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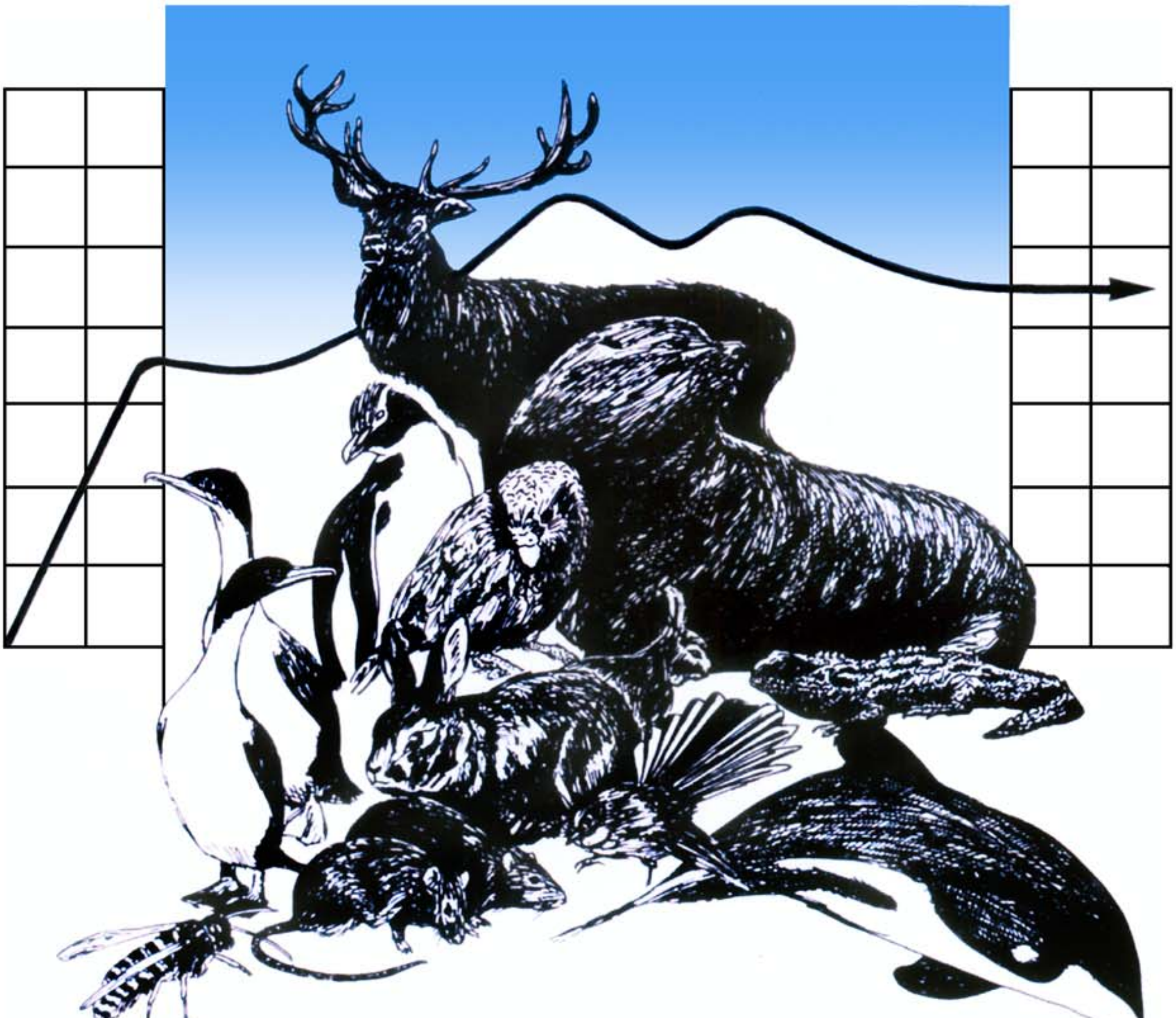

WILDLIFE MANAGEMENT

Baseline fish community surveys of the Rakatu Wetlands.

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A research report submitted in partial fulfilment of the requirements of the Diploma in Wildlife Management

University of Otago

Year 2008

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WLM Report Number: 216

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1 ABSTRACT

The Rakatu Wetlands is the main habitat restoration/creation project of the Waiau Fisheries and Wildlife Habitat Enhancement Trust. Construction began in 2001 and the Rakatu Wetland system now has approximately 50 ha of open water. The main purpose of this present study was to develop a regime to monitor the fish community and gain baseline data of the current level of fish utilisation in the ponds at the Rakatu Wetlands. The fish community was surveyed across twelve of the main ponds during Summer 07/08. A combination of fyke nets and minnow traps was used. Spotlighting surveys were also conducted to assess the level of colonisation of smaller fish species. Macrophyte and benthic macroinvertebrate surveys were carried out to assess the level of shelter and foraging resources available in the wetland system. Four fish species were recorded with longfinned (*Anguilla dieffenbachii)* and shortfinned (*A. australis*) eels being the most abundant. Brown trout (*Salmo trutta*) was observed in two out of the twelve surveyed ponds whereas the common river gallaxid (*Gallaxias* spp.) was observed in four. The overall mean abundance (measured as catch per unit effort (CPUE)) of each fish species across the entire Rakatu Wetlands is as follows: longfin eel = 0.2127 fish/net/hour (±0.1520); shortfin eel = 0.0157 fish/net/hour (±0.0285); brown trout = .0007 fish/net/hour (±0.0025). The structure of the eel populations had relatively low proportions of juveniles. Water depth or chemistry, macrophyte cover or availability of foraging resources did not appear to have any limiting effect on fish utilisation of the created habitat. The level of interconnectivity within the Rakatu system and with the surrounding waterbodies allowed the successful colonisation passage of fish into the system. Future monitoring and protection of the system is advised to ensure goals are continued to be met. A recommendation to future monitoring regimes includes the replacement of minnow traps and spotlighting techniques with backpack electrofishing or seine netting methods.

