1978

Changes in Aspen Parkland Habitats Bordering Alberta Sloughs

G. Merriam

The Canadian Field-Naturalist

Volume 92, Number 2 April-June 1978

Changes in Aspen Parkland Habitats Bordering Alberta Sloughs

GRAY MERRIAM

Department of Biology, Carleton University, Ottawa, Ontario K1S 5B6

Merriam, Gray. 1978. Changes in aspen parkland habitats bordering Alberta sloughs. Canadian Field-Naturalist 92(2): 109–122.

Aspen parkland habitats within 50 m of 913 sloughs in 74 quarter sections throughout Alberta's aspen parkland were mapped in the field and a subsample of 398 sloughs was compared with 1945–1949 airphotos. Between 1945–1949 and 1974 woody borders were reduced around 80% of sloughs in the subsample and eliminated completely from 32%. The average loss of border habitats was 1.0 ha per slough or 11.7 ha per quarter section. Average losses per slough were 32% of young aspen, 9% of older aspen, 68% of willows, and 74% of Wolf Willow, Buckbrush, and other shrubs taken together. These are net losses and are not explainable by maturation. The modal index of heterogeneity of habitats bordering sloughs was low throughout the parkland, and in some areas few sloughs had even moderate border heterogeneity. Existing heterogeneity and recent changes in slough border habitats both are strongly influenced by agricultural practices. Changes reported here have altered the basic nature of the habitat mosaic of Alberta's aspen parkland.

Key Words: agriculture, Alberta, aspen parkland, heterogeneity, sloughs, waterfowl.

Aspen parkland developed as an irregular mosaic of aspen groves and Rough Fescue parks mainly on poorly drained till between the mixed prairie and the boreal forest.

The parkland and its sloughs have been valuable habitats for many wild species, plant and animal, game and non-game (Bird 1961; Bird and Bird 1967). A particularly large proportion of North American ducks is produced in habitats associated with parkland sloughs. During dry years, the more stable water area of the parkland accommodates a reserve of breeding waterfowl that stabilizes prairie duck production (Stoudt 1971).

The aspen parkland is young and dynamic (Bailey and Wroe 1974; Kiel et al. 1972; Johnston and Smoliak 1968; Bird 1961) but its historical development is not fully understood (Coupland 1950; Hansen 1949; Moss and Campbell 1947). The clonal reproduction of aspen (Horton and Maini 1964) clearly was an important factor throughout the history of the parkland. Fire (Bailey and Wroe 1974; Bird 1930, 1961; Moss 1932) and mechanical disturbances (Roe 1939) may have been important at particular times. Recent technological and economic changes have made agriculture a major force of change in the parkland. Changes in the parkland probably were most rapid during the period of settlement after World War I but the changes during the quarter century after World War II were both extensive and intense (Kiel et al. 1972; Lodge 1969; Bird 1961) (see Figure 1).

About a quarter century ago the aspen parkland occupied about 222 000 km^2 of which about 52 000 km^2 were in Alberta (Moss 1932; Moss and Campbell 1947). The area of Alberta parkland has been changed substantially by agricultural development within the parkland mosaic. Lodge (1969) reported that about 1000 km^2 per year within the Alberta parkland was being removed just for conversion to improved pasture. These figures suggest that the parkland is still subject to important changes but there is little knowledge of the extent, nature or

FIGURE 1. Much of the Central parkland is now an agricultural mosaic composed of quarter sections under diverse land management.

rate of recent changes to aspen groves and habitats bordering parkland sloughs. The present study was undertaken to assess changes that have taken place in slough borders since World War II and to provide baseline descriptions against which future changes can be measured.

Methods

Study Area

Seventy-four quarter sections, each 64.75 ha (or 0.5 × 0.5 mi), were selected from 200 quarters previously chosen randomly from Alberta's black soil zone by Goodman and Pryor (undated. A preliminary study of the methods and rates of alteration of waterfowl habitat in the black soil zone of western Canada. Unpublished report, Canadian Wildlife Service, Edmonton, Alberta, 55 pp.). These 74 quarter sections met two criteria: (1) they had more than one slough, and (2) they were photographed from the air during the 1970 study. The majority of 913 sloughs studied were less than 0.2 ha (0.5 acres), over 700 were less than 0.4 ha, and only a few exceeded 2 ha (5 acres) but large sloughs were not excluded from the sample. Figure 2 shows the distribution of this sample throughout the Alberta aspen parkland.

Field Mapping

A base map was prepared for each quarter section from vertical airphotos, 5.7 × 5.7 cm, taken in the 1970 study. Negatives of those photographs were enlarged optically onto graph paper (25 × 25 cm) to a scale of 1:3706. All important landmarks, vegetation, and land use boundaries and slough features, as they appeared in 1970, were traced from the projected

