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NEW ZEALAND FRESHWATER FISHERIES MISCELLANEOUS REPORT NO. 55

EVIDENCE ON THE FISHERIES STATUS OF LAKE WAAHI, PREPARED FOR A HEARING IN RESPECT OF WATER RIGHT APPEALS 673 AND 1083/89

by

J.W. Hayes

Prepared on behalf of Kingett, Mitchell and Associates Ltd
for Coal Corporation of N.Z. Ltd

Freshwater Fisheries Centre

MAF Fisheries

PO Box 8324

CHRISTCHURCH

Servicing freshwater fisheries and aquaculture

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NEW ZEALAND FRESHWATER FISHERIES MISCELLANEOUS REPORTS

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Enquiries to: The Librarian
Freshwater Fisheries Centre
PO Box 8324
Riccarton, Christchurch
New Zealand

IN THE MATTER of the Water and Soil Conservation Act 1967

A N D

IN THE MATTER of two appeals under section 25 of the Act

BETWEEN WATCHDOG (WAIKATO) INCORPORATED AND MARUIA SOCIETY INCORPORATED (Appeals 673 and 1083/89)

Appellants

A N D THE WAIKATO REGIONAL COUNCIL (as successor to the Waikato Catchment Board)

Respondent

A N D COAL CORPORATION OF NEW ZEALAND LIMITED

Applicant

EVIDENCE OF JOHN WILLIAM HAYES

1. INTRODUCTION

1.1 I hold degrees in Bachelor of Science (Honours) in Zoology and Doctor of Philosophy in Zoology from Canterbury University. I have studied freshwater fish for the past 10 years and have been employed by the Freshwater Fisheries Centre, MAF Fisheries, for 6 years. I have specialised in salmonid ecology and also have experience with fish habitat modelling and fisheries environmental assessment. Since 1987 I have studied Lake

Waahi in an attempt to determine the impact of suspended solids and loss of submerged macrophytes on the fish community.

2. SCOPE OF EVIDENCE

2.1 In my evidence I will review the fisheries status of Lake Waahi for the period 1978 to the present. I will focus on the response of the fish community to suspended solids and turbidity which has characterised the lake since 1978. Finally I will describe the present status of the fish community in Lake Waahi in the light of recent sampling, and also the long term fishery management implications for the lake.

2.2 Four studies describe the fish and fisheries of Lake Waahi after 1978. These are Kingett (1984), Northcote and Ward (1985), Ward, Northcote, and Chapman (1987) and a study by myself carried out from 1986 to the present which is not yet published. A further study in Chapman, Lasenby and Hayes (1988) provides useful information on mysid shrimp - fish interactions in Lake Waahi.

3. FISH AND FISHERIES OF LAKE WAAHI

3.1 17 species of fish have been recorded from Lake Waahi but only 9 major species form the fish community (Table 1). All of the native species migrate to and from the sea whereas 6 of the 7 exotic species are lake resident.

3.2 Commercial and recreational fisheries exist for mullet and eels and the latter species are valued by the Maori people. The lake is a significant rearing environment for whitebait and smelt which contribute to the lower Waikato whitebait fishery, one of the largest in the country. The exotic fish species have little fisheries value. Catfish are a bycatch of the eel fishery and are processed into pet food, and recently koi have begun to be taken by bow hunters.

4. HISTORICAL STATUS OF THE LAKE WAAHI FISH COMMUNITY

4.1 The most obvious impact of elevated suspended solids and loss of macrophytes on fish has been the disappearance of a lake resident form of common smelt from the lake. This has been documented by Northcote and Ward (1985), Ward, Northcote and Chapman (1987) and is also mentioned by Kingett (1984).

4.2 Kingett (1984) and Ward, Northcote and Chapman (1987) document a serious deterioration in the eel fishing during 1979-1980 following a brief boom in the fishery immediately after the lake became turbid and macrophytes collapsed. Initially the loss of submerged macrophytes allowed greater and more efficient harvesting of the eels resulting in greatly increased catches. Thereafter the catch, along with the size and condition of the eels, declined into the early 1980's. By 1987 the eel fishery appeared to have recovered.

4.3 Until my study began in 1987 the only information available on how other species of fish were coping in the turbid environment of Lake Waahi was that of Ward, Northcote, and Chapman (1987). They found no evidence of any drastic change in fish species diversity in the lake since the mid 1970s.

Comparison of the fish communities of Lakes Waahi and Whangape

4.4 My study considered the entire fish community of Lake Waahi. It examined species richness, and catch per unit effort (CPUE) (total weight (g) of each species caught/net/hour), size and condition of the 9 major species (Table 1) forming the community. It also examined the diet of eels, common bully common smelt, and mosquitofish. For comparison I gathered the same data from nearby Lake Whangape which at the time was the only large shallow lake, linked with the lower Waikato River, that was still relatively clear and had submerged macrophyte beds intact. A comparison of this kind is the best alternative to a pre- and post-impact study design, which was not possible for Lake Waahi because comparative pre-impact data were not available.

4.5 Fish sampling was done quarterly at 4 sites in Lake Waahi and in the main body of Lake Whangape and at 3 sites in the turbid south arm of Lake Whangape. Gill nets and large fine mesh trap nets were set at 3 positions each progressively offshore. For diet analysis, 50 common bullies, common smelt, and mosquitofish were collected by beach seining around the shores of both lakes on 10 December 1987. Diet analysis was also carried out on 149 and 159 eels from Lakes Waahi and Whangape respectively. The eels were taken from fyke and trap net samples throughout the year. Diet was analysed by the number, occurrence, and points methods (Hynes 1950). With the points method, stomachs are allocated a fullness score between 1 and 10 and the contribution that each food category makes to that score is subjectively determined.

4.6 Lake Waahi had similar overall species richness (number of species caught at each site) and the same 9 major species as Lake Whangape. The only significant difference in overall species richness between the lakes was the absence of the lake resident form of common smelt in Lake Waahi.

4.7 In addition to fish, significant quantities of mysids, Tenagonmysis chiltoni were caught in the trap nets. These are small shrimp like crustaceans which my studies have shown to be an important food of carnivorous fishes especially in Lake Waahi. This data will be presented later but is introduced here because mysids are included in the analyses of CPUE which I will now address.

4.8 Overall differences in CPUE between Lakes Waahi and Whangape were found for mysids and four species of fish (Table 2). Lake Waahi produced significantly larger catches of mysids, common bullies, rudd, and goldfish greater than 140mm, but smaller catches of inanga, and goldfish smaller than 140 mm than Lake Whangape.

4.9 CPUE of migratory species such as inanga, and also common smelt and grey mullet, in Lake Waahi may have been artificially depressed because the water control structure on the Waahi Stream appeared to impede migration of these species into the lake.

4.10 Condition for 8 species of fish is compared between Lakes Waahi and Whangape in Table 3. Condition is believed to be a good indicator of the general 'well-being or fitness' of fish. Most fish were in better condition in Lake Waahi than in Lake Whangape. These included shortfinned eels, inanga, mosquitofish, goldfish greater than 140mm, catfish, and grey mullet. Condition of common bullies was more dependent on season. In February 1987 bullies were in better condition in Lake Waahi than in Lake Whangape but the reverse occurred in August and November. These differences may be related to different seasonal patterns in bully condition between the lakes or it may be due to an increase in the biomass of mysid shrimps, a major prey for bullies, which occurred during the winter in Lake Whangape.

4.11 Although overall mean CPUE for eels was not significantly different between the lakes, the total catch was 1.7 times larger in Lake Waahi than in Lake Whangape (Table 4). (The total catch, being a cumulative measure, gives an idea of annual yield from each lake.) Furthermore the percentage of commercially marketable eels in the catch was greater in Lake Waahi. The legal size limit on eels is 150g but there is a voluntary limit imposed by the local Waikato eel processor of 220g. Eels heavier than 150g and 220g were 1.1 and 1.5 times greater, respectively, in my catches in Lake Waahi than in Lake Whangape. This arose largely because of the better condition of eels in Lake Waahi.

