Frankton Marina development

Lake ecological assessment

prepared by

Ryder Consulting

Revised

May 2007

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prepared for

John Edmonds and Associates

on behalf of

Queenstown Marina Developments Limited

prepared by

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Cover: Lake Wakatipu in the vicinity of the proposed marina development.

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1. Introduction

1.1 Background

Queenstown Marina Developments Limited have proposed a Frankton Marina development on the shores of Lake Wakatipu. This proposal involves the creation of a marina on the lake shore, including some reclamation of the existing lakebed.

John Edmonds and Associates, on behalf of Queenstown Marina Developments Limited, engaged Ryder Consulting to undertake an aquatic assessment of the area to assess the feasibility of the proposed development, to summarise the current freshwater ecological values in the area and to assess any potential effects of the proposed development.

1.2 Objectives

The objectives of this report are:

- To summarise the freshwater ecological values in Lake Wakatipu at the site of the proposed development;
- To assess the feasibility of the proposed development from a freshwater ecological perspective; and
- To assess any potential effects of the proposed development on the aquatic ecosystems.

2. Sampling and Analysis Techniques

2.1 General

The aquatic survey was undertaken at the proposed development site in Lake Wakatipu on the 29th and 30th of November 2006. Weather conditions were overcast with heavy rain showers on the 30th of November. The survey encompassed the area potentially affected by the proposed development (Figure 1). Six transects from the shore out to a distance of 20m were surveyed in Lake Wakatipu. Water quality, macroinvertebrates and fish were surveyed, and general observations were made throughout the area including periphyton (benthic algae), aquatic vegetation (macrophytes) and bed character.

An additional survey to determine the distribution of macrophytes in deeper water was carried out by John Edmonds and Associates in May 2007 (Figure 2).

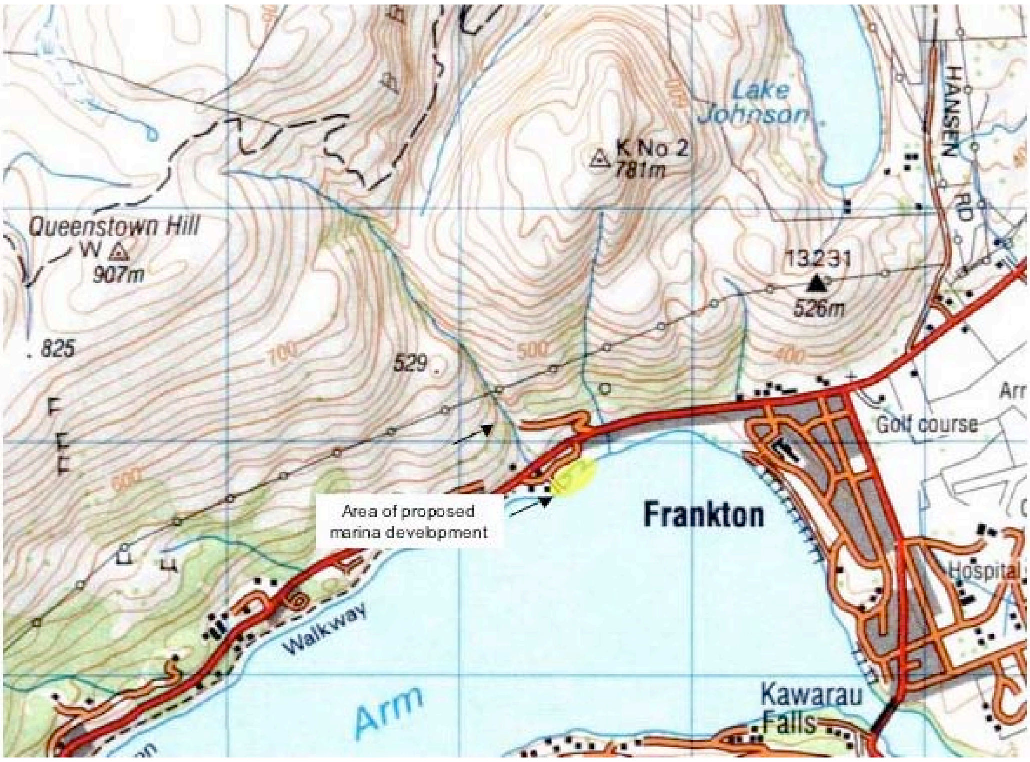

Figure 1 *Map of Lake Wakatipu in the vicinity of the proposed Frankton Marina development, with area of proposed works indicated.*

