Aquatic vegetation, salinity, aquatic invertebrates, and duck brood use at Bowdoin National Wildlife Refuge, Montana
by Kevin Mark Johnson

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University

Abstract:
Information on taxa, distribution, and abundance of aquatic vegetation, as well as aquatic invertebrates, is lacking for Bowdoin National Wildlife Refuge, Malta, Montana. Color infrared (CIR) aerial photographs of the refuge were taken in July of 1986. In summer, 1987, a cover map of aquatic vegetation on the 6294 hector refuge was produced and ground truthed. Salinity gradients and their relation to aquatic vegetation tolerances and distribution; shoreline terrestrial vegetation patterns; relative abundance, taxa, and distribution of aquatic invertebrates; and duck brood distributions were then determined during summer, 1988. CIR photos were effective in depicting features such as: shoreline, submergent and emergent vegetation, terrestrial vegetation communities, and salt crust on soil. Specific conductances on the refuge ranged from 540 to 11000 microsiemens per centimeter (uS/cm). Sago pondweed (Potamogeton pectinatus) was the most common submergent species found and hardstem bulrush (Scirnus acutus) the most common emergent species.

Conductivity appears to have some influence on aquatic vegetation and invertebrates. Chironomidae was the most abundant taxa of aquatic invertebrates collected. Species richness for both emergent and submergent plants decreased as conductivity increased. Abundance (#/m3) of invertebrates decreased as salinity increased and a slight negative linear relationship between invertebrate abundance and conductivity existed. High variability was found in invertebrate abundance within and between bodies of water with similar conductance and vegetative growth. Average soil conductivity and pH was highest in the. shrub/grassland and subirrigated/marsh communities and lowest in grasslands around Lake Bowdoin and Lakeside Unit. Terrestrial plant species present and their frequency of occurrence appears to be indicative of soil salinity which in turn is associated with lake water salinity. Occurrence of salt tolerant vegetative species decreased away from shoreline. Low duck production occurred on the refuge in 1988 due to drought conditions and only 81 broods were observed. Brood use was highest in areas of good invertebrate and macrophyte resources. Criteria used for future monitoring of salt accumulations and their effects on waterfowl brood habitat are discussed.

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APPROVAL

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Kevin Mark Johnson

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Information on taxa, distribution, and abundance of aquatic vegetation, as well as aquatic invertebrates, is lacking for Bowdoin National Wildlife Refuge, Malta, Montana. Color infrared (CIR) aerial photographs of the refuge were taken in July of 1986. In summer, 1987, a cover map of aquatic vegetation on the 6294 hector refuge was produced and ground truthed. Salinity gradients and their relation to aquatic vegetation tolerances and distribution; shoreline terrestrial vegetation patterns; relative abundance, taxa, and distribution of aquatic invertebrates; and duck brood distributions were then determined during summer, 1988. CIR photos were effective in depicting features such as: shoreline, submergent and emergent vegetation, terrestrial vegetation communities, and salt crust on soil. Specific conductances on the refuge ranged from 540 to 11000 microsiemens per centimeter (uS/cm). Sago pondweed (Potamogeton pectinatus) was the most common submergent species found and hardstem bulrush (Scirpus acutus) the most common emergent species. Conductivity appears to have some influence on aquatic vegetation and invertebrates. Chironomidae was the most abundant taxa of aquatic invertebrates collected. Species richness for both emergent and submergent plants decreased as conductivity increased. Abundance ($\#/m^3$) of invertebrates decreased as salinity increased and a slight negative linear relationship between invertebrate abundance and conductivity existed. High variability was found in invertebrate abundance within and between bodies of water with similar conductance and vegetative growth. Average soil conductivity and pH was highest in the shrub/grassland and subirrigated/marsh communities and lowest in grasslands around Lake Bowdoin and Lakeside Unit. Terrestrial plant species present and their frequency of occurrence appears to be indicative of soil salinity which in turn is associated with lake water salinity. Occurrence of salt tolerant vegetative species decreased away from shoreline. Low duck production occurred on the refuge in 1988 due to drought conditions and only 81 broods were observed. Brood use was highest in areas of good invertebrate and macrophyte resources. Criteria used for future monitoring of salt accumulations and their effects on waterfowl brood habitat are discussed.

INTRODUCTION

The national waterfowl refuge program was initially set up to restore, under existing land and land-use conditions, waterfowl breeding habitat and areas where migrating and wintering waterfowl could find food and rest (Salyer, 1945). Hence, northern refuges should be managed to adequately supply cover and a food base for both adult and juvenile waterfowl. Baseline data on taxa, distribution, and abundance of aquatic vegetation have not been available for Bowdoin National Wildlife Refuge (BNWR). Nor has the distribution and relative abundance of invertebrate organisms associated with the aquatic vegetation been documented.

BNWR has several lakes, all of which are closed drainage basins. Its climate is characterized by high evaporation and low precipitation. Because of this, refuge personnel are concerned with a potential salinity problem in the future. Thus, this study was initiated to provide baseline data relative to aquatic and terrestrial vegetation and aquatic invertebrate and duck brood distributions. Changes in wetland vegetation measured from baseline data may provide early indication of environmental contaminants in the wetlands. Information on waterfowl brood distribution may show which areas of the refuge should be targeted for management. Study objectives were:

1. Establish shoreline terrestrial and aquatic vegetation patterns.
2. Determine salinity gradients and relate these to vegetation tolerances and distribution.

3. Determine distribution, relative abundance and taxa of aquatic invertebrates.

4. Determine duck brood distribution in relation to 1, 2, and 3.

DESCRIPTION OF STUDY AREA

Bowdoin National Wildlife Refuge (BNWR) is located in northeast Montana (48° 24'N, 107° 40'W), approximately 11 kilometers (km) east of Malta, Phillips County (Fig. 1). Situated within the eastern glaciated plains of Montana, BNWR lies in the Central Flyway and is on the western fringe of the prairie pothole region. The refuge serves as a major resting area for waterfowl during spring and fall migrations, with up to 100,000 ducks and geese using its wetlands during fall. It also provides nesting habitat for Canada geese (Branta canadensis) and several species of ducks.

The 6294 hectare (ha) refuge was established in 1936 and is managed by the U.S. Fish and Wildlife Service. Its primary objective is to preserve resting, feeding, and nesting habitat for migratory birds. There are five main bodies of water on the refuge: 1) Lake Bowdoin, 1421 ha, 2.7 m deep; 2) Dry Lake, 769 ha, 0.9 m deep; 3) Drumbo Unit, 111 ha, 1 m deep; 4) Lakeside Unit, 100 ha, 3 m deep; and 5) Lakeside Extension, 32 ha, 4.6 m deep (Fig. 1). There is also a series of man-made ponds located throughout the refuge. These are linked through a system of canals which permits management for optimal water levels.

Lake Bowdoin is a remnant horseshoe bend of the ancestral Missouri River channel which originally flowed north to Hudson Bay. Ice sheets from the last glacial activity forced the river from this northerly channel to its present location 80 km south (G. Sipe, pers. commun.).

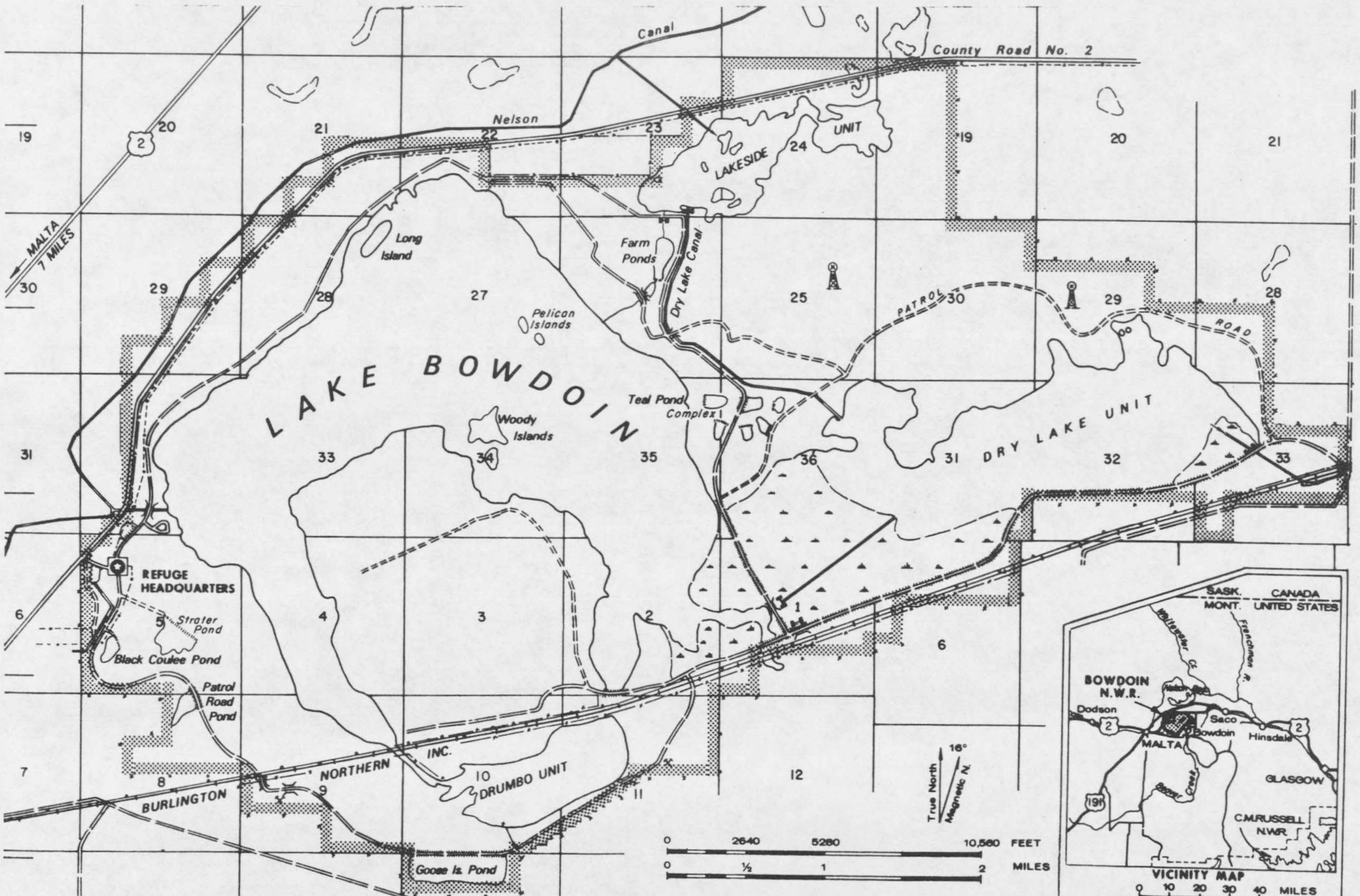

Fig. 1. Study area, Bowdoin National Wildlife Refuge, Phillips Co., Montana.

Water for the refuge wetlands comes from two primary sources: spring runoff and the Bureau of Reclamation's Milk River System. The Milk River drains the eastern slopes of the Montana and Alberta Rockies. The refuge receives a water right of 3500 acre-feet annually from this system which, combined with spring runoff, is usually sufficient to maintain acceptable water levels.

Physiography of the refuge and surrounding area is gently rolling to flat with elevations ranging from 672 to 701 m above sea level. There are also low lying areas of poor underground drainage where sodium, calcium, magnesium, and potassium salt accumulations are common on the soil surfaces.

Six range sites have been described for BNWR (U.S. Dept. of Agriculture 1966). They are: saline subirrigated, overflow, silty, thin silty, panspots, and dense clay.

Climate for BNWR is typical of the 25.4 - 35.6 cm precipitation zone of Montana's eastern glaciated plains (U.S. Dept. of Agriculture 1966). Average precipitation at Malta is 32.3 cm with 80% of this falling between April 1 and September 30. Drought conditions occurred during this study in 1988 and total precipitation for the April-September growing season was 19.2 cm.

Snow cover is highly variable from year to year, and is frequently removed by chinook winds during late December and January. Wind is more prevelant during spring, with average velocities greater than 32 km/hr 15% of the time. Speeds of 80 km/hr or greater often accompany a weather system as it passes through the area.

Cold winters and warm summers are typical with temperature extremes of -49° to 47° C (U.S. Dept. of Agriculture 1966). Long-term July and January averages are 19.2° and -10.4° C respectively. Average July temperature in 1988 was 21.7° C. The average frost free period is 131 days. Lake Bowdoin generally becomes ice-free in mid-April.

Vegetation of the area is primarily a short-grass prairie community, however two other communities, subirrigated/marsh and shrub/grassland can also be distinguished (Fig. 2). Well-drained upland sites are dominated by clubmoss (*Selaginella densa*). Dominant species of the grassland are needleandthread (*Stipa comata*), western wheatgrass (*Agropyron smithii*), blue grama (*Bouteloua gracilis*), prairie junegrass (*Koeleria pyramidata*), and inland saltgrass (*Disticlis stricta*). Fringed sagebrush (*Artemisia frigida*) is the dominant shrub. Other important species include plains prickly pear (*Opuntia polycantha*), prairie coneflower (*Ratibida columnaris*), cudweed sagewort (*Artemisia ludoviciana*), western yarrow (*Achillea millefolium*), and scarlet globemallow (*Sphaeralcea coccinea*). In the more moist grassland sites, milkweed (*Asclepias* spp.), sow thistle (*Sonchus arvensis*), and Canadian thistle (*Cirsium arvense*) are common.

Shrub/grassland areas are predominantly greasewood (*Sarcobatus vermiculatus*), western wheatgrass, inland saltgrass, aster (*Aster* spp.), foxtail barley (*Hordeum jubatum*), and curlycup gumweed (*Grindelia spuarrosa*).

