1999 American Avocet Research Project in British Columbia

Coordinated by
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Foreword

This volume consists of 4 parts:

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Les Gyug
Central Okanagan Naturalists Club
29 Sept 1999

1999 AMERICAN AVOCET RESEARCH

EXECUTIVE SUMMARY

American Avocets are known to have nested at seven locations in British Columbia. Only at Alki Lake, Kelowna, and Little White Lake, Clinton, have more than two nests been reported in any one year. The Alki Lake colony has been active for at least the last three years, with a maximum of 19 breeding pairs observed in 1998. Although breeding was not reported between 1994 and 1996, the high numbers of adults observed in these years (i.e., maximum of 8, 19, and 18 birds, respectively) suggest that nesting may also have occurred. A maximum of 12 nesting pairs was recorded at Little White Lake in 1999, but nesting likely also occurred in the previous three to four years.

The City of Kelowna has recently acquired the avocet colony site at Alki Lake and has plans to expand the Glenmore Landfill within the next 10 years. The Ministry of Environment, Lands and Parks, Water Management Board, is concerned about the escape of leachates from buried garbage at Alki Lake and requires the site to be dewatered. Both proposals would result in loss of important breeding habitat for avocets. Because of the value of the Alki Lake site to the British Columbia avocet population, the Central Okanagan Naturalists Club has partnered with other organizations to investigate options for maintaining a viable avocet breeding population in the central Okanagan. Since landfill development of all or a large portion of the current nesting site is inevitable, options for enhancing and/or creating habitats at other wetlands needed to be explored. To support avocet habitat creation or enhancement initiatives, several studies were undertaken in 1999 to investigate: a) avocet breeding populations, biology and habitat requirements; b) potential invertebrate prey of avocets; and c) water quality parameters in avocet nesting and foraging areas.

The maximum number of avocets observed at Kelowna and Little White Lake in 1999 was 45 (12 May) and 32 (01 June) adults, respectively. An estimated 13 breeding pairs were present at Alki Lake and 12 pairs nested at Little White Lake. Of 21 nesting attempts at Alki Lake, only five nests were known to have successfully hatched young. Fifteen nests were located on islands, five on artificial floating nesting platforms, and one on a mudflat. One of the nests on the floating platforms was successful. All nests were constructed on substrates devoid of vegetation. Territory size of nesting pairs at Alki Lake increased from 0.26 ha during incubation to 0.53 ha after hatching.

During the breeding season in Kelowna, avocets were observed foraging both at Robert and Alki lakes. At Robert Lake, avocets foraged primarily along shorelines where vegetation was absent. At Alki Lake, avocets foraged in all shallow mudflats and along gradually sloped shorelines devoid of vegetation. Most feeding (i.e., >72%) occurred in water 5 to 14 cm deep. In early spring, foraging adults were also observed along the Lake Okanagan lakeshore and at Chichester Bird Sanctuary.

Benthic and aquatic invertebrates were collected at Alki, Robert and Little White lakes, and several other suitable wetlands in the Kelowna and Little White Lake areas. American Avocet occurrence appeared to be related to high densities of invertebrates such as Chironomidae (midges), Ephydridae (brine flies), Hirudinea (leeches), Corixidae (water boatmen), and Cladocera (water fleas). The invertebrate fauna at Alki Lake was characterized by very dense chironomid populations (i.e., mean of ~20,000/ m^2), and high numbers of brine flies (~3,100/ m^2), water fleas (~2,200/ m^2), and water boatmen (~1,600/ m^2),. Robert Lake also had high numbers of chironomids (i.e., ~6,500/ m^2) and water fleas (~2,400/ m^2). The Chichester wetland was characterized by high numbers of chironomids (~8,700/ m^2), and very high densities of oligochaetes (blood worms; ~7,300/ m^2) and other annelids (~3,700/ m^2). No annelids were reported at either Alki or Robert lakes. East Little White Lake had moderate densities of chironomids (~1,700/ m^2) and water fleas (~1,700/ m^2). Interestingly, of the five sites in the Kelowna area, Bubna and #2 sloughs, north of Alki Lake, had the only high densities of amphipods (scuds), an important avocet food. Although high invertebrate densities may well attract avocets to certain wetlands, food supply alone does not explain the absence or presence of avocets. Potentially suitable sites not utilized by avocets in 1999 also had moderate invertebrate populations.

Particle size of substrates also appears to be a habitat attribute selected by avocets, which are known to require soft substrates for foraging. Substrates at sites where avocets were found in 1999 were softer than at sites where avocets were absent. Sediments at invertebrate rich sites such as Bubna and #2 sloughs were coarse and sandy and may have limited accessibility of prey to avocets.

Water chemistry analyses indicated that avocets appeared to occur at wetlands with high nutrients, high alkalinity, high total dissolved solids, and low dissolved oxygen. These parameters appear to be contributing to high densities of preferred invertebrate prey, and low vegetation cover on exposed substrates. Metal analyses indicated that concentrations of some elements, such as arsenic, were elevated at Alki Lake. The effect of potentially toxic metal concentrations on avocet breeding success at Alki Lake was not determined.

The results of the 1999 studies and published literature need to be carefully considered when designing wetlands for avocet foraging and nesting. With an estimated home range of approximately 0.5 ha per breeding pair, a target population of 12 nesting pairs and six non-breeding individuals would require the creation of about 10 ha of high quality habitat. Although there are many possible wetland designs, the most important features to be considered in the design are nesting islands comprised of shallow slopes and bare substrates, shallow water foraging areas (i.e., 1-17 cm) with soft substrates, and a deep water area to reduce access by terrestrial predators. A general guide to habitat design is that islands should comprise at least 10% of the overall area and that wide, shallow water foraging areas be located between islands. A deep water mote of approximately 1.5 m depth and 35 metres wide should be constructed around the nesting and foraging areas. Other considerations for the new wetland include maintenance of high salinity and alkalinity, control of water levels, and provision of vegetated nursery areas for chicks.

Preliminary discussions with CH2M, Gore & Storrie, the engineering firm responsible for landfill design, have identified three potential restoration sites in the Alki Lake vicinity: a) ponds and fields at north end of existing landfill; b) the marsh at eastern side of landfill; and c) at the south end of the future landfill. The preferred option is a wetland at the south end of the future landfill because of the long history of avocet use in the area, and proximity to other wetlands, such as Robert Lake, utilized for foraging. The Alki Lake option is preferred to habitat creation initiatives at other locations in the Kelowna area because: a) excavation and construction costs will likely be lower; b) water levels can be controlled; and c) avocets are already nesting in the area.

Sufficient biological information has been collected on avocet habitat and prey requirements to design a wetland highly attractive to avocets. The next important step is to undertake a cost-benefit analysis of: a) the various restoration sites; and b) different habitat design options. Once the analysis has been completed, a detailed design of the wetland must be undertaken ensuring that biological, engineering, substrate, and hydrological issues are carefully considered. Creation of a stable and attractive nesting and foraging location for avocets in the vicinity of Alki Lake will increase the likelihood that a viable breeding population of American Avocets will be maintained in British Columbia.

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Population Numbers, Breeding Success and Habitat Characteristics of the American Avocet (*Recurvirostra americana*) in British Columbia in 1999

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ABSTRACT

The only known American Avocet (*Recurvirostra americana*) colony in British Columbia prior to 1999, located at Alki Lake, Kelowna, is endangered because the site has been slated to become a sanitary landfill. We studied avocet population fluctuations, nesting and foraging habitat characteristics, reproductive biology and success, and predator risks in 1999 at Alki and Robert lakes, Kelowna, B.C. Former breeding sites in southern B.C. were surveyed for continued use by avocets.

In 1999, Alki Lake had 13 breeding pairs, Robert Lake had no breeding pairs, and a new colony discovered at Little White Lake, near Clinton had approximately 12 breeding pairs. Total provincial population is estimated to be 60 to 80 individuals. Kelowna is a major migration route for avocets in B.C. during April and May with avocet use noted at 5 wetlands and along shallow and exposed mudflats of the Okanagan Lake shoreline. By June, the Kelowna population mainly consists of breeding pairs at Alki Lake. By late June some avocets leave the breeding site at Alki Lake, but some remained until the end of August.

Egg laying dates ranged from 3 May to 22 June, and hatching dates ranged from 16 June to 20 July. Mean clutch size was 4.94 eggs per clutch. Single supernumerary nests were observed at Alki (six eggs) and Little White lakes (seven eggs), representing 7.7% of avocet nests at British Columbia colonies. Of 21 nesting attempts at Alki Lake, only five nests are known to have successfully hatched young, one of which was on a floating 1.2x1.2-m platform constructed specifically for avocets. Of 15 hatched chicks, 11-12 survived until sustained flight was observed at 28 to 29 days after hatching. Of the 21 nests at Alki Lake, 15 were located on islands, five on artificial 1.2-m square floating nesting platforms, and one on a shoreline mudflat. Nesting island substrates varied from clay at Alki Lake to rocky pebbles at Little White Lake. Mean distance of nesting islands to shore was 126 m at Alki Lake, and mean distance to nearest nesting neighbor was 44.6 m. Territory size of nesting avocet pairs increased from 0.26 ha during the incubation period to 0.53 ha after hatching. Avocets foraged primarily in soft substrates along non-vegetated shorelines and in shallow mudflats at a mean depth of 10 cm. Key foraging areas shifted as water levels fell over the course of the summer. Foraging accounted for 50.2% of all behaviours observed during repeated sweep scans of adults. Gulls, corvids, and various raptors were common potential predators. Of these, Golden Eagle (*Aquila chrysaetos*) was the most aggressively attacked by avocets.

The factors necessary to consider in the construction of avocet compensation habitat in Kelowna are outlined in detail and a schematic design of such a compensation habitat proposed. The best sites for such habitat are in and around the Alki Lake (Glenmore Landfill) site and at Robert Lake. Use of artificial floating nesting platforms can provide nesting opportunities for avocets that could be considered as a mitigation method. Further surveys should be undertaken in the alkali lake region of the Cariboo in the year 2000 to determine if there are any more colonies of avocets in B.C. that are as yet undiscovered. The Little White Lake colony is on Crown Land and should be considered for a formal protected status.

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1. BACKGROUND

The American Avocet was first recorded as a breeding bird in British Columbia in 1968 at Duck Lake, Creston (Campbell et al. 1990). Avocet breeding was not reported again until 1987 when three pairs nested in the province; two at Alki Lake, Kelowna, and one at Beresford Lake, southeast of Kamloops (Cannings et al 1987, Campbell et al. 1990). Since then, breeding has been documented at four other locations: 1) Serpentine Fen, Surrey, in 1988 and 1989 (Wilson 1989); 2) Robert Lake, Kelowna, in 1992 and 1998 (Gebauer in press); 3) Little White Lake, Clinton in 1995 (Gebauer in press); and 4) "White Lake", Douglas Lake area, in 1990 and 1991 (Gebauer in press). Alki Lake is the only site with documented nesting for more than two years. In 1997, 19 nests were found at Alki Lake (Weir 1997) representing the largest concentration of avocets in the province. In 1998, only 3 American Avocet nests were found at Alki Lake because high water levels covered all of the nesting islands used in 1997 (Gebauer, in press).

Beginning in the 1960's, Alki Lake became the City of Kelowna sanitary landfill. Trenches were dug in the lake bottom, filled with garbage and then covered. In the mid-1980's, the southern half of Alki Lake was allowed to revert to a shallow alkaline lake, while the northern half of the former lake continued to be used as landfill. Because water is currently on top of buried garbage in the southern portion of Alki Lake, the British Columbia Ministry of Environment is requiring the draining of this lake remnant. The American Avocet colony at Alki Lake is additionally threatened with extirpation by proposed re-expansion of the Glenmore Landfill into this southern half of Alki Lake. The City of Kelowna has agreed to look into ways to create compensation habitat for the American Avocet in the immediate vicinity of Alki Lake.

2. GOAL

The primary goal of the current study was to determine the ecological requirements of the currently breeding American Avocets in the Kelowna area, and by inference to determine the requirements necessary to maintain a viable breeding population of American Avocets in the Kelowna area. Based on these requirements, specific recommendations for creating compensation habitat and improving existing habitats were developed.

3. OBJECTIVES

This was only one portion of the Kelowna American Avocet Project in 1999 as spearheaded by the Central Okanagan Naturalists Club (CONC). A workplan, drawn up by Martin Gebauer under contract to CONC in March 1999, guided this project through the summer of 1999 and outlined objectives for the 1999 work. Other portions of the project (see Ambrozy 1999 and MacNeil 1999) dealt with water chemistry and with invertebrate prey respectively, of American Avocet habitat.

The specific research objectives of this portion of the Kelowna American Avocet project in 1999 were to:

- determine the breeding population of avocets in the Kelowna area;
- describe habitat characteristics of nesting locations;

- document reproductive success (i.e., number of nests, clutch size, and fledging success),
- identify foraging and rearing habitat characteristics (e.g., substrates and vegetation),
- investigate predator risks to breeding and foraging avocets, and
- determine if other areas in B.C., where avocet breeding was recorded in the past, were used in 1999.

One specific research objective was added to the ones suggested in the workplan. The high water levels that caused a general nesting failure in 1998, were threatening to occur again in 1999 since water levels were still flooding all the 1997 island nest sites in March 1999. We therefore decided to make floating nesting platforms modeled on those used for waterfowl, to see if avocets would find these acceptable and use them for nesting. We therefore added another objective to this 1999 project:

- determine if avocets would use floating nest platforms as nest sites as a potential mitigation measure.

4. STUDY SITES

Southern British Columbia is at the northern end of the breeding range of the American Avocet west of the Great Plains (Robinson et al. 1997). The main breeding site in B.C. was previously identified as Alki Lake (Appendix 1 and 2), Kelowna (Gebauer, in press, Weir 1997) and was the main study site for this project. Additional study sites visited regularly in the Kelowna area included some sites where avocets had been previously recorded: Robert Lake, Chichester Bird Sanctuary, Okanagan Lake and Simpson's (Acland Rd.) Pond; as well as other nearby wetlands where avocets had never been recorded: an unnamed wetland on North Glenmore Road (referred to as Slough No.2), Bubna Slough, and Carney Pond. Carney Pond was dropped from the study after about one month since we realized that the habitat was such (no shallow water except occupied by dense cattails) that avocets or other shorebirds were extremely unlikely to occur there. All other wetlands had some areas of relatively barren shallow water that might potentially be suitable for avocet foraging.

Study sites were selected outside the Kelowna area for cursory searches only to determine if there was a population of avocets in B.C. that had somehow gone unnoticed in the past few years. Study sites included only those lakes or wetlands where avocets had been seen in the past in the southern and central interior of B.C. (Gebauer, in press) and where other birders rarely visit. All lakes or wetlands visited were shallow alkali lakes or wetlands.

5. METHODS

5.1 Population Surveys

5.1.1 Kelowna Population Surveys

Population surveys of American Avocets were conducted three times a week throughout the breeding season from 19 April to 25 August at key wetlands in the Kelowna area. From 3 May to 21 May, population surveys were conducted in the morning and evening. All population surveys were conducted by volunteers from the Central Okanagan Naturalist Club (CONC) or by the authors. Time, cloud cover, wind, precipitation, and temperature were recorded at the start and end of each survey. Cloud cover was recorded as 0%, <50%, >50%, and 100%. Wind was recorded according to the Beaufort Scale. Precipitation was recorded as none, fog, misty drizzle, drizzle, light rain, hard rain, or snow. Temperature was estimated and recorded in degrees Celsius. At each site, observer arrival time, the total number of individual avocets, and the number of adults and young avocets were recorded.

Wetlands included in the survey were (followed by City of Kelowna Wetland No.):

- Chichester Pond or Bird Sanctuary (No. 18)
- Simpson's Pond or Acland Road Pond (No. 105),
- Carney Pond (No. 12),
- Robert Lake (No. 11),
- Glenmore Landfill Pond or New Bredin's Pond (not numbered),
- Alki Lake (No. 223),
- Bubna Slough (No. 5), and
- Slough No.2 (No. 2).

In addition, a series of sites along Lake Okanagan were surveyed from 24 April to 21 May during spring migration. We attempted to cover the entire lakeshore in Kelowna from Knox Mountain to Sarsons Beach with survey routes simplified as we learned the areas of mudflats that avocets frequented and collected sightings from interested amateur observers. From north to south, major sites included Hot Sands Beach, City Park, Mud Bay, Cedar Avenue, Gyro Beach, Rotary Beach, Thomson Creek Outlet (Small Boat Association), and Sarson's Beach.

Surveys were discontinued at Carney Pond after 26 May, and at Bubna Slough and Slough No. 2 after 4 August due to the absence of avocets at these sites. Surveys were discontinued along the lakeshore after 21 May when rising water levels flooded all mudflats avocets had been using. No avocets were seen along the lakeshore in 1999 after May 21 by any observers.

5.1.2 Surveys of Former Breeding Sites

Lakes in the Merritt and Cariboo Forest Districts, where American Avocets formerly bred, were surveyed. These included, Beresford Lake near Kamloops, "White Lake" near Kame Lakes in the Douglas Lake area, and Little White Lake near Clinton. Beresford, White and numerous alkali lakes in the their vicinities were surveyed on 4 May and 18 May, and Little White Lake was surveyed on 1 June, 24 June and 1 August. Avocets, if present, were counted at each site and signs of nesting were recorded.

No surveys were undertaken at Serpentine Fen in the Lower Mainland or Duck Lake at Creston. Avocets seem not to have occurred at either of the sites for the last 10 years. If avocets had been present at either site in 1999, their presence would likely have been noticed by other birders since these areas are regularly visited by many people.

5.1.3 Other Southern B.C. Observations

Naturalists and birders throughout the Southern Interior of B.C. were contacted to provide any and all of their observations of avocets made outside the Kelowna area through the end of July 1999. Notices were put in the B.C. Field Ornithologists Newsletter, and in local naturalists newsletters in the area, or read out as announcements at club meetings. The help of the B.C. Interior Birders e-mail group was also requested to provide any avocet sightings.

5.2 Reproductive Parameters

At Alki Lake, American Avocet reproductive behaviour was observed from vantage points approximately four times a week from 19 May to 31 July and three times a week from 1 August to 26 August. Vantage points included two locations on a small hill with an elevation approximately 70 m above the lake and one on a dirt mound approximately six meters above the lake. Most nesting sites were discovered by watching for avocets sitting regularly in the same spot. A number of nesting sites were also discovered by observing nest building activities, and a few nests were discovered only after thorough canoe searches. All suspected nesting sites were confirmed during canoe searches. The number of suspected nesting attempts at Little White Lake was determined on 1 June from several distant vantage points through spotting scopes to avoid any nest disturbance. On 24 June, the Little White Lake nesting island was thoroughly examined on foot and nesting site status was confirmed.

Nesting attempts were classified as either: a)unused nests (i.e., nests or scrapes constructed during nest site selection, see Sordahl 1980); b)dropped eggs (i.e., a single non incubated egg laid on ground); c)single egg nests (i.e., nests or scrapes that contained one non incubated egg; d)normal nests (i.e., two to five incubated eggs); or e)supernumerary nests (i.e., >5 incubated eggs) (Robinson et al 1997). Accurate nesting chronologies were only determined for nests occurring after 19 May at Alki Lake. Dates for nest building, egg laying, incubation periods, hatching, fledging, and adult abandonment of chicks were recorded for 17 nests. Clutch size was determined during canoe searches of Alki Lake and from ground searches at Little White Lake. Hatching success was determined by the number of eggs hatched divided by the total number of eggs. Fledging success was determined by the percentage of chicks that survived to approximately 27 days when most young were first capable of flight (Gibson 1971).

Reproductive parameters, as measured in 1999 and reported here in the Results sections, were compared in the same sections to the results from 1997 and 1998 where these were available. In most cases these were from Weir (1997) but were also from unpublished notes by one or both of the authors.

5.3 Physical Parameters of Nest Sites

5.3.1 Nest Site Measurements

On the initial discovery of a nest, measurements taken included, nest height above water, nest distance to water, and nesting material composition. After nesting, detailed measurements of nesting island length and width, nearest neighbor conspecific nest distance, and distance of nest to shore were measured. Nest distance to water was measured as the horizontal distance between the rim of the nest and water, and nest distance to shore was measured as the horizontal distance between the rim of the nest and the nearest shoreline of Alki Lake. Nest height above water was measured as the vertical distance between the water level at nest completion and the base of the nest. Nearest neighbor conspecific nest distances were measured as the horizontal distances to the next nearest avocet nest that was occupied at the time of nest building. Nesting island sizes were measured by recording the greatest island length and width during the nest building period.

Nest composition was recorded for each nest. Nests were defined as either: a)unlined nest scrape (i.e., a shallow, unlined depression in the ground); b)lined nest scrape (i.e., a shallow, sparsely lined depression in the ground); c)rimmed nest (i.e., a mere rim of nesting material with no bottom); d)sparse nest (i.e., nest with minimal amount of nesting material and poorly formed cup); or e)complete nest (i.e., nest with well formed cup and considerable amounts of nesting material). Substrates and percent cover of vegetation was determined within a one-meter radius of each nest. Maximum water depths between nesting islands and the shoreline were determined within the narrowest reach between the island and shoreline.

5.3.2 Artificial Nest Platforms

Based on descriptions of nesting platforms used by Ducks Unlimited for nesting waterfowl, we designed and built 8 floating nesting platforms. Basic design was 1.2 m by 1.2 m wide squares by 0.8 m thick foam core (1.2 m x 1.2 m x 10.2 cm) sandwiched between sheets of 13 mm or 16mm (½ or 5/8 inch) plywood. The 2 pieces of plywood were bolted together at 8 positions (corners and centers of sides) on the top and bottom of the foam core within 8 cm of the sides to provide some strength and support to the otherwise brittle and breakable foam core. The top piece of plywood had the center cut out of it (before assembly) to reduce weight so that only a 10 cm rim of plywood remained on the top surface. One of the platforms was made with 15 cm (6 inches) of foam core instead of 7.5 cm (4 inches). Two eyebolts were put into each top piece of plywood to provide places to tie anchor lines. The sides of the platforms were painted drab green to make them less visually obtrusive compared to the stark white foamcore.

Six of these were placed in Alki Lake on 16 April 1999, in areas used for nesting in 1997 and 2 in Robert Lake on publicly-owned portions of the lake on 19 April 1999. Platforms were floated out to position, anchor lines (thin polypropylene rope) tied to pieces of cinder blocks and the cinder blocks dropped as anchors to the bottom of the lakes. Water depth where the platforms were anchored varied from 5 cm to 65 cm on the days they were put out. "Dirt" taken from the edges of the lakes were placed on top of the platforms once they were anchored in positions to cover the exposed foam core to a depth of 2-5 cm.

Canada Geese had already finished establishing nests by the time the platforms were put out, so that we did not have to prevent any geese from nesting on the platforms. If they had done so, we would have removed the nests to give avocets a chance to use these as nesting platforms. Platforms were removed from the lakes at the end of August.

5.4 Breeding and Rearing Territories

Breeding territory size, i.e., the area in which an adult pair associated with a specific nest and/or their chicks occurred, was determined for: a)the incubation to hatching period; b)hatched chick broods from hatching until sustained flight at Day 27 (Gibson 1971). Maps of Alki Lake were drawn up from 1:20,000 orthophotos enlarged to 1:5,000 and 1:2500 with all landmarks shown on them. These were digitized (ArcView 3.0) and printed out to make field sheets. Positions of both members of the pair associated with specific nests were mapped on these, and these entered into the GIS system and total area of territories for the time period calculated. Since no birds were banded, individual avocets were followed either from the nest to their foraging sites or from their foraging sites to the nest so that territory size could be calculated for each nesting pair. These territories simply represent the area used by the pair, or by the chicks, and are not meant to represent defended area sizes.

Chicks were located almost daily from 16 June (i.e., date of first chick) to 29 July and observed for approximately one to two hours each visit. Chicks were located three times a week from 29 July to 19 August and observed for about five minutes each time. Locations were noted on a scaled map to determine the areas used by chicks.

5.5 Behaviour and Foraging Habitat Surveys

Surveys of American Avocet foraging habitat were conducted for a total of 35.17 hours from 12 May to 17 June and for 15.17 hours from 12 to 22 July at Alki Lake, and for 5.6 hours from 13 May to 3 June at Robert Lake. Time of survey was not chosen randomly and usually occurred between 06:00 and 13:00 (Pacific Daylight Time) although surveys started as early as 05:00 and ended as late as 19:00. Sweeps using a spotting scope were made from an elevated observation point. We attempted to locate every avocet present during each sweep. At Robert Lake, these were made from ground level in areas where the whole of the lake could be observed. At Alki Lake, these were made from a cliff top immediately to the northeast of the lake. Sweeps typically took 10-15 minutes depending on how many avocets were present, and were then repeated. Sweeps at Robert Lake, where there were often fewer avocets, sometimes took as little as 5 minutes.

On each sweep, the following data was collected for each avocet: a)age (i.e., chick, juvenile, or adult); b)cell location on map (see Appendices 10 and 11); c)behaviour (see below), and d)individual water depth (IWD as per Boettcher et al 1995). IWD was determined by the height of water on the adult leg as either: a)0 cm (on land); b)1 cm (foot covered); c)5 cm (half way between foot and tibiotarsus); d)10 cm (at tibiotarsus); e)13.5cm (between tibiotarsus and belly); f)17 cm (at belly); or g)>17 cm (swimming). Behaviour was recorded as feeding, aggression (intraspecific and interspecific), copulation, nest building, group circle display and similar group behaviour (see Hamilton 1975), preening, bathing, incubation, roosting (while standing), standing, sitting (including roosting while sitting), walking, flying, hiding, and other behaviour. Unique behaviours noted during observational time were also recorded.

To plot the location of foraging avocets in each lake, scaled maps of Alki and Robert lakes (Appendix 8) drawn from 1:20,000 aerial orthophotos were divided into small cells based on habitat differences that could be discerned from observation points adjacent to the lakes and were thought to influence avocets habitat use (principally water depth). Alki Lake was divided into 89 cells and Robert Lake into 26 cells. The boundaries of these cells were digitized into ArcView GIS so that the area of each cell could be calculated.

Percentage occurrence of the total number of observations made indicated the relative frequency of each behaviour type for adults, juveniles, and chicks. The relative value of each cell in Alki and Robert lakes for avocet foraging was calculated. For each cell, the percentage of the total foraging observations occurring in that cell was divided by the percentage of the total area of each lake occupied by that cell. If a cell was used for foraging in exact proportion to the area of the lake that it occupied, the index would be 1. Indices of greater than 1 would indicate a relative preference of those areas for foraging with indices of less than 1 indicating relative avoidance. Substrates of some of the most used foraging sites were determined with the help of a soils specialist, Herb Luttmerding, of Kelowna.

5.6 Aggressive Behaviour

Aggressive interactions between American Avocets and potential predators including, gulls, herons, raptors, corvids, coyotes (*Canis latrans*) and domestic dogs (*Canis domesticus*), was closely documented at Alki Lake during foraging habitat surveys or any other observation period. For each avocet/predator encounter the following was recorded: a)date; b)approximate time length of encounter; c)behaviour of predator (i.e., flying, soaring, walking, chasing, or attacking); d)number of predators; e)classification of antagonistic behaviour of avocets (Table 1); and f) number of avocets involved in agnostic behaviour. Avocet agnostic behaviours were classified in order of increasing aggressiveness and were rated on a scale of 1 to 10 for numerical analysis (Table 1). For each potential predator encountered, the range of avocet aggressiveness and its mean were determined. Aggressive interactions between avocets and non predators such as other bird species was also recorded for avocets defending feeding territories, nest sites, and chicks.

Table 1. Classification codes of American Avocet aggressive behaviours to potential predators that occurred in vicinity of nesting and/or feeding areas

Scale	Classification	Description
1	Mild Alarm	1-2 birds give alarm calls
2	Vigorous Alarm	>2 birds give alarm calls
3	Circling Alarm	1 or more birds give alarm calls while in circling flight
4	Attempted Chase	1 or more birds fly up to begin a chase but return
5	Mild Chase	1 or more birds mildly chase for short period
6	Medium Chase	1 or more birds vigorously chase for short period
7	Vigorous Chase	1 or more birds vigorously chase for long period
8	Mild Air Attack	1 or more birds make 1-2 swoops with near contact for short period
9	Medium Air Attack	1 or more birds make 3-5 swoops with near contact for < 3 minutes
10	Vigorous Air Attack	1 or more birds make repetitive swoops with near contact for > 3 minutes

5.7 Depredation and Nest Disturbance

Evidence of nest depredations (e.g., broken eggs, spilled yolk) were recorded while conducting nest searches. Factors resulting in nest disturbances, including possible research impacts caused by humans, were recorded during all observational time periods.

6. RESULTS

6.1 Population Surveys

6.1.1 Overall Census Results for Kelowna

The spring migration period of American Avocets to, and through, the Kelowna area appeared to extend from 16 April when the first avocets arrived, through to the end of May. The first pairs to arrive in April almost immediately started territory establishment and nest building even while other avocets were still arriving or migrating through. Avocet numbers varied widely during this period but peaked in Kelowna in May with most observations from Alki and Robert lakes, Chichester Bird Sanctuary, and the shoreline of Okanagan Lake (Figures 1 - 3). The highest population count occurred on 26 May when 45 individuals were seen at Alki Lake (Figure 1) and 12 May when a total of 45 individuals were seen at Robert and Alki lakes together (Figure 2). On 12 May, the Lake Okanagan shoreline was not surveyed for avocets. An additional eight individuals were seen at Okanagan Lake on 14 May suggesting that a minimum of 53 individuals were probably present on 12 May in the Kelowna region. These numbers are probably the peak figures for migration counts of avocets that were staying to breed in Kelowna as well as those that were probably heading further northward. From the end of May through June, population counts in Kelowna were much more stable, typically between 20 and 30 adults, with most of these being the breeding pairs at Alki Lake.

Numbers based on repeated sweep scans (see Section on Foraging Sites) were also compared to other population counts. Mean numbers of avocets observed per scan was 37.6 at Alki Lake in May (1881 obsns/57 sweeps), 20.9 at Alki Lake in June (1964 obsns/94 sweeps), 12.6 (1156 obsns/92 sweeps) at Alki Lake in July, and 9.4 (431 obsns/46 sweeps) at Robert Lake from 12 May to 3 June. After 3 June, sweep scans were discontinued at Robert Lake because so few avocets were found there and almost all avocet activity seemed to be at Alki Lake. The highest number observed on any single sweep at Alki Lake was 49 at 7:05 AM on 28 May. There were two additional sweep counts of 47 on that day. These high counts have not been cited in the previous paragraph as high counts because we did not take the same extra precautions during foraging surveys to make absolutely certain that some avocets weren't double counted. Average number observed per scan on 28 May at Alki Lake was 43.1 compared to an average number of 26.9 counted per sweep only 3 days later on 31 May.

Use of the various wetlands in Kelowna during the spring migration and early nesting period (mid April through late May) was not always predictable and was quite variable (Figure 3). On one early morning count (5 May) there were no avocets at Alki Lake while 17 were at Robert Lake. The female avocet from the nest found on 3 May (Nest 1 as shown in Appendix 1, p.37) had left her nest to feed at Robert Lake. However, over the course of that morning, avocets returned from foraging in Robert Lake, and the female returned to sit on the single nest that was there at the time.

Avocets would also make long distance movements even after dark. On 7 May, only 6 avocets were found at dusk (9 P.M.) at Chichester Bird Sanctuary. However, 22 were found in the same spot 1.5 hours later that must have moved there in almost complete darkness. This is not surprising since avocets are often known to forage at night (e.g. Dodd and Colwell 1996). We do not know if these avocets arriving at Chichester after dark were the 17 avocets that were at Robert Lake earlier that evening since we did not check back there again that evening, but they may have been. One property owner at Robert Lake reported that he would sometimes see avocets flying from Robert Lake southeast in the general direction of Chichester just at dusk (Brian Callaghan, personal communication 1999).

Figure 1. Population counts of American Avocet at Alki Lake for 1999. Included here are counts of adults (black diamonds), young (open squares), and combined (open triangles).

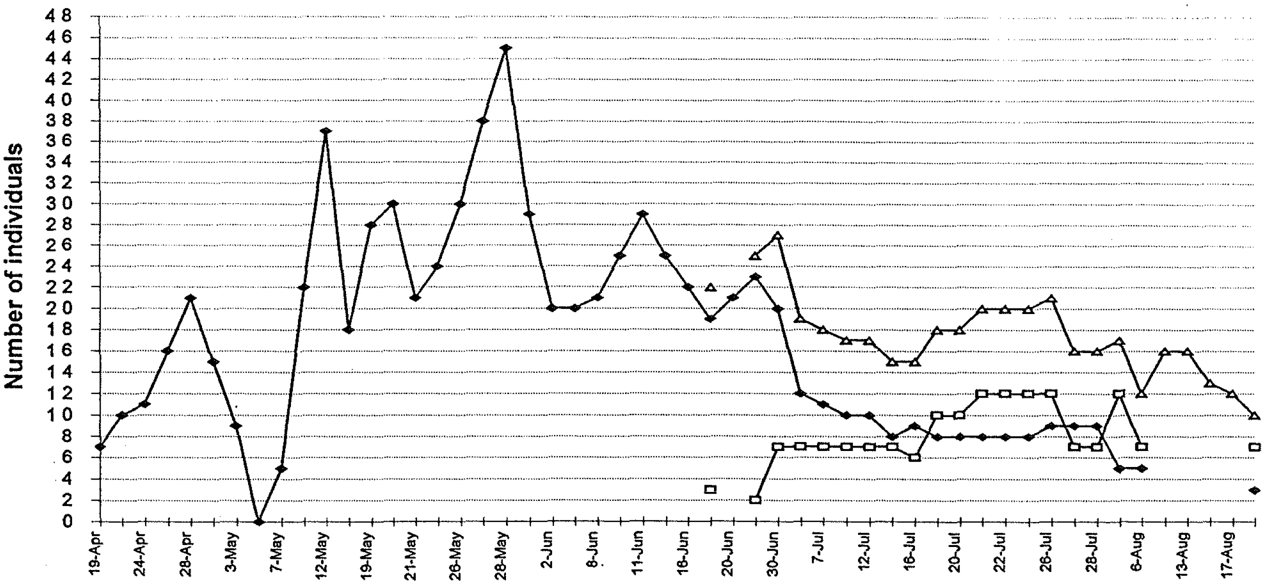


Figure 2. Population counts of American Avocet at Kelowna for 1999 based on 3x weekly surveys.

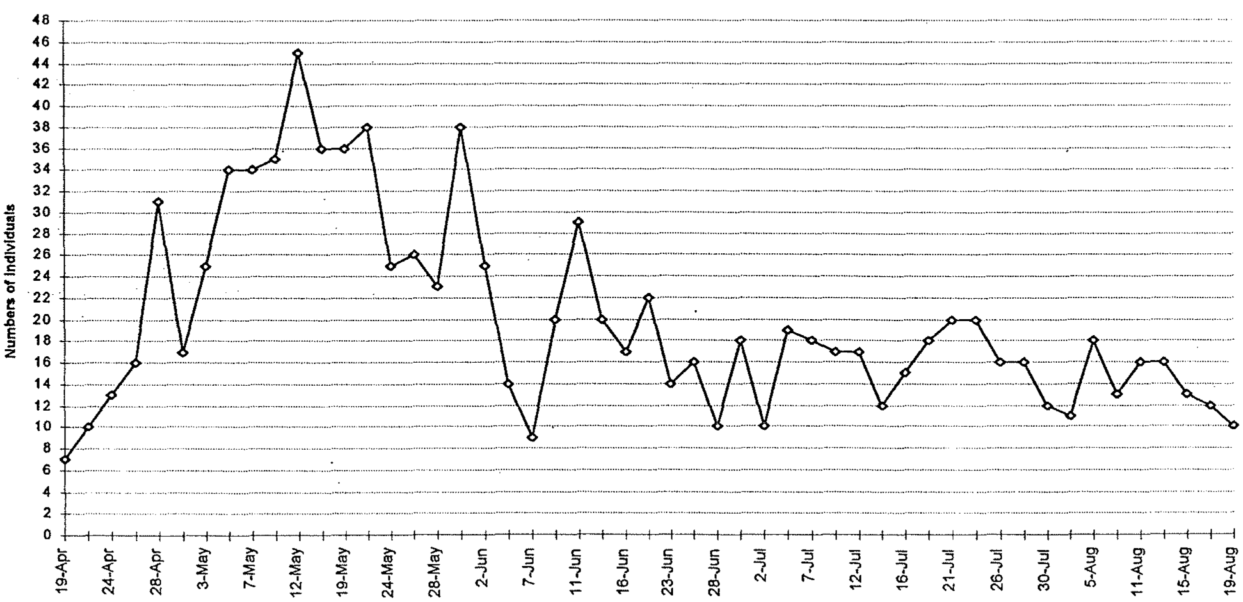
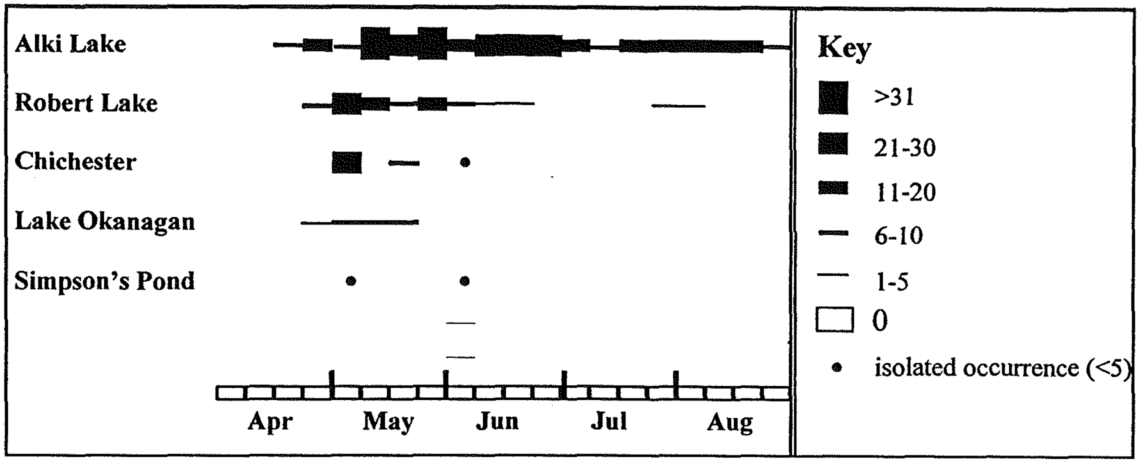


Figure 3 Greatest weekly observed abundance of the American Avocet at key wetlands in the Kelowna area. The last 2 or 3 days of each month are included in the 4th week.



6.1.2 Surveys of Former Breeding Sites

No American Avocets were observed at Beresford Lake, "White Lake" on the Douglas Lake Ranch or any other alkali lakes or wetlands in those areas during surveys of these areas. No nesting is suspected to have occurred in those areas in 1999.

On 1 June, 1999 a second American Avocet colony in British Columbia was discovered at Little White Lake, Clinton. A minimum count of 32 individual avocets was recorded but a population of 35-38 individuals was suspected since some of the nests later seen were out of line of sight from where that high count was made. A single large nesting island found had 12 avocets sitting either on observed nests or suspected nests. A quick ground search revealed evidence of only 10 nests on 24 June, although others may have occurred. In addition, 3 groups of chicks were located. Population size observed on 24 June was considerably smaller and was probably under 20 adult avocets. On 1 August, no American Avocets remained at Little White Lake. The breeding location data has been sent to the B.C. Conservation Data Center.

Once the Little White Lake site was discovered we realized that it would be beneficial to extend many of the observations being made in Kelowna to that site. However, logistics prevented more than 3 site visits so that very little data could be collected except for water chemistry, invertebrate prey densities (reported under Ambrozy 1999 and MacNeil 1999), and nest site data (reported here in later sections). Foraging appeared to be principally at a small (<1 ha) shallow pond isolated from Little White Lake by a low esker when the avocets were first seen. Later many were seen feeding in Little White Lake as well. This feeding pond is less than 200 m from the nesting island that all avocets used there. Considerable cattle tramping was seen in the clay at the water's edge even though the water is far too alkaline for livestock use (Ambrozy 1999).

6.1.3 *Other Southern B.C. Observations*

Relatively few observations of avocets were contributed from areas outside of Kelowna (Table 2) with most observed during the spring migration period. This represents a real lack of avocets outside this area, and not just a lack of observers. Most useful was the B.C. Interior Birders e-mail group. Members of the group regularly make postings of any interesting or noteworthy species they have contacted in an outing on a particular day. This means that negative data, i.e., lack of sightings, for areas regularly visited by these birders truly correlates with a lack of avocets in an area. Avocets did not stay at any of the sites for very long periods during spring migration. Sometimes the avocets stayed as little as a few hours.

Table 2. Contributed observations of American Avocets in 1999 in areas outside of Kelowna.

Observer	Date	Location	Number Observed	Comments
Phil Gehlen	April 24	Rose's Pond, Vernon	2	
Phil Gehlen	April 24	Head of Okanagan (OK) Lake	2	Believed to be same 2 seen earlier that AM at Rose's Pond. Flew away within half hour.
Ian Barnett	May 3	Stump Lake (S end)	1	less than 100 m from Hwy 5A
Phil Gehlen	May 11	Head of OK Lake	2	
Phil Gehlen	May 14	OK Lake-at mouth of Vernon Cr.	2	none at head of Lake
Dick Cannings	May 16	S end OK Lake at Giant Peach	7	
Louise Rice and others	May 20	Secwepcemc Museum Marsh, Kamloops	2	
Ed Boivin	May 23	Hidden Valley Ranch Rd	6	
Jerry Herzig	Aug 28	Quilchena Creek at Nicola Lake	5	
Phil Gehlen	Aug 29	Swan Lake, Vernon	1	
Wayne Weber	Sept 12	Quilchena Creek at Nicola Lake	1	

6.2 Reproductive Parameters

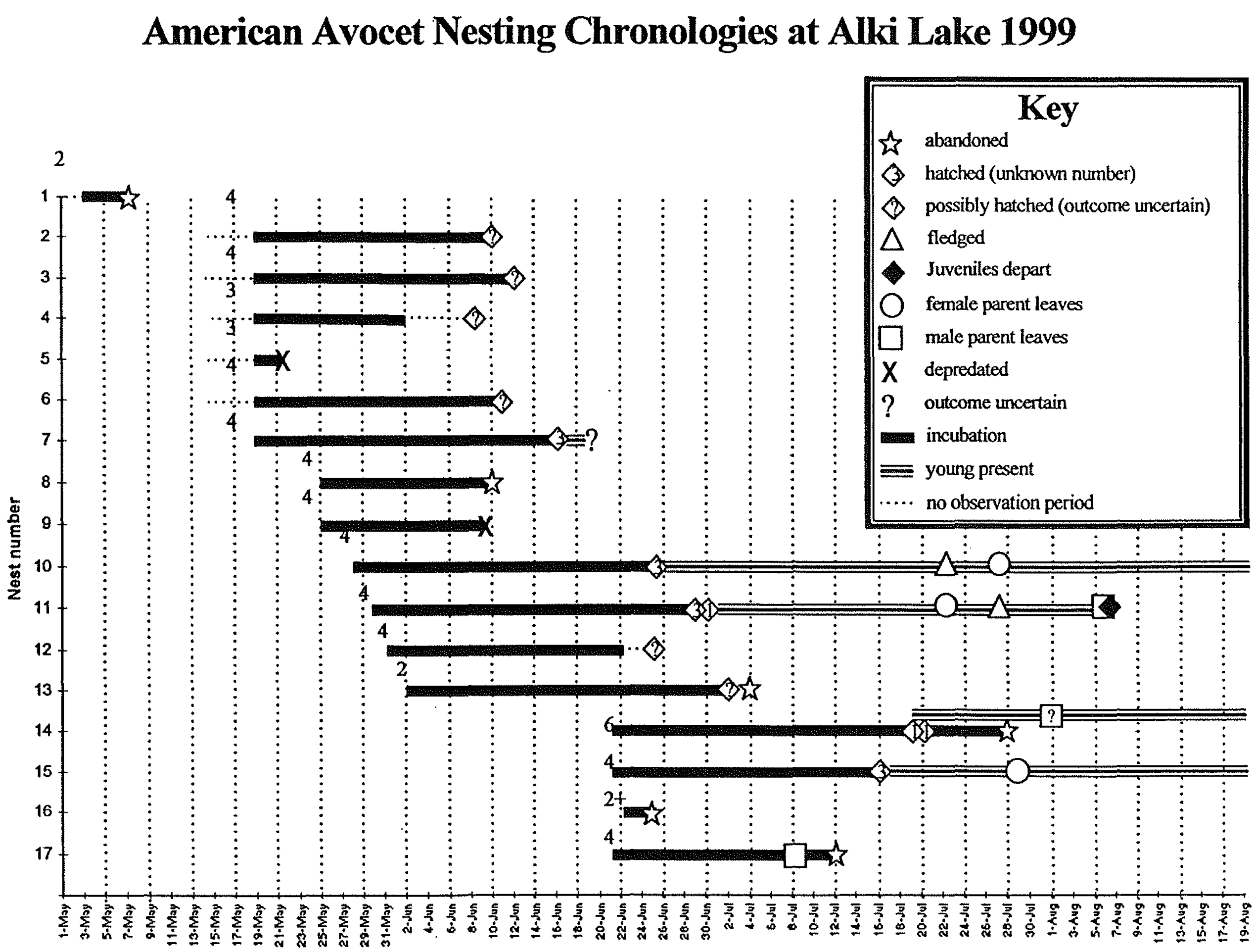
6.2.1 *Nesting Chronology*

The first nest initiated at Alki Lake in 1999 was found on 3 May (Figure 4) when it had two eggs. By 19 May, seven nests with eggs were found. Nests were initiated until 22 June. Estimated first egg laying dates for each nest ranged from 1 May to 18 June (no mean could be calculated as the initiation dates for nests 2-7 were not determined, Figure 4). Hatching dates of 15 eggs in 1999 ranged from 16 June to 20 July with a mean of 1 July. The latest hatching date of 20 July at Alki Lake in 1999 was later that the latest hatching date of about 10 July in 1997 (Weir 1997). Nests initiated in the second half of June (e.g. nests 14-17; Figure 4) are suspected to be renesting attempts by avocet pairs that failed in their first attempt. Hatching in 1997 at Alki

Lake occurred on a different timeline with fewer late nests. The mean hatching date in 1997 was June 9, a full 22 days earlier than in 1999. Avocet females are reported to abandon chicks usually before the male (Sordahl 1996). Of three groups of chicks, 2 were abandoned by the female before the male (Figure 4).

Nesting chronologies at Little White Lake are not well known because only 2 visits were made to the site during the breeding season. On 1 June, as many as 12 birds appeared to be incubating, some of which may have been sitting birds without nests. On 24 June, nine nests still contained eggs, 1 nest was found without eggs and three groups of young chicks (1-7 days old) were seen with one, two and four chicks per group. The single chick may have been from one of the nests that still contained eggs, and as such a minimum of 12 nests occurred.

Figure 4. American Avocet nesting chronologies for 17 nests at Alki Lake 1999. Nests 10, 14, and 15 had young remaining at last observation on 19 August. Nest 14 had female parent and nest 15 had male parent at last observation. Nest 10 may have had a parent at last observation. Numbers at start of each chronology indicate maximal clutch size over incubation period for nest.