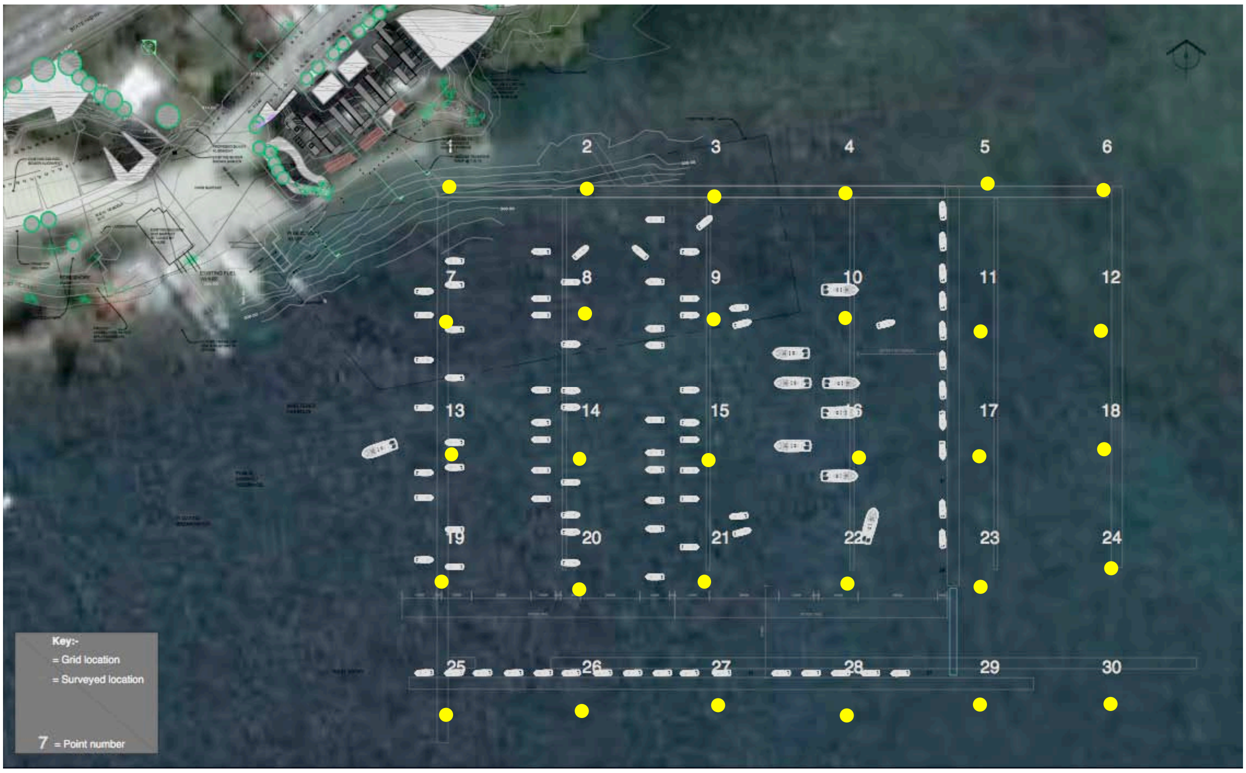

Figure 2 *Sampling locations for benthic plant survey (May 2007) marked by yellow spots.*

2.2 Water quality parameters

Water quality parameters were recorded at one site using a calibrated YSI 556 MPS meter and included temperature (°C), conductivity (µS/cm) (an indicator of nutrient enrichment), dissolved oxygen concentration (mg/L), dissolved oxygen saturation (%) and pH. The significance of these water quality variables is briefly discussed below.

Dissolved oxygen

Adequate supplies of dissolved oxygen are essential for sustaining healthy aquatic communities, particularly fish and macroinvertebrates. Dissolved oxygen guidelines involve those that relate to minimum oxygen concentration levels (or saturation) and minimum concentrations of oxygen demanding substances (i.e. BOD or biochemical oxygen demand) in water. A minimum dissolved oxygen saturation of 80% is an acceptable minimum standard for hill country and alpine aquatic environments and would protect trout, which is the fish species most sensitive to low dissolved oxygen in New Zealand waters. This level is also specified in the Third Schedule of the Resource Management Act 1991 (Classes AE - water managed for aquatic ecosystem purposes, F – water managed for fishery purposes, FS - water managed for fish spawning purposes, SG - water managed for the gathering or cultivating of shellfish for human consumption).

pH

The development of nuisance algae and plant growths due to nutrient enrichment can influence water quality by influencing dissolved oxygen and pH levels in the water column. During the day, algae photosynthesise (and respire) and, in doing so, produce oxygen. Conversely, at night, algae only respire and so consume oxygen. Thus, high abundance of algae can result in daily swings in dissolved oxygen and pH, potentially compromising sensitive fish and fish food (macroinvertebrates). A pH range of between 6.5 and 8.5 is typically cited as being appropriate for freshwater bodies of New Zealand.

Temperature

Fish are often strongly affected by temperature, with effects of temperature on mortality, growth and reproductive behaviour all described from New Zealand or elsewhere. Trout and salmon are generally regarded as being less tolerant of higher water temperatures than New Zealand native fish (e.g. bullies, eels and koaro) and therefore if trout are the species protected against elevated temperature, this will result in protection of other freshwater fish species. Adult trout cease feeding around 19°C and lethal effects occur at between 24-30°C. A daily maximum temperature of 11°C is recommended for salmonid spawning areas during winter (May-September).

The Third Schedule of the Resource Management Act 1991, Class F Water (water managed for fishery purposes) and Class FS Water (water managed for fish spawning purposes), states that the natural temperature of the water shall not be changed by more than 3°C.

2.3 Macrophytes

2.3.1 General

In oligotrophic (low nutrient) New Zealand lakes like Wakatipu, the dominant primary producers (converting sunlight to biomass using photosynthesis) are a variety of aquatic macrophyte species (Brown 1975). These grade from small amphibious species in shallower or occasionally exposed areas, through to large stands of macrophytes in deeper waters (Coffey and Clayton 1988a). A distinctive feature of lakes of the southern lakes of New Zealand is the presence of characean (algal) meadows at depths of around 10m and deeper (Figure 3). These ‘plants’ are in fact communal algae that grow in a plant-like form. The primary producers in the littoral areas of the lakes provide food and habitat for a variety of invertebrate and fish species, and form the basis of food chains in these lakes.

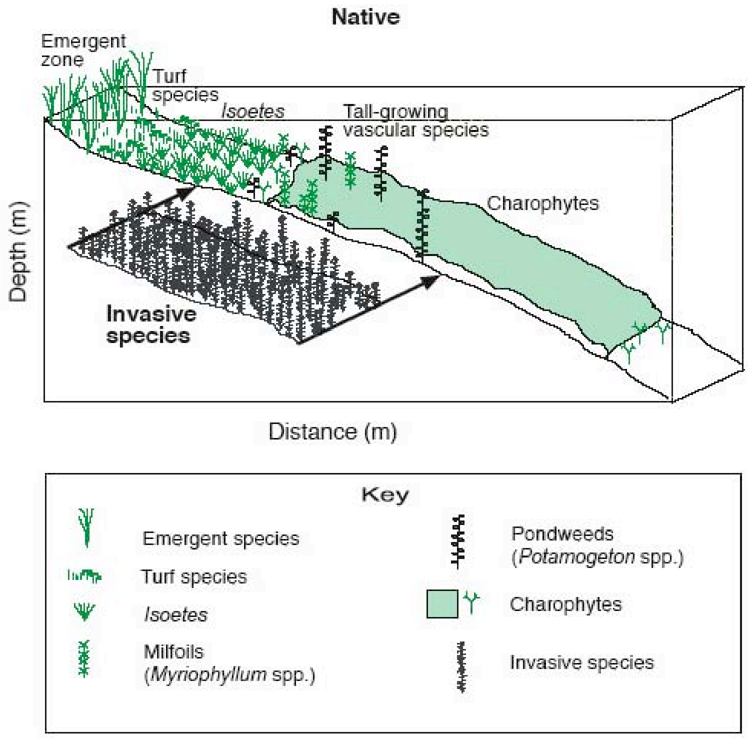

Figure 3 *Depth profile illustrating the main components of native lake vegetation and the region of substitution by invasive species (taken from Clayton and Edwards 2007).*

The Otago Regional Council Regional Plan: Water for Otago (2004) includes in its schedule of natural values several significant features of Lake Wakatipu, including:

- Outstanding natural feature or landscape: Outstanding for scientific value, in particular water clarity, and bryophyte community;
- Significant indigenous vegetation and significant habitat of indigenous fauna: *Significant vegetation*: rare association of aquatic plants.