4.12 Mysids were a major item in the diets of common bullies, common smelt, mosquitofish, and eels in Lake Waahi and in the turbid south arm of Lake Whangape (Figs. 1-8). Although generally of less importance in the diets of fish in the clearer, weedy main basin of Lake Whangape, mysids still contributed significantly to the diets of common smelt, common bullies, and shortfinned eels.

4.13 Chapman, Lasenby and Hayes (1988) found that high mysid biomass was generally associated with turbid lakes in the Waikato basin, and it was particularly high in Lake Waahi.

Comparison with past studies

4.14 Comparison of my 1987-1988 results with those of past studies done during the macrophyte phase in Lake Waahi provide additional evidence to determine the effect of turbidity on fish.

4.15 Over the period 1974 to 1978 studies were carried out on common bullies (Stephens 1982), common smelt (Northcote and Ward 1985), and mosquitofish (Wakelin 1986). Differences in sampling preclude comparisons of CPUE with my study, but some conclusions on comparative condition and size of fish can be inferred from these studies.

4.16 The natural log length-weight relationship for mosquitofish in 1987 had a greater slope (b) and a more negative intercept (a) than in 1977 when Wakelin did his study (1987 a = -13.00, b = 3.38; 1977 a = -12.09, b = 3.14

(samples for both periods were corrected for preservation in 105 formalin). This suggests that condition of the larger mosquitofish (greater than 25 mm) had improved between 1977 and 1987. The mean size of mosquitofish in 1987 also appeared greater than in 1977. Wakelin found few fish greater than 40 mm and none greater than 44 mm whereas such fish contributed substantially to my samples with some up to 53 mm being recorded.

4.17 Common bullies appeared to grow larger (possibly to a greater age) in 1987 than during the macrophyte phase. Maximum size of bullies recorded in 1976 was 62 mm (Stephens 1982) compared with 93 mm in 1987. Also the proportion of fish greater than 50 mm (older than 2 years) in combined trap net and beach seine samples from 1987 was much greater than in beach seine samples from 1976. Some of the difference between Stephens' and my results may be attributed to different sampling gear as trap nets tend to catch a greater proportion of larger bullies than do beach seines. However, Mitchell (1986) observed similar changes in size of common bullies in Lake Parkinson after macrophyte removal by grass carp and the associated decline in water clarity.

4.18 Migratory common smelt greater than 90 mm were also much more numerous in samples taken in 1987 than in samples taken between 1975 and 1977 by Northcote and Ward (1985). In fact these authors recorded this size shift in smelt as early as 1980, soon after Lake Waahi went turbid. Again, Mitchell (1986) recorded this phenomenon in a remnant population of lacustrine smelt in Lake Parkinson.

Synthesis of the Lakes Waahi and Whangape fish communities study

4.19 The above results show that in 1987-88 Lake Waahi, despite being turbid and devoid of extensive submerged macrophyte beds, supported a vigorous fish community and a good eel fishery which in many respects appeared superior than in the clearer Lake Whangape.

4.20 In a review of the effects of suspended solids and sediment on warmwater fishes, Muncy et al, (1979) found that the population level responses to this pollutant vary considerably between species. Advanced life stages are usually quite tolerant of direct toxic effects while the most sensitive stages occur during incubation and larval development. Among the fishes which most benefit from elevated suspended solids are those with pelagic eggs or larvae which are largely unaffected by bottom siltation and enjoy reduced susceptibility to predation in turbid waters. At the opposite extreme, the least tolerant species are those whose eggs and larvae develop on or in the substrate and which are not guarded and fanned by the parents. The early developmental stages of such species are particularly vulnerable to suffocation through siltation.

4.21 Most members of the fish community of Lake Waahi and other lakes in the lower Waikato basin, appear well adapted to cope with, or to avoid, the direct toxic effects of suspended and settleable solids on sensitive egg and larval stages. The only fish not so adapted, the lake resident form of common smelt, has died out in Lake Waahi.

4.22 The lake resident form of the common smelt scatters its eggs on the bottom where they would be particularly sensitive to suffocation by siltation. The migratory form of common smelt, along with inanga, grey mullet, and eels avoid any adverse effects of suspended and settleable solids on the critical stages of early development by spawning and undergoing larval development outside of the lake environment, either in the Waikato River or at sea. The remaining lake resident species all either spawn on emergent plant stems and thereby avoid bottom siltation or they exhibit some form of parental protection such as egg fanning.

4.23 Loss of cover and food once provided by submerged macrophytes appeared to have been compensated for by increased turbidity and an associated increase in the biomass of mysids. The unspecialised dietary requirements of many of the fish, particularly of the native species, has allowed them to take advantage of this abundant food resource.

5. PRESENT STATUS OF THE LAKE WAAHI FISH COMMUNITY

5.1 In late 1989 I was commissioned by Coal Corp to assess the current status of the Lake Waahi fish community and to compare this with the historical database. In February 1990 the fish community of Lake Waahi was sampled with trap nets and gill nets in the same manner as in 1987-1988. Species richness, condition and CPUE, for the major species, were compared between February 1987 and February 1990.

5.2 Species richness in Lake Waahi has not changed significantly since 1987. However some exotic species are now caught more frequently. These include koi, rudd, and possibly tench.

5.3 CPUE for February 1987 and February 1990 is compared in Table 5. Comparison of CPUE for mysids indicates that the mysid population in Lake Waahi has collapsed since 1987. CPUE for mosquitofish now appears to be significantly lower than in February 1987 but CPUE for rudd has increased dramatically by about 30 times.

5.4 Condition of species in February 1987 and February 1990 is compared in Table 6. Condition of shortfinned eels, common bullies, and inanga all show measurable declines since February 1987. The reduction in condition of eels between February 1987 and February 1990 is considerable. Condition of eels in Lake Waahi never got as low at any time during 1987. The value recorded in February 1990 is actually more similar to those recorded in Lake Whangape during 1987. Similarly, the condition of inanga in Lake Waahi in February 1990 is more similar to the low value recorded in Lake Whangape in 1987. However, the reduction in condition of common bullies between February 1987 and February 1990 is less likely to indicate a general decline. The condition of bullies in February 1990 is similar to that recorded in Lake Waahi in May 1987. Changes of this magnitude for bullies may occur seasonally. Alternatively the lower condition in 1990 may be related to the population being twice as large in February 1990 than in February 1987, as indicated by the comparative CPUEs for these times (Table 5).

6. SUMMARY

6.1 Without a long term data base it is difficult to determine with certainty whether the differences observed between February 1987 and February 1990 represent real changes in the fish community of Lake Waahi. Ideally annual variability in fish populations needs to be understood before any longer term trend can be detected.

6.2 My results from 1987 and February 1990 should be considered as "snap shots" of a dynamic fish community. Thus the differences observed between these times should be interpreted with caution.

6.3 With this in mind some differences in the fish community between February 1987 and February 1990 may be related to mysid population dynamics in Lake Waahi. Evidence from our 1987 survey and that of Chapman, Lasenby, and Hayes (1988) suggests that mysids are generally associated with turbid water in the lower Waikato basin and they were particularly abundant in Lake Waahi in 1987. During that year mysids were a prominent item in the diets of several species of fish in Lake Waahi, including shortfinned eels, common bullies, common smelt, mosquitofish, and probably also inanga since the latter species also feeds on invertebrates.

6.4 I concluded from my 1987 study that the food chain in the lake had been simplified as a result of turbidity, with energy being channelled through mysids to carnivorous fish species. Although at the time this situation seemed beneficial to such fish I suggested that it might destabilise carnivorous fish populations by making them vulnerable to fluctuations in mysid biomass. I speculated that if water clarity improved the mysid population might collapse, owing to fish predation, which might then adversely affect carnivorous fish species. The results of the February 1990 survey are consistent with this hypothesis. Mysids do appear to have collapsed and some fish species that were exploiting them have declined in condition; these include shortfinned eels, and inanga, and possibly common bullies. However, to move beyond speculation, the relationship between water clarity, mysid abundance, and fish predation needs to be understood.