6.2.2 Nesting Attempts and Clutch Size

Of a total of 26 nesting sites found at Alki Lake during 1999, only 21 nests contained eggs with the other 5 sites abandoned before egg-laying. For the purposes of the rest of this paper, only the 21 nesting sites that contained eggs will be called nesting attempts. Of nests with eggs, three contained single eggs, 17 were normal (2-5 egg) nests, and 1 nest was supernumerary, containing 6 eggs. This compares to 19 nesting attempts at Alki Lake in 1997 where one was a dropped egg, 13 were normal nests, two were supernumerary and three were of uncertain status (Weir 1997 and unpublished data). Of 12 nesting attempts at Little White Lake during 1999, nine were normal nests, one was supernumerary (7 eggs) and two were of uncertain status.

Clutch size of avocet nests at Alki Lake in 1999 ranged from one to six eggs (mean = 3.37; n = 19, including single egg abandoned nests). When abandoned single egg nests are excluded, clutch size ranged from two to six eggs (mean = 3.81; n = 16, Table 3). Clutch size in 1999 at Alki Lake was lower than in 1997 when mean clutch size was 4.94 eggs per nest (Weir 1997). Complete clutches in 1997 contained only four or more eggs while 3 complete clutches had had only three eggs and one had only two eggs in 1999 (Table 3). Three egg clutches are commonly reported (Harrison 1979) but two egg clutches are less frequently found (see Gibson 1971, Robinson et al. 1997, and Shipley 1984 for records).

Supernumerary clutches occurred in 1999 at both Alki and Little White lakes (Table 3). In British Columbia, the percentage of nests that are supernumerary is 7.7% (i.e., four of 52 nests) for avocet colonies of greater than five pairs or 6.4% (i.e., four of 63 nests) for all nests reported. Percentage of nests that were supernumerary at Alki and Little White lakes in 1999 was 4.8% and 8.3%, respectively, compared to 10.5% for Alki Lake in 1997 (Weir 1997). The percentage of supernumerary clutches is reported to be a function of nesting avocet density (Kondla and Pinel 1978, Giroux 1985). This appears to be the case in British Columbia. Supernumerary clutches in British Columbia have only occurred where colonies have been formed.

Table 3. Clutch sizes of American Avocet nests at Alki Lake and Little White Lake, B.C.

Clutch Size	Alki Lake 1997 [1]	Alki Lake 1998	Alki Lake 1999	Little White Lake 1999
2 eggs	0	0	1	?3 [2]
3 eggs	0	0	3	0
4 eggs	8	2	11	4
5 eggs	4	0	0	0
6 eggs	0	0	1	0
7 eggs	1	0	0	1
8 eggs	1	0	0	0
undetermined [3]	5	1	5	3
Mean	4.94	4.00	3.81	-

1 data from Weir 1997

2 clutches of 2 eggs are very unusual and some eggs may have already hatched or the nest been abandoned. Based on only one visit on 24 June, this data is not entirely reliable.

3 *nests which were terminated early or clutch size was not known for other reasons*

6.2.3 Hatching and Fledging Success

Of 67 observed eggs at Alki Lake in 1999, 15 were known to have hatched, 22 eggs did not hatch, and 19 may have hatched but were never seen. Based on these figures, hatching success was estimated to be between 22.4% and 50.7% which is low in comparison to the 77% hatching success rate in 1997 at Alki Lake (Weir 1997). Hatching success of avocet eggs at Little White Lake could not be calculated, but three groups of chicks, consisting of one, two and four chicks, were observed on 24 June.

Only two of six eggs in a single supernumerary clutch at Alki Lake hatched. Adult avocets continued to incubate the remaining four eggs for seven days after the second chick hatched before abandoning the eggs. Low hatching success is reported to be typical of supernumerary clutches (Gibson 1971; Rohwer et al. 1979; and Sordahl 1980, 1996), although two supernumerary clutches at Alki Lake in 1997 reportedly had high hatching success (Weir 1997). Hatching success of a supernumerary nest at Little White Lake is unknown.

Of 15 chicks observed at Alki Lake, four disappeared and were likely depredated. The remaining 11 chicks survived to fledging (i.e., around day 27 when sustained flight is achieved; Gibson 1971) representing a fledging success of 16.4% in terms of total eggs laid. In terms of eggs known to have hatched, fledging success was 73.3% (i.e., 11 of 15 chicks).

6.3 Physical Parameters of Nest Sites

6.3.1 Nesting Locations

Of 21 American Avocet nests with eggs at Alki Lake, 15 were located on islands, five on artificial nest platforms and one was located on an exposed shoreline mudflat on a small peninsula. Four of the 6 platforms put out in Alki Lake were used for nesting. One platform had two nests at different time periods. After the chicks hatched from the first nest, the same nest structure was reused by another pair for nesting. In comparison, all nests in 1997 were located on islands (Weir 1997), but only one of three nests was located on islands in 1998 when few islands were exposed above water level (Table 4).

Nest distance to water at Alki Lake ranged between 0.30 and 3.81 m and at Little White Lake between 3.05 and 15.50 m. The mean nest distance to water was much lower at Alki Lake than at Little White Lake (Table 4). At Alki Lake, nest height above water level was within 30 cm for 21 nests in 1999, compared to a range of 0.10 to 1.50 m (mean = 1.03; n = 3) in 1998 when two pairs nested on a high dike due to high water levels (Table 3). Nearest neighbor conspecific nest distances ranged from 4.3 to 270.0 m (mean = 44.6 m; n = 18).

Nests were located between 74 and 183 m from the main shoreline of Alki Lake in 1999 in contrast to 1997 when nests were between 21 and 140 m from the shore. The mean distance of nests to shore in 1999 was also further than in 1997 (126 vs. 86 m; Table 4). The natural islands on which nests were located ranged between 72 and 181 m from shore (mean = 120 m; n = 14) in 1999 at Alki Lake whereas in 1997 many of the islands used were closer to shore. The floating artificial platforms with nests ranged between 127 and 145 m from shore (mean = 140 m; n = 4). At Little White Lake, the nesting island was 78 m from shore. The deepest water between the closest point on shore to each nest was approximately 1.0 to 1.3 m at Alki Lake and about 1.1 m at Little White Lake.

Natural nesting island size at Alki Lake ranged from 1.4 x 1.7 m to 11.6 x 21.7 m (mean = 4.6 x 7.2 m; n = 12 nests on 10 islands). Artificial nesting platforms containing 5 nests were 1.2 x 1.2 m each. The only nesting island where the 12 nests occurred at Little White Lake was 34 m wide by 88 m long and 0.20 ha in area (Table 4).

In 1999, nesting island substrates for 15 nests consisted of clay intermixed with garbage. The single shoreline nest was also on clay. Four floating platforms with a total of five nests had substrates consisting of clay and loam mixtures taken from the nearest shoreline to put on the platforms. Nesting islands exposed in early spring attracted large numbers of ducks which left considerable amounts of droppings. This added a thin layer of loam-like soil to nesting islands on which nine nests occurred.

At Alki Lake, all 21 nests with eggs were constructed in areas with no vegetation. However, the nest located on the shoreline had about 40% cover of vegetation by the end of the incubation period.

Table 4. Comparison of the physical parameters for nest sites at Alki Lake in 1997, 1998 and 1999 and at Little White Lake in 1999. All n values are for the numbers of nests in calculations.

Location	% of Nests on Islands		Mean Distance to Shore[1]		Mean Distance to Water		Mean Height Above Water		Mean Nesting Island Dimensions	
	n	%	n	m	n	m	n	m	n	m
Alki Lake 1997 [2]	19	100	19	86	15	1.8	17	0.18	16	5.7 x 9.7
Alki Lake 1998 [3]	3	33.3	1	122	3	8.4	3	~1.00	-	
Alki Lake 1999 [4]	21	95.2	18	126	19	0.9	-		17	3.6 x 5.4
Little White Lake	10	100	10	~110	9	6.9	-		10	34.0 x 88.0

[1] *distances of nests on islands to shore of lake*
[2] *data from Weir 1997*
[3] *unpublished data collected 1998*
[4] *includes floating platform nests*

6.3.2 Nest Structure and Nesting Materials

Of 26 nesting attempts at Alki Lake, four nests were rimmed, six nests were sparse, and 16 nests were complete. Of 21 nests containing eggs at Alki Lake, four were rimmed, one was sparse, and 16 were complete. Of three nests at Alki Lake in 1998, one was rimmed and two were lined nest scrapes. Of 11 nesting attempts at Little White Lake in 1999, three nests were unlined scrapes and the remaining nests were rimmed, sparse, or complete. At Alki Lake, nests containing eggs typically differed from those not containing eggs by having a rim. Nests without eggs were flat, had little nesting material, and were likely nests that were never completed. Nests with eggs were maintained by the breeding pair on a regular basis. Non-incubating individuals of a pair were often seen tossing nesting material towards the nest before they began incubating. Incubating birds often were observed adding this nesting material to the rim and outer edges of the nest (see Robinson et al.1997).

Of 26 nests at Alki Lake in 1999, 16 were composed of Alkali Saltgrass (*Distichlis spicata*), three of saltgrass and feathers, two of other grasses, four of bird droppings, and one of undetermined vegetative material. Of 21 nests with eggs, 12 were composed of saltgrass, three of saltgrass and feathers, one of other grasses, four of bird droppings, and one of undetermined vegetative material. Of three nests at Alki Lake in 1998, one was probably composed of saltgrass and two of other grasses. Nests found on islands were generally composed of saltgrass as this alkali species abounds in shallow areas of Alki Lake and is often the only plant occurring around nesting islands early in the season when nest building occurs. Foxtail Barley (*Hordeum jubatum*) begins growing on breeding islands at Alki Lake towards the end of the incubation period of most nests (Weir 1997) and has never been observed as nesting material.

High water levels in 1998 and 1999 at Alki Lake covered over the places in which saltgrass grew in 1997. As a result, no live vegetation was available during the nest building season in 1999. Instead, avocets were observed using dead and submerged saltgrass from water less than 0.1 m deep around their breeding sites. Nests located along the dike or shoreline were typically composed of grasses other than saltgrass. Of four nest structures on floating platforms all were composed of shallow rims of duck droppings. Floating platform nests occurred in water that was initially too deep for avocets to wade in. As avocets gather nesting material from the area immediately surrounding the nest site (Gibson 1971), no vegetative material could be gathered adjacent to the floating platforms. Nesting material was not analyzed in detail for each nest at Little White Lake, but most nests consisted of grasses and three nests were observed with no nesting material and eggs being laid on a substrate of large pebbles.

6.3.3 Artificial Nest Platforms

As stated in the previous sections, 4 of the 6 artificial nesting platforms were used for avocet nesting at Alki Lake in 1999. As previously noted, one of the floating platforms was used twice by nesting avocets. Neither of the 2 platforms at Robert Lake were used for nesting. Three of the platforms used for nesting were floating in 30-50 cm deep water when nest building began. The fourth platform had been grounded by falling water levels so that is was no longer floating when first used for nesting but was still surrounded by 2-3 cm deep water.

Only one of the 5 nests on an artificial nesting platform successfully hatched young. In some cases, this was probably because of waves splashing on the nest and eggs (see Nest Disturbance section) although in other cases (as in the nest on the platform that was grounded) it was for unknown reasons.

Many other bird species were observed on the platforms but no nesting attempts by any other species were noted. Other species observed on the platforms included Mallard (*Anas platyrhynchos*), Gadwall (*Anas strepera*), Cinnamon Teal (*Anas cyaboptera*), American Wigeon (*Anas americana*), Redhead (*Aythya americana*), Ring-necked Duck (*Aythya collaris*), Green-winged Teal (*Anas crecca*), Bufflehead (*Bucephala albeola*), Barrow's Goldeneye (*Bucephala islandica*), American Coot (*Fulica americana*), Killdeer (*Charadrius montanus*), Spotted Sandpiper (*Actitis macularia*), and Caspian Tern (*Sterna caspia*).

6.4 Breeding Territories and Foraging Ranges

Ranges of 6 incubating pairs at Alki Lake ranged from 1,746 to 3,577 m^2 (mean = 2,427.2 m^2; n = 6; Table 5) over a period of seven observation days (i.e., 16 June to 22 June; ~ 20 hours observation time). Exclusive territories for incubating pairs ranged from 765 to 3,399 m^2 (mean = 1945.0 m^2; n = 6). Some nesting territories were highly exclusive and were usually surrounded by the principal feeding territory (e.g., nests 10, 12, 13, 14, and 15; Table 5). Other nesting territories were shared with nests only a few meters away and usually had distinct and exclusive feeding territories in other areas (e.g., nest 11, Table 4). Disjunct feeding areas of nesting birds ranged from 40 to 477 m (mean = 244; n = 9; for 7 nests) from nest to nearest point of feeding. One pair (i.e., Nest 25, Table 5) had disjunct areas of foraging territory that they shared with other avocets, as well as areas of occasional use on opposite ends of the lake, but no exclusive territory. Once a nest was built this pair continued to feed in one of these small areas located 477 m away from its nest. One non-breeding pair (i.e., pair 2, Table 5) allowed a third non-breeding individual to share their range after 21 June.

After the young hatched, the territory and foraging areas used increased (Table 6). Areas used were on the order of 0.5 ha for the adults and for the chicks.

At Alki Lake, chick rearing habitat consisted mainly of open mudflats, clay islands, and clay shoreline with little vegetative nursery areas as described by Robinson et al (1997). Of five groups of chicks, only three were ever observed wandering or resting in areas of terrestrial vegetative cover on islands. A 9 m^2 area of Yellow Clover and a 6 m^2 and 9 m^2 area of Alkali Saltgrass were observed being used by avocet chicks ranging from seven to 27 days old. For size of chick rearing habitats at Alki Lake, see section on Breeding Territory Analysis: Home Ranges of Chicks from Hatching to Fledging.

Table 5. American Avocet territories and foraging ranges in m^2 between 16 June and 22 June for two non-breeding pairs, six incubating pairs, and one nest building pair.

Nest or Pair #	Status	Exclusive Territory	Shared Territory	Areas of Occasional Use	Total Area (Foraging Range)
Pair 1	Not nesting	1717	0	0	1717
Pair 2	Not nesting	2118	747	0	2865
Nest 17	Incubating	1278	747	215	2240
Nest 19	Incubating	765	1325	0	2090
Nest 20	Incubating	1746	6	0	1746
Nest 21	Incubating	2112	0	109	2221
Nest 23	Incubating	3399	178	0	3577
Nest 24	Incubating	2370	178	141	2689
Nest 25	Nest building	0	1924	1013	2937
Average	-	***1938.1***	***849.8***	***369.5***	***2453.6***

Table 6. American Avocet ranges in m^2 for adult pairs before and after hatching, and for chicks in m^2.

Nest or Pair #	Pre Hatching Adult	Post Hatching Adult	Chicks 1-7 days	Chicks 1-27 days
Nest 17	2240	5261	-	4157
Nest 19	2090	5279	-	4274
Nest 24	2689		2476	
Average	2649	5270	-	4214

6.5 Foraging Sites

The relative importance of foraging sites within a lake, the range of avocet behaviours and the water depths used by avocets were based on repeated sweep scans. A total of 151 sweep scans were made on 13 separate days at Alki Lake in May-June taking a total of 35 hours and 10 minutes with 3845 avocet observations made. A total of 92 sweep scans were made on 5 separate days at Alki Lake in July taking a total of 15 hours and 10 minutes with 1156 avocet observations made. A total of 46 sweep scans were made on 4 separate days at Robert Lake in May-June taking a total of 5 hours and 36 minutes with 431 avocet observations made. Mean time per scan was 14.0 minutes at Alki Lake in May-June, 9.9 minutes at Alki Lake in July and 7.3 minutes at Robert Lake in May-June.

At Alki Lake, avocets foraged on all shallow mudflats and along all shorelines free of vegetation except those with steep slopes. Only a fraction of Alki Lake was actually used by avocets for foraging: 73% of the shoreline (1714 m of the 2339 m perimeter), and 29% of the lake area (76714 m^2 of the total 265867 m^2 area). In addition, these foraging areas changed as the season progressed and water levels changed (Figure 5). Shallow waters where avocets preferred to forage in late May and early June became exposed in July due to falling water levels. Avocets did not use these exposed mudflats for feeding once the surface had dried and hardened. Similarly, areas where little or no foraging occurred in May-June often had increased foraging in July as the water depths of those areas decreased to more optimal levels for foraging.

At Robert Lake, avocets foraged primarily along shorelines where vegetation was absent. At Robert Lake 32% of shoreline (700 m of 2176 m parameter) and 5 % of total lake (11000 m^2 of 218023 m^2 area) was utilized in May and early June. The areas used most heavily for foraging were the shallow mudflats within a few meters of shore at the northwest corner of Robert Lake. The only other areas used relatively commonly for foraging were the shallow waters at the southwest corner near the end of Curtis Road, and the shallow waters at the eastern edge of the lake where there is no road adjacent to the lake.

Substrates of foraging areas at Alki Lake were 100% loam to silt loam at site 1 and 100% silty loam to silty clay loam at site 2. At Robert Lake two distinct substrate layers occurred in foraging sites, with the top 0.5 cm of substrate composed of 100% silty loam and below 0.5 cm composed of 100% silty clay. At Bubna Slough and Slough #2 where avocets were not reported shoreline substrates were approximately 85% fine sandy loam to loam (15% organic matter) and 85% loam (15% organic matter) respectively.

American Avocets were observed foraging on land, in deep water while swimming, and in shallow water up to 17 cm deep (Table 7). Avocets fed most often in water 5.0 to 13.5 cm deep with 10 cm being the average depth.

Figure 5. Relative avocet foraging values of areas at Alki Lake in May-June and July, 1999, based on % of total foraging observations/% cell area of total lake. Cells with indices of 1 or below are shown blank.

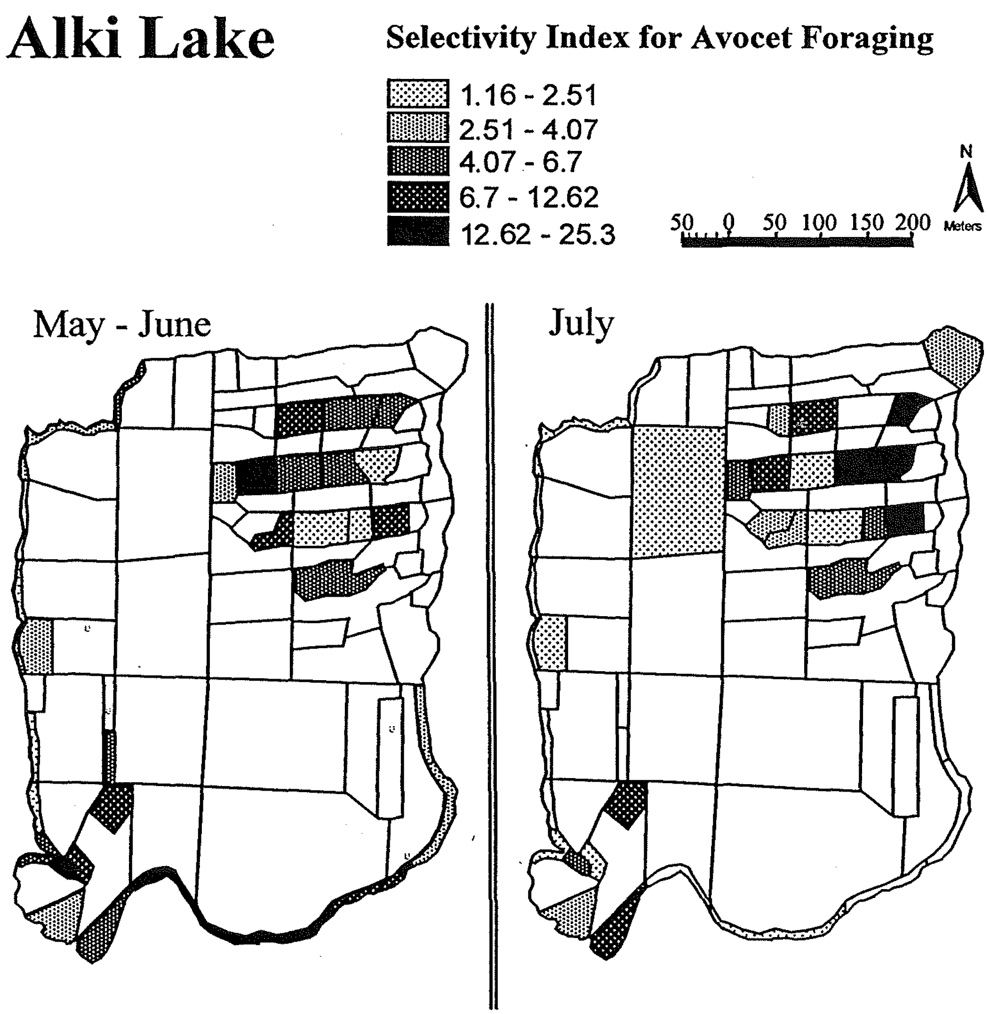


Table 7. American Avocet Individual Water Depths, expressed as percentages of total foraging, roosting, preening, and copulating behaviours at Alki and Robert lakes based on repeated sweep scans in May, June, and July of 1999.

Individual Water Depths	Feeding (%)	Roosting (%)	Preening (%)	Copulating (%)
(Number of observations)	(2434)	(200)	(389)	(23)
0 cm (land)	1.5	31.5	26.0	4.4
1 cm (foot)	6.8	14.0	15.2	0.0
5 cm (foot to tibiotarsus)	27.5	39.5	48.6	17.4
10 cm (tibiotarsus)	38.8	14.5	9.0	43.5
13.5 cm (between tibiotarsus and belly)	16.4	0.0	0.0	26.1
17 cm (belly)	4.7	0.0	0.0	0.0
>17 cm (swimming)	3.5	0.0	0.0	0.0
Unknown	0.7	0.5	1.3	8.7

6.6 Behaviour

Based on all sweep scans during the months of May, June and July, adult American Avocet behaviour consisted mostly of feeding (50.2%), incubating (23.1%), preening (7.0%), and resting (roosting, 4.1% and sitting, 4.1%; Table 8). In contrast, chicks and juveniles spent significant parts of their time sitting (16.8 and 38.7% respectively). Gibson (1978) reported feeding behaviour to occupy 36.4% of avocet's time before eggs were laid and 24% during incubation with actual incubation taking up 43% of time. We found feeding to take up much more of their time than in his study. However, the lower percentage we report here for incubation (23 vs. 43%) is not directly comparable because we could not separate pre-laying from incubation periods with our figures based on the whole colony rather than on individual avocets.

Other behaviours observed included a juvenile copulation in which two chicks approximately 19 days old attempted to mate. One chick assumed the female role and crouched low on the ground with neck extended horizontally. The other chick mounted, made cloacal contact, and appeared to copulate while wiggling its tail from side to side. Copulation behaviour was similar to that reported for adults (Sordahl unpublished data in Robinson et al. 1998) except that the post copulatory display in which both partners entwine necks and run for 1-7 m did not occur. The process lasted about two minutes.

On 17 June an adult male avocet located a floating white duck egg while feeding and began to move the egg from side to side with its bill and bobbing it in the water for approximately 10 seconds. After feeding for a few seconds it came back to the egg and kept playing with it. Once the avocet appeared to try and position the egg under its breast as incubating birds do. The avocet left and came back to the egg five times. As play behaviour was not recorded in the latest review on avocet biology (Robinson et al 1997), this observation is of importance.

Table 8. American Avocet behaviour as percentage of total observed behaviours at Alki and Robert lakes based on repeated sweep scans in May, June, and July of 1999.

Behaviour	Adult	Juvenile	Chick
Number of observations	**4857**	**287**	**190**
Feeding	50.2	36.6	57.9
Aggression	1.6	0.0	0.0
Copulating	0.5	0.0	1.1
Nest building	1.3	0.0	0.0
Group circling display	1.1	0.0	0.0
Preening	7.0	16.7	4.2
Bathing	0.2	0.0	0.0
Incubating	23.1	0.0	0.0
Roosting while standing	4.1	1.7	0.0
Standing	2.8	2.4	4.2
Sitting	4.1	38.7	16.8
Walking	1.7	3.8	3.7
Flying	1.5	0.0	0.0
Hiding	0.0	0.0	8.4
Other	0.9	0.0	3.7

6.7 Aggressive Behaviour

6.7.1 Aggression to Potential Predators

At Alki Lake, 44 aggressive encounters between American Avocets and potential predators or groups of predators were documented with 11 species of birds, and two mammals (Table 9). Common Ravens (*Corvus corvus*), Peregrine Falcons (*Falco peregrinus*) and Golden Eagles (*Aquila chrysaetos*) were aggressively encountered most often. Gulls and corvids were very abundant at Alki Lake, but gulls evoked little aggressive behaviour in avocets and corvids did so only at key points in the nesting period. Raptors always evoked aggressive behaviour when flying within 100 m above the water surface. Coyotes (*Canus latrans*), although commonly present, were seldom detected by avocets and evoked only mild aggression. Golden Eagles were the most aggressively attacked with almost all encounters resulting in vigorous air attacks by one to three individuals lasting for as long as six minutes. Avocets would chase and swoop at Golden Eagles until eagles were as far as 0.6 km away from the outer edges of the lake or 0.2 km above the ground. Though more commonly encountered than Golden Eagles, Peregrine Falcons did not evoke as intensive aggressive behaviour.

At Little White Lake three predator/avocet encounters were observed: 1)a Herring Gull (*Larus argentatus*) was vigorously chased by a single avocet, 2)two gulls (*Larus spp.*) were vigorously chased by several avocets, and 3)a flying hawk (*Buteo spp.*) caused eight avocets to fly up and begin a chase.

Table 9. Summary of avocet/predator encounters at Alki Lake. Each order of predators has a total to represent the group as a whole and is shown in bold italic. Numbers in the last two columns correspond to the classification scale of American Avocet aggressive behaviours defined in Table 1.

Predator	Number of Encounters	Range of Avocet Aggression	Mean Avocet Aggression
Great-blue Heron	***2***	***5-9***	***7***
Gull spp.	2	5	5
California Gull	1	5	5
Ring-billed Gull	1	6	6
Franklin's Gull	1	6	6
Total Gull	***5***	***5-6***	***5.4***
Red-tailed Hawk	4	1-10	4.8
Golden Eagle	5	4-10	8.8
Osprey	1	1	1
Peregrine Falcon	8	1-7	2.9
Total Raptor	***18***	***1-10***	***4.8***
American Crow	2	3-8	5.5
Common Raven	16	3-8	7.3
Total Corvid	***18***	***3-8***	***7.1***
Domestic Dog	1	1	1
Coyote	2	3	3
Total Canine	***3***	***1-3***	***2.3***

6.7.2 *Aggression to Non-Predators*

Adult avocets showed aggressive behaviour to other species in 1.6% of observational scans (Table 8). Species chased by avocets during the pre-egg hatching period at Alki Lake in 1999, included Mallard, Blue-winged Teal (*Anas discors*), Green-winged Teal, American Wigeon, Redhead, Killdeer, Wilson's Phalarope (*Phalaropus tricolor*), Spotted Sandpiper, Long-billed Dowitcher (*Limnodromus scolopaceus*), and Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*).

Avocets seemed to readily defend the immediate area around their chicks chasing almost any species of bird they encountered. Species observed being chased by avocets defending chicks included, Mallard, Cinnamon Teal, Killdeer, Wilson's Phalarope, Greater Yellowlegs (*Tringa melanoleuca*), Lesser Yellowlegs (*Tringa flavipes*), Spotted Sandpiper, Semipalmated Sandpiper (*Calidris pusilla*), and Western Sandpiper (*Calidris mauri*). Marshland species showing aggressive behaviour to American Avocets included, Canada Goose (*Branta canadensis*), Willet (*Catoptrophorus semipalmatus*), and Killdeer.

6.8 Depredation and Nest Disturbance

Although depredation of nests at Alki Lake was not observed, a nest at about 14 days of incubation was found with yolk and egg shell fragments around the nest (Nest 14, see pg 37 Appendix 1). Gulls and corvids were likely responsible for this and most other egg depredations.

An abandoned avocet egg was depredated by individuals within a large flock of Ring-billed Gulls (*Larus delawarensis*) and California Gulls (*Larus californicus*) on 12 July.

Nest disturbances caused by waterfowl likely caused destruction or abandonment of some nests at Alki Lake. Various duck species used the nesting islands and floating platforms for roosting and their movements probably pushed the eggs out of at least two avocet nests resulting in abandonment. Avocets generally defended the immediate area around the nest, but ducks were observed standing within 20 cm of both guarded and unguarded nests at certain times. Ducks are suspected to have pushed eggs out of a number of already abandoned nests.

One pair of avocets nested about 40 cm from an already initiated Killdeer nest. Killdeer persistently tried to chase or lead avocets out of this area by charging, fanning tails, and spreading wings. Avocets would also chase the Killdeer, which persistently would come back and keep defending their nest. This aggression lasted for about a week while avocets built their nest and laid eggs. The nest was eventually abandoned and two eggs were found rolled out of the nest.

Avocets react aggressively to human intrusions when the nesting area is approached as we witnessed many times over. Disturbance distances appear to be on the order of 100 m or greater when nests are approached. The pair from the most northerly nest at Alki Lake (no. 14) in 1999 would react aggressively to human observers about 100 m away. This was noticed many times when birders would come to the usual site they would use to view the avocet colony, not knowing that there was now a nest so close to this area, or when workers building up a roadway in that vicinity would leave their vehicles. No avocets nested on the islands in this northeast corner of Alki Lake in 1997 where 6 nests were made in 1999. We suspect the lack of nests there in 1997 was because the area of the landfill adjacent to this corner was being used as part of the recycling operations associated with the landfill with frequent heavy machinery and other human use in 1997. There was no sustained work activity in this area in 1999 until near the end of July so that nests were established during the period when this area was undisturbed.

We suspect that our disturbances resulted in the abandonment of two nests that had only one egg. At Alki Lake, two nests containing only one egg during first visit were abandoned 1 day after and within 7 days after we visited the nests on our weekly nest searches. This level of abandonment early in the egg-laying phase seems to be an unavoidable artifact of this type of research since it is not always possible to know the number of eggs in the nest before it is visited. In California 36% of nests visited by humans when only 1 egg had been laid were abandoned while only 9.5% of nests with >1 egg were abandoned when visited (Robinson et al. 1997).

Wave action in moderate to heavy winds caused the floating platforms to rock. Since nests on floating platforms never consisted of more than a circular rim of droppings, wave action potentially could cause eggs to roll into water. During heavy wave action, nests on floating platforms were drenched by spray several times. During these time periods, adults did not incubate eggs which may have resulted in cooling and death of the eggs, and later abandonment. The only nest that was successful on a nest platform, was where 15 cm of foam core was used for flotation instead of the usual 10 cm on the other platforms. This extra 5 cm of flotation appeared to be enough to keep the eggs high and dry from the wave action.

7. DISCUSSION

7.1 Kelowna Area Sites

Within the Kelowna region, avocets have nested at two sites (Robert and Alki lakes) in the last 12 years but only the Alki Lake site has had regular breeding activity of two or more pairs. Population surveys in the Kelowna area revealed that two other alkaline wetlands in the Glenmore Valley (Bubna Slough and Slough No. 2) were not used by avocets, while seemingly unsuitable habitat at Chichester Bird Sanctuary was utilized by birds before nesting occurred. Other factors at alkaline lakes likely limit their use by avocets.

Bubna Slough was probably not used as all available shoreline is covered in bulrush of varying densities and no mudflats occur. Slough No.2 on the other hand appears ideal, with areas of open shoreline. As avocets are primarily a prairie bird nesting in rather open situations, the steep wooded slopes surrounding Bubna and No. 2 sloughs may have reduced the attractiveness of these wetlands.

Chichester Bird Sanctuary is an important site for both spring migrants and local birds. As many as 20 individuals spent the night and early morning hours feeding at Chichester and then returned to Robert and Alki lakes for the remainder of the day mainly in the month of May. Chichester Bird Sanctuary is not suitable for nesting with no unvegetated nesting islands, thick stands of cattails, and high populations of Canada Geese that would probably disturb avocets. Various sites along the east shore of Lake Okanagan are important for migrant avocets in spring provided water levels are low enough to expose mudflats. Individuals or pairs of avocets occurred at a number of these sites for several weeks in late April and May. Such sites were typified by shallow mud or silt bars where avocets fed extensively.

7.2 Southern B.C. Sites

Small populations of American Avocets occur in 2 areas of British Columbia. Avocet numbers peaked by 26 May 1999 in Kelowna (minimum 45-53 birds) then returned to levels in the 20-30 range in June, suggesting the presence of at least a second colony in the province that these avocets were migrating to. Therefore, it was not a complete surprise when the second colony of at least 32 avocets was found at Little White Lake on 1 June. With some individuals headed apparently northward from the north end of Okanagan Lake as early as 24 April, avocets probably arrive in Little White Lake quite early to begin breeding.

The long-term history of the Little White Lake avocet colony is very unclear since no previous population counts have been done and only a few people were aware of its presence, and none of its significance, prior to this summer. Avocets have been there for many years (Daphne Ogilvie, pers. comm.) but numbers are unknown. At the time of discovery on 1 June, peak avocet migration may have been occurring at Little White Lake and a minimum of 12 birds were not there when the site was revisited on 24 June.

The interrelationship of the 2 breeding areas is as yet unknown. We do not know how much interchange of individuals there is between the 2 sites, or how faithful returning adults are to the sites. As non-breeding first year birds have been located 600 km from their natal site (Robinson and Oring 1997), dispersal from natal sites may help repopulate colonies after years of reproductive failures. Plissner et al (1999) found that philopatry rates for breeding and natal avocets in the Great Basin were low with 18% of breeding adults returning and 0.4% of chicks returning to their breeding sites (64% of chicks known to survive returned) the following year. Plissner et al (1999) concluded that some local populations serve as sources while others serve as sinks between years and that local populations in danger of extinction if alone persist as individuals from other successful populations immigrate (see also Stacy et al. 1997). This may have been the case for Alki Lake in 1998 when only 3 pairs bred. The following year 13 pairs bred indicating that immigration from other areas occurred. As sources and sinks may shift from year to year, based on local conditions for each colony (Brown and Kodric Brown 1977; Plissner et al 1999), it is imperative that more than one colony occur in southern and central British Columbia if the avocet is to persist as a breeding species.

Based on the spring 1999 Kelowna counts, the Kelowna area acts as a migration stop for avocets that continue on northward—probably to the Little White Lake area, and perhaps to other not-yet-known breeding sites. We made an attempt to collect all avocet records for 1999 seen by any birders in the southern interior of B.C. No great concentrations were found. Only small groups of transient birds were seen. Since no avocets are seen in any great numbers anywhere else in the province, there is a possibility that many of the avocets migrate in jumps from central Washington, to Kelowna, and then to Little White Lake, although some certainly make stops at other lakes and wetlands along the way.

The Kelowna population, although low in number, may be stable. With 13 breeding pairs in 1999, it appears that this species was able to rebound following a breeding failure in 1998 when only four breeding pairs were recorded in the Kelowna area (Gebauer in press). This ability to rebound in breeding numbers may be because the Little White Lake colony is acting as a population buffer. Young from that population may sometimes come to breed in Kelowna. Avocets are relatively long-lived shorebirds adapted to the variable climate of the arid west so that loss of a single year's breeding production should not usually be harmful to the overall populations (Robinson et al 1997). Adults that did not breed at Alki Lake in 1998, may have continued on to Little White Lake in that year, or simply have given up nesting attempts and returned southward. They probably stayed at Alki Lake in 1999 to breed. At this point this is simply speculation. However, it is probably true that having several sizable, suitable wetlands in the southern interior of the province where avocet breeding occurs may be necessary in order for a colony to persist after several years of poor or no breeding.

Southward migration appeared to begin at the end of June when many adults had left the Kelowna area. Adult avocets seen during July and August were mainly those with young. By 19 August, only three adults remained in the Kelowna area. Because a peak fall migration was not observed in the Kelowna area, it is likely that fall migrants from Little White Lake and elsewhere depart over a range of several weeks, with only a few migrants occurring in the Kelowna area at a time. However, based on a lack of reported sightings, no great concentrations of avocets seem to exist anywhere in the province in July or August except at the breeding sites. Avocets may simply proceed straight southward to their next fall migration area without stopping at any sites in B.C.

7.3 Reproductive Parameters

The highest number of nesting attempts ever reported in the province occurred this year at Alki Lake (n=21) by a total of 13 breeding pairs. The high numbers are a result of second and possibly third attempts by pairs unsuccessful during their first attempts and not because of high numbers of breeding birds. The breeding population of 1997 was larger than 1999, however, the fewer nesting attempts for 1997 may reflect the higher first-attempt nesting success in 1997. In 1997 there was considerably more available nesting habitat when birds first returned in the spring. Avocets were probably able to stake out breeding territories upon first arrival. In 1999 water levels were much higher, and very little suitable breeding habitat was available upon first arrival of pairs. Many pairs may have nested in fairly unsuitable habitat early in the season, or else waited until far too late in the nesting season. Either strategy would be likely to result in more nest abandonments, either early or late in the nesting season.

Although 1999 hatching success was low at Alki Lake in comparison to that reported for 1997 (Weir 1997), fledging success of eggs that did hatch was high indicating that reproductive failures at Alki Lake are more likely due to pre-hatching than post-hatching factors.

7.4 Physical Parameters of Nest Sites

American Avocets in British Columbia, as elsewhere, prefer to nest on islands (Sidle and Arnold 1982). In years when sufficient numbers of islands were exposed at Alki Lake, 95% (in 1999) and 100% (in 1997; Weir 1997) of avocet nests were located on islands. When high water levels covered over nesting islands in 1998, only one of three nests was located on islands and nesting attempts diminished by 84%. Similarly, Robinson et al (1997) found that when nesting islands were removed at an evaporation pond in Tulare Lake Basin, nesting attempts diminished by 50% in two years and no nesting attempts occurred by the eighth year. Giroux (1985) found that more breeding birds were present in specifically managed impoundments during drought years when other breeding habitat was scarce. Since water levels at Alki Lake and other alkali wetlands usually fluctuate on a multi-year basis, water level management will be necessary to maintain suitable habitat through high and low water years.

Nesting island sizes varied considerably. The single large island at Little White Lake was used by the entire colony for nesting and had densities of 60 nests/ha (12 nests on 0.2 hectare island). Avocets can nest in much higher densities of 250 nests/ha (15 nests on 0.06 ha island in Alberta, Vermeer 1971) or as close to each other as 1 m (Robinson 1996).

The minimum observed distance of avocet nesting islands to shore in this study was 74 m in 1999 although some nests were closer than 74 m to the shore of Alki Lake in 1997. Maximum water depth between nesting island and shore was shown by Giroux (1985) to play a role in avocet densities. Maximum water depths of one meter or more as seen at Alki and Little White lakes are probably sufficient to discourage most ground predators from getting to nesting islands.

Very dense colonies with many avocet nests may attract predators, and pairs nesting singly outside any colony may not be able to adequately ward off predators (Robinson et al 1997). Therefore, loose colonies with lower avocet densities on nesting islands may be desirable with nearest neighbor nest distances in the range of 10-20 m (e.g. Robinson 1996, Hamilton 1975; Grant 1982; Giroux 1985; and Grover and Knopf 1982). Alki Lake appears to be such a colony with nests spread out on a number of islands over the entire lake and nearest nest neighbor distances of 45 m in 1999. Group mobbing still functions to drive away predators, but predators are less likely to discover nest sites as nests are not closely congregated.

Girard and Yesou (1991) found for the Pied Avocet (*Recurvirostra avosetta)* that colonies would establish each year in slightly different spots within the same general area. They found that colonies would grow from "epicentres" as additional pairs started nests around the first pairs to begin nesting. This may explain why 4 of 6 artificial islands were used in 1999 at

Alki Lake, but none at Robert Lake. The first pair to nest was in early May at Alki Lake on a natural island. Other avocets simply begin looking for breeding territories at that site first, before looking elsewhere. Indeed, the islands within 20 m of this first nest eventually had 8 other nests (with eggs) on them accounting for 43% of the total nesting attempts. The first artificial nesting platform to be used for nesting was about 70 m from this first nest.

With nesting island substrates at British Columbia colonies composed of alkali clay, garbage and loamy soils at one site (Alki Lake) and rocky pebbles at another (Little White Lake) it does not appear that nesting island substrates affect avocet nest site selection. This also appeared to be shown when they accepted artificial floating platforms as nesting sites at Alki Lake.

More important than substrate, lack of vegetation coverage was shown by Giroux (1985) in a regression model to explain 55% of avocet nest densities on islands with increasing vegetation negatively correlated with avocet density. While all nests at Alki Lake in 1998 and 1999 had no vegetation coverage, 41% of nests were located in vegetation in 1997 (Weir unpublished data).

Nesting island heights above water were generally low (less than 1 m and often almost at water level) at Alki and Little White lakes. No nests were flooded in the 1999 breeding season at Alki Lake because water levels slowly dropped through the 1999 summer. In 1997, however, a few nests experienced flooding as water levels rose during the nesting period.

7.5 Avocet Foraging Sites

Shallow water, particularly 5-13.5 cm deep water, and silt or clay substrates were probably the most important physical components of foraging sites of American Avocets based on our data. At Alki and Robert lakes avocets foraged most often where shallow mudflats occurred in addition to non-vegetated shorelines. Shorelines with steep slopes were avoided at Alki Lake and heavily vegetated shorelines were avoided at both Alki and Robert lakes but not at Chichester wetlands where avocets foraged in shallow ponds surrounded by cattail.

For avocets to make full use of foraging sites, it is important to have nesting areas nearby. Otherwise suitable foraging habitat may go largely unused. This happened in 1999 at Alki and Robert lakes in the month of June. Foraging habitat that had been used extensively at Robert Lake in May, was used very little in June because most adult avocets were staying near their nests at Alki Lake. The structure of Alki Lake with numerous islands (nesting sites) and shallow water depths with a fine silt or clay bottom (foraging habitat) appear to be some of the most important physical factors attracting avocets to Alki Lake.

7.6 Predation and Nest Disturbance

Gulls and corvids (particularly Common Ravens) are the greatest avian threat to egg depredation. Control measures on gulls and corvids may prove difficult near landfill sites since these species are so abundant.

Golden Eagles evoked the most aggressive and drawn out reactions from avocets, and due to their abundance around Alki Lake may be a significant threat to both adults and chicks. Peregrine Falcons may also be something of a threat since they were found regularly at Alki Lake in 1999, including a one-year old bird that was reared as a chick in Kelowna in 1998. Porter and

White (1973) reported avocet chicks as being taken by Peregrine Falcons. In Utah, nests of Peregrine and Prairie falcons (*Falco mexicanus*) contained 22 and six avocet carcasses, respectfully (Porter and White 1973). Raptors can be somewhat minimized at avocet breeding grounds by ensuring that no perches are available for them. Dead snags, and trees with dead tops or large dead branches should be removed around sites in which avocets breed and forage.

7.7 Chick Rearing Habitats

While vegetated nursery sites at Alki Lake were rare in 1999, the few sites available probably increased the survival rate of chicks by providing areas for chicks to hide. Wetland reconstruction projects should include nursery rearing sites of short vegetation in water 1-5 cm deep. In alkaline areas in central British Colombia, Alkali Saltgrass is the most likely species to be used for nursery sites as it grows well in shallow alkaline water were most other species do not grow.

7.8 Breeding Territory Sizes

Since we did not have any marked avocets, we could not do long term breeding territory size, but were limited to short times when we could associate specific avocets with specific nests to identify them. Therefore, the 0.24 ha foraging area or territory size reported here for an 8-day period should be considered the minimum space that a pair needs at one time. American Avocet territories are flexible and change throughout the season. As breeding pairs come and go, the territories will shift. Parts of a territory may also become useless due to changing water levels so that the actual area that an avocet pair needs may be considerably larger than 0.24 ha.

Ranges of entire broods of pre-fledging chicks were nearly double the size of the short term adult territories, and adult ranges after egg hatching were between 2.3 and 2.5 times larger than before hatching. Besides basic behavioural requirements for a secure (predator-free) space around the nest site, densities of aquatic and benthic invertebrates used as food sources also probably determine size of feeding territories, as well as their relative accessibility in suitable water depths. A minimum of 0.5 ha of suitable area with invertebrate densities similar to Alki Lake (see MacNeil 1999) and suitable water depths (5-13 cm) is probably needed in order to provide adequate space and food for a nesting avocet pair and their chicks.

7.9 Provincial Status and Ranking

Gebauer (in press) proposed a red listed provincial ranking of S1S2B based on documented avocet occurrence up to 1998 as opposed to its current blue listed ranking of S2S3B (B.C. Ministry of the Environment 1999). Based on 1999 data, and even the discovery of another colony at Little White Lake, the ranking criteria proposed by Gebauer (in press) does not appear to have changed. None of the other nesting occurrences outside of the Kelowna area and Little White Lake are currently occupied, or appear to have been so for many years.

8. MITIGATION CONSIDERATIONS

Considerations for possible mitigation derived from this phase of the Kelowna American Avocet Project fall under three categories:

1. Design of Compensation Habitat on City of Kelowna lands at Glenmore Landfill,
2. Possible Compensation Habitat elsewhere in Kelowna area, and
3. Other actions recommended outside the Kelowna area, or not tied to a specific place.

8.1 Design of Compensation Habitat at Glenmore Landfill

Location: Staff of the City of Kelowna have indicated that up to three sites near the Glenmore Landfill site might be used for compensation habitat. Because avocets are colonial and because of the way they establish nesting colonies each year around epicentres, the best compensation habitat for breeding would be in one area only. Areas at Glenmore Landfill include:

(1) northeast meadow near buffer zone with Quail Ridge - trees would have to be cleared within at least 100 m of compensation habitat;
(2) a small portion of south Alki Lake – depending on how this area was designed, it might not be large enough for breeding but may be used for foraging if water is shallow;
(3) area north of present landfill - a large open field occurs here which would appear to be the best area for creation of the proposed 7 hectare lake (Appendix 10). Principal drawback is that the field is steep, and major earth works may be necessary to create a large flat wetland.

Size: Recommended minimum size is 10 ha of suitable foraging habitat, large enough for 30 adult avocets. 6.6 ha would be the requirement based on 12 breeding pairs (average number of breeding pairs in past 3 years, 0.5 ha for each pair and chicks) and 6 non-breeding avocets (0.1 ha for each floater or first-year adult which usually does not breed, Robinson and Oring 1997, Robinson et al. 1997). However, this does not account for the fact that avocets never use all the apparently suitable breeding habitat in a colony (Girard and Yesou 1991). Girard and Yesou (1991) found for the Pied Avocet (*Recurvirostra avosetta*) that only two-thirds of the apparently suitable habitat would be used in a breeding colony after closely monitoring a large colony for 6 years. The total compensation habitat will also need to be larger than 10 ha since not all of it will be foraging habitat.

Surrounding Area: Land areas surrounding compensation habitat should be relatively flat and open with few trees so that it mimics its natural prairie-like habitat. In particular, all perch sites used by raptors should be cleared within 150 m from compensation habitat. Dead snags, or conifers with dead tops or larger dead branches are typical perches of raptors. To avoid human disturbance during nesting, the site needs to be designed so that no work operations associated with the landfill need to be carried out within 150 m of the site during the period when avocets are present (approximately April 15 to August 31).

Substrate: Clay or clay-silt should be used as substrate of compensation habitat as it is impermeable to water and thus stops underground water loss, forcing water losses through evaporation which aids in increasing salinity and alkalinity.

