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HABITAT USE BY BREEDING WATERFOWL
OF SEVERAL UTAH MARSHES

by

Paul M. Suchanek

A thesis submitted in partial fulfillment
of the requirements for the degree

of

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in

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Paul M. Suchanek

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ABSTRACT

Habitat Use by Breeding Waterfowl
of Several Utah Marshes

by

Paul M. Suchanek, Master of Science

Utah State University, 1980

Major Professor: Dr. John A. Kadlec
Department: Wildlife Science

Habitat use by waterfowl (breeding pairs and broods) of several Utah marshes was studied during 1978 and 1979. A number of ponds found on 5 different marshes located near Great Salt Lake were studied. Perimeter, area, depth, and emergent vegetative type were measured on each pond. Waterfowl use of the ponds was determined using a fixed point observation system. Multiple regression was used to analyze the relationships between the measured habitat variables and waterfowl use.

Area of the pond was the variable most strongly related to both pair and brood use. Perimeter was highly correlated to area, but a calculated edge index reduced the confounding between the two variables. The edge index was positively related to pair use by 3 species of waterfowl and to total brood use, but it explained relatively little of the total variation in waterfowl use. Pond depth had little effect on duck use, but the type of emergent edge often had a significant effect on both pair and brood use. Waterfowl use of the ponds differed slightly between marshes.

The multiple regressions explained from 53 to 79 percent of the variation in pair use by species. From 31 to 77 percent of the variation in brood use by group or species was explained. The 1978 data were used to validate the regression models developed with the 1979 data.

(84 pages)

INTRODUCTION

Waterfowl breeding habitat in the United States and parts of Canada has been reduced substantially by the loss of wetlands to agricultural drainage and development, and more continues to be lost annually. While the amount of waterfowl habitat decreases, the demand for substantial waterfowl populations by hunters and nonconsumptive users remains at a high level. Therefore, management techniques designed to produce more ducks from remaining wetlands are an important means of maintaining viable waterfowl populations. The purpose of this study was to ascertain how several habitat characteristics are related to breeding waterfowl use so that marshes might be managed to increase breeding populations of waterfowl. The term "waterfowl", as used in this paper, is defined to be limited to North American ducks of the genera *Anas*, *Aythya*, and *Oxyura*.

One factor often assumed to greatly influence breeding populations and habitat use by waterfowl is the amount of edge between cover and water. Waterfowl managers have attempted to increase the interspersion of cover and open water, and thus shoreline length or edge, by such means as blasting (Provost 1948, Mendall 1949), water level manipulation (Green et al. 1964:562), and level ditching (Lacy 1959). Some data have suggested that these procedures increase breeding pair populations; however, the influences of edge on waterfowl habitat use have not been well quantified.

Emphasis of the study, therefore, was placed on evaluating the relative importance of edge on habitat use by pairs and broods.

Several other environmental variables perceived as being important to waterfowl were measured on each experimental unit in addition to the calculation of an index of edge. Each experimental unit (hereafter referred to as a "pond") consisted of an open body of water surrounded by emergent vegetation or moist ground. Environmental variables measured dealt with pond morphometry and peripheral emergent vegetation exclusively.

The objectives of the study were twofold. The primary objective was to quantify relationships between habitat use by breeding waterfowl (pairs or broods) and the edge index, area, depth, and emergent vegetative type of ponds in several Utah marshes. If one or more of these relationships were present, a pond with optimum levels of these factors for which breeding waterfowl use would be maximized might then be described. Attainment of either of these objectives could have immediate management implications.

LITERATURE REVIEW

Edge influences on breeding pairs

The amount of edge has been hypothesized to influence waterfowl breeding pair habitat use in two different manners. Bennett 1938:106) and Sowls (1955:73-75) found that most ducks nest close to water, so they concluded that the interspersion of water and nesting cover must be important because it makes nesting cover available to pairs using the adjacent water area. As nesting cover is an essential habitat component (Hochbaum 1944:58-62), its presence and availability is necessary to attract breeding pairs. Hochbaum (1944:78-79), on the other hand, noted a relationship between breeding pair densities and the amount of shoreline available and concluded that the amount of shoreline edge affected the number of potential territories available. Mendall (1958:235) believed the amount of edge influenced both the number of territorial sites and the amount of nesting cover available.

An examination of these two possible influences of edge on waterfowl pair habitat use reveals that the hypothesized effect on nesting cover availability corresponds most closely to Leopold's (1933) classic discussion of the importance of "simultaneous availability" of two important habitat types, each of which provides an essential need. At the edge, both the nesting cover and the open water for feeding and loafing would be instantly accessible. Interspersion of water and nesting cover may have an important influence on the number of available nesting sites for diving ducks and so affect habitat use since these species typically nest in emergents over water, or as McKnight (1974) found, on dry land very close to water. Low (1945:53) concluded that interspersion of emergents and open water was very important to redheads (Aythya americana) in Iowa as 85 percent of the nests located were within 50 m of open water.

Dabbling ducks, however, are not so restricted in their choice of nesting sites because they typically nest on dry land, often far from water. Evans and Black (1956:40) concluded that "although most species (of dabbling ducks) show at least a slight tendency to nest near water, it is not generally near the water on which they spend the most of their time." Duebbert (1966) noted that some pairs of gadwalls (Anas strepera) traveled 5 km from loafing areas to a favored nesting island. Duebbert and Lokemoen (1976:43-44) found that some ducks traveled over 1.6 km from wetlands to nesting cover, while the average distance of nests from water varied from 287 to 485 m over several years.

Gates (1962) noted large differences in home range sizes of gadwalls in Utah. Many pairs nested close to water and had small home ranges, but some pairs nested about 1.5 km from water. Gilmer et al. (1975:787) found that most of their radio-tagged mallard (Anas platyrhynchos) hens generally used shorelines in the vicinity of the nest, but one hen traveled about 2.4 km between the nest and a favorite feeding or loafing site. They also concluded that home range sizes of mallard pairs were influenced by the distribution of essential habitat components, or stated in another manner, a pair will go as far as necessary (up to a point) to fulfill its requirement for nesting cover. It would appear from these studies that immediate access of nesting cover is not a major factor affecting habitat use by dabbling ducks.

On the other hand, the possible influence of edge on the capacity of a water body to hold territorial pairs has little to do with the classic view of Leopold (1933) on why edge is important. It is related to the behavioral characteristics of waterfowl rather than a need for quick access to 2 environmental types.

Hochbaum (1944:56-87) was the first to discuss the manifestation of territorialism in the behavior of waterfowl. He believed a paired male defended a certain water area against all other sexually active birds of the same species, thus sharing no resources in his territory with other members of the same species. The pair rarely left this area except when the hen went to the nest which often was not in the territory.

A number of later studies (Dzubin 1955, Smith 1955, Sowls 1955:47-57, Evans and Black 1956, Gates 1962, Gilmer et al. 1975, Derrickson 1978), however, disclosed that many species of waterfowl typically use a number of potholes or water areas in their breeding home range along with other pairs of the same species. Pairs of the same species shared loafing sites (Sowls 1955:56-57, Evans and Black 1956) and feeding areas (Smith 1955). Sowls (1955:53) also noted that some drakes defended more than 1 area, and Dzubin (1955), Smith (1955), and Gates (1962) found that in some species, the drake defends a space around the hen. These finding rendered Hochbaum's (1944) classical concepts of territorialism in waterfowl too rigid for most species. However, northern shovelers (Anas clypeata) and blue-winged teal (Anas discors) have been found to exhibit nearly classical territorial behavior in some instances (McKinney 1965; Seymour 1974a, 1974b; Rothe 1977).

Although classic territorial behavior is not displayed by many species of waterfowl, researchers generally agree that males of most species of waterfowl exhibit intraspecific agonistic behavior during the height of the breeding season when nesting is initiated. Diving ducks typically display much lower levels of this behavior (McKinney 1965). This agonistic behavior is believed to space out pairs on the breeding grounds (McKinney 1965, Dzubin 1969b). Dzubin (1969a:41), after an extensive review of the literature concerning the concept of pond carrying capacity for waterfowl pairs, concluded that all "authors suggest that space and spacing mechanisms affect breeding pair density...." There are no definitive data, however, that prove spacing effects either limit pair density or influence reproductive success (Dzubin and Gollop 1972).

Circumstantial evidence that breeding pair densities, habitat use, and production are affected by behavioral spacing mechanisms does exist. Researchers have concluded that during times of drought when territorial space is limited, many waterfowl are displaced into inferior habitat or crowd into the remaining potholes and make little attempt to breed (Bellrose et al. 1961, Dzubin 1969a, Smith 1970). A direct relationship between the number of wet potholes and the number of breeding pairs has been noted for large geographical regions (Crissey 1969, Pospahala et al. 1974) and on smaller study areas (Evans and Black 1956, Drewien and Springer

1969, Krapu et al. 1970, Stoudt 1971). If more water (territorial space) is made available during the spring when breeding pairs are selecting a breeding area, production increases (Anderson and Glover 1967, Schroeder et al. 1976). Lacy (1959:56) estimated that the increase in production due to artificial water area development varied between 29 and 80 percent on 3 study areas.

Pair use of individual ponds is also believed to be affected by space requirements of the breeding pair. An abundance of the necessary pair requirements as discussed by Hochbaum (1944:58-62), Beard (1953), and Sowls (1955:73) does not necessarily lead to heavy pair use of a pond. Evans and Black (1956:48) concluded that breeding pairs "showed little preference for areas especially attractive from the standpoint of food, cover, or any other measurable factor." Possibly pairs are prevented from using the most desireable areas in large numbers by other agonistic conspecific pairs.

Small water areas have been hypothesized to serve mainly as territorial space (Hochbaum 1944:80, Lacy 1959), though as discussed previously, most species of waterfowl do not set up territories. The use of these small areas may be a result of the tendency for pairs to isolate themselves from other pairs or males of the same species during the breeding season, either by avoidance or by fleeing from attacks of other males (McKinney 1965). On a small water body, the pair is visually isolated from other pairs because the vegetation growing around the edge screens pairs on nearby ponds from view.

The intensity of habitat use, expressed in pairs per ha is usually greatest on these small water areas, particularly for the dabbling ducks (Hochbaum 1944:79; Evans et al. 1952; Benson and Foley 1956; Evans and Black 1956; Jenni 1956; Drewien and Springer 1969; Stoudt 1969, 1971). Most diving ducks are rarely found on water bodies less than 0.25 ha in size during the breeding season (Evans and Black 1956, Lacy 1959, Hoffman 1970).

