Electrofishing survey of the fish community in the Whangamarino Wetland

CBER Contract Report 67

Client report prepared for
Department of Conservation

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Executive summary

A previous fish community survey carried out in the Whangamarino Wetland system recorded 18 different fish species by netting, electrofishing, and interviews with local eel fishermen and reports from Acclimatisation Society staff (Strickland, 1980). Strickland reported that the most widespread and common species in the wetland were shortfinned eels, mosquitofish, goldfish and catfish. In August 2007 and March 2008, the Centre for Biodiversity and Ecology Research (CBER) were contracted to carry out an electric fishing survey of the fish community in the Whangamarino Wetland and its tributaries. Boat and backpack electrofishing caught a diverse range of native and introduced fish. A total of 1,491 fish comprising 8 native fish species and 5 introduced fish species were caught in a total fished area of 26,600 m^2 or 2.66 ha from a total of 34 sites. Koi carp, shortfinned eels, goldfish and common smelt were the most widespread fish species throughout the wetland system. Fish distribution, density and biomass varied between sites throughout the Whangamarino Wetland as well as between the two different time periods (August 2007 and March 2008). Mean densities and biomasses of fish species at most sites increased substantially in March 2008 compared to August 2007.

Major changes in the fish community from October 1980 to August 2007 and March 2008 were the presence of koi carp and the decrease in numbers of catfish. No koi carp were discovered by Strickland in 1980 in his survey of the Whangamarino wetland whereas we found that koi carp were widespread and abundant throughout the Whangamarino wetland system, with mean densities of up to 6.1 fish 100 m^{-2} at some sites. Biomass is a more accurate reflection of the potential ecological impact of koi carp than their density and koi carp dominated the biomass at all of the sites in the Whangamarino wetland both in August 2007 (mean biomass ranging from 0.6 to 13.6 g m^{-2}) and March 2008 (mean biomass ranging from 9.7 to 85.7 g m^{-2}). Previous results suggest that 15-65% of the total population estimate is caught on the first removal, depending on the total number present (Hicks et al., 2006). As we fished over the area at each site only once, the estimates in this survey represent a minimum abundance, and true population sizes would be 1.6-6.5 times greater. Of ecological concern for the Whangamarino wetland system is the dominance of the fish biomass by introduced koi carp (74-92% of total fish biomass), which have a deleterious impact on aquatic habitats.

In 1980, before the construction of the weir in the Whangamarino River, Strickland found that populations of grey mullet were present in the lower reaches of the Whangamarino and Maramarua rivers. Due to high water levels in August 2007, grey mullet were found in the lower reaches of the Whangamarino and Maramarua rivers. However, in March 2007, grey mullet were only present below the weir in the Whangamarino River. A possible explanation for this is that the water levels had significantly dropped which exposed the weir and prevented fish passage to the Maramarua River.

1. Introduction

The Whangamarino Wetland, a listed Ramsar site (site no. 443), is the second largest bog and swamp complex in the North Island of New Zealand. It is located in the Waikato region 62 km south of Auckland and it includes 5,923 ha of peat bog, swampland, mesotrophic lags, open water and river systems. The wetland system is contained within three large shallow basins drained by the Maramarua and Whangamarino rivers and the Reao Stream (Reeves, 1994). The hydrology of the wetland has been impacted by numerous factors such as the instigation of the Lower Waikato-Waipa Flood Protection Scheme in 1961, sand extraction, hydro-power generation on the Waikato River and the development of land for agricultural purposes. The construction of a weir in 1993 was commissioned by the Department of Conservation (DOC) and Auckland/Waikato Fish & Game Council to reinstate a hydrological regime which offers a "wet/dry" seasonal cyle. The completed weir provides improved minimum water levels to over 2,000 ha of the Whangamarino Wetland system (Environment Waikato, 2008).

Eighteen species of fish have been recorded in the wetland by a number of different groups. In October 1980, Strickland from the Ministry of Agriculture and Fisheries (MAF) carried out a survey to report on the fisheries values of the Whangamarino Wetland. The purpose of the survey was to determine the presence and distribution of fish species within the wetland and its catchment as well as correlating their presence with habitat factors. Strickland (1980) recorded the presence of long and shortfinned eels (*Anguilla dieffenbachii* and *Anguilla australis* respectively), common smelt (*Retropinna retropinna*), banded kokopu (*Galaxias fasciatus*), black mudfish (*Neochanna diversus*), catfish (*Ameiurus nebulosus*), goldfish (*Carassius auratus*), mosquitofish (*Gambusia affinis*), grey mullet (*Mugil cephalus*), torrentfish (*Cheimarrichthys fosteri*) and common bullies (*Gobiomorphus cotidianus*). Acclimatisation society staff recorded the presence of inanga (*Galaxias maculatus*), tench (*Tinca tinca*) and rudd (*Scardinius erythrophthalmus*). The Whangamarino Wetland is known to provide valuable habitat for inanga downstream of the Waikato River thermal power stations (Strickland, 1980). The presence of lamprey (*Geotria australis*), giant kokopu (*Galaxias argenteus*), rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) were also recorded by local eel fisherman who found the species alongside their catch in the eel nets (Strickland, 1980).

Shortfinned eels are abundant throughout the wetland and they were found to occur in many different habitat types. The Whangamarino Wetland, including Lake Waikare and the catchments for both areas, forms part of the largest eel fishery in New Zealand. In 1979 the eel harvest from this area was in excess of 163 tonnes (Strickland, 1980). According to local eel fisherman in 1979, the weight of catfish caught in the fyke nets far exceeded that of the weight of eels suggesting that they were very abundant. Mosquitofish and goldfish are also reported as being abundant throughout the system. Species such as giant kokopu, banded kokopu and torrentfish are not common in the wetland and are only found in certain habitats. Trout are also not very common as they are unlikely to be present in waters of the swamp all year round but rather they stray in

from the Waikato River. Introduced species such as rudd and tench are also found in low numbers and are reported to occur mainly in the Whangamarino River (Strickland, 1980). The presence of grey mullet is reported to occur mainly in the lower reaches of the Whangamarino and Maramarua rivers.

DOC contracted the Centre for Biodiversity and Ecology Research (CBER) to carry out an electric fishing survey of the fish community present in the Whangamarino Wetland and its tributaries. The objectives of the survey was:
- to use an independent method (electrofishing boat) to determine the distribution, densities and biomasses of fish species residing in the wetland system and compare these results to the ones found by Strickland (1980).
- to examine seasonal variation in distribution, density and biomass of fish species residing in Whangamarino Wetland system.
- to determine the fish communities residing in the tributaries which flow into the wetland system by backpack electrofishing.
- to examine fish passage issues concerning the constructed weir by looking at distribution of fish above and below the weir.

2. Methods

2.1 Boat electrofishing

We used a 4.5-m long aluminium hulled electrofishing boat (Fig. 2) with a 5-kilowatt gas-powered pulsator (GPP, model 5.0, Smith-Root Inc, Vancouver, Washington, USA) powered by a 6-kilowatt custom-wound generator. Two anode poles, each with an array of six droppers, create the fishing field at the bow, with the boat hull acting as the cathode.

Electrical conductivity was measured with a YSI 3200 conductivity meter and horizontal water visibility was measured using a black disc (Davies-Colley, 1988). Specific conductivity, i.e., standardised to 25^{o}C, ranged from 136.4 to 165.0 µS cm^{-1} and so all sites (with the exception of one site which had a conductivity of 296.8 µS cm^{-1}) were fished with the GPP set to low range (50-500 V direct current) and a frequency of 60 pulses per second. We adjusted the percent of range setting of the GPP to between 50 and 70% to give an applied current of 3-4 A root mean square. We assumed from past experience that an effective fishing field was developed to a depth of 2-3 m, and about 2 m either side of the centre line of the boat. We thus assumed that the boat fished a transect about 4 m wide, which was generally consistent with the behavioural reactions of fish at the water surface. This assumption was used to calculate area fished from the linear distance measured with the boat-mounted Lowrance 2400 global positioning system GPS unit.

For this survey, six sites were chosen for boat electrofishing and these sites were located on the Whangamarino River (below Whangamarino weir, downstream of Reao Stream and both on and off the river at Falls Road), the Maramarua River and up the Reao Stream. The six sites that were fished between 20 and 23 August 2007 (Table 1; Figure

1) with the electrofishing boat correlated with netting sites used by DOC. Water levels were significantly lower between 3 and 6 March 2008 compared to August 2007 and thus fishing could only be repeated at sites which were still accessible to the electrofishing boat (Table 1; Figure 1). The fishing effort was apportioned equally between each of the zones with five 10-minute long electric fishing passes occurring at each site. Each electric fishing pass was in a different area within the individual site (i.e. different sides of channel, off river). We attempted to fish littoral areas, macrophyte beds, willow fringes, and tributary junctions (confluences) within each of these zones.

