HABITAT FACTORS INFLUENCING DUCK BROOD USE OF SEMI-PERMANENT AND PERMANENT PRAIRIE POTHOLES IN NORTH DAKOTA

by

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INTRODUCTION

The prairie pothole region, encompassing about 300,000 square miles of prairie grasslands and parklands in north central United States and south central Canada, is the most important waterfowl breeding ground in North America. Although the prairie pothole country comprises only one-tenth of the waterfowl-producing area, over half of the ducks produced on this continent are reared on the potholes, marshes, and shallow lakes of this region (Munro, 1963; Smith, Stoudt, and Gollop, 1964).

During the past two decades, the foremost problem in waterfowl conservation has been increasing agricultural drainage of wetlands in the fertile prairie pothole region. In the United States, the prairie pothole country originally may have produced 15 million ducks per year and covered 115,000 square miles in North Dakota, South Dakota, Minnesota, and Iowa. Drainage has eliminated more than half of this waterfowl breeding habitat, and 56,000 square miles remain in the Dakotas and Minnesota that produce about five million ducks annually (Nord, Evans, and Mann, 1951; Schrader, 1955).

The United States Fish and Wildlife Service conducted field studies in 1949 and 1950 to appraise the significance of agricultural drainage in the prairie pothole region. These studies indicated that more than 32,000 wetlands of value to ducks were eliminated annually in the Dakotas and

Minnesota. During the 12-year period, 1943-54, an estimated 350,000 potholes and marshes, representing approximately one million acres of valuable waterfowl habitat, were destroyed in north central United States (Mann, 1958).

In order to formulate land use programs and policies aimed at waterfowl habitat preservation, the United States Fish and Wildlife Service initiated a wetlands inventory, based on a wetlands classification outlined by Martin, Hotchkiss, Uhler, and Bourn (1953), for delineating, classifying, and evaluating the remaining wetlands in the United States. Shaw and Fredine (1956) summarized the results of this inventory and stressed the need for wetland preservation, particularly in the prairie pothole region of the North Central States.

Nevertheless, agricultural drainage continued to destroy waterfowl breeding habitat. During 1954 to 1958, over 50,000 wetlands totaling 60,000 acres were drained in North Dakota, South Dakota, and Minnesota (United States Fish and Wildlife Service, 1961). In 1958, Congress authorized the United States Fish and Wildlife Service to establish a program for preservation of waterfowl production habitat. Further legislation in 1961 provided funds for an accelerated wetlands acquisition program to be administered by the Bureau of Sport Fisheries and Wildlife. Proposed objectives of this program were to purchase semi-permanent and permanent potholes and marshes in strategic locations to provide brood-rearing habitat for ducks and to obtain easements on small wetlands surrounding these larger potholes and marshes to protect them from draining, filling, and burning (Mann, 1964).

Recently, Gottschalk (1965) reviewed the progress of waterfowl habitat preservation in the United States, and Munro (1965) discussed the program proposed by the Canadian Wildlife Service for preservation of prairie pothole habitat in Canada. Preliminary studies by Lynch, Evans, and Conover (1963) and Rose and Morgan (1964) have provided basic information and suggested approaches for preservation of Canadian wetlands. In addition, various state and provincial conservation agencies, e.g. Minnesota (Moyle, 1964), have acquired wetlands for waterfowl production in the United States and Canada, and Ducks Unlimited, a non-governmental organization, has engaged in preservation and restoration of waterfowl breeding areas in Canada (Leitch, 1966). Thus, the acquisition of potholes and marshes for duck production has received considerable emphasis throughout the prairie pothole region in recent years.

As programs for preserving habitat for waterfowl production developed, the paucity of information on habitat requirements and preferences of duck broods became apparent. Many workers had studied waterfowl on the breeding grounds, but few intensive investigations dealt with prairie nesting ducks during the brood-rearing period. Hence, specific information was needed to formulate guidelines for the purchase and preservation of brood-rearing habitat.

In response, the Northern Prairie Wildlife Research Center and the Iowa Cooperative Wildlife Research Unit initiated a 2-year investigation to evaluate the importance of several habitat factors influencing duck brood use of prevalent types of semi-permanent and permanent potholes. The primary objective of this study was to determine the relationship of cover interspersion to brood use, but the significance of related physical features of the pothole basin and chemical characteristics of the pothole water were also investigated.

This is a report of studies conducted during two brood-rearing seasons, from June 8 to September 11, 1964, and from June 1 to September 10, 1965, near Woodworth, North Dakota. Scientific names follow the nomenclature adopted by the American Ornithologists' Union (1957) for birds, Miller and Kellogg (1955) for mammals, and Fernald (1950) for plants, except a few species of algae, liverworts, and mosses found in Fassett (1960).

LITERATURE REVIEW

Compared with existing literature relating to other aspects of the reproductive cycle of waterfowl, a paucity of information is available on the habitat preferences and requirements of duck broods. In the past, waterfowl production studies concentrated on nesting ecology rather than rearing ecology. Early workers, e.g. Furniss (1935), Bennett (1938), Girard (1939, 1941), Munro (1941; 1943; 1944), and Low (1940; 1945), contributed generalized descriptions of brood-rearing habitat, but its use by broods was established through implication rather than supported with quantitative information. Most important contributions to knowledge of habitat preferences and requirements of duck broods in the prairie pothole region were studies by Evans, Hawkins, and Marshall (1952) and Evans and Black (1956). Sowls (1955) and Hochbaum (1959) described hen and brood behavior during the brood-rearing period and discussed general habitat preferences of dabbling ducks and diving ducks for brood rearing. A valuable review of literature pertaining to waterfowl brood behavior and rearing was presented by Weller (1964). Beard (1964) reported on a recent study of duck brood behavior.

Movements of Duck Broods

Within a few hours after hatching, duck broods move from the nest to potholes and marshes providing suitable rearing habitat. Bennett (1938) observed numerous overland movements of blue-winged teal (Anas discors) broods in northwest Iowa. During these movements, broods did not always utilize the shortest routes or the nearest potholes, but frequently followed trails or paths. Hochbaum (1959) found several species using roads or paths in their overland travels from nesting areas to the marsh at Delta, Manitoba. He concluded that broods generally followed the path of least resistance in overland movements.

Low (1945) reported that redhead (Aythya americana) broods deserted the small potholes and marshes used for nesting and moved to larger lakes and marshes for brood rearing in northwest Iowa. Hochbaum (1959) noted a conspicuous movement of broods of all species from the sloughs to the marsh at Delta. For some species, these movements were often a necessity, because shallow potholes generally went dry during the summer, and broods were forced to move to more permanent potholes and marshes (Bennett, 1938; Hochbaum, 1959).

Evans et al. (1952), Dzubin (1952), Berg (1956), and Evans and Black (1956) studied movements of color-marked broods following procedures described by Evans (1951). In south central Manitoba, Evans *et al.* (1952) found that different species varied in their mobility, i.e. ability and willingness to move. Pintail (*Anas acuta*) broods were the most mobile followed in order by canvasbacks (*Aythya valisineria*), mallards (*Anas platyrhynchos*), redheads, blue-winged teal, American widgeons (*Mareca americana*), and ruddy ducks (*Oxyura jamaicensis*). Hochbaum (1959) described the activities of duck broods while moving overland and compared movements of dabbling ducks with diving ducks.

Duck broods are capable of overland movements involving considerable distances. These movements allow the ducks to select potholes and marshes providing suitable brood-rearing habitat. Several workers have reported the distances travelled by broods on overland movements. The following list presents the maximum distance reported for movements of individual broods for each species: mallard - 1.49 miles (Berg, 1956), gadwall (*Anas strepera*) - 1.15 miles (Gates, 1962), American widgeon - 0.20 miles (Evans *et al.*, 1952), pintail - 3.10 miles (Blankenship, 1952), blue-winged teal - 2.25 miles (Evans and Black, 1956), shoveler (*Spatula clypeata*) - 1.10 miles (Blankenship, 1952), wood duck (*Aix sponsa*) - 0.50 miles (Stewart, 1958), redhead - 5.00 miles (Hochbaum, 1959), canvasback - 4.00 miles (Erickson, 1948), ring-necked duck (*Aythya collaris*) - 0.50 miles (Mendall, 1958), ruddy duck - 0.09 miles (Evans *et al.*, 1952).

Erickson (1948) noted that the greatest mobility in canvasback broods at the Malheur National Wildlife Refuge in Oregon occurred during the first weeks after hatching. Evans et al. (1952) found brood mobility increased as broods became older. Cowardin (1965) reported that once broods reached an age of about 2 weeks they remained on the same impoundment at the Montezuma National Wildlife Refuge in New York.

Evans et al. (1952) in Manitoba and Evans and Black (1956) in South Dakota found no cause to account for brood movements, but movements appeared to be initiated by the hen since no broods without hens were known to move overland. After carefully studying the movements of 23 marked broods, they concluded that the direction of brood movements was completely random. However, in Ohio, Stewart (1958) identified a definite congregating movement of marked wood duck broods when they were about 2 weeks of age. Broods moved to new areas that were occupied by other broods after leaving the nesting pond.

In western South Dakota, Blankenship (1952) observed that broods often moved away from stock ponds that appeared to be the better ones, especially with respect to food and cover. Evans and Black (1956) found that brood movements were not always from poor to perceptibly better potholes in northeastern South Dakota, but they were never to areas obviously poorer than those last occupied. Berg (1956) studied nine marked broods on stock ponds in Montana and found a general trend of movements from bare ponds to those with emergent vegetation, from smaller to larger ponds, and from ponds with greater to those with less water loss.

Erickson (1948) found canvasback broods moved in response to falling water levels, but Evans *et al*. (1952) concluded that brood movements were stimulated both by high or rising water levels and by rapidly falling water levels. Benson (1948) in Minnesota and Dzubin (1952) in Manitoba also found receding water levels influenced brood movements, especially if the water level was below the edge of the emergent vegetation. However, Evans and Black (1956) did not consider drought as a cause of brood movements. Keith (1961) speculated that the relative permanency of the many small potholes on his studyarea in southeastern Alberta discouraged brood movements from small areas to larger areas. Only a limited movement of broods from potholes less than 1 acre to larger potholes and lakes was noted. In Utah, Gates (1962) followed marked gadwall broods that moved off the study area to deep-water marshes and large impoundments when smaller water areas became dry in mid-summer.

Evans *et al*. (1952) found brood movements were greatest where potholes were closely spaced, yet movements of broods between wetlands occurred in an area where pond densities averaged only 1.3 per square mile in western South Dakota

(Blankenship, 1952; Bue, Blankenship, and Marshall, 1952).

Evans et al. (1952) believed human intrusion influenced brood movements in some cases, while it often had little effect in other instances. They concluded that it might be difficult to drive broods from an area that was otherwise suitable. Evans and Black (1956) stated that disturbance did not cause brood movements. Jessen, Lindmeier, and Farmes (1964) thought banding operations probably influenced movements of broods, but they observed other broods moving from one pothole to another even though undisturbed by banding operations.

Many other waterfowl workers, e.g. Harris (1954), Sowls (1955), Lokemoen (1966), and others, have observed or studied overland movements of duck broods between different types of wetlands. In addition, Low (1945), Hochbaum (1959), Beard (1964), and Duebbert (1966) described movements of duck broods between feeding and loafing areas in large marshes.

Evidence of Habitat Preferences

Throughout the prairie pothole region, Nord et al. (1951) found duck broods more or less concentrated on larger and deeper potholes during the summer. Apparently, broods were more selective as to size, depth, and cover of potholes than were breeding adults, since broods moved overland for considerable distances to take advantage of favorable types of habitat. This selectivity and apparent lack of competition between broods contributed to greater concentration of broods on potholes. In Manitoba, Dzubin (1952) found concentrations of broods on deeper potholes as early as mid-June.

Evans _et al_. (1952) assumed that broods selected potholes which were attractive to them during the rearing season in Manitoba. They concluded that the ability to select potholes varied with the mobility of species, but in most cases, brood use of potholes provided an indication of brood preferences. In South Dakota, Evans and Black (1956) found the distribution of broods on potholes differed considerably from the distribution of breeding adults. There was no longer a tendency for the ducks to disperse, and there was a greater selectivity for definite types of potholes. In addition, they found that various species differed in their habitat preferences. For example, diving ducks and gadwalls definitely favored open water areas, whereas other dabblers, particularly the mallard and pintail, made greater use of deep marshes.

Mann (1959) observed that potholes which did not appear to provide suitable duck habitat were often heavily used by breeding pairs and broods in western Minnesota, whereas other potholes with the outward appearance of being excellent habitat for ducks were seldom used. He believed that much of the use or lack of use of potholes by ducks was controlled by factors outside of the pothole basin, yet there appeared to be definite factors within potholes that made one pothole more attractive than another for ducks.

Physical Factors Affecting Brood Use

Furniss (1935) studied 99 potholes in Saskatchewan, but only 44 potholes contained broods in 1934. He presented data showing broods favored potholes of larger size. Based on percentage of potholes occupied, broods preferred potholes larger than 2 acres in size. Between 1932 and 1936, Bennett (1938) conducted brood counts on a large number of potholes, sloughs, and marshes in northwest Iowa. These brood counts showed the number of broods per water area increased as the pothole size increased, but the corresponding number of broods per acre decreased. Bennett concluded that potholes of 0.5 acres were optimum for dabbling duck production, but he misinterpreted a graph prepared by Furniss (1935) showing the relationship of pothole size to brood use in substantiating his findings.

In south central Manitoba, Evans et al. (1952) studied pothole preferences of broods on a 1.5-square-mile study area containing 127 potholes in 1949. They found considerable variation in the preferences of various species of ducks for pothole size, but brood use of potholes that held water throughout the summer was influenced by pothole size. Brood-days per pothole increased as pothole size increased with the largest pothole (10.9 acres) receiving the greatest use by broods. Potholes between 2.5 and 3.0 acres were the most heavily used on a brood-days per acre basis. Mallards preferred the small areas for brood rearing, while canvas-backs and redheads used larger potholes. Blue-winged teal, American widgeons, and pintails were more variable in pot-hole size preferences. However, the number and species composition of broods used to evaluate various habitat factors was not presented. In appraising the productivity of the area, about 50 broods per square mile were estimated for the study area, but 140 Class I broods and 273 total broods representing 10 species of ducks were tabulated in the analysis of brood size.

Nord _et_ _al_. (1951) summarized data from studies in Minnesota and South Dakota that showed the greatest brood use occurred on the largest potholes. Brood use of potholes under 2 acres in size was practically negligible both in terms of broods per pothole and broods per acre on the Waubay Study Area in South Dakota. The greatest percentage of broods (broods per pothole) occurred on potholes over 12 acres, but the concentration of broods (broods per acre) did not increase with size on potholes over 2 acres. During

1950 and 1951, about 80 per cent of the brood use occurred on potholes larger than 5.0 acres in size at Waubay. In 1951, 60 per cent of the potholes containing broods during July and August were over 4.0 acres in size along Minnesota transects.

In eastern Montana, Smith (1953) studied waterfowl production on 116 artificial reservoirs constructed to provide water for livestock and irrigation. He found that the larger the reservoir the greater the number of broods produced in 1951. Smith concluded that size was a more important factor than vegetative type in determining brood production. During 1953-54, Berg (1956) conducted a more intensive evaluation of waterfowl production on 44 artificial reservoirs in the same area. He found brood movements were generally from smaller to larger ponds and concluded that size of reservoirs appeared to have more influence on brood usage than vegetative type. However, ponds with vegetation were utilized more than those without vegetation. These results verified Smith's (1953) earlier findings.

Harris (1954) found no preference by duck broods for a particular size-class of pothole in Washington. He concluded that broods used potholes of any given size in approximate proportion to their abundance during 1950-51. However, Johnsgard (1956), who conducted further studies in the same area, tabulated duck broods in relation to pothole size and found that the greatest numbers of broods had consistently occurred on potholes larger than 5 acres between 1950 and 1953. Greater brood use of smaller potholes (less than 2 acres) resulted in 1953 and 1954 when larger potholes were inundated and destroyed by an impoundment constructed for irrigation purposes. Overall duck production in the area declined as a result of the loss of larger potholes during the 5-year period.

In South Dakota, Evans and Black (1956) studied duck production from 1950 to 1953 on the 11.25-square-mile Waubay Study Area containing 391 potholes. Eleven species of ducks produced broods on the area, but blue-winged teal, gadwalls, mallards, pintails, and ruddy ducks were the most abundant species. During the 4-year study, 1,618 brood observations provided information on pothole utilization and preferences of duck broods. They found duck broods preferred the larger water areas during the rearing season. The most heavily used potholes were 2 to 5 acres in size, and the least heavily used potholes were less than 1 acre in size. Jenni (1956) continued waterfowl studies at Waubay in 1954. He noted an increase in brood use with an increase in size of potholes. Most broods used potholes 2 acres and larger.

Farmes (1956) conducted a study of habitat factors influencing waterfowl use of 15 potholes in western Minnesota. These potholes were less than 5 acres in size and usually became dry in late summer. During 1950-52, 26 broods representing six species of ducks were observed on the potholes. He noted almost a total absence of duck broods on the potholes after the middle of the brood season. However, these potholes were heavily used by breeding pairs of ducks. Apparently, the broods moved to more permanent water areas, since large numbers of broods were observed on the larger bodies of water near the study area. Farmes recommended potholes about 10 acres or more in size and 3 feet or more in depth as essential habitat for broods, particularly diving duck broods.

Mendall (1958) reported that ring-necked duck broods were reared on large bodies of water adjacent to small marshes and sloughs used for nesting in Maine. In Manitoba, Dzubin (1959) found the 45 permanent potholes most commonly used by canvasbacks with broods varied in size from 0.8 to 12.0 acres.

Keith (1961) conducted a study of waterfowl production on small impoundments in southeastern Alberta between 1953 and 1957. The three largest impoundments received the greatest brood use during the 5-year investigation, and the 12 smallest and shallowest potholes received the lowest brood use. Moderate brood use was recorded for 49 potholes that were intermediate in size and depth. Gadwall and American widgeon broods were not observed on the small potholes, but they were abundant on the larger, open lakes. Broods of diving ducks also avoided the smaller potholes, and canvas-backs were drawn mainly to the larger impoundments. Shovelers and blue-winged teal appeared to be least affected by differences in size, depth, and other factors.

Lokemoen (1966) noted that redhead broods moved from the nesting potholes to larger potholes or to the nearby reservoir in Montana. Potholes utilized by broods exceeded 0.5 acres in size and most were larger than 1 acre. Low (1940; 1945) also reported that redhead broods were reared on larger marshes and lakes in Iowa.

Bennett (1938) concluded that water depth was the key to providing suitable rearing cover for duck broods. The preferred types of rearing cover grew in water 1 to 5 feet deep. If marshes had 4 to 5 feet of water in May, Bennett reasoned, sufficient water to maintain water levels at least 1 to 2 feet deep throughout the summer would be provided. Low (1945) observed that water depth affected rearing cover for broods in two ways: 1) cover was rendered useless by water receding from the vegetation, 2) high water levels over a period of time resulted in a drastic reduction in emergent cover.

Nord _et al_. (1951) found that over 70 per cent of the potholes occupied by broods along transects in Minnesota were more than 2 feet deep. Fewer than 10 per cent of the potholes holding broods were less than 1 foot in depth; none were less than 6 inches in depth. Evans *et al*. (1952) concluded that water depth was an important factor influencing selection of potholes by duck broods. During periods of low water, potholes more than 2 feet deep were preferred to shallower areas. Broods abandoned potholes when water receded from shore cover and became too shallow for diving. Benson (1948) and Dzubin (1952) observed similar responses of duck broods when water levels declined and exposed the edge of the emergent vegetation.

Beard (1953) considered water depth as one of six important environmental factors accounting for the attractiveness of beaver (*Castor canadensis*) ponds and marshes to duck broods on the Seney National Wildlife Refuge in Michigan.

Wolf (1955) found little or no difference in survival of broods between areas of falling, stable, and fluctuating water levels on impoundments in Utah. Yeager and Swope (1956) considered high, but stable water levels favorable to waterfowl production in Colorado. Berg (1956) found brood movements were away from stock ponds with greater water loss to those with less water loss in eastern Montana.

Evans and Black (1956) found increased water levels of the potholes in 1952 and 1953 resulted in a decline in brood use of open-water potholes and an increase in use of deep marshes and shallow marshes on the Waubay Study Area. They tentatively rated the various species in order of decreasing demand for deep water as follows: canbasback, lesser scaup (*Aythya affinis*), redhead, gadwall, ruddy duck, American widgeon, shoveler, green-winged teal (*Anas carolinensis*), blue-winged teal, mallard, and pintail. Jenni (1956) studied pothole water levels in relation to duck production on the Waubay Study Area in 1954, and concluded that potholes with less than 5 inches of water were not used by broods under any condition. Potholes with less than 10 inches of water were used by only 2 per cent of the broods. The failure of broods to use intermittent potholes, temporary potholes, and shallow marshes was believed to have been due to the shallowness of those types of potholes.

Mendall (1958) considered the relationship of water levels to rearing conditions of paramount importance for ring-necked ducks in Maine. The most satisfactory water levels for rearing were slightly higher than water levels optimum for nesting. Dzubin (1959) found canvasback broods used potholes containing more than 1.5 feet of water in Manitoba. Keith (1961) showed that diving ducks preferred relatively deep water for brood rearing, while dabbling species primarily used the potholes less than 4 feet in depth. Lokemoen (1966) reported that all the potholes used by redhead broods were over 4 feet in depth and were relatively permanent, however, Low (1945) found redhead broods were reared where water depths ranged from 24 to 48 inches.

Nord _et al_. (1951) stated that information regarding the relationship of water chemistry to brood use of potholes was lacking, however, Evans and Black (1956) thought it improbable that water chemistry was a factor in pothole use by ducks. They believed that no extreme chemical variations were indicated by the pothole vegetation, but water samples from the potholes were not analyzed.

Smith (1953) measured pH and turbidity in stock ponds studied for waterfowl use in eastern Montana, but these measurements were not related to waterfowl production. In western Minnesota, Farmes (1956) analyzed water samples from potholes to show that the water was alkaline, very fertile, and capable of supporting good growths of aquatic vegetation, but comparisons were not made between water chemistry and waterfowl use. Perret (1957; 1958) conducted detailed limnological studies, including determinations of pH, total dissolved solids, alkalinity, and dissolved oxygen, in relation to waterfowl use of potholes in south central Manitoba, but results of these studies remain unpublished. Keith (1961) used determinations of pH and sälinity to describe habitat changes within waterfowl impoundments in southeastern Alberta, and Jessen _et al_. (1964) measured several chemical characteristics of pothole water in western Minnesota. However, brood production and use was not studied in relation to water chemistry in either of these studies. Webster and McGilvrey (1966) used water chemistry to aid in characterizing optimum brood-rearing habitat for wood ducks in Maryland.

Mann (1959) reported that two potholes with the highest water temperatures had the most consistent waterfowl use during one season. This observation prompted him to speculate on the relationship between water temperatures and aquatic organisms in potholes during the rearing season.

Biological Factors Influencing Brood Use

Evans and Black (1956) concluded from observations of duck brood behavior that the selection of brood-rearing habitat depended on the availability of a means of escape from predators. This requirement was satisfied in two ways: 1) sufficient cover to conceal a brood but not dense enough to restrict brood movements, 2) open water of sufficient size and depth that broods could dive to escape enemies. They found no broods on potholes containing less than 5 inches of water in any cover type, but potholes with no cover were used by broods if they were at least 20 inches in depth and 5 acres in size. Dabbling duck broods, except gadwalls, made free use of potholes as small as 1 acre and as shallow as 5 inches if escape cover was present. Potholes less than 20 inches in depth and 2 acres in size, and totally overgrown with vegetation were seldom used by diving ducks or gadwall broods.

Waterfowl workers, e.g. Bennett (1938), Low (1945), Griffith (1948), Kadlec (1962), and Cowardin (1965), have long emphasized the importance of cover in brood-rearing habitat of ducks, but few studies have objectively evaluated the relationship between brood use and vegetative cover in potholes and marshes. The most detailed study of the interspersion of cover and water in relation to brood use of marshes was conducted by Beard (1953) in northern Michigan. She determined an "Index of Interspersion" to reflect the amount, composition, and juxtaposition of cover and water based on the number of cover types occurring along a transect and the average width of these units of cover. A correlation was found between this index and the number of ducklings produced on four beaver ponds and marshes based on 67 broods representing seven species of ducks during the 3-year study. In the prairie pothole region, Nord et al. (1951) found a higher percentage of the more open potholes were used by broods along transects in Minnesota. Evans et al. (1952) reported the greatest brood use on potholes with the largest areas of open water in Manitoba. Evans and Black (1956) observed twice as many broods on potholes classified as open-water areas in comparison with deep marshes in South Dakota.

Nord et al. (1951) characterized brood habitat preferences with respect to use of cover by broods and described sparse cover surrounding open water and permitting free movement of broods between stems of emergent vegetation as most favorable. Low (1945), Beard (1953), and Mendall (1958) also found broods preferred rearing cover growing in stands not too dense for easy swimming. This type of cover was generally provided in potholes with sedge-whitetop (*Carex*-*Scolochloa*) margins in south central Manitoba, bulrush (*Scirpus*) and cattail (*Typha*) islands scattered throughout potholes and connected by channels of open water also furnished ideal conditions (Nord et al. 1951). Potholes with dense cover received less use if it restricted brood movements, and extremely dense cover, often found in potholes with cattail margins, was even less desirable. Steel, Dalka, and Bizeau (1956) observed that solid stands of otherwise good cover were usually avoided by ducks at Gray's Lake in Idaho.

Evans et al. (1952) presented results showing that bulrush potholes received over three times the brood use on a brood-days per pothole basis as sedge-whitetop potholes. However, sedge-whitetop and bulrush potholes received about equal use based on brood-days per acre. Cattail potholes ranked third in brood use by both standards of comparison.

Evans and Black (1956) found over 97 per cent of the broods at Waubay on open-water potholes and deep marshes between 1950 and 1951. In general, most of the brood use of marshes occurred early in the brood season with more and more of the broods using open water as the season progressed. During 1952 and 1953, higher water levels resulted in a thinning of marsh vegetation, and broods made increased use of deep marshes and shallow marshes. The larger open-water areas were bare and wind-swept during these years and were less attractive to broods. However, when water levels declined on the Waubay Study Area in 1954, Jenni (1956) observed 80 per cent of the broods on these open-water areas.

Bue *et al*. (1952) studied 50 stock ponds in western South Dakota and found that brood usage of ponds with grassed shorelines was definitely higher for all species than mud or mud-grass shorelines. Ponds with grassed shorelines were utilized by broods three to four times as much as ponds with mud shorelines. In eastern Montana, Smith (1953) studied waterfowl production on 116 artificial reservoirs constructed to provide water for livestock and irrigation. He determined that differences in brood production between vegetative types were not statistically significant. Smith concluded that size was more important than vegetation in determining brood production. Berg (1956), working in the same area, found a general pattern of brood movement from bare ponds to those with emergent vegetation, but his results verified Smith's (1953) earlier findings concerning size and vegetation of ponds in relation to brood production. Keith (1961) expressed surprise when brood-responses to a change from rush-grass to mud shorelines brought only a 23 per cent decrease in brood use when he considered the marked differences in these shoreline types and the supposed attractiveness to broods of cover in juxtaposition with water.

Yocom and Hansen (1960) believe that cover in itself was not an important factor in determining lakes used by duck broods. They observed that many bodies of water in Washington possessed very little cover but were important brood-rearing areas. On permanent lakes, little emergent vegetation was found growing because of the steep shorelines. However, on these bodies of water, more broods were seen than on lakes with considerable hardstem bulrush (*Scirpus acutus*). Most of the more important brood ponds for ducks had only a narrow fringe of rush (*Juncus*) growing on the shoreline. Deep, steep-walled lakes were not used extensively by broods unless a shallow, marshy border was present some place on the lake.

Knight (1965) studied the waterfowl usage of a 296-acre water area in Montana in 1956 and 1959. When significant changes occurred in the marsh and aquatic vegetation, the waterfowl breeding populations and nesting increased on the area, but the number of broods declined. In 1956, 20 broods were observed, but only 15 broods were reported in 1959. The significance of these observations was not clear, because the density and extent of cover made brood counting relatively more difficult in 1959.

In northwest Iowa, Bennett (1938) found blue-winged teal remained in or near dense cover until they were able to fly. During feeding periods, broods were led out to open water for feeding, but emergent cover usually was nearby. Bennett observed that blue-winged teal depended upon six plant associations for brood-rearing cover. Hard-stem, softstem (*Scirpus validus*), and river bulrush (*Scirpus fluviatilis*), cattail (*Typha latifolia*), and burreed (*Sparganium eurycarpum*) provided the cover for 75 per cent of broods observed between 1932 and 1936. Benson (1948) also found bulrushes and cattails preferred rearing cover for blue-winged teal and mallard broods on three potholes in Minnesota.

Girard (1939) noted that shoveler broods never ventured more than a few feet from shorelines of peninsulas or artificial islands at the Ninepipe Reservoir in Montana. Mallard broods also took advantage of food and cover along the shorelines, because Girard (1941) found that broods of mallards spent the first 6 weeks of life in close proximity to the shore.

In a series of papers on the waterfowl of British Columbia, Munro (1941; 1943; 1944; 1949a; 1949b) described the importance of escape cover for various duck species. Mallard broods were observed on the open water of ponds and lakes less frequently than other species of dabbling ducks, and most of their early life was spent in thick grassy cover, brush thickets, and other places of concealment. Pintail broods spent considerable time in meadow or marsh cover, but visited larger bodies of water for feeding. Green-winged teal used marsh vegetation for escape cover along pond margins, but on larger lakes, broods swam towards the center of the lake. Broods of American widgeon frequented the open water of marshy areas. When the broods were frightened, they swam into the emergent cover of marshes, but on other occasions they swam from the marshy shore to open water. Lesser scaup broods generally escaped by swimming to another portion of the lake or marsh; broods rarely used emergent vegetation for escape cover.

Low (1940; 1945) identified six fairly distinct types of rearing cover used by redheads in northwest Iowa. Most of the broods used hardstem and river bulrush, cattail, reed (*Phragmites communis*) and burreed associations. Tall emergent plants served as rearing cover more than shorter plants, and rearing cover was less dense than nesting cover. Broods were reared in sparse to open cover in semi-open marshes, since lack of cover, and possibly food, prevented broods of redheads from using large, deep, open lakes. Lokemoen (1966) stated that emergent cover was never seen to be used for escape cover by redhead broods. Potholes used by broods of redheads in Montana were large, deep, and open, and had little emergent vegetation. Erickson (1948) in Oregon and Hochbaum (1959) in Manitoba found canvasback broods used open water for rearing habitat. Even in stormy weather, canvasbacks were generally found in open water. Dzubin (1959) found young canvasbacks on bulrush and cattail potholes in Manitoba. Keith (1961) noted that broods of ruddy ducks displayed a strong preference for areas with emergent vegetation.

Evans et al. (1952) found considerable variation in the preference of various species for cover type. Mallards were apparently the most adaptable species in relation to cover type, but greatest use by mallards was made of sedge-whitetop potholes. American widgeon and ruddy duck broods were the least tolerant of cover type. Widgeons used sedge-whitetop most extensively while ruddy ducks preferred hardstem bulrush potholes. Blue-winged teal and canvasback were fairly tolerant to varying types of cover, but sedge-whitetop potholes were still the preferred type. Redheads and pintails showed a definite preference for sedge-whitetop potholes, and shovelers exhibited a strong preference for cattail potholes.

In New York, Foley (1954) studied the survival of three "semi-wild" strains of mallard ducklings released on ponds without adult hens. A direct relationship between the amount of cover available on the ponds and the survival of the ducklings was noted. Composition of this cover made little difference to survival as long as cover types remained equally penetrable by swimming ducklings. High, stable water levels and extensive stands of vegetation provided excellent conditions for survival, but low or falling water levels made escape cover untenable and resulted in the lowest survival of ducklings. However, Hochbaum (1959) pointed out that parentless young were much less wary than ducklings attended by a hen. Benson (1948), Evans *et al*. (1952), and Dzubin (1952) found broods moved off potholes when water receded from marginal emergent vegetation, but broods without hens were not known to move (Evans *et al*., 1952).

Harris (1954) described six cover types important as rearing cover for broods in Washington. Hardstem bulrush was used extensively as feeding cover by many broods and as escape cover by 70 per cent of all broods. Baltic rush (*Juncus balticus*) provided favorable feeding cover, but slightly less desirable escape cover. Open water played an important part in the rearing of nearly all waterfowl broods, since broods of all species used open water as a feeding area. In addition, many broods used open water as a means of escape by swimming to the center of the pothole. Broods of dabbling ducks and redheads usually hid in the nearest available cover when the observer was visible, but ruddy ducks merely swam further away. Furniss (1935) stated that he observed female ducks with broods almost invariably swim out into open water with their young behind them when they were disturbed. Only when surprised on the smaller potholes did they try to hide in emergent cover. Ellig (1955) found broods in cattails, alkali bulrush (*Scirpus paludosus*), and small bays barren of emergent vegetation at Greenfields Lake in Montana. When broods on the lake were encountered by the observer, they generally swam from the shoreline into open water, but broods in the marsh swam into emergent cover.

Sowls (1955) found that flooded vegetation, particularly flooded whitetop (*Scolochloa festucacea*), was the preferred brood rearing cover for dabbling ducks at Delta, Manitoba. Open waters were not used extensively by dabblers, but diving ducks used the open water of bays in the Delta Marsh (Hochbaum, 1959). Evans and Black (1956) tentatively rated the species in order of increasing demand for and use of escape cover as follows: canvasback, lesser scaup, redhead, gadwall, ruddy duck, American widgeon, shoveler, green-winged teal, blue-winged teal, mallard, and pintail.

In Maine, Mendall (1958) noted that ring-necked ducks generally used the zone of emergents bordering sedge-meadow habitat as rearing cover. Apparently, the species composition of this cover was not important, since broods of ring-necked ducks used a variety of species of emergent vegetation for rearing cover depending on what was available.

Webster and McGilvrey (1966) described suitable wood duck brood habitat as a patchy pattern of emergent cover interlaced with a network of open water passageways in Maryland. Optimum brood habitat consisted of at least 75 per cent emergent cover with just enough water for broods to move about and feed. The ideal growth form of cover plants appeared to be a dense, spreading, low growth. They outlined three general types of cover plants, including shrubs, broad-leafed herbs, and medium to narrow-leafed herbs. The key to heavy brood use of certain impoundments appeared to be an abundance of brood cover in early spring.

