Breeding waterbirds on mid-Vancouver Island lakes and marshes – 1981 and 1996.

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Abstract: In 1981, we conducted a preliminary study of nesting waterbirds on 31 lakes and wetlands on the east coast of Vancouver Island and in the Alberni valley of the mid-Vancouver Island region. Data were gathered on the numbers of waterbirds using the wetlands, along with numbers of indicated pairs and young they produced. Data on the wetland characteristics, including chemical and physical attributes, as well as vegetation, invertebrates, and sundry species using the wetlands such as fish, amphibians, reptiles, and mammals, were recorded. Optimum responses by the waterbirds to these wetland characteristics were determined: wetland depth and dissolved oxygen levels were significantly related to the species data. A comparative waterbird survey was repeated in 1996. We found 11 waterbird species using the wetlands in both 1981 and 1996, eight of which were breeding species in 1981 and seven in 1996. Total numbers of adult birds were about the same in both years, as were the total numbers of indicated pairs. The 216 young we observed in 1996 were significantly higher than the 119 young counted in 1981. Comparisons were made with waterbird use of lakes and marshes in the Cariboo Parklands. We concluded that waterbird nesting habitat on Vancouver Island may be significant for some species in these disjunct populations, particularly in light of the potential impacts of climate change on interior populations. Additional studies of a larger number of Vancouver Island wetlands are needed to reveal their true value to the maintenance of avian biodiversity in British Columbia.

Key words: *Aix sponsa*, *Anas discors*, *Anas platyrhynchus*, Blue-winged Teal, *Branta canadensis*, breeding, Canada Goose, Common Loon, Common Merganser, *Gavia immer*, Hooded Merganser, lacustrine, *Lophodytes cucullatus*, Mallard, *Mergus merganser*, nesting, palustrine, Pied-billed Grebe, *Podilymbus podiceps*, Vancouver Island, waterbirds, waterfowl, wetlands, Wood Duck.

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Introduction

In the 1960s, 1970s, and early 1980s, the land capability for waterfowl in rural Canada was mapped as a component of the Canada Land Inventory (CLI) (Government of Canada 2013). The inventory rated most of Vancouver Island as having little or no waterfowl production capability (Canadian Wildlife Service 1966).

In 1974, a project to test the validity of the CLI on Vancouver Island was initiated by Ian Smith, then Regional Biologist for the British Columbia Fish and Wildlife Branch. Smith felt that the CLI classification "was wrong and that some areas were fairly productive" (Davies 1976). The result was a report by Robinson and Dorst (1974), which subsequently underwent some analysis by Khan (1977). The latter analysis mentions nothing about waterfowl production, although Robinson and Dorst (1974) do mention confirmed and suspected waterbird nesting data, albeit in rather low numbers. That seemed to confirm the CLI results. However, those results may have been due to a number of factors including "poor sampling technique," "inconsistency in the period of observations," and "inconsistency in sampling intensity" (Khan 1977).

Aside from studies of a Mew Gull (*Larus canus*) colony on Kennedy Lake (Ricker and Neave 1961; Campbell 1970; Vermeer and Devito 1986), and some cursory sampling from the Brook's Peninsula (Campbell and Summers 1997), we know of no other research of nesting waterbirds on Vancouver Island lakes and marshes.

Incidental to other fieldwork, we had noted that many of our local, small wooded wetlands and open marshes were important to species such as Wood Duck (*Aix sponsa*), Mallard (*Anas platyrhynchos*), Hooded Merganser (*Lophodytes cucullatus*), and Pied-billed Grebe (*Podilymbus podiceps*). Some larger lakes often held a pair of Common Loons (*Gavia immer*) along with some of the above species, depending on the extent of the lakeshore marshes. As a result of these observations coupled with the nebulous results of the Robinson and Dorst (1974) effort, in 1981 we conducted a preliminary study of breeding waterbirds and their habitats in the central Vancouver Island area. We wanted to learn how many nesting waterbirds used these wetlands, how many young they produced, and what lake and marsh characteristics were attracting these species, in an attempt to improve our understanding of waterbird use of Vancouver Island lakes and marshes. We repeated the waterbird surveys in 1996 to see what changes, if any, had occurred in the 15-year interim. Throughout the paper, the term *wetland* applies to both lakes and marshes.

Study area

The wetlands in our study area lie within the Nanaimo Lowland and Leeward Island Mountain ecosections of the Georgia Depression Ecoprovince (Campbell *et al.* 1990: 81). The wetlands are situated in an area roughly from Nanaimo northwest to Cumberland and include a portion of the Alberni valley (Figure 1). All wetlands were surrounded by forested lands. Official names were used where available (Province of BC 2017).

The bedrock geology of the area consists of basins of soft shale, sandstone, and conglomerate, lying on a basement of altered basic volcanic and sedimentary rocks and small granodiorite bodies of late Cretaceous age. Both the coastal lowland and most of the Alberni valley bottom are surfaced with a mantle of overburden that completely covers the bedrock and controls the topography (Fyles 1963).

The Nanaimo Lowland is a narrow coastal plain that rises from the shore of the Salish Sea to about 215 m asl. The lowland lies in the rain shadow of the Vancouver Island Mountains, offering the mildest climate in Canada

Figure 1. The study area showing the locations of the survey wetlands. From north to south: 1–*Black Lake*, 2–*Pigeon Pond*, 3–Teal Lake and adjacent wetlands, 4–*Cumberland Marsh*, 5–*Skeet Club Marsh*, 6–Allen Lake, 7–Langley Lake, 8–Fanny Bay Highway Marsh, 9–*Fanny Bay Marsh*, 10–Turnbull Lake, 11–Lois Lake, 12–Lowry Lake, 13–*Reserve Marsh*, 14–*Moran Pond*, 15–Moran Lake, 16–Somers Lake, 17–Patterson Lake, 18–Illusion Lakes, 19–Spider Lake, 20–*Spider Pond*, 21–*Turtle Marsh*, 22–*Rosemary Marsh*, 23–Turtle Lake, 24–*Shuhum Lake*, 25–*Hamilton Marsh*, 26–Enos Lake, 27–*Nook Creek Marsh*, 28–Devil's Den Lake, 29–Kidney Lake, 30–Boomerang Lake, 31–Cottle Lake. Names in italics are unofficial names not found in the provincial gazetteer.

(Green and Klinka 1994). Within the study area the Nanaimo Lowland averages approximately 12 km in width. Here, the Moist Maritime subzone of the Coastal Douglas-fir biogeoclimatic zone (CDFmm) forms a narrow strip averaging approximately 5 km in width along the lowland from Nanaimo northwest to Deep Bay and rises to about 150 m asl. Wetlands are typically surrounded by forests that are dominated by Douglas-fir (*Pseudotsuga menziesii*), western redcedar (*Thuja plicata*), and grand fir (*Abies* grandis) with a shrub layer dominated by salal (*Gaultheria shallon*), Oregon grape (*Mahonia nervosa*) and ocean spray (*Holodiscus discolor*). The area has been heavily developed; today only one-half of one percent of relatively undisturbed, old CDFmm now covers the coastal plain (Flynn 1999).

Inland from the CDFmm zone to the eastern edge of the Leeward Island Mountain Ecosection at just over 200 m asl lies the moist maritime subzone of the Coastal Western Hemlock biogeoclimatic zone (CWHxm). Here, forests are dominated by Douglas-fir and western hemlock (*Tsuga heterophylla*) with a shrub layer dominated by salal, Oregon grape, and red huckleberry (*Vaccinium parvifolium*) (Green and Klinka 1994).

The Alberni Valley is a northwest trending depression that lies within the Leeward Island Mountain Ecosection. The valley is about 40 km long, averaging 8 km in width. It is surfaced with unconsolidated deposits and rises from sea level to over 450 m asl (Fyles 1963). The valley also lies within the moist maritime subzone of the Coastal Western Hemlock biogeoclimatic zone.

Methods

Fieldwork

We conducted our surveys on 31 wetlands; 13 were in the Alberni Valley and 18 on the east coast of Vancouver Island (ECVI). Surveys began on 5 May and continued until 16 July 1981, dates that would exclude all but late migrants. Each wetland was visited from 5–7 times at 7–14 d intervals throughout the nesting season. At each wetland, one or two observation points were chosen on the initial visit that would give observers a view of as much of the wetland as possible. On subsequent visits, we approached observation points as unobtrusively as possible. We recorded all wildlife observed or heard for a 15–20 minute period, but with a focus on waterbirds. We used binoculars (7 x 35) and a spotting scope (20 x). At the end of the 1981 nesting season, we examined each site by canoe to look for waterbird nests, collect samples of the vegetation and invertebrates and to gather water chemistry data. In 1996, from 14 May through 28 June, only waterbirds were surveyed.

Waterbirds

We recorded all geese, dabbling ducks, diving ducks, grebes, and loons that we saw or heard on each wetland. Pair status and the sex of individual birds were noted where possible. Broods were aged according to Bellrose (1976, p. 27) in order to differentiate them on subsequent surveys. At the end of the 1981 nesting season, we canoed the wetlands for the presence of nests and the resulting data helped strengthen our determination of the number of breeding pairs. For example, a nest could confirm use by a pair of Canada Geese if these early nesters had moved their young to better rearing habitat and were not observed on the wetland.

For the purposes of this study, a breeding pair was indicated when the following criteria were met: for dabbling ducks, if lone drakes or drakes in flocks of five or fewer (considered "indicated pairs") or a distinctive pair was recorded at least once at the site or a brood or nest was recorded and for diving ducks, if a distinctive pair was recorded at least once at the site or a brood or nest was recorded (Dzubin 1969; Danell and Sjöberg 1978; Mulhern *et al.* 1985); for loons and grebes, if a distinctive pair was recorded at least once, or if single birds were recorded on at least two separate surveys, or if a brood or nest was recorded. Birds known to winter or occasionally summer but not known to breed in the area were noted, such as Bufflehead (*Buecphala albeola*) and Ring-necked Duck (*Aythya collaris*), and we have included them as non-breeders.

In 1996, only the waterbird survey was repeated although not necessarily from the same 1981 observation points. Due to time constraints, the nest search by canoe was not undertaken, which could make the 1996 results more conservative.

Bird taxonomy follows American Ornithological Society (2017).

Limitations

Despite care to approach the wetlands with minimal noise and disturbance, thick undergrowth made this virtually impossible for some sites. In addition, although we worked to establish observation points that would allow a view of the entire wetland, convoluted shorelines or extensive areas of emergent vegetation could hide waterbirds from our view. In addition, we would have missed reporting some broods of species such as Canada Goose and Mallard that began nesting earlier than our survey start dates and subsequently left the study wetland. Thus we believe the waterbird use we recorded in both years was conservative.

More recently, Campbell (2015) has pointed out a lack of correlation between pre-survey counts and "in-marsh" surveys noting that some species detected in counts are not necessarily found nesting on the wetland and some species found nesting are not necessarily detected in the counts. For example, some ducks, such as Mallard (Drilling *et al*. 2002) and Blue-winged Teal (Rohwer *et al*. 2002) nest in upland areas and may not use the wetland despite the possibility of counting the lone males as indicated pairs. However, some do ultimately make use of the nearest wetland for brood-rearing: 37% of Mallards in Saskatchewan used the nearest water (Drilling *et al*. 2002). While there are drawbacks to nearly every survey type, consistent survey methodologies of a group of wetlands over time should reveal relative population shifts adequate enough to highlight changes for the wildlife manager.

Incidental wildlife

In 1981 only, incidental to the waterbird survey, we recorded the presence of fish, amphibians, reptiles, and mammals including wildlife signs such as beaver dams or cuttings. Following our concentrated effort to monitor nesting waterbirds, we set minnow traps baited with canned dogfood and salmon roe to document the occurrence of fish and amphibians. Traps were set just prior to conducting the vegetation surveys (see below) and were retrieved after those surveys were completed (approximately 2–3 h). Also, prior to the vegetation collection, we used an aquatic insect net to sweep for insects. The net was plunged into the water about 0.5 m and drawn up through the aquatic and emergent vegetation in an approximately 2.5 m arc. Invertebrates from each collection point were preserved in 70% denatured methyl-ethyl alcohol, labeled, and sent to the British Columbia Provincial Museum (now the Royal British Columbia Museum) in Victoria for identification. Taxonomy follows Scott and Crossman (1990) for fishes, Crother (2012) for amphibians and reptiles, and Wilson and Reeder (2005) for mammals.

Vegetation

Upon completion of the waterbird nesting surveys in July 1981 only, we returned to each wetland to document the dominant surrounding vegetation, *e.g.* trees and shrubs, and the wetland submergent, floating-leaved, emergent, and shoreline vegetation. Plants were collected at each cardinal compass point (Danell and Sjöberg 1978). The chosen sites were slightly adjusted if the compass point fell in, *e.g.*, a dense monospecific community which did not appear to represent the proximate shore. Also some points were inaccessible due to logs or other debris. In that case, collection points as close to the original points were chosen. Specimens of all wetland plants within an arm's length of the canoe and in a two square meter area of shore and adjacent water were collected. Each obligate or facultative wetland species (USDA, NRCS 2017) was assigned a Braun-Blanquet relative abundance number for subsequent analysis (Mueller-Dombois and Ellenberg 1974). Plant specimens from each wetland were collected and subsequently pressed and identified. Specimens were sent to the Royal British Columbia Museum for confirmation of identification and were archived there. Plant taxonomy follows Hitchcock and Cronquist (1973).

