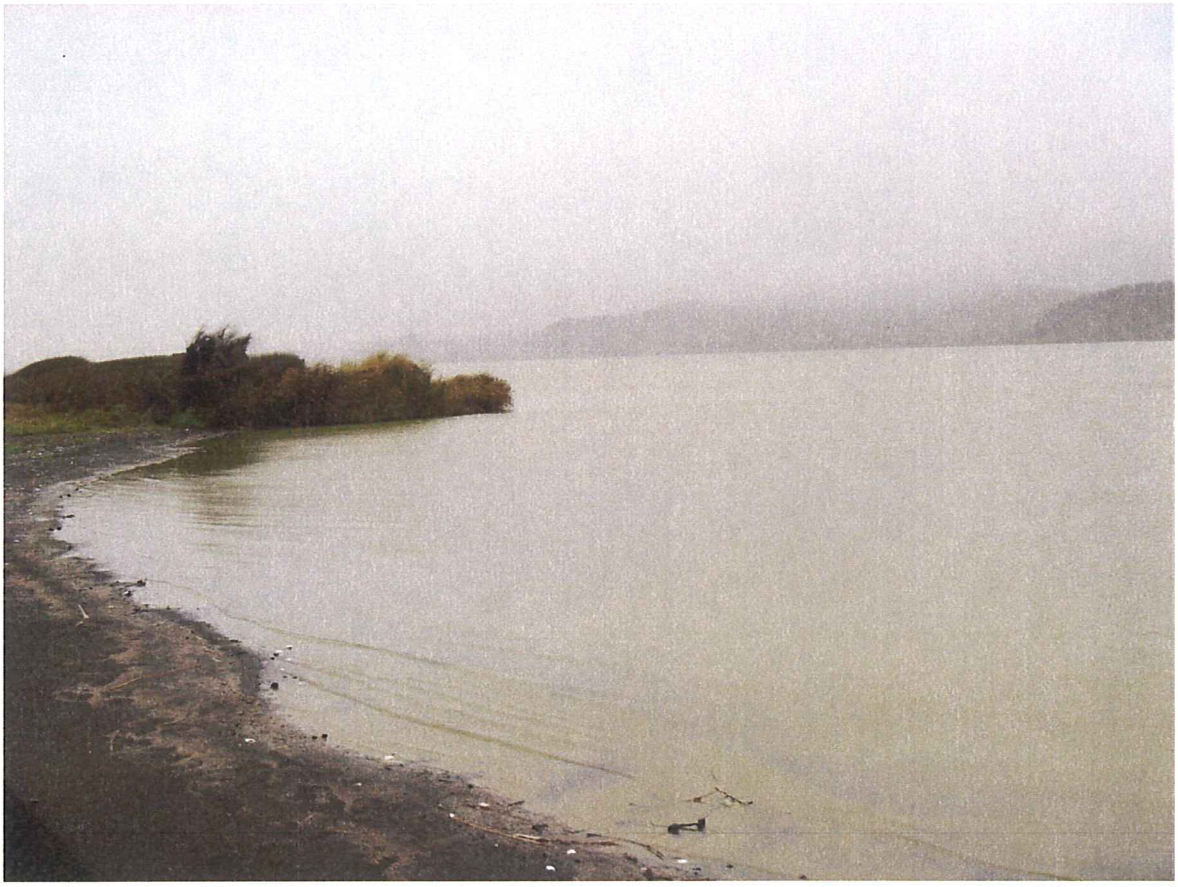
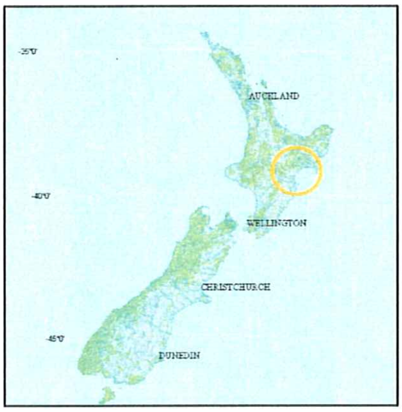
TE ROTO O TE WHAKAKI

Nga Matauranga me Nga Tikanga Ecosystem Research Project





The Whakaki Lake Trust and Nga Mahi Te Taiao Consultants

November 2008

Te Roto o Te Whakaki

Nga Matauranga me Nga Tikanga

Contents

Nga Mahi Te Taiao
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*Research *Education *Development

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Te Roto o Te Whakaki
Nga Matauranga me Nga Tikanga

Executive Summary

Te Roto o Te Whakaki - Nga Matauranga me Nga Tikanga is a research project looking at the structure and functioning of Lake Whakaki, the largest coastal lake on the east coast of the North Island of Aotearoa NZ. The project is a collaborative effort between the Whakaki Lake Trust and Nga Mahi Te Taiao Consultants, involving the Tangata Whenua in the management and implementation of the work, and draws heavily on their traditional knowledge and customary practices.

Lake Whakaki comprises a range of ecosystem types and settings, from freshwater tributaries to the brackish body of the Lake itself. Physical, climatic and biochemical conditions combine here to create a highly dynamic aquatic environment. While this environment is marked by dramatic change, the Lake maintains a remarkable level of abundance particularly in terms of macroinvertebrate numbers and the shortfin eel population.

The invertebrate assemblages present in the Lake itself, however, are marked by their simplicity (a few key species predominating), their resilience, and their abundance. To a large extent reflecting these invertebrate assemblages and the vegetated littoral margins where they thrive, is also an abundant shortfin eel population. This level of abundance, and the high ratio of female to male fish present, we believe to also be a direct outcome of the traditional harvest practices of the Tangata Whenua, their management of the fishery under a Maori customary regime, and their ongoing restoration initiatives in terms of the Lake hydrology and its margins.

Intensification of land use practices in the Lake catchment have been identified as posing a potential threat to the ecology of this critical resource for the people of Whakaki. While we have begun establishing a methodology and some data relating to these concerns,we believe that a more detailed program is necessary to establish the scale of potential threat. This is particularly so in terms of the role of phytoplankton and microalgae in supporting the populations of zooplankton that appear to underpin the levels of abundance currently present here.

Similarly, we believe local knowledge suggesting relatively recent changes in the Lake ecology, including increased algal blooming during the summer months and morphological changes to the eel population, require further investigation.

No reira

Murray Palmer
(on behalf of Nga Mahi Te Taiao Consultants) November 19th 2008.

TE ROTO O TE WHAKAKI

NGA MATAURANGA ME NGA TIKANGA

1 Introduction

Whakaki is a small rural coastal settlement 17 km north east of Wairoa in the region known as Hawke's Bay on the eastern seaboard of the North Island of Aotearoa New Zealand. One of the most significant features of the landscape of Whakaki is the large coastal lake that abuts State Highway 2, and is separated from the sea by a narrow strip of dunelands formed in the high energy coastal environment.

Lake Whakaki, *Te Roto o Te Whakaki*, covers an area of over 600 hectares, and is the largest coastal lake of the North Island's east coast. It is also comprises the last significant wetland of a system that ran for 32 kilometers between the Wairoa and Nuhaka rivermouths.

As such, Lake Whakaki embodies a rich and complex series of interrelated ecological settings, and a concomitant diversity of indigenous species, both in its waters, and on the lands adjoining.

The Lake also provides a traditional indigenous resource base of the utmost significance for the people of Whakaki, Ngati Kirituna, and is considered by them, *taonga tuku iho*, a great treasure of the natural world.

Whakaki, and indeed the wider region as a whole, is an area rich in history and tradition. One component of this tradition involves the knowledge and customary practices that have evolved over many generations to comprise what is now referred to as the sustainable management of their natural resource base. This suite of knowledge forms and customary practice we refer to as *matauranga* and *tikanga*, and the overall place in implementing these, their *tino rangatira* and *kaitiaki* or guardianship roles.

Te Roto o Te Whakaki - Nga Matauranga me Nga Tikanga is a research project exploring the structure and functioning of the ecology of Lake Whakaki. The project draws strongly on the traditional knowledge base and customary practices of the Tangata Whenua of this area, and the relevance of these to the contemporary management of the Lake, its fishery, and the terrestrial ecosystems which are connected to it.

Nga Matauranga was initiated on the 10th September 2007. The Project was conceived by Tumanako Walter Wilson, kaumatua of Whakaki and a powerful driver in the protection and restoration of the Lake, and Murray Palmer, a researcher from the nearby Tairawhiti region. Matua Walter oversaw the project, which was implemented by Pani Hook of the Whakaki Lake Trust, Robert Walker and Harold Ngarimu, the Trust's managers, and Murray and his team.

2 Background

Te Roto o Te Whakaki is a shallow coastal lake (<2 metres deep) made up of a series of interrelated settings that together comprise a distinctive and unique ecosystem and natural resource base. This was the historical context, and is the current situation, but has not always been the state of this environment.

During the 1950's, the existing Lake was drained by the local authorities, severely restricting all the hunting and fishing resources for the hapu of the area, and transforming the Lake ecology. This situation continued until 1996, when the kaumatua of Whakaki decided to initiate the restoration and protection of their taonga. This process of challenge, negotiation and restoration has been documented by the Trust, and has been acknowledged by central and local government and NGO's in several awards and commendations.

