman and Todd (1982), although in a cold oligotrophic lake, migrating females could average 90+ years (Jellyman 1995). Such longevity, coupled with an efficient capture system, has lead to concern about the ability of the fishery to sustain present levels of exploitation (Jellyman 1993, Jellyman et al. 2000). The South Island eel fishery is now in the Quota Management System, and this should result in a reduction in harvest although it is not possible to target the reduction of longfinned eels as quotas are for both species combined.

Concern about the status of longfins has arisen from various quarters. Research conducted by NIWA as part of a PGSF funded project on the sustainability and enhancement of commercial and cultural eel fisheries, has found evidence of a major decline in recruitment of longfins into three small streams (NIWA unpublished data). Results of a review of evidence for a decline in abundance of longfins commissioned by the Ministry of Fisheries (Jellyman et al. 2000), also concluded that recruitment of longfins had declined significantly over recent years. Modeling of female escapement has indicated the likelihood that present management measures are inadequate to provide sufficient escapement (Hoyle and Jellyman, 2002); for example, the 4 kg maximum size limit within the South Island is ineffectual as the probability of females surviving to this size is very low.

It is generally accepted that the best way of conserving eel stocks is to set-aside areas free from exploitation. In New Zealand, such areas are provided by National Parks, various reserves, and some other parts of the Department of Conservation conservation estate (hereafter referred to as the DoC estate) where access can be denied to commercial eel fishers. Although the DoC estate comprises approximately one-third of the country, much of this is in high country areas that offer limited habitats for eels. Further, access for eels to considerable portions of the estate is compromised by the installation of hydro dams. When reviewing the extent of such reserve areas throughout the whole country, Jellyman (1993) concluded that this was inadequate, and further catchments would need to be reserved in future. For example, only 9% of original lake and lagoon habitat is protected and potentially produces migrants.

With the advent of various Geographic Information System (GIS) databases, the Ministry of Fisheries decided it was worth carrying out a national inventory of areas closed to commercial eel fishing. The original tender document contained 4 objectives:

1. To determine the number and size of areas in the Department of Conservation estate that may provide escapement for female longfin eels.

2. To survey selected areas in the Department of Conservation conservation estate to determine the size and age structure of longfin eel populations.

3. To determine the potential contribution to the spawning escapement of longfin female eels from areas with the Department of Conservation conservation estate.

4. To estimate the potential spawning escapement of longfin female eels from a selected river system subject to commercial fishing.

The tender evaluation panel accepted the NIWA tender for Objective 1, and this objective has subsequently been funded by the Department of Conservation (DoC). The panel considered that Objectives 2 and 3 should be put on hold subject to the completion of Objective 1; Objective 4 was approved, and forms the basis of the present report. Given that NIWA researchers were investigating the distribution and abundance of juvenile longfinned eels in the Aparima River, Southland as part of their Public Good Science Funded (PGSF) research programme on Eel Sustainability, it was appropriate that the present study be carried out in conjunction with the PGSF work. The present study required sampling by fyke nets to capture larger eels than would normally have been caught using electric fishing, the technique used to quantitatively sample juvenile eels. To increase data obtained from this additional sampling, gonad samples were taken from eels to determine sex ratios; although reporting of these data are outside the reporting requirements of objective 4, some summary results are presented as we considered the outcomes were important, and had significant management implications.

9. Methods

9.1 Study Area

The Aparima River drains a catchment area of 1375 km^2 in Southland. The river is 113 km long, with two main tributaries, the Otautau Stream and the Hamilton Burn, and numerous smaller streams and drains. Over half the catchment is farmland devoted to growing crops, dairying, and raising sheep, cattle, and deer (Robertson 1992). The substrate varies through the catchment. Most of substrate in the mainstem consists of fine and coarse gravel, cobbles, with some boulders and exposed bedrock, and there is little aquatic vegetation. Much of the mainstem below the Hamilton Burn confluence is lined with willows (*Salix* spp.). Commercial eel fishing using baited fyke nets takes place in the willow-lined pools, where water depth, tree roots, debris clusters, and occasional undercut banks, provide habitat for longfin eels.

The river was originally chosen as:

- It is a medium-sized river, whereas previous studies on recruitment have focused on small streams

- It is readily accessible along virtually its entire length.

- Considerable sections of the main steam and tributaries are able to be electric fished.

- It maintains an important commercial fishery, with an estimated yield of 2.5 t per annum, (Beentjes and Chisnall 1997) and is also of importance to local iwi (Oraka Aparima Runaka)

- Data on length-frequencies and age distributions of longfins are available from commercial catches (Beentjes and Chisnall 1997)

9.2 Field sampling

Eels were collected in February 2001 at 45 sites by electric fishing and in February 2002 at 15 sites by electric fishing and at six sites with baited fyke nets (Fig. 1). Electric fishing was done by wading, primarily in riffles and runs, and to a lesser extent in willow-shaded pools and debris clusters, in the mainstem and larger tributaries and in all habitats present in the smaller tributaries.

Originally, it was proposed to use experienced local fishers to sample larger eels. However, the sampling period chosen, February 2002, coincided with a very busy time for commercial fishers, meaning they were not available to assist with sampling. Further, because we needed to sample in a "scientific" manner (to obtain population estimates), rather than a commercially efficient manner, it was not possible to simply join with a commercial eel fisher and observe the catch. Therefore, we carried out our own sampling using nets provided by a local eel processor (Victor Thompson, Mossburn Enterprises).

Fyke netting was done in pools and deep runs in the mainstem and in the two largest tributaries, which were too deep to electric fish. Commercial fyke nets were used (25 mm mesh), but the escapement tubes were closed off with plastic electrical ties. Nets were baited with paua (*Haliotis*) guts, the bait most commonly used by commercial eel fishers. Approximately 0.5 kg of bait was placed inside a 2-litre plastic jar that had a numerous 1-cm diameter holes drilled in the sides. Nets were secured to the bank or branches of willows by stout nylon cord, and weights were attached to both the codend and the mouth to ensure that the net remained on the bottom.

Eight or ten nets were set in a line approximately 30 m apart overnight for two or three nights at each of 5 sites. In addition, three nets were set over one night at a tidal site near the upper limit of salt penetration in the estuary. They repeat sampling at each site (except in the estuary), was part of a progressive removal technique to estimate local population size. At stream side, eels were anesthetized in a solution of 2-phenoxyethanol, identified to species, and measured (mm). All eels were externally examined for signs of maturity, using the features recorded by Todd (1981). In 2001, samples of longfin eels, nearly all <400 mm long, were killed by overdose of anesthetic and frozen for later determination of age and sex. In 2002, samples of longfin eels, mostly 300-600 mm long were similarly frozen for later determination of sex. Samples of longfin eels came from all reaches of the catchment and from both mainstem sites and tributaries (Table 1). Eels not kept were allowed to recover and were returned to the waterways.