2 INTRODUCTION

2.1 Wetland mitiagation, restoration and creation

Wetlands are amongst the Earth's most diverse and productive ecosystems, however, they are also one of the most threatened (Mitsch & Wilson 1996). Today only half of the world's wetlands remain intact. Ongoing human development in the form of land reclamation, irrigation and construction of hydroelectric dams is largely responsible (Bobbink *et al.* 2006). Wetland habitats are being degraded through processes including loss of wetland area, changes in water regimes and water quality, the over-exploitation of wetland products and by the introduction of exotic species (Bobbink *et al.* 2006). Through the loss of their habitat many wetland species have been locally extirpated, others are facing total extinction (Brinson & Malvarez 2002).

Recently the importance of the mitigation, restoration and creation of these unique systems has become realised (Zelder 1996; Bobbink *et al.* 2006). Wetlands can provide a variety of biological, ecological and hydrologic based ecosystem services, such as flood prevention and habitat for fish and birds (Mitsch & Gosselink 2000; Bobbink *et al.* 2006; Rewa 2007). The rationale behind wetland mitigation projects may therefore be driven by a variety of goals and objectives. These include habitat replacement for fish and wildlife, water quality enhancement and flood minimisation (Simenstad & Thom 1996; Mitsch & Gosselink 2000; Brinson & Malvarez 2002).

In New Zealand only eight percent of the former wetland area remains (Jones *et al.* 1995). A large variety of New Zealand's flora and fauna, both terrestrial and aquatic, are dependent on wetland systems for the provision of habitat (Mitsch & Gosselink 2000). Wetland mitigation projects within New Zealand are largely conservation driven. These aim to prevent further extinctions, stabilise declining populations and promote population increases (McDowall 2000).

Wetland habitats are utilised by approximately one third of New Zealand's native fish species, some of which are of considerable conservation concern (McDowall 2000). Wetland restoration/creation projects must understand the ecological functioning of wetlands to ensure that the wetland fish communities can utilise the restored/created wetland habitats. The three general factors that must be considered are 1) preferable physical habitat; 2) sufficient foraging resources; 3) interconnectivity with surrounding wetland and stream/river systems (Baber *et al*. 2002). Furthermore the level and composition of biodiversity in a restored or created wetland can be largely influenced by wetland size, diversity of water depths and vegetation, wetland age and the degree of maintenance (Baber *et al*. 2002; Rewa 2007). Wetland managers have to make key decisions regarding the above aspects as these will ultimately determine the final structure and composition of the wetland system (Baber *et al*. 2002; Laffaille *et al*. 2004; Rewa 2007). The success of a newly created or enhanced wetland is dependent on the systems ability to promote colonisation and sustain fish populations. Therefore, any newly created or restored wetland may not simply be declared as a successful project after creation is complete. The project must be monitored to evaluate how successful it is at achieving its desired goals (Mitsch & Wilson 1996).

2.2 The Rakatu Wetlands project

In 2000 the Waiau Fisheries and Wildlife Habitat Enhancement Trust (hereafter the Waiau Trust) purchased 278ha of land on the flood plains of the Waiau River, Southland, New Zealand. This area of land has been progressively developed into the Rakatu Wetlands – a large-scale wetland system designed to enhance the habitat available to fish and wildlife in the region (Riddell 2001). The overarching goal of the Waiau Trust for the Rakatu Wetlands is: *to create an ecologically sustainable wetland/small stream ecosystem complex, for the benefit of fisheries and wildlife in the Rakatu area of the lower Waiau River catchment* (Riddell 2001). This goal intends to be met by successfully restoring and maintaining the processes that contribute to sustaining the wetland ecosystem (Riddell 2001).

The purpose of this study was to develop a monitoring regime to collect baseline data on the fish community that has successfully colonised the Rakatu Wetlands approximately six years post construction. The main objective was to investigating the ability of the Rakatu Wetlands to support wetland fish communities (i.e. fish utilisation of the created/restored habitat). Habitat features including water depth, water chemistry, vegetation cover and foraging resources were also surveyed to help assess the value of the newly created habitat.