Heavy use by dabblers of small ponds on an area basis is probably because even a small pond can be used by a pair. Other ponds with much more area may still have only 1 pair using them at any given time because 2 pairs cannot be visually isolated, and a pair occupying the area will drive other pairs away. On this basis, Evans and Black (1956) and Jenni (1956) concluded the ideal distribution of water for breeding pairs would be many small potholes. In general, however, the total amount of use by breeding pairs increases as the size of the water body increases (Smith 1953, Lacy 1959, Hopper 1972, Lokemoen 1973, Evrard 1975, Flake et al. 1977).

On larger ponds, irregular shapes with more edge may be important in forming visual barriers which "break up" the water body so it may function as a group of small areas, each of which could hold a pair of waterfowl at any given time. As the edge of emergent vegetation forming visual barriers increases on a water body of given area, the probability that 2 breeding pairs will be visually isolated also increases.

Actual data supporting the hypothesis that the amount of edge can increase the intensity of habitat use by breeding pairs of large ponds are limited. Knight (1965) found pair numbers increased as the amount of emergent vegetation and edge increased on a Montana water area. Sill (1966) erected artificial visual barriers on several sections of channel at Ogden Bay, Utah in an attempt to increase pair use. His results were negative; however, the channels were located in areas where pair densities and the number of agonistic encounters were low. Flake et al. (1977) found no significant relationship between an edge index and breeding pair use of South Dakota stock ponds. Kaminski (1979) and Murkin (1979) found artificially manipulated areas of marsh with an intermediate amount of edge had highest pair use.

The amount of edge may not be the only aspect of edge influencing pair habitat use as the quality or type of edge could also be important. A number of researchers (Hochbaum 1944:79, Evans et al. 1952, Sowls 1955:72-73, Shearer 1960, Keith 1961, Smith 1971, Stoudt 1971) have concluded that shorelines vary in their attractiveness to waterfowl pairs. The attractiveness of a given edge type seems to be species-specific in most instances.

In summary, the amount of edge may influence waterfowl pairs by either making an essential habitat component such as nesting cover accessible or by increasing the capacity of a water body to hold agonistic breeding pairs. If edge does indeed have these influences, it might have an important effect on habitat use by breeding pairs. Few studies, however, have addressed the subject in detail.

Edge influences on broods

The simultaneous accessibility of two necessary habitat components may be an important factor affecting habitat use by broods because of their limited mobility. Intraspecific intolerance between broods is not an important factor because hens with broods may aggregate on favored habitat and little antagonism between broods has been noted (Evans et al. 1952, Gates 1958, Beard 1964).

Broods can move overland several km (Evans et al. 1952), therefore, the water body used by broods may be by choice if water bodies are spaced closely. A movement of broods to larger water bodies has been noted (Berg 1956, Evans and Black 1956, Keith 1961), often because small water bodies are less permanent and dry up during the brood season.

However, broods do not always move to the largest water bodies available. Bennett (1938:108) found that the number of water ha per brood was lowest on potholes of approximately 0.20 ha in size. Smith (1971) and Stoudt (1971) found that dabbling duck broods moved to areas about 0.50 ha in size, while Evans et al. (1952) concluded that potholes slightly larger than 1 ha in size were most heavily used by broods of dabblers on an area basis. Lokemoen (1973) found that stock ponds in North Dakota about 0.60 ha in size were most heavily used by broods of dabblers. Total brood use in these studies was highest on the larger ponds, but intensity of use was highest on ponds of intermediate size. Diving duck broods used larger ponds than did broods of dabblers (Smith 1971, Stoudt 1971).

Broods of dabbling ducks have a need for open water to feed upon and a need for emergent cover for escape from predators (Beard 1953:422). Researchers have concluded that escape cover accessibility is more of a factor influencing pothole use by dabblers than is food availability (Evans et al. 1952, Spencer 1953, Evans and Black 1956). Hochbaum (1944:105) noted that "river ducks rear families largely in the dense cover of the edges." Redhead broods also rarely venture more than 50 m from escape cover (Low 1945:55). Ponds with emergent vegetation or brushy or grassy shorelines are preferred over those without vegetation (Bue et al. 1952, Berg 1956, Lokemoen 1973). Broods of gadwalls and diving ducks, however, often escape from predators by fleeing to the middle of open water bodies (Hochbaum 1944:105, Beard 1964) so the amount of edge may not be a factor influencing pond selection by these species.

The availability of a food resource, however, must also be considered as a possible habitat factor influencing brood use. During the first few weeks of life, invertebrates constitute much of a duckling's diet (Chura 1961, Bartonek and Hickey 1969, Sugden 1973, and others). Invertebrate abundance has been correlated with use of oligotrophic Swedish lakes by goldeneye (Bucephala clangula) broods (Eriksson 1978). Collias and Collias (1963) found that the distribution of broods at Delta, Manitoba was similar to the distribution of favored invertebrate foods. McKnight and Low (1969) concluded that reservoirs at Fish Springs National Wildlife Refuge with larger invertebrate populations were more heavily used by broods. It is possible the amount of edge influences the amount of invertebrate food resource, as Voights (1976) found invertebrate abundance was greatest at the edge where submergents were mixed with emergents.

Most of the studies cited thus far were of brood behavior or brood numbers and were not directed toward quantitative evaluation of habitat use. Lokemoen (1973) studied brood habitat selection on stock ponds in North Dakota, but he did not include an edge index as a habitat variable. He found ponds used more heavily by broods were characteristically older, closer to other water, less turbid, and had more brushy or emergent lined shoreline. Patterson (1976), in another study, concluded broods responded both to water body morphometry and to pond fertility (an index of food resources). His studies were done on Canadian beaver ponds where food resources and cover could be expected to be in short supply as compared to prime waterfowl breeding habitat. These studies suggest, however, as have other less quantitative studies, that the amount and type of edge may be an important factor influencing brood habitat use.

STUDY AREA

Utah marshes used as study areas during the project are listed in Table 1. All these marshes are located around the north and east sides of Great Salt Lake (Figure 1). They are an important migration stopping point and historically have supported dense populations of breeding waterfowl (Williams and Marshall 1938, Wingfield 1951, Bellrose 1976).

All the marshes are managed for waterfowl by state or federal agencies. They have all been partly modified by man and have extensive canal and dike developments to stabilize and control water levels. Nelson (1954) has detailed the development of the Ogden Bay marsh. Water sources are streams or rivers, although the water source for Salt Creek and Public Shooting Grounds is mostly spring fed. The marshes are partially or totally open to hunting, although access to the areas is greatly restricted during the waterfowl breeding season with the exception of Bear River Refuge where visitors may drive a tour route around Unit 2.

Dominant vegetation on the study areas varies with location. At Ogden Bay, Farmington Bay, and Bear River, the low lying marsh vegetation is typically either saltgrass (Distichlis stricta), cattail (Typha spp.), hardstem bulrush (Scirpus acutus), alkali bulrush (S. paludosus), or samphire (Salicornia rubra), with a mixture of other species. Upland areas (typically spoil dikes) are covered with a variety of introduced and native grasses and forbs. At Salt Creek and Public Shooting Grounds, Olney's bulrush (S. olneyi) forms extensive beds while hardstem bulrush, alkali

Table 1. List of study areas

Study Area	Years of study	Ownership	County	Total Area (ha)
Ogden Bay Waterfowl Management Area (WMA) (Unit 1)	1978-79	State	Weber	6900
Public Shooting Grounds WMA	1978-79	State	Box Elder	4900
Salt Creek WMA	1978	State	Box Elder	1900
Bear River Migratory Bird Refuge (Units 1 and 2)	1979	Federal	Box Elder	26300
Farmington Bay WMA (Units 1 and 2)	1979	State	Davis	3600

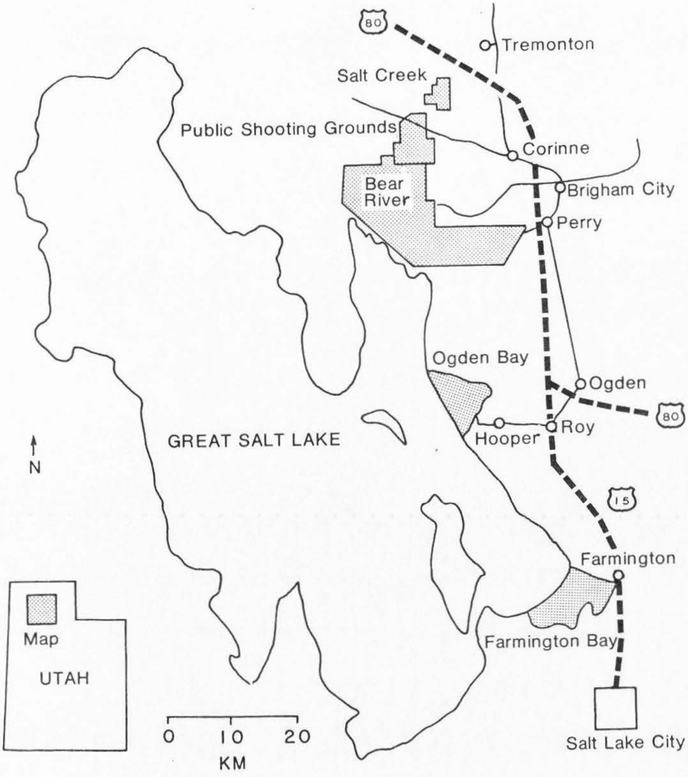

Figure 1. Location of study areas. Study areas are stippled.

bulrush, and cattail are present in only minor amounts. Uplands, interspersed with marsh areas and salt pans, at Public Shooting Grounds are covered with a salt-desert shrub community dominated by greasewood (Sarcobatus vermiculatus) and cheatgrass (Bromus tectorum). Submergent vegetation on all areas is dominated by sago pondweed (Potamogeton pectinatus).

METHODS

Field methods

A number of ponds were selected for study at each of the major study areas (Table 2). Salt Creek was deleted as a study area in 1979 due to lack of accessibility. Ponds studied in 1978 were a subset of those studied in 1979 with a few exceptions. Ponds were selected from a size range of approximately 0.04 to 40 ha and were well distributed in this range, except in the larger size classes. Few ponds were found on the study areas in the 20 to 40 ha size range. Ponds were also selected to encompass a wide range of edge indices and vegetative types. Many ponds were connected to other water areas and therefore not totally surrounded by vegetative edge. These ponds were sectioned off and treated as if discrete entities, although connections were assumed to have no edge.