Data recorded for each pass included number of fish caught, length and weight of fish, presence of macrophytes, habitat characteristics and depth range of water column fished. No effort was made to try and quantify the abundance or biomass of the mosquitofish due to difficulty in successfully quantifying their abundance with the electrofishing boat.

2.2 Backpack electrofishing

We used a Kainga EFM 300 back-pack electrofisher to fish four sites in three different tributaries (Table 2; Figure 1) which drain into the Whangamarino Wetland. The output voltage of the machine was set at 300 V to achieve a current of 200-400 mA flowing through the circuit. This successfully caused the fish to be attracted to anode and go into a state of narcosis so that they could be captured. At each sample site 100 m^2 of stream was fished and the fish that were collected were identified, weighed and measured before being released back into the stream once electrofishing had been completed.

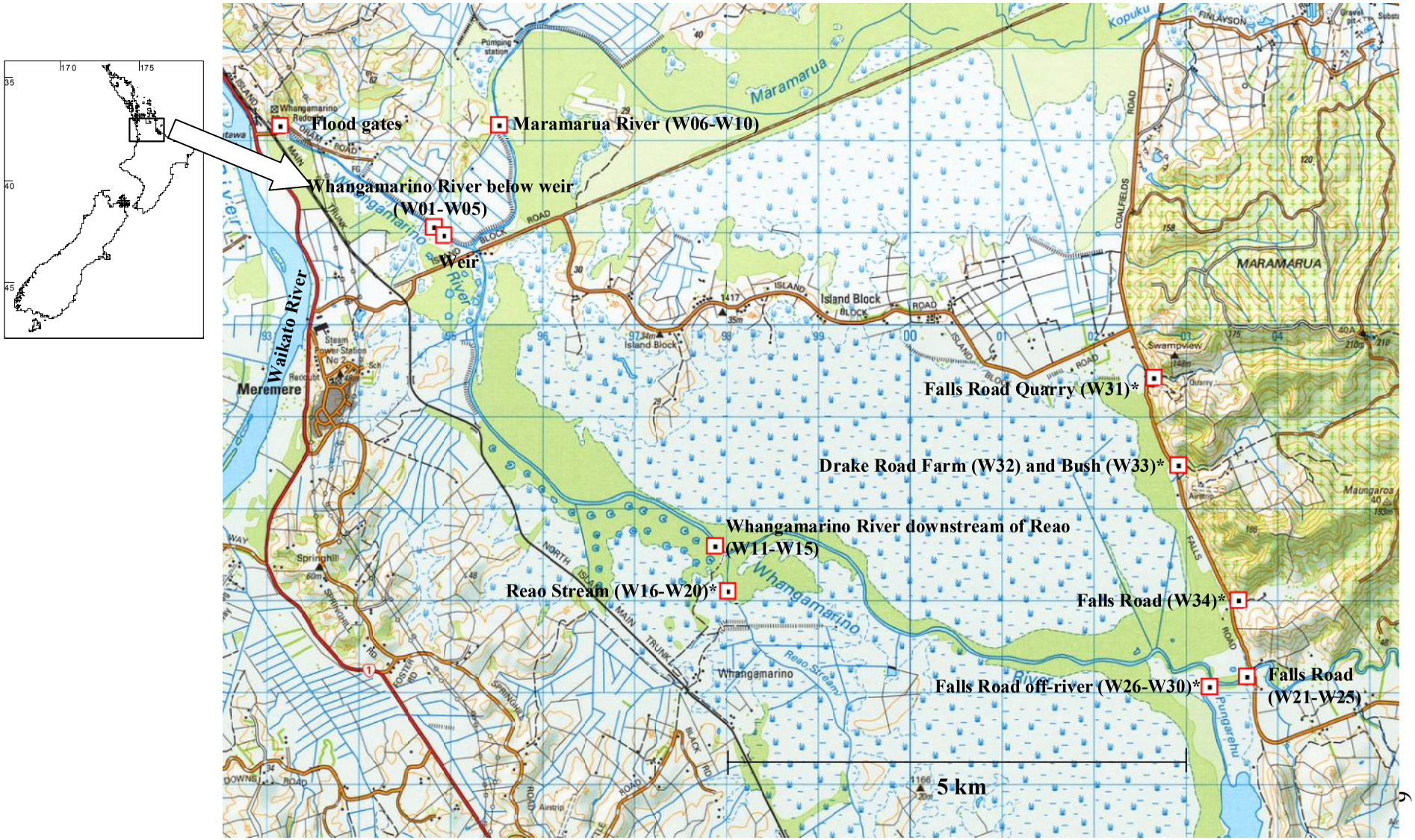
Table 1. Locations of sites fished with electric fishing boat between 20-23 August 2007 and 3-6 March in the Whangamarino wetland. – represents that site was not fished, NZMG = New Zealand Map Grid.

			20-23 August 2007		3-6 March 2008	
Site code	Location	Habitat type	NZMG E	NZMG N	NZMG E	NZMG N
Whangamarino River below weir						
W01	Main channel	Stop bank fringe	2694816	6431062	2694811	6431038
W02	Main channel	Willow fringe	2694507	6431228	2694518	6431228
W03	Flooded backwater	Submerged vegetation	2693948	6431557	-	-
W03	Main channel	Stop bank fringe	-	-	2693795	6431734
W04	Main channel	Submerged vegetation	2693939	6431555	-	-
W04	Main channel	Stopbank fringe	-	-	2693630	6431842
W05	Main channel	Willow fringe	2694008	6431572	2694009	6431577
Maramarua River						
W06	Main channel	Willow fringe	2695534	6432174	2695529	6432184
W07	Main channel	Stop bank fringe	2695511	6432210	2695504	6432222
W08	Main channel	Willow fringe	2695474	6432398	2695476	6432405
W09	Main channel	Flooded farmland	2695947	6433203	2695954	6433200
W10	Farm inlet	Cove, farm inlet	2695746	6433049	2695737	6433042
Whangamarino River downstream of Reao Stream						
W11	Main channel	Glyceria river fringe	2697883	6427593	2697876	6427608
W12	Main channel	Willow fringe	2697751	6427742	2697771	6427730
W13	Main channel	Glyceria river fringe	2697755	6427724	2697753	6427728
W14	Main channel	Willow fringe	2697625	6427841	2697617	6427841
W15	Main channel	Willow fringe	2698034	6427475	2698029	6427470
Reao Stream						
W16	Flooded backwater	Submerged vegetation	2698021	6427097	-	-
W17	Flooded backwater	Submerged vegetation	2698011	6427061	-	-
W18	Main channel	Stop bank fringe	2698042	6427072	-	-
W19	Main channel	Willow fringe	2698128	6426911	-	-
W20	Flooded wetland	Submerged vegetation	2698241	6426886	-	-
Falls Road						
W21	Main channel	Stopbank fringe	2703675	6426168	2703674	6426179
W22	Main channel	Stopbank fringe	2703510	6426075	2703520	6426079
W23	Main channel	Willow fringe	2703321	6426104	2703316	6426105
W24	Main channel	Willow fringe	2703688	6426206	2703690	6426214
W25	Main channel	Willow fringe	2703238	6426249	2703244	6426260
Falls Road off-river site						
W26	Flooded swamp	Swamp	2703259	6426060	-	-
W27	Flooded swamp	Open Swamp	2703395	6425903	-	-
W28	Flooded swamp	Swamp	2703515	6425846	-	-
W29	Flooded swamp	Willow fringe	2703388	6425811	-	-
W30	Flooded swamp	Swamp	2703247	6426272	-	-

Table 2. Locations of tributaries flowing into the Whangamarino wetland system fished by backpack electrofishing between 20-23 August 2007.

			NZ map grid	
Site code	Site	Habitat type	Easting	Northing
W31	Falls Road Quarry	Open stream, culverts and drains	2702665	6429425
W32	Drake Road Farm	Open stream, farmland	2702925	6428470
W33	Drake Road Bush	Forest stream, pools and riffles	2703045	6428505
W34	Falls Road	Forest stream, pools and riffles	2703585	6427005

Figure 1. Sites fished in the Whangamarino wetland between 20-23 August 2007 and 3-6 March 2008. Source: Freshwater Fish Database Assistant (Jowett 2005). Site codes correspond to the GPS points in Table 1 and 2. * sites only fished between 20-23 August 2007.