3 METHODS

3.1 Site description

Rakatu is a 278ha property situated on the flood plain of the Waiau River, 13km south of Manapouri (45° 40' S, 167° 37' E). The Rakatu Wetland system has been enhanced from the remnants of natural oxbow lakes situated on a modified pastoral landscape with exotic forest plantations and spring-fed streams (Riddell 2001). Since the purchase of the land in June 2000 the Waiau Trust has successfully created around 20 interconnecting wetland ponds, approximately 50ha of open water. This was achieved by constructing earth dams and taking advantage of the natural undulations of the landscape (Fig. 1). The Rakatu system is connected to the neighbouring Redcliff Wetland system via diverted water from its outlet stream, Little Creek. Rakatu is also connected to the Waiau River by its tributaries: Speight's Stream, Low Creek and Rakatu Stream (Fig. 2). This study focused sampling effort within twelve of the main Rakatu wetland ponds. LC4 retained no water during the course of this survey. The riparian vegetation of the majority of the ponds was comprised of self seeding *Carex* spp. and scattered broom clumps (*Cytisus scoparius*) aggregations (Fig. 3). Ponds SS4 and LC6 were edged by exotic pasture species, LC3 was divided with a row of *Eucalyptus cordata* and Rakatu pond contained a row of willows (*Salix* spp.).

3.2 Sampling protocol

A total of 43 sample sites were surveyed within twelve of the Rakatu Wetland ponds (Speight's Stream (SS) 1,2,3,4, SS Head Pond (SSHP), Low Creek Head Pond (LCHP), LC 1,2,3,5,6 and Rakatu pond) between November and December 2007. Sampling effort was proportional to the size of each pond. This was achieved by ponds being divided into three size classes, small (<2ha), medium (2-10ha) and large (>10ha) (see Appendix 1). Ponds allocated in the small size class had three sampling sites, medium had four and large had five. Sampling locations were predetermined on a map (Fig. 3) and were allocated evenly in the wadable areas of the ponds. The SSHP required a row boat to access the wadable areas. Identical sampling procedures were carried out at each sampling site and GPS coordinates were recorded (see Appendix 2).

3.3 Fish community monitoring

Fyke nets and minnow traps were the techniques used to sample the Rakatu fish community. These were chosen due to the large variety of fish species and size classes caught using these sampling methods (Hayes 1989). Furthermore the use of these techniques allowed comparison with results of a previous study of the wetlands at Rakatu and the surrounding area (Paterson 2006). Fyke nets were used to sample the larger fish species, for example eels and trout (Fig. 4). The minnow traps were intended to sample the smaller fish species, such as bullies and *Gallaxids* spp.. Ethical approval was given the by the Animal Ethics Committee.

At each sampling site, one un-baited fyke net (wing length 250cm, stretched mess size 20mm) was extended at a 45˚ degree angle from the shoreline. Two un-baited non-buoyant minnow traps (height 25cm, length 45cm, stretched mesh size 5mm) were then placed 10m either side of the middle section of the fyke net and a further two minnow traps were place 10m either side of the cod end of the fyke net. All nets and traps were secured in position with fencing standards. An arrangement of fyke nets and minnow traps were set at each sampling site within each pond over three (small), four (medium) and five (large) consecutive nights. Nets were set for an average of 20 hours and retrieved every morning between 0900 – 1200 hours.

All fish captured were weighed, length measurement taken and identified to species level (Fig. 5). After processing, all fish were released back into the pond in the vicinity of their point of capture. The abundance of the fish species for each of the twelve ponds was defined as a catch per unit effort (CPUE) value, calculated by the total number of fish/net/hour. Average abundance, weight and length comparisons were made between longfin and shortfin eels. The proportion of juvenile eels within the eel population was also investigated.

Due to the unexplained lack of any smaller fish species being caught in the minnow traps, spotlighting surveys were conducted in early February 2008. Shore transects of 50m were traversed at each of the twelve ponds and numbers of small fish seen were recorded. All 50 meters reaches were marked out and pegged during daylight hours and spotlighting was carried out after 2200 hours. All spotlighting was conducted from the banks to out as far as the spotlight beam allowed.

3.4 Depth and water chemistry monitoring

Readings of water chemistry and water depth were recorded at each sampling site. Both depth and water chemistry measurements were taken at the cod end of each fyke net prior to its retrieval each day. Using a Yellow Springs Instruments (YSI) Model 85 meter the temperature (^{o}C), dissolved oxygen (mg/L), conductivity (µS), and salinity (ppt) were recorded. The probe of the meter was placed in the water and readings recorded once values had stabilised.

For the purpose of this analysis the water chemistry and depth values taken at each sample location were averaged for each pond to give one representative value. To assess any differences in the water chemistry and depth between the twelve ponds one-way ANOVA tests were conducted. Tukey's *post-hoc* tests were then used to determine which ponds the water chemistry varied significantly in ($p < 0.05$).

3.5 Macrophyte community monitoring

Macrophyte community surveys were completed to investigate the habitat resources available to the fish species present in each of the twelve ponds (Fig. 6). At each sample site macrophyte species composition was recorded as percentage cover over a three meter sampling radius from the cod end of the fyke net. Percentage cover for each species was averaged across the sampling sites within each pond to give representative macrophyte composition values.

