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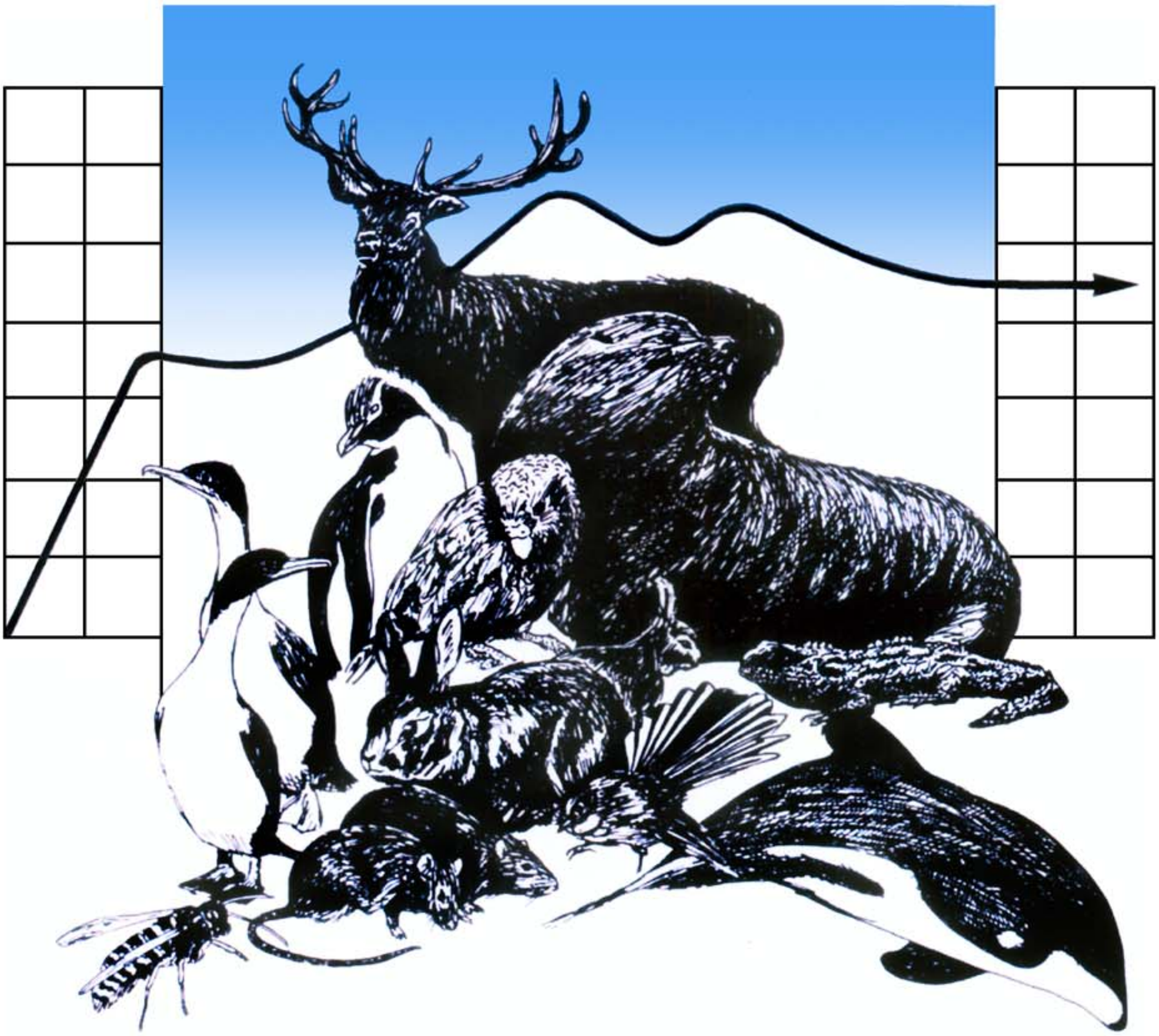

WILDLIFE MANAGEMENT

Ecological impact of *Didymosphemia germination* on river birds in the Upper Waitaki Basin, New Zealand

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Project: Ecological impact of *Didymosphenia germinata* on river birds in the Upper Waitaki Basin, New Zealand

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Executive summary

- *Didymosphenia geminata* (Didymo) is a diatom native to the northern hemisphere whose global distribution is currently undergoing extensive range increases due to human activity. The spread of Didymo is of concern for stream ecosystems for several reasons as the diatom has "drastic" implications for aquatic environments.