One of the most significant outcomes of this restoration project has been the rapid regeneration of the ecology of the Lake and its environs. The primary focus of our particular research here, has been to gain an understanding of the structure and functioning of the Lake ecosystems as they now exist, and the relationship of this understanding with the traditional management of these ecosystems and resource base.

A secondary focus, however, is a preliminary investigation into the impacts of land use practices occurring within the Lake's catchment, on the ecology of the Lake itself. Historical information is available regarding the productivity of the Roto prior to drainage by the Catchment Board and there is also anecdotal reference to factors that may be impacting negatively on the current ecosystem functioning of the Lake.

The initial findings identified in this report relating to the ecology of Te Roto o Te Whakaki point to the possibility of links amongst specific species underpinning the restoration of abundance in the aquatic and particularly the littoral environments. These findings further suggest the significance of an informed Maori customary fishery management process in the maintenance and enhancement of this abundance.

3 Goals of the Project

The goals guiding our research at the commencement of the project were as follows:

1. To provide an understanding of the structure and functioning of the Lake ecosystem, and in particular the existing food webs and trophic relationships;

2. To initiate some preliminary guidelines to an assessment of the fishery resource;

3. To initiate research into the potential impacts of land use activities within its catchment on the ecology of the Lake;

4. To initiate the development of a sustainable research capacity within the Whakaki Lake Trust and wider hapu.

Researchers Pani Hook and Murray Palmer head off to work, Whakaki-style.

4 Research Methodology

4.1 Introduction

Considering the primary goals of the Project, the overall techniques for investigating the ecological characteristics of Lake Whakaki have been based upon a combination of the SHMAK program[1] and the GLOBE monitoring protocols[2], and incorporating these with the Matauranga, or Maori science component of the Tangata Whenua of Whakaki. This, we believe, will provide for both a good range of information, and the potential foundation for an iwi based research capability moving forward.

Within this overall context, it was anticipated that an adaptive approach would be maintained relating to our goals and to the research methodology as a whole. That is, our team remained open to adopting an appropriate level of change to the program in order to address unforeseen characteristics, or to explore valuable areas of interest that may not have been evident at the outset of the work.

4.2 Site selection

Monitoring sites were chosen for a range of characteristics that identified them as representative of the diverse physical settings comprising the wider Lake ecosystems. These characteristics included:

- Historical use patterns and information;
- Littoral vegetation;
- Lake substrate;
- Proximity to the managed Lake outlet; and
- Current adjacent land use.

The sites chosen were ultimately further classified into a series of potential aquatic Habitat Types sufficiently distinct to provide some background to the possible patterns of species distribution throughout the Lake. This classification of Habitat Types comprises Section 5 of this report.

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[1] SHMAK, the New Zealand Stream Health Monitoring and Assessment Kit, developed initially between Federated Farmers and the National Institute of Water and Atmospheric Research in 1998, was designed to enable landowners and community groups to gather robust data to assess and monitor stream health.

[2] GLOBE (Global Learning and Observations to Benefit the Environment) is an international earth science project promoting and supporting students, teachers, communities and scientists to collaborate on inquiry-based investigations of the environment and the Earth system working in close partnership with the National Aeronautics and Space Association and the US National Science Foundation Earth System Science Projects.

A total of eleven monitoring sites were ultimately selected for the Project. The position of these on the Lake are shown in Figure 2, page 8 below. The names and grid references of the sites are contained in Figure 1 below.

Figure 1: Monitoring Sites Te Roto o Te Whakaki

Site no.	Site Name	Habitat Type	Grid reference
1	Te Awa Waahi (Old Bar)	5	S39*03.202 E177*33.878
2	P, Mildon's Maimai	7	S39*03.051 E177*33.162
3	Te Awa a Puruate – Blue's Maimai	6	S 39*02.651 E39*34.589
4	First Bluff	6	S39*02.496 E177*33.836
5	Te Ewe (Uncle Tere's)	2	S39*02.068 E177*05.142
6	The Landing	3	S39*02.559 E177*35.330
7	Paaka	4	S39*03.077 E177*35.998
8	Patangata	8	S39*03.080 E177*36.742
9	Te Ara Waerea	1	(not registered)
10	Ramarama (Junction)	1	(not registered)
11	Lake Centre	0	S39*02.651 E 177*33.853

4.3 Periodicity

Four separate monitoring periods were established that corresponded to the overall seasonal characteristics of the local environment, thus providing a cross-seasonal range of information. These periods were:

- September 12th to the 19th 2007
- December 3rd to the 7th 2007
- March 10th to 12th 2008
- July 28th to August 1st 2008.

Another complete monitoring period (ie at all sites) was added four days after what was to be the final period in July/August. This period was included as the Lake outlet was artificially opened on August 1st, and we believed it was necessary to evaluate, albeit in one brief investigation, the effects (if any) of this process on the ecosystem characteristics of the Lake. This final monitoring period was from August 5th to the 8th.

The four seasonal periods were also adjusted slightly to accommodate for the main *Tuna Rere* or migratory period for the *Hao* and *Pakarara* (the mature male and female shortfin eels), and a special monitoring program was allotted to catching and evaluating the tuna fishery at this important economic and cultural time. This period spanned from March 10th to April 11th.

Two sites were also monitored on the 24th January 2008 after a very heavy fresh in late December had appeared to significantly increase the levels of sedimentation in the Lake. This investigation was intended to gain a snapshot of the impacts on the Lake ecology of this type of intense climatic event.

4.4 Physical Water Quality Parameters

A range of physical parameters for water quality were monitored for. These included:

- Water temperature (calibrating thermometer and Eutech temperature meter)
- pH (Eutech pH meter)
- Conductivity (Eutech conductivity meter)
- Salinity (Eutech salinity meter)
- Water clarity (SHMAK clarity tube)

4.5 Biological Monitoring

4.5.1 Introduction

The presence of aquatic species was a key focus of the research program. A range of biological groups were chosen for the sampling. These include:

- Aquatic macroinvertebrate species (eg crustacea such as shrimp and isopods; gastropoda such as snails; oligochaeta or worm-like organisms);
- Fish (eg including freshwater eels, *Tuna*; goldfish, *Morehana*; and common bullies);
- Macro algae; and
- Littoral vegetation.

The presence of bird species was also noted.

It is anticipated that microalgae and phytoplankton in the Lake will also be explored as part of an ongoing research program. While calling for somewhat more resources than at present, this should provide material to help complete a picture of the structure and dynamics of the Lake's levels of biological diversity and abundance.

4.5.2 Littoral Vegetation

It was one of our initial informal hypotheses, based on the experience of the tangata whenua of Lake Whakaki, and our own experiences with other freshwater ecosystems, that the vegetation composition in the littoral areas would be critical to species distribution and abundance.[3]

In this context, we classified each monitoring site on a range of criteria, particularly on the types and density of the littoral vegetation present. This classification is outlined in detail below, and is recorded on the program database along with species composition for each given area.

4.5.3 Macroalgae

Where possible, the presence of macroalgae was noted but detailed records of species were not kept. NIWA, however, are in the process of producing a report that refers to the presence of particular algal species present in the Lake benthos, and our current work should be read in conjunction with this report.[4]

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[3] Unpublished research from the east coast of the North Island, Nga Mahi te Taiao, 2008.
[4] Draft report on benthic algae along two transects across the body of Lake Whakaki, NIWA and the Whakaki Lake Trust, 2008.

Figure 2: Map of Monitoring Sites Te Roto o Te Whakaki

4.5.4 Fish Species

The primary fish species of interest to our research program was the freshwater shortfin eel. This is a key indigenous resource and iconic species for the people of Whakaki. The method of capture was by standard Dutch fyke nets with an extended mesh size of 12mm. No escapement tubes were used.

Initially, the nets were set for two nights at each site, however this proved too onerous considering the scope of the project, and consequently only one set and capture was conducted at each site at each monitoring period, generally providing a minimum of nine fish captures per monitoring period, except where heavy flooding precluded this. The modified streams at Te Ramarama and Te Ara Waerea were not sampled for eels.

Initially, the eels were counted, and their overall maximum and minimum length recorded. The fish were then classified by the Tangata Whenua researcher, Pani Hook, as to the following basic categories, and recorded:

- Pakangaua (shortfin; sexually immature; maybe either male or female)
- Pakarara (shortfin; sexually mature ie migratory female)
- Hao (shortfin; sexually mature ie migratory male)
- Tangaehe (longfin; sexually immature; maybe either male or female)
- Whakaahua (longfin; sexually mature migratory female)

Some fish were taken (usually four to six per day), and their gut contents, level of gonad development (if any), and presence of parasites identified.

A special fish survey period was carried out at the Tuna Rere time. This survey period extended from the 10th March 2008 to the 11th April 2008 and included three sites that were believed by the Tangata Whenua as the venue for the tuna migration, and six further sites in the main body of the Lake that provided a 'control' for comparison.

The three migration sites at Paaka were monitored a total of 19 times over this period, and the control sites a total of nine times. Fish were trapped as before using unbaited fyke nets generally set at right angles to, and within 10 metres of the shoreline. The traditional tuna identification methods referred to above were employed to classify the fish, which were then counted and weighed in groups, and the average individual weights recorded.[5]

Beginning the process of identifying the eels by sex and maturity at the *Tuna Rere* time.

Other fish species present were also identified, and their length recorded.