Foraging Habitat: Shallow feeding areas of 1-17 cm depth are necessary in order for avocets to forage. Water depth in majority of feeding areas should average 10 cm and be in the range of 5-13.5 cm deep. Small areas of deeper water (17-60 cm) should be scattered throughout the compensation as some invertebrate species may need deeper water at certain portions of their life cycles.

Water Control: As water levels in the Glenmore Valley fluctuate, it will be necessary to control water levels in Compensation habitat to keep nesting islands exposed in high water years, to keep water depth in foraging areas at an optimal level, and to achieve a relatively constant level through the incubation period. Other considerations with water level control are salinity and alkalinity, which may be reduced when water is flushed through the system instead of allowing solutes to build up through evaporative water loss, impacts on invertebrate prey abundance, and vegetation control. The site should be designed so water levels can easily be manipulated, particularly to raise water levels on some occasions to prevent buildup of permanent vegetation on low nesting islands and in shallow foraging habitat.

Shoreline: Shoreline slopes should be 10:1 to 12:1 slope maximizing the shoreline area which can be used for foraging.

Nesting Islands: Compensation habitat should have numerous small islands or several large islands for nesting. Artificial nesting islands can be constructed in existing alkaline wetlands provided that foraging habitat exists already at those sites. In creating artificial nesting islands for American Avocets, a number of factors need to be considered as identified in this study and in others. These include: 1)distance and depths between island and shore; 2)size and dispersion; 3)slope; 4)degree of vegetative covering; 5)substrate, 6)height above water; and 7)life span or durability.

1. Minimum 30 m to shore, average distance of nest islands to shore of 100 m or more, and depth of water at least 1 m somewhere between shore and island.
2. Islands can be of almost any size, but if small islands are used they should be clustered.
3. Side slopes at 10:1 to 12:1 under water and above water. At Tulare Lake Drainage District in California, artificially created nesting islands with side slopes of 12:1 attracted large numbers of avocets but islands with side slopes of 3:1 were used to discourage avocet nesting (Tulare Lake Drainage District 1999). Burgess and Hirons (1992) constructed nesting islands for Pied Avocets (*Recurvirostra avosetta*) in Great Britain with side slopes of 10:1.
4. Vegetative coverage, if any, should be sparse and short on nesting islands. If vegetation is not to be controlled by water levels, then vegetation can be discouraged by placing several layers of weed resistant plastic over islands and then placing highly alkaline and saline clay on top of plastic. Salt can be spread over island surface to discourage plant growth.
5. Any substrate acceptable, but should be resistant to wave erosion. Islands with a base constructed of large rocks and clay topping is recommended.
6. Island height should be great enough to reduce chances of sudden flooding but should not usually exceed 30 cm because then the island would have to be very large to not exceed the recommended side slopes. Islands should also be low so that permanent vegetation does not establish, and thereby negate the value to avocets. On such low islands, both occasional flooding and a rooting zone that would extend into relatively toxic alkali waters are likely to keep most vegetation to a minimum. An alternative would be to construct islands with clay placed over a vegetation-impermeable plastic or other barrier.
7. Erosion caused by wave action can reduce island life. To prolong island life and avoid having to reconstruct them at regular intervals, artificial nesting islands constructed in Great Britain were designed to reduce erosion. Techniques included: 1) using a 10:1 slope at base;

2) covering island with plastic netting; 3) placing stakes on windward side of island; and 4) placing pebble like substrates along water margin of islands (Burgess and Hirons 1992).

Nursery sites: Short vegetation in very shallow water 1-5 cm deep should be created near each nesting island for chicks to hide in. Such nursery sites should occur naturally if Alkali Saltgrass occurs. Saltgrass will not grow in deep water.

Overall design: There are many possible wetland designs that incorporate all or most of the above recommendations. Obviously any design would need to incorporate existing site constraints and other factors, particularly the requirement to maintain high alkalinity. A "generic" example that we have developed and proposed here (see Appendix 10) incorporates the above recommendations to be 10 ha in size (250 m x 400 m). Five island ridges would run parallel to each other with shallow wide feeding lanes between each island. Island ridges would be 45 m apart from each other. The exact width of the islands would depend on the water level at any given time but should generally be 3 m wide, to reduce the amount of area exposed out of the water, and maximize the foraging area in shallow water. A shallow 35 m periphery zone would surround the island ridges and would have incorporated into it a deep-water mote of ~ 1.5 m depth and 5-10 m width. Overall depth of water would be 5-17 cm.

This is not the only possible design. Clusters of shorter islands could work just as well as the proposed island ridges, or ridges that are not as continuous could work as well. However, the Tulare Lake Drainage District found that long island ridges did work very successfully as avocet nesting habitat. This design would also depend on relatively fine control of water levels. Other designs would be necessary if fine control of water levels is not possible while maintaining high alkalinity.

8.2 Possible Compensation Habitat at other Kelowna Sites

Other wetlands in the Kelowna area can be altered to create additional breeding and feeding places for avocets. The most successful alteration is likely to be at Robert Lake. While other sites are mentioned here, there is really no proof that these might work, and there may be serious impediments to any avocet habitat at these sites.

Robert Lake: It would appear that nesting islands are all that are lacking at Robert Lake in order for a colony of avocets to breed there. There is ample shoreline, which attracts a number of migrant and local birds to forage. Clusters of artificial floating nesting islands might be used to stimulate colony development, but this would have to be tested before this could be relied on as a mitigation method. These might be preferable to constructing permanent low islands with 1:12 side slopes on public land or rights-of-way in the lake. Since water levels cannot be controlled, these islands might be flooded in some years, and connected to the mainland in other years. Unless private owners were amenable to making portions of land available, the best option on public land would be for a single island (0.07 ha or 30-m diameter) in the south west corner which is presently owned by Central Okanagan Regional District to be managed as parkland. However, this cannot be relied on for a colony since in low water levels this island would no longer be an island.

Slough Number 2 on Glenmore Road: There is a chance that this wetland might be used by a few avocet pairs if the area around the lake were thinned of trees and if several nesting islands were constructed. However, based on the lack of any avocets ever seen foraging there, the habitat might not be suitable for foraging at any rate. This wetland is on private land.

MacNeil (1999) indicated that this site is less alkaline than avocets would normally prefer so that, while outwardly appearing suitable, there may be serious impediments to its use by avocets.

There are probably no further realistic possibilities to create avocet Compensation habitat anywhere in the Glenmore Valley. The Glenmore Valley is the only mappable concentration of clayey Gray Luvisol soils of lacustrine origin in the central Okanagan (Figure 17 of Roed 1995) that are likely to naturally contain large alkali playas (i.e. shallow lakes where evaporation is the dominant or only form of water loss). These soils and the landscape of the Glenmore Valley contain the only 2 large clay-bottomed alkali playas of the central Okanagan, i.e. Alki and Robert lakes. The rest of the Kelowna area rests on soils developed from morainal, colluvial, fluvial or fluvioglacial material that are either better drained than the Glenmore Valley, or not as flat as the Glenmore Valley. However, 2 possibilities for compensation habitat are mentioned here anyway, since as shown at Chichester Bird Sanctuary, hyposaline wetlands can sometimes develop in other areas (MacNeil 1999). Both of the possibilities mentioned below are on private land.

Sexsmith Wetlands: Open fields bounded by Sexsmith Road to the north, Longhill Road to the west and Campion Road industrial area to the east. Creation of avocet habitat in this large open field could create a nice transition zone between the industrial and residential areas on opposite sides of it. The field is devoid of trees and appears to be an ideal location for creation of compensation habitat for avocets. A relatively small 7 ha wetland would take up only a fraction of the total area. The site is gently sloping and the site of existing cattail marshes along a drainage. The site would need to be assessed to see if an alkali evaporation pan could be built there, and how much earth works might be required. Alterations to the present surrounding habitat would be unnecessary because if is presently very open and likely suitable (in general) for avocets. Soil substrates appear to be clay but would have to be assessed. A natural gas pipeline occurs to one side of the field and would have to be avoided.

Fields south of Duck Lake: large open meadows and hayfields occur to the south and south east of Duck Lake in which compensation habitat could be created, but would have to be assessed.

8.3 Other Mitigation

The possibility of further nesting colonies of avocets in the Cariboo area cannot be dismissed; they are very real possibilities. This possibility should be confirmed or denied in the summer of the year 2000. While alkali lakes are scattered across the more arid regions of southern B.C. there is a very high concentration of alkali lakes in only a small area of B.C. in the vicinity of Clinton and 70-Mile House (Renaut 1993). Little White Lake is in that area.

The total anticipated budget would be on the order of $5000. A fairly simple search scheme would involve:

- aerial photo examination of that area at Forest Service offices for suitable nesting sites, and apparently shallow waters that might be suitable for foraging,
- aerial surveys (Cessna 172) for concentrations of avocets in potential sites, and
- follow-up ground surveys for any concentrations of avocets seen from the air.

The Little White Lake colony site is on Crown Land and should be considered for formal protected status, or at least have the principal small (<1 ha) feeding pond fenced off from cattle use. This pond is isolated from Little White Lake except at very high water levels by a low esker. The water is far too alkaline for livestock use, but many cattle wander into the area anyway, and do considerable trampling of the very soft clays at the water's edge.

9. ACKNOWLEDGMENTS

Funding for this portion of the American Avocet Project at Kelowna was supplied by the City of Kelowna, the Central Okanagan Naturalists Club, the Central Okanagan Foundation, the James Baillie Memorial Fund, the Environment Youth Team of B.C. Environment and Canada Trust's Friends of the Environment Fund. These funds were ably managed by a volunteer committee from the Central Okanagan Naturalists Club, principally by Gwynneth Wilson and Janice Casling. University of Toronto supplied the canoe we used for nest searches and Okanagan University College supplied a rowboat and many other miscellaneous supplies with many thanks to Dr. Ian Walker in particular. We would also like to thank the City of Kelowna for providing access to the Alki Lake site as well as to city staff for providing support for this project. We would like to thank those landowners around Robert Lake and other wetlands who supported the project and provided access to these wetlands on and across their lands.

A special thanks to volunteers from the Central Okanagan Naturalist Club and others who participated in the surveys of avocets at Kelowna including Margaret Bryan, Janice and Mike Casling, Eileen Chappell, Bill Cutfield, Lisa Dreger, Elke Fischer, Les Gyug, Laura Ha, Judy Latta, Robin Yellowlees, Nettie and Deiter Overhoff, Lesley Robertson, George and Etta Scotter, James Weir, Pat and Hugh Westheuser, Frank Williams, Don Wilson, Gwynneth Wilson and any others whom we might have inadvertently missed in this list. We'd like to thanks Daphne Ogilvie for her hospitality and for leading us to the Cariboo colony of avocets. We would like to thank all the birders of B.C. who supplied observations of avocets for this project, particularly through the B.C. Interior Birders e-mail Group. We would like to thank Martin Gebauer who created the research design for this project and edited an earlier draft of this manuscript.

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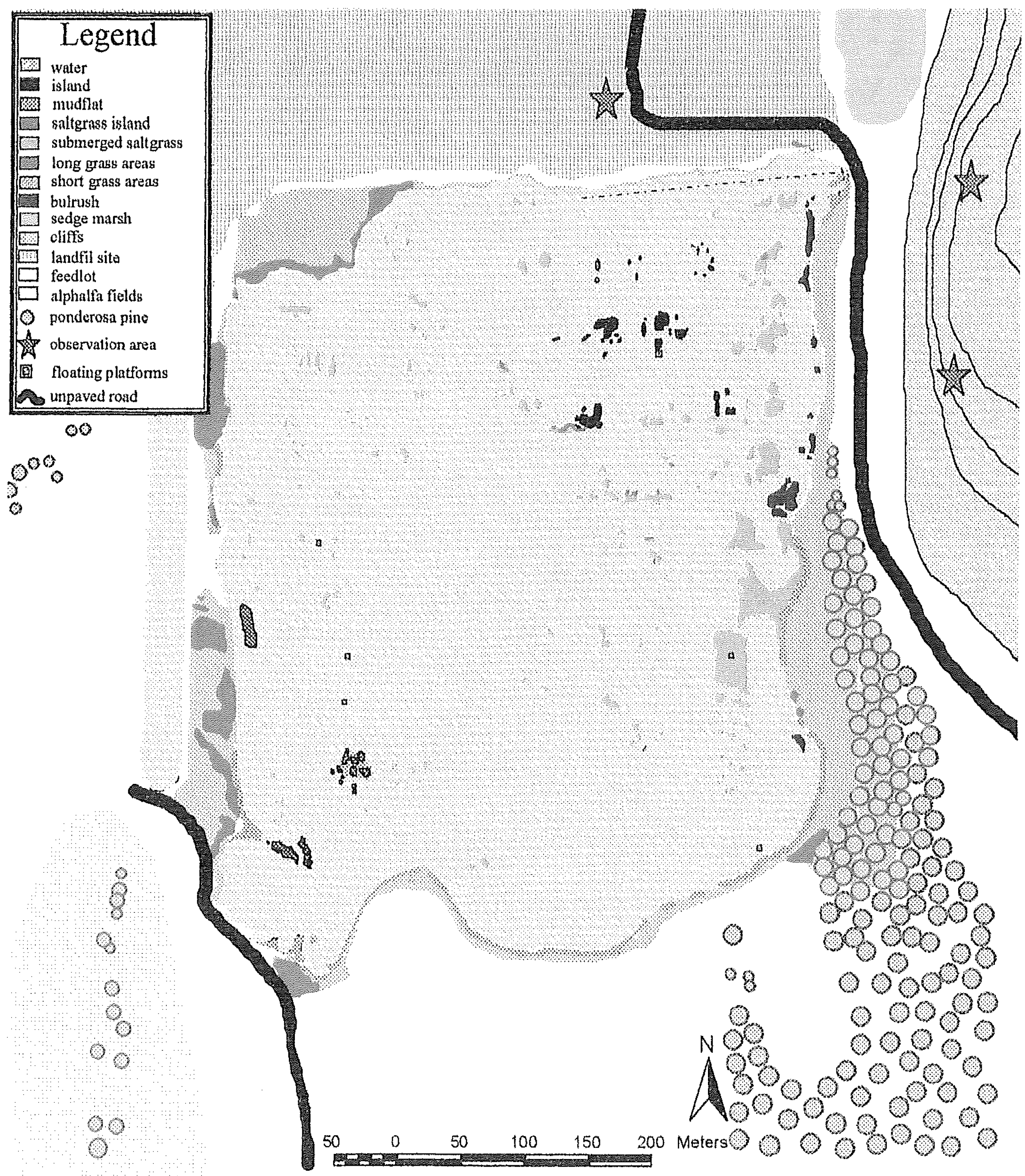
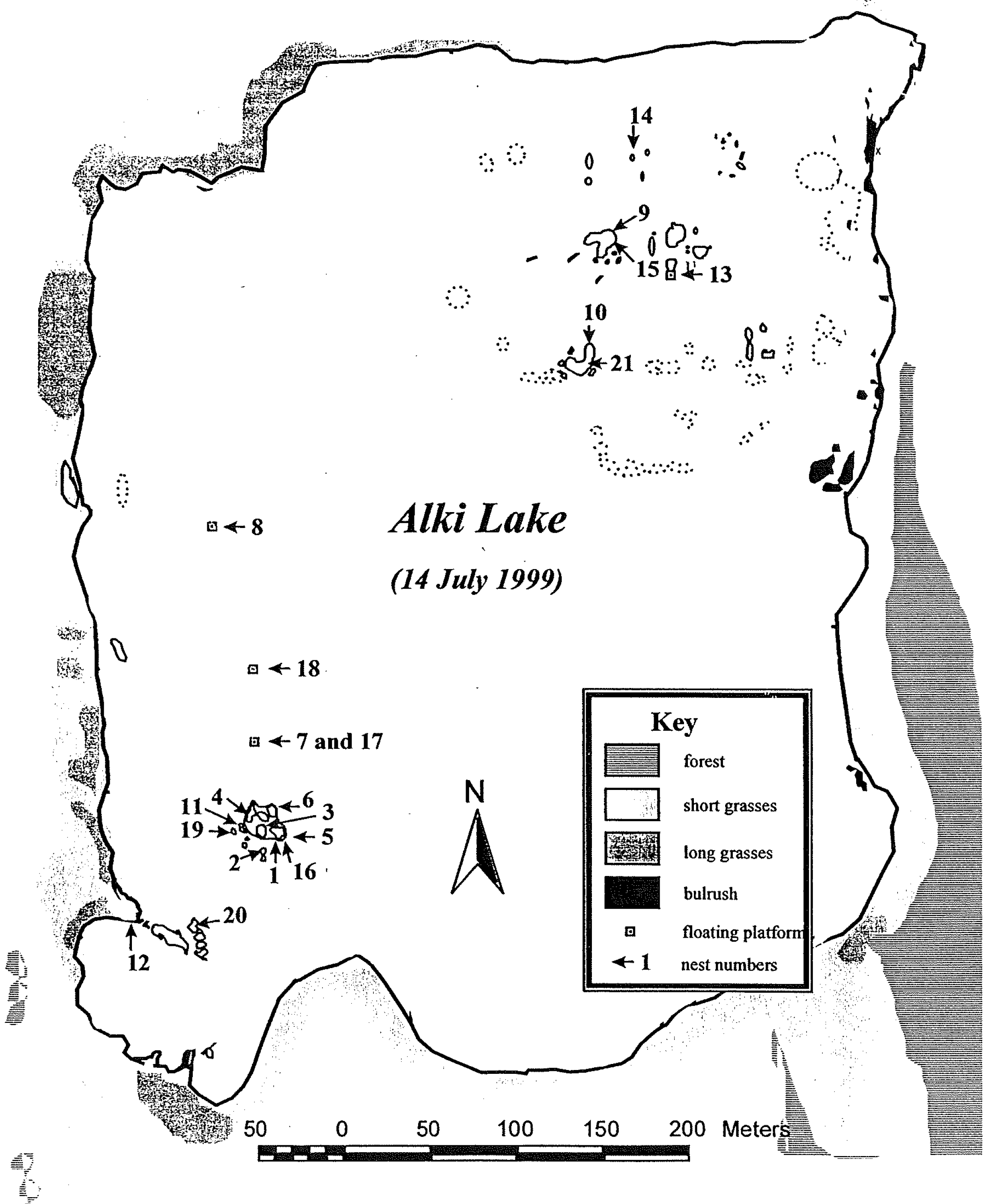
11. APPENDIX 1. Wetland Maps

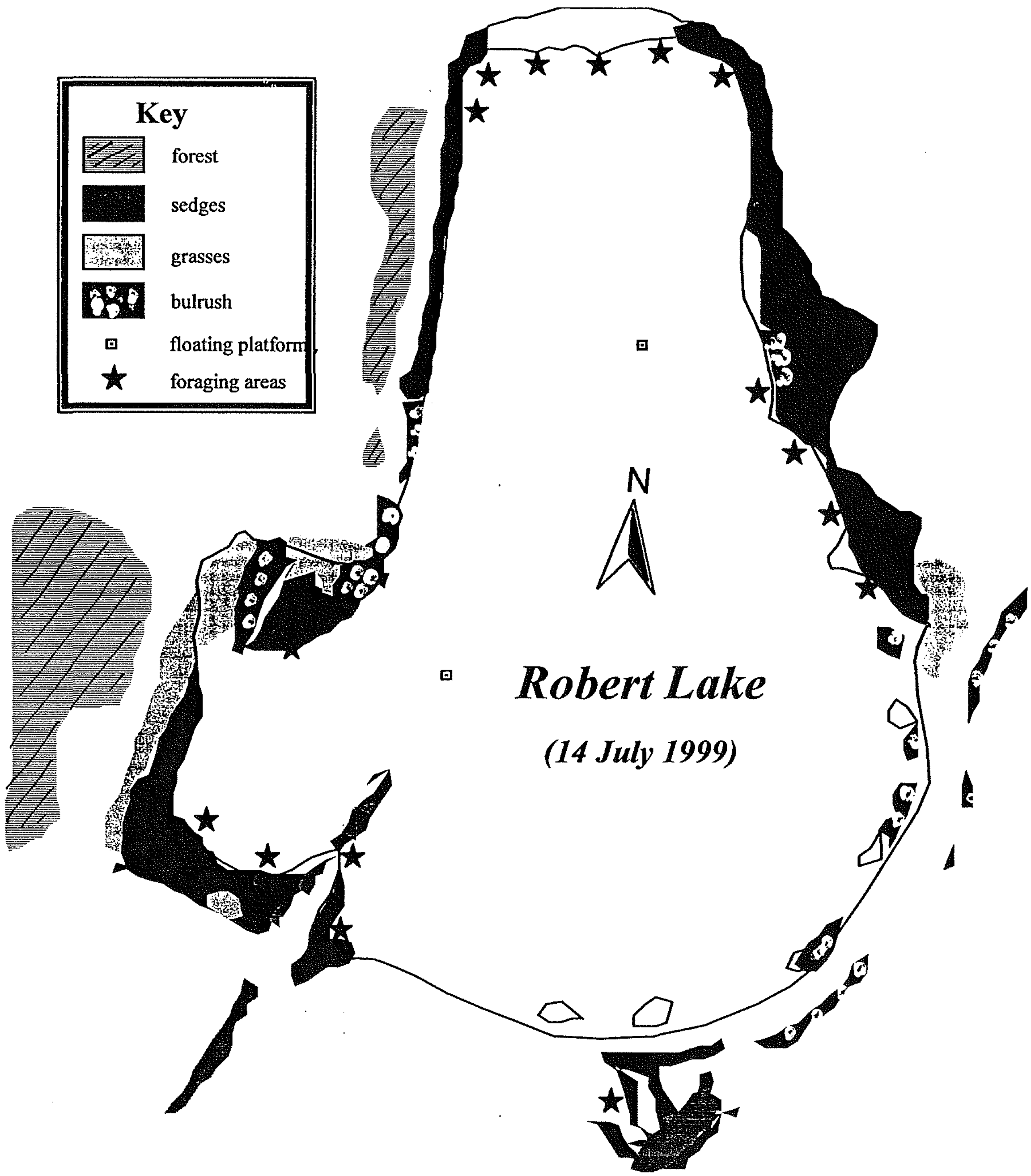
Map of Alki Lake with physical characteristics as appeared on 14 July 1999.



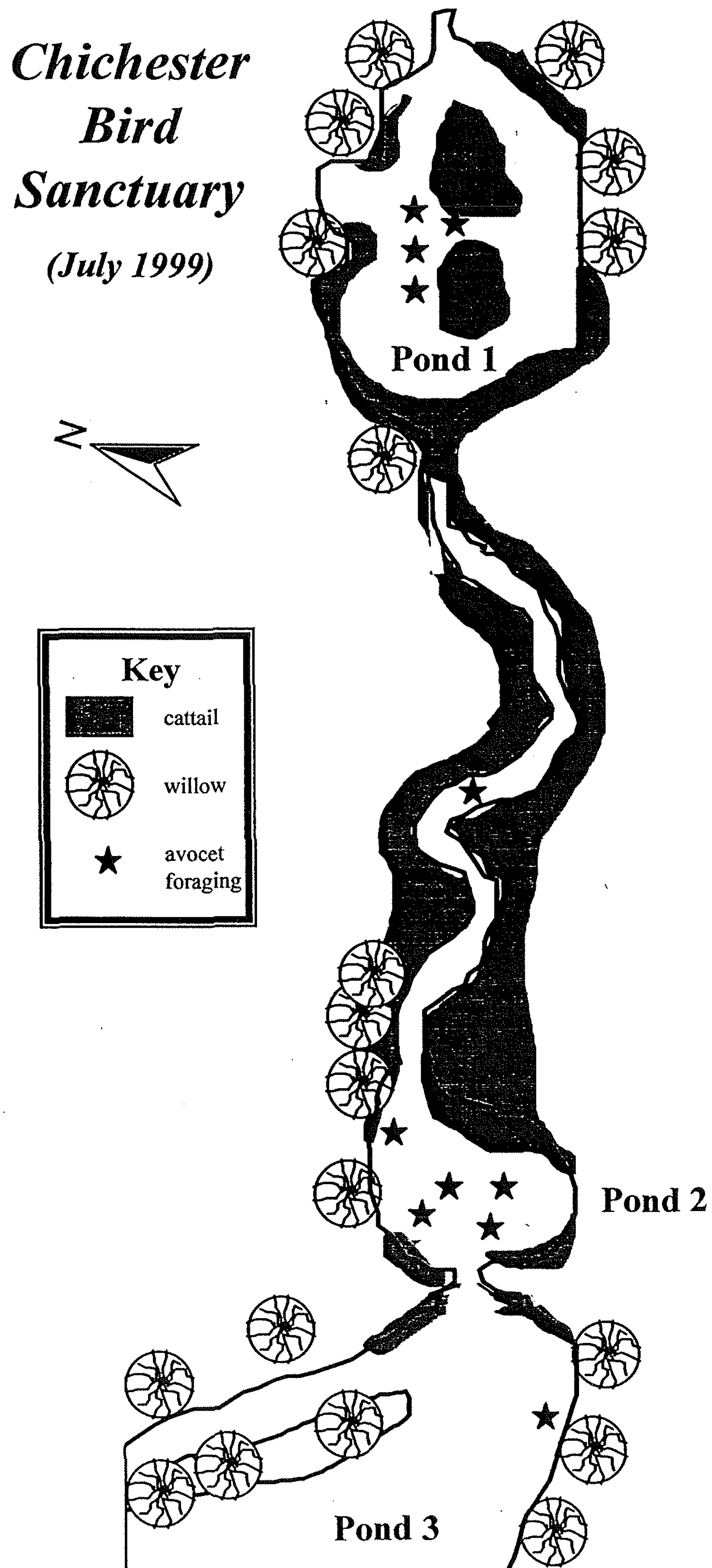
Map of Alki Lake, Kelowna showing nesting islands the way they appeared on 14 July 1999. Nesting locations shown were not all active on 14 July but are shown here. Nest numbers correlate with nesting chronology numbers above.



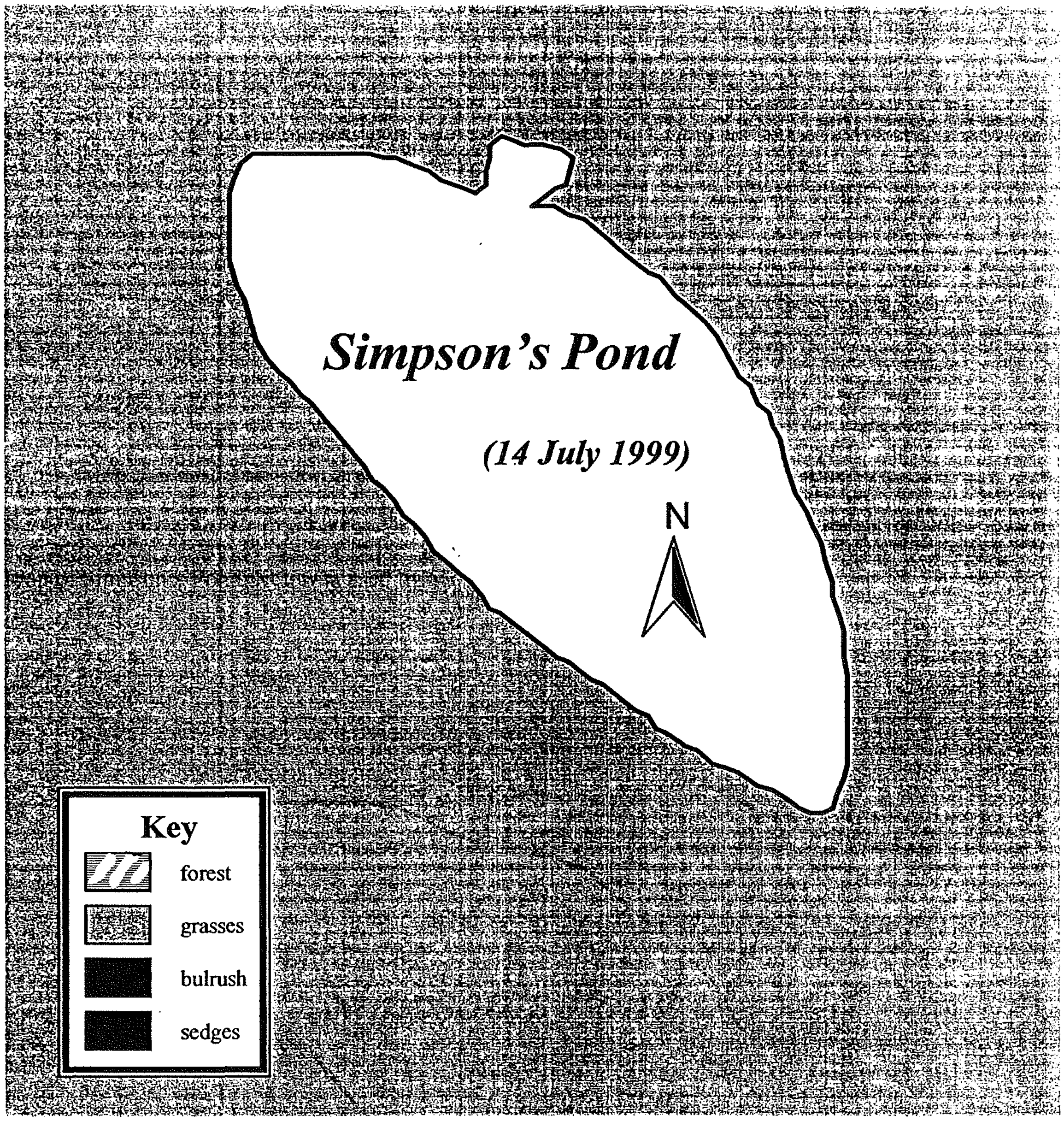
Map of Robert Lake, Kelowna on 14 July 1999.



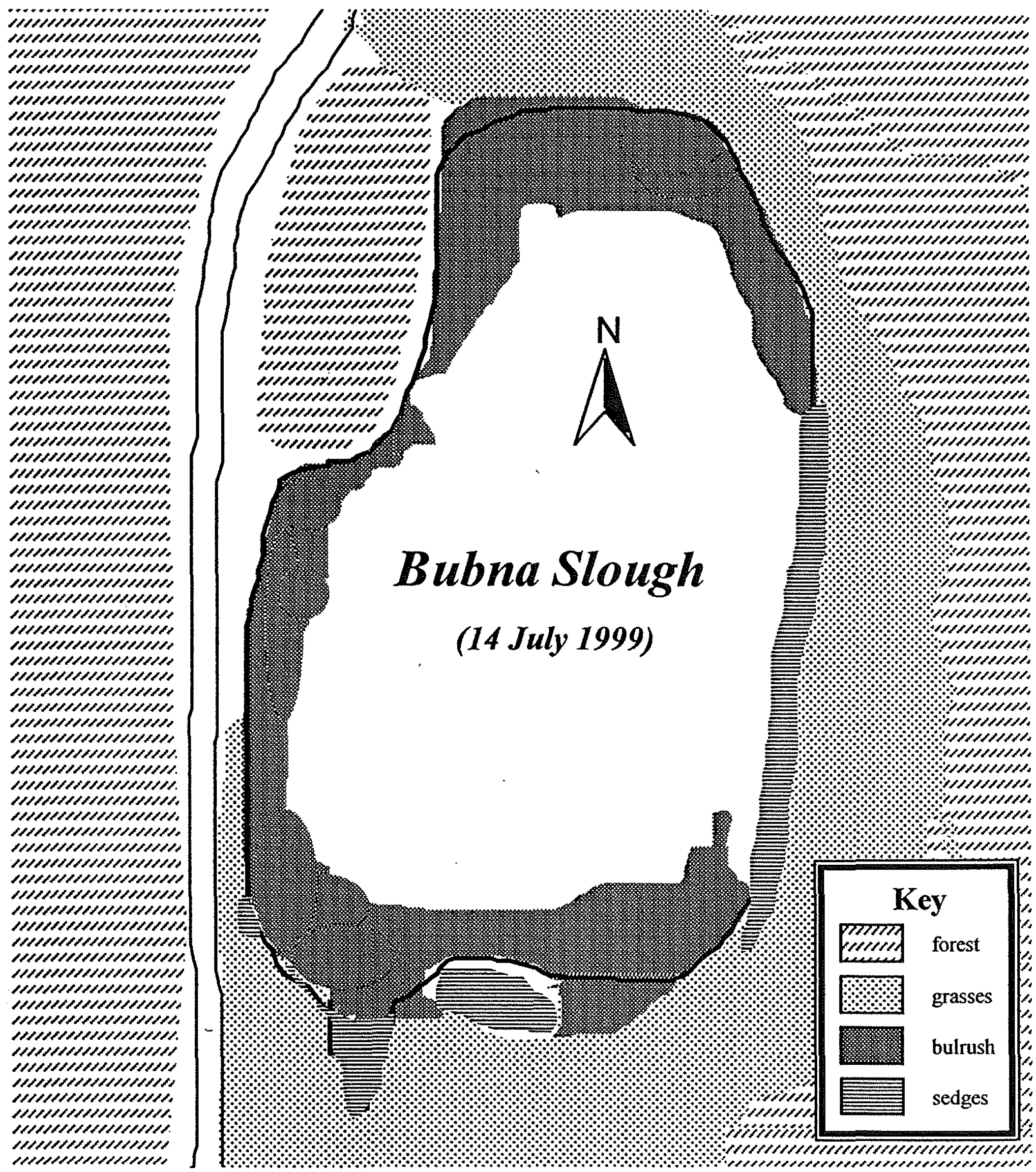
Map of wetlands used by avocets at Chichester Bird Sanctuary, Kelowna B.C. during 1999.



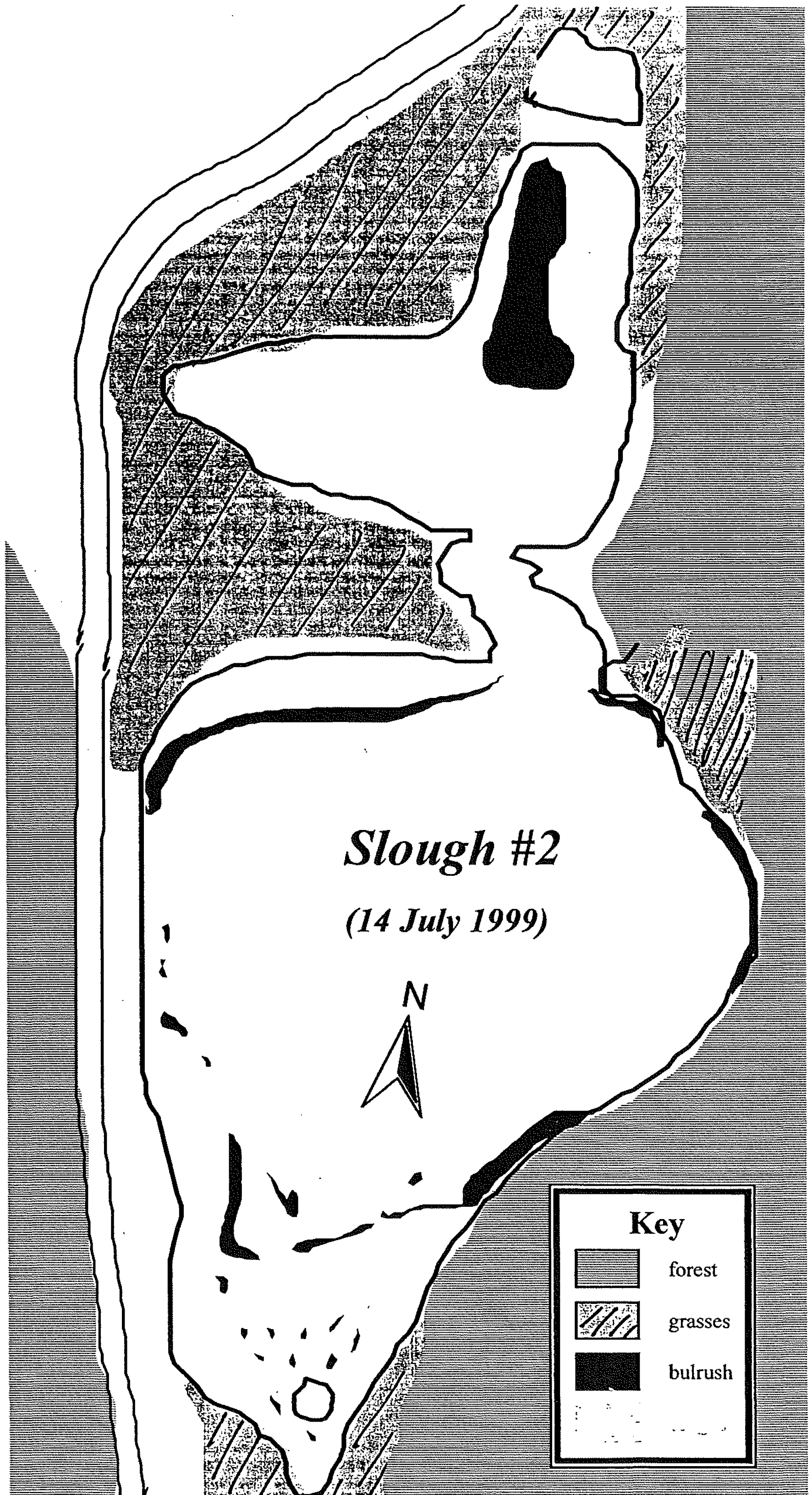
Map of Simpson's Pond, Kelowna used by avocets during 1999.



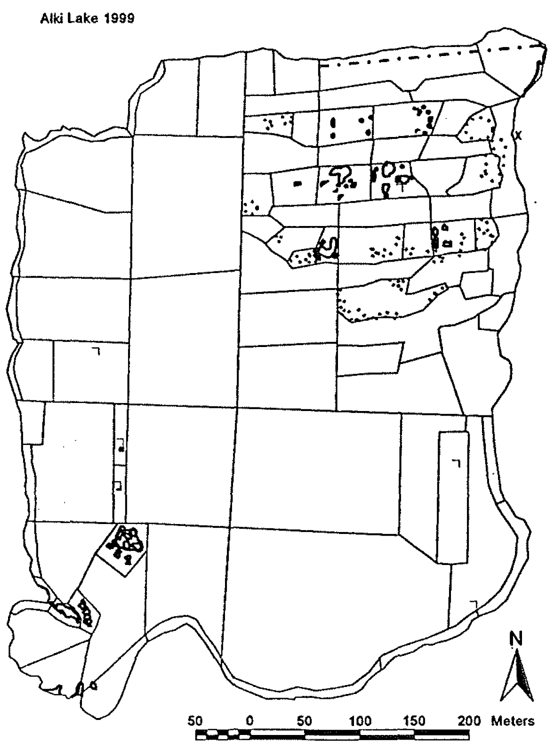
Map of Bubna Slough, Kelowna B.C. during 1999.

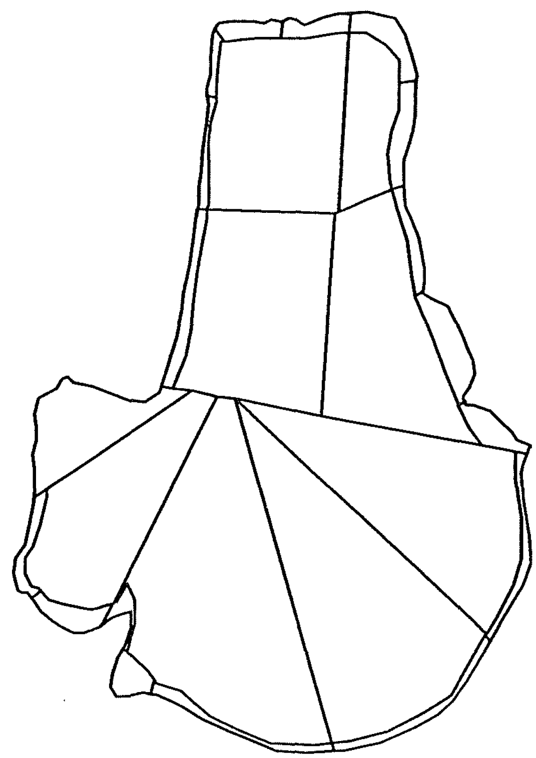


Map of Slough # 2, Kelowna B.C. during 1999.



APPENDIX 2. Map of Alki Lake (left) and Robert Lake (right) showing plotted cells used for avocet foraging habitat surveys. Maps not drawn to scale with each other.

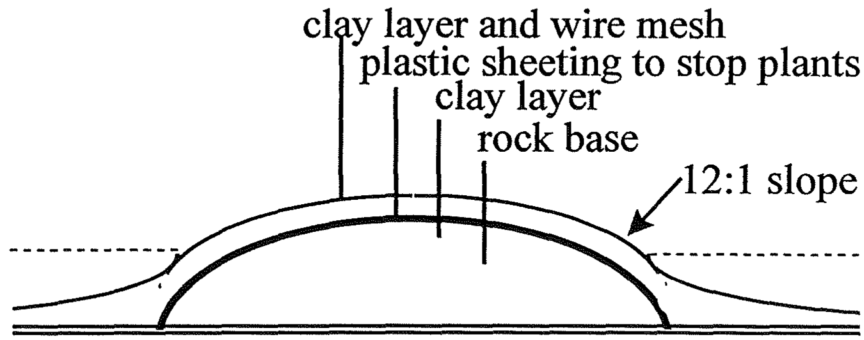




APPENDIX 3: Schematic diagrams of Proposed Compensation Islands and Habitats.

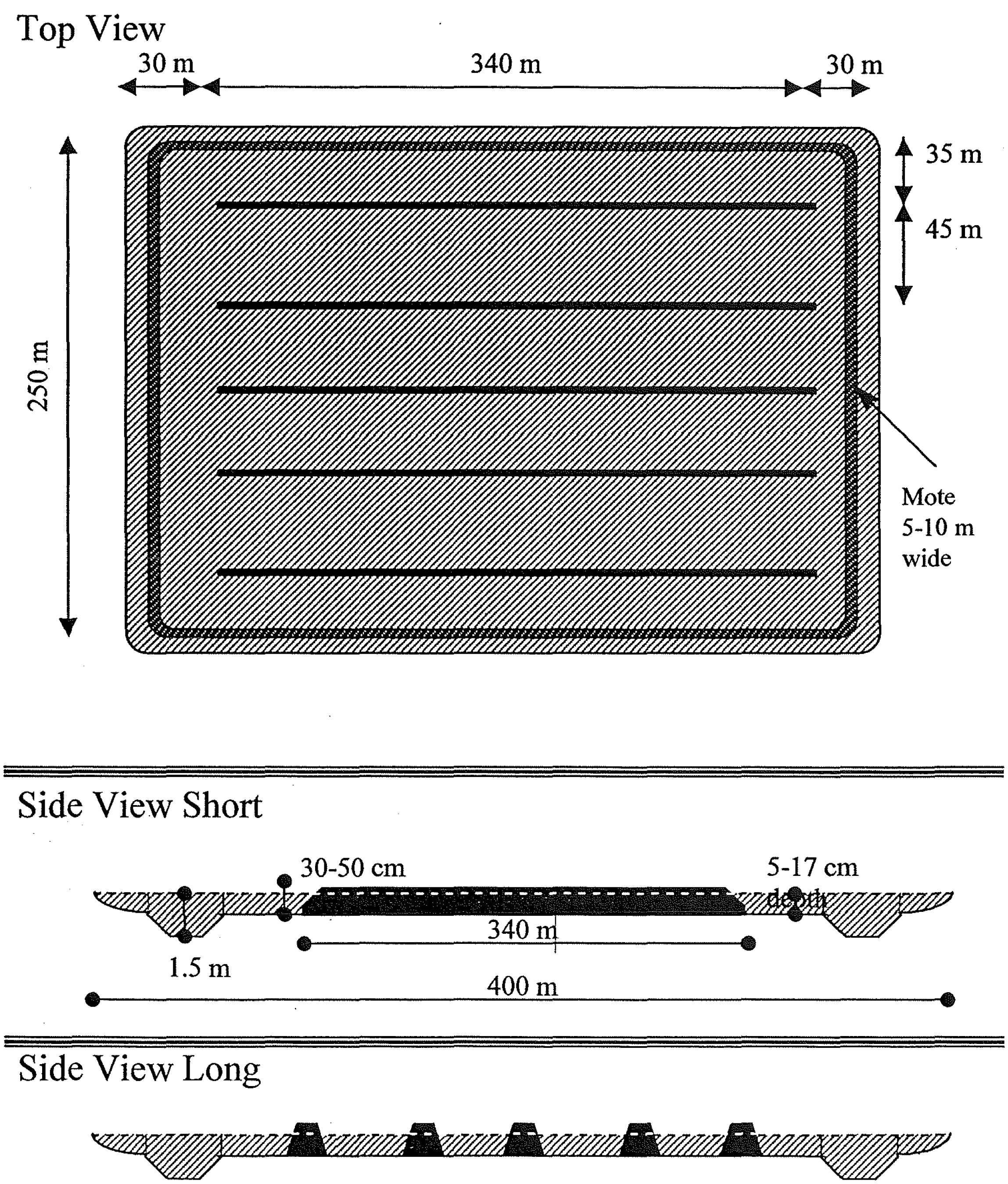
Possible nesting island structure as an alternative to simply ridging clay to 12:1 slopes. In water depths of 17 cm, entire island would be about 9 m wide at the base on the wetland bottom. Height of entire structure would be about 38 cm.

Schematic of Possible Nesting Island



Schematic diagram of proposed wetland design based on recommendations for 12 pairs of breeding and 6 non-breeding avocets incorporating most of the recommendations as outlined in this report. Entire habitat would have a 100-m treeless buffer, and a 150-m "no-work" zone for the avocet breeding season (April 15-August 15).

Schematic of a Proposed Compensation Habitat



Abundance and Types of Potential Invertebrate Prey of American Avocets in British Columbia

Prepared by Chrissy MacNeil
August 3, 1999
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Prepared for Central Okanagan Naturalists Club, Box 396, Kelowna, B.C. V1Y 7N8

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Samantha Ambrozy, my partner, and Lisa Dreger, my tutor, for helping me with my sampling and with writing this paper.

Abstract

The most important colony of American Avocets in British Columbia is located at Alki Lake, Kelowna (Weir 1997). This colony is next to the City of Kelowna Glenmore Landfill, which will be expanded within ten years to include Alki Lake, causing the loss of this colony. The objective of the American Avocet Conservation project, of which this paper is a part, is to collect the knowledge required to engineer a new habitat for the American Avocets. The purpose of this paper is to determine whether there is a difference in benthic and aquatic invertebrate diversity and density between areas where American Avocets are present and areas where they are absent. Information was also collected concerning substrate at each of these sites. Samples were taken using a (6.5 cm diameter) column sampler at 5 sites where American Avocets are present and 5 sites where they are absent. These samples were sieved and the invertebrates found were identified and counted. Sites where American Avocets are present have high numbers of Chironomidae and are abundant in certain other taxa of invertebrates as well. At least one of these taxa was found at every site where American Avocets are present. It was found that an abundance of Chironomidae along with a food that American Avocets prefer such as Ephydridae, Hirudinea, Corixidae, or Cladocera contribute to American Avocet presence. Substrate at sites where American Avocets were found was softer than at sites where American Avocets are absent. A soft substrate with no particles larger than 0.25mm in diameter contributes to American Avocet presence. All these features should be incorporated into the new wetland.