Saltbush (*Atriplex patula*), summmercypress (*Kochia scoparia*), prickly lettuce (*Lactuca serriola*), salt wort (*Salicornia rubra*),

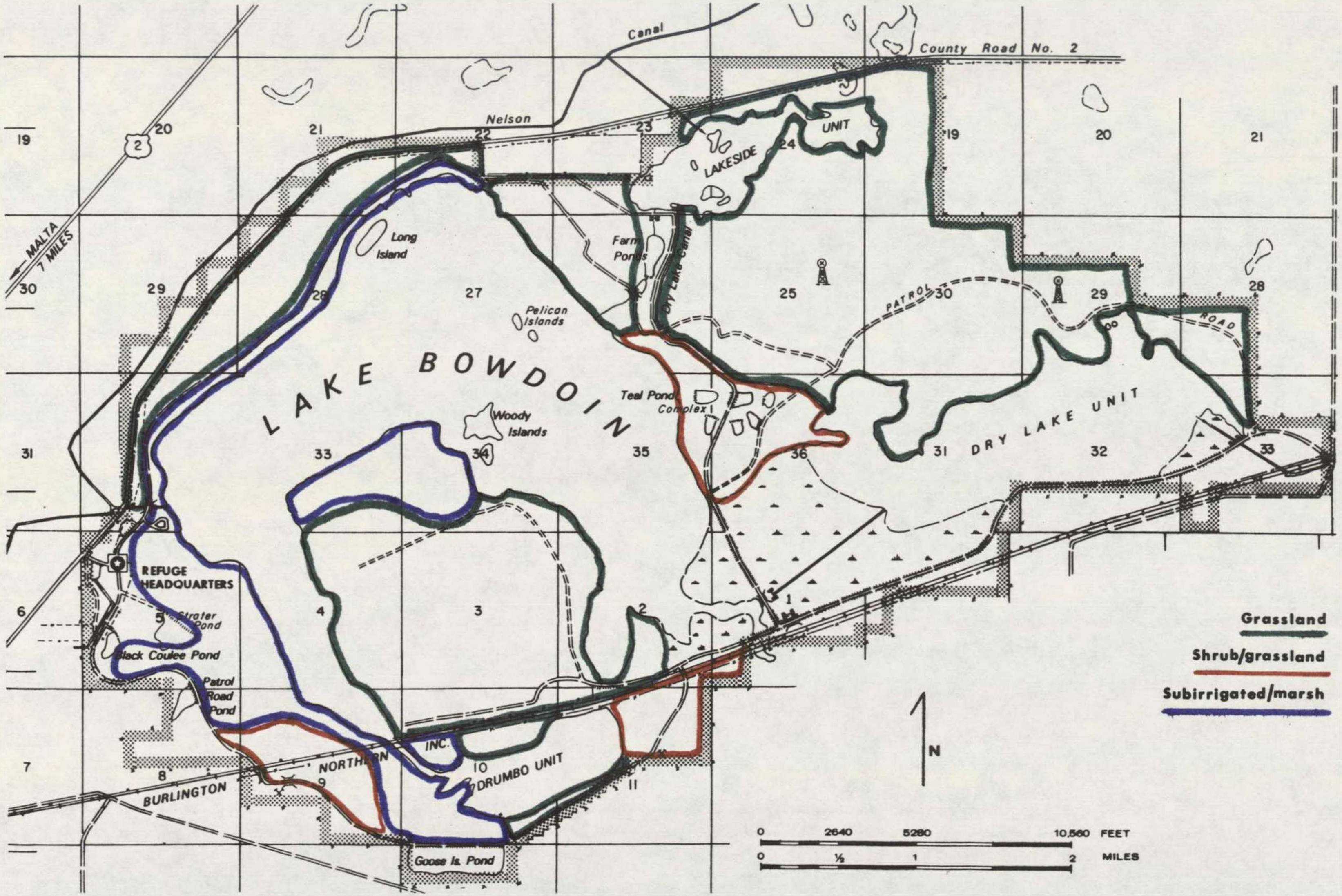

Fig. 2. Locations of terrestrial plant communities on BNWR, Montana.

aster, and foxtail barley can readily be found in the subirrigated/marsh communities. Along the lake shores, alkali bulrush (Scirpus paludosus), hardstem bulrush (Scirpus acutus), and common three square (Scirpus americanus) are abundant.

The more common aquatic emergent plants are hardstem bulrush, alkali bulrush, and broadleaf cattail (Typha latifolia). Submergents include sago pondweed (Potamogeton pectinatus), northern watermilfoil (Myriophyllum exalbescens), and widgeongrass (Ruppia maritima). Appendix Table 17 lists all aquatic species found on the refuge in 1988.

Most of the trees on the refuge are exotics introduced in the 1930's and 1940's. Some of the species planted were Russian olive (Elaeagnus angustifolia), Siberian pea (Caragana arborescens), chokecherry (Prunus virginiana), plains cottonwood (Populus deltoides), and buffaloberry (Shepherdia canadensis).

A complete list of vertebrate fauna observed on BNWR during the course of this study is included in Appendix Table 18.

METHODS

Aquatic Vegetation Patterns

Aerial Photography

Small scale (1:32000) color infrared (CIR) aerial photographs were taken of the entire refuge for gross delineation of submerged and emerged aquatic vegetation in July, 1986. Vertical images were taken from a Cessna model 150 single engine high wing aircraft at an altitude of about 2900 m. Flight lines were oriented along east-west section lines. A Hasselblad EL-M500, 70mm format camera with a 50mm lens was used and photographs were recorded on Kodak Aerochrome 2443 CIR film. Large scale (1:2000) CIR photos were also taken of selected areas along Lake Bowdoin's east and west shores to examine the potential for more detailed vegetational analysis from photos (Fig. 3).

Cover Map

Transects (21 m long) BW-3, 4, 8, and LU-1 were established in July, 1987 (Fig. 4). Aquatic vegetation species were collected every 3 m and identified from these transects. Using the aerial photographs, results from these transects were extended to produce a cover map of the entire area.

The following methods employed in cover map construction are similar to those described by Long (1986).

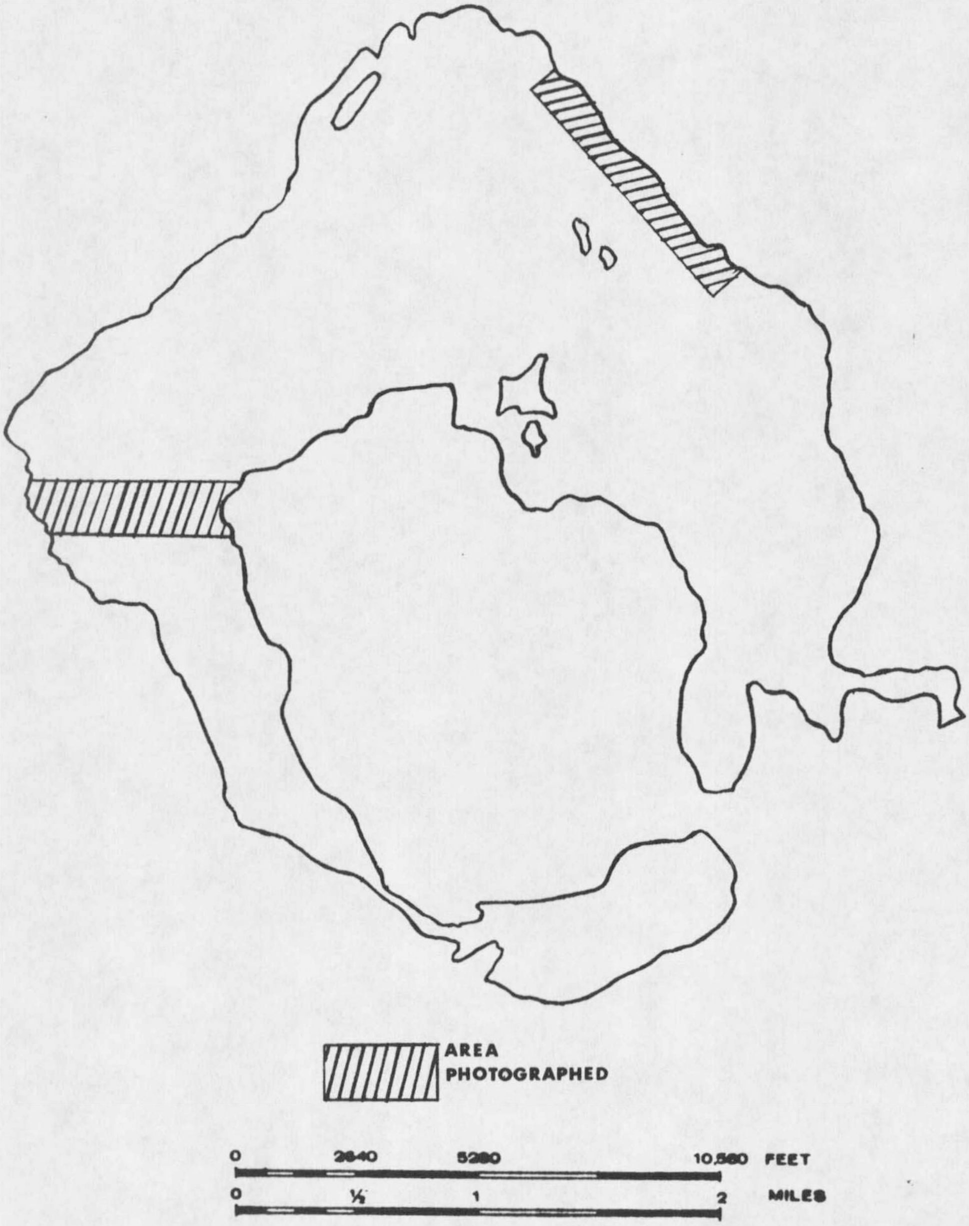

Fig. 3. Selected areas of Lake Bowdoin (BNWR) where large scale (1:2000) color infrared imagery was taken.

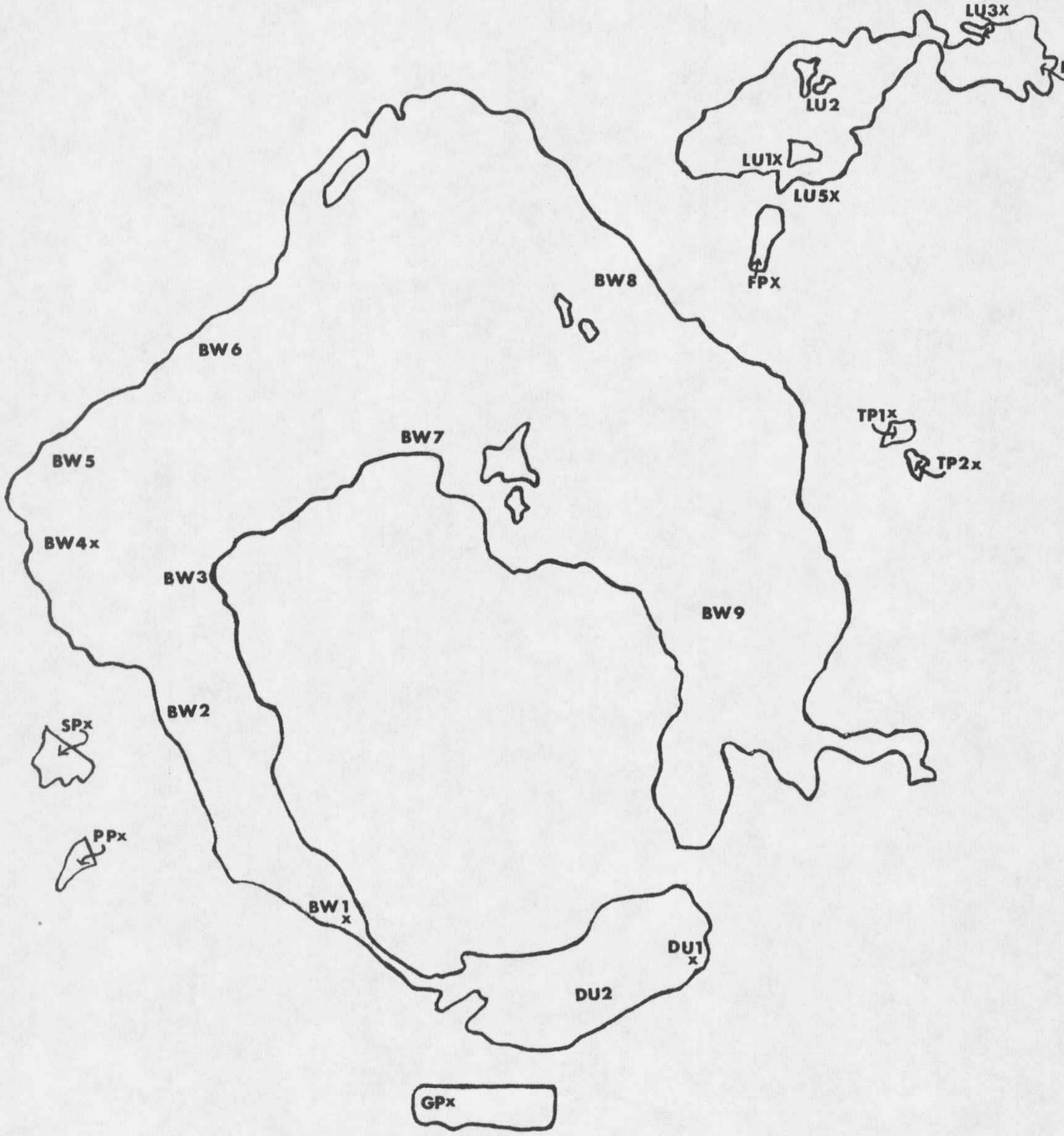

Fig. 4. Locations of aquatic transects established on BNWR. X denotes a transect surveyed for duck brood use in 1988.

Because the 1:32000 scale was too small to map aquatic vegetation and shorelines directly from photographs, a Measuronics System I Linear Measuring set (video image analyzer) was used to project each photograph, a 70mm transparency, to a scale of 1:7920. The projected image was traced onto a white piece of paper, each piece representing a single section (1 mile sq.). This was done for each section within the refuge.

Resolution was lost when the original image was enlarged and only general outlines of aquatic vegetation and shorelines could be mapped. Therefore, each photograph was viewed on a light table using stereo lenses and/or a Bausch and Lomb monocular magnifier and detail was then drawn into the general outlines. Roads and man-made structures were also mapped using this process.

Three classes of aquatic vegetation, emergent, submergent, and complex (interspersed emergent and submergent), were mapped and their densities recorded, i.e., scattered and dense. An airphoto interpretation key (Lillesand and Kiefer 1979) was used to aid in separating the classes from each other and from the shorelines. Determination of where dense vegetative growth ended and scattered began was a judgment call and is therefore ambiguous. Their dividing lines are not meant to show exact boundaries between the 2 but give an approximation of where dense growth begins to disperse and vice versa.