Water and chemical analysis

In 1981 only, following the nesting period and the completion of the waterbird surveys, we collected water samples from the centre of each wetland at a depth of approximately 0.25m. Air contamination was avoided by filling and capping the plastic sample bottles underwater. Each water sample was tested for dissolved oxygen, carbon dioxide, calcium carbonate, magnesium carbonate and total hardness using methods outlined in a Lamotte® Limnology test Kit (model number since lost). In addition, pH, conductivity, and temperature readings were taken at the centre of each wetland using a Lamotte® pH, conductivity, and temperature meter. The depth of each wetland was recorded from approximately the wetland centre using a 1 kg lead weight attached to a rope marked in decimeters. Relative turbidity was estimated with a Secchi disk attached to a rope marked in decimeters.

Wetland physiography

The area of each wetland was initially estimated from topographic maps (1:50,000) by comparison to an area of known size; wetland area was later refined using the polygon area tool of Google Earth Pro (Google Earth 2016). In 1981 only, percentages of open water, aquatic and emergent vegetation were estimated in the field by two observers during the first pair count and the mean of the two estimates was recorded. Aquatic vegetation included submerged and floating-leaved plants; emergent vegetation included plants that grew in shallow water and along the wetter shore margins. Wetland classifications were based largely on Cowardin *et al.* (1979).

Data analysis

Standard statistical tests such as χ^2 tests or *t*-tests follow Zar (1974). Since many of the wetland variables had different units of measurement, the raw data were standardized by applying a logarithmic transformation; percentage data were arcsine transformed (Zar 1974). Because a number of the environmental variables were highly correlated, we excluded some to reduce the number of variables in the analysis (ter Braak 1986) (Table 1). Summary statistics were prepared with the statistical package, PAST (Hammer *et al.* 2001).

The statistical package R was used for multivariate analyses (R Core Team 2017). We conducted a multivariate analysis of variance (MANOVA; dplyr package in R) on the environmental variables of the two distinct sets of wetlands (lacustrine and palustrine) to determine if there was an overall difference between the two wetland types. The overall MANOVA was significant so we ran a univariate ANOVA to determine which factors contributed to the overall significant effect.

We used Canonical Correspondence Analysis (CCA; vegan package in R) (ter Braak 1986; ter Braak and Verdonschot 1995) to determine the influence of the independent wetland environmental variables on the wetland use by the various waterbird species and incidental species (fish, amphibians, reptiles, mammals). CCA is a direct gradient

Table 1. Environmental variables excluded from the Canonical Correspondence Analysis showing the variables with which they were highly correlated ($P < 0.001$). Variables with the highest correlations are shaded; negative correlations are in parenthesis.

	Environmental variable					
	Openwater	Secchi disk	CO_2	Hardness	Ca Hardness	Mg Hardness
Correlated variables	Depth	Depth	(Open water)	Conductivity	Conductivity	Conductivity
	(Emergent cover)	Open water	Emergent cover	Ca hardness	Hardness	Hardness
	(Aquatic cover)	(Emergent cover)	(Secchi disk)	Mg Hardness		
	Secchi disk	Dissolved Oxygen	(Dissolved Oxygen)			
	(CO_2)	(CO_2)				

analysis technique, using a weighted averaging ordination that simultaneously orders sites and species; it gives good performance when species have unimodal and non-linear relationships with environmental variables (Palmer 1993). The significance of the ordination was determined by the Monte Carlo permutation tests in the vegan package. To further assist in the interpretation of the CCA axes, in PAST we conducted a simple linear correlation of the raw environmental data with the first two CCA axes scores.

Permutation tests in a CCA of the influence of the environmental variables on the vegetation were not significant so we opted for simple correspondence analysis (CA; ca package in R) to determine any relationship between the wetlands and the vegetation. CA maximizes the correspondence between species scores and sample scores such that the weighted correlation between the two is maximized. Best estimates of mean cover-abundance for each species (Mueller-Dombois and Ellenberg 1974) were calculated by using the midpoints of each species Braun-Blanquet cover class, i.e., by setting r = 0.01, + = 0.5, 1 = 3, 2 = 15, 3 = 37.5, 4 = 62.5, 5 = 87.5; the mean value of each species was calculated using the best estimate values from the four compass points. For the CA we used only those species with a frequency of occurrence of 10% or greater. The Modal Nutrient Regime Class for each species was taken from Klinkenberg (2017).

Results

Wetland characteristics

Table 2 shows the environmental characteristics of the 31 wetlands, discussed in some detail below. Of the 31 wetlands, 19 were classified as lacustrine and 12 as palustrine wetlands. Table 3 shows the differences in the maximum, minimum, mean and median values of the environmental variables between the two wetland types and mean values that are significantly different.

The lacustrine wetlands tended to be significantly larger, deeper sites with more open water and a lower proportion of aquatic vegetation (Table 3). Based on Secchi disk measurements, lacustrine wetlands had significantly less turbidity than the palustrine wetlands. Most of the wetlands, however, had relatively clear waters with relatively low turbidity at the time of reading. Although the mean secchi disk reading of palustrine wetlands was less than a metre, that was due mainly to the shallowness of the wetland waters rather than lack of water clarity. However, some wetlands did have turbid waters, *e.g.* Hamilton Marsh had peat-stained water with visibility depth limited to 0.4 m and Moran Pond also had suspended organic matter limiting visibility depth to the first 1.8 m of its 5 m depth.

There were no significant differences in pH, hardness, or temperature values between the lacustrine and palustrine wetlands. The pH values of the wetland waters ranged from 5.8–6.8 indicating they were circumneutral. Lacustrine waters tended to have significantly higher dissolved oxygen levels while palustrine waters had significantly higher conductivities and CO_2 levels (Table 3).

Wetland vegetation

A list of the obligate and facultative wetland vegetation species found in the 31 wetlands is shown in Appendix I. *Nuphar polysepala*, *Utricularia macrorhiza*, and *Brasenia schreberi* were the most common submergent or floating-leaved species while *Mentha arvensis*, *Drosera rotundifolia* (growing primarily on floating logs), *Dulichium arundinaceum*, and *Typha latifolia* were the most common emergent species. *Spirea douglasii* and *Myrica gale* were the most common shrubs in the wetlands.

Most of the wetlands had some vegetative cover with only seven having more than 90% open water. A slight majority of the wetlands (52%) had 10% or less submergent and floating-leaved vegetation cover. Nearly one-third of the wetlands had emergent vegetation cover of 10 % or less while 48% had emergent vegetation cover of over 30%.

Figure 2 is a bi-plot of a CA of the study wetlands and their attendant obligate and facultative vegetation. Although the variance explained is less than 20%, the figure does reveal some interesting information. The first axis separates the species based on their dominance in the wetlands determined by their frequency and cover as well as their non-occurrence. The positive side of the first axis tends toward those wetlands with species dominated by *Typha latifolia*, *Lemna minor*, *Carex utriculata*, and *Comarum palustre*. The negative side tends toward wetlands with species dominated by *Brasenia schreberi*, *Menyanthes trifoliata*, *Carex lasiocarpa*, *Carex sitchensis*, *Dulichium arundinaceum*, *Rhododendron groenlandicum*,

Table 2. Some physical and chemical characteristics of 31 study area wetlands in the mid-Vancouver Island region.

No.[1]	Wetland	UTM[2]		Area	Depth	Open water	Emergent cover	Aquatic cover	Secchi disk	Conductivity	Temp	Dissolved O_2	pH	CO_2	Total Hardness	Ca Hardness	Mg Hardness
		Easting	Northing	ha	m	%	%	%	m	μmhos/cm	° C	ppm		ppm	ppm	ppm	ppm
6	Allen Lake-L[3]	352992	5495972	18.7	9.8	94	4	2	4.5	28	20.0	9	6.7	5.8	22	12	10
1	Black Lake-L	350548	5500740	3.9	8.5	30	70	0	3.8	80	20.5	10	6.6	33.0	46	26	20
30	Boomerang Lake-L	415775	5448042	12.0	12.5	97	1	2	4.4	33	15.5	7.8	5.8	2.5	20	8	12
31	Cottle Lake-L	415684	5447576	2.8	5.5	97	3	0	3.7	42	19.5	7.2	6.3	2.0	23	15	8
4	Cumberland Marsh-P	351643	5498132	0.9	1.3	60	35	5	0.8	86	15.0	5	6.3	14.0	46	30	16
28	Devil's Den Lake-L	364437	5456918	10.4	3.8	50	45	5	3.3	78	23.0	6.2	5.8	2.0	44	16	28
26	Enos Lake-L	415894	5459296	18.7	9.5	70	20	10	3.0	120	19.0	8	6.5	2.5	48	30	18
8	Fanny Bay Highway Marsh-P	368157	5484219	1.2	1.0	10	85	5	1.0	63	21.5	6.8	6.9	8.0	38	20	18
9	Fanny Bay Marsh-P	367800	5483860	6.0	1.5	35	65	0	1.3	63	16.0	4	6.3	21.0	36	22	14
25	Hamilton Marsh-P	393740	5463628	32.9	1.0	5	60	35	0.4	53	14.5	2	5.6	34.0	32	8	24
18	Illusion Lakes-L	380963	5467836	12.6	3.5	95	5	0	3.5	42	21.5	10.7	6.6	1.0	22	12	10
29	Kidney Lake-L	415607	5450619	8.8	11.5	88	10	2	5.3	50	15.5	7.7	6	6.5	24	10	14
7	Langley Lake-L	361115	5491646	29.0	6.0	67	30	3	3.2	31	18.5	8.8	6.2	2.5	20	12	8
11	Lois Lake-L	345173	5476487	11.4	15.0	98	2	0	7.9	36	18.0	8.5	5.8	2.0	20	16	4
12	Lowry Lake-L	345068	5472892	45.8	11.0	80	5	15	9.1	47	21.0	9.2	5.8	2.3	32	6	26
15	Moran Lake-L	352940	5470447	52.5	4.8	20	75	5	3.1	58	20.0	6.8	6.8	6.0	30	20	10
14	Moran Pond-L	351637	5470883	1.5	5.0	60	40	0	1.8	65	25.0	5.2	5.9	10.5	26	10	16
27	Nook Creek Marsh -P	363051	5456945	7.9	.07	20	75	5	0.7	92	19.5	5.2	6.4	12.0	50	34	16
17	Patterson Lake-L	355024	5468046	18.3	1.5	45	40	15	1.5	55	22.5	7.8	6.4	2.5	28	12	16
2	Pigeon Pond-P	352134	5500287	0.5	.08	55	35	10	0.8	220	17.0	2.7	6.3	16.0	84	62	22
13	Reserve Marsh-P	383536	5472566	1.1	1.3	60	15	25	1.3	70	16.0	11.2	6.6	2.0	24	16	8
22	Rosemary Marsh-P	357285	5465687	2.3	0.5	5	90	5	0.5	34	22.0	3.6	5.8	27.0	22	11	11
24	Shuhum Lake-L	358577	5464364	15.9	6.7	59	40	1	4.6	31	18.0	6.5	6.6	3.0	8	4	4
5	Skeet Club Marsh-P	351682	5497974	5.3	1.4	35	40	25	1.0	46	14.0	4.3	6.1	35.0	36	22	14
16	Somers Lake-L	355155	5469254	21.3	6.0	95	5	0	5.4	42	20.0	6.3	6.8	2.3	20	12	8
19	Spider Lake-L	381856	5467378	55.0	12.5	95	3	2	6.8	42	19.5	9.5	6.6	4.5	20	10	10
20	Spider Pond-P	382204	5466805	1.5	1.0	10	25	65	1.0	45	19.5	5.2	6.5	9.5	22	9	13
3	Teal Lake-P	353272	5499995	4.6	0.3	20	40	40	0.3	108	18.5	6.8	5.3	12.0	36	20	16
10	Turnbull Lake-L	347737	5477013	20.9	2.5	85	10	5	2.5	38	18.5	8.8	6.5	2.5	18	8	10
23	Turtle Lake-L	357548	5465644	24.0	11.3	65	25	10	3.1	24	18.0	8.5	6.2	5.0	19	8	11
21	Turtle Marsh-P	358262	5465861	19.0	0.7	5	20	75	0.7	30	23.0	7.4	5.3	12.0	12	4	8

[1] Wetland number refers to the numbers in Figure 1.
[2] Zone 10
[3] Wetland type: L = lacustrine; P = palustrine

Table 3. Differences in the maximum, minimum, mean and median values of the environmental variables between lacustrine and palustrine wetlands in the mid-Vancouver Island region. Multivariate Analysis of Variance between the mean (shaded) lacustrine and palustrine values determined there was a difference overall between the two ($F_{14,16} = 12.6$; $P < 0.001$). Since the test was significant, a univariate ANOVA was applied to determine which of the factors contributed to the significant overall effect.