Although information regarding the influence of food on brood use of potholes was lacking, Nord _et al_. (1951) considered food sufficient in all potholes to support more broods than were present. Evans _et al_. (1952) did not study the availability or utilization of foods by broods, but concluded after "casual inspection" of potholes that food, primarily invertebrates, was abundant and not a critical item in potholes. Hence, food was considered an unimportant factor in the selection of potholes by duck broods. Previous work by Benson (1948) was cited in support of this conclusion, but a review of Benson's work revealed that he had stated that food was secondary to the influence of territoriality in the distribution of breeding pairs of ducks. The three potholes studied by Benson (1948) went dry during the summer, and throughout the rearing season, these potholes were used by an estimated seven blue-winged teal and possibly three mallard broods. He reached no conclusions concerning the relationship of food to brood selection of potholes as implied by Evans et al. (1952).

Other workers have formulated various opinions of the importance of food in brood habitat. Furniss (1935) found many potholes contained an abundance of food, yet did not shelter a single brood in central Saskatchewan. However, he rated only plant foods in the potholes and failed to evaluate the availability of animal foods. In Iowa, Low (1945) thought the lack of food possibly prevented redhead broods from remaining on deep lakes during the rearing season. Beard (1953) considered plant and animal foods of vital importance, and one of six basic factors contributing to brood usage of beaver ponds at the Seney National Wildlife Refuge in northern Michigan. Kadlec (1962) contended that cover was more important than food in limiting brood use of waterfowl impoundment in central Michigan. Keith (1961) was convinced that there was no shortage of plant and animal foods in most of the potholes and lakes studied in southeastern Alberta.

In attempting to evaluate these viewpoints and the significance of food in brood habitat, one is faced with a paucity of information. Limited food habits studies by Bennett (1938), Cottam (1939), Beard (1953), Mendall (1958), and Keith (1961) verified the general observations of Griffith (1948), Benson (1948), Harris (1954), and others relating to the importance of animal foods, particularly aquatic invertebrates, in the diets of young ducks and suggested a general pattern of food utilization by duck broods described by Beard (1953). However, these studies are of limited value in understanding the relationship of food to brood use of potholes, since the ducklings were collected in diverse habitats from widely scattered locations. In addition to the usual shortcomings of early food habits work, small samples of young ducks were obtained for study, and in the presentation of the results, juveniles of various age classes were combined.

Recently, several intensive studies have attempted to evaluate food availability and food habits of young ducks during the brood-rearing period, but they have produced conflicting results. Chura (1961) reported on a study of food availability and food preferences of juvenile mallards at the Bear River Migratory Bird Refuge in Utah. He found that

Class I mallards consumed primarily terrestrial invertebrates, in spite of the fact that low water levels allowed easy access to aquatic forms. However, between Class Ic and Class IIa, an abrupt change occurred; aquatic invertebrates were favored even though terrestrial forms were accessible. As the ducklings approached Class III, the gradual shift from fauna to flora in food preferences was completed, and prior to flight, the diet of the juveniles resembled the adult hen's.

In south central Manitoba, Perret (1962) conducted a study of the spring and summer foods of the mallard. Foods of 135 juvenile mallards of all age classes were studied. He found no significant difference in the diets of the three age classes, but there was a significant difference in the proportion of animal foods in the diets of non-flying and flying young. Foods of adults collected in the summer were composed of a large percentage of animal foods and compared in composition with the diets of young collected during the same period. Perret (1962) believed the differences encountered between the food habits of juvenile mallards in Manitoba and in Utah (Chura, 1961) reflected differences in relative availability of food organisms.

Collias and Collias (1963) studied the foods and feeing behavior of 10 species of downy young ducks at Delta, Manitoba. Downy ducklings, whether in the laboratory or the field, readily fed on aquatic invertebrates, and there was evidence that different species of ducklings specialized on different kinds of invertebrate food organisms. The relative abundance and species composition of invertebrates varied with the type of vegetation in the Delta Marsh. The distribution of broods was roughly correlated with the abundance of invertebrates. These invertebrates apparently comprised the main food of many species of ducklings in their first week after hatching.

DESCRIPTION OF STUDY AREA

The study was conducted on 64 semi-permanent and permanent potholes in northwestern Stutsman County in south central North Dakota (Figure 1). Field headquarters were located at the Northern Prairie Wildlife Research Center's field laboratory, Woodworth Station, near Woodworth. The potholes were located within 15 miles of Woodworth along the eastern edge of the hilly physiographic region known as the Coteau du Missouri, i.e. "hills of the Missouri" (Table 27). The Coteau du Missouri, or Missouri Coteau, is a belt of stagnation moraine, including occasional terminal moraines and glacial outwash, trending from northwest to southeast across the state (Hainer, 1956). This region of high altitude and high relief encompasses about 7,000 square miles of high-quality waterfowl habitat in North Dakota (United States Fish and Wildlife Service, 1955).

The Study Area

Physiography, geology, and topography

The major phsiographic features and the geology of North Dakota are discussed by Hainer (1956). Kresl (1964) reviewed the physiographic divisions of the state, and Winters (1963) studied the geology of Stutsman County. The Missouri Escarpment, marking the eastern edge of the Missouri Plateau,

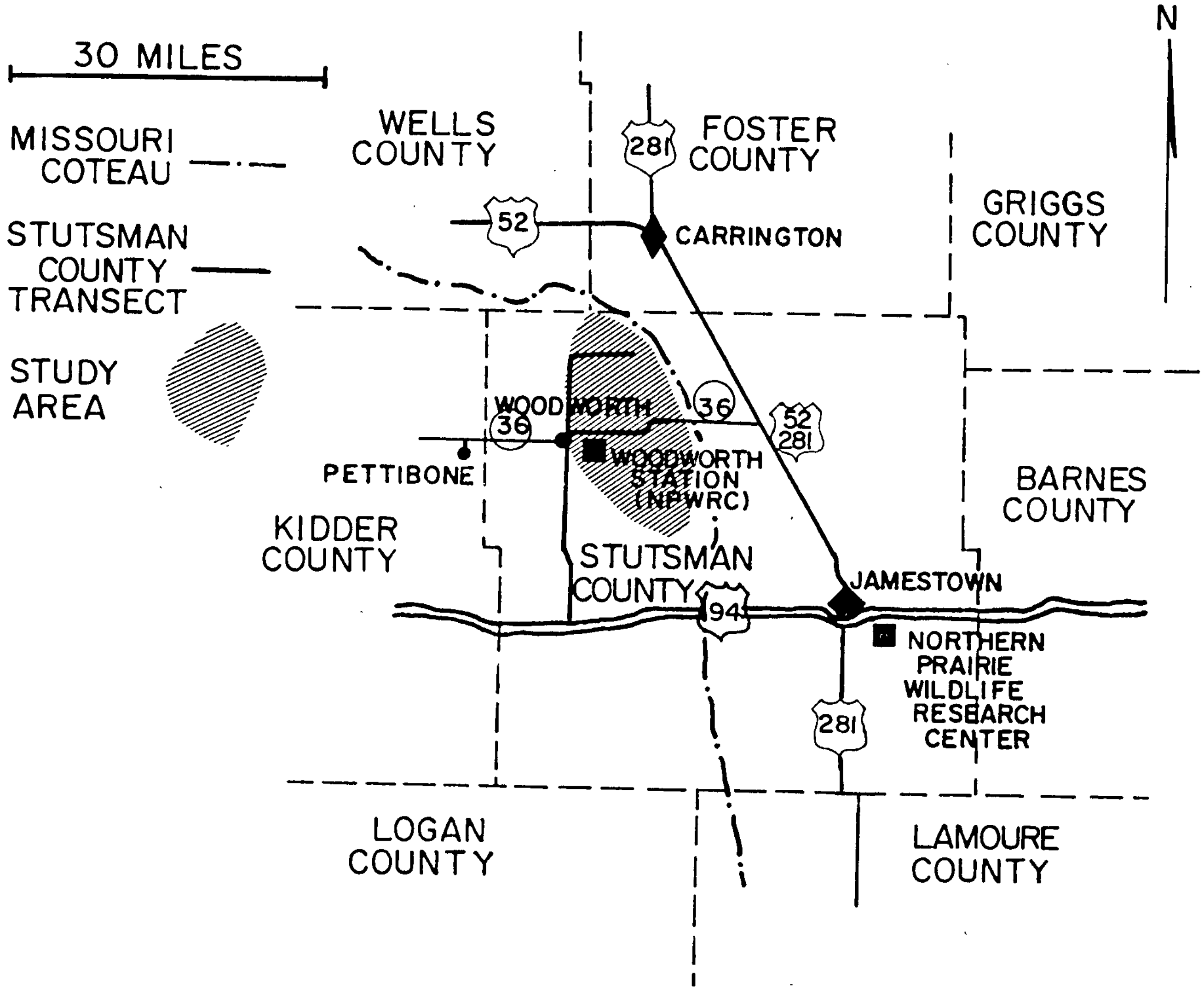


Figure 1. Location of the study area in northwestern Stutsman County, North Dakota

divides North Dakota and Stutsman County into two physiographic regions: the Drift Prairie of the Central Lowlands Province on the east and the Missouri Coteau of the Great Plains Province on the west (Winters, 1963, Kresl, 1964).

The Missouri Coteau, one of the most remarkable morainic belts in the United States (Fenneman, 1931), rises abruptly 300 to 500 feet above the Drift Prairie (Hainer, 1956; Kresl, 1964). Winters (1963) described the Missouri Coteau in western Stutsman County as primarily hummocky stagnation moraine forming typical knob and kettle topography. This hilly glacial moraine probably formed when a glacial ice sheet was disintegrating in place rather than from an actively retreating glacier. Stutsman County lies within the area glaciated during the Wisconsin Stage of the Pleistocene Epoch.

Winters (1963) characterized the knob and kettle topography of the Missouri Coteau as closely spaced hills and numerous closed depressions (Figure 2). The rolling morainal hills, separating the numerous depressions, consist mainly of glacial till and vary greatly in size and height. Local relief frequently exceeds 100 feet per square mile and ranges from 20 to 200 feet per square mile. Maximum altitudes of these hills range from 1,750 feet above sea level to over 2,000 feet above sea level.

Figure 2. Hilly native prairie of the Missouri Coteau in Stutsman County, North Dakota (Photo: D. L. Trauger)

Figure 3. Prairie potholes, conspicuous features of the Coteau prairie, are important waterfowl breeding, nesting, and rearing habitats (Photo: D. L. Trauger)

The closed depressions, varying greatly in size and shape, were formed at least in part, by the melting of buried ice blocks (Winters, 1963). Since there is an absence of any integrated drainage systems within the hummocky stagnation moraine, puddles, ponds, marshes, and lakes commonly occur in these depressions (Figure 3). Throughout the prairies, these water-holding depressions have collectively been termed "potholes" or "wetlands" by waterfowl biologists.

Climate

North Dakota has a typical continental climate. Precipitation and temperatures exhibit extreme seasonal and annual variations. Prevailing strong northwesterly winds and high evaporation are characteristic of the region (Bavendick, 1941).

Subhumid conditions prevail in Stutsman County with maximum precipitation occurring in summer. Average annual precipitation for northwestern Stutsman County is between 16-18 inches with about 50 per cent falling during May, June, and July (Dietrich and Hove, 1962). Precipitation was above average during 1964 and 1965 in the vicinity of the study area (Table 1). In 1964, highest rainfall came during June, but unusually heavy rainfall occurred in July, August, and September during 1965.

Table 1. Climatological data pertinent to northwestern Stutsman County, North Dakota[a] (United States Weather Bureau, 1962-1966)

Observation	1931-1963	1964	1965
Monthly precipitation (inches)			
April	1.30	2.46	2.07
May	2.50	2.80	2.87
June	3.26	7.04	2.30
July	2.96	2.32	4.57
August	2.24	2.80	3.69
September	1.59	1.55	4.04
Annual precipitation (inches)	17.65	21.29	21.83
Mean monthly temperature (^{o}F)			
April	40.6	43.1	39.7
May	53.3	56.4	52.1
June	63.0	62.3	62.4
July	69.6	71.2	68.0
August	67.9	63.8	66.0
September	56.8	53.4	45.5
Mean annual temperature (^{o}F)	39.8	39.8	37.7
Maximum temperature (^{o}F)	118	100	100
Minimum temperature (^{o}F)	-50	-26	-30
Last spring minimum below 32^{o}F	-	June 1	May 28
First fall minimum below 32^{o}F	-	September 11	September 5

[a]Precipitation data are averages from recording stations at Woodworth, Pettibone, Carrington, and Jamestown (FAA Airport), North Dakota; temperatures are averages from recording stations at Pettibone, Carrington, and Jamestown (FAA Airport), North Dakota.

Significant variations from average precipitation are measured at weather stations near the study area from year to year and between stations for the same year. Total annual precipitation at Woodworth varied from 10.35 inches in 1961 to 29.60 inches in 1962 (United States Weather Bureau, 1965a). Between weather stations at Woodworth, Pettibone, Carrington, and Jamestown (Figure 1), total annual precipitation varied from 17.59 inches to 26.31 inches in 1964 and from 19.48 inches to 24.53 inches in 1965 (United States Weather Bureau, 1965b; 1966).

Temperatures are generally low in winter and moderately high in summer. The average January and July temperatures for Stutsman County range between 6-8°F and 68-70°F, respectively (Dietrich and Hove, 1962). In 1964, mean monthly temperatures were above average in April, May, and July, but below average in June, August, and September (Table 1). The mean annual temperature was average in 1964. During 1965, mean monthly and annual temperatures were generally lower than long-term and 1964 mean temperatures. Highest monthly temperatures occurred in July during both years, but maximum temperatures were reached in August (United States Weather Bureau, 1965b; 1966).

In northwestern Stutsman County, the growing season extends for a period of 110 to 120 days between May 20-25 and September 15-20 (Dietrich and Hove, 1962). On clear days, the sun shines for more than 15 hours from the middle of May to the end of July (Bavendick, 1941).

Vegetation

Two distinct types of natural vegetation are characteristic of the Missouri Coteau: grassland and wetland vegetation (Figure 3). Prairie grassland is the predominant vegetative type on the rolling uplands of the Coteau, but considerable acreages have been plowed for growing agricultural crops. Wetland vegetation occurs whenever topography and soils allow water to concentrate in depressions and basins.

According to Küchler (1964), the potential natural vegetation of the Missouri Plateau, including the Missouri Coteau, would be a moderately dense, short to medium tall wheatgrass-needlegrass (*Agropyron*-*Stipa*) grassland. Western wheatgrass (*Agropyron smithii*), needle-and-thread (*Stipa comata*), green needlegrass (*Stipa viridula*), and blue grama (*Bouteloua gracilis*) would be the dominant grasses. Weaver and Clements (1938) and Shelford (1963) included this region in the Mixed Grass Grassland and described the upland flora of the prairie in detail.

The vegetation of the prairie grassland may be described in terms of three zones: upland prairie, slope prairie, and lowland prairie. Green needlegrass, needle-and-thread, and little bluestem (*Andropogon scoparius*) are common grasses throughout the upland prairie, but Junegrass (*Koeleria cristata*), blue grama, and sedges (*Carex stenophylla* and *Carex filifolia*) become more abundant on the drier knolls. In the slope prairie, little bluestem, side-oats grama (*Bouteloua curtipendula*), needlegrass (*Stipa spartea*), western wheatgrass, and plains muhly (*Muhlenbergia cuspidata*) are abundant on hillsides. Big bluestem (*Andropogon gerardi*), switchgrass (*Panicum virgatum*), Canada wild rye (*Elymus canadensis*), and prairie dropseed (*Sporobolus heterolepis*) are fairly common grasses in the moist lowland prairie. Kentucky bluegrass (*Poa pratensis*) is often abundant in slope and lowland prairie during wet years, particularly in grazed areas.

Patches of brush, primarily buckbrush (*Symphoricarpos occidentalis*) and silverberry (*Elaeagnus commutata*), are locally common throughout the prairie grassland. Around semi-permanent and permanent wetlands and along coulees, woody thickets of choke cherry (*Prunus virginiana*) and wild plum (*Prunus americana*) are of fairly common occurrence. Several potholes have groves of aspen (*Populus tremuloides*) growing in the immediate vicinity, and occasionally willows, especially *Salix interior* and *Salix cordata*, grow around potholes.

Soils

Regosol and Chernozem soils have developed from the calcareous glacial drift on the Missouri Coteau in Stutsman County. The Wisconsin Agricultural Experiment Station (1960) included this region in the Buse soil association. These hilly soils have shallow, dark brown to black surface layers, and have developed in morainic areas within the Chernozem soil zone. The Buse soils (Regosols) occupy the steeper slopes, and Barnes and Aastad soils (Chernozems) are found on the gently rolling and undulating slopes. Barnes and Aastad soils have thick, black to nearly black surface layers, and have developed under tall to mixed grasses in a temperate, subhumid climate.

A general soil map of Stutsman County prepared by the North Dakota Agricultural Experiment Station shows Buse and Barnes loams and clay loams associated with Sioux, Svea, and Renshaw loams, clay loams, and sandy loams near Woodworth. Parnell and related soils occur in the numerous, undrained depressions (Wisconsin Agricultural Experiment Station, 1960). Loose stones and boulders abound in the glacial drift.

Land use

Bayha (1964) reviewed the history of land use in the vicinity of Woodworth. According to early accounts, the Coteau hills were "a vast sea of waving prairie grasses."

Before white man brought his livestock, barbed wire, and plow, this region was inhabited by nomadic bands of Dakota Indians. They followed and hunted the herds of bison (Bison bison) roaming in the hills of the Coteau.

Between 1880-1900, a few ranchers held "squatters rights" to large tracts of the Coteau prairie, a stockman's paradise with an apparent abundance of water and grass without end. Homesteaders, holding legal title to the land, began arriving about 1900, and the peak of settlement came between 1905 and 1915. In 1910, the townsite of Woodworth was platted when the Northern Pacific Railroad built a branch line from Pingree to Wilton, North Dakota.

The first prairie sod was broken shortly after the arrival of the settlers, but large acreages of cropland were not broken until after World War I. Blizzards, prairie fires, droughts, and grasshopper plagues were adversities endured by early settlers, but a decline in human population has occurred since 1915. Average farm sizes and cultivated cropland acreages have increased during this period.

Since homestead days small grain farming, haying, and grazing have been the major land uses. Present land use categories include native prairie, grazed prairie, cropland, hayland, and soil bank. Approximately 65 to 70 per cent of the Coteau prairie remains as grazed or ungrazed prairie near Woodworth. Cattle, sheep, and horses are grazed in pastures or on the prairie.

The remaining 30 to 35 per cent of the Coteau prairie has been broken for growing crops. Wheat (Triticum aestivum), oats (Avena sativa), barley (Hordeum vulgare), rye (Secale cereale), and flax (Linum usitatissimum) are the most important agricultural crops. Corn (Zea mays) is grown and cut for fodder. Hay, including alfalfa (Medicago sativa), red clover (Trifolium pratense), timothy (Phleum pratense), and smooth brome (Bromus inermis), is planted as a forage crop, and wild hay is cut on the prairie. Smooth brome, crested wheatgrass (Agropyron cristatum), and western wheatgrass have been planted in soil bank land. Summer fallowing of cropland is practiced to increase soil moisture.

Potholes

Bach (1951) estimated over one million potential wetlands in North Dakota, and the United States Fish and Wildlife Service (1955) delineated over 700,000 potholes during a wetlands inventory of the state. However, the number and acreage of potholes varies seasonally and annually depending on natural water losses and weather conditions. During a 4-year period, 1948-1951, Bach (1951) found the number and acreage of potholes declined an average of 60 per cent from early spring to late summer. Between 1948 and 1963, Schroeder (1964) calculated an average of 359,954 wetlands in North Dakota during mid-May waterfowl breeding ground surveys. In 1964, the 320,746 wetlands in the stated based on mid-May surveys were 11 per cent below this 16-year average, but the 772,802 wetlands tallied in 1965 were 116 per cent above the 1948-1964 average of 357,648 wetlands (Schroeder, 1964; 1965).

The United States Fish and Wildlife Service (1955) found that each type of glaciated topography in North Dakota possessed a characteristic complex of wetlands. Pothole distribution, densities, and characteristics were closely related to physiographic regions of the state.

With respect to interspersion of a large number and diversity of wetlands, the Missouri Coteau is superb. The United States Fish and Wildlife Service (1955) found many sections of the Coteau contained as many as 60 potholes per square mile. Pothole densities in northwestern Stutsman County ranged from about 20 to over 100 potholes per square mile and averaged about 80 wetland basins per square mile on four intensively studied areas (Stewart and Kantrud, 1963; Kruse, 1964; Kirsch and Bayha, 1965). However, Stewart and Kantrud (1964) found that the total wetland acreage on these areas was inversely related to the number of potholes. For example, on the Mount Moriah Study Area, 94 potholes contained 58 wetland acres, but the 25 potholes on the Cottonwood Lake Study Area covered 289 acres.

The majority of potholes on the Missouri Coteau consist of small, shallow, temporary and seasonal wetlands holding water for a few weeks or a few months. Temporary potholes hold water for a few days or weeks after the spring run-off or after a heavy rain. Seasonal potholes normally go dry during July and August, but during wet years, these wetlands may carry water throughout the summer. Semi-permanent and permanent potholes generally maintain water levels throughout the summer, but semi-permanent potholes go dry during periods of drought. Permanent potholes usually hold water through severe droughts.

Waterfowl populations

The prairie potholes of North Dakota provide breeding habitat for over a million waterfowl annually, and on the Missouri Coteau, 60 to 70 breeding waterfowl per square mile are regularly observed in many areas (United States Fish and Wildlife Service, 1955).

In the Woodworth vicinity, the Bureau of Sport Fisheries and Wildlife has conducted several waterfowl production studies. Kirsch and Bayha (1965) presented duck breeding populations for the 6-square-mile Woodworth Study Area centered around Woodworth Station (Figure 1), and Kruse (1964; 1965) reported on duck breeding populations along the 25-mile-long, ¼-mile-wide, Stutsman County Transect located north and east of Woodworth. Duck breeding populations from these studies are presented to show the relative abundance of the various duck species in the vicinity of the semi-permanent and permanent potholes used in this investigation (Table 2).

Seven species of dabbling ducks comprised 80 to 85 per cent of the breeding population during 1964 and 1965, and five species of diving ducks accounted for the remaining 15 to 20 per cent. Blue-winged teal were the most abundant of the breeding ducks. Gadwalls, mallards, shovelers, and pintails were next in abundance followed by ruddy ducks, and redheads. Small numbers of lesser scaup, canvasbacks, American widgeons, green-winged teal, and ring-necked ducks also nested in the area.

Waterfowl breeding populations increased 48 per cent in 1965 over 1964 in the Woodworth vicinity (Table 2). The number of breeding pairs increased for all species, except canvasback, lesser scaup, and ring-necked ducks. Greatest increases were recorded for the blue-winged teal, but pintail and ruddy duck breeding populations showed relatively large increases compared with gains indicated for other species.

State-wide duck breeding populations increased for all species, particularly the blue-winged teal, in 1965 and in comparison with 1964 (Table 3). Duck breeding populations in North Dakota were about equal to the 16-year average in

Table 2. Duck breeding pair populations in the vicinity of Woodworth, North Dakota, during 1964 and 1965

Species	Woodworth Study Area[a]		Stutsman County Transect[b]		Combined breeding pair populations	
	1964	1965	1964	1965	1964	1965
Mallard	58	51	41	65	99 (11.3)[c]	116 (8.9)
Gadwall	59	82	80	112	139 (15.8)	194 (14.9)
Pintail	34	42	34	63	68 (7.7)	105 (8.1)
Green-winged teal	6	11	4	12	10 (1.1)	23 (1.8)
Blue-winged teal	142	242	162	299	304 (34.5)	541 (41.6)
Shoveler	40	52	39	56	79 (9.0)	108 (8.3)
American widgeon	10	12	12	12	22 (2.5)	24 (1.8)
Dabbling ducks	349	492	372	619	721 (81.9)	1111 (85.5)
Redhead	14	15	36	50	50 (5.7)	65 (5.0)
Ring-necked duck	1	1	-	-	1 (0.1)	1 (0.1)
Canvasback	15	10	20	13	35 (4.0)	23 (1.8)
Lesser scaup	24	14	13	15	37 (4.2)	29 (2.2)
Ruddy duck	20	37	16	34	36 (4.1)	71 (5.5)
Diving ducks	74	77	85	112	159 (18.1)	189 (14.5)
Totals	423	569	457	731	880	1300

[a]Source: Kirsch and Bayha (1965).

[b]Source: Kruse (1964, 1965).

[c]Per cent in parentheses.

Table 3. Breeding waterfowl population indices in North Dakota for 1964 and 1965[a]

Species	1964	1965	1948-1963
Mallard	166,707 (15.2)[b]	211,691 (10.8)	156,128 (14.7)
Gadwall	144,772 (13.2)	185,622 (9.5)	85,509 (8.0)
Pintail	172,191 (15.7)	240,112 (12.2)	248,285 (23.3)
Green-winged teal	14,258 (1.3)	21,169 (1.1)	5,559 (0.5)
Blue-winged teal	331,221 (30.2)	790,704 (40.3)	336,833 (31.6)
Shoveler	114,063 (10.4)	217,963 (11.1)	103,352 (9.7)
American widgeon	18,645 (1.7)	30,774 (1.6)	20,890 (2.0)
Dabbling ducks	961,857 (87.7)	1,698,035 (86.6)	956,556 (89.8)
Redhead	61,418 (5.6)	71,348 (3.6)	34,223 (3.2)
Canvasback	27,419 (2.5)	38,222 (2.0)	25,758 (2.4)
Lesser scaup	29,612 (2.7)	95,653 (4.9)	33,063 (3.1)
Ruddy duck	15,355 (1.4)	48,022 (2.4)	13,677 (1.3)
Diving ducks	133,804 (12.2)	253,245 (12.9)	106,721 (10.0)
Others	1,097 (0.1)	8,820 (0.5)	1,589 (0.2)
Totals	1,096,758	1,960,100	1,064,866

[a]Source: Schroeder (1964, 1965).

[b]Per cent in parentheses.

1964, but breeding populations in 1965 were 79 per cent above the 1964 index and 84 per cent above the 1948-63 index (Schroeder, 1964, 1965). The 1965 duck breeding population index was the largest recorded in the past 15 years.

Duck breeding pair densities were 71 pairs per square mile on the Woodworth Study Area in 1964, and 73 pairs per square mile along the Stutsman County Transect. In 1965, breeding pair densities were 95 pairs per square mile on the Woodworth Study Area and 117 pairs per square mile along the Stutsman County Transect. For the Woodworth vicinity, 72 pairs per square mile in 1964 and 106 pairs per square mile in 1965 could be considered average duck breeding pair densities.

Wetland wildlife

During 1964 and 1965, a large variety of water birds, shore birds, and marsh birds used the potholes near Woodworth in addition to waterfowl. The most abundant nesting species included pied-billed grebes (*Podilymbus podiceps*), American coots (*Fulica americana*), black terns (*Chlidonias niger*), yellow-headed blackbirds (*Xanthocephalus xanthocephalus*), and redwinged blackbirds (*Agelaius phoeniceus*). Eared grebes (*Podiceps caspicus*), horned grebes (*Podiceps auritus*), Virginia rails (*Rallus limicola*), soras (*Porzana carolina*), willets (*Catoptrophorus semipalmatus*), marbled godwits (*Limosa fedoa*), long-billed marsh wrens (*Telmatodytes palustris*), short-billed marsh wrens (*Cistothorus platensis*), and marsh hawks (*Circus cyaneus*) were other common nesting species. Numerous other species of birds were occasional breeders or summer visitors in the study area.

Muskrats (*Ondatra zibethicus*) were virtually eliminated throughout vast areas of Coteau pothole habitat during the recent drought (1959-61). Apparently, muskrat populations have not responded to improved habitat conditions in the potholes near Woodworth as there was little evidence of their activity during the study. Mink (*Mustela vison*) were also relatively scarce in the area.

The Study Potholes

Pothole types

Since semi-permanent and permanent potholes usually function as the most important brood-rearing habitat for prairie nesting ducks (Nord *et al*., 1951; Evans *et al*., 1952; Evans and Black, 1956; Stewart and Kantrud, 1963; Leitch, 1966), these were the principal types of potholes selected for intensive study. The majority of the potholes represented semi-permanent potholes, but several permanent potholes were studied. These potholes provided brood-rearing habitat ranging from potholes that nearly went dry during late summer to those that would maintain water levels throughout periods of severe drought. In addition, the distributional pattern and species composition of pothole vegetation reflected further differences in water depth and in water chemistry.

The distribution of emergent vegetation in the potholes represented three basic patterns, but ranged from emergents occurring throughout the pothole basin to emergents virtually lacking in the pothole. One type of vegetative pattern consisted of broken stands or patches of emergents interspersed with areas of open water (Figure 4). Another pattern of vegetation occurred in potholes containing a large central area of open water with a border of emergent vegetation (Figure 5). The third type of pothole possessed a large area of open water with scattered clumps or narrow fringes of emergent vegetation along a bare or rocky shore (Figure 6).

The species composition of the marsh and aquatic plant associations typified the pothole vegetation found in fresh, slightly brackish, and moderately brackish potholes. The specific conductance of pothole water was less than 400 μmhos/cm (25^{o}C) in fresh potholes, was between 400 and 2000 μmhos/cm (25^{o}C) in slightly brackish potholes, and was more than 2000 μmhos/cm (25^{o}C) in moderately brackish potholes. Most of the potholes represented slightly brackish potholes. These were the predominant types of potholes in the Woodworth vicinity.

Figure 4. Small semi-permanent potholes were used by ducks for nesting, but most ducks preferred larger potholes for brood-rearing (Photo: A. O. Haugen)

Figure 5. Large semi-permanent potholes with a fringe of emergent vegetation were used by many duck broods during the rearing season (Photo: A. O. Haugen)

Figure 6. Large permanent potholes offering little emergent cover were moderately used by duck broods (Photo: A. O. Haugen)

Pothole vegetation

The pothole vegetation occurred in four vegetative zones. These zones were termed the wet-meadow, shallow-marsh, deep-marsh, and open-water zones in relation to increasing water depth. The vegetation in each zone possessed distinctive distributional and structural characteristics. Certain potholes contained all four vegetative zones whereas only two or three zones were present in other potholes.

The wet-meadow zone was dominated by numerous relatively short grasses or grass-like plants. Prairie cordgrass (Spartina pectinata), northern reedgrass (Calamagrostis inexpansa), wild barley (Hordeum jubatum), and fowl bluegrass (Poa palustris) were the principal dominants in wet-meadow zones. Numerous sedges, including Carex praegracilis, Carex laeviconica, Carex sartwellii, Carex lanuginosa, and Carex vulpinoidea, frequently occurred as codominants. Baltic rush (Juncus balticus) and Torrey's rush (Juncus torreyi) were often important components of this zone. Other wet-meadow plants included arrowgrass (Triglochin maritima), marsh cress (Rorippa islandica), silverweed (Potentilla anserina), water hoarhound (Lycopus asper), wild mint (Mentha arvensis), hedgenettle (Stachys palustris), germander (Teucrium occidentale), and white aster (Aster simplex).

Dominant species of shallow-marsh zones were usually grasses or coarse grass-like plants of intermediate height. Slough sedge (*Carex artherodes*) and whitetop (*Scolochloa festucacea*) were the primary shallow-marsh species in most potholes but common spikerush (*Eleocharis palustris*), common threesquare (*Scirpus americanus*), slough grass (*Beckmannia syzigachne*), burreed (*Sparganium eurycarpum*), and tall manna-grass (*Glyceria grandis*) were common associates. Principal subdominant species included broadleaf waterplantain (*Alisma triviale*), narrowleaf waterplantain (*Alisma gramineum*), arrowhead (*Sagittaria cuneata*), water parsnip (*Sium suave*), and marsh smartweed (*Polygonum coccineum*). Frequently, star duckweed (*Lemna trisulca*) and common duckweed (*Lemna minor*) were found floating on the surface of the water.

Deep-marsh vegetation was characterized by coarser and taller species. Hardstem bulrush (*Scirpus acutus*), common cattail (*Typha latifolia*), and river bulrush (*Scirpus fluviatilis*) were the principal deep-marsh plants in these potholes. Several other species, including narrowleaf cattail (*Typha angustifolia*), softstem bulrush (*Scirpus validus*), slender bulrush (*Scirpus heterochaetus*), alkali bulrush (*Scirpus paludosus*), and common reed (*Phragmites communis*) were occasionally associated with these plants in deep-marsh zones. Star duckweed, common duckweed, and aquatic liverworts (_Riccia fluitans_ and _Ricciocarpus natans_) were commonly floating on the water, and bladderwort (_Utricularia vulgaris_) and aquatic moss (_Drepanocladus_ spp.) were submerged plants found in this zone.

Dense beds of submerged aquatic plants were found in open-water zones of semi-permanent and permanent potholes. The most abundant species were whitestem watermilfoil (_Myriophyllum exalbescens_), claspingleaf pondweed (_Potamogeton richardsonii_), and sago pondweed (_Potamogeton pectinatus_). Grassleaf pondweed (_Potamogeton pusillus_), coontail (_Ceratophyllum demersum_), and white watercrowfoot (_Ranunculus trichophyllus_) were other plants commonly found in open-water areas of potholes. Bladderwort, marestail (_Hippuris vulgaris_), muskgrass (_Chara_ spp.), aquatic moss, and horned pondweed (_Zannichellia palustris_) were also fairly common or occasional associates in various potholes.

METHODS

Selection of Study Potholes

The investigation was based on a selected sample of potholes to provide a variety of slightly brackish semi-permanent and permanent potholes for study. Emphasis was placed on these particular types of potholes, because slightly brackish semi-permanent and permanent potholes have received high priority in the wetlands acquisition program of the Bureau of Sport Fisheries and Wildlife.

Species composition of the deep-marsh vegetation in potholes was the basic consideration in selecting potholes for study. Potholes were selected if the primary deep-marsh vegetation consisted of various combinations of hard-stem bulrush, common cattail, and river bulrush. Other types of semi-permanent potholes of local importance dominated by hardstem bulrush and alkali bulrush associations or pure stands of alkali bulrush were not studied.

Two specific criteria used in selecting potholes were cover interspersion and pothole size. The objective was to select a series of potholes for detailed study ranging from an absence of emergent cover to a closed stand of emergent vegetation. The three distributional patterns of emergent vegetation and several general pothole size categories were followed for selecting potholes in the field.