9.3 Sex determination

The gonads of yellow eels lie as a long ribbon from approximately the level of the liver to beyond the vent on each side of the body cavity approximately along the junction of the swim bladder and the body wall. Sex of longfin and shortfin eels in the present study was determined by criteria given by Todd (1974). He described undifferentiated gonads (stages 1, 2) as thin ribbons of uniform density and without distinct lobes. Early developing testes (stages 3, 4) were described as having distinct white opaque zones joined by clear areas of tissue, with the opaque zones becoming lobed. Early developing ovaries (stages 6, 7) began as an opaque ribbon with an anastomosing network of veinlike structures and gradually became a frilled ribbon, with closely spaced transverse ridges on the lateral face.

To determine sex, each eel was thawed, the abdomen cut open from vent to pectoral girdle, and the left body wall cut and laid open to expose the gonad. Intact gonads first were examined under a binocular microscope at 8-20X. Sometimes, a drop of blue Wright's stain was placed along the intact gonad, and it flowed under the gonad by capillary action. In many cases, a small piece of gonad tissue was removed (before any stain was added) and placed on a microscope slide with a few drops of aceto-carmine stain, which selectively stains gonad tissue (Guerrero and Sheldon 1974). After a few minutes, the tissue was squashed with a cover slip or just covered with a cover slip, and examined with a compound microscope at 40-200X magnification.

Eels were classified as **not differentiated** if the intact gonad was a transparent or translucent ribbon without the presence of developing opaque whitish areas, and if the gonad tissue resisted being squashed and showed uniform absorption of aceto-carmine stain. Eels were classified as **male** if there were developing, regularly spaced, whitish opaque areas separated by transparent tissue, even if the opaque areas did not extend the full length of the gonad. The presence of even early developing lobes was highlighted by the addition of blue stain to the body cavity. Also, developing testicular tissue resisted squashing, and the developing lobes absorbed aceto-carmine, while the tissue between lobes scarcely did so. Eels were classified as **females** if the intact gonad was a frilly ridged ribbon. Such gonads had a soft texture, squashed easily, and showed clearly developing oocytes under the compound microscope. In one case, a smaller female was identified on the basis of an anastomosing veinlike network.

9.4 <u>Age determination</u>

Ages were determined for 362 longfin eels >100 mm long from throughout the catchment (Table 1). All but five eels were <400 mm long, and all were <437 mm, as a focus of the wider study was recruitment and distribution of juvenile longfin eels. Aging was by the sawing and burning method described by Graynoth (1999), a modification of the breaking and burning technique described by Hu and Todd (1981): i.e. saggital otoliths were removed from each eel, placed on a strip of double-sided adhesive tape, and held in place with a strip of transparent tape. One otolith was sawn along the transverse plane through the nucleus with a fine scalpel under a binocular microscope. The two halves were placed on a scalpel blade and heated for 10-15 s over a high temperature gas flame. The halves were then mounted cut side down in clear silicone sealant on glass slides. Slides were inverted and examined under reflected light with a compound microscope at 50-400X magnification. Annuli were counted along the long ventral axis, and age recorded as the number of years in fresh water.

9.5 <u>Maturation model</u>

The proportion of female eels maturing per annum could not be determined directly from the proportion of migratory or near-migratory eels in the catches, as only 11 female eels (>700 mm) were caught and none of these were classified from external features as "mature" or "maturing". Therefore the proportion maturing at different lengths was estimated using the De Leo and Gatto model (De Leo and Gatto 1996; Francis and Jellyman 1999) and field data from three small coastal streams (Glova et al. 1998).

P = gamma / (1+exp(lambda - Length (cm) / eta)

where:

P = proportion of female eels maturing

gamma is the maximum rate of metamorphosis

lambda is a semi saturation constant (mean length at migration)

eta is inversely proportion to the slope of the metamorphosis curve at the mean length.

Simulation models (Jellyman et al. 2000) were used to determine the best fit between the actual and estimated length frequency of the population and derive estimates for the parameters used in the model.

9.6 Estimation of eel stocks and spawning escapement

GIS based models (NIWA unpublished data) were used to estimate the total population of all sizes of longfinned eels in the Aparima River.

As relatively few large female eels were caught, the size frequency of the female eels present was modelled based on the length frequency and abundance of smaller eels. Values for the recruitment, survival and maturity parameters were derived from Jellyman et al. (2000). Growth rates of 17 mm y^{-1} were used and it was assumed that 95% of the fish present were males (this study).

The maturity model was then applied to the modelled length frequency distribution of female eels in order to estimate the numbers and size of female eels migrating.

10. Results

10.1 Catches

Totals of longfins caught over two years by both electric fishing and fyke netting are given in Table 1, together with catch by catchment reach and category. Over both years, 3205 longfin were measured, and 738 sexed. The fyke net catches per night (Table 2) indicate the predominance of longfins in the total catch of 3806 eels, and the reducing numbers caught on successive nights.

10.2 Length and age at sexual differentiation of longfin eel

Longfin eels differentiated into males over a range 280–530 mm, with 95% differentiated by 450 mm. Only one female longfin eel, 368 mm long and 20 years old, was in the sample of eels aged.

10.3 Sex ratio and distribution of longfin eels within the catchment

Female longfin eels were rare in the Aparima catchment. Only five of 738 longfin eels examined for sexual differentiation were female. All five were in the lower reaches of the catchment. The four largest females were caught in a stretch of one small tributary, while the smallest was caught in the mainstem. There is a high probability that about 25 of the largest longfin eels were females, including the four just mentioned and those measured but not examined for sexual differentiation. The four largest positively identified females, plus 18 other eels >680 mm, assumed female (on the basis of the size distribution of identified females), were mostly in tributaries (Fig. 2), especially the smaller tributaries.

Undifferentiated longfin eels 100–139 mm long were mostly found in the lower reaches of the mainstem of the catchment. Male longfin eels were distributed throughout the catchment. Further, their size distributions were similar throughout the catchment, except that the distributions in the mainstem and lower reaches are sharply truncated at the upper ends, a little above the minimum legal commercial size (Fig. 2).

There is a low representation of longfin eels in the lengths 140-400 mm in the length-frequency histograms (Fig. 2), but the low representation is likely because of sampling bias rather than rarity of these size classes in the population. Electric fishing and fyke netting were done to sample various habitats but effort was not equal between methods or among habitats, and fyke nets are size selective. Both sampling methods revealed the sharp decline at the upper ends of the length-frequency distributions.

10.4 Age composition

In contrast, longfin eels differentiated into males over a wide range of ages. Eels 100–437 mm long ranged in age from 1–31 years. Males were present as a small proportion beginning at age 10, but with a high proportion still undifferentiated around age 20 (Fig.3). In the age classes from 17–22, 70% of those aged were still undifferentiated. However, the proportion undifferentiated at the greater ages (Fig. 3) is biased somewhat high because eels that differentiated at younger ages were the faster growing ones (Figure 4). In each age class from 10 upward, the longest eels are the ones differentiated. Many of the faster growing males in the population were larger than the length limit of those sampled for aging (mostly <400 mm).