The edge between vegetation and water around ponds was delineated on aerial photos. Pond areas and perimeters were then measured from these aerial photos with the use of a planimeter and map wheel respectively. Photos were taken as early as 1971. A comparison of aerial photos of Ogden Bay taken in 1978 with aerial photos taken in 1973 disclosed that although a few changes had taken place in some pond sizes and shapes due to vegetative changes, the photos were generally accurate. Cattail stands had invaded the edges of some areas. Ground comparisons on the other areas with no recent aerial photos available also showed few changes over the years.

Table 2. Numbers of ponds censused for pairs and broods at each location by year.

	1978 No. of ponds		1979 No. of ponds	
Location	Pairs	Broods	Pairs	Broods
Ogden Bay WMA	32	24	35	12
Public Shooting Grounds WMA	10	11	27	14
Salt Creek WMA	2	2	-	-
Bear River Migratory Bird Refuge	-	-	29	6
Farmington Bay WMA	-	-	27	12
TOTAL	44	37	118	37

Peripheral emergent vegetation on the ponds was categorized into gross vegetative types, and each type category was mapped on each pond. Pond depth was thought to be important to waterfowl, so mean pond depth was estimated by walking several transects across representative areas of the pond and measuring the depth at fixed intervals of 5 to 30 paces depending upon pond size. Gauges were installed in some ponds so depths could be recorded several times during the study. Depths were measured or recorded once in early July in 1978 and twice in 1979, once in late April and once in early July.

A fixed point observation system was used to census both pairs and broods. Days of waterfowl use, not actual numbers of pairs or broods, were estimated. Waterfowl pairs and broods of all species were counted. The pond was scanned once carefully with a spotting scope from a marked observation point on a given count.

It was impossible to see all the area of some ponds from a single observation point; therefore, a correction factor for the proportion of unseen area analagous to that used by Cowardin and Ashe (1965) for camera sampling was calculated. The amount of waterfowl use on the visible area for a given count was then multiplied by this factor to estimate use on the entire pond. The correction factor was calculated once in 1978 and twice in 1979 for both the pair and brood census periods, as occasionally seasonal vegetative growth obscured more area from view. Correction factors ranged up to 2.0 but 69 (58 percent) of the 118 ponds censused for pairs in 1979 had correction factors of 1.0 while 104 (88 percent) had correction factors of 1.2 or less.

Pair counts were made approximately weekly from early April to mid-June (Table 3). Censuses were not conducted on days with high winds or steady rains. A given pond was censused once per census period in 1979, while in 1978, a pond was sometimes not censused due to time limitations on a given census or occasionally was censused more than once per census. The order of census of ponds was varied to eliminate any time of day effect, because variations in waterfowl pair use of water areas at different times of the day has been noted (Sowls 1955:54-56, Diem and Lu 1960, Klett and Kirsch 1976).

Table 3. Dates of pair censuses

Census No.	1978	1979
1	April 12-16	April 4-7
2	April 22	April 16-19
3	April 26-28	April 23-26
4	May 1	April 30-May 4
5	May 7-10	May 7-12
7	May 19-21	May 21-24
8	May 25-29	May 28-31
9	June 5-7	June 4-9
10	June 14-17	June 10-13

Daily pair counts were made in the period from sunrise to approximately 1100. Pairs, lone males, and groups of up to 5 males of each dabbler species were tabulated as breeding pairs as recommended by Hammond (1969) for large marsh habitats. Females in excess of males were also tabulated as pairs (Stewart and Kantrud 1972). Redheads and ruddy ducks (Oxyura jamaicensis) often were not spaced out and all individuals were divided up into pairs or lone males and counted as breeding pairs.

In 1978, counts were taken upon arrival at a pond and then approximately 15 minutes later from the same observation point. Paired randomization tests (Green 1977) between the two counts for redhead, cinnamon teal (Anas cyanoptera), gadwall, ruddy duck, and northern shoveler failed to reveal any significant differences at the 0.05 probability level (Table 4). In 1979, therefore, a count was taken only upon arrival at the pond.

Broods on each pond were censused approximately once a week from mid-June to the end of July in both 1978 and 1979 (Table 5).

Table 4. Results of paired randomization tests (Green 1977) between pair counts taken at arrival and counts taken 10 to 20 (mostly 15) minutes after arrival when at least 1 bird was seen.

Species	df	t	Prob[1]
Redhead	22	0.432	0.710
Cinnamon teal	19	1.528	0.191
Gadwall	44	-0.275	0.900
Ruddy duck	15	-0.187	1.000
Northern shoveler	13	0.268	1.000

[1] Two-tailed probability of randomization tests; a non-parametric form of t-test.

Table 5. Dates of brood censuses

	1978		1979
Census No.	PSG & SC[1]	Ogden Bay	All study areas
1	June 14,18	June 17	June 16-19,22
2	June 24	June 23,26	June 23-26
3	July 1	July 3-6	June 30-July 3
4	July 10	July 21-22	July 7-10
5	July 24	July 26-27	July 14-17
6	July 29		July 21-26
7			July 30-August 2

[1] Public Shooting Grounds and Salt Creek

In 1978, 5 or 6 counts were taken on each pond, while in 1979, 7 counts were taken on each pond. Censuses were discontinued about August 1, because at this time many broods were fledged or ready to fledge, few broods were hatching out, and consequently brood numbers were decreasing.

Brood counts were made during both morning and afternoon hours and the order of census was varied. Normally the morning census period extended from sunrise to approximately 1100, and the afternoon period ran from approximately 1700 to sunset. These time periods coincide with the optimum times for brood counts as found by Robbins and Anderson (1956). In a few instances, censuses were run throughout the day. A count was taken upon arrival and then at 15 and 30 minutes after arrival. Broods were recorded to species, number, and age class (Gollop and Marshall 1954). Replicate observations of the same brood on a given census were eliminated using species and age class as criteria. No attempt was made to eliminate observations of the same brood from week to week.

In 1978, a given pond was censused for broods during both morning and afternoon periods on different censuses. A chi-square test failed to reveal any significant differences (X^2=1.87, df=1, P=0.172) between average numbers of broods censused per pond for these 2 time periods over all locations. During 1979, therefore, a pond was either censused exclusively in the morning or in the afternoon to take advantage of optimum light conditions. Brood location and species identification consequently were much easier in 1979.

Data analysis

Breeding chronology was first calculated for each species of breeding waterfowl by examining field observations of pair behavior, by studying changes in lone male to pair ratios, and by backdating broods. Mean daily pair use was then calculated for each pond for each species during the period of maximum breeding activity when nesting is initiated. Pair counts for each species were first adjusted by the pond correction factors and then transformed by $\log_e(x+1)$ before means were taken. The $\log_e$ transformation was taken to normalize the data.

Average daily brood use was determined by averaging over the entire brood census period. Pond correction factors were used to adjust a census count, and again a $\log_e(x+1)$ transformation was made before means were calculated. Broods were categorized by species and age class. Since a significant percentage of broods was not identified to species, total brood use was also calculated.

In order to incorporate habitat use data from all species of breeding waterfowl into one variable, a Shannon-Wiener diversity index (H') was calculated (Pielou 1974):

$$H' = -\sum_{i=1}^{s} p_i \log_e p_i$$

p_i = proportion of community (total days of use) belonging to the ith species

s = number of species censused

Breeding pair diversity was calculated only for ponds censused in 1979 with 4 counts for each species. For the 4 censuses corresponding to the breeding period of each species, the total number of indicated pair days of use (multiplied by the pond correction factor and rounded to the lowest whole number) was calculated for each pond. The index, therefore, was calculated over an entire breeding season, even though each species had its numbers totaled over only a portion of that period. Brood diversity was calculated for ponds studied in 1979 with 7 censuses. Brood use totals for each species were calculated over the entire census period. The total number of species censused (s), a simple measure of species richness, was also calculated for both pairs and broods on the same ponds for which H' was calculated.

Some preliminary calculations on the pond data were also needed to more fully analyze the waterfowl-habitat relationships. An edge index was first calculated for each pond (Patton 1975):

$$\text{Patton's Index} = \frac{TP}{2\sqrt{A\pi}}$$

TP = Perimeter of pond plus any edge within pond (m)

A = Area of pond (m^2)

$\pi = 3.142$

Patton's Index is a ratio of the amount of edge for a given area relative to the amount of edge of a circle of the same area. The index is identical to the shoreline development index used by limnologists (Reid 1961). Mean pond depths were coded into 3 classes: 1) 0-10 cm 2) 11-25 cm 3) >25 cm. The amount of each vegetative type around a pond was coded into 5 classes corresponding to the percent perimeter of that type: 0) 0-5 percent 1) 6-33 percent 3) 67-96 percent 4) 96-100 percent.

Forward stepwise multiple regression was used to relate pair or brood use (dependent variables) to the pond habitat characteristics (independent variables). Regressions were run on the Burroughs 6700 computer at Utah State University using the Statistical Package for the Social Sciences (SPSS) (Nie et al. 1975). A 0.05 probability level was used as the significance level throughout the analysis.

The independent variables measured did not take into account differences between the major study areas such as age of the marsh or predominant vegetative types. To test for the importance of the location as a factor influencing duck use, additional regressions were run. First, 3 dummy variables were coded for the 4 locations studied in 1979 with Ogden Bay the reference area (Nie et al. 1975). In 1978, only 1 dummy variable was needed as Salt Creek was coded the same as Public Shooting Grounds, and Ogden Bay was again the reference area. These dummy variables were then entered as a group into the regressions after the significant independent variables to see if any additional variation could be explained.

Multiple regressions were run on both the 1978 and 1979 data, but the 1979 regressions provided the most insight into waterfowl-habitat use relationships for several reasons. More ponds were censused in 1979 and they were spread over more locations; therefore, ponds with a wider range of vegetative types, edge indices, and depths were sampled. This made the chance of spurious conclusions based on a poor representation of different levels of factors such as vegetative type less likely. To test if factors correlated to habitat use in 1979 were the same as in 1978, the "best" regressions of duck use developed with the 1979 data were used to "predict" duck use in 1978. Chi-square tests were used to test the goodness of fit between observed levels of waterfowl use in 1978 and the expected levels of waterfowl use "predicted" by the 1979 regressions.

RESULTS

Habitat variables

Means and standard deviations of areas, edge indices, and depths of ponds used in the study are listed in Table 6. The pond depths measured in April in 1979 were used to analyze both the 1978 and 1979 pair use data. Emergent vegetation on the edge of ponds was classified into ten cover types (Table 7). Saltgrass cattail, alkali bulrush, and hardstem bulrush were the only vegetative types found in large amounts (Table 7). Some cover types were found mainly on ponds at only one or two of the major study areas.