Table of Contents

Addendum prepared by Les Gyug (2 pages) follows Appendix.

1.0 Introduction

1.1 Background

The American Avocet *(Recurvirostra Americana)* was first sighted in British Columbia in 1908 (Brooks 1909). Since then many sightings have been reported, especially after the 1950s, when habitats, particularly artificially created habitats, became more available (Robertson et al. 1997). American Avocets prefer alkaline sloughs, which are shallow with mud flats (Gebauer 1999). The first recorded sighting of breeding was at Duck Lake, near Creston, in 1968. Since then only six other locations of nests have been reported in British Columbia (Gebauer 1999). The most important colony reported was at Alki Lake in Kelowna where 19 pairs were reported in 1997 (Weir 1997). Breeding was first reported here in 1987 when two pairs were observed. Nesting may also have occurred between 1994 and 1996 as many adults were sighted. Three pairs were observed in 1998 (Gebauer 1999). Another colony has been found recently at Little White Lake west of the Clinton area (pers.comm. J. Weir 1999).

1.2 Present Situation

The City of Kelowna owns Alki Lake, including the southern half where the American Avocets now breed. The City plans to expand the Glenmore landfill, which already occupies the northern end of what was the original lake. This plan would involve the de-watering of the site and would destroy the American Avocets' habitat creating a need for another breeding area. Unfortunately, to create a new habitat for the American Avocets much knowledge needs to be collected concerning issues such as physical features, water chemistry and invertebrates. If this information can be collected, the possibility of developing a new nesting and foraging habitat could be looked in to.

1.3 Purpose and Sampling

The objective of this research was to determine the abundance, diversity, and availability of potential prey of American Avocets in British Columbia. This research will help to determine which species and densities of aquatic and benthic invertebrates promote the presence of American Avocets. American Avocets feed mainly on invertebrates, especially insects such as Diptera and Coleoptera, Crustacea such as Cladocera and Anostraca, and Annelids such as Hirudinea and Oligochaeta (Davis and Smith 1998). Sampling to identify the benthic and aquatic invertebrates present was done at five sites where American Avocets are breed and forage. These sites are:

- Alki Lake (Glenmore Marsh)
- Robert Lake
- Chichester Wetlands
- East Little White Lake
- East Pond

Sampling was also done at five sites where American Avocets are not present. These sites are:

- West Little White Lake

- West Pond
- Bubna Slough
- Slough #2
- Simpson's Pond

1.4 The American Avocet Project

This report is part of a larger project that encompasses characteristics of foraging and breeding habitats of the American Avocet in British Columbia. These characteristics include water chemistry, prey abundance, substrate, vegetation, and location. It also addresses American Avocet population and reproductive success in British Columbia. The objective is to identify which traits are favorable for the nesting and foraging of these birds so as a new wetland habitat can be constructed to replace the one which will be lost at Alki Lake.

2.0 Materials

2.1 Sampling Materials

Graduated column sampler

A 60cm long cylindrical acrylic column sampler with an inside diameter of 6.5cm and an outside diameter of 7cm was used to collect samples. It was graduated with markings at every centimeter up to 40 cm. The column sampler was used with a #13 2.75cm thick rubber stopper which is 6.5cm wide at top and 6cm wide at bottom and a 7.0cm wide cover made of a plastic bottle cut into two 7.5cm long halves.

Sieve (.297mm)

A USA standard testing sieve with an aperture of .297mm was used to check for aquatic invertebrates. It was composed of stainless steel mesh with a brass frame.

Forceps

Number 4 or 5 rust-less, non-magnetic steel forceps we used to the check the sieve for aquatic organisms.

Plastic bags

Ziploc plastic bags were used to contain the samples while taking them from the field to the lab. They were 18cm wide and 20cm long. They had a white strip that was used for labeling.

95% ethanol

A solution of 95% ethanol (denatured) was used for the preservation of the invertebrates.

Meter stick

A metal meter stick marked in centimeters up to 1m was used to measure the depth of the water.

Benthic survey field data sheet

A sheet modified from the City of Kelowna benthic biomonitoring data sheets created with Microsoft Excel (fig 2.1) was used to record characteristics of each site.

Collecting jars

Sixty-milliliter glass jars filled with the ethanol solution were used to preserve the invertebrates found in the water and to transport them to the lab.

2.2 Classification and Counting Materials

The same collecting jars and forceps used when collecting samples were used while classifying and counting the invertebrates.

Sieves

A set of three USA standard laboratory sieves was used to sift through the samples. The apertures were either 3.35mm mesh or 4.75mm mesh, with .850mm mesh or .600mm mesh, and .297mm mesh or .250mm mesh. As the .297mm sieve is of a smaller diameter than the rest, when it was used the .106mm mesh sieve was placed underneath it to catch any material it may have missed. All sieves are composed of stainless steel mesh and a brass rim other than the .106mm sieve that was composed of p/bronze.

White pan

The sifted through sieves were placed in a 41cm long, 26cm wide, 6.5cm deep white pan containing approximately 4cm of water to make the invertebrates easier to find.

70% ethanol

The invertebrates were placed in a solution of 70% ethanol (denatured) to preserve them.

Petri dish

The invertebrates were placed in a petri dish for identification and counting.

Microscope

The invertebrates were placed under an Olympus dissecting microscope with an SZ40 (40x) objective lens for counting and identification.

Classification Keys

The invertebrates were classified using the invertebrate keys in "How to Know the Aquatic Insects" (Lehmkuhl 1979), "How to Know the Freshwater Crustacea" (Fitzpatrick 1983), "An Introduction to the Aquatic Insects of North American" (Merritt and Cummins 1984) and "Ecology and Classification of North American Freshwater Invertebrates".

Figure 1: Example of Benthic survey field data sheet

Modified from the City of Kelwona benthic biomonitoring field data sheets

Benthic Survey Field Data Sheet

Marsh:	Time:
Location:	Sample#:
Date:	

Weather Conditions:

Now	Past 24hrs		Air Temp. ________
☐	☐	storm(heavy rain)	
☐	☐	rain(steady)	
☐	☐	intermittent rain	

Cloud cover: 0% ☐ 10% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐

Site Location Map:

Pond Features:

Origin		Watershed: predominant surrounding land use			
ground water	☐	forest	☐	commercial	☐
stream	☐	field/pasture	☐	industrial	☐
storm drain	☐	agriculture	☐	logging	☐
other	________	residential	☐	other	________

Riparian Vegetation: (10m buffer)

Indicate the dominant type and record the dominant species present: ________

☐ barren ☐ grasses ☐ brush ☐ deciduous ☐ herbaceous ☐ conifer other: ________

Aquatic Vegetation:

Indicate the dominant type and record species present

☐ rooted vegetation ☐ rooted submergent

☐ floating algae ☐ attached algae

dominant species present:

Inorganic Substrate Components						Organic Substrate Components	
substrate type	code	diameter (mm)	substrate type	code	diameter (mm)	substrate type	Characteristics
Stones	S	>25 cm	very fine	VFS	.10-.05	Detritus	sticks, wood, coarse plant material
Cobbles	C	7.5-25 cm	silt	SI	.05-.002	Muck-Mud	black, very fine organic
Gravel	G	<7.5 cm	clay	C	<.002		
very coarse	VCS	2.0-1.0	fine clay	FC	<.0002		
coarse sand	CS	1.0-.5					
medium sand	MS	.5-.25					
fine sand	FS	.25-.10					

description of substrate:

3.0 Methods

3.1 Choice of Sites

Sampling was done at five sites where American Avocets breed and forage. These sites are Alki Lake, Robert Lake, Chichester Wetlands, East Little White Lake, and East Pond. Sampling was done as well at five sites where American Avocets are not present. These sites are West Little White Lake, West Pond, Bubna Slough, Slough #2, and Simpson's Pond.

At most areas only one sample was taken. Exceptions to this protocol were Chichester Wetlands, Alki Lake, and Robert Lake. Four samples were taken at each of these sites and one was chosen at random for analysis. In ponds where American Avocets are present, areas where they forage were chosen as sampling sites. If the American Avocets do not forage at a site, areas with similar characteristics as where they forage, such as the depth of the water, were chosen as testing sites.

3.2 Sampling Methods

All the sites were visited during the morning between 8am and 10am from June 24 and July 16, 1999. To collect benthic and aquatic invertebrate samples a method similar to the system described by Swanson (1978) was used. In water less than 24cm deep, five sub-sample spots were chosen at random. The water depth was measured and the column sampler was stuck into the sediment 5cm deep at each sub-sample area to obtain a 5cm benthic sample. If more than five centimeters of substrate was collected, sediment was removed from the bottom of the column sampler. Then the top of the column sampler was plugged with the rubber stopper and lifted out of the water then the half-bottle cover was placed on the bottom. The column sampler was taken to the shore where the rubber stopper was removed and any water poured into the .297mm sieve. The sieve was checked for invertebrates if any were found they were removed with forceps, placed in a jar with 90% ethanol and taken back to the lab.

The remainder of the sample was taken from the column sampler by removing the half-bottle cover on the bottom and placed in a labeled plastic bag with 90% ethanol to be taken back to the lab. The information on the label included the sites, the date and the sample number.

This process was repeated at each sub-sample site to collect five sub-samples, which formed one sample.

At the sample sites weather conditions, pond features, riparian and aquatic vegetation, and substrate components were recorded on the benthic survey field data sheet.

3.3 Classification and Counting Methods

The samples, other than those from the Clinton area, were sieved the same day that they were collected. Identification was done either the same day that the samples were sieved or the following day. The samples from the Clinton area were sieved a few days after being collected.

The sediment was placed in the top sieve in a tier of sieves. The sediment was sifted through each sieve as water was run through the sieves to help the sediment pass through them. Each sieve was then placed in a white pan of water. Any invertebrates found were removed using forceps and placed in a jar of 70% ethanol.

Either that same day or the next, the invertebrates, contained in a petri dish with 70% ethanol, was placed under the microscope. They were identified either to order or to family if possible and counted using an invertebrate classification key. The species and numbers were documented. After being identified and counted they were returned to the jar. Aquatic and benthic invertebrates were counted together as one sample.

4.0 Results

4.0.1 Site Descriptions

Some information was collected at each site using the benthic survey field data sheets (fig. 1). The entire sheets can be found in Appendix A.

Table 1: Substrate of 10 alkaline sloughs in British Columbia whereas 0= not present 1= present

Sites	Gravel(<7.5cm)	Very Coarse Sand (2.0-1.0mm)	Coarse Sand (1.0-0.5mm)	Medium Sand (0.5-0.25mm)	Fine Sand (0.25-0.10mm)	Very Fine Sand (0.10-0.05mm)	Silt (0.05-0.002mm)	Clay (<.002mm)	Plant Matter/Algae
Alki Lake	0	0	0	0	1	1	0	1	1
Robert Lake	0	0	0	0	0	1	1	1	1
Chichester Wetlands	0	1	0	0	0	1	0	0	1
East Little White Lake	1	1	1	0	0	0	0	1	1
East Pond	1	1	0	0	0	0	1	1	0
West Pond	1	1	1	0	0	0	0	1	1
West Little White Lake	1	1	1	0	0	0	1	1	1
Simpson's Pond	0	0	0	0	0	0	0	1	1
Bubna Slough	1	1	1	0	0	0	0	0	0
Slough #2	1	1	0	0	0	0	0	0	0

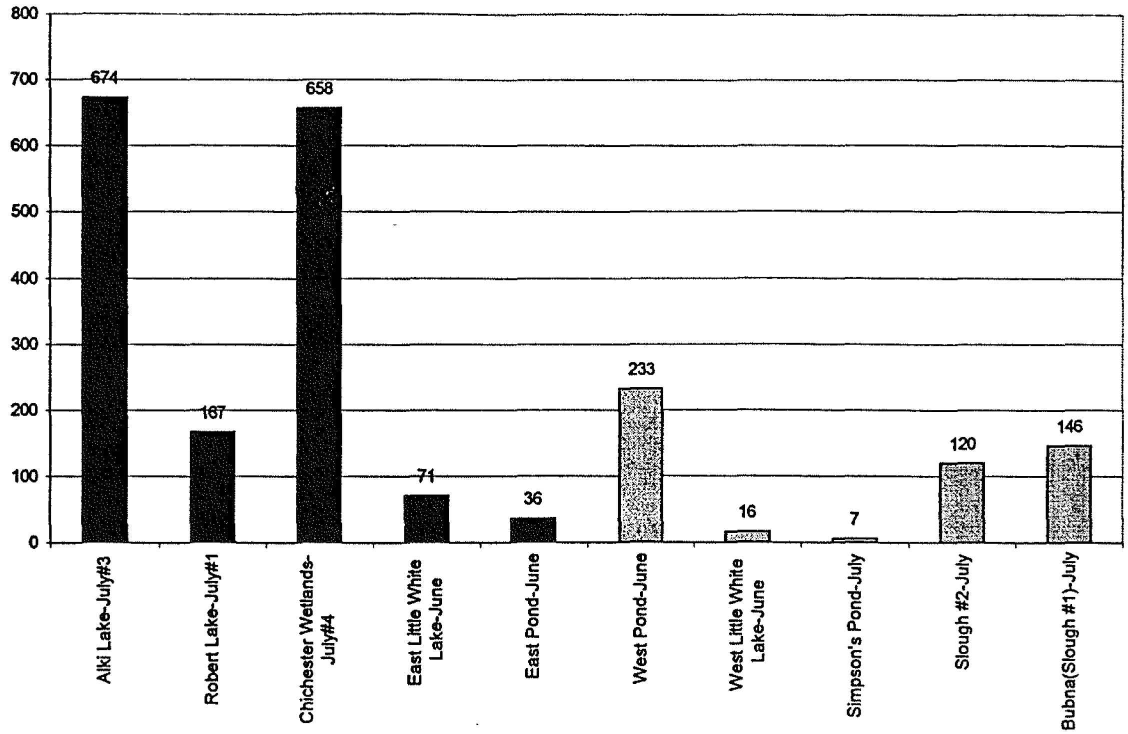
4.0.2 Invertebrate Counts

The density and taxa of benthic and aquatic invertebrates in ten marshes in British Colombia were compared. The taxonomy, life stage, and common name of each of the invertebrates found were recorded (table 2). Analysis enabled a comparison of the food available to American Avocets in areas where they forage, breed, or are not present. This information will be used to determine what characteristics of invertebrates would favour the presence of American Avocets in an artificially created wetland.

Table 2: Taxonomy, life stage, and common name of potential invertebrate prey of American Avocets in British Columbia.

Phylum	**Subphylum**	**Order**	**Family or suborder**	**Life stage**	**Common name**
Arthropoda	Insecta	Diptera	Chironomidae	Larvae	Midges
			Ephydridae	Larvae	Brine flies
			Ceratopogoniidae	Larvae	
			Other Diptera	Pupae	
		Corixidae		Adult	Water boatmen
		Ephemeroptera		Nymph	Mayflies
		Hymenoptera		Nymph	Wasps
		Odonata		Nymph	Dragon/Damselflies
		Coleoptera		Adult	Beetles
	Crustacea	Diplostraca	Cladocera	Adult	Water fleas
		Anostraca		Adult	Fairy shrimp
		Amphipoda		Adult	Scuds
		Calanoida		Adult	
Annelida		Hirudinea		Adult	Leeches
		Oligochaeta		Adult	Blood worms
		Other Annelida		Adult	Worms
Mollusca	Gastropoda			Adult	Snails

Figure 2: Abundance of Invertebrates in 10 Alkaline Sloughs in BC



4.1 Alki Lake

4.1.1 Site Description

Alki Lake is a ground water fed evaporation pond. The surrounding land is primarily used for fields or pastures and as a landfill. The substrate is composed of some fine grade plant matter, very fine sand (0.10-0.05mm in diameter), fine sand (0.25-0.10mm in diameter), and clay (<0.002mm) (Table 1).

4.1.2 Invertebrate Counts

More invertebrates (674) were found at Alki Lake than at the other sites (fig. 2). The majority of the invertebrates were Diptera (75%), of which Chironomidae were the most abundant. More Cladocera, Ceratopogoniidae, and Corixidae were found at Alki Lake than at any of the other sites. Ephydridae were only found at this site (fig. 3).

4.2 Robert Lake

4.2.1 Site Description

Rainwater, snowfall, and surface drainage collect and flow into Robert Lake (Tera Planning 1993). The surrounding land is used as a forest, fields and pastures, and residences. The substrate is composed of very fine sand (0.10-0.05mm), silt (0.05-0.002mm), clay (<0.002mm), and plant matter (algae) (Table 1).

4.2.2 Invertebrate Counts

There were fewer invertebrates in Robert Lake than Alki Lake, Chichester Wetlands, or West Pond (fig. 2). Most of the invertebrates found in Robert Lake were Diptera, of which all except for one were Chironomidae. The other Diptera was a Ceratopogoniidae. Three Corixidae and 17 Ephemeroptera were also found (fig. 4).

4.3 Chichester Wetlands

4.3.1 Site Description

The Chichester Wetlands are storm drain fed. The surrounding land is predominantly residential. The substrate is composed of very coarse sand (2.0-1.0mm in diameter), very fine sand (0.10-0.05mm in diameter), and plant matter (Table 1).

4.3.2 Invertebrate Counts

Chichester Wetlands had the most invertebrates, after Alki Lake (fig. 2). The majority of the invertebrates were Annelida, of which 59% were Oligochaeta. There was also one Hirudinea. There were far less Diptera than at Alki Lake and approximately two-thirds as many as at Robert Lake. There were also three Odonata (fig. 5).

4.4 East Little White Lake

4.4.1 Site Description

East Little White Lake is surrounded by land used for fields and pastures. The substrate is composed of cobbles (7.5-25cm), gravel (<7.5cm), very coarse sand (2.0-1.0mm), coarse sand (1.0-0.5mm), and algae (Table 1).

4.4.2 Invertebrate Counts

East Little White Lake had only one tenth as many invertebrates as Alki Lake (fig. 2). The majority was Diptera and Crustacea. There were equal numbers of Chironomidae and Cladocera. There were also three Amphipoda, a Calanoida and a Corixidae, as well as a Coleoptera (fig. 6).

4.5 East Pond

4.5.1 Site Description

The surrounding land is predominantly composed of fields and pastures. The substrate is composed of gravel (<7.5cm), coarse sand (1.0-0.5mm), clay (<0.002mm), and silt (0.05-0.002mm) (Table 1).

4.5.2 Invertebrate Counts

East Pond had the least invertebrates of any area where American Avocets are present (fig. 2). The majority of the invertebrates were Crustacea, of which 85% were Amphipoda. Three Cladocera and an Anostraca were also present. There were nine Diptera. Eight of these Diptera were Chironomidae (fig. 7).

4.6 West Pond

4.6.1 Site Description

Fields and pastures surround West Pond. The substrate is composed of gravel (<7.5cm), very coarse sand (2.0-1.0mm), coarse sand (1.0-0.5mm), clay (<0.002mm), roots, plant matter, and stringy algae (Table 1).

4.6.2 Invertebrate Counts

West Pond had the most invertebrates of any area where the American Avocets are not present (fig. 2). It had more invertebrates than Robert Lake, East Little White Lake, and East Pond. All except for one of the invertebrates were Diptera, of which all but 2 were Chironomidae. There was also a Ceratopogoniidae, as well as a Corixidae (fig. 8).

4.7 West Little White Lake

4.7.1 Site Description

Fields and pastures surround West Little White Lake. The substrate is composed of gravel (<7.5cm), very coarse sand (2.0-1.0mm), coarse sand (1.0-0.5mm), clay (0.002mm), silt (0.05-0.002mm) and plant matter (Table 1).

4.7.2 Invertebrate Counts

West Little White Lake had 16 invertebrates (fig. 2). Six of these invertebrates were Diptera, which were all Chironomidae. There were also 5 Crustacea, all Calanoida, as well as 5 Coleoptera and 2 Ephemeroptera (fig. 9).

4.8 Simpson's Pond

4.8.1 Site Description

Simpson's Pond is fed by Mill Creek. The surrounding land is used as fields and pastures as well as for agriculture. The substrate is composed of clay (<0.002mm) and plant matter (Table 1).

4.8.2 Invertebrate Counts

Simpson's Pond had the least invertebrates of any site (fig. 2). Three of these invertebrates were Diptera, which were all Chironomidae. There were two Ephemeroptera, one Annelida and one Gastropoda (fig. 10).

4.9 Bubna Slough

4.9.1 Site Description

Bubna Slough is fed by ground water and the surrounding area is a forest. The substrate is composed of gravel (<7.5cm), very coarse sand (2.0-1.0mm), and coarse sand (1.0-0.5mm) (Table 1).

4.9.2 Invertebrate Counts

Bubna Slough had more invertebrates than East Little White Lake and East Pond (fig. 2). Most of these invertebrates were Diptera (70), of which 69 were Chironomidae. The other Diptera was a Ceratopogoniidae. Fifty-six Crustacea, all Amphipoda, were found. There was also one Corixidae, one Odonata, one Ephemeroptera and one Coleoptera (fig. 11).

4.10 Slough #2

4.10.1 Site Description

Slough #2 is ground water fed and the surrounding area is a forest. The substrate is composed of gravel (<7.5cm) and very coarse sand (2.0-1.0mm) (Table 1).

4.10.2 Invertebrate Counts

Slough #2 had more invertebrates than East Little White Lake and East Pond (fig. 2). Seventy-one percent of these invertebrates were Diptera, of which all but 3 were Chironomidae. There was also one Ceratopogoniidae. There were 2 Crustacea, both Amphipoda. There were also 17 Ephemeroptera, 11 Corixidae and 2 Coleoptera (fig. 12).

Figure 3: Invertebrate Composition of Alki Lake

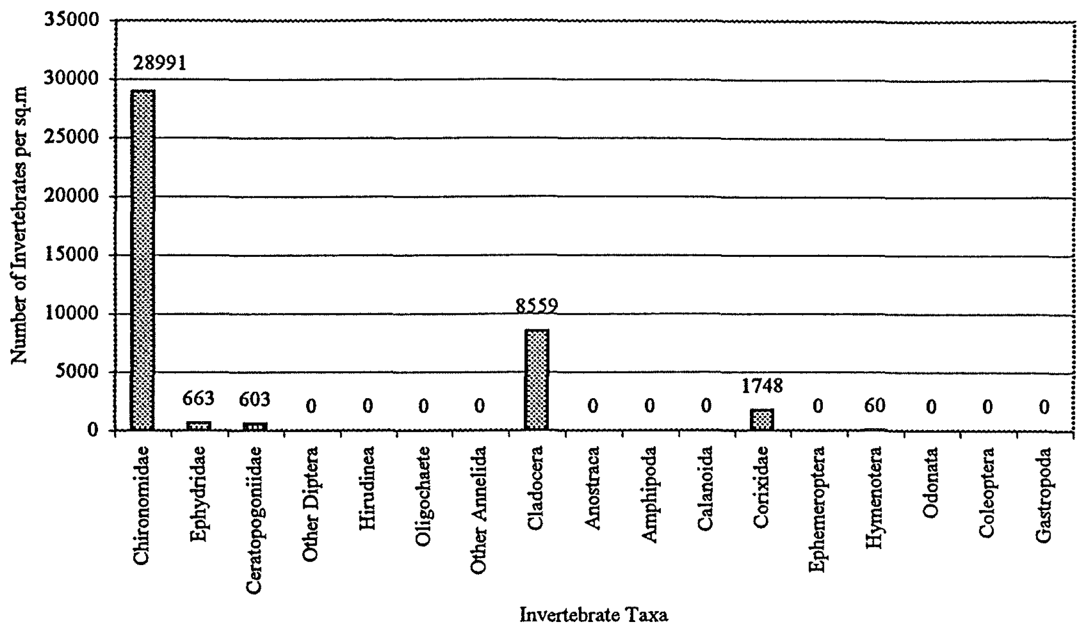


Figure 4: Invertebrate Composition of Robert Lake

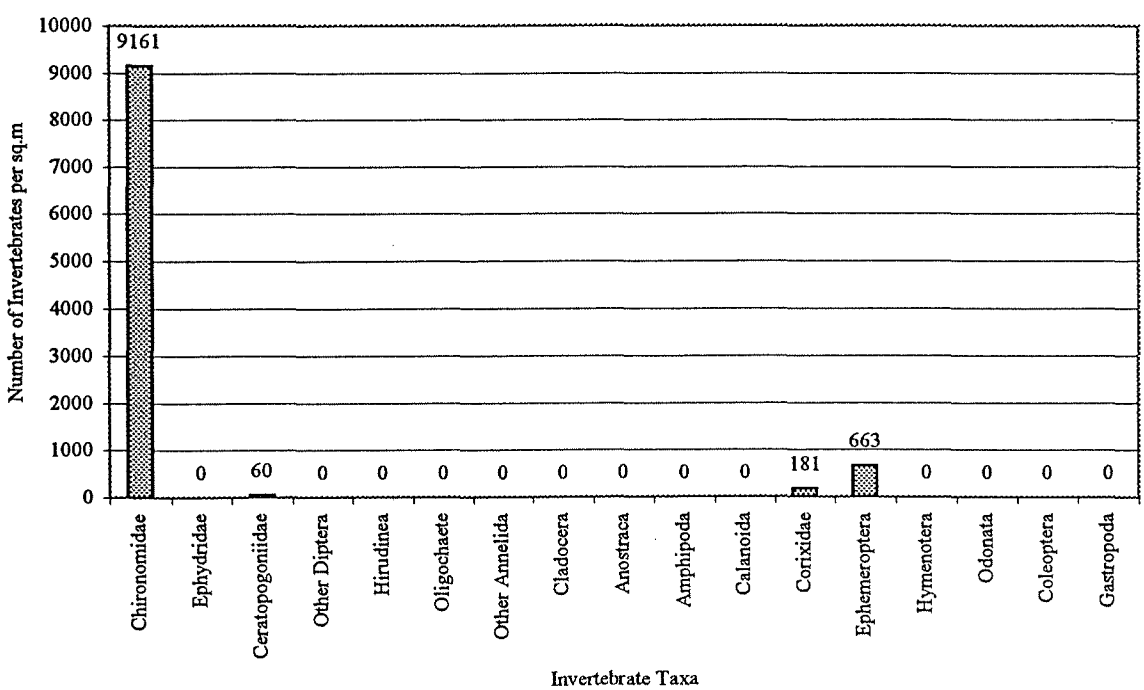


Figure 5: Invertebrate Composition of Chichester Wetlands

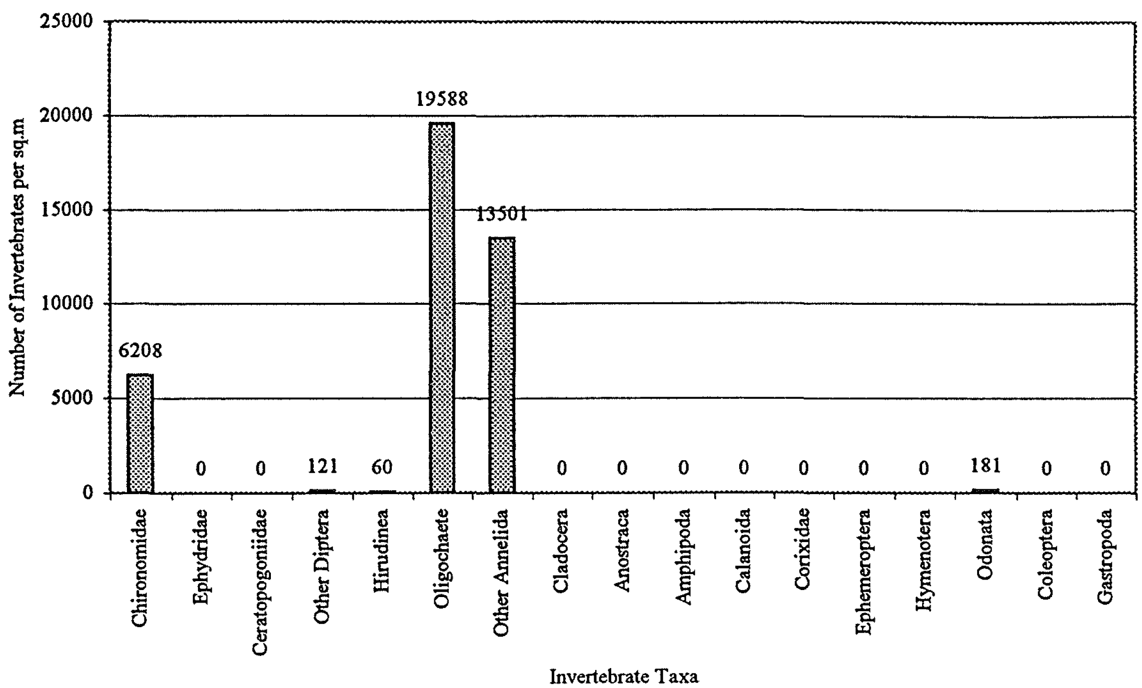


Figure 6: Invertebrate Composition of East Little White Lake

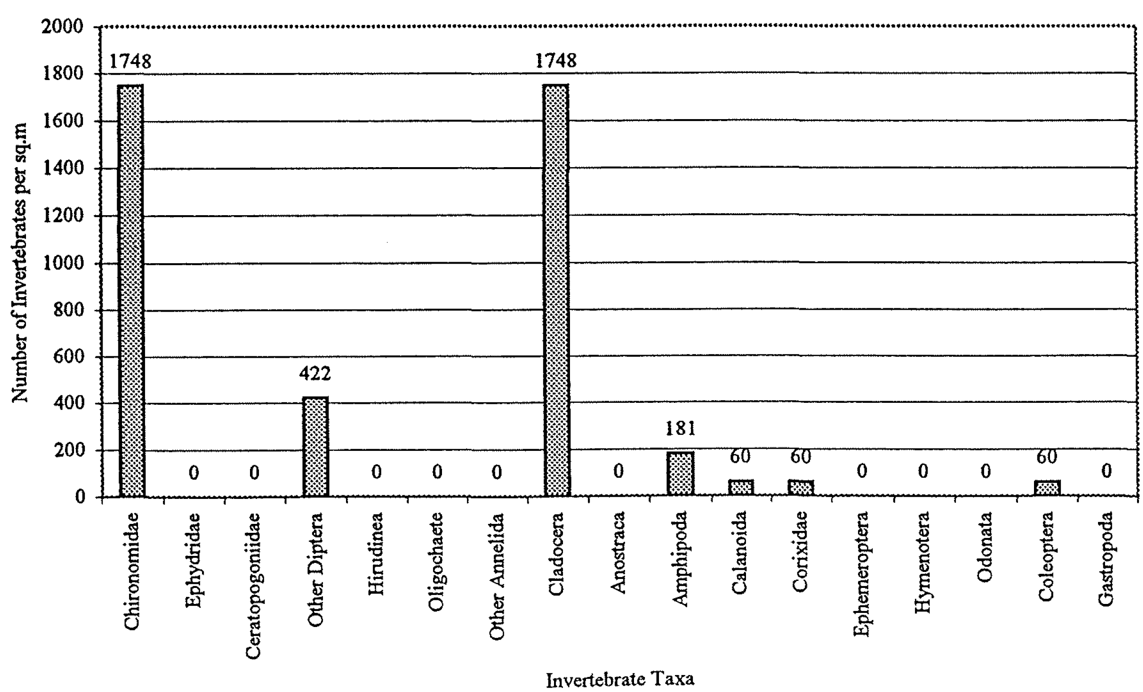


Figure 7: Invertebrate Composition of East Pond

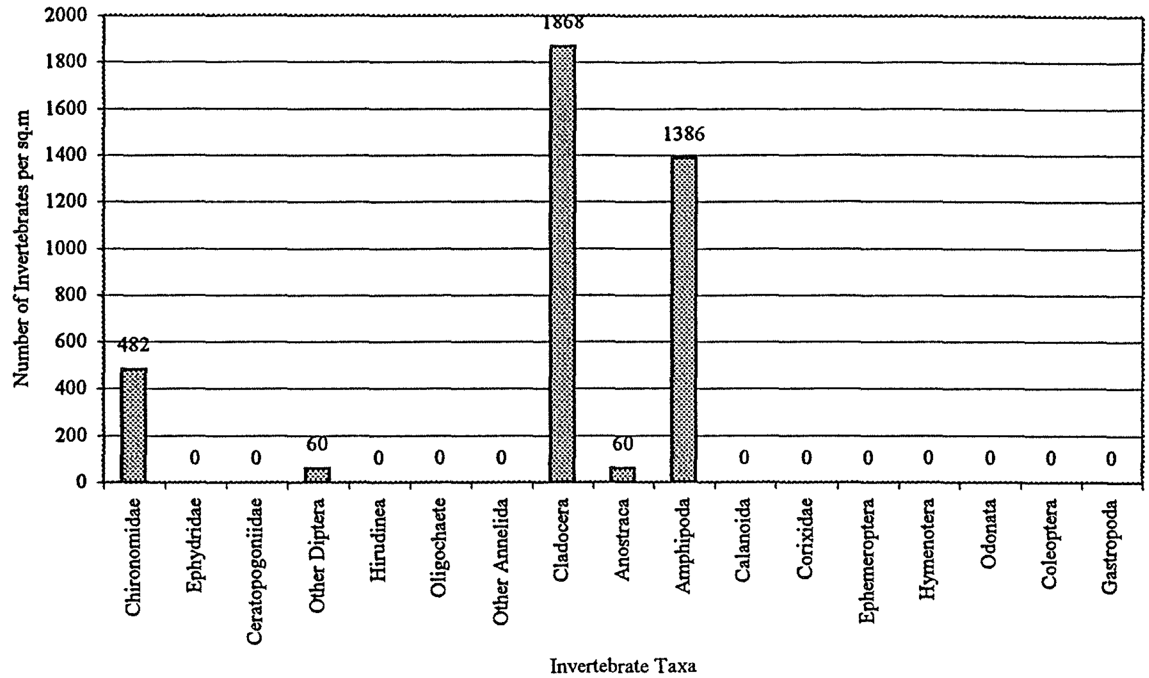


Figure 8: Invertebrate Composition of West Pond

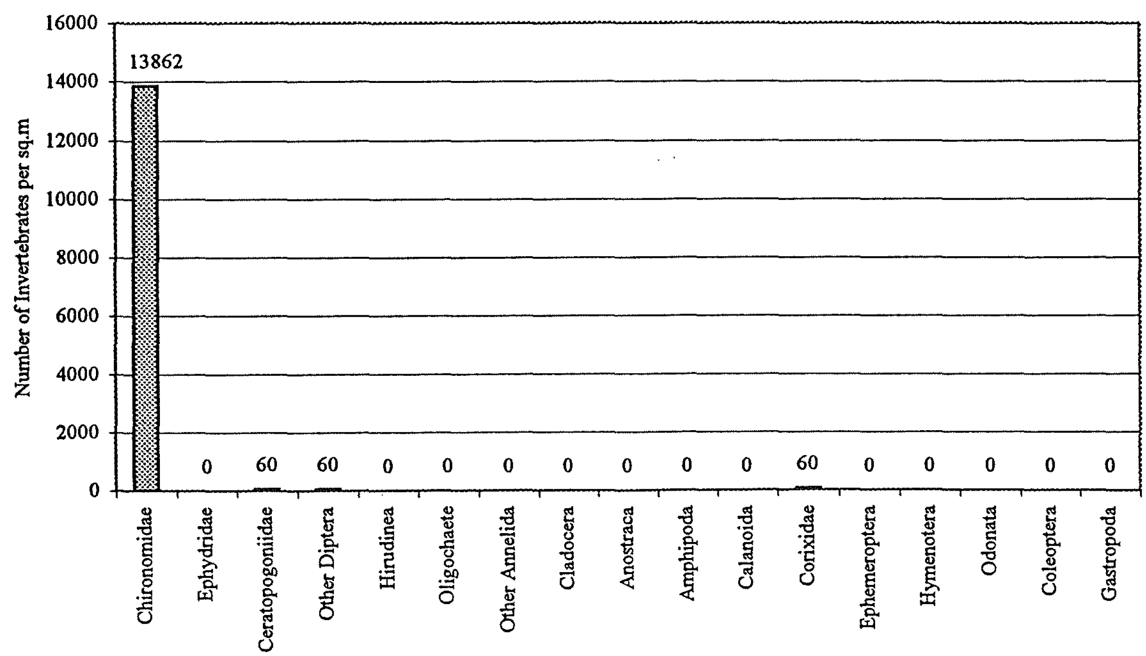


Figure 9: Invertebrate Composition of West Little White Lake

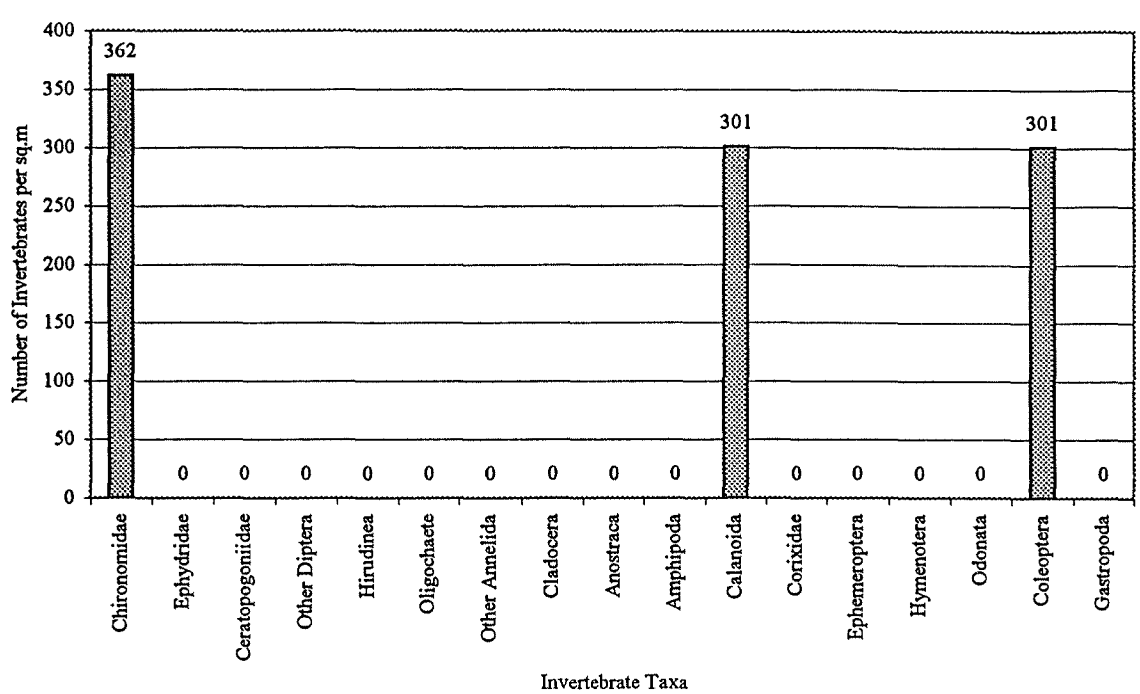


Figure 10: Invertebrate Composition of Simpson's Pond

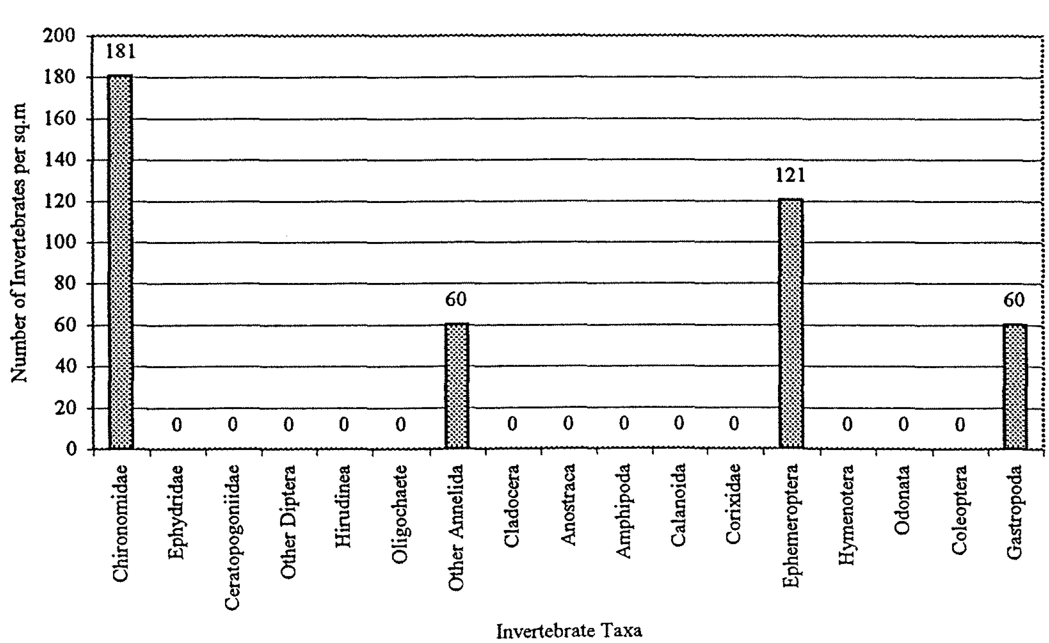


Figure 11: Invertebrate Composition of Bubna Slough

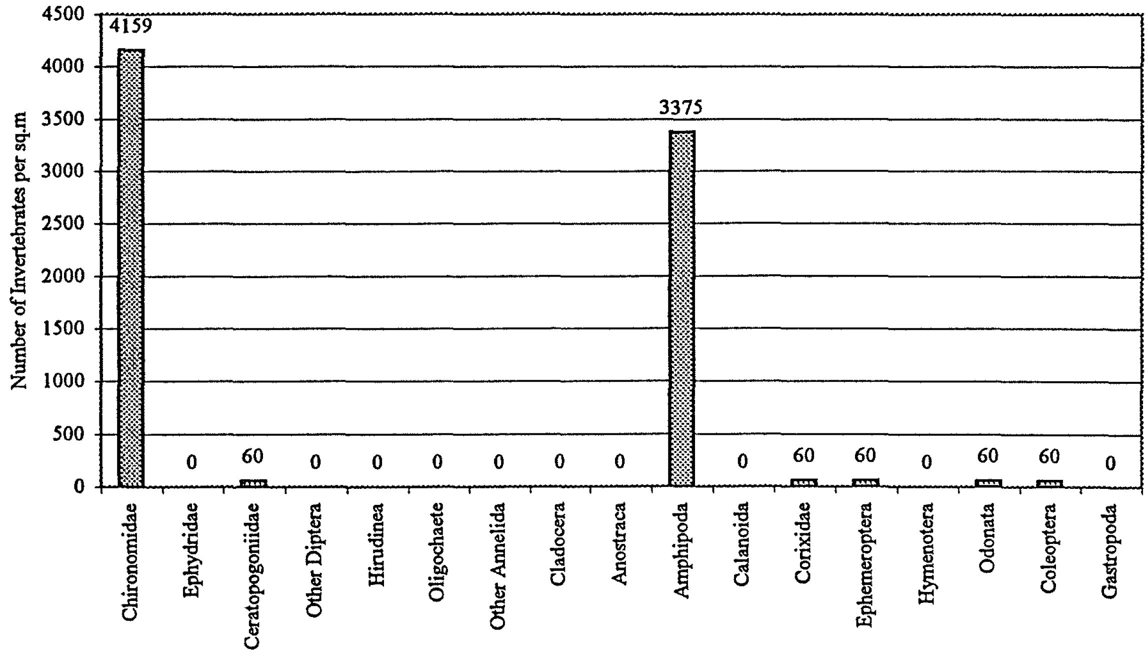
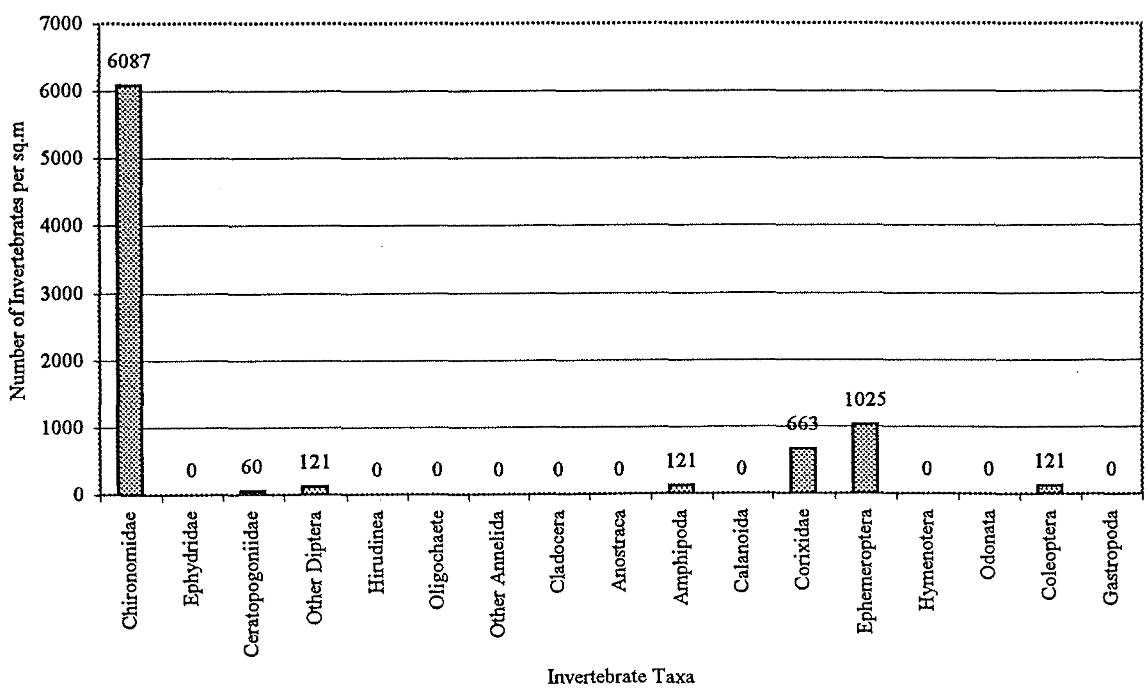


Figure 12: Invertebrate Composition of Slough #2



5.0 Discussion

It was found that areas used by American Avocets for foraging and breeding have different invertebrate densities, taxa and substrate as areas not used by these birds. It was also found those areas only used for foraging and areas used for foraging and breeding have different substrate, invertebrate densities and taxa.

All invertebrates are not equal in biomass (i.e. one Chironomidae is could be equal to 100 Cladocera) therefore they do not attribute the same amount of food to the birds. As the mean biomass of each species of invertebrate was not available, proper proportion can not be determined at this time. Further interpretation of these numbers as grams per sq. m. will be necessary in order to determine how much food is available to American Avocets at each site.

5.1 Alki Lake

One reason that the American Avocets favour Alki Lake is due to its abundance of invertebrates, which compose 92.4% of their diet in the spring (Davis and Smith 1998). The high number of Diptera, especially Chironomidae, also gives preference to this area. Diptera larvae, particularly Chironomidae, are a major part of the American Avocet diet (Davis and Smith 1998; Safran *et al.* 1997). Ephydridae were only found at this site, where the American Avocets breed the most. Ephydridae are an important component of American Avocet diet in lakes that are high in salinity or alkalinity (Mahoney and Jehl

1985, cited in Gebauer 1999). The abundance of Cladocera also attracts the American Avocets. Although Cladocera are not an important part of the American Avocet diet (≤0.5%) (Davis and Smith 1998), their presence does coincide with American Avocet presence. Cladocera are only found at three sites where American breed and forage. Corixidae were also most abundant at Alki Lake and are a major portion of American Avocet diet in wetlands (Robinson *et al.* 1997).