10.5 Maturation model from the three coastal streams

A total of 73 longfinned eels more than 700 mm in length were caught in the 3 coastal streams (Glova et al. 1998), of which 7 were considered to be either mature females or were likely to mature and migrate that season. Mature females averaged 1063 mm (sd = 99) in length and were similar to or slightly smaller than mature fish from other waters (range of means 1063–1208 mm) (Burnet 1969; Todd 1980). Fish in these three streams grew relatively slowly (11–15 mm y^{-1}) and at slightly slower rates than fish caught in the Aparima River (Fig. 4).

Figures 5 and 6 show the estimated total population of females and the percentage maturing per year at different sizes. Simulation modeling (Jellyman et al. 2000) showed the best fit to the observed and actual length frequency distributions was obtained with the following maturity parameters

gamma = 0.24, lambda = 108, eta = 5.1

Plot of changes in maturation rate with fish length (Fig. 6) showed this model appears to slightly underestimate the numbers of large fish (>1000 mm) migrating in the three streams. Surveyors could have either overestimated the number of mature fish present or some mature fish may have remained resident in the stream. Modelling indicates that if the observed proportion of fish matured and went to sea, then very few would survive and exceed 1100 mm in length.

10.6 Distribution and abundance of longfinned eels in the Aparima River

Most of the longfinned eels caught in the Aparima River were small juveniles and less than 400 mm in length (Fig. 7). Field data and GIS based models (Graynoth and Jellyman in prep.) indicated that larger "adult" eels (400–700 mm) were most abundant in the mainstem of the Aparima River and in some of the larger slow flowing and deep tributaries. Crop rates by commercial fishers appear to be about 18% per annum and computer simulation models (Hoyle and Jellyman 2002; Jellyman et al. 2000) showed that virtually no large females survive to maturity in fished areas under this level of cropping.

Relatively few large eels were caught during the field surveys and only 11 of those exceeding 700 mm were assumed to be females (Fig 8). Because of the high proportion of male eels present in this river system, we suspect most of the eels in the 700–750 mm size class were males. Note that this estimate is slightly more conservative than that derived independently from examination of gonads (Section 10.3).

Large eels (>700 mm) were found mainly in the smallest unfished streams (Figs 9 and 10) and the total population of fish was estimated to be about 7500 fish (±50%). Because only one large female was present among the 1000 or more fish captured using fyke nets and electric fishing, we suspect there are less than 100 female eels left in the mainstem.

10.7 Spawning escapement

Models indicated that the numbers of females present steadily decreased with increasing fish size (Fig 11) – this reduction would be a consequence of natural and fishing mortality, but mainly maturing eels migrating to sea. Because these large fish were confined to small tributaries, it was assumed that crop rates were minimal at 1% per annum.

Calculations show that if the Aparima River supports about 7500 female fish (>700 mm), then, on average, about 240 (3.2%) would migrate each year. This equates to about 5.7% of the biomass of female eels and about 1% of the biomass of all sizes of eels. The *actual* numbers migrating are virtually impossible to determine without a large amount of field work to catch and identify pre-migratory eels, or trap the annual migration.

The length and weight frequency of migrants are shown in Figs 12 and 13. In the unlikely event of migrant fish being caught by commercial fishers, then only 22% would be protected by the current maximum size limits of 4 kg.

11. Discussion

11.1 Skewed sex ratios in southern South Island rivers

The preponderance of male longfin eels in the present electric fishing and fyke netting samples (93:1 M:F) and in the commercial fyke netted catch (14:1) from the Aparima River also occurred in other rivers in the southern half of the South Island, although the Aparmia was the extreme. In the five large southernmost catchments, the ratio of males to females in the commercial catches ranged from 2.4:1 to 13.6:1 . Because of the conservative assignment of sex by Beentjes and Chisnall (1998) and Beentjes (1999), the actual ratios are probably even higher. Approximately three-quarters of the South Island longfin eel catch is made in those five catchments (data from Beentjes and Bull 2002). In the headwaters of the southern Taieri River, only recently accessible to commercial fishing, the catch was dominated by females (0.2:1 M:F). The Waitaki River (1.1:1) and other northern South Island rivers had approximately equal sex ratios of longfin eels in the commercial catches. Sex ratios in catches from the other northern rivers ranged from 0.4:1 to 2.0:1, but sample sizes were small.

11.2 Why are sex ratios skewed toward males in southern rivers?

Given the predominance of female longfin eels in the southern rivers prior to commercial fishing (Cairns 1941, 1942; Burnet 1952), what has caused the change to a predominance of males, especially in the Aparima River? As a detailed consideration of possible causes is outside the scope of the present report, only a brief outline is provided. More detailed consideration of this issue will be reported in a subsequent paper.

There would seem to be three possibilities, although of course, the cause might be a combination of factors.

- The selective commercial harvest of larger, longer lived females created truncated size distributions with an associated skew of expressed sex ratios.
- Commercial harvest has restructured the river populations such that biotic environmental conditions (e.g., social interactions) now favour the development of males.
- Other environmental features of the catchments, natural or anthropogenic, have changed to favour the development of males.

While commercial fishing is selective for larger eels, and hence produces skewed length distributions (e.g., Beentjes and Chisnall 1997,1998), it cannot directly influence the sex proportions of eels below the minimum commercial size i.e., approximately 450 mm. It seems more likely that changed factors in the environment caused differentiation of a greater proportion of the population into males in the last two decades than in earlier decades. However, as it is not known at what size environmental factors exert their influence on sex determination, the influence is probably well before differentiated testes are discernable.

A reduced proportion of large eels in the southern river populations might have allowed a greater survival rate of smaller eels, e.g., through reduced cannibalism or competition for food. A consequent increase in population density of small eels might have favoured differentiation of males (Parsons et al. 1977, Kennedy and Vickers 1990, Krueger and

Oliveira 1999). It is also possible that the reduction of large eels resulted in increased encounter rates among smaller eels, and that this might act in a similar way as an increase in density and perhaps result in differentiation of more males. Climatic factors, particularly temperature and precipitation, have changed in recent decades, but it seems unlikely that the slight trends could have caused the dramatic shift in sex ratio.

In summary, commercial fishing selectively harvests female longfin eels, but does not, per se, account for lack of immature females below legal size. Climatic and anthropogenic changes to the environment, while occurring in the southern South Island, seem to have been more gradual and on different time scales than the changes in sex ratio in the Aparima River and nearby rivers. Commercial fishing has altered the size structure of the eel population, probably altering the social structure such that differentiation into males has been enhanced. Perceived increases in the density of small eels may be the driving factor. Irrespective of the cause (s), the lack of immature females below the commercial threshold is of particular concern and warrants further research.

11.3 Estimation of migrants

In order to estimate the number of female migrants it was necessary to make several assumptions about:

- The number of female eels present
- Growth rates
- Natural and fishing mortality rates
- Changes in maturation rates with increasing fish size and age.

Only approximate estimates (± 50%) were made of the numbers of female eels present because these fish were relatively scarce and were only found in a few locations. Errors in the estimation of growth mortality and maturation rates may have also added additional, but probably small, errors to the estimates of the numbers of female migrants.

