

**EVALUATING THE HEALTH OF RIPARIAN HABITATS:
WATER USE DECISIONS, DENSITY AND BREEDING
PERFORMANCE OF YELLOW WARBLERS IN
REVELSTOKE REACH, B.C.**

2006/7 SUMMARY REPORT



Active yellow warbler nest built in a willow shrub

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EXECUTIVE SUMMARY

Human activity has resulted in dramatic declines in the amount of riparian habitat across North America. Parallel to this loss have been widespread population declines of bird species that use riparian habitat. Conservation of riparian dependant bird populations may be facilitated by minimizing any further impacts on birds using remnant patches of riparian habitat, but are also likely to require active restoration effort to ensure populations remain viable. Studies evaluating the success of restoration efforts have often compared bird densities in restored habitat with those under “natural” (i.e. reference) conditions. However, it is far from clear that bird abundance or density is related to the reproductive success and survival of individuals and/or the growth rate of bird populations.

We studied yellow warblers (*Dendroica petechia*) breeding in three types of riparian habitat adjacent to the Upper Arrow Reservoir near Revelstoke, BC. We assessed the impact of dam operations on the breeding performance of the yellow warbler and evaluated whether yellow warbler density provides a reliable measure of riparian habitat quality.

We found that current dam operations did not have a major impact on the breeding success of yellow warblers in Revelstoke Reach in either 2005 or 2006, even though water levels were close to the maximum currently allowed in 2006. Nest mortality due to flooding was low because native riparian vegetation is no longer found below 435m, yellow warblers place nests 3m above the ground, and the majority of nests fledged or failed prior to increases in the water level. However, changes in the timing of reservoir fill of even 2 weeks, while maintaining the current maximum allowable fill, would have increased yellow warbler nest mortality due to flooding from 6 to 16%. We also found evidence that rising water levels may have an indirect effect on yellow warbler productivity as broods raised on territories that were partially flooded tended to be lighter than broods on territories that were not impacted by rising water levels. This is likely to reduce juvenile survival since lighter nestlings have lower survival in many species of birds.

Yellow warblers appeared to prefer riparian habitat that included mature cottonwoods bordered by willow since they consistently arrived and initiated reproduction at Machete Island, the site representative of this habitat type, before starting to breed at other sites. Riparian habitat at Machete Island is therefore apparently perceived as being of higher quality than the patchier riparian habitat at Drimmie Creek or restored riparian habitat at Illecillewaet. Yellow warbler densities provided some insight into what defined high quality riparian habitat for this riparian dependent songbird, but were not closely related to productivity. Machete Island had the highest density of breeding pairs in 2005 and 2006 and pairs breeding at this site fledged more young than pairs at either of the other two sites in both years. However, the density of breeding pairs at Illecillewaet varied two-fold between years and although densities approached that of Machete in 2006, productivity at this restored site was consistently far lower than that of the reference site. These results suggest that concerns raised about the validity of using avian densities to evaluate habitat quality and the success of restoration activities are warranted. However, the use of data on avian densities from multiple years

may reduce the potential for error since densities at poor quality sites are likely to be more variable than densities at high quality sites.

TABLE OF CONTENTS

Executive Summary	2
Table of Contents	4
List of Tables	5
List of Figures	5
Introduction.....	7
Methods.....	8
Study species	8
Study site	8
Habitat differences between sites	9
Territory establishment, nest monitoring and bird banding	9
Statistical analyses.....	10
Results.....	11
Vegetation and habitat structure in riparian habitat within Revelstoke Reach	11
Use and performance of yellow warblers breeding in different riparian habitat within Revelstoke Reach	11
Annual variation in water levels and breeding performance of yellow warblers in Revelstoke Reach	12
Nest site locations and vulnerability to rising water levels in the Upper Arrow Reservoir	13
Discussion.....	13
Recommendations for management	15
Recommendations for future research.....	16
Acknowledgements.....	16
References.....	17

LIST OF TABLES

Table 1.	Variables measured at four different spatial scales used in analyses examining differences in vegetation and habitat structure in remnant and riparian habitat within Revelstoke Reach.....	19
Table 2.	Comparisons of habitat variables that discriminate between riparian habitat at three sites within Revelstoke Reach.....	20
Table 3.	Inter-annual variation in breeding performance of Yellow warblers at three sites in Revelstoke Reach.....	21

LIST OF FIGURES

Figure 1:	Locations of the three study sites selected from the available floodplain area above the 435m water level in the Revelstoke Reach section of the Columbia River.....	23
Figure 2:	Temporal distribution of the number of Yellow warbler nests active during the 9-week breeding season beginning on May 24 (week 1) to July 24 (week 9) (A) and reservoir water levels of the Upper Arrow Reservoir during the same period (B). Thick black line indicates the elevation at which willow shrubs are present in the floodplain and therefore nesting habitat potentially affected by rising reservoir water levels.....	24
Figure 3:	Site maps illustrating the spatial distribution of Yellow warbler nests in relation to floodplain elevation at:	
	Machete Island (A).....	26
	Drimmie Creek (B).....	27
	Illecillewaet Island (C).....	28
Figure 4.	Proportion of total nests active per one week interval in 2005 (A) and 2006 (B) with corresponding proportion of nests that would be affected by 3 different water level scenarios. Proportion actually flooded in either year is shown in red.....	29

INTRODUCTION

Human activities have resulted in dramatic declines in the amount of riparian habitat in North America. On the Columbia River, for example, 250 dams have been constructed over the last 100 years which have played a significant role in the estimated loss of 87 % of riparian habitat within the Columbia River Basin (Moody et al. 2006). Parallel to the loss and degradation of riparian habitat in North America have been widespread population declines of bird species that use this habitat (DeSante and George 1994, Sauer et al. 2001). Given the level of habitat loss, while conservation of riparian dependant bird populations may be facilitated by minimizing any further impacts on birds using remnant patches of riparian habitat, active restoration effort is likely to be essential.

The effects of habitat restoration on bird populations, if evaluated at all, are often examined by comparing bird densities in restored habitat with those under “natural” (i.e. reference) conditions (e.g. Fletcher and Koford 2003, Gardali et al. 2006). However, bird abundance or density can be unrelated to reproductive success and survival (Van Horne 1983), and this is particularly likely in areas disturbed by humans (Bock and Jones 2004). Demographic parameters that determine whether a habitat functions as a source or a sink may therefore be more prudent measures of restoration efficacy (Block et al. 2001, Fletcher et al. 2006). These parameters also allow the construction of source-sink models that can be used to determine the amount of restored habitat required to maintain stable populations in a particular geographic area (see Keagy et al. 2005).

Revelstoke Reach, BC, remains one of largest relatively intact floodplain/wetlands in the Columbia Basin, despite hydroelectric development that regulates water flow, and provides critical habitat for a diversity of bird species (Jarvis 2001, Boulanger et al. 2002). Birds in remnant riparian habitat are likely, however, to be influenced by water use decisions that result in fluctuating water levels in Arrows Lake that can lead to the flooding of active nests (Jarvis 2006) and/or reductions in the amount of foraging habitat available during the breeding season. Efforts have therefore been made to restore and recreate riparian habitat, and further restoration activities are planned, that will allow viable bird populations to persist in Revelstoke Reach. Data on the extent to which birds in remnant riparian habitat are impacted by current or future water use decisions and examination of methods used to evaluate the efficacy of restoration efforts are essential if this goal is to be accomplished.