Alki Lake has no sediment larger than .5mm in diameter. American Avocets prefer to forage in soft sediment as opposed to sandy or hard sediment, even if the prey abundance is the same (Tjallingii 1972; Racy 1988, 1992, cited in Boettcher *et al.* 1997; Quammen 1982).

5.2 Robert Lake

The presence of American Avocets at Robert Lake can not be contributed to invertebrate abundance because invertebrates were either more abundant or almost as abundant (within 47) in three of the areas where American Avocets are not present. There are sufficient Chironomidae for American Avocet presence. Ephemeroptera, which American Avocets prefer during the spring (Smith and Davis 1998), are present. These Ephemeroptera could contribute to the presence of American Avocets at Robert Lake. There are also Corixidae, a major part of American Avocet diet in wetlands (Robinson *et al.* 1998).

The substrate at Robert Lake is composed of very small particles (<.10 mm) which American Avocets prefer to forage in (Tjallingii 1972; Racy 1988, 1992, cited in Boettcher *et al.* 1997; Quammen 1982).

5.3 Chichester Wetlands

Invertebrates are very abundant at the Chichester Wetlands, nearly as much as at Alki Lake. Chironomidae are abundant enough for American Avocet presence (>100). The high percentage of Annelida, specifically Oligochaeta and Hirudinea, which Davis and Smith (1998) determined were preferred by American Avocets, also contribute to American Avocet presence. Odonata are a food preferred by American Avocets (Davis and Smith 1998) but were also found at several sites where American Avocets are not present.

The sediment at Chichester Wetlands is coarse and harder than at the other sites where American Avocets are present. American Avocets prefer to forage in softer sediment (Tjallingii 1972: Racy 1988, 1992, cited in Boettcher *et al.* 1997: Quammen 1982)

No reason was found, as per invertebrates or sediment, as to why American Avocets do not breed at Chichester Wetlands. Analyses of other characteristics of the site need to be done to determine why American Avocets do not breed at Chichester Wetlands.

5.4 East Little White Lake

The presence of the American Avocets at East Little White Lake can be contributed to the presence of some Chironomidae, though not as much as at other sites. Coleoptera and Corixidae are also present and are major components of the American Avocet diet (Robinson *et al.* 1998). There are some Cladocera which are not a large portion of the American Avocet diet, but are only present at sites where American Avocets breed and forage.

The sediment was not soft but American Avocets forage in the water column in addition to in the benthic layer (Quammen 1982, cited in Boettcher *et al.*).

5.5 East Pond

The presence of American Avocets can be attributed to the presence of Chironomidae and some other Diptera and Crustacea, including Cladocera.

There was little gravel and coarse sand (pers. comm. L. Dreger 1999) so it is mainly soft sediment that American Avocets prefer to forage (Tjallingii 1972; Racy 1988, 1992, cited in Boettcher *et al.* 1997; Quammen 1982).

5.6 West Pond

All the invertebrates found at West Pond were all Diptera, primarily Chironomidae, except for one Corixidae. This can not explain the lack of American Avocets at West Pond.

The sediment at West Pond is primarily composed of gravel, very coarse sand, and coarse sand. This hard sediment discourages American Avocets from foraging in the benthic layer.

5.7 West Little White Lake

The absence of the American Avocets at West Little White Lake could be explained by the overall lack of invertebrates.

The sediment at West Little White Lake is mainly sandy, which discourages American Avocet foraging (Tjallingii 1972; Racy 1988, 1992, cited in Boettcher *et al*. 1997; Quammen 1982).

5.8 Simpson's Pond

The absence of American Avocets at Simpson's Pond can be explained by the general lack of invertebrates found during this sampling.

The substrate was only composed of clay; all sites where American Avocets are present more than one type of substrate was present. This could also help to explain why American Avocets are absent at Simpson's Pond.

5.9 Bubna Slough

There are less Diptera, and therefore Chironomidae, at Bubna Slough than at sites where the American Avocets are present, other than those in the Clinton area. There were also no Cladocera, which seem to contribute to American Avocet presence.

The sediment at Bubna Slough was coarse and sandy. This is not what American Avocets prefer to forage in (Tjallingii 1972; Racy 1988, 1992, cited in Boettcher *et al.* 1997; Quammen 1982).

5.10 Slough #2

At Slough #2 there were numbers of Diptera and Chironomidae similar to those at Chichester Wetlands and superior to those at East Pond and East Little White Lake. There were Corixidae, which are generally present in areas where American Avocets breed, and which Davis and Smith (1998) found that American Avocets prefer. Invertebrates were abundant enough; there were fewer invertebrates at East Pond and East Little White Lake where American Avocets are present. The absence of American

Avocets at Slough #2 can not be attributed to invertebrate factors as Robert Lake had almost identical counts, other than the presence of 4 Crustacea and 2 Coleoptera at Slough #2.

The sediment at Slough #2 is hard and sandy, not preferred by American Avocet for foraging (Tjallingii 1972; Racy 1988, 1992, cited in Boèttcher *et al.* 1997; Quammen 1982). This is also true about East Little White Lake, where American Avocets are present.

No reasons, as per invertebrates or sediment, was found to explain why American Avocets are not present at Slough #2.

5.11 Summary

In areas where American Avocets are present there was an abundance (>100) of Diptera larvae, primarily Chironomidae. The presence of Corixidae also coincided with American Avocet presence. Certain foods that American Avocets prefer such as Crustacea, and Annelida (Oligochaeta and Hirudinea) favour American Avocet presence but are not necessary. Ephydridae may also contribute to American Avocet presence. There was at least one species that American Avocets prefer, but that is not a major part of the American Avocet diet, at each site where American Avocets were present. There were also Cladocera, which Davis and Smith (1998) found are not a major part of the American Avocet diet, but which are only present at sites where American Avocets breed and forage.

Amphipoda were variable American Avocet and non-American Avocet areas. A lack of Amphipoda could be beneficial as they can only survive in environments where salinity is less than 40 ppt while Chironomidae can survive in salinity up to 70 ppt. As salinity increases the number of Amphipoda decrease and the number of Chironomidae, the most important part of American Avocet diet (Davis and Smith 1998) increases (Velasquez 1992).

Coleoptera, Ephemeroptera, Hymenoptera, Anostraca, Calanoida, Odonata and Gastropoda do not appear to have any effect on American Avocet presence. Each was found only in small numbers at few sites. If any of these taxa was found at more than one site it was found in similar numbers at sites where American Avocets are present as well as sites where they are absent. As the sampling was not large enough to conduct any statistical analysis, further sampling would be necessary to determine whether these taxa have any effect on American Avocet presence.

The substrate in areas where American Avocets forage was soft and composed of sediment of diameters less than .25mm. There were few rocks and little sand, if any.

6.0 Recommendations

If construction of a new wetland habitat for the American Avocets of British Columbia takes place, it would be recommend that it be constructed to guarantee the presence of Chironomidae, as they are the primary food of the American Avocets. Salinity should be higher than 40 ppt but lower than 70 ppt, because this contributes to high numbers of Chironomidae (Velasquez, 1982). Substrate should be soft, composed of sediments such as very fine sand, silt, and clay to enable the American Avocets to easily obtain their prey. Also, no fish should be present in the new wetland as they consume Chironomidae (pers. comm. I. Walker 1999). The highest possible numbers of Chironomidae should be maintained. There should also be an abundance of invertebrates, preferably over $40{,}000/m^2$. Some Crustacea, Corixidae, Ephydridae and Annelida (Oligochaeta and Hirudinea) should be present as they favour American Avocet presence.

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Appendix A
Benthic Survey Field Data Sheets

Modified from the City of Kelowna benthic biomonitoring field data sheets

Benthic Survey Field Data Sheet

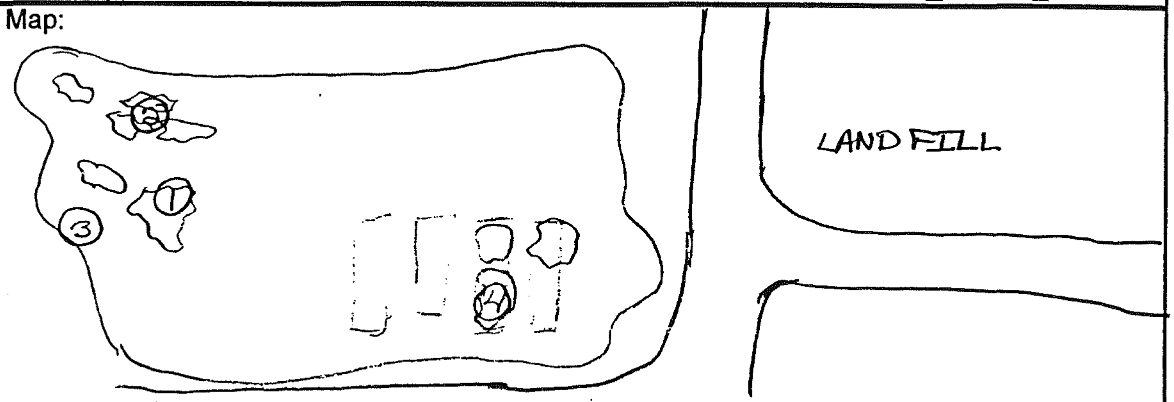
Marsh: Alki Lake | Time: 9:15
Location: Glenmore | Sample#: 3
Date: July 20, 1999

Weather Conditions: clear, sunny, warm

Now	Past 24hrs		Air Temp. 23C
☐	☐	storm(heavy rain)	
☐	☐	rain(steady)	
☐	☐	intermittent rain	

Cloud cover: 0% ■ 10% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐

Site Location Map:



Pond Features: mud flats, garbage

Origin		Watershed: predominant surrounding land use			
ground water	■	forest	☐	commercial	☐
stream	☐	field/pasture	■	industrial	☐
storm drain	☐	agriculture	☐	logging	☐
other	______	residential	☐	other	landfill

Riparian Vegetation: (10m buffer)

Indicate the dominant type and record the dominant species present: fox-tail barley, spike rush

☐ barren ■ grasses ☐ brush ☐ deciduous ☐ herbaceous ☐ conifer other: ______

Aquatic Vegetation:

Indicate the dominant type and record species present

■ rooted vegetation ☐ rooted submergent

☐ floating algae ☐ attached algae

dominant species present:

Inorganic Substrate Components						Organic Substrate Components	
substrate type	**code**	**diameter (mm)**	**substrate type**	**code**	**diameter (mm)**	**substrate type**	**Characteristics**
Stones	S	>25 cm	very fine	VFS	.10-.05	Detritus	sticks, wood, coarse plant
Cobbles	C	7.5-25 cm	silt	SI	.05-.002	Muck-Mud	black, very fine organic
Gravel	G	<7.5 cm	clay	C	<.002		
very coarse	VCS	2.0-1.0	fine clay	FC	<.0002		
coarse sand	CS	1.0-.5					
medium sand	MS	.5-.25					
fine sand	FS	.25-.10					

description of substrate: Sample 3: Some fine grade plant matter, C, VFS, FS

Modified from the City of Kelowna benthic biomonitoring field data sheets

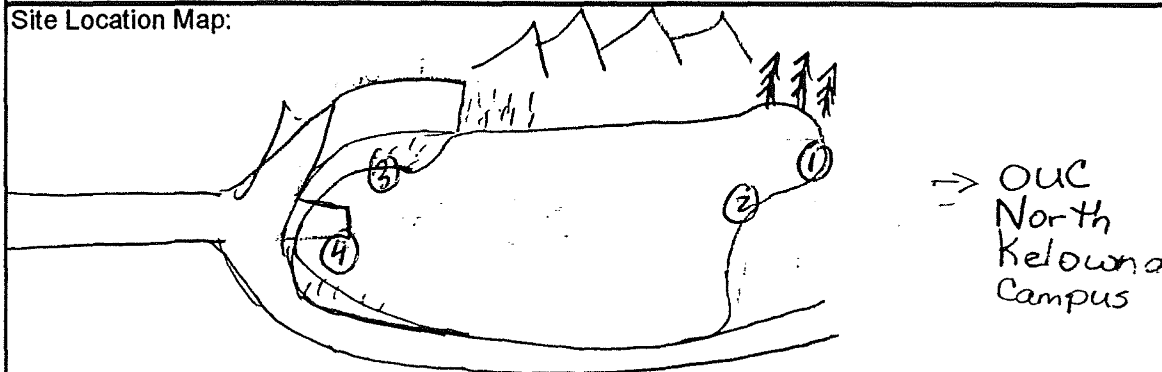
Benthic Survey Field Data Sheet

Marsh: Robert Lake
Location: Kelowna
Date: July 8/99

Time: 9:00
Sample#: 1

Weather Conditions:	Now	Past 24hrs		Air Temp.	13C	
	□	□	storm(heavy rain)			
Cloud Cover	□	■	rain(steady)			
	□	□	intermittent rain			
	Cloud cover: 0% □	10% □	25% □	50% □	75% ■	100% □

Site Location Map:



Pond Features:	**Origin**		**Watershed:** predominant surrounding land use			
	ground water	□	forest	■	commercial	□
	stream	□	field/pasture	■	industrial	□
	storm drain	□	agriculture	□	logging	□
	other	rain	residential	■	other	

Riparian Vegetation: (10m buffer)

Indicate the dominant type and record the dominant species present:

□ barren ■ grasses □ brush □ deciduous □ herbaceous □ conifer other:

fox-tail barley, spike rush

Aquatic Vegetation:

Indicate the dominant type and record species present

■ rooted vegetation ■ rooted submergent

□ floating algae □ attached algae

dominant species present: cattails

Inorganic Substrate Components						Organic Substrate Components	
substrate type	**code**	**diameter (mm)**	**substrate type**	**code**	**diameter (mm)**	**substrate type**	**Characteristics**
Stones	S	>25 cm	very fine	VFS	.10-.05	Detritus	sticks, wood, coarse plant
Cobbles	C	7.5-25 cm	silt	SI	.05-.002	Muck-Mud	black, very fine organic
Gravel	G	<7.5 cm	clay	C	<.002		
very coarse	VCS	2.0-1.0	fine clay	FC	<.0002		
coarse sand	CS	1.0-.5					
medium sand	MS	.5-.25					
fine sand	FS	.25-.10					

description of substrate: C,SI, VFS, plant matter(algae)

Modified from the City of Kelowna benthic biomonitoring field data sheets

Benthic Survey Data Sheet

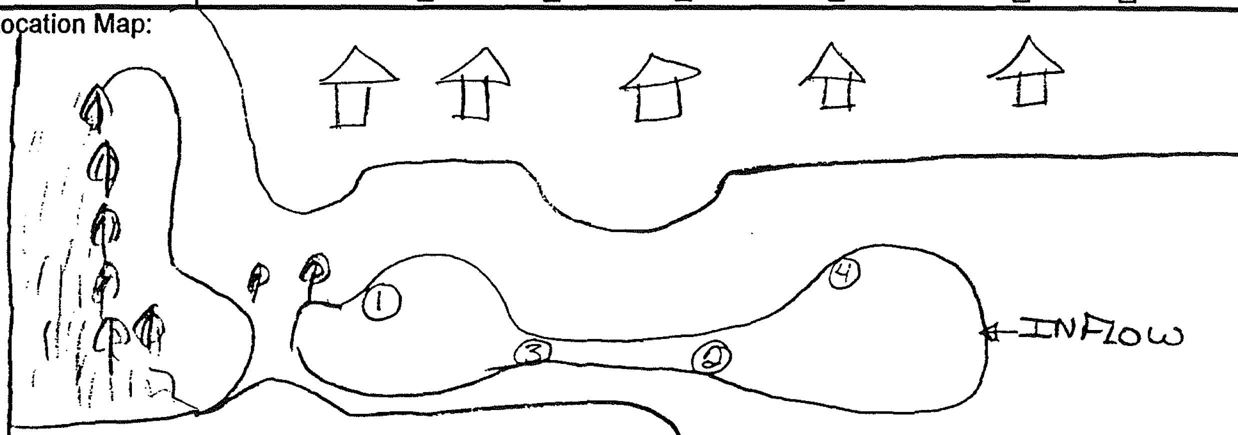
Marsh: Chichester Wetlands — Time: 9:40

Location: Glenmore — Sample#: 4

Date: July 16/99

Weather Conditions:	Now	Past 24hrs		Air Temp.	21C		
clear, sunny	☐	☐	storm(heavy rain)				
	☐	☐	rain(steady)				
	☐	☐	intermittent rain				
	Cloud cover:	0% ☐	10% ☐	25% ■	50% ☐	75% ☐	100% ☐

Site Location Map:



Pond Features:

Origin		Watershed: predominant surrounding land use			
ground water	☐	forest	☐	commercial	☐
stream	☐	field/pasture	☐	industrial	☐
storm drain	■	agriculture	☐	logging	☐
other	______	residential	■	other	______

Riparian Vegetation: (10m buffer)

Indicate the dominant type and record the dominant species present: ______

☐ barren ■ grasses ☐ brush ■ deciduous ☐ herbaceous ☐ conifer other: ______

thistle, willow tree, spike rush, bull rush

Aquatic Vegetation:

Indicate the dominant type and record species present

■ rooted vegetation ☐ rooted submergent

☐ floating algae ☐ attached algae

dominant species present: cattails

Inorganic Substrate Components						Organic Substrate Components	
substrate type	**code**	**diameter (mm)**	**substrate type**	**code**	**diameter (mm)**	**substrate type**	**Characteristics**
Stones	S	>25 cm	very fine	VFS	.10-.05	Detritus	sticks, wood, coarse plant
Cobbles	C	7.5-25 cm	silt	SI	.05-.002	Muck-Mud	black, very fine organic
Gravel	G	<7.5 cm	clay	C	<.002		
very coarse	VCS	2.0-1.0	fine clay	FC	<.0002		
coarse sand	CS	1.0-.5					
medium sand	MS	.5-.25					
fine sand	FS	.25-.10					

description of substrate: VCS, VFS, plant matter

Modified from the City of Kelowna benthic biomonitoring field data sheets

Benthic Survey Field Data Sheet

Marsh: East Little White Lake
Location: Clinton
Date: June 24/99

Time: midday
Sample#: 1

Weather Conditions:	Now	Past 24hrs		Air Temp. 12C
	☐	☐	storm(heavy rain)	
rain	■	☐	rain(steady)	
	☐	☐	intermittent rain	
	Cloud cover: 0% ☐ 10% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐			

Site Location Map:

NO SITE MAP IS AVAILABLE

Pond Features:	**Origin**		**Watershed:** predominant surrounding land use			
	ground water	☐	forest	☐	commercial	☐
	stream	☐	field/pasture	■	industrial	☐
	storm drain	☐	agriculture	☐	logging	☐
	other	____	residential	☐	other	____

Riparian Vegetation: (10m buffer) Indicate the dominant type and record the dominant species present: ____
☐ barren ■ grasses ☐ brush ☐ deciduous ☐ herbaceous ☐ conifer other: ____

Aquatic Vegetation: Indicate the dominant type and record species present
☐ rooted vegetation ☐ rooted submergent
☐ floating algae ☐ attached algae
dominant species present:

Inorganic Substrate Components						Organic Substrate Components	
substrate type	**code**	**diameter (mm)**	**substrate type**	**code**	**diameter (mm)**	**substrate type**	**Characteristics**
Stones	S	>25 cm	very fine	VFS	.10-.05	Detritus	sticks, wood, coarse plant
Cobbles	C	7.5-25 cm	silt	SI	.05-.002	Muck-Mud	black, very fine organic
Gravel	G	<7.5 cm	clay	C	<.002		
very coarse	VCS	2.0-1.0	fine clay	FC	<.0002		
coarse sand	CS	1.0-.5					
medium sand	MS	.5-.25					
fine sand	FS	.25-.10					

description of substrate: G, VCS, CS, C, algae

Modified from the City of Kelowna benthic biomonitoring field data sheets

Benthic Survey Field Data Sheet

Marsh: East Pond
Location: Clinton
Date: June 24/99

Time: midday
Sample#: 1

Weather Conditions:	Now	Past 24hrs		Air Temp. 12C
rain	☐	☐	storm(heavy rain)	
	■	☐	rain(steady)	
	☐	☐	intermittent rain	

Cloud cover: 0% ☐ 10% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐

Site Location Map:

NO SITE MAP IS AVAILABLE

Pond Features:

Origin		Watershed: predominant surrounding land use			
ground water	☐	forest	☐	commercial	☐
stream	☐	field/pasture	■	industrial	☐
storm drain	☐	agriculture	☐	logging	☐
other	LWL	residential	☐	other	

Riparian Vegetation: (10m buffer)

Indicate the dominant type and record the dominant species present:

☐ barren ■ grasses ☐ brush ☐ deciduous ☐ herbaceous ☐ conifer other:

Aquatic Vegetation:

Indicate the dominant type and record species present

☐ rooted vegetation ☐ rooted submergent
☐ floating algae ☐ attached algae

dominant species present: cattail, sedges

Inorganic Substrate Components						Organic Substrate Components	
substrate type	**code**	**diameter (mm)**	**substrate type**	**code**	**diameter (mm)**	**substrate type**	**Characteristics**
Stones	S	>25 cm	very fine	VFS	.10-.05	Detritus	sticks, wood, coarse plant
Cobbles	C	7.5-25 cm	silt	SI	.05-.002	Muck-Mud	black, very fine organic
Gravel	G	<7.5 cm	clay	C	<.002		
very coarse	VCS	2.0-1.0	fine clay	FC	<.0002		
coarse sand	CS	1.0-.5					
medium sand	MS	.5-.25					
fine sand	FS	.25-.10					

description of substrate: G, CS, C, SI

Modified from the City of Kelowna benthic biomonitoring field data sheets

Benthic Survey Field Data Sheet

Marsh: West Pond
Location: Clinton
Date: June 24/99

Time: midday
Sample#: 1

Weather Conditions: rain

Now	Past 24hrs		Air Temp. 12C
☐	☐	storm(heavy rain)	
■	☐	rain(steady)	
☐	☐	intermittent rain	

Cloud cover: 0% ☐ 10% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐

Site Location Map:

NO SITE MAP IS AVAILABLE

Pond Features:

Origin		Watershed: predominant surrounding land use			
ground water	☐	forest	☐	commercial	☐
stream	☐	field/pasture	■	industrial	☐
storm drain	☐	agriculture	☐	logging	☐
other	______	residential	☐	other	______

Riparian Vegetation: (10m buffer)

Indicate the dominant type and record the dominant species present: ______

☐ barren ■ grasses ☐ brush ☐ deciduous ☐ herbaceous ☐ conifer other: ______

Aquatic Vegetation:

Indicate the dominant type and record species present

☐ rooted vegetation ☐ rooted submergent

■ floating algae ☐ attached algae

dominant species present: cattail, sedges

Inorganic Substrate Components						Organic Substrate Components	
substrate type	**code**	**diameter (mm)**	**substrate type**	**code**	**diameter (mm)**	**substrate type**	**Characteristics**
Stones	S	>25 cm	very fine	VFS	.10-.05	Detritus	sticks, wood, coarse plant
Cobbles	C	7.5-25 cm	silt	SI	.05-.002	Muck-Mud	black, very fine organic
Gravel	G	<7.5 cm	clay	C	<.002		
very coarse	VCS	2.0-1.0	fine clay	FC	<.0002		
coarse sand	CS	1.0-.5					
medium sand	MS	.5-.25					
fine sand	FS	.25-.10					

description of substrate: G, VCS, CS, C, roots, plant matter, stringy algae

Modified from the City of Kelowna benthic biomonitoring field data sheets
Benthic Survey Field Data Sheet

Marsh: West Little Whtie Lake
Location: Clinton
Date: June 24/99

Time: midday
Sample#: 1

Weather Conditions: rain

Now	Past 24hrs		Air Temp. 12C
☐	☐	storm(heavy rain)	
■	☐	rain(steady)	
☐	☐	intermittent rain	

Cloud cover: 0% ☐ 10% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐

Site Location Map:

NO SITE MAP IS AVAILABLE

Pond Features:

Origin		Watershed: predominant surrounding land use			
ground water	☐	forest	☐	commercial	☐
stream	☐	field/pasture	■	industrial	☐
storm drain	☐	agriculture	☐	logging	☐
other	______	residential	☐	other	______

Riparian Vegetation: (10m buffer)

Indicate the dominant type and record the dominant species present: ______

☐ barren ■ grasses ☐ brush ☐ deciduous ☐ herbaceous ☐ conifer other: ______

Aquatic Vegetation:

Indicate the dominant type and record species present

☐ rooted vegetation ☐ rooted submergent
■ floating algae ☐ attached algae

dominant species present:

Inorganic Substrate Components						Organic Substrate Components	
substrate type	code	diameter (mm)	substrate type	code	diameter (mm)	substrate type	Characteristics
Stones	S	>25 cm	very fine	VFS	.10-.05	Detritus	sticks, wood, coarse plant
Cobbles	C	7.5-25 cm	silt	SI	.05-.002	Muck-Mud	black, very fine organic
Gravel	G	<7.5 cm	clay	C	<.002		
very coarse	VCS	2.0-1.0	fine clay	FC	<.0002		
coarse sand	CS	1.0-.5					
medium sand	MS	.5-.25					
fine sand	FS	.25-.10					

description of substrate: G, CS, VCS, C, SI, plant matter

Modified from the City of Kelowna benthic biomonitoring field data sheets

Benthic Survey Field Data Sheet

Marsh: Simpson's Pond
Location: Kelowna
Date: July 13/99

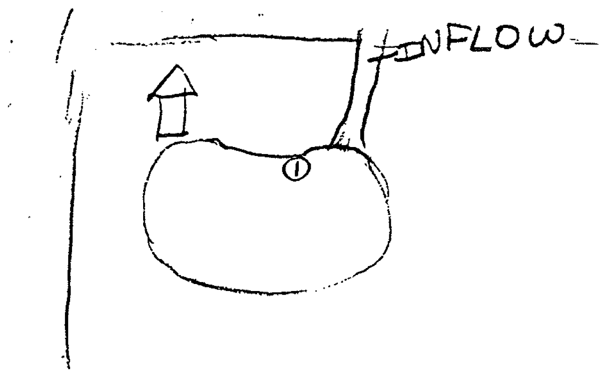
Time: 8:55
Sample#: 1

Weather Conditions: clear, warm, sunny

Now	Past 24hrs		Air Temp. 22C
☐	☐	storm(heavy rain)	
☐	☐	rain(steady)	
☐	☐	intermittent rain	

Cloud cover: 0% ■ 10% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐

Site Location Map:



Pond Features:

Origin		Watershed: predominant surrounding land use			
ground water	☐	forest	☐	commercial	☐
stream	■	field/pasture	■	industrial	☐
storm drain	☐	agriculture	■	logging	☐
other (Mill Creek)		residential	☐	other	

Riparian Vegetation: (10m buffer)

Indicate the dominant type and record the dominant species present:

☐ barren ■ grasses ☐ brush ☐ deciduous ☐ herbaceous ☐ conifer other:

Aquatic Vegetation:

Indicate the dominant type and record species present

☐ rooted vegetation ☐ rooted submergent
■ floating algae ☐ attached algae

dominant species present:

Inorganic Substrate Components						Organic Substrate Components	
substrate type	code	diameter (mm)	substrate type	code	diameter (mm)	substrate type	Characteristics
Stones	S	>25 cm	very fine	VFS	.10-.05	Detritus	sticks, wood, coarse plant
Cobbles	C	7.5-25 cm	silt	SI	.05-.002	Muck-Mud	black, very fine organic
Gravel	G	<7.5 cm	clay	C	<.002		
very coarse	VCS	2.0-1.0	fine clay	FC	<.0002		
coarse sand	CS	1.0-.5					
medium sand	MS	.5-.25					
fine sand	FS	.25-.10					

description of substrate: C, plant matter

Modified from the City of Kelowna benthic biomonitoring field data sheets

Benthic Survey Field Data Sheet

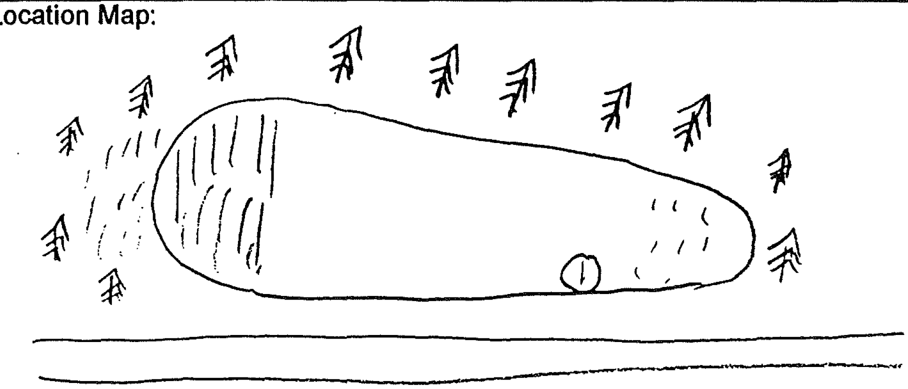
Marsh: Bubna (Slough #1) | Time: 9:20
Location: Glenmore | Sample#: 1
Date: July 12/99

Weather Conditions: clear, sunny, hot

Now	Past 24hrs		Air Temp. 23C
□	□	storm(heavy rain)	
□	□	rain(steady)	
□	□	intermittent rain	

Cloud cover: 0% ■ 10% □ 25% □ 50% □ 75% □ 100% □

Site Location Map:



Pond Features: surrounding high grasses

Origin		Watershed: predominant surrounding land use			
ground water	■	forest	■	commercial	□
stream	□	field/pasture	□	industrial	□
storm drain	□	agriculture	□	logging	□
other	______	residential	□	other	______

Riparian Vegetation: (10m buffer)

Indicate the dominant type and record the dominant species present: ______

□ barren ■ grasses □ brush □ deciduous □ herbaceous □ conifer other: ______

Aquatic Vegetation:

Indicate the dominant type and record species present

■ rooted vegetation □ rooted submergent

■ floating algae □ attached algae

dominant species present: cattails

Inorganic Substrate Components						Organic Substrate Components	
substrate type	code	diameter (mm)	substrate type	code	diameter (mm)	substrate type	Characteristics
Stones	S	>25 cm	very fine	VFS	.10-.05	Detritus	sticks, wood, coarse plant
Cobbles	C	7.5-25 cm	silt	SI	.05-.002	Muck-Mud	black, very fine organic
Gravel	G	<7.5 cm	clay	C	<.002		
very coarse	VCS	2.0-1.0	fine clay	FC	<.0002		
coarse sand	CS	1.0-.5					
medium sand	MS	.5-.25					
fine sand	FS	.25-.10					

description of substrate:

Modified from the City of Kelowna benthic biomonitoring field data sheets

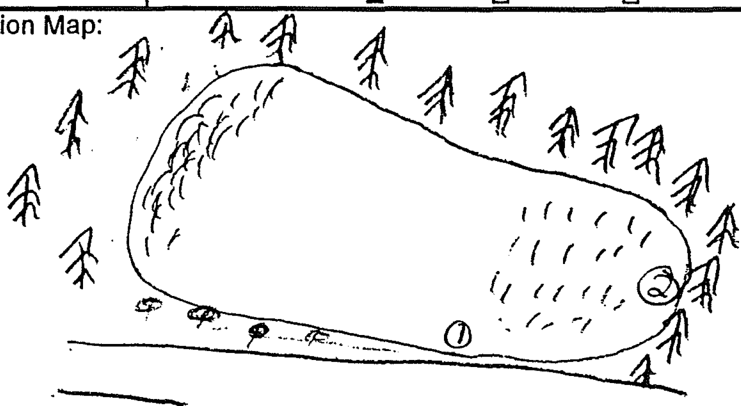
Benthic Survey Field Data Sheet

Marsh: Slough #2
Location: Glenmore
Date: July 12/99

Time: 9:35
Sample#: 1

Weather Conditions:	Now	Past 24hrs			Air Temp.	25C	
clear, sunny, hot	☐	☐	storm(heavy rain)				
	☐	☐	rain(steady)				
	☐	☐	intermittent rain				
	Cloud cover:	0% ■	10% ☐	25% ☐	50% ☐	75% ☐	100% ☐

Site Location Map:



Pond Features:	**Origin**		Watershed: predominant surrounding land use			
	ground water	■	forest	■	commercial	☐
	stream	☐	field/pasture	☐	industrial	☐
	storm drain	☐	agriculture	☐	logging	☐
	other	______	residential	☐	other	______

Riparian Vegetation: (10m buffer)	Indicate the dominant type and record the dominant species present: ______ ☐ barren ■ grasses ☐ brush ☐ deciduous ☐ herbaceous ■ conifer other: ______
Aquatic Vegetation:	Indicate the dominant type and record species present ■ rooted vegetation ■ rooted submergent ☐ floating algae ☐ attached algae dominant species present: cattails

Inorganic Substrate Components						Organic Substrate Components	
substrate type	**code**	**diameter (mm)**	**substrate type**	**code**	**diameter (mm)**	**substrate type**	**Characteristics**
Stones	S	>25 cm	very fine	VFS	.10-.05	Detritus	sticks, wood, coarse plant
Cobbles	C	7.5-25 cm	silt	SI	.05-.002	Muck-Mud	black, very fine organic
Gravel	G	<7.5 cm	clay	C	<.002		
very coarse	VCS	2.0-1.0	fine clay	FC	<.0002		
coarse sand	CS	1.0-.5					
medium sand	MS	.5-.25					
fine sand	FS	.25-.10					

description of substrate: G, VCS, CS

ADDENDUM TO

Abundance and Types of Potential Invertebrate Prey of American Avocets in British Columbia

By Christina MacNeil

Addendum prepared by Les Gyug, 11 Sept 1999

Some of the data collected during this project was inadvertently left out of this report. This addendum includes all the data collected during the main sampling period in 1999. Additional observations were made at East Pond (Little White Lake) on August 1, that came too late to be included in the report.

A single data sample consisted of the sum of 5 6.5-cm diameter bottom cores and the water column above the core. Each data sample therefore consisted of 165.9 sq. cm surface area. Four data samples (i.e. 20 cores in total) were collected at Alki Lake, Robert Lake and Chichester Bird Sanctuary (Table 1) and only one sample (5 cores) at all other sites (Table 2).

At East Pond (Little White Lake) thousands of brine flies (Ephydridae) blackened the shoreline where the avocets had been feeding heavily in June. The single sample at East Pond did not sample any brine fly larvae. If the distribution of brine fly larvae is very spotty, as at Alki Lake where brine flies were only found in 2 of 4 samples, then the single sample at East Pond might have missed brine flies that were actually present.

Based on this data, it appears the following wetlands are preferred by avocets because they have the following major invertebrate prey groups in them:
Alki Lake: brine flies (Ephydridae), water boatmen (Corixidae), midges (Chironomidae), water fleas? (Cladocera)
East Little White Lake: midges, water fleas?
East Pond (LWL): brine flies, amphipods, water fleas?
Robert Lake: midges, water boatmen, amphipods, water fleas?
Chichester: midges, blood worms (Oligochaeta)

I have placed a question mark after water fleas because they were abundant there and we suspect avocets were eating them, but we are not sure they are preferred prey groups based on the available literature.

While some of the other wetlands sampled also have these same prey groups, it appears that substrate or vegetation parameters are not suited to avocets at those wetlands.

Addendum Table 1. Invertebrates per sq.m in Alki Lake, Robert Lake and Chichester Wetlands, Kelowna, sampled in 1999 by Deep River Science Academy Students.

Sample #	Water depth (cm)	Chironomidae	Ephydridae	Ceratopogonidae	Other Diptera	Corixidae	Ephemeroptera	Hymenotera	Odonata	Coleoptera	Cladocera	Anostraca	Amphipoda	Calanoida	Copepods	Hirudinea	Oligochaete	Annelida	Gastropoda	Total Invertebrates
Alki Lake																				
1	5	17961	0	60	1266	1688	0	0	0	0	0	0	0	0	0	0	0	0	0	20975
2	9	32004	11693	0	1386	1447	0	0	0	0	60	0	0	0	0	0	0	0	0	46590
3	8	28991	663	603	0	1748	0	60	0	0	8559	0	0	0	0	0	0	0	0	40623
4	6	2170	0	60	60	1447	0	0	0	0	0	0	60	0	0	0	0	0	0	3797
Mean		20282	3089	181	678	1582	0	15	0	0	2155	0	15	0	0	0	0	0	0	27996
Robert Lake																				
1	11	9161	0	60	0	181	663	0	0	0	0	0	0	0	0	0	0	0	0	10065
2	8	7233	0	0	0	1085	0	0	121	0	3375	0	542	0	0	0	0	0	0	12356
3	9.5	5485	0	362	60	301	0	0	121	0	0	0	0	0	0	0	0	0	0	6329
4	9	4219	0	0	121	121	0	0	0	0	6268	0	0	0	2712	0	0	0	0	13441
Mean		6524	0	105	45	422	166	0	60	0	2411	0	136	0	678	0	0	0	0	10548
Chichester																				
1	20	10186	0	0	241	0	60	0	0	0	0	0	0	0	241	0	8438	0	60	19227
2	12.5	8739	0	0	0	0	121	0	60	0	0	0	0	0	0	0	1205	1205	0	11331
3	18	9523	0	0	121	0	60	0	0	0	0	0	0	0	0	0	0	0	0	9704
4	12	6208	0	0	121	0	0	0	181	0	0	0	0	0	0	60	19588	13501	0	39659
Mean		8664	0	0	121	0	60	0	60	0	0	0	0	0	60	15	7308	3677	15	19980

Addendum Table 2. Summary of all invertebrate data (expressed per sq.m.) collected for the American Avocet Project during main sampling session by Deep River Science Academy students in 1999. Relative foraging importance to avocets based on preferences in Davis and Smith (1998) and other sources as cited in the MacNeil report. Relative level of avocet use based on observations made during other phases of this project in 1999.

Importance to Avocets		High				Medium	Medium to Low			Low or Unknown										
Pond	Avocet Use (0-10)	Ephydridae	Corixidae	Coleoptera	Amphipoda	Chironomidae	Hirudinea	Oligochaete	Annelida	Ceratopogonidae	Other Diptera	Ephemeroptera	Hymenotera	Odonata	Cladocera	Anostraca	Calanoida	Copepods	Gastropoda	Total Invertebrates
Alki Lake Mean	10	3089	1582	0	15	20282	0	0	0	181	678	0	15	0	2155	0	0	0	0	27996
East Pond (LWL)	8	0	0	0	1386	482	0	0	0	0	60	0	0	0	1868	60	0	0	0	3857
East Little White Lake	7	0	60	60	181	1748	0	0	0	0	422	0	0	0	1748	0	60	0	0	4279
Robert Lake Mean	5	0	422	0	136	6524	0	0	0	105	45	166	0	60	2411	0	0	678	0	10548
Chichester Mean	3	0	0	0	0	8664	15	7308	3677	0	121	60	0	60	0	0	0	60	15	19980
Akland Rd. Pond	1	0	0	0	0	181	0	0	60	0	0	121	0	0	0	0	0	0	60	422
West Little White Lake	1	0	0	301	0	362	0	0	0	0	0	0	0	0	0	0	301	0	0	964
Bubna Slough	0	0	60	60	3375	4159	0	0	0	60	0	1025	0	60	0	0	0	0	0	8800
Slough #2	0	0	663	121	121	6087	0	0	0	60	121	60	0	0	0	0	0	0	0	7233
West Pond (LWL)	0	0	60	0	0	13863	0	0	0	60	60	0	0	0	0	0	0	0	0	14043

WATER CHEMISTRY PREFERENCES FOR HABITAT OF AMERICAN AVOCET IN BRITISH COLUMBIA

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WATER CHEMISTRY PREFERENCES FOR HABITAT OF THE AMERICAN AVOCET IN BRITISH COLUMBIA

Abstract

Alki Lake, in Kelowna, is the most important colony of American Avocets in British Columbia (Weir, 1997). Glenmore Landfill, next to this colony, will be expanded within 10 years to include Alki Lake, causing the loss of this colony. The objective of the American Avocet Conservation project is to collect knowledge required to engineer a new habitat for the American Avocets. The purpose of this paper is to study the water chemistry preferences of the American Avocet. Five sites where Avocets either breed, forage or both were compared to five sites where Avocets were not found. Also, analysed was the water chemistry of a proposed site for the new wetland. Tests included ICP 31 metals scan, conductivity, dissolved oxygen, alkalinity, orthophosphate, NO_3-N, NH_3-N, and SO_4. Results showed that Avocets prefer to live in areas of high alkalinity, high conductivity, high TDS and low dissolved oxygen. The new wetland should be engineered to these parameters.

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1.0 Introduction

The American Avocet (*Recurvirostra americana)* is a shorebird rare to British Columbia, fortunately populations have been increasing in recent years. Avocets prefer to breed and forage in alkaline sloughs that are shallow and contain mud flats (Wilson, 1989).

Figure 1 *The American Avocet*

1.1 The American Avocet in British Columbia

American Avocets are found in different areas of British Columbia. A previously unknown colony was discovered in June of 1999 west of Clinton, BC, breeding on Little White Lake (L. Dreger – personal communication, 1999). There were reports of only one pair breeding there in 1995 (Gebauer, 1999a).

Alki Lake, just North of Kelowna, BC, has been the only marsh consistently used as a breeding ground (Weir, 1997). Alki Lake was once the site of the Glenmore

Landfill, however in the mid-1980s the lease that the City of Kelowna held was cancelled (Gebauer, 1999b). The garbage was buried under a layer of clay. The area, no longer being used for waste management, filled with water. The American Avocets flocked to this evaporation pond now called Alki Lake. What resulted from buried garbage mounds were tiny islands that serve as mud flats for Avocet nests (J. Weir – personal communication 1999). Alki Lake is a wetland where breeding is recurrent with several nests (Gebauer, 1999b).

As part of a 10-year plan the City of Kelowna has designated Alki Lake a future site of another landfill (L Gyug – personal communication, 1999). Consequently, the American Avocets will be losing necessary breeding habitat in British Columbia.

1.2 Preservation Plans

A new wetland for the American Avocets will be engineered specifically for Avocet breeding (Gebauer, 1999b). One of the proposed sites studied in this paper is Glenmore Marsh. This project has many research objectives, water chemistry is just one of the parameters being studied. In this paper, the water chemistry of five wetlands where Avocets are found (Robert Lake, Alki Lake, East LWL, East Pond, Chichester Pond) and five where they are not found (West Pond, West LWL, Slough #2, Bubna Slough, Simpson's Pond) are investigated to find and record if there are any differences.

2.0 Site Descriptions

The following is a brief description of the sample areas.

2.1 Alki Lake

Alki Lake is situated beside the Glenmore Landfill in North Kelowna. It is a frequently used breeding ground by American Avocets. The lake is dotted with many tiny mudflats used as nesting sites. The substrate is composed of clay forming an impermeable basin (MacNeil - unpublished, 1999). This basin makes Alki Lake a playa, where the only water lost is from evaporation (L. Gyug personal communication 1999). Riparian and aquatic vegetation is foxtail barley and spike rush respectively. The surrounding area is used for irrigation farming, pasture and landfill.

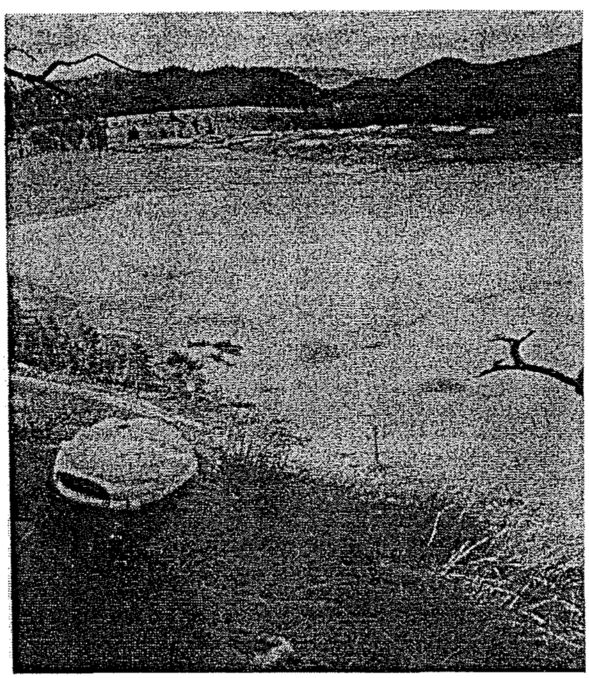

Figure 1 *Alki Lake – Avocet inhabited site showing the mudflats*

2.2 Robert Lake

Robert Lake is located in North Kelowna, in the Glenmore Valley. Robert Lake is an area where Avocets forage frequently but have only bred in 1992, 1995 and 1998 (Gebauer, 1999a). The water comes from both surface and ground water (Tera Planning Ltd., 1993). The clay and silt substrate creates an evaporation pond. Riparian and aquatic vegetation consists of fox tail barley, grasses and spike rush respectively (MacNeil - unpublished, 1999). The surrounding area is used for pasture, irrigation farming and residential homes.

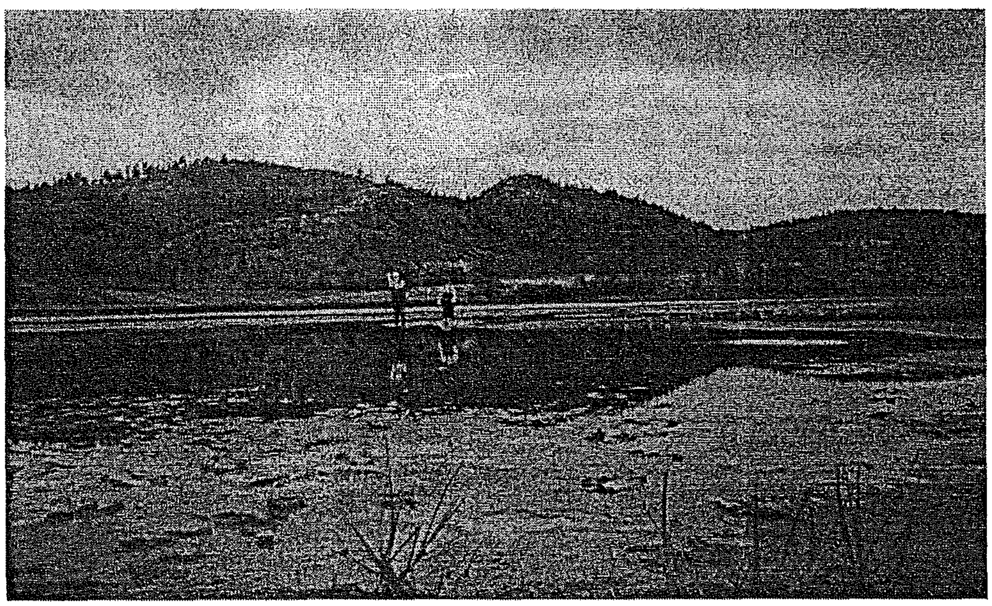

Figure 2 *Robert Lake – Avocet inhabited site*

2.3 East Little White Lake

East Little White Lake (East LWL) is found west of Clinton, BC. On a large island a colony of nesting Avocets were discovered in 1999 (L. Dreger – personal communication, 1999). The bottom is composed of sand and gravel (C. MacNeil -

unpublished, 1999). The surrounding vegetation is grass and the land around is used for field and pasture.