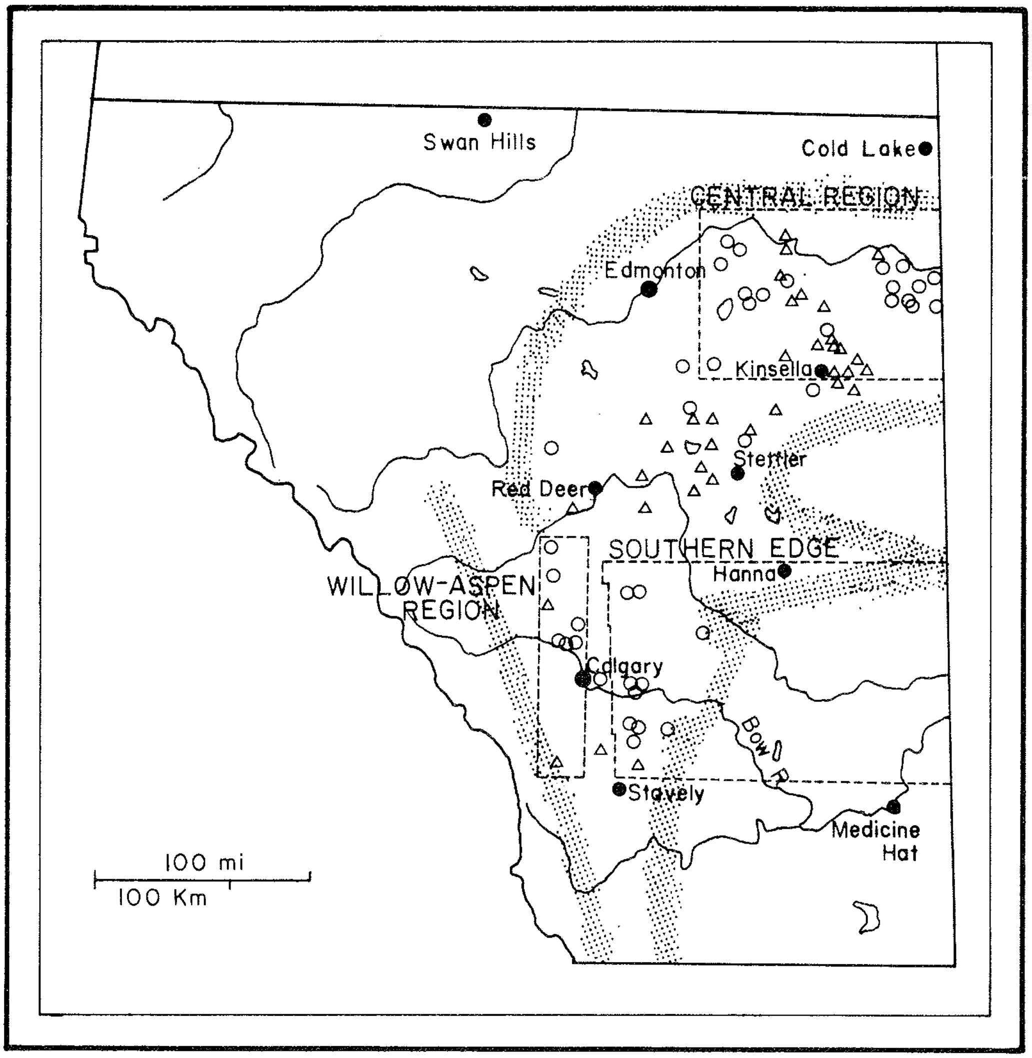

FIGURE 2. Distribution of 74 quarter sections studied in the field (circles and triangles) and those also studied from 1945–1949 airphotos (triangles only). Boundaries for three regional subsamples and approximate limits of Alberta parkland also are shown.

image onto 1-mm graph paper. These base maps were used in the field to map vegetation and land use boundaries at 1 mm = 3.7 m and to note changes since 1970. Figure 3 is an example of a completed field map.

Vegetation Types

Major vegetation types within 50 m of the edge of each slough were mapped to characterize the habitats bordering the sloughs. Woody vegetation bordering sloughs was usually dominated by Trembling Aspen (*Populus tremuloides*). *Populus balsamifera balsamifera* and ssp. *trichocarpa* (Brayshaw 1965) are not separated from *P. tremuloides*.

Findings of Maini (1960) and Horton and Maini (1964) suggested that growth, senescence, and rejuvenation of aspen groves are not usually strict functions of age or of diameter (evident also in definitions, below). A classification of stand maturity was devised to give useful inventories of existing habitat conditions in slough borders. Four aspen maturity classes were used: (1) PO IV, overmature stands with