In this study we evaluate whether yellow warbler (*Dendroica petechia*) density provides a reliable measure of riparian habitat quality and assess the impact of dam operations on the breeding performance of the yellow warblers. Yellow warblers are thought to be particularly sensitive to the alteration and loss of riparian habitat and have been identified as a focal species that should be monitored intensively to assess the health of riparian habitat. Specifically, we:

- Determine how remnant riparian habitat differs from restored habitat within Revelstoke Reach
- Evaluate whether bird densities could be used to monitor the effectiveness of riparian restoration projects by investigating the relationship between density and productivity of Yellow warblers in remnant and restored riparian habitat within Revelstoke Reach
- Examine how variation in the maximum water level in the Upper Arrow Lake Reservoir influences Yellow warbler nest mortality
- Evaluate how varying the timing of full pool in the Upper Arrows Lake Reservoir would influence susceptibility of yellow warbler nests to flooding
- Investigate whether rising water levels that reduces available foraging habitat on Yellow warbler territories influences the quality of nestlings raised

METHODS

Study species

Western populations of the yellow warbler are common among deciduous riparian habitats where they are associated with willow thickets, other stream-side shrubs and large deciduous trees, such as black cottonwood (Cilimburg et al. 2002). In British Columbia, males arrive first to the breeding grounds in May to establish permanent territories with females arriving about a week later (Campbell et al. 2001). Females construct open-cup nests about 1.5 to 4m high in shrubs and less often in the canopy of larger cottonwood trees. Females are the sole incubators of 4-5 eggs, while both sexes feed nestlings and fledglings.

Study site

Revelstoke Reach is situated within the drawdown zone of the Arrow Lakes Reservoir, a 230-km long reservoir system in the Columbia River valley separating the Monashee and Selkirk mountain ranges, east of the Kootenay region of British Columbia (N50.58'56"/W-118.20'00", Fig. 1). The study area is characterized by a patchy network of willow-cottonwood habitats associated with the higher elevations within the drawdown zone of the reservoir (435m to 442m). We worked at three sites that are representative of the three major riparian habitat types found in Revelstoke Reach. The site at Machete Island covers 30 ha, much of it slightly above the highest allowable flood elevation of 440m. This site includes a large stand of mature black cottonwoods with a diverse understorey and an adjacent area of dense, mixed-woody plant species bordered almost entirely by a strip of willow shrubs. The second site centred at the mouth of Drimmie

Creek is more representative of much of the riparian habitat within the drawdown zone of Revelstoke Reach. This 37.5 ha site comprises a thin strip of mature cottonwood forest, grading into a contiguous area of willow followed by more isolated patches of willow at lower elevations (<438 m) that are imbedded in grassland (mainly reed canary grass and to a lesser extent, planted fall rye grass). The third site located at the mouth of the Illecillewaet River is a 39 ha area where restoration efforts have been conducted by part by the Illecillewaet Greenbelt Society and BC Hydro. Restoration projects between 1999 and 2006 have included dredging to create wetland pools and the planting of various riparian shrubs and trees (F. Maltby, pers. comm). Riparian habitat at this site varies from areas of short willow shrub to small stands of mature cottonwood.

Habitat differences between sites

We sampled vegetation at four spatial scales surrounding randomly selected points within the three sites. Random points were determined using randomly-generated *x* and *y* UTM positions. In the event that the point fell upon an open area without suitable nesting substrate, we centred the survey plot around the nearest stem within 5m of the original location or omitted that point if no stem was present. Habitat measurements were taken at the end of the breeding seasons of 2005 and 2006. We measured variables using standard BBIRD protocols at three scales: (1) a nest-site scale, (2) within a 5m radius of the random point, and (3) within a 11.3m radius centred on the random point. We also assessed the configuration of the riparian habitat at a larger territory scale, with these variables being measured within a 50m radius centred on the random point. At the “nest-scale” we identified the species and measured the height and dbh of the stem closest to the random point (ie the potential nesting substrate). At the “5m-scale”, we identified all tree and shrub species within a 5m radius centred on the random point and, for each species, counted the number of stems with a dbh of less than 8cm. We also estimated the percent of the ground within the 5m radius circle covered by grass, forbs, moss, leaf litter and logs. At the “11.3m-scale” we identified the larger trees and shrubs present and counted the number of stems within three size classes (8-23cm, 23-38 cm and > 38 cm) for each species present. We also estimated the cover provided by the lower (<5m) and upper (>5m) canopy vegetation. Finally, at the “territory-scale” we measured the proportion of the 50 m radius area covered by riparian habitat contiguous to mature forest using ArcGIS software, and measured the distance of the random points to edge of riparian habitat contiguous with forest (-ve numbers indicate points within contiguous habitat, +ve numbers indicate points in isolated riparian patches or points in the grassland matrix). For analyses, we combined stem counts for some species and size classes present in small numbers into composite variables. The habitat variables used in analyses are described in Table 1.

Territory establishment, nest monitoring and bird banding

We monitored all three sites at 2-3 day intervals from early April onwards in both 2005 and 2006 to determine when individuals returned to the three sites, established territories, paired and initiated breeding. If returning birds had not been banded previously they were caught within 2 days of being seen at a site using 12-m mist nests

combined with playbacks of yellow warbler songs. Birds were then fitted with a Canadian Wildlife Service-issued aluminium band and a unique combination of three-colour bands. A small number of birds were not captured over the course of the breeding season.

The onset of breeding, nest success and territory productivity were estimated by monitoring all nesting attempts made by marked individuals throughout the breeding season. We located and monitored all yellow warbler nests initiated by breeding pairs within each study site using standard techniques (Martin and Geupel, 1993). Twenty-four breeding pairs were monitored in 2005 and 36 breeding pairs were monitored in 2006. Attempts were made to find nests during the building stage in order to identify all cowbird parasitism events and early depredations. We checked the status of all nests every 1-3 days during each stage and daily to observe timing of important events (incubation initiation, hatching, and fledging). We defined the onset of breeding as the date females laid the first egg of their first clutch. Nests were considered parasitized if one or more cowbird eggs were laid during the nest's laying or incubation period. Nests were considered to have fledged young if a warbler nestling was present at day 7 (yellow warbler nestlings fledge 9-10 days after hatch). We did not visit nests after that point because such visits can lead to nestlings fledging prematurely. In most cases, fledging was confirmed by observations of banded nestlings or adults carrying food to concealed areas around the nest.

The potential impact of adjusting the timing and maximum water level of the Upper Arrows Lake Reservoir at full pool on nest mortality was evaluated by determining the proportion of active nests that would have flooded if water levels reached maximum allowable pool (440.13m), maximum allowable pool -1 m, or the average maximum pool observed between 1994-2006 by week 1 through 7 of the breeding season.

Statistical analyses

We used a discriminant function analysis (DFA) to identify the habitat variables that could be used to distinguish between riparian habitat in the three study areas. We first conducted a DFA for each spatial scale separately. We report all variables that were correlated with the discriminant axis at $r > 0.3$ at each scale, since these variables account for 10% or more of between-group differences (Misenhelter and Rotenberry 2000). We subsequently conducted another DFA using only variables selected in the first round of analyses to determine the relative importance of variables from each scale in discriminating between sites.

We used generalized linear models to examine the performance of yellow warblers breeding in Revelstoke Reach in two years with dramatic differences in the timing of reservoir fill and the maximum water level in the Upper Arrows Reservoir. We evaluated year and site effects on 8 variables; 1) the onset of breeding, 2) clutch sizes of first nesting attempts, 3+4) the likelihood of re-nesting if the first breeding attempt failed or successfully fledged young, 5) the probability nest fledged young, 6) the probability a female produced successfully fledged at least on young, 7) annual productivity (fledglings/female) and 8) nestling mass on Day 7 of the nestling period. In all analyses

we initially fitted a full model and sequentially removed all non-significant terms until only significant factors remained. We report the variance ratio or change in deviance when the term of interest is dropped from the final model. Where appropriate, we subsequently evaluate whether differences in breeding performance result from differences in the timing of breeding or partial flooding of a pairs' territory.