Initial pothole selections were made in early June, 1964, prior to the appearance of duck broods. From over 100 potholes originally selected, 64 were intensively studied during the 2-year investigation. Potholes deleted from the study represented duplications of pothole sizes or cover patterns.

Measurement of Habitat Factors

Pothole morphometry

Pothole maps, prepared from aerial photographs, provided the basis for measuring size of potholes and length of shorelines. Dobie and Johnson (1951) discussed pond mapping from aerial photographs and recommended photographing individual ponds at low altitudes for accurate work.

Aerial photographs were taken of each pothole by John Winship in August, 1964 (Figure 7). These photographs (Scale: 1 mile = 12.25 inches) were taken from an altitude of approximately 2500 feet above the terrain. Since slight variations in scale resulted from the irregular topography, United States Geological Survey topographic maps were used to obtain accurate scale for the aerial photographs.

Pothole sizes were determined from the maps using the dot grid method described by Stains (1962). Shore lengths were determined by tracing pothole outlines with a map measurer (Welch, 1948). Pothole sizes were expressed in acres and shore lengths in feet (Table 28).

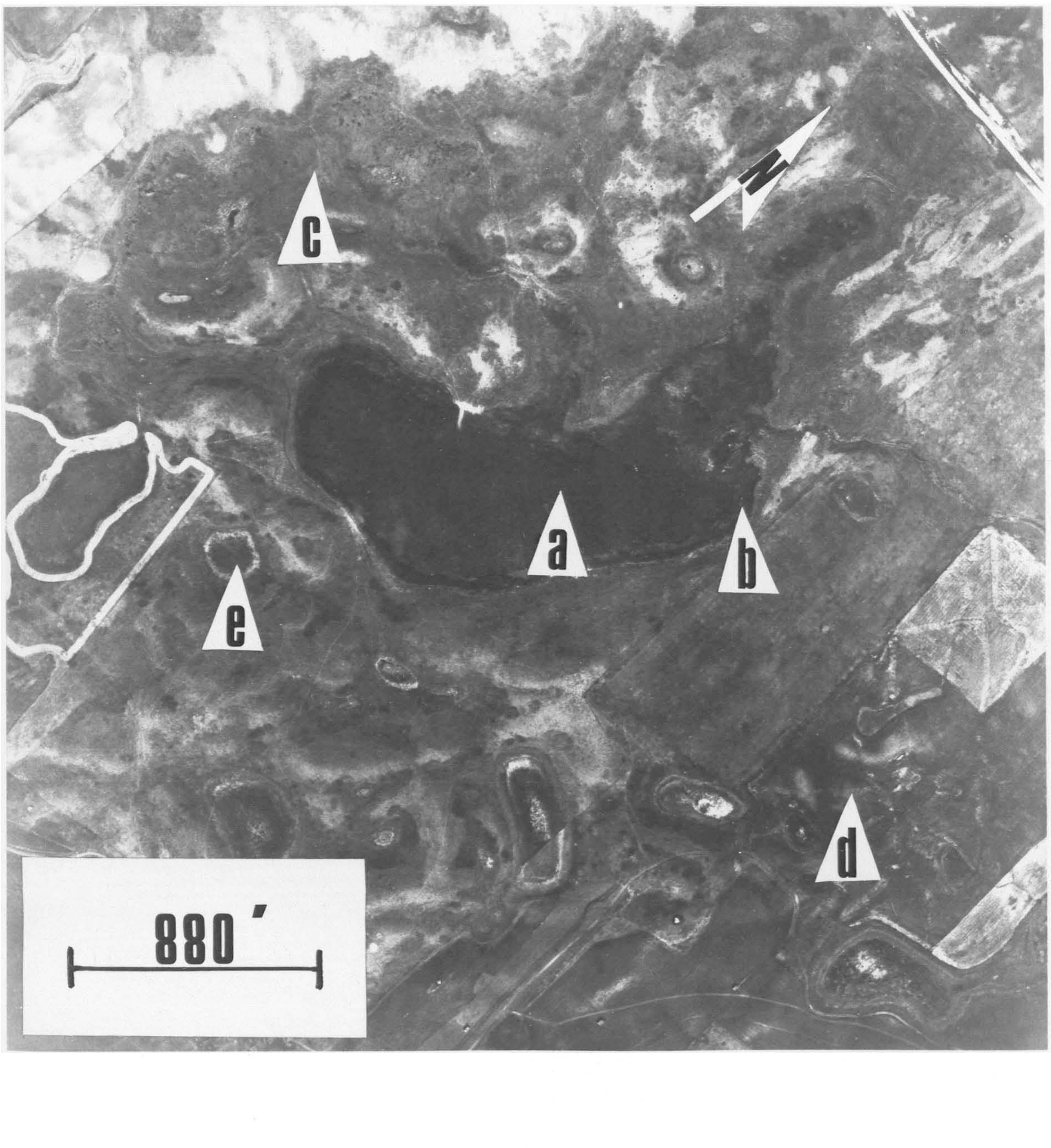
A sounding pole was used to measure water depths in potholes (Welch, 1948). This pole was constructed from a 12-foot length of bamboo and was marked at 1-inch intervals. On the lower end, a wooden disc, about 6 inches in diameter, was attached to prevent the pole from sinking into soft bottom deposits.

Maximum water depth was determined by lowering the sounding pole into the water at various intervals throughout the pothole basin. In shallow potholes, soundings were made while wading, but in deeper potholes, soundings were made from a small boat. Measurements were made each year between July 15 and August 31. Maximum depths were expressed in inches (Table 29).

Water gauges were established in 27 potholes between July 2-4, 1964. In eight additional potholes, water gauges had previously been established by either Bureau of Sport Fisheries and Wildlife or United States Geological Survey personnel. Thus, 35 potholes contained gauges for measuring water level fluctuations.

Generally, water gauges were checked at 2-week intervals, but incidental readings were recorded whenever it was convenient or whenever a heavy rain occurred. Geological Survey personnel checked water gauges weekly.

Figure 7. Aerial photos were used to determine pothole size and to prepare cover maps; a) open-water zone, b) deep-marsh zone, c) native prairie, d) cultivated cropland, e) one of many adjacent potholes forming a pothole complex around the larger semi-permanent pothole (Photo: John Winship)



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Cover analysis

In 1964 and 1965, cover maps of the potholes were prepared showing the distribution and composition of the major marsh and aquatic plant associations. These maps were drawn during an intensive coverage of each pothole basin between July 15 and August 31. The aerial photographs were used to determine the distribution and zonation of emergent vegetation, and black and white photographs were taken from vantage points on the ground to record the general appearance of each pothole.

A comparison of cover maps prepared in 1964 and 1965 revealed no marked changes in vegetative distribution and composition in individual potholes between the two years. Field observations and the photographs supported this conclusion. Therefore, a composite cover map was prepared for each pothole to provide a basis for analyzing cover interspersion.

Pothole outlines and zones of emergent vegetation and open water were traced from the aerial photographs. The field maps and photographs were used to identify the plant associations within the zones. The composite cover maps showed the distributional pattern of emergent vegetation and listed the species composition of plants occurring in the four zones of marsh and aquatic vegetation (Figure 8).

From these cover maps, the relative acreages of emergent vegetation and open water occurring in the pothole basin were

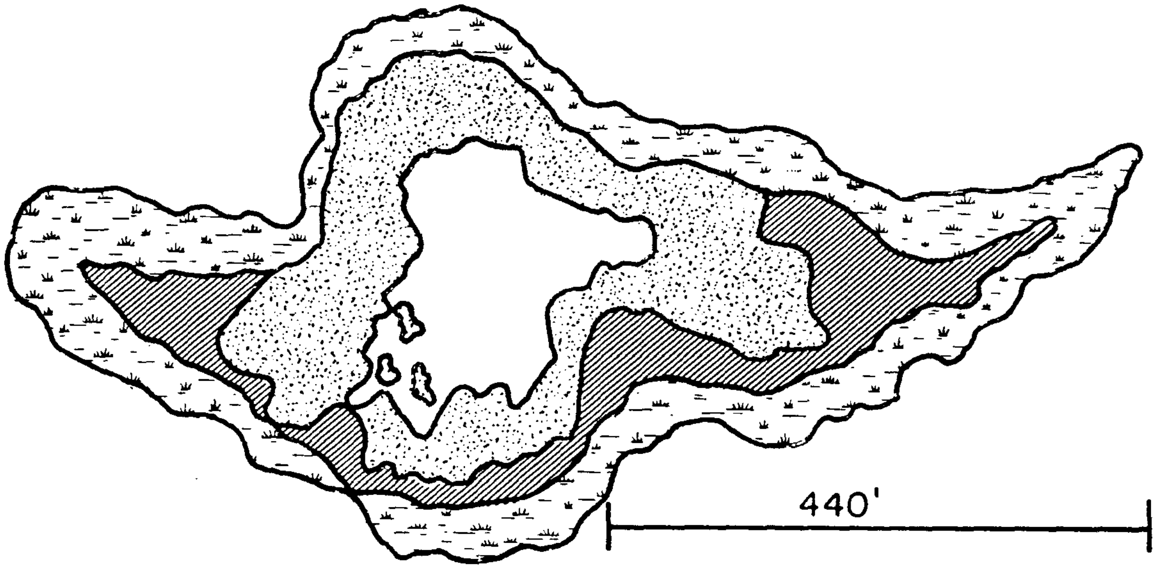
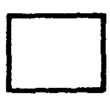
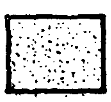


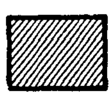
Figure 8. Cover maps showing the four major vegetation zones were prepared for each pothole (Example: Pothole #86)



Open-water Zone: *Utricularia vulgaris*, *Potamogeton pectinatus*, *Myriophyllum exalbescens*, and *Hippuris vulgaris* were the principal submerged plant species.



Deep-marsh Zone: *Typha latifolia* was dominant with *Scolochloa festucacea* and *Carex atherodes* subdominant. *Scirpus acutus* and *Scirpus validus* occurred in a few scattered clumps.



Shallow-marsh Zone: *Scolochloa festucacea* and *Carex atherodes* were the primary species with scattered patches of *Scirpus americanus* and *Carex aquatilis*.

Wet-meadow Zone: *Calamagrostis inexpansa*, *Juncus balticus*, *Eleocharis palustris*, *Spartina pectinatus* and several species of *Carex* were the most numerous species.

measured. Emergent cover and open water were expressed as percentages of the total area of the pothole (Table 29). In addition, a ratio of emergent cover to open water was calculated based on the acreages of emergent cover and open water within the pothole basin.

Water analysis

Water samples were collected in open-water zones of potholes, or in areas of open water in deep-marsh zones of potholes, where the wind could keep the water well mixed. Samples were taken from the surface of the water, following recommendations of Dobie and Moyle (1962), where the water was from 2 to 3 feet in depth. Care was taken to collect water that had not been roiled by stirring the bottom soil. Samples were collected in 500-milliliter polyethylene bottles. Each bottle was thoroughly rinsed with water from the pothole before a sample was taken for water analysis.

A Solu Bridge (Model RB-2; Industrial Instruments, Incorporated; Cedar Grove, New Jersey) was used to measure electrical conductivity of water samples. Conductivity measurements were made in the field immediately after the samples were collected. Specific conductance was read directly from the instrument as micromhos per centimeter (μmhos/cm) at 25°C. Measurements were taken between June 27-July 2, 1964 and between June 25-July 5 and August 25-

September 7, 1965 (Table 30).

Hydrogen-ion concentration (pH) of water samples was measured with a Beckman pH meter (Model N; Beckman Instruments, Incorporated; Fullerton, California) buffered at pH = 7.00. Determinations of pH were made in the laboratory within several hours after a series of samples was collected from the potholes. Measurements of pH were made between July 10-15 and between August 25-September 7, 1965 (Table 30).

Further analysis of water chemistry included determinations of total hardness, calcium hardness, total alkalinity, sulfates, and chlorides. Hach water testing equipment (Model DR-EL, Hach Chemical Company, Ames, Iowa) was used to make chemical determinations. These measurements were made in the laboratory and were completed within 7 days after the samples were collected.

Total hardness, calcium hardness, and alkalinity were expressed as parts per million (ppm) of an equivalent amount of calcium carbonate ($CaCO_3$). Sulfates and chlorides were expressed as parts per million (ppm). Magnesium hardness was obtained by subtracting parts per million of calcium hardness from parts per million of total hardness. Determinations were completed between August 25-September 7, 1965 (Table 31).

Determination of Brood Use

Duck brood counts were the major source of information on brood use of potholes. Brood "beatouts" and incidental brood observations provided additional information. For each brood observation, field notes were recorded on species, number and age class of ducklings, date and time of observation, and pothole number. Broods were aged in the field according to age classes based on plumage development as described by Gollop and Marshall (1954).

Since all of the potholes were located near a road or a trail, all brood counts and most incidental brood observations were either made from a car or a pickup truck. These vehicles served as effective blinds for studying broods and tended to minimize brood disturbances. The hilly topography offered many convenient observation points and greatly facilitated the counting of broods. Throughout the study, a 15-60X "spotting scope" and 7X35 binoculars were used to observe and to identify broods. In general, the techniques for the study of duck broods followed recommendations of Evans _et al_. (1952), Blankenship _et al_. (1953), Gollop and Marshall (1954), Murdy and Anderson (1955), Evans and Black (1956), and Robbins and Anderson (1956).

Brood census

During 1964 and 1965, 111 duck brood counts were made to obtain brood observations on the study potholes. Brood counts were made during periods of peak brood activity from 4:30 to 8:30 AM and in the evening from 5:00 to 9:00 PM. Since weather was known to influence brood activity and observability, brood counts were not attempted if the wind was greater than 10-15 mph or if rain was falling.

The potholes were visited for 57 counts in 1964 and for 54 counts in 1965. Several potholes were visited on each brood count, but it was impossible to count broods on all potholes. Instead, the potholes were visited at least every 5 to 10 days for brood counting beginning in early June and continuing through early September.

On each visit to a pothole, the entire pothole was scanned with binoculars in order to locate broods. Then the broods were identified and counted using a "spotting scope". Frequently, two persons participated in brood counts; one observed the broods while the other recorded the information.

Depending on the size of the pothole, amount of emergent vegetation, and number of broods, the time spent at any given pothole for brood counting varied. Considerably less time was necessary to count broods on small potholes, and often more than 30 minutes were needed to complete observations on larger potholes. In some cases, several hours were required to adequately observe broods on large or densely vegetated potholes. If many broods were present on a pothole, observations were rechecked several times before moving to the next pothole.

Brood "beatouts" were employed to obtain brood information for certain types and sizes of potholes, since a lack of time and manpower precluded brood "beatouts" on all potholes. Two to four beaters were needed to beat out potholes for duck broods, depending on the size of the pothole and the amount of emergent cover. An observer was usually stationed at a vantage point with a "spotting scope" to record broods flushed from emergent vegetation by the beaters. Maternal or "broody" hens were recorded as evidence of broods.

"Beatouts" were most useful on small or medium-sized potholes, which were overgrown with emergent vegetation but could be adequately covered by the beaters. On large, densely vegetated potholes, broods were difficult to flush from the cover, and on deep, sparsely vegetated potholes, brood "beatouts" were unnecessary. Broods on these potholes were counted most efficiently by careful observation during periods of peak brood activity in the early morning and evening.

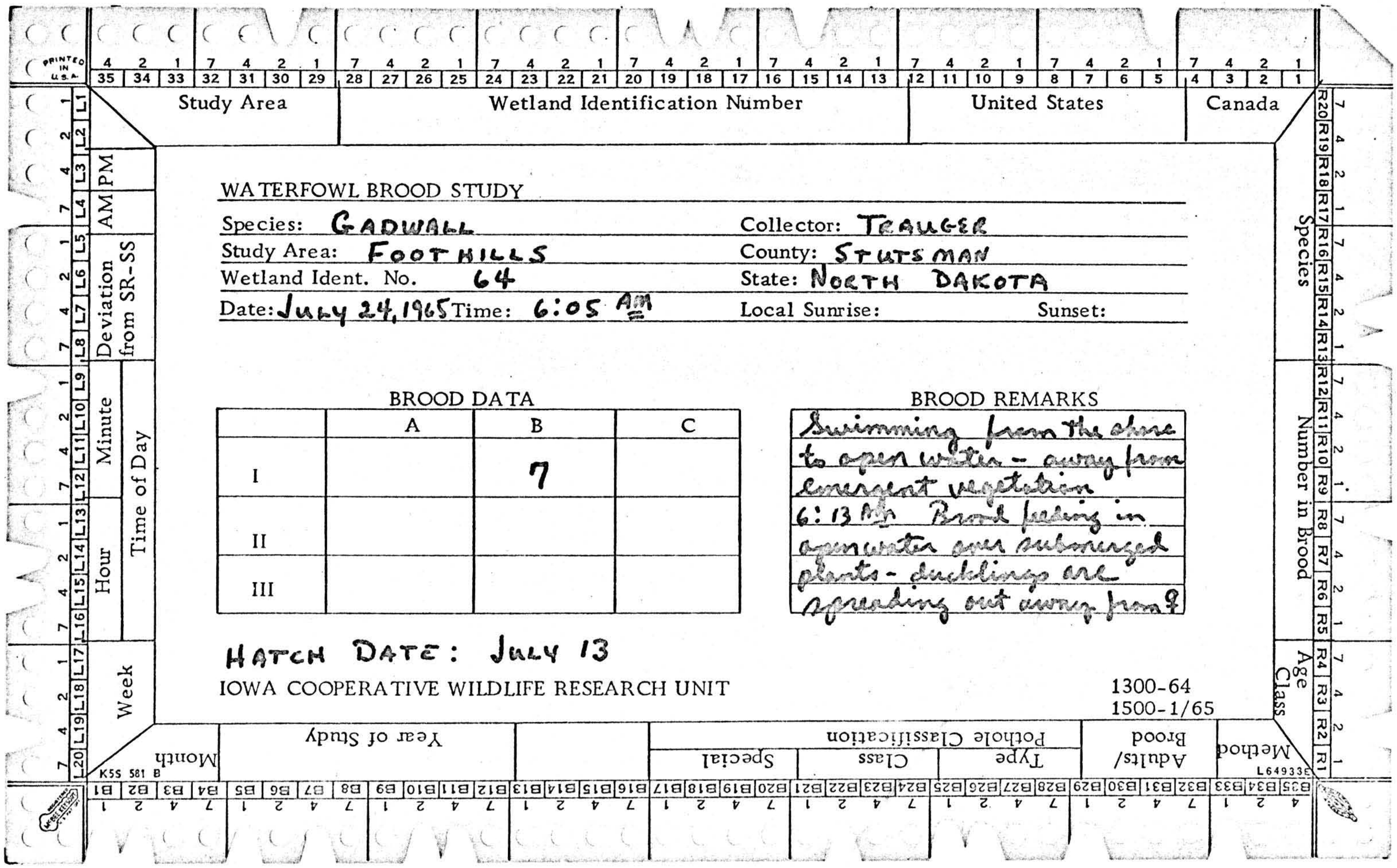
"Beatouts" were conducted throughout the day during the peak of the brood-rearing season. In 1964, brood "beatouts" were carried out during July 6-10, July 14-17, and July 27-31, and in 1965, during July 9-10, July 15-17, and August 3-6.

Incidental observations of broods were a third source of brood information. These observations were noted while engaged in other research activities, e.g. checking water gauges, collecting water samples, or mapping emergent cover patterns. These incidental brood sightings, collected throughout the day and under various types of weather conditions, provided information on the general activities of duck broods. In addition, incidental brood records were received from other Bureau of Sport Fisheries and Wildlife biologists who were working in the Woodworth area.

Brood use

Since frequent brood counts were made during the rearing season, the possibility of observing individual broods more than once was recognized. The procedure used to identify duplicate brood observations was a modification of the method described by Blankenship *et al*. (1953) and Gollop and Marshall (1954).

Brood observations were recorded on McBee keysort cards (Figure 9) and were accumulated throughout the rearing season.


Study Area | Wetland Identification Number | United States | Canada

WATERFOWL BROOD STUDY

Species: GADWALL	Collector: TRAUGER
Study Area: FOOTHILLS	County: STUTSMAN
Wetland Ident. No. 64	State: NORTH DAKOTA
Date: JULY 24, 1965 Time: 6:05 AM	Local Sunrise: Sunset:

BROOD DATA

	A	B	C
I		7	
II			
III			

BROOD REMARKS

Swimming from the shore to open water - away from emergent vegetation 6:13 AM Brood feeding in open water over submerged plants - ducklings are spreading out away from ♀

HATCH DATE: JULY 13

IOWA COOPERATIVE WILDLIFE RESEARCH UNIT

1300-64
1500-1/65

Figure 9. Keysort cards were used for recording data on brood observations

One card was used for each brood observation. After all brood observations were coded and punched on the cards, the observations for each pothole were sorted into groups. These cards were segregated by species within individual potholes. By comparing brood sizes and ages on consecutive dates of observation, duplicate observations of individual broods were identified. In this way, the number of broods for each species was determined for each pothole. The number of broods per pothole was ascertained by totaling the number of broods for each species (Table 32). This total was divided by the pothole acreage to obtain the number of broods per wetland acre.

The number of broods per pothole and the number of broods per wetland acre represented the brood use observed on a pothole during an entire rearing season. Since the length of time that individual broods occupied a given pothole varied, brood-days-use of potholes (the presence of one brood for one day on a pothole) was thought to provide a better measure of pothole utilization. Brood-days-use was calculated following the procedures described by Evans et al. (1952) to determine the duration of residence of broods on potholes. For each pothole, the number of brood-days-use for each brood and for each species was estimated. Brood-days-use per pothole was obtained by adding the brood-days-use for all species on the pothole (Table 32), and brood-days-use per wetland acre was calculated by dividing the brood-days-use for the pothole by the pothole acreage.

Although none of the broods in this study were color-marked, several brood movements between adjacent study potholes were observed or detected. In these cases, each pothole was credited with a brood of that species for a certain number of brood-days-use even though only one brood was involved. However, only one brood was used in calculating the species composition of broods observed on the study potholes.

Hatching dates

Hatching dates for broods could be determined by "back-dating" the mid-point age of broods in various age classes from the date of observation (Gollop and Marshall, 1954). For the green-winged teal and ruddy duck, information on age and plumage development of ducklings was unavailable. Therefore, hatching dates for green-winged teal broods were estimated by using the mid-point ages of age classes presented for the blue-winged teal. Hatching dates for ruddy duck broods were determined by using the approximate mid-point ages of age classes estimated by Hammond (1963).

When more than one brood observation was available for a given brood, an average date of hatch was determined. This date was based on two or more observations of a brood on different dates. For example, if these observations indicated hatching dates of July 13, July 14, and July 15, the date used in determining chronology of hatching was July 14. If a brood moved between two study potholes, only one date of hatch was used in tabulations. Hatching dates were not available for broods indicated by "broody" hens.

Analysis of Data

Three methods were used to study the number of duck broods and brood-days-use per pothole and per 10 wetland acres in relation to the habitat factors of the potholes. First, brood data were tabulated in relation to individual habitat factors to show the relationship of brood use with each factor. Second, correlation analysis was utilized to measure the relative linear association between brood use and individual habitat factors. Third, multiple regression analysis was employed to study the joint relationship of the habitat factors with brood use. The first two methods of analysis ignore any possible relationship between habitat factors, but the third method accounts for any correlation between habitat factors through the mode of calculation. Statistical methods follow Steel and Torrie (1960), except where another reference is cited.

Descriptive statistics were often used to compliment the presentation of data in tabular and graphical form. Proper interpretation of correlation analysis and multiple regression analysis may be facilitated by a review of these statistical methods as applied in this study. In correlation analysis, correlation coefficients (r) were computed to provide measures of the degree of linear association between various habitat factors and between brood use and habitat factors. Theoretically, correlation coefficients may range from -1 (perfect negative linear association) to +1 (perfect positive linear association), but biological relationships seldom result in correlations of this intensity (Snedecor, 1956). However, correlation coefficients are large when the degree of association between variables is high and small when the degree of association is low. Correlation coefficients near 0 indicate no linear association between the variables, but the variables may be perfectly correlated in a curvilinear relationship. A positive (+) sign indicates that large values of one variable are associated with large values of the other variable. Conversely, a negative (-) sign indicates that small values of one variable are associated with large values of the other variable.

Tests of significance for correlation coefficients were not valid, because brood use and habitat factors of the potholes did not represent bivariate normal distributions.

Hence, the basic assumptions for correlation analysis were not satisfied. However, the interpretation of the correlation coefficients is valid as previously outlined, regardless of the underlying assumptions (Ostle, 1963). If tests of significance were valid, critical values would be $\underline{r}$ = ± 0.2464 at the 5 per cent level of significance and $\underline{r}$ = ± 0.3204 at the 1 per cent level of significance with 62 degrees of freedom. Correlation coefficients ranging between ± 0.5000 to 0.7500 were arbitrarily considered "correlated" for descriptive purposes; values of $\underline{r}$ between ± 0.7500 and 1.0000 were considered "highly correlated".

Multiple regression analysis provided partial regression coefficients ($\underline{b}$) for brood use in relation to various habitat factors. These partial regression coefficients were tested for significance to identify the habitat factors that were most closely associated with brood use of the potholes. The results of these tests are displayed in Tables 23 through 26. The calculated $\underline{t}$ values are shown rather than the partial correlation coefficients and their corresponding standard errors to facilitate comparisons between the species and the habitat factors. In the results, "significant" refers to statistical significance at the 5 per cent level, and "highly significant" refers to significance at the 1 per cent level. Coefficients of determination ($\underline{R}^2$) were also computed to determine the amount of the total sum of squares that was attributable to the multiple regression. These coefficients of determination are discussed as percentages ($100R^2$) of the total variation in duck brood use that was accounted for by the combined effect of the habitat factors.

Data on brood use and habitat factors of potholes were transferred to punch cards at the Iowa State University Computation Center. Computations for correlation analysis and multiple regression analysis were done on the IBM System 360 computer at a considerable saving of time.

RESULTS

The results are based on a selected sample of 64 fresh to moderately brackish, semi-permanent and permanent potholes. The majority of the potholes represented slightly brackish semi-permanent potholes. These potholes provided a variety of rearing habitats for duck broods during 1964 and 1965.

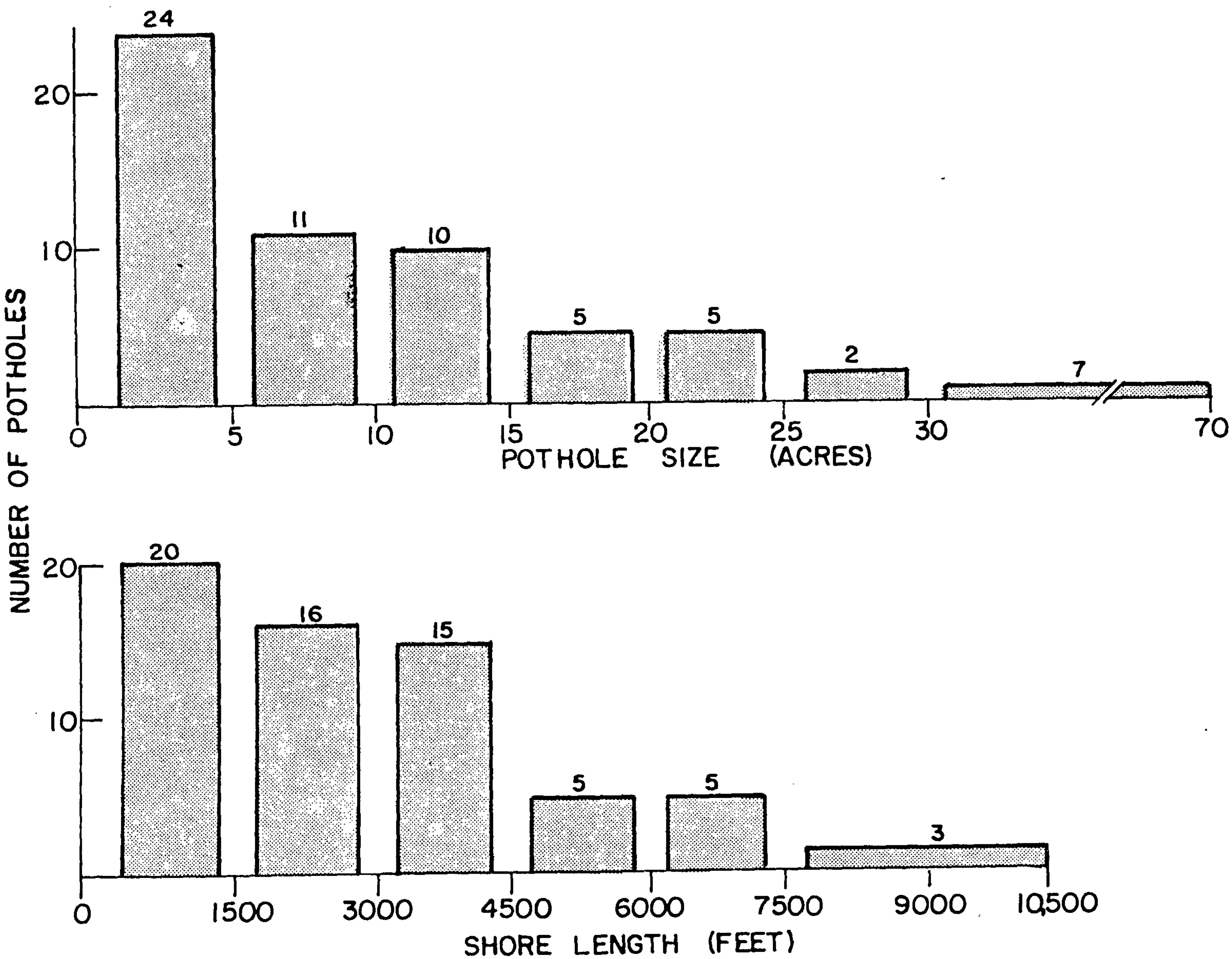
Habitat Factors of the Potholes

Pothole morphology

Morphometrical measurements were made of several structural features of the potholes to evaluate the relationship of pothole size, shore length, and water depth to other habitat factors and brood use. The size of the potholes formed the basis for calculating percentages of emergent cover and open water and expressing densities of duck broods. The potholes ranged in size from 0.5 to 69.5 acres and averaged 13.6 acres (Figure 10). There were 871.8 wetland acres represented within the 64 pothole basins.

Length of shorelines ranged from 583 to 9948 feet and averaged 3,054 feet (Figure 10). As indicated by the similar distributions, shore length was highly correlated with pothole size ($\underline{r}$ = +0.8684). Generally, as the size of the potholes increased, there was a corresponding increase in the length of the shorelines.

Figure 10. Size and shore length distributions of 64 semi-permanent and permanent potholes in Stutsman County, North Dakota

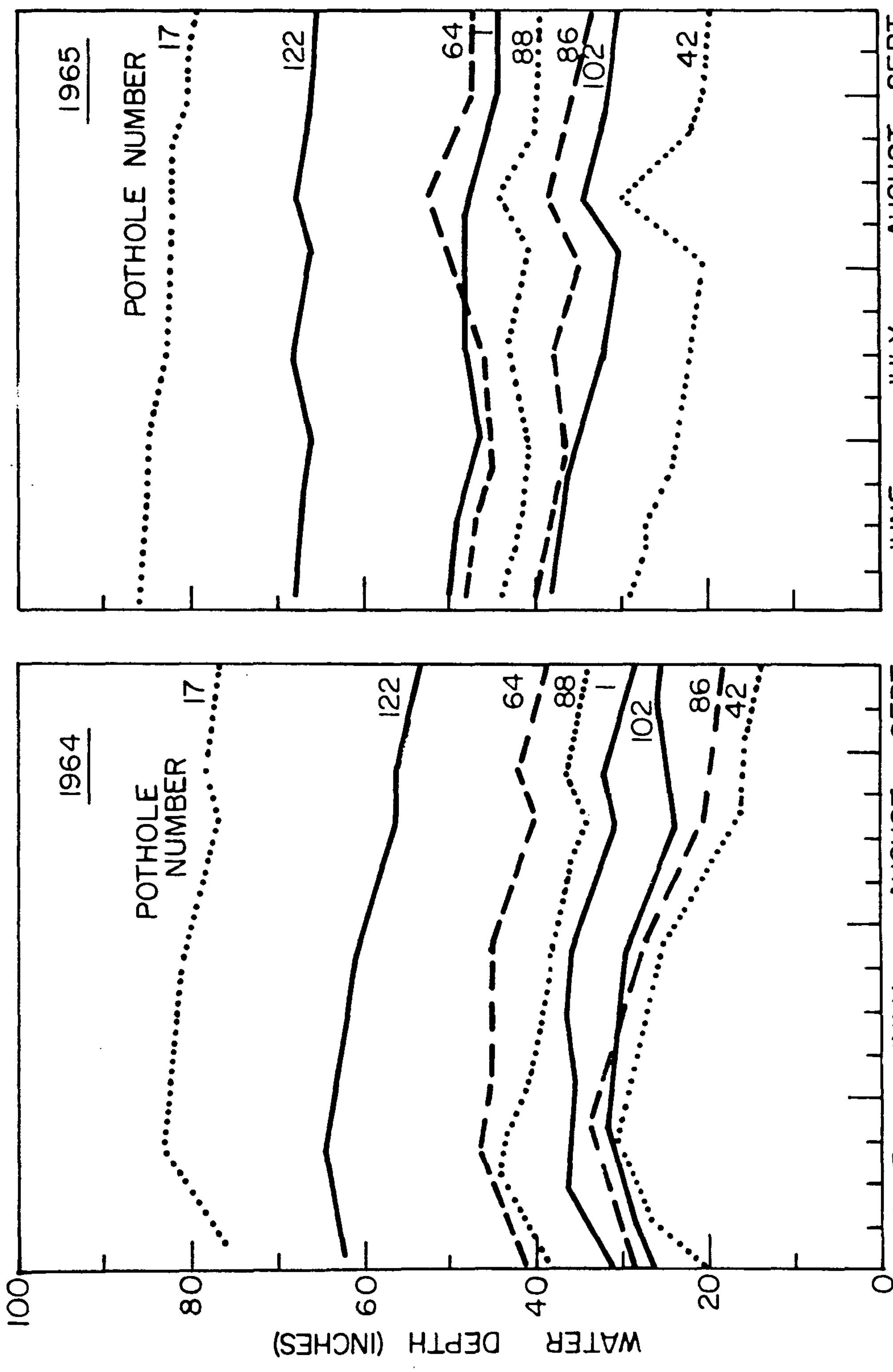

NUMBER OF POTHOLES
24
11
10
5
5
2
7
20
10
0
5
10
15
20
25
30
70
POTHOLE SIZE (ACRES)
20
16
15
5
5
3
0
1500
3000
4500
6000
7500
9000
10,500
SHORE LENGTH (FEET)

Fluctuations in water depth were measured in 35 potholes representing various sizes of potholes and patterns of cover interspersion. In 1964, heavy rains throughout the study area during June resulted in abruptly rising water levels in the potholes (Figure 11). Highest water levels were reached in the last 2 weeks of June. Throughout July and early August, water levels gradually declined in most potholes. Locally heavy rains raised water levels in some potholes in late August, but levels continued to decline during September. Several potholes were nearly dry at the end of the 1964 field season.