After detail had been transferred to individual section maps, one large base map was constructed by tracing the information onto a mylar sheet. This base map, too large to be of practical use, was divided into three: Lakeside Unit, Lakeside Extension, and the upper half of

Lake Bowdoin; Drumbo Unit and the lower half of Lake Bowdoin; and Dry Lake Unit. The maps and CIR photographs are on file at BNWR.

Aquatic Transects

Aquatic transects, 21 m in length, were established in June, 1988 (Fig. 4). Transects BW-1, 4, PP, SP, GP, DU-1, TP-1, 2, FP, and LU-1, 3, and 5 were placed in areas considered to be good brood rearing habitat (Lokemoen 1973 and Patterson 1976). All other transects were established in selected areas to sample different aquatic habitats.

In late July and early August aquatic vegetation species along each transect were identified. Many submergent species could not be identified until this time when seeds appeared. Water depths were recorded every 3 m, providing an average transect depth. A Beckman RB 3 portable battery operated solu bridge was used in July, 1988 to record specific conductivity at each transect. Because salinity is defined by concentrations of dissolved solids, which is measured by specific conductance (Hem 1970), these 3 terms will be used synonymously.

Aquatic Invertebrates

Aquatic invertebrates were sampled using a 'D' shaped sweep net with 1 mm mesh and an opening of 265 cm^2. Two samples per transect, one on each end, were collected mid-July during early morning (0530-1130) or evening (1800-2100) hours since both Chura (1963) and Sugden (1973) reported diurnal feeding patterns in ducklings. Each sample consisted of six sweeps (3 back and 3 forth) through 1.5 m of water to sample a volume of 0.04 m^3. Ducklings feed at water depths of 17-46 cm (Sugden 1973). Therefore, the net's center was held roughly at a depth of 25 cm which allowed sampling of a zone between 10 and 40 cm deep. In shallower water the bottom of the net was allowed to ride along the substrate.

Organisms were stored in a 60% solution of ethyl alcohol. Samples were later washed with water and invertebrates separated from plant material. Although a tedious and time consuming process, Krull (1970) pointed out "...it was the only method that furnished useful data." Aquatic organisms were keyed to family level and counted. Nomenclature follows that of Roemhild (1986) for insects and Pennak (1978) for other invertebrates. Because animals less than 1 mm in size could pass through the net they were not counted, however their presence in a sample was noted. Samples are stored at refuge headquarters for future reference.

Terrestrial Vegetation Patterns

Plant Communities

Ground surveys and CIR photos were used to identify major differences in shoreline terrestrial plant communities. Thirty-two sites around Lake Bowdoin, Lakeside Unit, Lakeside Extension, and Drumbo Unit were selected (Fig. 5).

Percent frequency of occurrence of plant species was estimated at each site using a modification of the plot frame method described by Daubenmire (1959). Starting at high water mark, using a compass and

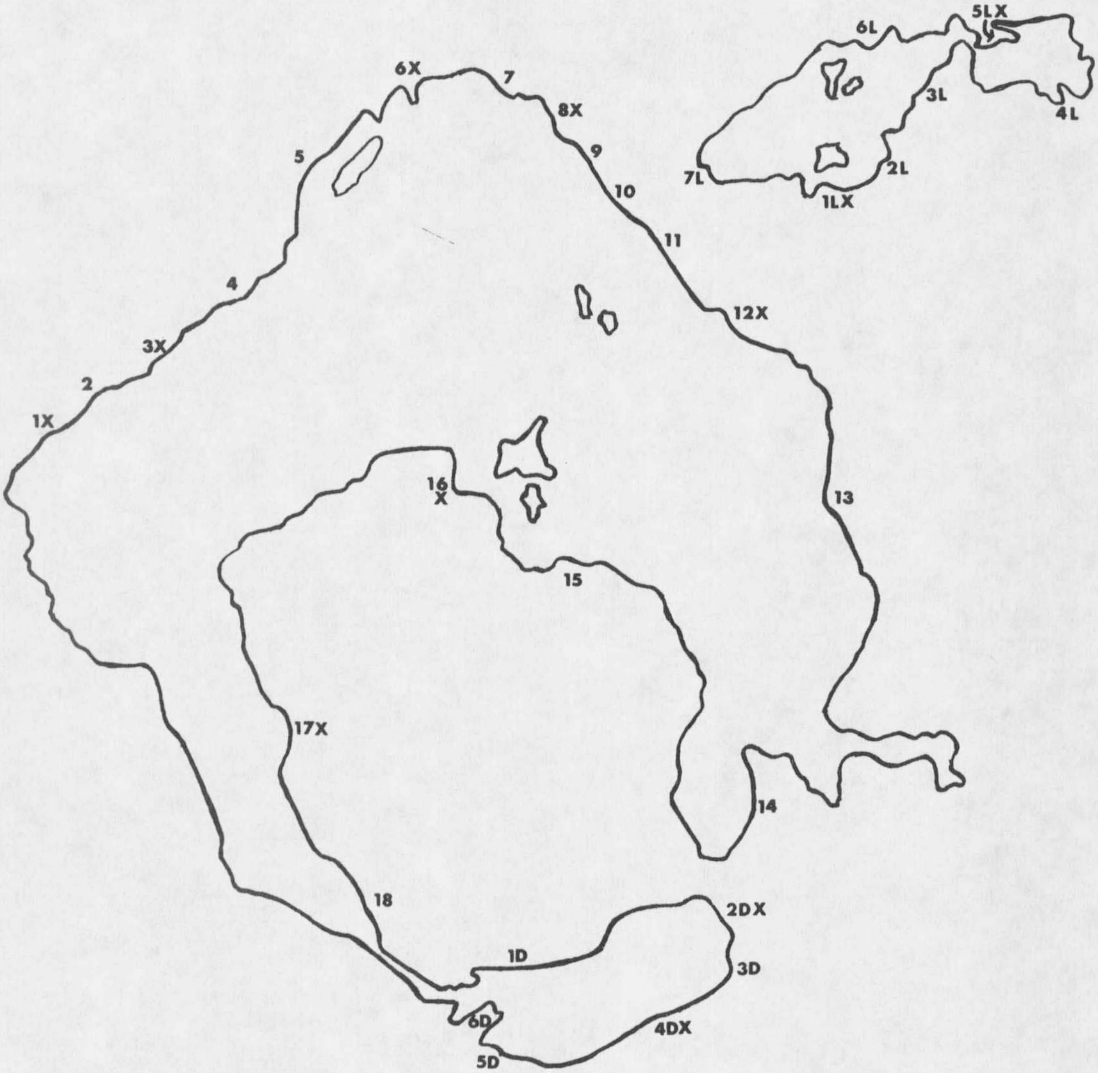

Fig. 5. Locations of shoreline terrestrial transects established on BNWR, Montana, 1988. X denotes location of soil sample.

refuge map, a transect 40 m long was extended perpendicular to shoreline. A second transect of equal length ran perpendicular to the first forming a 'T'. Forty 2 x 5 dm plots, spaced one plot diameter apart, were placed along each transect. Percent frequency for each plant species was determined within each plot. Data from both transects were combined to give a description of the community surrounding each site. Bare ground/rock, lichens, and litter were also recorded.

To determine any change in plant species composition away from the shore, transects perpendicular to shoreline were divided into 4, 10-plot segments. The average percent frequency of occurrence for plant species was calculated for each segment.

Transects were set up in late July but were not "read" until mid-August. This was to allow for the recovery of any plants inadvertently trampled during transect construction. All plant species encountered are listed in Appendix Table 19.

Soil Salinity

Twelve sites surveyed for terrestrial plant species were also sampled for soil pH and electrical conductivity (EC) (Fig. 5). Soil collections were made 20 m from shore, at depths of 30 and 60 cm. Samples were stored in plastic bags and allowed to air dry. Soil pH and EC were then taken from a 2:1 saturation extract (40 ml distilled water/20 gm dry soil mixture) (U.S. Salinity Lab. 1954). This mixture was shaken for 3 minutes and allowed to settle 30 minutes. Settled water was drawn off and provided pH and EC. Three mixtures were made for each depth at every site.

Duck Brood Distribution

Transects set up to sample brood habitats were monitored for duck brood use in 1988. Brood surveys were conducted from late June through August. Each transect was monitored for 20 minutes every 2 days.

A survey "run" would consist of starting at BW-4 at 0600 hours and continue on to SP, PP, BW-1, GP, DU-1, TP-2, TP-1, FP, LU-1, 5, and 3. That evening beginning at 1830 hours, transects BW-4, SP, PP, BW-1, GP, and DU-1 would be monitored. Two days later this sequence would be reversed. Broods were characterized by species, number of ducklings, and age class from plumage characteristics (Gollop and Marshall 1954).

Duck broods were observed with the aid of Bushnell 7 x 50 and/or 7-21 x 35 binoculars. Most transects could be observed from the refuge's patrol road while standing in the box of a pickup truck. Three transects, FP, SP, and LU-3 required short drives off patrol road; every effort was made to not disturb the broods.

Statistical Analyses

All statistical analyses were performed using the MSUSTAT package (1987 microcomputer version 4.00 MS-DOS) developed by Dr. Richard Lund, Montana State University, Bozeman, MT 59717. Two-tailed t-tests, one-way analysis of variance (ANOVA), multifactor ANOVA, and linear regression (Snedecor and Cochran 1980) were used to analyze soil salinity and aquatic invertebrate data. Numbers of aquatic invertebrates were transformed by taking their natural log, thus, producing a normal distribution. A level of 0.05 was used in all analysis to determine significance.

RESULTS

Aquatic Vegetation Patterns

Cover Map

Color infrared aerial photographs were very effective in depicting physiographic features of BNWR. Refuge features that could be identified on CIR photographs included: 1) shoreline, 2) submergent vegetation, 3) emergent vegetation, 4) different terrestrial vegetation communities, and 5) salt crust on soil.

Shoreline. Water color varied from dark blue/black (deep, >1 m, waters) to very light blue (shallow, <.5 m, and turbid waters). Terrestrial coloration was dull green/gray (shrubs and grass) to red (trees and lush shoreline vegetation within the subirrigated/marsh community type). Distinct color differences permitted accurate shoreline delineation. The only exception was the west shoreline of Lake Bowdoin south of the refuge headquarters and north of the railroad (Fig. 1). This area is a wetland type and demarcation of shoreline was very indistinct.

Submergent Vegetation. Submergent vegetation was easily recognized in shallower waters (1 m or less) due to its darker color. In deeper waters (up to 2 m) care had to be taken to prevent confusing dark coloration of deep water with that of submergents. In waters deeper than 2 m it was difficult, if not impossible, to identify submergents. This was particularly evident on Lakeside and Lakeside Extension (Fig. 1). Species composition of submergents could not be made from the CIR photos at any depth.

Emergent Vegetation. Emergent vegetation found in refuge wetlands and lakes included: hardstem bulrush, broadleaf cattail, alkali bulrush, water smartweed (*Polygonum amphibium*), marsh smartweed (*Polygonum coccineum*), and common reed (*Phragmites australis*). All species, except smartweeds and common reed, were readily identifiable on the CIR photos. Smartweeds and common reed occurred in few places and then only in modest densities making them difficult to detect in photos. Hardstem bulrush showed up as dull green either in open water or along shore. Alkali bulrush appeared pink and occurred in shallow open water, along shore, or spread throughout wetlands such as those found along the southwest arm of Lake Bowdoin. Broadleaf cattail appeared dark red and was found in habitats similar to those occupied by hardstem bulrush.

Where the two occurred together, stereo lens were needed to distinguish hardstem bulrush from dead, nonphotosynthesizing, algae due to spectral similarities. This was difficult at times and "ground truthing" was necessary to permit confidence in classification. Actively photosynthesizing algae also appeared on the photos but its spectral pattern was "hot pink" and could readily be distinguished from macrophytes.

Terrestrial Vegetation. Differences in terrestrial plant communities were detectable on CIR photos through changes in color and texture. Subirrigated/marsh communities were more easily distinguished from shrub and grassland types than shrub was from grassland communities. On-site visitation was needed to accurately distinguish between these two communities.

Salt Crust. Salt crust appeared in the CIR photos as white patches along shoreline or in low lying areas. Salt crusts were prominent on the northernmost shore of Lake Bowdoin, east shore of Drumbo Unit, west shore of Dry Lake, and throughout the wetland area of Lake Bowdoin's southwest arm.

Aquatic Transects

Water Salinity

Specific conductance of the various bodies of water throughout the refuge ranged from 540 microsiemens per centimeter (uS/cm) at 25° C in Lakeside Unit to 11000 uS/cm in Lake Bowdoin. The following six categories of salinity (Stewart and Kantrud 1972) were used in describing the wetlands and lakes of BNWR: fresh (< 500 uS/cm), slightly brackish (500-2000 uS/cm), moderately brackish (2000-5000 uS/cm), brackish (5000-15000 uS/cm), subsaline (15000-45000 uS/cm), and saline (> 45000 uS/cm). Lakeside and Lakeside Extension were the freshest bodies of water, Lake Bowdoin and Drumbo Unit the most saline, and the various ponds fell somewhere in between. Only 3 of the 6 salinity categories were found on the refuge: slightly brackish, moderately brackish, and brackish (Table 1).

Table 1. Salinity categories and their specific conductance (uS/cm) ranges of BNWR's wetlands and the aquatic transects falling within each.

Slightly Brackish		Moderately Brackish		Brackish	
500-2000		2000-5000		5000-15000	
LU-1	(540)[a]	FP	(3000)	PP	(6000)
LU-2	(560)	TP-2	(3500)	DU-2	(8000)
LU-4	(700)	DU-1	(5000)	BW-3	(8000)
LU-3	(900)	BW-1	(5000)	BW-4	(8000)
LU-5	(950)	BW-2	(5000)	BW-6	(8000)
SP	(1000)			BW-7	(8000)
GP	(1400)			BW-8	(8000)
TP-1	(2000)			BW-9	(8000)
				BW-5	(11000)

[a] Specific conductance (uS/cm) recorded for corresponding transect in 1988.

Aquatic Macrophytes

Sago pondweed was the most abundant submergent found on the refuge, occurring in 17 out of 22 transects. Northern watermilfoil was the second most abundant, occurring in 10 transects. The least abundant were redhead-grass (Potamogeton perfoliatus), narrowleaf waterplantain (Alisma gramineum), muskgrass (Chara spp.), whitewater buttercup (Ranunculus aquatilis), coontail (Ceratophyllum demersum), and whorled watermilfoil (Myriophyllum verticillatum), each occurring in only one transect. Hardstem bulrush was the most abundant emergent and marsh smartweed the least observed.