3. Results

3.1 Boat electrofishing

Specific conductivities were moderate and consistent at the sampling sites throughout the Whangamarino Wetland in August 2007 with values ranging between 136 to 165 μS cm^{-1} (Table 3). In March 2008, the specific conductivities of sites found in the Whangamarino River (below the weir, downstream of the Reao Stream and Falls Road) were similar to the conductivities found in August 2007 with values ranging from 141 to 175 μS cm^{-1} (Table 4). The specific conductivity of the Maramarua River decreased from 161 μS cm^{-1} in August 2007 to 118 μS cm^{-1} in March 2008 (Table 3 and 4). In August 2007 one of the sites in the Maramarua River had a specific conductivity of 296 μS cm^{-1} which was substantially higher than any of the conductivities found elsewhere. This site was located by a waste outlet from a neighbouring farm which explains the high conductivity reading as runoff from farms are known to have a high content of dissolved ions.

Water temperatures in August 2007 ranged from 10.9 to 13.7^{o}C (Table 3) in the main channels of the rivers but on the flooded paddocks and backwaters the water temperatures were higher at values of 14.1 to 14.7 ^{o}C. Water levels were significantly lower during the March 2008 sampling (Figure 2 and 3) and thus habitats such as the flooded paddocks and backwaters (Figure 4) were no longer accessible or in many cases they had completely disappeared. The water temperatures in March 2008 (20.7 ^{o}C to 21.9 ^{o}C) were higher than temperatures found in August 2007 (Table 4). The highest temperatures in the main channel of the rivers were measured in the Whangamarino River (below the weir and at Falls Road) on 3 and 4 March 2008. The depth of water that was fished varied depending on the habitat. In the main channel of the Whangamarino and Maramarua rivers the depth fished ranged from 0.3 to 3.5 m, while in the Reao Stream the depth fished ranged from 0.4 to 1.7 m. The flooded paddocks and backwaters fished in August 2007 were the shallowest environments with depths ranging from 0.4 to 1.2 m.

Throughout the Whangamarino Wetland a range of submergent macropohytes were identified such as willow weed (*Polygonum persicaria*), hornwort (*Ceratophyllum demersum*), azolla (*Azolla* sp.), floating sweet grass (*Glyceria maxima*), duckweed (*Lemna minor*), alligator weed (*Alternanthera philoxeroides*) and water milfoil (*Myriophyllum aquaticum*). The rivers through the wetland system were either lined by man-made stop banks or stands of willow trees and rubble.

289 Table 3. Physical conditions in the Whangamarino Wetland at the fishing sites between
290 20 and 23 August 2007.

Site code	Macrophytes	Bank and substrate	Specific conductivity (µS cm^{-1})	Water temperature (ºC)	Distance fished (m)	Area fished (m^2)	Water depth (m)
Whangamarino River below weir							
W01	Willowweed, hornwort, *Azolla* sp.	Stop bank, grass, mud	143	12.9	248	993	0.4-2.2
W02	Hornwort, *Azolla* sp.	Willows, submerged stop bank	143	12.9	105	419	0.5-3.5
W03	Willowweed	Flooded paddocks	143	14.7	242	969	0.4-0.6
W04	Willowweed	Flooded paddocks	143	14.7	169	676	0.4-0.6
W05	Willoweed, hornwort, *Azolla* sp.	Willows, silt edge	143	12.9	111	443	0.5-3.5
Maramarua River							
W06	Floating sweet grass	Willows, silt edge	161	13.0	70	278	0.75-3.0
W07	Floating sweet grass	Grass	161	13.0	114	457	0.3-2.8
W08	Floating sweet grass, hornwort	Willows, silt edge	161	13.0	104	416	0.75-3.0
W09	None	Flooded farm edge	161	13.0	151	606	0.5-1.0
W10	None	Flooded farm edge, inlet from farm	297	13.4	92	368	0.5-2.3
Whangamarino River downstream of Reao Stream							
W11	Floating sweet grass	*Glyceria* river edge	142	12.8	145	579	0.5-2.5
W12	Floating sweet grass	Willows, silt edge	142	12.8	66	265	0.5-3.4
W13	Floating sweet grass	*Glyceria* river edge	142	12.8	102	408	0.5-2.3
W14	Floating sweet grass, duckweed	Willows, silt edge	142	12.8	73	292	0.5-2.2
W15	Alligator weed	Willows, silt edge	142	12.8	69	274	0.4-2.3
Reao Stream							
W16	Willow weed, grasses	Off river, flooded backwater	136	14.2	273	1094	0.5-1.0
W17	Willow weed, grasses	Off river, flooded backwater	136	14.2	248	990	0.4-1.1
W18	Flooded marginal vegetation	Stopbank	143	13.7	168	672	0.4-1.3
W19	Willow weed	Willow, submerged vegetation	143	13.7	194	774	0.5-1.7
W20	Willow weed	Flooded wetland	143	13.7	199	795	0.5-0.5
Falls Road							
W21	None	Stopbank, grass, willow weed, hookgrass	165	10.9	175	698	0.4-1.2
W22	None	Stopbank, grass, willow weed, hookgrass	165	10.9	176	703	0.4-2.3
W23	Floating sweet grass, water milfoil	Willow	165	10.9	122	490	1-2.7
W24	None	Willow	165	10.9	84	337	2-3.7
W25	Floating sweet grass	Willow	165	10.9	123	494	0.5-3.3
Falls Road off-river site							
W26	Willowweed	Swamp	139	14.1	305	1220	0.4-1.2
W27	Willowweed	Open Swamp	139	14.1	257	1030	0.4-1.1
W28	Willowweed	Swamp	139	14.1	241	963	0.4-1.1
W29	Willowweed	Willows	139	14.1	300	1200	0.4-1.1
W30	Willowweed, duckweed, *Azolla* sp.	Swamp	139	14.1	311	1246	0.7-1.0

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Table 4. Physical conditions in the Whangamarino Wetland at the fishing sites between 3 and 6 March 2008. – signifies that the site was not accessible for fishing.

Site code	Macrophytes	Bank and substrate	Specific conductivity (µS cm^{-1})	Water temperature (ºC)	Distance fished (m)	Area fished (m^2)	Water depth (m)
Whangamarino River below weir							
W01	Willowweed, hornwort, *Azolla* sp.	Stop bank, grass, mud	141	21.9	121	484	0.6-2.0
W02	Hornwort, *Azolla* sp.	Willows, stop bank	141	21.9	76	304	1.0-1.4
W03	Willowweed	Willows, silt edge	141	21.9	41	164	0.6-2.4
W04	Willowweed	Willows, stop bank	141	21.9	54	216	0.6-2.6
W05	Willowweed, hornwort, *Azolla* sp.	Willows, silt edge	141	21.9	72	288	0.7-1.8
Maramarua River							
W06	Floating sweet grass	Willows, silt edge	118	20.7	35	140	1.0-2.0
W07	Floating sweet grass	Grass	118	20.7	97	388	0.2-0.8
W08	Floating sweet grass, hornwort	Willows, silt edge	118	20.7	61	244	1.0-1.8
W09	None	Farm edge	118	20.7	164	656	0.4-1.0
W10	None	Farm edge, inlet from farm	118	20.7	124	496	0.4-1.0
Whangamarino River downstream of Reao Stream							
W11	Floating sweet grass	*Glyceria* river edge	172	20.7	51	204	0.8-1.4
W12	Floating sweet grass	Willows, silt edge	172	20.7	35	140	0.3-1.7
W13	Floating sweet grass	*Glyceria* river edge	172	20.7	58	232	0.3-1.6
W14	Floating sweet grass, duckweed	Willows, silt edge	172	20.7	29	116	0.4-1.8
W15	Alligator weed	Willows, silt edge	172	20.7	28	112	0.3-2.4
Reao Stream							
W16	-	-	-	-	-	-	-
W17	-	-	-	-	-	-	-
W18	-	-	-	-	-	-	-
W19	-	-	-	-	-	-	-
W20	-	-	-	-	-	-	-
Falls Road							
W21	Willowweed	Stopbank, grass, hookgrass	175	21.9	107	428	0.4-1.6
W22	Willowweed	Stopbank, grass, hookgrass	175	21.9	118	472	0.3-1.2
W23	Floating sweet grass, water milfoil	Willow	175	21.9	77	308	0.6-1.4
W24	None	Willow	175	21.9	82	328	1.2-1.8
W25	Floating sweet grass	Willow	175	21.9	82	328	0.6-1.4
Falls Road off-river site							
W26	-	-	-	-	-	-	-
W27	-	-	-	-	-	-	-
W28	-	-	-	-	-	-	-
W29	-	-	-	-	-	-	-
W30	-	-	-	-	-	-	-

Figure 2. The main channel of the Whangamarino River below the weir in August 2007 (left) and March 2008 (right). Photos: Brendan Hicks (left) and Michael Lake (right).