There is historical evidence that female eels used to be much more abundant before commercial fishing and densities reached 300 per km in stable lowland streams in Southland (Cairns 1942). The total population in the Aparima River prior to fishing is not known but may have in the order of 20 000 to possibly 40 000 fish. The spawning escapement could therefore have been 3 to 5 times greater prior to fishing.

There is very little information in the literature on spawning escapements from other waters in New Zealand. Burnet (1969) caught 11 mature female eels during 6 years of trapping in the South Branch and 7 were caught during intensive electricfishing over 3 summers in 3 coastal streams (Glova et al. 1998). By contrast, Hobbs (1947) estimated that 3850 mature female migrants with a mean weight of 6 kg (13.2 lbs) were present at the outlet to Lake Ellesmere in the autumn and winter of 1942. Therefore the numbers estimating to have migrated from the Aparima River (240) are broadly consistent with the numbers migrating from the above waters when the relative size and productivity of catchments is taken into account.

12. Publications

The data will contribute to two manuscripts to be submitted to refereed journals.

13. Data storage

As the work was a contribution to NIWA's PGSF Eel Sustainability programme, the raw data (field sheets, otoliths etc) are retained at NIWA's Christchurch laboratory.

14. Acknowledgements

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Table 1. Numbers and size ranges (in parentheses) of longfin eels >100 mm long measured, sexed, and aged in the Aparima River catchment in February 2001 and 2002. One estuarine site is included in the categories lower reach and mainstem.

	Reach of catchment			Category of stream		
	Lower	Middle	Upper	Mainstem	Tributary	Total
Collection year 2001						
Number of electric fishing sites	11	17	17	15	30	45
Number measured	436 (100-882)	424 (102-1008)	232 (140-1000)	575 (100-830)	517 (140-1008)	1092 (100-1008)
Number sexed and aged	79 (226-437)	45 (244-395)	50 (268-398)	96 (226-419)	78 (244-437)	174 (226-437)
Number aged, not sexed	102 (100-276)	47 (108-272)	39 (157-276)	137 (100-276)	51 (157-276)	188 (100-276)
Number sexed, not aged	1 (353)	1 (495)	1 (348)	1 (353)	2 (348-495)	3 (348-495)
Collection year 2002						
Number of sites	8	9	4	11	10	21
Electric fishing	4	8	3	7	8	15
Fyke netting	4	1	1	4	2	6
Number measured	1117 (100-746)	733 (104-729)	263 (213-670)	1565 (100-729)	548 (122-746)	2113 (100-746)
Number sexed	200 (246-746)	251 (123-602)	110 (253-670)	385 (123-670)	176 (253-746)	561 (123-746)

Table 2. Numbers of eels caught in baited fyke nets, Aparima River, February 2002.

Location	Number of nets	Number of eels caught			% longfins
		Day 1	Day 2	Day 3	
Fairfax	10	256	121		98.3
Thornbury	10	700	232	83	98.2
Bayswater Rd	10	1071	198		100.0
Hamilton Burn	8	386	43		99.7
Otautau Stream	8	536	180		99.1
Totals	46	2949	774	83	

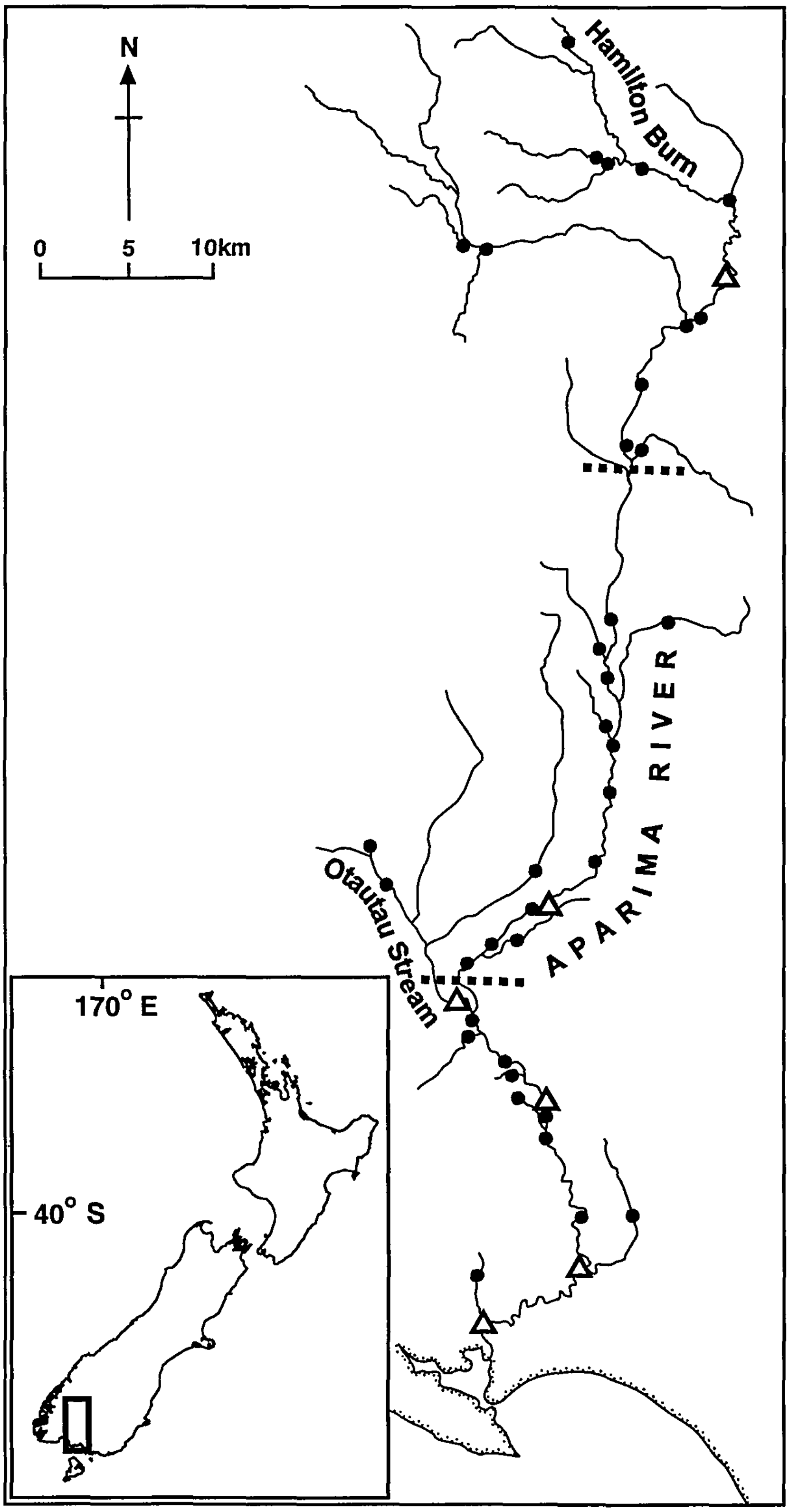

Figure 1. Map of Aparima River showing sampling locations. Solid circles = electric fishing sites, triangles = fyke netting sites, horizontal dashed lines = separation by lower/middle/upper catchment