Species richness for both emergents and submergents decreased as conductivity increased. All five species of emergents were present in slightly brackish waters (Table 2). Broadleaf cattail and both

Table 2. Aquatic macrophytes found along 8 transects in slightly brackish waters on BNWR. Transects listed from left to right in order of increasing conductivity.

Species	LU-1 D[a]	LU-2 D	LU-4 S	LU-3 S	LU-5 S	SP D	GP D	TP-1 D	Total[b]
Submergents									
Sago pondweed	X	X	X	X			X	X	6
Northern Watermilfoil	X	X				X	X	X	5
Widgeongrass	X								1
Threadleaf pondweed		X							1
Flatstem pondweed		X			X	X			3
Horned pondweed						X	X		2
Narrowleaf waterplantain		X							1
Redhead-grass		X					X		2
Muskgrass							X		1
Emergents									
Hardstem bulrush			X	X	X				3
Cattail		X				X	X	X	4
Alkali bulrush						X	X		2
Water smartweed			X		X				2
Marsh smartweed		X							1

[a] D=Densely covered, S=Sparsely covered. Transects which had greater than one half their length covered by a stand of submergents, by either one species or a combination of species, were considered densely covered

[b] Total number of transects species was found in

bulrushes were found in moderately brackish waters (Table 3) while only hardstem bulrush was found in brackish waters (Table 4). All species of submergents identified (except whorled watermilfoil) were present in slightly brackish waters (Table 2), the most abundant being sago pondweed and northern watermilfoil. Sago pondweed was also the most abundant in brackish waters. Six species of plants were collected in moderately brackish and 4 in brackish (Table 3 and 4). Sixteen of the 22 transects were densely covered with submergent macrophytes. Five transects within the slightly brackish category

Table 3. Aquatic macrophytes found along 5 transects in moderately brackish waters on BNWR. Transects listed from left to right in order of increasing conductivity.

Species	FP D[a]	TP-2 S	DU-1 S	BW-1 D	BW-2 S	Total[b]
Submergents						
Sago pondweed		X	X	X		3
Northern watermilfoil	X	X		X		3
Widgeongrass	X			X	X	3
Threadleaf pondweed				X		1
Flatstem pondweed				X		1
Whitewater buttercup	X					1
Whorled watermilfoil					X	1
Coontail	X					1
Emergents						
Hardstem bulrush	X	X		X	X	4
Cattail	X		X			2

[a] D=Densely covered, S=Sparsely covered. Refer to Table 2 for definition
[b] Total number of transects species was found in

(Table 2), 2 in the moderately brackish category (Table 3) and all 9 transects in brackish waters were densely covered (Table 4).

Sago pondweed was by far the dominant macrophyte, singularly densely covering 11 out of 16 possible transects (Table 5). Redhead-grass, muskgrass, whitewater buttercup, and whorled watermilfoil never occurred in large enough abundance to densely cover a transect.

Aquatic Invertebrates

Thirty-seven taxa of aquatic invertebrates were collected on the refuge (Appendix Table 20). Chironomidae (midges) were the most abundant comprising 31.9% of all individuals (N=36360). Talitridae (scuds) were 21.3%, Corixidae (water boatmen) 14.5%, Physidae (pouch

Table 4. Aquatic macrophytes found along 9 transects in brackish waters on BNWR. Transects listed from left to right in order of increasing conductivity.

Species	PP D[a]	DU-2 D	BW-3 D	BW-4 D	BW-6 D	BW-7 D	BW-8 D	BW-9 D	BW-5 D	**Total**[b]
Submergents										
Sago pondweed	X	X	X	X	X	X	X	X		**8**
Northern watermilfoil	X			X						**2**
Widgeongrass							X		X	**2**
Threadleaf pondweed			X				X			**2**
Emergents										
Hardstem bulrush	X		X	X						**3**

[a] D=Densely covered, S=Sparsely covered, refer to Table 2 for definition
[b] Total number of transects species was found in

Table 5. Number of times a submerged macrophyte species densely or sparsely covered an aquatic transect within different salinity categories on BNWR, Montana, 1988.

	SB[a]		MB		B		Totals	
Species	D[b]	S	D	S	D	S	D	S
Sago pondweed	3	3	1	2	7	1	11	6
Widgeongrass	1		2	1	2	2	5	3
Northern watermilfoil	2	3	1	2	1	1	4	6
Threadleaf pondweed	1		1		1	1	3	1
Flatstem pondweed	1	2		1			1	3
Horned pondweed	1	1					1	1
Others	2[c]	3[d]		1[e]				

[a] SB=Slightly brackish, MB=Moderately brackish, and B=Brackish
[b] D=densely and S=sparsely covered, refer to Table 2 for definition
[c] One narrowleaf waterplantain and 1 coontail
[d] One muskgrass, 1 whitewater buttercup, and 1 redhead-grass
[d] One whorled watermilfoil

snails) 10.0%, Coenagrionidae (damselflies) 6.4%, Planorbidae (orb snails) 6.1%, Caenidae (mayflies) 3.9%, Coleoptera larvae (beetles) 1.4%, Hydracorina (watermites) 1.4%, and all others 3.1%.

Total abundance ($\#/m^3$) of invertebrates per transect decreased with increasing salinity (Table 6). In slightly brackish water, an average of $60756/m^3$ per transect (n=8) were collected. This decreased to $45070/m^3$ in moderately brackish (n=5) and to $21956/m^3$ (n=9) in brackish water. Analysis of variance indicated these three groups of invertebrate abundance were significantly different (p=0.01). A slight negative linear relationship occurred between invertebrate abundance and conductivity (Fig. 6).

Table 6. Aquatic invertebrate taxa and their abundance (#/m^3) per salinity category on BNWR, Montana, 1988.

Taxa	SB[a]	MB	B	Total
Talitridae	107825	72825	12525	**193175**
Hydracarina	9450	900	2325	**12675**
Caenidae	34650	900	325	**35875**
Coenagrionidae	16075	17550	24300	**57925**
Corixidae	49750	39375	42925	**132050**
Chironomidae	138475	50350	100275	**290100**
Planorbidae	49925	4750	550	**55225**
Physidae	59900	27200	3550	**90650**
Coleoptera larva	4525	3975	4575	**13075**
All others[b]	15475	6525	6250	**28250**
Total	**486070**	**225350**	**197600**	

[a] SB=Slightly brackish, MB=Moderately brackish, and B=Brackish
[b] Includes: Nematoda; Oligochaeta; Hirudinea; Cladocera; Copepoda; Gammaridae; Baetidae; Aeshnidae; Libellulidae; Notonectidae; Phryganeidae; Leptoceridae; Polycentropodidae; Culicidae; Ceratopogonidae; Stratiomyidae; Tabanidae; Ephydridae; Muscidae; Lepidoptera; Lymnaeidae; Cicadellidae; Formicidae; Aphidae; and Unk. Ephemeroptera, Hemiptera, Tricoptera, and Diptera

Average abundance of invertebrates found in densely covered transects decreased in moderately brackish from slightly brackish and were lowest in brackish (Table 7). Analysis of variance showed some degree of variation of invertebrate numbers in densely covered transects between the different salinities ($p=0.01$). Abundance in slightly brackish were similar to those in moderately brackish, yet differed from those in brackish waters. Invertebrate abundance in sparsely covered, slightly and moderately brackish waters were not significantly different (p=0.51).

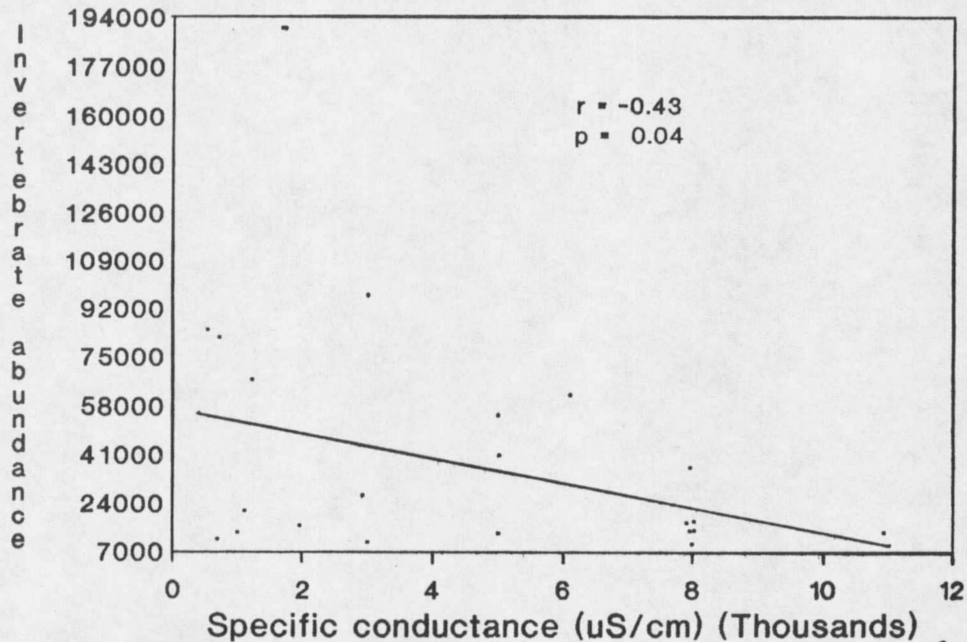

Fig. 6. Linear relationship between invertebrate abundance (#/m^3) and specific conductance from 22 aquatic transects, BNWR, Montana, 1988.

Average abundance of invertebrates in densely covered transects within slightly brackish waters was significantly larger (p=0.01) than in sparsely covered transects (Table 7). No significant relationship was found between densely and sparsely covered transects in moderately brackish waters (p=0.53).

Because invertebrate abundance was significantly different within the 3 salinity categories and the 2 vegetation densities, a multifactor ANOVA was performed to determine if salinity and plant densities were affecting invertebrate abundance simultaneously. The effect of salinity on invertebrates was independent of plant density and vice versa (p=0.47).

Table 7. Aquatic invertebrate taxa and their abundance (#/m^3) within densely and sparsely covered transects per salinity category on BNWR, Montana, 1988.

	SB		MB		B	Total	
Taxa	D[a]	S	D	S	D	D	S
Talitridae	107250	575	51650	21175	12525	**171425**	**21750**
Hydracarina	8875	575	425	475	2325	**11625**	**1050**
Caenidae	34625	25	875	25	325	**35825**	**50**
Coenagrionidae	15925	150	3750	14800	24300	**42975**	**14950**
Corixidae	34225	15525	6325	33050	42925	**83475**	**48575**
Chironomidae	120050	18425	8100	43250	100275	**228425**	**61675**
Planorbidae	49225	700	1250	3500	550	**51025**	**4200**
Physidae	59150	750	3300	23900	3550	**66000**	**24650**
Coleoptera larva	4100	425	1425	2550	4573	**10100**	**2975**
All others[c]	13425	2050	1675	4850	6250	**21350**	**6900**
Total	**446850**	**39200**	**77775**	**147575**	**147600**	**722225**	**186775**
	(5)[d]	(3)	(2)	(3)	(9)	(16)	(6)
$\bar{x}$	89370	13075	38900	49200	21950	45150	31125

[a] SB=Slightly brackish, MB=Moderately brackish, and B=Brackish
[b] D=Densely covered, S=Sparsely covered, refer to Table 2 for definition
[c] Refer to Table 6
[d] Number of transects per vegetation density class

Number of invertebrate taxa differed little between the 3 salinity categories. Thirty four taxa were collected in slightly brackish waters, 27 in moderately brackish waters, and 28 in brackish waters. An average of 16.3, 14.4, and 13.3 taxa per transect were found in slightly brackish, moderately brackish, and brackish waters respectively. This decrease in average number of taxa with increased salinity was not statistically significant. Average abundance of invertebrates was less in transects 0-30 cm deep ($26378/m^3$) compared to those in 31-60 cm ($51656/m^3$), but the difference was not statistically significant.

Terrestrial Vegetation Patterns

Community Types

Forty-five plant species were identified from the 31 transects in all terrestrial community types (grassland, shrub/grassland, and subirrigated/marsh) on the refuge. Twenty-seven species were recorded from 10 transects within the grasslands around Lake Bowdoin and Drumbo Unit (Bgrass) (Appendix Table 21) and 24 around Lakeside (Lgrass). Within the shrub/grassland around Lake Bowdoin and Drumbo Unit (S/G) 21 plant species were found and 18 were identified in subirrigated/marsh around Lake Bowdoin and Drumbo Unit (SIM).

Four plant species were common to all community types: inland saltgrass, western wheatgrass, *Aster* spp., and sow thistle. Of these, inland saltgrass occurred most often. Salt tolerant species such as inland saltgrass, foxtail barley, Nuttall alkaligrass (*Puccinella airoides*), saltwort, seablite (*Suaeda depressa* and *Suaeda moquinii*), greasewood, saltbush, seaside arrowgrass (*Triglochin maritima*), and alkali bulrush occurred mostly in the Bgrass, S/G, and SIM communities.

Six of the 8 most frequently occurring plants in SIM were salt tolerant (Fig. 7). Five were among the 8 most dominant in S/G (Fig. 8). Three salt tolerant species were among the most dominant in

Bgrass (Fig. 9) and inland saltgrass was the only real salt tolerant species present in Lgrass (Fig. 10).