- It was discovered in New Zealand in October 2004 and has since spread amongst several South Island river systems. Classified as an unwanted organism under the Biosecurity Act of 1993, recent studies indicate impacts upon river system functions, food webs and aesthetic recreational values.

- We aim to determine the impact of Didymo upon river birds in the Upper Waitaki Basin through the study of both the direct and indirect effects the species has on river bird behaviour, physiology, nest location and habitat choice. We will also examine impacts upon macroinvertebrate community structure and monitor Didymo growth patterns.

- This knowledge is vital to future management of the local flora and fauna found in the Upper Waitaki Basin; including several rare, threatened and locally endemic species. As the spread of Didymo throughout these river systems is inevitable, its impact upon species already vulnerable to extinction must be determined.

- Through the findings of this study we will be able to determine if Didymo poses a serious threat or potential benefit to the braided river birds of the Upper Waitaki Basin. It will also provide important baseline knowledge to help guide future management directions and decisions.

Background:

Didymosphenia geminata (Didymo) is a freshwater diatom historically found in cool freshwater rivers, streams and lakes in northern Europe, North America and Asia (Spaulding *et al.,* 2005). In recent years, it has begun to take on the characteristics of an invasive species within this native range; increasingly forming extensive blooms which persist throughout the year and expand its geographical range (Sherbot and Bothwell, 1993; Kawecka and Sanecki, 2003; Kilroy, 2004; Spaulding *et al*., 2005).

Didymo was first identified in New Zealand in the Mararoa River, Southland, in October 2004; the only known case in the Southern hemisphere (Kilroy, 2004). It was initially thought to be contained within this catchment but by September 2005 it had spread to several other South Island waterways (Kilroy, 2004; Duncan, 2006). The most recent discovery was in the Ahuriri River in the Upper Waitaki Basin (UWB) in early February 2006 and to date the species has not spread beyond the South Island (www.biosecurity.govt.nz, accessed 23 April 2006).

The most likely cause of Didymo dispersal at both a regional and global scale is through human activity (Kilroy, 2004; www.biosecurity.govt.nz, accessed 23 April 2006). Especially significant are recreational users of freshwater environments such as fisherman, kayakers and boaters (Kilroy, 2004). There is also the potential for animal vectors to play a role as live Didymo cells can be passed on through the guts or carried on the outer surfaces of birds and animals moving between adjacent waterways (Kociolek and Spaulding, 2003; Kilroy, 2004).

Many of New Zealand's waterways exhibit conditions thought to allow for and encourage Didymo contamination (Kilroy, 2004). As such, there is concern as to what implications the species may hold for New Zealand's aquatic food webs (Kilroy, 2004; Kilroy *et al.,* 2005). Investigations into the favoured flow conditions of Didymo have revealed an apparent preference for oligotrophic waters with high light conditions and periods of low (or stable) flows (such as those below hydroelectric dams/reservoirs) (Kawecka and Sanecki, 2003; Kilroy, 2004). It has also been observed however that Didymo can successfully occupy waters beyond the range of depths and velocities that can safely be sampled (Jonsson *et al.*, 2000, Kawecka and Sanecki, 2003; Kilroy, 2004; Kilroy *et al*., 2005).

Didymo has been seen to cover almost all available benthic substrate forming dense mucilaginous mats several centimetres thick (Kilroy, 2004; Spalding *et al.,* 2005). Being both epilithic (attaching to stones) and epiphytic (attaching to plants), Didymo is known to exclude other diatom species; some of which are an important source of food for local aquatic invertebrates (Kilroy, 2004; Spalding *et al.,* 2005). Studies undertaken in British Colombia, Canada, also indicate the species can have significant effects on both local invertebrate and fish habitats (Sherbot and Bothwell, 1993).

In New Zealand the National Institute of Water and Atmospheric Research (NIWA) was commissioned by Biosecurity New Zealand in 2004 to do a series of studies on the ecology of this invasive diatom aiming to gain a better understanding of likely aesthetic and biological impacts of *Didymo* on the river environment and to provide information applicable to future control and eradicate attempts (www.biosecurity.govt.nz, accessed 23 April May 2006).