6.5 The increase in the rudd population is difficult to explain. This species also probably preys on mysids as it is omnivorous generally feeding on invertebrates and plant material. It may have responded to temporary improved feeding efficiency on mysids if water clarity has improved and, as this species lays its eggs on aquatic vegetation, it may have experienced improved spawning success if aquatic macrophytes are recovering.

6.6 Despite the uncertainty over recent changes in the fish community of Lake Waahi, there is no indication of major change since 1987. The lake continues to support a diverse fish community of similar structure to that present in 1987, and species biomasses (as measured by CPUE) have remained high.

7. IMPLICATIONS FOR FUTURE FISHERIES STATUS OF LAKE WAAHI

7.1 In the long term Lake Waahi can be expected to continue to support a diverse and productive fish community, providing access for migratory fish is maintained. As I have already stated most members of the fish community that inhabit the lower Waikato, including Lake Waahi, are well adapted to cope with turbid water. By the standards set by Alabaster & Lloyd (1982), the suspended solids concentration and turbidity in Lake Waahi, which is 20-40 g m^{-3}, is low to moderate. Therefore it shouldn't be surprising that these lowland fish species, which probably are adapted to sluggish relatively turbid water, cope well with these conditions.

7.2 Obviously however, the tolerance of these fish to turbidity and suspended solids is finite. Inanga are the only species of native fish for which there exists data on tolerance to suspended sediment. Ingram & Boubee (1990) found that inanga will avoid turbid water. They begin to do so as turbidities approach 100 NTU and 75% of inanga would be expected to avoid turbidity of 360 NTU. Inanga are unlikely to avoid Lake Waahi water to a significant degree as turbidity in the lake is usually less than 70 NTU with a median of 25 NTU (Waikato Valley Authority 1987).

7.3 If the turbidity of Lake Waahi increased, which is now unlikely, its effect on the fish populations would probably be indirect through the lowering of primary productivity - resulting in reduced growth and condition of species.

7.4 A more likely scenario is a gradual clearing of the lake with re-establishment of aquatic macrophytes. Ultimately the fish would probably adjust to these conditions and form a fish community and fishery similar to that occurring before 1978, heavily dependent on the macrophytes and their accompanying invertebrate fauna. However, it is uncertain whether or not lacustrine smelt would re-establish without human intervention. In the interim, as the lake clears but before aquatic macrophytes dominate the lake once more, carnivorous fish species may experience a shortage of food. If fish predation is a major factor controlling the mysid populations then clearer water will promote more efficient feeding by fish on this prey. This could cause a collapse of the mysids population, which may already have occurred, and the remaining biomass of mysids would be insufficient to support the present biomass of fish without alternative foods becoming available. As a result the eel fishery would likely suffer a temporary decline.

<u>Future management and monitoring</u>

7.5 It is now known that apart from lacustrine smelt, the fish community of Lake Waahi is robust and well adapted to both clear and moderately turbid conditions. Consequently as the water clarity in the lake is unlikely to deteriorate further, with the reverse more likely, there should not be cause for concern over the long term response of the fish to water clarity. Fish populations may decline in the short term as mentioned previously but this may be inevitable as water managers seem committed to improving water clarity in the lake.

7.6 Continued monitoring of mysids and fish would aid understanding of the relationships between water clarity, mysid biomass and fish populations but it would be of more direct benefit in determining if migratory fish are having difficulties entering Lake Waahi and in determining the effect of any changes to management of the eel fishery in the future.

The latter two issues are now discussed in detail.

Migration of fish into Lake Waahi

7.7 Historically the flood gates at Te Ohaaki Road on the Waahi Outlet Stream have impeded fish migration, particularly for common smelt (eg Ward et al 1987) and possibly also for grey mullet and other species. Recently a rock rubble weir was installed downstream of the Te Ohaaki Road flood gates to improve fish access through the gates, and a further weir is proposed at the lake outlet to control the level of Lake Waahi. The effect of these weirs on fish migration into Lake Waahi has been carefully assessed by Meredith (1990). Theoretical and practical studies suggest that the Te Ohaaki weir will improve fish migration through the floodgates and theoretical studies of the proposed lake margin weir suggest that it is unlikely to significantly impede fish migration.

7.8 Common smelt, inanga, and grey mullet are the migratory species most susceptible to obstruction to migration. I examined the length frequencies for these species sampled in Lake Waahi in February 1990 and found no evidence for impeded migration. Disruptions to immigration could be one of size selective immigration or intermittent immigration. The former could result in skewed or bimodal length frequency distributions and the latter would result in bimodal distributions and a larger mean size of lake fish versus that of Waikato River fish.

7.9 The length frequency distributions for Lake Waahi common smelt and inanga in February 1990 were both approximately normal (Fig 9) suggesting no size selective immigration.

For smelt this is in contrast with the length distribution recorded in 1983 by Ward et al (1987) who found the length distribution skewed toward fish larger than 70 mm. They found few fish smaller than 70 mm in the lake whereas such fish were common in the outlet below the flood gates. Smelt smaller than 70 mm were common in Lake Waahi in February 1990.

7.10 Although the length distribution for mullet is skewed toward larger fish this pattern is also characteristic for mullet sampled in summer by gill netting in the Waikato River (Jacques Boubee, personal communication) (Fig 10). This suggests that mullet were able to access Lake Waahi successfully during the summer of 1990.

7.11 The combined effect of the weir and flood gates on fish migration would be most severe when river levels are at their lowest.

The Eel Fishery

7.12 There have been complaints that the traditional Maori fishery for migratory eels in the Waahi Stream near the Waahi Marae has deteriorated in recent years. The reason for this decline is unlikely to be related to water quality in Lake Waahi as my studies have found that eels in particular have coped well with the turbid environment of Lake Waahi. My results indicate that eels are abundant, growing well and are in good condition in Lake Waahi.

7.13 The main reason for the decline in the traditional Maori fishery for migrant eels in the Waahi Stream is no doubt commercial eel fishing. Lake Waahi has experienced heavy fishing pressure for eels in the last 20 years and there are now few eels larger than the commercially marketable size of 220 g in the lake. Figure 11 shows this clearly. Male shortfinned eels in the Waikato migrate to the sea at about 200 g and female shortfins at about 800 g. However, before most eels can reach this weight they are harvested by the commercial eel fishery.

7.14 In the past before commercial eel fishing the biomass of eels in the Waikato, including Lake Waahi, would have been dominated by fish heavier than 200 g with fish greater than 800 g being common. The numbers of migrants leaving the population each year would have been very large and would have allowed impressive catches to be made by Maori fisherman.

7.15 If the traditional Maori fishery for migrant eels in the Waahi Stream is to return to something of its former self the eel fishery in Lake Waahi will need to be managed to a much greater degree than at present.

7.16 The issue of how to achieve Maori involvement in the eel fishery nationwide is presently being considered by MAF in a review of management of New Zealand's eel fishery.

7.17 Continued monitoring of the eel population of Lake Waahi would allow the success of any management initiatives to be assessed. If monitoring included mysids and small fish species the interactions between water clarity and abundance of eel prey could be distinguished from the effect of any management initiatives on the eel fishery.

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TABLE 1. Fish species recorded from Lake Waahi. (Species that are major components of the fish community are in bold.)

Species	Migratory	Lake resident
NATIVE		
Shortfinned eel, *Anguilla australis*	*	
Longfinned eel, *Anguilla dieffenbachii*	*	
Common bully, *Gobiomorphus cotidianus*	*	*
Common smelt, *Retropinna retropinna*	*	
Inanga, *Galaxias maculatus*	*	
Giant kokopu, *Galaxias argenteus*	*	
Koaro, *Galaxias brevipinnis*	*	
Grey mullet, *Mugil cephalus*	*	
Lamprey, *Geotria australis*	*	
EXOTIC		
Mosquitofish, *Gambusia affinis*		*
Catfish, *Ictalurus nebulosus*		*
Goldfish, *Carassius auratus*		*
Rudd, *Scardinius erythrophthalmus*		*
Koi, *Cyprinus carpio*		*
Perch, *Perca fluviatilis*		*
Tench, *Tinca tinca*		*
Brown trout, *Salmo trutta*	*	

TABLE 2. Mean CPUE+1 (g/net/hr) ± SE of combined quarterly samples for nine species of fish and for mysids for Lakes Waahi and Whangape during 1987-88. (ANOVA P values for comparisons between the lakes - P <0.05 in bold; N = number of replicates per lake.)