RESULTS

Vegetation and habitat structure in riparian habitat within Revelstoke Reach

Riparian habitat at Machete Island and restored riparian habitat at the mouth of the Illecillewaet River was at slightly higher elevation than remnant riparian habitat near Drimmie Creek (Average elevation calculated using a digital elevation model for each site: Machete 438.52m; Illecillewaet 438.19m; Drimmie 436.50m). Seven of the 27 vegetation and habitat metrics helped distinguish between riparian habitat at the three sites. At the nest scale, the potential nesting substrate was highest at Machete Island and lowest at Drimmie Creek. At the 5m-scale, the density of small willow stems was greatest in the restored riparian site at Illecillewaet, but the density of other shrub stems and the proportion of ground cover composed of forbs was highest at Machete Island. At the 11.3m-scale the density of large (>23 cm dbh) cottonwood stems was higher at Machete Island than the other two sites. However, the lower canopy cover was highest at Illecillewaet, intermediate at Machete Island and lowest at Drimmie Creek. Finally, at the territory-scale, random points within Drimmie Creek were further from the edge of riparian habitat linked to forest than random points within Machete Island or Illecillewaet. In the global model, the variables that contributed most to distinguishing between the sites were the proportion of forbs in the ground cover, the density of large cottonwoods, and the distance to the riparian edge (Table 2).

Use and performance of yellow warblers breeding in different riparian habitat within Revelstoke Reach

We monitored a total of 106.5 ha of riparian habitat used by yellow warblers during the 2005 and 2006 breeding season. Riparian habitat at Machete Island contained higher density of breeding birds than remnant patches of riparian habitat at Drimmie Creek and restored riparian habitat at Illecillewaet in 2005, but densities of breeding birds were more similar in 2006. The density of breeding birds at Illecillewaet was higher in 2006 due to an influx of second year birds largely absent from this site in 2005 (Table 3).

Females breeding in riparian habitat at Machete Island initiated their first clutch significantly earlier than those breeding at Drimmie Creek or Illecillewaet in both 2005 and 2006 (Table 2). These females also laid significantly larger first clutches than females at the other sites in both years (Table 3). This difference was partially due to seasonal variation in clutch size as after controlling for laying date (date effect, $v.r.=2.89$, $df=1$, $p=0.03$) clutch sizes of breeding females at the three sites did not differ (site effect, $v.r.=1.67$, $df=1$, $p=0.20$).

Females that successfully fledged young from their first nesting attempt rarely attempted to nest again (3 of 31 cases over the 2 years; Table 3). However, females breeding at in riparian habitat at Machete Island whose first attempt failed were more likely to re-nest than females breeding at Drimmie Creek or Illecillewaet (Table 3). This difference resulted from the earlier onset of breeding at Machete Island as after controlling for when nests failed (date effect, change in deviance=9.68, $df=1$, $p=0.002$) females in all habitats were equally likely to re-nest (site effect, change in deviance=1.76 $p = 0.41$).

We monitored the fate of 35 nests in 2005 and 49 nests in 2006. Fifty-one per cent of these nests successfully fledged at least one young. The success of individual nesting attempts varied significantly across the three sites, being highest at Machete Island in both 2005 and 2006, low at Drimmie in both years, and variable at Illecillewaet. Causes of nest failure varied among sites and between years with nests at Drimmie Creek having relatively high rates of cowbird parasitism and predation in 2005 but not 2006, while nests in the restored habitat at Illecillewaet had high rates of predation but relatively low rates of parasitism by cowbirds in both years.

Females breeding at Machete Island, as a result of breeding earlier and being more likely to re-nest, were more likely to fledge at least one young during the breeding season than females breeding at Drimmie Creek or Illecillewaet. Overall, the combination of laying larger first clutches, having lower nest loss, and having a higher probability of re-nesting meant females at Machete Island also produced more fledglings per season than females at the other two sites. Nestlings raised in the three sites did not differ in mass immediately prior to fledging so differences in productivity were not offset by differences in nestling quality (Table 3).

Annual variation in water levels and breeding performance of yellow warblers in Revelstoke Reach

Reservoir operations resulted in dramatically different water levels in Revelstoke Reach over the two years of this study. Water levels rose above 435m in 2006 – the lowest elevation at which riparian vegetation currently persists in the study area – by June 5 and but remained under this elevation in 2005 (Fig 2a). These differences, however, had no detectable impact on the timing of breeding, the size of the first clutches laid, the success of individual nesting attempts or whether birds re-nested after the failure of their first nesting attempt, all of which were the same in 2005 and 2006 (Table 3).

Females were more likely to re-nest after successfully fledging their first brood in 2005 than 2006, which may have been due to the rising water levels. However, since few females attempted to fledge two broods this difference did not result in more females

fledging at least one young or females having significantly higher productivity over the entire breeding season in 2005 than 2006 (Table 3).

Mean nestling mass at Day 7 was the same in 2005 and 2006 (Table 3). However, broods raised when their territory was partially flooded due to reservoir operations tended to be lighter than broods raised on territories not inundated by water (partially flooded $8.3 \text{ g} \pm 0.5 \text{ SD}$, not flooded $8.6 \text{ g} \pm 0.5$; $v.r=3.78 \text{ df}=1$, $p=0.06$). This result is not confounded by seasonal declines in nestling mass since nestling mass did not vary with julian date ($v.r= 0.29 \text{ p}=0.6$).

Nest site locations and vulnerability to rising water levels in the Upper Arrow Reservoir

We located a total of 84 nests at the three study sites, 35 in 2005 and 49 in 2006. The majority of nests were built in willow spp. (71%), cottonwoods (14%), and dogwood (6%), with the remainder being built in rose, birch, alder, and spruce. Nest sites were placed 0.75 – 21 m (mean=2.9m, SE=0.350,SD=3.20) above the ground at elevations of between 436.75m and 460.2m (mean = 440.96m; Fig 3). Rising water levels in Revelstoke Reach did not result in the loss of any nests in 2005 but led to the failure of 6% of nests in 2006 (Table 3, Fig 3).

Flooding had a relatively small impact on whether yellow warbler nests were successful, even in 2006, because the timing of breeding meant that most nests were completed before water levels had reached full pool (Fig 2b). The number of active yellow warbler nests initiated in Revelstoke Reach peaked on June 16 (21 active nests) and June 17 (27 active nests) in 2005 and 2006, with 95% of nests having failed or fledged young by July 16 (Julian date=197). However, if reservoir reached full pool earlier in the breeding season flooding could potentially have resulted in the failure of up to 31% of yellow warbler nests in 2005 and 20% of nests in 2006 (Fig 4).