Studies by Kilroy (2004) and Kilroy *et al.* (2005) have attempted to assess the potential effects of Didymo on higher trophic levels through the comparison of invertebrate communities in affected and unaffected water systems. Results have indicated shifts in macroinvertebrate community structures (Kilroy *et al*., 2005). In general, individual invertebrates from the unaffected sites appear to be larger (mean dry weight) and affected sites show higher abundances of choronimids and oligochaetes (Kilroy *et al.,* 2005). No significant difference in taxonomic richness between affected and unaffected sites has however been observed (Kilroy *et al.,* 2005).

Study site

In New Zealand Didymo was most recently found in the Ahuriri River of the UWB, (www.biosecurity.govt.nz, accessed 23 April 2006). This region of the South Island (Fig. 1) possesses braided river systems' home to a faunal and floral makeup unique to the New Zealand environment (Darby *et al.,* 2003). The Ahuriri River is known internationally as a pristine wilderness renowned for its fishing and rated as a conservation area of "outstanding value" for native wildlife (Robertson *et al*., 1983; Graynoth, 1995; Maloney, 1995).

Research incentive - ecological impacts on river birds

Within the UWB, more than twenty bird species are known to make use of the braided river habitats for breeding, feeding and residence and include locally endemic and threatened species (Maloney *et al.* 1999). The UWB supports around 15% of the remaining 5,000 wrybills; 60% of the remaining 5,000 black-fronted terns; and 100% of the remaining black stilts known to exist in New Zealand (www.doc.govt.nz, accessed: 23 April, 2006). However it must be stated that no negative impacts of Didymo on bird populations have so far been published in either the New Zealand or overseas literature.

River birds are known however to feed upon the local macroinvertebrates, fish and aquatic plants previously mentioned as being under possible threat from Didymo impacts (Caruso, 2006). The densities of river birds of the UWB are also negatively correlated with altitude and are observed to generally prefer river sections with low or moderate flows and vegetation cover (Caruso, 2006). These are the same regions where Didymo was earlier identified as being most likely to persist (Kilroy, 2004; Kilroy *et al*., 2005). As such, the river birds of the UWB may suffer from indirect impacts upon their environment or themselves.

When the invasive Russell lupin (*Lupinus polyphyllus*) arrived in the UWB, its expected impact upon the local bird fauna was likely underestimated. Now the species is one of the main two species of plant in the UWB and is having a direct negative impact on both the regions flora and fauna (Maloney, 1995). This proposed study intends on filling the large knowledge gap surrounding the effects of Didymo on New Zealand's river birds (and to a certain extent on the braided river habitat) to prevent such a misinterpretation occurring again.

Through the findings of this study we will be able to ascertain if Didymo possess a serious threat or potential benefit to the braided river birds of the Upper Waitaki Basin. It will also provide important baseline knowledge to help guide future management decisions and directions.

Research Proposal

Direct impacts

1.1 Determine if Didymo directly affects the behaviour of river birds in the UWB

Explanation:

Didymo growths have been said to irritate and clog fish gills (Kilroy *et al.,* 2005) and cause eye irritation in swimmers (Kilroy, 2004). It is hypothesised river birds may also be subjected to these irritations, directly affecting such behaviours as foraging abilities and thus overall bird survival and fecundity.

To determine the direct impact of Didymo on river bird behaviour in the UWB we propose the use of in vitro testing of three river bird species tested separately in four week periods (due to aviary size constraints). In vitro testing eliminates many confounding variables that have the potential to affect animal behaviour in nature such as threat of predation as well as allowing for known and controlled levels of interaction with Didymo. It also provides the opportunity for setting up a control group which is not possible in nature due to the large dispersal patterns often attributed to river birds (Robertson et al., 1983, Murphy *et al.,* 2003).

The proposed species for this study include the threatened black stilt (*Himantopus novaezelandiae*), black fronted tern (*Sterna albostriata*) and the wrybill (*Anarhynchus frontalis*). For the Black Stilt, the morphologically (Maloney pers comm., 2006), physiologically (Sancha *et al.,* 2004) and behaviourally (Pierce, 1982; Maloney pers comm., 2006) similar Pied Stilt species *Himantopus himantopus* will be used as an indicator species due to the priors' exceedingly small population size (As applied in similar circumstances by Sancha *et al.,* 2004).