4.5.5 Macroinvertebrate Species

Aquatic macroinvertebrates occupy a key place in aquatic ecosystem functioning, and may also provide robust indications of water quality and potential changes to this. It is our belief that Maori have had a detailed knowledge of many of these species and their roles in aquatic ecosystems, but that however, much of this detail may no longer be freely available.[6]

The focus of our research was not so much to establish a water quality 'index' for Lake Whakaki, as to identify trophic levels and potential food webs, and to provide a 'snapshot' of invertebrate species diversity, abundance and potential resilience.

Samples were collected during a two minute sampling period using a fine mesh net with a collection area of .25sqm. Wherever possible, samples were gathered separately from the water column, the sediments (benthos) and the littoral margins (see Figure 3, p12 below). This was not always

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[5] While it would have been of value to individually assess the weight and length of the male and female fish caught, the sheer volume of tuna present at this time precluded this, given the scope and resources available.

[6] Winterbourne, M.J., and Collier, K.J., *New Zealand Stream Invertebrates: Ecology and Implications for Management*, Caxton Press, 2000.

possible, as for instance at the 'Lake Centre' and the two modified stream sites feeding into the Lake at Te Ara Waerea and Te Ramarama.
For these sites, an overall sample was taken and referred to as a 'General' sample.

Each sample was collected in plastic dishes for identification and counting. Because of the huge numbers of some species (especially mysid shrimp and snails), actual numbers of these species was visually assessed. Early in the project, these assessments were 'calibrated' against a smaller sample, and were found to be sufficiently accurate to provide good data for our purposes.

4.5.6 Land use impacts

This included gathering 600ml samples of stream sediment, and similar sized samples of soil from adjacent cropping and farm land. These were then frozen and ultimately sent to HortResearch NZ in Ruakura to be analysed for a wide range of active pesticides and their residual compounds. Attention was also paid to the biology of the waterways from which the sediment samples were taken.

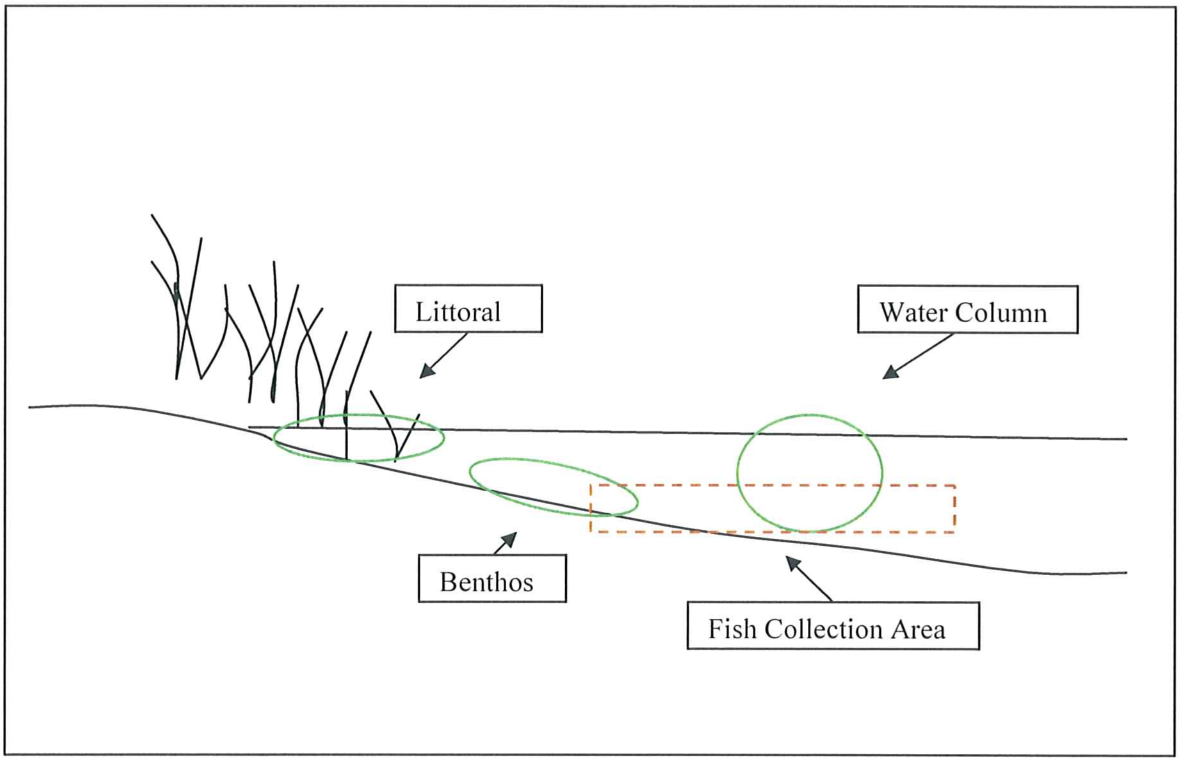
4.5.7 Research capacity

A fully collaborative approach was adopted by the research team to ensure a high level of participation amongst members of the hapu of Whakaki. This involved work establishing the methodology of the program and playing key roles in the 'hands on' data gathering, as well as regular and ongoing information sharing and liason with Lake trustees and staff, and the wider whanau.

This process of collaboration and 'growing knowledge together' included the incorporation of other research that had been focused on the Lake. This included:

- The NIWA algal surveys conducted during late 2007 and referred to above;
- The Hawke's Bay Regional Council 2007 survey of the Lake Whakaki environment as part of their biennial wetland survey program;
- The HortResearch assessment of pesticide residues in soils and sediments in the Lake catchment also referred to above.

Figure 3: Macroinvertebrate and Fish Collection Areas



5 Habitat Types

5.1 Introduction

As referred to above (Section 4.2, p4), we chose the monitoring sites on the Lake to provide a representation of the potential diversity of aquatic ecological settings present here. After these sites were decided upon, we then sorted them into what we considered may be distinct aquatic environments across the whole Lake system, and in particular its perimeter, and the areas traditionally fished and considered by the Tangata Whenua to be of significance.

After our first monitoring period, it appeared evident that there was very likely to be a direct correlation between littoral vegetation and species abundance and diversity. The sorting process into habitat types has thus been strongly influenced by the density and composition of this vegetation.

This categorization of habitat types may be compared to that adopted by the Hawkes Bay Regional Council, but differs in that our focus is on those areas either usually wet, or at least periodically inundated, rather than including distinct terrestrial vegetation areas as well.

> "Seven major vegetation types were identified in 1999 and mapped. The observations made then were found to be valid in 2001, 2003, 2005 and 2007:
> **W** Low herbfield-sedgeland in zone of wave action and periodic inundation; contains turfs of *Mimulus repens* and *Lilaeopsis ruthiana*, much used by waterfowl.
> **SR** Lagoon shore fringe of dense sedges and rushes; dominated by *Juncus kraussii* and *Bolboschoenus fluviatilis*; shore ribbonwood (*Plagianthus divaricatus*) present in places.
> **MG** Mosaic of rushes, sedges, blackberry and grazed pasture; mainly backing the shore fringe on the west, north and east sides of the lagoon.
> **MR** Mosaic of rank grasses, rushes, sedges, pohuehue, lupin, blackberry and other shrubs (including gorse and boxthorn); backing the shore fringe on the south side of the lagoon.
> **Ra** Sparse vegetation containing cushions of *Raoulia* aff. *hookeri* and various exotic grasses on open sand-shingle flats at the rear of the dunes. The presence of *Raoulia* aff. *hookeri* is of significance: this species is at the northern end of its geographic range.
> **Sp** Spinifex grassland on foredunes; one of the best populations of this native sandbinder left on the East Coast of the North Island (strangely virtually free of marram grass).
> **Ma** Marram grassland; two eradicable patches near the south-west corner of the lagoon."[7]

5.2 Type 0

This refers to the central Lake environment, approximately one hundred and fifty metres from the shore. This setting was included to provide both an indication of water quality and the presence of eels in the central parts of the Lake, and also as a 'control' for the areas around the Lake's perimeter.

Site 11: 'Lake Centre'.
S39*02.651 E 177*33.853

7

5.3 Type 1

This comprises the modified streams draining the farmlands of the Lake's northeastern catchment and the highway stormwater system. These streams are characterized by a range of native and exotic littoral vegetation, and at times considerable stream algae. They may be exposed to a range of anthropogenic influences, including the application of pesticides for both agricultural purposes and road vegetation control, and the direct suppression of aquatic plants.

Right: Site 9, Te Ramarama (Junction), on the 13th March 2008.

Below left: Site 10: Te Ara Waerea, sampled in September 2007 prior to cultivation. Below right: the same site on 13th March 2008.

5.4 Type 2

This is a lowland stream type, based on our Te Ewe (Site 5) stream monitoring site approximately 180m north of the Whakaki Marae. This is a freshwater site up to 1.2 metres deep with only low levels of salinity present (average 0.2 ppt). The riparian areas are vegetated with a mix of native and exotic species, including Ririwaka (*Bolboschoenus fluviatilis*), and there is a range of stream algae present. The substrate comprises firm to soft sediments, and there is a gentle flow towards the lake.

5.5 Type 3

Habitat Type 3 is exemplified by the site known as 'The Landing'. This site is at the bridge crossing over the restored channel, Rahui, approx. 600m from Te Awa a Puruaaute. Rahui is the site of the original river channel prior to Catchment Board drainage programs, and carries the Lake to the current outlet at Paaka. The water here is considerably deeper than elsewhere in the main body of the lake, possibly due to the periodic scouring of the riverbed during the bar opeining times.