Species	CPUE+1 Waahi	CPUE+1 Whangape	N	P
Mysid	14.0 ± 7,3	4.2 ± 2.2	48	**0.021**
Shortfinned eel	427.9 ± 157.7	313.9 ± 107.7	48	0.209
Common bully	59.8 ± 17.5	7.4 ± 2.4	48	**<0.001**
Common smelt	2.3 ± 1.1	3.4 ± 1.9	16	0.091
Inanga	1.3 ± 0.3	1.9 ± 0.6	16	**0.040**
Mosquitofish	2.5 ± 1.5	1.4 ± 0.4	16	0.955*
Goldfish <140 mm	1.0	1.3 ± 0.2	16	**<0.001**
Goldfish ≥140 mm	10.3 ± 3.6	5.2 ± 1.9	48	**0.016**
Grey mullet	23.4 ± 14.9	81.6 ± 35.0	48	0.097
Catfish	12.4 ± 5.7	6.7 ± 3.5	48	0.357
Rudd	2.9 ± 1.5	1.1 ± 0.2	16	**<0.001**

* heterogeneous variance - P for Mann Whitney U

TABLE 3. Condition factors ± SE for eight species of fish in Lakes Waahi and Whangape in 1987-88 and P values for tests of significance between lakes and location (t test or Mann Whitney U test significance levels (P < 0.05 in bold)).

	Condition factor				P
	N	Waahi	N	Whangape	
Shortfinned eel (>6 g)	222	0.120 ± 0.001	155	0.107 ± 0.001	**<0.001**
Common bully (≥20 mm)					
February	352	0.918 ± 0.009	337	0.848 ± 0.008	**<0.001**
May	58	0.859 ± 0.011	59	0.889 ± 0.012	0.057
August	102	0.992 ± 0.010	103	1.050 ± 0.010	**<0.001**
November	101	0.965 ± 0.012	102	1.020 ± 0.010	**<0.001**
Common smelt (≥50 mm)	255	0.223 ± 0.002	295	0.217 ± 0.002	0.106
Inanga (≥ 54 mm)	62	0.250 ± 0.005	269	0.228 ± 0.003	**0.001**
Mosquito fish (≥20 mm)	369	0.651 ± 0.007	228	0.578 ± 0.008	**<0.001**
Goldfish ≥140 mm)	94	1.358 ± 0.012	28	1.282 ± 0.028	**0.005**
Catfish	109	0.396 ± 0.006	136	0.349 ± 0.004	**<0.001**
Grey mullet	154	0.605 ± 0.005	273	0.566 ± 0.004	**<0.001**

TABLE 4. Weight (kg) of the total catch and the weight and percentage of eels greater than 150 g and 220 g (commercial grade) caught in Lakes Waahi and Whangape over the quarterly sampling periods in 1987-88.

Site	Total catch (kg)	Catch exceeding 150 g (kg)	%	Catch exceeding 220 g (kg)	%
Lake Waahi	645.174	219.623	34.0	80.115	12.4
Lake Whangape main body	376.396	115.580	30.7	31.627	8.4

TABLE 5. Mean CPUE + 1 (g/net/hr) ± SE for nine species of fish and for mysids from Lake Waahi for February 1987 and February 1990, including ANOVA P values for comparisons between years (n = 12) (P ≤0.05 in bold).

Species	CPUE February 1987	February 1990	P
Mysid	14.1 ± 6.0	0.1 ± 0.01	**0.005**
Shortfinned eel	1886.1 ± 257.0	1045.5 ± 207.9	0.075
Common bully	82.1 ± 14.9	171.1 ± 48.6	0.246
Common smelt	4.2 ± 1.8	2.4 ± 1.1	0.500
Inanga	1.1 ± 0.5	1.0 ± 0.4	0.882
Mosquitofish	9.4 ± 2.7	5.5 ± 2.3	0.051
Goldfish ≥140 mm	16.6 ± 5.0	19.8 ± 3.5	0.316
Grey mullet	181.0 ± 106.0	226.5 ± 53.7	0.198
Catfish	22.3 ± 4.8	28.4 ± 5.6	0.688
Rudd	2.6 ± 1.1	76.0 ± 17.8	**<0.001**

TABLE 6. Comparison of condition factors ± SE for six species of fish sampled in Lake Waahi in February 1987 and February 1990 (t test P values for comparisons between years (P ≤0.05 in bold).

Species	N	February 1987	N	February 1990	P
Shortfinned eel (>6 g)	65	0.115 ± 0.002	105	0.108 ± 0.001	**0.001**
Common bully ≥20 mm	352	0.918 ± 0.009	165	0.865 ± 0.011	**<0.001**
Common smelt (>50 mm)	154	0.214 ± 0.003	138	0.209 ± 0.002	0.430
Inanga (≥54 mm)	92	0.251 ± 0.004	70	0.231 ± 0.004	**0.005**
Mosquitofish ≥20 mm	291	0.821 ± 0.009	193	0.810 ± 0.010	0.431
Grey mullet	72	0.642 ± 0.006	58	0.646 ± 0.007	0.605