DISCUSSION

Riparian habitat in Revelstoke Reach varies considerably, but includes one large stand of mature cottonwoods with a diverse understory bordered by willow (Machete Island), remnant patches of willow that grade into thin strips of deciduous woodland at higher elevations (Drimmie / Draw-down zone), and restored areas with plantings riparian shrubs and trees (Illecillewaet). Yellow warblers were found to breed in sites representative of the range of riparian habitat within Revelstoke Reach. However, three lines of evidence suggest yellow warblers preferred habitat that include mature cottonwoods bordered by willow that likely made up a large proportion of riparian habitat within Revelstoke Reach prior to the construction of Revelstoke Dam and the creation of Upper Arrows Lake Reservoir. First, yellow warblers consistently arrived and initiated reproduction at Machete Island, the site representative of this habitat type, before starting to breed at the other sites. Second, a greater proportion of individuals at Machete Island

were old birds, and older more dominant individuals are expected to be found more often within preferred habitat (Robertson and Hutto 2006). Finally, breeding densities at Machete Island were extremely consistent over the two years of this study and population densities in preferred habitat are expected to be more stable than those perceived as being of lower quality (O'Connor 1981). Riparian habitat at Machete Island is therefore apparently perceived as being of higher quality than the patchier riparian habitat at Drimmie Creek or restored riparian habitat at Illecillewaet.

The preferences of yellow warblers for riparian habitat at Machete Island suggest that yellow warblers may use the density of mature cottonwood stems, the density of non-willow shrubs and/or the height of potential nesting substrate as cues for selecting breeding habitat since these variables discriminate between riparian habitat at Machete Island and other sites. These potential habitat selection cues differ slightly from the habitat variables that discriminate between nest sites and random sites within riparian habitat. Quinlan and Green (2006) found that yellow warblers placed nests in locations containing higher densities of taller willow stems that were contiguous with mature forest and avoided riparian habitat broken up into small patches. These differences could mean that yellow warblers use one set of cues to select a habitat type and another set of cues to select a nest site. Alternatively, the differences may arise because of the use of habitat or vegetation metrics that do not reflect how yellow warblers perceive the environment. For example, both this study and Quinlan and Green used the number of willow stems and the number of other shrub stems within 5 m of a random point as two independent variables. However, if warblers select sites based on shrub density and the diversity of shrub species, the total number of shrub stems and the number of shrub species present would be more relevant metrics. Further exploration of habitat selection cues that operate at different temporal and spatial scales (i.e., within and between sites), would improve the quality of information provided to managers setting goals for restoration activities in riparian habitat.

Yellow warbler densities provided some insight into what defined high quality riparian habitat for this riparian dependent songbird, but were not closely related to productivity. Machete Island had the highest density of breeding pairs in 2005 and 2006 and pairs breeding at this site fledged more young than pairs at either of the other two sites in both years. However, the density of breeding pairs at Illecillewaet varied two-fold between years and although densities approached that of Machete in 2006, productivity at this restored site was consistently far lower than that of the reference site (0.43 and 0.4 young raised per ha compared to 1.5 and 1.3 per ha in 2005 and 2006, respectively). These results suggest that concerns raised about the validity of using avian densities to evaluate habitat quality (Van Horne 1983) and the success of restoration activities (Block 2001) are warranted. The use of data on avian densities from multiple years may reduce the potential for error since densities at poor quality sites are likely to be more variable and lower when competition for breeding vacancies is reduced. However, even multi-year data on densities would lead to erroneous conclusions if the attractiveness of a habitat is uncoupled from its suitability for survival and reproduction, and consequently acts as an ecological trap. While this does not appear to be the case for yellow warblers (this study, Quinlan and Green 2006), there is a need for more data on the relationship between density, reproduction and survival in other riparian dependant species before bird counts are used to inform management decisions.

Songbirds breeding in riparian habitat within valleys where hydroelectric power generation regulates water levels may suffer increased nest mortality or reduced survival if rising water levels flood active nests or reduce food availability. Nest mortality due to flooding did not have a major impact on the breeding success of yellow warblers in Revelstoke Reach in either 2005 or 2006, even though water levels were close to the maximum currently allowed in 2006. Nest mortality due to flooding was low because native riparian vegetation is no longer found below 435m, yellow warblers place nests 3m above the ground, and the majority of nests fledged or failed prior to increases in the water level. Nevertheless, changes in the timing of reservoir fill of even 2 weeks, while maintaining the current maximum allowable fill, would have increased yellow warbler nest mortality due to flooding from 6 to 16% in 2006. We also found evidence that rising water levels may have an indirect effect on yellow warbler productivity as broods raised on territories that were partially flooded tended to be lighter than broods on territories that were not impacted by rising water levels. Nestling mass has been found to influence subsequent survival in numerous studies (Magrath 1991, Green and Cockburn 2001). Further data on the relationship between water levels, nestling growth rates and juvenile and adult survival would determine whether, and when, the yellow warbler population in Revelstoke Reach functions as a source. The overall impact of water use decisions on populations of riparian dependant songbirds in Revelstoke Reach will require additional detailed studies on other species since dam operations are likely to have a greater impact on ground nesting species or species that breed later in the year.

Recommendations for management

1. Monitoring should be conducted to evaluate whether restoration efforts are effective at providing suitable habitat for wildlife. Effectiveness should be evaluated using a suite of species selected to represent the range of spatial and functional requirements of wildlife in a restored ecological system
2. We advocate using measures of productivity and survival to assess efficacy given that they are directly related to population viability. Where abundance measures are used data should be collected in multiple years and attention should be given to variance in abundance. High quality reference and restored sites are likely to have both higher densities and less variance in density than low quality sites.
3. Within Revelstoke Reach, the timing of full pool in Upper Arrows Lake Reservoir determines the proportion of bird nests lost to flooding. For yellow warblers, a shrub nesting species that initiates nests between late May and early June, delaying full pool until July 12 ensures that >90% of nests have a chance to fledge. Species that nest in patchier riparian habitat, closer to the ground and later in the year will be impacted more. Restoration activities that increase the amount of riparian at low elevations will increase the importance of regulating the timing of reservoir fill in relation to the breeding schedules of riparian birds to minimise nest mortality.

Recommendations for future research

1. Exploration of temporal and spatial variation in habitat selection cues would improve the quality of information provided to managers setting goals for restoration activities in riparian habitat. This should include examining how varying the vegetation and habitat metrics used influence the conclusions drawn in this study, and evaluation of whether nest site selection cues vary between sites.
2. Conclusions about the utility of abundance as a measure of the success of ecological restoration projects would be strengthened by a) having replicates for the three different types of riparian habitat monitored in this study and b) obtaining similar data on the relationship between abundance, nest success and productivity for other riparian dependent songbird.
3. The ability to assess how dam operations impact Yellow warblers would be improved by data on adult and juvenile survival in relation to annual and spatial variation in water levels within individual territories. This would allow estimation of population growth in relation to variation in water level and assessment of whether populations in riparian habitat function as a source or sink.
4. This study should be extended to cover multiple years to allow more detailed analysis of how dam operations impact productivity and survival of Yellow warblers, and b) cover additional focal species that may have different ecological requirements and/or may be more vulnerable to fluctuations in water levels within Upper Arrows Lake Reservoir. Savannah sparrows, that nest on the ground, and willow flycatchers, that use more isolated willow patches and have an extended breeding season, may be suitable candidates since they are common breeding birds in riparian habitat within Revelstoke Reach.

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Table 2. Variables measured at four different spatial scales used in analyses examining differences in vegetation and habitat structure in remnant and riparian habitat within Revelstoke Reach.