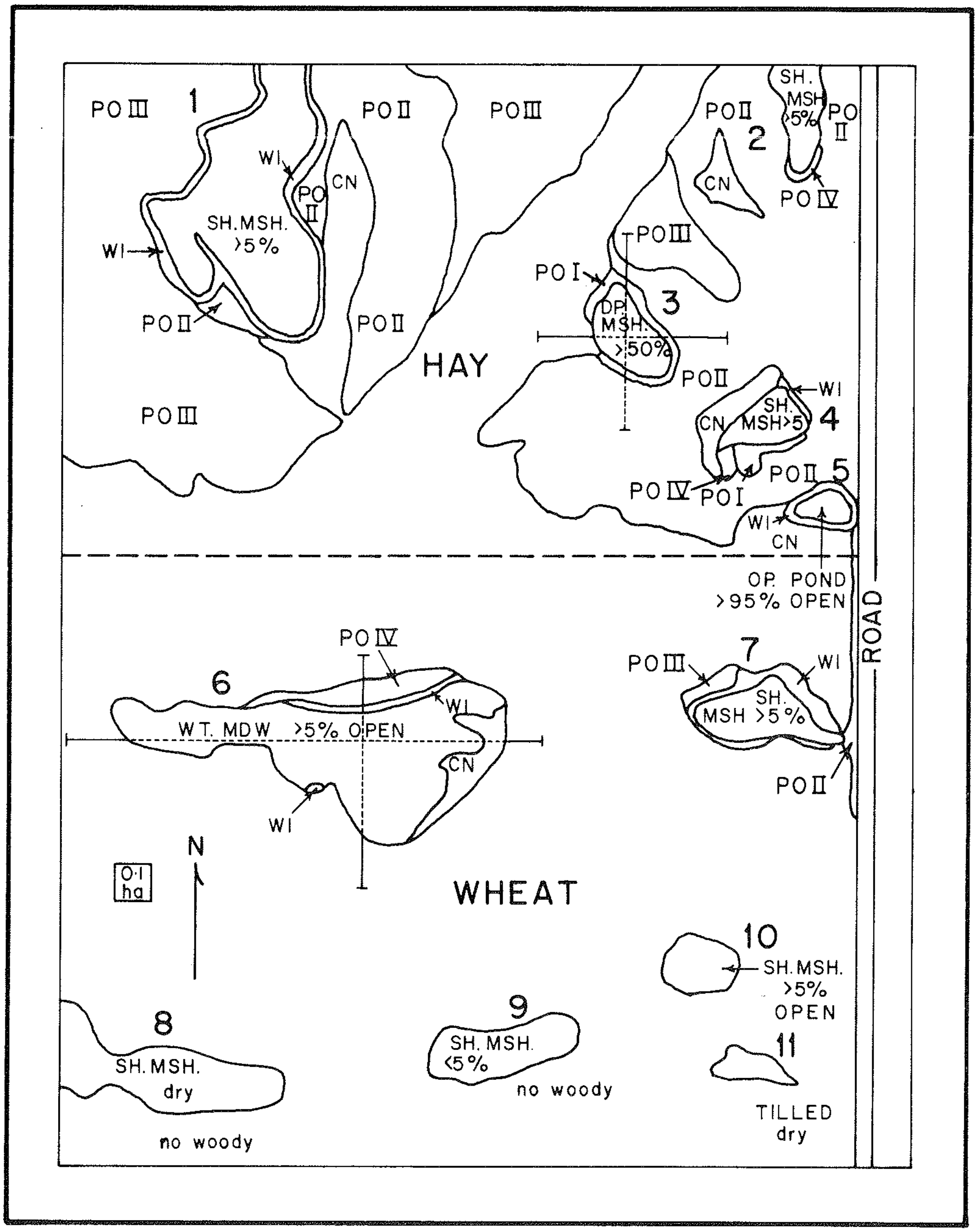

FIGURE 3. Composite map of part of a quarter section to illustrate methods of field mapping and indexing heterogeneity. Slough types: shallow marsh, deep marsh, wet meadow, and percent open water area. Vegetation: PO I, PO II, PO III, PO IV — aspen maturity classes; Wi — willows; CN — natural clearing. Coarse dashed line, land-use boundary. Transects for indexing heterogeneity are drawn on sloughs 3 and 6. On slough 3, the N, W, S, and E transects score 3, 1, 2, and 2 for 50 m out from water's edge (solid line). For slough 6 the scores are 3, 1, 1, and 2 in the same order. The heterogeneity index is 8 for slough 3, and 7 for slough 6.

butt rot or rotting and falling limbs or tops, diameter at breast height (dbh) > 12 cm, averaging > 19 cm, ages > 32 yr, averaging > 50; (2) PO III, prime maturity, dbh > 5 cm, averaging near 11 cm, ages > 16 yr, averaging > 26 yr; (3) PO II, immature, dbh > 3 cm, averaging > 5 cm, usually > 6 yr, averaging near 12; (4) PO I, suckers or saplings up to 3 m tall or 3 cm dbh. Dead aspen also was recorded in these classes. These maturity classes were assigned by visual inspection during field mapping; ages and diameters were not measured on mapped stands. Defining measurements given above were taken from 130 trees in representative stands.

Willows (*Salix* spp.) were common in slough borders. They were mapped and noted as live or dead but not designated by species.

Upland shrubs that were mapped for 50 m back from every slough were Wolf Willow (*Elaeagnus commutata*), Buckbrush (*Symphoricarpos occidentalis*), roses (*Rosa* spp), raspberries (*Rubus* spp.), and Saskatoons (*Amelanchier alnifolia*). These five species (hereafter called "shrubs") were analyzed as a group. Adjacent agricultural land use also was mapped. Plant names follow Moss (1959).

Slough Types and Sizes

Aquatic and semi-aquatic vegetation was not mapped but was the basis for the classification of each slough. Six slough types were recognized (see, for example, Figure 3) (cf., Stewart and Kantrud 1969, 1971): (1) Tilled — cultivated or hay or grain; (2) Low Prairie — all grasses and forbs with no semi-aquatics or sedges, may have been tilled previously; (3) Wet Meadow — grasses and sedges, central portion may be dominated by semi-aquatics, may have been tilled previously; (4) Shallow Marsh — few or no grasses in central portion, sedges usually important, *Polygonum, Eleocharis, Juncus, Sium, Ranunculus, Alisma,* or *Sparganium* usually among the emergents, *Lemna* and *Utricularia* often in open water; (5) Deep Marsh — sedges not important in deepest portion, *Typha* or *Scirpus* often present, *Potomageton, Ceratophyllum, Myriophyllum, Utricularia, Ranunculus* may be present in open water; (6) Open Pond — not characterized by vegetation, usually 0 to 5% cover. Low prairies and wet meadows were divided into wet or dry. Marshes were subclassed by area of open water into dry, < 5%, 5% to 50%, 50% to 95% or > 95%.

Boundaries of tilled sloughs, low prairies, and wet meadows followed the poorly drained basin as indicated by vegetation types. Boundaries of sloughs with woody borders were drawn through the willow ring. When lacking woody borders, the shallow marshes, deep marshes, and open ponds were bounded through the zone of semi-aquatic vegetation with reference to topography and drainage changes. Water levels were abnormally high in 1974 and often exceeded slough boundaries. Slough sizes were measured from field maps by dot grid planimeter.

Habitat Heterogeneity

A heterogeneity index was devised to summarize the mapped descriptions of habitats bordering the sloughs and to permit their quantitative comparison. Crossed transects were laid over each slough on the field maps with four arms radiating N, S, E, and W for 50 m from the slough edge (see Figure 3). These arms were treated as four separate transects. Each mapped vegetation type, land-use type or adjacent slough cut by each transect was recorded in order from slough edge to transect end. Thus transect N described the S-facing slough border, etc. If a transect went off the quarter section before it reached 50 m from the slough, its record was terminated with "off quarter" and excluded from the analysis.

Total number of occurrences of vegetation types, land-use types, and adjacent sloughs intercepted by each of the four transect arms was used to index the heterogeneity of habitats around each slough. Dead woody vegetation was included with live of the same type. If a habitat type repeated itself along a transect arm, say as habitats 1 and 3 in a sequence, it scored twice. The mean of the scores for the transect arms that did not go "off quarter" was the heterogeneity index for that slough. For sloughs that were not on the quarter section boundary, an index of 1 would mean one habitat type on each transect arm, an index of 2 would mean two habitat types on each transect arm or five on one arm and one on each of three others, etc. The heterogeneity index can be subdivided to show how much of the heterogeneity was due to (1) woody vegetation (aspen + willows), (2) natural habitats (woody vegetation + shrubs and roses + non-agricultural clearings + any adjacent sloughs), and (3) agricultural land uses.

Slough borders also were characterized by the degree to which the aspen or willow border (not "shrubs") encircled each slough. This was indexed by counting the number of transect arms which crossed aspen or willow habitats provided only that the vegetation units actually were connected together to form a slough border. These index values were grouped into Smith's (1971) original classes. Class 1 ("open") had scores of 0 or 1, class 2 ("half closed") scored 2, and class 3 ("closed") scored 3 or 4.

Regional Comparison

After field work was completed, in order to compare different types of parkland, three regions were defined as shown in Figure 2. These are "Central" (West of Meridian (M) 4, Township (T) > 45, Range (R) < 19), "Southern Edge" ($M = 4$, $T < 32$, $R < 28$), and "Willow-Aspen" ($M = 5$, $T \leqslant 34$, $R < 5$). Regions were defined to show whether these subsamples contained different types of habitats associated with the sloughs. Therefore regional samples were defined to fall clearly within each region and to avoid the boundaries. Consequently some sloughs that are included in the total sample of 913 are not included in the total of these regional samples (655). The total sample (913) is used wherever possible but regional samples are used for comparisons that demonstrate regional differences in woody slough borders.