Water levels were generally higher in all potholes in 1965 than in 1964 (Figure 11). Rainfall during June and July in 1965 resulted in relatively stable water levels in most potholes. In other potholes, water levels gradually declined until locally heavy rains in early August resulted in rapidly rising levels. Water depths were greatest in most potholes during the first 2 weeks of August. In September, water levels gradually declined, but at the end of the 1965 field season, water depths were greater in most potholes than water depths in mid-September, 1964.

Since water levels were highest during June in 1964 and during August in 1965, maximum water depths were estimated at mid-July levels for comparison with other habitat factors and brood use. These estimates were based on measured maximum

Figure 11. Water level fluctuations measured in eight representative semi-permanent and permanent potholes in Stutsman County, North Dakota


1964
POTHOLE NUMBER
1965
POTHOLE NUMBER
17
122
64
88
1
102
86
42
JUNE
JULY
AUGUST
SEPT.
WATER DEPTH (INCHES)
100
80
60
40
20
0

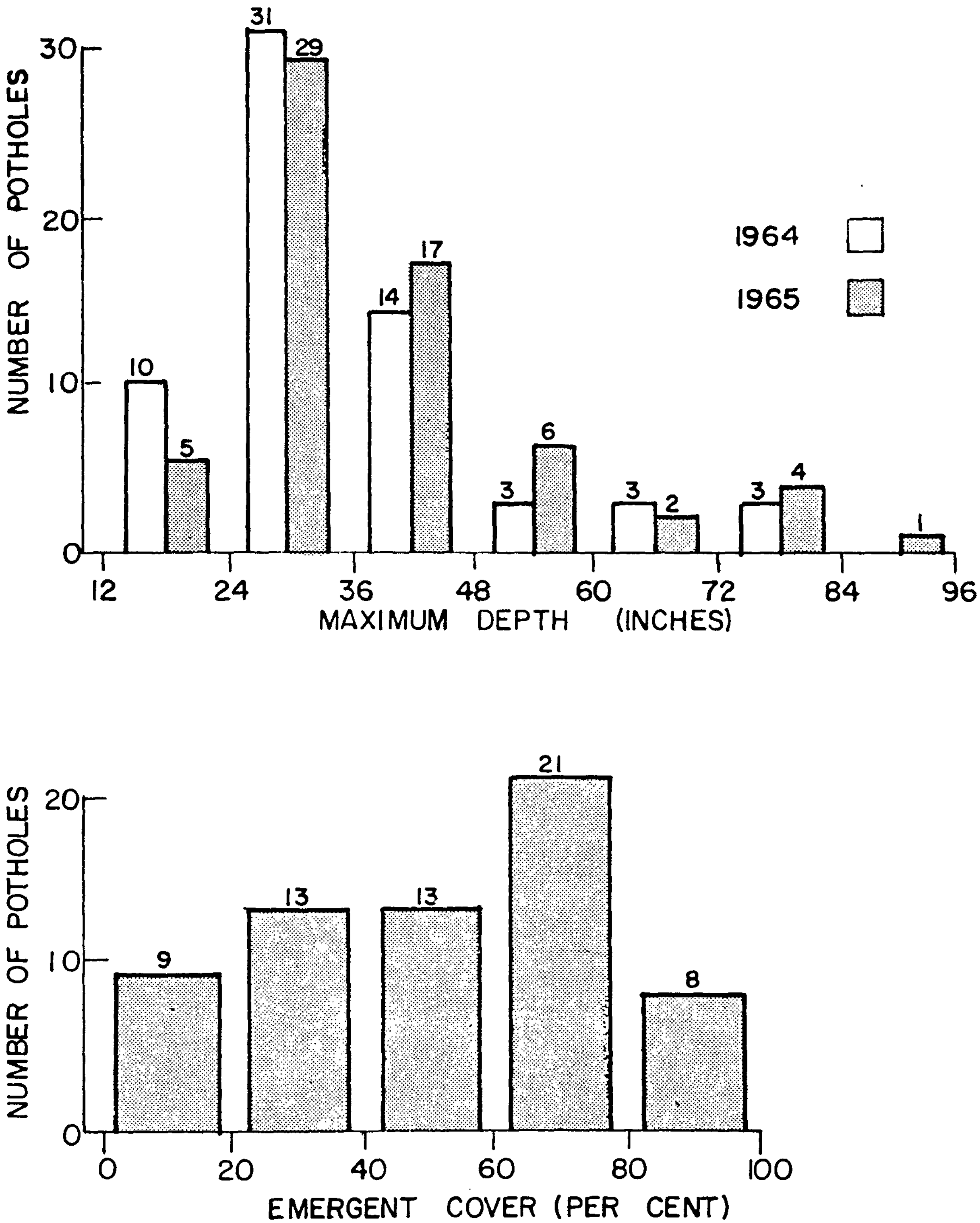


Figure 12. Maximum water depth (mid-July) and emergent cover distributions of 64 semi-permanent and permanent potholes in Stutsman County, North Dakota

water depths during late summer in 1964 and 1965 and on recorded water level fluctuations in representative potholes. The mid-July water levels were used because the peak of the brood-rearing season coincided with the mid-July water levels, and water depths in mid-July were believed to represent "average" water conditions in the potholes during 1964 and during 1965.

Maximum water depths in individual potholes ranged from 14 to 83 inches and averaged 36 inches in 1964 (Figure 12). In 1965, maximum water depths ranged from 21 to 86 inches and averaged 40 inches. Although water depths were generally greater in 1965 than in 1964, the maximum water depths measured in the potholes were highly correlated for the 2 years ($\underline{r}$ = +0.9489).

Cover interspersion

The potholes were classified according to one of three basic patterns of cover interspersion. These patterns were descriptively termed "patchy", "border", and "open" based on the distribution of emergent vegetation throughout the pothole basin. Potholes classified as "patchy" contained a semi-open stand of emergent vegetation covering from 5 to 95 per cent of the pothole. Potholes with open water surrounded by a peripheral band of emergents covering from 5 to 95 per cent of the pothole basin were termed "border" potholes. Potholes containing open water and stands of emergents covering less than 5 per cent of the pothole basin were classified as "open" potholes. The majority of the potholes represented either "patchy" or "border" patterns of cover interspersion. These potholes were divided about equally into 28 with "patchy" patterns and 31 with "border" patterns. The remaining 5 potholes contained "open" patterns of cover interspersion. Further division of the potholes with "patchy" and "border" patterns of cover interspersion into three cover categories within these classifications proved to be extremely difficult and arbitrary.

Since the concept of cover interspersion is qualitative rather than quantitative, the classification of potholes into three patterns of cover interspersion provided only general information on the relative proportions of emergent vegetation and open water in the potholes. Therefore, the ratio of emergent cover to open water and the percentage of emergent cover and open water were calculated to quantitatively express varying degrees of emergent cover. This information was used to study the relationship of emergent cover to other habitat factors and to duck brood use of the potholes.

Cover:water ratios ranged from 0.0:1.0 to 12.5:1.0 and averaged 2.0:1.0 in the 64 potholes. A 2.0:1.0 ratio indicates twice as much emergent cover in a pothole as open water. About two-thirds of the potholes had ratios of cover to water less than 2.0:1.0 and slightly less than half of the potholes had ratios of less than 1.0:1.0.

The percentage of emergent cover in the potholes ranged from 0 to 93 per cent with an average of 52 per cent (Figure 12). The range for percentage of open water was from 7 to 100 per cent with an average of 48 per cent. Since the percentage of emergent cover and percentage of open water represented reciprical distributions, the responses of duck broods to increasing amounts of emergent cover would show the same trend as observed in relation to decreasing amounts of open water. The percentage of emergent cover and percentage of open water were correlated with the ratio of emergent cover to open water (r = +0.7496).

Water chemistry

In early summer, specific conductance of water in individual potholes ranged from 140 to 2,400 µmhos/cm in 1964 and from 180 to 2,300 µmhos/cm in 1965 (Figure 13). The average was 1,005 µmhos/cm in 1964 and 1,023 µmhos/cm in 1965. Measurements of specific conductance were highly correlated between the 2 years (r = +0.8560). In 1965, specific conductance was also measured in late summer. These measurements ranged from 160 to 2,500 µmhos/cm and averaged 961 µmhos/cm. Although the means differed by 62 µmhos/cm, the correlation coefficient indicated that in 1965 specific conductance measured in early summer was highly correlated with measurements taken in late summer (r = +0.9163). In addition,

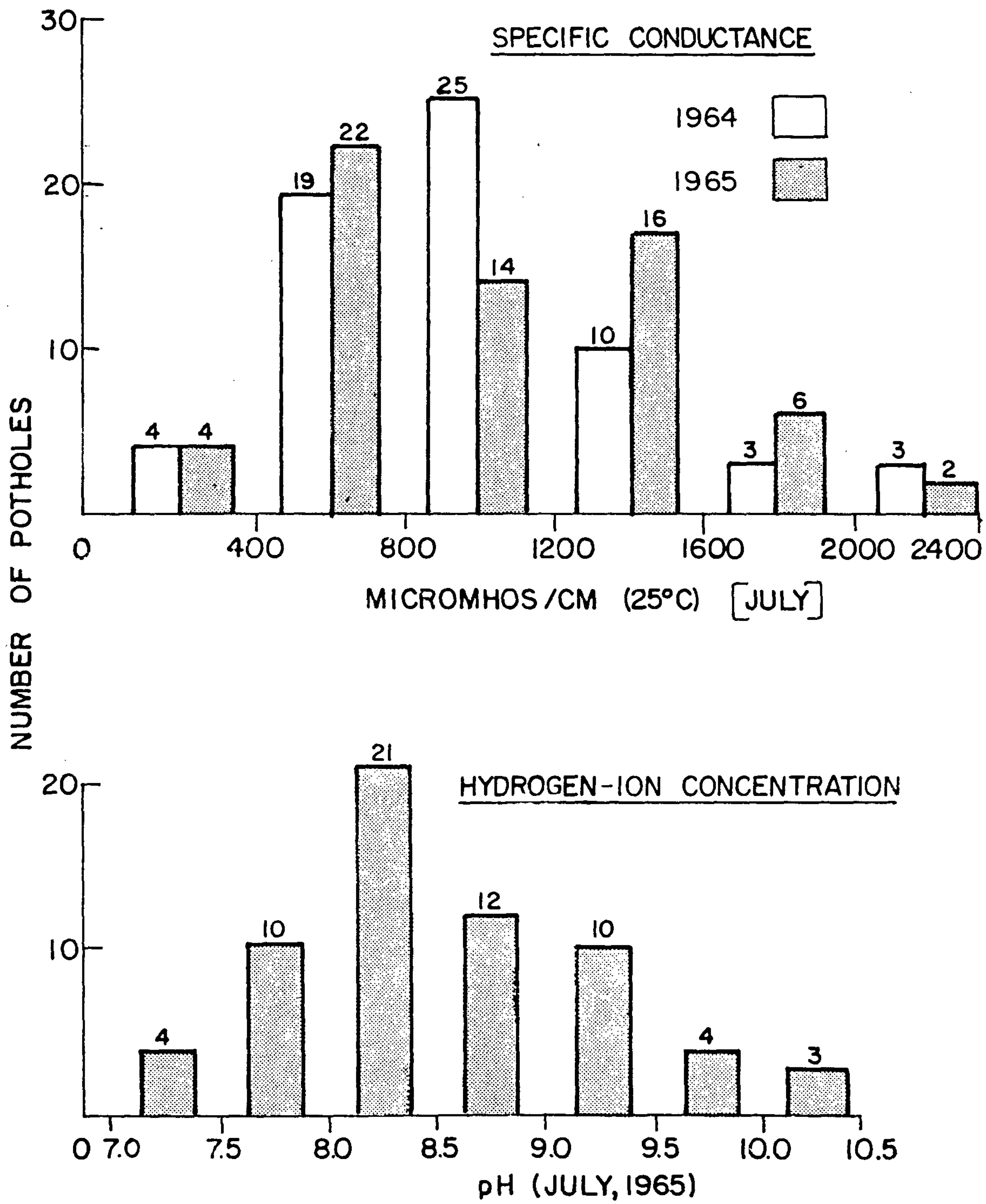


Figure 13. Specific conductance and hydrogen-ion concentration (pH) of water from 64 semi-permanent and permanent potholes in Stutsman County, North Dakota

measurements of specific conductance in early summer 1964 were highly correlated with those measured in late summer 1965 ($\underline{r}$ = +0.9054).

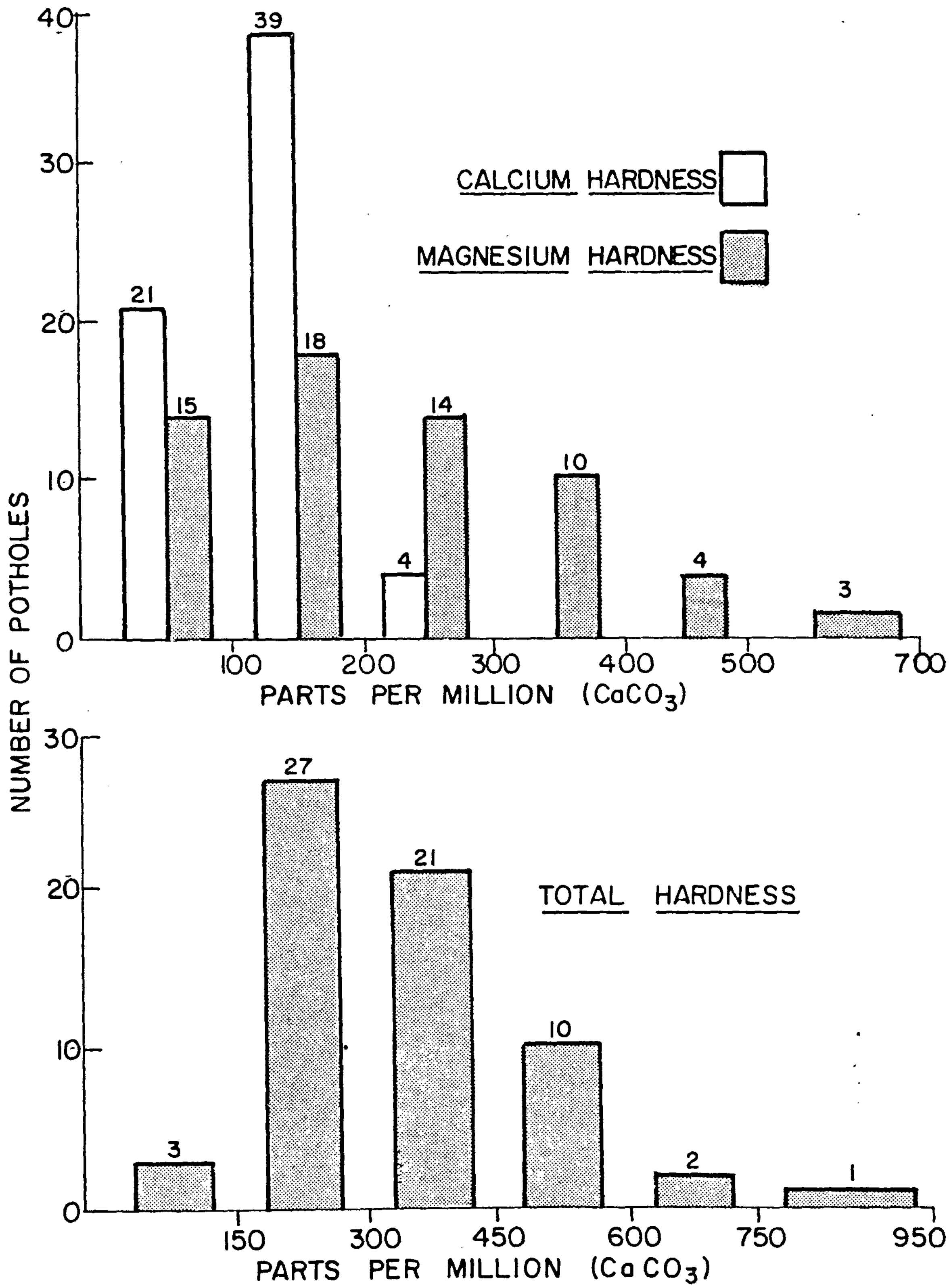
The pothole waters were mildly alkaline to alkaline as indicated by hydrogen-ion concentration (pH) measurements in July and August, 1965. The range of pH was from 7.3 to 10.5 and the mean was 8.6 in July (Figure 13). Determinations of pH in August ranged from 7.2 to 10.4 with a mean of 8.7. Despite slight seasonal differences in pH of water in individual potholes, the measurements of pH in July and August were highly correlated ($\underline{r}$ = +0.7550).

The pothole waters were relatively high in concentrations of calcium, but magnesium was the predominant cation. Calcium hardness ranged from 40 to 259 ppm with an average of 126 ppm, and magnesium hardness ranged from 0 to 660 ppm with an average of 216 ppm (Figure 14). Total hardness ranged from 100 to 910 ppm and averaged 342 ppm.

The pothole waters were high in sulfate and carbonate content but were low in chloride content. Concentration of sulfate ions ranged from 20 to 650 ppm and averaged 322 ppm (Figure 15). Total alkalinity ranged from 40 to 410 ppm and averaged 179 ppm. Chloride ions were only measured in 30 potholes, but concentrations ranged from 5 to 100 ppm and averaged 15 ppm.

Since measurements of specific conductance were highly

Figure 14. Calcium hardness, magnesium hardness, and total hardness of water from 64 semi-permanent and permanent potholes during 1965



CALCIUM HARDNESS
MAGNESIUM HARDNESS
NUMBER OF POTHOLES
0
10
20
30
40
21
15
39
18
4
14
10
4
3
100
200
300
400
500
700
PARTS PER MILLION ($CaCO_3$)
TOTAL HARDNESS
3
27
21
10
2
1
150
300
450
600
750
950
PARTS PER MILLION ($CaCO_3$)

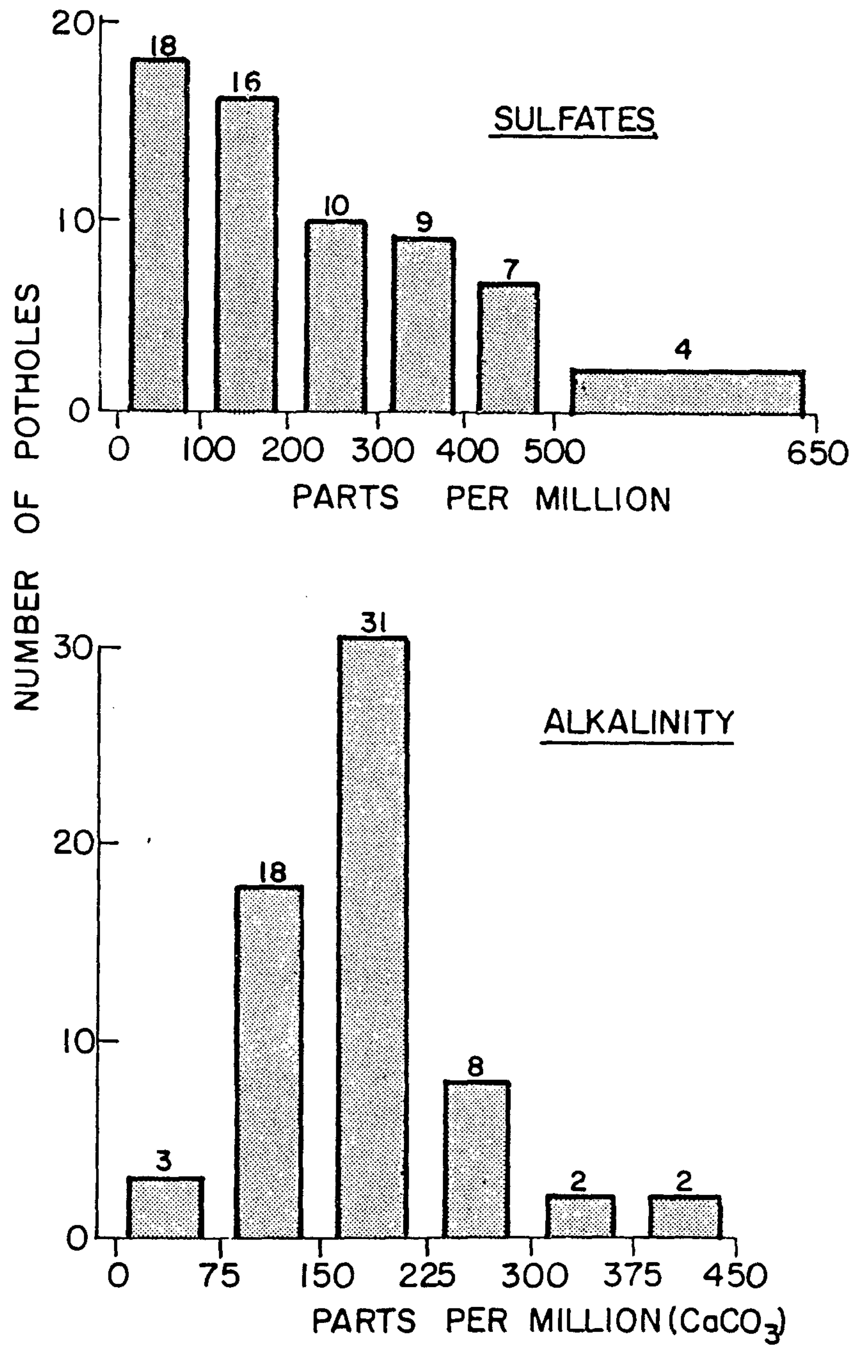


Figure 15. Sulfates and alkalinity of water from 64 semi-permanent and permanent potholes during 1965

correlated between the 2 years and within the same year, specific conductance was selected to represent the general water chemistry of potholes for comparison with other habitat factors and brood use. Specific conductance was highly correlated with magnesium hardness, total hardness and total alkalinity (Table 4). Calcium hardness was correlated with total hardness and sulfates. Magnesium hardness was highly correlated with total hardness and sulfates, and was correlated with total alkalinity. Total hardness was highly correlated with sulfates. However, there was little linear association between specific conductance and pH. Therefore, pH was another chemical characteristic used to study in relation to habitat factors and brood use of potholes.

<u>Correlation of habitat factors</u>

Pothole size was correlated with most of the habitat factors, except specific conductance and pH of pothole water (Table 5). In general, as potholes increased in size, the length of shoreline increased, the water depth increased, the amount of emergent cover decreased, and the amount of open water increased. Since shore length was highly correlated with pothole size, the relationship of shore length to other habitat factors was similar to the relationship of pothole size to these factors. Water depths in 1964 and 1965 were correlated with emergent cover and open water. Emergent cover decreased with an increase in water depth, and open water

Table 4. Correlation matrix of the chemical characteristics of water in 64 semi-permanent and permanent potholes measured in late summer, 1965

Variables	Specific conductance	pH	Calcium hardness	Magnesium hardness	Total hardness	Total alkalinity	Sulfates
Specific conductance	1.0000						
pH	0.1161	1.0000					
Calcium hardness	0.5981	-0.0518	1.0000				
Magnesium hardness	0.9027	0.1223	0.4485	1.0000			
Total hardness	0.9282	0.0903	0.6489	0.9711	1.0000		
Total alkalinity	0.4637	0.1286	0.0815	0.5270	0.4704	1.0000	
Sulfates	0.9288	0.1020	0.6041	0.8516	0.8863	0.3884	1.0000

Table 5. Correlation matrix of the habitat factors of 64 semi-permanent and permanent potholes during 1964 and 1965

Variable	Pothole size	Shore length	Water depth 1964	Water depth 1965	Emergent cover	Open water	Specific conductance 1964	Specific conductance 1965	pH July 1965
Pothole size	1.0000								
Shore length	0.6884	1.0000							
Water depth 1964	0.6564	0.6377	1.0000						
Water depth 1965	0.6926	0.6467	0.9489	1.0000					
Emergent cover	-0.6868	-0.6528	-0.6409	-0.6605	1.0000				
Open water	0.6868	0.6528	0.6409	0.6605	-1.0000	1.0000			
Specific conductance 1964	0.1799	0.0980	0.1023	0.1615	-0.1315	0.1315	1.0000		
Specific conductance 1965	0.1626	0.0742	0.0796	0.0879	-0.0997	0.0997	0.8560	1.0000	
pH July, 1965	0.2790	0.3309	0.3088	0.3113	-0.5152	0.5152	-0.0020	-0.0796	1.0000

increased with a corresponding increase in water depth. Emergent cover and open water were correlated with pH of the pothole water. An increase in the amount of emergent vegetation was generally associated with a decrease in the pH of the water. An increase in the amount of open water was generally associated with an increase in pH of the water. Specific conductance of the pothole water was not correlated with any of the other habitat factors.

Brood Composition and Hatching

Species composition

Composition of duck broods using the 64 semi-permanent and permanent potholes is based on 1,728 observations of 613 duck broods during 1964 and 1965. These observations represented 962 sightings of 334 broods in 1964 and 766 sightings of 279 broods in 1965. Brood observations indicated that 11 duck broods moved between two adjacent study potholes. These broods were counted only once in the tabulation of species composition (Table 6), but they were considered as individual broods in analyzing brood use of potholes in relation to various habitat factors.

Broods of 12 duck species were observed on the 64 potholes during 1964 and 1965. Dabbling duck broods were more abundant than diving duck broods on the semi-permanent and permanent potholes (Table 6). Gadwall broods were more

Table 6. Species composition of duck broods observed on 64 semi-permanent and permanent potholes during 1964 and 1965 near Woodworth, North Dakota[a]

Species	1964	1965	Total
Mallard	16 (4.8)[b]	13 (4.8)	29 (4.8)
Gadwall	100 (30.1)	80 (29.6)	180 (29.9)
Pintail	11 (3.3)	16 (5.9)	27 (4.5)
Green-winged teal	3 (0.9)	3 (1.1)	6 (1.0)
Blue-winged teal	51 (15.4)	59 (21.9)	110 (18.3)
Shoveler	21 (6.3)	9 (3.3)	30 (5.0)
American widgeon	17 (5.1)	13 (4.8)	30 (5.0)
Dabbling ducks	219 (66.0)	193 (71.5)	412 (68.4)
Redhead	32 (9.6)	13 (4.8)	45 (7.5)
Ring-necked duck	0 (0.0)	1 (0.4)	1 (0.2)
Canvasback	14 (4.2)	11 (4.1)	25 (4.1)
Lesser scaup	12 (3.6)	14 (5.2)	26 (4.3)
Ruddy duck	55 (16.6)	38 (14.1)	93 (15.4)
Diving ducks	113 (34.0)	77 (28.5)	190 (31.6)
Total	332	270	602

[a]Corrected for presumed brood movements.

[b]Per cent in parentheses.

numerous than broods of any other species and accounted for about 30 per cent of the broods. Ruddy duck broods ranked second in abundance in 1964, but blue-winged teal broods ranked second in abundance in 1965. For the 2-year period, blue-winged teal comprised about 18 per cent of the broods, and ruddy ducks represented about 15 per cent of the broods. Broods of redheads, American widgeons, shovelers, mallards, pintails, lesser scaup, and canvasbacks accounted for 4 to 8 per cent of the total number of broods, respectively. Green-winged teal and ring-necked duck broods were few in number on the potholes during the study.

Year-to-year variations in brood populations for all species of dabblers generally corresponded to relative changes in the breeding populations for these species in the Woodworth area (Tables 2 and 6). Gadwall broods were more abundant on the study potholes, and blue-winged teal were less abundant, than the indicated breeding populations for these species. Diving duck broods were considerably more numerous on the semi-permanent and permanent potholes in comparison to their respective breeding populations. These differences probably represented species preferences of gadwalls and diving ducks for more permanent types of potholes for brood-rearing. Year-to-year changes in brood populations of diving ducks were not correlated with fluctuations in breeding populations. Probably habitat conditions, particularly water level fluctuations during the nesting season and numbers of potholes available for brood rearing, were responsible for these differences in brood composition between 1964 and 1965.

Duck broods observed on other Stutsman County study areas during 1964 and 1965 are presented for comparison in Table 7. The species composition of broods observed on the 64 semi-permanent and permanent potholes differs markedly from the composition of broods on the areas where all types of potholes were represented. Broods of diving ducks were more numerous in relation to dabbling duck broods on the semi-permanent and permanent potholes as compared with the two study areas near Woodworth (Tables 6 and 7). However, broods of divers were more abundant than broods of dabblers on the Woodworth Study Area and the Stutsman County Transect in relation to their respective breeding populations (Tables 2 and 7).

A higher proportion of blue-winged teal broods and a lower proportion of gadwall broods was found on the Stutsman County study areas in relation to the 64 semi-permanent and permanent potholes (Tables 6 and 7) suggesting definite habitat preferences for these two species. The relative numbers of broods observed on the Woodworth Study Area and on the Stutsman County Transect during 1964 and 1965 corresponded to relative year-to-year changes in abundance and

Table 7. Species composition of duck broods observed on the Woodworth Study Area and the Stutsman County Transect during 1964 and 1965

Species	Woodworth Study Area[a]		Stutsman County Transect[b]	
	1964	1965	1964	1965
Mallard	8 (7.5)[c]	11 (5.9)	8 (7.8)	9 (6.9)
Gadwall	14 (13.2)	28 (15.1)	21 (20.6)	21 (16.0)
Pintail	6 (5.7)	20 (10.8)	2 (2.0)	5 (3.8)
Green-winged teal	2 (1.9)	5 (2.7)	2 (2.0)	0 (0.0)
Blue-winged teal	37 (34.9)	79 (42.5)	36 (35.3)	48 (36.6)
Shoveler	7 (6.6)	13 (7.0)	3 (2.9)	8 (6.1)
American widgeon	9 (8.5)	6 (3.2)	8 (7.8)	3 (2.3)
Dabbling ducks	83 (78.3)	162 (87.1)	80 (78.4)	94 (71.8)
Redhead	5 (4.7)	8 (4.3)	2 (2.0)	3 (2.3)
Canvasback	6 (5.7)	2 (1.1)	3 (2.9)	6 (4.6)
Lesser scaup	3 (2.8)	5 (2.7)	5 (4.9)	3 (2.3)
Ruddy duck	9 (8.5)	9 (4.8)	12 (11.8)	25 (19.1)
Diving ducks	23 (21.7)	24 (12.9)	22 (21.6)	37 (28.2)
Totals	106	186	102	131

[a]Source: Kirsch and Bayha (1965).

[b]Source: Kruse (1964, 1965).

[c]Per cent in parentheses.

species composition of the breeding populations on these areas (Tables 2 and 7).

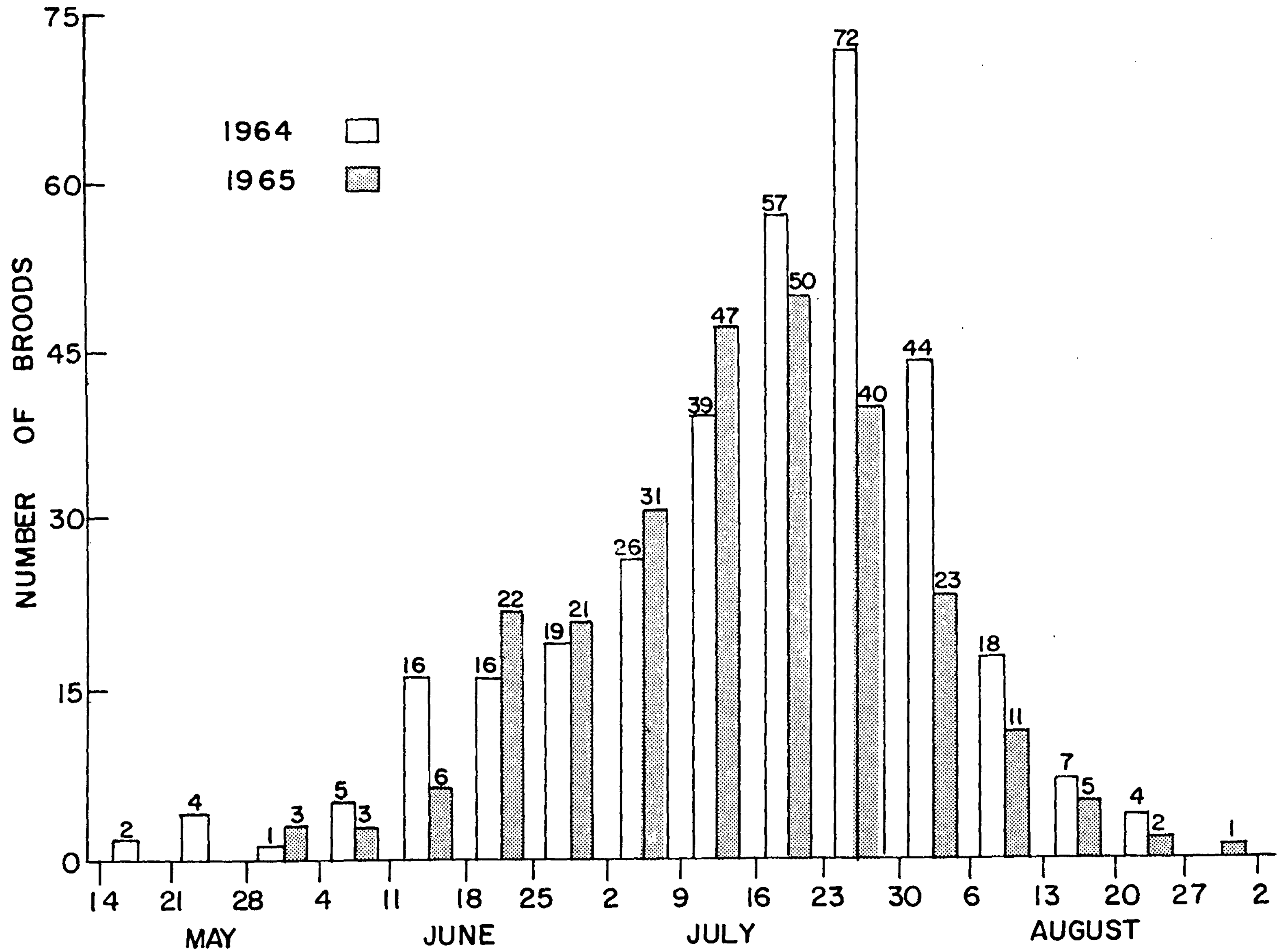
<u>Chronology of hatching</u>

Dates of hatching were determined for 595 broods and were tabulated by weekly intervals for 1964 and 1965 (Figure 16). The hatching dates for seven broods were unavailable, beca;se these broods were determined from observations of "broody" hens. Duplicate hatching dates for the 11 broods that apparently moved between study potholes were excluded.