Figure 3. Whangamarino River near Falls Road boatramp with a willow lined edge and a stopbank edge in August 2007 (left) and March 2008 (right). Photos: Jeroen Brijs (left) and Michael Lake (right).

Figure 4. Flooded backwater with submerged vegetation and willows near the Whangamarino River in August 2007. Photo: Brendan Hicks.

272 fish were caught comprising five introduced and five native fish species at 6 sites in 5.04 km of fished length of rivers in the Whangamarino Wetland system between 20 and 23 August 2007. On March 2008, 816 fish were caught comprising five introduced and six native fish species from 4 sites in 1.51 km of fished length of rivers. Native species captured included common bullies, common smelt, grey mullet, inanga, shortfinned eels. In March 2008, longfinned eels were also captured. The exotic species of fish comprised of koi carp (*Cyprinus carpio*), goldfish, catfish, rudd and mosquitofish. Mosquitofish were observed to be significantly more abundant in March 2008 compared to numbers observed in August 2007.

Variation in fish density occurred between sites (Table 5) throughout the wetland system as well as between the 10-minute fishing efforts at individual sites (Appendix 1). Sites such as the Whangamarino River below the weir and downstream of the Reao Stream proved to be hotspots for particular species whereas sites such as the Maramarua River had relatively consistent densities of all the species (Table 5A). Variations in fish density within individual sites also occurred as the density of smelt below the weir in the Whangamarino River ranged from 6.0 to 35.7 fish 100 m^{-2} (Appendix 1).

Mean densities of most fish species in the Whangamarino Wetland increased in March 2008 compared to August 2007 (Table 5A). Exceptions to this rule were decreases in the density of common bullies downstream of Reao Stream and at Falls Road, decreases in common smelt density downstream of Reao Stream and the absence of grey mullet in the Maramarua River in March 2008. In August 2007, the most widespread and abundant fish species throughout the Whangamarino wetland were koi carp, goldfish, common smelt and shortfinned eels with mean densities at each site between 0.1 and 1.1 fish 100 m^{-2} (Table 5A). In March 2008, these species were still the most widespread and abundant species but their densities had significantly increased. Comparing mean densities in August 2007 to March 2007 in the Whangamarino River downstream of the Reao Stream, koi increased from 0.7 to 6.1 fish 100 m^{-2} and goldfish increased from 0.0 to 29.3 fish 100 m^{-2} (Table 5A). Downstream of the weir in the Whangamarino River, the mean density of common smelt increased significantly between time periods as it increased from 0.0 fish 100 m^{-2} to 18.0 fish 100 m^{-2} in March 2008. Grey mullet were only present in low densities below the Whangamarino weir and the Maramarua River in August 2007 (mean density of 0.1 fish 100 m^{-2}), whereas in March 2008 they were only found below the weir but in higher densities (mean density of 1.0 fish 100 m^{-2}) (Table 5A).

In August 2007, catfish were not widespread throughout the system as they were only present in low densities (mean density of 0.1 fish 100 m^{-2}) in the Whangamarino River downstream of the Reao Stream and in the off-river sites by Falls Road. In March 2008, catfish were only present downstream of the Reao Stream in the Whangamarino River but the mean density had increased to 1.7 fish 100 m^{-2}. Low densities of common bullies were observed at most of the sites in the Whangamarino wetland in both August 2007 and March 2008 with mean densities at the sites ranging from 0.0 to 0.7 fish 100 m^{-2}. Rudd and inanga were rare throughout the entire wetland system with only a few individuals of each species being captured during the August 2007 sampling period. The

densities of both and inanga and rudd increased in March 2008 but were still relatively low (Table 5A).

Variations in mean fish biomass (g m^{-2}) occurred between sites (Table 5B) as biomasses found in sites such as downstream of the Reao Stream in the Whangamarino River were significantly larger than biomasses found elsewhere throughout the Whangamarino Wetland. Variations in fish biomass within individual sites (Appendix 2) also occurred, especially with species such as grey mullet which had biomasses ranging from 0.0 to 15.5 g m^{-2} below the weir in the Whangamarino River (Appendix 2).

Koi carp dominated the biomass during both sampling periods comprising of 144 kg out of 158 kg of fish caught (92% of total fish biomass) in August 2007 and 115 kg out of 155 kg of fish caught (74 % of total fish biomass) in March 2008. In August 2007, the majority of carp were caught in the Whangamarino River below the weir, downstream of the Reao Stream and in the Reao Stream, where mean biomasses of 13.6, 10.8 and 9.9 g m^{-2} respectively were recorded (Table 5B). In March 2008, high biomasses of koi carp were found at all the sites fished and in the Whangamarino River downstream of the Reao Stream there were very high mean biomasses of 9.7-85.7 g m^{-2} or 97-857 kg ha^{-1} (Table 5B). With the exception of the sites downstream of the weir in the Whangamarino River, koi carp biomass had increased at all of the other sites in March 2008 compared with August 2007. Goldfish were found at most of the sites that had koi carp but only totalled 4% of the total fish biomass caught in August 2007, increasing to 16% of the total fish biomass caught in March 2008. The mean biomass of goldfish increased significantly in March 2008 (mean biomass of 28.8 g m^{-2}) compared to August 2007 (mean biomass of 0.1 g m^{-2}) in the Whangamarino River downstream of the Reao Stream (Table 5B). Other introduced species such as rudd and catfish had relatively low biomasses at all of the sites throughout the wetland except downstream of the Reao Stream where mean biomasses of 0.8 g m^{-2} and 2.4 g m^{-2} respectively were recorded.

Although the shortfinned eels comprised the greatest biomass of any native fish species (Table 5B), they were only a small percentage of the total biomass (2% of the total fish biomass caught in August 2007 and 5% of the total fish biomass caught in March 2008). Mean biomasses of native species such as common bully, common smelt, inanga and longfinned eels were low in both sampling periods ranging from 0.0 to 0.2 g m^{-2} (Table 5B). The mean biomass of grey mullet increased significantly from 0.3 (August 2007) to 3.8 g m^{-2} (March 2008) below the weir in the Whangamarino River.

Table 5. Abundance of introduced and native fish species caught in the Whangamarino wetland between 20-23 August 2007 and 3-6 March 2008. Means calculated from five 10-minute boat-electrofishing passes. – represents site not fished.

A. Mean densities

Mean fish density (fish 100 m-2)												
	Whangamarino River below weir (W01-W05)		Maramarua River (W06-W10)		Whangamarino River downstream of Reao Stream (W11-W15)		Reao Stream (W16-20)		Falls Road (W21-25)		Falls Road off river sites (W26-30)	
Species	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08
Introduced												
Catfish	0.0	0.0	0.0	0.0	0.1	1.7	0.0	-	0.0	0.0	0.1	-
Goldfish	0.1	1.2	0.1	1.0	0.0	29.3	0.2	-	0.2	1.8	0.3	-
Koi carp	0.6	1.2	0.1	1.3	0.7	6.1	0.4	-	0.1	1.5	0.3	-
Rudd	0.0	0.0	0.0	0.0	0.0	0.5	0.0	-	0.0	0.1	0.0	-
Native												
Common bully	0.0	0.3	0.1	0.4	0.1	0.0	0.0	-	0.7	0.1	0.0	-
Common smelt	0.0	18.0	0.0	0.1	0.2	0.1	0.4	-	0.1	0.1	1.1	-
Grey mullet	0.1	1.0	0.1	0.0	0.0	0.0	0.0	-	0.0	0.0	0.0	-
Inanga	0.0	1.0	0.0	0.0	0.0	0.3	0.0	-	0.0	0.2	0.0	-
Longfin eel	0.0	0.1	0.0	0.0	0.0	0.0	0.0	-	0.0	0.0	0.0	-
Shortfin eel	0.2	1.8	0.6	1.7	0.2	1.0	0.1	-	0.2	0.6	0.1	-
Sum	1.0	24.6	1.0	4.5	1.3	39.0	1.1	-	1.3	4.4	1.9	-

B. Mean Biomasses

Mean biomass (g fresh weight m^{-2})												
	Whangamarino River below weir (W01-W05)		Maramarua River (W06-W10)		Whangamarino River downstream of Reao Stream (W11-W15)		Reao Stream (W16-20)		Falls Road (W21-25)		Falls Road off river sites (W26-30)	
Species	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08
Introduced												
Catfish	0.0	0.0	0.0	0.0	0.1	2.4	0.0	-	0.1	0.0	0.2	-
Goldfish	0.2	0.5	0.1	0.6	0.1	28.8	0.3	-	0.4	1.8	0.4	-
Koi carp	13.6	9.7	0.7	20.7	10.8	85.7	9.9	-	0.6	14.2	5.2	-
Rudd	0.0	0.0	0.0	0.0	0.1	0.8	0.0	-	0.1	0.2	0.0	-
Native												
Common bully	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0	0.0	0.0	-
Common smelt	0.0	0.3	0.0	0.1	0.0	0.0	0.0	-	0.0	0.0	0.0	-
Grey mullet	0.3	3.8	0.0	0.0	0.0	0.0	0.0	-	0.0	0.0	0.0	-
Inanga	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0	0.0	0.0	-
Longfin eel	0.0	0.2	0.0	0.0	0.0	0.0	0.0	-	0.0	0.0	0.0	-
Shortfin eel	0.2	2.4	0.7	1.5	0.2	1.6	0.1	-	0.2	0.6	0.1	-
Sum	14.3	16.9	1.5	22.9	11.3	119.3	10.3	-	1.4	16.8	5.9	-

The fork length of koi carp caught at the sampling sites throughout the Whangamarino wetland ranged from 112 mm to 590 mm in August 2007. In March 2008, more juveniles were caught and the fork lengths ranged from 46 mm to 650 mm. The length frequency distribution showed that there are at least four distinct size classes of koi carp in the

Whangamarino wetland system in both sampling periods (Figure 5). There was a far greater number of large koi (>350mm) captured than small koi during the August 2007 sampling period but during the March 2008 sampling period the numbers of large and small koi captured were more even.