Wetland type		Area	Depth	Open water	Emergent cover	Submer-gent cover	Secchi disk	Conductiv-ity	Dis-solved O_2	pH	CO_2	Hard-ness	Ca Hard-ness	Mg Hard-ness	Temp.
		ha	m	%	%	%	m	µmhos·cm^{-1}	ppm		ppm	ppm	ppm	ppm	°C
Lacustrine (n = 19)	Min	1.5	1.5	20.0	1.0	0.0	1.5	24.0	5.2	5.8	1.0	8.0	4.0	4.0	15.5
	Max	55.0	15.0	98.0	75.0	15.0	9.1	120.0	10.7	6.8	33.0	48.0	30.0	28.0	25.0
	Mean	20.2	7.7	73.2	22.8	4.1	4.2	49.6	8.0	6.3	5.2	25.8	13.0	12.8	19.7
	SE	3.6	0.9	5.5	5.3	1.1	0.5	5.3	0.3	.01	1.6	2.4	1.5	1.5	0.5
	Median	18.3	6.7	80.0	10.0	2.0	3.7	42.0	8.0	6.4	2.5	22.0	12.0	10.0	19.5
Palustrine (n = 12)	Min	0.5	0.3	5.0	15.0	0.0	0.3	30.0	2.0	5.3	2.0	12.0	4.0	8.0	14.0
	Max	32.9	1.5	60.0	90.0	75.0	1.3	220.0	11.2	6.9	35.0	84.0	62.0	24.0	23.0
	Mean	6.9	1.0	26.7	48.8	24.6	0.8	75.8	5.4	6.1	16.9	36.5	21.5	15.0	18.0
	SE	2.8	0.1	6.3	7.4	7.2	0.1	14.8	0.7	0.1	3.0	5.3	4.5	1.4	0.9
	Median	3.5	1.0	20.0	40.0	17.5	0.8	63.0	5.1	6.3	13.0	36.0	20.0	15.0	17.8
ANOVA[1]	$F_{1,29}$	13.2**	82.4***	28.7***	9.6**	14.0**	81.4***	4.4*	17.0***	1.6^{ns}	23.0***	3.8^{ns}	3.3^{ns}	1.8^{ns}	3.1^{ns}

[1] P values: * = P < 0.05; ** = P < 0.01; *** = P < 0.001; ns = P > 0.05

and a lack of *Lemna minor*, *Potamogeton oakesianus*, *Phalaris arundinacea*, *Myosotis laxa*, and *Lisichitum americanum*. The ecological significance of this separation is difficult to determine. The second axis, however, appears to separate the species and their attendant wetlands on a nutrient basis, based on the Modal Nutrient Regime Class for each species. Those species on the positive end of the axis tend towards more nutrient rich wetlands, predominately palustrine wetlands, while those on the negative end of the axis tend towards nutrient poorer wetlands, mostly lacustrine wetlands.

Invertebrates

Table 4 shows the frequency of occurrence and number of individuals of invertebrates collected in our net sweeps of the aquatic vegetation. A total of 451 individuals in 54 taxa were collected. Dragonflies, backswimmers, damselflies, water spiders, and water striders were the five dominant taxa appearing in at least 50% of the 31 wetlands. Of the 40 taxa identified from the 19 lacustrine wetlands sampled, only three taxa were found in at least 50% of the samples: dragonflies, water mites, and water striders. Of the 45 taxa identified from the 12 palustrine wetlands sampled, 12 taxa were found in at least 50% of the samples: dragonflies, backswimmers, damselflies, chironomid larvae, water spiders, freshwater snails, mayflies, predaceous diving beetles, water striders, caddisflies, water boatmen, and leaf beetles. Palustrine wetlands had significantly more invertebrate taxa ($t_{0.05(2),29}$=-3.522; $P < 0.002$) and total number of individuals ($t_{0.05(2),29}$=-3.058; $P < 0.008$) than the lacustrine wetlands.

Waterbirds

Total adult waterbirds

In 1981, we observed a total of 196 adult waterbirds on the 31 wetlands (Table 5). Pied-billed Grebe had the highest numbers with 47 birds counted followed by Mallard (33), Bufflehead (22), Common Loon (19), and Hooded Merganser (17). In 1996, 194 adult waterbirds were counted (Table 5). Highest numbers recorded in 1996 were Mallard with 70 birds counted, followed by Canada Goose (28), Hooded Merganser (24), Wood Duck (19), and Common Loon (19). Blue-winged Teal, Green-winged Teal, Bufflehead, Common Merganser, and Pied-billed Grebe numbers were significantly higher in 1981 than in 1996. Canada Goose, Wood Duck, Mallard, and Ring-necked Duck numbers were significantly higher in 1996 than in 1981. There were no differences between years in the number of Hooded Mergansers, Common Loons, and unidentified species.

In 1981, Hamilton Marsh had the highest numbers of adult birds and species with 37 individuals counted from 8 species. In 1996, Enos Lake had the highest numbers of individuals (20); Langley Lake had the highest number of species (6).

Breeding pairs

Table 6 gives comparative data for the total waterbird indicated pairs in 1981 and 1996 and indicated pairs used in our CCA analyses of 1981 data. A total of 69 pairs from eight species were found on 27 of the 31 wetlands in 1981 compared to 81 pairs from seven species recorded on 26 wetlands in 1996. There was no significant difference

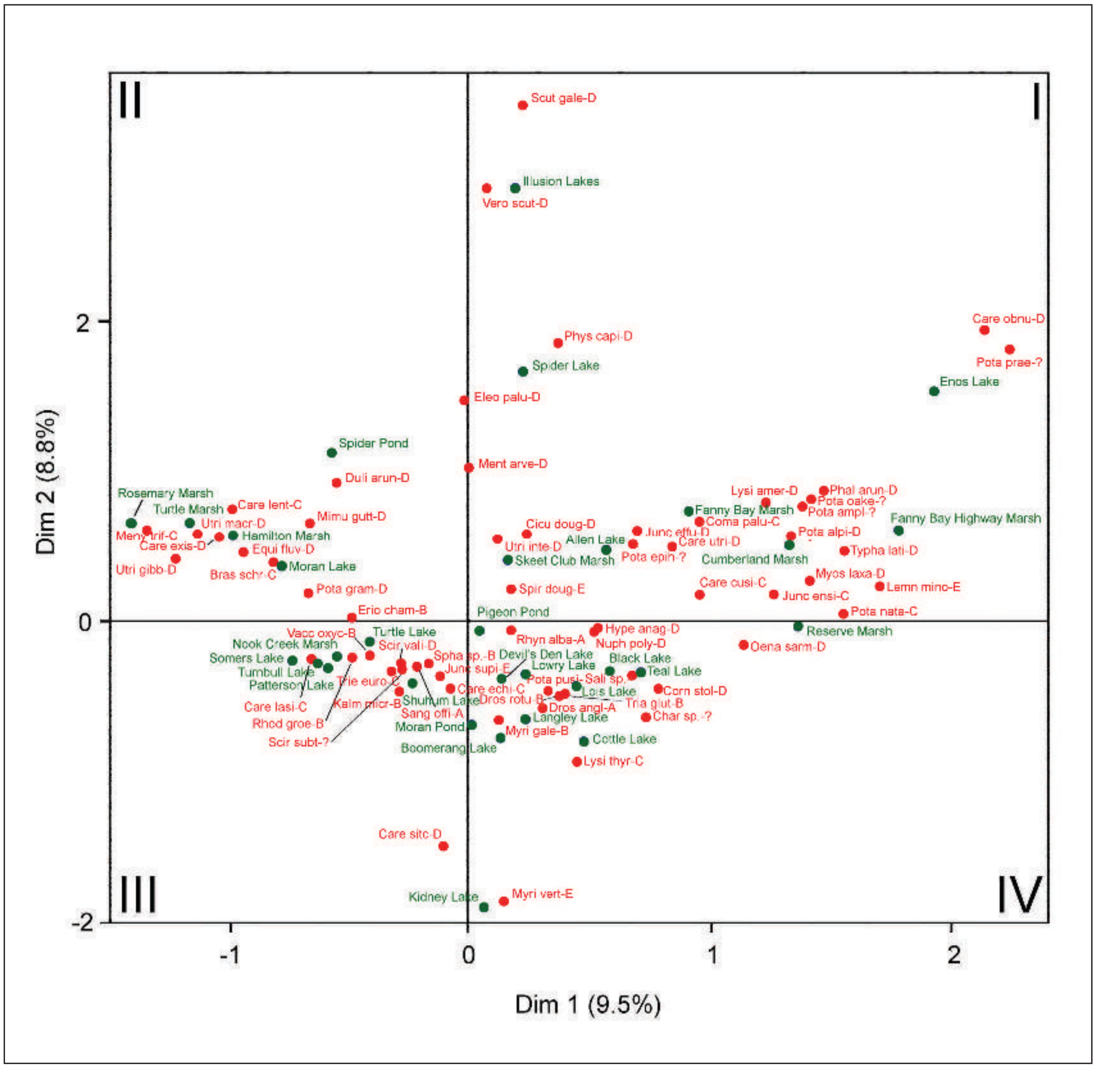


Figure 2. Correspondence analysis (CA) of the study wetlands (green disks) and their attendant obligate and facultative vegetation species (red disks). Letters after the species codes indicate the species' modal nutrient regime class taken from Klinkenberg (2017): A-very poor; B-poor; C-medium; D-rich; E-very rich. The CA explains only 18.3% of the variation in the dataset but does offer some ecological insight. The positive end of the first axis features wetlands dominated by *Typha latifolia*, *Lemna minor*, *Carex utriculata*, and *Comarum palustre* while on the negative end of the axis, wetlands are dominated by *Brasenia schreberi*, *Menyanthes trifoliata*, *Carex lasiocarpa*, *Carex sitchensis*, *Dulichium arundinaceum*, *Rhododendron groenlandicum*, and a lack of *Lemna minor*, *Potamogeton oakesianus*, *Phalaris arundinacea*, and *Myosotis laxa*. The second axis tends to separate wetlands on their nutrient regime, based on the nutrient regime class of the vegetation. Those wetlands in quadrants I and II tend towards nutrient richness while those in quadrants III and IV tend to be nutrient poorer. Full names for the vegetation codes are given in Appendix II.

between years for total indicated pairs. However, the Canada Goose showed a significant increase of 10 pairs in 1996 from the 1981 count. Pied-billed Grebe showed a significant decrease of 12 pairs between years. In both years, we failed to record any waterbirds on Black Lake, Boomerang Lake, Cottle Lake and Lois Lake; in 1996, waterbird pairs were not found on Fanny Bay Marsh, as well. In both years, Mallards had the most pairs of the dabbling ducks; of the diving ducks, the Hooded Merganser had the most pairs.

Hamilton Marsh held the highest number of indicated pairs in 1981; Enos Lake had the highest number of pairs in 1996. Of the 26 wetlands that supported waterbird pairs in 1981, 85% held 1–3 pairs; in 1996, 68% of 25 wetlands had 1–3 pairs.

Broods and total young

Table 7 shows comparative data for waterbird broods in 1981 and 1996. Thirty-five broods were found on 23 wetlands in 1981 compared to 49 broods on 20 wetlands in

Table 4. Frequency of occurrence (F) and number of individual invertebrates (I) collected in aquatic sweeps of 31 wetlands in the mid-Vancouver Island region. Taxa are listed in order of overall frequencies. Also shown are taxa frequencies (LF; PF) and number of individuals (LI; PI) for lacustrine and palustrine wetlands respectively.

Taxa	F (%)	I	LF (%)	LI	PF (%)	PI
Dragonfly - Odonata	77	62	74	28	83	34
Dragonfly - Aeshnidae	55	29	47	12	67	17
Dragonfly - Libellulidae	39	19	26	6	58	13
Dragonfly - Unidentified	19	7	32	7	0	0
Dragonfly - Cordilegastridae	10	3	5	1	17	2
Dragonfly - Cordulegastridae	6	2	0	0	17	2
Dragonfly - Gomphidae	6	2	11	2	0	0
Backswimmer - Notonectidae	61	45	47	21	83	24
Damselfly - Odonata	58	33	47	13	75	20
Damselfly - Coenagrionidae	58	27	47	12	75	15
Damselfly - Lestidae	10	6	5	1	17	5
Water Spider - Cybaeidae	52	20	47	13	58	7
Water Strider - Hemiptera	52	24	53	12	50	12
Water Strider - Gerridae	45	21	42	10	50	11
Water Strider - Veliidae	10	3	11	2	8	1
Chironomid - Chironominidae	45	24	32	12	67	12
Caddisfly larva - Trichoptera	42	24	37	14	50	10
Caddisfly larva - Unidentified	32	11	32	6	33	5
Caddisfly larva - Lepidostomatidae	13	8	16	6	8	2
Caddisfly larva - Leptoceridae	6	2	5	1	8	1
Caddisfly larva - Hydropsychidae	3	1	0	0	8	1
Caddisfly larva - Limnephilidae	3	1	0	0	8	1
Caddisfly larva - Polycentripododae	3	1	5	1	0	0
Freshwater snail - Basommatophora	42	24	32	10	58	14
Leaf Beetle - Chrysomelidae	42	19	37	10	50	9
Water mite - Trombidiformes	39	15	58	14	8	1
Mayfly - Ephemeroptera	35	18	21	4	58	14
Mayfly - Unidentified	16	5	11	2	25	3
Mayfly - Baetidae	13	7	0	0	33	7
Mayfly - Ephemerellidae	6	2	0	0	17	2
Mayfly - Metretopodidae	6	2	5	1	8	1
Mayfly - Caenidae	3	1	5	1	0	0
Amphipod - Amphipoda	32	13	26	7	42	6
Water Boatman - Corixidae	29	15	16	4	50	11
Water Treader - Mesoveliidae	29	15	32	11	25	4
Freshwater clam - Unionoida	26	8	26	5	25	3
Predaceous Diving Beetle - Dytiscidae	26	10	5	2	58	8
Crawling water beetle - Haliplidae	23	13	26	11	17	2
Water Scorpion - Nepidae	23	9	11	4	42	5
Giant waterbug - Belostomatidae	19	7	26	6	8	1
Whirlygig Beetle - Gyrinidae	19	7	11	2	33	5
Aphid - Aphididae	13	5	11	3	17	2
Leech - Hirudinea	13	6	11	3	17	3
Primitive Minnow Mayfly - Siphlonuridae	13	5	5	1	25	4
Meniscus Midges - Dixidae	10	3	5	1	17	2
Phantom Midge - Chaoboridae	10	4	0	0	25	4
Dancefly - Empididae	6	2	5	1	8	1
Daphnia - Diplostraca	6	2	5	1	8	1
Freshwater mussel - Unionoida	6	3	11	3	0	0
Rove Beetle - Staphylinidae	6	2	5	1	8	1
Water Scavenger Beetle - Hydrophilidae	6	3	0	0	17	3
Dobsonfly - Corydalidae	3	1	0	0	8	1
Ground Beetle - Carabidae	3	1	5	1	0	0
Mosquito - Culicidae	3	1	0	0	8	1
Mosquitoes, midges - Nematocera	3	1	5	1	0	0
Shorebugs - Saldidae	3	1	0	0	8	1
Spider - Filistatidae	3	1	0	0	8	1
Stonefly - Plecoptera	3	1	0	0	8	1
Unidentified worm	3	1	5	1	0	0
Weevil - Curculionidae	3	1	5	1	0	0
Fly - Cyclorrhapha	3	1	0	0	8	1
Proturan - Protura	3	1	0	0	8	1
Total number of individuals		**451**		**221**		**230**

►

◄ Table 4

1996. There was no significant difference in total number of broods between years. Of the wetlands that supported broods in 1981, 83% had only one brood; in 1996, 70% held 1–2 broods. Mallard had the highest number of broods in both years.