Habitat Changes 1945–1949 to 1974

Airphotos were available from 1945–1949 for 398 sloughs which had woody borders then and also were studied in 1974. Data from these airphotos were compared with 1974 field data for the same sloughs to measure changes in vegetation during the 25 to 29 years following World War II. This sample was defined solely by the availability of airphotos from 1945–1949 at 1:15840 scale, and the resulting sample distribution means that changes revealed by this comparison apply primarily to the area north of Hanna (Figure 2).

Data for 1945–1949 were obtained by airphoto interpretation. Vegetation types were (a) PO I and II, (b) PO III and IV, (c) willows, (d) Wolf Willow, Buckbrush, and roses. Grouping into these more inclusive categories reduced the chance of interpretation error and still gave satisfactory comparisons with 1974 data. Interpretation of these vegetation types was based on crown diameter, height, texture, and tone. Since both aspen types usually appeared on every photo, their interpretation also was comparative.

Areas of each vegetation type were measured by dot grid planimeters. One was scaled for the 1945–1949 airphotos, the other for the 1974 maps. Both measured in units of 0.16 ha (0.395 acres).

Some factors causing change in parkland slough borders also were evaluated. Clearing of aspen or willow since 1970 was recorded in the field and by comparing 1970 photos with 1974 field maps. Clearing was recorded as extensive (large areas bulldozed or many slough borders totally removed), or minor (fence lines bulldozed or a few slough borders trimmed back), or moderate if between these extremes. Use of herbicide for clearing was recorded similarly. Agricultural intensity was rated in five classes for each quarter section. Intensity ratings were based on amount, type, and distribution of machinery, livestock, woody and weedy vegetation, and tillage. Other developments, such as gas or oil rigs and lines, roads, buildings, drainage and filling operations were recorded where they affected sloughs or their borders.

Results

Distribution and Abundance of Slough Types

The abundance of all slough types in each region of Alberta parkland and in the total sample is given in Table 1. Tilled sloughs are uncommon in the Willow-Aspen because it is primarily rangeland; they are most common in the Southern Edge owing to intensive agriculture and easily tilled slough types. Wet meadows and low prairies are most common in the Southern Edge and Willow-Aspen but these areas were nearly all dry in 1974, and in those same regions shallow marshes commonly had less than 5% open water (more than 95% vegetative cover). Open ponds and deep marshes were much less frequent in the Southern Edge and the Willow-Aspen.

Table 2 reduces the slough types to five so that their occurrence in five size classes can be examined by region. Deep marshes (Central

TABLE 1—Frequency distribution of slough types for all sloughs[1] examined and for three parkland regions[2]

Slough type (vegetation, open water)	All sloughs, no. (%)	Central, no. (%)	Southern Edge, no. (%)	Willow-aspen, no. (%)
Open pond	64(7.0)	27(5.8)	3(3.2)	3(3.0)
Deep marsh, > 95%	22(2.4)	5(1.1)	0(0)	0(0)
Deep marsh, > 50%	50(5.5)	37(8.0)	0(0)	0(0)
Deep marsh, > 5%	46(5.0)	28(6.1)	1(1.1)	0(0)
Deep marsh, dry	4(0.4)	3(0.6)	0(0)	0(0)
Shallow marsh, > 95%	18(2.0)	6(1.3)	0(0)	0(0)
Shallow marsh, >50%	71(7.8)	48(10.4)	1(1.1)	6(6.1)
Shallow marsh, > 5%	101(11.1)	69(14.9)	3(3.2)	5(5.1)
Shallow marsh, < 5%	165(18.1)	107(23.2)	1(1.1)	13(13.1)
Shallow marsh, dry	52(5.7)	10(2.2)	6(6.4)	9(9.1)
Wet meadow, wet	23(2.5)	17(3.7)	1(1.1)	0(0)
Wet meadow, dry	176(19.3)	60(13.0)	34(36.1)	49(49.5)
Low prairie, wet	3(0.3)	2(0.4)	0(0)	1(1.0)
Low prairie, dry	33(3.6)	2(0.4)	15(15.9)	10(10.1)
Tilled	85(9.3)	41(8.9)	29(30.8)	3(3.0)
Totals	913	462	94	99

[1]Total sample of 913 sloughs from the whole Alberta parkland.
[2]These subsamples, totalling 655 of the 913 sloughs, represent each region of the Alberta parkland. The regions are considered natural but they were defined here by political (linear) boundaries. Consequently 258 sloughs are excluded from the regional subsamples but included in the total sample (see Figure 1).

region) formed 6% of the smallest class and were less common as size increased. Small shallow marshes are the commonest slough type in the Central region and become less common as size increases. Wet meadows and low prairies are the commonest slough types in Southern Edge and

TABLE 2—Regional distribution of slough types in five size classes expressed as percentage of all sloughs in each region and total number of sloughs of each size by region. A—all sloughs, C—Central Parkland, SE—Southern Edge, WA—Willow-Aspen (see Figure 1).

Size class	Region	Open pond	Deep marsh	Shallow marsh	Low prairie and wet meadow	Tilled	Number of sloughs
0.04–0.20 ha	A	1.5	4.5	27.0	18.9	7.4	543
(0.1–0.5 ac)	C	1.5	5.8	33.3	14.1	6.7	284
	SE	2.1	1.1	3.2	28.7	24.5	56
	WA	0	0	15.2	50.5	3.0	68
0.21–0.42 ha	A	1.9	3.9	10.6	4.3	1.2	200
(0.6–1.0 ac)	C	1.1	3.9	12.8	1.5	1.3	95
	SE	1.1	0	5.3	17.0	4.2	26
	WA	1.0	0	5.0	9.1	0	15
0.43–0.82 ha	A	1.2	2.3	3.7	2.1	< 1	90
(1.1–2.0 ac)	C	1.5	3.0	3.0	1.7	< 1	47
	SE	0	0	2.1	6.4	1.1	9
	WA	1.0	0	7.1	1.0	0	9
0.83–2.02 ha	A	1.4	1.4	2.3	< 1	< 1	52
(2.1–5.0 ac)	C	1.1	1.7	1.5	< 1	0	21
	SE	0	0	0	1.1	1.1	2
	WA	0	0	6.1	0	0	6
> 2.2 ha	A	< 1	1.2	< 1	0	0	28
(> 5.0 ac)	C	< 1	1.3	1.3	0	0	15
	SE	0	0	1.1	0	0	1
	WA	1.0	0	0	0	0	1

Willow-Aspen. They also become less common as size increases and are rare above 0.82 ha. Tilled sloughs were uncommon above the two smallest sizes (0.42 ha) and tilled sloughs were three times as frequent in the Southern Edge as anywhere else.