2.3.2 Field collection

On 2 May 2007, staff from John Edmonds and Associates sampled bottom flora (macrophytes) at 30 locations at the site of the proposed marina (Figure 2) using a day grab sampler worked from a boat. Grab samples were bagged and couriered to Ryder Consulting for analysis.

In the laboratory, plant samples were cleaned, sieved and processed to identify plant species and their abundance in each sample.

2.4 Benthic macroinvertebrates

2.4.1 General

Freshwater benthic macroinvertebrates are small organisms that live on the beds of rivers, lakes and wetlands, have no backbone and are larger than 250 microns (0.25mm) in size. This broad grouping includes insect larvae (e.g. caddisflies, mayflies, stoneflies), aquatic worms (oligochaetes), snails and crustaceans (e.g. amphipods, isopods and freshwater crayfish). Macroinvertebrates utilise a variety of food sources depending on the species, with benthic algae or 'periphyton' a key food item for many species in both lakes and rivers.

Macroinvertebrates are important in lakes because they are an important food item for many New Zealand freshwater fish species and a number of wetland and lake bird species. Their ability to transfer primary production (i.e. algae or 'periphyton' growth) into a food source for fish and birds is a fundamental aspect of healthy aquatic ecosystems.

The invertebrate communities associated with the littoral zone of New Zealand lakes have received limited attention relative to rivers. Species typically found in our lakes include a variety of grazing molluscs (e.g. *Potamopyrgus antipodarum*, *Gyraulus* spp., *Physa* spp.), species feeding on organic detritus (midge larvae, particularly *Chironomus zelandicus* or the 'blood worm' and oligochaetes) and larger species filling a variety of ecological niches (caddis-flies, dragon-flies). These species are the main food source of small fish (mainly bullies), which in turn are the major food source of larger sport fish such as trout (McDowall 1990). It is known that the productivity of these littoral invertebrate and fish communities is the main factor driving trout productivity in New Zealand lakes.

2.4.2 Field collection

Benthic macroinvertebrates were sampled in Lake Wakatipu by a SCUBA diver using a core sampler with a diameter of 85mm, to a depth of approximately 100mm. Two samples were taken from each transect at distances of approximately 5 and 15m from the shore.

2.4.3 Laboratory analysis

In the laboratory the invertebrate samples were passed through a 500µm sieve to remove fine material. Contents of the sieves were then placed in a white tray and macroinvertebrates removed. The macroinvertebrate samples were then identified under a dissecting microscope (10-40X) using criteria from Winterbourn *et al.* (2000).

Macroinvertebrate abundance data may be converted into coded abundance scores using the codes established by Stark (1998) (Table 1).

Table 1 *Coded abundance scores used to summarise macroinvertebrate data (after Stark 1998).*

Abundance	Coded abundance	Weighting factor
1 - 4	Rare (R)	1
5 - 19	Common (C)	5
20 – 99	Abundant (A)	20
100 - 499	Very abundant (VA)	100
>500	Very very abundant (VVA)	500

For each site, benthic macroinvertebrate community health was assessed by determining the following characteristics:

Number of taxa: Reflects health of the community through a measurement of the variety of the taxa present. Taxonomic richness generally increases with increasing water quality, habitat diversity, and habitat stability.

Ephemeroptera, Plecoptera and Trichoptera index (EPT): These insect groups are generally dominated by pollution sensitive taxa, although plecopterans are generally uncommon in New Zealand lakes while mayflies tend to occur around the edges in the wave lap zone. This index usually increases with better water quality and increased habitat diversity.

Invertebrate community structure was also compared with that found in nearby lakes Hawea and Wanaka.

2.5 Fish

To the public, fish are probably the most identifiable living component of lake ecosystems, having biodiversity, commercial, cultural, and recreational values. The New Zealand freshwater fish fauna is regarded as having low diversity and lake fisheries are no exception, particularly in inland, oligotrophic lakes like Wakatipu. For example, in a national survey, Jowett and Richardson (2003) found an average of five species per survey site and three per site were found in the NZ Freshwater Fisheries Database.

2.5.1 Fyke nets

Fyke nets (Figure 4) were used in Lake Wakatipu. Fyke nets are commonly used to capture eels and other native fish that may be present in areas unable to be efficiently electric fished, such as deep pools and lakes. The fyke nets were baited with 'Marmite' and set overnight for a period of approximately 15 hours. After retrieval, fish were identified and measured before being returned to the area in which they were captured.

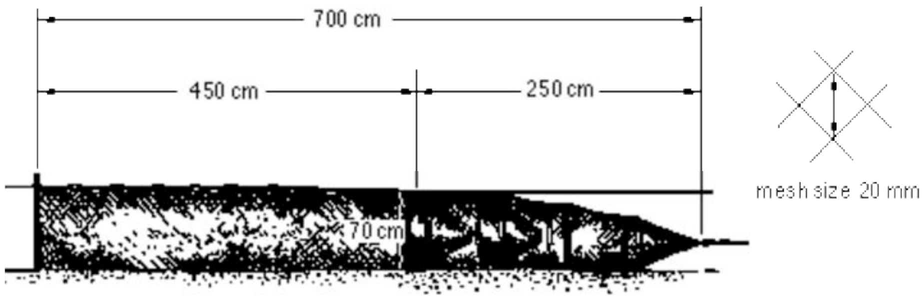

Figure 4 *Fyke nets used during sampling of Lake Wakatipu.*

2.5.2 Minnow traps

Minnow traps (Figure 5) were also used in the Lake Wakatipu fish survey. Minnow traps are commonly used to capture small native fish that may be present in areas unable to be efficiently electric fished. The nets were baited with 'Marmite' and set overnight for a period of approximately 15 hours. After retrieval fish were identified and measured before being returned to the area in which they were captured.