Pair use

The nine major species of ducks breeding on the marshes were the redhead, cinnamon teal, ruddy duck, mallard, gadwall, northern shoveler, pintail (*Anas acuta*), green-winged teal (*Anas crecca*), and blue-winged teal. Other species of ducks observed during the spring breeding season which may have been breeding on the marshes in small numbers included the canvasback (*Aythya valisineria*), lesser scaup (*Aythya affinis*), and American wigeon (*Anas americana*). Pair breeding chronology for the major species of waterfowl for both years of study was very similar (Table 8). Breeding chronology was assumed to be the same on all study areas.

The mean number of indicated pair days of use per census during each respective species time of breeding in 1979 is given in Table 9. The relative amount of pair use by species was very similar in 1978. Less than 2 percent of the waterfowl observed

Table 6. Means and standard deviations of pond areas, edge indices, and depths.

	Ponds used for censuses of:			
	Pairs 1978 n=44		Broods 1978 n=37	
	Mean	SD	Mean	SD
Area (ha)	3.81	7.57	4.60	8.05
Patton's Index	2.08	0.97	2.08	0.77
Depth (cm)	21.80	12.65	16.16	12.41
Depth (coded into 3 classes)	2.16	0.68	1.70	0.66

	Pairs 1979 n=118		Broods 1979 n=44	
	Mean	SD	Mean	SD
Area (ha)	3.79	7.26	8.06	9.37
Patton's Index	2.10	0.79	2.37	0.94
Depth (cm)	21.20	13.17	20.50	11.26
Depth (coded into 3 classes)	2.09	0.73	2.07	0.63

Table 7. List of types of emergent edge with the number of ponds having more than 5 percent perimeter of each respective edge type.

	No. of ponds used for censuses of:			
Vegetative type	Pairs 1978 n=44	Broods 1978 n=37	Pairs 1979 n=118	Broods 1979 n=44
Saltgrass	27	24	78	23
Cattail	25	19	63	30
Alkali bulrush	13	13	30	12
Hardstem bulrush	7	4	24	12
Saltgrass-alkali bulrush mixture	7	8	23	8
Mud-*Salicornia*	5	5	12	8
Olney's bulrush	3	3	9	4
Phragmites (*Phragmites communis*)	3	3	3	1
Dike[1]	3	3	5	3
Other[2]	3	1	3	1

[1] Dike = Steep walled banks with a mixed vegetative type of cattail, hardstem bulrush, saltgrass, and/or upland forbs interspersed with a barren mud shoreline

[2] Other = Rice cutgrass (*Leersia oryzoides*) or Spikerush (*Eleocharis* sp.)

Table 8. Pair chronology as indicated by periods of maximum breeding activity.

	1978		1979	
Species	Dates	Census Nos.	Dates	Census Nos.
Mallard	April 12-May 1	1-4	April 4-May 4	1-4
Pintail	April 12-May 1	1-4	April 16-May 12	2-5
Cinnamon teal	May 7-29	5-8	April 23-May 18	3-6
Redhead	May 1-21	4-7	April 30-May 24	4-7
Northern shoveler	May 1-21	4-7	April 30-May 24	4-7
Ruddy duck	May 7-29	5-8	May 7-31	5-8
Gadwall	May 15-June 17	6-10	May 7-31	5-8
Green-winged teal	May 15-21	6-7	May 7-31	5-8
Blue-winged teal	May 15-21	6-7	May 7-31	5-8

Table 9. Mean breeding pair use per census during 1979 field season. Means for each species were calculated only during period when in breeding condition.

	Ogden Bay		PSG[1]		Bear River		Farmington Bay		Total	
Species	No.	%	No.	%	No.	%	No.	%	No.	%
Redhead	111	53	44	27	89	49	170	50	413	47
Cinnamon teal	35	17	36	22	20	11	25	7	115	13
Ruddy duck	11	5	1	1	8	4	88	26	108	12
Mallard	18	9	37	23	17	9	9	3	80	9
Gadwall	17	8	13	8	21	12	19	6	70	8
Northern shoveler	11	5	16	10	11	6	20	6	58	7
Pintail	3	1	8	5	10	6	3	1	22	2
Green-winged teal	1	tr	6	4	2	1	5	1	13	1
Blue-winged teal	4	2	1	1	2	1	2	1	8	1
TOTAL	211	100%	162	101%	180	99%	341	101%	887	100%

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[1] Public Shooting Grounds

were not identified to species and these birds have been ignored for purposes of analysis. Relatively more ducks went unidentified or possibly unobserved on larger ponds, so pair means by species may be slightly biased negatively for larger ponds. The observability for different species varies somewhat due to differences in size, coloration, or behavior, but probably a very high proportion of the pairs on a pond were observed.

Mean pair use by the 6 major species of breeding ducks of the group of ponds studied in both 1978 and 1979 was essentially constant (Table 10). The only exception was the higher mean pair use by cinnamon teal at Ogden Bay during 1979.

Means, standard deviations, and sample sizes (numbers of ponds) of the pair use data are given in Table 11. Means for pairs in 1979 were based on 3 to 4 censuses for each species while means in 1978 were based on 2 or more censuses. The $\log_e$ transformation of the data reduced the magnitude of deviations from normality in the data, but the large number of ponds with no duck use by a given species (Table 12) caused the distribution of the data to be skewed to the right. This deviation from assumptions of the multiple regression technique makes F statistics and probability levels calculated by this method somewhat questionable. For a given species, many of the ponds with no use were 0.20 ha in area or less.

An examination of scattergrams of area versus pair use revealed the presence of a strong relationship. A $\log_e(x+1)$ transformation of area was found to fit the data as well or better than area alone as evidenced by simple correlation coefficients. The $\log_e$

Table 10. Mean pair use comparisons of the group of ponds censused in both 1978 and 1979.

	Ogden Bay			Public Shooting Grounds		
Species	df	t	Prob[1]	df	t	Prob[1]
Redhead	18	0.98	0.349	9	1.05	0.313
Cinnamon teal	20	-4.16	0.001	9	0.23	0.904
Ruddy duck	20	0.98	0.379	9	1.51	0.250
Mallard	17	0.16	0.883	-	-	-
Gadwall	21	-0.97	0.101	9	-0.73	0.541
Northern shoveler	18	-1.33	0.210	9	1.02	0.336

[1] Two-tailed probability of randomization tests; a non-parametric form of t-test.

Table 11. Means and standard deviations of pair observations (data transformed by $\log_e(x+1)$ before means taken except for No. of species and Diversity).

	1978			1979		
Species or group	n	Mean	SD	n	Mean	SD
Redhead	33	1.26	1.02	118	0.93	1.00
Cinnamon teal	35	0.62	0.66	118	0.48	0.48
Ruddy duck	35	0.30	0.49	118	0.32	0.62
Mallard	18	0.25	0.31	118	0.35	0.45
Gadwall	36	0.42	0.40	118	0.33	0.41
Northern shoveler	33	0.42	0.47	118	0.26	0.39
Pintail	18	0.07	0.12	118	0.12	0.24
Green-winged teal	31	0.11	0.26	118	0.06	0.20
Blue-winged teal	31	0.09	0.23	118	0.05	0.12
No. of species (s)	-	-	-	107	4.31	2.28
Diversity (H')	-	-	-	107	0.84	0.45

Table 12. Number and percentage of ponds having no pair use by a particular species.

	1978		1979	
Species	No.[1]	Percent	No.[1]	Percent
Redhead	5	15	35	30
Cinnamon teal	8	23	29	25
Ruddy duck	22	63	78	66
Mallard	8	44	40	34
Gadwall	8	22	47	40
Northern shoveler	11	33	54	46
Pintail	13	72	80	68
Green-winged teal	25	81	103	87
Blue-winged teal	26	84	98	83

[1] Numbers of ponds with no use. For total pond numbers by species and year see Table 11.

transformation of area was subsequently used in place of area in the multiple regressions. The fit of other functions of area to the data, especially those with a maximum, was also examined, but there was no evidence of other better fitting functions in either the 1978 or 1979 data.

Multiple regressions were run separately for pair use in both 1978 and 1979. For input into the SPSS program REGRESSION, each dependent and independent variable was given a mnemonic variable name (Table 13). Regressions by species were run on pair use data for redhead, ruddy duck, cinnamon teal, mallard, gadwall, and northern shoveler. Sample sizes were too small for pintail, green-winged teal, and blue-winged teal for regressions to be run. Mallard use was measured on too small a sample of ponds in 1978 for regressions to be meaningful.

Some ponds censused for pairs in 1978 had less than two counts for some species, and no means were calculated for that species at those ponds. Pair data for 1978, therefore, are unbalanced because each species had a different set of ponds for which means were calculated. Correlation matrices for the 1978 data vary by species for reasons discussed above, but as an example, the correlation matrix for gadwalls is given in Appendix A. The correlation matrix for the 1979 pair use data is also given in Appendix A. Pair use diversity and number of species was not calculated on some ponds in 1979 as eleven ponds dried up and were not censused a total of four times for each species. Therefore, the correlation matrix for these two variables is somewhat different. None of the correlation

Table 13. Mnemonic names of variables input into SPSS programs.

Independent variables		Dependent variables	
Variable	Mnemonic	Variable	Mnemonic
Area of pond (ha)	AREA	Redhead[1]	RH
$\log_e$(AREA+1)	TRAREA	Cinnamon teal[1]	CT
Coded pond depths	DEP[2]	Ruddy duck[1]	RD
Patton's Index	PI	Mallard[1]	MAL
Vegetation:[3]		Gadwall[1]	GW
Saltgrass	SG	Northern shoveler[1]	SH
Cattail	CT	No. of species (s)	NOSPEC
Alkali bulrush	ABR	Shannon-Wiener Index (H')	DIV2
Hardstem bulrush	HSBR		
Saltgrass-alkali bulrush mixture	SGABR		
Mud-*Salicornia*	MUD		
Olney's bulrush	OBR		
Phragmites	PHRAG		
Dike-steep walled banks-mixed veg.	DIKE		
Other-Rice cut-grass-spikerush	OTHER		

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[1] Values transformed by $\log_e(x+1)$ before means taken

[2] Depths coded: 1) 0-10 cm 2) 11-25 cm 3) >25 cm

[3] Vegetation coded: 0) 0-5% 1) 6-33% 2) 34-66% 3) 67-95% 4) 96-100%

among the independent variables exceeded 0.80, therefore, no variables were dropped from the analysis because of multicollinerity (Nie et al. 1975).