3.6 Benthic macroinvertebrate community monitoring

Benthic macroinvertebrate community surveys were completed to investigate the foraging resources available to the fish species in each of the twelve ponds. A total of 43 benthic invertebrate samples were collected between November – December 2007 and analysed. Samples were collected using a 500µm mesh D-frame kick net (29.5cm inner width). This sampling method was chosen on the basis of following previous studies of the Rakatu invertebrates (Paterson 2006). A $0.22m^2$ sample was collected at each sample location by sweeping the net across the upper 5cm of sediment for a distance of 75cm. Samples were then thoroughly rinsed and preserved in 100% ethanol and taken back to lab for processing. All benthic macroinvertebrate samples were processed and individuals were identified to genus level when possible.

Samples were examined with the use of sorting trays and a 40x dissection binocular microscope. Invertebrates were identified with the aid of keys from Winterbourn *et al.* (2000).

4 RESULTS

4.1 Fish community monitoring

A total of 349 fish were captured. Three species were caught in the fyke nets (longfin eel, *Anguilla dieffenbachii* (n = 279); shortfin eel, *A. australis* (n = 35); brown trout, *Salmo trutta* (n =1)) and one taxa of small fish was observed during spotlighting (Common river galaxid, *Galaxias spp.* (n = 34)) (Table 1). The overall mean abundance (CPUE) of each fish species across the entire Rakatu Wetlands is as follows: longfin eel = 0.2127 fish/net/hour (±0.1520); shortfin eel = 0.0157 fish/net/hour (±0.0285); brown trout = .0007 fish/net/hour (±0.0025).

Longfin eels were found in the highest abundance at LCHP (CPUE = 0.4572 fish/net/hour), followed by SS1 (CPUE = 0.4440 fish/net/hour) and LC3 pond (CPUE = 0.3417 fish/net/hour) and occurred at their lowest abundance in SS3 (CPUE = 0.0142 fish/net/hour) (Table 2). Shortfin eels appeared in lower abundances across the wetland system, being present in only six out of the twelve surveyed ponds. Shortfin eels' highest abundance occurred in SS1 (CPUE = 0.0949 fish/net/hour) (Table 2). Only one brown trout was caught across all the ponds during the sampling period in SS1 pond (CPUE = 0.0087 fish/net/hour), however, through discussion with local fishermen up to three brown trout have been spotted in the SS1 pond. D uring the sampling period a brown trout was also observed in LCHP.

The *Gallaxias* spp. was found to be present in only four of the surveyed ponds (SS2, SSHP, LC6 and Rakatu pond) (Table 1). There is potential that the *Gallaxias* spp. may be present in several of the other ponds as they appeared in shallow silty, soft bottom habitat which was not observed within the 100m sampling sections of every pond during the spotlighting.

The average length of captured longfin eels (n = 279) was 60.41cm (min = 25cm, max = 120cm) and shortfin eels (n = 35) was 63.83cm (min = 30cm, max = 120cm). The average weights were 726.20g (min 50g, max 2700g) and 814.12g (min = 50g, max 3800g) respectively (Table 3). Generally juvenile eels (Longfin ≤40cm; Shortfin ≤70cm; Jellyman 1989) were not common for either eel species (Longfin average proportion of juveniles = 6%; Shortfin average proportion of juveniles 42%). SSHP had the highest proportion of juvenile eels at 21% whereas no juvenile longfin eels were caught in any of the SS3, SS4, LCHP, LC2 and LC5 ponds (Table 4). Interestingly LC2 displays the highest level of variation in length of longfin eels (SD = 15.34), however, all of the 15 longfin eels caught in this pond were of adult size. LC5 had the greatest variation in shortfin eel length (SD = 27.8) with five of the seven shortfin eels caught being juveniles.

4.2 Depth and water chemistry monitoring

Across the sampling locations SS3 and LC6 had the highest average depth whereas SSHP and LC2 had the shallowest (Table 5). However SSHP was the only pond which required the row boat to access wadeable areas of the pond thus this data may not provide a good representation of the pond's depth profiles. The general variation in depth across the Rakatu Wetlands is relatively low (mean = 63.17cm; SD = 16.17) and was found to not be significantly different (One-way ANOVA p=0.167, df=11)

SS3, LC1 and LC2 ponds displayed the highest average temperatures which were significantly higher than that of SS1's (One-way ANOVA p=0.003, df=11). For dissolved oxygen, SS3 and SS4 were significantly lower and SSHP was significantly higher than the remaining ponds (One-way ANOVA p=<0.001, df=11). Similarly conductivity was significantly different in SS3 and SSHP than the other surveyed ponds (One-way ANOVA p=<0.001, df=11). However, salinity was found to be consistent across the twelve ponds surveyed (One-way ANOVA p=0.167, df=11) (Table 5). SS3 presented the lowest dissolved oxygen but the highest level of conductivity whereas SSHP had the highest dissolved oxygen and lowest conductivity (Table 5).

4.3 Macrophyte community monitoring

Only four macrophyte taxa were identified across the Rakatu Wetland complex. The average overall percentage contributions are as follows: *Ranunculus fluitans*: 49%;

Potamogeton spp.: 29%; *Juncus* spp. 19%; *Glyceria fluitans*: 2%. SS3 exhibited the highest macrophyte diversity (4 taxa) where as LC1 and LC2 ponds only had one taxa present (*Ranunculus fluitans*) (Fig. 5). Sweet grass (*Glyceria fluitans*) was only found present in SS3. SS4 had the highest percentage of macrophyte cover and LC1 and LC2 ponds had the least (Fig 5).