Salinity levels in the upper water layer of the Landing averaged 1.1 parts per thousand (ppt) during our monitoring periods prior to the opening of the Lake bar, after which it rose to 4.2ppt. The predominant littoral and aquatic vegetation here is raupo, with the free living azolla also present during December to March.

Site 6, The Landing. S39*02.559 E177*35.330.

5.6 Type 4

Close proximity to the sea and the site of periodic artificial opening of the Lake outlet characterizes the Habitat Type represented at Lake Whakaki by Paaka. Paaka is believed to by the Tangata Whenua to now be the primary venue for the tuna migration, and our research has confirmed this. Here, extensive stands of ririwaka dominate the littoral area along with considerable raupo beds, and varying quantities of free living and benthic algae.

Site 7: Paaka. S39*03.077 E177*35.998.

5.7 Habitat Type 5

This Habitat Type is represented by Site 1, Te Awa Wahi, the first well-vegetated headland adjacent to the sandy beaches comprising the previous artificial Lake outlet and bar sites. The old bars are devoid of littoral vegetation, although there is some free living and benthic algae present. At the headland, littoral vegetation is predominantly a form of wiwi (*Juncus kraussii*) with ririwaka behind, and some benthic algae present also.

Site 1: Te Awa Wahi. S39*03.202 E177*33.878.

5.8 Type 6

This Habitat Type is characterized in the monitoring sites on the northern side of the Lake. These sites, The First Bluff, which is currently our westernmost monitoring site, and Te Awa a Puruaaute, which lies at the entrance from the Roto to the awa Rahui, exhibit a shallow wetland perimeter and extensive littoral vegetation. Here wi wi combines with ririwaka in the shallows at the Lake's edge, with ririwaka extending extensively landward across a broad flood plain. Substrates appear to include fine sediments and organic muds.

Site 4: The Bluff. S39*02.496 E177*33.836

Site 3: Te Awa a Puruaute. S 39*02.651 E39*34.589

5.9 Type 7

Habitat Type 7 is exemplified by dense littoral vegetation with the form of wiwi (*Juncus kraussii*) in the deeper shallows, combining with ririwaka in the shallower water, and ririwaka and convolvulus at the landward edge of the Lake, these latter species together extending back towards the drier dunelands. The site known as P Mildon (Site 2) is our example of this type. Substrates here include predominantly beach and pumice sands overlain with organic muds.

Habitat Type 7: P Mildon. S39*03.051 E177*33.162. At right, prior to the spring growth of the ririwaka. Left, the young shoots beginning to come away.

5.10 Type 8

Habitat 8: Site 8 Patangata. S39*03.080 E177*36.742

Habitat Type 8 is exemplified by Patangata (Site 8). Patangata is the remnant waterbody of the ancient channel carrying Lake Whakaki to the outlet at Opoho. The bed of this waterbody is deeper than the Lake itself, and drops off more rapidly. Vegetation comprises some ririwaka and wiwi with extensive free living macroalgae.

For almost the whole year, Patangata is separated from Paaka by a narrow strip of land. During April, however, at the *Tai Tipi* time[8] however, there was a stream flow back to the Lake. Patangata was consistently the most saline of the sites monitored, except after the opening of the bar, when seawater flooded back through Paaka to the main body of the Lake.

[8] The time of year when the tides and oceanic conditions combine to create a 'mini tsunami' (Tumanako Walter Wilson 2005).

6 Research Findings

6.1 The Physical Characteristics of Te Roto o Te Whakaki

6.1.1 Salinity

While considering the development of the Matauranga project, it was anticipated that the main body of the Lake would be slightly to moderately brackish, ie exhibiting levels of salinity above that of its freshwater feeder streams, but possibly less than an estuarine environment regularly open to the ocean.

This generally proved to be the case, although salinity levels across the various Lake environments exhibited some unexpected results. Prior to the artificial opening of the Lake to the sea on the 1st of August, however, these results remained consistent at each individual site. Average salinity and conductivity readings prior to the Lake opening are outlined in Figure 4 at p23 below.

Some of the findings are as follows.

- The main body of the Lake is overall usually the most saline of the Lake system (excluding the remnant waterbody at Patangata). At the four sites here (Sites 1, 2, 3 and 4, including Te Awa a Puruaute) the average salinity was 2.0 parts per thousand (ppt). Such a level of salinity is usually described as brackish.

- Salinity levels began to decrease at Te Awa a Puruaute (the mouth of the river feeding back to the new outlet) and continued to gradually decrease along the river towards the new Lake outlet at Paaka.

- Paaka also appears to be fed by one, or possibly a series of freshwater springs. These can be observed flowing up through the sand and back into the Lake at high tide. This results in the waters at Paaka, despite being closest and periodically opened to the sea, having the least salinity of any of the actual Lake sites monitored. The presence of freshwater at this site is known to the local people, who remember their tipuna living on the dunes adjacent to Paaka, and gather their drinking water from springs there.

The new bar opening g at Paaka. Water emanating from the dunes (above) is fresh. This appears to coincide with the spring high tides, the freshwater possibly forced upwards by hydraulic forces. At low tide the remnants of its flow paths can be seen where they have entered the Lake. March 2008.

- This decreasing levels of salinity from the main body of the Lake to Paaka, however, is reversed as soon as the Lake outlet is opened. Seawater then floods into Paaka and appears to migrate rapidly back to the main body of the Lake itself. The presence of highly saline water up to Te Awa a Puruaute after the outlet opening on August 1st (salinity at Paaka >10ppt and 4.2ppt at Te Awa a Puruaaute) had continued during our final monitoring period on the 5th and 6th of August.

- Salinity levels, especially on the northern side of the Lake at Te Awa a Puruaute, the First Bluff and at the Landing, decrease markedly after very heavy rain. This may be partly explained by the large amount of freshwater entering the Lake via precipitation and overland flow, remaining in the normally dry parts of the wetland here, and mixing with the otherwise more saline waters.

6.1.2 Conductivity

Electrical conductivity provides a measure of the levels of minerals present in a water body. This can include both non-metallic minerals such as sands, stone and phosphates, and metallic minerals such as gold, copper and aluminium.

It was anticipated that high conductivity levels found in the main body of the Lake were the result of sea water (sodium) influence. This proved to be the case, with decreasing salinity levels here reflected in decreasing conductivity levels.

The streams feeding into the lake, however, maintained conductivity levels common in lowland streams passing through production landscapes. At Te Ewe, these levels ranged from 320 to 580 ppm. At Te Ramarama and Te Waerea the range was from 310 to 540 ppm. Salinity levels in all these waterways remained between 0.2 and 0.3ppt. At these sites, increased rainfall was reflected in a decrease in conductivity levels, suggesting that the migration of minerals from land use in their catchment is not currently having a significant impact on these waterways.

6.1.3 Water Clarity

Water clarity is most commonly used as an indication of turbidity and levels of sediment suspended in the water column of flowing streams and rivers. In the context of a large shallow Lake such as Whakaki, it may also provide an indication of the presence of phytoplankton and microalgae reducing water transparency.

We believe that this was the case during our sampling periods from September 2007 to August 2008. Clarity in the main body of the Lake at Sites 1, 2, 3 and 4 remained very low despite much higher clarity levels in the main feeder stream (Te Ewe) in the northern section of the Lake, and even higher levels in the streams draining cropped land to the north east.

This may indicate:

- Fine sediments in the Lake are being held in suspension for long periods. This may in turn be due to currents operating within the Lake itself, or possibly by the action of the wind in maintaining turbidity;
- The shallow and potentially warm waters of the Lake are supporting high levels of phytoplankton and microalgae. A distinctive change in the colouration of the Lake was evident between our first and second sampling periods. Local knowledge indicates that the extent of this discolouration is a relatively recent phenomenon. The emerald green colouration had persisted to the middle of March 2008, and was still evident in mid April. Questions raised about the potential role of microalgae and phytoplankton in the Lake ecosystem are discussed in our Conclusion at Section 7, p?.