Method:

Two new aviaries will be constructed using a similar design to that used in the Kaki Recovery Programme. Two lots of eight birds will be placed into each aviary (four adult birds of each sex). One aviary will be contaminated with Didymo at similar levels observed in nature during blooming conditions through the addition of contaminated substrate material from infected reaches of the Ahuriri and upper Waitaki rivers. The second aviary will use a substrate of similar characteristics but remain uncontaminated. Birds of the contaminated aviary will be fed a Didymo infected diet to ensure live and dead diatom consumption while the second aviary will be fed a matching food type without the presence of Didymo.

An ethogram will be employed weekly for a period of four consecutive weeks (Vahl *et al*., 2005) to examine potential behavioural changes and a record will be made noting any obvious change in visual appearance i.e. changes in feeding patterns, visual irritations etc. Under ideal circumstances, all river bird species of the UWB would be considered but as this is not economically feasible we propose the study encompass only threatened species showing high levels of interaction with the river environment and distributions restricted to the UWB. These populations, already on the brink of extinction, are most at risk if Didymo is found to have a negative impact.

1.2 Determine if Didymo directly affects the physiology of river birds in the UWB

Explanation:

Historically, studies assessing the impact of stress, whether anthropogenic or environmental have focused on the behavioural consequences to individuals (Weimerskirch *et al.,* 2002). However, using only one method to assess stress responses is inadequate as many hormonal, immunological, and behavioural systems are triggered in other ways and follow different time courses (Whitten *et al*., 1998; Weimerskirch *et al*., 2002). As such we propose the examination of both blood and urine samples of the in vitro Kaki to add to the results gained through the behavioural observations in study **1.1.**

Blood samples can be used to measure corticosterone (the avian stress hormone) while urine samples allow for monitoring of mineral balance; a factor potentially under threat of change through Didymo consumption (Whitten *et al.*, 1998, Sancha *et al.,* 2004). Stress and bodily mineral contents are important to look at as changes in their levels often relate to changes in gonadal hormones (Wingfield *et al.,* 1992) and as such directly affect species reproduction.

Methods:

Using the aviary kept birds mentioned in setup **1.1,** blood and urine samples will be collected using the techniques developed through the Kaki recovery programme (Sancha *et al.*, 2004), at the end of each monitoring session. Blood and urine analysis will be carried out to measure stress hormone and bird mineral levels and compare between trial groups to determine if a difference exists between birds interacting with Didymo and those who are not.

N.B. To gain more power for studies **1.1.** and **1.2,** we shall conduct a reverse treatment (switch the birds between aviaries) to be employed only if a noticeable difference is observed in the initial study periods.

1.3: Determine if clutch size changes in river birds using contaminated rivers of the UWB

Explanation

A female's health affects both the number of eggs she lays and the number of young she can raise (Marzal *et al.,* 2005). This is shown to occur even in species where clutch size is heritable (Price and Liou, 1989). As clutch size plays a direct role in the recruitment of a species, Didymo's impact upon river birds is especially relevant for threatened species such as the Black stilt whose recruitment levels are already of key concern (Sancha *et al*., 2000).

Methods:

Labour and resource constraints result in the proposed monitoring focusing on the Black stilt species as the Kaki Recovery Programme is currently collecting eggs from the nests of Black stilts though the course of their ongoing studies. We propose the upkeep of a journal recording the numbers of eggs taken from each nest throughout the breeding season (September to late December) to allow for a comparison of clutch sizes between nests located near contaminated and non-contaminated rivers. Comparison can also be made using historical nesting data from the programme. If results of the study indicate significant differences, future monitoring is advised to incorporate other at risk species (such as the wrybill and black fronted tern).

Indirect impacts

2.1: Determine effect of Didymo on the macroinvertebrate community structure in the UWB river systems.