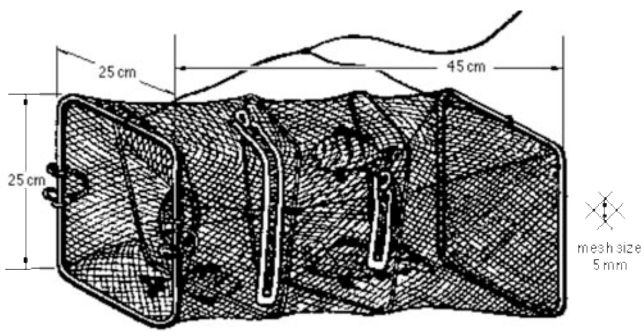

Figure 5 *Minnow traps used during sampling of Lake Wakatipu.*

3. Results and Discussion

3.1 November 2006 survey

3.1.1 General

The aquatic habitat was surveyed at six transects extending perpendicular from the shore of the lake out to a distance of 20m. At the time of the survey the lake was high and there was construction works taking place in the lake in the area of the existing wharf.

Transects one and two (Figure 6) were located away from the proposed development area to provide references sites. It was initially planned to survey lake habitats both down-shore and up-shore of the proposed development, however due to discolouration of the lake below the outlet of the small creek emptying into the lake at the site (Marina Creek), both reference transects were located up-shore (towards Queenstown).

Four transects were located in the immediate area of the proposed development, transect three was located immediately beside the wharf construction area (Figure 7), transect six was located at the mouth of the marina inlet (Figure 8) and transects four and five were spaced evenly between these points (Figures 7 and 8). Riparian vegetation at all sites consists of exotic pasture grasses and willow, the roots of which are visible on the lake bottom in places. Piles of woody debris are present along the shore in the zone of wave movement.

Photographs of the lake substrate were taken at 5m intervals along each transect (Appendix One Figures A1.1 and A1.2). The substrate at the 5 and 10m points on transects 1 and 2 consists of clean gravels and cobbles, in contrast at the 15m and 20m points on both transects dense macrophyte (plant) beds are present including charophytes (possibly *Chara globularis*), *Isoetes kirkii, and Myriophyllum* species (Figure A1.1). Transect 3 is the first of the four transects located within the proposed development area. It appears to be affected by the presence of the wharf and disturbance of the surrounding area by the current construction work, with a fine layer of silt covering the gravel and cobble dominated substrate (Figure A1.1). The remaining three transects in the proposed development area have substrates dominated by silt and sand, with macrophyte beds (e.g. charophytes, *Isoetes kirkii, Myriophyllum* species, *Potamogeton* species) located around the 15 and 20m points (Figure A1.2). In places these macrophyte beds are covered with a layer of diatoms (e.g. *Tabellaria*, *Epithemia*, *Gomphoneis*, *Cymbella*) and filamentous algae (e.g. *Bulbochaete*). Freshwater mussels were observed at a density of approximately

1 per m^2 around the 20m point on Transect 5. The habitat observed at this transect appeared to be less disturbed than that at Transects 3 and 4, which are closer to the area of the existing wharf and construction works.

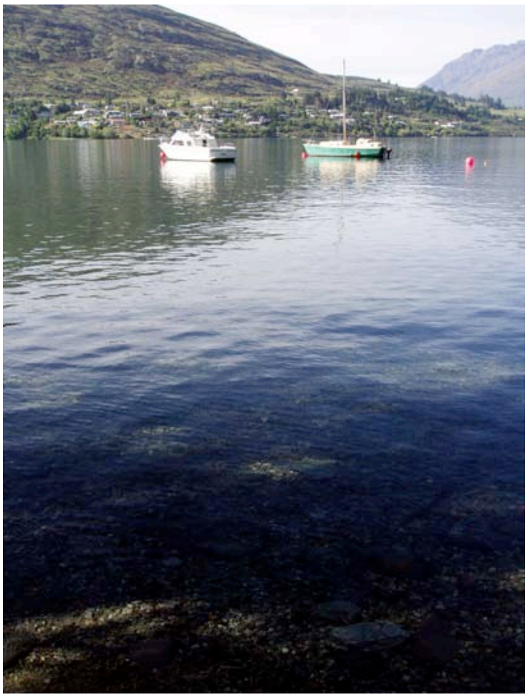
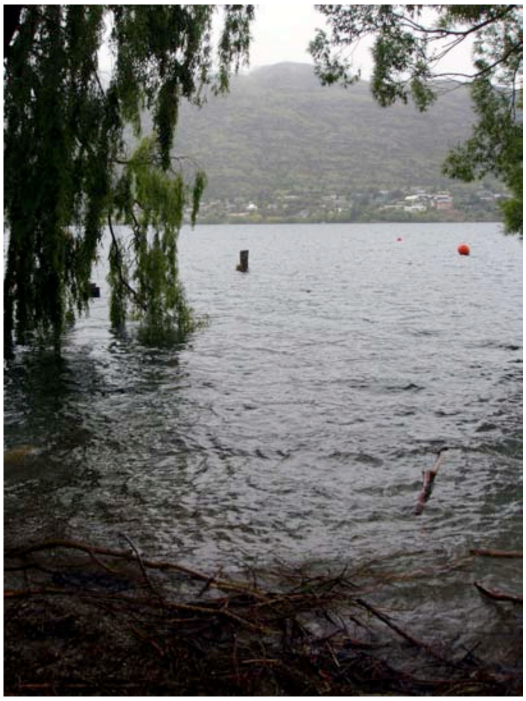

Figure 6 *Left: Lake Wakatipu transect site 1.*
Right: Lake Wakatipu transect site 2.


Figure 7 *Left: Lake Wakatipu transect site 3.*
Right: Lake Wakatipu transect sites 3 and 4, note wharf construction works.


Figure 8 *Left: Lake Wakatipu transect sites 4, 5 and 6.*
Right: Lake Wakatipu transect site 6.

The existing marina inlet is approximately 90m long and 20m wide (Figure 9). Marina Creek enters at the head of the inlet. The inlet has a maximum depth of approximately 2m and drops off steeply from the shore in most places, near the outlet to Lake Wakatipu though it is shallow on the edges. The substrate is dominated by silt and sand with a covering of woody debris, macrophyte beds and algae in places (Figure 10).


Figure 9 *Left: Lake Wakatipu existing marina inlet.*
Right: Macrophyte beds at Marina Creek inflow to inlet.

Figure 10 *Left: Algae in Lake Wakatipu existing marina inlet.*
Right: Sandy substrate in existing marina inlet

3.1.2 Water quality

Water quality measurements were taken at one location along the edge of Lake Wakatipu (Table 2). As expected, water quality parameters were well within guideline levels, with the water quality typical of a clean, high country, oligotrophic (low nutrient status) lake. Although a one-off survey, these water quality indicators are not expected to change widely throughout the year in Lake Wakatipu apart from a moderate increase in water temperature along shallow shore line areas in summer.