The modal heterogeneity index (see Methods) of 1.0 for all regions in Table 3 means that only one vegetation type or land-use type was found on each transect through a slough (Figure 3). The percentage of index values >2.0 is a measure of the commonness of slough borders having the equivalent of two vegetation types or one vegetation type and one land-use type on each transect. Alternatively, a value of 2.0 could mean three different vegetation types on each of two transects and one land use on each of two others. The Southern Edge has only 1% of sloughs above an index of 2.0 compared to 29% for the Willow-Aspen, 36% for the Central region, and 27% for all sloughs.

Wolf Willow, Buckbrush, and roses form preferred nest sites for Mallards (*Anas platyrhynchos*) and are common nest sites for other species in the parkland (Smith 1971). For all sloughs studied and for Central parkland sloughs, these shrubs were found commonly within 50 m of sloughs only if the heterogeneity index was above 1.75.

Table 4 shows that total heterogeneity exceeded agricultural heterogeneity in only a little over half of all sloughs. In other words, in nearly half the sloughs, agricultural crops accounted for all the heterogeneity indexed! This relationship is extreme in the Southern Edge where crops constituted all the heterogeneity for over 94% of the sloughs. In the Central and Willow-Aspen regions over 30% of sloughs had heterogeneity due to vegetation other than agricultural crops.

The difference between total heterogeneity and agricultural heterogenity was due to natural components (woody, clearings, other sloughs). This natural heterogeneity equalled or exceeded agricultural heterogeneity in over 30% of all sloughs studied except those in the Southern Edge.

Where natural heterogeneity exceeded woody heterogeneity, the excess was due to natural clearings or neighboring sloughs. These natural

TABLE 3—Frequency distribution of mean heterogeneity index values[1] for all sloughs and for sloughs in each study region of Alberta

Total heterogeneity index	All sloughs	Central	Southern Edge	Willow-Aspen
1.00	359	147	87	28
1.25	81	50	0	5
1.33	24	9	3	4
1.50	55	32	0	6
1.67	29	13	1	6
1.75	52	17	0	12
2.00	63	29	2	9
2.25	46	26	1	5
2.33	22	12	0	6
2.50	40	28	0	3
2.67	20	14	0	1
2.75	32	22	0	5
3.00	44	27	0	5
3.25	14	9	0	1
3.33	6	3	0	2
3.50	9	9	0	0
3.67	5	5	0	0
3.75	4	4	0	0
4.00	6	4	0	1
4.25	1	1	0	0
4.33	1	1	0	0
Number of sloughs	913	462	94	99

[1]Defined in Methods.

TABLE 4—Regional comparison of heterogeneity of slough borders as shown by components of heterogeneity, absence of particular vegetation types, and the completeness of the ring of woody vegetation

	Percentage frequencies			
	All sloughs	Central	Southern Edge	Willow-Aspen
Total heterogeneity[1] > agricultural heterogeneity	56.6[2]	64.9	5.3	68.7
Natural heterogeneity ⩾ agricultural heterogeneity	34.1	40.3	4.3	32.3
Natural heterogeneity > woody heterogeneity	26.1	34.5	0.0	19.2
Aspen and willow absent	43.8	43.3	93.6	37.4
Shrub vegetation[3] absent	92.4	90.3	100.0	90.9
Aspen, willow, and shrub absent	48.1	43.3	93.6	31.3
Woody border Class 1 (open)[4]	58.4	53.3	94.7	40.4
Class 2 (half closed)	8.8	6.9	2.1	17.2
Class 3 (closed)	32.8	39.8	3.2	37.4

[1]Heterogeneity components defined in Methods.
[2]No categories are mutually exclusive, percentages will not sum to 100 except for the three classes of woody border.
[3]Wolf Willow and/or Buckbrush and/or roses and/or raspberries and/or Saskatoons.
[4]The degree of completeness of the woody border around sloughs. Class 1 means a quarter ring or less of continuous border, class 2 means .25 to .75 of the perimeter is continuously bordered, class 3 means from .75 to a complete ring (see Methods).

sources of heterogeneity were most frequent (34%) in the Central region, much less frequent (19%) in Willow-Aspen, and totally absent from the sample in the Southern Edge. Slough densities are lower there and natural clearings are no longer common.

The percentage of sloughs that lacked aspen and willow was very high in the Southern Edge (93%, Table 4) and no sloughs in that region had the three shrub species. The combined absence of woody and "shrub" vegetation is much less common in the Willow-Aspen region because willow is so widespread.

Woody border classes index the continuity of aspen and willow on the slough perimeter. Sloughs tend to be either open or closed except in the Willow-Aspen region where half-closed borders are more common (Table 4). In other regions and especially in the Southern Edge, open borders predominate. Smith (1971) showed that Mallards and Lesser Scaup (*Athya affinis*) preferred half-closed borders, Blue-winged Teal (*Anas discors*) preferred open, and American Wigeon (*Mareca americana*) preferred closed.

Forces Changing Slough Borders

In 1974 dead and dying aspen and willow were frequent components of slough borders because of two years of continuous inundation. Some plants leafed out again in 1974 but failed by July and were totally dead by August or September. Some had died in 1973 and already were dropping woody material into the sloughs.

Dead willow was recorded 65 times on transects on 29 sloughs in 13 quarter sections mainly in the Central region. Dead aspen occurred 64 times on transects through 34 sloughs on 13 quarters. In most cases, if water levels killed willow, aspen also was killed. Generally the killed aspen was in the two immature classes. But mature trees certainly were not immune.

Clearing of aspens and/or willows for agricultural purposes from 1970 to 1974 was observed on 17 of 74 quarter sections (23%). Of the 17, 8 had extensive clearing, 8 had little clearing, and only 1 had moderate clearing. Six of the 8 with extensive clearing also were subject to very intensive agriculture. The 8 with little clearing showed no clear relationship with agricultural intensity. These results suggest that extensive clearing often is associated with intensive agriculture. It also seems that clearing usually was either extensive or minor and seldom moderate. Discussions with farmers indicated that amount of clearing depends more on availability of capital than on land-use considerations. Marginal farming operations can fund aspen clearing with heavy equipment less frequently and to lesser extents. Extensive clearing, however, does occur on marginal lands, very often with no agricultural follow-up and consequent aspen regrowth.