Total numbers of young recorded each year are shown in Table 8. In 1981, 119 young were found on 23 wetlands; 216 young were counted on 20 of the wetlands in 1996, a significant increase from 1981. With the exception of Blue-winged Teal, Common Loon and unidentified species, the total young numbers for each species were significantly higher in 1996. Mallards produced the most young in both years (64 and 96 respectively); in 1996, Canada Goose, Hooded Merganser, and Wood Duck followed with 41, 39, and 24 young respectively.

Of the 31 study wetlands, Hamilton Marsh in 1981 and Enos Lake in 1996 held the highest numbers of broods and young.

Table 9 shows the number of indicated pairs, broods, and young counted on the 19 lacustrine and 12 palustrine wetlands in the mid-Vancouver Island study area. With the exception of indicated pairs in 1996, palustrine wetlands had significantly more indicated pairs, broods, and young than the lacustrine wetlands in our study area.

Waterbird production from wetlands in quadrants I & II of Figure 2, where 88 young were produced in 1981, is

Table 5. Total number of adult birds recorded and number of species per wetland from surveys of 31 wetlands in the mid-Vancouver Island region in 1981 and 1996.

No.[1]	Wetland	CAGO[2]		WODU		BWTE		MALL		GWTE		RNDU		BUFF		HOME		COME		PBGR		COLO		UNID		Totals		No. species	
		1981	1996	1981	1996	1981	1996	1981	1996	1981	1996	1981	1996	1981	1996	1981	1996	1981	1996	1981	1996	1981	1996	1981	1996	1981	1996	1981	1996
6	Allen Lake																			4		2	2			**6**	**2**	**2**	**1**
1	Black Lake																									**0**	**0**	**0**	**0**
30	Boomerang Lake																1				1					**0**	**2**	**0**	**2**
31	Cottle Lake																									**0**	**0**	**0**	**0**
4	Cumberland Marsh				1				4											6						**6**	**5**	**1**	**2**
28	Devil's Den Lake						1	1	2								1				1		2			**1**	**7**	**1**	**5**
26	Enos Lake	2	8	3	2			1	4			2		4		1	6	3								**16**	**20**	**7**	**4**
8	Fanny Bay Highway Marsh		2			1		3								2										**6**	**2**	**3**	**1**
9	Fanny Bay Marsh							1								2										**3**	**0**	**2**	**0**
25	Hamilton Marsh			4	2	2		8	8	6			2	5						9	3			2	2	**37**	**17**	**8**	**5**
18	Illusion Lake		4					3						11		2		2		1						**19**	**4**	**5**	**1**
29	Kidney Lake								4											5						**5**	**4**	**1**	**1**
7	Langley Lake		2		2			1	2								2			2		2	2		2	**5**	**12**	**3**	**6**
11	Lois Lake																									**0**	**0**	**0**	**0**
12	Lowry Lake		2																2			2				**2**	**4**	**1**	**2**
15	Moran Lake		2		2			1	2				3							2	3	4	2			**7**	**14**	**3**	**5**
14	Moran Pond							1	3				2				2			1						**2**	**7**	**2**	**3**
27	Nook Creek Marsh	2			2			2									4			2	2					**6**	**8**	**3**	**3**
17	Patterson Lake	2							5											2						**4**	**5**	**2**	**1**
2	Pigeon Pond					2		2	5		1					2										**6**	**6**	**3**	**1**
13	Reserve Marsh		2					1	8							3	2	2						2		**8**	**12**	**4**	**3**
22	Rosemary Marsh				4				6				5											2		**2**	**15**	**1**	**3**
24	Shuhum Lake	1			2				6			1		1						2		1	4			**6**	**12**	**5**	**3**
5	Skeet Club Marsh					3			4								2			2						**5**	**6**	**2**	**2**
16	Somers Lake																					2	2			**2**	**2**	**1**	**1**
19	Spider Lake		4															2		1		2	2			**5**	**6**	**3**	**2**
20	Spider Pond	2						1						1			2	1								**5**	**2**	**4**	**1**
3	Teal Lake							1	2							2	2			3						**6**	**4**	**3**	**2**
10	Turnbull Lake							1								2				1		2	1			**6**	**1**	**4**	**1**
23	Turtle Lake				2				1	6										2	2	2	2			**10**	**7**	**3**	**4**
21	Turtle Marsh		2			2		5	4							1				2	2					**10**	**8**	**4**	**3**
Total number of birds		**10**	**28**	**7**	**19**	**10**	**1**	**33**	**70**	**12**	**1**	**3**	**12**	**22**	**0**	**17**	**24**	**10**	**2**	**47**	**14**	**19**	**19**	**6**	**4**	**196**	**194**		
Change from 1981–1996		**18**		**12**		**-9**		**37**		**-11**		**9**		**-22**		7		**-8**		**-33**		0		-2		-2			
Significance of change (χ^2_{Yates})		7.61**[3]		4.65*		5.82*		12.58***		7.69**		4.27*		20.05***		0.88^{ns}		4.08*		16.79***		0.26^{ns}		0.1^{ns}		0.003^{ns}			

[1] Number refers to the wetland location in Figure 1

[2] Species code: BWTE = Blue-winged Teal; CAGO = Canada Goose; COLO = Common Loon; COME = Common Merganser; HOME = Hooded Merganser; MALL = Mallard; PBGR = Pied-billed Grebe; UNID = unidentified waterbird; WODU = Wood Duck

[3] P values: * = P < 0.05; ** = P < 0.01; *** = P < 0.001; ns = P > 0.05

Table 6. Number of waterbird indicated pairs observed during mid-Vancouver Island wetland surveys in 1981 and 1996.

No.[1]	Wetland	CAGO[2]		WODU		BWTE		MALL		GWTE[3]		RNDU[3]		BUFF[3]		HOME		COME		PBGR		COLO		UNID		Total indicated pairs		**Totals used in analyses[4]**	
		1981	**1996**	**1981**	**1996**	**1981**	**1996**	**1981**	**1996**	**1981**	**1996**	**1981**	**1996**	**1981**	**1996**	**1981**	**1996**	**1981**	**1996**	**1981**	**1996**	**1981**	**1996**	**1981**	**1996**	1981	1996	**1981**	**1996**
6	Allen Lake																					1	1			1	1	**1**	**1**
1	Black Lake																									0	0	**0**	**0**
30	Boomerang Lake																									0	0	**0**	**0**
31	Cottle Lake																									0	0	**0**	**0**
4	Cumberland Marsh								2											3						3	2	**3**	**2**
28	Devil's Den Lake							1	1														1			1	2	**1**	**2**
26	Enos Lake	1	4	2	1				2			1		2			3									6	10	**3**	**10**
8	Fanny Bay Highway Marsh		1					2								1										3	1	**3**	**1**
9	Fanny Bay Marsh							1																		1	0	**1**	**0**
25	Hamilton Marsh			2	1	1		6	4	3			1	1						4	1			1	1	18	8	**14**	**7**
18	Illusion Lake		2					2						5		1		1								9	2	**4**	**2**
29	Kidney Lake								2											1						1	2	**1**	**2**
7	Langley Lake		1					1	1								1			1		1	1		1	3	5	**3**	**5**
11	Lois Lake																									0	0	**0**	**0**
12	Lowry Lake		1																1			1				1	2	**1**	**2**
15	Moran Lake		1		1				2				3							1	1	1	1			2	9	**2**	**5**
14	Moran Pond								1				1				1									0	3	**0**	**2**
27	Nook Creek Marsh	1			1			1									1			1	1					3	3	**3**	**3**
17	Patterson Lake	1							2											1						2	2	**2**	**2**
2	Pigeon Pond					1		1	2		1															2	3	**2**	**2**
13	Reserve Marsh		1					1	4							1		1						1		4	5	**4**	**5**
22	Rosemary Marsh				2				3				1											1		1	7	**1**	**5**
24	Shuhum Lake				1				3			1								1		1	2			3	6	**2**	**6**
5	Skeet Club Marsh					1			2								1			1						2	3	**2**	**3**
16	Somers Lake																					1	1			1	1	**1**	**1**
19	Spider Lake		2															1				1	1			2	3	**2**	**3**
20	Spider Pond	1															1									1	1	**1**	**1**
3	Teal Lake							1	1							1	1			1						3	2	**3**	**2**
10	Turnbull Lake															1										1	0	**1**	**0**
23	Turtle Lake				1															1	1	1	1			2	3	**2**	**3**
21	Turtle Marsh		1			1		4	2											1	1					6	4	**6**	**4**
Totals		**4**	**14**	**4**	**8**	**4**	**0**	**21**	**34**	3	1	2	7	8	0	**5**	**9**	**3**	**1**	**17**	**5**	**8**	**9**	**3**	**2**	82	89	**69**	**81**
Change from 1981–1996		**10**		**4**		**-4**		**13**		-2		5		-8		**4**		**-2**		**-12**		**1**		**-1**		7		**12**	
Significance of change (χ^2_{Yates})		4.5^{*5}		0.75^{ns}		2.25^{ns}		2.24^{ns}								0.64^{ns}		$.25^{ns}$		5.5^{*}		0^{ns}		0^{ns}				0.81^{ns}	

[1] Number refers to the wetland location in Figure 1

[2] Species code: BUFF = Bufflehead; BWTE = Blue-winged Teal; CAGO = Canada Goose; COLO = Common Loon; COME = Common Merganser; GWTE = Green-winged Teal; HOME = Hooded Merganser; MALL = Mallard; PBGR = Pied-billed Grebe; RNDU = Ring-necked Duck; UNID = unidentified waterbird; WODU = Wood Duck

[3] Species that met the definition of a wetland pair but likely late migrant or non-breeder; they were excluded from analysis

[4] Totals with GWTE, RNDU, and BUFF removed; the 1981 data were used in the Canonical Correspondence Analysiis

[5] P values: * = P < 0.05; ** = P < 0.01; *** = P < 0.001; ns = P > 0.05

Table 7. Number of waterbird broods observed during mid-Vancouver Island wetland surveys in 1981 and 1996.

No[1]	Wetland	CAGO		WODU		BWTE		MALL		HOME		COME		PBGR		COLO		UNID		Totals	
		1981	1996	1981	1996	1981	1996	1981	1996	1981	1996	1981	1996	1981	1996	1981	1996	1981	1996	1981	1996
6	Allen Lake															1				**1**	**0**
1	Black Lake																			**0**	**0**
30	Boomerang Lake																			**0**	**0**
31	Cottle Lake																			**0**	**0**
4	Cumberland Marsh								1											**0**	**1**
28	Devil's Den Lake							1												**1**	**0**
26	Enos Lake	1	4								3									**1**	**7**
8	Fanny Bay Highway Marsh		1					2		1										**3**	**1**
9	Fanny Bay Marsh							1												**1**	**0**
25	Hamilton Marsh			1		1		4	3					3	1				1	**9**	**5**
18	Illusion Lake		1							1										**1**	**1**
29	Kidney Lake													1						**1**	**0**
7	Langley Lake		1													1	1			**1**	**2**
11	Lois Lake																			**0**	**0**
12	Lowry Lake												1			1				**1**	**1**
15	Moran Lake				1				2							1	1			**1**	**4**
14	Moran Pond								1		1									**0**	**2**
27	Nook Creek Marsh				1						1			1						**1**	**2**
17	Patterson Lake	1							1											**1**	**1**
2	Pigeon Pond							1	2											**1**	**2**
13	Reserve Marsh							1	4											**1**	**4**
22	Rosemary Marsh				2				3									1		**1**	**5**
24	Shuhum Lake								2								1			**0**	**3**
5	Skeet Club Marsh								1		1			1						**1**	**2**
16	Somers Lake															1				**1**	**0**
19	Spider Lake															1				**1**	**0**
20	Spider Pond										1									**0**	**1**
3	Teal Lake							1	1	1	1									**2**	**2**
10	Turnbull Lake									1										**1**	**0**
23	Turtle Lake				1											1				**1**	**1**
21	Turtle Marsh							2	2											**2**	**2**
Totals		**2**	**7**	**1**	**5**	**1**	**0**	**13**	**23**	**4**	**8**	**0**	**1**	**6**	**1**	**7**	**3**	**1**	**1**	**35**	**49**
Change from 1981–1996		5		4		-1		10		4		1		-5		-4		0		14	
Significance of change (χ^2_{Yates})		1.78^{ns3}		1.5^{ns}		0^{ns}		2.25^{ns}		0.75^{ns}		0^{ns}		2.29^{ns}		0.9^{ns}		0.5^{ns}		2.01^{ns}	

[1] Number refers to the wetland numbers in Figure 1

[2] Species code: BWTE = Blue-winged Teal; CAGO = Canada Goose; COLO = Common Loon; COME = Common Merganser; HOME = Hooded Merganser; MALL = Mallard; PBGR = Pied-billed Grebe; UNID = unidentified waterbird; WODU = Wood Duck

[3] P values: ns = P > 0.05

significantly higher than wetlands in quadrants III & IV with 31 young produced ($\chi^2_{Yates} = 48.56$; $P < 0.001$; the difference in the proportion of wetlands on each side of the axis was considered in the calculations). This further supports the contention that the second axis of Figure 2 tends to separate nutrient rich wetlands from those that are nutrient poor.