Broods were hatched over a period of 15 weeks in 1964 and a period of 14 weeks in 1965 (Figure 16). The earliest broods were hatched during the week of May 14 through 21 in 1964 and the week of May 28 through June 4 in 1965. The peak of the hatch occurred during the week of July 23 through 30 in 1964 and the week of July 16 through 23 in 1965. The latest broods were hatched during the week of August 20 through 27 in 1964 and the week of August 27 through September 2 in 1965.

Hatching curves were constructed to compare the chronology of hatching in 1964 and 1965 for broods of all species. Figure 17 shows that broods started hatching earlier in 1964 than in 1965 but that the peak of hatch was reached earlier in 1965 than in 1964. Fifty per cent of the hatch was reached about one week earlier in 1965 than in 1964, but broods

Figure 16. Hatching dates by weekly intervals for 595 broods studied during 1964 and 1965



1964
1965
NUMBER OF BROODS
75
60
45
30
15
0
2
4
1
3
5
3
16
6
16
22
19
21
26
31
39
47
57
50
72
40
44
23
18
11
7
5
4
2
1
14
21
28
4
11
18
25
2
9
16
23
30
6
13
20
27
2
MAY
JUNE
JULY
AUGUST

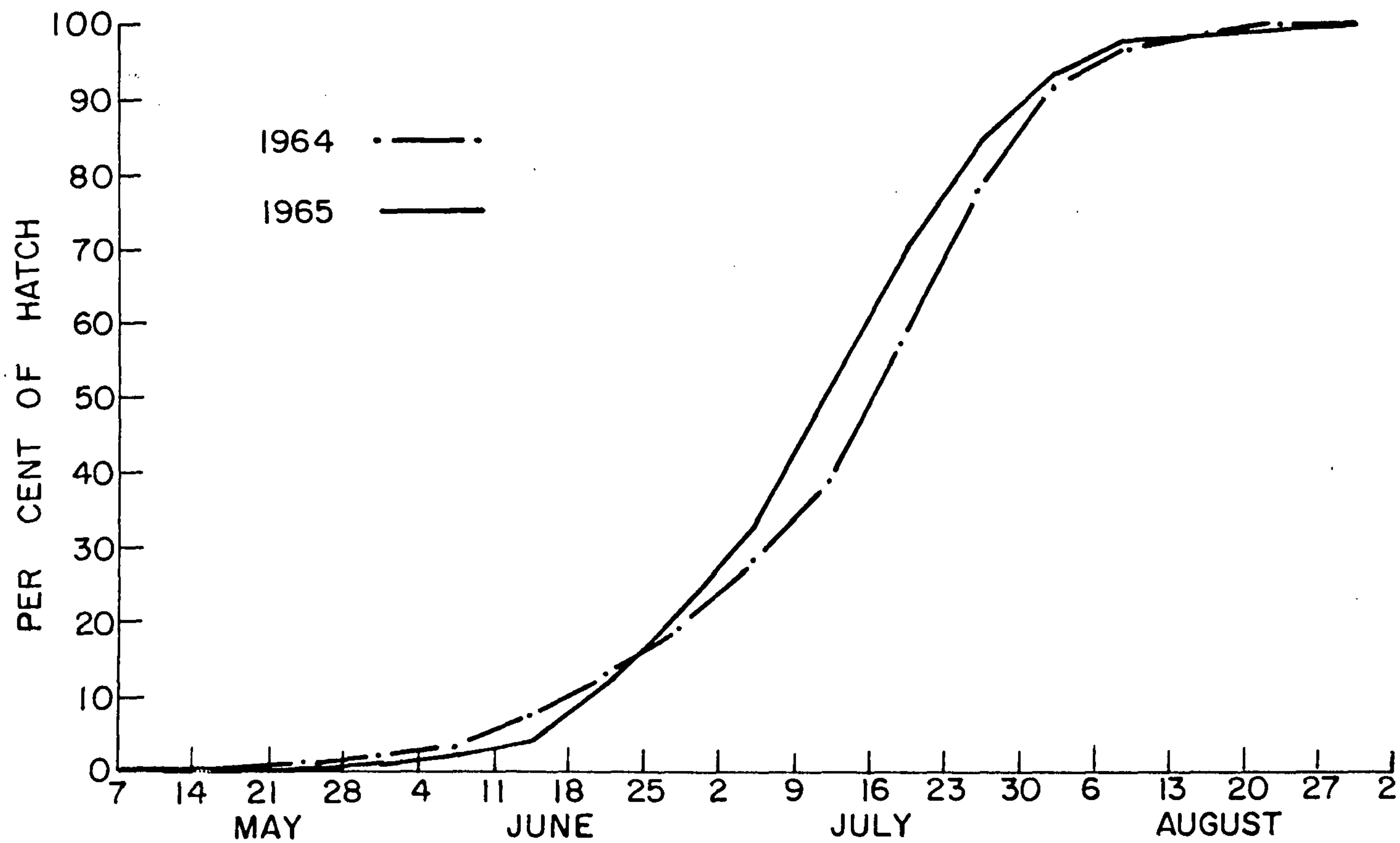


Figure 17. Cumulative hatching curves for 595 duck broods studied during 1964 and 1965

continued to hatch at least one week longer in 1965 than in 1964.

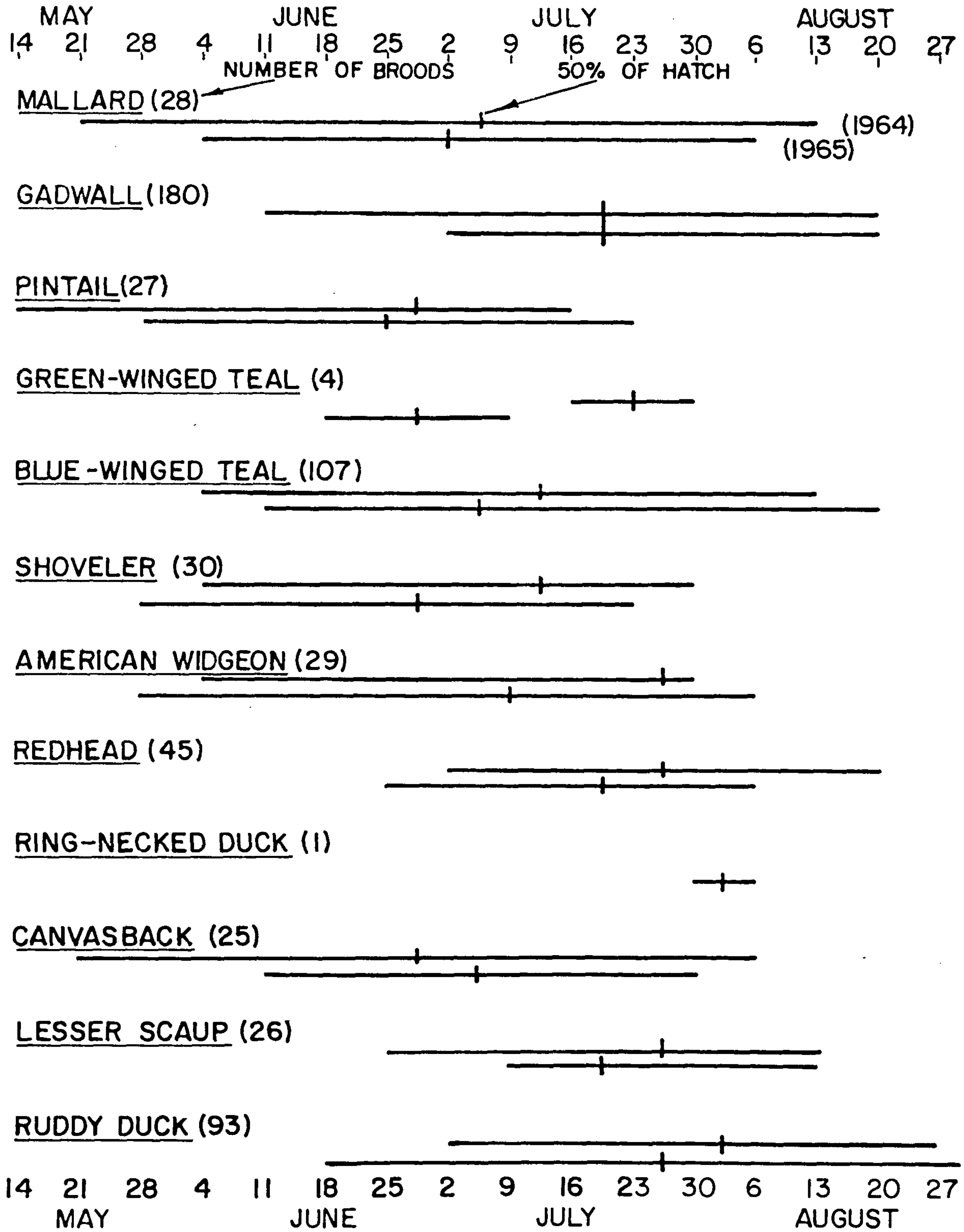
Hatching periods for the various species were determined to compare the chronology of hatching for each species during 1964 and 1965 (Figure 18). In 1964, hatching periods were generally longer for most species, particularly the early nesting mallards, pintails, and canvasbacks, than in 1965. In addition, the median hatch date was 1 to 2 weeks later in 1964 than in 1965 for all species, except the gadwall and canvasback.

Brood Populations and Use

Brood populations ranged from 0 to 32 broods per pothole and averaged 5.2 broods per pothole in 1964. Brood densities ranged from 0 to 40.0 broods per 10 wetland acres and averaged 5.6 broods per 10 wetland acres. Five potholes provided rearing habitat for 15 or more broods, and 27 potholes had five or more broods. No broods were observed on 15 potholes, but 49 potholes were used by at least one brood during the 1964 rearing season.

In 1965, the number of broods per pothole ranged from 0 to 25 and averaged 4.4, and the number of broods per 10 wetland acres ranged from 0 to 16.9 and averaged 3.5. Four potholes were used by 15 or more broods, and 22 potholes had five or more broods. Broods were not observed on 23

Figure 18. Hatching periods for 12 species of duck broods using 64 semi-permanent and permanent potholes in 1964 and 1965


MAY
JUNE
JULY
AUGUST
14 21 28 4 11 18 25 2 9 16 23 30 6 13 20 27
NUMBER OF BROODS
50% OF HATCH
MALLARD (28)
(1964)
(1965)
GADWALL (180)
PINTAIL (27)
GREEN-WINGED TEAL (4)
BLUE-WINGED TEAL (107)
SHOVELER (30)
AMERICAN WIDGEON (29)
REDHEAD (45)
RING-NECKED DUCK (1)
CANVASBACK (25)
LESSER SCAUP (26)
RUDDY DUCK (93)
14 21 28 4 11 18 25 2 9 16 23 30 6 13 20 27
MAY
JUNE
JULY
AUGUST

potholes, but 41 potholes provided brood habitat for at least one brood in 1965.

Total brood populations on the 64 potholes during the 2-year study showed a range of 0 to 41 broods per pothole and an average of 9.6 broods per pothole. Brood densities on individual potholes ranged from 0 to 40.0 broods per 10 wetland acres and averaged 9.2 broods per 10 wetland acres. Five potholes were used by more than 30 broods, and 25 potholes provided rearing habitat for 10 or more broods. Ten of the potholes did not harbor a single brood during the 2-year study, but at least one brood was observed on 54 of the potholes.

Brood populations for dabbling ducks ranged from 0 to 22 broods per pothole in 1964 and from 0 to 17 broods per pothole in 1965. Diving duck brood populations ranged from 0 to 17 broods per pothole in 1964 and from 0 to 8 broods per pothole in 1965. For the 2-year study, brood populations of dabblers ranged from 0 to 29 broods per pothole and of divers ranged from 0 to 22 broods per pothole.

In 1964, 220 broods of dabbling ducks were observed on the 64 potholes. These broods used the study potholes for an estimated 4,693 brood-days-use. In 1965, 197 broods of dabblers occupied the potholes for 4,374 brood-days-use. A total of 417 dabbling duck broods were studied on the 64 potholes during the 2-year period. These broods accounted for 9,067 brood-days-use of the potholes.

In 1964, 114 diving duck broods were observed on the 64 potholes. These broods used the study potholes for 3,703 brood-days-use. During 1965, 82 diving duck broods occupied the potholes for 2,919 brood-days-use. A total of 196 broods of divers were studied on the 64 potholes during 1964 and 1965. These broods accounted for 6,622 brood-days-use of the potholes.

Total brood populations for all species on the 64 potholes declined from 334 broods in 1964 to 279 broods in 1965. Brood-days-use on the study potholes decreased from 8,396 in 1964 to 7,293 in 1965. During 1964 and 1965, a total of 613 broods used the potholes for a total of 15,689 brood-days.

Correlation coefficients indicated a close relationship between the broods on the potholes in 1964 and the broods on the potholes in 1965 ($\underline{r} = +0.6058$). Brood-days-use between the 2 years was also correlated between 1964 and 1965 ($\underline{r} = +0.6397$). Since the brood use of the potholes was strongly correlated for 1964 and 1965, the data for the 2 years were combined, and the total number of broods and brood-days-use was used to evaluate the influence of various habitat factors on brood use of potholes.

The number of broods per pothole was highly correlated with the number of brood-days-use ($\underline{r}$ = +0.9838), but the number of broods per pothole and the number of broods per wetland acre were only slightly correlated ($\underline{r}$ = +0.3899). Therefore, brood use of potholes in relation to habitat factors will be discussed in terms of broods per pothole and broods per wetland acre. Brood-days-use per pothole and brood-days-use per wetland acre will be included in tabulations for comparative purposes, but in graphical analysis, brood-days-use per pothole and per wetland acre will not be shown. However, brood-days-use per pothole and per wetland acre would reflect similar trends in brood use as indicated by the broods.

Brood Use in Relation to Habitat Factors

Since the primary objective was to study duck brood use of potholes in relation to cover interspersion of pothole vegetation, considerable emphasis was placed on evaluating this relationship in brood-rearing habitat. However, brood use appeared to be related to other habitat factors of potholes independent of the influence of cover interspersion. Therefore, brood use was studied in relation to several physical features of the pothole basins and chemical characteristics of the pothole waters in addition to cover interspersion to appraise the significance of these factors in brood-rearing habitat. Habitat factors were independently analyzed in relation to brood use to show the response of duck broods to each factor. Then, habitat factors were jointly analyzed in relation to brood use to determine the relative importance of each factor in relation to the influence of the other factors.

<u>Brood use in relation to cover interspersion</u>

Brood use was tabulated in relation to the three distributional patterns of emergent vegetation in the semipermanent and permanent potholes to investigate the relationship between brood use and cover interspersion. During 1964 and 1965, the greatest number of broods per pothole was found on "open" potholes with relatively little emergent cover, but the greatest number of broods per 10 wetland acres was found on "border" potholes with prominent peripheral bands of emergent vegetation (Table 8). Potholes with a "patchy" distribution of emergent vegetation received the lowest brood use by both standards of comparison. The number of broods per pothole differed between the three distributional patterns of cover, but the number of broods per 10 wetland acres was nearly identical for "patchy" and "open" potholes. The number of broods per pothole and per 10 wetland acres was equivalent on "border" potholes. Brood-days-use per pothole and per 10 wetland acres showed corresponding patterns of brood use in relation to cover interspersion as found for broods per pothole and broods per 10 wetland acres (Table 8).

Table 8. Duck brood use in relation to cover interspersion of 64 semi-permanent and permanent potholes during 1964 and 1965

Observation	Cover pattern		
	"patchy"	"border"	"open"
Number of potholes	28	31	5
Number of broods	191	324	98
Broods per pothole	6.8	10.5	19.6
Broods per 10 wetland acres	8.1	10.5	8.4
Number of brood-days-use	5093	8244	2352
Brood-days-use per pothole	181.9	265.9	470.4
Brood-days-use per 10 wetland acres	171.8	221.6	178.4

Brood use was studied in relation to the ratio of emergent cover to open water and the percentage of emergent cover to determine the influence of varying degrees of emergent vegetation within the pothole basin on brood use. Brood populations were greatest where the ratio of cover to water was less than 0.5:1.0 (Table 9), but brood densities were greatest on potholes with cover:water ratios ranging from 1.0:1.0 to 2.0:1.0. Brood-days-use per pothole showed the same general pattern of brood use as found for broods per pothole, but brood-days-use per 10 wetland acres suggested greater brood use of potholes possessing ratios of cover to water from 0.0:1.0 to 1.0:1.0 than indicated by broods per 10 wetland acres. Potholes with cover:water ratios greater than 3.5:1.0 received little use by duck broods during 1964 and 1965.

The number of broods and brood-days-use per pothole was greatest on potholes with less than 40 per cent of the pothole basin covered with emergent vegetation (Table 10). Brood populations decreased from 20.7 broods per pothole on potholes containing less than 20 per cent emergent cover to 1.3 broods per pothole on potholes with more than 80 per cent emergent cover. Brood densities ranged from 7.1 broods per 10 wetland acres on potholes with 81 to 100 per cent emergent cover to 11.3 broods per 10 wetland acres on potholes with 41 to 60 per cent emergent cover. The number of brood-days-use per 10 wetland acres was relatively high for potholes containing less than 60 per cent emergent cover and particularly high for potholes with 21 to 60 per cent emergent cover (Table 10).

Table 9. Duck brood use in relation to the ratio of emergent cover to open water in 64 semi-permanent and permanent potholes during 1964 and 1965

Observation	Cover:water				
	0.00-0.50	0.51-1.00	1.01-2.00	2.01-3.50	3.50-12.50
Number of potholes	15	14	14	11	10
Number of broods	330	119	91	62	11
Broods per pothole	22.0	8.5	6.5	5.6	1.1
Broods per 10 wetland acres	9.4	10.3	11.1	7.8	6.3
Number of brood-days-use	8471	2978	2240	1827	173
Brood-days-use per pothole	564.7	212.7	160.0	166.1	17.3
Brood-days-use per 10 wetland acres	230.1	249.8	196.7	199.6	67.4

[a] Ranges of cover:water ratios in relation to 1.00, e.g., a 0.25:1.00 cover:water ratio is tabulated in the interval 0.00-0.50.

Table 10. Duck broods in relation to the percentage of emergent cover in 64 semi-permanent and permanent potholes during 1964 and 1965

Observation	Emergent cover (per cent)				
	0-20	21-40	41-60	61-80	81-100
Number of potholes	9	13	13	21	8
Number of broods	186	206	93	118	10
Broods per pothole	20.7	15.8	7.2	5.6	1.3
Broods per 10 wetland acres	8.9	9.9	11.3	8.5	7.1
Number of broods-days-use	4727	5286	2416	3096	164
Brood-days-use per pothole	525.2	406.6	185.8	147.4	20.5
Brood-days-use per 10 wetland acres	213.7	242.9	241.3	178.1	76.8

The number of broods per pothole decreased as the percentage of emergent cover increased, but the number of broods per 10 wetland acres remained relatively constant (Figure 19). Brood populations were definitely greater on potholes with less than 40 per cent of emergent cover, but brood densities continued to increase until the peak was reached on potholes with between 40 and 60 per cent of emergent cover.

Potholes with a central zone of open water surrounded by a peripheral band of emergent vegetation provided the best

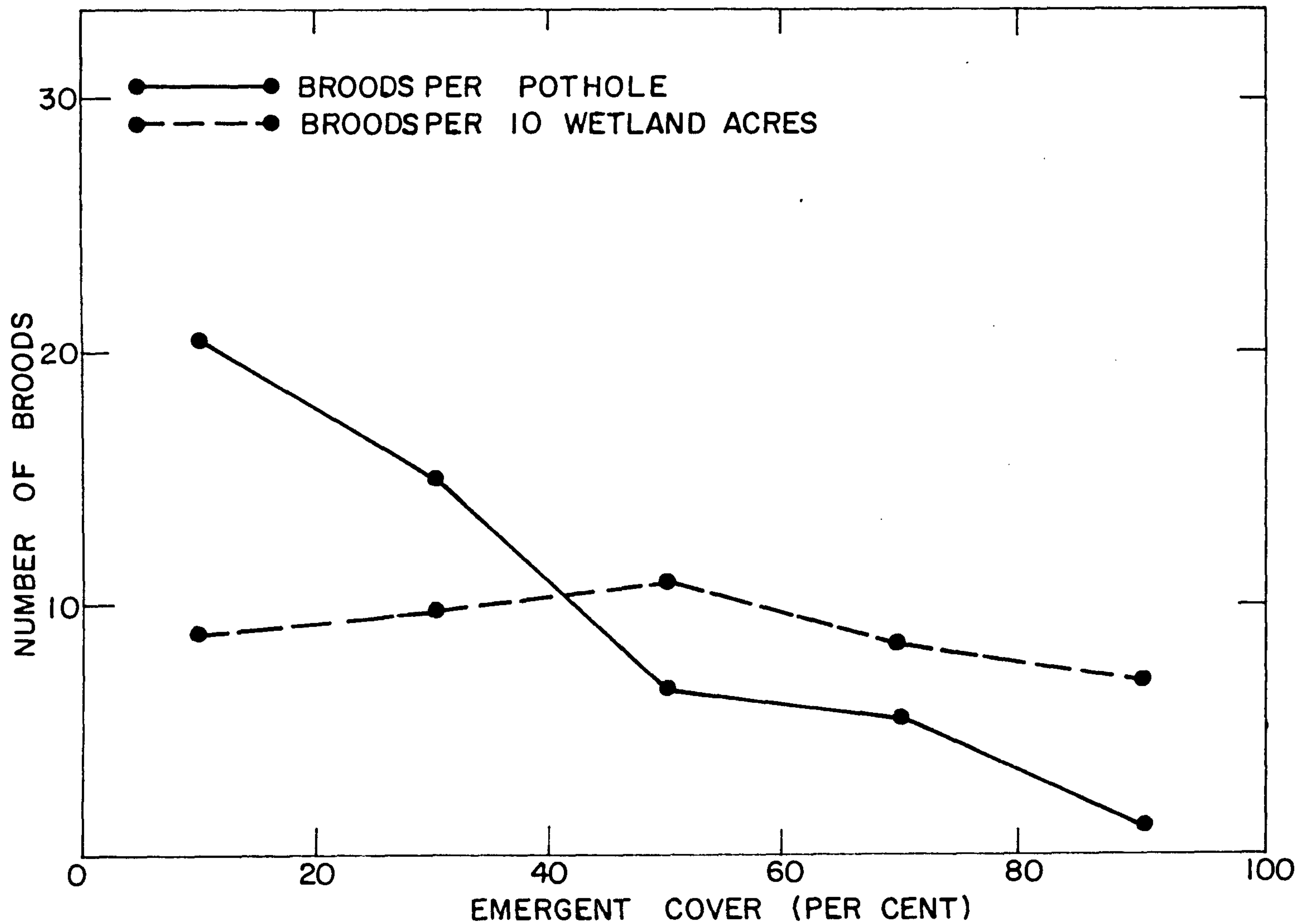


Figure 19. Comparison of number of broods per pothole and broods per 10 wetland acres in relation to the percentage of emergent cover during 1964 and 1965

habitat for brood rearing. Seven of the 10 potholes with the greatest number of broods and brood-days-use during 1964 and 1965 had this type of cover interspersion. Two of the remaining potholes had peripheral fringes of emergent vegetation covering less than 5 per cent of the pothole basin. The other pothole contained a semi-open stand of emergent vegetation that was interspersed with several large areas of open water. Ratios of emergent cover to open water ranged from 0.0:1.0 to 2.0:1.0 on these potholes, but the three potholes with the greatest number of broods and brood-days-use possessed cover:water ratios of 0.3:1.0, 0.4:1.0, and 0.2:1.0, respectively. Therefore, the most desirable ratios of emergent cover to open water probably would range from 0.2 to 1.5:1.0, since six of the 10 potholes receiving the greatest brood use contained emergent vegetation covering 20 to 60 per cent of the pothole basin. Three of the best potholes had less than 20 per cent of emergent cover, but only one contained more than 60 per cent of emergent cover.

Correlation coefficients were computed to study the responses of various duck species to varying degrees of emergent cover in the semi-permanent and permanent potholes (Table 11). During 1964 and 1965, a linear correlation was indicated for broods per pothole and brood-days-use per pothole in relation to the percentage of emergent cover. In general, as the percentage of emergent cover increased, the

Table 11. Correlation of the percentage of emergent cover and duck brood use of 64 semi-permanent and permanent potholes during 1964 and 1965

Species	1964	1965	Total
Mallard	-0.2544(-0.1166)[a]	-0.2665(-0.1297)	-0.3457(-0.1444)
Gadwall	-0.4725(-0.4092)	-0.5184(-0.4197)	-0.5775(-0.4729)
Pintail	-0.2932(-0.2403)	-0.2882(-0.2309)	-0.3366(-0.2704)
Green-winged teal	-0.0980(-0.0845)	-0.1412(-0.0854)	-0.1734(-0.1221)
Blue-winged teal	-0.2777(-0.2478)	-0.3492(-0.3871)	-0.3543(-0.3626)
Shoveler	-0.1848(-0.2131)	-0.0804(-0.0068)	-0.1569(-0.1297)
American widgeon	-0.3108(-0.2746)	-0.2973(-0.2221)	-0.3696(-0.3175)
Dabbling ducks	-0.4344(-0.3991)	-0.5090(-0.4256)	-0.5208(-0.4532)
Redhead	-0.3861(-0.3754)	-0.3923(-0.3281)	-0.4424(-0.4282)
Canvasback	-0.3029(-0.2939)	-0.2057(-0.2973)	-0.3071(-0.3174)
Lesser scaup	-0.4477(-0.4506)	-0.4695(-0.4489)	-0.5760(-0.5530)
Ruddy duck	-0.4274(-0.4086)	-0.3429(-0.3179)	-0.4720(-0.4244)
Diving ducks	-0.4814(-0.4869)	-0.5248(-0.4816)	-0.5819(-0.5498)
All species	-0.5083(-0.5029)	-0.5576(-0.5020)	-0.5920(-0.5548)

[a]Correlation coefficients for broods (brood-days-use in parentheses).

brood use of the potholes decreased. Conversely, as the percentage of open water increased, the brood use of the potholes increased (*r* = +0.5920 for broods per pothole and *r* = +0.5548 for brood-days-use per pothole). Broods per 10 wetland acres and brood-days-use per 10 wetland acres were not correlated with the percentage of emergent cover in potholes during the 2-year study (*r* = -0.0791 and *r* = -0.1911, respectively).

The response of duck broods of various species to emergent cover in potholes was quite similar in 1964 and 1965 (Table 11). Emergent cover was correlated with the total number of dabbling duck broods and diving duck broods during the 2-year study, but the correlation was slightly stronger for broods of diving ducks than for broods of dabbling ducks. The relationship between emergent cover and broods of dabblers was strongly influenced by the apparent preference of gadwalls for relatively open potholes for brood rearing. Shovelers and green-winged teal showed the greatest preference for emergent cover in brood habitat of the dabbling ducks. Broods of lesser scaups exhibited the strongest preference for open potholes of the diving ducks. Canvasbacks and redheads showed a greater preference for emergent cover for brood rearing than did other species of diving ducks, but these species used potholes with considerably less emergent vegetation than was preferred by most species of dabblers.

Brood use in relation to pothole morphology

Pothole size, shore length, and water depth were used to investigate the influence of pothole morphology on brood use of semi-permanent and permanent potholes. Since pothole size was closely related to other physical features of the pothole basin (Table 5), brood use was tabulated in relation to the size of potholes (Table 12). Brood populations increased from 1.5 broods per pothole on potholes less than 5 acres in size to 19.6 broods per pothole on potholes between 20 and 25 acres in size. Brood densities ranged from 3.6 broods per 10 wetland acres on potholes more than 25 acres in size to 14.0 broods per 10 wetland acres on potholes between 5 and 10 acres in size. Brood-days-use per pothole and per 10 wetland acres showed corresponding trends in brood use in relation to pothole size as found for broods per pothole and broods per 10 wetland acres (Table 12).

In general, the number of broods per pothole showed four distinct levels of brood use in relation to pothole size (Figure 20). The lowest level of brood use was found on the smallest potholes ranging from 0 to 5 acres in size.

Table 12. Duck brood use in relation to pothole size of 64 semi-permanent and permanent potholes during 1964 and 1965

Observation	Pothole size (acres)					
	0.0-5.0	5.1-10.0	10.1-15.0	15.1-20.0	20.1-25.0	25.1-70.0
Number of potholes	24	11	10	5	5	9
Number of broods	37	112	137	68	98	161
Broods per pothole	1.5	10.2	13.7	13.6	19.6	17.9
Broods per 10 wetland acres	8.6	14.0	11.4	8.5	8.3	3.6
Number of brood-days-use	584	2831	3497	1762	2484	4531
Brood-days-use per pothole	24.3	257.4	349.7	352.4	496.8	503.4
Brood-days-use per 10 wetland acres	110.9	355.7	292.3	218.4	211.9	102.5

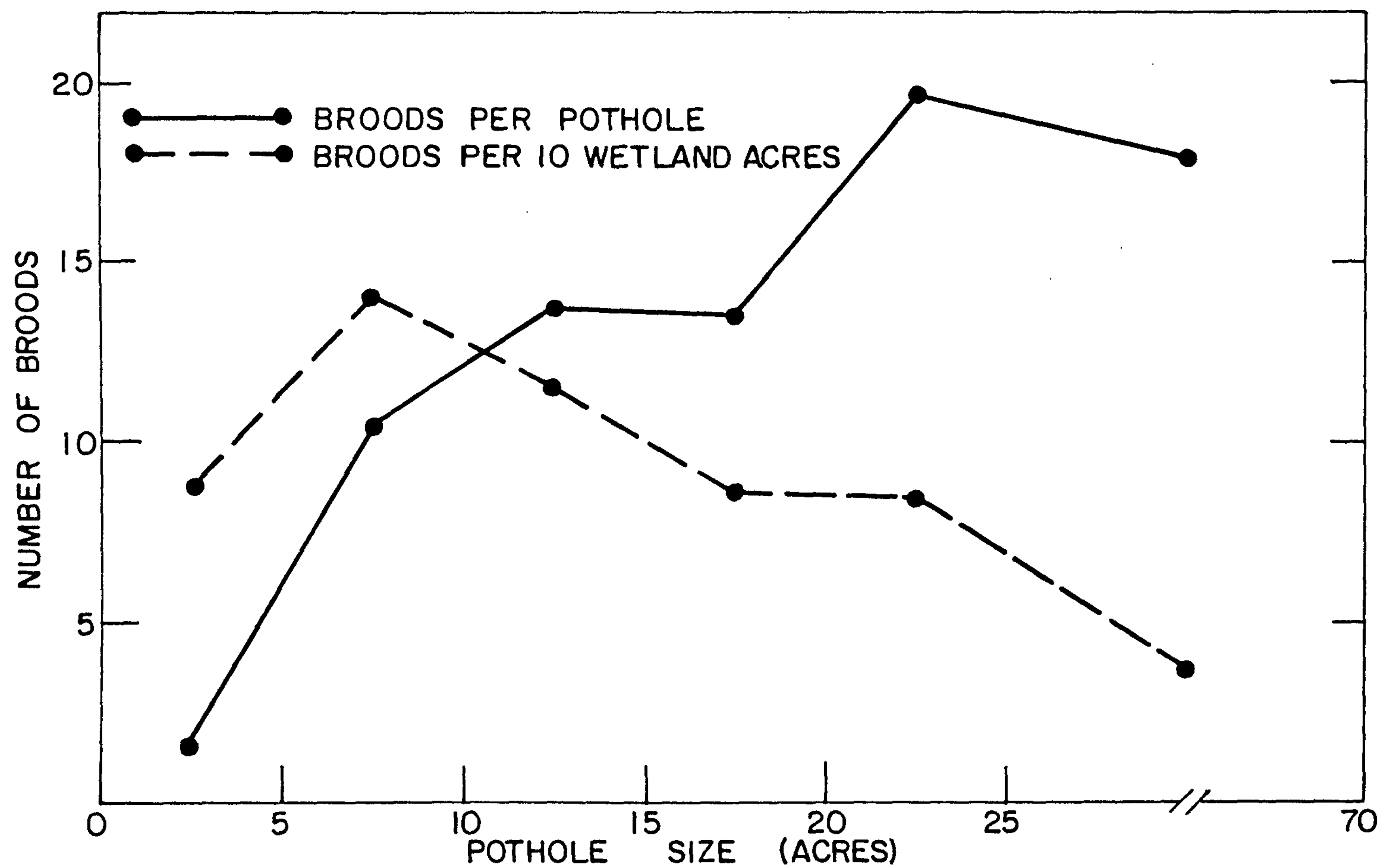


Figure 20. Comparison of number of broods per pothole and broods per 10 wetland acres in relation to pothole size during 1964 and 1965

The second level of brood use occurred on potholes between 5 and 10 acres in size, and a third level was indicated for potholes between 10 and 20 acres in size. The highest level of brood use was exhibited by the largest potholes between 20 and 70 acres in size. However, brood densities were lowest on the largest potholes. Brood densities were highest on potholes between 5 and 15 acres in size.

Semi-permanent and permanent potholes between 5 and 25 acres in size provided the preferred brood-rearing habitat in 1964 and 1965. Five of the 10 potholes with the greatest number of broods and brood-days-use were between 5 and 15 acres in size, and three of these potholes were between 15 and 25 acres in size. The remaining two potholes were larger than 25 acres in size. Potholes smaller than 5 acres in size received relatively little use by duck broods.