Variables significant at the 0.05 probability level in the multiple regressions, along with regression coefficients (B), standard errors of B, F ratios, probability levels, and coefficients of multiple determination (R^2) for a given species for both the 1978 and 1979 data are given in Tables 14 and 15, respectively. All pair use regression equations were significant at the 0.001 probability level.

The regression models explained from 43 to 77 percent of the variation in pair use for the 6 major species of breeding ducks. About one-half the variation in pair use diversity and species richness was explained by the regression equations. Area, transformed by $\log_e(x+1)$, was significant in all regression equations except 1 and explained 31 to 70 percent of the variation in pair use in the equations for which it was significant.

When location was added as a factor to the regression equations developed, about one-half the time it was significant at the 0.05 level in explaining additional variation in pair use (Table 16). Location was found to be significant much more frequently in 1979 when more locations were studied. Reductions in the amount of unexplained variation ranged from 2 to 12 percent. Location had no significant effect on either pair species richness or diversity.

The 1979 regressions are most valuable because sample sizes were greater than in the 1978 regressions, making the chance of spurious conclusions less likely. Chi-square tests run between the observed levels of pair use in 1978 and the expected levels of

Table 14. Pair use multiple regressions by species with 1978 data.

Dependent[1] Variable	Independent[1] Variable	B	S.E. (B)	F_{var}	Prob.	R^2	R^2 change
RH	TRAREA	1.052	0.148	50.43	<0.001	0.45	-
n=33	OBR	-0.689	0.205	11.32	0.002	0.54	0.09
	MUD	-0.843	0.270	9.73	0.004	0.61	0.07
	OTHER	-1.552	0.700	4.92	0.035	0.67	0.06
	constant	0.400					
CT	OBR	0.697	0.140	24.96	<0.001	0.31	-
n=35	SG	0.230	0.053	18.85	<0.001	0.51	0.20
	TRAREA	0.196	0.073	7.11	0.012	0.60	0.09
	constant	-0.059					
RD	TRAREA	0.425	0.072	35.33	<0.001	0.38	-
n=35	MUD	-0.445	0.140	10.03	0.003	0.53	0.15
	constant	-0.079					
GW	TRAREA	0.323	0.040	66.18	<0.001	0.60	-
n=36	OBR	-0.193	0.076	6.48	0.016	0.67	0.07
	constant	0.105					
SH	MUD	0.417	0.103	16.50	<0.001	0.27	-
n=33	OBR	0.462	0.100	21.21	<0.001	0.52	0.25
	SG	0.086	0.038	5.01	0.033	0.59	0.07
	constant	0.115					

[1] Variable mnemonics from Table 13.

Table 15. Pair use multiple regressions with 1979 data.

Dependent[1] Variable	Independent[1] Variable	B	S.E. (B)	F_{var}	Prob.	R^2	R^2 change
RH	TRAREA	0.829	0.050	277.40	<0.001	0.70	-
n=118	CAT	0.130	0.035	13.98	<0.001	0.74	0.04
	MUD	-0.406	0.115	12.51	<0.001	0.77	0.03
	constant	0.083					
CT	TRAREA	0.286	0.035	66.45	<0.001	0.33	-
n=118	CAT	-0.103	0.025	17.05	<0.001	0.41	0.08
	PI	0.100	0.044	5.14	0.025	0.44	0.03
	constant	0.141					
RD	TRAREA	0.401	0.041	95.35	<0.001	0.47	-
n=118	CAT	0.129	0.029	20.30	<0.001	0.57	0.10
	MUD	-0.222	0.095	5.49	0.021	0.59	0.02
	constant	-0.172					
MAL	TRAREA	0.274	0.034	65.59	<0.001	0.36	-
n-118	CAT	-0.058	0.024	5.75	0.018	0.39	0.03
	OBR	0.211	0.094	5.06	0.026	0.41	0.02
	PI	0.091	0.042	4.65	0.033	0.43	0.02
	constant	-0.040					
GW	TRAREA	0.273	0.026	115.02	<0.001	0.52	-
n=118	PI	0.109	0.034	10.51	0.002	0.55	0.03
	DEP	-0.091	0.036	6.39	0.013	0.57	0.02
	constant	0.045					
SH	TRAREA	0.225	0.028	65.19	<0.001	0.43	-
n=118	MUD	0.166	0.066	6.32	0.013	0.46	0.03
	constant	0.031					
NOSPEC	TRAREA	1.456	0.153	90.96	<0.001	0.47	-
n=107	CAT	-0.481	0.159	9.08	0.003	0.52	0.05
	PI	0.618	0.200	9.53	0.003	0.54	0.02
	DEP	-0.635	0.251	6.41	0.013	0.56	0.02
	SG	-0.350	0.147	5.66	0.019	0.58	0.02
	constant	4.125					
DIV2	TRAREA	0.223	0.035	41.31	<0.001	0.34	-
n=107	CAT	-0.154	0.033	22.06	<0.001	0.46	0.12
	SG	-0.069	0.031	5.06	0.027	0.48	0.02
	PI	0.109	0.041	7.23	0.008	0.51	0.03
	MUD	0.165	0.076	4.75	0.032	0.53	0.02
	constant	0.672					

[1] Variable mnemonics from Table 13.

Table 16. Tests for effect of location on pair use.

1978 Models

Dependent[1] Variable	F	Prob	R^2 w/o loc	R^2 w/loc	R^2 change
RH	3.67	0.066	0.67	NS[2]	NS[2]
CT	0.40	0.533	0.60	NS	NS
RD	0.19	0.663	0.53	NS	NS
GW	0.53	0.470	0.67	NS	NS
SH	6.13	0.020	0.59	0.66	0.07

1979 Models

Dependent[1] Variable	F	Prob	R^2 w/o loc	R^2 w/loc	R^2 change
RH	3.41	0.020	0.77	0.79	0.02
CT	5.75	0.001	0.44	0.51	0.07
RD	10.19	<0.001	0.59	0.68	0.09
MAL	9.49	<0.001	0.43	0.55	0.12
GW	3.39	0.021	0.57	0.61	0.04
SH	0.55	0.647	0.46	NS	NS
NOSPEC	1.73	0.166	0.58	NS	NS
DIV2	2.27	0.085	0.53	NS	NS

[1] Variable mnemonics from Table 13.

[2] Change in R^2 not significant at 0.05 level.

pair use "predicted" by the 1979 regressions failed to reveal ($P > 0.50$) a significant lack of fit. This indicated the 1979 regression models fit the 1978 data as well, and thus the 1979 models are validated over the two years of study.

Brood use

The total number of observations of brood use by each species is given in Table 17. Significant numbers of broods could not be identified to species. Because of the difficulty in classifying broods of the 3 species of teal breeding on the marshes to species, all observations of these species were simply tabulated as "teal" use. Only a few of the teal observations were likely to have been blue-winged or green-winged teal.

On a given pond census, most broods were initially observed on the count immediately after arrival at a pond with varying numbers subsequently observed on the counts 15 and 30 minutes after arrival (Table 18). By waiting 30 minutes per pond, more representative numbers of dabbler broods were seen in relation to numbers of diver broods. Some broods undoubtedly were never seen, and brood observability varied markedly by species. The number of observations of broods of a given species was assumed to be proportional to actual use of the pond by that species.

Brood observations peaked about the middle of July in both 1978 and 1979 (Table 19). At this time, many early hatched broods have yet to fledge, and most late hatching broods have come off

Table 17. Total observed days of brood use by species and year.

1978 data

Species	Ogden Bay		PSG[1]		Salt Creek		Total	
	No.	%	No.	%	No.	%	No.	%
Redhead	18	40	84	43	12	60	114	44
Ruddy duck	7	16	-	-	3	15	10	4
Mallard	7	16	15	8	3	15	25	10
Teal	-	-	10	5	1	5	11	4
Gadwall	4	9	12	6	1	5	17	7
Pintail	-	-	7	4	-	-	7	3
Northern shoveler	-	-	5	3	-	-	5	2
Unidentified	9	20	63	32	-	-	72	28
TOTAL	45	101%	196	101%	20	100%	261	102%

1979 data

Species	Ogden Bay		PSG[1]		Bear River		Farmington Bay		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Redhead	66	55	63	50	6	8	84	44	219	42
Ruddy duck	11	9	1	1	3	4	75	39	90	17
Mallard	9	8	26	20	14	18	10	5	59	11
Teal	11	9	19	15	16	20	7	4	53	10
Gadwall	11	9	-	-	28	35	4	2	43	8
Pintail	-	-	1	1	3	4	2	1	6	1
Northern shoveler	2	2	4	3	-	-	-	-	6	1
Unidentified	9	8	13	10	10	13	10	5	42	8
TOTAL	119	100%	127	100%	80	102%	192	100%	518	98%

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[1] Public Shooting Grounds

Table 18. Total brood observations by count number, 1978 and 1979 data combined.

	Count Number							
	1*		2*		3*		Total	
Species	No.	%	No.	%	No.	%	No.	%
Redhead	247	74	48	14	38	11	333	99
Ruddy duck	64	64	22	22	14	14	100	100
Mallard	42	50	19	23	23	27	84	100
Teal	27	42	24	38	13	20	64	100
Gadwall	42	70	16	27	2	3	60	100
Other dabblers	37	52	16	23	18	25	71	100
All broods	498	64	163	21	118	15	779	100
Class I	183	56	89	27	57	17	329	100
Class II	183	70	44	17	34	13	261	100
Class III	49	72	11	16	8	12	68	100

*Count 1 taken upon arrival, Count 2 taken 15 minutes after arrival, Count 3 taken 30 minutes after arrival.

Table 19. Brood observations by census number. Dates of census numbers by year given in Table 5.

1978-Public Shooting Grounds and Salt Creek combined

Species	Census No. 1	2	3	4	5	6
Redhead	10	16	16	20	19	15
Ruddy duck	-	-	-	-	1	2
Mallard	9	2	2	2	-	3
Teal	2	3	3	-	1	2
Gadwall	-	-	-	7	4	2
Pintail	4	2	-	1	-	-
Northern shoveler	1	-	1	3	-	-
Unidentified	9	15	20	12	5	2
TOTAL	35	38	42	45	30	26

1978-Ogden Bay

Species	Census No. 1	2	3	4	5
Redhead	-	2	1	11	4
Ruddy duck	1	-	1	3	2
Mallard	2	1	3	1	-
Teal	-	-	-	-	-
Gadwall	-	-	1	3	-
Pintail	-	-	-	-	-
Northern shoveler	-	-	-	-	-
Unidentified	-	1	1	6	1
TOTAL	3	4	7	24	7

1979-All locations combined

Species	Census No. 1	2	3	4	5	6	7
Redhead	25	22	31	44	36	35	26
Ruddy duck	8	10	10	20	14	17	11
Mallard	8	11	10	14	10	6	-
Teal	6	4	9	13	10	9	2
Gadwall	-	3	4	5	6	15	10
Pintail	1	-	1	3	1	-	-
Northern shoveler	1	-	-	1	1	2	1
Unidentified	3	4	5	8	11	7	4
TOTAL	52	54	70	108	89	91	54

the nest. Peaks of observed brood use for a given species varied with breeding chronology.