Variable	Description of variable
NEST scale	
Substrate height (m)	Height of the tree/bush/shrub species measured with a 2m pole
Substrate DBH (cm)	Diameter of potential nesting substrate at breast height
LOCAL scale (5m)	
No. Willow stems <8 cm DBH	All willow stems in this size class within the 5m radius were counted
No. Other shrub spp. stems <8 cm DBH	All stems from other shrub species were counted and combined in this variable
No. Conifer spp stem <8 cm DBH	All stems from coniferous tree spp in this size class within the 5m radius were counted
No. Cottonwood stems <8 cm DBH	All cottonwood stems in this size class within the 5m radius were counted
% Grass	Percent of ground covered by grass
% Forbs	Percent of ground covered by forbs
% Moss	Percent of ground covered by moss
% Leaf litter	Percent of ground covered by leaf litter
% Log	Percent of ground covered by logs
BROAD scale (11.3m)	
No. cottonwood stems 8-23 cm DBH	All cottonwood stems in this size class within the 11.3m radius were counted
No. cottonwood stems >23 cm DBH	All cottonwood stems in this size class within the 11.3m radius were counted
No. other deciduous tree stems >8 cm DBH	All non-cottonwood deciduous spp. stems > 8cm DBH within the 11.3m radius were counted and combined in this variable
No. conifer spp stems > 8cm DBH	All coniferous tree spp stems > 8cm DBH within the 11.3m radius were counted and combined in this variable
No. willow stems > 8 DBH	All willow stems in this size class within the 11.3 m radius were counted
No. other shrub species > 8 cm DBH	All non-will shrub stems in this size class were counted and combined in this variable
%High (>5m) canopy cover	Percent of upper canopy shielding sky –estimated visually
%Low (<5m) canopy cover	Percent of lower canopy covered by vegetation < 5m in height – estimated visually
Avg. canopy height (m)	Height of tree typical of habitat within the 11.3m radius of nest
TERRITORY scale (50m)	
Contiguous riparian habitat (%)	Percentage of 50 m radius area composed of riparian habitat contiguous with
Distance to edge of contiguous riparian habitat	Linear distance to contiguous edge; -ve values indicate point is within contiguous habitat, +ve values point is in patchy habitat

Table 2. Comparisons of habitat variables that discriminate between riparian habitat at three sites within Revelstoke Reach.

SCALE	Machete Island (n=24)		Drimmie Creek (n=10)		Illecillawaet (n=12)	
	Mean	SD	Mean	SD	Mean	SD
Nesting substrate characteristics						
Substrate height	7.1	6.3	2.3	5.6	5.2	5.1
Local vegetation characteristics (5m)						
No. Willow stems <8cm dbh	43	57	34	15	129	138
No. other shrub stems <8 cm dbh ^a	98	128	4	14	25	37
Per cent forbs in ground cover ^a	19	15	2	5	13	10
Broad vegetation characteristics (11.3m)						
No. Cottonwood stems >23 cm dbh ^a	3.5	3.9	0.7	2.2	0.4	0.9
% Low Canopy Cover	14	16	4	6	23	23
Territory scale characteristics						
Distance from edge of continuous riparian habitat ^a	7	75	152	118	-7	13

^a indicates variables that discriminate between sites in DFA that incorporates variables from all four spatial scales

Table 3. Inter-annual variation in breeding performance of Yellow warblers at three sites in Revelstoke Reach

Parameter		2005	(N)	2006	(N)	Year Stats (P)	Site Stats (P)	Year *Site Stats (P)
Area monitored (ha)	Machete	30		30				
	Drimmie	37.5		37.5				
	Illacillewaet	39		39				
Number of territorial males	Machete	12		13				
	Drimmie	5		8				
	Illacillewaet	7		15				
Number of breeding females	Machete	12		13				
	Drimmie	5		9				
	Illacillewaet	7		14				
Density (pairs/ha)	Machete	0.40		0.43				
	Drimmie	0.13		0.24				
	Illacillewaet	0.18		0.36				
% ASY	Machete	78	(23)	88	(26)			
	Drimmie	55	(11)	42	(12)			
	Illacillewaet	80	(10)	42	(26)			
Clutch \pm SD initiation date (Jan1=1)	Machete	155 \pm 7	(12)	149 \pm 4	(13)	0.46	13.0	3.1
	Drimmie	157 \pm 8	(5)	164 \pm 9	(9)	(0.50)	(< 0.001)	(0.06)
	Illacillewaet	163 \pm 8	(7)	161 \pm 7	(14)			
Size of first clutch (N)	Machete	4.4 \pm 0.5	(10)	4.7 \pm 0.5	(10)	0.29	3.95	0.50
	Drimmie	4.0 \pm 0	(4)	4.2 \pm 0.8	(5)	(0.59)	(0.03)	(0.63)
	Illacillewaet	4.0 \pm 1.2	(5)	3.7 \pm 0.9	(12)			
Renest after failure of first nest (%)	Machete	100	(1)	100	(4)	0.71	8.54	0.01
	Drimmie	75	(4)	60	(5)	0.40	(0.01)	(1.0)
	Illacillewaet	50	(4)	30	(10)			
Renest if first nest fledges (%)	Machete	18	(11)	0	(8)			
	Drimmie	0	(2)	0	(4)			
	Illacillewaet	33	(3)	0	(4)			
% nests successful	Machete	81	(16)	65	(17)	2.46	5.34	0.57
	Drimmie	33	(9)	33	(15)	(0.12)	(0.005)	0.56
	Illacillewaet	60	(10)	29	(17)			
% nests parasitized	Machete	25	(16)	29	(14)			
	Drimmie	55	(9)	27	(15)			
	Illacillewaet	20	(10)	29	(17)			
% nests predated	Machete	13	(16)	25	(32)			
	Drimmie	44	(9)	27	(15)			
	Illacillewaet	40	(10)	53	(17)			
% nests flooded	Machete	0	(16)	0	(17)			
	Drimmie	0	(9)	7	(15)			
	Illacillewaet	0	(10)	12	(17)			

% Females fledging \geq 1 young	Machete	92	(12)	85	(13)	1.97	9.85	0.79
	Drimmie	60	(5)	56	(9)	(0.16)	(0.007)	(0.67)
	Illacillewaet	71	(7)	36	(14)			
Number fledged/female	Machete	3.8 ± 2.1	(12)	3.0 ± 2.1	(13)	1.35	7.05	1.87
	Drimmie	0.8 ± 0.8	(5)	2.0 ± 2.1	(9)	(0.25)	(0.002)	(0.16)
	Illacillewaet	2.4 ± 1.7	(7)	1.1 ± 1.6	(14)			
Mass at Day 7	Machete	8.5 ± 0.4	(12)	8.6 ± 0.4	(6)	2.43	0.33	3.1
	Drimmie	9.1 ± 0.4	(3)	8.2 ± 0.4	(4)	(0.13)	(0.72)	(0.06)
	Illacillewaet	8.6 ± 0.3	(6)	8.2 ± 0.4	(4)			

Figure 1: Locations of the three study sites selected from the available floodplain area above the 435m water level in the Revelstoke Reach section of the Columbia River.