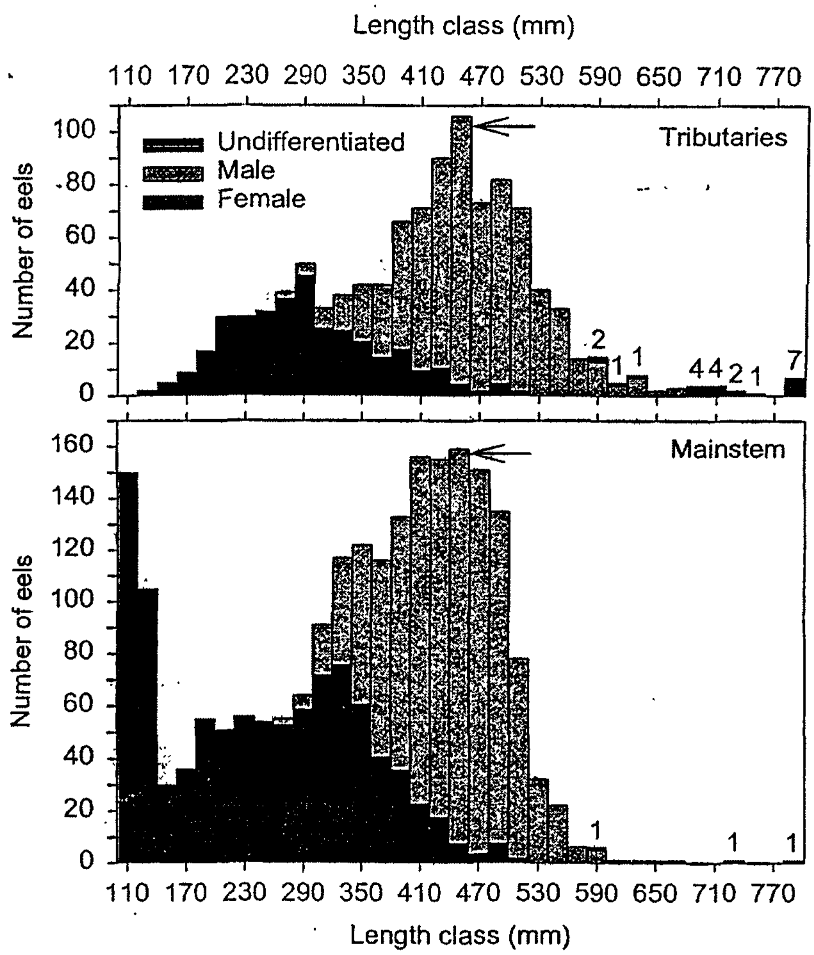

Figure. 2. Length–frequencies of longfin eels from the Aparima mainstem and Tributaries classified as undifferentiated, male, or female. Arrows marked the size class it entry into the commercial fishery. Numbers above the bars are the estimated numbers of females.

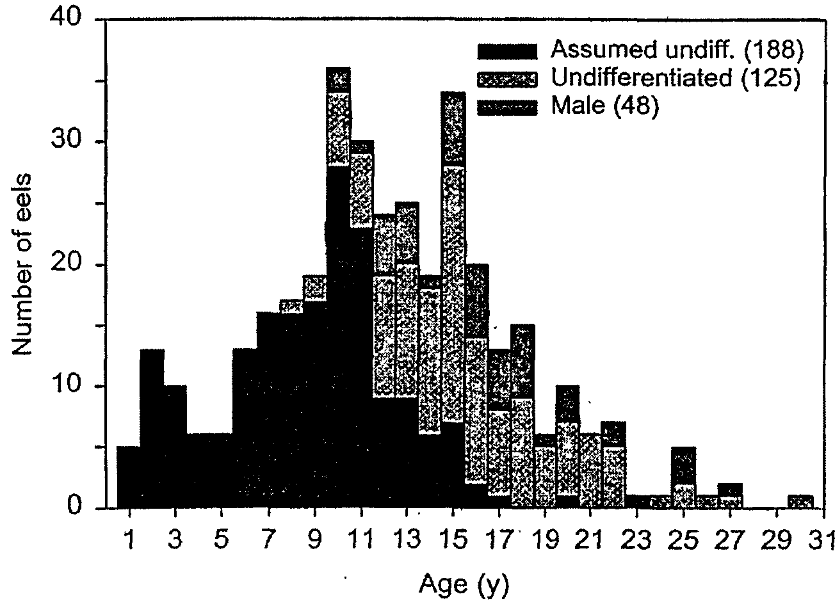

Figure 3. Age-frequencies of longfin eels from the Aparima River classified as undifferentiated or male. The "Assumed" category were eels that were sufficiently small to have a high probability of being undifferentiated. Sample sizes in brackets.

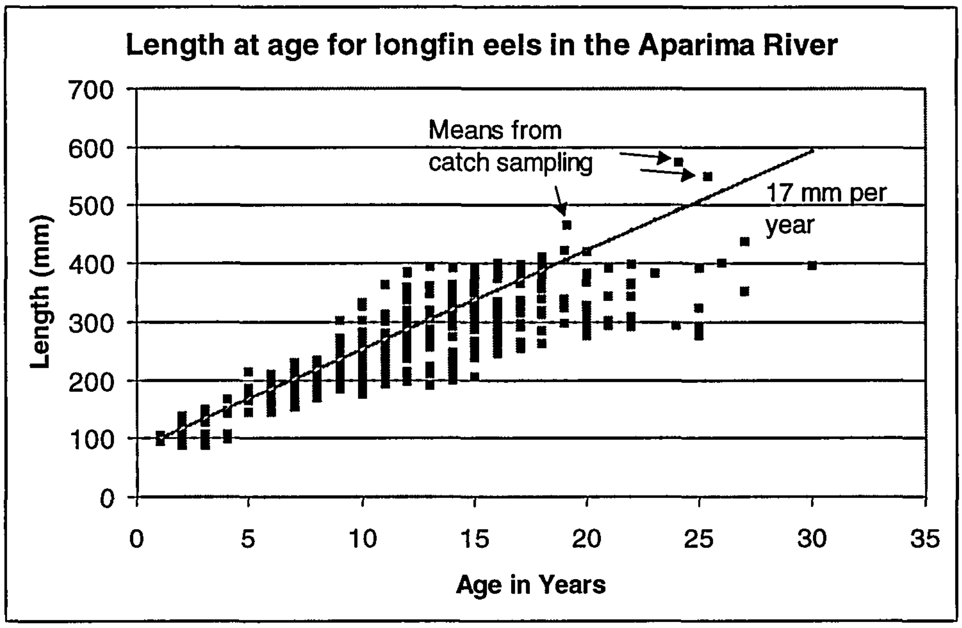

Figure 4: Length at age for longfinned eels in the Aparima and mean lengths at age from catch sampling data of Beentjes & Chisnall (1998), and Beentjes (1999).