The number of broods per pothole and brood-days-use per pothole was correlated with the size of semi-permanent and permanent potholes during 1964 and 1965 (Table 13). Correlation coefficients indicated that brood use of potholes increased with a corresponding increase in pothole size. Correlation was low between the number of broods and brood-days-use per 10 wetland acres and pothole size ($\underline{r}$ = -0.1949 and -0.0673, respectively).

Table 13. Correlation of pothole size and duck brood use of 64 semi-permanent and permanent potholes during 1964 and 1965

Species	1964	1965	Total
Mallard	0.0868(0.1097)[a]	0.1144(0.1658)	0.1330(0.1566)
Gadwall	0.2899(0.2681)	0.4082(0.3336)	0.4059(0.3445)
Pintail	0.4181(0.4205)	0.5242(0.4726)	0.5663(0.5282)
Green-winged teal	0.1892(0.1599)	0.3401(0.2895)	0.3838(0.3139)
Blue-winged teal	0.1855(0.1700)	0.3888(0.5297)	0.3180(0.3981)
Shoveler	0.2620(0.2243)	0.0485(0.0092)	0.1934(0.1376)
American widgeon	0.0896(0.0745)	0.2281(0.1288)	0.1909(0.1230)
Dabbling ducks	0.3009(0.2832)	0.4845(0.4491)	0.4300(0.4024)
Redhead	0.4803(0.4916)	0.6142(0.6003)	0.5965(0.6429)
Canvasback	0.2721(0.2694)	0.2524(0.3747)	0.3074(0.3240)
Lesser scaup	0.4342(0.4222)	0.4496(0.4286)	0.5292(0.5238)
Ruddy duck	0.4410(0.4800)	0.3872(0.4352)	0.5060(0.5355)
Diving ducks	0.5162(0.5474)	0.6074(0.6265)	0.6451(0.6610)
All species	0.4292(0.4667)	0.5677(0.5856)	0.5496(0.5783)

[a]Correlation coefficients for broods (brood-days-use in parentheses).

Broods of diving ducks were strongly correlated with pothole size, but the relationship between broods of dabbling ducks and pothole size was less intense (Table 13). Broods of pintails showed the strongest correlation of the dabbling ducks with pothole size, but broods of gadwalls, green-winged teal, and blue-winged teal were also closely associated with pothole size. Broods of redheads were strongly associated with pothole size, but lesser scaup and ruddy duck broods were also correlated with pothole size. Canvasback broods showed the lowest relationship with pothole size of the diving ducks, but mallard broods showed the least relationship with pothole size of all species.

Since the length of shorelines was highly correlated with the size of potholes (Table 5), brood use in relation to shore length followed a similar pattern of brood use as found for pothole size (Table 14). The number of broods per pothole ranged from 1.1 on potholes with shore lengths less than 1,500 feet to 23.0 on potholes with shore lengths between 6,000 and 7,500 feet. The number of broods per 10 wetland acres ranged from 2.7 on potholes with shorelines more than 7,500 feet in length to 12.4 on potholes with shorelines between 1,500 and 3,000 feet in length. Brood-days-use per pothole and per 10 wetland acres showed the same general trend in brood use in relation to shore length

Table 14. Duck brood use in relation to shore length of 64 semi-permanent and permanent potholes during 1964 and 1965

Observation	Shore length (feet)					
	0-1500	1501-3000	3001-4500	4501-6000	6001-7500	7501-10,500
Number of potholes	20	16	15	5	5	3
Number of broods	21	145	199	94	115	39
Broods per pothole	1.1	9.1	13.3	18.8	23.0	13.0
Broods per 10 wetland acres	8.4	12.4	10.3	6.2	6.2	2.7
Number of brood-days-use	274	3654	5118	2480	3110	1053
Brood-days-use per pothole	13.7	228.4	341.2	496.0	622.0	351.0
Brood-days-use per 10 wetland acres	94.9	304.8	262.8	162.7	162.9	75.3

as indicated by broods per pothole and broods per 10 wetland acres (Table 14).

The number of broods per pothole increased as shore length increased from 0 to 7,500 feet, but the number of broods per pothole declined sharply on potholes with the largest shorelines (Figure 21). The number of broods per 10 wetland acres followed a pattern of brood use in relation to shore length closely resembling the pattern observed for the number of broods per 10 wetland acres in relation to pothole size. Brood densities were greatest on potholes with shorelines between 1,500 and 4,500 feet in length and were lowest on potholes with shorelines more than 7,500 feet in length.

The best potholes for brood rearing had shore lengths ranging from 1,500 to 7,500 feet. Six of the 10 potholes with the highest brood use during 1964 and 1965 had shore lengths between 1,500 and 4,500 feet. Nine of the 10 potholes had shore lengths between 1,500 and 7,500 feet, and the other pothole had a shore length greater than 7,500 feet. Potholes with shorelines less than 1,500 feet in length received little use by duck broods.

Correlation coefficients for broods per pothole and brood-days-use per pothole in relation to shore length emphasized the close relationship between pothole size and shore length with respect to use by duck broods (Tables 13 and 15).

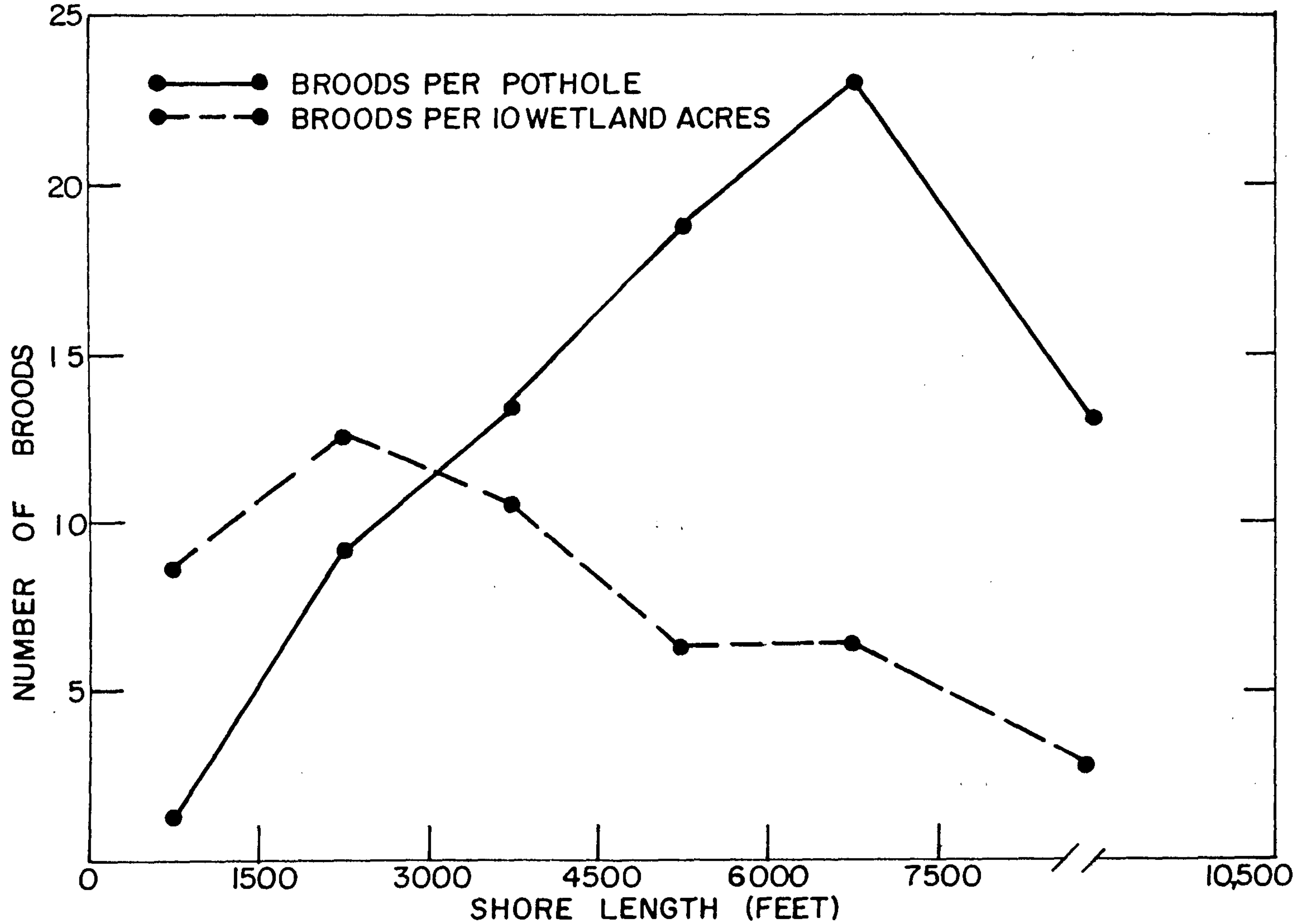


Figure 21. Comparison of number of broods per pothole and broods per 10 wetland acres in relation to shore length during 1964 and 1965

Table 15. Correlation of shore length and duck brood use of 64 semi-permanent and permanent potholes during 1964 and 1965

Species	1964	1965	Total
Mallard	0.1584(0.0989)[a]	0.1260(0.1319)	0.1895(0.1328)
Gadwall	0.2991(0.2825)	0.3756(0.3190)	0.3927(0.3437)
Pintail	0.4122(0.3601)	0.5317(0.5070)	0.5696(0.5344)
Green-winged teal	0.3956(0.3852)	0.3097(0.2202)	0.5114(0.4478)
Blue-winged teal	0.2734(0.2859)	0.4047(0.4750)	0.3806(0.4345)
Shoveler	0.2980(0.2485)	0.1156(0.0876)	0.2468(0.1942)
American widgeon	0.2130(0.1959)	0.2578(0.1798)	0.2853(0.2380)
Dabbling ducks	0.3670(0.3516)	0.4842(0.4445)	0.4685(0.4375)
Redhead	0.3301(0.3470)	0.5411(0.5943)	0.4536(0.5359)
Canvasback	0.3078(0.3152)	0.3269(0.3388)	0.3669(0.3469)
Lesser scaup	0.3446(0.3668)	0.4329(0.3915)	0.4946(0.4686)
Ruddy duck	0.3293(0.3558)	0.3719(0.4064)	0.4249(0.4470)
Diving ducks	0.4011(0.4416)	0.5912(0.5911)	0.5577(0.5765)
All species	0.4271(0.4499)	0.5621(0.5659)	0.5454(0.5583)

[a] Correlation coefficients for broods (brood-days-use in parentheses).

Shore length was correlated with the number of broods per pothole and the number of brood-days-use per pothole during the 2-year study. This relationship suggested that brood use of potholes increased as the length of shorelines increased. However, broods per 10 wetland acres and brood-days-use per 10 wetland acres showed no linear relationship with shore length (r = -0.1609 and r = +0.0113, respectively).

Diving duck broods were more closely associated with shore length than dabbling duck broods (Table 15). Pintail and green-winged teal broods were most strongly correlated with shore length, but broods of gadwall and blue-winged teal were more closely associated with shore length than other species of dabblers. Broods of lesser scaup were most strongly associated with shore length of the diving ducks, but redhead and ruddy duck broods were also closely associated with shore length. Canvasback broods showed the lowest correlation with shore length of the diving ducks, but mallard broods showed the least association with length of shoreline of all species.

Brood use of the semi-permanent and permanent potholes was studied in relation to the relative water-holding capacity of the pothole basins, because water depths fluctuated seasonally and annually in response to natural water losses and weather conditions. Since water depths in the potholes were highly correlated at the mid-July water levels in 1964 and 1965 (Table 5), brood use was tabulated in relation to the maximum water depth during the 2-year period (Table 16).

Brood populations ranged from 6.3 broods per pothole on potholes with maximum depths between 25 and 36 inches to 18.7 broods per pothole on potholes with maximum depths between 61 and 72 inches (Table 16). Brood densities ranged from 3.2 broods per 10 wetland acres on potholes with maximum depths between 73 and 96 inches to 19.1 broods per 10 wetland acres on potholes with maximum depths between 12 and 24 inches. Brood-days-use per pothole and per 10 wetland acres followed corresponding trends in brood use in relation to water depth as observed for broods per pothole and broods per 10 wetland acres (Table 16).

Brood use in relation to water depth showed no consistant pattern (Figure 22). In general, the number of broods per pothole was greater on potholes more than 36 inches in depth. The number of broods per 10 wetland acres was greater on potholes less than 60 inches in depth. The trends became more apparent when the brood use for the three potholes with water depths between 12 and 24 inches was combined with the brood use for potholes with water

Table 16. Duck brood use in relation to maximum water depth of 64 semi-permanent and permanent potholes during 1964 and 1965

Observation	Maximum water depth (inches)					
	12-24	25-36	37-48	49-60	61-72	73-96
Number of potholes	3	31	16	7	3	4
Number of broods	26	196	186	94	56	55
Broods per pothole	8.7	6.3	11.6	13.4	18.7	13.8
Broods per 10 wetland acres	19.1	8.6	10.0	11.9	3.8	3.2
Number of broods-days-use	836	4708	5004	2264	1637	1240
Broods-days-use per pothole	278.7	151.9	312.8	323.4	545.7	310.0
Brood-days-use per 10 wetland acres	371.9	158.3	255.8	262.7	103.7	69.7

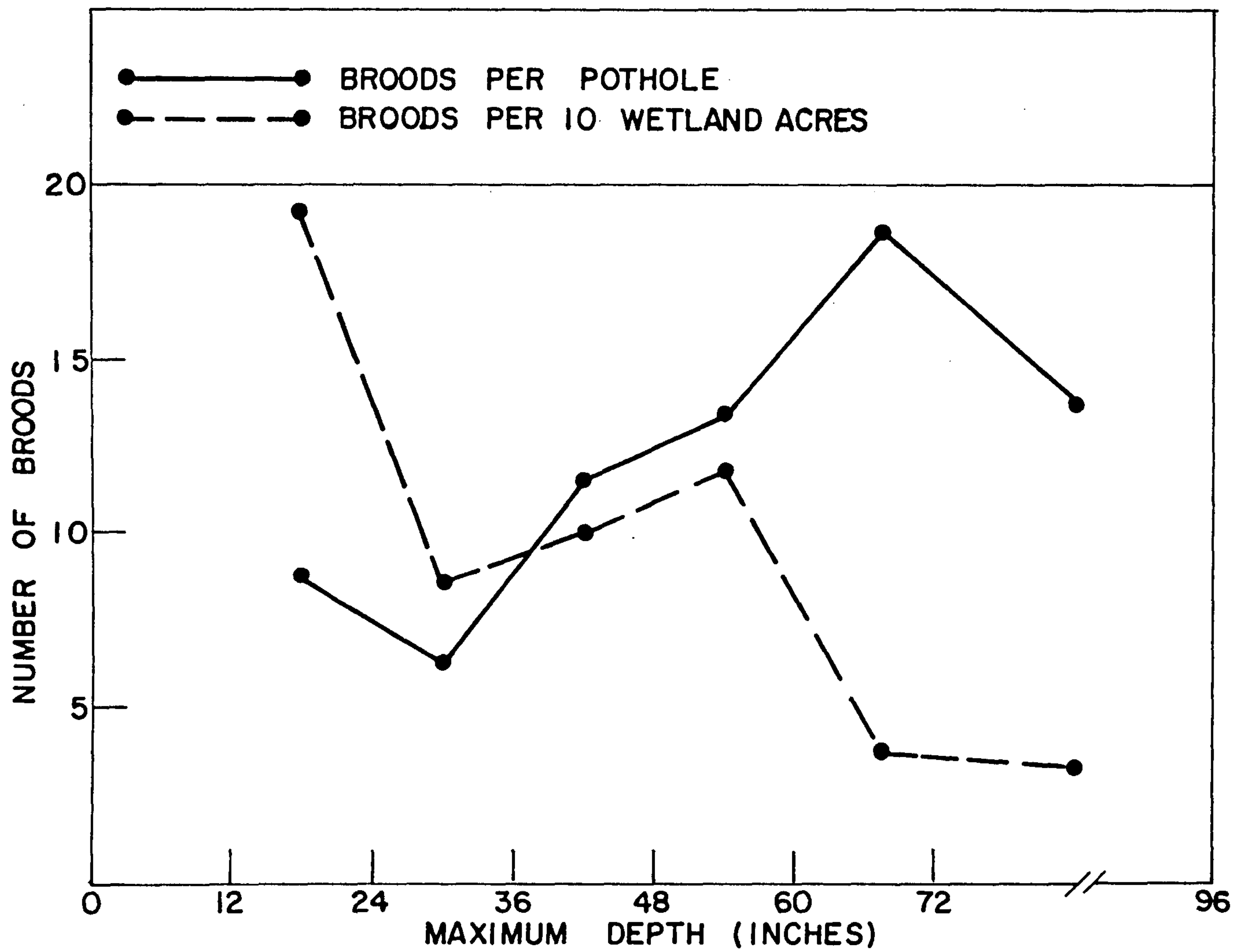


Figure 22. Comparison of number of broods per pothole and broods per 10 wetland acres in relation to maximum water depth during 1964 and 1965

depths between 25 and 36 inches, and when the brood use for the seven potholes with water depths greater than 60 inches was combined. Then, the number of broods per pothole increased from 6.5 for potholes with water depths less than 36 inches to 15.9 for potholes with water depths greater than 60 inches. The number of broods per 10 wetland acres was relatively uniform for potholes less than 60 inches in depth ranging from 9.5 broods per 10 wetland acres on potholes between 12 and 36 inches in depth to 11.9 broods per 10 wetland acres on potholes between 49 and 60 inches in depth. Potholes with water depths greater than 60 inches had relatively low brood densities. Hence, the potholes with the greatest water-holding capacity, and perhaps the greatest permanence, had the highest average brood populations but the lowest average brood densities during 1964 and 1965.

The optimum water depths for brood rearing ranged between 24 and 60 inches. Six of the 10 potholes with the greatest numbers of broods and brood-days-use had water depths between 36 and 60 inches in 1964 and 1965. The remaining four potholes with high brood use had water depths between 24 and 36 inches. In general, broods of dabbling ducks preferred shallower potholes ranging from 24 to 48 inches in depth while broods of diving ducks preferred deeper potholes ranging from 36 to 60 inches in depth.

Maximum water depths in mid-July were used in computing correlation coefficients between brood use and water depth in 1964 and 1965 (Table 17). However, maximum water depths for 1965 were used in computing correlation coefficients between total brood use during the 2-year period and water depth, because water levels were generally higher in 1965 than in 1964. Therefore, the 1965 water depths were more indicative of the relative water-holding capacity of the pothole basins than the 1964 water depths.

Correlation coefficients were relatively low between brood use and water depth in comparison with the degree of association indicated between brood use and other habitat factors (Table 17). Correlations were stronger between broods and brood-days-use per pothole and water depth in 1965 than in 1964, but broods of diving ducks were more closely associated with water depth than broods of dabbling ducks during both years. Broods per 10 wetland acres and brood-days-use per 10 wetland acres were poorly correlated with water depth in 1964 (r = -0.1464 and r = -0.0689) and in 1965 (r = -0.1533 and r = -0.0796).

Brood use in relation to water chemistry

Specific conductance and hydrogen-ion concentration (pH) of pothole water were used to investigate the influence of water chemistry on brood use of semi-permanent and

Table 17. Correlation of water depth and duck brood use of 64 semi-permanent and permanent potholes during 1964 and 1965

Species	1964[a]	1965[b]	Total[c]
Mallard	0.1983(0.0470)[d]	0.0656(0.0330)	0.1718(0.0830)
Gadwall	0.0825(0.0130)	0.2914(0.1850)	0.2357(0.1343)
Pintail	0.3380(0.1841)	0.4080(0.3228)	0.4424(0.3358)
Green-winged teal	0.1808(0.1635)	0.2158(0.1244)	0.2750(0.1927)
Blue-winged teal	0.0181(-0.0158)	0.1293(0.2394)	0.0629(0.1128)
Shoveler	-0.0987(-0.1206)	-0.0749(-0.0808)	-0.0415(-0.0736)
American widgeon	0.0114(0.0953)	0.0284(-0.0152)	0.0797(0.0544)
Dabbling ducks	0.1042(0.0327)	0.2773(0.2183)	0.2173(0.1520)
Redhead	0.2017(0.2446)	0.3591(0.3772)	0.3407(0.3732)
Canvasback	0.1755(0.1983)	0.0511(0.1138)	0.1707(0.1859)
Lesser scaup	0.1845(0.2012)	0.4648(0.3864)	0.4679(0.3981)
Ruddy duck	0.1940(0.2118)	0.1750(0.1810)	0.2592(0.2585)
Diving ducks	0.2346(0.2750)	0.3866(0.3537)	0.3901(0.3761)
All species	0.1722(0.1692)	0.3403(0.3078)	0.3024(0.2811)

[a]Correlated with maximum water depth (July, 1964).

[b]Correlated with maximum water depth (July, 1965).

[c]Correlated with maximum water depth (July, 1965).

[d]Correlation coefficients for broods (brood-days-use in parentheses).

permanent potholes. Since specific conductance of the water in individual potholes varied seasonally and annually in response to physical and biological phenomena within the potholes, e.g. fluctuations in water depth, brood use was tabulated in relation to the average of three measurements of specific conductance obtained during 1964 and 1965 (Table 18). However, brood use could have been studied with comparable results in relation to any one of the three series of specific conductance measurements because of the high correlation between specific conductance measured in 1964 and specific conductance measured in 1965.

Brood populations ranged from 1.0 brood per pothole on potholes with specific conductance ranging from 0 to 400 µmhos/cm to 131 broods per pothole on potholes with specific conductance ranging from 1201 to 1600 µmhos/cm during 1964 and 1965 (Table 18). Brood densities ranged from 4.5 broods per 10 wetland acres on potholes with specific conductance ranging from 0 to 400 µmhos/cm to 15.2 broods per 10 wetland acres on potholes with specific conductance ranging from 1201 to 1600 µmhos/cm. Brood-days-use per pothole and per 10 wetland acres showed corresponding trends in brood use in relation to specific conductance as found for broods per pothole and broods per 10 wetland acres (Table 18).

Brood use in relation to specific conductance in terms of broods per 10 wetland acres followed a similar pattern of

Table 18. Duck brood use in relation to specific conductance of water in 64 semi-permanent and permanent potholes during 1964 and 1965

Observation	Specific conductance (μmhos/cm)				
	0-400	401-800	801-1200	1201-1600	1601-2400
Number of potholes	3	22	21	11	7
Number of broods	3	154	239	144	73
Broods per pothole	1.0	7.0	11.4	13.1	10.4
Broods per 10 wetland acres	4.5	8.4	8.7	15.2	6.5
Number of brood-days-use	50	3818	6157	3754	1910
Brood-days-use per pothole	16.7	173.5	293.2	341.3	272.9
Brood-days-use per 10 wetland acres	68.2	160.4	223.0	300.9	120.7

brood use as observed for broods per pothole (Figure 23). Brood use was lowest on potholes with relatively fresh water where the specific conductance was less than 400 µmhos/cm during 1964 and 1965. As specific conductance increased from 400 to 1200 µmhos/cm, brood use increased. Brood use was greatest on slightly brackish potholes where specific conductance ranged between 1200 and 1600 µmhos/cm.

In this study, potholes containing water with specific conductance ranging between 800 to 1600 µmhos/cm provided the best rearing habitat for duck broods during 1964 and 1965. Seven of the 10 potholes with the greatest brood use contained water with specific conductance within this range. Two of these potholes had water with specific conductance between 400 and 800 µmhos/cm, and the other pothole had water with specific conductance greater than 1600 µmhos/cm.

For 1964 and 1965, specific conductance measured in early summer was used to compute correlation coefficients in relation to brood use of the semi-permanent and permanent potholes (Table 19). However, specific conductance measured in late summer, 1965, was used to compute correlation coefficients in relation to total brood use during 1964 and 1965, because specific conductance measurements in early summer in 1964 and 1965 were most highly correlated with the specific conductance measurements in late summer, 1965.

Figure 23. Comparison of number of broods per pothole and broods per 10 wetland acres in relation to specific conductance of pothole water during 1964 and 1965

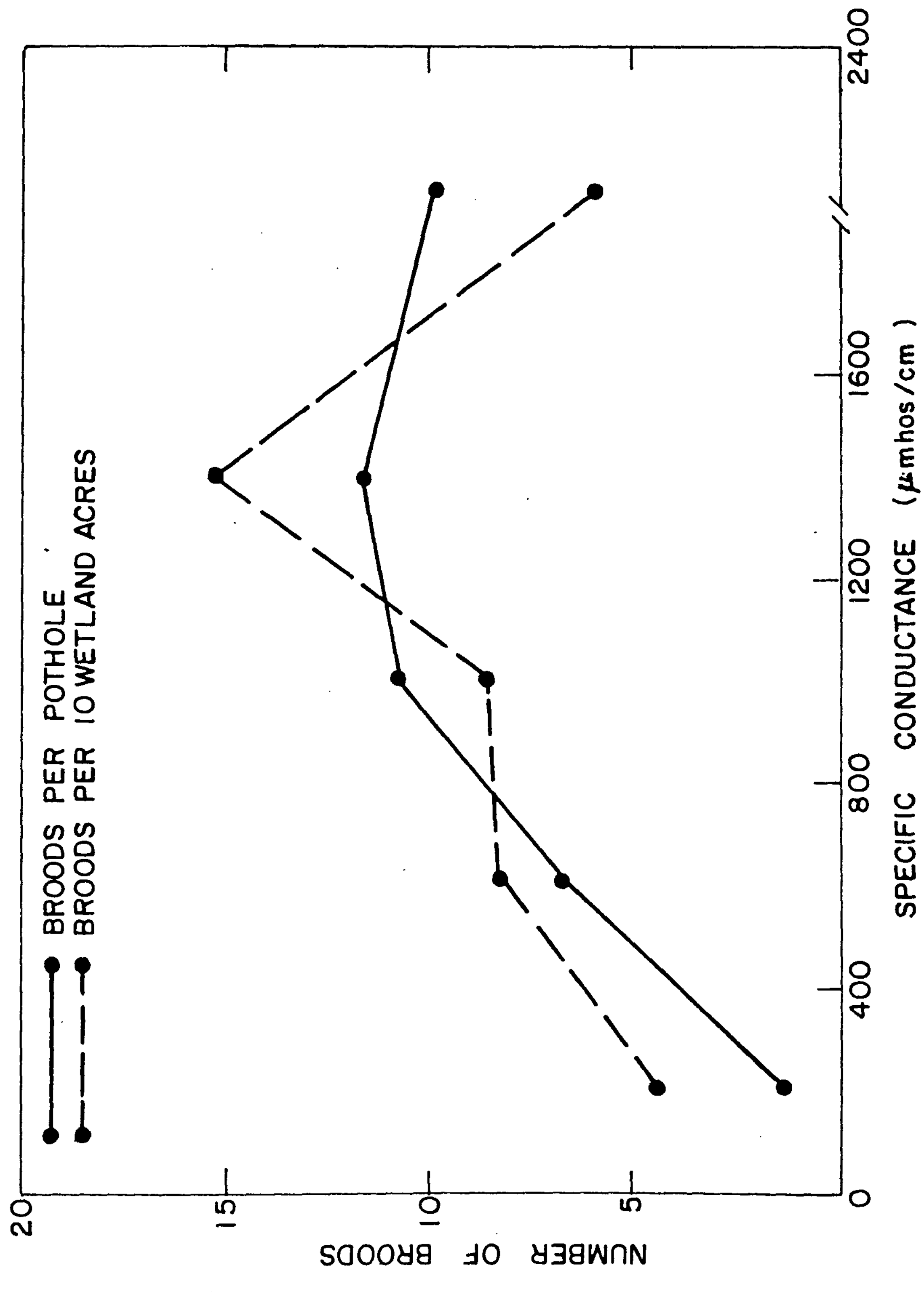

BROODS PER POTHOLE
BROODS PER 10 WETLAND ACRES
NUMBER OF BROODS
0
5
10
15
20
SPECIFIC CONDUCTANCE (µmhos/cm)
0
400
800
1200
1600
2400

Table 19. Correlation of specific conductance of pothole water and duck brood use of 64 semi-permanent and permanent potholes during 1964 and 1965

Species	1964[a]	1965[b]	Total[c]
Mallard	0.1325(0.1381)[d]	-0.0167(-0.0225)	0.1097(0.1209)
Gadwall	0.0402(0.0618)	0.1873(0.1627)	0.1491(0.1573)
Pintail	0.0946(0.1294)	0.1460(0.1394)	0.1805(0.1690)
Green-winged teal	0.1038(0.0896)	0.0330(0.0398)	0.2473(0.2542)
Blue-winged teal	0.0525(0.0430)	0.1447(0.1686)	0.1349(0.1642)
Shoveler	0.1968(0.1511)	0.0975(0.0721)	0.1672(0.1149)
American widgeon	0.0931(0.1157)	0.1180(0.0504)	0.0451(0.0357)
Dabbling ducks	0.1025(0.1150)	0.1926(0.1763)	0.1775(0.1825)
Redhead	0.1359(0.0462)	0.2162(0.1625)	0.1512(0.1134)
Canvasback	0.0410(0.0382)	0.0534(0.0540)	0.0223(0.0111)
Lesser scaup	0.1113(0.1231)	0.1330(0.0829)	0.1691(0.1398)
Ruddy duck	0.2461(0.2506)	0.2084(0.1885)	0.2372(0.2379)
Diving ducks	0.1850(0.1093)	0.2421(0.2000)	0.2121(0.1954)
All species	0.1501(0.1607)	0.2259(0.2082)	0.2073(0.2105)

[a]Correlated with specific conductance (June-July, 1964).

[b]Correlated with specific conductance (June-July, 1965).

[c]Correlated with specific conductance (August-September, 1965).

[d]Correlation coefficients for broods (brood-days-use in parentheses).

Correlation coefficients were low for broods per pothole and brood-days-use per pothole in relation to specific conductance during 1964 and 1965 (Table 19), but correlation coefficients were even lower for broods per 10 wetland acres and brood-days-use per 10 wetland acres ($\underline{r}$ = +0.0777 and $\underline{r}$ = +0.1093, respectively). Hence, correlation analysis indicated no linear association between brood use and specific conductance. However, the relationship may be curvilinear rather than linear, since correlation coefficients provide no basis for evaluating this type of relationship.

Brood use was analyzed in relation to the hydrogen-ion concentration (pH) of the water in the semi-permanent and permanent potholes, because pH apparently measured chemical characteristics of the pothole water that were not related to specific conductance (Table 4). Since pH was only measured in 1965, brood use in relation to pH in 1965 was tabulated separately from the combined brood use during 1964 and 1965 (Tables 20 and 21). However, the trends in brood use for broods per pothole and broods per 10 wetland acres were sufficiently similar to justify the tabulation of brood use on the potholes for the 2-year period in relation to the pH measured in 1965 (Figure 24).

Table 20. Duck brood use in relation to pH of water in 64 semi-permanent and permanent potholes during 1965

Observation	pH (July, 1965)					
	7.0-7.5	7.6-8.0	8.1-8.5	8.6-9.0	9.1-9.5	9.6-10.5
Number of potholes	4	10	21	12	10	7
Number of broods	3	27	44	63	89	53
Broods per pothole	0.8	2.7	2.1	5.3	8.9	7.6
Broods per 10 wetland acres	1.9	4.7	2.6	3.5	3.1	7.2
Number of brood-days-use	34	626	1218	1638	2469	1308
Brood-days-use per pothole	8.5	62.6	58.0	136.5	246.9	186.9
Brood-days-use per 10 wetland acres	17.9	83.6	75.3	70.9	85.6	158.3

Table 21. Duck brood use in relation to pH of water in 64 semi-permanent and permanent potholes during 1964 and 1965

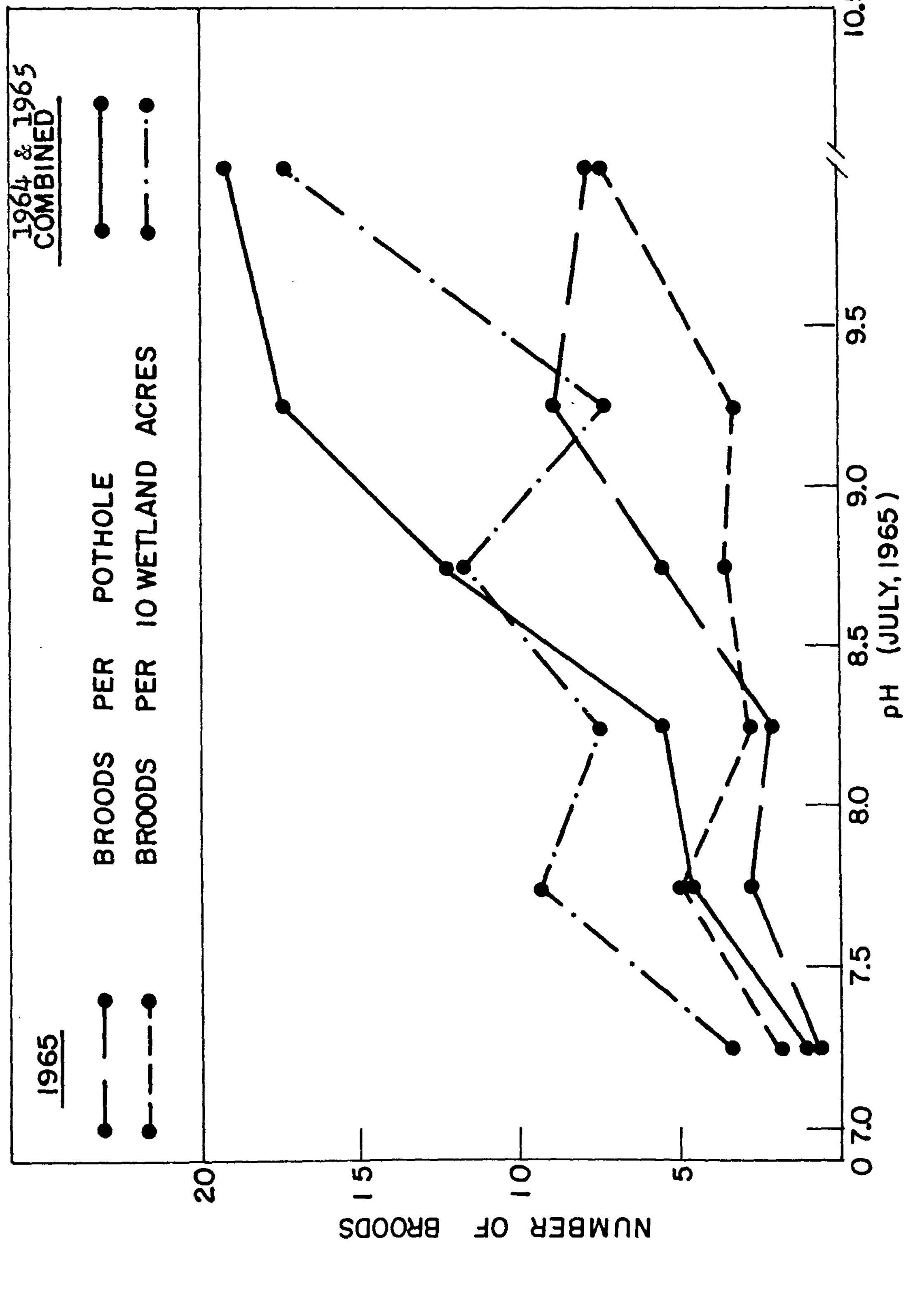
Observation	pH (July, 1965)					
	7.0-7.5	7.6-8.0	8.1-8.5	8.6-9.0	9.1-9.5	9.6-10.5
Number of potholes	4	10	21	12	10	7
Number of broods	4	45	113	145	172	134
Broods per pothole	1.0	4.5	5.4	12.1	17.2	19.1
Broods per 10 wetland acres	3.3	9.2	7.3	11.9	7.1	17.2
Number of brood-days-use	40	1061	3038	3585	4566	3399
Brood-days-use per pothole	10.0	106.1	144.7	298.8	456.6	485.6
Brood-days-use per 10 wetland acres	26.7	161.6	154.9	230.1	184.1	323.6

In 1965, brood populations ranged from 0.8 broods per pothole where the pH was less than 7.5 to 8.9 broods per pothole where the pH was between 9.1 and 9.5 (Table 20). Brood densities ranged from 1.9 broods per 10 wetland acres on potholes where the pH was less than 7.5 to 7.2 broods per 10 wetland acres on potholes where the pH was greater than 9.6. Brood-days-use per pothole and per 10 wetland acres followed corresponding patterns of brood use in relation to pH as found for broods per pothole and per 10 wetland acres, (Table 20).