2.4 East Pond

East pond is located 200m from the nesting island in Little White Lake near Clinton, BC. It is less than one ha in area. Avocets have been found foraging here but not breeding (L. Dreger - personal communication, 1999) because there are no mud flats. The substrate is composed of clay, silt, gravel and coarse sand (C. MacNeil - unpublished, 1999). Aquatic vegetation is cattails and sedges. The surrounding land is used for fields and pastures.

2.5 Chichester Pond

Chichester Pond is beside a residential sub-division in Rutand. Avocets have been found foraging, however there are no breeding records for the area. Water from a storm drain runoff is the primary source of water. Substrate is composed of coarse and fine sand as well as plant matter (MacNeil - unpublished, 1999). There is an abundance of vegetation including willow trees, bull rush, thistle, cattail, sedges and spike rush.

2.6 West Little White Lake

West Little White Lake (West LWL) is part of the same body of water as East LWL. For this study the western part was named West LWL and the eastern named East LWL. No Avocets have been seen breeding or foraging here. The substrate is made of clay, silt, sand and gravel (C. MacNeil - unpublished, 1999). The surrounding vegetation is grass and this area is used for field and pasture.

2.7 West Pond

West Pond is west of West LWL near Clinton, BC. No Avocets have been recorded breeding or foraging here. Substrate was composed of gravel, sand, clay, roots and plant matter (MacNeil - unpublished, 1999). The surrounding area is used primarily for field and pasture, with many grasses.

2.8 Slough #2

Slough #2 is northwest of the Glenmore Landfill. Avocets have not been found breeding or foraging here. It is a ground water fed lake with a bottom of coarse sand and gravel (MacNeil - unpublished, 1999). Aquatic vegetation is mostly cattails. Surrounding area is a coniferous forest.

2.9 Bubna Slough

Bubna Slough is just south of Slough #2. Avocets have not been seen here. It is ground water fed as well as Slough #2. The substrate consists of gravel and sand (MacNeil - unpublished, 1999). Surrounding vegetation is mostly grasses and this area is dominated by coniferous forest.

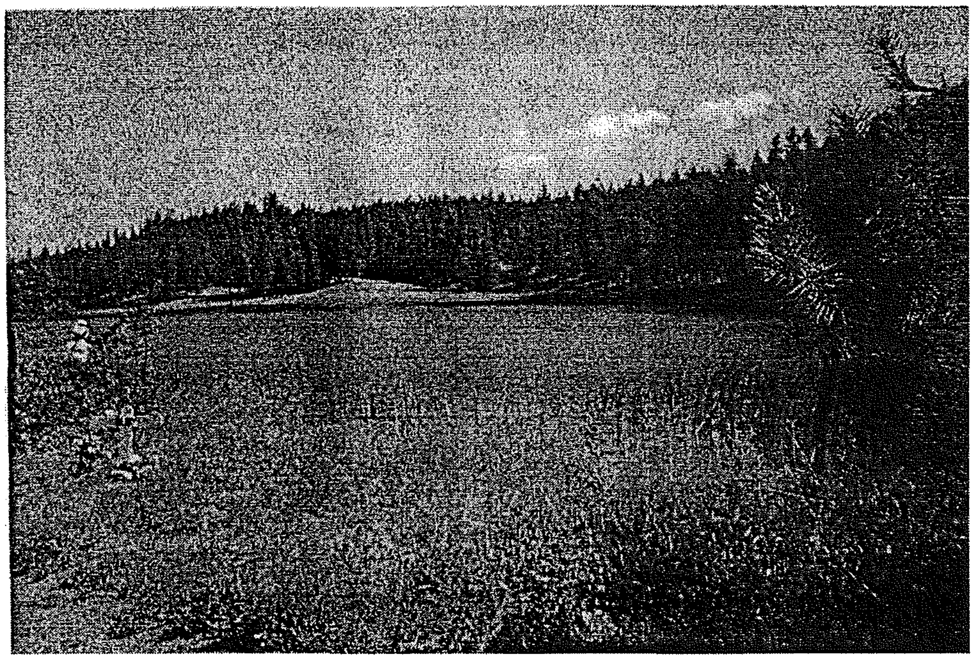

Figure 3 *Bubna Slough – Non-Avocet site*

2.10 Simpson's Pond

Simpson's Pond is on farmland east of highway 97 in Kelowna, BC. This area has been classified as a non-Avocet site. The source of this pond is Mill Creek. The bottom is predominantly clay and plant matter (MacNeil - unpublished, 1999). Aquatic vegetation is algae, while riparian vegetation is mostly grasses. The surrounding area is predominately used for agriculture.

2.11 Glenmore Marsh

Glenmore Marsh is on the northwest side of the Glenmore Landfill and has run into Alki Lake in past years (M. Browne – personal communication, 1999). There have been no Avocets seen here thus far. Surrounding vegetation is grasses and coniferous trees. It is the proposed site for the replacement marsh. The surrounding area is predominately forest and landfill.

3.0 Materials And Methods

All methods of sampling and testing were adapted from Standard Methods for the Examination of Water and Wastewater (1989). All samples bottles were standard collecting plastic and were rinsed three times with the sample water then filled to capacity. Samples of 250ml were sent to Norwest Labs for ICP31 metals scan on July 6, 1999. The following day, seven 1L bottles of water from each site was brought back to the lab. Each sample of water was filtered through standard 0.45um filter paper, and collected in seven separate 500ml glass beakers. From these containers necessary amounts of sample water was used to perform each test.

3.1 Tests Conducted in the Field

The following tested were performed on site.

3.1.1 Conductivity

500ml samples of water were collected from each marsh. Using the Fisher Scientific Model #52 Conductivity Meter an electrode was removed from storage in deionized water and submerged it into the sample water. The dial was then set for the most precise reading (i.e. 10K or 100K).

3.1.2 Dissolved Oxygen (DO)

300ml of sample water was collected in a standard glass BOD bottle with an airtight cap by completely submerging it and capping under water to ensure NO AIR BUBBLES WERE IN THE CONTAINER. Using the HACH field titrator, dissolved oxygen was tested for by adding alkaline iodide-azide reagent pillow and manganous sulphate reagent pillow to the sample and inverting 10 times. The floc was left to settle 5 minutes, before again inverting and letting settle for another 5 minutes. Next sulphuric acid powder pillow was added, the bottle was inverted and the floc was left to settle (5 min.). 2ml of starch indicator solution was added by a dropper. If the solution turned blue there was detectable dissolved oxygen. If it did not turn blue, titration was impossible. To determine the amount of dissolved oxygen 100ml of solution was measured out into an Erlenmeyer flask using a graduated cylinder. Using a HACH field titration instrument, the dial was set to zero, and the knob was slowly turned to release titrate (0.2000 ± 0.0010 normal of sodium thiosulfate) all the while swirling the flask. When the solution was clear in colour the volume of titrate used was calculated (volume of titrate on gauge multiplied by 0.02, a standard multiplier for 100ml of solution given by kit).

3.1.3 Temperature

A thermometer was submerged into the area where the sample water was being taken from. It was held there until the temperature stabilised, then the reading was recorded.

3.2 Tests Conducted in the Lab

The following tests were conducted in the City of Kelowna Water Treatment Plant laboratory.

3.2.1 pH

A 40ml beaker of sample water was taken from each container and an electrode from the Corning 245pH meter was submerged. Once the value stabilised the reading was recorded.

3.2.2 Alkalinity

Sample water was diluted accordingly to decrease interference (Appendix A). 50ml of dilute sample was measured out into a 125ml Erlenmeyer flask and placed on a magnetic stirrer. The speed was turned to six and an electrode submerged from the Corning 245 pH meter and made sure the flea and electrode were not in contact. If the pH measured more than 8.3 for phenolphthalein alkalinity titration was performed using H_2SO_4 (if it read less than 8.3 total alkalinity titration was performed). To test for phenolphthalein alkalinity, a 25ml burette was filled to the last graduation with H_2SO_4. Slowly, H_2SO_4 was added to diluted sample water, while observing the pH meter. When the meter read 8.3 titration was paused to record volume and refill the burette with H_2SO_4 to the last graduation. To test for total alkalinity, the same water was tested that had just used to test for phenolphthalein alkalinity. H_2SO_4 was slowly added, while watching the pH meter. When the meter read 4.5 titration was stopped and the volume of H_2SO_4 was recorded. NOTE: When calculating final volume of titrate, the multiplier assigned to the dilution volume must be factored in.

3.2.3 Sulphate

The HACH DR 3000 spectrophotometer measures from 0 – 50 mg/L of sulphate. 25 ml of sample water was measured out into one-inch glass cells. Additionally, one 25ml of deionized water (the "*blank*") and one 25ml of sulphate standard solution (the "*standard*") was placed, into two separate one-inch glass cells. Then a SulfaVer 4 reagent pillow was added to each 25ml sample and shaken vigorously for one minute, then let sit for 5 minutes. If a sample was darker than the *standard* it was diluted (see Appendix B). The *blank* was inserted to zero the HACH DR 3000 spectrophotometer and the reading was taken (0.00). Then, in sequence, each sample was inserted and the reading recorded. When all samples had been tested the *standard* was inserted to check and make sure there was no instrument error (1.0 is the correct *standard* reading).

3.2.4 Orthophosphate

The HACH DR 3000 spectrophotometer was used to measure from 0 – 2.00 mg/L of ortho-phosphate. 25ml of each sample was measured out into 25ml vials. Also 25ml of deionized water was measured out (for the "*blank*") and 25ml of phosphate standard solution concentration of 1mg/L (for the "*standard*") into separate sample vials. Into each vial one PhosVer 3 reagent pillow was added and the vial was swirled until reagents were dissolved. Pouring through the blank zeroed the HACH DR 3000 spectrophotometer. If any sample was darker than the *standard* it was diluted (see Appendix B). In sequence each sample was poured through the spectrophotometer and a reading was recorded. When all samples had been tested the *standard* was poured through to ensure no instrumental error (1.0 is the correct *standard* reading).

3.2.5 Nitrate-Nitrogen

The HACH DR 3000 spectrophotometer was used to measure from 0 – 5.0mg/L of $N0_3$-N. 25ml of each sample was measured out into 25ml vials. Also measured out, was 25ml of deionized water (the *"blank"*) and 25ml of nitrate standard solution with a concentration of 1mg/L (the "*standard*") was placed in separate sample vials. Into each vial, one NitraVer 5 reagent pillow was emptied, it was swirled and let sit for one minute. If any sample was darker than the *standard* it was diluted (see Appendix B). The *blank* was poured through the HACH DR 3000 spectrophotometer to zero the instrument. In sequence each sample was poured through the spectrophotometer and the reading recorded. When all samples had been tested the *standard* was poured through to ensure there was no instrument error (1.0 is the correct *standard* reading).

3.2.6 Ammonia-Nitrogen

The HACH DR 3000 spectrophotometer measures from 0 – 3.00 mg/L of NH_3-N. 25ml of each sample was measured out into 25ml sample vials. Also 25ml of deionized water was measured out (for the *"blank"*) and 25ml of nitrate standard solution concentration of 1mg/L (for the "*standard*") was placed into separate vials. Into each vial, 1ml of Nessler reagent was added, 3 drops of mineral stabilizer and 3 drops of polyvinyl alcohol dispersing agent and swirled for one minute. If any sample was darker than the *standard* it was diluted (see Appendix B). The *blank* was poured through the HACH DR 3000 spectrophotometer to zero the instrument. In sequence each sample was poured through the spectrophotometer and the reading recorded. When all samples had been tested the *standard* was poured through to ensure there was no instrument error (1.0 is the correct *standard* reading). NOTE: A correction reading, for colour interference, was completed by pouring through a pure undiluted sample and subtracting the reading from the test samples.

3.2.7 Avocet Foraging Scale

The Avocet Foraging Level (as seen in figures 22 - 26) was developed by Les Gyug, Kelowna Avocet Project Co-ordinator, based on 1999 avocet foraging surveys and population censuses (unpublished data). Zero indicates complete absence of avocets. Ten is set at the abundance of avocets and foraging levels at Alki Lake. Each other wetland is fit somewhere between these values based on the numbers of foraging avocets relative to Alki Lake. Each avocet level was developed for the broad time period when the water chemistry sample was actually taken. The levels were then examined for correlation with water chemistry data.

Figure 4 *Conducting chemical tests on the spectrophotmeter*

4.0 Results

NOTE: ICP 31 metals scan was not performed on the following sites or dates:

- Alki Lake – June
- Robert Lake – June
- Chichester Pond – June
- Slough #2 – June
- Bubna Slough – June

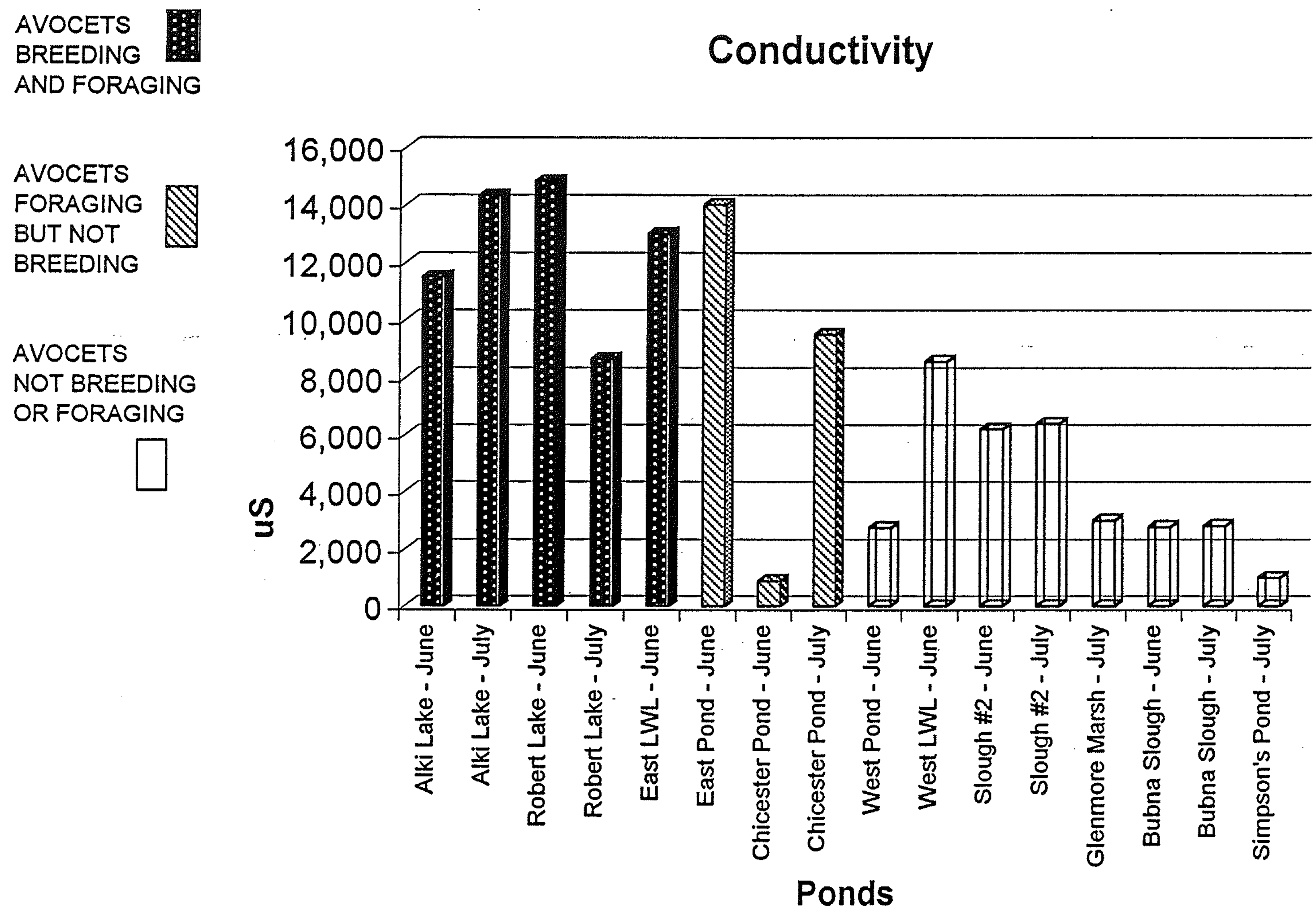

Figure 6 *Conductivity of Sample Water*
Avocets live in highly conductive water.

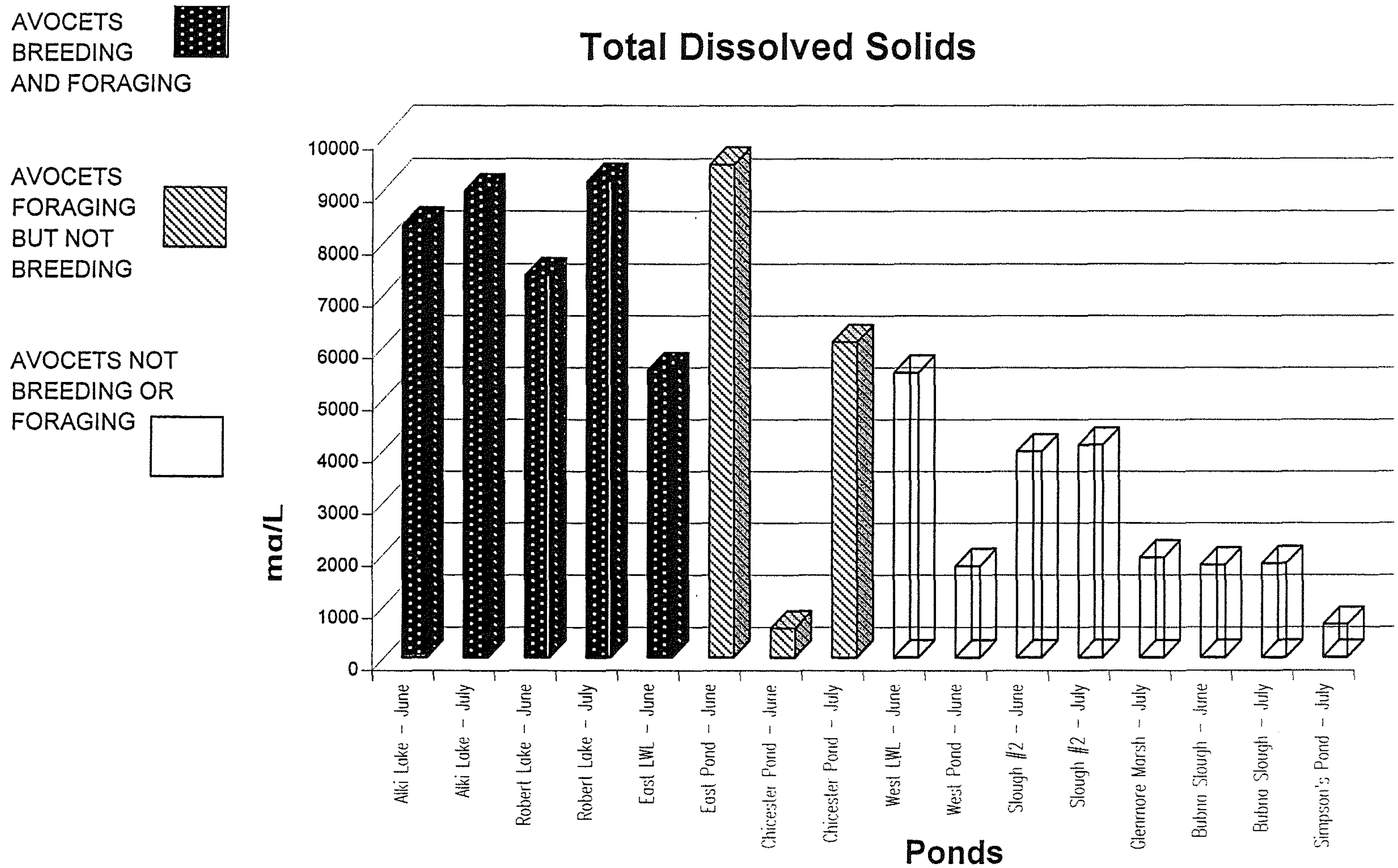

Figure 7 *Total Dissolved Solids in Sample Water*
The areas where Avocets live have high levels of dissolved solids

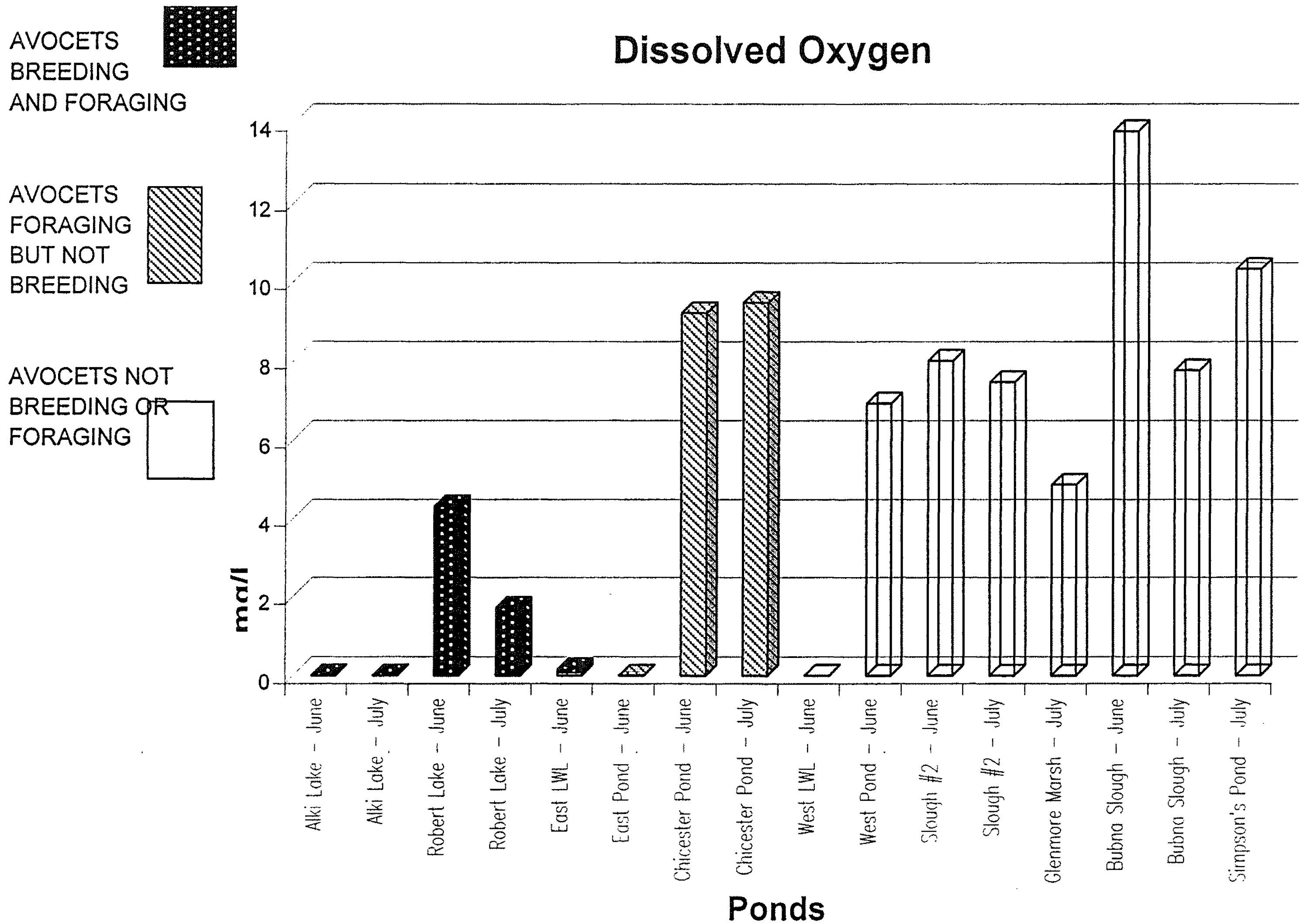

Figure 8 *Levels of Dissolved Oxygen*
Avocets live in areas of low dissolved oxygen.

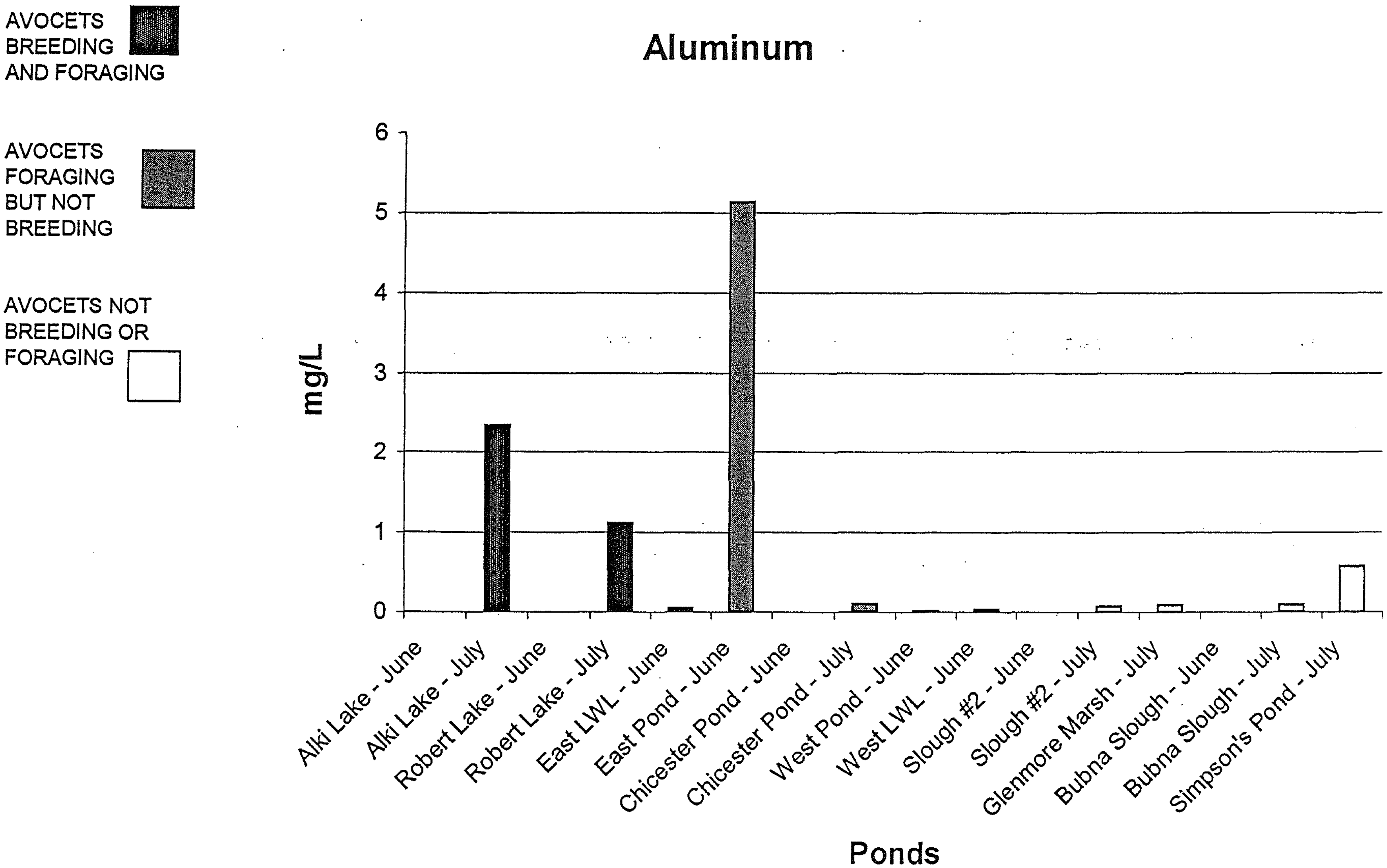

Figure 9 *Aluminum Concentration of Sample Waters*
Avocets live in areas of high aluminum.

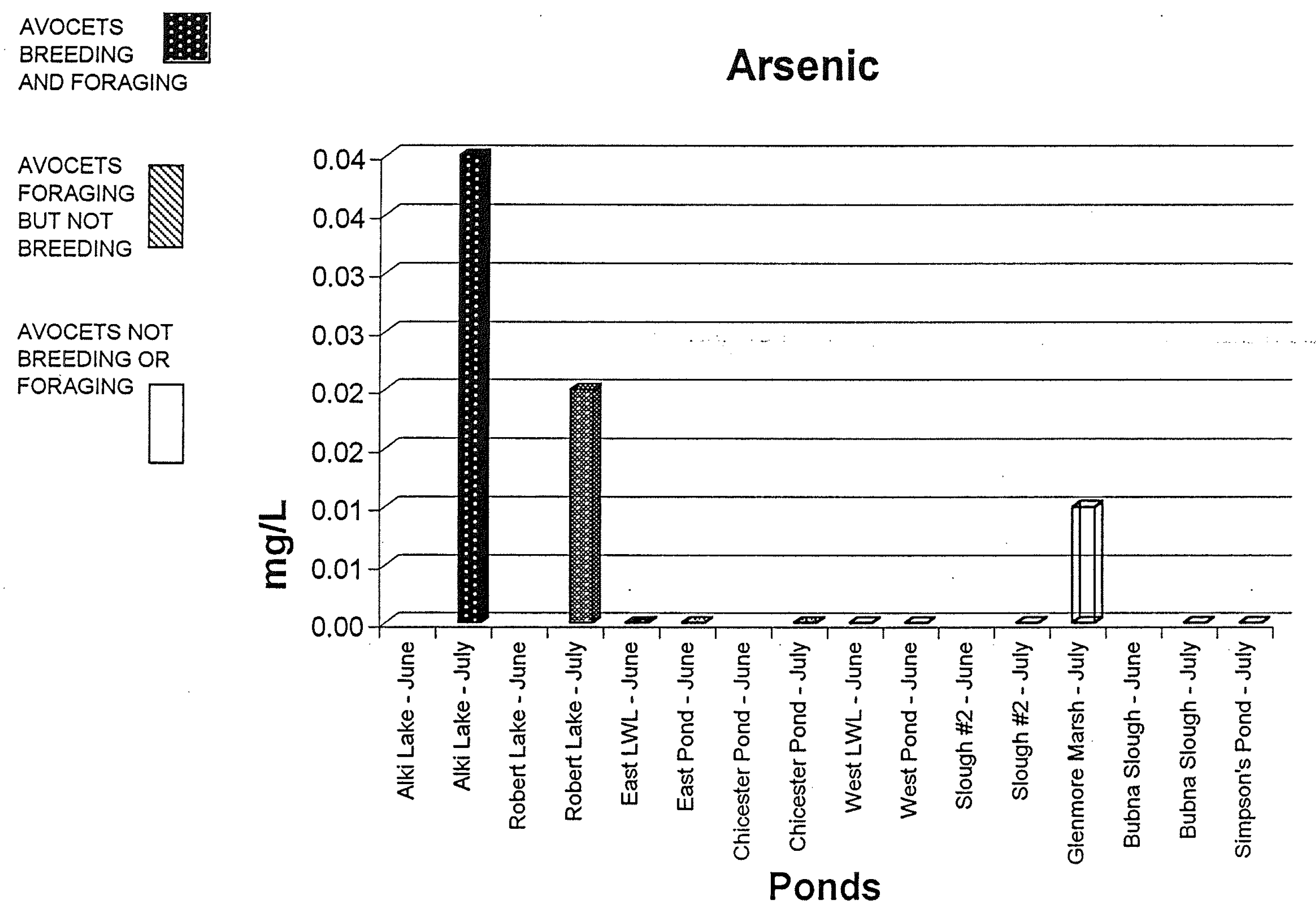

Figure 10 *Arsenic Concentration of Sample Water*
Arsenic levels in Alki and Robert Lake was higher than all other sample sites.

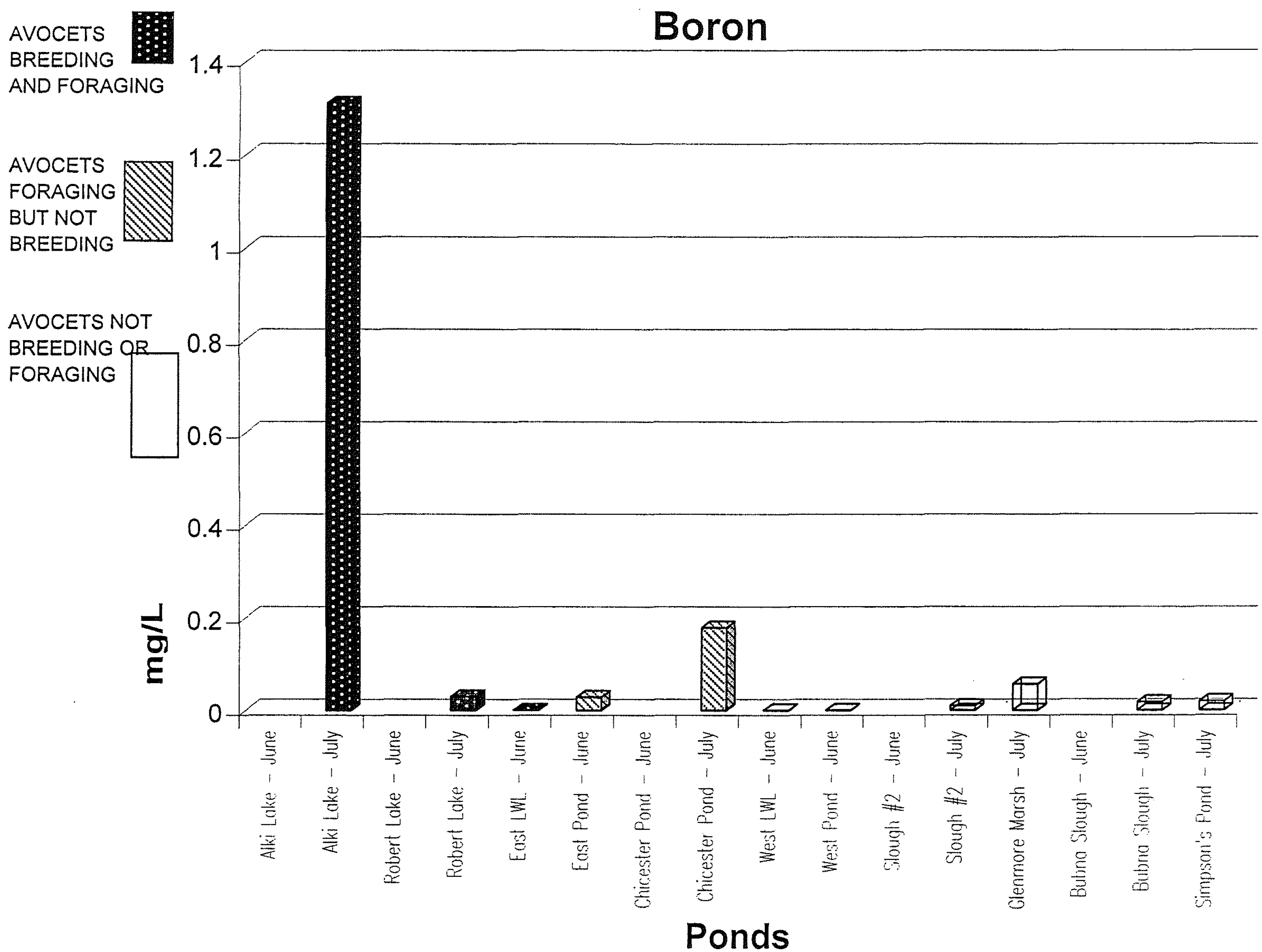

Figure 11 *Boron Concentrations of Sample Water*
Avocet habitat has high levels of Boron.

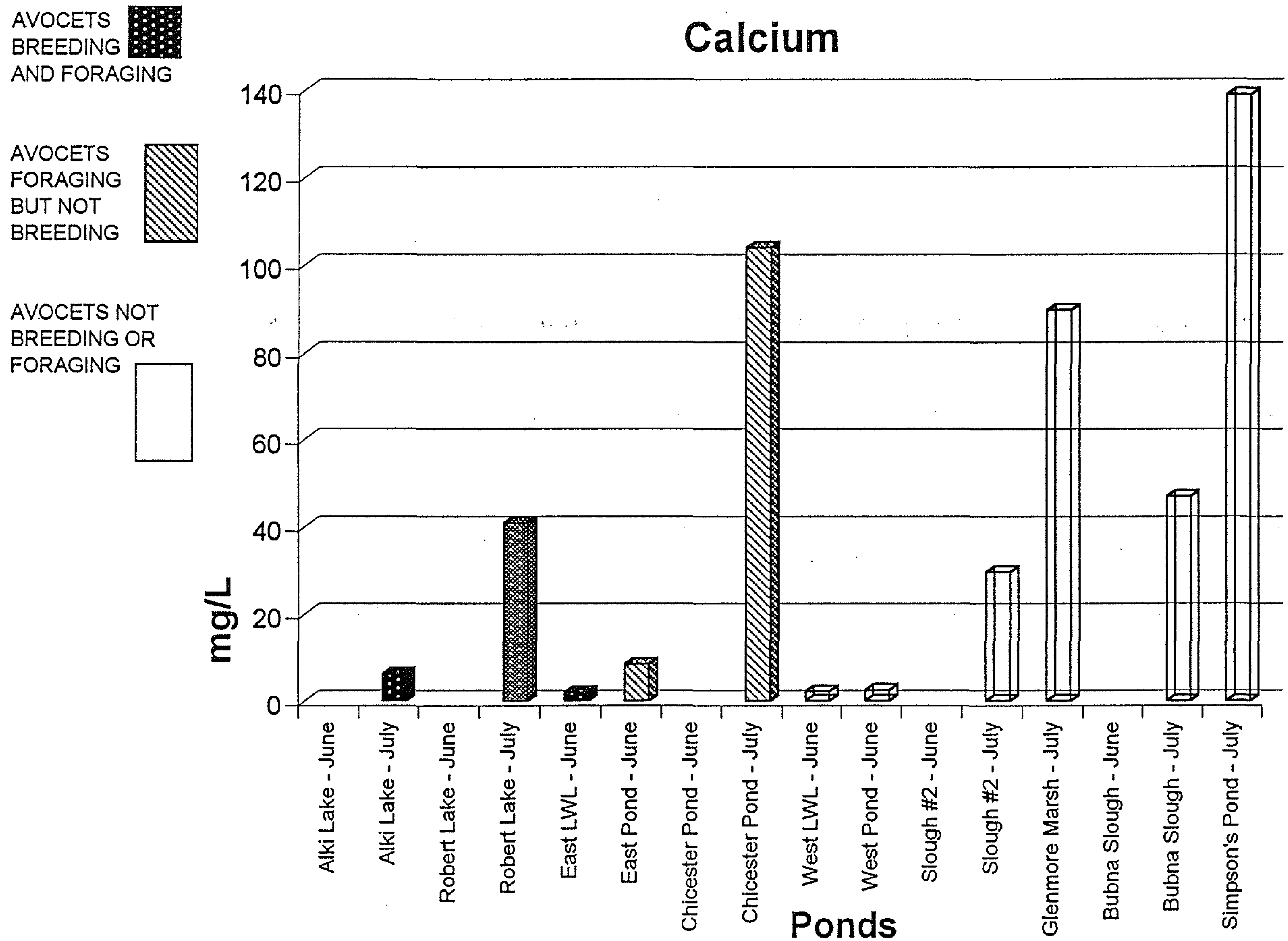

Figure 12 *Calcium Concentrations of Sample Waters*
Avocets live in area where there is low dissolved calcium ions.

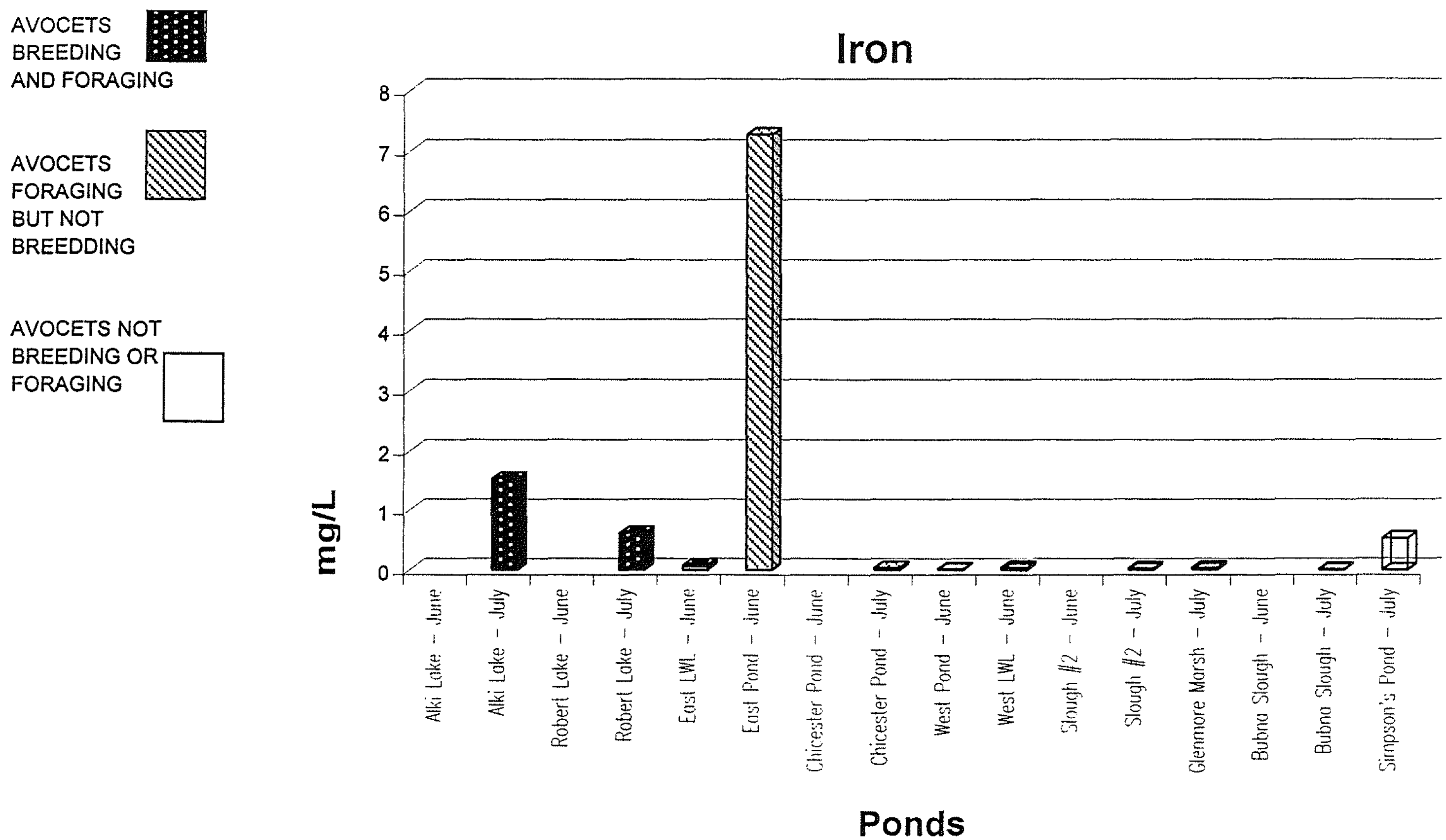

Figure 13 *Iron Concentration of Sample Water*
Avocets inhabit areas of high iron concentration.

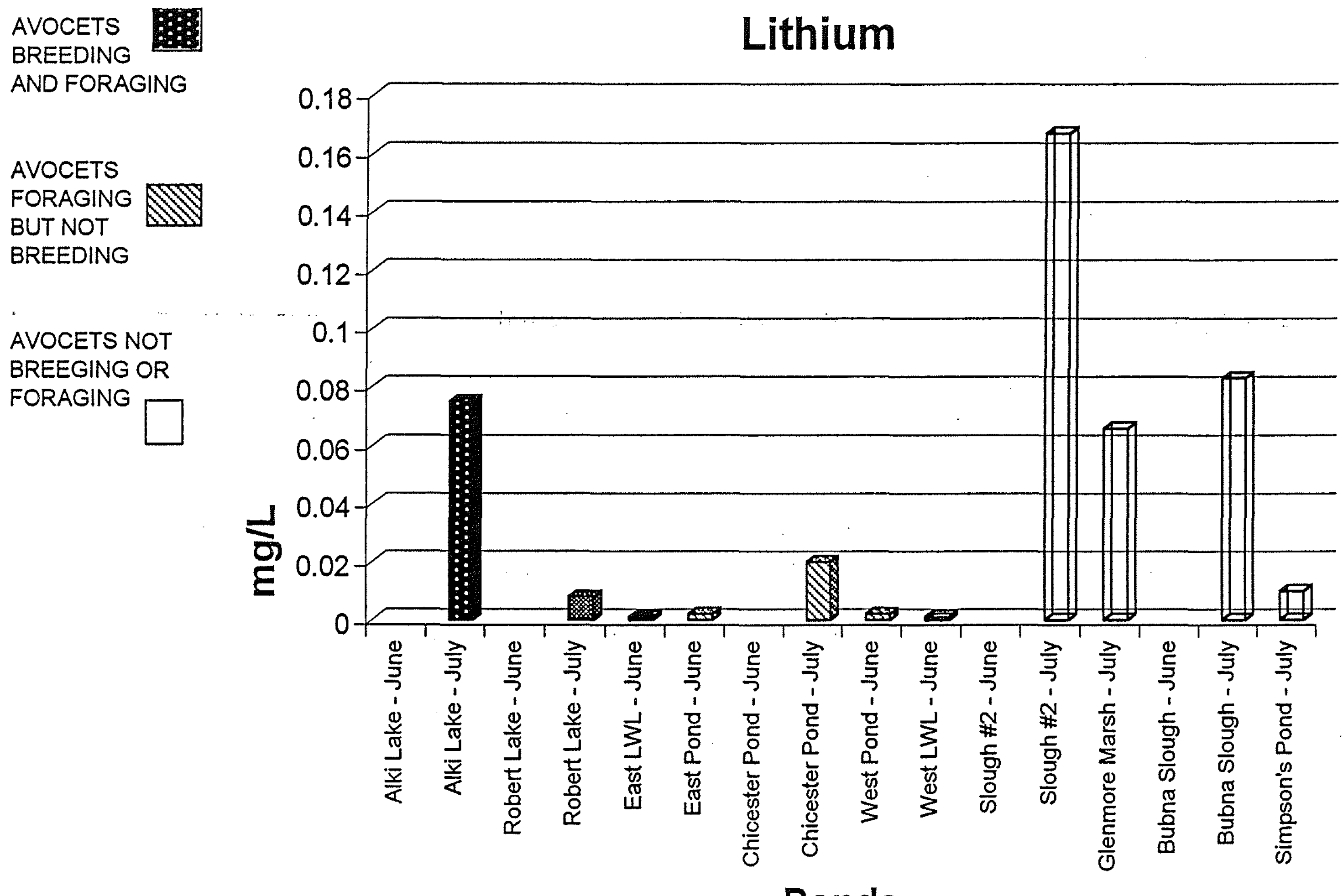

Figure 14 *Lithium Concentrations of Sample Water*
Avocets live in areas of low lithium concentration dissolved in the water.