Table 2 *Water quality measurements for Lake Wakatipu at the site of the proposed development.*

Location	pH	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)	Conductivity (μS/cm)
Lake Wakatipu	8.2	10.1	10.7	95.3	46

3.1.3 Macroinvertebrates

Five macroinvertebrate taxa were identified from the core samples collected from the edges of Lake Wakatipu (Table 3). Taxonomic richness in samples from all sites (range 0–3) was very low, however this is expected in a lake environment due to the dynamic habitat and wave effects, and the effects of lake level fluctuations.

Invertebrate communities in Lake Wakatipu were comprised of chironomid larvae, snails, oligochaete worms and *Pycnocentrodes* caddisflies (Table 3). The taxa were typical of that expected in a soft sediment lake bed, and are commonly found in lakes throughout the South Island (see Conclusions).

Table 3 *Coded abundance macroinvertebrate data from Lake Wakatipu. Coded abundance after Stark (1998). Transects 1 and 2 are located outside of the proposed development area and transects 3-6 are located in the vicinity of the proposed development area. R = rare, C = common, A = abundant.*

		T1		T2		T3		T4		T5		T6	
		5m	15m	5m	15m	5m	15m	5m	15m	5m	15m	5m	15m
TAXON	**MCI score**												
DIPTERA													
Chironomidae	2	R	R			R	R					C	C
MOLLUSCA													
Potamopyrgus antipodarum	4						R						R
Sphaerium novaezelandiae	3												R
OLIGOCHAETA	1	R	C	C	C								
TRICHOPTERA													
Pycnocentrodes species	5	R	R										
Number of taxa		3	3	1	1	1	2	0	0	0	0	1	3
EPT taxa		1	1	0	0	0	0	0	0	0	0	0	0

3.1.4 Fish

An examination of the New Zealand Freshwater Fish Database and other available published and unpublished reports has identified three freshwater fish species in the Frankton area of Lake Wakatipu. Two of these species are native (*Anguilla dieffenbachii* or longfin eel and *Galaxias brevipinnis* or koaro), with one introduced species (*Salmo trutta*, or brown trout).

The fisheries survey in this study utilised passive netting techniques, where fish have to actively move into the minnow traps and fyke nets. These netting techniques are suitable for slow flowing and deep waters such as lakes, where the use of electric fishing is restricted.

Longfin eels, common bullies and an unidentified galaxiid larvae were caught in the nets set in Lake Wakatipu (Figure 11). Two adult longfin eels were caught, with sizes of approximately 60cm and 100cm in length. Nine common bullies were caught, ranging in size from 30 to 57mm. The galaxiid larvae was 45mm in length and was likely koaro, due to the previous records of this species in the area.

Figure 11 *Longfin eels caught in fyke nets in Lake Wakatipu.*

3.2 May 2007 plant survey

The May 2007 plant survey revealed that charophytes dominated the area with some relatively dense patches of *Elodea, Isoetes* and *Potamogeton* also evident (Table 4). No bryophytes were found.

Table 4 *Abundance of benthic macroflora at proposed marina site. Sites correspond to those in Figure 2 above.*

Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Charophytes		3	3	1	1		1		2	1	3		5	1	4	3	2	1	5	5	5	2	3	3	5	5	1	3	3	2
Bryophytes																														
Elodea	5	4	1	1				3										4												
Potamogeton			2			1		2			2							2				4	2	2				2		1
Isoetes					4	4						4			1															
Glossostigma						1																								

Absent	blank
Rare	1
Occasional	2
Common	3
Abundant	4
Dominant	5

Charophytes

In Lake Wakatipu, *Myriophyllum triphyllum* and *Potamogeton* species extend to a depth of 9m (Howard-Williams *et al.* 1986, Coffey and Clayton 1988b), while characean meadows have been known to grow to depths in excess of 30m (Coffey and Clayton 1988b, Schwarz *et al.* 2000). A comparison of large lakes in the South Island indicates that charophytes (*Chara* and/or *Nitella* species) are commonly found at the maximum depth recorded for submerged aquatic macrophytes (Table 5).

Table 5 *Physical characteristics and maximum recorded depths for submerged aquatic macrophytes (Z_c) for several South Island lakes. Adapted from Schwarz* et al. *(2000).*

Lake	Area (km^2)	Maximum depth (m)	Altitude (m a.s.l.)	Latitude	Z_c (m)	Macrophytes recorded at Z_c
Hawea	141	384	342	44.28	34.4	*Nitella hookeri*
Manapouri	153	444	179	45.31	12.6	*Chara corallina*
Te Anau	352	417	203	45.13	13.7	*Chara corallina*
Wakatipu	**293**	**380**	**309**	**45.06**	**30.6**	***Nitella hookeri***
Wanaka	193	311	277	45.28	23.6	*Chara corallina / Nitella hookeri*

Charophytes were the most abundant plants in lakes Te Anau, Manapouri, Monowai, Hauroko, and Poteriteri (Wells *et al.* 1998) and were dominant in terms of biomass in Lakes Wanaka and Hawea (Thompson and Ryder 2002). Comparison with other large South Island lakes indicates that charophyte beds are common throughout these lakes and are present at a range of water depths.

Bryophytes

New Zealand lakes have a relatively frequent occurrence of deep-water bryophytes, particularly in the deep, unproductive lakes of the South Island, such as Lake Wakatipu (de Winton and Beever 2004). Deep-water bryophytes were present at 15 out of 60 South Island lakes surveyed by de Winton and Beever (2004). The occurrence of bryophytes is primarily linked to high water clarity, which enables bryophytes to penetrate deeper than other plant competitors (de Winton and Beever 2004). Coffey and Clayton (1988b) recorded bryophytes to a maximum depth of 70m in Lake Wakatipu, while de Winton and Beever (2004) found bryophytes to a maximum depth of 60m, with the average maximum depth limit of 41.5m.

Bryophytes are primarily found in deep water and are generally absent from the mid-depth region of lake vegetation where high covers of vascular or charophyte vegetation occur (de Winton and Beever 2004). de Winton and Beever (2004) found that in 70% of database records obtained in their study, deep-water bryophytes were recorded as a discrete, deeper community with minimum depths of ≥10 m.