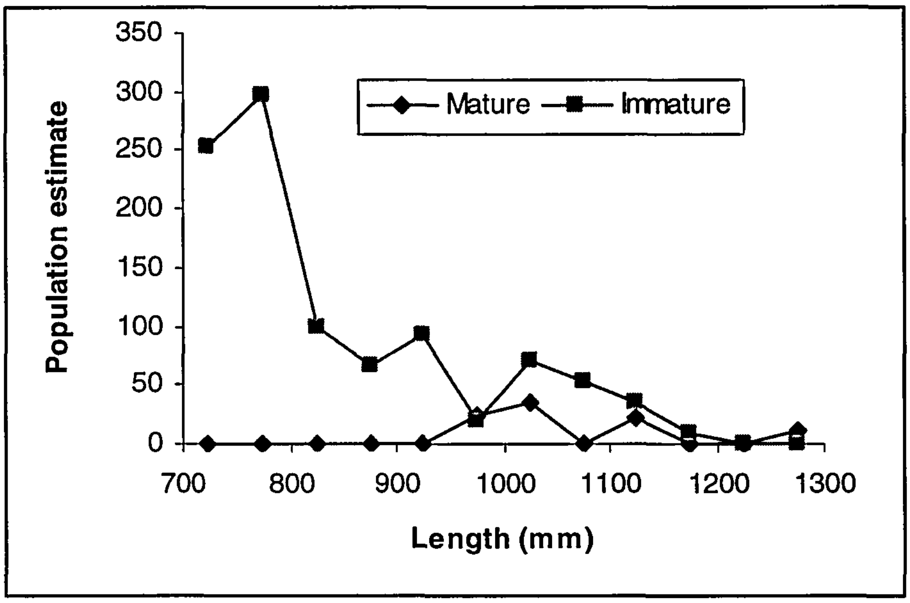

Figure 5: Estimated population of mature and immature female longfinned eels in three small coastal streams

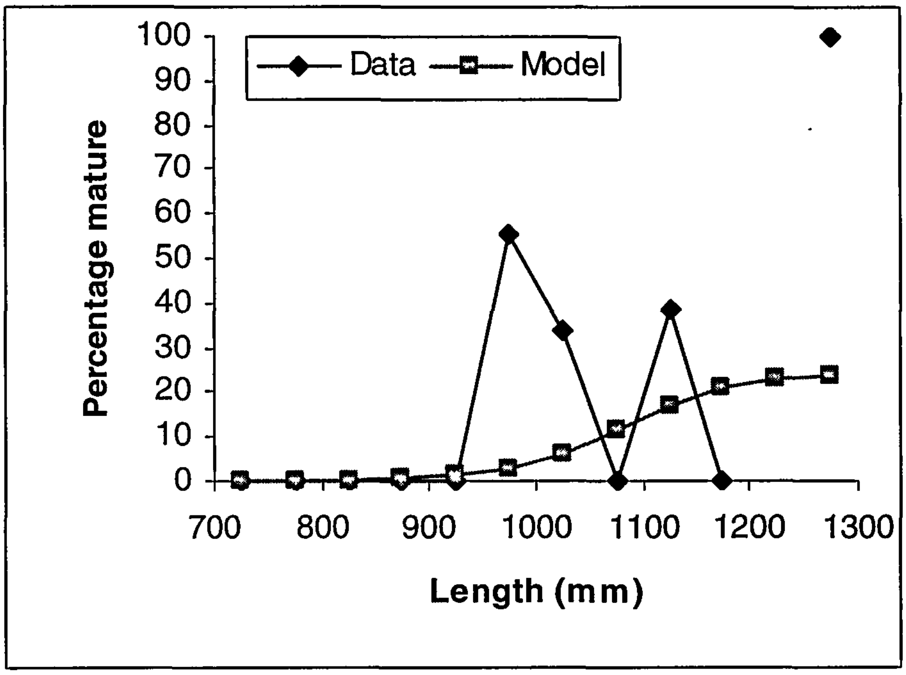

Figure 6: Percentage of mature females observed in the three small coastal streams, and the percentage of females maturing per annum estimated from a length-based model of maturity

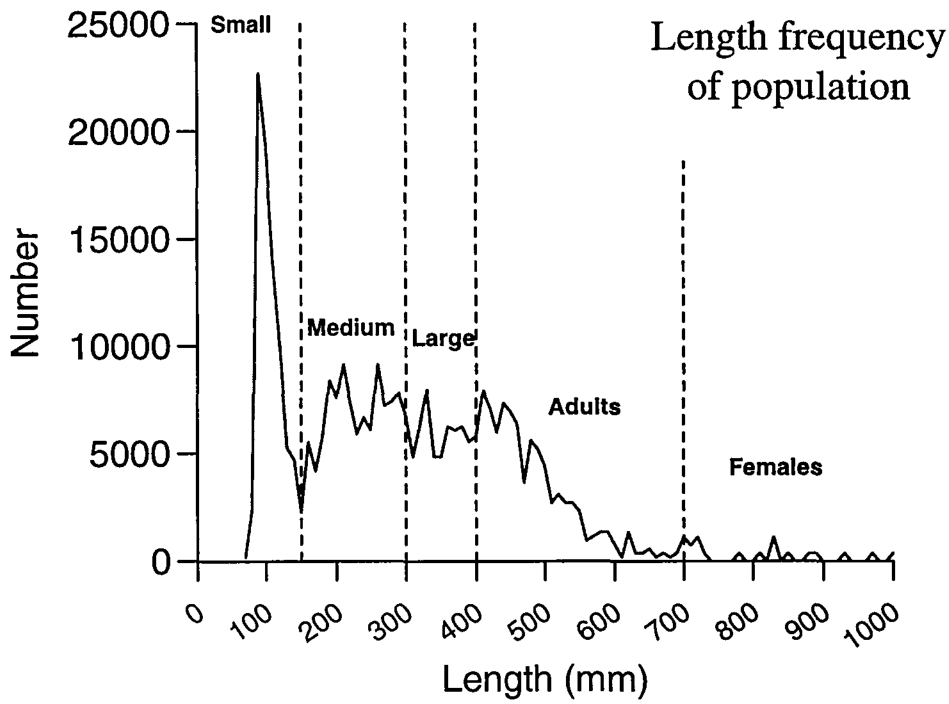

Figure 7: Length frequency of the population of longfinned eels in the Aparima River