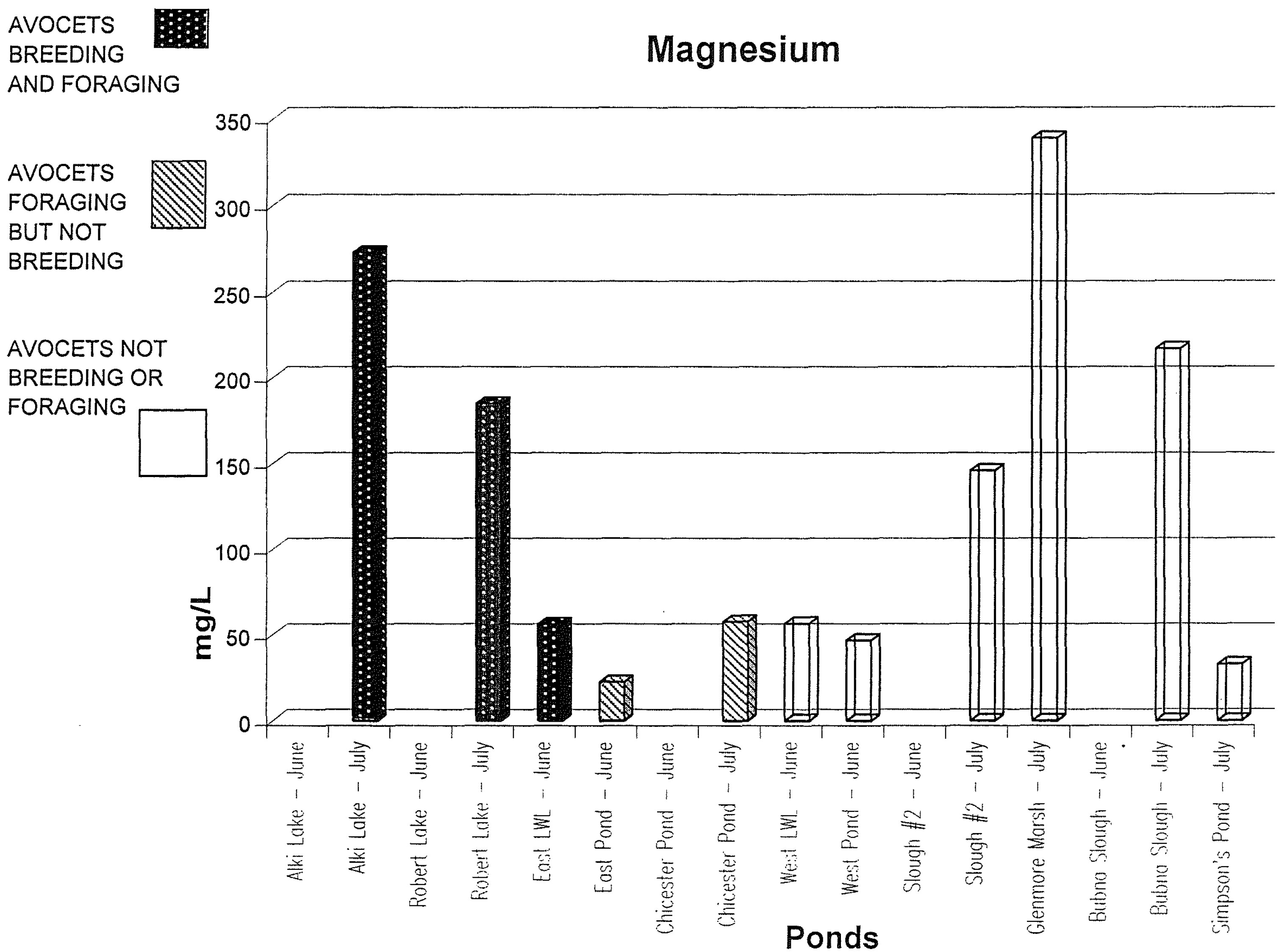

Figure 15 *Magnesium Concentration of Sample Water*
Areas where Avocets inhabit and areas where they do not inhabit have varying levels of magnesium.

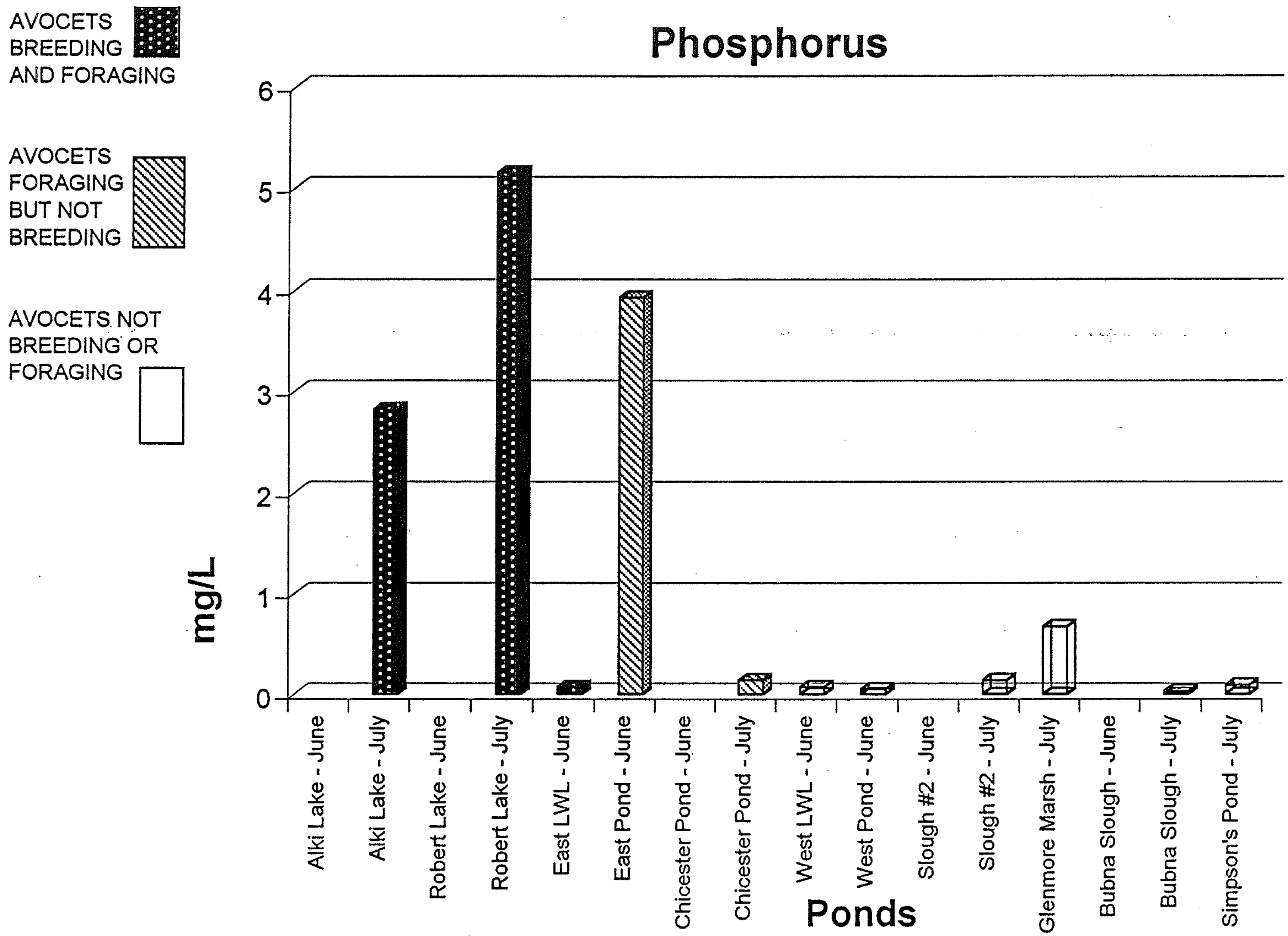

Figure 16 *Phosphorus Concentration of Sample Water*
Avocets live in areas of high dissolved phosphorus content.

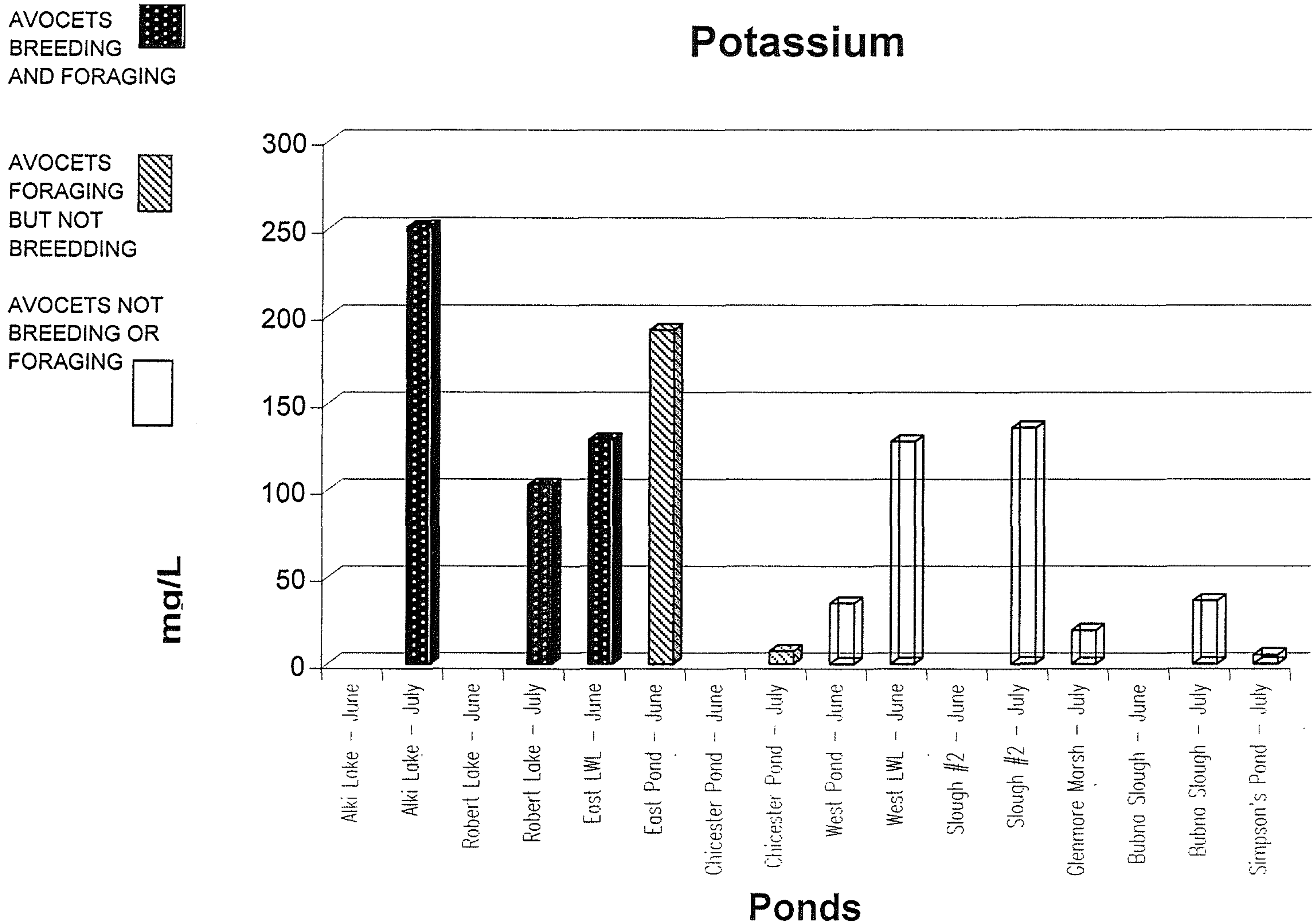

Fig. 11 *Potassium Concentrations in Sample Water*
Avocets live in areas of high potassium.

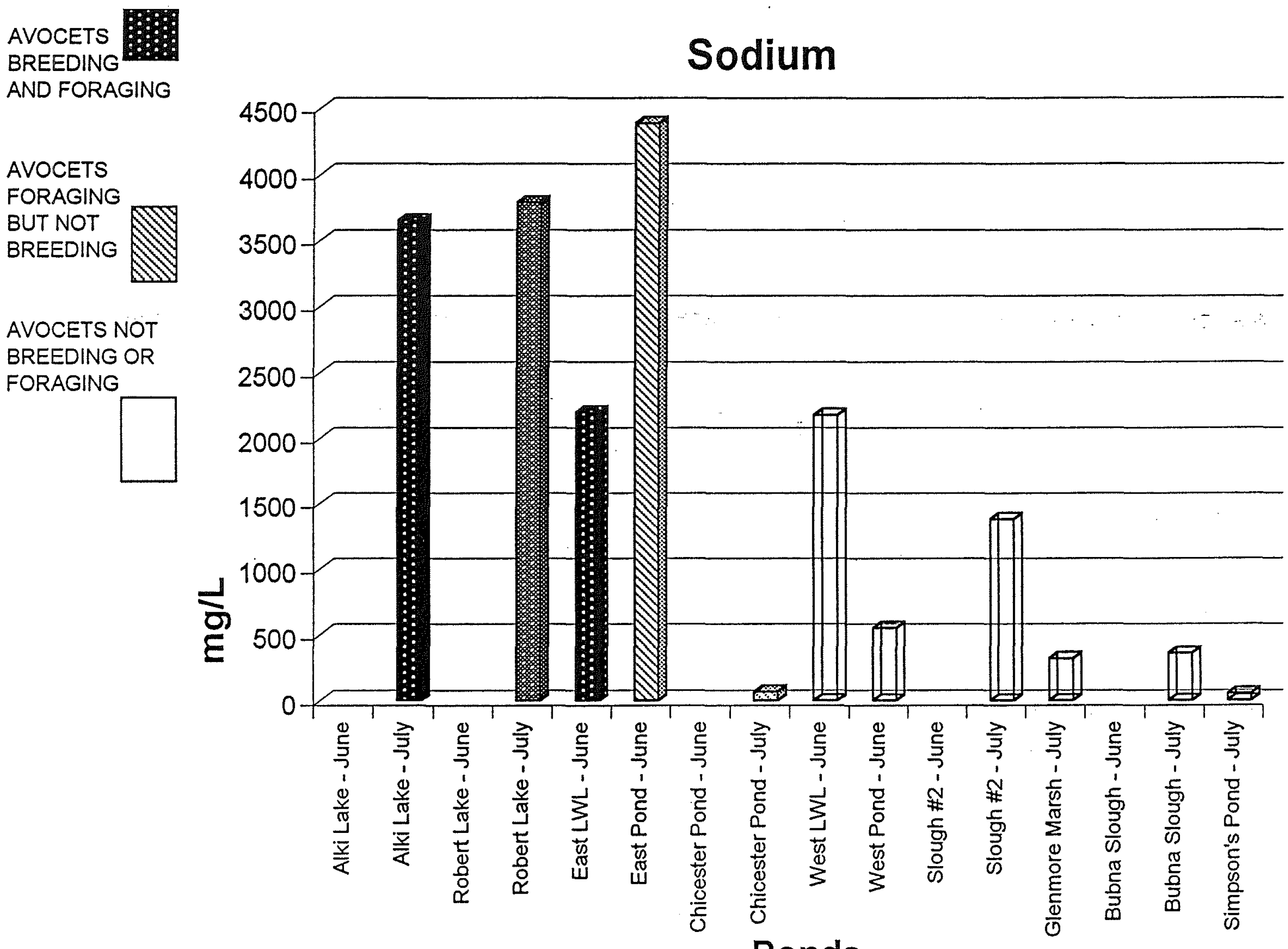

Figure 18 *Sodium Concentrations of Sample Water*
Avocets live in areas of high sodium concentration.

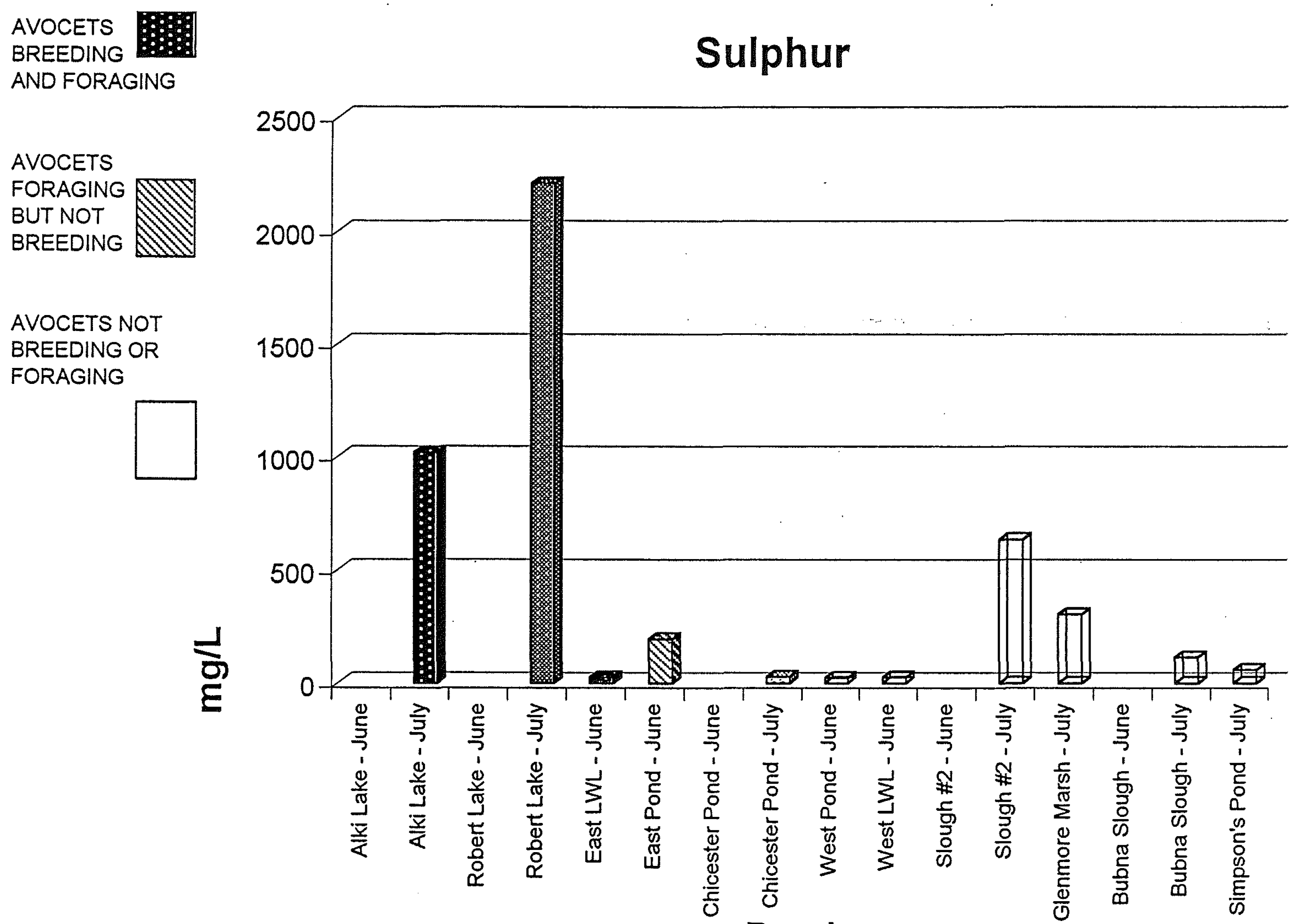

Figure 19 *Sulphur Concentrations of Sample Water*
Avocets live in waters high in sulphates.

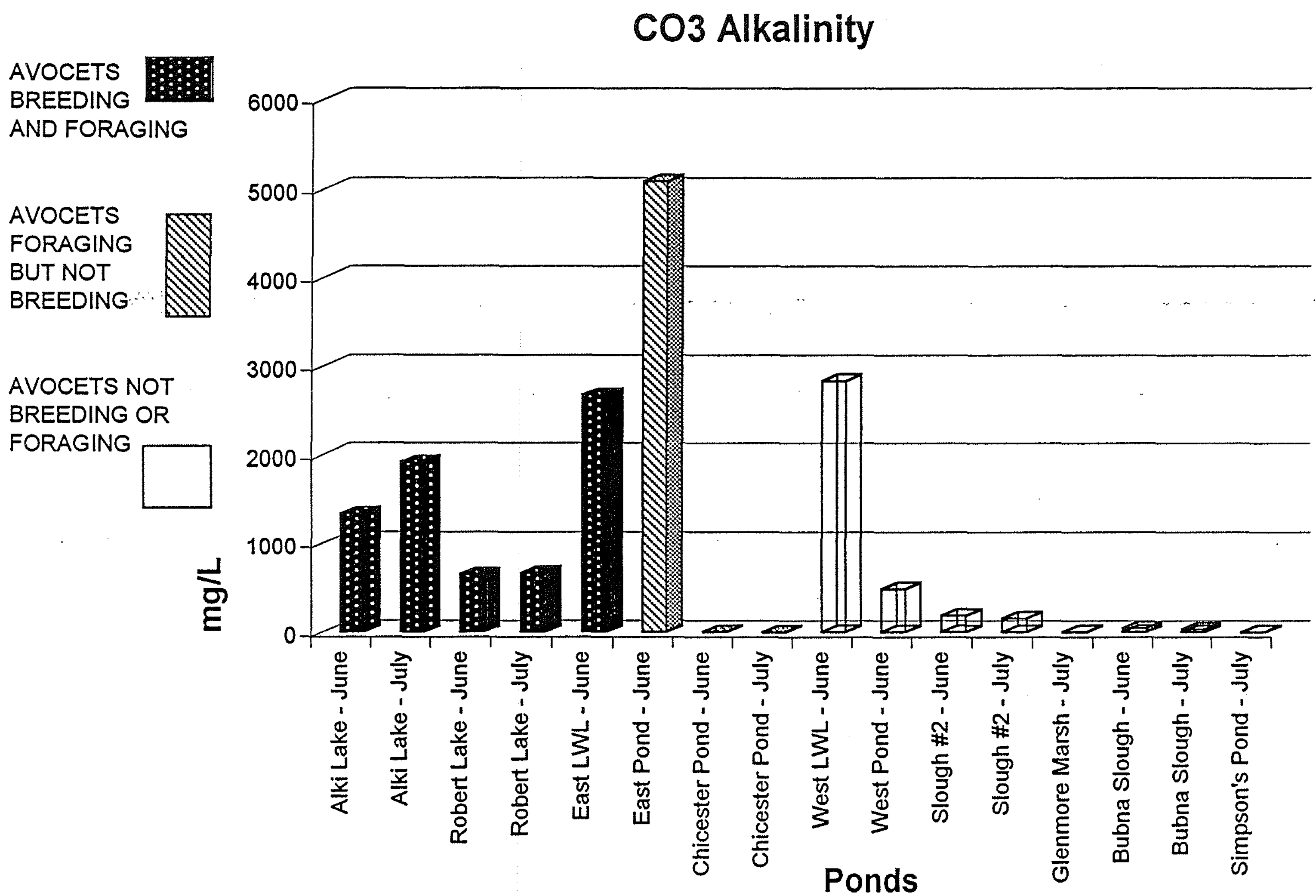

Figure 20 *Carbonate Alkalinity of Sample Waters*

There is very low carbonate levels where avocets are not found.

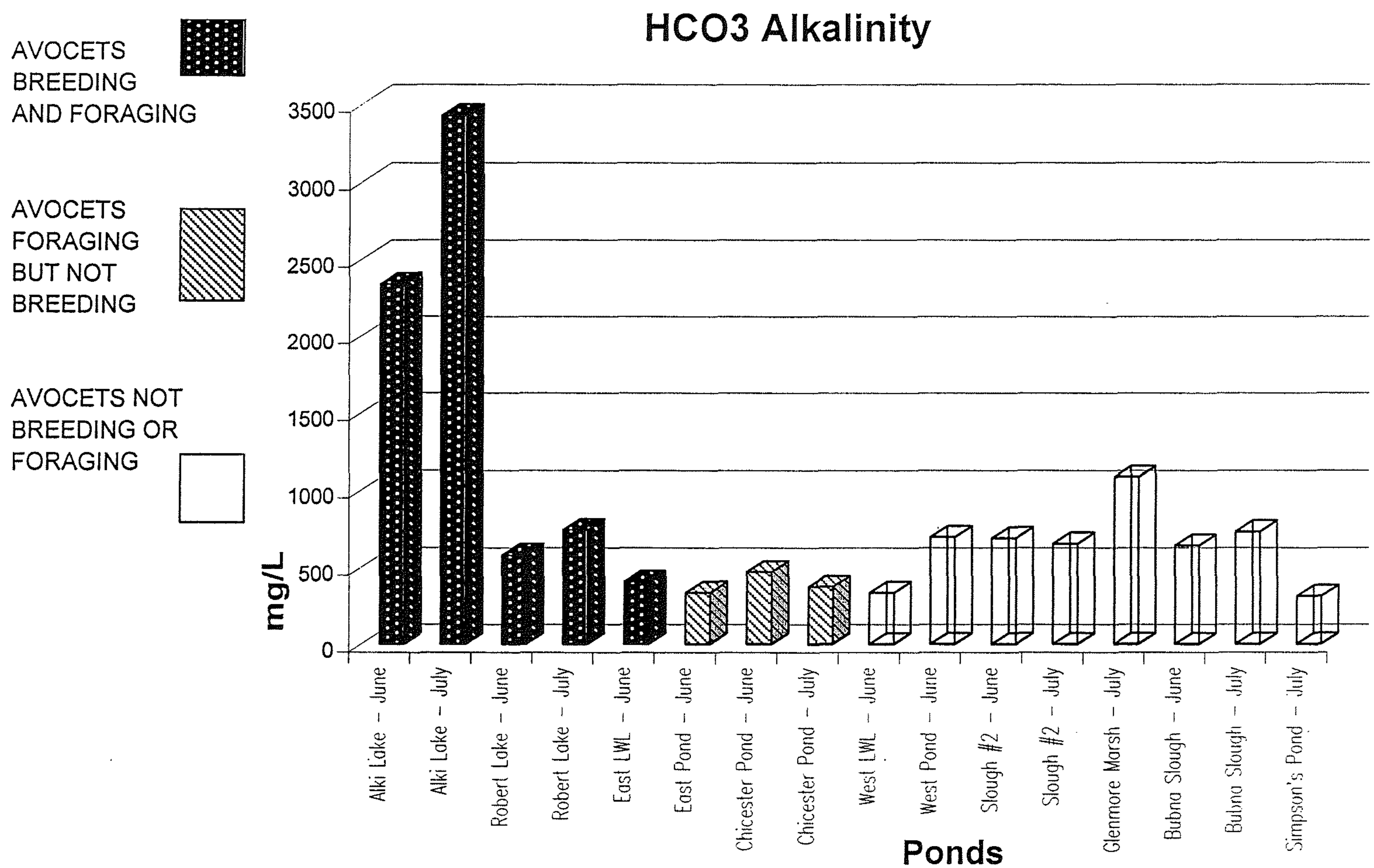

Figure 21 *Bicarbonate Alkalinity of Sample Waters*
Alki Lake is highest in bicarbonate alkalinity.

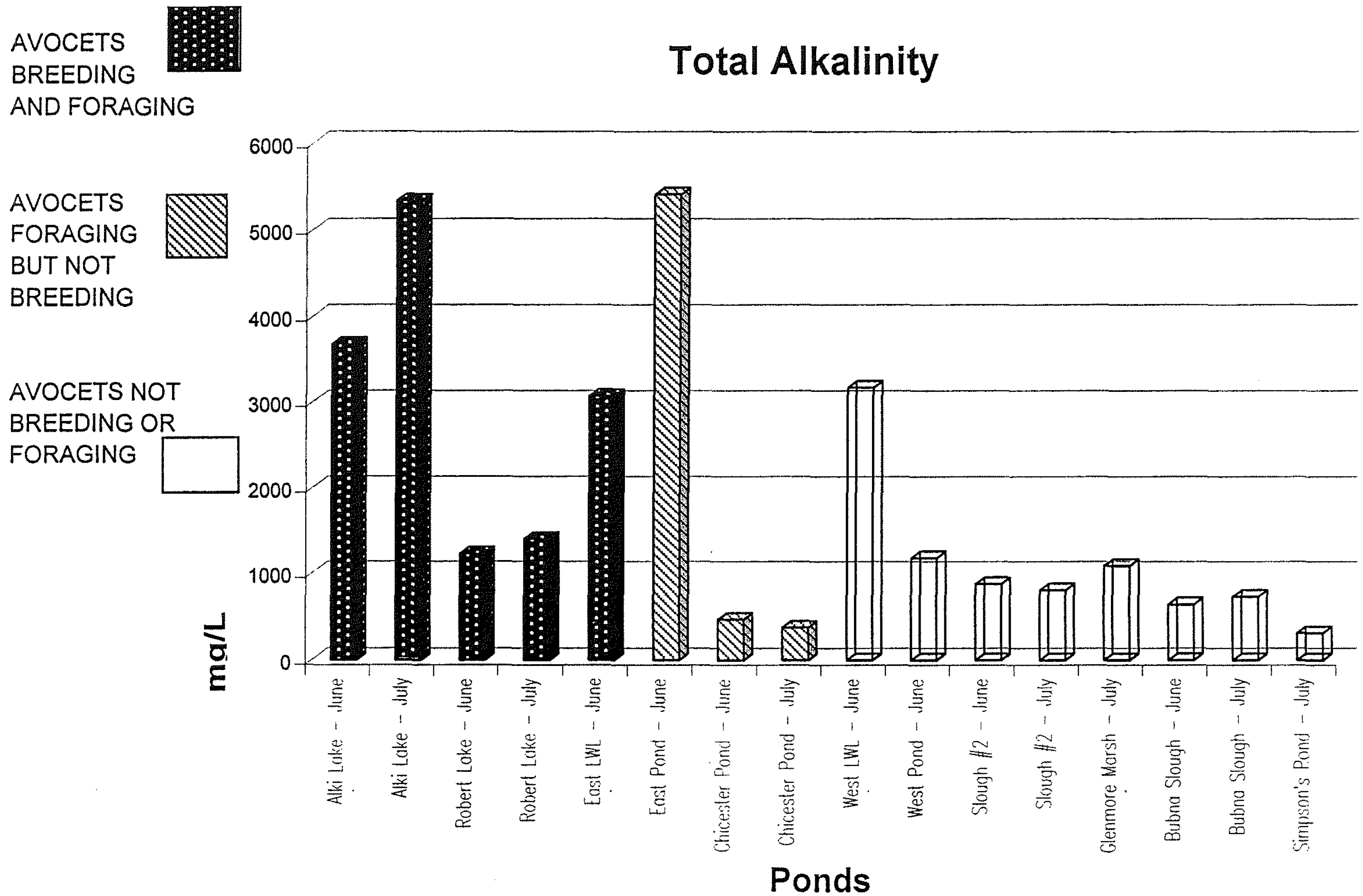

Figure 22 *Total Alkalinity of Sample Waters*
Avocets are present in highly alkaline waters.

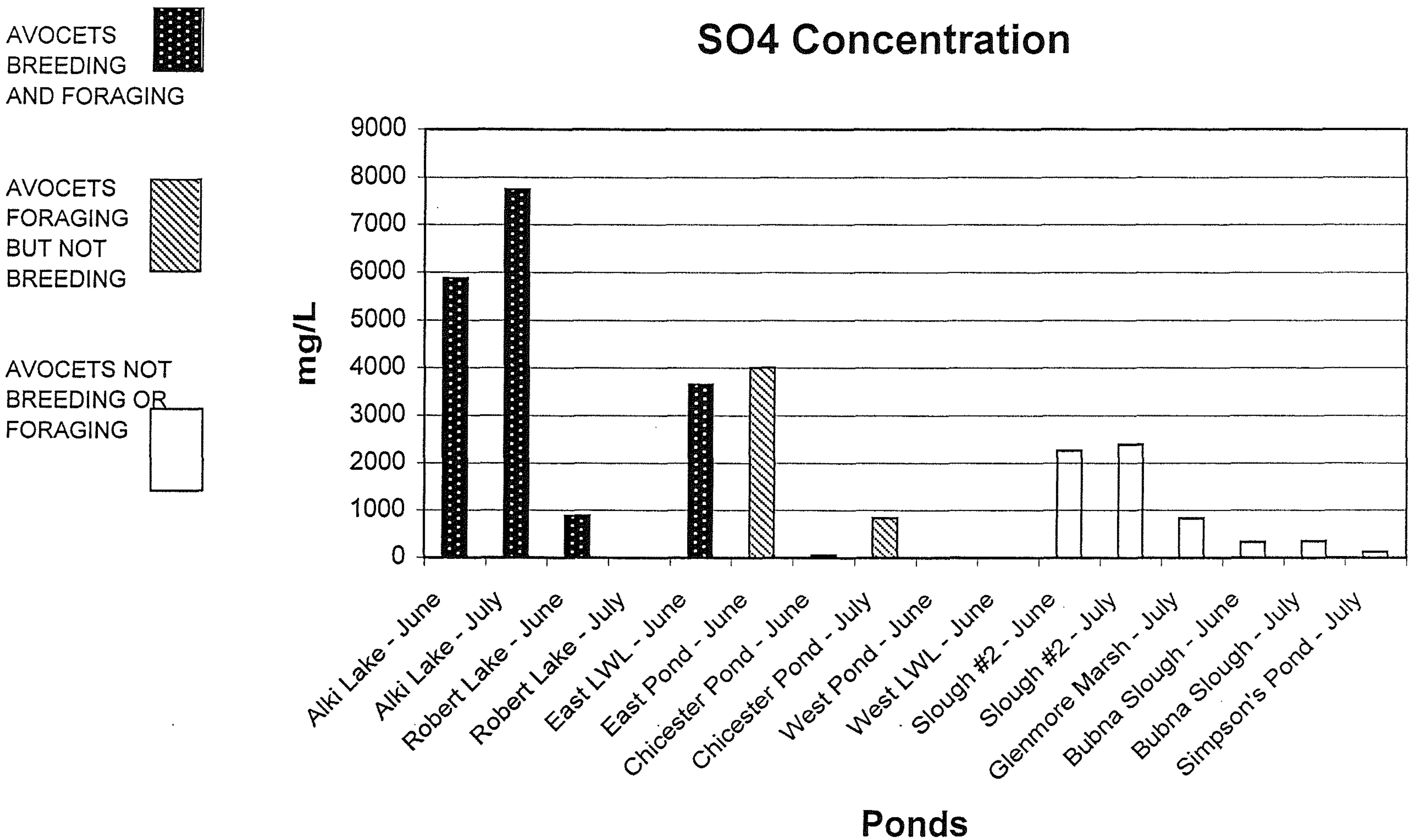

Figure 23 *Sulphate Concentration of Sample Water*
Avocets live in waters of high sulphate concentration.

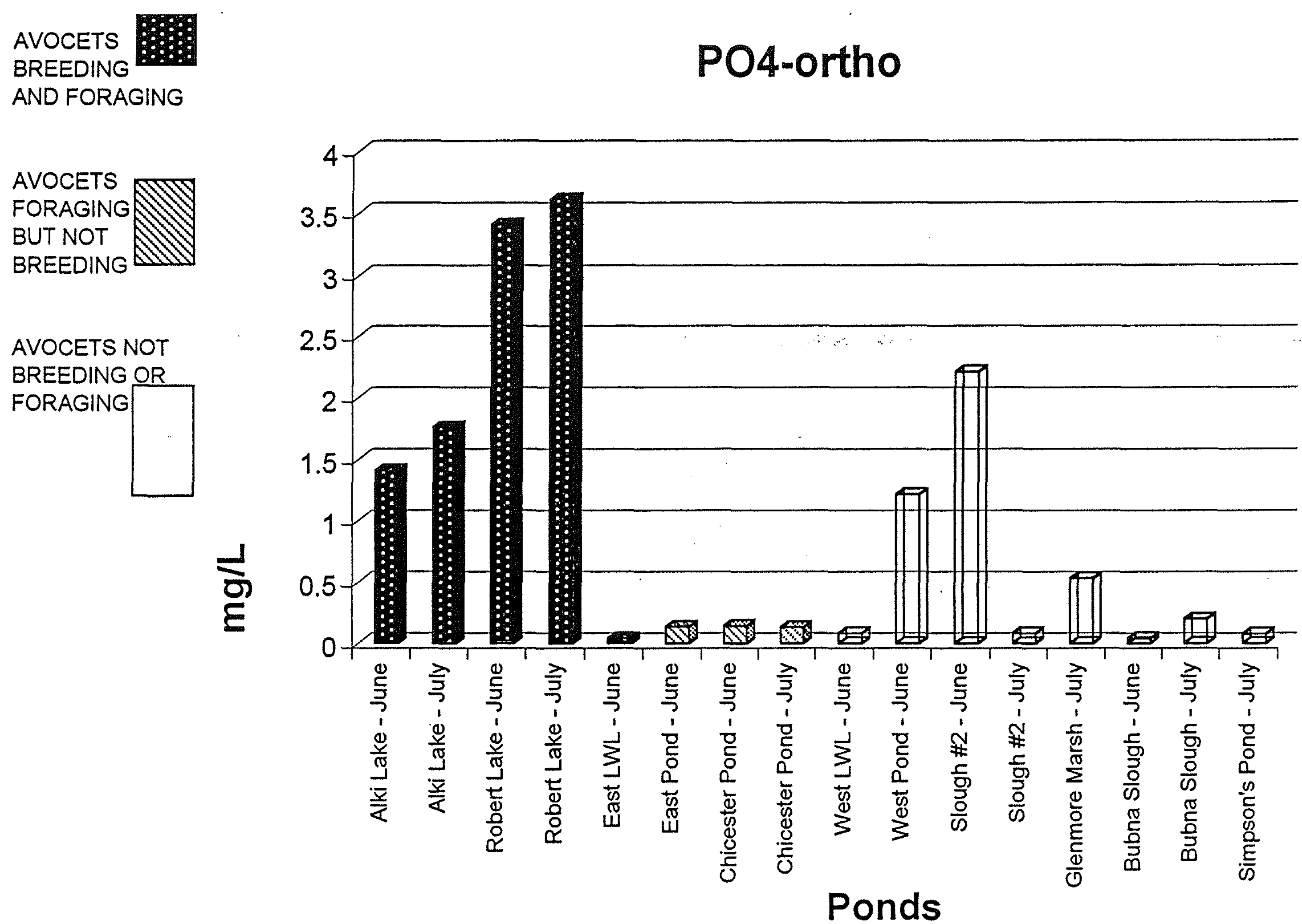

Figure 24 *Orthophosphate Concentrations of Sample Water*
Avocets live in areas of high PO4-ortho.

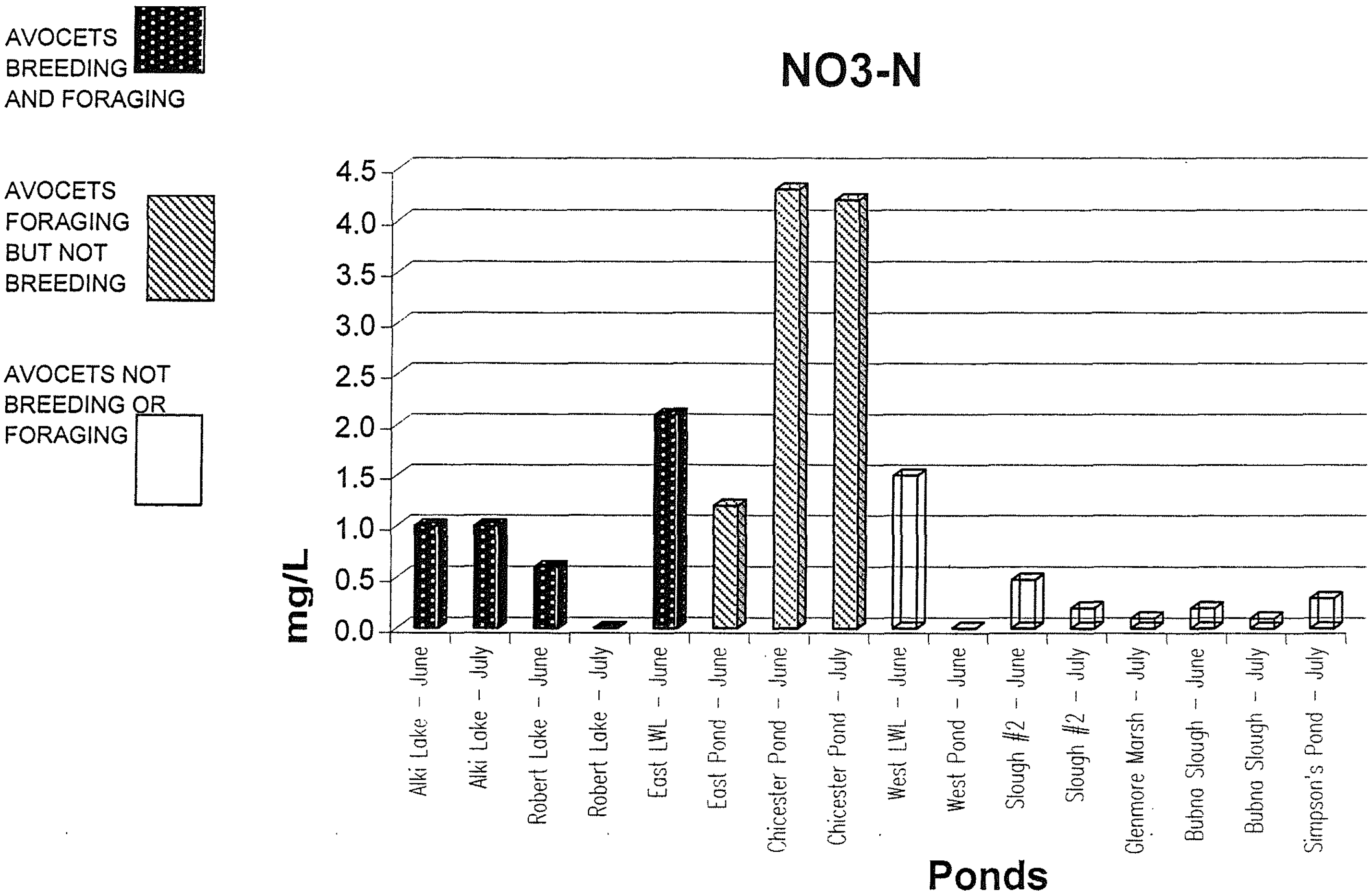

Figure 25 *Nitrate-Nitrogen Concentration in Sample Water*

Avocets breed in areas of moderate nitrate concentration and forage in areas of high nitrate concentration.

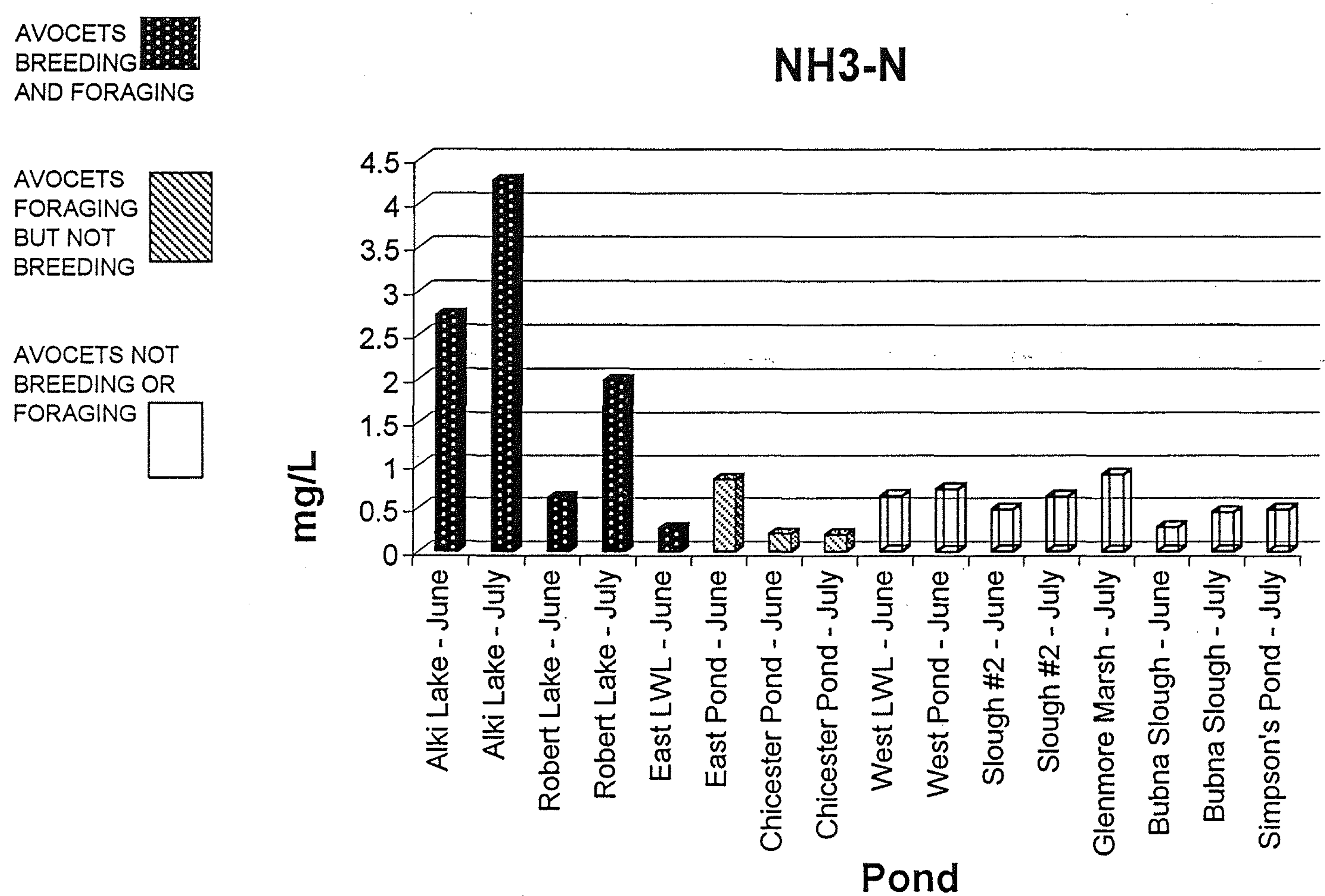

Figure 26 *Ammonia-Nitrogen Concentrations of Sample Waters*
Avocets live in areas of high NH3-N.