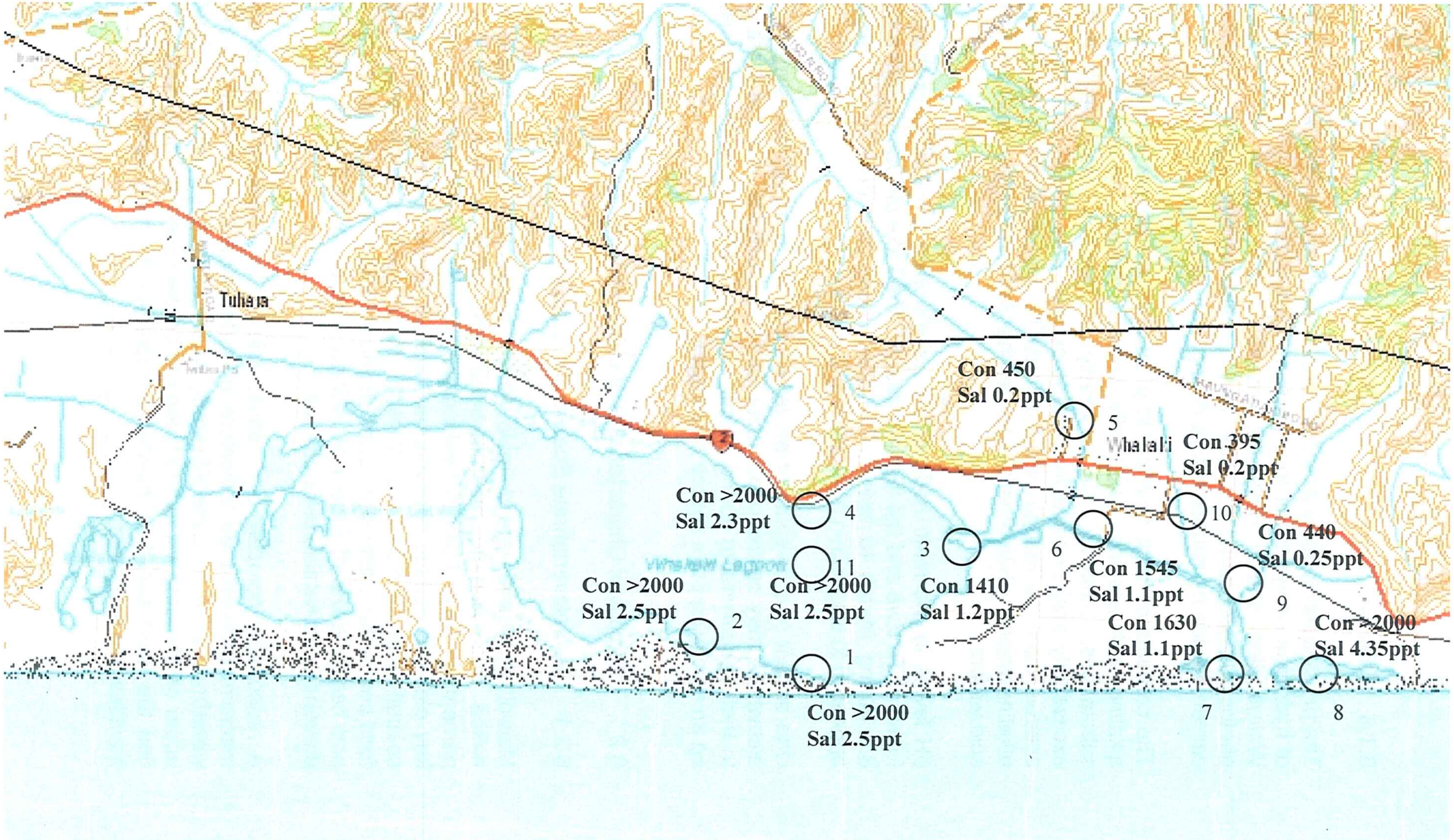
6.1.4 Water Temperature

Water temperature in the main body of the Lake ranged from 6.5c at 7.30am on August 5th 2008 at the Lake Centre, to 26c on December 3rd 2008 at Te Awa Wahi and P Mildon. These are remarkable variations although consistent with similar shallow lakes elsewhere.

One characteristic of note, however, is the ability of Lake Whakaki to maintain its temperature despite fluctuations in the diurnal air temperature. That is, once a given water temperature has been reached, this appears to change only relatively slowly in response to changes in air temperature. This characteristic of the Lake as a 'heat and chill sink' may possibly go some way to explaining the fecundity and early ripening of stone fruit orchards adjacent to the Lake's edge.

The considerable fluctuations in water temperature may also partially explain the absence of the more sensitive aquatic macroinvertebrates from the Lake body, and the rapid development of an extensive 'algal bloom' at the onset of warmer weather. On the other hand, such a temperature fluctuation may also facilitate a resilience in the species assemblages and overall ecosystem functioning within the Lake, and indeed help support what we have observed as extremely high levels of such resilience and species abundance.

Figure 4: Aquatic Monitoring Sites Te Roto o Te Whakaki – Average Salinity and Conductivity Levels



6.1.5 Water pH

The pH of water reflects its acidity or alkalinity, essentially the concentration of hydrogen or hydroxide ions present. Pure water has a 'neutral' pH of 7. Waterbodies exhibit daily fluctuations in pH due to the process of photosynthesis during the day, and the subsequent acidifying release of carbon dioxide by aquatic plants during the night.

The contents of most animal and plant cells are neither strongly acidic nor alkaline but are an essentially neutral mixture of acidic and basic substances. Similarly, for a variety of reasons, waterways that are excessively acidic or alkaline tend to support little aquatic life. Several fish species such as Inanga and Common bullies eg seem to prefer slightly alkaline waters while others, such as the Banded kokopu, may prefer more acid waters.

pH levels in the main body of the Lake's were more alkaline than those found at Te Ewe and the feeder streams. The Lake pH varied from a high of 8.7 during March to low of 7.6 after heavy rain in July, but generally appeared to stay within a range from 8 to 8.4.

One aspect of a diversity of pH levels present in an aquatic system noted elsewhere may be the opportunity for fish to relocate to areas more suited to their requirements during events adversely affecting water pH (such as eg an acidifying point source discharge).

6.2 Biological Characteristics of Lake Whakaki

6.2.1 Macroinvertebrate Species: Introduction

Macroinvertebrates are animals without backbones that are visible to the naked eye. Aquatic macroinvertebrates range in size from the just perceptible water fleas to freshwater koura. These invertebrates occupy a key place in aquatic ecosystems, whether these be mountain streams or coastal lakes such as Lake Whakaki. Macroinvertebrates provide a primary food source for most fish species during at least at some stage of their lives, and hence levels of fishery abundance can often be directly linked to the presence of palatable invertebrates.

A reasonably complex and robust science has developed using aquatic macroinvertebrates as indicators of water quality. In a shallow, lowland waterbody such as Lake Whakaki, where suspended sediments from the upper catchments will naturally tend to be deposited, it would be unusual to find the most sensitive invertebrate species such as certain caddis flies, mayflies and stoneflies.

However, given the natural lowland and coastal character of the Lake, it is clear that although the majority of invertebrate species here are tolerant of a range of water conditions, the Lake contains a remarkable abundance of these species, and that these in turn might be expected to support an abundance of the eel fishery.

6.2.2 Macroinvertebrate Assemblages

Over the five monitoring periods undertaken, we discovered a total of 26 species in whole Lake system including the adjacent tributary streams. In the main body of the lake itself from Paaka to P Mildon to the south west, and to the Bluff to the north west, two species were by far the most numerous. These were the Mysid shrimp, *Tenagomysis novae-zealandiae*, and the rounded snail, *Potamopyrgus*, or *Ngata pouri*. The next most common species were:

- Backswimmers and Waterboatmen (*Hemiptera*)
- Estuarine Isopods (*Crustacea*)
- Midge larvae (*Diptera*)
- Amphipods (*Crustacea*)

The Whakaki Lake ecosystem is notable for the abundance of macroinvertebrate life, particularly the mysid shrimp (above left) and the freshwater snail, across a range of environmental gradients.

Each of these species occupies a somewhat different ecological niche in the Lake system. *Tenagomysis*, for instance, is a free living zooplankton feeding largely on a phytoplanktonic or microalgal diet. The *Ngata*, on the other hand, grazes on aquatic plants, detritus, and organic matter present in the benthic sediments.

As we have seen earlier, a characteristic feature of the Lake environment is the often dramatic variation in water temperature and salinity attendant on seasonal changes and the bar opening. We believe it is significant that the macroinvertebrate species present here are sufficiently resilient to withstand these changes, and to maintain a high level of abundance across the year. Thus we suggest that the three aspects that characterize these macroinvertebrate assemblages are: simplicity, resilience and abundance.

6.2.3 Other Factors

6.2.3.1 Isopods

A species that emerged in significant numbers in the latter half of the program was an estuarine isopod.

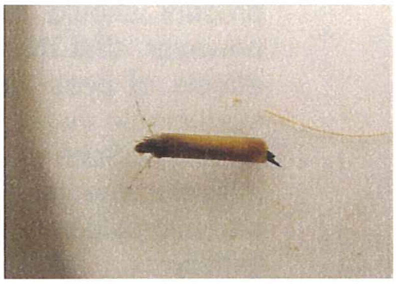
6.2.3.2 Patangata

Patangata is the remnant waterbody of the original channel carrying Lake Whakaki to its historical outlet at the Opoho Stream. This area is of great cultural significance to the hapu of Whakaki. It also provides evidence of macroinvertebrate species that have remained here despite the impounding of the waterway due to the artificial drainage programs between the 1950's and 1996, and the subsequent high levels of salinity and the absence of water flow (except after very heavy rainfall and then back into the waters at Paaka).

This would suggest that:

- The substrate and littoral or riparian areas at Patangata were originally comprised of materials and species sufficient to support those macroinvertebrates requiring water quality characterized by high dissolved oxygen, cool temperatures and low levels of salinity.

- These species, however, appear to be considerably more resilient, and tolerant of changes in water quality parameters than previously believed.



The woody cased caddis at right is an example of an invertebrate normally associated with cooler freshwater streams but present at Patangata in relative abundance.

6.2.3.3 Land Use and Invertebrates

Soil and sediment samples were gathered from the two monitoring sites situated at the modified streams set in the cropping lands adjacent to the Lake (Te Ara Waerea Site 9 and Te Ramarama Site 10). These samples were tested for the presence of a range of pesticides and their residual compounds.[9] The streams were also sampled by our team for the presence of macroinvertebrate life.