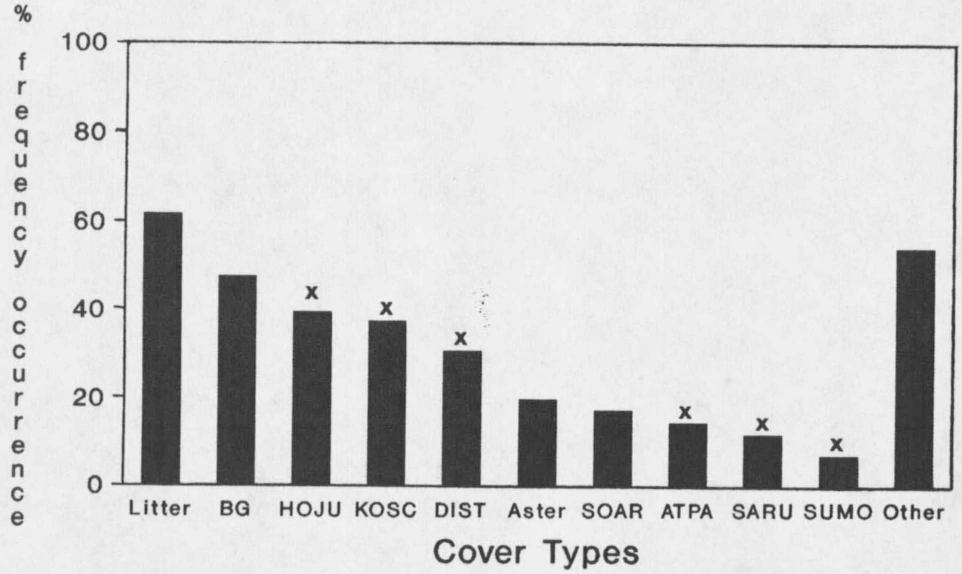

Fig. 7. Average frequency of occurrence for the most dominant cover types in subirrigated/marsh community. X denotes salt tolerant plants. Refer to Appendix Table 19 for key to plant names.

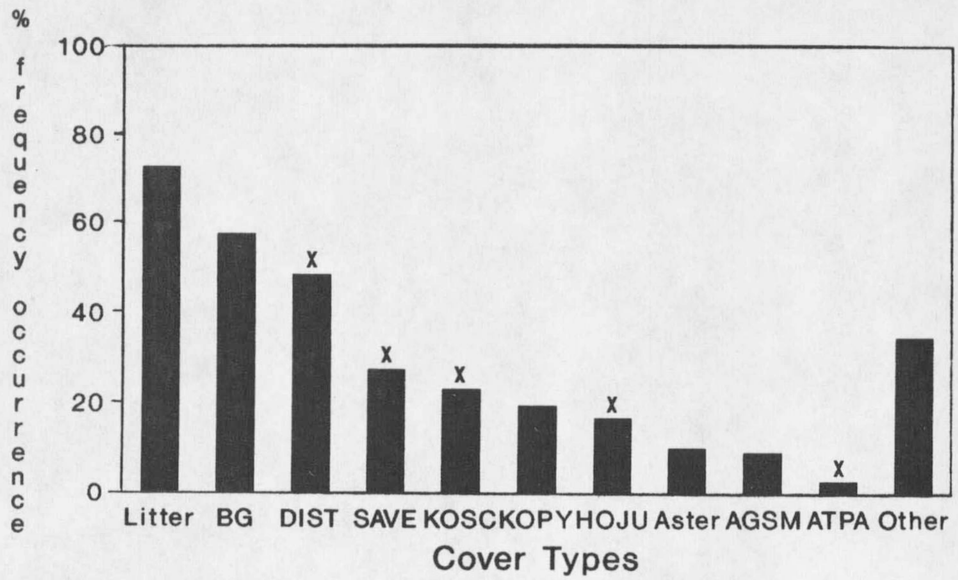

Fig. 8. Average frequency of occurrence for the most dominant cover types in shrub/grassland community. X denotes salt tolerant plants. Refer to Appendix Table 19 for key to plant names.

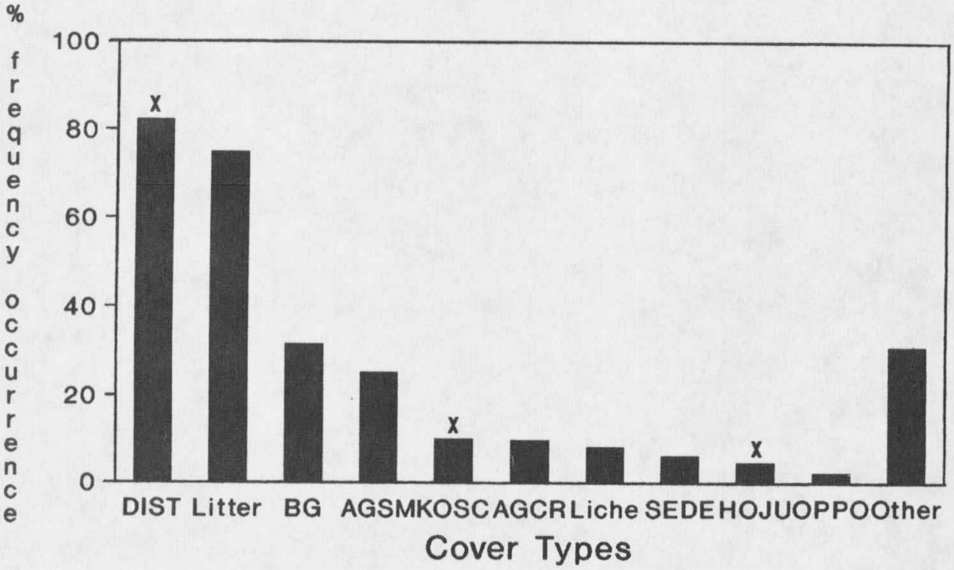

Fig. 9. Average frequency of occurrence for the most dominant cover types in Bowdoin grassland community. X denotes salt tolerant plants. Refer to Appendix Table 19 for key to plant names.

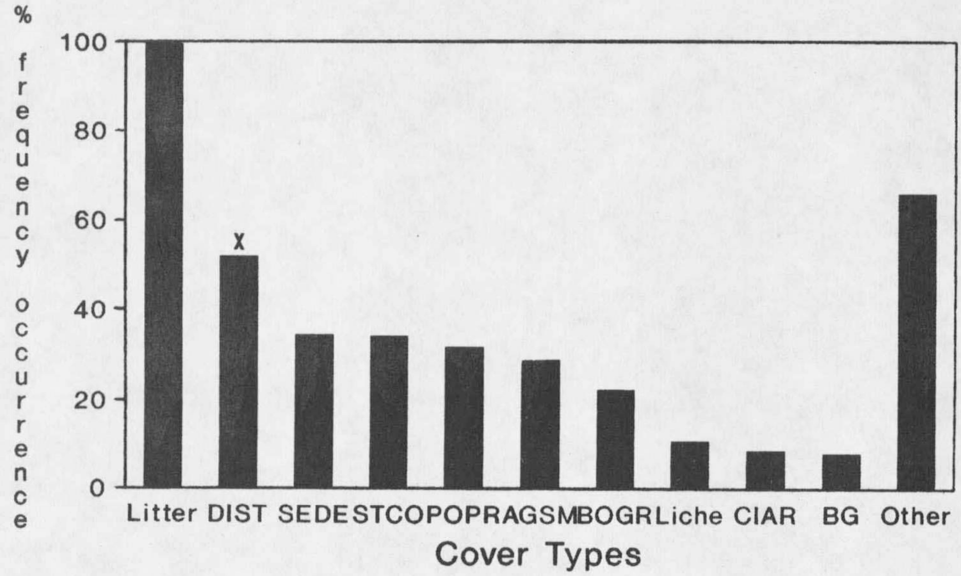

Fig. 10. Average frequency of occurrence for the most dominant cover types in Lakeside grassland community. X denotes salt tolerant plants. Refer to Appendix Table 19 for key to plant names.

Within SIM, all of the most dominant plants (species were considered dominant if they occurred in 50% or greater of all transects within each community) in the transects perpendicular to shore were salt tolerant (Table 8). Three of these (summercypress, saltbush, and saltwort) decreased in occurrence farther from shore while inland saltgrass and foxtail barley increased. Three of the 4 dominant species in S/G were salt tolerant (Table 9). Inland saltgrass and summercypress increased away from shore while greasewood changed very little. Two of the 3 dominants in Bgrass were salt tolerant (Table 10), inland saltgrass increased and summercypress decreased away from shore. In Lgrass only 1 out of 8 dominants, inland saltgrass, was salt tolerant and it decreased away from shore (Table 11).

Bare ground/rock decreased away from shore in all communities except Lgrass. Bare ground/rock was virtually nonexistent in the first 10 m around Lakeside. Communities SIM and S/G had the highest percent frequency for bare ground/rock 0-40 m from shoreline.

Eight plants in SIM were more frequent farther from shore, 5 closer to shore and 1, <u>Aster</u> spp., did not change (Table 8). Ten increased, 7 decreased, and 3 did not change in frequency occurrence farther from shore in S/G (Table 9). In Bgrass 11 increased, 13 decreased, and 1 stayed constant (Table 10). Nine increased, 11 decreased, and 3 did not change in Lgrass (Table 11).

Table 8. Average percent frequency of cover types at 0-10, 11-20, 21-30, and 31-40 m from shoreline in subirrigated/marsh community on BNWR, Montana, 1988. Refer to Appendix Table 19 for key to plant names. X denotes salt tolerant plants.

Cover Types	0-10	11-20	21-30	31-40
BG[a]	70.0	71.3	66.3	36.3
Litter	51.3	53.8	60.0	60.0
KOSC[x]	47.5	42.5	38.8	30.0
ATPA[x]	30.0	23.8	18.8	16.3
SARU[x]	15.0	11.3	8.8	11.3
DIST[x]	10.0	12.5	15.0	37.5
HOJU[x]	10.0	15.0	25.0	52.5
Aster	23.8	18.8	15.0	23.8
SCPA[x]	15.0			7.5
SUDE[x]	12.5	11.3	5.0	10.0
PUAI[x]	8.8	22.5	23.8	17.5
SOAR	6.3	8.8	12.5	20.0
SUMO[x]	1.3	1.3	10.0	15.0
TRMA[x]		2.5	6.3	6.3
SCAM				2.5
GRSQ				2.5

[a] BG=Bare ground

Table 9. Average percent frequency of cover types at 0-10, 11-20, 21-30, and 31-40 m from shoreline in shrub/grassland community type on BNWR, Montana, 1988. Refer to Appendix Table 19 for key to plant names. X denotes salt tolerant plants.

Cover Types	0-10	11-20	21-30	31-40
Litter	81.6	73.3	80.0	93.3
BG[a]	71.7	76.7	51.7	38.3
DIST[x]	38.3	20.0	41.7	56.7
SAVE[x]	23.3	21.7	30.0	23.3
KOPY	20.0	23.3	33.3	13.3
KOSC[x]	3.5	40.0	41.7	16.6
GRSQ	50.0			3.3
SARU[x]	16.7	16.7		
AGSM	16.7	1.7	3.3	16.7
HOJU[x]	10.0	8.3	25.0	21.7
SUMO[x]	8.3	11.7	3.3	
Aster	3.3		1.7	16.7
HEHO	3.3			
OPPO				3.3
Liche				3.3
ARFR				3.3
SOAR			1.7	6.7
Artem			6.7	5.0
SUDE[x]		3.3	1.7	
PUAI[x]			8.3	3.3
SCAM			6.7	1.7
ATPA[x]		1.7	13.3	5.0

[a] BG=Bare ground

Table 10. Average percent frequency of cover types at 0-10, 11-20, 21-30, and 31-40 m from shoreline in Bowdoin grassland community type on BNWR, Montana, 1988. Refer to Appendix Table 19 for key to plant names. X denotes salt tolerant plants.

Cover Types	0-10	11-20	21-30	31-40
DIST[x]	68.0	73.0	87.0	95.0
Litter	67.0	62.0	55.0	65.0
KOSC[x]	40.0	25.0	22.0	7.0
BG[a]	37.0	37.0	45.0	27.0
AGSM	14.0	26.0	22.0	33.0
AGCR	14.0	8.0	4.0	5.0
HOJU[x]	12.0	9.0	5.0	3.0
GLLE	10.0	2.0		
TRMA[x]	6.0			
SUMO[x]	6.0	3.0	1.0	
PSAR[x]	4.0			
SEDE	4.0	14.0	15.0	12.0
AGTR	4.0	9.0	2.0	2.0
BOGR	4.0	3.0		
SOAR	3.0	1.0		
Aster	3.0		1.0	6.0
ARFR	2.0	3.0	4.0	8.0
PUAI[x]	1.0	2.0		
LASE			1.0	
ARLU				8.0
POPR			2.0	6.0
SUDE[x]			1.0	2.0

Table 10. Continued

Cover Types	0-10	11-20	21-30	31-40
SARU[x]			3.0	
OPPO		4.0	3.0	
SAVE[x]		3.0	1.0	
Liche		9.0	10.0	18.0
STCO		5.0	4.0	4.0

[a] BG=Bare ground

<u>Soils</u>

Shrub/grassland soils had the highest average conductivity and pH levels at depths of 30 and 60 cm (Table 12). The grasslands around Lakeside Unit and Extension had the lowest. Conductivity increased with depth in all community types except S/G. Soil pH increased as sample depth increased in all community types.

Conductivity at soil depths of 30 and 60 cm was not significantly different between SIM-S/G (p=0.07) and Bgrass-Lgrass communities (p=0.10) but was significantly different between all other community types.

The only nonsignificant pH difference between communities at a soil depth of 30 cm was between SIM-Bgrass (p=0.89). At a depth of 60 cm pH in SIM was not significantly different from S/G (P=0.14), Bgrass (p=0.51), or Lgrass (p=0.17). Bowdoin grasslands were not significantly different in pH to Lakeside grasslands (p=0.14), but pH in S/G was significantly different from Bgrass (p=0.00) and Lgrass (p=0.00).

Table 11. Average percent frequency of cover types at 0-10, 11-20, 21-30, and 31-40 m from shoreline in Lakeside grassland community type on BNWR, Montana, 1988. Refer to Appendix Table 19 for key to plant names. X denotes salt tolerant plants.

Cover Types	0-10	11-20	21-30	31-40
Litter	100	100	100	100
DIST[x]	57.1	57.1	50.0	45.7
POPR	52.9	48.6	34.3	31.4
SOAR	37.1	12.9	2.9	
SEDE	12.9	24.1	32.9	45.7
BOGR	11.4	11.4	18.6	25.7
STCO		22.9	34.3	40.0
ARLU		10.0	5.7	11.4
AGSM	24.3	12.9	31.4	31.4
BRIN	21.4	17.1	11.4	12.9
Aster	18.6	8.6		
Ascle	14.3	10.0	1.4	
CIAR	12.9	7.1	10.0	2.9
LIPU	4.3	1.4		
RACO	2.9			2.9
SPCO	2.9	2.9	5.7	7.1
BG[a]	1.4	10.0	10.0	7.1
Liche	1.4	5.7	4.3	1.4
Astra		4.3		1.4
AGCR		4.3	20.0	14.3
ARFR			2.9	
PSAR				4.3

Table 11. Continued

Cover Types	0-10	11-20	21-30	31-40
AGTR		2.9	2.9	2.9
OPPO		2.9		
GRSQ		2.9		

[a] BG=Bare ground

Percent frequency of plants was recorded from 10 m on either side of soil samples (Appendix Table 22). Bare ground/rock dominated the more saline soils. No species was found to occur at a specific salinity and salt tolerant species (most notably inland saltgrass) were present in all ranges of soil pH and conductivity.