"Developments" other than agriculture were not frequent individually but together they affected 14 of the 74 quarter sections sampled. Usually these were not the same quarters subject to intense agriculture so that these "developments" additively increase the potential impact on wildlife habitat. The number of quarters on which various developments occurred were ditching and dugout ponds, 3; gas lines, wells and flares, 3; gravel pits, 1; housing, 3; municipal dump, 1; oil rigs and wells, 1; power lines, 2.

Only one successful removal of a slough by drainage was noted but water levels were so high in 1974 that much slough drainage in the parkland was not observable. Filling of sloughs with soil for agricultural purposes was noted only once. Filling with trash, car bodies, etc. is all too common. Although death or damage to woody vegetation by herbicide was observed frequently away from sloughs, records do not indicate that use of herbicide was a major controller of woody vegetation around sloughs. This does not reduce the possibility that herbicides may enter sloughs and significantly affect them in other ways.

In addition to these particular forces slough borders are shaped by the major, but poorly-defined forces of successional maturation.

Changes in Slough Borders 1945–1949 to 1974

Table 5 summarizes changes in the woody vegetation types for a subsample of sloughs studied in the field in 1974 and for which airphotos taken between 1945 and 1949 were available. Measurements of changes in vegetation during the 25- to 29-year interval are described in Methods.

Immature aspen decreased around 85% of the sloughs and mature aspen decreased around 59% of them. PO I/II decreased around 250 sloughs but less than half of those changes can be explained by aspen maturation because only 102 sloughs had an increase in PO III/IV. The sloughs with no change are approximately balanced between PO I/II and PO III/IV and can be assumed to indicate stable replacement in those few cases. If 102 of the decreases in PO I/II are explained by the number of increases in PO III/IV, then a minimum of 148 decreases in PO I/II are not explained by maturation. A maximum of 30 of the 183 decreases in PO III/IV could be cancelled by the 30 increases in PO I/II. These remaining decreases in both maturity classes are not explainable by maturation and indicate a lack of stable replacement. This also is shown by the mean net losses per slough of 32% of young aspen and 9% of older aspen. The mean net losses of the two aspen classes underestimates the importance of aspen losses from around many sloughs spread widely through the study area and overestimates losses for a few areas in the central parkland with large numbers of sloughs and large net gains in aspen.

Willows increased around 22% of the sloughs (Table 5) in those quarter sections where water levels and land management permitted, but willows decreased much more than they gained. Of the 209 decreases in Table 5, only 29 were caused by high water in 1972–1974; apparently losses have continued for a long time. Even over a quarter century, a mean net loss of 0.22 ha (0.66 acres) or 68% of the willow area around

TABLE 5—Changes in area of major vegetation types within 50 m of 398 sloughs from 1945–1949 to 1974

	PO I/II[1]	PO III/IV[1]	Willow[2]	Shrub[3]
No. sloughs with increase	30	102	61	17
No. sloughs with no change[4]	16	23	10	5
No. sloughs with decrease	250	183	209	161
$\bar{x}$ hectares per slough 1945–1949[5]	1.53	1.78	0.32	0.23
$\bar{x}$ hectares net change per slough	−0.48	−0.16	−0.22	−0.17
$\bar{x}$ % loss of area per slough	32	9	68	74

[1]PO I — aspen saplings or suckers, PO II — growing immature aspen, PO III — prime mature aspen, PO IV — overmature aspen (see Methods for definitions).
[2]Willow (*Salix* spp.).
[3]As defined in Table 4.
[4]Sloughs were excluded from consideration if the vegetation type was absent in both 1945–1949 and 1974.
[5]Variable sample size (See [4]).

TABLE 6—Changes from 1945–1949 to 1974 in total area of all major woody vegetation in borders of 398 sloughs in 35 quarter sections[1]

	Quarter sections	Sloughs
No. with no net change	2	15
No. with net increase	3	62
No. with net decrease	30	321
$\overline{x}$ net change (ha)	-11.7	-1.0
$\overline{x}$ loss (% 1945–1949 area)	55.7	55.7

[1]Complete data available from Canadian Wildlife Service, Western Region, Edmonton, or from the author.

each slough, is a striking reduction.

"Shrub" vegetation decreased in area around 90% of sloughs and increased around only 9% of them. The average loss of 0.17 ha (0.43 acres) or 74% of the 1945–1949 shrub area within 50 m of these sloughs is another massive habitat change.

Table 6 summarizes the changes shown in Table 5 by quarter sections and by sloughs with no distinction of border vegetation types. There was a net decrease in woody vegetation within 50 m of sloughs in 86% of the quarter sections while only 9% had an increase. Vegetation types recorded here decreased on 80% of the sloughs and increased on only 15% which are located mainly on a small number of quarter sections with high densities of sloughs in the Central region. The net loss of four major vegetation types around 398 sloughs amounted to 413 ha (1020 acres) over about three decades.

Records of total removal of woody borders by 1974 from sloughs which had woody borders in 1945–1949 give another view of clearing. Woody borders were totally eliminated from 126 out of 398 sloughs compared (on 21 of 35 quarter sections). Three of the 35 quarters lost all woody borders from over 75% of woody-bordered sloughs, 8 lost all woody borders from 50 to 75%, and 5 lost them from 25 to 50%. Only 8 sloughs gained new woody borders between 1945–1949 and 1974 and most of those were simple willow rings.

A minimum estimate of the dynamics of woody vegetation within 50 m of slough margins during this period of 25 to 29 years can be given by adding total decreases in area to total increases in area for each of the four vegetation classes. These are minimum rates of turnover because compensatory changes at the same slough cannot be measured. Turnover for immature aspen was 221 ha compared to 240 ha present in 1945–1949. For mature aspen it was 224 ha compared to 277 ha, for willows 124 ha compared to 124 ha, and for shrubs it was 86 ha compared to 93 ha present in 1945–1949. Thus, the minimum total turnover of the four vegetation types around these 396 sloughs was 655 ha compared to 734 ha present in 1945–1949.

Discussion

Alberta's aspen parkland needs to be treated regionally in considering environmental relationships or management interventions. Moss (1932) divided the parkland into a northern "poplar area," with coniferous associates, and a southern "parkland" of aspen groves and grassland parks. Others have separated a willow-aspen region along the foothills south of the Bow River, an aspen-poplar region northeast from there, and an aspen ecotone northwest from the Bow to the boreal forest (Alberta Government 1969). The parkland regions that I used for data analysis show differences both in the sloughs and in the habitats bordering them. Division of Alberta parkland into Willow-Aspen, Southern Edge, and Central regions is preliminary and the natural boundaries are undefined but these regions were meaningful in this study.