Bryophytes form a low-growing (<0.1 m high) variable cover on bottom substrates, and occurred on a mixture of rock and silt in Lake Wakatipu (de Winton and Beever 2004). The average cover for deep-water bryophytes within the lakes surveyed by de Winton and

Beever (2004) was typically low (1–5%), whereas maximum covers exceeded 95% in Lakes Wakatipu, Wanaka, and Rotoroa. Maximum bryophyte biomass in Lakes Wakatipu and Wanaka was from the mid to lower depth range of the deep-water bryophyte assemblage (30–50 m) (de Winton and Beever 2004).

4. Conclusions

The freshwater ecological values of Lake Wakatipu in the area of the proposed development are as expected for those of a clean, high country oligotrophic lake. Transect surveys identified macrophyte beds within 15m of the shore and a typical lake macroinvertebrate community, which included freshwater mussels. Brown trout, common bullies, koaro and longfin eels have been recorded from the area.

The ecology of Lake Wakatipu in the vicinity of the proposed marina development area is broadly similar to that found in nearby lakes Hawea and Wanaka (Thompson and Ryder 2002). Both Hawea and Wanaka are characterised by distinct macrophyte zonation, with charophyte species dominating at depth (>7m), a distinctive midwater flora in depths of 3-5m, and a shallow water community close to the lake edge. The typical mid water species in Lake Wanaka is *Lilaeopsis ruthiana*, but this species is nearly absent from Lake Hawea, probably due to the effects of lake level fluctuations (Thompson and Ryder 2002).

Sixteen to eighteen macroinvertebrate taxa were found in both Hawea and Wanaka by Thompson and Ryder (2002), none of which are considered to be rare or threatened. This compares to six species found in our November 2006 survey of the Frankton marina area. However the Hawea and Wanaka surveys involved many transects spread around the lake and so would be expected to find more species. The dominant invertebrate species in Lakes Hawea and Wanaka were the ‘blood-worm’ midge *Chironomus zelandicus*, the sphaerid bivalve *Sphaerium* sp. and the snail *Potamopyrgus antipodarum*. All of those species existed across a broad range of depths. *Potamopyrgus* and other grazing molluscs tended to be associated with coarse substrates, whereas *Sphaerium*, *Chironomus*, other chironomids and the freshwater mussel *Hyridella menziesii* were associated with fine silts. These taxa, apart from *Sphaerium*, dominated the samples collected for the Frankton marina survey.

The fish communities in Hawea and Wanaka are dominated by common bully and salmonids (brown trout, rainbow trout and quinnat salmon). Longfin eel and koaro are also present (Thompson and Ryder 2002). A similar fish community is likely to exist in the vicinity of the Frankton marina area. Common bully is the only species likely to be resident to the area (they are territorial), the others will come and go in association with seasonal feeding and migration cycles. There is no unique or uncommon fish habitat in the vicinity of the marina development area.

The proposed development will involve reclaiming the existing marina inlet area of Lake Wakatipu. The ecological values of the inlet area are similar to that of shallow areas of the wider lake environment and the reclamation of this area is, therefore, not expected to result in the loss of significant habitat and no loss of rare or uncommon habitat. Marina Creek enters the lake at the head of the inlet, but it is understood that a new outlet for the creek will be designed as part of a diversion. Details on how the reclamation will be achieved are not specific at this stage, but attempts should be made to minimize the amount of sediment movement into Lake Wakatipu and/or prevent fish becoming trapped in the inlet as it is reclaimed.

Construction of the proposed marina is expected to have limited, localised effects on the macrophyte communities of the Frankton Arm of Lake Wakatipu. These effects are due to the proposed removal of areas of macrophyte beds to allow for fixing the marina to the lake bed. As charophytes are the dominant macrophytes in the proposed marina site and are abundant throughout Lake Wakatipu and other New Zealand lakes, it is likely that the removal of small areas of macrophytes will have no more than a localised impact.

The absence of bryophytes in the proposed marina development area, as determined by the macrophyte survey undertaken by John Edmonds and Associates, and the general absence of bryophytes from areas where high cover of charophytes occur, indicates that bryophytes are not locally abundant in the proposed marina site. It is therefore unlikely there will be any effects of the proposed marina on the bryophyte communities of Lake Wakatipu.

The Otago Regional Council Regional Plan: Water for Otago (2004) includes the bryophyte community and the rare association of aquatic plants as significant natural values of Lake Wakatipu. Although there may be localised impacts on macrophyte communities within the proposed marina development area, the development will not adversely affect the wider natural values of Frankton Arm and Lake Wakatipu

The proposed development will also involve modification of the existing shoreline to incorporate the proposed marina. Short term increases in sediment deposition are expected in the vicinity of the proposed works during the construction process, similar to those seen at transect three during the November 2006 survey, although possibly larger in scale. This may result in the partial smothering of macrophyte beds and macroinvertebrates with fine silt and movement of fish out of the area, however communities are expected to recover to those previously present after the completion of the works. Water quality is not expected to alter as a result of the marina development although there is likely to be a temporary reduction in local water clarity associated with disturbance of the lake bed.

5. References

Brown, J.M.A. 1975. Ecology of macrophytes in New Zealand lakes (Chapter 17). In: Jolly, V.H. and Brown, J.M.A. (eds.), New Zealand lakes, pp. 244-262. Auckland University Press/Oxford University Press.

Clayton, J. and Edwards, T. 2007. LakeSPI. A method for monitoring ecological condition in New Zealand lakes. Technical Report Version 2. NIWA Information Series 63.

Coffey, B.T. and Clayton, J.S. 1988a. New Zealand waterplants: a guide to plants found in New Zealand freshwaters. MAF Publication, Ruakura Agricultural Centre, Hamilton.

Coffey, B.T. and Clayton, J.S. 1988b. Contrasting deep-water macrophyte communities in two highly transparent New Zealand lakes and their possible association with freshwater crayfish, *Paranephrops* spp. *New Zealand Journal of Marine and Freshwater Research* **22**: 225-230.

de Winton, M.D. and Beever, J.E. 2004. Deep-water bryophyte records from New Zealand lakes. *New Zealand Journal of Marine and Freshwater Research* **38**: 329–340.

Howard-Williams, C., Davies, J. and Vincent, W.F. 1986. Horizontal and vertical variability in the distribution of aquatic macrophytes in Lake Waikaremoana *New Zealand Journal of Marine and Freshwater Research* **20**: 55-65.