Although more shortfin eels were captured in March 2008 than in August 2007, the size distribution and average length was fairly similar between time periods. In August 2007, total lengths of shortfin eels caught by electrofishing in the Whangamarino wetland system ranged from 130 mm to 570 mm with a mean length of 354 mm. Total lengths of shortfin eels caught in March 2008 ranged from 93 mm to 580 mm with a mean length of 371 mm (mean weight of 92 g). The length frequency distribution (Figure 6) shows that there are low numbers of shortfin eels over 480 mm in both time periods. The weight frequency distribution also shows a similar pattern with very few eels exceeding a weight of 300 g (Figure 7).

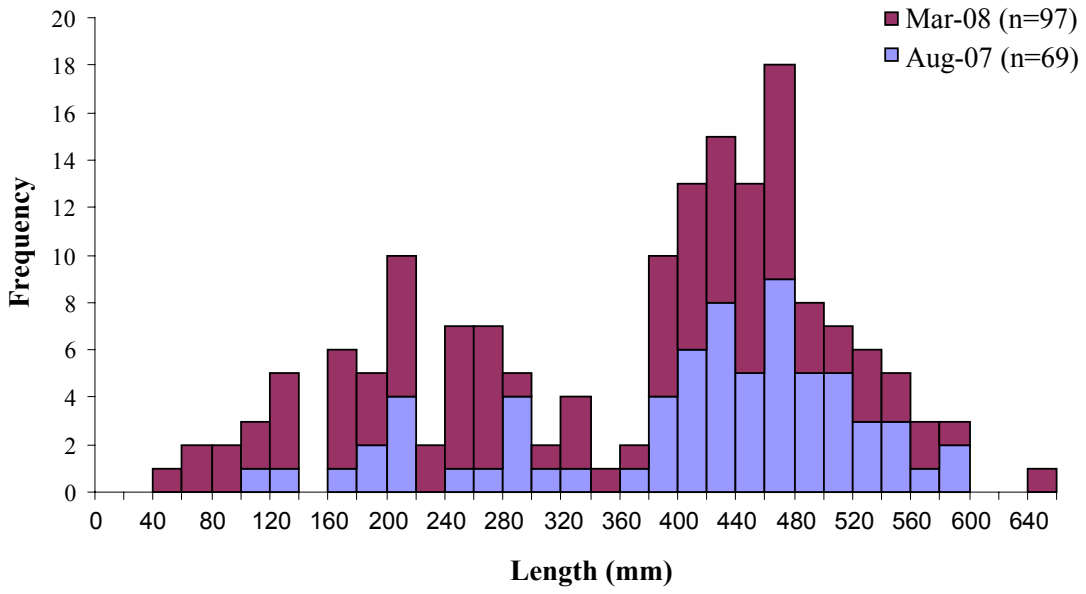

Figure 5. Length frequency of koi carp caught in the Whangamarino wetland system between 20-23 August 2007 (n=69) and 3-6 March 2008 (n=97).

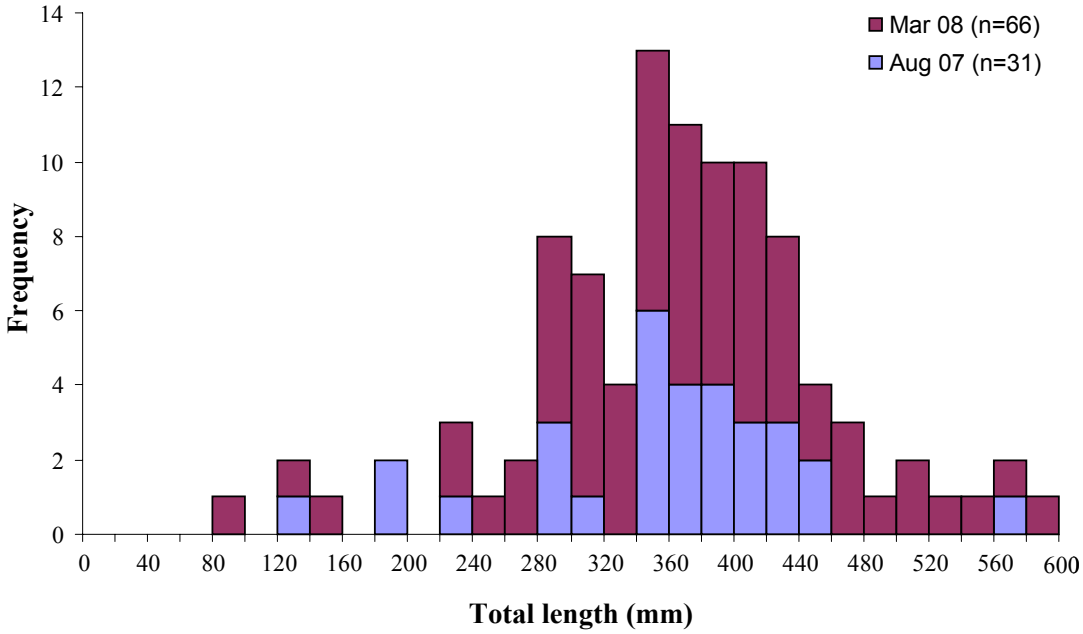

Figure 6. Length frequency of shortfinned eels caught in the Whangamarino wetland system between 20-23 August 2007 and 3-6 March 2008.

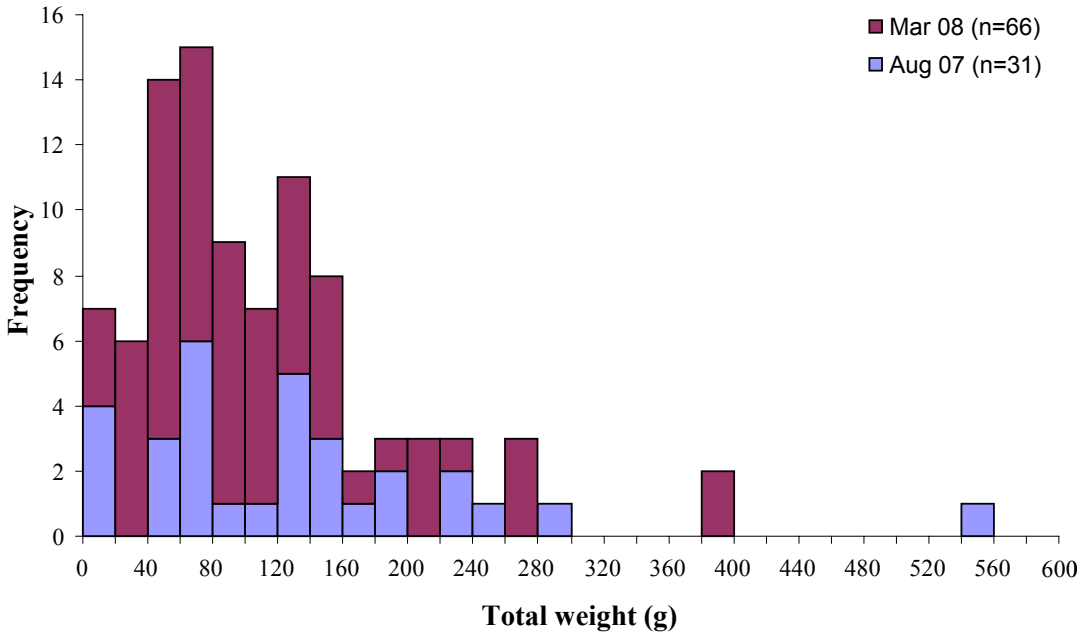

Figure 7. Weight frequency of shortfinned eels caught in the Whangamarino wetland system between 20-23 August 2007 and 3-6 March 2008.