On the 18th September 2007, during our first monitoring period, there was no evidence of any aquatic animals, either fish or invertebrates, at Te Ara Waerea. At Te Ramarama, no invertebrates could be found, although four common bullies (*Gobiomorphus cotidianus)* were caught in the stream.

On the 13th March invertebrate sampling was again undertaken, and this time three macroinvertebrate species were present at Site 10, and two at Site 9, but in low numbers. Common bullies were present at both sites (12 and 40 animals respectively).

The presence of invertebrates continued to increase during monitoring periods four (1.8.08) and five (6.8.08). Not only were numbers reestablished, but there was also an increase in the diversity of species, including the apparent presence of some more sensitive species such as mayflies.

It is at present uncertain if there may be a correlation between the absence of macroinvertebrate life in these waterways during our first monitoring period, and the presence of detectable levels of Glyphosate and its principle metabolite, AMPA.

[9] See Northcott, G.L., and Ponga, H., *Investigation of Pesticide Residues in Lake Whakaki Sediments* (Draft), HortResearch, Ruakura, July 2008.

The available research appears to suggest that the herbicide at the levels present should not adversely affect invertebrate life.[10] We do believe, however, that there is an opportunity to extend our understanding of the effects of pesticides on aquatic life, particularly so in the context of the sustainable management of the catchment and waterways feeding into Lake Whakaki. Such effects should be framed both in terms of macroinvertebrate indicator species, and also the effects of herbicides on the phytoplankton and microalgae supporting the ecosystem functioning of the Lake and its eel fishery.

These considerations are referred to in our Conclusion in Section 7 below.

6.2.2 Fish Species: Introduction

Six species of fish were caught in the Lake and streams feeding to it. These were:

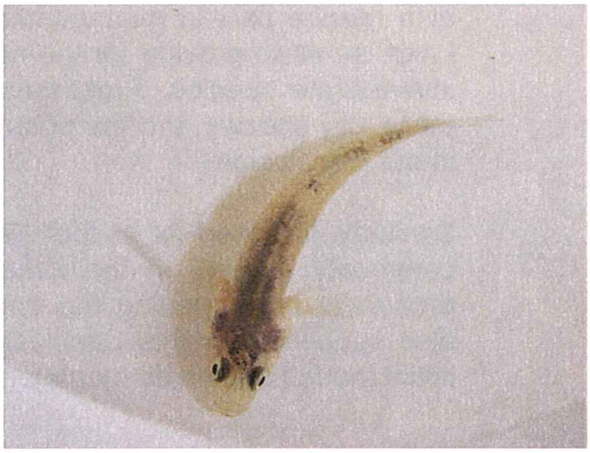
- Shortfin eel (*Tuna, Anguilla australis*)
- Longfin eel (*Tuna, Anguilla dieffenbachia*)
- Common bully (*Gobiomorphus cotidianus*)
- Goldfish (*Morehana, Carassius auratus*)
- Yellow belly flounder (*Patiki, Rhombosolea leporina*)
- Grey mullet (*Kanae, Mugil cephalus*)
- Inanga (*Galaxias maculates*)

By far the most numerous species is the Shortfin Eel, followed by the Common Bully, then Goldfish and Longfin Eel, and then Flounder, Mullet and Inanga. Many very juvenile fish were found throughout the year. These appear to be young bullies breeding in large numbers in the lake's littoral margins.

[10] Northcott and Ponga, July 2008.

Above, two welcome inhabitants of Lake Whakaki: at left, Patiki, and a large Morehana at right.

To our immediate right, a medium size Common Bully. The presence of relatively abundant populations of these fish throughout the Lake systems suggests an important food component underpinning the level of abundance of the shortfin eel population.



The shortfin eel fishery is of the utmost cultural, social and economic importance to the Tangata Whenua of the Whakaki Lake area. Similarly, the management of the habitats and catchments feeding into the Lake comprises one of their most pressing environmental concerns.

During the period of our research, the abundance and composition of this fishery appeared to have been influenced predominantly by two main factors. These are:

- Habitat type, both specific and in the context of the wider Lake ecosystem and the availability of food;
- The existence of a solely Maori customary fishery management regime.

6.2.2.1 Food Webs at Lake Whakaki

Investigation of the gut contents of the 32 shortfin eels dissected indicated that all of the major macroinvertebrate species in the Lake as well as the Common bullies were being utilized as sources of food. The significance of the Mysid shrimp population to the maintainence of a thriving eel population was difficult to accurately gauge, however, due to the high levels of soft tissue and presumed digestibility of this species. Nevertheless, considering the abundance of these crustacea, it is our belief that they provide, along with the snail, *Ngata pouri*, the foundation for the eel populations here.

This would suggest that sustainable management of the eel fishery may also require careful management of the Lake habitat, and inputs into the Lake, so as to provide for the maintenance of healthy populations of these invertebrate species. Processes necessary to explore the significance of these key species and the potential impacts on their habitat are suggested in our Conclusion.

Similarly, the need for an identification of the phytoplankton and microalgae commonly present in the Lake system, and the role of these primary producers in supporting the consumers and predatory species here, are also suggested in this Conclusion, along with potential threats and some initial thoughts towards management guidelines.

6.2.2.2 Eel Fish Stocks

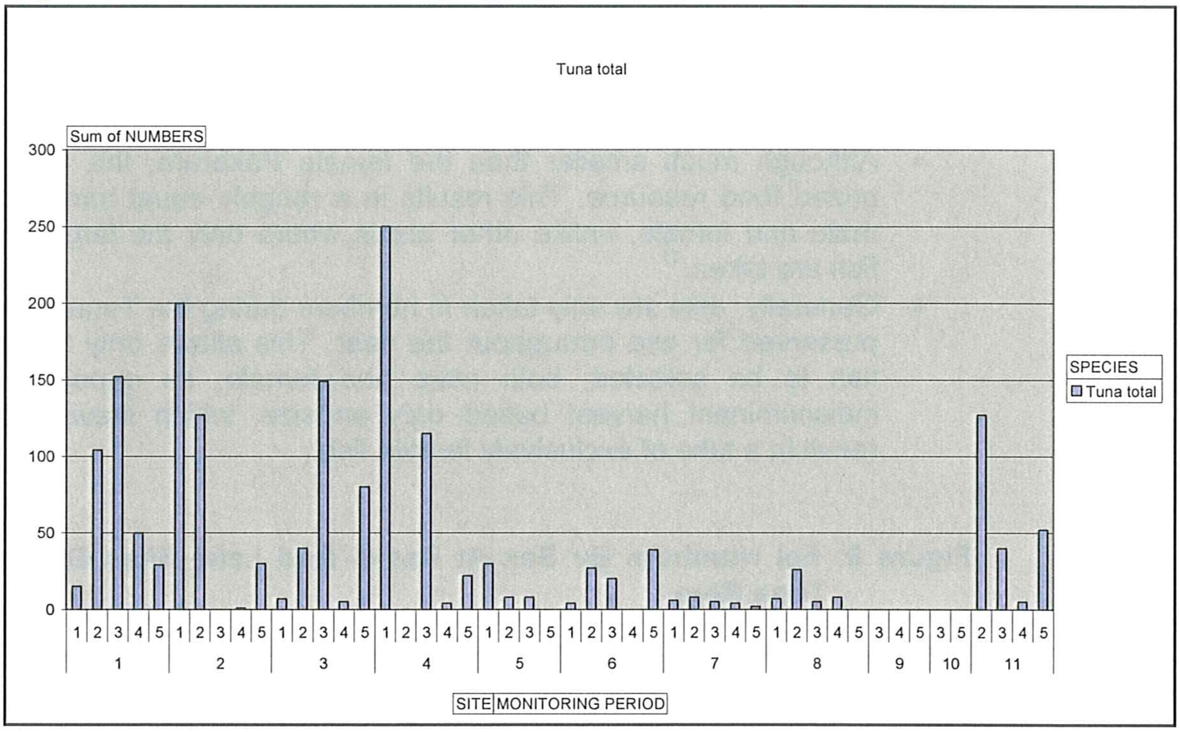
During the four main monitoring periods, from early September 2007 to late July 2008, there were 34 net sets. The total number of eels caught during these periods was 1564, and the Catch per Unit Effort (CPUE) 46. After the Lake outlet was artificially opened on August 1st, we had a further 7 net sets, catching 196 eels with a CPUE of 28.

During the Tuna Rere, we carried out a further 29 net sets, 20 of these at three sites at Paaka, and the rest at sites within the Lake itself. The total fish caught over this period was 1044 with a CPUE of 36.

The total CPUE from all sites at all periods, from September 2007 to August 2008, based on a total catch of 2590 from 70 sets, was 37.

This figure, however, contains catches that we believe may have been significantly impacted by an illegal fishing operation carried out clandestine ely at the Lake at some time between mid March and mid April. In particular, there were several of our net sets when very few eels were taken, yet the catches immediately prior to these sets had been considerable.