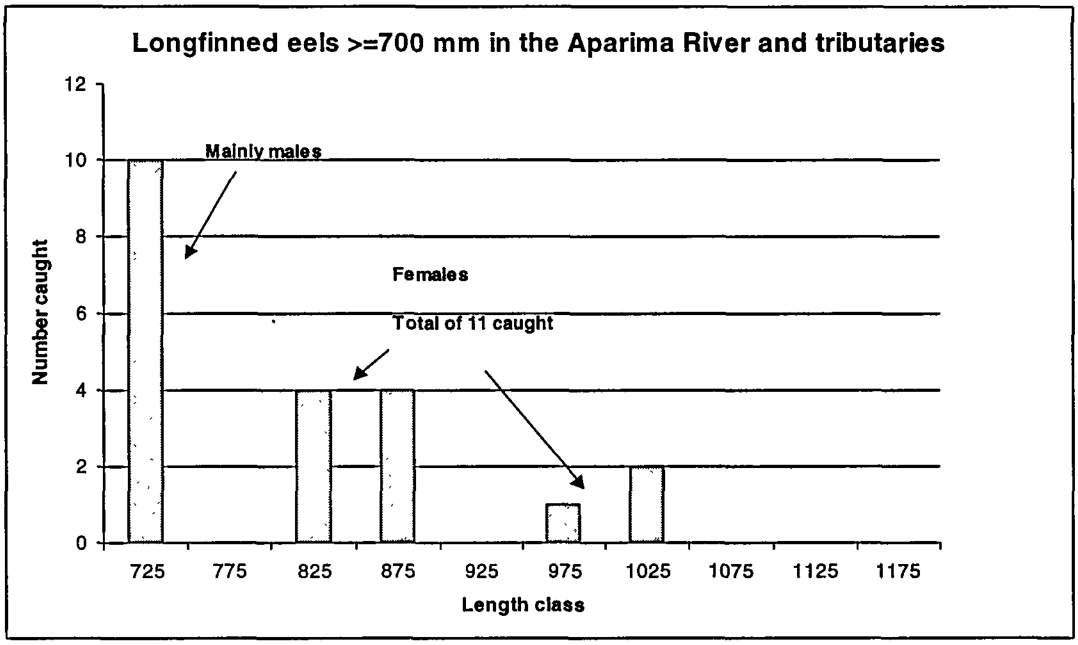

Figure 8: Length frequency of eels greater than 700 mm in length in the Aparima River

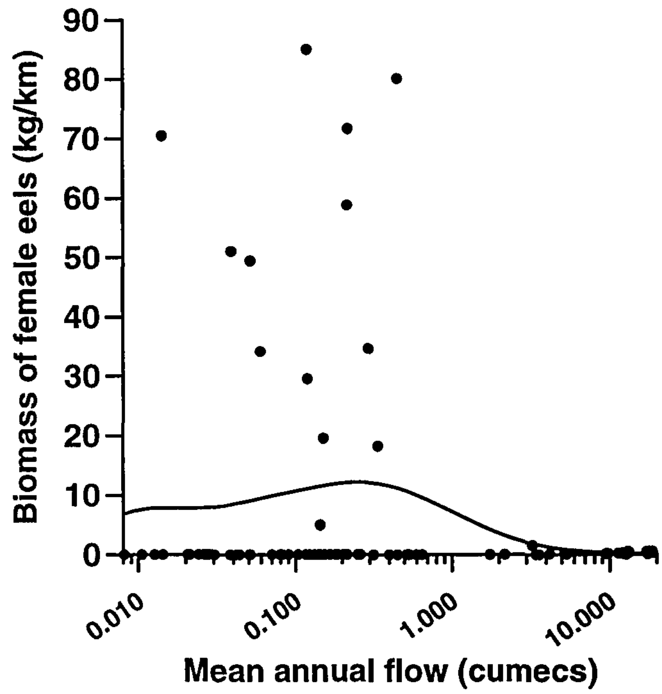

Figure 9: Biomass of female longfinned eels in tributaries of different sizes in the Aparima River.

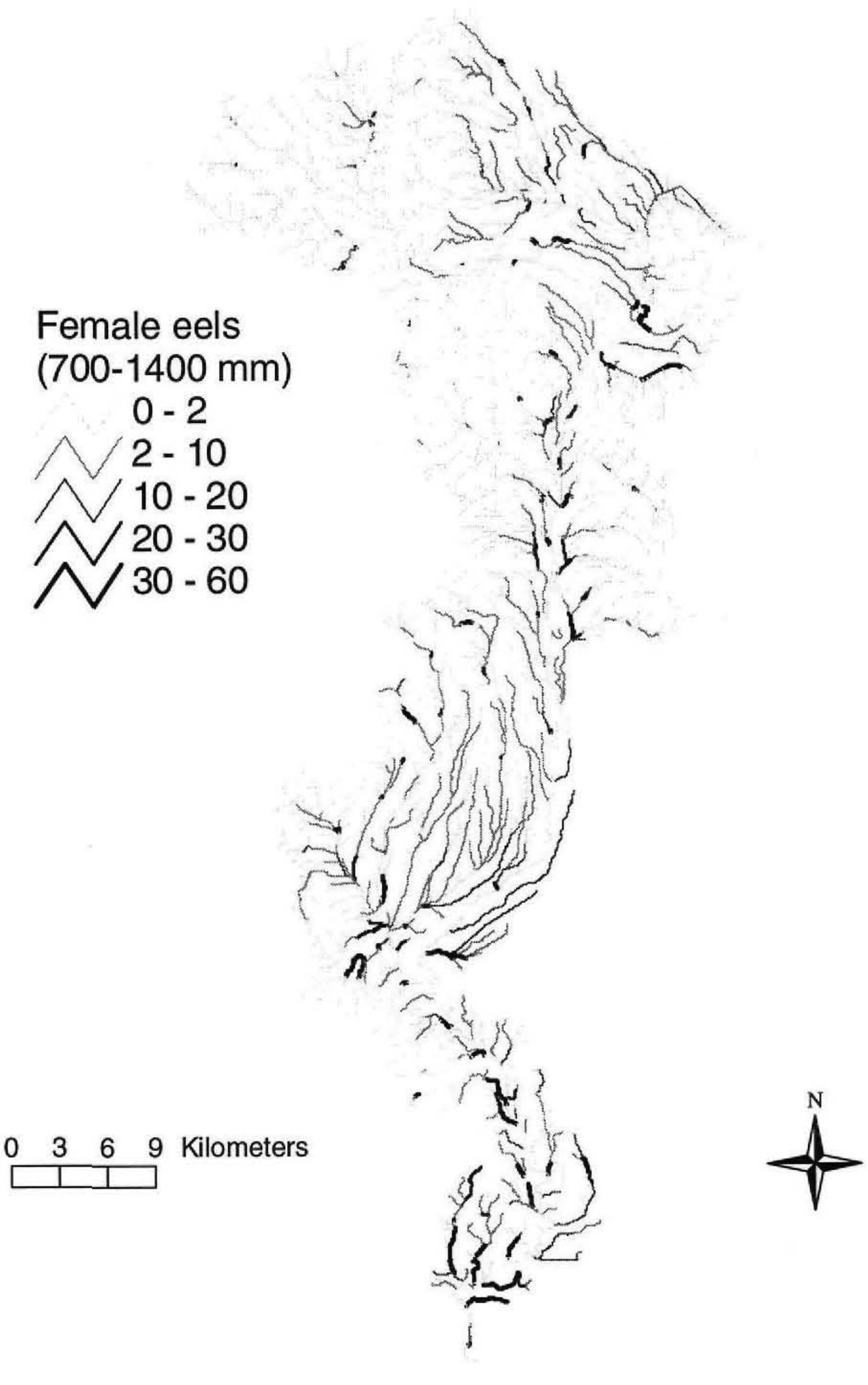

Figure 10: GIS map of the abundance (n/km) of female longfinned eels in the Aparima River system.