Heterogeneity of habitats bordering sloughs in all three regions, and in the total sample, had a modal index value of 1.0 (Table 3). This value indicates a norm of only one vegetation or land-use type on any side of the slough. Index values > 2.0 were as common in the Willow-Aspen and Central as they were in the total sample. Southern Edge had significantly fewer index values > 2.0 indicating that the chance of finding two different vegetation or land-use types on every side of a slough was rare in the Southern Edge.

Separation of the basic heterogeneity index into some of its major components reveals the origins of heterogeneity in the slough margins. Agricultural components contributed the total heterogeneity around 94% of sloughs in the Southern Edge compared to about 30% in all other regions. Agriculture can add important components to the heterogeneity of sloughcentered habitat mosaics, but clearly agriculture also can severely reduce the total heterogeneity of the mosaic. Because differences in land use follow ownership boundaries, the minimum area affected often is a quarter section. Woody vegetation might be expected to control heterogeneity of slough borders in the Central parkland but it does not. Few quarter sections are completely colonized by woody vegetation and these are balanced by a few with no remaining slough borders. Most quarters have slough borders narrower than 50 m and so the transects crossed them and recorded agricultural land use as a major component of total heterogeneity.

The contribution of natural habitats to total heterogeneity equals or exceeds the agricultural component in about one third of all sloughs. Natural habitats in the Central parkland are dominated by aspen and willow but frequently also included other sloughs and some natural clearing. In the Willow-Aspen parkland, natural habitats were mainly willow.

The "shrub" group was not included in the "woody" vegetation as discussed here but was an important component of natural heterogeneity. These shrubs which are important habitats for many species, including ducks, were not recorded for over 90% of sloughs even in the Central parkland. "Shrubs" were common within 50 m of sloughs only when the heterogeneity index was above 1.75.

The transect index of heterogeneity that was used here efficiently yielded meaningful quantitative data. This data base can be compared against future surveys to measure changes in the structure of habitat mosaics around sloughs. The same approach should be useful in many other situations both on the ground and from airphotos.

Both the theoretical and applied ecological literature supports the contention that heterogeneity can be related to faunal richness (Telfer 1974; MacArthur 1972; Elton 1966; Levins 1962). The losses of vegetation types recorded over the last quarter century imply that heterogeneity around sloughs is decreasing. If faunal richness is valued, these reductions in heterogeneity deserve attention in both management and research.

Changes in amount of four classes of woody vegetation during 25 to 29 years were measured around 398 of the total 913 sloughs studied. Although encroachment of woody vegetation into grassland clearings in the aspen parkland has received much attention (see, for example, Bailey and Wroe 1974; Johnston and Smoliak 1968; Moss and Campbell 1947), the net changes in woody vegetation recorded here, mainly from farming regions, are all losses. All four vegetation classes lost area from within 50 m of sloughs. Compared to the 1945–1949 areas, the 1974 areas were reduced by 32% for immature aspen, 9% for mature aspen, 68% for willow, and 74% for shrubs. Each vegetation type was reduced around the majority of sloughs, but all vegetation types were not reduced around every slough. During about three decades of this country's rapid technological change following World War II, about 408 ha of four major vegetation types disappeared from within 50 m of all the sloughs in 35 quarter sections of Alberta parkland. Average losses from each slough included nearly half a hectare of immature aspen, one third as much mature aspen, nearly a quarter hectare of willows, and almost as much upland "shrubs." Woody borders were lost completely from 32% of these sloughs while only 2% added new woody borders.

Agricultural land management is a major cause of these changes. Clearing of woody vegetation, mainly by hand, was becoming common around sloughs in the 1945–1949 airphotos. Clearing has continued with increasing technological aid from then until the end of the study. In 1974 extensive clearing was associated with intensive agriculture both on particular farms and in intensively farmed regions such as the Southern Edge of the parkland. Cultivation practices also have been important in changing these habitats. Repeated cultivation is necessary to prevent revegetation of cleared land, especially by aspen suckers. Cultivation right to the edge of sloughs and tillage of the entire slough basin are clearly important to slough habitats. It is not clear that these practices always produce substantial economic benefits for agriculture (see also, Lodge 1969). There are many examples, particularly in the Central parkland, of beef, grain, and cash-crop farming without major reductions of slough borders.

Both natural and human forces will interact to determine the future of parkland sloughs and their bordering habitats. Merriam (1975. Aspen parkland slough habitats in Alberta. Unpublished report, Canadian Wildlife Service, Edmonton, Alberta, 68 pp.) discusses these influences in relation to management. In fact some of the present qualities of sloughs which we value may have resulted from human intervention. For example, some small deep marshes and shallow marshes which were studied in 1974 were almost totally shaded by overhanging aspen canopies in 1947. Early stages of hand-clearing were seen on 1947 airphotos. By 1974 no aspen borders remained on these sloughs but the plant and waterfowl productivity of the sloughs themselves was high, probably much higher than under those early aspen canopies. It also was evident in the field in 1974, however, that these and many other sloughs without woody borders were filling both with their own production of organic matter and with eroded soil. Clearing and cultivation of slough borders may have given many parkland sloughs a substantial boost in productivity which could drastically shorten their lifespan by accelerating filling.

Bird (1961) in a historical review of land use in Canada's parkland noted that introduction of the bulldozer into parkland agriculture in 1945–1948 was a signal event. Between 1946 and 1952 in Manitoba parkland alone Bird reported that from 120 000 to 170 000 ha were cleared and broken. More than agricultural production had to be affected by new technological interventions in the dynamics of parkland vegetation. Smith (1971) noted that "The greatest change in the Lousana environment (near Elnora, Alberta) resulted from the cutting of trees and the plowing and planting of individual pond basins . . .". Smith's data show that in 1953 on his study area, about 50% of sloughs had complete woody borders, 18% were half-bordered, and 32% were unbordered. By 1969 these figures reversed and became 28% completely bordered, 18% half-bordered, and 54% unbordered. Kiel et al. (1972) reported that for their Manitoba study area, clearing of woody slough borders increased greatly after 1954. They found that land-clearing altered more sloughs in the period 1961–1964 than in the previous 12 years (1949–1960). From 1949 to 1964 they found that 37% of 120 sloughs were altered by land-clearing. These 44 sloughs were affected 57 times by clearing operations.