Jowett, I.G. and Richardson, J. 2003. Fish communities in New Zealand rivers and their relationship to environmental variables. *New Zealand Journal of Marine and Freshwater Research* **37(2)**: 347-366.

McDowell, R.M. 1990. New Zealand freshwater fishes: a natural history and guide. Heinemann Reed. Auckland.

Otago Regional Council. 2004. Regional Plan: Water. Otago Regional Council, Dunedin.

Schwarz, A-M., Howard-Williams, C. and Clayton, J. 2000. Analysis of relationships between maximum depth limits of aquatic plants and underwater light in 63 New Zealand lakes. *New Zealand Journal of Marine and Freshwater Research* **34**: 157-174.

Stark, J.D. 1998. SQMCI: a biotic index for freshwater macroinvertebrate coded abundance data. *New Zealand Journal of Marine and Freshwater Research* **32**: 55-66.

Thompson, R. and Ryder, G.I. 2002. Study Brief CLU #22: Lake Hawea Supplementary Study – Fisheries and Low Lake Level Ecological Study. Prepared by Ryder Consulting for Contact Energy Ltd.

Wells, R.D.S., Clayton, J.S. and de Winton, M.D. 1998. Submerged vegetation of Lakes Te Anau, Manapouri, Monowai, Hauroko, and Poteriteri, Fiordland, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 32: 621-638.

Winterbourn, M.J., Gregson, K.L.D. and Dolphin, C.H. 2000. Guide to the aquatic insects of New Zealand. *Bulletin of the Entomological Society of New Zealand* **13**.

Appendix One: Lake Wakatipu transect photographs

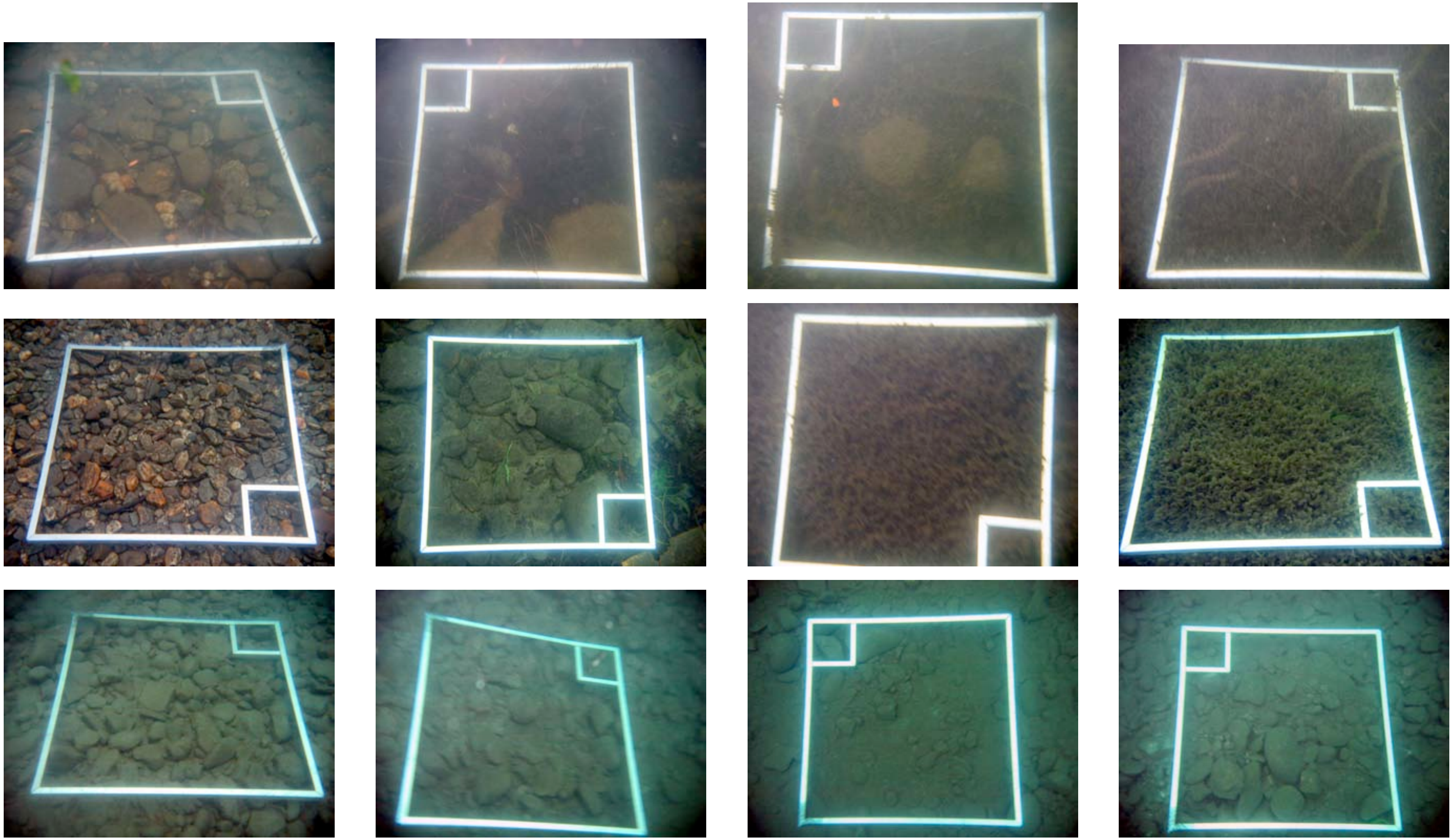

Figure A1.1 *Top to bottom: Transects 1, 2 and 3. Left to right: 5m, 10m, 15m, and 20m.*