4.4 Benthic macroinvertebrate community monitoring

A total of nine invertebrate taxa were sampled across the twelve surveyed Rakatu ponds (Table 6). The Oligochaete and Dipteria – *Tanypodae* and *Ceratopongonidae* were the only three taxa that commonly occurred in all of the twelve ponds. The most dominant taxa found across the Rakatu Wetland complex were *Tanypodae* (n = 197) and Oligochaete (n = 158), whereas *Sigara* (n = 1) was only found present at the Rakatu pond and *Potamopyrgus* (n = 9) only occurred in SS1 (Table 6). Generally Oligochaete (40% contribution) dominated the Speight Stream ponds whereas *Tanypodae* (50% contribution) dominated the Low Creek ponds (Table 6).

SS2, LC5 and Rakatu ponds had the highest taxon richness (6 taxa) however they differed slightly in species composition (Table 6). SS4 presented the lowest taxon richness with only three taxa sampled. SS1 and LC5 had the least similar taxa composition (Table 6).

5 FIGURES AND TABLES

Figure 1. Photo of SS1 pond showing an example of pond being constructed with a dam (at far right).

Figure 3. Photo of Low Creak Head Pond demonstrating typical riparian vegetation of the Rakatu Wetlands system.

Figure 4. Photo of fyke net with a catch of eels after being retrieved at Low Creek 6 pond, sample site D.

Figure 5. Photo of a catch of eels after being retrieved and ready for processing at Low Creek 3 pond, sample site B.

Figure 6. Photo of macrophyte community at Low Creek Head Pond, sample site A.

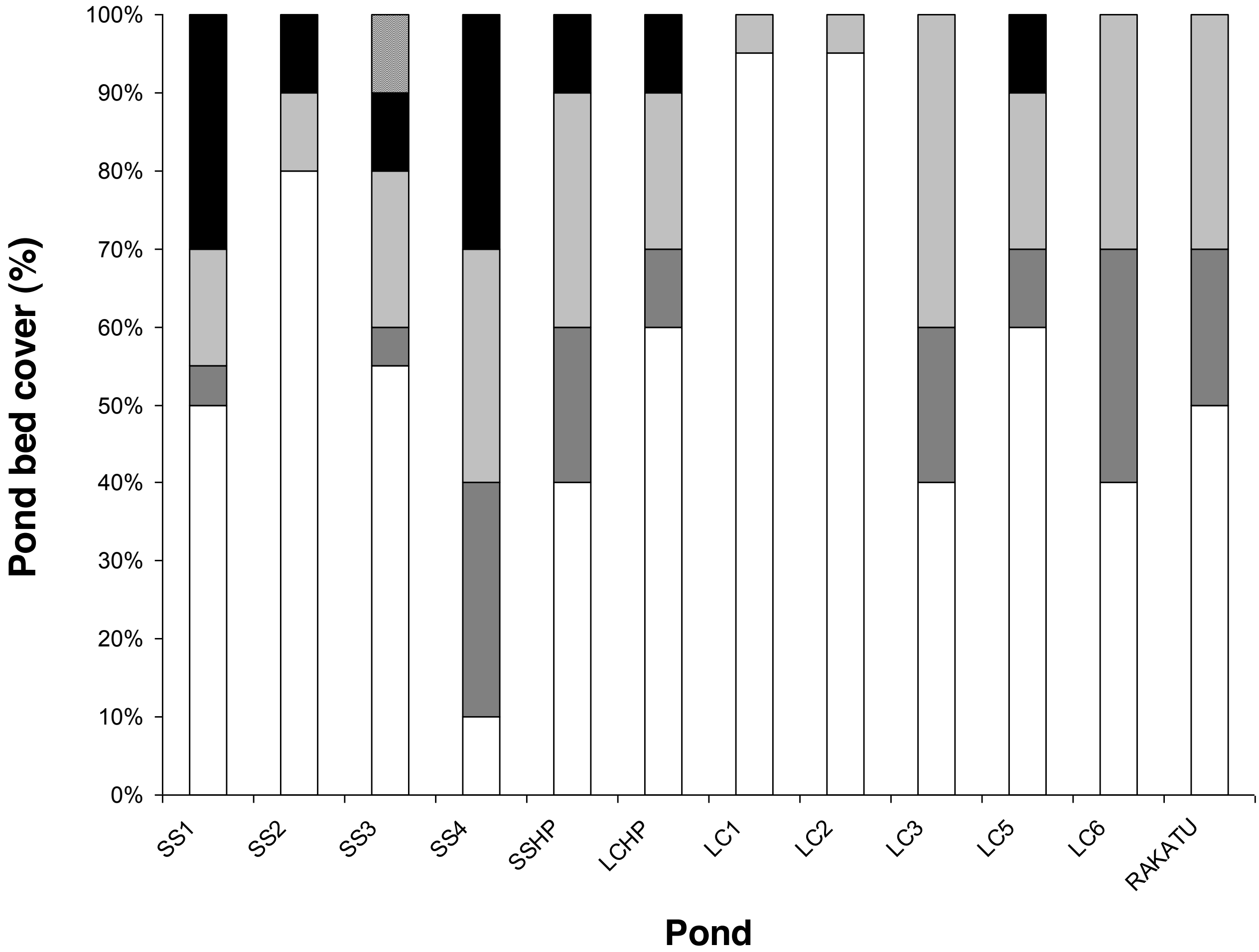

Figure 7. Average percentage (%) bed cover of macrophytes of the twelve ponds surveyed of the Rakatu Wetlands during Summer 07/08. The bare sediment and species are represented by the following shades:

6. DISCUSSION

6.1 Fish community structure

The vision of the Rakatu Wetlands project is: *to create an ecologically sustainable wetland/small stream ecosystem complex, for the benefit of fisheries and wildlife in the Rakatu area of the lower Waiau River catchment* (Riddell 2001). The enhanced and created habitat that now is the Rakatu Wetland's has successfully provided an exploitable habitat for fish species of the local area. The fish community is typical in terms of being dominated by the two *Anguilla* spp. (Glova & Sagar 2000; Glova 2001) and also has great conservational value with the colonisation of the *Gallaxias* spp. (McDowall 1998). On comparing the sampled Rakatu fish community to that of the surrounding source populations (i.e. Moss 2000) it is apparent that there is a good representation of the majority of these species.

When comparing the results of the present study to that of Paterson (2006) the fish community structure of the Rakatu Wetlands system appears to have similar longfin and brown trout populations of that of the natural wetland, Wairaki. Whereas Rakatu's shortfin eel populations is more similar to that of the well established Redcliff ponds. Paterson (2006) used the Jaccard Index, also known as the Jaccard similarity coefficient, ($\boldsymbol{Cj = j \,/\, (a + b - j)}$ where $\boldsymbol{j}$ = numbers of species present at both A and B, $\boldsymbol{a}$ = number of species present at A, $\boldsymbol{b}$ = number of species present at B) (Jaccard 1912) to compare the differences in presence/absence of species for the entire fish communities between the three studied wetlands (Wairaki = natural; Redcliff = 25 years old; Rakatu = 14 months old). To compare Rakatu Wetlands now with the oldest ponds being approximately six years old to Paterson's (2006) results we can see that the Rakatu fish community is most similar to the created Redcliff ponds ($\boldsymbol{Cj}$ = 0.75) and slightly least similar to Wairaki ($\boldsymbol{Cj}$ = 0.50). Furthermore the present Rakatu system is least similar to its former state ($\text{Rakatu}_{14\ \text{months}} - \text{Rakatu}_{\sim 6\ \text{years}}$ = 0.25). Interestingly the newly created Rakatu Wetlands are more similar to the Wairaki system in terms of fish community than Redcliff was at 25 years (Rakatu-Wairaki: $\boldsymbol{Cj}$ = 0.50; Redcliff-Wairaki: $\boldsymbol{Cj}$ = 0.33). From this it can be seen the Rakatu Wetland complex has be successfully colonised and is in the process of developing a fish community similar to that of well established wetland systems.

The average size of both eel species caught in the fyke nets were similar to those found in Paterson (2006), however, greater than in other studies (e.g. Jellyman & Graynoth 2005: mean length of longfins 424 mm (range 228–612 mm, SE 1.7 and mean length of shortfins 498 mm (range 355–647 mm, SE 20.0)). There does not appear to be an even level of all age cohorts present for either species of eel as the juveniles are considerably underrepresented (particular longfinned eel) in this present study. This skewing in the size structure of the eel species portrays a potential negative aspect of the colonisation success of these species. This could be a result of factors such: 1) physical barrier reducing their ability to colonise the new habitat; 2) the event of cannibalism by larger eels 3) inappropriate habitat for juveniles 4) other large scale influences effecting recruitment rates (Baber *et al.* 2002; Jellyman 2007). However, there are several feasible explanations as to why the smaller size classes were not sampled in large numbers in relation to the present studies methods, including: 1) avoidance of nets with captured large eels; 2) size selectivity of the sampling gear (i.e. fyke nets); 3) mortality including cannibalism within the net (adult eels become piscovourous; Jellyman 1989); 4) dietary, habitat or behavioural differences (Chisnall & West 1996; Naismith & Knights 1990; Sagar *et al.* 2005).

A major limitation of using fyke nets (particularly with large mesh) is that they are ineffective in sampling smaller size classes of eels (Chisnall & West 1996; Naismith & Knights 1990). Fish samples caught in fyke nets generally have a size frequency distribution skewed towards larger fish and few have fish recorded <35-40cm (Chinsall & West 1996). A way to overcome this limitation is to use complimentary methods such as electro-fishing or seine netting to target the small size classes of the eels (eg. Jellyman 1989; Chisnall & Kalish 1993). However, a study of an unexploited eel population in a lowland Waikato stream revealed that small eels were also uncommon even with a mixture of both netting and electrofishing techniques (Chisnall & Kalish 1993). Chisnall & Kalish (1993) concluded that this phenomenon was occurring due to cannibalism by the larger longfin eels.