Revelstoke Reach - Columbia River

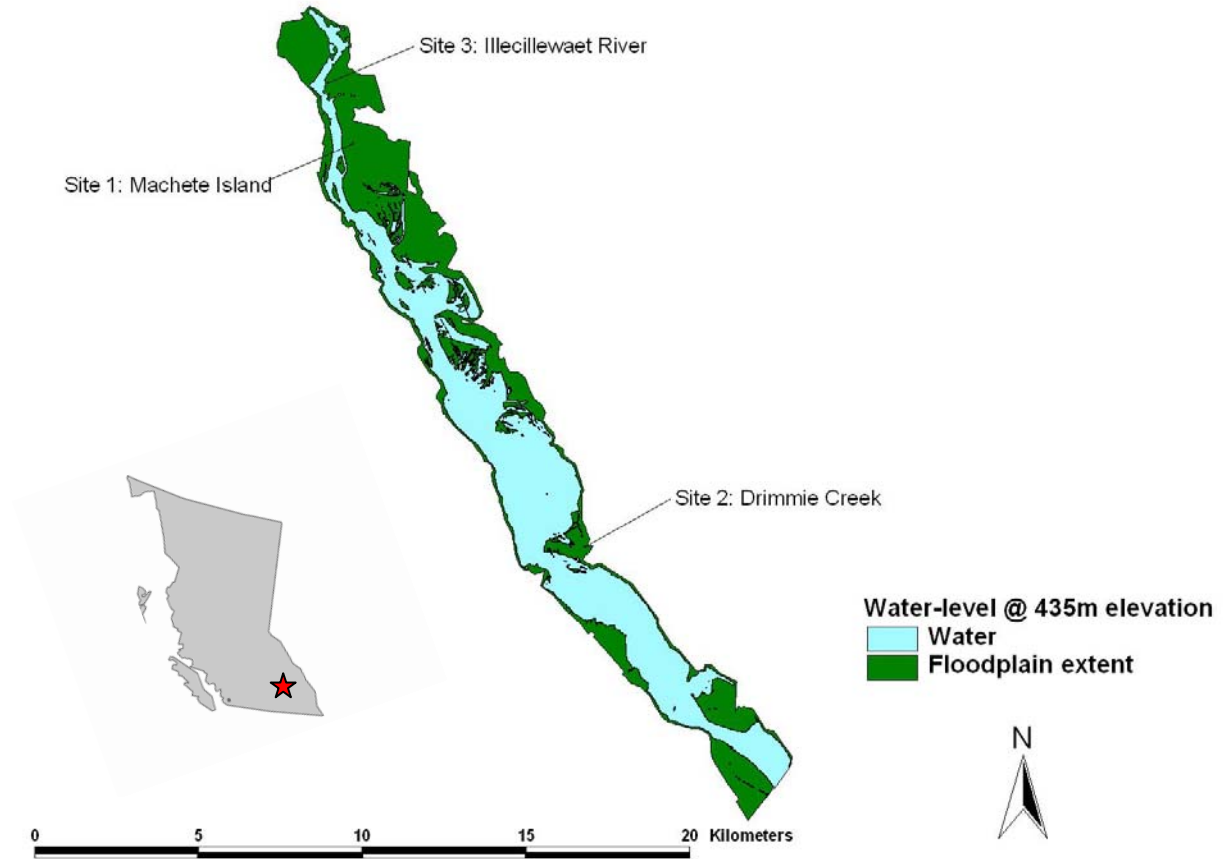
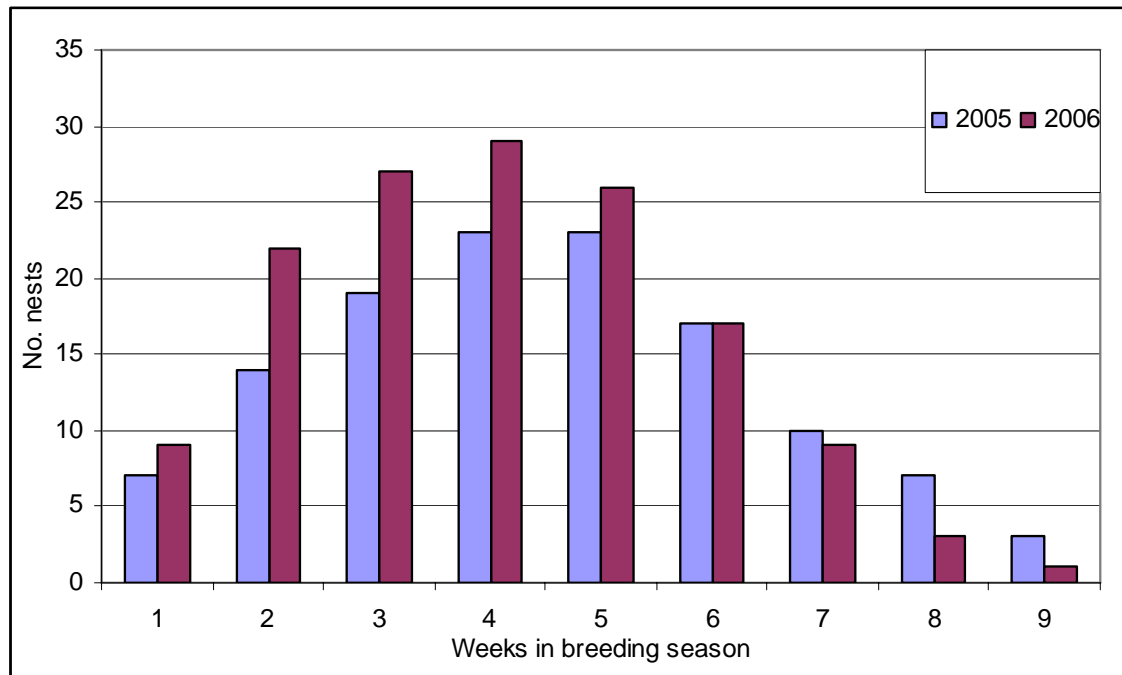


Figure 2: Temporal distribution of the number of Yellow warbler nests active during the 9-week breeding season (A) beginning on May 24 (week 1) to July 24 (week 9) and reservoir water levels of the Upper Arrow Reservoir during the same period (B). Thick black line indicates the elevation at which willow shrubs are present in the floodplain and therefore nesting habitat potentially affected by rising reservoir water levels.

(A)



(B)