Duck Brood Distribution

Of the 12 species of ducks known to have successfully nested on the refuge in 1988, 9 were observed during this study: gadwall (*Anas strepera*), blue-winged/cinnamon teal (bwt) (*A. discors/cyanoptera*), northern shoveler (*A. clypeata*), northern pintail (*A. acuta*), mallard (*A. platyrhynchos*), American wigeon (*A. americana*), lesser scaup (*Aythya affinis*), redhead (*Aythya americana*), and ruddy duck (*Oxyura jamaicensis*). There were no brood observations for green-winged teal (*A. crecca*), canvasback (*Aythya valisineria*), or bufflehead (*Bucephala albeola*).

Table 12. Specific conductance (dS/m) and pH of soil samples at depths of 30 and 60 cm, on BNWR, Montana, 1988.

		Conductivity		pH	
Community type	Site[a]	30cm	60cm	30cm	60cm
Shrub/grassland	12	8.16	6.15	7.90	8.10
		7.22	7.05	7.80	8.20
		8.60	7.16	7.90	8.10
		12.00	14.10	8.10	8.20
	2D	10.70	11.90	8.00	8.20
		12.70	10.90	8.10	8.10
	$\bar{x}$	**9.90**	**9.54**	**7.97**	**8.15**
Subirrigated/marsh	1	6.20	5.80	7.60	7.80
		4.40	5.10	7.50	7.80
		5.80	4.80	7.50	7.70
	6	11.76	16.50	6.70	6.60
		11.80	15.78	6.60	6.70
		10.01	16.53	6.60	6.70
	16	1.03	4.33	7.70	8.30
		1.43	4.82	7.60	8.50
		1.52	5.11	7.50	8.60
	$\bar{x}$	**5.99**	**8.75**	**7.29**	**7.63**
Bowdoin grassland	3	1.70	0.66	6.60	6.70
		1.20	1.13	6.60	6.80
		1.20	0.96	6.60	6.80
	8	4.41	6.90	8.00	7.70
		4.24	6.65	8.10	8.00
		6.27	6.69	8.10	7.90
	17	0.48	2.00	7.40	7.50
		0.60	2.19	7.30	7.50
		0.62	2.08	7.30	7.50
	4D	4.05	5.19	7.10	7.70
		3.74	4.57	7.00	7.70
		4.53	5.25	7.00	7.60
	$\bar{x}$	**2.75**	**3.69**	**7.26**	**7.45**
Lakeside grassland	1L	1.97	3.67	6.10	7.00
		1.30	2.03	7.00	7.40
		2.44	2.68	6.90	7.40
	5L	0.67	3.18	6.80	7.20
		0.63	3.28	6.60	7.00
		0.60	3.79	6.60	6.90
	$\bar{x}$	**1.27**	**3.11**	**6.67**	**7.15**

[a] Refer to Fig. 5

Eighty-one different duck broods were observed (Table 13). Mean number of broods per transect was 6.75. The first brood observed was a blue-winged/cinnamon teal on 28 June at LU-5 and the last brood observed was a lesser scaup on 22 August at PP. No broods were seen at transect DU-1. Blue-winged/cinnamon teal comprised the largest number of broods followed by lesser scaup, gadwall, mallard, ruddy, redhead, and 1 brood each for American wigeon, northern shoveler and northern pintail.

Table 13. Number and species of duck broods observed per aquatic transect on BNWR, Montana, 1988.

Location[a]	Blue-winged/ cinnamon teal	Lesser scaup	Gadwall	Mallard	Ruddy	**Total**
PP	5	6	4		4	**20**[b]
BW-1	6	1	3	2	3	**15**
TP-2	1	4	2	1	1	**11**[c]
LU-5	3		3	4		**10**
FP	3	2		3	1	**10**[d]
BW-4	1		2			**4**[e]
TP-1	3				1	**4**
SP	1			1		**2**
GP	1	1				**2**
LU-1	1			1		**2**
LU-3					1	**1**
Total	**25**	**14**	**14**	**12**	**11**	**81**

[a] Refer to Fig. 4
[b] Includes 1 northern pintail brood
[c] Includes 1 northern shoveler and 1 redhead brood
[d] Includes 1 redhead brood
[e] Includes 1 American wigeon brood

As age of ducklings increased number of observations decreased (Table 14). Two hundred fifty-five age class Ia ducklings were sighted: 89 gadwalls, 75 lesser scaup, 41 bwt, 28 ruddy, 20 mallard, and 2 American widgeon. Thirteen age class III bwt and 1 mallard were also observed.

Table 14. Number of ducklings observed per age class (I, II, or III) per transect. BNWR, Montana, 1988.

	Blue-winged/ cinnamon teal			Lesser scaup		Gadwall		Mallard			Ruddy		**Total**		
Location[a]	I	II	III	I	II	I	II	I	II	III	I	II	I	II	III
PP	25		6	90	12	35					16		**174[b]**	**12**	**6**
BW-1	5	12	7	20		18			5	1	12	2	**55**	**19**	**8**
TP-2		2		52	5	13	6	13				2	**91[c]**	**18[d]**	**0**
LU-5	13	7				20		14					**47**	**7**	**0**
FP	7	4		6				10	5		2		**25**	**12[e]**	**0**
BW-4	3					14							**19[f]**	**0**	**0**
TP-1	13										7		**20**	**0**	**0**
SP		2							1				**0**	**3**	**0**
GP		3		5									**5**	**3**	**0**
LU-1		5							2				**0**	**7**	**0**
LU-3											4		**4**	**0**	**0**
Total	**66**	**35**	**13**	**173**	**17**	**100**	**6**	**37**	**13**	**1**	**41**	**4**			

[a] Refer to Fig. 4
[b] Includes 8 class I northern pintail ducklings
[c] Includes 13 class I redhead ducklings
[d] Includes 3 class II northern shoveler ducklings
[e] Includes 3 class II redhead ducklings
[f] Includes 2 class I American wigeon ducklings

Patrol road pond (PP) had the most age class I ducklings. Excluding DU-1, LU-3 had the fewest observed broods. Most age class II ducklings were observed at TP-2 and BW-1. Only BW-1 and PP had age class III ducklings: 7 bwt and 1 mallard (BW-1) and 6 bwt (PP).

Of transects examined, PP had the highest percent use (Table 15) including nearly one-half of all lesser scaup observed and the highest percent of gadwall and ruddy duck brood. This was the only location where a northern pintail brood was seen.

Table 15. Aquatic transects and percent of broods using them, BNWR, Montana, 1988.

	Transects										
Species	PP[a]	BW-1	TP-2[b]	FP	LU-5	BW-4[c]	TP-1	SP	GP	LU-1	LU-3
Blue-winged/ cinnamon teal	20.0	24.0	4.0	12.0	12.0	4.0	12.0	4.0	4.0	4.0	
Gadwall	28.6	24.4	14.3		21.4	14.3					
Ruddy	36.4	27.3	9.1	9.1			9.1				9.1
Lesser scaup	42.9	7.1	28.6	14.3					7.1		
Mallard		16.7	8.3	25.0	33.3			8.3		8.3	
Redhead			50.0	50.0							
Total[d]	24.7	18.5	13.6	12.3	12.3	4.9	4.9	2.5	2.5	2.5	1.2

[a] One northern pintail brood found here
[b] One northern shoveler brood found here
[c] One American wigeon brood found here
[d] Percent of total broods (N=81) using each transect

DISCUSSION

Aquatic Transects

To aid in assessing changes in aquatic macrophyte communities due to increasing salinization, baseline cover maps depicting emergent and submergent vegetation of BNWR were constructed from CIR photographs. One potential problem with mapping wetlands is determining their size and continuity (Stewart et al. 1980). Delineation of shoreline and macrophytes from CIR photographs was fairly simple with the exception of Lake Bowdoin's southwest shore. This wetland consisted of alkali bulrush stands interspersed with pools of shallow water and salt crust. I included these pools as part of the lake proper and ground truthing proved this to be an accurate assessment.

Although outcome was the same, small scale (1:32000) imagery required more time than large scale (1:2000) imagery for interpretation and transfer due to loss of detail during enlargement with the video image analyzer. This problem was also experienced by Long (1986).

Cost of obtaining large scale photographs is greater than small scale since more flying time and larger amounts of film are needed to cover a comparable amount of area. If a video image analyzer is unavailable, large scale photographs of small areas of concern would be necessary. Scales of 1:11000 were demonstrated to be useful in mapping and evaluating ponds (Meyer et al. 1973) while Stewart et al. (1980) found scales of 1:24000 workable.

Species of submergent vegetation could not be separated due to lack of spectral differences on the CIR photos. This may have been influenced by type of film used since CIR has a water depth limit of about 3 m. There was little or no difficulty in identifying species of emergents. Small scale photographs should not be used to determine emergent species composition without site visitation however. A few species of emergents, because of their modest densities, were undetectable at this scale. It was not determined if large scale photographs would permit detection because these species did not occur in areas of large scale imagery.

Salt concentrations within prairie wetlands fluctuate both seasonally and annually (Ficken 1967, Stewart and Kantrud 1972, Arndt and Richardson 1985, LaBaugh et al. 1987, Swanson et al. 1988, Kantrud et al. 1989, and LaBaugh 1989). In spring, concentrations are low due to high water levels and salts being "locked-up" in frozen substrate. Later as substrates thaw and as water levels drop during summer, an increase in dissolved solids is experienced. Dissolved solid concentrations are highest in winter as ice forms, thus concentrating salts in the water. This will also generate diffusion of salts into sediments. Annual fluctuations are due to increased wet or dry years. These temporal fluctuations should indicate that specific conductance taken at any one time of the year (such as those taken in this study) may not adequately depict dissolved solid concentrations for a particular body of water. However, my conductance readings, taken in mid-July, were similar to averages over the previous 2 years (un. publ. data BNWR) and salinity categories were no different than what the averages would indicate. However, I do not wish to imply that mid-July conductance levels are the same as yearly averages.

Several authors have presented criteria used to distinguish one body of water from another based on salinity (Rawson and Moore 1944, Robinove et al. 1958, Millar 1976, and Cowardian et al. 1979). In defining the wetlands and lakes of BNWR, salinity categories presented by Stewart and Kantrud (1972) were used because their gradations are based upon correlations between different plant communities and specific conductances.

Specific conductances on BNWR ranged from 540 - 11000 uS/cm or slightly brackish to brackish. These levels were well within the realm of 42 - 472000 uS/cm for northern prairie wetlands (LaBaugh 1989). Smaller bodies of water (ponds in particular) were lowest in specific conductance. This may be due to smaller water surface areas with less evaporation. Concentration of ions is modified, in part, by the amount of evaporation (Swanson et al. 1988). These smaller ponds could also be more effectively "flushed" with precipitation and runoff.

Lakeside Unit was an exception. This was the deepest, freshest, and second largest body of water sampled. Water chemistry is related partly to a lakes position in regard to local groundwater flow systems (Swanson et al. 1988). Surface water can act as either a discharge or recharge area for groundwater (Winter 1989). I suspect Lakeside Unit is a recharge area. In winter, under ice cover, Lakeside loses up to

1 m of water (G. Sipe, pers. commun.). Subsequently, spring runoff and supplied water replenishes this loss. The water balance of wetlands controls input and output of nutrients (LaBaugh 1986). Thus, this continual flushing of Lakeside with fresh water probably accounts for its low conductivity. However, there have been no hydrological studies on BNWR to support this hypothesis.

Concentrations of dissolved solids appear to have an influence on aquatic macrophyte distributions and abundances on BNWR. My data support the general trend of decreasing number of species with increasing salinity (Stewart and Kantrud 1972, Cowardin et. al. 1979, Swanson et al. 1988, and Kantrud et al. 1989).

Sago pondweed, the most abundant and widespread submergent plant on the refuge, is stated to be one of the most cosmopolitan submerged plant species (Anderson 1978). Widgeongrass and sago occurred in all 3 salinity categories and increased in abundance as salinity increased. Similar findings were reported by Swanson et al. (1988), who found widgeongrass to eventually predominate at higher salinities. I found widgeongrass to be the only species present at 11000 uS/cm. This may be insignificant, however, since sago has been found in water of 60000 uS/cm (Kantrud et al. 1989).

The fact that salt tolerant plants such as widgeongrass, sago, horned pondweed and Chara spp. were found within the entire range of salinities demonstrates their tolerance to low and high salt concentrations. This was also reported by Ungar (1966), Stewart and Kantrud (1972), and Brock and Lane (1983). Fresh water species seem to be less tolerant to these fluctuations (Brock and Lane 1983).

Aquatic macrophytes, found in this study and others, and their observed tolerance of dissolved solids are presented in Table 16. Kantrud et al. (1989) points out that these are crude estimates. This may explain why a few of my conductances fell above their maximums.

The use of plant communities as indicators of average salinity is reported to be more accurate than single measurements of specific conductance due to unstable water chemistry characteristic of prairie ponds and lakes (Stewart and Kantrud 1972). The best method is to identify a range over which a species grows and try to determine where it grows best (Kantrud et al. 1989).

Chironomids and amphipods were the most abundant aquatic invertebrates found on the refuge, and are also reported to be the most abundant in prairie wetlands (Murkin 1989). Even so, it was evident that a high degree of "patchiness" existed in aquatic invertebrate abundances within and between bodies of water with similar conductances and vegetative growth.

As salinity increased, invertebrate abundance decreased and a slight linear relationship was found between salinity and invertebrate abundance. There was however a wide degree of variability in this relationship.

Variability was also found in invertebrate response to macrophytes. When densely covered transects were compared to those sparsely covered, the average abundance of invertebrates was 45150 and 31125/m^3 respectively. This would be expected since submergent vegetation is a focal point for aquatic invertebrates (Rosnie 1955, Krull 1970, Voights 1976, Swanson and Hammer 1983, Nelson and Kadlec

Table 16. Aquatic macrophytes of Bowdoin National Wildlife Refuge, Montana arranged according to increasing maximum observed tolerance of dissolved solids[a].