3.2 Backpack electrofishing

The three tributaries chosen for backpack electrofishing were located off Falls Road and all flowed into the Whangamarino Wetland (Table 2; Figure 1). All three streams had depths ranging from 0.10 to 0.65 m and thus were relatively shallow tributaries.

The tributary referred to as Falls Road Quarry was surrounded by pasture on the left and the local quarry on the right (Figure 9 A). Emergent vegetation in this stream consisted mainly of *Glyceria sp.* with some native trees overhanging. This stream had a very high specific conductivity of 456 µS cm^{-1} (Table 7) which is due to the high influx of dissolved ions from the quarry runoff which also made the water fairly turbid. The water temperature of this stream (11.8ºC) was also slightly higher than the other streams although the Drake Road tributary was fished on a different day and thus the difference in temperature could be attributed to differing environmental conditions on those days.

The Drake Road tributary flowed through native bush, then pasture and finally into the wetland system. The water temperature of the stream was the same in both the bush and pasture portion of the stream and the specific conductivity was similar to the conductivity found in the wetland during boat electrofishing (Table 7). The Drake Road Farm site (Figure 9 B) flowed through open pasture and was surrounded by sedges and rushes as well as the presence of *Glyceria* in the upper reaches. The Drake Road Bush site (Figure 9 C) flowed through dense native bush and consisted of some moderately deep pools as well as shallow riffles with no emergent vegetation.

The last site located off Falls Road (Figure 9 D) was very similar to the Drake Road Bush site as it flowed through dense native bush and consisted off some deep pools as well as shallow riffles. The water temperature of this site was the lowest out of the three tributaries with a value of 8.5ºC and the specific conductivity (203.4 µS cm^{-1}) was slightly higher than the Drake Road sites but still significantly lower than the quarry site (Table 7).

Figure 8. Different types of tributaries flowing into the Whangamarino wetland system. Stream flowing next to an outlet drain from Falls Road Quarry (A), stream flowing through pasture at Drake Road Farm (B), stream flowing through Drake Road Bush with both shallow riffles and deeper pools (C) and the stream flowing through the Falls Road site (D).

Table 6. Sites and physical conditions in tributaries flowing into the Whangamarino Wetland on 24 August and 3 September 2007.

Site Code	Site	Date	Macrophytes	Bank and substrate	Specific conductivity (µS cm^{-1})	Water temperature (ºC)	Distance fished (m)	Area fished (m^2)	Water depth (m)
W31	Falls Road Quarry	24-Aug	*Glyceria* sp.	Few native trees, pasture, quarry and rocky bottom	456	11.8	75	100	0-1
W32	Drake Road Farm	3-Sep	*Glyceria* sp., rushes and sedges	Pasture and silty substrate with a few rocks	163	10.5	100	100	0-1
W33	Drake Road Bush	3-Sep	none	Native bush, large boulders and rocky bottom	163	10.5	50	100	0-1
W34	Falls Road	24-Aug	none	Native bush, large boulders and rocky bottom	203	8.5	50	100	0-1

403 fish were caught from the three different tributaries using backpack electrofishing on 24 August and 3 September. No exotic species of fish were found in these tributaries only native species such as banded kokopu, shortfinned eels, longfinned eels, common bullies, redfin bullies (*Gobiomorphus huttoni*) and koura (freshwater crayfish).

At presumably the most contaminated tributary, Falls Road Quarry, only shortfinned eels were present. The Falls Road Farm site and the Falls Road Site had a high diversity as well as a high density of native New Zealand freshwater fishes (Table 8). At both sites the common bullies, shortfinned eels and koura dominated the population. The Drake Road Bush site also had a high diversity of native fish but with significantly lower densities. At all four sites the biomass was mainly comprised of shortfinned and longfinned eels (Table 9) due to their large individual size. The total biomass of all species was significantly the highest at the Drake Road Farm site with a value of 58.7 g fresh weight m^{-2}.

Table 7. Density of fish caught in tributaries flowing into the Whangamarino Wetland on 24 August and 3 September 2007.

		Density of fish per site (number 100 m^{-2})					
Site code	Site	Common bully	Redfin bullly	Shortfinned eel	Longfinned eel	Banded kokopu	Koura
W31	Falls Road Quarry	0	0	12	0	0	0
W32	Drake Road Farm	96	14	69	20	1	39
W33	Drake Road Bush	10	1	1	6	0	19
W34	Falls Road	69	5	10	1	4	26
	Mean	44	5	23	7	1	21

Table 8. Biomass per unit area of the most abundant fish species caught in tributaries flowing into Whangamarino Wetland on 24 August and 3 September 2007.

		Biomass (g fresh weight m^{-2})				
Site code	Site	Common bully	Redfin bullly	Shortfinned eel	Longfinned eel	Banded kokopu
W31	Falls Road Quarry	0	0	15.64	0	0
W32	Drake Road Farm	1.54	0.47	39.47	17.21	0.01
W33	Drake Road Bush	0.11	0.02	0.02	13.1	0
W34	Falls Road	1.16	0.24	2.06	10.82	3.24
	Mean	0.70	0.18	14.30	10.28	0.81

4. Conclusions

Boat and backpack electrofishing caught a diverse range of native and introduced fish with a large size range (from a 35-mm common bully to a 650-mm koi carp weighing 5.5 kg). Previous fishing with the electrofishing boat in the North Island, in similar conductivities and habitats and with similar machine settings, has caught a full size range eels, smelt, bullies, grey mullet, rudd, brown bullhead catfish, perch, tench, goldfish, and koi carp (Hicks et al., 2005). The moderate conductivities found in the waterways of the Whangamarino wetland system allowed efficient power transfer from the water to the fish as the range of conductivities was about the same as the presumed conductivity of the fish. Goldfish have effective conductivities of about 100-160 $\mu S\ cm^{-1}$ (Kolz and Reynolds 1989). Out of the eighteen fish species previously recorded in the Whangamarino wetland system (Strickland, 1980), 11 species were captured (common bullies, common smelt, grey mullet, inanga, shortfinned eels, longfinned eels, banded kokopu, goldfish, catfish, rudd and mosquitofish) as well as a further two fish species (koi carp and redfin bullies) not previously recorded to occur in the wetland system by Strickland (1980). Black mudfish, known obligate swamp dwellers (Ling, 2001), were not caught in the survey as the habitat they reside in (infertile or oligotrophic bogs dominated by reeds) is inaccessible by the electrofishing boat. Also the low flows and poor visibility found in these habitats make backpack electrofishing very difficult and thus no attempt was made to capture them. Although Strickland (1980) observed numerous congregations of black mudfish fry, only one adult mudfish was captured and thus he concluded that the occurrence of black mudfish was sparse, although widely distributed. Ongoing research with the use of fine-mesh minnow traps has shown that black mudfish are abundant in bog areas within the Whangamarino wetland (Ling and Willis, 2005).

Strickland (1980) found that shortfinned eels, mosquitofish, catfish and goldfish were the most prevalent fish species in the wetland system during his survey as they made up the majority of the catch and they occurred in most of the habitat types fished. In August 2007 and March 2008 we found that koi carp, shortfinned eels, goldfish and common smelt were the most widespread fish species throughout the Whangamarino wetland as they were found at all of the sites fished with the electrofishing boat during both time periods (August 2007 and March 2008).

Like Strickland (1980), we found that shortfinned eels were the most widely distributed fish species in the Whangamarino wetland system as they were found at all of the sites in the wetland as well as in the sites located in the tributaries which flow into the wetland. In August 2007 and March 2008, the mean densities of shortfinned eels ranged from 0.2 to 1.8 fish 100 m^{-2} at sites located within the wetland. Shortfinned eels are under represented in boat-electrofishing due to the difficulty of capturing them with the nets in macrophyte beds and thus the density and biomass in reality is higher than what we have observed. Densities of shortfinned eels fished by backpack electric fishing in the tributaries which flow into the wetland were significantly higher with values ranging from 1 to 69 fish 100 m^{-2}. The length of eels caught by Strickland (1980) ranged from 81 mm to 755 mm whereas in our survey the length ranged from 93 mm to 580 mm. In both surveys, there was a significant reduction in the number of eels with lengths over 480 mm. This could be due to the fact that the legal size of eels for commercial fishing nationwide is 220 g which correlates to a length of 480 mm using a weight-length relationship calculated from eels caught with the electrofishing boat (Hicks, unpublished data). Examining the weight frequency data gathered during this survey we can see that there is a decrease in the frequency of eels once they approach the legal harvestable size. Beentjes et al. (2006) carried out a study on the changing population structure of eels in southern New Zealand and found that commercial fishing has resulted in a reduction in the size of both species of eels. In 1979, the Whangamarino wetland formed part of the largest eel fishery in New Zealand with an annual eel harvest in excess of 78 tonnes. The wetland supported four full-time fishermen plus an unknown number of itinerants, part-timers and amateurs (Strickland, 1980). The Whangamarino wetland is still heavily used by eel fishermen and thus this could be influencing the size range of shortfinned eels.