Wetlands and waterbird associations

Figure 3 shows a CCA triplot of the ordination of the waterbirds and sundry species (fish, amphibians, reptiles, mammals, invertebrates), the wetlands, and the wetland environmental characteristics. The permutation test indicated the ordination and the first two axes were significant (CCA: $P = 0.001$; Axis 1: $P = 0.002$; Axis 2: $P = 0.001$). The first two axes explained 62% of the variance in the weighted averages of the species with respect to the environmental variables. Two of the environmental variables were significantly related to the species data: depth ($P = 0.001$) and dissolved oxygen ($P = 0.010$).

The first canonical axis tended to separate the smaller and shallower wetlands with high vegetative cover and lower dissolved oxygen levels (palustrine wetlands) on the positive side of the axis from the deeper and larger wetlands with higher dissolved oxygen and lower vegetative cover (lacustrine wetlands) on the negative side. Simple linear correlations with the site constraint scores and the raw environmental data showed a significant negative correlation with percent open water, turbidity (secchi disk), and dissolved oxygen and a positive correlation with carbon-dioxide (all $P < 0.01$) The second canonical axis also tends to separate the palustrine wetlands on the positive side of the axis from lacustrine wetlands on the negative side of the axis. Simple linear correlations with the site constraint scores and the raw environmental data showed a significant negative correlation with the deeper, larger wetlands with clearer waters (all $P < 0.01$).

Breeding waterbirds were not found on Black Lake, Boomerang Lake, Cottle Lake, and Lois Lake in both 1981 and 1996; those wetlands appeared similar to wetlands

Table 8. Number of waterbird young counted during mid-Vancouver Island wetland surveys in 1981 and 1996.

No[1]	Wetland	CAGO[2]		WODU		BWTE		MALL		HOME		COME		PBGR		COLO		UNID		Totals	
		1981	1996	1981	1996	1981	1996	1981	1996	1981	1996	1981	1996	1981	1996	1981	1996	1981	1996	1981	1996
6	Allen Lake															1				**1**	**0**
1	Black Lake																			**0**	**0**
30	Boomerang Lake																			**0**	**0**
31	Cottle Lake																			**0**	**0**
4	Cumberland Marsh								5											**0**	**5**
28	Devil's Den Lake							3												**3**	**0**
26	Enos Lake	3	21								19									**3**	**40**
8	Fanny Bay Highway Marsh		7					9		2										**11**	**7**
9	Fanny Bay Marsh							7												**7**	**0**
25	Hamilton Marsh			9		1		25	7					10	1				3	**45**	**11**
18	Illusion Lake		11							2										**2**	**11**
29	Kidney Lake													?[3]						**1**	**0**
7	Langley Lake		2													1	1			**1**	**3**
11	Lois Lake																			**0**	**0**
12	Lowry Lake												9			1				**1**	**9**
15	Moran Lake				10				10							1	1			**1**	**21**
14	Moran Pond								2		3									**0**	**5**
27	Nook Creek Marsh				1						4			?[3]						**1**	**5**
17	Patterson Lake	1							3											**1**	**3**
2	Pigeon Pond							5	12											**5**	**12**
13	Reserve Marsh							5	19											**5**	**19**
22	Rosemary Marsh				12				10									2		**2**	**22**
24	Shuhum Lake								8								1			**0**	**9**
5	Skeet Club Marsh								7		7			6						**6**	**14**
16	Somers Lake															1				**1**	**0**
19	Spider Lake															1				**1**	**0**
20	Spider Pond										3									**0**	**3**
3	Teal Lake							1	7	6	3									**7**	**10**
10	Turnbull Lake									3										**3**	**0**
23	Turtle Lake				1											2				**2**	**1**
21	Turtle Marsh							9	6											**9**	**6**
Totals		**4**	**41**	**9**	**24**	**1**	**0**	**64**	**96**	**13**	**39**	**0**	**9**	**18**	**1**	**8**	**3**	**2**	**3**	**119**	**216**
Change from 1981–1996		**37**		**15**		-1		**32**		**26**		**9**		**-17**		-5		1		**97**	
Significance of change (χ^2_{Yates})		28.8***[4]		5.94*		0^{ns}		6.01*		12.01***		7.11**		13.47***		1.46^{ns}		0^{ns}		27.51***	

[1] Number refers to the wetland numbers in Figure 1

[2] Species code: BWTE = Blue-winged Teal; CAGO = Canada Goose; COLO = Common Loon; COME = Common Merganser; HOME = Hooded Merganser; MALL = Mallard; PBGR = Pied-billed Grebe; UNID = unidentified waterbird; WODU = Wood Duck

[3] Nest found with egg shells indicating successful hatch; number of young unknown but "1" included in totals

[4] P values: * = P < 0.05; ** = P < 0.01; *** = P < 0.001; ns = P > 0.05

used by Common Loons and grouped with them in Figure 3. A MANOVA of Common Loon wetland characteristics with those of the four wetlands showed a significant difference between the two groups ($F_{2,7} = 6.75$; $P < 0.05$). However, only wetland area contributed to the overall significant effect ($F_{1,10} = 19.61$; $P < 0.001$). Common Loon wetlands had a mean area of 32.8 ha (± 5.6 ha SE; min: 15.9 ha; max: 55 ha) while the four wetlands without birds had a mean area of 7.5 ha (± 2.4 ha SE; min: 2.8 ha; max: 12 ha).

Table 9. The number of indicated pairs, broods, and young counted on the lacustrine and palustrine wetlands in the mid-Vancouver Island study area. Chi-square tests of the difference in indicated pairs, broods, and young between the wetland types showed significant differences with the exception of indicated pairs in 1996. The difference in the proportion of the two wetland types was considered in the calculations.

	N	Indicated pairs		Broods		Young	
		1981	1996	1981	1996	1981	1996
Lacustrine	19	28	47	13	22	21	102
Palustrine	12	43	35	22	27	98	114
Totals	31	71	82	35	49	119	216
χ^2_{Yates}		**12.98***[1]**	0.33^{ns}	**7.40****	**4.69***	**92.2*****	**16.66*****

[1] P values: * = P < 0.05; ** = P < 0.01; *** = P < 0.001; ns = P > 0.05

Most of the waterbirds in our study occupied a wide niche (Figure 3), occurring in both lacustrine and palustrine wetlands (*e.g.* Mallard, Canada Goose, Hooded Merganser, Common Merganser, and Pied-billed Grebe); only two species were confined to specific wetland types: Common Loon to lacustrine and Blue-winged Teal to palustrine wetlands. Table 10 shows summary statistics of the attributes of wetlands used by the four species that occurred on over 20% of the study wetlands; sample sizes for the other species were considered too small to be meaningful.

Waterbird species

The following descriptions of the individual species and wetland attributes they used are discussed in general terms based on Figure 3, principally because of small sample sizes; the two significant attributes from the CCA, depth and dissolved oxygen, are emphasized. Where the sample sizes are larger, we give more details (Table 10).

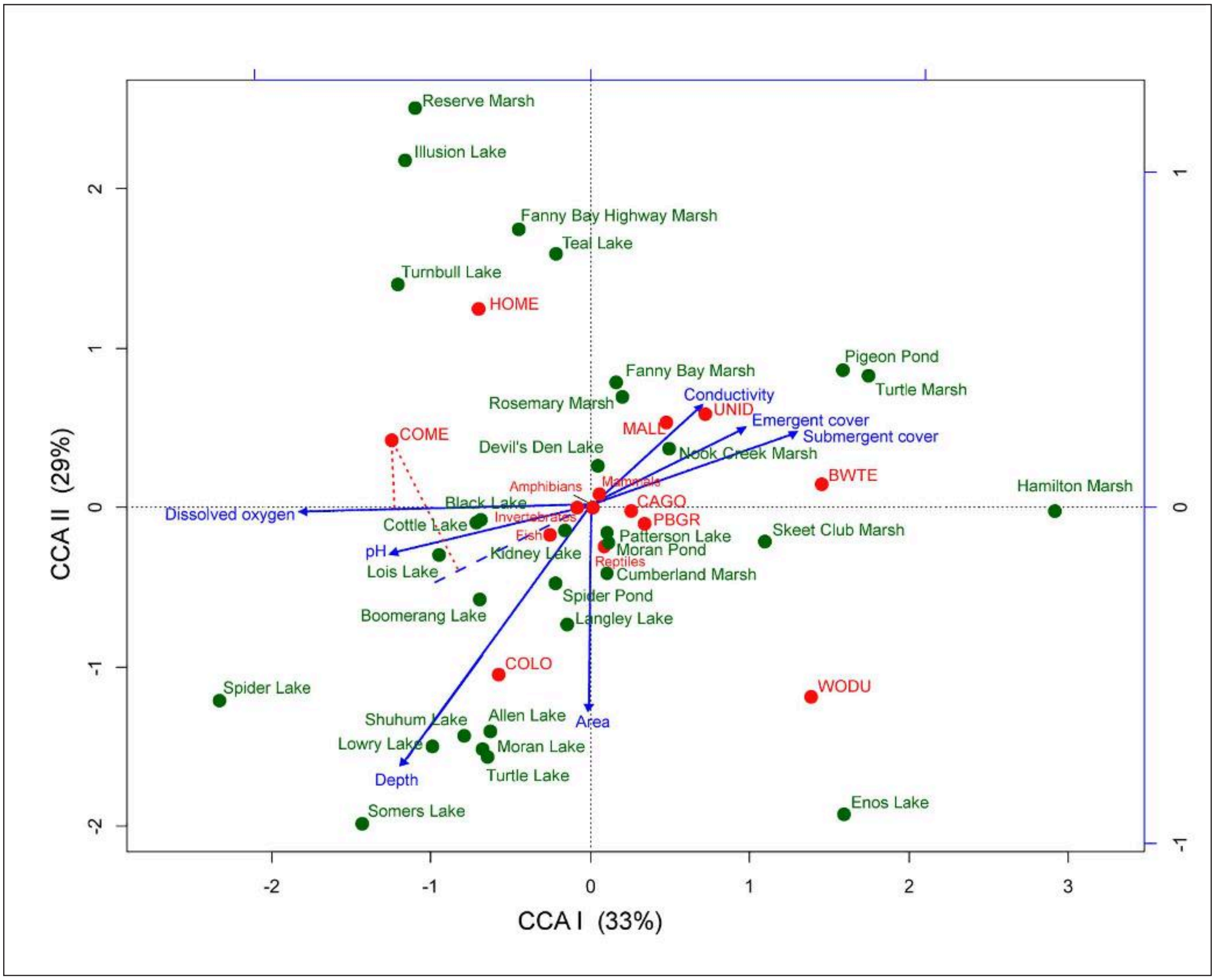


Figure 3. Canonical Correspondence ordination triplot (Type II scaling) of the waterbird and sundry species (red disks), wetlands (green disks), and environmental indicators (blue arrows). The eigenvalues of the first two axes are 0.13 and 0.11 respectively; 62% of the variance in the weighted averages of species constrained by the environmental variables is shown. The first axis tends to separate lacustrine wetlands on the negative side of the axis from palustrine wetlands on the positive side. The second canonical axis also tends to separate the palustrine wetlands on the positive side of the axis from lacustrine wetlands on the negative side of the axis. Arrow lengths indicate the relative importance of the environmental variables; the grand mean of each environmental variable falls at the origin of the graph. Orthogonal projections (dashed red lines) of a species onto the environmental arrows suggests the environmental optimum for that species. For example, Common Merganser (COME) tends to favour wetlands with high levels of dissolved oxygen and a low percentage of emergent vegetation cover. Although all arrows can aid in interpreting species positions, only depth and dissolved oxygen were significantly related to the species data in the CCA. Waterbird species codes: BWTE = Blue-winged Teal; CAGO = Canada Goose; COLO = Common Loon; COME = Common Merganser; HOME = Hooded Merganser; MALL = Mallard; PBGR = Pied-billed Grebe; UNID = unidentified waterbird; WODU = Wood Duck.

Canada Geese favoured lacustrine and palustrine wetlands equally; they had an optimal response to environmental variables that were near their grand means (Figure 3). Depth of Canada Goose wetlands ranged from 0.7 m to 9.5 m with a mean depth of 3.4 ± 1.5 m SE; their dissolved oxygen levels averaged 5.8 ppm ± 0.9 ppm SE.

Wood Ducks and **Blue-winged Teal:** Little can be said of their optimal response to wetlands due to the small sample sizes.

Mallards in both years, occurred significantly more often in palustrine rather than lacustrine wetlands (1981: $\chi^2_{\text{Yates}} = 13.8$; $P < 0.001$; 1996: $\chi^2_{\text{Yates}} = 10.3$; $P < 0.002$) thus we have separated the lacustrine and palustrine wetland attributes for Mallard in Table 10. Figure 3 suggests Mallards had an optimum response to using shallower, smaller wetlands, some as small as 0.5, ha although some were as large as 52.5 ha (Figure 3; Table 10). They also seemed to prefer wetlands with higher levels of submer-

Table 10. Select species and summary statistics of the attributes of wetlands adult waterbirds were found using on mid-Vancouver Island in 1981.