Species	Specific conductance (uS/cm) Mean or single measurement	Min.	Max.
Emergents			
Water smartweed	600 (700, 950)[b]	100	2200
Marsh smartweed	1300 (540)	<50	3400
Broadleaf cattail	2100 (540, 1000, 1400 2000, 3000, 5000)	100	13600
Hardstem bulrush	4300 (700, 900, 950, 3000, 3500, 5000, 6000, 8000)	200	37000
Alkali bulrush	10300 (1000, 1400)	200	76400
Submergents			
Whorled watermilfoil	600 (5000)	400	1100
Flatstem pondweed	1000 (560, 950, 1000, 5000)	300	2800
Redhead-grass	1700 (560)	300	4000
Whitewater buttercup	1400 (2000)	200	4500
Coontail	2100 (2000)	100	5100
Northern watermilfoil	2200 (540, 560, 1000, 1400, 2000, 3000 3500, 5000, 6000 8000)	200	6700
Horned pondweed	4800 (1000, 1400)	300	25000
Chara spp.	2200 (1000)	300	42000
Sago pondweed	6500 (540, 560, 700, 900, 1400, 2000, 3500, 5000, 6000, 8000)	5500	60000

Table 16. Continued

	Specific conductances (uS/cm)		
Species	Mean or single measurement	Min.	Max.
Widgeongrass	36100 (540, 3000, 5000, 8000, 11000)	5500	66000

[a] Source of mean, min. and max.: Adapted Kantrud et al. 1989
[b] Numbers in parenthesis indicate specific conductances collected in this study.

1984, and LaGrange and Dinsmore 1989). This general trend did however, differ among and between salinity groups. In fresher waters invertebrate densities were higher in dense growth compared to sparse, yet the opposite was true in brackish waters.

Patchiness of invertebrate distribution may be due to several factors in addition to vegetative growth and salinity. Large wind-swept openings are characterized by low invertebrate survival and abundance. Conversely areas sheltered by emergent communities or surrounding uplands are generally the most productive macroinvertebrate habitat (Nelson and Kadlec 1984). Berg (1949) reported that few insects were found associated with Potamogeton spp. collected in unsheltered areas of large lakes. Lake Bowdoin and Drumbo Unit had the highest concentrations of dissolved solids and most of the sites sampled here were devoid of emergents, unprotected by uplands, dominated by Potamogeton spp., and often wind-swept. This may explain why invertebrate abundance decreased with increased salinity.

As aquatic plant species richness decreased with increasing salinity, I found invertebrate numbers to decrease. Low plant species richness in wetlands is associated with low numbers of aquatic invertebrates (LaGrange and Dinsmore 1989) while invertebrate species richness decreases with increased salinity (Swanson et al. 1988). I did not however, find a statistically significant decrease in invertebrate taxa diversity. This may be explained in that invertebrates in this study were only identified to family level whereas the species level may show more sensitivity to salt concentrations.

On BNWR, areas with the greatest submergent-emergent interspersion harbored the most invertebrates. Voights (1976) reported that maximum number of invertebrates occur where submergent and emergent vegetation are interspersed.

Probably a myriad of interacting factors affect invertebrate numbers on BNWR. It would be difficult from my data to determine which variable(s) present(s) the greatest influence.

Terrestrial Vegetation

The type of terrestrial plants present and their frequency of occurrence on BNWR appears to be indicative of soil salinity which in turn is associated with lake water salinity. Grassland soils were not considered saline by the 4 dS/m criteria (U.S. Salinity Lab. 1954), but soils in SIM and S/G types were.

Salt tolerant species were the dominant plants in SIM and S/G. Inland saltgrass was the most frequently occurring plant along shorelines. This plant has been found to occupy some of the most saline soils (Keith 1958 and Ungar 1966). I found inland saltgrass dominant on soils ranging from high to low salinity. Other halophytes such as seaside arrowgrass, Nuttall alkaligrass, foxtail barley, and greasewood were observed on soils of both high and low conductivities in this study and others (Keith 1958, Ungar 1966, Dodd and Coupland 1966, and Dix and Smeins 1967). It is evident that what holds true for some aquatic plants and their presence in low and high salt concentrations also holds true for terrestrial halophytes.

Several indicator plants for saline soils are presented by the U.S. Salinity Lab. (1954) and Kantrud et al. (1989). However, the U.S. Salinity Lab. (1954) cautions against the use of indicator plants for diagnosis of saline soils since some species tolerate a wide range of salinity. They also point out that large conductivity differences occur in soils only a few feet apart. Lastly they emphasize the importance of purity, density, and vigor of a species in its use as an indicator. Another reason halophytes should not be used as indicator species is that their seeds have the ability to remain dormant up to 4 years in soils of high salinity only to germinate later when salinity is reduced (Ungar 1978). I found that between and within transects where soils were sampled, most plant species varied in percent frequency to such a degree it was impossible to tell from conductivity levels alone what plant species would be present and at what frequency.

Bare ground dominated in SIM and S/G and large areas of salt crust were present in these communities. Since salts can be brought into wetlands by overland runoff, predictions about salinity of a wetland can be made, in part, from examinations of adjacent soil salinity

(Kantrud et al. 1989). Thus areas of Lake Bowdoin's north and west shores and Drumbo Unit's east and west shores could be substantial contributors to the high conductivities of these lakes. With increased distance from shoreline and influence of lake waters, a decrease in occurrence of bare ground and salt tolerant species was noted.

In most soil samples a high conductance was associated with a high pH, however, as a salt predictor pH is not very reliable (U.S. Salinity Lab. 1954). This was seen in the sample collected at site #6 in the SIM community. Conductivity was very high ($\bar{x}$= 16.3 dS/m) yet pH was slightly acidic ($\bar{x}$= 6.7). This phenomenon, explained by Brady (1984), occurs when excessive leaching frees the solum of calcium carbonate resulting in mild acidity of the surface horizons.

Duck Brood Distribution

Waterfowl production on BNWR in 1988 was at a low, second only to 1985 (F. Prellwitz, un. publ. data). An estimated 950 ducks hatched, down significantly from 4653 in 1987. Low nest success was attributed to drought, extremely high temperatures, and predation. I feel the 81 broods was too small a sample, when compared to size of study area and available brood habitat, to draw any conclusions relative to habitat preference.

Food resources contribute substantially to patterns of habitat use by hens and broods in prairie wetlands (Talent et al. 1982). Several authors have reported on a variety of foods eaten by the different species of ducklings which were found in this study. Species such as blue-winged teal, ruddy duck, and lesser scaup ate predominantly invertebrates through all age classes (I-III) (Cottam 1939, Collias and Collias 1963, Sugden 1973, Swanson 1985, and Swanson 1986). These authors also reported that the other species I observed initially rely upon invertebrates, but ingest more plant material as they mature. A variety of taxa of invertebrates and plants have been reported as food items. However it appears that ducklings consume the most available invertebrates and make conscious selections only in regard to their characteristic feeding adaptations (Bartonek and Hickey 1969 and Sugden 1973). Plant foods are determined more by preference (Sugden 1973).

From this, one can expect hens to focus on areas with adequate escape cover and total invertebrate resources irrespective of invertebrate species. Habitat selection by broods appears directed more towards biologically productive wetlands in response to increased macrophyte production and food availability (Patterson 1976). The broods I observed on BNWR predominantly used areas of good invertebrate and macrophyte resources while areas with good vegetative cover and low invertebrate numbers were less used. Transects GP and SP had large invertebrate numbers and abundant cover yet received very little brood use. This may be due, in part, to low duck production, but also the luxuriant cattail growth found in both areas. Keith (1961) reported that, although broods did not avoid areas of extensive cattail growth, use of these areas was not heavy. He also found brood numbers to increase in these areas after cattail growth was reduced with chemical treatments.

Few age class III ducklings were observed. Although mortality may have been a factor, Keith (1962), Bellrose (1976), and Duebbert and Frank (1984) reported no serious reductions in numbers as age of ducklings increased. Brood movements were probably responsible for the reduced number of observations. Brood movements are usually from small, shallow wetlands to deeper, larger ones (Berg 1956, Evans and Black 1956, Young 1967, and Sugden 1973). Thus Lake Bowdoin, Drumbo Unit, and Lakeside Unit should have increased brood use as the season progresses. The low invertebrate numbers in most of these areas would be less significant at that time since older ducklings of many species tend to feed more on plant material. Sago pondweed and widgeongrass are important food sources (Swanson et al. 1988) and their dense growth here would be beneficial. Lack of escape cover in these areas would also be less important to ducklings in advanced stage of development.

MANAGEMENT RECOMMENDATIONS

Excessive salts within the wetlands of BNWR are presently not a problem, however, due to the closed drainage basins, semiarid conditions, and adjacent soils containing large quantities of soluble salts, the potential does exist. It is evident that salinity affects both plants and invertebrates and careful monitoring of these will give insight into the progression of salt accumulations.

After a decision has been made as to frequency and intensity of monitoring desired, the following guidelines are provided for monitoring salt accumulations and their effects on waterfowl brood habitat.

1. Baseline information on the aquatic vegetation cover maps will be of greatest value when used in future studies. As salinity increases the tall emergents which presently provide escape cover for ducklings will decrease (Stewart and Kantrud 1972). The extent to which density or species composition of emergents may change should be of key interest.

2. Information from each aquatic area sampled in this study will be of greatest benefit if these same areas are continually monitored for water salinity using specific conductance readings <u>and</u> presence and extent of submergent species. Submergents are easiest to identify with seeds in mid-July to early August.

3. Soils adjacent to wetlands should be monitored since they are a viable source of wetland salts. Actual soil samples, rather than

plants present, will provide a better assessment of salt content. Soil analysis as outlined in this paper, excluding pH, should prove the easiest. Number of samples should be abundant at each site to reduce the effects of variability within soils of close proximity.

4. Ducklings utilized areas of tall emergent growth and greatest abundance of invertebrates. Wide ranges in water chemistry provide a variety of food types and escape cover (Swanson et al 1988). Optimal management of BNWR should be for the "hemi-marsh" state as described by Weller (1978). Monitoring water chemistry in the fashion outlined above will indicate areas less-then-optimal for broods. In these situations water level manipulations such as those described by Murking and Kadlec (1986) and LaBaugh et al. (1987) would prove beneficial. Phosphorus and nitrogen concentrations are inversely related to conductance and they are rapidly leached from standing dead macrophytes which can be the result of water manipulations (Barica 1975 and LaBaugh et al. 1989). Emergent litter accumulations are also important invertebrate production sites (Nelson and Kadlec 1984).

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APPENDIX

Table 17. Aquatic macrophytes found on BNWR, Montana, 1988. Nomenclature follows Hotchkiss (1972).

Common name	Scientific name
Emergents	
Hardstem bulrush	(*Scirpus acutus*)
Broadleaf cattail	(*Typha latifolia*)
Alkali bulrush	(*Scirpus paludosus*)
Water smartweed	(*Polygonum amphibium*)
Marsh smartweed	(*Polygonum coccineum*)
Common reed	(*Phragmites australis*)[a]
Common three square	(*Scirpus americanus*)
Submergents	
Sago pondweed	(*Potamogeton pectinatus*)
Northern watermilfoil	(*Myriophyllum exalbescens*)
Widgeongrass	(*Ruppia maritima*)
Threadleaf pondweed	(*Potamogeton filiformis*)
Flatstem pondweed	(*Potamogeton zosteriformis*)
Horned pondweed	(*Zannichellia palustris*)
Redhead-grass	(*Potamogeton perfoliatus*)
Narrowleaf waterplantain	(*Alisma gramineum*)
Muskgrass	(*Chara* spp.)
Whitewater buttercup	(*Ranunculus aquatilis*)
Coontail	(*Ceratophyllum demersum*)
Whorled watermilfoil	(*Myriophyllum verticillatum*)

[a] Nomenclature follows Booth (1972)

Table 18. Vertebrate fauna observed on BNWR, Montana, 1988.

Common name	Scientific name
Aves	
Pied-billed grebe	(Podilymbus podiceps)
Eared grebe	(Podiceps nigricollis)
American white pelican	(Pelecanus erythrorhynchos)
Double-crested cormorant	(Phalacrocorax auritus)
American bittern	(Botaurus lentiginosus)
Great blue heron	(Ardea herodias)
Black-crowned night-heron	(Nycticorax nycticorax)
Cattle egret	(Bubulcus ibis)
White-faced ibis	(Plegadis chihi)
Canada goose	(Branta canadensis)
Wood duck	(Aix sponsa)
Green-winged teal	(Anas crecca)
Mallard	(Anas platyrhynchos)
Northern pintail	(Anas acuta)
Blue-winged teal	(Anas discors)
Cinnamon Teal	(Anas cyanoptera)
Northern shoveler	(Anas clypeata)
Gadwall	(Anas strepera)
American wigeon	(Anas americana)
Canvasback	(Aythya valisnieria)
Redhead	(Aythya americana)
Lesser scaup	(Aythya affinis)
Bufflehead	(Bucephala albeola)
Ruddy duck	(Oxyura jamaicensis)
Harlequin duck	(Histrionicus histrionicus)
Northern harrier	(Circus cyaneus)
Swainson's hawk	(Buteo swainsoni)
Ferruginous hawk	(Buteo regalis)
American kestrel	(Falco sparverius)
Gray partridge	(Perdix perdix)
Ring-necked pheasant	(Phasianus colchicus)
Sage grouse	(Centrocercus urophasianus)
Sharp-tailed grouse	(Tympanuchus phasianellus)
Sora	(Porzana carolina)
American coot	(Fulica americana)
Killdeer	(Charadrius vociferus)
Black-necked stilt	(Himantopus mexicanus)
American avocet	(Recurvirostra americana)
Lesser yellowlegs	(Tringa flavipes)
Willet	(Catoptrophorus semipalmatus)
Long-billed curlew	(Numenius americanus)
Marbled godwit	(Limosa dedoa)
Long-billed doeitcher	(Limnodromus scolopaceus)
Wilson's phalarope	(Phalaropus tricolor)
Franklin's gull	(Larus pipixcan)

Table 18. Continued

Common name	Scientific name
Ring-billed gull	(Larus delawarensis)
California gull	(Larus californicus)
Common tern	(Sterna hirundo)
Black tern	(Chlidonias niger)
Mourning dove	(Zenaida macroura)
Great horned owl	(Bubo virginianus)
Common nighthawk	(Chordeiles minor)
Common flicker	(Colaptem auratus)
Eastern kingbird	(Tyrannus tyrannus)
Horned lark	(Eremophila alpestris)
Cliff swallow	(Hirundo pyrrhonota)
Barn swallow	(Hirundo rustica)
Black-billed magpie	(Pica pica)
Marsh wren	(Cistothorus palustris)
Mountain bluebird	(Sialia currucoides)
American robin	(Turdus migratorius)
Brown thrasher	(Toxostoma rufum)
European starling	(Sturnus vulgaris)
Rufous-sided towhee	(Pipilo erythrophthalmus)
Lark bunting	(Calamospiza melanocorys)
Savannah sparrow	(Passerculus sandwichensis)
Red-winged blackbird	(Agelaius phoeniceus)
Western meadowlark	(Sturnella neglecta)
Yellow-headed blackbird	(Xanthocephalus xanthocephalus)
Common grackle	(Quiscalus quiscula)
House sparrow	(Passer domesticues)
Mammalia	
Little brown bat	(Myotis lucifugus)
Long-tailed weasel	(Mustela frenata)
Badger	(Taxidea taxus)
Striped skunk	(Mephitis mephitis)
Red fox	(Vulpes vulpes)
Coyote	(Canis latrans)
Richardson ground squirrel	(Citellus richardsonii)
Deer mouse	(Peromyscus maniculatus)
Muskrat	(Ondatra zibethicus)
White-tailed jackrabbit	(Lepus townsendii)
Mountain cottontail	(Sylvilagus nuttalli)
White-tailed deer	(Odecoileus virginianus)
North American pronghorn	(Antilocapra avericana)
Reptilia	
Bull snake	(Pituophis meanoleucus)
Western rattlesnake	(Crolatus viridis)
Plains garter snake	(Thamnophys radix)

Table 19. Complete list of plants found along lake shores of BNWR, Montana, 1988.