Explanation:

River bird abundance is often directly associated with the availability of aquatic prey (Sanders, 2000). Feeding location and rates of river birds are also directly related to prey availability (Pierce, 1982, 1986). In the UWB, the greater part of the bird species using the waterways feed on macroinvertebrates (Caruso, 2006) and as such any impact of Didymo upon the macroinvertebrate community structure will indirectly affect them. Previous research by Spaulding *et al.*, (2005) and Kilroy *et al.*, (2005) has indicated changes in macroinvertebrate communities do occur as a result of interaction with Didymo blooms.

As such, any large community shift may have flow-on effects to higher trophic levels including avian classes. This study will create a before and after picture to determine any impact of Didymo upon the macroinvertebrate community structure and as such if river birds are likely to be affected; positively or negatively.

Methods:

Using a replicated design, we will compare invertebrate communities between affected and unaffected reaches of the Ahuriri River. Monthly samples will be taken at infected sites below (x2) and clean sites above (x2) the main infestation over a one year period with five replications at each site. If spread of Didymo in the Ahuriri River makes 'clean' samples impossible to collect, other rivers in the UWB such as the Dobson; Cass and Godley Rivers with similar physical characteristics will be used (Maloney, 1995).

Data analysis will focus on the invertebrate density (number of individuals per m^3), average biomass of individuals (dry weight) and species richness from Didymo infected and uninfected sites. The findings will be compared with historical data from Maloney (1995) and resent NIWA studies. As such sampling methodology and data analysis will be conducted using similar methods as Maloney (1995) and those proposed by NIWA (Kilroy *et al.*, 2005); involving surber sampling, Simpson's index of evenness, ETP species richness and MCI analysis to evaluate the impact of Didymo upon the invertebrate community to enable valid comparison with historic data.

2.2: Determine if nesting behaviour of UWB river birds is altered by Didymo presence

Explanation:

Research by Pierce (1986) and Rebergen *et al.* (1998) in the Waitaki basin has shown that river bird nest site location influences breeding success and that nest sites correspond to areas where favoured food types are prominent. As such factors which affect these food types will indirectly control where river birds choose to nest. Didymo produces massive mucoplysaccaride stalks that appear resistant to decomposition (Spaulding *et* al., 2005) and hence persist beyond the death of cells; stabilizing river beds. Large amounts of dislodged biomass (due to high flow events) will eventually accumulate along river edges (Kilroy, 2004; Spaulding *et al*., 2005) and associated sediment accumulations generally encourage vegetation growth (Rebergen *et al.,* 1998). This carries the potential to affect nest location with many species choosing nest sites in areas devoid of vegetation (Rebergen *et al.*, 1998). A change in nest location due to these accumulations may result in nest positioning in areas more prone to predation threat, environmental damage and of poorer rearing ability.
Method:

Due to conservation status and current research, focus will lie on the Black stilt species. The Kaki programme possesses the locations of current nest sites as well as having historical data on past locations within the UWB. Future nest sites can be compared with these known site locations to see if significant changes have occurred in their distributions and relationships looked for in regards to Didymo presence.

Nest location and clutch size data gathered during the Kaki nesting season (September to late December) by the Kaki Recovery Program will be compared with Didymo growth data for the same locations. This data will be gathered at two week intervals from August 1 until the end of December and be categorised according to standardised NIWA practise (Kilroy *et al.,* 2005).

2.3: Determine if habitat selection by river birds changes with Didymo presence

Explanation:

River bird habitat selection is controlled in part by surrounding environmental factors such as vegetation makeup (Robertson *et al*., 1993; Maloney, 1995; Maloney *et al*., 1999; Caruso, 2006). The main aim of this study will be to look into feeding location selection and where the birds reside when they are not nesting. Though river bird nesting behaviour and macroinvertebrate structures looked at in studies **1.1** and **2.1** may show no indications of change, bird movement may still be influenced by Didymo nonetheless as has been observed with Salmonid parr (*Salmo trutta*)(Kilroy, 2004; Erickson *et al*., 2004) where Didymo directly impacted upon the animal's distribution pattern.

Methodology:

Bird counts will be carried out at several locations along both the infected reaches of the Ahuriri and Upper Waitaki rivers as well as clean regions of the Dobson, Godley and Tasman rivers of all visible river birds. These counts will consist of a tally being made when the observers first arrive at the sample location and will undergo weekly repetition over a one year period to ensure sampling of all life stages.