Figure 5: Total Eels Taken During The Five Monitoring Periods

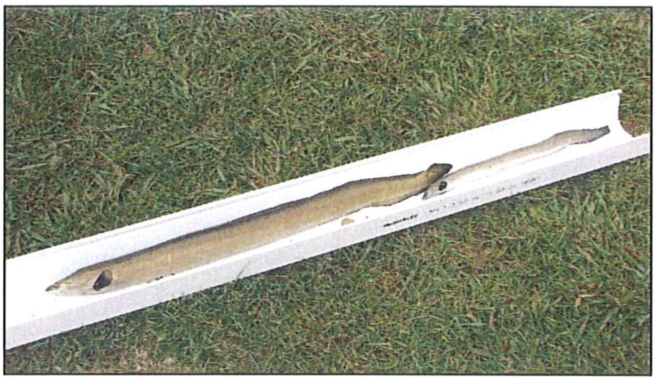


6.2.3.3 Sexual Distribution

Because of the ability of the Tangata Whenua of Whakaki to accurately identify the sex of the migratory eels in the Lake, we were able to establish the ratio of mature male to female fish present during the eels' migratory season.

During this time, we gathered fish from 29 net settings, 20 of which were sited at Paaka, which is believed to be the primary venue for the eel's migration to the ocean, as well as 9 other 'control' settings at other sites within the Lake system.

Of the 1019 sexually mature shortfin eels caught during the Tuna Rere, 288 were Pakarara, mature females, and 731 were Hao, mature males. This provides a ratio of 1 female to 2.5 males.

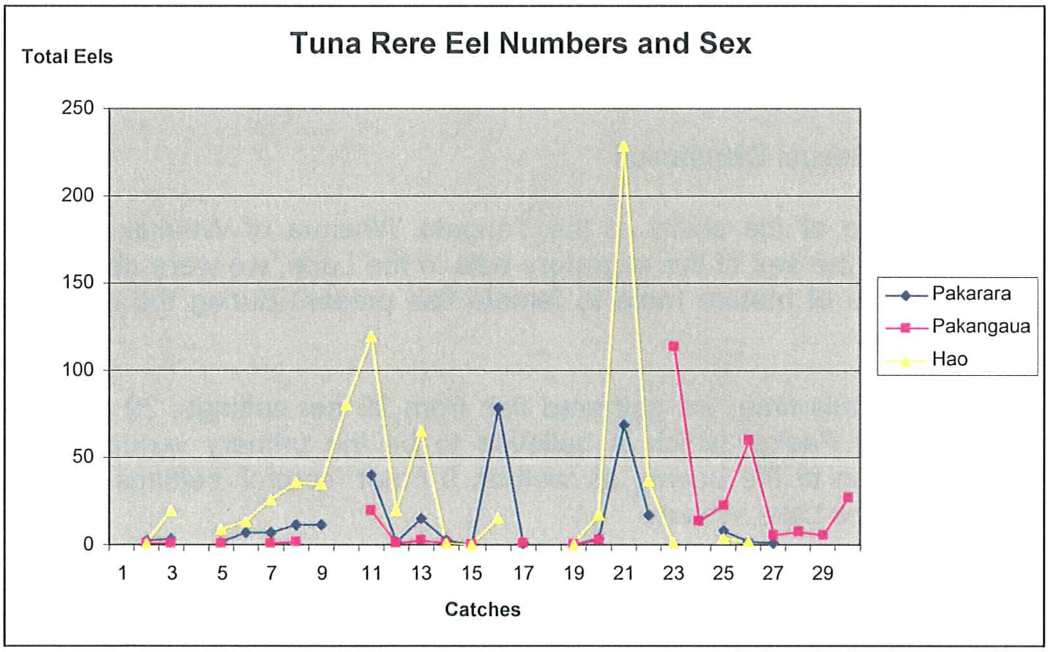


Pakarara and Hao. March 2008.

We believe that the distribution of male to female shortfin eels in Lake Whakaki can be directly attributed to the Maori customary fishery management practices. This is ostensibly for two reasons:

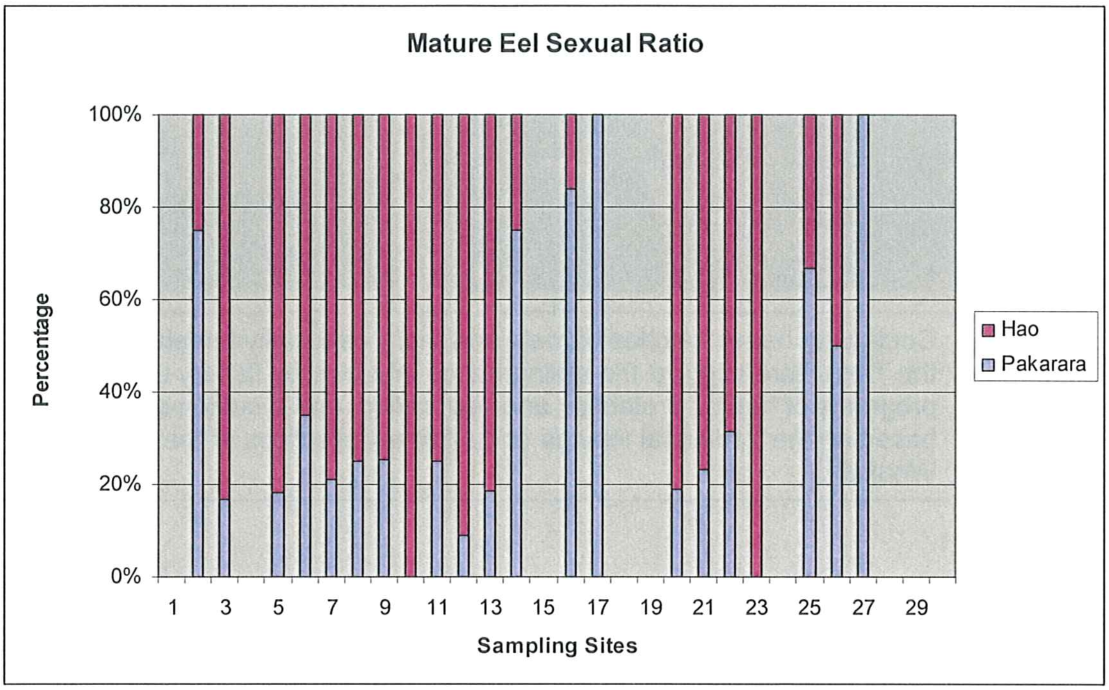
- Although much smaller than the female Pakarara, the Hao are a prized food resource. This results in a roughly equal harvest of the male and female, unlike other areas where only the larger, female fish are taken.[11]
- Generally, eels are only taken in numbers during the Tuna Rere, and preserved for use throughout the year. This allows only the mature fish to be selected, both male and female, as opposed to an indiscriminant harvest based only on size, which inevitably must result in a take of exclusively female fish.

Figure 6: Eel Numbers By Sex At Paaka And Lake Sites During The Tuna Rere



[11] By requiring a minimum size take of 220gm, current fisheries legislation mitigates against the type of sustainable harvest as carried out at Whakaki under a traditional customary model.

Figure 7: Male to Female Ratios of Shortfin Eels at Tuna Rere Monitoring Sites



6.2.3.3.1 Mature Eel Weights

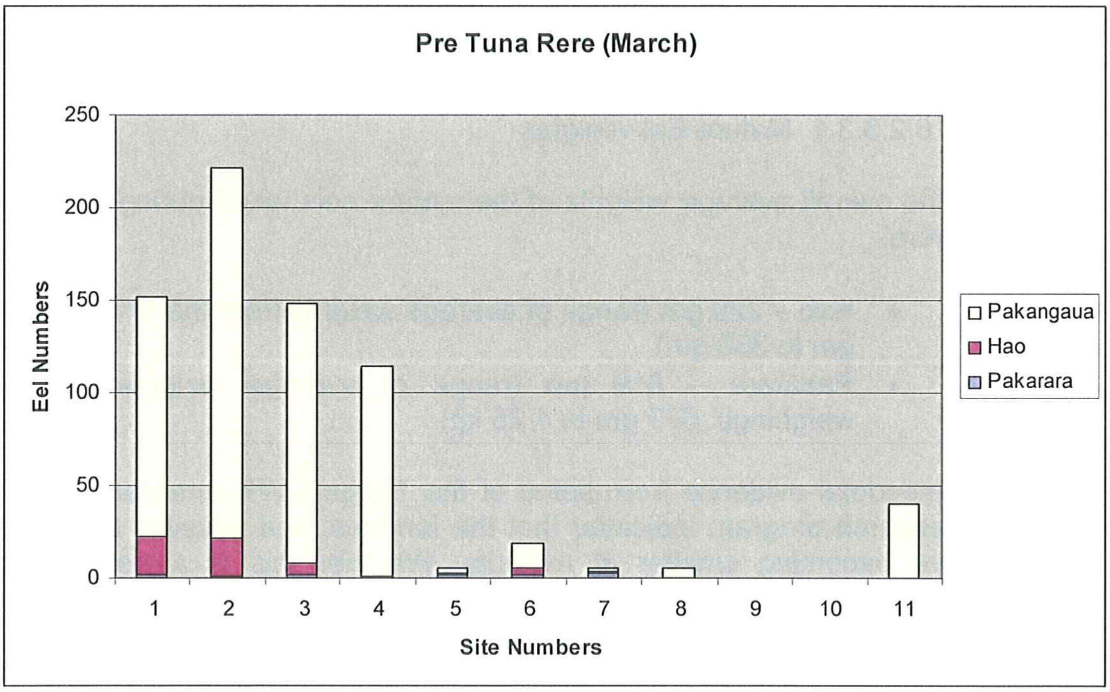
The overall average weights of the mature eels taken during the Tuna Rere were:

- Hao – 220 gm (range of average weights from the 11 weighings: 176 gm to 330 gm)
- Pakarara – 819 gm (range of average weights from the 11 weighings: 679 gm to 1.25 kg)

Anecdotal evidence from some of the Tangata Whenua participants in the research program indicated that the females, and possibly the males also, are becoming smaller at maturity. Whether this is a trend, a 'one-off' response to climatic or other environmental conditions, or a consequence of abundant fish numbers in the Lake is at present unknown.