For the 2-year period, brood populations ranged from 1.0 brood per pothole where the pH was less than 7.5 to 19.1 broods per pothole where the pH was more than 9.6 (Table 21). Brood densities ranged from 3.3 broods per 10 wetland acres where the pH was less than 7.5 to 17.2 broods per 10 wetland acres where the pH was greater than 9.6. Brood-days-use per pothole and per 10 wetland acres showed similar trends in brood use in relation to pH as indicated by broods per pothole and per 10 wetland acres (Table 21).

Brood use of potholes was relatively low on mildly alkaline to alkaline potholes where the pH ranged from 7.0 to 8.5, but on alkaline to strongly alkaline potholes where the pH was greater than 8.5, brood use in terms of broods per pothole abruptly increased (Figure 24). The number of broods per 10 wetland acres also increased on potholes where

Figure 24. Comparison of number of broods per pothole and broods per 10 wetland acres in relation to hydrogen-ion concentration (pH) of pothole water in 1965 and during 1964 and 1965


1965
1964 & 1965 COMBINED
BROODS PER POTHOLE
BROODS PER 10 WETLAND ACRES
NUMBER OF BROODS
0
5
10
15
20
pH (JULY, 1965)
7.0
7.5
8.0
8.5
9.0
9.5
10.5

the pH was greater than 8.5. Clearly, the brood use of potholes was lower where the pH was less than 8.5 than the brood use on potholes where the pH was greater than 8.5. In fact, the average number of broods per pothole for the 35 potholes where the pH ranged from 7.0 to 8.5 was 4.6 and for the 29 potholes where the pH ranged from 8.6 to 10.5 was 15.6. The corresponding number of broods per 10 wetland acres for these pH ranges was 7.3 and 12.6, respectively.

During the 2-year study, the 10 potholes with the greatest brood use had pH measurements greater than 8.5 in 1965. Seven of these potholes had pH readings between 8.6 and 9.5, and the remaining three potholes had pH readings between 9.6 and 10.5. Nine of the 10 potholes where no broods were observed during 1964 and 1965 had pH readings lower than 8.5 in 1965.

The total number of broods and brood-days-use per pothole during 1964 and 1965 was correlated with the pH of the water in the semi-permanent and permanent potholes (Table 22). In addition, the strongest correlations for broods per 10 wetland acres and brood-days-use per 10 wetland acres with any habitat factor were found in relation to pH of the pothole water ($\underline{r}$ = +0.2736 and $\underline{r}$ = +0.3906, respectively). The association between the number of

Table 22. Correlation of pH of pothole water and duck brood use of 64 semi-permanent and permanent potholes during 1964 and 1965[a]

Species	1964	1965	Total
Mallard	0.1756(0.1306)[b]	0.1486(0.0920)	0.2158(0.1364)
Gadwall	0.5046(0.4748)	0.4395(0.4051)	0.5514(0.5002)
Pintail	0.3447(0.2891)	0.1943(0.1972)	0.2856(0.2606)
Green-winged teal	-0.0182(-0.0318)	0.1284(0.1005)	0.0800(0.0397)
Blue-winged teal	0.4407(0.4589)	0.3459(0.3619)	0.4533(0.4709)
Shoveler	0.3554(0.3054)	0.2070(0.2114)	0.3249(0.2948)
American widgeon	0.2198(0.1884)	0.2342(0.2241)	0.2755(0.2564)
Dabbling ducks	0.5011(0.4822)	0.4381(0.4277)	0.5226(0.5001)
Redhead	0.3022(0.3161)	0.1451(0.1983)	0.2869(0.3230)
Canvasback	0.3828(0.3863)	0.2902(0.2949)	0.4022(0.3863)
Lesser scaup	0.1023(0.1601)	0.0579(0.0556)	0.0862(0.1235)
Ruddy duck	0.3102(0.2794)	0.2315(0.1882)	0.3327(0.2728)
Diving ducks	0.3553(0.3736)	0.2348(0.2276)	0.3572(0.3502)
All species	0.5019(0.4907)	0.4066(0.3833)	0.5109(0.4849)

[a]Correlated with pH measured in July, 1965.

[b]Correlation coefficients for broods (brood-days-use in parentheses).

broods and brood-days-use per pothole and the pH of the pothole water was stronger for the dabbling ducks than for the diving ducks. The relationship between broods of dabbling ducks and pH was mostly due to the close association between broods of gadwall and blue-winged teal and pH of the pothole water. Canvasback and ruddy duck broods showed the strongest degree of association between pH of the pothole water and the number of broods and brood-days-use per pothole of the diving ducks. Green-winged teal and lesser scaup broods were least associated with pH of the pothole water.

Multiple regression analysis

In preceding sections, brood use was presented in tabular and graphical form in relation to several habitat factors. Correlation coefficients were also examined to determine the relative intensity of association between brood use and various habitat factors. By analyzing the habitat factors independently and by ignoring any relationship between various factors, brood use was found to be related to several habitat factors of the potholes, e.g. emergent cover, pothole size, and pH. However, correlation analysis indicated a relatively high degree of association between several of these factors (Table 5). Therefore, the possibility existed that the relationship of one habitat factor with brood use was merely reflecting brood use associated with another closely related habitat factor, e.g. brood use in relation to pothole size and shore length. Hence, a multiple regression analysis was used to identify the habitat factors most strongly associated with brood use of the potholes.

Brood use of the potholes in 1964 was analyzed in relation to four habitat factors: emergent cover (per cent), pothole size, water depth (mid-July, 1964), and specific conductance (June-July, 1964). In 1965, brood use was analyzed in relation to five habitat factors: emergent cover (per cent), pothole size, water depth (mid-July, 1965), specific conductance (June-July, 1965), and pH (July, 1965). Shore length was not included in the analysis, because it was highly correlated with pothole size.

In 1964, the percentage of emergent cover was a highly significant factor in brood-rearing habitat (Tables 23 and 24). However, the partial regression coefficients were negative (reflected in sign of t value) indicating that the total number of broods and brood-days-use increased as the percentage of emergent cover decreased. Hence, the absence of cover on the potholes was the important relationship with brood use rather than the presence of cover. Brood use of the potholes by dabbling ducks showed greater significance

Table 23. Results of multiple regression analysis of habitat factors in relation to the number of broods on the 64 semi-permanent and permanent potholes in 1964

Species	Emergent cover *t* value[a]	Pothole size *t* value	Water depth *t* value	Specific conductance *t* value	Coefficient of determination R^2
Mallard	-1.737	-1.332	0.843	0.962	0.104
Gadwall	-4.203**	0.662	-2.701**	-0.223	0.311
Pintail	0.192	2.011*	0.741	0.186	0.183
Green-winged teal	0.600	0.845	0.775	0.584	0.052
Blue-winged teal	-2.227*	0.640	-1.829	0.092	0.127
Shoveler	-1.204	2.641*	-3.352**	1.247	0.237
American widgeon	-2.793**	-1.195	-0.4.6	0.603	0.134
Dabbling ducks	-3.363**	0.831	-2.118*	0.347	0.252
Redhead	-1.238	3.047**	-1.694	0.400	0.274
Canvasback	-1.395	0.864	-0.517	-0.094	0.104
Lesser scaup	-2.423*	2.172*	-1.965	0.232	0.279
Ruddy duck	-2.062*	2.200*	-1.766	1.480	0.289
Diving ducks	-2.242*	2.897**	-1.994	0.820	0.349
Total	-3.466**	1.841	-2.480*	0.605	0.344

[a]*t* value tests the null hypothesis that the partial regression coefficient is zero; single asterisks indicates rejection at 0.95 confidence level (critical value = 2.001, 59df) and double asterisks indicates rejection at 0.99 confidence level (critical value = 2.662, 59df).

Table 24. Results of multiple regression analysis of habitat factors in relation to the number of brood-days-use on the 64 semi-permanent and permanent potholes in 1964

Species	Emergent cover *t* value[a]	Pothole size *t* value	Water depth *t* value	Specific conductance *t* value	Coefficient of determination R^2
Mallard	-0.551	0.344	-0.415	0.924	0.032
Gadwall	-3.728**	1.056	-3.134**	0.011	0.287
Pintail	0.232	3.043**	-0.889	0.450	0.195
Green-winged teal	0.526	0.654	0.763	0.508	0.040
Blue-winged teal	-2.086*	0.772	-2.020*	0.033	0.122
Shoveler	-1.893	2.129*	-3.560**	0.884	0.234
American widgeon	-2.471*	-1.122	-0.370	0.810	0.112
Dabbling ducks	-3.350**	1.147	-2.858**	0.479	0.265
Redhead	-0.847	3.131**	-1.171	-0.421	0.263
Canvasback	-1.207	0.778	-0.205	-0.103	0.096
Lesser scaup	-2.435**	1.876	-1.682	0.362	0.264
Ruddy duck	-1.502	2.781*	-1.671	1.479	0.303
Diving ducks	-1.944	3.138**	-1.666	0.629	0.358
Total	-3.218**	2.458*	-2.749**	0.653	0.367

[a] *t* value tests the null hypothesis that the partial regression coefficient is zero; single asterisks indicates rejection at 0.95 confidence level (critical value = 2.002, 58df), and double asterisks indicates rejection at 0.99 confidence level (critical value = 2.664, 58 df).

in relation to emergent cover than diving ducks, but these results were strongly influenced by the response of gadwall, blue-winged teal, and American widgeon broods to emergent cover. Lesser scaup broods also showed a strong preference for relatively open potholes for brood rearing.

Pothole size was a highly significant factor in relation to brood use of the potholes by diving ducks in 1964 (Tables 23 and 24). The analysis indicated that the number of broods and brood-days-use for diving ducks increased as the pothole size increased. This relationship was especially strong for redheads, but ruddy ducks also responded in this way to pothole size. There appeared to be no general relationship between pothole size and brood use by dabbling ducks, but pothole size was apparently an important factor for pintail and shoveler brood rearing in 1964.

Water depth was another important factor in brood-rearing habitat in 1964 (Tables 23 and 24), particularly in relation to brood use of the potholes by dabbling ducks. However, brood use was inversely related to water depth, i.e. the number of broods and brood-days-use increased as the water depth decreased. The significance of water depth in relation to dabbling ducks was strongly influenced by the highly significant relationship of water depth with brood use of the potholes by gadwalls and shovelers. During

1964, there was no significant association between the number of broods or brood-days-use and the specific conductance of the pothole water (Tables 23 and 24).

The coefficient of determination for total broods indicated that 34 per cent of the variation in the distribution of broods on the potholes was attributable to emergent cover, pothole size, water depth, and specific conductance in 1964 (Table 23). However, these four factors accounted for about 36 per cent of the variation in the number of brood-days-use between the potholes (Table 24). Regression of the four habitat factors and brood use by diving ducks accounted for about 10 per cent more variation than the regression of habitat factors and brood use by dabbling ducks in 1964 (Tables 23 and 24).

In 1965, the percentage of emergent cover on the potholes was not a significant factor in brood rearing habitat (Tables 25 and 26). The number of broods was significant in relation to emergent cover for mallards and lesser scaup, but lesser scaup was the only species for which the number of brood-days-use was significant in relation to emergent cover.

Pothole size was a highly significant factor in brood-rearing habitat during 1965 (Tables 25 and 26). The number of broods was significant in relation to pothole size for

Table 25. Results of multiple regression analysis of habitat factors in relation to the number of broods on the 64 semi-permanent and permanent potholes in 1965

Species	Emergent cover *t* value[a]	Pothole size *t* value	Water depth *t* value	Specific conductance *t* value	pH *t* value	Coefficient of determination R^2
Mallard	-2.043*	-0.229	-0.950	-0.280	-0.017	0.095
Gadwall	-1.978	-1.109	-1.020	1.480	2.201*	0.356
Pintail	1.536	3.274**	0.965	0.726	1.077	0.313
Green-winged teal	1.303	2.482*	0.144	-0.078	0.851	0.143
Blue-winged teal	-0.639	2.725**	-2.242*	0.983	2.121*	0.288
Shoveler	-0.169	0.642	-1.465	0.916	1.672	0.092
American widgeon	-1.654	1.212	-2.209*	0.775	0.952	0.178
Dabbling ducks	-1.482	2.459*	-1.722	1.453	2.449*	0.400
Redhead	0.102	4.347**	-0.781	1.125	0.070	0.399
Canvasback	0.042	2.030*	-1.672	0.338	1.999	0.163
Lesser scaup	-2.054*	0.609	1.348	0.384	-1.732	0.312
Ruddy duck	-0.834	2.199*	-1.505	1.369	0.973	0.226
Diving ducks	-1.502	3.316**	-1.023	1.465	0.206	0.424
Total	-1.672	3.080**	-1.675	1.655	1.998	0.458

[a] *t* value tests the null hypothesis that the partial regression coefficient is zero; single asterisks indicates rejection at 0.95 confidence level (critical value = 2.002, 58 df), and double asterisks indicates rejection at 0.99 confidence level (critical value = 2.664, 58 df).

Table 26. Results of multiple regression analysis of habitat factors in relation to the number of brood-days-use on the 64 semi-permanent and permanent potholes in 1965

Species	Emergent cover *t* value[a]	Pothole size *t* value	Water depth *t* value	Specific conductance *t* value	pH *t* value	Coefficient of determination R^2
Mallard	-0.336	1.250	-1.025	-0.377	0.283	0.049
Gadwall	-1.474	1.228	-1.479	1.284	2.235*	0.282
Pintail	1.685	3.312**	0.383	0.744	1.374	0.269
Green-winged teal	1.303	2.573*	-0.445	0.025	0.851	0.122
Blue-winged teal	0.187	4.118**	-1.946	1.094	2.438*	0.390
Shoveler	0.573	0.613	-1.023	0.822	2.059*	0.088
American widgeon	-1.358	0.622	-1.813	0.359	1.069	0.119
Dabbling ducks	-0.675	2.775**	-1.871	1.342	2.762**	0.361
Redhead	1.363	4.536**	-0.117	0.758	1.042	0.389
Canvasback	-0.298	2.885**	-2.074*	0.125	1.719	0.238
Lesser scaup	-2.170*	0.928	0.479	-0.068	-1.655	0.267
Ruddy duck	-0.398	2.973**	-1.622	1.092	0.730	0.245
Diving ducks	-0.889	4.186**	-1.438	1.017	0.405	0.429
Total	-0.901	3.961**	-2.002*	1.429	2.124*	0.455

[a]*t* value tests the null hypothesis that the partial regression coefficient is zero; single asterisks indicates rejection at 0.95 confidence level (critical value = 2.002, 58 df), and double asterisks indicates rejection at 0.99 confidence level (critical value = 2.664, 58 df).

dabbling ducks and highly significant for diving ducks. The number of brood-days-use was highly significant for both dabbling ducks and diving ducks. Brood use of the potholes for several species increased in relation to an increase in pothole size, particularly for pintails, green-winged teal, blue-winged teal, redheads, canvasbacks, and ruddy ducks.

Water depth was not a significant factor in brood-rearing habitat in relation to the total number of broods in 1965, but water depth was significant in relation to the total number of brood-days-use (Tables 25 and 26). Brood use of the potholes by dabbling ducks and diving ducks was not significant in relation to water depth. In 1965, there was no significant relationship between specific conductance of the pothole water and brood use of the potholes. However, the number of dabbling duck broods was significantly related to pH of the pothole water, and the number of dabbling duck broods-days-use was highly significant in relation to pH. In addition, pH was nearly significant in relation to the total number of broods and significant in relation to the total number of brood-days-use. Brood use of the potholes by gadwalls and blue-winged teal was significant in relation to pH of the pothole water.

Coefficients of determination indicated that about 46 per cent of the variation in the total number of broods and brood-days-use was attributable to the five habitat factors measured in 1965 (Tables 25 and 26). In addition, these five factors accounted for about the same amount of variation in the distribution of dabbling duck broods as in diving duck broods (Table 25), but about 7 per cent more variation in the number of brood-days-use for diving ducks than for dabbling ducks (Table 26).

Although the results of the multiple regression analysis for 1964 and 1965 are not directly comparable, it is interesting to speculate on the possibility that the influence of pH on brood use was reflected in the apparent significance of emergent cover in 1964 when pH of the pothole water was not measured. Emergent cover was a highly significant factor in relation to brood use in 1964, particularly in relation to dabbling ducks, but in 1965, emergent cover was nonsignificant for total broods and brood-days-use and for dabbling duck broods brood-days-use. However, pH of the pothole water was significant in relation to dabbling duck broods and highly significant in relation to dabbling duck brood-days-use in 1965. In addition, pH approached significance in relation to total broods and attained significance for total brood-days-use. Correlation analysis indicated that pH was more closely associated with emergent cover than with any other habitat factor (Table 5).

DISCUSSION

Brood use of potholes is influenced by a multitude of interrelated environmental and biological factors. Ecological relationships between brood use and potholes are further complicated by the behavioral characteristics of several species of waterfowl. In this study, brood use was analyzed in relation to cover interspersion of pothole vegetation, physical features of pothole basins, and chemical characteristics of pothole waters. However, there was no attempt to measure all of the physical, chemical, and biological factors that might influence brood use. Therefore, some subjective discussion of various factors that may affect brood use of potholes may aid in orienting these results in proper context with the complex problem of brood-rearing ecology.

Factors Influencing Brood Use

In 1964 and 1965, broods congregated on certain semi-permanent and permanent potholes during the rearing season. As a result, several study potholes accounted for a majority of the brood use, e.g., 16 (25 per cent) of the potholes were used by 407 (66 per cent) of the broods. However, the disparity in brood use between the potholes was even greater than suggested by this comparison. In fact, five (8 per cent) of the study potholes with more than 30 broods per pothole were used by 189 (31 per cent) of the broods during the 2-year period, while 20 (47 per cent) of the study potholes with less than five broods per pothole were used by only 43 (7 per cent) of the broods. Waterfowl workers, notably, Nord *et al*. (1951), Evans *et al*. (1952), Dzubin (1952), Evans and Black (1956), and Mann (1959) have observed that brood concentrations occur on certain potholes in the prairie pothole region. Stewart (1958) described congregations of wood duck broods on ponds in Ohio, and Beard (1964) studied brood concentrations on a marsh in Michigan. In Maryland, Webster and McGilvrey (1966) noted that relatively few impoundments received the majority of brood use by wood duck broods. Hence, brood congregations occur on various types of wetlands during the rearing season.

In attempting to explain brood congregations or concentrations on potholes, four possibilities must be considered. First, brood distribution on potholes may occur as a consequence of random chance. Second, brood congregations on potholes may occur as a result of a behavioral attraction of broods for potholes which are occupied by other broods. Third, brood distribution on potholes may occur as a result of habitat conditions outside of potholes where broods are observed. Fourth, brood concentrations on potholes may occur in response to requisites within potholes of survival value for broods. For purposes of discussion, these factors are termed random factors, social factors, complex factors, and habitat factors.

Random factors

Brood distribution on potholes may occur as a consequence of random chance. Evans *et al*. (1952) and Evans and Black (1956) stated the brood movements appeared to be completely random; there was no general trend of broods to move toward any one goal. However, in this study, brood use of the potholes in 1964 was correlated with brood use in 1965. In general, potholes with high brood use in 1964 had high brood use in 1965, and potholes with low brood use in 1964 had low brood use in 1965. For example, 14 (70 per cent) of the 20 potholes with the greatest brood use in 1964 ranked among the 20 potholes with the greatest brood use in 1965. In addition, 10 (67 per cent) of the 15 potholes where no broods were observed in 1964 were not used by broods in 1965. Therefore, it is improbable that the element of random chance was a factor influencing brood use of study potholes.

Social factors

Brood congregations on potholes may occur as a result of a behavioral attraction of broods for potholes which are occupied by other broods. Stewart (1958) believed that social factors might play an important role in brood congregations of wood ducks, since broods moved to ponds occupied by other wood duck broods. He described these congregating movements and discussed possible origins of this behavior. Interestingly, brood congregations occurred on the same ponds in each year, although the distribution of occupied nesting boxes was different. Since waterfowl are characteristically gregarious, except during the breeding season, it is not illogical that hens might seek to rear their broods in association with other hens and their broods. However, an equally plausible explanation may account for the apparent behavioral affinity between broods and particular ponds used for rearing habitat. Conceivably, female ducklings could form attachments to specific rearing areas during their early experience that could influence where they would rear their broods. Sowls (1955) and others have shown conclusively that yearling females return to nest in the immediate vicinity of former rearing areas where they were banded or released. Tendencies for migrational homing are even more strongly developed in adult hens. Further, ducks are known to return to the same areas and to nest in the same meadows over a period of several years. If a semi-permanent pothole used as a rearing area in previous years continues to provide acceptable brood-rearing habitat, would there be any reason for a hen to seek other rearing areas? In this study, several potholes, e.g., #1, #5, #85, and #117, were consistantly used by from 4 to 10 gadwall broods during each year while many other potholes were not used by gadwall broods in either year. Was this the result of a behavioral attraction of gadwall broods for particular potholes occupied by other broods of gadwalls or was this a response to requisite habitat factors within the pothole basins that were required by gadwall broods for survival? Unfortunately, these observations cannot be fully explained or understood based on present knowledge of brood-rearing ecology.

However, if the behavioral attraction of broods to potholes occupied by other broods is untenable, the presence of duck broods on certain potholes probably would provide clues to acceptable rearing habitat for other hens with broods. For example, Berg (1956) intensively studied 25 marked broods on stock ponds in eastern Montana. Nine of these broods moved overland from one pond to another. Numerous observations of 16 other marked broods indicated that these broods remained on their respective ponds. The nine broods that moved went from bare ponds to those with emergent vegetation, from small to larger ponds, and from ponds with greater to those with less water loss. The 16 "resident" broods occupied larger ponds with emergent vegetation and less water loss. These broods may have indicated which ponds provided desirable conditions for other broods. In addition, the tendency must be for broods to remain on potholes if habitat conditions are acceptable.

On the other hand, social relationships between broods of the same or different species of ducks, or other species of marsh or water birds, may not be entirely advantageous or desireable. Beard (1964) observed that competition for loafing sites, i.e., muskrat houses, mud bars, tussocks, or mounds, between broods resulted in a definite limiting influence on the number of broods using the marsh and on the length of time they spent there. Bennett (1938), Low (1945), Sowls (1955), and Hochbaum (1959) have discussed brood use of loafing sites during the rearing period and have emphasized the importance of loafing sites in waterfowl habitat. In addition, Beard (1964) considered overcrowding of broods in rearing marshes as detrimental to duckling survival, since brood mixing leads to strife between hens and to straying by ducklings. In experimental studies, Collias and Collias (1956) found aggression could be provoked by moderately crowding ducklings. Several isolated observations of outright conflict between broods were noted in this study, but the relationship between these incidents and brood use of the potholes is unknown.

Although the number and distribution of loafing sites was not determined, several of the potholes, e.g., #1, #58, #64, #83, and #85, with high levels of brood use contained a variety of loafing sites that were used by broods, including rocks occurring along the shorelines or emerging above the water, fence posts or wooden platforms floating on the water, and exposed shorelines or mud banks resulting from grazing and trampling by livestock. Whether these loafing sites were responsible for the brood use observed on the potholes, or whether these observations were coincidental was not determined. Further study of this relationship probably would have revealed an abundance of suitable loafing sites on most of the semi-permanent and permanent potholes. During the study, competition between duck broods for loafing sites was not apparent. However, loafing sites will become less of a critical item when muskrats return to the potholes, since there were no muskrat houses on any of the potholes in 1964 and 1965.

Occasionally, duck broods were chased by coots, grebes, and other ducks, but these encounters rarely resulted in direct physical contact between the birds. Mortality of ducklings as a result of these skirmishes was never observed. Munro (1939) and Sooter (1945) determined that mortality of young ducks from encounters with coots and grebes was not a serious problem. Harris (1954) suspected that the presence of coots on small potholes made these ares less desirable to duck broods but Ryder (1961) found that duck production was not appreciably greater on larger marshes where coots were artificially reduced. Evans _et al_. (1952) found no decrease in brood use of potholes occupied by coots, grebes, and black terns. In fact, brood use was greater on potholes with a high level of use by other marsh birds. In general, this same relationship was observed during this study. The potholes receiving the greatest brood use were usually visited by or populated with a large number of other marsh, water, and shore birds.

Hence, behavioral and social factors may have beneficial as well as detrimental consequences for duck broods, but the significance of these factors in affecting brood use of potholes has not been adequately appraised. In this study, there was no attempt to measure these factors. Except under controlled conditions, behavioral and social factors that could influence brood use of potholes, e.g., innate need for loafing sites or significance of intraspecific strife or interspecific conflict, would be difficult to measure.

Complex factors

Brood distribution on potholes may occur as a result of habitat conditions outside of potholes where broods are observed. In general, the size and species composition of duck breeding populations governs the size and species composition of brood populations in an area. Evans and Black (1956) observed that the size of duck breeding populations paralleled the number of available water areas in early spring. Stewart and Kantrud (1964) determined that the acreage of potholes containing water was closely related to duck breeding populations. Hence, the number of breeding pairs associated with individual potholes might be influenced by the particular complex of potholes, i.e., number, size, distribution, and permanence of associated potholes, in which individual potholes were located. Thus, differences in breeding populations between various pothole complexes could influence brood use of individual potholes, but the number of broods would really be related to the attractiveness of the potholes to breeding pairs rather than broods. Although the breeding populations associated with the study potholes were recognized as important factors influencing brood use, breeding pair counts were virtually meaningless because of breeding pairs mutually shared with other potholes in the pothole complex.

The distribution of nests and differences in nesting success as related to land use could result in differential brood use of potholes which also might be mistaken for differences in pothole attractiveness to broods. Since broods may move considerable distances from nesting areas to rearing areas, brood observations on potholes probably have little relation to the productivity of the surrounding uplands. Nevertheless, during 1959 Salyer (1962) found that brood use was greatest for potholes located in ungrazed prairie at Lostwood National Wildlife Refuge in North Dakota. However, potholes surrounded by moderately grazed pastures received greater use by broods than potholes surrounded by ungrazed prairie in 1960. During the 2-year study, intensive land use, including haying, cropping, and grazing, resulted in the lowest brood use of potholes. Bue et al. (1952), Smith (1953), and Berg (1956) found that heavy grazing and trampling of shorelines made stock ponds less attractive to broods. Evans and Black (1956) observed that smaller and shallower potholes were rendered unsuited for brood use if the emergent cover was removed by intensive grazing. Thus, land use appears to be an important factor influencing brood use of potholes. However, the relationship between brood use and land use is extremely difficult and complex.

In this study, brood use was not analyzed in relation to land use, because it was impossible to classify individual potholes according to independent categories of land use. Within the range of brood mobility, as many as four land use categories were associated with most of the study potholes. In several cases, the land use of pothole margins was different from the land use of the surrounding uplands. Another problem was the difficulty in distinguishing between various degrees of land use, e.g., "heavily grazed" versus "lightly grazed". However, observations of brood use on the 64 semi-permanent and permanent potholes indicated that brood use was not directly related to land use of the potholes.

The type of pothole complex in which a pothole is situated could result in differences in brood use which might be mistaken for differences in the attractiveness of the potholes to broods. For example, one pothole might have numerous, less permanent or smaller potholes nearby contributing to increased brood use of the pothole, while another pothole might have relatively few adjacent small potholes but several larger and more permanent potholes. During the study, the number of potholes surrounding individual study potholes was recognized as an important factor that could influence brood use of the potholes. Since it was impossible to select potholes with the same number of peripheral potholes, an attempt was made to evaluate the significance of this factor.

Based on field surveys and the aerial photos, the number of potholes within 1320 feet (0.25 miles) of the pothole perimeter of each study pothole was counted. These associated wetlands were also classified according to size and permanence. There were 1044 potholes associated with the 64 semi-permanent and permanent potholes. Each study pothole had an average of 16.3 potholes within 0.25 mile of the pothole perimeter, but the range was from 4 to 38 potholes. Correlation and multiple regression analysis indicated no linear relationship between brood use of the 64 potholes and the number, size, and permanence of these associated wetlands. Hence, there did not appear to be any direct influence of the associated potholes on the brood use of the study potholes, but there remained many unknown variables. For example, since water conditions varied from day to day, particularly in temporary and seasonal potholes, it was impossible to determine how long each pothole held water. Therefore, a more precise conclusion was that there appeared to be no linear relationship between brood use of the study potholes and the potential wetland habitat associated with the 64 semi-permanent and permanent potholes. Evans et al. (1952) found no significant difference in brood use between three portions of their study area that had varying pothole densities. They concluded that the potholes were so closely spaced that there was no effect on brood use.

However, brood populations on the 64 semi-permanent and permanent potholes decreased nearly 20 per cent between 1964 and 1965. This observation was interpreted with respect to a general increase in the number of potholes containing water, reflecting improved water conditions in 1965, rather than an actual decline in waterfowl populations or production. On the Woodworth Study Area, Kirsch and Bayha (1965) reported a 35 per cent increase in duck breeding populations and a 43 per cent increase in duck brood production in 1965 as compared with 1964. The number of potholes of all types containing water on the area during August, 1965, was 30 per cent greater than in August, 1964. Therefore, brood use of individual potholes is influenced to some extent by the amount of habitat available for brood rearing, i.e., the number of potholes holding water during the brood season.

Habitat factors

Brood concentrations on potholes may occur in response to requisites within potholes of survival value for broods. According to Webster and McGilvrey (1966), brood habitat must meet both physiological and psychological needs of hen and young. Physiological requirements would include food, water, space, and cover, whereas psychological needs involve a sense of security and well being. After broods reach rearing areas, regardless of other factors influencing brood use of potholes, these needs must be satisfied. Otherwise, broods will seek more favorable rearing habitat or perish.

Although the ecological relationships of physical, chemical, and biological factors within potholes are extremely complex and interrelated, habitat factors can at least be measured and quantified. Therefore, brood use was studied in relation to several habitat factors in order to identify those factors influencing brood use of potholes. These factors included cover interspersion of the pothole vegetation, physical features of the pothole basins, and chemical characteristics of the pothole waters. The problems encountered were numerous and complex, but since the habitat factors that could influence brood use were also numerous and interrelated, there was no alternative. To subject brood use data to single factor analysis, e.g., brood use in relation to cover interspersion, would be inadequate and hazardous just as it would be questionable to attribute brood use of potholes to a single factor, e.g., pH of pothole waters. During 1964 and 1965, the association between brood use and emergent cover, pothole size, water depth, specific conductance, and pH accounted for only 34 to 46 per cent of the total potholes (Tables 23-26). Other habitat factors, plus complex factors and social factors, presumably would account for the remainder of variation in brood use.

Habitat Factors Influencing Brood Use

Since the study was based on a selected sample of 64 slightly brackish semi-permanent and permanent potholes, limitations are placed on the interpretation and application of the results. In addition to the small number and restricted types of potholes that were intensively studied, field work was conducted over a relatively short period of time. In the following discussion, an attempt will be made to identify the limitations of the study, to evaluate the validity of the results, and to suggest possible explanations for the phenomena observed.

Critique

Individual potholes were selected for study, because major emphasis was placed on identifying the habitat factors influencing brood use of slightly brackish semi-permanent and permanent potholes. The selection of potholes insured a variety of these types of potholes for study and facilitated the observation of broods, since the potholes were selected in accessible locations. In addition, the problem of brood movements between potholes encountered in most waterfowl production studies, e.g., Jessen *et al*. (1964), was minimized, because brood use was measured on individual potholes independent of the brood use on other potholes.

Brood observations were collected "systematically" to obtain the greatest amount of information on brood use of potholes in the shortest period of time. This was accomplished by making regular censuses throughout the rearing season during periods of peak brood activity. Statistically, this approach was valid, because the objective was to identify habitat factors of the potholes associated with brood use rather than to compare habitat factors and brood use between potholes. The null hypothesis was that the measures of habitat factors and brood use were unrelated. Therefore, there was no need to sample either the habitat factors or the brood use randomly. Since the habitat factors were measured quantitatively, correlation analysis and multiple regression analysis were the appropriate statistical tools for analyzing these data. This method of attack was similar to the approach recommended by Greig-Smith (1964) for the correlation of vegetation with habitat factors when quantitative measures were available for both plants and habitat factors.