The lower proportion of shortfinned eels found in the Rakatu fish community is not surprising as this species is predominately coastal and Rakatu is located approximately 82km upstream (Beentjes *et al.* 2006). However the capture efficiency for shortfins has been found to be considerably lower for than longfins (Jellyman & Graynoth 2005). The presence of larger longfins appears to regulate the density and size structure of eel populations, such that removal of larger longfins results in increased recruitment of shortfins (Chisnall & Hicks 1993). Similarly, Glova (2001) found the presence of large longfinned eels restricted the diversity of habitats used by juveniles of both species.

6.2 Factors influencing fish community structure

Managing a restored/created wetland to guarantee its biological success requires meeting the requirements of the fish species that will potentially colonise the area and to ensure their populations can be sustained (Laffaille *et al*. 2004). The rate and levels of success that fish communities can colonising new habitats (such as that of the Rakatu Wetland complex) depends on three elements 1) the level of connectivity between neighbouring wetlands and stream/river system; 2) the number of colonist; 3) the level of habitat quality (if there ecological requirements are met) (Baber *et al*. 2002). All three of these factors for the eel species appear to be met (given the numbers and range of size classes) whereas further population investigations maybe needed for the gallaxid and trout populations due to their small numbers sampled.

The Rakatu Wetland complex has a well developed hydraulic capacity with extensive connectivity and long hydroperiods. The construction of the Rakatu Wetlands successfully allowed connectivity with the neighbouring Redcliff Wetlands, the Waiau River and connecting streams (Speight's Stream, Low Creek and Rakatu Stream). It is through these passages that the fish were successfully able to colonise the Rakatu Wetland ponds. Due to the large level of interconnectivity between the ponds within the wetland complex there is a rather uniform level of ecological response between the surveyed water bodies with exception of the more isolated SS3 and SS4 ponds. Furthermore, the new/enhanced wetland system has created an increased amount of drought refugee for the fish communities in the area. Prior to construction inventories of the fish communities were carried out in the Waiau River and its tributaries (Moss 2000). When comparing these source populations to the current Rakatu fish community there is a lot of similarity. This gives evidence that the colonisation of fish species has been successful with a new fish community representing one similar to that of the surrounding water ways.

The colonisation capacity of a restored/created wetland environment also depends on the physical and chemical environmental factors in which the biota are be exposed to (Laffaille *et al.* 2004). Upon reviewing the literature the abiotic factors present in the Rakatu Wetland's pond habitats appear to fall within the preferred limits of the New Zealand wetland fish species (Richardson *et al.* 1994; Dean & Richardson 1999). From this it can be concluded neither depth nor water chemistry composition are limiting factors to the biological carrying capacity of the enhanced/created Rakatu Wetland system.

Available cover and foraging resources can also have large influence on the fish community that is able to exploit the restored/enhance habitat (Baber *et al.* 2002). Aquatic plant cover is found to be a key habitat component in ensuring sustained fish populations (Cross & McInerny 2006). Different life stages of the wetland fish species utilise macrophytes for varying purposes. Fish are attracted to higher level (40-70%) of macrophyte cover due the increased level in habitat heterogeneity (Brazner & Beals 1997). Furthermore the number of macroinvertebrates present has been related to the density of macrophytes (Brown *et al.* 1997). Therefore as the Rakatu Wetlands become more colonised by submerged and emergent macrophytes there is a huge potential for a positive influence on fish abundance and diversity: a) directly through cover provision and b) indirectly through the increase in invertebrates (ie foraging resources) (Cross & McInerny 2006). When Paterson (2006) surveyed the Rakatu ponds in 2003 they were still lined with decaying pasture, thus they are slowly succeeding and abundant macrophyte beds are beginning to form throughout the wetland complex providing increasingly level of habitat variation.

The biological diversity and the numbers of each taxa that a wetland system can support can be greatly influenced by the abundance and diversity of the aquatic invertebrate community (ie sufficient foraging resources) (Brown *et al.* 1997; Baber *et al.* 2002). The Rakatu Wetland complex appears to have a benthic macroinvertebrate community suitable to sustain the fish community given the results of those studies that investigated the prey species eels (e.g. Jellyman 1989; Sagar & Glova 1998; Sagar *et al.* 2005), brown trout and gallaxids (e.g. Eldon & Taylor 1990).

6.3 Assessing success of habitat enhancement/creation

In terms of assessing the success of the habitat enhancement/creation project of the Rakatu Wetlands in its ability to successfully provide adequate habitat for a fish community I can conclude it has so far been a great success. As we can see from a previous study conducted in the area (Paterson 2006) the Rakatu Wetland system has had a good portion of the local fish community already colonised into the new provided habitat. McDowall (1998) listed several measures for determining high quality habitats for fish communities: 1) high species richness; 2) high fish abundance; 3) good recruitment rates; 4) complete series of cohorts recruited in the population. The Rakatu Wetland system is well on its way to achieving all four of these goals within the relatively short colonisation period. The major physical and abiotic factors investigated do not appear to be implicating the success of the fish community colonising and sustaining populations within the Rakatu system. The requirements for successful colonisation appear to be met relatively well with the exception of the extremely low juvenile longfinned eels sampled (but this is most likely a result of sampling technique). The Rakatu Wetland system has shown its ability to support natural populations of typical wetland fish populations and thus it can be concluded that it is a well designed and managed viable wetland ecosystem that is providing great conservational value to the area.