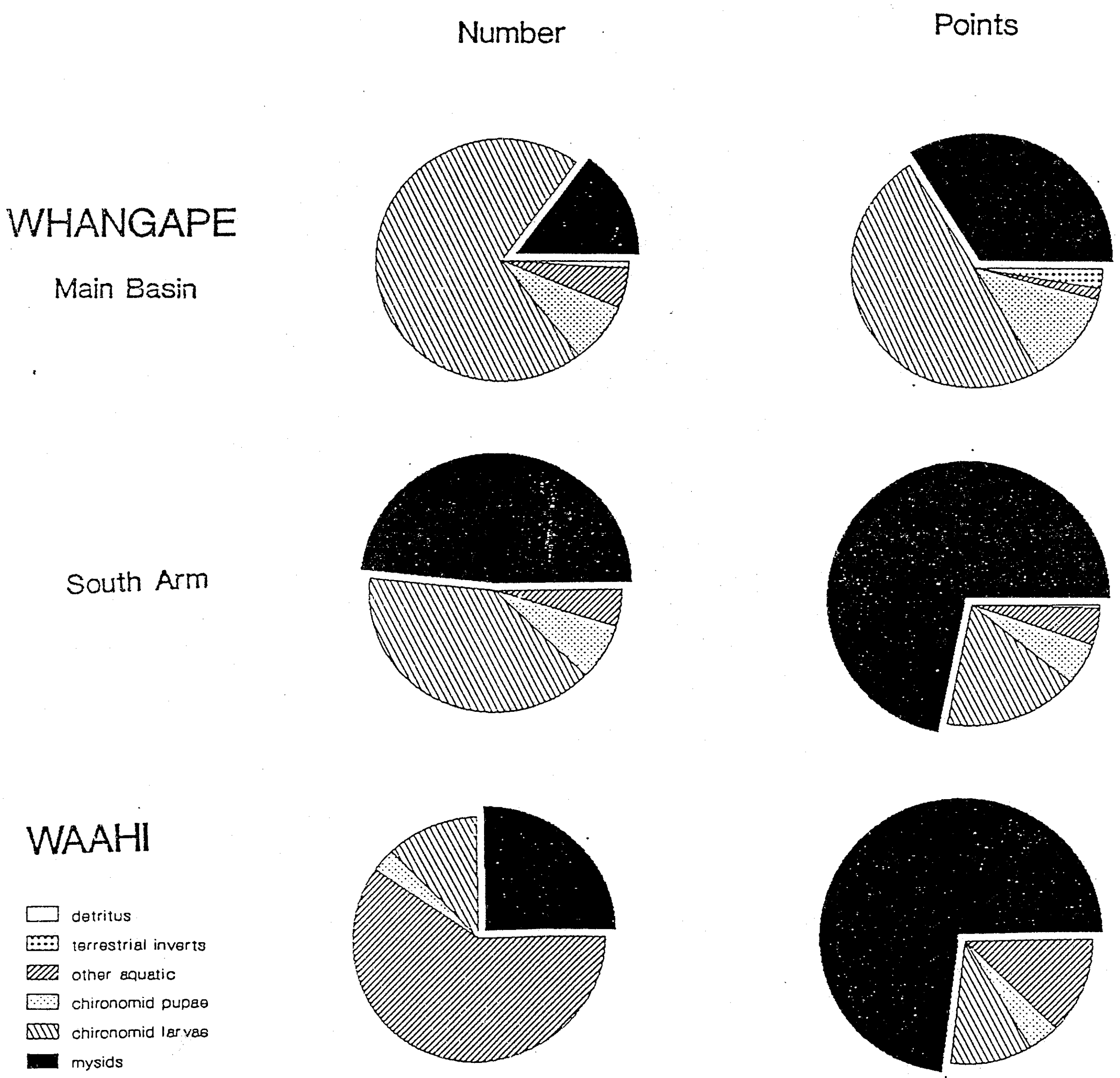

Figure 1 Percent by number and points for 6 food categories in the diet of common bullies from Lake Waahi and the main basin and south arm of Lake Whangape.

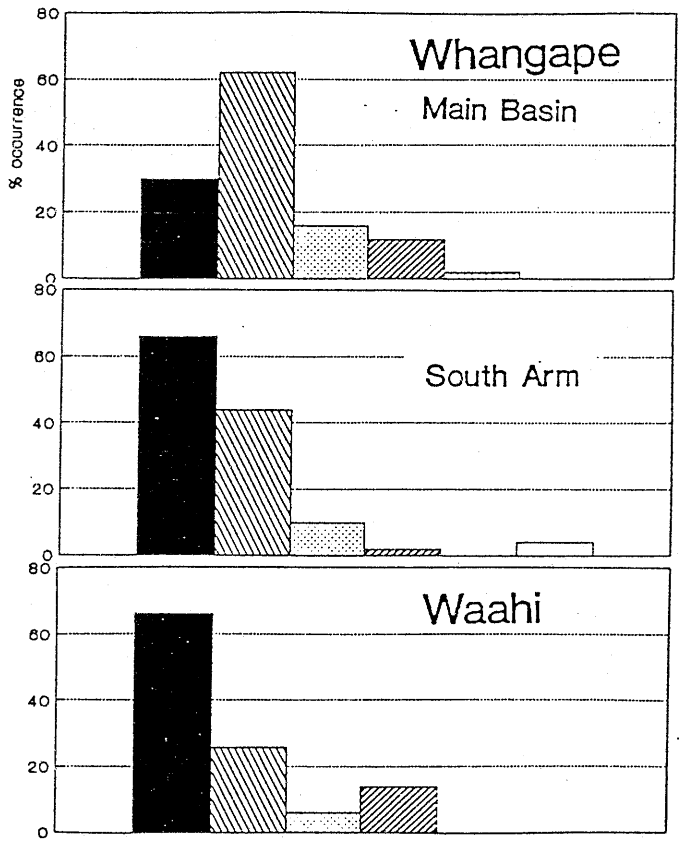

Figure 2 Percent occurrence for 6 food categories in the stomachs of common bullies from Lake Waahi and the main basin and south arm of Lake Whangape (use key in Figure 1).

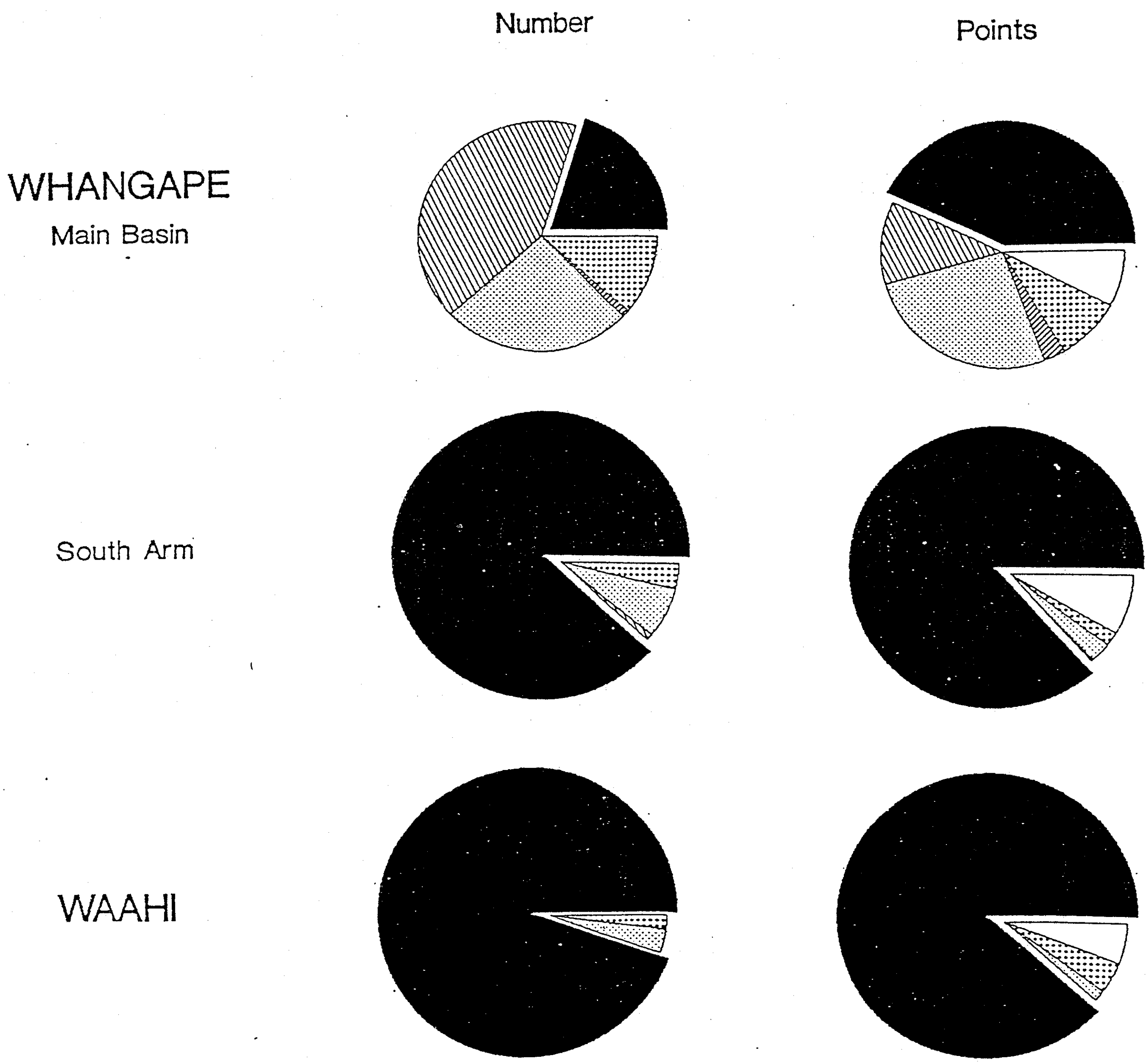

Figure 3 Percent by number and points for 6 food categories in the diet of common smelt from Lake Waahi and the main basin and south arm of Lake Whangape (use key in Figure 1).