Code	Scientific name	Common name
ACMI	Achillea millefolium	Western yarrow
AGCR	Agropyron cristatum	Crested wheatgrass
AGSM	Agropyron smithii	Western wheatgrass
AGTR	Agropyron trachicaulum	Slender wheatgrass
ARFR	Artemisia frigida	Fringed sagebrush
ARLU	Artemisia ludoviciana	Cudweed sagewort
Artem	Artemisia spp.	Sagebrush
Ascle	Asclepias spp.	Milkweed
Aster	Aster spp.	Aster
Astra	Astragalus spp.	Milkvetch
ATPA	Atriplex patula	Saltbush
BOGR	Bouteloa gracilis	Blue grama
BRIN	Bromis inermis	Smoothe brome
CHJU	Chondrilla juncea	Skeletonweed
CIAR	Cirsium arvense	Canadian thistle
DIST	Disticlis stricta	Inland saltgrass
ELAN	Elaeagnus angustifolia	Russion olive
GLLE	Glycyrrhiza lepidota	Wild licorice
GRSC	Grindelia squarrosa	Curlycup gumweed
GUSE	Gutierrezia serothrae	Broom snakeweed
HEHO	Helictotrichon hookeri	Spike oat
HOJU	Hordeum jubatum	Foxtail barley
KOPY	Koeleria pyramidata	Prairie Junegrass
KOSC	Koschia scoparia	Summercypress
LASE	Lactuca serriola	Prickly lettuce
LIPU	Liatrus punctata	Dotted gayfeather
MEOF	Meliotus officinalis	Yellow sweetclover
OPPO	Opuntia polycantha	Plains prickly pear
POPR	Poa pratensis	Kentucky bluegrass
PSAR	Psoralea argophylla	Silverleaf scurfpea
PUAI	Puccinella airoides	Nuttall alkaligrass
RACO	Ratibida columnaris	Prairie coneflower
SARU	Salicornia rubra	Saltwort
SAVE	Sarcobatus vermiculatus	Greasewood
SCAC	Scirpus acutus	Hardstem bulrush
SCAM	Scirpus americanus	Common threesquare
SCPA	Scirpus paludosus	Alkali bulrush
SEDE	Selaginella densa	Club moss
SOAR	Sonchus arvensis	Sow thistle
SPCO	Sphaeralcea coccinea	Scarlet globemallow
STCO	Stipa comata	Needleandthread
SUDE	Suaeda depressa	Seablite
SUMO	Suaeda moquinii	Seablite
TRMA	Triglochin maritima	Seaside arrowgrass

Table 20. Densities (#/m^3) of aquatic invertebrates per transect on BNWR, Montana, 1988. Two samples were collected per transect.

Transect[a]	Invertebrates										
	Tal[b]	Hyd[c]	Cae[d]	Coe[e]	Cor[f]	Chi[g]	Pla[h]	Phy[i]	Col[j]	Oth[k]	Total
LU-1[x]	17950[+]	4575	26300	1750	325	1875	425	1350	550	850	
(30-60)	18325	900	5100	1550	75	3575	100	450	225	500	86750
LU-2	45200[+]	875	1300	400	1050	3300	600	3050	125	750	
(30-60)	21525	625	875	275	1875	2400	350	1050	50	325	86000
LU-4	50	125		50	4325	100	100			50	
(30-60)	75	150			3200[+]	200					8425
LU-3[x]	375				1225	1175	25				
(0-30)	75	50			3000	2900					8825
LU-5[x]		175	25	25	1300	8550[+]	150	100	125	950	
(0-30)		75			2475	5500[+]	425	650	300	125	21900
SP[x]	1625	1225	800[+]	6075	2200	450	35000	11875	50	1150	
(0-30)	975[+]	25	175	350	2175[+]	200	1425[+]	925	25	175	66900
GP[x]	1150	400		1350	15675	53400	3175	20000	1400	4600	
(30-60)	350	225	75	1825	10525	54450	2275	17450	1300	4350	193975

Table 20. Continued

Transects[a]	Invertebrates Tal[b]	Hyd[c]	Cae[d]	Coe[e]	Cor[f]	Chi[g]	Pla[h]	Phy[i]	Col[j]	Oth[k]	Total
TP-1[x]	75	25		1375	175	275	3500	1625	225	550	
(30-60)	75			1050	150	125	2375	1375	150	175	13350
FP[x]	475		275	125	250	4850	200	500	225	450	
(30-60)	12975	200	5500	325	200	575	1050	2050	400	625	26300
TP-2[x]	10650	200		6050	525	11100	1425	9025	825	1775	
(30-60)	10475	275	25	8675	350	14750	2050	14600	1500	2625	96900
DU-1[x]	50			50	2925+	3250+			125	200	
(30-60)				25	1075+	1975+			100	175	9950
BW-1[x]	8250	75+		325	2300+	425+		100	150	100	
(0-30)	22950	150	50	1975	3575	2250+		650	650	525	51500
BW-2					6775	6625	25	225		50	40700
(0-30)											
PP[x]	900	875		400	1225+	47850+	425	1700	2450	1125	
(30-60)	100	575	25	100	800+	2475		50	350	300	61725

Table 20. Continued

Transects[a]	Invertebrates										
	Tal[b]	Hyd[c]	Cae[d]	Coe[e]	Cor[f]	Chi[g]	Pla[h]	Phy[i]	Col[j]	Oth[k]	Total
BW-4[x]		+	50		3075^{+}	200		25	50	100	
(0-30)		+	225	150	4950	2525		25	200	400	11975
BW-3					50	3900			25	350	
(0-30)					200	2500				100	7125
BW-6	75			25	2900^{+}	1750^{+}		50	50	350	
(0-30)	200	125		150	1800	8275^{+}		25		475	16375
BW-7	775^{+}			25^{+}	1775^{+}	1475			25	75	
(0-30)	925			700	3850^{+}	2200			25	275	12175
BW-8	425	25		9425	325	425				25	
(30-60)	175			7750	100	425				125	19225
BW-9	3950^{+}			1000	25	3975^{+}		25		400	
(30-60)	4600^{+}	25		350	25	3575		75		150	18225
DU-2	25	300		2535	13400	6425	125	575	750	750	
(30-60)	200	175		1400	2725	9675			600	825	40475

Table 20. Continued

Transects[a]	Invertebrates										
	Tal[b]	Hyd[c]	Cae[d]	Coe[e]	Cor[f]	Chi[g]	Pla[h]	Phy[i]	Col[j]	Oth[k]	Total
BW-5		+		75+	800	425				25	
(30-60)	175	150	25	225+	4900	2200		1000		225	10225
Total	193175	12675	35875	57925	132050	290100	55255	90650	13075	28250	909030

[a] Transects listed in order of increasing conductivity
[b] Tal=Talitridae
[c] Hyd=Hydracarina
[d] Cae=Caenidae
[e] Coe=Coenargionidae
[f] Cor=Corixidae
[g] Chi=Chironomidae
[h] Pla=Planorbidae
[i] Phy=Physidae
[j] Col=Coleoptera larva
[k] Oth=All others, refer to Table 6
[x] Denotes transects surveyed for duck brood use
[+] Number is not indicative of total taxa found since organisms < 1mm in size were not counted

Table 21. Average percent frequency of terrestrial cover types, listed in order of decreasing occurrence, found in the different communities (Bowdoin grassland, Lakeside grassland, shrub/grassland, and subirrigated/marsh) on BNWR, Montana, 1988. Refer to Appendix Table 19 for key to plant names.

Bgrass		Lgrass		S/G		SIM	
Plant	$\bar{x}$ (n=10)	Plant	$\bar{x}$ (n=7)	Plant	$\bar{x}$ (n=6)	Plant	$\bar{x}$ (n=8)
DIST	82.0	Litter	99.6	Litter	72.7	Litter	61.6
Litter	75.1	DIST	51.9	BG	57.3	BG	47.7
BG[a]	31.6	SEDE	34.3	DIST	48.4	HOJU	39.2
AGSM	25.3	STCO	34.0	SAVE	27.3	KOSC	37.5
KOSC	10.3	POPR	31.6	KOSC	23.1	DIST	30.8
AGCR	10.0	AGSM	28.9	KOPY	19.0	Aster	19.9
Liche	8.4	BOGR	22.3	HOJU	16.7	SOAR	17.5
SEDE	6.5	Liche	10.9	Aster	10.2	ATPA	14.6
HOJU	4.9	CIAR	8.8	AGSM	9.2	SARU	11.9
OPPO	2.4	BG	8.0	ATPA	2.7	SUMO	7.0
AGTR	4.9	BRIN	12.9	PUAI	6.1	PUIA	17.8
ARFR	4.3	AGCR	12.1	SCAM	5.4	GRSQ	12.6
STCO	3.5	SOAR	7.5	SARU	4.6	SUDE	8.6
POPR	2.8	ARLU	5.7	ARFR	3.3	SCPA	4.7
BOGR	2.0	SPCO	4.7	Artem	3.1	MEOF	4.1
SOAR	2.0	AGTR	4.5	SUMO	2.9	TRMA	3.9
Aster	1.8	Aster	3.8	GRSQ	2.3	SCAC	1.6
SAVE	1.5	GRSQ	3.8	SUDE	1.7	SCAM	0.5
GLLE	1.5	Ascle	3.2	OPPO	1.5	AGSM	0.3

Table 21. Continued

Bgrass		Lgrass		S/G		LSM	
Plant	$\bar{x}$ (n=10)	Plant	$\bar{x}$ (n=7)	Plant	$\bar{x}$ (n=6)	Plant	$\bar{x}$ (n=8)
SUMO	1.3	OPPO	1.6	Liche	1.3	ELAN	0.2
SUDE	1.1	PSAR	1.4	SOAR	1.1		
ARLU	1.0	RACO	1.3	PSAR	0.6		
TRMA	0.8	LIPU	1.3	HEHO	0.4		
SARU	0.5	CHJU	0.7				
ACMI	0.5	Astra	0.7				
PSAR	0.5	ARFR	0.5				
PUAI	0.4						
GUSE	0.4						
LASE	0.1						

[a] BG=Bare ground

Table 22. Average conductance (dS/m) and pH of soil samples and percent frequency of occurrence of surrounding cover types on BNWR, Montana, 1988. Refer to Appendix Table 19 for key to plant names.

			Conductance		pH	
Site[a]	Cover Type	Frequency	30[b]	60	30	60
#6	BG[c]	100	11.2	16.3	6.73	6.67
	SUDE[x]	65				
	DIST[x]	10				
	Litter	5				
#2D	BG	100	11.8	12.3	8.07	8.17
	Litter	100				
	SAVE[x]	20				
#12	KOSC[x]	85	8.0	6.8	7.87	8.13
	KOPY	65				
	BG	65				
	SAVE[x]	65				
	Litter	60				
	DIST[x]	20				
	SUDE[x]	10				
#8	Litter	95	5.0	6.8	8.07	7.87
	AGCR	60				
	AGSM	45				
	BG	40				
	DIST[x]	30				
#1	ATPA[x]	95	5.5	5.2	7.53	7.77
	Litter	95				
	SOAR	85				
	HOJU[x]	75				
	Aster	55				
	SUMO[x]	20				
	KOSC[x]	5				
#4D	DIST[x]	100	4.1	5.0	7.03	7.67
	Litter	100				
	AGSM	85				
#16	BG	100	1.3	4.7	7.60	8.47
	Litter	90				
	KOSC[x]	65				
	Aster	15				

Table 22. Continued

Site	Cover Types	Freqency	Conductance 30	Conductance 60	pH 30	pH 60
#1L	Litter	100	1.9	2.8	6.67	7.27
	BRIN	90				
	AGCR	55				
	SEDE	20				
	Astra	15				
	ARFR	5				
#5L	Litter	100	0.6	3.4	6.67	7.03
	DIST[x]	85				
	STCO	80				
	AGSM	60				
	SEDE	60				
	BG	20				
	BOGR	15				
	GRSQ	10				
	OPPO	5				
	Liche	5				
#17	BG	100	0.6	2.1	7.33	7.50
	KOSC[x]	80				
	DIST[x]	35				
	HOJU[x]	20				
	SUMO[x]	20				
	AGSM	5				
	Litter	5				
#3	DIST[x]	100	1.4	0.9	6.60	6.77
	Liche	75				
	AGTR	55				
	Litter	45				
	STCO	40				
	ARFR	30				
	BG	25				
	BOGR	15				
	OPPO	5				

[a] Refer to Fig. 5
[b] Depth of soil sample in cm
[c] BG=Bare ground
[x] denotes salt tolerant plants