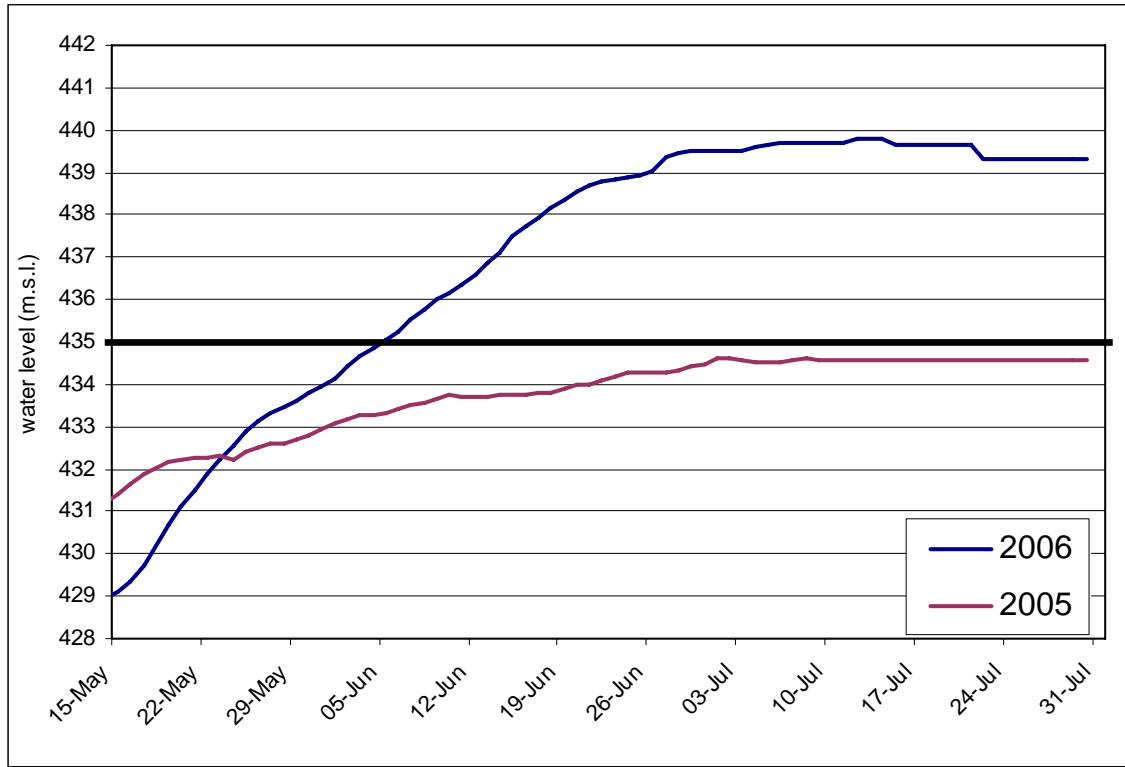
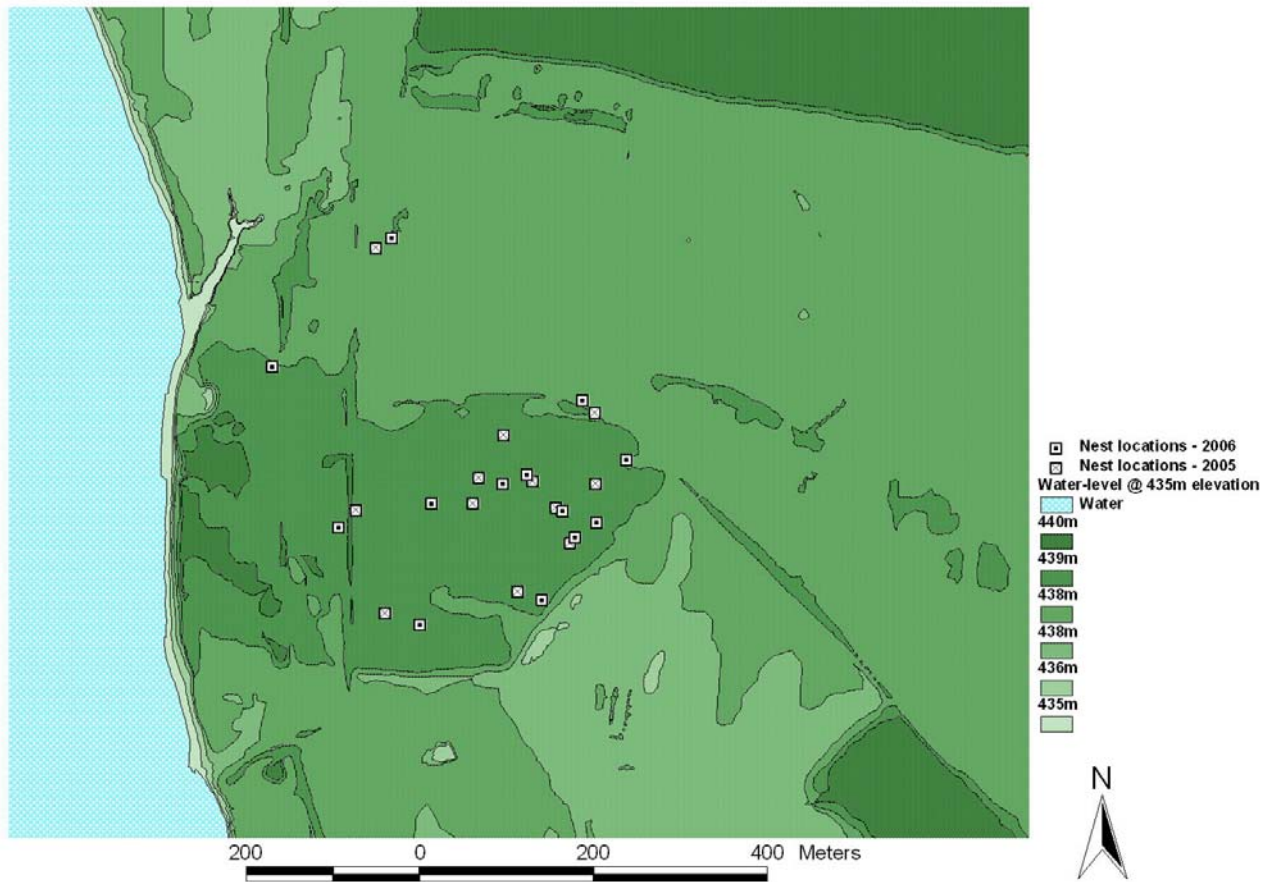


Figure 3: Site maps illustrating the spatial distribution of Yellow warbler nests in relation to floodplain elevation at Machete Island (A), Drimmie Creek (B), and Illecillewaet Island (C).

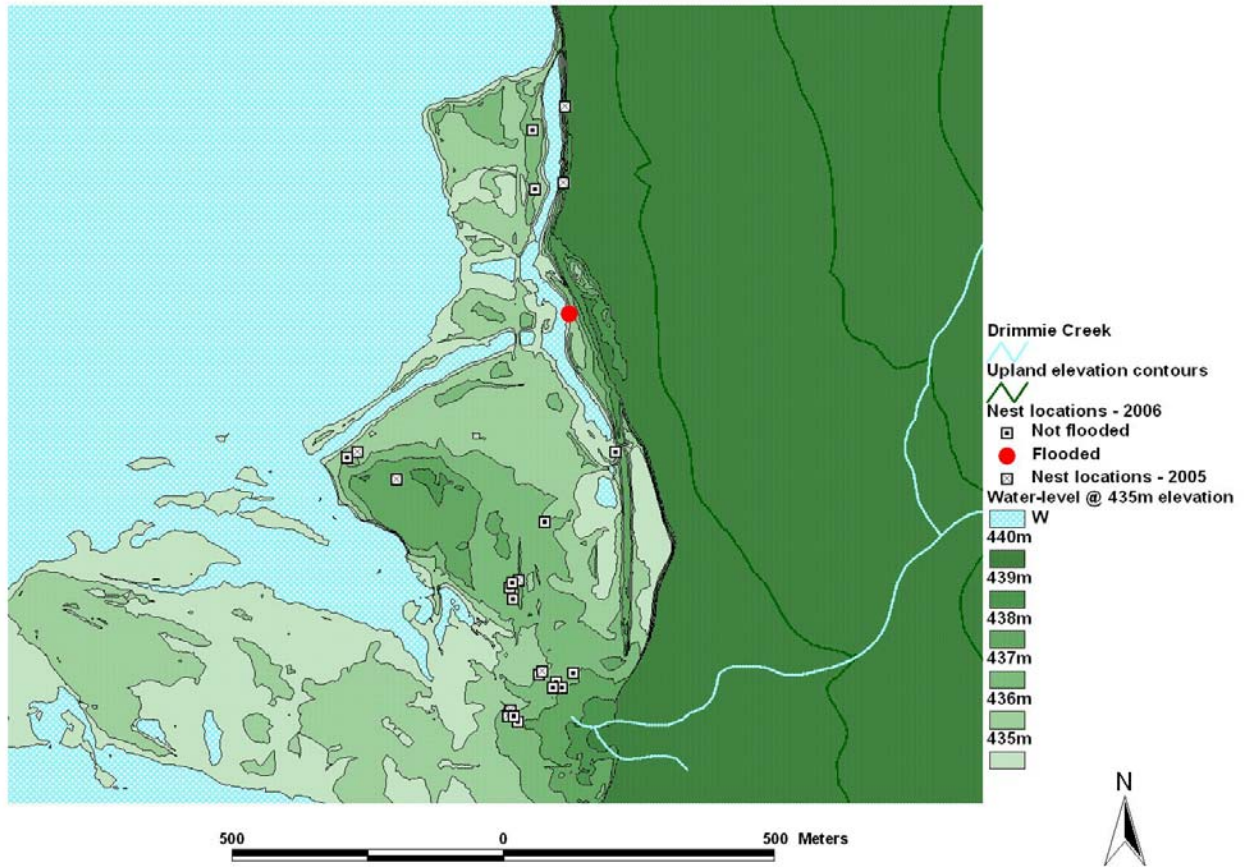
(A)