Randomization tests indicated that observed brood use of the study ponds was not constant from 1978 to 1979. At Ogden Bay, the mean total brood use at 10 ponds was significantly ($t=-2.90$, $P=0.020$) higher in 1979, while at Public Shooting Grounds, mean total brood use at 8 ponds was higher in 1978 ($t=2.73$, $P=0.039$). Given the lack of differences in mean pair use over the 2 years on the two areas (Table 10), the contrary trends in mean brood use suggest differences in productivity or distribution of broods from 1978 to 1979 which varied by location.

Means, standard deviations, and sample sizes (number of ponds) of the brood observation data are given in Table 20. The data were pooled to form the groups, dabblers and total broods, because of small sample sizes for individual species. Brood observation means were based on four to six censuses in 1978, while means in 1979 were calculated on five to seven censuses. As for pairs, the distribution of the data was skewed due to the number of ponds having no use by a given species (Table 21). Larger ponds were selected for study in 1979 because ponds less than 0.50 hectare in area had essentially no brood use in 1978.

Multiple regressions could not be run for some species due to small sample sizes. Therefore, brood observation data were analyzed for two species, redhead and ruddy duck (1979 data only), and the two groups, dabblers and total broods. Correlation matrices for the 1978 and 1979 data are given in Appendix B. Brood diversity and species richness could not be calculated for some ponds in

Table 20. Means and standard deviations of brood observations (data transformed by $\log_e(x+1)$ before means taken except for No. of species and diversity)

	1978			1979		
Species or group	n	Mean	SD	n	Mean	SD
Redhead	37	0.24	0.41	44	0.38	0.43
Ruddy duck	37	0.03	0.08	44	0.18	0.34
Mallard	37	0.08	0.12	44	0.14	0.15
Teal	37	0.04	0.09	44	0.12	0.18
Gadwall	37	0.05	0.10	44	0.10	0.24
Pintail	37	0.03	0.09	44	0.02	0.05
Northern shoveler	37	0.02	0.06	44	0.02	0.08
Class 1	37	0.25	0.34	44	0.43	0.38
Class 2	37	0.21	0.33	44	0.34	0.35
Class 3	37	0.09	0.20	44	0.08	0.15
Dabblers	37	0.22	0.29	44	0.38	0.39
Total broods	37	0.46	0.60	44	0.78	0.60
No. of species (s)	-	-	-	39	2.76	1.46
Diversity (H')	-	-	-	39	0.53	0.39

Table 21. Number and percentage of ponds having no brood use by a particular species or group.

	1978 n=37		1979 n=44	
Species or group	No.[1]	Percent	No.[1]	Percent
Redhead	24	65	15	34
Ruddy duck	32	86	28	64
Mallard	24	65	17	39
Teal	30	81	23	52
Gadwall	28	76	32	73
Pintail	33	89	39	89
Northern shoveler	34	92	41	93
Class 1	18	49	9	20
Class 2	22	60	12	27
Class 3	25	68	30	68
Dabblers	18	49	9	20
Total broods	13	35	3	7

[1] Numbers of ponds with no use. For total pond numbers by species or group and year see Table 21.

1979 because they dried up and were not censused seven times. The correlation matrix, therefore, for these variables is slightly different from the 1979 matrix given. Multicollinearity among independent variables was not a problem. The $\log_e$ transformation of area was found to explain more variation in brood use than simple area with the exception of redhead use. Therefore, transformed data were used in the regressions.

The proportion of variation in the data explained by the regressions ranged from 16 to 77 percent (Table 22). The fit of the statistical models to the data was much better in 1978 than in 1979. Usually much less than one-half the total variation in brood use in 1979 was explained by the regressions. The $\log_e$ transformation of the area accounted for a large proportion of the explained variation in brood use and was significant in every regression.

Location was significant in only two of the eight regression equations for brood use (Table 23) In the equations for which it was significant, location explained 21 and 26 percent more of the total variation. Location was not significantly related to either brood species richness or diversity.

Chi-square tests run between the observed levels of brood use in 1978 and the expected levels of brood use "predicted" by the 1979 regressions failed to reveal ($P > 0.50$) a lack of fit. The 1979 models are therefore validated over the 2 years of study. In general, however, they explained less than one-half of the variation in brood use and so are of limited predictive value.

Table 22. Brood use multiple regressions.

1978 data

Dependent[1] Variable	Independent[1] Variable	B	S.E. (B)	F_{var}	Prob	R^2	R^2 Change
RH	MUD	0.214	0.096	4.91	0.034	0.45	-
n=37	SG	0.129	0.029	19.40	<0.001	0.53	0.08
	TRAREA	0.176	0.049	12.81	<0.001	0.66	0.13
	DEP	0.161	0.060	7.18	0.012	0.72	0.06
	constant	-0.466					
DABBLE	TRAREA	0.114	0.038	9.14	0.005	0.46	-
n=37	MUD	0.280	0.072	15.00	<0.001	0.63	0.17
	constant	0.035					
TOT	TRAREA	0.414	0.052	62.32	<0.001	0.50	-
n=37	SG	0.201	0.037	30.08	<0.001	0.69	0.19
	DEP	0.269	0.079	11.63	0.002	0.77	0.08
	constant	-0.763					

1979 data

Dependent[1] Variable	Independent[1] Variable	B	S.E. (B)	F_{var}	Prob	R^2	R^2 change
RH	TRAREA	0.216	0.054	15.75	<0.001	0.22	-
n=44	DEP	0.211	0.091	5.36	0.026	0.31	0.09
	constant	-0.421					
RD	ABR	0.244	0.090	7.25	0.010	0.14	-
n=44	TRAREA	0.116	0.044	6.92	0.012	0.26	0.12
	constant	-0.089					
DABBLE	TRAREA	0.161	0.050	10.59	0.002	0.18	-
n=44	ABR	-0.235	0.102	5.36	0.026	0.28	0.10
	constant	0.179					
TOT	TRAREA	0.376	0.065	33.38	<0.001	0.41	-
n=44	PI	0.166	0.073	5.23	0.027	0.48	0.07
	constant	-0.249					
NOSPEC	TRAREA	0.553	0.208	7.04	0.011	0.16	-
n=39	constant	1.773					
DIV2	TRAREA	0.158	0.054	8.55	0.006	0.19	-
n=39	constant	0.249					

[1] Variable mnemonics from Table 13 except: DABBLE = Total dabbler brood use, TOT = Total brood use.

Table 23. Tests for effect of location on brood use.

		1978 Models			
Dependent Variable[1]	F	Prob	$R^2_{w/o\ loc}$	$R^2_{w/loc}$	R^2_{change}
RH	1.47	0.235	0.72	NS[2]	NS[2]
DABBLE	3.33	0.077	0.63	NS	NS
TOT	3.48	0.071	0.77	NS	NS

		1979 Models			
Dependent Variable[1]	F	Prob	$R^2_{w/o\ loc}$	$R^2_{w/loc}$	R^2_{change}
RH	1.32	0.282	0.31	NS	NS
RD	5.14	0.004	0.26	0.47	0.21
DABBLE	7.29	<0.001	0.28	0.54	0.26
TOT	0.13	0.942	0.48	NS	NS
NOSPEC	0.97	0.419	0.16	NS	NS
DIV2	1.34	0.278	0.19	NS	NS

[1] Variable mnemonics from Table 13 except: DABBLE = Total dabbler brood use, TOT = Total brood use.

[2] Change in R^2 not significant at 0.05 level.

DISCUSSION

Uses of multiple regression

Multiple regression has become a standard means of analyzing an animal's response to habitat characteristics where levels of habitat use can be measured. Lokemoen (1973), Patterson (1976), and Flake et al. (1977) used multiple regression to analyze duck use in relationship to habitat characteristics. Others have used regression in attempts to quantify relationships between habitat and other animals (Anderson et al. 1972, Shannon et al. 1975, Slough and Sadlier 1977, Schijf 1978, Gephart 1979, and others). The success of the method in quantifying habitat use relationships in these studies has been variable.

The results of the regressions must be interpreted carefully. A statistically significant relationship in the context of a regression does not necessarily imply cause and effect. An animal may not be responding to the habitat characteristic measured, but may instead be keying in on another factor whose presence is correlated with the measured habitat variable. Further, assuming an animal reacts in a linear way to some habitat characteristic may be simplistic because an animal's responses to and interactions with its environment are often complex (Moen 1973).

A regression model, however, may be valuable if it reliably predicts habitat use, even though measured habitat characteristics are not in themselves important to the animals. Managers can use the models as guidelines from which the potentials of a habitat can be evaluated. The relative worth of measured components of the habitat may also be evaluated. The results of this study must be evaluated with these limitations and potentials of the multiple regression analysis in mind.

Pair use by species

The area of the pond was the variable most strongly related to pair use (Table 15). This result is in agreement with previous studies (Evans and Black 1956, Lokemoen 1973, Patterson 1976, and others). Several methods were used in attempts to find an optimum pond size. An optimum might be where the amount of pair use was maximized or where the intensity of pair use was maximized. Pair use was found to increase with area through the size range of ponds studied; therefore, no optimum was evident in this respect.

Relative intensity of use by pairs is not easily evaluated. It is not statistically valid to regress pair use per area against area, as there is a significant sampling correlation between area and its reciprocal. The form of the relationship between pond area and pair use by the 4 most common species is shown in Figure 2. Pair use by redheads kept increasing with area much faster than did pair use by the other species of ducks. The relative increase in pair use with a doubling of area is less than double, therefore, the intensity of use of smaller ponds is greater. This relationship indicates that small water areas are best for breeding pairs as concluded by Evans and Black (1956) and Jenni (1956). Due to the form of the relationships, the greatest intensity of pair use would be on ponds of zero area where pair use would be nil, therefore no optimum could be found.