		Depth m	Area ha	Open water %	Emergent cover %	Aquatic cover %	Secchi disk m	Conduct-ivity μmhos/cm	Dissolved O_2 ppm	pH	CO_2 ppm	Hardness ppm	Ca Hardness ppm	Mg Hardness ppm	Temperature °C
Mallard n=7; 23% Lacustrine	Min	2.5	1.5	20	5	0	1.8	31	5.2	5.8	1	18	8	8	18.5
	Max	9.5	52.5	95	75	10	3.5	120	10.7	6.8	10.5	48	30	28	25
	Mean	5.0[1]	20.8	63.9[1]	32.1	4.0[1]	2.9[1]	61.7	7.8	6.3	3.9[1]	29.7	15.4	14.3	20.8
	Std. error	0.9	6.2	9.3	9.1	1.3	0.2	11.5	0.7	0.1	1.3	4.5	2.9	2.7	0.9
	Median	4.75	18.7	67	30	5	3.1	58	8	6.5	2.5	26	12	10	20
Mallard n=9; 29% Palustrine	Min	0.3	0.5	5	15	0	0.3	30	2	5.3	2	12	4	8	14.5
	Max	1.5	32.9	60	85	75	1.3	220	11.2	6.9	34	84	62	24	23
	Mean	0.9[1]	8.3	24.4[1]	46.7	28.9[1]	0.8[1]	82.7	5.7	6.1	14.1[1]	37.1	21.7	15.4	18.4
	Std. error	0.1	3.6	7.0	8.5	9.1	0.1	18.9	0.9	0.2	3.0	6.9	5.9	1.8	0.9
	Median	1	4.6	20	40	25	0.8	63	5.2	6.3	12	36	20	16	18.5
Hooded Merganser n=9; 29%	Min	0.3	0.5	5	5	0	0.3	30	2.7	5.3	1	12	4	8	16
	Max	9.5	20.9	95	85	75	3.5	220	11.2	6.9	21	84	62	22	23
	Mean	2.3	9.4	48.3	32.8	18.9	1.6	83.8	7.4	6.3	8.6	35.3	21.6	13.8	19.0
	Std. error	1.0	2.8	10.9	8.9	8.2	0.4	19.8	0.9	0.2	2.4	7.2	5.7	1.7	0.8
	Median	1.3	6.0	55.0	20.0	10.0	1.3	63.0	7.4	6.5	8.0	36.0	20.0	14.0	18.5
Pied-billed Grebe n=17; 55%	Min	0.33	0.9	5	3	0	0.3	24	2	5.3	1	8	4	4	14
	Max	12.5	55	95	75	75	6.8	108	10.7	6.8	35	50	34	24	25
	Mean	4.7	19.3	54.0	32.5	13.5	2.6	51.7	7.1	6.2	9.9	26.4	13.9	12.5	18.9
	Std. error	1.0	3.9	7.7	5.5	4.9	0.5	5.8	0.5	0.1	2.4	2.7	2.1	1.1	0.7
	Median	3.5	18.3	60	35	5	2.5	46	7.4	6.3	6	24	12	11	18.5
Common Loon n=9; 29%	Min	2.5	15.9	20	3	0	2.5	24	6.3	5.8	2.3	8	4	4	18
	Max	12.5	55	95	75	15	9.1	58	9.5	6.8	6	32	20	26	21
	Mean	7.8	31.5	73.3	21.9	4.8	4.7	37.9	8.2	6.5	3.8	21.0	10.2	10.8	19.3
	Std. error	1.1	5.1	8.1	8.0	1.6	0.7	3.5	0.4	0.1	0.5	2.3	1.5	2.0	0.4
	Median	6.7	24	80	10	3	4.5	38	8.8	6.6	3	20	10	10	19.5

[1] These attributes between the lacustrine and palustrine wetlands used by Mallards are significantly different based on the two-sample *t*-test; P all < 0.05

gent and emergent vegetation cover and conductivity levels and lower levels of dissolved oxygen and pH. There was no significant difference in size between the lacustrine and palustrine wetlands the Mallard used; however, the palustrine wetlands were significantly shallower with a mean depth of less than 1 m compared to a mean depth of 5 m in the lacustrine wetlands they used. The palustrine wetlands they frequented also had significantly less open water, more aquatic vegetative cover with higher turbidity and CO_2 levels (Table 10). Figure 3 also suggests that the unidentified waterbirds were likely Mallards.

Hooded Mergansers had an optimum response toward the shallower, smaller wetlands, with mid levels of vegetative cover and higher levels of conductivity, dissolved oxygen, and pH. The wetlands they used averaged 9.4 ha in size and 2.3 m in depth with dissolved oxygen levels averaging 7.4 ppm (Figure 3).

Common Mergansers favoured the deeper (mean: 5.6 m ± 2.3 m SE), smaller wetlands with lower vegetation cover (higher open water cover) and conductivity levels (Figure 3). Dissolved oxygen (mean: 8.9 ppm ± 1.1 ppm SE) and pH levels were in the higher ranges.

Pied-billed Grebes had an optimum response to mid-sized and mid-depth wetlands (Figure 3); however, they were found on wetlands as small as 0.9 ha and as large as 55 ha (Table 10). The grebes frequented wetlands with mid levels of emergent and submergent and floating-leaved vegetation cover. Pied-billed Grebes had an optimum response to mid conductivity, dissolved oxygen, and pH levels (Figure 3; Table 10) and showed no preference for lacustrine or palustrine wetlands in 1981 ($\chi^2_{\text{Yates}} = 0.94$; $P > 0.05$) or 1996 ($\chi^2_{\text{Yates}} = 0.25$; $P > 0.05$).

Common Loons had an optimum response to the deeper, larger lacustrine wetlands with large areas of clear, open water and low levels of emergent and submergent cover and conductivity (Figure 3; Table 10). Higher dissolved oxygen and pH levels were also factors in their optimum response to wetland use.

Incidental wildlife species

Table 11 shows the incidental aquatic species (fish, amphibians, reptiles, mammals) we recorded during our surveys. Incidental species presence or absence data were used in the CCA and the species are all centered around the origin of Figure 3 suggesting each occurred equally in both types of wetlands. Chi-square analysis of the frequencies of these species showed there was no difference in their occurrence between lacustrine and palustrine wetlands (χ^2_{Yates}; $P > 0.05$).

Table 11. Incidental aquatic species observed during waterbird surveys in 1981 in the mid-Vancouver Island region.

Taxa
Fishes – 77%[1]
Trout spp. – *Oncorhynchus* spp. – 23%
Threespine Stickleback – *Gasterosteus aculeatus* Linnaeus – 45%
Pumpkinseed – *Lepomis gibbosus* (Linnaeus) – 26%
Amphibians – 68%
Northwestern Salamander – *Ambystoma gracile* Baird – 3%
Rough-skinned newt – *Taricha granulosa* (Skilton) – 19%
Western Toad – *Anaxyrus boreas* - Baird and Girard – 6%
Pacific Treefrog – *Pseudacris regilla* Baird and Girard – 23%
Northern Red-legged Frog – *Rana aurora* Baird and Girard – 3%
American Bullfrog – *Lithobates catesbeianus* Shaw – 6%
Reptiles – 13%
Puget Sound Gartersnake – *Thamnophis sirtalis pickeringii* Baird and Girard – 29%
Northwestern Gartersnake – *Thamnophis ordinoides* Baird and Girard – 13%
Mammals – 21%
American Beaver – *Castor canadensis* Kuhl – 71%
Muskrat – *Ondatra zibethicus* Linnaeus – 23%
American Mink – *Neovison vison* Schreber – 3%

[1] Frequency of occurrence in 31 wetlands

Discussion

Wetlands

Vancouver Island wetlands were not considered optimum production areas for waterfowl by the Canada Land Inventory biologists in the 1960-1980s. In our study area, 58% of the 31 surveyed wetlands were classified by the CLI as having *moderately severe limitations* for waterfowl production followed by 19% with *severe limitations* (Table 12). Only three wetlands had *moderate* to *slight limitations*. In comparison, the Cariboo Parklands hold some of the best waterbird nesting habitats in British Columbia. In a 2001 study of 50 Cariboo wetlands, Dawe *et al.* (2003) found that 78% of the CLI classifications ranged from *no significant limitations* to *moderate limitations* followed by 20% with *moderately severe limitations*. Vancouver Island wetlands were not considered optimum production areas for waterfowl by the Canada Land Inventory biologists. Nevertheless, the use by and production of some waterbird species in our study wetlands on Vancouver Island were comparable to or exceeded those of the Cariboo Parklands, despite some significant differences in biological attributes (Table 13).

CLI rating	Description	Cariboo[1]		Vancouver Island[2]	
		No. wetlands	%	No. wetlands	%
1	No significant limitations	7	14	0	0
2	Very slight limitations	5	10	0	0
3	Slight limitations	5	10	1	3
4	Moderate limitations	22	44	2	7
5	Moderately severe limitations	10	20	18	58
6	Severe limitations	1	2	6	19
nr	Not rated			4	13
Totals		50	100	31	100

[1] (Dawe *et al.* 2003)
[2] This study

Table 12. Comparison of Cariboo and Vancouver Island Canada Land Inventory (CLI) general wetland classes for waterfowl production.

The lacustrine wetlands in our study tended to be smaller and deeper with less turbidity, lower conductivity and with pH levels slightly acidic or circumneutral compared to the high conductivity, alkaline lakes of the Cariboo (Table 13). Our palustrine wetlands tended to be smaller, shallower wetlands with a smaller proportion of open water than those of the Cariboo. While there was no significant difference between the turbidity of the Cariboo palustrine wetlands versus those of Vancouver Island, the Cariboo palustrine wetlands had significantly higher conductivities and were considerably more alkaline (Table 13). Generally, the higher the conductivity, the more productive the water body (Leech Lake Band of Ojibwe 2017).

In both lacustrine and palustrine wetlands, studies have shown that the more acidic a wetland, the lower the rate of plant production and the slower the decomposition rate of plant material. This would affect key aspects of the nutrient cycle such as the diversity of detritivore invertebrates, which would ultimately affect organisms higher in the food chain such as waterbirds (Kok *et al.* 1990; Kok and Velde 1994; Silk and Ciruna 2005). Higher plant species richness and rates of plant production and faster decomposition rates have been documented in wetlands having alkaline waters (Kok and Velde 1994; Silk and Ciruna 2005; Lacoul and Freedman 2006).

A number of studies have shown that the highest densities of dabbling duck pairs occur on wetlands with an open water-emergent vegetation ratio of 50:50 with considerable intermixing of the vegetation and open water, often called a hemi-marsh (Dennis 1982; Murkin *et al.* 1997). Hemi-marsh conditions appear to be better approximated on the Cariboo palustrine wetlands than the wetlands in this study.

Invertebrates

Invertebrate abundance and availability, both of which play significant roles in breeding waterfowl populations (Dennis 1982; Batzer and Wissinger 1996; Paszkowski and

Table 13. Comparative wetland characteristics between select Cariboo wetlands from Dawe et al. (2003) and wetlands in this study.

Location	Statistic	Lacustrine wetlands						Palustrine wetlands					
		Area	Depth	Open water	Secchi disk	Conduct-ivity	pH	Area	Depth	Open water	Secchi disk	Conduct-ivity	pH
		ha	m	%	m	µmhos·cm^{-1}		ha	m	%	m	µmhos·cm-1	
Cariboo	n (v1=n-1)	27	20	27	25.0	24	25	23	20	23	13.0	23	23
	Min	9.3	0.5	28.0	0.2	82.0	0.9	0.7	1.0	7.7	0.3	98.0	8.3
	Max	159.2	15.0	100.0	5.6	5885.0	9.9	116.0	5.0	100.0	2.2	5000.0	10.0
	Mean	56.2	4.6	75.1	2.1	1044.9	8.0	12.0	2.1	60.1	1.4	1668.8	9.1
	Std. error	6.9	0.9	3.8	0.2	319.0	0.5	4.9	0.3	6.7	0.1	282.8	0.1
	Median	50.1	3.4	74.2	2.0	537.5	8.8	5.7	1.5	55.6	1.5	1380.0	9
This study	n (v2=n-1)	19	19	19	19.0	19	19	12	12	12	12.0	12	12
	Min	1.5	1.5	20.0	0.3	24.0	5.8	0.5	0.3	5.0	0.5	30.0	5.3
	Max	55.0	15.0	98.0	9.1	120.0	6.8	32.9	1.5	60.0	7.9	220.0	6.9
	Mean	20.2	7.7	73.2	3.3	49.6	6.3	6.9	1.0	26.7	2.3	75.8	6.1
	Std. error	3.6	0.9	5.5	0.5	5.3	0.1	2.8	0.1	6.3	0.7	14.8	0.1
	Median	18.3	6.7	80.0	3.1	42.0	6.4	3.5	1.0	20.0	1.2	63.0	6.3
t-test$_{(2),v1+v2}$	*t*	4.64***	-2.48*	0.29^{ns}	-2.06*	3.12**	3.10**	0.72^{ns}	3.65**	3.24**	-1.45^{ns}	5.62***	16.21***

[1] P values: * = P < 0.05; ** = P < 0.01; *** = P < 0.001; ns = P > 0.05

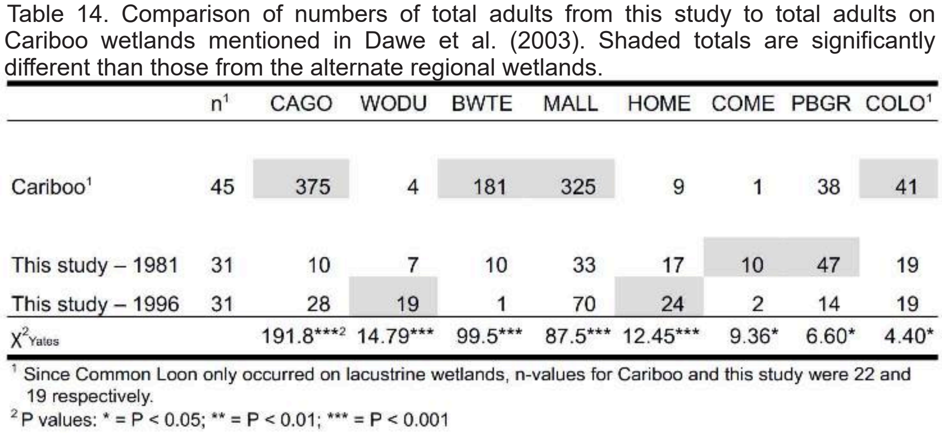


Table 14. Comparison of numbers of total adults from this study to total adults on Cariboo wetlands mentioned in Dawe et al. (2003). Shaded totals are significantly different than those from the alternate regional wetlands.

	n^1	CAGO	WODU	BWTE	MALL	HOME	COME	PBGR	COLO[1]
Cariboo[1]	45	375	4	181	325	9	1	38	41
This study – 1981	31	10	7	10	33	17	10	47	19
This study – 1996	31	28	19	1	70	24	2	14	19
X^2_{Yates}		191.8***[2]	14.79***	99.5***	87.5***	12.45***	9.36*	6.60*	4.40*

[1] Since Common Loon only occurred on lacustrine wetlands, n-values for Cariboo and this study were 22 and 19 respectively.