Continuing heavy catches of male and more especially female shortfin eel during the Tuna Rere suggest the maintenance of a healthy fishery under the dual programs of habitat protection and restoration, and a customary harvest regime based on the traditional tikanga or customary practices of the Tangata Whenua of Whakaki.

Figure 8: Shortfin Eels Taken Just Prior to the Tuna Rere



6.2.2.4 Eel Parasites

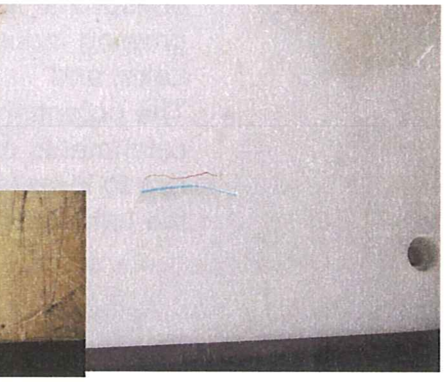
Over the period of our research program, 26 eels of varying sizes and stages of maturity were taken for gut analysis and dissection. Of these, only the very youngest (ie those just big enough to be able to be trapped within the fyke net mesh) were found to be free of the worm-like parasites and parasitic cysts shown in the photographs below. These parasites and their cysts are present predominantly in the gut and gut wall, although they have been observed migrating from here, and into the flesh of the fish itself.

According to local knowledge, the pervasiveness of these parasites is a new phenomenon, virtually unknown prior to 1990, but now comprising what appears to be total infection of the maturing eel population.

At present, our research team is engaged in a more accurate identification of these parasites, their biological and ecological characteristics, and their potential impact on the tuna fishery at the Lake.

Above, the cysts are clearly visible attached to the outer lining of the gut and intestines of a heavily infected medium sized shortfin eel. Above left, the coiled worm just having emerged.

At right, the worm extended. Some of these parasites are also white coloured.



7 Conclusion: Initial Recommendations for Management and Ongoing Research

7.1 Introduction

Our research program over the last year has identified a range of characteristics relating to the structure and functioning of the ecology of Lake Whakaki. These include:

- An initial indication of some physical aspects of the Lake waters, and the dynamic context of water quality here;
- An outline of likely food webs amongst the more visible species in the Lake, and the relationship of these with riparian and littoral vegetation types;
- An indication of levels of macroinvertebrate species diversity, abundance and resilience;
- Potential levels of abundance of the tuna population, their migratory habits, ratios of male to female fish, and possible morphological changes over recent time; and
- The relationship of the Maori customary fishery management regime with the overall Lake ecosystem structure and functioning.

Certain related factors became apparent during the year's research. These include:

- The importance of littoral and riparian vegetation in providing for macroinvertebrate and fish habitat;
- The key role that phytoplankton and microalgae may play in the abundance of the trophic levels, particularly from shrimp to fish;
- The potential impact that pesticides, and nitrogenous and phosphatic fertilizers (attendant on the burgeoning corn and maize growing industries), may have on the ecosystem functioning of the Lake; and
- The potential impacts of other intensified land use activity within the catchments of the main feeder streams to the Lake, possibly giving rise to increased sediment and nutrient loadings to the main body of the Lake itself.

7.2 Recommendations

Arising out of these, we have included as part of our conclusions, a series of recommendations for mitigation or enhancement of these considerations, and further research, aimed at supporting the goal of sustainable management of the Lake catchment and the body of the lake itself.

These recommendations include:

- Fencing and the exclusion of stock from the riparian and littoral perimeter of the Lake, and preferably from as many as possible of the stream banks feeding into the main water body itself. In some cases, replanting with appropriate species may also be desirable;
- Providing for a setback of cropping areas from the waterways' edge (eg a minimum of five to ten metres) and the creation of vegetated buffer strips (preferably shrubs and tall grasses) or hedgerows between these cultivated areas and the waterways;
- Investigating the use of raupo or similar vegetative 'filters' and/or sediment traps to intercept sediment and other waterborne contaminants where feeder streams or farm drains enter the tributaries or the main body of the Lake;
- Further research into the effects of increasing pesticide use and the practice of tile draining farm and cropping lands on the Lake ecology;
- Encouraging education about the potential effects of pesticides and increased sediment loads on the aquatic life and resources of the Lake, and the advocacy of 'best practice' scenarios for mitigating these; and
- A reassessment of current national eel fisheries management regimes, given the beneficial effects of the seasonal harvest of small male shortfin eels, as well as the larger females, on the sex and size distribution and levels of abundance of eels in Lake Whakaki.

Our year's research has raised some important questions relating to the Lake ecology and species behaviour here. We believe these questions may provide the basis for an ongoing research program, particular aspects of which might include:

- Identification of the age range of the mature shortfin eel population through otolith sampling, along with a more detailed analysis of their sizes and weights. This information could then be compared with other studies to determine the relationship between the Lake ecology and fish growth rates;

- A thorough investigation of the food sources of the tuna at the different times of the year. This would involve radiometric sampling of fish gut contents at the seasonal monitoring periods;
- A continuation of the current monitoring program with certain adaptions, such as the inclusion of sampling for dissolved oxygen (DO), a simplified macroinvertebrate assessment model, and the development of a geographic information systems (GIS) mapping database to store ecological and cultural material for the Lake and environs;
- An investigation into the role of the wind and sub surface currents in oxygenating the Lake waters and maintaining sediments in suspension;
- Identification of important species of phytoplankton, microalgae and macroalgae, waterborne bacteria, etc in the Lake ecosystem and in particular in relation to the biology of the *Mysid* shrimp population; and
- The commencement of a program looking at recruitment of *Tuna* (as glass eels or *Ngoiro*) at the Lake; and also *Inanga* spawning, habitat and recruitment here.

We believe that the basis for a suite of more intensive and singular research projects has been laid by our current work, including especially participation from the Lake Trust and Whakaki whanau. It is also suggested that the engagement of a suitably qualified research coordinator to help establish a level of investigative rigour necessary to gather robust scientific data and information about the Lake and its wider environmental context, in order to help validate and inform the individual perceptions of the local people.

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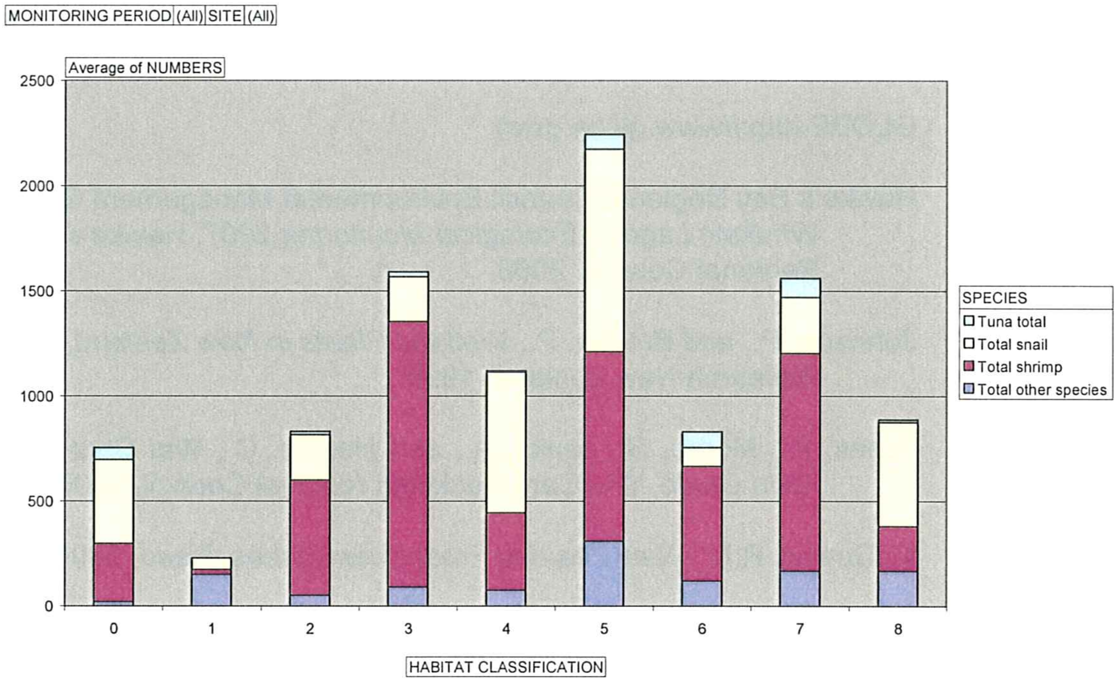
Appendix 1: Invertebrate and Eel Species Numbers by Habitat Type



Discussion

An overview of invertebrate and eel species numbers by Habitat Type was added as an Appendix to our final draft report rather than an integrated topic, because of uncertainties in the appearance of the data. That is, our researchers believed that there may have been some misrecording of the original worksheets, and these are currently being reassessed.