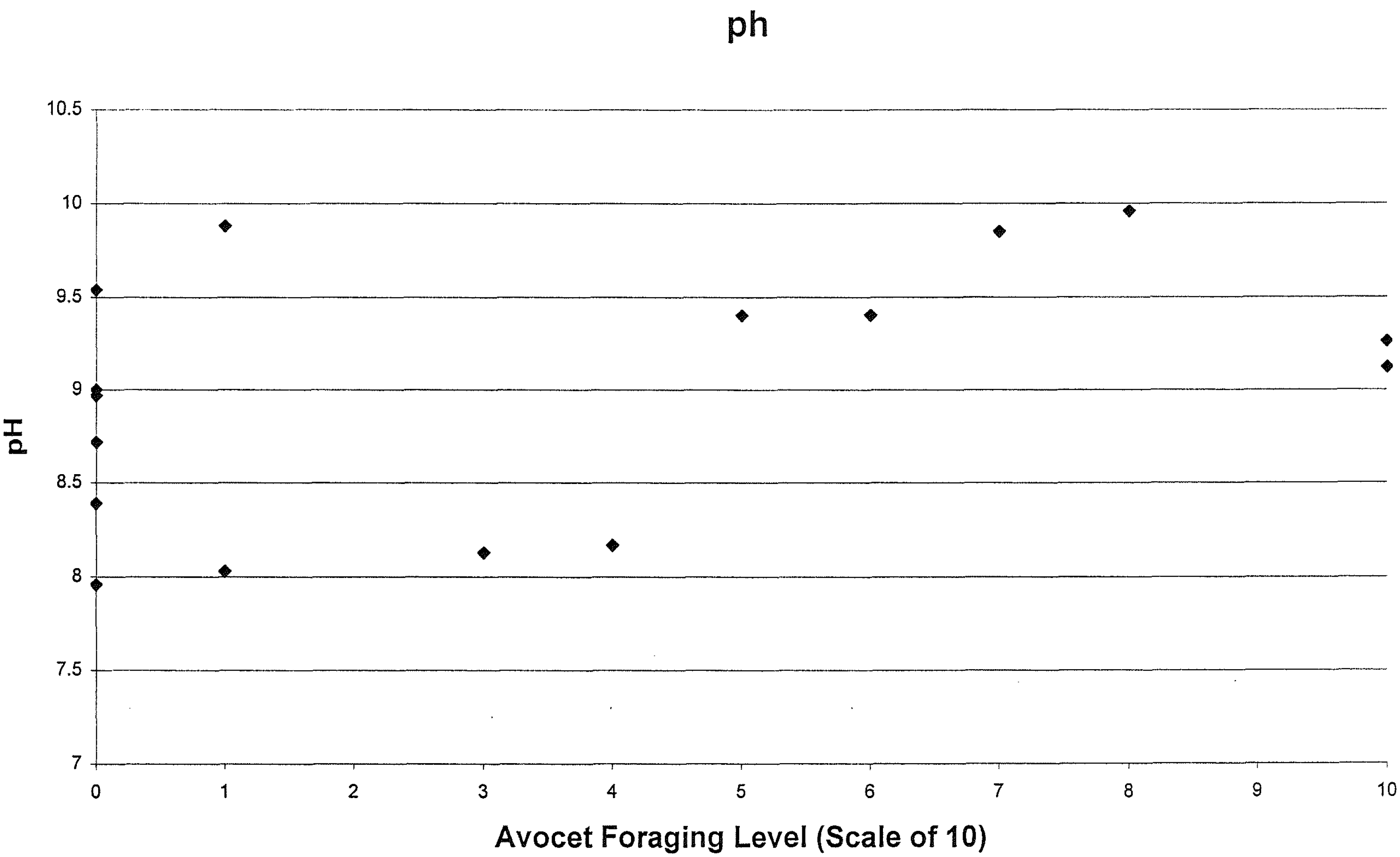

Figure 29 *pH vs. Avocet Foraging Level*
Avocets forage mkost in areas of high pH.

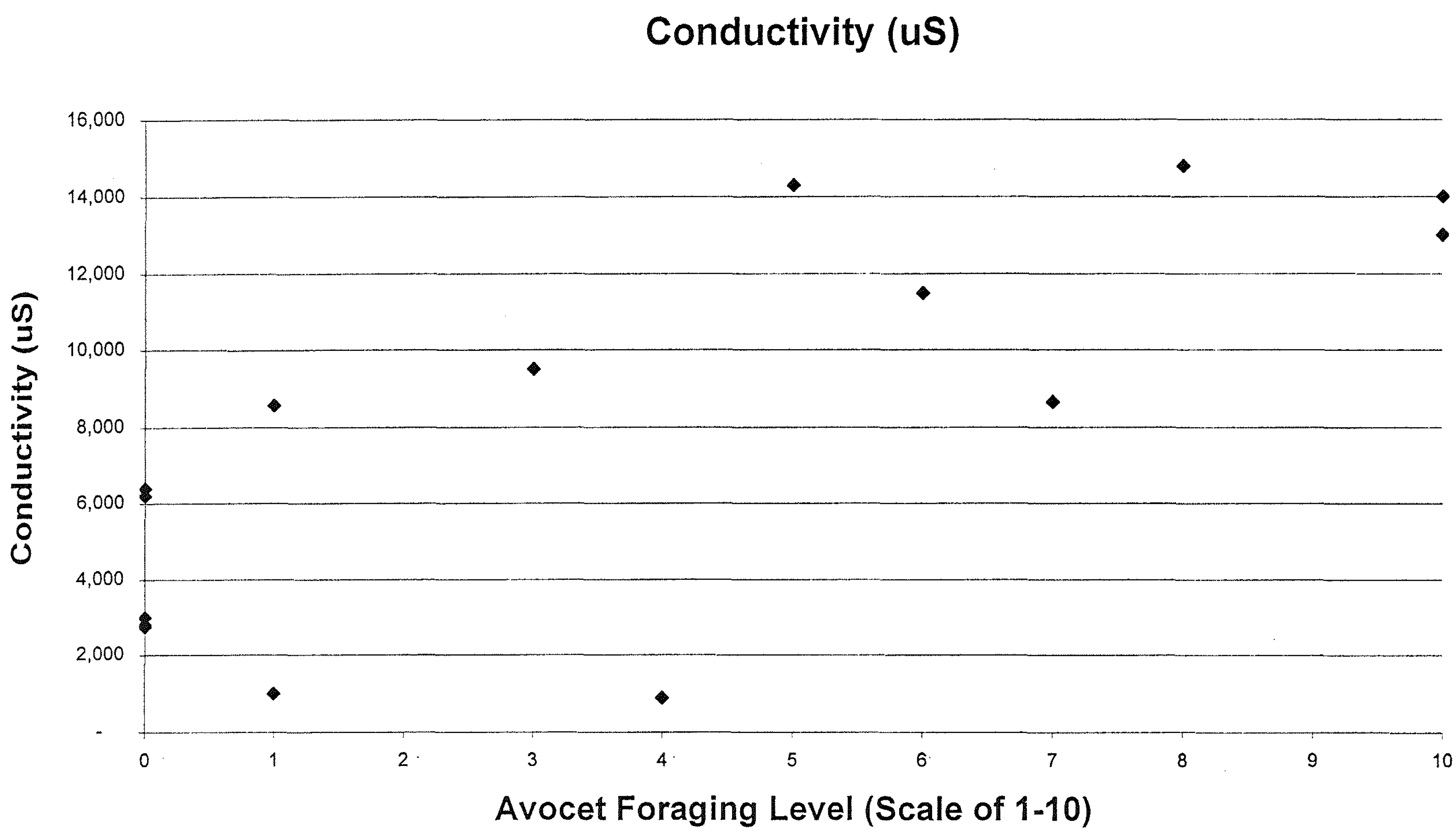

Figure 27 *Conductivity vs. Avocet Foraging Level*
Water with higher conductivity has more Avocets foraging.

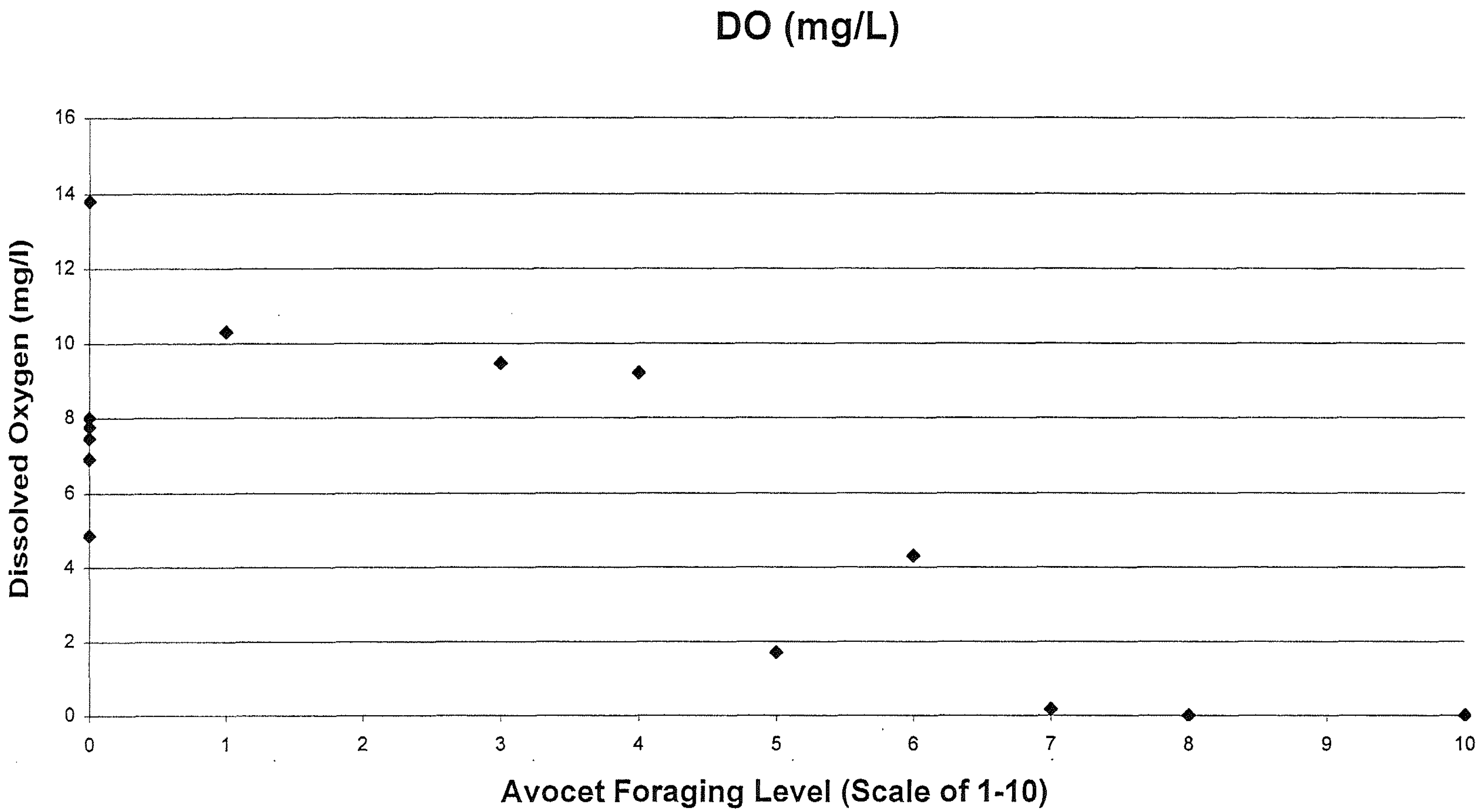

Figure 28 *Dissolved Oxygen vs. Avocet Forgaing Level*
Avocets forage in areas of low DO concentrations.

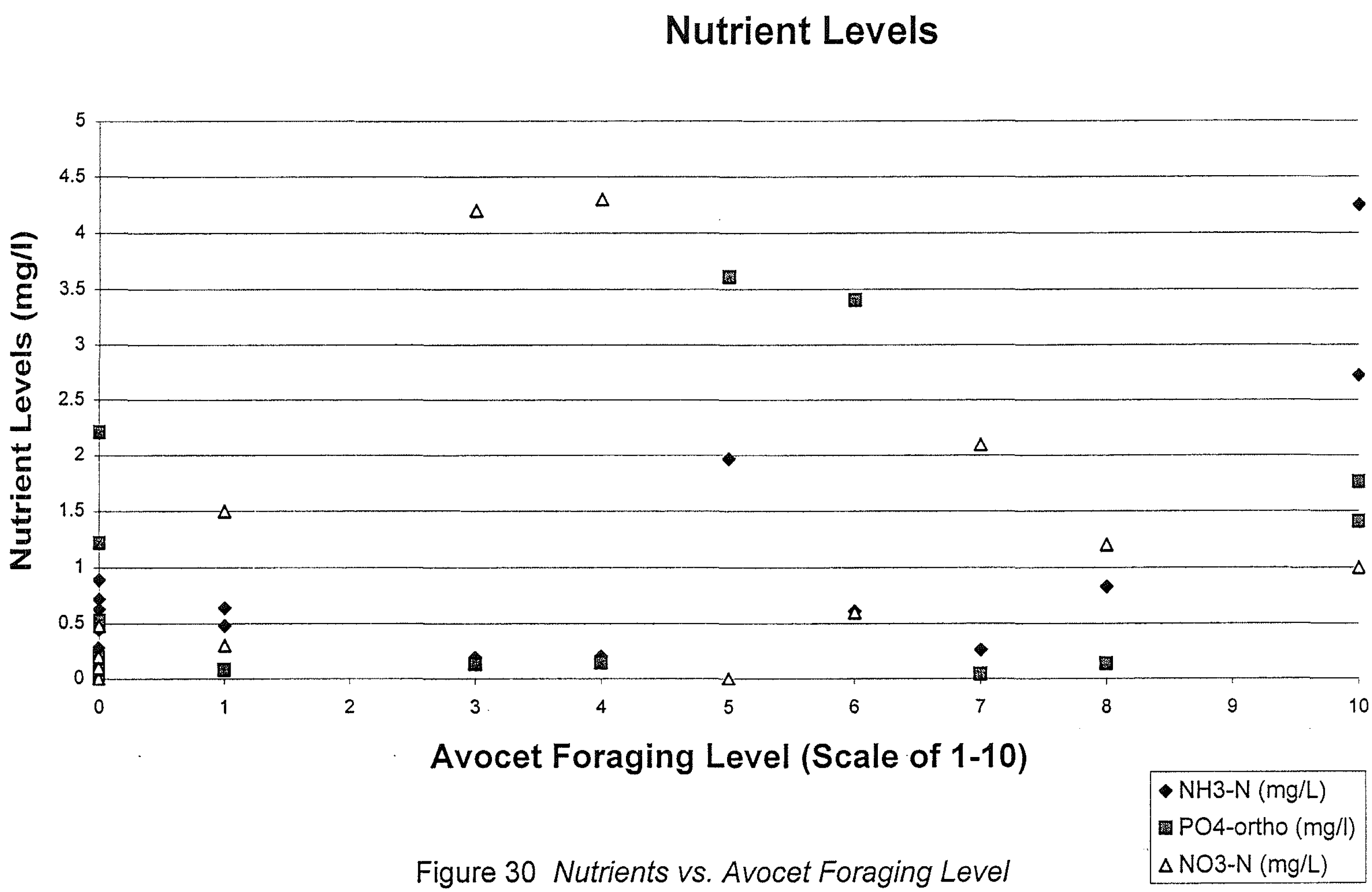

Figure 30 *Nutrients vs. Avocet Foraging Level*
Avocets forage in areas of high and low nutrient levels.

5.0 Discussion

American Avocets have specific preferences for their breeding and foraging habitat. The results described below reflect particular water chemistry preferences of the Avocet.

5.1 Alki Lake

Alki Lake is the most consistently used breeding ground in BC (Weir, 1997), therefore the water quality is preferred for Avocet breeding and foraging habits. Water chemistry composition of Alki Lake is often similar to Robert Lake. Alki Lake has high levels of most dissolved metals. Boron levels are 1.2mg/L higher than the average levels found in surface waters (Canadian Council of Environment Ministries [CCEM], 1996). Alki Lake is the only site with significantly high boron levels. In addition, Alki Lake has arsenic concentrations 10ug/L less than maximum allowed for aquatic freshwater life (Water Quality Branch Environmental Protection Department Ministry of Environment, Lands and Parks [EDP], 1995). These arsenic concentrations in combination with high boron and selenium levels have been known to be immunotoxic to Avocets (Fairbrother et. al., 1994). Fortunately, selenium was undetectable. Although Alki Lake is looked at as the most favourable conditions for Avocets, arsenic levels should not be duplicated in the new wetland to protect the Avocets from its possible damaging effects.

Alki Lake reported the second highest levels of dissolved ionic sulphur of all sites tested and the third highest levels of phosphorus. The TDS are third highest of all sites sampled and almost double the other sites of inhabitation. As the summer goes on and evaporation exceeds precipitation, levels of TDS increase and in turn the salinity increases. This is consistent with past findings at Alki Lake (M. Browne - personal communication, 1999). It had high concentrations of potassium, sodium and magnesium. This site had relatively high levels of the other dissolved metals that minimally contribute to salinity. As such, the classification of Alki Lake is hyposaline correlating with high conductivity (see Appendix C) with potassium, magnesium and sodium being the major contributors.

Alki Lake had the highest levels of bicarbonate alkalinity, contributing to high total alkalinity.

Due to many, unavoidable interferences the results for DO were undetectable (M. Browne - personal communication, 1999). Sulphate levels are 40 times higher than aquatic life can support (tentative measurement affects some species and life stages) (EPD, 1995). Concentrations of orthophosphates are one and one half times higher than aquatic life can support. Alki Lake has extremely high levels of NH_3-N in relation to all other sites sampled. Overall, Alki Lake had high nutrient levels.

5.2 Robert Lake

Robert Lake was one of the top three areas with the highest concentrations of dissolved metals. Robert Lake reported moderate arsenic levels, non-toxic thus far. Robert Lake presents high levels of sodium, magnesium, potassium, and calcium therefore classifying it as a hyposaline lake (see Appendix C).

Since, DO varies, (time of year and location) it is difficult to have set parameters. However, Canadian Council of Environment Ministries (1996) stated that <10mg/L is a common level nation-wide or in BC >10mg/L is frequently encountered. Robert Lake's

DO concentration is nearly 10 times higher than East LWL, yet still lower than sites where Avocets do not inhabit. Robert Lake had SO_4 concentrations that are 80 times higher than what the Ministry of Environment's Working Criteria for Water Quality (1995) allowed for freshwater aquatic life (tentative measurement because this maximum value affects some species and life stages) to survive. This site had the highest values of phosphorus of all areas tested. However, it is not considered high in general. According to Wetzel (1983) phosphorus is a nutrient that is responsible for algae growth. In closed saline lakes phosphorus levels can reach as high as 200mg/L (CCEM, 1996), but the levels found here don't approach that number. Periodic algal blooms may be triggered by 0.08 - 0.1 mg/L orthophosphate concentrations (Bartenhagan et. al., 1998). Robert Lake levels exceed this at this time. Other substances are responsible prohibiting frequent algal blooms. High pH levels and temperature contribute to high NH3-N concentrations (Bartenhagan et. al., 1998). Consequently, Robert Lake had high levels of NH3-N, which are detrimental to aquatic fresh water life (M. Browne - personal communication, 1999).

5.3 East Little White Lake

East LWL typically held the lowest values for dissolved substances of the 5 areas where Avocets are found. The levels of sulphur, phosphorus, aluminum, arsenic and iron resemble the levels of the other 6 areas where avocets are not found. Therefore even though Avocets appear to be attracted to areas with high concentrations of dissolved metals, it is not necessarily a requirement for their breeding habitat. The total dissolved solids (TDS) in East LWL are lower than other areas where Avocets inhabit but higher than all areas where they do not inhabit. This parameter contributes to the salinity of the marsh and classifies East LWL as a hyposaline lake (see Appendix C). The concentration of the specific ions that are responsible for salinity is low in comparison to other places where Avocets inhabit. Although East LWL is highly conductive it is the least conductive of the sites where Avocets inhabit.

Dissolved Oxygen values are very low in comparison to sites where Avocets are not found. These oxygen levels are consistent with other Avocet sites. Orthophosphate levels fit into the range of natural levels, 0.01-0.05mg/L (CCEM, 1996). NO_3-N is high in comparison to all sites where Avocets breed.

5.4 East Pond

Since Avocets only forage here and have not been found breeding, it can be assumed that water conditions are favourable and other physical variables are prohibiting breeding. Extremely high levels of iron can be found in East Pond. These iron levels were approximately 23 times higher than aquatic life can sustain (EPD, 1995). There was also exceptionally high concentrations of aluminum, 50 times the maximum value for aquatic life (EDP, 1995). However, levels of boron at East Pond are inversely proportional to Alki Lake concentrations. East Pond is highly conductive and has nearly double the TDS of sites where Avocets do not inhabit. The TDS are very similar to Alki Lake, classifying it as hyposaline (see Appendix C). East Ponds had very high levels of these ions that contribute to salinity: potassium and sodium; but lacked in calcium, magnesium and sulphate concentrations.

Alki Lake and East Pond have almost identical levels of total alkalinity but their alkalinity's come from different sources. The alkalinity of East Pond is due to the predominant species of CO_3, where as Alki Lake is almost entirely HCO_3. Thus, the conclusion drawn from this data is Avocets require alkaline waters but it is negligible whether it is bicarbonate or carbonate alkalinity.

Similarly to Alki Lake, DO concentrations could not be detected, due to the many interferences in the water. There are high levels of dissolved ionic phosphorus. Orthophosphate and NH_3-N values for East Pond were similar to values found in non-Avocet sites. Overall, East Pond was low in nutrients.

5.5 Chichester Pond

All water chemistry readings are highly variable in the area because the inflow to Chichester Pond is a storm drain runoff. Variable concentrations are dependent upon heavy rainfall and possible contaminants from the surrounding subdivision (Dreger - personal communication, 1999). This is exemplified in the conductivity and TDS results. In June Chichester had the lowest conductivity levels of all sites but in July conductivity rose higher than all non-Avocet sites. The same rise was visible in TDS, since TDS is connected to conductivity (see Appendix C). Chichester was classified as dilute subsaline in June but because of rising levels of TDS, it was classified as hyposaline in July (see Appendix C).

The concentrations of dissolved metals are very low in comparison to the other sites where avocets forage. However, dissolved metals tested were within normal parameter ranges (EPD, 1995; CCEM, 1996). These readings are not consistent with the other sites where Avocets are found. The water chemistry of Chichester resembles the areas where Avocets don't forage more than where they do. Chichester registered low levels of potassium, sodium and sulphates in comparison to all Avocet sites.

The alkalinity was due entirely to bicarbonate concentration. Chichester Pond is the least alkaline of all places where Avocets are found.

Dissolved oxygen levels are extremely high in comparison to the sites Avocets forage. Aeration from storm drain runoff causes increased DO levels (Lee - personal communication, 1999). Chichester registered high levels of the nutrient NO3-N. The high nitrogen values can be associated with abundant vegetation in the area, since nitrate is needed to for assimilation by algae (Wetzel, 1983).

5.6 West LWL – Non-Avocet Site

West LWL was tested because the Avocets were found in high density at the East LWL but not here. West LWL was extremely low in all dissolved metals that do not contribute significantly to salinity (Appendix C). This site had virtually no sulphate concentration, which is different from all other sites (except East LWL). It had very low calcium and magnesium readings in comparison to other places where Avocets do not inhabit. Despite low specific dissolved metal values, the conductivity and TDS levels are high enough to resemble Chichester Pond. West LWL is classified hyposaline (see Appendix C) with predominant ions being potassium and sodium.

It had alkalinity levels similar to Avocet inhabited sites, mostly composed of CO_3 alkalinity.

This site had very similar levels of NH_3-N to the other sites where Avocets are not found. The similarities in water chemistry between West LWL and East LWL demonstrate that the water chemistry here does not influence Avocet presence or absence.

5.7 West Pond – Non-Avocet Site

West Pond was low in all dissolved metals that do not significantly contribute to salinity (Appendix C). In fact, it was one of the lowest readings of all the sites sampled. Concentrations of calcium, sodium, and potassium were extremely low and there were virtually no sulphate readings. This relates to the very low conductivity and TDS (Bartenhagan et. al., 1998). As such, West Pond is classified as a dilute subsaline pond (see Appendix C).

DO levels were similar to other areas where Avocets are not found. Virtually no NO_3-N levels were found, this is consistent with other non-Avocet sites.

5.8 Slough #2 - Non-Avocet Site

Slough #2 had highest levels of lithium of all sites, doubling that of Alki Lake indicating that lithium is not a deterrent or attractant to Avocets. It was the only non-Avocet sites that had readings of arsenic. Slough #2 had the highest reading of dissolved ionic sulphur of non-Avocet sites. Dissolved ionic sulphur readings of Slough #2 were more then double those of East Pond. There were minimal readings of dissolved ionic phosphorus, boron and aluminum, lowering the TDS levels that attract Avocets. Slough #2 had the second highest levels of calcium and magnesium of non-Avocet sites. However, the levels are still much lower than sites where Avocets do inhabit. Slough #2 was classified as hyposaline (see Appendix C) with major contributing ions being potassium, sodium and sulphate. Though conductivity values are high for non-Avocet sites, they are much lower than sites where Avocets breed.

Bicarbonate is the major species responsible for total alkalinity. Even though this type of alkalinity coincides with the type of alkalinity in Alki Lake, the value is lower than what Avocets prefer.

Slough #2's DO concentrations are characteristic of non-Avocet sites. Orthophosphate levels exceed the necessary amount to sustain aquatic life (CCEM, 1996) and are highest among non-Avocet inhabited sites. Water chemistry at Slough #2 is not consistent with Avocets breeding sites, therefore one possible reason they are not found here. Slough #2 had low nitrogen nutrient radicals for all sites.

5.9 Bubna Slough - Non-Avocet Site

Bubna Slough had similar lithium levels to Alki Lake. Low sodium, sulphate and potassium concentrations contribute to its low conductivity. Conductivity levels were approximately one fourth that of Alki Lake, Robert Lake and East Pond. Bubna Slough had a dilute subsaline classification (see Appendix C) mostly due to magnesium and calcium. This pond had low alkalinity almost entirely of the bicarbonate species.

Further support that, Avocets prefer low oxygenated water, can be seen in July when the DO levels were the highest of all sites. Nutrient levels of NO_3-N, NH_3-N and PO_4.ortho were low in relation to Avocet inhabited sites but similar to non-Avocet sites.

5.10 Simpson's Pond

Simpson's Pond (also referred to as Akland Rd. Pond) had the highest aluminum and iron recorded of non-Avocets site. Boron and dissolved ionic sulphur levels were similar to sites where Avocets are not found. Simpson's Pond held the lowest concentrations of all sites for potassium, sodium and sulphates, therefore conductivity was lowest of all sites tested. Classification of Simpson's Pond is dilute subsaline (see Appendix C) with calcium as the major contributor. Total alkalinity was lowest of all sites.

The DO levels were high. Nutrient levels were low in Simpson's Pond, similar to Bubna Slough. Low phosphorous levels are similar to other non-Avocet sites. Low conductivity, alkalinity and high DO concentrations are all reasons Avocets choose not to breed or forage here.

5.11 Glenmore Marsh

Glenmore Marsh is the proposed area for the replacement marsh of Alki Lake. Water levels when sampling occurred were not optimal. Low water levels caused the marsh to shrink to a puddle. The City of Kelowna contributed data from 1996 (Appendix D). Past data from 1996 show high conductivity (mean=10,233uS), just lower than Alki Lake readings. In 1996 high TDS and high total alkalinity (mean=4,046mg/L), very similar to Alki Lake June concentrations in 1999.

Current data shows that lithium levels resembled those of Alki Lake and Bubna Slough. Traces of arsenic were also detected, however they were half as much as Robert Lake and one fourth that of Alki Lake. Dissolved ionic phosphorus levels were highest amongst sites where Avocets do not inhabit but, the value was still not high as Alki Lake, East Pond or Robert Lake. Glenmore Marsh had similar low concentrations of iron, boron and aluminum to non-Avocet inhabited sites.

Concentrations of potassium, sodium and sulphates were much similar to places where Avocets do not inhabit but much lower than those where Avocets do inhabit. Despite high magnesium and calcium levels conductivity and TDS at Glenmore Marsh are significantly lower than places where Avocets inhabit, but similar to sites where they do not live. Total alkalinity was low in comparison to Avocet inhabited sites. These levels contradict 1996 data. However, the more accurate results to refer to would be at a time of high water level in 1996.

5.12 Final Conclusions

This paper has found that Avocets need highly alkaline waters to breed. Whether the alkalinity is derived from bicarbonate or carbonate sources is insignificant as long as the total alkalinity is high. In addition, waters with elevated levels of dissolved metals and thus high conductivity are most attractive to the Avocets. Therefore, Avocets prefer lake that are highly saline.

These results are similar to Mahoney and Jehl (1985) who documented that Avocets inhabit hypersaline lakes that were highly alkaline. Tulare Lake Drainage District (1999) proved promising results of American Avocet breeding when Compensation Habitats were created with saline waters or a mixture of freshwater and saline water (1999). Velasquez (1992) also found increases the salinity of a saltpan in South Africa increased Avocet foraging.

Recommendations for the new wetland would be to create a highly alkaline (over 4000mg/L), highly saline lake with high conductivity (12,000uS). If Glenmore Marsh can be engineered for these conditions it would make an ideal breeding habitat for the American Avocet.

Acknowledgements

I'd like to thank Les Gyug for guiding us on this project. I'd also like to express my gratitude towards Marcia Browne for always being there, Jason Weir for being so unaccommodating when we got stuck in the muck, and Ian Walker for all generous his help. Thanks are also awarded to Anne Gasoir for outside insight and Greg Lee for knowing *almost* everything. Thank you to Anna-Leena Lesnowski for filling my stomach and my mind with wonderful things. My parents for sending love and support across the country. My very good friends: Tiffany, Elicia, Danielle, Somardi, Mike, Michael, Tristan etc. for helping me keep my sanity in the long hours. I'd like to acknowledge my wonderful partner in crime Chrissy MacNeil, and thank her for taking the part that scared me the most. Finally, I'd like to thank Lisa Dreger for her immeasurable patience and assistance, I am forever indebted to you.

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Appendix A

Alkalinity Dilution Procedure

Range as $CaCO_3$	Volume of Sample	Multiplier	How to dilute	Where dilution was used
400-1000 mg/L	25ml	40	• Pipette 25ml of sample into a 50ml graduated cylinder. • Fill to 50ml graduation with deionized water. • Swirl	• Alkalinity test for Akland Rd. Pond, July 6, 1999 • Alkalinity test for Chichester Pond, July 6, 1999 • Alkalinity test for Glenmore Marsh, July 6, 1999
1000-2500 mg/L	10ml	100	• Pipette 10ml of sample into a 50ml graduated cylinder. • Fill to 50ml graduation with deionized water. • Swirl	• Alkalinity test for Slough #2, July 6, 1999 • Alkalinity test for Bubna Slough, July 6, 1999 • Alkalinity test for Robert Lake, July 6, 1999
2000-5000 mg/L	5ml	200	• Pipette 5ml of sample into a 50ml graduated cylinder. • Fill to 50ml graduation with deionized water. • Swirl	• Alkalinity test for Alki Lake, July 6, 1999

Appendix B

Radical Dilution Procedure

Volume of sample	Multiplication factor	How to dilute	Where this dilution was used
0.5 ml	200	• Pipette 1 ml of sample water into a 100ml round bottomed volumetric flask. • Fill the flask up to the etched line with deionized water. • From that dilution pipette 1 ml of diluted sample water into another 100ml round bottomed volumetric flask. • Fill the second flask up to the etched line with deionized water. • Invert several times • From this final dilution extract the needed amount for testing.	• Sulphate test for Robert Lake, July 6, 1999
1 ml	100	• Pipette 1ml of sample water into a 100ml round bottomed volumetric flask. • Fill up to the etched line with deionized water. • Invert several times • From this final dilution extract the needed amount for testing.	• Sulphate test for Alki Lake, July 6, 1999 • Sulphate test for Slough #2, July 6, 1999
5 ml	20	• Pipette 5ml of sample water into a 100ml round bottomed volumetric flask. • Fill up to the etched line with deionized water. • Invert several times • From this final dilution extract the needed	• Sulphate test for Chichester, July 6, 1999 • Sulphate test for Glenmore Marsh, July 6, 1999

		amount for testing.	
10 ml	10	• Pipette 10ml of sample water into a 100ml round bottomed volumetric flask. • Fill up to the etched line with deionized water. • Invert several times • From this final dilution extract the needed amount for testing.	• Phosphate test for Alki Lake, July 6, 1999 • Phosphate test for Robert Lake, July 6, 1999 • Ammonia test for Alki Lake, July 6, 1999 • Ammonia test for Robert Lake, July 6, 1999 • Nitrate test for Alki Lake, July 6, 1999 • Nitrate test for Robert Lake, July 6, 1999 • Sulphate test for Bubna Slough, July 6, 1999 • Sulphate test for Akland Rd. Pond, July 6,1999

Appendix C

Salnity

Lake/Time	Conductivity (uS)	Conversion Factor	TDS (mg/L)	Salinity Classificaion
Robert Lake-June	11,500	X 0.64	7360.0	Hyposaline
Robert Lake-July	14,300	X 0.64	9152.0	Hyposaline
East Pond-June	14,800	X 0.64	9472.0	Hyposaline
East LWL-June	8,650	X 0.64	5536.0	Hyposaline
Alki Lake-June	13,000	X 0.64	8320.0	Hyposaline
Alki Lake-July	14,000	X 0.64	8960.0	Hyposaline
Chichester Pond-June	885	X 0.64	566.4	Dilute subsaline
Chichester Pond-July	9,500	X 0.64	6080.0	Hyposaline
West Pond-June	2,750	X 0.64	1760.0	Dilute subsaline
West LWL-June	8,570	X 0.64	5484.8	Hyposaline
Slough#2-June	6,200	X 0.64	3968.0	Hyposaline
Slough#2-July	6,400	X 0.64	4096.0	Hyposaline
Glenmore Marsh-July	3,000	X 0.64	1920.0	Dilute subsaline
Bubna Slough-June	2,780	X 0.64	1779.2	Dilute subsaline
Bubna Slough-July	2,820	X 0.64	1804.8	Dilute subsaline
Simpson's Pond	1,000	X 0.64	640.0	Dilute subsaline

- Dilute subsaline: <3g/L TDS
- Hyposaline: 3-20g/L TDS
- Mesosaline: 20-50g/L TDS
- Hypersaline: >50g/L TDS

Bartenhagen et. al (1998) states ions that contribute to salinity are:

- carbonates
- chloride
- sulphates
- sodium
- magnesium
- calcium
- potassium

City of Kelowna
Glenmore Landfill 1995
Surface Water

Glenmore Marsh

Parameter / Units	Temp. C	pH Units	Color TCU	Turbidity NTU	Conductivity umhos/cm2	SO4 2- mg/L	Cl- mg/L	N-NO3 mg/L	N-NH3 mg/L	O-PO4(P) mg/L	Fe mg/L	Total Hardness as CaCO3 mg/L	Total Alkalinity as CaCO3 mg/L	Total Coliform CFU/100mL	Fecal Coliform CFU/100mL	Chemical Oxygen Demand Total
Date																
March 27/95	9	7.5	232	9	320	280	146	0	24	3.15		1113	1684	<2	<2	258
May 3-95	11	9.3	786	24	4900	250	356	0	10	4.57	0.61	1274	2962	0	0	583
Jun-13-95	20	8.7	1624	61	11000		614	5	55	5.62		1843	2440			1302
Jul-25-95	20	9.1	5320	164	15000	180	291		102	7.90		2540	8662	25	10	3100
Aug 23/95	25	9.5	5575	601	17000	104	1628	1	40	0.38		1692	7295	<5	<5	3610
Sep-27-95	13	8.9	4171	71	21000	169	1965	0.8	118	5.20		1944	8584	260	140	3320
Oct-25-95		8.5	3500	104	17000	132	1483		145	31.90				100	2	2480
Average	16	8.78	3030	147.7	12317	186	926	1.4	70.6	8.39	0.61	1734	5271	7	3	2093
Irrigation criteria		5.0-9.0			700-5000		100-700				5.00				** < 1000	
Livestock watering					1400-4200	1000		100.0							200 max	

** reported as geometric mean

(dotted shading) exceeds irrigation criteria

(hatched shading) exceeds livestock criteria

Measured Chemical Properties of Ponds and Wetlands sorted by Avocet Foraging Use with highest use at top.

							All concentrations in these columns are mg/l								
Pond	Date	Relative Avocet Foraging Level (0-10)	Water Depth(cm)	ph	Conductivity (uS)	Temp. (C)	OH alkalinity	CO3 alkalinity	HCO3 alkalinity	Total alkalinity	DO	NH3-N	PO4-ortho	NO3-N	SO4
Alki Lake	16-Jun	10	9	9.26	13,000	27	0	1344	2338	3682	0	2.72	1.407	1.0	3642
Alki Lake	6-Jul	10	5	9.12	14,000	16	0	1916	3426	5342	0?	4.25	1.76	1.0	4003
East Pond (LWL)	24-Jun	8	13	9.96	14,800	14	0	5084	336	5420	0?	0.83	0.135	1.2	880
East end Little White Lake	24-Jun	7	12	9.85	8,650	16	0	2670.4	406.4	3076.8	0.16	0.26	0.04	2.1	0.073
Robert Lake	16-Jun	6	10	9.40	11,500	35	0	644	579	1223	4.3	0.61	3.403	0.6	5880
Robert Lake	6-Jul	5	8	9.40	14,300	33	0	658	741	1399	1.7	1.97	3.61	0?	7740
Chichester Pond	16-Jun	4	15	8.17	885	15	0	0	470	470	9.2	0.2	0.143	4.3	52.08
Chichester Pond	6-Jul	3	18	8.13	9,500	15	0	0	374.8	374.8	9.46	0.19	0.13	4.2	834
Akland Rd. Pond	6-Jul	1	19	8.03	1,000	24	0	0	312	312	10.3	0.48	0.077	0.3	126.7
West end Little White Lake	24-Jun	1	15	9.88	8,570	15	0	2836	336	3172	N/A	0.64	0.083	1.5	0.465
Bubna Slough	16-Jun	0	75	8.72	2,780	22	0	40	642	682	13.8	0.28	0.039	0.2	331.6
Bubna Slough	6-Jul	0	30	8.39	2,820	21	0	30	731	761	7.76	0.45	0.199	0.1	349.7
West Pond (LWL)	24-Jun	0	15	9.54	2,750	15	0	480	696	1176	6.92	0.72	1.215	0?	4.163
Glenmore Marsh	6-Jul	0	8	7.96	3,000	16	0	0	1083.6	1083.6	4.86	0.89	0.531	0.1	832
Slough #2	16-Jun	0	100	9.00	6,200	26	0	186	689	875	8	0.48	2.21	0.48	2272
Slough #2	6-Jul	0	22	8.97	6,400	21	0	152	654	806	7.46	0.63	0.083	0.2	2395

N/A = Not Available

0? = below detection limit

Where Dissoled Oxygen is 0, it was felt that high concentrations of some solutes in water were interfering with the particular titration process used so that results are not necessarily accurate.

Surrey Ph (604) 514-3322 FAX (604) 514-3323
Edmonton Ph (403) 438-5522 FAX (403) 438-0396
Calgary Ph (403) 291-2022 FAX (403) 291-2021
Lethbridge Ph (403) 329-9266 FAX (403) 327-8527
Winnipeg Ph (204) 982-8630 FAX (204) 275-6019

Client Code: CITKET

Name: CITY OF KELOWNA TREATMENT PLT.	Workorder: **45448**
Address: 951 RAYMER AVE.	WO (Other):
	PO Num: 203617
KELOWNA	Project: Avocets
BC V1Y 4Z7	Date Sampled: Jun 24, 1999
Attn: Marianne Toma	Date Received: Jun 28, 1999
Phone: (250) 862-5510	Date Reported: Jul 05, 1999
Fax: (250) 862-9276	

Metal Analysis – Little White Lake Samples

	Detection Limit	Units	45448-1 5 East Pond	45448-2 6 West Pond	45448-3 4 WLWL West end LWL	45448-4 3 E... LWL East end
Dissolved Semi-Trace Metals Scan in Water						
Aluminum	0.008	mg/L	5.13	0.015	0.026	0.044
Antimony	0.005	mg/L	<0.005	<0.005	<0.005	<0.005
Arsenic	0.01	mg/L	<0.01	<0.01	<0.01	<0.01
Barium	0.0002	mg/L	0.0273	0.003	0.0014	0.0016
Beryllium	0.0005	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Bismuth	0.007	mg/L	0.03	<0.007	<0.007	<0.007
Boron	0.002	mg/L	0.029	<0.002	<0.002	<0.002
Cadmium	0.0005	mg/L	0.0009	<0.0005	<0.0005	<0.0005
Calcium	0.2	mg/L	8.5	2.51	2.22	1.97
Chromium	0.0008	mg/L	0.0068	<0.0008	<0.0008	<0.0008
Cobalt	0.0007	mg/L	0.0068	0.0026	0.0033	0.0037
Copper	0.001	mg/L	0.007	0.003	0.001	0.001
Iron	0.003	mg/L	7.28	0.007	0.038	0.079
Lead	0.002	mg/L	<0.002	<0.002	<0.002	<0.002
Lithium	0.001	mg/L	0.002	0.002	0.001	0.001
Magnesium	0.05	mg/L	22.5	46.8	56.6	56.2
Manganese	0.0002	mg/L	0.0906	0.0006	0.0018	0.0024
Molybdenum	0.001	mg/L	0.043	0.001	<0.001	<0.001
Nickel	0.001	mg/L	0.012	0.003	<0.001	<0.001
Phosphorus	0.03	mg/L	3.93	0.05	0.07	0.07
Potassium	0.4	mg/L	192	34.8	128	129
Selenium	0.004	mg/L	<0.004	<0.004	<0.004	<0.004
Silicon	0.004	mg/L	26.2	0.244	1.6	1.32
Silver	0.001	mg/L	<0.001	<0.001	<0.001	<0.001
Sodium	0.4	mg/L	4390	552	2180	2200
Strontium	0.0001	mg/L	0.0418	0.026	0.0044	0.0046
Sulphur	0.008	mg/L	196	22.8	26.1	26
Thallium	0.004	mg/L	<0.004	<0.004	<0.004	<0.004
Tin	0.003	mg/L	0.007	<0.003	<0.003	<0.003
Titanium	0.0004	mg/L	0.28	0.0005	0.0015	0.0027
Vanadium	0.001	mg/L	0.035	0.001	<0.001	<0.001
Zinc	0.0006	mg/L	0.0128	0.0008	<0.0006	<0.0006

Approved By: ____________________

John Davidson, Dipl. T., C.P.H.I. (C)

Supervisor, Inorganics Lab

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Surrey Ph (604) 514-3322 FAX (604) 514-3323
Edmonton Ph (403) 438-5522 FAX (403) 438-0396
Calgary Ph (403) 291-2022 FAX (403) 291-2021
Lethbridge Ph (403) 329-9266 FAX (403) 327-8527
Winnipeg Ph (204) 982-8630 FAX (204) 275-6019

Client Code: CITKET

Name: CITY OF KELOWNA TREATMENT PLT.	Workorder: **45697**
Address: 951 RAYMER AVE.	WO (Other):
	PO Num:
KELOWNA	Project:
BC V1Y 4Z7	Date Sampled: Jul 06, 1999
Attn: MARCIA BROWNE	Date Received: Jul 07, 1999
Phone: (250) 862-5510	Date Reported: Jul 12, 1999
Fax: (250) 862-9276	

Metal Analysis

	Detection Limit	Units	45697-1 Slough #2	45697-2 Alki Lake	45697-3 Robert Lake	45697-4 Chichester
Dissolved Semi-Trace Metals Scan in Water						
Aluminum	0.008	mg/L	0.069	2.34	1.11	0.098
Antimony	0.005	mg/L	<0.005	0.005	<0.005	<0.005
Arsenic	0.01	mg/L	<0.01	0.04	0.02	<0.01
Barium	0.0002	mg/L	0.0085	0.0734	0.084	0.0438
Beryllium	0.0005	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Bismuth	0.007	mg/L	<0.007	<0.007	<0.007	<0.007
Boron	0.002	mg/L	0.01	1.31	0.03	0.179
Cadmium	0.0005	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Calcium	0.2	mg/L	29.6	6.22	40.9	104
Chromium	0.0008	mg/L	<0.0008	0.0029	<0.0008	<0.0008
Cobalt	0.0007	mg/L	0.0034	0.0049	0.0044	0.0009
Copper	0.001	mg/L	<0.001	0.003	0.003	0.006
Iron	0.003	mg/L	0.027	1.53	0.615	0.035
Lead	0.002	mg/L	<0.002	<0.002	<0.002	<0.002
Lithium	0.001	mg/L	0.167	0.075	0.008	0.02
Magnesium	0.05	mg/L	146	273	185	57.7
Manganese	0.0002	mg/L	0.0168	0.0349	0.179	0.0182
Molybdenum	0.001	mg/L	<0.001	0.033	0.138	0.004
Nickel	0.001	mg/L	<0.001	0.022	0.008	<0.001
Phosphorus	0.03	mg/L	0.14	2.82	5.15	0.14
Potassium	0.4	mg/L	136	251	103	7.2
Selenium	0.004	mg/L	<0.004	<0.004	<0.004	<0.004
Silicon	0.004	mg/L	5.06	6.53	7.84	18.6
Silver	0.001	mg/L	<0.001	<0.001	<0.001	<0.001
Sodium	0.4	mg/L	1380	3650	3790	68.8
Strontium	0.0001	mg/L	0.637	0.955	3.78	0.744
Sulphur	0.008	mg/L	636	1020	2210	28.7
Thallium	0.004	mg/L	<0.004	<0.004	<0.004	<0.004
Tin	0.003	mg/L	0.005	0.006	<0.003	0.004
Titanium	0.0004	mg/L	<0.0004	0.0781	0.0396	<0.0004
Vanadium	0.001	mg/L	0.003	0.008	0.008	0.004
Zinc	0.0005	mg/L	0.0006	0.0041	0.0044	0.002

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Metal Analysis (con't.)

	Detection Limit	Units	45697-5 Glenmore Marsh	45697-6 Akland Rd.	45697-7 Bubna Slough
Dissolved Semi-Trace Metals Scan in Water					
Aluminum	0.008	mg/L	0.086	0.573	0.083
Antimony	0.005	mg/L	<0.005	<0.005	<0.005
Arsenic	0.01	mg/L	0.01	<0.01	<0.01
Barium	0.0002	mg/L	0.0818	0.067	0.0063
Beryllium	0.0005	mg/L	<0.0005	<0.0005	<0.0005
Bismuth	0.007	mg/L	<0.007	<0.007	<0.007
Boron	0.002	mg/L	0.057	0.02	0.018
Cadmium	0.0005	mg/L	<0.0005	<0.0005	<0.0005
Calcium	0.2	mg/L	89.8	139	47
Chromium	0.0008	mg/L	<0.0008	<0.0008	<0.0008
Cobalt	0.0007	mg/L	0.0031	0.0012	0.0019
Copper	0.001	mg/L	0.004	0.004	0.002
Iron	0.003	mg/L	0.029	0.535	0.009
Lead	0.002	mg/L	<0.002	<0.002	<0.002
Lithium	0.001	mg/L	0.066	0.01	0.083
Magnesium	0.05	mg/L	339	32.8	217
Manganese	0.0002	mg/L	0.0325	0.103	0.0044
Molybdenum	0.001	mg/L	0.047	0.013	<0.001
Nickel	0.001	mg/L	0.007	<0.001	<0.001
Phosphorus	0.03	mg/L	0.67	0.09	0.03
Potassium	0.4	mg/L	19.2	5.2	36.2
Selenium	0.004	mg/L	<0.004	<0.004	<0.004
Silicon	0.004	mg/L	9.43	14.6	13.9
Silver	0.001	mg/L	<0.001	0.001	0.002
Sodium	0.4	mg/L	321	54.3	359
Strontium	0.0001	mg/L	6.04	0.73	2.01
Sulphur	0.008	mg/L	307	59.7	116
Thallium	0.004	mg/L	<0.004	<0.004	<0.004
Tin	0.003	mg/L	0.004	0.005	0.004
Titanium	0.0004	mg/L	<0.0004	0.0309	<0.0004
Vanadium	0.001	mg/L	0.009	0.007	0.004
Zinc	0.0005	mg/L	0.0015	0.0008	<0.0005

Approved By: ______________________________

John Davidson, Dipl. T., C.P.H.I. (C)

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