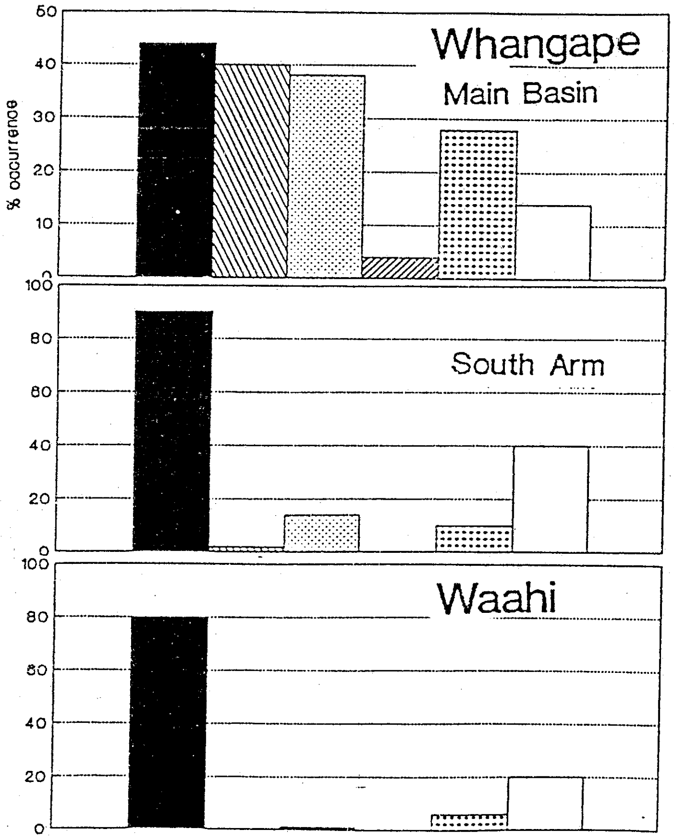

Figure 4 Percent occurrence for 6 food categories in the stomachs of common smelt from Lake Waahi and the main basin and south arm of Lake Whangape (use key in Figure 1).

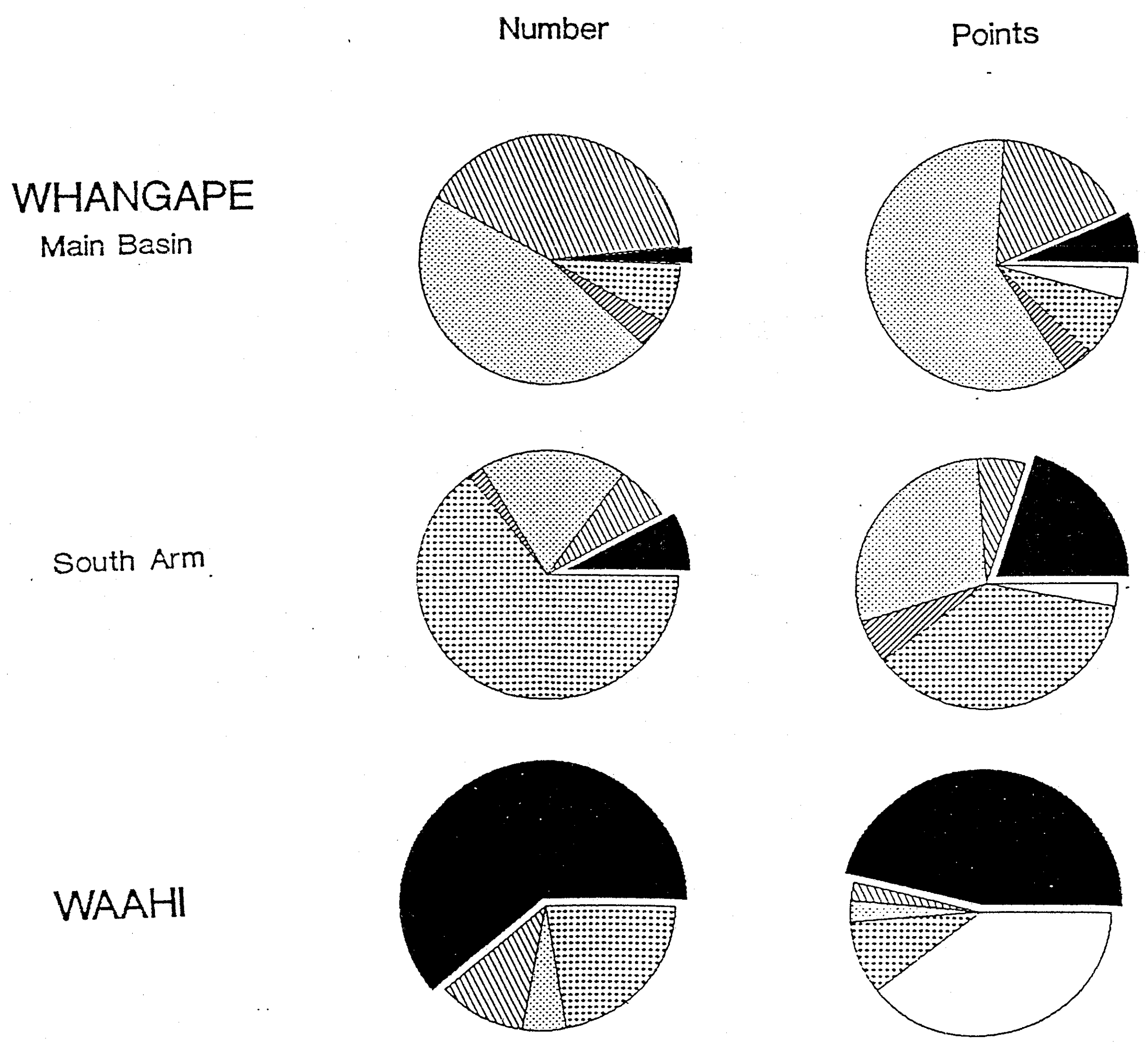

Figure 5 Percent by number and points for 6 food categories in the diet of mosquitofish from Lake Waahi and the main basin and south arm of Lake Whangape (use key in Figure 1).

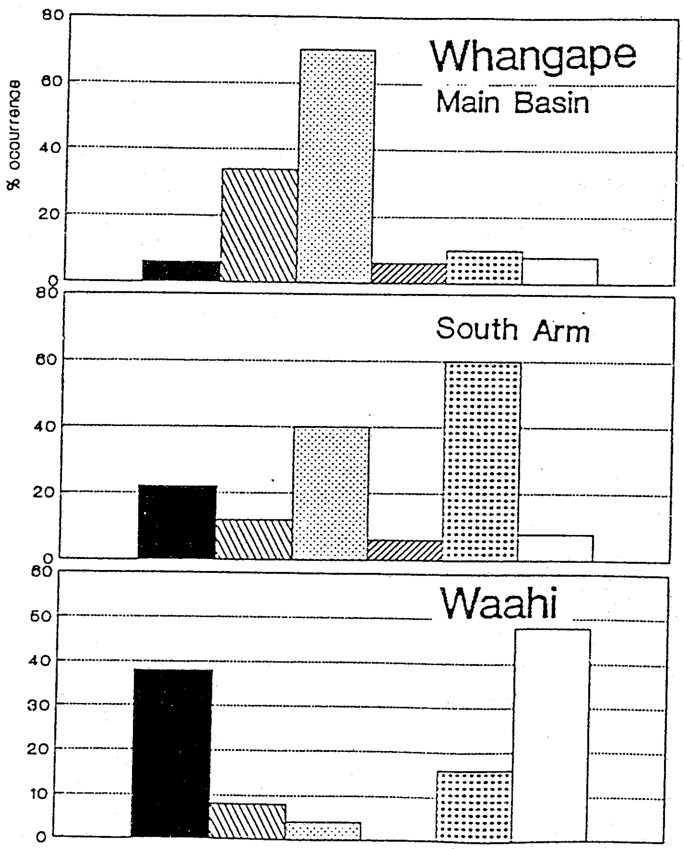

Figure 6 Percent occurrence for 6 food categories in the stomachs of mosquitofish from Lake Waahi and the main basin and south arm of Lake Whangape (use key in Figure 1).