In the analysis of data, correlation and multiple regression were valuable analytic tools for handling the formidable amount of data collected in the field. Correlation analysis was useful for showing the degree of linear association between habitat factors and brood use of the potholes, but tests of significance were not valid as previously stated. Since correlation coefficients measured only the association between two variables, brood use associated with one habitat factor could be reflected in the relationship of brood use and another closely related habitat factor. Multiple regression analysis overcame these difficulties and was of considerable assistance in identifying habitat factors most closely associated with brood use, since tests of significance were valid for the null hypothesis. However, statistical significance between habitat factors and brood use does not necessarily denote biological significance. For example, a significant relationship between an individual habitat factor and brood use does not indicate that a cause and effect relationship exists between the variables either directly or indirectly. In reality, the habitat factors and brood use may be related to or caused by a mutual indirect factor which was not measured. Hence, satisfactory biological interpretations for certain relationships were difficult to make on the basis of the results, because the basic variables and basic mechanisms within the pothole environment have not been fully elucidated. Faced with a paucity of basic information on wetland ecology, it is premature to suggest causal or functional relationships between habitat factors and brood use of the potholes. To do so would be misleading, if not erroneous, based on this rather limited and short-term study. However, these results may prove useful as starting points for further research.

Difficulties were encountered in determining what measure of brood use was most meaningful for evaluating habitat factors of the potholes. Since the number of ducklings reared to flight has survival implications for the various species, ducks reared per pothole would probably be the best measure for evaluating brood habitat. On the other hand, waterfowl managers might be more interested in ducks reared per wetland acre for measuring relative waterfowl productivity between various wetland habitats. However, in pothole habitat, brood movements rule out the possibility of using ducks reared per pothole or per wetland acre for expressing brood use, since broods may not spend an entire rearing season on one pothole. In addition, without permanent color-markers for hens and ducklings, the possibilities for recognizing individual broods and for determining ducklings reared is open to question, because of brood mixing and combination during the rearing season.

In the wetlands acquisition program, one objective is to purchase semi-permanent and permanent potholes to provide brood-rearing habitat. Hence, potholes providing habitat for the greatest numbers of broods (broods per pothole) for the greatest length of time (brood-days-use per pothole) should receive high priority as wetlands to be purchased. However, wetlands are generally purchased on a cost per acre basis. Therefore, economics dictates that the various wetlands also should be appraised on a brood per wetland acre or brood-days-use per wetland acre basis.

In addition, waterfowl biologists have frequently attempted to evaluate waterfowl productivity in relation to upland and wetland habitat on a nest per acre or brood per acre basis. However, the number of broods per pothole or the number of brood-days-use per pothole of each species is probably most indicative of habitat preferences for various species. In the past, brood use of potholes has been expressed both in terms of broods per pothole and broods per wetland acre. Hence, brood use in this study was measured in terms of the number of broods and brood-days-use per pothole and the number of broods and brood-days-use per wetland acre. Each standard of comparison has its particular usefulness and limitations. No single measure of brood use was completely satisfactory for evaluating the relationship of various habitat factors to brood use.

Cover interspersion

A specific goal of this study was to determine the relationship of cover interspersion to brood use of potholes. During 1964 and 1965, semi-permanent and permanent potholes with central zones of open water surrounded by peripheral bands of emergent cover provided optimum habitat for brood rearing. However, since the concept of cover interspersion is qualitative rather than quantitative, the ratio of emergent cover to open water and the percentages of emergent cover and open water were used to express varying degrees of emergent vegetation on the potholes. Cover:water ratios on preferred potholes ranged from 0.0:1.0 to 2.0:1.0, since potholes with less than 60 per cent emergent cover and with more than 40 per cent open water received the majority of the brood use. Hence, these potholes might best be characterized as open potholes with relatively large proportions of the pothole basin occupied by open water and relatively small proportions of the pothole basin covered with emergent vegetation.

These observations appear to be at variance with the supposed attractiveness to broods of cover in proper juxtaposition with water in rearing habitat. However, the importance of "escape cover" in brood habitat has been widely held but never satisfactorily evaluated. In the past the size, ratio, and pattern of cover and water has largely been a matter of subjective judgement based on general observations and experience.

Waterfowl biologists, who have stressed the importance of cover in rearing habitat, have conducted their studies in the eastern portion of the United States, e.g., Beard (1953) in Michigan, Stewart (1958) in Ohio, Kadlec (1962) in Michigan, Cowardin (1965) in New York, and Webster and McGilvrey (1966) in Maryland. They have described suitable brood-rearing habitat as "semi-open stands of emergent vegetation" or a "patchy pattern of emergent cover". Throughout the prairie pothole region, waterfowl workers, e.g., Nord (1951), Evans et al. (1952), and Evans and Black (1956) reported that brood use was greatest on potholes with the largest areas of open water and on potholes classified as "open-water areas". Keith (1961) and Lokemoen (1966) noted similar preferences of broods for open potholes that provided good visibility of the surrounding terrain.

In rearing habitat, emergent cover may provide protection from predators and weather for broods. Since adverse weather is characteristically sporadic in occurrence and random in effect, its importance as a selective mechanism is open to question. Therefore, predation, or the threat of predation, must be the factor responsible for establishing patterns of brood behavior in relation to cover interspersion. Throughout the breeding ranges of most species of ducks, predators of significance to broods would be either mammalian or avian species; however, retiles, fish, and crustaceans have been known to kill ducklings.

Wooded areas associated with most of the wetlands in eastern United States provide ideal habitat for numerous avian predators, i.e., hawks and owls. These avian predators must present the greatest menace to duck broods on large expanses of open water; mammalian predators would be more of a threat along the margins of wetlands. In comparison, avian predators in the open habitat of the prairie would be of little consequence to broods on open water in potholes. Hence, it is entirely conceivable that differences in the response of broods to cover interspersion between these areas are explained on the basis of differences in avian predator populations.

In waterfowl production studies, biologists have frequently encountered problems of observing broods in dense vegetation, e.g., Jessen et al. (1964). This results in an observability bias where broods on open potholes are observed in greater proportion to their abundance than on closed potholes. In addition, various species of ducks are known to vary in observability (Murdy and Anderson, 1955; Diem and Lu, 1960). Unfortunately, the significance of this bias cannot be measured or evaluated at the present time. However, the possibility of observability bias was recognized at the onset of the study. Therefore, several types of brood censuses were used to obtain information on brood use of the potholes. Brood censuses were conducted during periods of the day when the greatest opportunity to observe broods was afforded. One measure of the validity of these findings is the general agreement with other workers in the prairie pothole region concerning the relationship of emergent cover and other habitat factors to brood use.

In retrospect, potholes encompassing a broader spectrum of cover types should have been studied. For example, potholes with closed stands of emergents should have been included in the study. The reason that they were not studied was because of the census and observability problems In addition, a larger number of open potholes should have been studied, but these types were relatively scarce under the prevailing water conditions in 1964 and 1965.

Physical features

Semi-permanent and permanent potholes between 5 and 25 acres in size provided the preferred brood-rearing habitat in 1964 and 1965. Brood populations were highest on potholes larger than 20 acres in size, but brood densities were lowest on these areas. Perhaps, the low number of broods per unit area on larger potholes was a contributing factor to the greater number of broods observed on these potholes. Lower concentrations of broods might reduce competition for food yet provide security in the social association of large congregations of broods. Although potholes less than 5 acres in size individually provided rearing habitat for relatively few broods, these areas probably are quite important as brood habitat, since smaller wetlands are more numerous than larger potholes. Brood use in relation to shore length followed a similar pattern of brood use as found for pothole size, since the length of shorelines was highly correlated with the size of potholes.

In general, brood populations on the potholes increased as the maximum water depth increased, but brood densities decreased. Brood use was greatest on potholes between 24 and 60 inches in depth, but dabbling ducks preferred shallower potholes ranging from 24 to 48 inches in depth, while broods of diving ducks preferred deeper potholes ranging from 36 to 60 inches in depth. Since there was considerable variation in brood use in relation to water depth, mean depth may have provided a better indication of the water-holding capacity of the pothole basin than maximum depth. However, in 30 potholes where water depths were measured along transect lines, mean depths were highly correlated with maximum depths (r = +0.9617). Apparently, water fluctuations measured in individual potholes were not great enough to affect brood use of the study potholes. However, broods abandoned potholes when water depths became shallower than 9 inches.

Patterns of brood use in relation to the size and depth of potholes observed in this study agree with findings of other workers in the prairie pothole region, e.g., Nord *et al*. (1951), Evans *et al*. (1952), Evans and Black (1956). who have characterized brood potholes as "larger, deeper, and more permanent potholes". The survival value for ducks in utilizing this type of habitat for brood rearing should be apparent. Undoubtedly, the major factor responsible for the evolution of habitat requirements for brood rearing is the seasonal decline, spring to fall, year after year, of water levels in potholes. In addition, recurrent periods of severe drought, characteristic of the northern prairie region, have doubtless had their affect. Patterns of brood movement support this view (Bennett, 1938; Berg, 1956; Hochbaum, 1959; Gates, 1962; and Lokemoen, 1966).

Chemical characteristics

Slightly brackish semi-permanent and permanent potholes with specific conductance of the water ranging between 800 and 1600 μmhos/cm received the greatest brood use in 1964 and 1965. Brood use was lowest on potholes where the specific conductance was less than 400 μmhos/cm.

Limnologically, specific conductance provides a relative measure of the total dissolved solid content of the water. Since acids, bases, and salts in solution are conductors of electricity, they are termed electrolytes. Welch (1952) stated that, other things being equal, the richer a body of water in electrolytes the greater its biological productivity. In general, the fertility of water is dependent upon the concentrations of nutrient salts in the water. Hence, as the total dissolved solids increase, the water becomes more fertile. However, Moyle (1956) pointed out that this was not a straight line relationship and that there were many exceptions in individual waters.

In this study, brood use showed a general increase in relation to specific conductance, but there was no linear relationship between brood use and specific conductance based on correlation and multiple regression analysis. The existance of a curvilinear relationship was not explored.

During 1964 and 1965, brood use of the semi-permanent and permanent potholes was lowest on potholes where the pH of the water ranged from 7.0 to 8.5 in 1965, but brood use was highest on potholes where the pH ranged from 8.5 to 10.5 in 1965.

In recent years, the trend of opinion suggests that the pH, or hydrogen-ion concentration, of natural waters is of less importance as a limiting factor than previously supposed, but that pH may be of considerable value as an indicator of certain environmental conditions. Welch (1952) considered the limnological roles of pH as a limiting factor and an index of general environmental conditions. Ruttner (1963) stated that "The hydrogen-ion concentration of water is one of those environmental factors that are very strikingly linked to the species composition of communities and their life processes."

Since the basic factors which determine pH are often inconvenient or impossible to determine, its exact meaning is difficult to know. At present, the hydrogen-ion concentration of fresh waters is not well understood, primarily because of the variety of contributing factors and the complexity and dynamics of the water environment. Hence, pH should be considered with respect to what it represents, namely, the result of a number of underlying physical, chemical, and biological conditions within a body of water. In this context, it is strongly suspected that the higher pH values (greater than 8.5) were related to the dense beds of submerged aquatic plants and populations of phytoplankton occupying open water areas of the potholes. Conceivably, pH values greater than 8.0 or 8.5 were produced by a photosynthetic rate that demanded more carbon dioxide from the water than was furnished by respiration and decomposition. Determinations of pH were more strongly correlated with the percentage of open water than any other habitat factor (Table 5). Ruttner (1963) discussed in considerable detail the relationship of aquatic plants to the hydrogen-ion concentration of fresh waters.

During 1964 and 1965, brood use of the potholes in terms of broods per pothole and broods per 10 wetland acres showed the same general trends in relation to the specific conductance and pH of the pothole waters (Figures 23-24). A plausible explanation for this relationship is that the chemical characteristics measured by specific conductance and pH were relatively independent of the size of the potholes (Table 5).

Moyle (1956) discussed the geological, climatological, and biological phenomena that influence water chemistry in lakes and ponds. He stressed that any water analysis represents but a momentary picture of the chemical conditions in a body of water. Dobie and Moyle (1962) emphasized that all chemical analyses are at best estimates and are subject to analytical error. In addition, Welch (1952) and Ruttner (1963) discussed annual, seasonal, and diurnal variations that occur in the chemistry of fresh waters. Hence, the relationship between brood use and water chemistry must be considered as exploratory, because of unavoidable problems involving limitations in water analysis and representativeness of water samples, i.e., frequency and intensity of water sampling.

However, variations in pH and specific conductance of pothole waters during 1964 and 1965 probably had little practical significance in relation to the distribution of duck broods, although these variations would have been of considerable academic interest. Careful review of Table 5 supports this conclusion: consider that measurements of specific conductance in 1964 were highly correlated with measurements of specific conductance in 1965; consider that measurements of specific conductance in 1964 and 1965 were associated with other habitat factors at the same relative intensity; consider that pH of pothole waters measured in mid-summer were highly ocrrelated with measurements of pH in late summer; consider that the relative amounts of emergent cover and open water did not change between 1964 and 1965; and then consider that pH was more strongly correlated with open water and emergent cover than any other habitat factor. Thus, the measurements of specific conductance and pH were considered adequate for purposes of this study.

Water chemistry of pothole water is related to brood use of potholes, since water chemistry influences the distribution of marsh and aquatic plants (Metcalf, 1931; Moyle, 1945) and the distribution and abundance of aquatic invertebrates (Moyle, 1961; Collias and Collias, 1963). Ducklings utilize aquatic invertebrates as food organisms.

Synthesis

In view of the previous considerations, the following relationships of brood use to habitat factors of slightly brackish semi-permanent and permanent potholes are suggested.

These deductions are based on the results of correlation analysis (Tables 11, 13, 15, 17, 19, and 22) and multiple regression analysis (Tables 23-26) of the data, but they must be interpreted with respect to the types of potholes that were studied, the species composition of the duck brood populations, and the prevailing water conditions throughout the study area in 1964 and 1965.

Habitat factors, including pothole size, water depth, emergent cover, specific conductance, and pH, accounted for 34 to 46 per cent of the total variation in brood use of the potholes during 1964 and 1965. These factors accounted for 6 to 10 per cent more of the variation in brood use of the potholes by diving ducks than by dabbling ducks. More of the variation was explained in 1965 when five factors were studied than in 1964 when four factors were studied. The number of broods and brood-days-use on the potholes showed similar patterns of brood use in relation to the habitat factors.

Pothole size was the basic factor governing brood use of potholes for all species of duck broods, but particularly broods of diving ducks. Dabbling duck broods were more strongly associated with shore length than with pothole size. Broods used larger potholes in 1965 than in 1964.

The presence of emergent cover on the potholes was definitely not a requisite factor influencing brood use of potholes. Brood use was more directly related to the percentage of open water than to the percentage of emergent cover. Diving ducks preferred more open potholes for brood rearing than dabbling ducks. Broods used more open potholes in 1964 than in 1965.

Water depth was not a primary factor influencing brood use of potholes, but diving ducks preferred slightly deeper potholes for brood rearing than dabbling ducks. Broods used deeper potholes in 1965 than in 1964.

Brood use of potholes in 1965 was strongly influenced by the pH of the pothole water, particularly in relation to brood use by dabbling ducks. Specific conductance of the pothole water was not linearly related to brood use of the potholes in either 1964 or 1965.

Before relationships between broods of individual species and particular habitat factors can be compared, known characteristics of the various species must be used to appraise the biological or ecological significance of the correlation analysis or multiple regression analysis. A relationship may be statistically significant for a given habitat factor and species, but it may or may not be biologically or ecologically meaningful. However, these results allow one to appreciate the differences in the habitat preferences and requirements for brood rearing of the various species (Tables 23-26). Habitat requirements of the various species are suggested by the brood use of potholes in 1964, and habitat preferences are indicated by brood use of potholes in 1965, because there were more wetlands of all types available to the ducks for brood rearing in 1965 than in 1964. Although the habitat factors accounted for less than 50 per cent of the total variation in brood use of the potholes, these observations suggest that if the breeding populations could have been determined for the particular pothole complex in which the semi-permanent or permanent pothole was located, and if the number of adjacent potholes containing water throughout the brood-rearing season could have been measured, a greater proportion of the total variation in brood use of the potholes could have been explained.

RECOMMENDATIONS

Although brood-rearing habitat is probably not a limiting factor affecting waterfowl production in the prairie pothole region at the present time, deficiencies in suitable brood habitat are known to be an important limitation to duck production in intensive agricultural areas (Gates, 1965). With increasing demands for agricultural lands in the fertile northern prairie region, there will be concommitant pressures for drainage of prairie wetlands.

Since optimum waterfowl production can only be maintained on the basis of the entire pothole complex, waterfowl managers should strive to preserve the proper interspersion of various sizes and types of potholes. This is the goal of the wetlands acquisition program administered by the Bureau of Sport Fisheries and Wildlife. It is recommended that this program be extended at least five more years beyond Fiscal Year 1968, when the present program is scheduled for termination, in order to acquire the necessary wetland habitat for waterfowl management purposes.

One phase of the wetlands acquisition program is the purchase of semi-permanent and permanent potholes in strategic locations in order to provide more dependable brood-rearing habitat for prairie nesting ducks during dry years.

Semi-permanent and permanent potholes between 5 and 25 acres in size offer the best wetlands purchases for brood-rearing habitat, dollar for dollar and acre for acre. However, potholes larger than 20 acres in size will accommodate more broods of ducks for a greater period of time during the rearing season.

Potholes recommended for purchase should consist mainly of open water surrounded by a margin of moderately dense to sparse emergent vegetation. The ratio of emergent cover to open water should be less than 2:1, since emergent vegetation should cover less than 60 per cent of the pothole basin.

Potholes providing optimum brood habitat are relatively deep. Dabbling ducks prefer shallower potholes ranging from 24 to 48 inches in depth while diving ducks prefer deeper potholes ranging from 36 to 60 inches in depth.

Brood use is greatest on potholes where the hydrogen-ion concentration (pH) of the water ranges between 8.5 and 10.5 and specific conductance of the water ranges between 800 and 1600 µmhos/cm.

Before specific management recommendations can be made to improve brood-rearing habitat on individual water areas, a vigorous and balanced program of basic and applied research must provide the answers to a multitude of questions bristling with difficulties for the investigators. An experimental rather than a survey approach will be most valuable in future research on certain aspects of brood-rearing ecology.

Brood behavior should be studied under controlled and natural conditions to clarify the importance of loafing sites in brood habitat. The social implications of brood congregations and concentrations should also be investigated. Behavioral affinity for individual rearing areas could be studied with permanent color-markers placed on ducklings.

Food habits and nutritional requirements of duck broods should be determined in relation to food availability and abundance throughout the rearing season. In addition, the nutritional values of plant and animal foods should be compared. The relationship between submerged aquatic plants and the production of animal foods should be explored in relation to brood use of potholes.

Causes and rates of duckling mortality need to be determined with marked broods, since most existing data on brood size are of questionable value. Brood mortality needs to be investigated in relation to the composition and interspersion of emergent vegetation in wetlands. Brood mortality needs to be compared for various species in different ecological habitats. The significance of parasite infestations as a mortality factor in young ducklings needs to be appraised.

Brood movements need to be studied with marked hens and broods in relation to upland cover to evaluate the relationship of land use to brood use of potholes. Brood use also needs to be investigated with marked hens in relation to the pothole complex both from the standpoint of breeding populations and the number of water areas available for brood rearing. Further information on brood mobility of the various species is needed as well as an understanding of inherent mobility of individual hens.

Much basic research must be done to determine species preferences and species requirements for brood-rearing habitat. These studies will require long-term investigations under varying water conditions and population levels. Habitat preferences for brood rearing can be determined during "flood conditions" when potholes of all types are a available for brood rearing, and habitat requirements can be studied during "drought conditions".

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APPENDIX

Table 27. Location of 64 semi-permanent and permanent potholes in northwestern Stutsman County, North Dakota[a]

Pothole number	Township	Range	Section
1	144 N	68 W	NE¼NE¼, 3
3	144 N	68 W	SE¼SW¼, 2
5	144 N	68 W	NE¼NW¼, 11
7	144 N	68 W	SW¼NW¼, 14
10	144 N	68 W	NE¼NE¼, 15
14	144 N	68 W	SE¼SE¼, 34
15	144 N	68 W	SE¼SW¼, 24
16	144 N	67 W	SW¼SW¼, 19
17	144 N	67 W	S½SE¼, 19
18	144 N	67 W	SW¼SW¼, 20
19	144 N	67 W	NE¼NW¼, 29
20	144 N	67 W	SE¼SW¼, 20
21	144 N	67 W	N½NE¼, 29
22	144 N	67 W	NW¼NW¼, 28
24	144 N	67 W	NE¼SE¼, 20
25	144 N	67 W	SE¼NE¼, 20
26	144 N	67 W	NE¼NE¼, 20
42	143 N	67 W	SE¼SW¼, 5
45	143 N	67 W	NE¼SE¼, 8
46	143 N	67 W	SE¼NE¼, 20
48	143 N	67 W	SE¼NE¼, 29
49	143 N	67 W	SW¼SE¼, 33
50	143 N	67 W	NW¼NE¼, 33
51	143 N	67 W	NW¼SE¼, 28
55	143 N	67 W	NW¼NW¼, 9
58	143 N	67 W	SE¼NE¼, 15
60	143 N	67 W	SE¼SW¼, 23
63	143 N	67 W	SE¼SE¼, 34
64	143 N	67 W	SW¼SW¼, 35
65	143 N	67 W	SW¼SE¼, 35

[a]Legal descriptions are surveyed from the Fifth Principal Meridan.

Table 27. (continued)

Pothole number	Township	Range	Section
66	143 N	67 W	NE¼SE¼, 25
67	143 N	66 W	SW¼SE¼, 30
68	142 N	67 W	NE¼NE¼, 5
70	142 N	67 W	SW¼NW¼, 9
71	142 N	67 W	NE¼NE¼, 17
72	142 N	67 W	SE¼NE¼, 17
73	142 N	67 W	W½NW¼, 16
74	142 N	67 W	W½SE¼, 17
75	142 N	67 W	NE¼SE¼, 3
76	142 N	67 W	SW¼SW¼, 2
78	142 N	67 W	NW¼NW¼, 1
81	142 N	67 W	NW¼SE¼, 13
82	142 N	68 W	NW¼NE¼, 9
83	142 N	68 W	NE¼NW¼, 2
84	142 N	68 W	SW¼NE¼, 14
85	142 N	68 W	SW¼SE¼, 14
86	142 N	68 W	SE¼SW¼, 13
87	142 N	68 W	S½NE¼, 24
88	142 N	67 W	SE¼SW¼, 18
89	142 N	67 W	NE¼NW¼, 19
90	142 N	67 W	NE¼NE¼, 19
91	142 N	67 W	SE¼SW¼, 18
92	142 N	67 W	NW¼NE¼, 18
94	142 N	68 W	E½, 7
96	142 N	67 W	NW¼NW¼, 7
97	142 N	67 W	NE¼SW¼, 6
100	142 N	66 W	S½SW¼, 18
102	142 N	66 W	NW¼SW¼, 17
106	142 N	66 W	SE¼SW¼, 15
108	142 N	66 W	SE¼SW¼, 28
117	142 N	66 W	SW¼SW¼, 32
118	142 N	67 W	SW¼SW¼, 36
120	141 N	67 W	NW¼SW¼, 11
122	141 N	67 W	W½NW¼, 24

Table 28. Pothole sizes and shore lengths of 64 semi-permanent and permanent potholes

Pothole number	Pothole size (acres)	Shore length (feet)
1	8.3	2522
3	2.6	1269
5	14.8	3685
7	2.1	1244
10	2.6	1211
14	1.5	971
15	0.5	604
16	0.9	974
17	60.6	6063
18	4.8	1873
19	8.3	2432
20	7.9	3136
21	24.7	5306
22	1.2	902
24	1.7	1073
25	0.7	625
26	7.5	3030
42	1.1	786
45	1.4	970
46	0.6	583
48	0.6	755
49	15.6	3398
50	16.3	3649
51	1.4	942
55	1.7	1181
58	10.4	2977
60	0.5	1108
63	3.8	1535
64	24.8	4772
65	1.2	879

Table 28. (continued)

Pothole number	Pothole size (acres)	Shore length (feet)
66	15.6	3789
67	5.9	2329
68	5.5	1894
70	21.2	3279
71	10.4	3064
72	13.8	2907
73	69.5	7325
74	50.4	6869
75	2.5	1372
76	4.0	1739
78	5.5	1940
81	5.9	1832
82	16.9	3428
83	22.4	6310
84	10.8	3340
85	12.2	4460
86	3.6	1919
87	26.0	5730
88	27.4	4298
89	5.1	1855
90	13.5	3075
91	10.5	2950
92	17.7	5140
94	52.6	9447
96	47.4	7084
97	22.3	9948
100	11.0	2598
102	1.7	1123
106	9.6	3302
108	8.2	2171
117	45.3	5538
118	12.8	3669
120	2.7	1395
122	51.8	7893

Table 29. Maximum water depth and percentage of emergent cover and open water in 64 semi-permanent and permanent potholes

Pothole number	Maximum depth (mid-July) 1964	(inches)	1965	Cover	Water
1	36		49	5	95
3	38		41	54	46
5	28		34	20	80
7	33		40	86	14
10	26		39	85	15
14	17		27	80	20
15	23		24	60	40
16	28		29	78	22
17	82		83	0	100
18	38		40	42	58
19	29		32	42	58
20	34		34	42	58
21	72		74	5	95
22	23		25	75	25
24	26		26	76	24
25	33		37	67	33
26	46		51	48	52
42	27		22	82	18
45	36		36	85	15
46	26		26	83	17
48	34		34	67	33
49	24		29	26	74
50	30		28	39	61
51	30		30	64	36
55	30		30	76	24
58	26		46	38	62
60	33		33	80	20
63	50		46	34	66
64	45		46	14	86
65	26		24	75	25

Table 29. (continued)

Pothole number	Maximum depth (mid-July) 1964	(inches)	1965	Cover	Water
66	26		28	32	68
67	38		41	73	27
68	29		34	49	51
70	26		36	65	35
71	24		21	75	25
72	40		47	36	64
73	46		61	1	99
74	45		43	52	48
75	23		27	84	16
76	26		35	85	15
78	222		38	64	36
81	27		34	71	29
82	14		21	77	23
83	48		45	24	76
84	24		25	70	30
85	25		28	73	27
86	30		40	72	28
87	29		34	27	73
88	40		43	12	88
89	27		30	43	57
90	33		35	93	7
91	37		39	34	66
92	29		33	44	56
94	83		86	3	97
96	81		84	18	82
97	50		52	58	42
100	51		56	30	70
102	29		56	76	24
106	41		42	54	46
108	48		58	57	43
117	45		59	28	72
118	71		75	40	60
120	19		26	78	22
122	62		69	23	77

Table 30. Specific conductance and hydrogen-ion concentration of water from 64 semi-permanent and permanent potholes

Pothole number	Specific conductance (microhos/cm-25°C) June-July 1964	June-July 1965	August-September 1965	Hydrogen-ion concentration (pH) July 1965	August 1965
1	625	540	450	10.5	10.4
3	400	340	380	9.5	8.4
5	925	730	850	8.0	9.4
7	850	860	850	8.1	8.6
10	2300	1750	2000	8.0	8.2
14	1100	600	625	8.3	8.6
15	1200	1225	1400	9.0	8.6
16	525	560	525	8.5	7.9
17	1000	1275	1400	9.1	9.3
18	580	625	650	8.4	8.8
19	1300	1050	1050	8.3	9.2
20	1600	1500	1700	8.1	8.6
21	1800	1700	1900	9.1	9.4
22	1175	2000	1700	9.0	9.2
24	2250	2300	2500	8.3	8.6
25	2400	1775	2000	8.6	8.9
26	875	1000	1050	8.9	9.1
42	450	370	310	7.3	8.0
45	1700	1570	1500	7.9	8.2
46	450	570	450	7.7	7.9
48	1700	860	650	7.8	8.5
49	925	1150	800	8.8	8.8
50	1050	1500	900	7.6	8.2
51	1200	1650	1080	8.2	9.1
55	1000	1250	1200	7.8	7.9
58	1500	1400	1400	8.7	8.9
60	1200	1250	1150	8.3	8.8
63	600	620	525	9.8	9.1
64	1200	1250	1050	9.2	10.1
65	975	1300	650	7.6	7.5

Table 30. (continued)

Pothole number	Specific conductance (microhos/cm-25°C) June-July 1964	June-July 1965	August-September 1965	Hydrogen-ion concentration July 1965 (pH)	August 1965
66	1200	1750	1400	8.0	8.6
67	1250	1290	1250	8.3	7.6
68	950	1000	660	8.4	8.0
70	1200	1250	950	8.3	7.5
71	415	725	340	10.0	10.0
72	1190	1020	1000	9.8	9.5
73	1580	1280	1200	9.2	9.5
74	550	580	550	8.5	8.1
75	500	580	480	7.4	7.3
76	1000	770	650	8.1	8.2
78	1350	1150	1025	8.0	8.4
81	300	540	490	7.3	8.1
82	450	600	525	9.2	9.2
83	580	560	650	10.3	9.0
84	1350	850	840	9.5	10.2
85	1000	1050	1100	9.9	10.2
86	625	850	550	8.4	8.2
87	700	800	550	8.3	10.3
88	850	780	800	9.0	8.9
89	490	610	500	8.8	9.7
90	790	940	750	7.6	7.7
91	850	775	1150	10.2	10.3
92	1400	1225	1100	8.2	8.2
94	1100	1200	1300	9.2	9.2
96	1450	1200	510	8.3	8.3
97	510	490	510	8.4	8.6
100	525	410	400	8.8	8.5
102	140	180	160	7.3	7.2
106	1175	1225	1180	8.1	9.0
108	475	400	490	8.6	8.1
117	1800	1475	2000	8.7	8.2
118	550	725	700	9.5	9.2
120	350	700	550	8.2	8.0
122	1600	1950	2300	9.1	9.6

Table 31. Summary of water analysis for 64 semi-permanent and permanent potholes

Pothole number	Calcium hardness	Total hardness	Alkalinity	Sulfate	Chloride
	(ppm of $CaCO_3$)			(ppm)	(ppm)
1	90	180	150	45	15
3	60	180	110	10	5
5	70	330	410	125	15
7	135	315	200	110	10
10	170	750	320	550	-
14	160	230	210	100	-
15	130	540	220	350	15
16	110	260	200	60	10
17	100	430	410	350	-
18	120	190	240	60	5
19	120	470	190	250	-
20	240	600	190	495	-
21	150	580	180	445	-
22	170	600	200	550	20
24	250	910	190	450	10
25					
25	220	740	170	650	15
26	80	400	190	350	10
42	100	140	110	40	5
45	160	590	230	450	20
46	120	210	150	90	10
48	180	300	200	100	10
49	110	290	160	175	-
50	110	340	160	350	10
51	150	450	220	350	-
55	160	480	210	450	-
58	190	460	250	450	-
60	210	435	180	260	-
63	90	160	190	60	-
64	80	310	140	240	-
65	110	240	140	200	15

Table 31. (continued)

Pothole number	Calcium hardness	Total hardness	Alkalinity	Sulfate	Chloride
	(ppm of $CaCO_3$)			(ppm)	(ppm)
66	200	420	170	450	20
67	180	400	160	350	15
68	150	290	50	175	-
70	80	310	120	200	-
71	100	100	60	25	-
72	100	270	240	290	-
73	180	330	160	300	-
74	140	180	80	55	-
75	110	180	100	25	-
76	80	220	150	125	-
78	120	380	150	300	-
81	140	180	110	150	5
82	80	190	90	125	-
83	100	230	140	125	-
84	180	350	90	325	-
85	130	350	110	300	-
86	110	270	190	85	-
87	80	260	150	85	-
88	100	330	230	160	-
89	100	190	80	55	-
90	80	220	130	160	-
91	60	360	240	175	-
92	110	320	160	350	-
94	110	430	240	275	25
96	80	440	160	325	20
97	130	250	180	70	-
100	110	160	160	90	5
102	40	80	40	20	5
106	120	430	180	300	15
108	120	220	170	70	5
117	130	490	280	500	25
118	110	280	120	200	10
120	120	190	170	125	10
122	130	490	210	520	100

Table 32. Duck brood use of 64 semi-permanent and permanent potholes

Pothole number	1964		1965		Total	
	Broods	Brood-days	Broods	Brood-days	Broods	Brood-days
1	9	195	14	257	23	452
3	2	44	0	0	2	44
5	12	259	12	335	24	594
7	0	0	0	0	0	0
10	2	32	2	52	4	84
14	1	9	0	0	1	9
15	2	26	0	0	2	26
16	0	0	0	0	0	0
17	5	99	6	116	11	215
18	5	86	1	6	6	92
19	9	298	9	292	18	590
20	10	237	9	243	19	480
21	2	18	8	170	10	188
22	0	0	1	3	1	3
24	1	13	0	0	1	13
25	0	0	0	0	0	0
26	4	48	0	0	4	48
42	0	0	0	0	0	0
45	0	0	0	0	0	0
46	1	9	1	3	2	12
48	0	0	0	0	23	0
49	14	304	9	206	7	510
50	3	94	4	48	5	142
51	3	16	2	22	1	38
55	1	33	0	0	22	33
58	11	247	11	259	0	506
60	0	0	0	0	9	0
63	7	199	2	7	39	206
64	24	577	15	265	0	1042
65	0	0	0	0	18	0

Table 32. (continued)

Pothole number	1964 Broods	1964 Brood-days	1965 Broods	1965 Brood-days	Total Broods	Total Brood-days
66	6	196	12	289	2	485
67	8	279	5	185	13	464
68	2	39	0	0	2	39
70	5	125	0	0	5	125
71	2	60	6	229	8	289
72	10	332	4	141	14	473
73	24	674	11	374	35	1048
74	11	320	2	104	13	424
75	0	0	1	6	1	6
76	0	0	1	12	1	12
78	5	71	6	184	11	255
81	0	0	2	28	2	28
82	2	54	14	467	16	521
83	32	770	9	265	41	1035
84	13	357	6	113	19	470
85	19	466	15	376	34	842
86	0	0	0	0	0	0
87	1	34	0	0	1	34
88	6	232	4	119	10	351
89	3	73	1	10	4	83
90	0	0	2	50	2	50
91	2	69	3	33	5	102
92	2	78	2	25	4	104
94	2	47	17	402	19	449
96	5	134	10	254	15	388
97	1	26	2	68	3	94
100	5	92	0	0	5	92
102	1	6	0	0	1	6
106	5	126	1	6	6	132
108	10	260	0	0	10	260
117	15	406	25	706	40	1112
118	4	79	0	0	4	79
120	0	0	0	0	0	0
122	5	148	12	262	17	510