Site 1: Machete Island



(B)

Site 2: Drimmie Creek



(C)

Site 3: Illecillewaet River

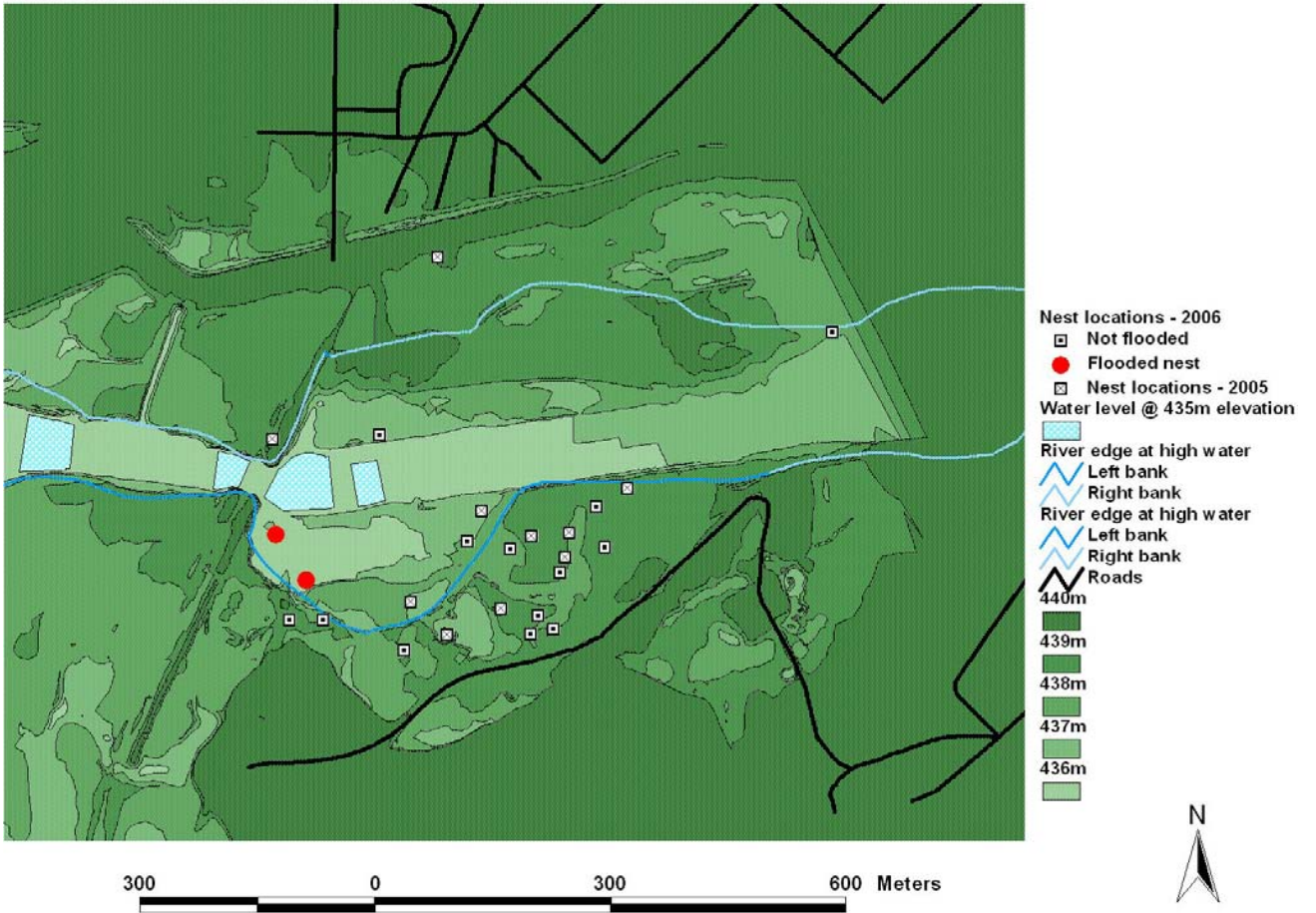


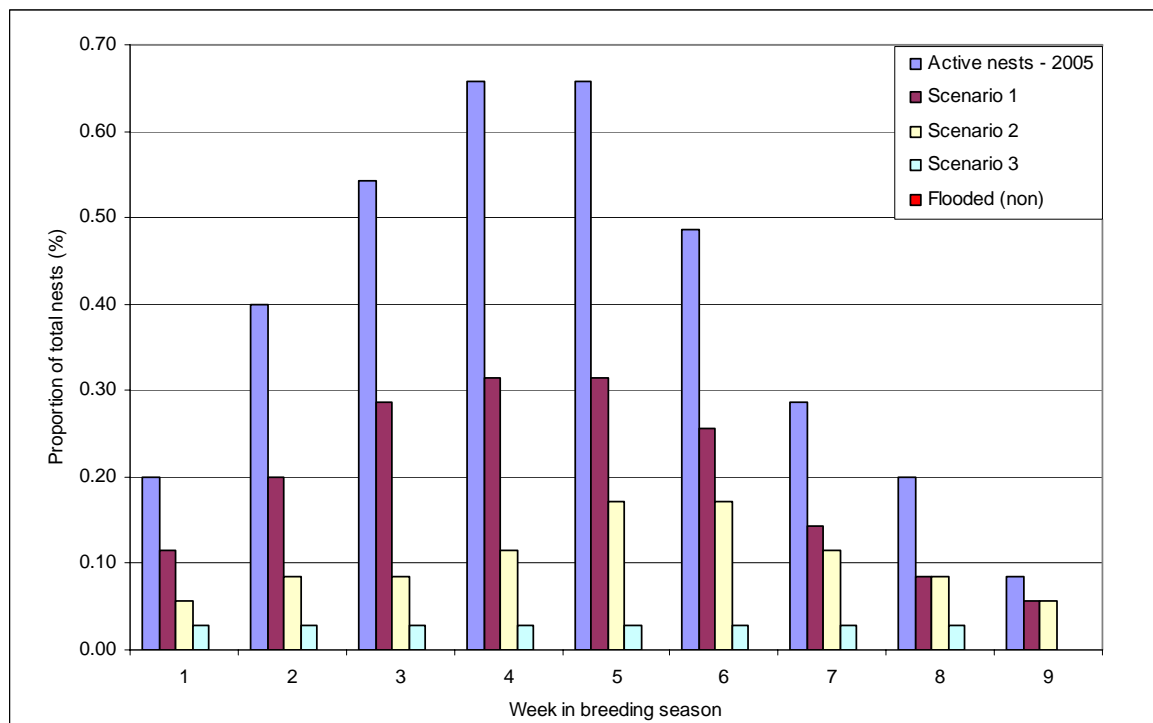
Figure 4. Proportion of total nests active per one week interval in 2005 (A) and 2006 (B) with corresponding proportion of nests that would be affected by 3 different water level scenarios. Proportion actually flooded in either year is shown in red.

Scenario 1: Maximum allowable pool (440.1m).

Scenario 2: Reduction of maximum allowable pool by one meter (439.0m)

Scenario 3: Average maximum pool reached during the Yellow warbler breeding period averaged over the previous 12-years (437.9m).

(A)



(B)