[2] P values: * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$

Tonn 2000), are determined by the density, abundance, and species composition of the vegetation (Dennis 1982; Maurer 2013). Although the pH of Vancouver Island wetland waters tended towards slightly acidic or circumneutral (Tiner 1999) rather than alkaline, the acidification of wetlands has been shown to have little impact on insects and may actually benefit some by reducing fish populations (Batzer and Wissinger 1996). However, higher macroinvertebrate diversity has been associated with more alkaline as opposed to acidic wetlands (Friday 1987; Kok and Velde 1994). Invertebrate taxa richness has been shown to decrease with increasing water depth due to increasing fish abundance and declining plant abundance, the latter having adverse effects on invertebrates (Maurer 2013).

A number of studies document midge larvae and emerging adults of most importance to ducks with caddisfly larvae, odonate nymphs, water beetle larvae and adults, and water boatmen also being of some importance (Batzer and Wissinger 1996). The dominant invertebrates in our study were from the latter group with few midges recorded. Boyd and Smith (1988) found large numbers of invertebrates in a study of their wetlands in the Chilcotin area of the Cariboo Parklands. The dominant taxa were, in order from highest to lowest numbers of individuals, the Cladocera (water fleas), Copepods , Amphipods, Coroxids (water boatmen), Chironomids (non-biting midges), and Chaoborids (phantom midges) with numbers such that "on some Cariboo ponds the ducks are literally swimming in a soup full of invertebrates" (W.S. Boyd, pers. comm.). Our wetlands held no such "invertebrate soup" nor did we note any significant invertebrate blooms that are important for brood rearing (Dennis 1982), which likely plays a role in the smaller numbers of waterbirds these Vancouver Island wetlands support.

Waterbirds

While numbers of Canada Geese, Mallards, Blue-winged Teal and Common Loons were significantly higher on wetlands in the Cariboo Parklands compared to numbers we found in our study wetlands on Vancouver Island, the opposite was true for Wood Duck, Hooded Merganser, Common Merganser and Pied-billed Grebe (Table 14).

We reported 52 and 55 instances of confirmed or suspected nesting from 8 and 6 species in 1981 and 1996 respectively from 31 wetlands. In an earlier Vancouver Island study, Robinson and Dorst (1974) report a total of 46 instances of confirmed or suspected nesting of 10 species (Canada Goose, Mute Swan, Wood Duck, Mallard, Harlequin Duck, Hooded Merganser, Common Merganser, Pied-billed Grebe, Red-throated Loon, Common Loon) from 49 areas on Vancouver Island in 1974, including lakes, marshes, rivers, estuaries, bays, and lagoons.

Brief comments on the nesting species of some significance from our study follow.

Canada Goose

The Canada Goose nests in a wide range of habitats (Campbell *et al.* 1990: 278; Mowbray *et al.* 2002; Martell 2015) and this was evident in our study in 1981 where they tended to favour lacustrine and palustrine wetlands equally and had an optimal response to the environmental variables that were near their grand means. Nesting Canada Geese showed a significant increase in numbers on the wetlands between 1981 and 1996. This is in line with the general increase in Canada Goose numbers on the east coast of Vancouver Island over the same period (Dawe and Stewart 2010). In fact, our numbers are likely conservative as Canada Geese can begin nesting much earlier than the starting dates of our surveys (Campbell *et al.* 1990: 278). For example, in 1995, up to 10 pairs of Canada Geese were reported from Hamilton Marsh (Cousens *et al.* 1996: 104). In 1996, 10–15 pairs of nesting geese were reported from Hamilton Marsh prior to the start of our survey (Bruce Cousens, pers. comm.); however, because of our later start, we observed no pairs on the marsh. Once the young leave the nest, the adults tend to move them to brooding areas, likely nearby agricultural fields, where young grasses suitable for goslings are available but are lacking in the marsh.

Large numbers of Canada Geese now occur on Vancouver Island and they are severely impacting estuarine habitats (Dawe and Stewart 2010; Dawe *et al.* 2011, 2015). It would be of management value to have a better idea of their nesting areas and other aspects of their breeding biology.

Wood Duck

Wood Duck breeding habitat includes abundant plant and invertebrate foods that are near their nest sites. Wetlands with dense stands of emergent vegetation and shrubs are important. Another important factor for this species is the requirement for nest cavities of a certain size, in trees with a dbh near 60 cm, preferably near or adjacent to the wetland, although they will nest up to 2 km from water (Hepp and Bellrose 1995). However, numbers of natural cavities are low on Vancouver Island. The increase in adult Wood Duck numbers between 1981 and 1996 is likely due to the installation of nest boxes by local Fish and Game Clubs. For example, in the general Errington area, only two breeding Wood Duck pairs were known in the early 1990s. By 1995, 15 pairs were found, two of which nested at Hamilton Marsh where 12 nest boxes were available (Cousens *et al.* 1996).

Mallard

In this study, Mallards tended to use the shallower, smaller wetlands, with higher levels of submergent and emergent vegetation cover and conductivity levels with lower levels of dissolved oxygen and pH. They used palustrine wetlands significantly more than lacustrine wetlands but were found on a wide variety of wetlands. Other authors found similar results, with Mallards using a wide variety of structurally different wetlands according to their availability although they tended to favour smaller wetlands that were not devoid of vegetation (Mulhern *et al.* 1985*;* Drilling *et al.* 2002).

Hooded Merganser

The Hooded Merganser is not a common nesting species anywhere in the Cariboo Parklands or on the coast, including Vancouver Island (Campbell *et al.* 1990: 360; Dawe *et al.* 2003) although numbers tend to be higher on Vancouver Island than in the Cariboo Parklands (Table 14). This species also benefits from the installation of nest boxes adjacent to wetlands (Campbell *et al.* 1990; Dugger *et al.* 1994). It is tied to forested wetlands and, in Ontario, females with broods tend to favour small, oligotrophic, fishless, headwater ponds, with neutral acidity (Dugger *et al.* 1994), much of which we found on the Vancouver Island wetlands with this species (Table 2).

Common Merganser

The Common Merganser appears to be a very rare nesting species in the Cariboo Parklands (Dawe *et al.* 2003), presumably because those wetlands are not connected or associated with streams or rivers. In addition, many of the wetlands in the Cariboo Parklands lack aquatic vertebrates (amphibians; fish) (Brent Gurd, pers. comm.). These factors likely account for the significantly larger adult numbers we found on Vancouver Island, where it is a common nesting species in summer (Campbell *et al.* 1990: 362). The Common Merganser tends to prefer nesting near oligotrophic water bodies surrounded by forests and with abundant fish populations and moderate to high pH values (Pearce *et al*. 2015), similar to the Vancouver Island wetlands where we found this merganser. Females move their broods downstream to larger water bodies or to the coast so drainage systems are important. The Common Merganser is a cavity nester that will also use nest boxes (Pearce *et al*. 2015). For this and the previous two species in other regions, the availability of cavity-producing trees has been reduced through forestry practices (Dugger *et al.* 1994; Hepp and Bellrose 1995; Pearce *et al*. 2015).

Pied-billed Grebe

Pied-billed Grebes occurred on 55% of the 31 wetlands we studied in 1981 but only on 23% of the wetlands in 1996 and grebe numbers in 1996 were significantly lower than in 1981. Nest searches conducted by canoe in 1981, but not in 1996, could account for some of this decrease. In the Cariboo Parklands, Savard *et al.* (1994) found this grebe on 22% of their 112 wetlands; Dawe *et al.* (2003) found Pied-billed Grebes on 27% of their 45 Cariboo wetlands. Breeding bird survey data for the period 1980–1999 indicate that British Columbia populations declined at a rate of 13.3% ($P < 0.01$) (Sauer *et al.* 2002), which reflects the decline in their numbers from our wetlands over the 15 years. However, the data on which that negative trend is based has important deficiencies that should be considered (Sauer *et al.* 2002). In 1981, this grebe had significantly more adults on our Vancouver Island wetlands compared to those of the Cariboo in 2000 (Table 14); however, that was not the case in 1996. Pied-billed Grebes in our study were found on wetlands ranging from 0.9–55 ha in size. Other authors found that this grebe used wetlands ranging from 0.6–20 ha with some concluding that Pied-billed Grebes are wetland area dependent (Faaborg 1976; Brown and Dinsmore 1986; Naugle *et al.* 1999); that did not appear to be the case on Vancouver Island, considering the large range in wetland sizes the grebes were using. Pied-billed Grebes in this study tended to have an optimum response near the grand mean of each environmental variable suggesting the bird was somewhat of a generalist. In other studies, the Pied-billed Grebe usually occurred where there were dense stands of emergent and aquatic vegetation with large areas of adjacent open water and a water depth > 25 cm —an important requirement for nesting—and lower pH and conductivity levels (Faaborg 1976; Savard *et al.* 1994; Muller and Storer 1999; Darrah and Krementz 2010), none of which differed substantially from what we found.

Common Loon

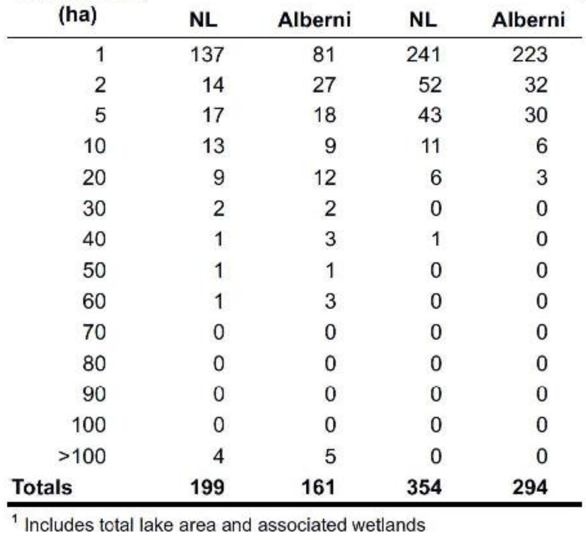
Lakes used by Common Loons in our study ranged from 15.9–55 ha in size (Table 10) and of the 11 lacustrine wetlands ≥ 15.9 ha, all but two were occupied by loons. Evers *et al.* (2010) found that loons prefer lakes larger than 24 ha with clear water, an abundance of small fish—although fish are not absolutely necessary (Paszkowski and Tonn 2000)—and an irregular shoreline. Similar to our study, others found that preferred breeding habitats were the larger, oligotrophic lakes with high water clarity for efficient foraging; their foraging behaviour is changed at secchi disk readings of less than 1.5 m (McNicol *et al.* 1995; Evers *et al.* 2010; Radomski *et al.* 2014). The pH of lakes in our study tended to be above the sub-optimal range for breeding loons found by Alvo (2009) in Ontario. Gibbs *et al.* (1991) found that the areal extent of open water was an important aspect of lakes in Maine used by Common Loons, with nesting loons avoiding lakes with only 33% open water; however, we had a nesting pair on Moran Lake with only 20% open water. Still, the mean open water extent of the lakes used by loons in our study was over 73%. While the Common Loon is noted for its overt aggression to heterospecifics on its breeding lakes (Evers *et al.* 2010), of the nine lakes in our study that supported breeding pairs of loons, seven also included breeding waterfowl and grebes.

Conclusion

It is important to emphasize that only two years of surveys of 31 wetlands were involved in this study. As a result, sample sizes are minimal when comparing 1981 to 1996 data and our study wetlands to those of the Cariboo Parklands. Water chemistry analysis was only carried out in 1981 so changes could have occurred in the interim. However, we believe the data are valuable as a baseline, especially if the surveys are repeated to assess, *e.g.*, effects of climate change on wetlands and their use by waterbirds.

While the numbers of breeding waterbirds we found are relatively low compared to those of the Cariboo Parklands, and tend to support the initial CLI results, they may not be insignificant considering the total number of wetlands that lie within our general study area (Table 15; Figure 4) let alone Vancouver Island as a whole. We surveyed only 5% of the lacustrine and 2% of the palustrine wetlands within our general study area. Using the Common Loon as an example, there are 44 lakes >15.9 ha in the total study area (Table 15). Of the 11 lakes we surveyed >15.9 ha, 9 were used by loon pairs in 1996, which suggests, c*eteris paribus*, there could be 36+ pairs of loons nesting within our general study area. In addition, a number of nesting species we found on our wetlands in some years actually held significantly higher numbers compared to those in the Cariboo Parklands where some of the finest waterbird nesting habitat in the province occurs (Table 14).

Table 15. Estimated total number of lacustrine and palustrine wetlands in the Nanaimo Lowland (NL) and Alberni valley study areas. Data taken from the British Columbia Freshwater Atlas (2017).