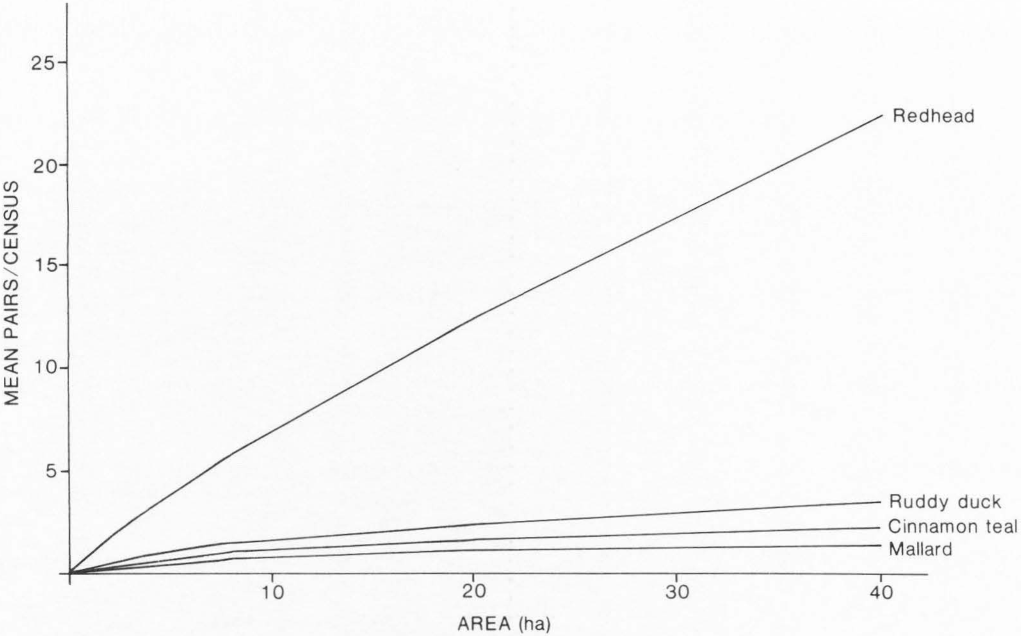

Figure 2. Derived plot of pair use versus pond area for the 4 most common species of breeding waterfowl.

Area effects are confounded with edge effects. For a pond to be an entity, it must have both an area and an edge. Pond area and perimeter were very highly correlated on ponds used in the study. It was impossible to pick ponds within the range of pond areas studied in order to break up the correlation. In the 118 ponds examined for pair use in 1979, the correlation between area and perimeter was 0.915. Patton's Index is a means of isolating edge effects from area effects. It too, however, was sometimes correlated to area, though not highly (see Appendices A and B). Larger ponds are more likely to have bays and indentations than small ponds.

Patton's Index was not significant in any of the 1978 pair use regressions, but it was significant in several of the 1979 regressions. Pair use by cinnamon teal, mallard, and gadwall were all significantly related to Patton's Index. The index explained from 2 to 3 percent of the variation in pair use. Perhaps more variation would have been explained if the range of edge indices had been greater, but the greatest edge index of a pond was 5.90. Few ponds with extremely irregular shapes were to be found on the marshes.

Patton's Index was positively related to habitat use by cinnamon teal, mallard, and gadwall. All these species openly engage in agonistic behavior such as pursuit flights (McKinney 1965). Perhaps the relationships are linked to the effect of edge in forming visual barriers which increase the capacity of a pond to hold agonistic pairs. The lack of a significant relationship between use by northern shovelers and the index could be due to small sample sizes, for they typically exhibit pursuit flights and other territorial behavior during the breeding season (Seymour 1974a,b). Redheads and ruddy ducks are not territorial and display only low levels of agonistic behavior (Lokemoen 1966, Siegfried 1976), therefore, edge would not be expected to be important for these species on a behavioral spacing basis.

Pair use was also related to the other habitat variables measured, though significant factors varied by species. Depth was significant only in the 1979 regressions of gadwall use, and it explained only a small amount of variation. Mean pond depths were usually much less than 50 cm and did not exceed 1 m. With such a small range of pond depths, a significant relationship to pair use was unlikely.

The amount of certain edge types was significant in nearly every regression of pair use by species. The amount of mud or *Salicornia* edge was negatively related to use by redheads and ruddy ducks but positively related to use by northern shovelers. These relationships were evident through both years of study. Ponds with large amounts of cattail edge were used more heavily by redheads and ruddy ducks but less heavily by cinnamon teal and mallards in 1979. These differences in species response to an edge type presumably reflect specific preferences for types of nesting cover, loafing sites, and feeding areas. Differences in habitat preferences by divers and dabblers are most evident. Such habitat differences have been discussed in the literature for some time (Hochbaum 1944).

Some edge types were of minor importance, and little may be said of their possible influence on pair use. Conclusions based on the significant relationships between use by four species of ducks and the amount of Olney's bulrush edge in the 1978 regressions (Table 14) are tentative as only three of the 44 ponds studied in 1978 had more than 5 percent Olney's bulrush edge (Table 7). Other edge types may have major effects on pair use, but due to small sample sizes, they had no statistically significant relationship.

The results of this study compare well to Flake et al. (1977), who reported R^2 values ranging from 0.34 to 0.65 in multiple regressions explaining habitat use by four species of dabbling ducks of stock ponds in South Dakota. They also found species-specific preferences of emergent vegetation characteristics, though they did not delineate edge types on a plant species basis. Mean emergent vegetation height, percent pond hemi-marsh, percent pond dense marsh, and emergent vegetation height diversity were some of the factors they found to be significant in the regressions. One variable found by both Lokemoen (1973) and Flake et al. (1977) to be related to pair use of several species of dabblers was distance to other water. It may not be important on the Utah study areas because ponds generally were spaced fairly closely.

One limitation of the models is that pair use is evaluated on only 1 pond even though ducks use a number of ponds in their breeding home range (Dzubin 1955, Gilmer et al. 1975, Derrickson 1978). Different ponds could be used for different purposes such as feeding or loafing, so behavioral observations would be needed to determine the actual reasons for use of particular ponds.

The significant effect of location in some of the regressions suggests that site specific environmental characteristics are also important to waterfowl. Perhaps use of an area is influenced by tradition or good reproductive success by that species in the past. Such effects indicate that the models are very site specific and cannot safely be generalized over a wide geographical area.

Pair use diversity

Meaningful data for analysis of pair use diversity were collected only during 1 year of study. The number of species and the Shannon-Wiener Index (H') were highly correlated ($r=0.941$, $P<0.001$), so factors influencing both are basically the same. Area was most highly related to pair species richness and diversity. The size of the pond calculated to have average pair diversity was 0.30 ha.

Cattail was the second most important factor influencing diversity, and it was negatively related in the regression equation. The presence of cattail edge has previously been shown to be detrimental to pair use (Keith 1961), but its negative influence on species diversity has not been quantified. Apparently, cattail edge was attractive to redheads and ruddy ducks, but depressed pair use by dabblers (Table 15).

The edge index was positively related to diversity although its relative contribution to reduction of unexplained variability was small. As behavioral intolerance between species has not been noted, the contribution of edge to diversity may be due to any number of factors. Since the regressions explain only about one-half the variation and only 1 year of data are available, perhaps not too much emphasis should be placed on the data. The concept of diversity is itself open to many interpretations (Peet 1974).

Brood use

Observed brood use was only a small fraction of the observed pair use. Due to differences in behavior, broods were much more difficult to observe; also, only a fraction of the brood hens on the marshes hatched a brood. The large numbers of unidentified broods and small sample sizes reduced the usefulness of a breakdown of brood use by species. Redheads and ruddy ducks were the easiest species to identify, so unidentified broods are heavily weighted toward other species. On larger ponds, broods were more difficult to identify to species, therefore, the total numbers of broods observed is probably most valuable as an index to use. It must be remembered, however, that 42 to 44 percent of the total observations were of redhead broods.

Of the habitat variables examined, area was the most important factor influencing brood use, though other factors were sometimes significant (Table 22). The form of the relationship between area and brood use was similar to that for pairs, hence, no optimum was found. Depth was found to be positively correlated to redhead brood use in both years of study. Other factors influencing dabbler and total brood use varied by year. The edge index was significant in 1979 for total broods, but in the group, dabblers, for whom one might expect edge to be important as escape cover, no relationship was evident. Perhaps dabblers are much harder to see where escape cover is very accessible.

When location was significant, it explained nearly as much variation as all habitat variables combined (Table 23). Ruddy duck brood use was significantly higher ($P < 0.05$) at Farmington Bay where ruddy duck pair numbers were also very high in comparison to the other areas (Table 9). Brood numbers, in this instance, presumably reflect pair numbers. Dabbler brood use in 1979 was significantly higher ($P < 0.05$) at Bear River in comparison to the other study areas. The greater use of the Bear River ponds by dabblers was probably due to dry conditions on the refuge which forced broods to concentrate on the few ponds still flooded.

In comparison to the regressions of pair use, brood use was much less well explained. The low reliability of brood use regressions is probably caused by broods responding to factors not measured in the study. Food abundance is a factor that was not measured and is widely believed to influence brood use of habitat (McKnight and Low 1969, Patterson 1976, Eriksson 1978). Lokemoen (1973) measured several habitat characteristics which were significantly related to brood use of North Dakota stock ponds and were not measured in this study. The habitat characteristics of importance were pond age, turbidity, and distance to adjacent ponds.

Use of ponds could be related to availability of water rather than habitat characteristics of the ponds. Some ponds go dry during the brood season, particularly shallow ponds with a saltgrass or alkali bulrush edge. At Bear River, most small ponds were dry by early July, the beginning of the peak of the brood season. If all the ponds in an area go dry but one, broods have no choice of habitat types.

Brood use diversity

Variations in brood use diversity and number of species were not well explained by the habitat characteristics studied (Table 22). Both variables were highly correlated ($r=0.931$, $P<0.001$), and only area had any significant relationship to brood use diversity or species richness. The low predictive capabilities of the regressions can probably be linked to low levels of brood observations, large numbers of unidentified broods, and unidentified, important habitat characteristics.

SUMMARY AND CONCLUSIONS

Habitat use by breeding waterfowl was studied on ponds on several Great Salt Lake marshes. Multiple regressions, with the effect of location included, explained from 53 to 79 percent of the variation in pair use by species. From 31 to 77 percent of the variation in brood use by groups or species was explained. Pair and brood use diversity were generally less well explained.