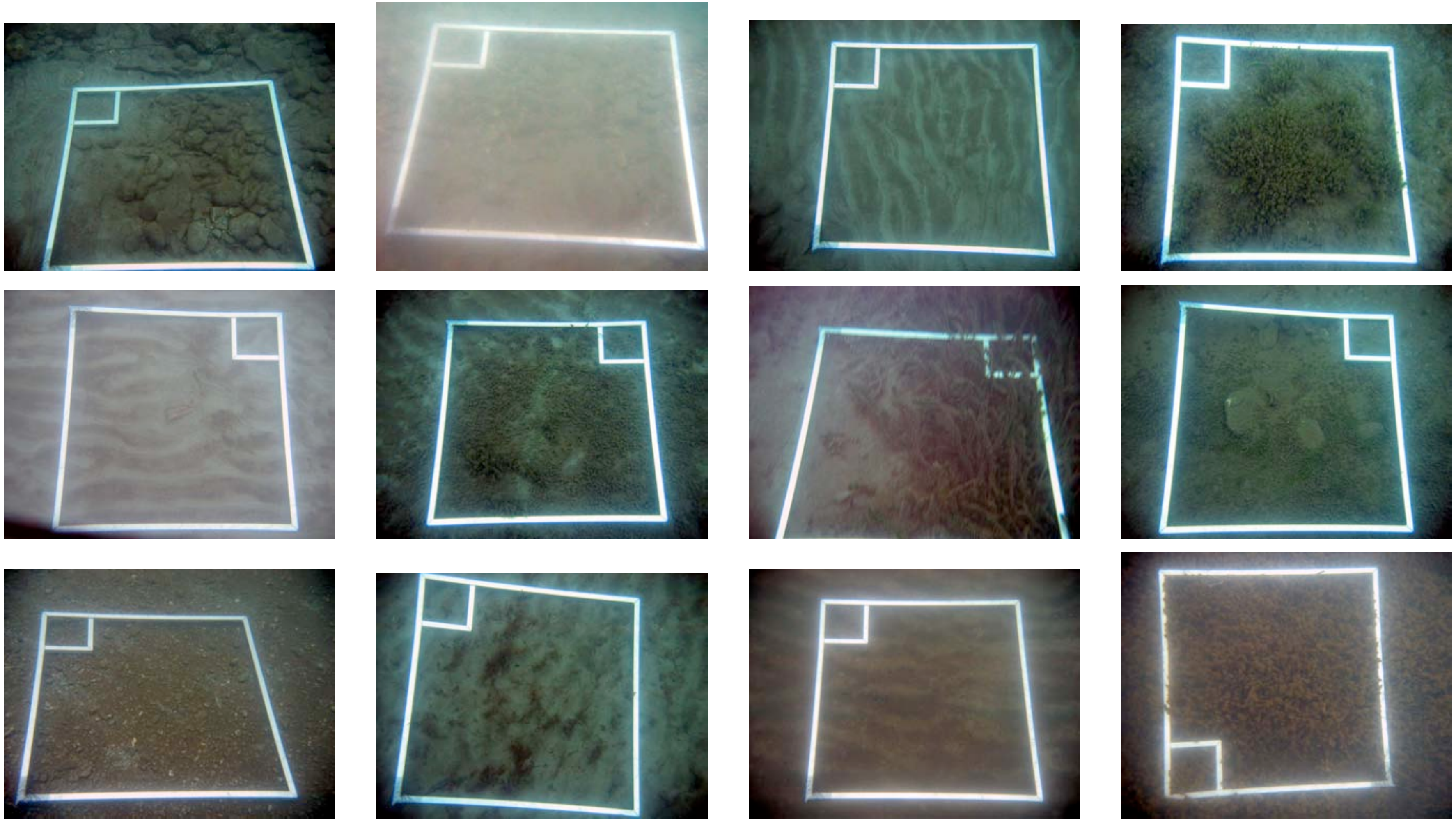

Figure A1.2 *Top to bottom: Transects 4, 5, and 6. Left to right: 5m, 10m, 15m, and 20m.*

Appendix Two: Fish Species: Notes on distribution and significance

(photos by R.M. McDowall, S. Moore, C. McCullough, B. Ludgate)

Longfin eel (*Anguilla dieffenbachii*)

Longfin eels are a native fish species that are widespread and common in a variety of habitats (streams, rivers, wetlands and lakes) throughout New Zealand where they are found from sea level up to 314km inland. This species has extraordinary climbing abilities and is often found above high and steep waterfalls. Longfin eels are distinguished from shortfin eels by the length of the dorsal fin; when viewed side-on, the dorsal fin is longer than the anal fin and extends well forward past the end of the anal fin. Longfin eels can reach up to nearly 2000mm in length and 25kg in weight. Longfin eels mature at about 25 to 35 years of age and migrate to sea in autumn where they travel to subtropical Pacific Ocean locales where spawning occurs. Larval eels (Leptocephalus) hatch and return to New Zealand in spring where they enter rivers as transparent glass eels. Longfin eel diet is comprised of stream insects, fish and even small birds. Activity and feeding is greatly reduced in cold temperatures (<10ºC).

Koaro (*Galaxias brevipinnis*)

Koaro (average length 160-180mm) are a diadromous galaxiid species that is widespread throughout New Zealand, although less often in the east. They are very strong climbers and are present long distances inland. Koaro favour clear, swift flowing boulder/cobbles streams in forested catchments, although they are also present in high elevation tussock streams. They spawn in autumn/winter and after three to four weeks the larvae hatch and go to the ocean, returning in September-October as whitebait.

Common bully (*Gobiomorphus cotidianus*)

Common bullies are a native fish species that are widespread and common throughout New Zealand especially in lowland areas and inland lakes. This species occupies varied habitats, including margins of lakes and wetlands and throughout gravel bed rivers and streams, is commonly observed moving throughout river and lake shallows but can be cryptic amongst rocks, vegetation and debris. Common bullies often reach 100mm in length with lake populations generally slightly smaller (about 60mm). Spawning occurs from spring to summer with hundreds to thousands of eggs produced in a single layer on nest substrate. Eggs hatch and larvae go to sea, returning approximately three to four months later. Landlocked populations complete life cycles (including spawning) in lakes, abandoning the marine life stage. Common bullies feed on a variety of stream insects, snails, crustaceans and small fish.

Brown Trout (*Salmo trutta*)

Brown trout were first introduced to New Zealand in 1867 and are now widespread throughout the country comprising a significant component of the New Zealand freshwater sports fishery. They are found in a variety of habitats from low elevation lakes to headwater streams and subalpine lakes. Adult brown trout in New Zealand may reach up to 950mm in length. Brown trout is an anadromous species, with breeding taking place in freshwater following migrations from the sea. However, land-locked populations also exist, with migrations from downstream areas rather than from the sea. Adult brown trout migrate upstream in autumn or early winter to reach spawning grounds located in gravel bed headwater rivers and streams. The females dig depressions in the gravel and deposit the eggs, which are fertilised by the male. The eggs develop for one or two months then hatch as fry to shoal around the stream margins. Some smolt move towards the sea for early growth, while others remain in freshwater areas. Unlike chinook salmon, adult brown trout usually survive spawning. Brown trout feed on a variety of stream insects, snails, crustaceans and small fish.