The biggest difference between the survey carried out by Strickland (1980) and our survey is the presence and dominance of koi carp in the Whangamarino wetland system. Although koi carp were recognised as a threat to New Zealand's aquatic ecosystems in the 1970s (Pullan & Little 1979), they were not widespread at that stage since Strickland (1980) found no koi carp in his survey of the Whangamarino wetland. Feral populations of koi carp did not cause significant concern until self-sustaining populations were discovered in the Waikato River system in 1983 (Pullan 1986). Koi carp are now widespread and very abundant throughout the Whangamarino wetland system as there were reasonable densities of koi carp at all of the sites in August 2007 (mean densities ranging from 0.1 to 0.7 fish 100 m^{-2}) and high densities of koi carp at all of the sites in March 2008 (mean densities ranging from 1.2 to 6.1 fish 100 m^{-2}). Biomass is a more accurate reflection of the potential ecological impact of koi carp than their density. Koi carp dominated the biomass at all of the sites in the Whangamarino wetland both in August 2007 (mean biomass ranging from 0.6 to 13.6 g m^{-2}) and March 2008 (mean biomass ranging from 9.7 to 85.7 g m^{-2}). Previous results suggest that 21-73% of the total population estimate is caught on the first removal, depending on water visibility (Hicks, unpubl. data). As we fished over the area at each site only once, the estimates in this survey represent a minimum abundance, and true population sizes would be 1.4-4.8 times greater. The presence of at least four distinct size classes from the koi carp that were captured and removed during our survey provides very strong evidence that recruitment of koi carp into the Whangamarino wetland system is occurring. We found

that we captured a greater number of large koi (>350mm) than the small koi but this could be due to sampling bias as the large koi are affected by greater potential electrical difference and thus more current can be developed through them and they enter the state of narcosis more easily.

Another difference between the two surveys was in the distribution and abundance of catfish in the Whangamarino wetland. In 1980, catfish were widespread and abundant throughout the wetland as Strickland caught high numbers of them at most of the habitats. According to local eel fishermen that were interviewed by Strickland in 1980, the weight of catfish removed from their fyke nets far exceeded the weight of eels removed. In our survey we found that catfish were not prevalent throughout the system as they were only present at a few sites and in low numbers. Catfish are known to be very difficult to catch by electric fishing as they tend to sink to the bottom sediments which makes it difficult to capture them due to poor water visibility. Strickland (1980) also found that electric fishing was not effective at catching catfish as he caught low numbers of catfish by electric fishing but high numbers through the use of fyke nets. So whether or not the low numbers of catfish we obtained is an accurate representation of the catfish population needs to be determined by the use of fyke nets before any conclusions can be made.

The abundance of mosquitofish in the Whangamarino wetland was seasonally dependent as we observed very few in August 2007 whereas in March 2008 we observed that they were very widespread and abundant which is similar to the observations made by Strickland in October 1980. No attempt was made to quantitatively measure the abundance of mosquitofish as it is difficult and relatively inaccurate to quantify their abundance with the electrofishing boat. This is because mosquitofish generally reside in the shallow margin habitat which is inaccessible to the electrofishing boat. In 1980, common smelt were observed to be present in the Whangamarino wetland by Strickland but their densities were relatively low. In both August 2007 and March 2008, common smelt were widespread throughout the wetland system but in relatively low densities (mean densities ranging from 0.1 to 0.4 fish 100 m^{-2}) with the exception of the site located downstream of the weir in the Whangamarino River. The mean density of common smelt at this site increased significantly between time periods as it increased from 0.0 fish 100 m^{-2} to 18.0 fish 100 m^{-2} in March 2008.

Species such as rudd, tench, torrentfish and banded kokopu were not common in the Whangamarino Wetland system (Strickland, 1980), and our survey found similar results. We only found a few individual rudd, no tench, no torrentfish and the banded kokopu were only present in low numbers in some of the tributaries flowing into the wetland (site W32 and W34). Strickland (1980) found that longfinned eels comprised 33% of the eel catch in stream habitats throughout the Whangamarino wetland system. Longfinned eels were absent from all the habitats we sampled by boat electrofishing with the exception of two individuals found in March 2008 below the weir in the Whangamarino River. Backpack electric fishing carried out on the tributaries was more successful and at the Drake Road Farm site (W32) the longfinned eels made up 30% of the catch.

The lower reaches of the Whangamarino and Maramarua rivers provided a limited amount of grey mullet fishing in 1980 (Strickland, 1980) as grey mullet were observed to run into these reaches in the early summer months. For a brief period these fish were commercially exploited and in 1979 the fishery was worth approximately $17,500. In August 2007, grey mullet were found in the lower reaches of the Whangamarino and Maramarua rivers in relatively low numbers (mean density of 0.1 fish 100 m^{-2}). In March 2007, grey mullet were only present below the weir in the Whangamarino River but the mean density had increased to 1.0 fish 100 m^{-2}. The biggest difference between sampling in August 2007 and March 2008 was the significant difference in water level. In August 2007, the water levels were high and the weir was completely submerged which allowed the passage of grey mullet to the lower reaches of the Maramarua River. In March 2008, the water levels had significantly and the weir was completely exposed preventing the passage of grey mullet to the Maramarua River.

Variation in fish density and biomass occurred between sites throughout the Whangamarino wetland system as well as between the two different time periods (August 2007 and March 2008). Sites such as the Whangamarino River below the weir and downstream of the Reao Stream proved to be hotspots for particular species whereas sites such as the Maramarua River had relatively consistent densities of all the species. Mean densities and biomasses of fish species at most of the sites in the Whangamarino wetland system increased in March 2008 compared to August 2007. The increase in density and biomass could be due to a lot of different factors with changes in temperature and water level only being a few of these.

5. Acknowledgements

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Appendix 1. Densities of introduced and native fish species caught in the Whangamarino wetland between 20-23 August 2007 and 3-6 March 2008. – represents site not fished.