2.4: Determine annual Didymo growth patterns

Explanation:

If Didymo is found to impact upon river bird behaviour or physiology, an understanding of peak Didymo biomass levels would be beneficial in determining when control measures could best be utilised. It would also allow for knowledge on when river birds are likely to be most impacted by the species or alternately the macroinvertebrate community if this is where the important impacts reside.

Methodology:

To determine Didymo growth patterns, monitoring of the contaminated reaches in the Ahuriri and Waitaki rivers will be employed with all noticeable Didymo blooms being recorded (the species is most noticeable at these times (Duncan 2006). Ongoing monitoring is advisable but for the scope of this study we propose a two year period of observation to ensure study of the species full life stage changes. The study will be extended if no noticeable blooms become apparent within this two year time frame.

Evaluation:

An advisory committee composed of representatives from NIWA, the Kaki Recovery Program, Programme River Recovery and Otago University delegates will be set up from the project's onset to monitor and guide its development. Regular reporting and updates from those directly involved in this study and outside research on Didymo will be included in committee meetings. Short term monitoring evaluations (<1 year period) will be carried out for studies **1.1, 1.2, 1.3** and **2.2** while long term monitoring evaluation (>1 year period) will be needed for studies: **2.1, 2.3, 2.4.** Evaluations of results from these studies will not rely solely on statistically significant findings alone as the severity of the threats faced by certain river bird species means even small impacts of Didymo may have substantial biological effects. The resulting findings hopefully utilised in future DoC management decisions.

Costs / requirements:

1.1: Two new temporary aviaries, bird upkeep costs (food and initial trapping), 24 weeks technician costs (x2), transport costs, biosecurity approval for Didymo relocation and animal ethic permits.

1.2: Two new temporary aviaries, bird upkeep costs (food and initial trapping), 24 weeks technician costs (x2), transport costs, endocrinology and urine analysis costs and animal ethic permits.

1.3: 16 weeks technician costs (Costs will be lessened through the use of ongoing Kaki research).

2.1: Sampling equipment and labour costs for sample collection and analysis (monthly for a one year period), transport costs.

2.2: No cost – will use data collected through ongoing Kaki research programme and study design 2.4.

2.3: Part time technician (x2) and transport costs for weekly bird counts over a one year period.

2.4: Part time technician (x2) and transport costs for two year period of monitoring of bloom conditions

N.B. above costs are based on each individual studies merits only though in reality construction, technician and sampling costs will overlap cancel out (Table 1.). The failure to procure consent forms may result in changes to studies overall design or its eventual deletion.

Table 1. Timeline of when each sub-study will commence, overlap and cease.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Comment
1.1	■	■	■	■	■	■							
1.2	■	■	■	■	■	■							
1.3									■	■	■	■	
2.1	■	■	■	■	■	■	■	■	■	■	■	■	
2.2									■	■	■	■	
2.3	■	■	■	■	■	■	■	■	■	■	■	■	
2.4	■	■	■	■	■	■	■	■	■	■	■	■	2 Years

Funding:

To fund the proposed project and meet these costs we recommend applications be sent to Biosecurity New Zealand and NIWA, both of whom have a key interest and current funding involvements with Didymo.

Potential funds may also be found through specialist research and conservation organisations working in fields related to the topic at hand such as Project River Recovery, a Meridian Energy based exercise and the Kaki Recovery Programme, a programme run through the Department of Conservation.

Future Directions:

As no known eradication techniques exist for the Didymo threat, information on factors which may aid in the control of the species become paramount if it is found to have a negative impact upon the New Zealand environment. It has been proposed that one such natural control method may in fact be direct flooding of the waters the species inhabit; water flows of over 100 m^3/s (Kilroy *et al.*, 2005). Studies in British Colombia suggest that flow conditions over the previous winter also determined weather or not Didymo would bloom the following spring (Sherbot and Bothwell, 1993).

As such, the flow data from NIWA available from the monitoring site in the lower Ahuriri River (Diamden gorge site) and weather data from the Tara Hillsa research may be useful in looking for relationships between flow rates and the Didymo bloom growth patterns determined in study **2.4**.

If the opportunity arises for Necropsies to be carried out on deceased birds in the UWB it is also recommended that the bodies be examined for Didymo presence. This may provide valuable information for future studies.