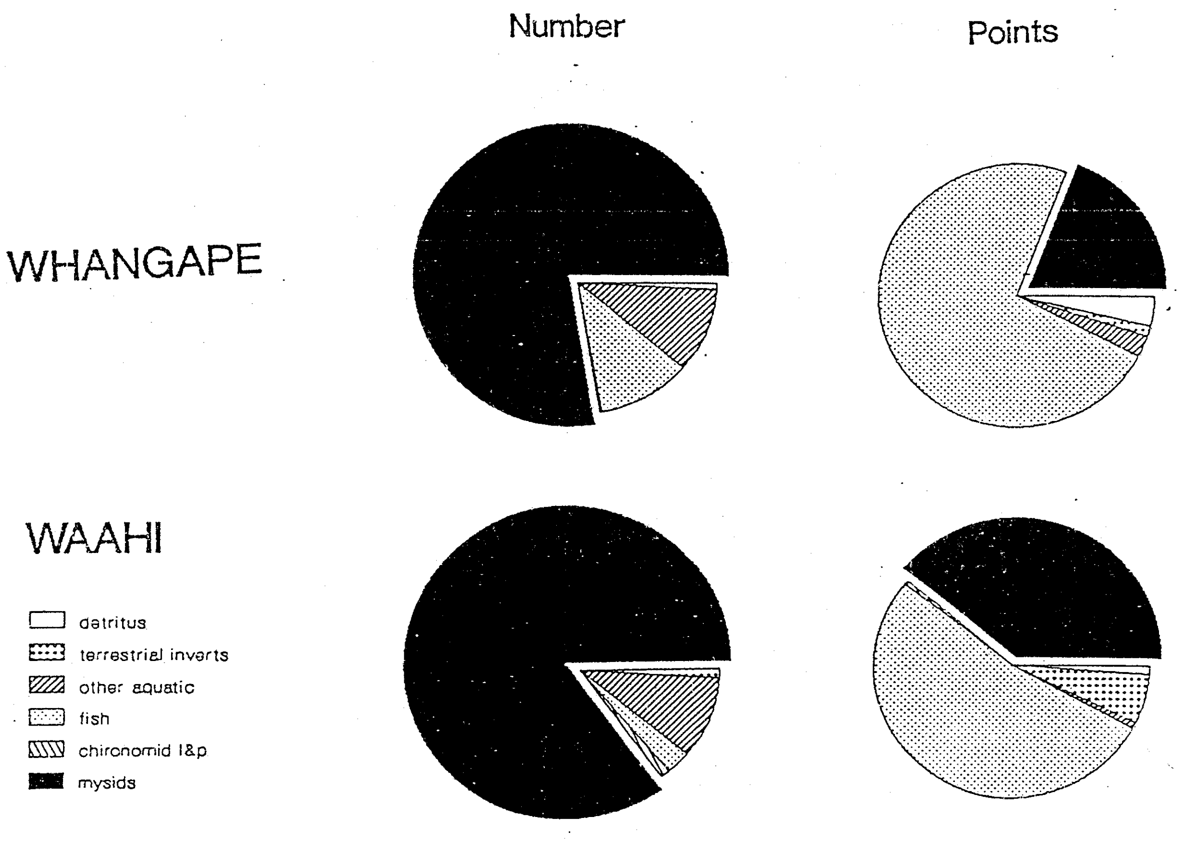

Figure 7 Percent by number and points for 6 food categories in the diet of shortfinned eels from Lakes Whangape and Waahi.

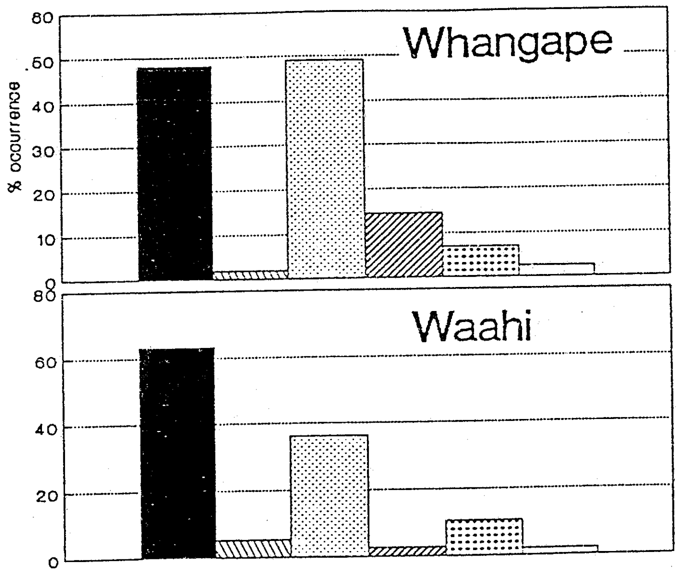

Figure 8 Percent occurrence for 6 food categories in the stomachs of shortfinned eels from Lakes Whangape and Waahi (use key in Figure 7).

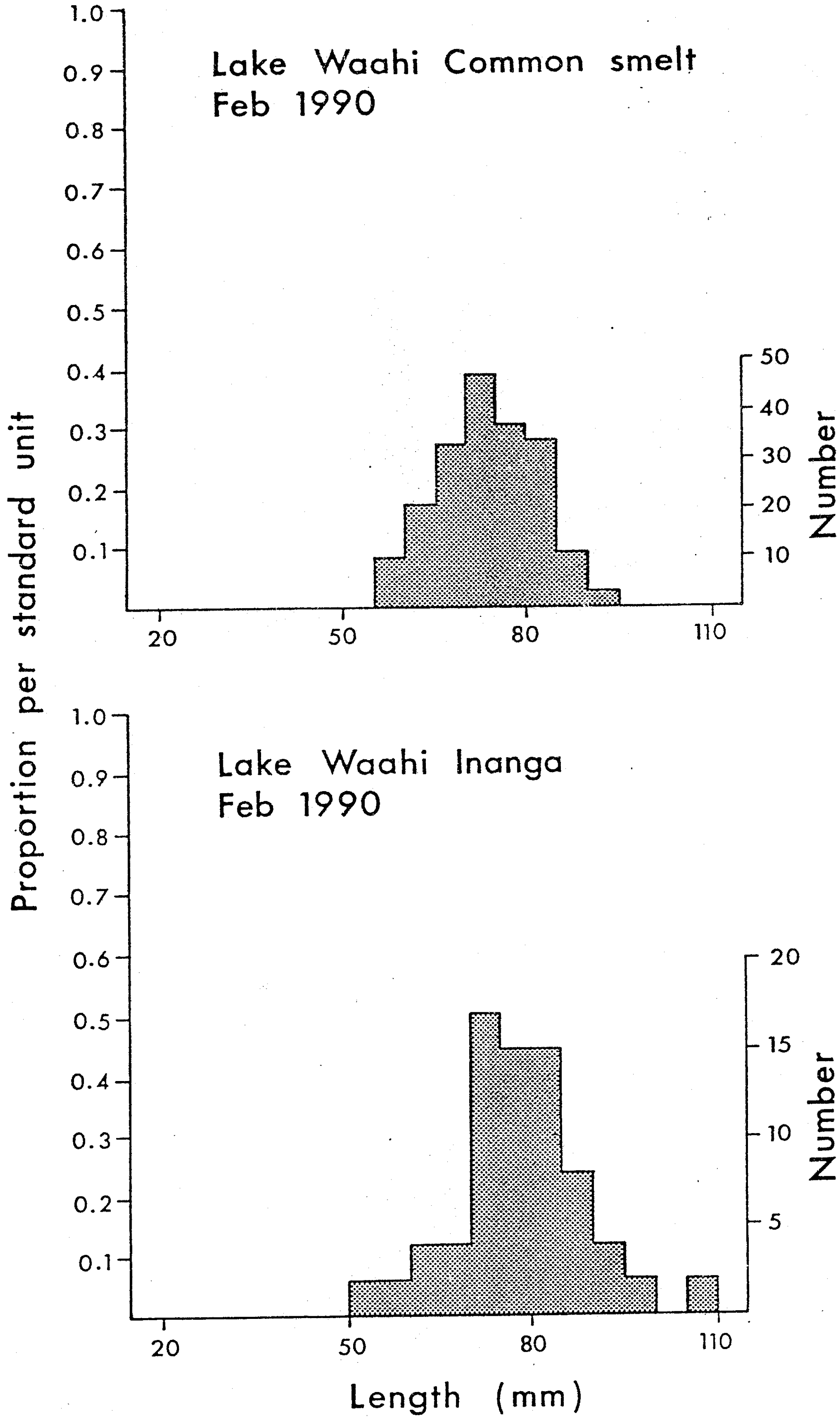

Figure 9. Length distributions of common smelt and inanga sampled by trap net from Lake Waahi in February 1990.