Area of the pond was the variable most highly related to both pair and brood use, but other habitat characteristics were also significantly related to use. Edge effects were confounded with effects of area, although a calculated edge index reduced this confounding. The edge index was significantly related to pair habitat use by 3 species of dabblers, but it explained relatively little of the total variation. Total brood use in 1979 was also significantly related to the edge index. The amount of certain emergent vegetative edge types, categorized by species, also had a significant influence on both pair and brood use. Depth was of minor importance in influencing either pair or brood use. Pair use diversity was influenced by both Patton's Index and the amount of certain emergent edge types.

Due to the variability inherent in biological systems and the crudeness of the methods used in estimating duck use and quantifying environmental variables, regression models with R^2 values approaching 0.90 are not to be expected. Hence, the results obtained are not trivial. It is important to note that the pair use by redheads and total brood use, for which sample sizes were greatest, had the largest portion of variation explained by the habitat variables measured. The validation of the 1979 regressions with the 1978 data indicates the measured variables are important from year to year.

Management implications of the study are several. The regressions explain a large portion of the variation in pair use and so the measured variables are reliably linked to pair use. With these regressions, therefore, some ideas can be obtained on how to manipulate the habitat to favor a given species or to maximize species richness or diversity. By manipulating habitat to increase pair use of a group of ponds, overall pair populations should be increased.

There is a danger in applying these findings to management schemes. The physical environmental variables measured in the study are probably only a few of the proximate factors used by the birds in selecting habitat. Ultimate factors characterizing optimal habitat for ducks are closely linked to these proximate factors in natural environments. Management techniques designed to modify the environment to enhance levels of important proximate factors could create artificial systems which are not truly optimal habitat. Management schemes which work with natural processes to change the environment should be used so this danger is minimized.

Explained variation in observed brood use was lower than for pairs, which indicates more work needs to be done to evaluate factors influencing habitat use by broods. Unfortunately, sample sizes are so small it is difficult for progress to be made in this area. During the course of the study, broods were observed on almost all water areas available during the brood season.

This indicates brood habitat requirements are not so rigid as to be fixed to a certain type of pond. Therefore, perhaps most emphasis should be placed on evaluating a habitat's attractiveness to breeding pairs, as broods can probably fend for themselves. Also if few breeding pairs of a given species have been attracted to an area, the suitability of an area as brood habitat is of little consequence.

The regression models developed are directly applicable only to Great Salt Lake marshes. These marshes are not typical of the entire breeding range, but they are a locally important breeding grounds, especially for the redhead and cinnamon teal. Although the study is local in scope, it is important to evaluate breeding habitat use by waterfowl on this excellent waterfowl habitat. In order for waterfowl populations to be maintained, all remaining sectors of the breeding range have to be made more productive of waterfowl. This study provides some insight into the factors influencing habitat use by breeding waterfowl, which in turn are linked to production capabilities of the Great Salt Lake marshes.

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APPENDICES

Appendix A

Pair use correlation matrices

Part 1. Correlation matrix of habitat variables associated with pair use by gadwall in 1978. Variable mnemonics from Table 13.

	TRAREA	DEP	PI	MUD	SG	ABR	OBR	CAT	HSBR	PHRAG	DIKE	SGABR	OTHER
DEP	0.141												
PI	0.348	0.232											
MUD	0.601	-0.014	-0.063										
SG	-0.137	-0.524	-0.218	0.155									
ABR	-0.274	-0.275	-0.281	-0.216	-0.166								
OBR	0.210	0.174	-0.014	0.003	-0.174	-0.072							
CAT	0.040	0.473	0.288	-0.344	-0.723	-0.157	-0.238						
HSBR	-0.059	0.485	0.097	-0.141	-0.335	-0.216	-0.098	0.339					
PHRAG	-0.082	-0.062	-0.103	-0.091	-0.009	-0.139	-0.063	0.141	-0.091				
DIKE	-0.113	0.365	0.443	-0.106	-0.210	-0.162	0.323	0.006	-0.106	-0.069			
SGABR	-0.079	-0.347	-0.095	-0.037	-0.071	0.259	0.103	-0.304	-0.141	-0.091	-0.106		
OTHER	0.069	0.313	-0.008	-0.091	-0.265	0.040	-0.063	0.323	-0.091	-0.059	-0.069	-0.091	
GW	0.778	-0.006	0.465	0.413	-0.113	-0.286	-0.086	0.164	-0.052	0.071	-0.208	-0.005	0.111

Part 2. Correlation matrix of habitat variables associated with pair use by the 6 common species of waterfowl in 1979. Variable mnemonics from Table 13.

	TRAREA	DEP	PI	MUD	SG	ABR	OBR	CAT	HSBR	PHRAG	DIKE	SGABR	OTHER	RH	CT	RD	MAL	GW
DEP	0.170																	
PI	0.272	0.280																
MUD	0.338	-0.068	-0.043															
SG	-0.286	-0.445	-0.043	-0.018														
ABR	0.077	-0.096	-0.149	-0.074	-0.223													
OBR	-0.099	0.033	-0.110	-0.028	-0.138	-0.031												
CAT	0.265	0.520	0.118	-0.136	-0.731	-0.130	-0.061											
HSBR	0.115	0.141	0.181	-0.144	-0.243	-0.148	-0.091	0.032										
PHRAG	-0.062	-0.020	-0.092	-0.048	-0.034	0.030	-0.041	-0.024	-0.069									
DIKE	0.048	0.202	0.295	-0.005	-0.104	-0.028	-0.051	0.004	-0.085	-0.028								
SGABR	-0.169	-0.194	-0.199	-0.022	-0.128	0.165	0.208	-0.265	-0.166	0.045	-0.082							
OTHER	0.002	0.128	-0.060	-0.051	-0.170	-0.005	-0.044	0.208	-0.074	-0.025	-0.030	-0.070						
RH	0.835	0.194	0.293	0.087	-0.444	0.077	-0.067	0.428	0.204	0.012	0.038	-0.103	-0.007					
CT	0.578	-0.073	0.297	0.325	-0.025	0.101	0.052	-0.119	0.001	-0.059	0.172	-0.023	-0.078	0.455				
RD	0.685	0.240	0.208	0.030	-0.405	0.089	-0.105	0.486	0.104	-0.054	0.067	-0.189	-0.035	0.708	0.209			
MAL	0.598	0.066	0.289	0.244	-0.061	0.023	0.093	-0.004	0.077	-0.061	-0.024	-0.050	-0.016	0.545	0.583	0.126		
GW	0.719	0.014	0.356	0.329	-0.184	0.067	-0.074	0.070	0.172	0.031	0.148	-0.148	0.016	0.690	0.653	0.373	0.633	
SH	0.652	0.012	0.218	0.383	-0.066	-0.042	-0.030	0.046	-0.033	0.013	0.111	-0.083	0.000	0.579	0.655	0.319	0.551	0.741

Appendix B

Brood use correlation matrices

Part 1. Correlation matrix of habitat variables associated with brood use in 1978. Variable mnemonics from Table 13.

	TRAREA	DEP	PI	MUD	SG	ABR	OBR	CAT	HSBR	PHRAG	DIKE	SGABR	OTHER	RH	DABBLE
DEP	0.249														
PI	0.329	0.361													
MUD	0.585	0.250	-0.061												
SG	-0.115	-0.089	-0.231	0.185											
ABR	-0.273	-0.436	-0.191	-0.214	-0.239										
OBR	0.193	0.352	-0.012	0.005	-0.161	-0.090									
CAT	0.109	0.033	0.287	-0.321	-0.651	-0.235	-0.222								
HSBR	0.037	0.249	0.220	-0.121	-0.349	-0.189	-0.084	0.336							
PHRAG	-0.190	-0.194	-0.168	-0.103	-0.043	-0.004	-0.071	-0.038	-0.091						
DIKE	-0.140	0.448	0.451	-0.103	-0.196	-0.161	0.324	0.012	-0.091	-0.078					
SGABR	-0.226	-0.254	-0.207	-0.094	-0.034	0.217	0.043	-0.326	-0.160	0.093	-0.136				
OTHER	0.262	-0.180	0.151	-0.062	-0.178	0.091	-0.043	0.220	-0.054	-0.046	-0.046	-0.081			
RH	0.602	0.397	0.140	0.668	0.414	-0.328	0.046	-0.369	-0.080	-0.139	-0.011	-0.202	-0.009		
DABBLE	0.681	0.371	0.074	0.727	0.229	-0.339	0.111	-0.281	-0.015	-0.136	-0.036	-0.083	-0.128	0.704	
TOT	0.704	0.423	0.157	0.673	0.357	-0.377	0.100	-0.309	-0.053	-0.162	-0.013	-0.206	-0.068	0.948	-0.839

Part 2. Correlation matrix of habitat variables associated with brood use in 1979. Variable mnemonics from Table 13.

	TRAREA	DEP	PI	MUD	SG	ABR	OBR	CAT	HSBR	PHRAG	DIKE	SGABR	OTHER	RH	RD	DABBLE
DEP	-0.166															
PI	-0.037	0.189														
MUD	0.341	-0.048	-0.216													
SG	-0.040	0.056	-0.187	0.181												
ABR	0.018	-0.284	-0.227	-0.099	-0.117											
OBR	-0.200	-0.033	-0.109	-0.026	-0.099	0.062										
CAT	0.211	-0.045	0.200	-0.320	-0.693	-0.116	-0.247									
HSBR	-0.095	0.027	0.186	-0.231	-0.278	-0.256	-0.156	0.022								
PHRAG	-0.066	-0.017	-0.111	-0.067	-0.123	-0.089	-0.045	0.150	-0.080							
DIKE	-0.172	0.309	0.312	-0.036	-0.004	-0.064	-0.074	-0.160	-0.131	-0.038						
SGABR	-0.378	-0.108	-0.224	-0.065	-0.037	0.472	0.640	-0.388	-0.232	-0.067	-0.110					
OTHER	0.147	-0.017	0.066	-0.067	-0.123	0.213	-0.045	0.150	-0.080	-0.023	-0.038	-0.067				
RH	0.471	0.218	0.234	0.172	0.061	0.024	-0.091	0.056	-0.198	0.159	0.144	-0.339	0.113			
RD	0.360	-0.064	-0.065	-0.097	-0.180	0.368	-0.139	0.303	-0.097	-0.081	-0.046	-0.196	-0.023	0.338		
DABBLE	0.427	-0.184	0.229	0.124	0.063	-0.300	-0.069	-0.077	0.196	0.260	-0.037	-0.240	-0.152	0.344	-0.059	
TOT	0.642	-0.038	0.234	0.128	0.014	-0.013	-0.153	0.098	-0.041	0.202	0.055	-0.402	0.009	0.794	0.508	0.710