Wetland size (ha)	Lacustrine wetlands[1]		Palustrine wetlands	
	NL	Alberni	NL	Alberni
1	137	81	241	223
2	14	27	52	32
5	17	18	43	30
10	13	9	11	6
20	9	12	6	3
30	2	2	0	0
40	1	3	1	0
50	1	1	0	0
60	1	3	0	0
70	0	0	0	0
80	0	0	0	0
90	0	0	0	0
100	0	0	0	0
>100	4	5	0	0
Totals	**199**	**161**	**354**	**294**

[1] Includes total lake area and associated wetlands

Even those species occurring in lower numbers on Vancouver Island compared with the Cariboo Parklands, such as Mallard and Blue-winged Teal, could be ecologically important. These disjunct populations may have diverged genetically through genetic drift and adaptations to their local, sub-optimal environment, and could impart novel evolutionary pathways for future migration and speciation events (Leppig and White 2006). As Noss (1994) points out, "If we are concerned with maintaining opportunities for speciation—future biodiversity—then conservation of peripheral and disjunct populations is critical." Species from disjunct populations in British Columbia may be all the more important as wetlands become vulnerable to climate change, particularly in the Central Interior where moisture loss is projected to cause wetland shrinkage due to temperature and precipitation changes. Such changes will affect waterbird species dependent on those wetlands (Compass Resource Management 2007).

This preliminary study has shown that Vancouver Island wetlands can provide nesting and young-rearing sites for a number of waterbird species with some species having significant numbers of individuals and young produced compared to the best waterfowl nesting habitat in the province. Further studies that include a greater number of wetlands in the sample size as well as those that compare the genetic makeup of Vancouver Island populations to those of the Cariboo Parklands could further reveal the value of these wetlands to the maintenance of avian biodiversity in British Columbia.

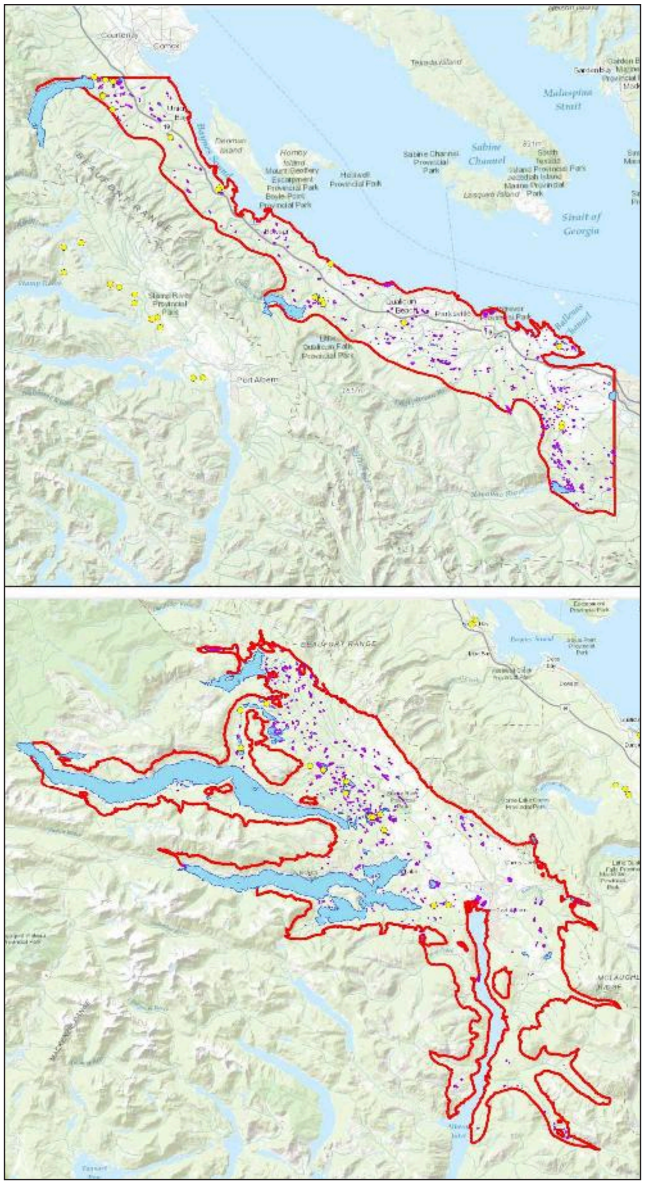


Figure 4. General study area for (top) the Nanaimo Lowland and (bottom) the Alberni valley (red outlines) showing the study wetlands (yellow dots), total number of palustrine wetlands (purple polygons), and total number of lacustrine wetlands (dark-blue polygons).

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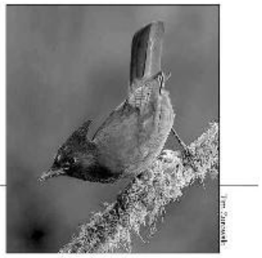
Appendices ►



Appendix I. Frequency of occurrence (F) and mean cover (MC) of obligate and facultative wetland species from 20 minute sample surveys of 31 wetlands in the mid-Vancouver Island region. Species are ordered within groups according to their frequency of occurrence.

Species	F	C
Alga		
Chara sp.	35	24
Moss		
Sphagnum spp.	16	33
Aquatics – submerged and floating-leaved		
Nuphar polysepala Engelm (Engelm.) E.O. Beal	90	7
Brasenia schreberi J.F. Gmel.	55	20
Utricularia macrorhiza Leconte	55	11
Potamogeton gramineus L.	29	4
Potamogeton pusillus L.	29	t
Menyanthes trifoliata L.	26	21
Potamogeton amplifolius Tuck.	23	4
Utricularia gibba L.	19	13
Potamogeton sp	19	3
Potamogeton epihydrus Raf.	19	1
Utricularia intermedia Hayne	16	11
Potamogeton cf. *oakesianus* J.W. Robbins	16	2
Lemna minor L.	16	2
Myriophyllum verticillatum L.	13	28
Utricularia sp.	13	7
Potamogeton praelongus Wulfen	13	7
Potamogeton natans L.	13	4
Potamogeton foliosus Raf.	6	14
Potamogeton robbinsii Oakes	6	11
Sparganium natans L.	6	3
Potamogeton alpinus Balbis	6	2
Sparganium eurycarpum Engelm.	6	2
Persicaria amphibia (L.) S.F. Gray	6	2
Potamogeton pusillus L.	6	t
Utricularia minor L.	3	19
Sparganium angustifolium Michx.	3	5
Sparganium emersum Rehmann	3	1
Ceratophyllum echinatum A. Gray	3	t
Aquatics – typical emergents		
Typha latifolia L.	55	14
Dulichium arundinaceum (L.) Britton	55	3
Carex utriculata Boott	48	5
Carex lasiocarpa Ehrh.	42	19
Carex sitchensis Prescott ex Bong.	39	15
Scirpus subterminalis Torr.	35	3
Juncus effusus L.	35	1
Scirpus validus Vahl	32	6
Eleocharis palustris (L.) Roem. & Schult.	32	4
Carex echinata Murray *subsp. echinata*	26	t
Carex cusickii Mack. ex Piper & Beattie	23	6
Carex exsiccata L.H. Bailey	23	10
Carex obnupta L.H. Bailey	16	10
Carex sp.	16	1
Juncus supiniformis Engelm.	13	1
Juncus ensifolius Wikstr.	13	t[1]
Eriophorum chamissonis C.A. Mey.	13	t
Carex lenticularis Michx.	10	t
Juncus sp.	6	13
Scirpus cf. cyperinus (L.) Kunth	6	2
Equisetum fluviatile L.	6	t
Juncus acuminatus Michx.	3	4
Juncus balticus Willd.	3	t
Scirpus sp.	3	t
Grasses		
Phalaris arundinacea L.	16	1
Glyceria borealis (Nash) Batchelder	6	1
Torreyochloa pauciflora (J. Presl) Church	6	1
Glyceria striata (Lam.) Hitchc.	3	1
Alopecurus geniculatus L.	3	t
Deschampsia sp.	3	t
Glyceria elata (Nash ex Rydb.) M.E. Jones	3	t
Calamagrostis canadensis (Michx.) P. Beauv.	6	1
Herbs		
Mentha arvensis L.	65	1
Drosera rotundifolia L.	58	1
Comarum palustre L.	52	2
Rhynchospora alba (L.) Vahl	32	2
Veronica scutellata L.	23	6
Hypericum anagalloides Cham. & Schltdl.	23	t
Myosotis laxa Lehm.	19	1
Lysichitum americanum Hulten & H. St. John	19	t
Cicuta douglasii (DC.) J.M. Coult. & Rose	16	t
Triantha glutinosa (Michx.) Baker	16	t
Scutellaria galericulata L.	13	1
Oenanthe sarmentosa C. Presl ex DC.	13	t
Trientalis europaea subsp. arctica L. (Fisch. ex Hook.) Hulten	13	t
Drosera anglica Huds.	10	t
Lysimachia thyrsiflora L.	10	t
Sanguisorba officinalis L.	10	t
Mimulus guttatus DC.	6	1
Sium suave Walter	6	1

► ◄ Appendix I ►

[1] trace

Species	F	C
◄ Appendix I		
Galium trifidum L.	6	t
Lycopus uniflorus Michx.	6	t
Alisma gramineum Lej.	3	1
Epilobium ciliatum Raf.	3	1
Hypericum scouleri Hook.	3	t
Lycopus americanus Muhl. ex W. Bartram	3	t
Persicaria maculosa Gray	3	t
Ranunculus aquatilis L.	3	t
Rorippa curvisiliqua (Hook.) Besser ex Britton	3	t
Veronica anagallis-aquatica L.	3	t
Veronica beccabunga L.	3	t
Viola cf. lanceolata L.	3	t
Shrubs		
Spiraea douglasii Hook.	81	9
Myrica gale L.	61	28
Salix sp.	39	5
Rhododendron groenlandicum (Oeder) K.A. Kron & W.S. Judd	39	4
Vaccinium oxycoccos (L.) MacMill.	23	2
Kalmia microphylla (Hook.) A. Heller	19	5
Physocarpus capitatus (Pursh) Kuntze	13	3
Cornus stolonifera Michx.	10	5
Salix lucida Muhl.	3	4
Viburnum edule (Michx.) Raf.	3	t

[1] trace

Appendix II. Vegetation codes used in the text.

Code	Species
Alop geni	*Alopecurus geniculatus*
Bras schr	*Brasenia schreberi*
Care cusi	*Carex cusickii*
Care echi	*Carex echinata*
Care exsi	*Carex exsiccata*
Care lasi	*Carex lasiocarpa*
Care lent	*Carex lenticularis*
Care obnu	*Carex obnupta*
Care sitc	*Carex sitchensis*
Care utri	*Carex utriculata*
Cera echi	*Ceratophyllum echinatum*
Char sp.	*Chara* sp.
Cicu doug	*Cicuta douglasii*
Coma palu	*Comarum palustre*
Corn stol	*Cornus stolonifera*
Dros angl	*Drosera anglica*
Dros rotu	*Drosera rotundifolia*
Duli arun	*Dulichium arundinaceum*
Eleo palu	*Eleocharis palustris*
Equi fluv	*Equisetum fluviatile*
Erio cham	*Eriophorum chamissonis*
Glyc bore	*Glyceria borealis*
Glyc elat	*Glyceria elata*
Glyc stri	*Glyceria striata*
Hype anag	*Hypericum anagalloides*
Junc acum	*Juncus acuminatus*
Junc balt	*Juncus balticus*
Junc effu	*Juncus effusus*
Junc ensi	*Juncus ensifolius*
Junc supi	*Juncus supiniformis*
Kalm micr	*Kalmia microphylla*
Lemn mino	*Lemna minor*
Lysi amer	*Lysichitum americanum*
Lysi thyr	*Lysimachia thyrsiflora*
Ment arve	*Mentha arvensis*
Meny trif	*Menyanthes trifoliata*
Myos laxa	*Myosotis laxa*
Myri gale	*Myrica gale*
Myri vert	*Myriophyllum verticillatum*
Nuph poly	*Nuphar polysepala*
Oena sarm	*Oenanthe sarmentosa*
Pers amph	*Persicaria amphibia*
Phal arun	*Phalaris arundinacea*
Phys capi	*Physocarpus capitatus*
Pota alpi	*Potamogeton alpinus*
Pota ampl	*Potamogeton amplifolius*
Pota oake	*Potamogeton oakensianus*
Pota epih	*Potamogeton epihydrus*
Pota foli	*Potamogeton foliosus*
Pota gram	*Potamogeton gramineus*
Pota nata	*Potamogeton natans*
Pota prae	*Potamogeton praelongus*
Pota pusi	*Potamogeton pusillus*
Pota pusi	*Potamogeton pusillus*
Pota robb	*Potamogeton robbinsii*
Rhod groe	*Rhododendron groenlandicum*
Rhyn alba	*Rhynchospora alba*
Sali sp	*Salix* sp.
Sang offi	*Sanguisorba officinalis*
Scir cype	*Scirpus cyperinus*
Scir subt	*Scirpus subterminalis*
Scir vali	*Scirpus validus*
Scut gale	*Scutellaria galericulata*
Spar angu	*Sparganium angustifolium*
Spar emer	*Sparganium emersum*
Spar eury	*Sparganium eurycarpum*
Spar nata	*Sparganium natans*
Spha spp.	*Sphagnum* sp.
Spir doug	*Spiraea douglasii*
Torr pauc	*Torreyochloa pauciflora*
Tria glut	*Triantha glutinosa*
Trie euro	*Trientalis europaea*
Typh lati	*Typha latifolia*
Utri gibb	*Utricularia gibba*
Utri inte	*Utricularia intermedia*
Utri macr	*Utricularia macrorhiza*
Utri mino	*Utricularia minor*
Vacc oxyc	*Vaccinium oxycoccos*
Vero scut	*Veronica scutellata*