For studies **1.1** and **1.2** we also propose the direct use of Black Stilt adults if the opportunity arises. I.e. if the captive Kaki breeding programme has an especially successful year, sixteen birds may be available for use as opposed to direct release into the wild where success has been limited in the past.

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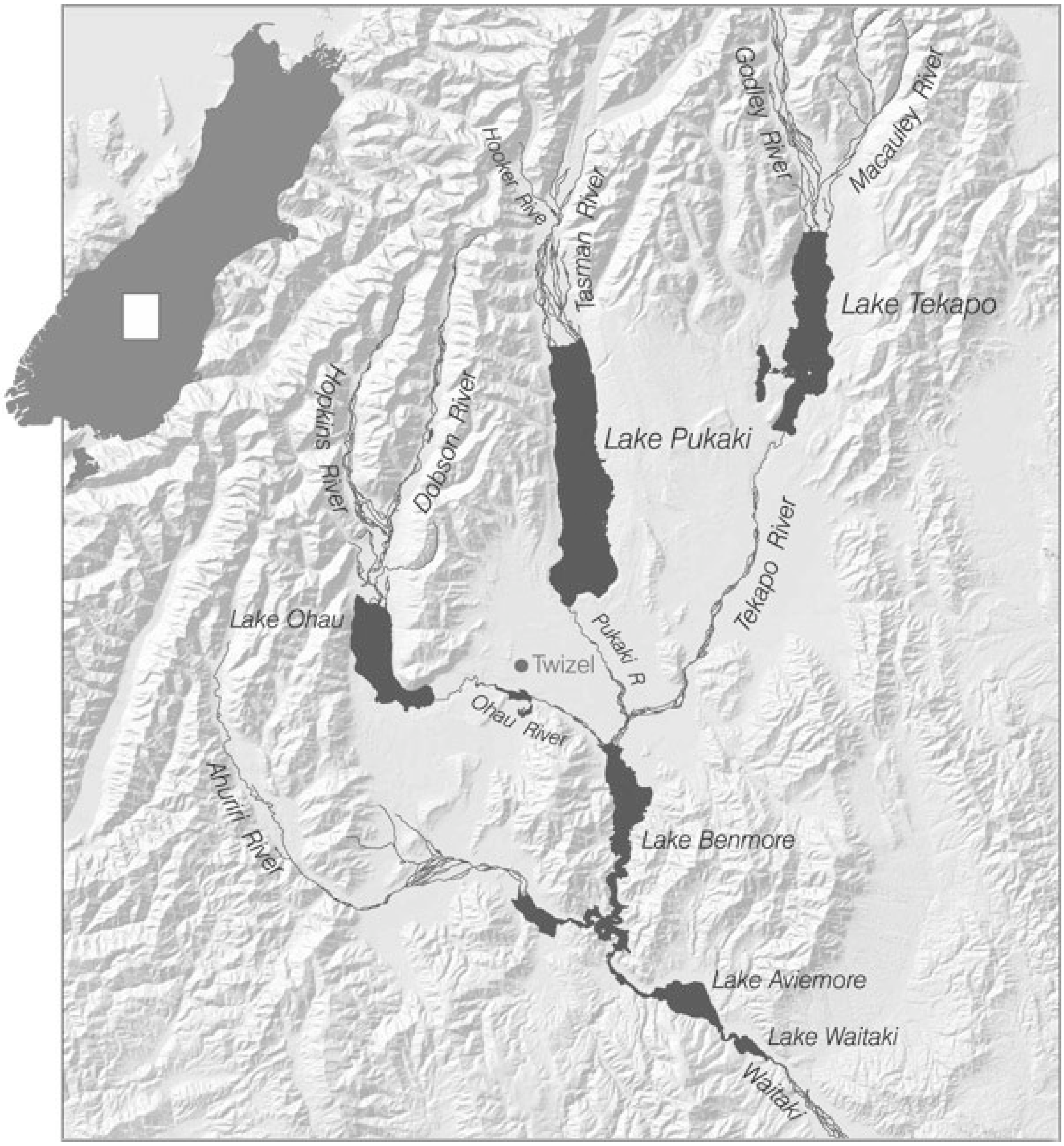

Figure 1: Map of Upper Waitaki Basin region (Modified from http://www.doc.govt.nz)