	Fish density (fish 100 m^{-2})																					
	Catfish		Common bully		Common Smelt		Goldfish		Grey mullet		Inanga		Koi Carp		Longfin eel		Rudd		Shortfin eel		Sum	
Site	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08
Whangamarino River below weir																						
W01	0.0	0.0	0.2	0.0	0.0	35.7	0.3	0.0	0.1	2.7	0.0	1.4	0.3	0.2	0.0	0.4	0.0	0.0	0.1	1.4	1.0	41.9
W02	0.0	0.0	0.0	0.3	0.0	19.7	0.0	1.6	0.0	0.0	0.0	1.3	0.2	0.7	0.0	0.0	0.0	0.0	0.2	0.3	0.5	24.0
W03	0.0	0.0	0.0	0.6	0.0	22.0	0.0	1.8	0.0	1.8	0.0	0.6	0.4	3.0	0.0	0.0	0.0	0.0	0.1	2.4	0.5	32.3
W04	0.0	0.0	0.0	0.0	0.0	6.0	0.1	2.3	0.0	0.5	0.0	0.5	1.6	2.3	0.0	0.0	0.0	0.0	0.1	0.9	1.9	12.5
W05	0.0	0.0	0.0	0.7	0.0	6.6	0.2	0.3	0.2	0.0	0.0	1.4	0.5	0.0	0.0	0.0	0.0	0.0	0.2	3.8	1.1	12.8
Maramarua River																						
W06	0.0	0.0	0.0	0.0	0.0	0.0	0.4	3.6	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	0.4	2.9	0.7	10.0
W07	0.0	0.0	0.2	0.0	0.0	0.5	0.0	0.8	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	1.1	1.5	1.3	4.1
W08	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	1.6	0.0	3.3
W09	0.0	0.0	0.0	0.5	0.0	0.2	0.0	0.3	0.0	0.0	0.2	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.5	1.2	0.7	2.6
W10	0.0	0.0	0.3	1.0	0.0	0.0	0.0	0.2	0.3	0.0	0.0	0.0	0.3	0.2	0.0	0.0	0.0	0.0	0.8	1.2	1.6	2.6
Whangamarino River downstream of Reao Stream																						
W11	0.0	0.5	0.0	0.0	0.0	0.5	0.2	26.0	0.0	0.0	0.0	0.0	0.3	1.5	0.0	0.0	0.0	0.0	0.0	0.5	0.5	28.9
W12	0.0	2.1	0.4	0.0	0.4	0.0	0.0	26.4	0.0	0.0	0.0	0.7	1.5	10.0	0.0	0.0	0.0	0.0	0.0	1.4	2.3	40.7
W13	0.2	0.4	0.0	0.0	0.2	0.0	0.0	11.2	0.0	0.0	0.0	0.0	0.2	1.7	0.0	0.0	0.2	0.0	0.5	0.4	1.5	13.8
W14	0.0	0.0	0.0	0.0	0.3	0.0	0.0	31.9	0.0	0.0	0.0	0.0	0.3	9.5	0.0	0.0	0.0	1.7	0.3	0.0	1.0	43.1
W15	0.4	5.4	0.0	0.0	0.0	0.0	0.0	50.9	0.0	0.0	0.0	0.9	1.1	8.0	0.0	0.0	0.0	0.9	0.4	2.7	1.8	68.8
Reao Stream																						
W16	0.0	-	0.0	-	0.0	-	0.1	-	0.0	-	0.0	-	0.5	-	0.0	-	0.0	-	0.1	-	0.6	-
W17	0.1	-	0.0	-	1.6	-	0.2	-	0.0	-	0.0	-	0.7	-	0.0	-	0.0	-	0.3	-	2.9	-
W18	0.0	-	0.0	-	0.0	-	0.1	-	0.0	-	0.0	-	0.6	-	0.0	-	0.0	-	0.0	-	0.7	-
W19	0.0	-	0.0	-	0.3	-	0.1	-	0.0	-	0.0	-	0.1	-	0.0	-	0.0	-	0.0	-	0.5	-
W20	0.0	-	0.0	-	0.1	-	0.4	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.5	-
Falls Road																						
W21	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.1	0.5	0.1	0.5	0.0	0.0	0.0	0.2	0.3	1.2	1.0	3.0
W22	0.0	0.0	0.0	0.6	0.0	0.2	0.0	0.2	0.0	0.0	0.0	0.6	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.4	0.0	3.6
W23	0.2	0.0	0.2	0.0	0.0	0.3	0.0	1.6	0.0	0.0	0.0	0.0	0.0	4.2	0.0	0.0	0.2	0.0	0.0	1.0	0.6	7.1
W24	0.0	0.0	0.0	0.0	0.3	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.5
W25	0.0	0.0	2.8	0.0	0.4	0.0	1.2	4.9	0.0	0.0	0.0	0.0	0.2	1.2	0.0	0.0	0.0	0.3	0.6	0.6	5.3	7.0
Falls Road - Off river sites																						
W26	0.2	-	0.1	-	2.0	-	0.1	-	0.0	-	0.0	-	0.1	-	0.0	-	0.0	-	0.0	-	2.5	-
W27	0.1	-	0.0	-	2.2	-	0.3	-	0.0	-	0.0	-	0.1	-	0.0	-	0.1	-	0.0	-	2.8	-
W28	0.0	-	0.0	-	0.3	-	0.5	-	0.0	-	0.0	-	0.3	-	0.0	-	0.1	-	0.1	-	1.3	-
W29	0.1	-	0.1	-	0.4	-	0.3	-	0.0	-	0.0	-	0.1	-	0.0	-	0.0	-	0.0	-	0.9	-
W30	0.1	-	0.0	-	0.2	-	0.5	-	0.0	-	0.0	-	0.8	-	0.0	-	0.0	-	0.2	-	1.8	-

Appendix 2. Biomass of introduced and native fish species caught in the Whangamarino wetland between 20-23 August 2007 and 3-6 March 2008. – represents site not fished.

	Biomass (g freshweight m^{-2})																					
	Catfish		Common bully		Common Smelt		Goldfish		Grey mullet		Inanga		Koi Carp		Longfin eel		Rudd		Shortfin eel		Sum	
Site	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08	Aug-07	Mar-08
Whangamarino River below weir																						
W01	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.9	3.8	0.0	0.8	0.0	0.0	0.0	1.7	1.3	6.7
W02	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.2	0.0	0.0	0.0	0.1	0.4	18.8	0.0	0.0	0.0	0.0	0.0	0.3	0.4	19.7
W03	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5	0.0	15.5	0.0	0.0	16.6	11.2	0.0	0.0	0.0	0.0	0.0	2.2	16.6	29.9
W04	0.0	0.0	0.0	0.0	0.0	0.2	0.5	1.8	0.0	3.5	0.0	0.0	41.6	14.8	0.0	0.0	0.0	0.0	0.4	2.2	42.5	22.5
W05	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	1.6	0.0	0.0	0.0	8.6	0.0	0.0	0.0	0.0	0.0	0.4	5.4	10.8	5.5
Maramarua River																						
W06	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.4	0.0	0.0	0.0	0.0	0.0	77.6	0.0	0.0	0.0	0.0	0.0	1.6	0.5	81.6
W07	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.5	0.0	0.0	0.0	0.0	0.0	6.5	0.0	0.0	0.0	0.0	1.2	2.0	1.2	9.2
W08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.3	0.0	0.0	0.0	0.0	0.0	1.0	0.0	13.3
W09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	0.0	0.0	0.4	1.2	0.4	5.7
W10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	3.6	2.7	0.0	0.0	0.0	0.0	1.7	1.8	5.4	4.5
Whangamarino River downstream of Reao Stream																						
W11	0.0	0.3	0.0	0.0	0.0	0.0	0.4	25.3	0.0	0.0	0.0	0.0	0.8	13.5	0.0	0.0	0.0	0.0	0.0	1.7	1.2	40.8
W12	0.0	2.9	0.0	0.0	0.0	0.0	0.0	25.2	0.0	0.0	0.0	0.0	27.3	133.6	0.0	0.0	0.0	0.0	0.0	0.7	27.3	162.4
W13	0.1	0.1	0.0	0.0	0.0	0.0	0.0	11.1	0.0	0.0	0.0	0.0	1.6	21.6	0.0	0.0	0.5	0.0	0.2	0.2	2.4	33.0
W14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.0	0.0	0.0	0.0	0.0	9.1	118.6	0.0	0.0	0.0	3.1	0.7	0.0	9.8	149.7
W15	0.6	8.6	0.0	0.0	0.0	0.0	0.0	54.4	0.0	0.0	0.0	0.0	15.4	141.2	0.0	0.0	0.0	0.8	0.3	2.5	16.3	207.5
Reao Stream																						
W16	0.0	-	0.0	-	0.0	-	0.1	-	0.0	-	0.0	-	14.5	-	0.0	-	0.0	-	0.0	-	14.6	-
W17	0.1	-	0.0	-	0.0	-	0.5	-	0.0	-	0.0	-	19.6	-	0.0	-	0.0	-	0.4	-	20.6	-
W18	0.0	-	0.0	-	0.0	-	0.2	-	0.0	-	0.0	-	12.6	-	0.0	-	0.0	-	0.0	-	12.8	-
W19	0.0	-	0.0	-	0.0	-	0.2	-	0.0	-	0.0	-	2.7	-	0.0	-	0.0	-	0.0	-	2.9	-
W20	0.0	-	0.0	-	0.0	-	0.6	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.6	-
Falls Road																						
W21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	1.7	3.4	0.0	0.0	0.0	0.6	0.3	1.6	2.0	6.2
W22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	20.3	0.0	0.0	0.0	0.0	0.0	0.4	0.0	21.0
W23	0.6	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	23.7	0.0	0.0	0.5	0.0	0.0	0.6	1.1	25.8
W24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.9
W25	0.0	0.0	0.1	0.0	0.1	0.0	2.0	4.4	0.0	0.0	0.0	0.0	0.1	23.5	0.0	0.0	0.0	0.4	0.7	0.4	3.0	28.7
Falls Road - Off river sites																						
W26	0.8	-	0.0	-	0.1	-	0.1	-	0.0	-	0.0	-	1.4	-	0.0	-	0.0	-	0.0	-	2.4	-
W27	0.2	-	0.0	-	0.1	-	0.4	-	0.0	-	0.0	-	1.6	-	0.0	-	0.0	-	0.0	-	2.3	-
W28	0.0	-	0.0	-	0.0	-	0.6	-	0.0	-	0.0	-	2.4	-	0.0	-	0.1	-	0.1	-	3.2	-
W29	0.0	-	0.0	-	0.0	-	0.3	-	0.0	-	0.0	-	0.4	-	0.0	-	0.0	-	0.0	-	0.7	-
W30	0.2	-	0.0	-	0.0	-	0.5	-	0.0	-	0.0	-	20.1	-	0.0	-	0.0	-	0.4	-	21.2	-