My results show that heterogeneity of habitats bordering sloughs also is strongly influenced by agriculture. For example, in the Southern Edge more than 94% of slough borders derived their heterogeneity entirely from agricultural crops (Table 4). If the Willow-Aspen region were not used primarily as rangeland, it is unlikely that woody vegetation and natural features could control the heterogeneity of nearly 70% of the slough borders (Table 4). The strength of agricultural forces in the Central region is evident from differences among slough borders in Figure 1 as well as from the data. It seems clear that although habitat changes are functions of natural phenomena, they also are directed by socio-economic forces.

Goodman and Pryor (undated. A preliminary study of alteration of waterfowl habitat in the black soil zone of western Canada. Unpublished report, Canadian Wildlife Service, Edmonton, Alberta, 55 pp.) concluded that for Canada's parkland the net loss of water-surface area of sloughs by 1970 was between 14% and 23% of the pristine surface area. Net losses of entire sloughs by 1970 were between 6% and 10% of the pristine number of sloughs. My results show that changes in habitats around sloughs in Alberta's parkland were more extensive than could be inferred from the changes that Goodman and Pryor reported for the sloughs themselves. The average loss of the four major vegetation types studied was just over 1 ha per slough or 11.7 ha per quarter section during a quarter century. At the same time 33% of the sloughs studied lost their woody borders completely.

When woody slough borders are lost, most other woody parkland habitats have already disappeared. The extensive habitat changes reported here for slough borders and the reduction of heterogeneity by application of agricultural practices to whole quarter sections have changed the basic structure of Alberta parkland. The natural mosaic of grassland, woody habitats, and sloughs is becoming a coarser mosaic of more homogeneous quarter sections.

Acknowledgments

Jim Patterson interested me in the aspen parkland and facilitated the study in many ways. Aileen Merriam shared the field work equally and provided botanical expertise. Len Shandruck, Ed Telfer, Gordon Miller, Alex Johnston, Art Bailey, and Jack Miller all were generous with their time and knowledge. Criticisms of manuscripts by Al Barlow, David Munro, and especially by George La Roi were very helpful. John Wegner gave critical assistance in final analyses and manuscript preparation. The study was financed by the Canadian Wildlife Service, Western Region and by Carleton University.

Literature Cited

Alberta Government. 1969. Atlas of Alberta. Government of Alberta and the University of Alberta, University of Toronto Press, Toronto. 158 pp.

Bailey, A. W. and **R. A. Wroe.** 1974. Aspen invasion in a portion of the Alberta parklands. Journal of Range Management 27(4): 263–266.

Bird, R. D. 1930. Biotic communities of the aspen parkland. Ecology 11: 356–442.

Bird, R. D. 1961. Ecology of the aspen parkland of western Canada in relation to land use. Contribution 27, Research Station, Canada Department of Agriculture, Winnipeg, Research Branch, Canada Department of Agriculture, Ottawa. 155 pp.

Bird, C. D. and **R. D. Bird.** 1967. The aspen parkland. *In* Alberta, A natural history. *Edited by* W. G. Hardy. Hurtig Publishers, Edmonton. pp. 135–150.

Brayshaw, T. C. 1965. Native poplars of southern Alberta and their hybrids. Canada Department of Forestry Publication 1109. 40 pp. + map.

Coupland, R. T. 1950. Ecology of mixed prairie in Canada. Ecological Monographs 20: 271–315.

Elton, C. S. 1966. The pattern of animal communities. Methuen, London. 432 pp.

Hansen, H. P. 1949. Postglacial forests in south central Alberta, Canada. American Journal of Botany 36: 54–65.

Horton, K. W. and **J. S. Maini.** 1964. Aspen reproduction, its characteristics and control. Canada Department of Forestry Monograph, Project 0-2, Richmond Hill, Ontario. 85 pp.

Johnston, A. and **S. Smoliak.** 1968. Reclaiming brushland in southwestern Alberta. Journal of Range Management 21(6): 404–406.

Kiel, W.H., Jr., A. S. Hawkins, and **N. G. Perret.** 1972. Waterfowl habitat trends in the aspen parkland of Manitoba. Canadian Wildlife Service Report Series Number 18. 63 pp.

Levins, R. 1962. The theory of fitness in a heterogeneous environment. I. The fitness set and adaptive function. American Naturalist 96: 361–378.

Lodge, R. W. 1969. Agricultural use of wetlands. *In* Saskatoon Wetlands Seminar. Canadian Wildlife Service Report Number 6. pp. 11–15.

MacArthur, R. L. 1972. Geographical ecology. Harper and Row, New York. 269 pp.

Maini, J. S. 1960. Invasion of grassland by *Populus tremuloides* in the northern great plains. Ph.D. thesis, University of Saskatchewan, Saskatoon. 231 pp.

Moss, E. H. 1932. The vegetation of Alberta. IV. The poplar association and related vegetation of central Alberta. Journal of Ecology 20: 380–415.

Moss, E. H. 1959. Flora of Alberta. University of Toronto Press, Toronto. 546 pp.

Moss, E. H. and **J. A. Campbell.** 1947. The fescue grassland of Alberta. Canadian Journal of Research C 25: 209–227.

Roe, F. G. 1939. Buffalo as a possible influence in the development of prairie lands. Canadian Historical Review 20: 275–287.

Smith, A. G. 1971. Ecological factors affecting waterfowl production in the Alberta parklands. United States Department of the Interior, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, Resource Publication 98. 49 pp.

Stewart, R. E. and **H. A. Kantrud.** 1969. Proposed classification of potholes in the glaciated prairie region. *In* Saskatoon Wetlands Seminar. Canadian Wildlife Service, Report Number 6. pp. 57–69.

Stewart, R. E. and **H. A. Kantrud.** 1971. Classification of natural ponds and lakes in the glaciated prairie region. Resource Publication U.S. Bureau of Sport Fisheries and Wildlife. 26 pp.

Stoudt, J. H. 1971. Ecological factors affecting waterfowl production in the Saskatchewan parklands. United States Department of the Interior, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, Resource Publication 99. 58 pp.

Telfer, E. S. 1974. Logging as a factor in wildlife ecology in the boreal forest. Forestry Chronicle 50: 1–5.

Received 26 September 1975
Accepted 10 February 1978