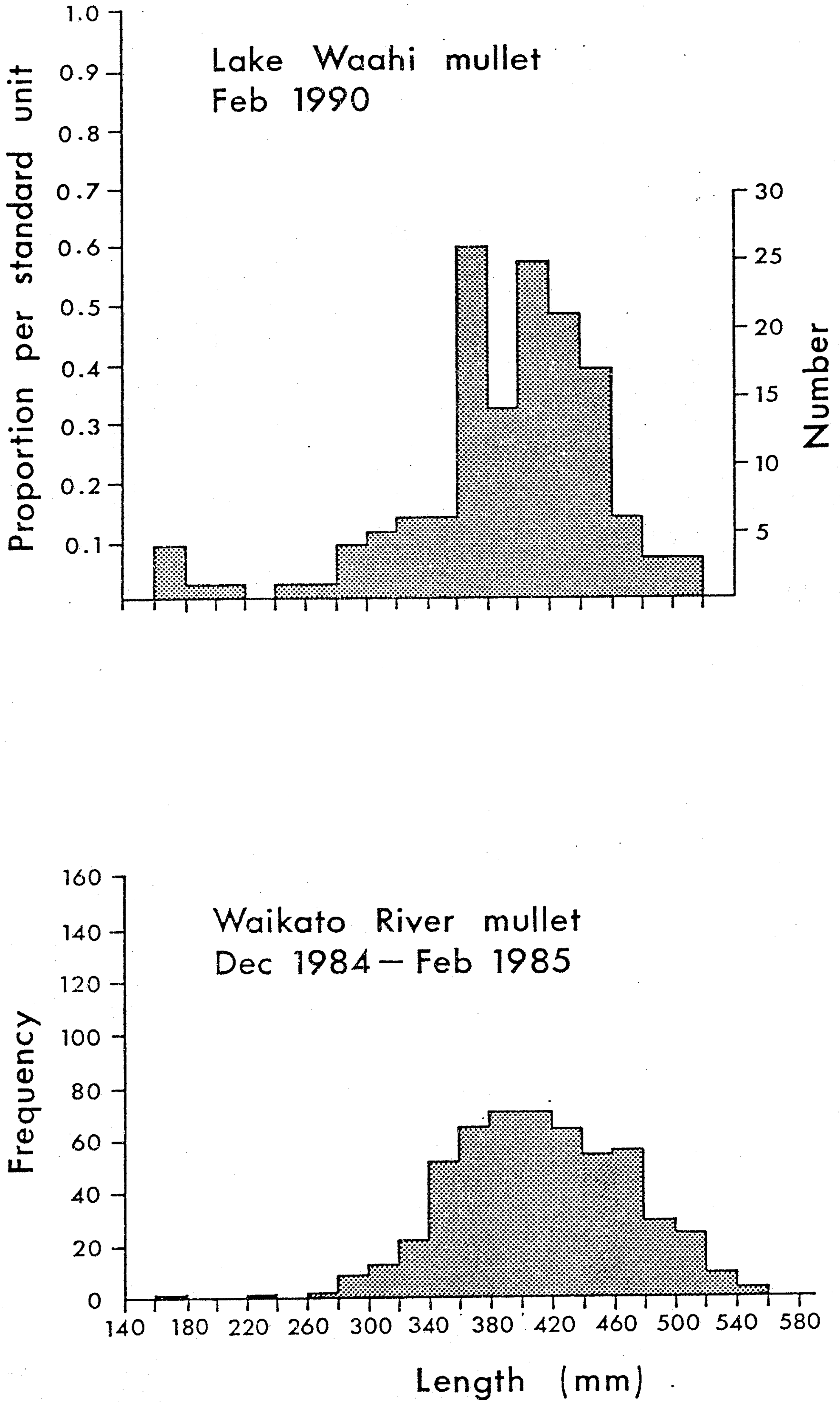

Figure 10. Length distributions of grey mullet sampled by gill net from the Lake Waahi in February 1990 and from the Waikato River during December 1984 and February 1985.

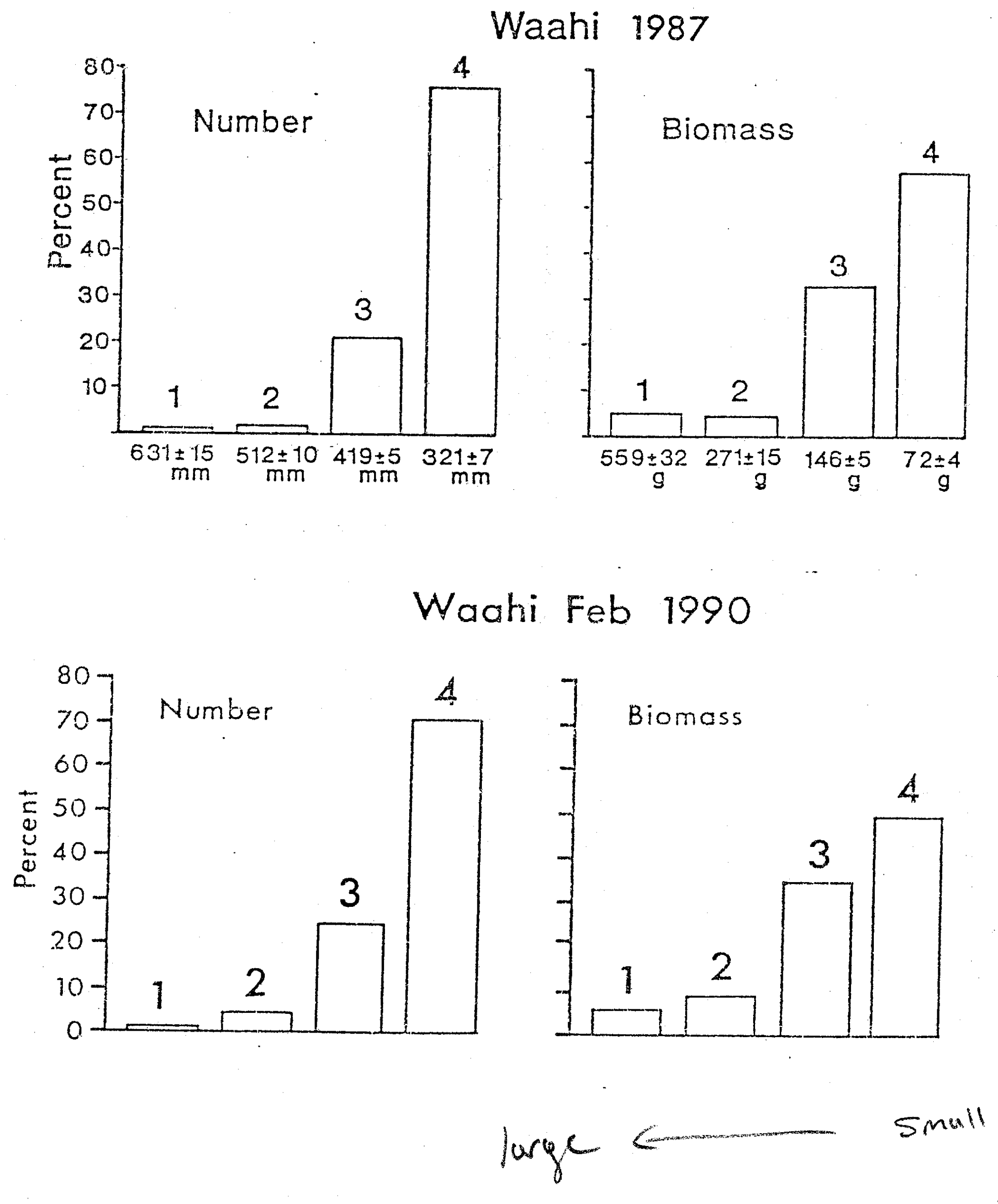

Figure 11. Percentage of shortfinned eels by number and by biomass in four size grades from samples taken from Lake Waahi in 1987 (N = 6768) and February 1990 (N = 2245).