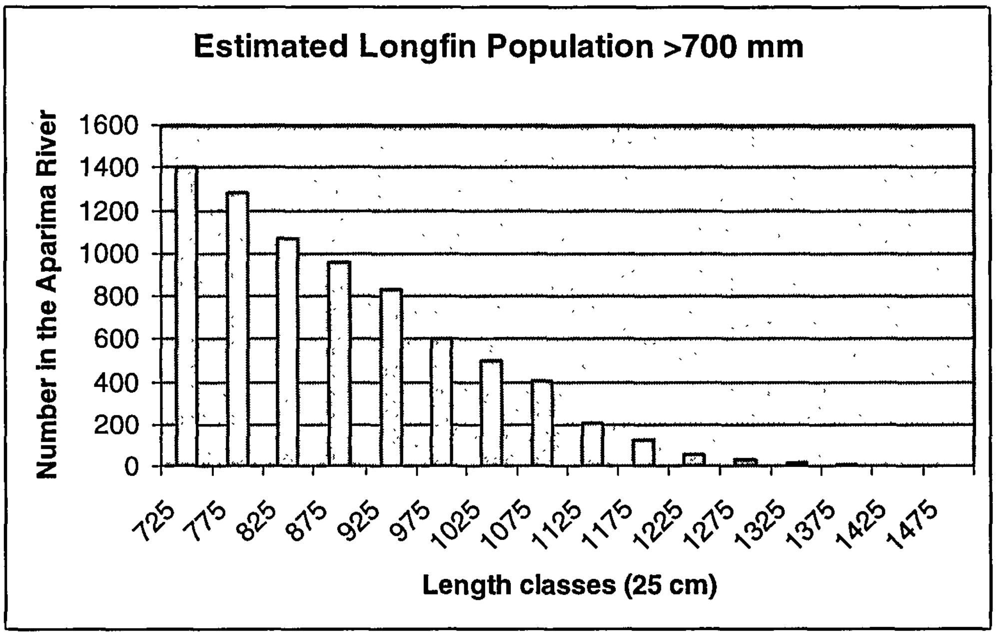

Figure 11: Modeled length frequency of female longfinned eels in the Aparima River

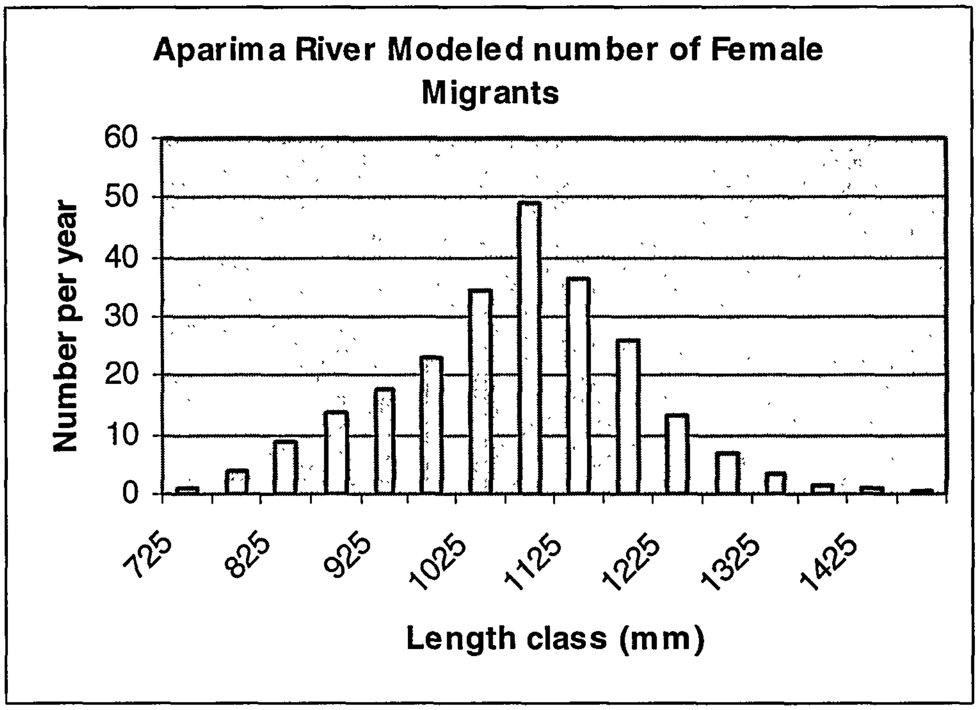

Figure 12: Modeled length frequency of migrating female longfinned eels in the Aparima River

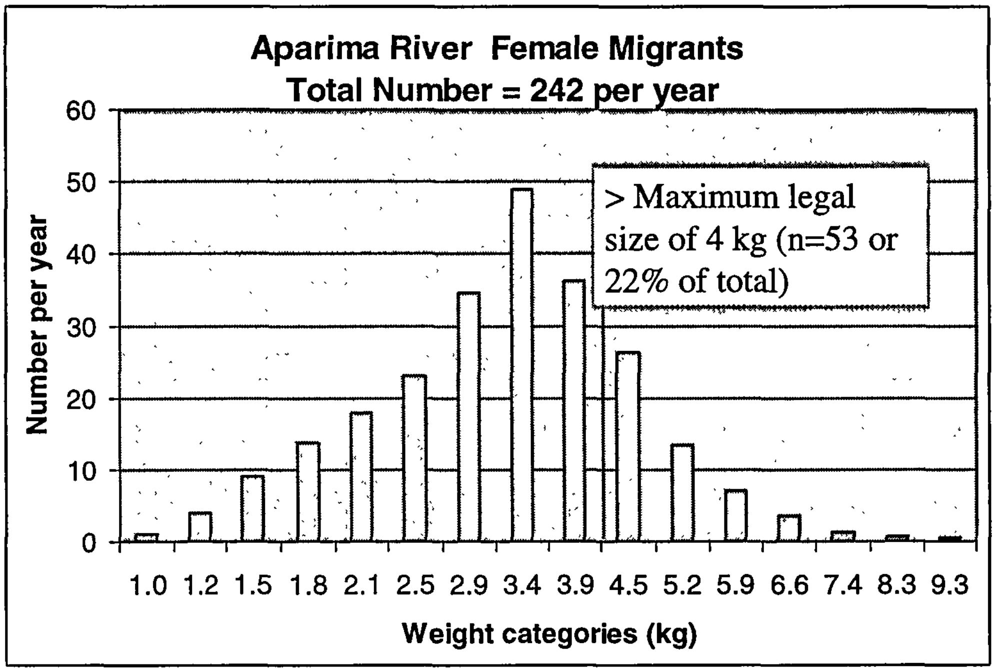

Figure 13: Modeled weight frequency of migrating female longfinned eels in the Aparima River