6.4 Management implications

This study demonstrates that the developing wetland system of Rakatu is a valuable and utilised fish habitat in the Waiau catchment and that future protection and management should be continued. The results of this study give the baseline data for the abundance of the fish species present within the Rakatu Wetlands. The importance of monitoring a project such as the Rakatu Wetlands has been discussed and it is in the interest of the managers that monitoring of the fish community be continued (every 3-5 years) to ensure the continued success of the project at reaching its goals. I would recommend the repetition of this present studies methods as the regime for future monitoring of the fish community of the Rakatu Wetland complex. However I feel that the relocation of two of the sample sites SS1 D and SS4 B would give much better representation of the SS1 and SS4 ponds. Potential relocation sites have been outlined in Figure 2.

The result of capturing no small fish species in the minnow traps was not expected given the success of several small fish species being caught in Paterson's (2006) study. The spotlighting technique used in this present study did reveal the presence of a *Gallaxias* spp. in some of the surveyed ponds however did not allow the identification of this species. There are several advantages to using spotlighting in a monitoring regime including its non invasive nature and its unlikeliness to cause movement of specimens out of the surveying zone (Hickey & Closs 2006). However due to the inability to identify fish to species level it tends to lose some of it credibility for the purposes of fish community monitoring. The use of backpack electrofishing or seine netting on the other hand would allow a more accurate assessment of fish species composition and abundance. Furthermore it would also allow capture for weight and length processing of smaller fish species and significantly increase the assessment of not only brown trout but also juvenile eel populations. For future monitoring efforts of the Rakatu Wetland's fish community I would recommend that the minnow traps and spotlighting techniques be replaced with backpack electrofishing (or seine netting if the conductivity of the ponds is inappropriate for electrofishing). The combination of fyke nets and electrofishing should allow a more thorough assessment of all species and size classes present. A suggested electrofishing regime would be at each sampling location across the ponds a 30m reach is electro fished over consecutive days.

Macrophyte and benthic macroinvertebrate surveys are very useful in terms of helping explain the structure of fish communities and water quality. The importance of retaining these surveys in future monitoring efforts would be desirable to monitor the succession and colonisation nature of these habitat features. However should resources not permit the conduction of this surveys they should be carried out to assess the availability of foraging resources if negative results are found in the fish community surveys (i.e. population declines etc.).

The major recommendation for the future management of the fish communities in the Rakatu Wetland complex is continued monitoring and protection. Further investigation of trout and gallaxid populations is desirable to gain knowledge on the level of establishment of these species. Should future surveys reveal a low abundance of juvenile eels, perhaps management needs to implement wider based studies on the factors that are causing this trend to occur. The current eel population structure of the Rakatu Wetlands may be stable while dominated by larger eels, if not management of the factors influencing eel recruitment rates needs to be challenged (e.g. harvesting etc.) (Gerry Closs *pers. comm. 31/03/08*). The interpretation of the present studies results on the fish community composition relies on the initial goals set out by the Waiau Trust. If the Rakatu Wetlands system aims to serve firstly as a sanctuary for the *Anguilla* spp. then the desired outcome has been met, however, if large populations of bullies and gallaxids are more desirable then perhaps the presence of a large population of piscovourous fish is not ideal.

To further increase the conservation value of the Rakatu Wetlands for the Waiau River catchment area and for New Zealand's native fish species, the introduction of species such as the giant kokopu (*Gallaxias argenteus*) could be investigated. Bonnett & Sykes (2002) reported that the five key habitat features important to giant kokopu are 1) in-stream cover; 2) deep water (>0.5 m); 3) low water velocity (<0.1 m s–1); 4) proximity to the sea; 5) overhead shade/riparian cover. Furthermore the occurrence of landlock populations in ponds are known to exist at considerable elevation and distance from the sea (McDowall 1990) thus there is definite scope for Rakatu Wetlands to provide suitable habitat for this endangered native fish species.

7. ACKNOWLEDGEMENTS

I would like to thank Jan Riddell and Mark Sutton of the Waiau Trust for the opportunity to do my placement with them at the Rakatu Wetlands, thank you for your time and patience and for such a beautiful place to work. I would also like to thank Shane Gibbs and his family and workers for the welcomed access across the farm and for the loan of the fence standards. I am grateful to my chief field assistant Hamlin Boyde-Manson and to all my family and friends for their aid and support. I would also like to pay gratitude to Phil Seddon and Gerry Closs for their wisdom and guidance and to all the support staff at the Zoology Department, University of Otago. And lastly to Rachel Paterson for all her great advice and willingness to share her knowledge, this was much appreciated.

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Appendix 1. Approximate age (years) and open water area (ha) of the twelve surveyed Rakatu Wetland ponds. Sourced from Jan Riddel, Waiau Fisheries and Wildlife Habitat Enhancement Trust.

Factor	SS1	SS2	SS3	SS4	SSHP	LCHP	LC1	LC2	LC3	LC5	LC6	RAKATU
Age	4	4	5	4	5	6	6	6	6	6	6	4
Open water area (ha)	14.10	4.90	1.40	1.64	1.40	2.00	0.46	0.84	3.90	0.46	7.68	6.20