Spatial changes in waterfowl habitat

by G.D. Adams
and G.C. Gentle

Occasional Paper
Number 38

Canadian
Wildlife Service

Fisheries and Environment Canada
Pêches et Environnement Canada

Spatial changes in waterfowl habitat, 1964–74, on two land types in the Manitoba Newdale Plain

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Canadian Wildlife Service
Occasional Paper Number 38

SCF

Issued under the authority of the
Minister of Fisheries and the Environment

Canadian Wildlife Service

Catalogue No. CW69-1/38
ISBN-0-662-10042-5
ISSN-0576-6370

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Acknowledgements
We are indebted to K. Lumbis and D. W. Goerzen for technical field assistance on the project, and to E. J. McLaren of the Canada Centre for Remote Sensing for photography of the study areas in 1973. We acknowledge the advice of personnel of the US Fish and Wildlife Service: D. L. Trauger, Jamestown, N. Dak., and A. S. Hawkins, Minneapolis, Minn.; also officers of the Canadian Wildlife Service (CWS), Saskatoon, Sask.: J. H. Patterson, E. A. Driver, and J. B. Millar. We also thank D. Fowler who wrote the computer program for digitizing maps, and J. E. G. Smith for statistical advice.

Abstract
The effects of land use on two waterfowl habitat types were assessed by documenting spatial changes in wetlands and vegetative cover occurring between 1964 and 1974. We selected study area blocks of 124 km² within waterfowl capability class 1 land (Block I) near Minnedosa and Rapid City, and within class 3 land (Block II) near Hamiota. Aerial photography from the years 1964–65 and 1974 was interpreted and detailed cover maps were prepared of 36 plots, each 65 ha, randomly selected within the two blocks. We digitized the cover maps and allocated spatial data to five land-use classes in order to make comparisons between the years 1964–65 and 1974.

Block I showed a higher density and surface area in wetlands. On Block II, wetlands were more permanent, but cultivated land occupied proportionately more area. Both blocks showed net decreases in grassland and woodland areas, and net increases in wetland areas. On Block II, grassland area was reduced by 31% and cultivated area increased by 4%. On Block I in 1974, near-record precipitation caused flooding of grassland and reduced available agricultural land. Wetland areas increased by 20% on Block I and 31% on Block II. Flooding in 1974 resulted in a gain of 49 temporary wetlands, and 49 wetlands present in 1964 disappeared due to cultivation, drainage, and filling. Partial drainage influenced 15% of 424 wetlands on Block I, but 20% were altered by drainage and clearing, and 7% were lost during the decade. Open water marsh perimeter increased by 24% on Block I, but total wetland perimeters increased only slightly. The perimeters of 49 wetlands were completely cleared on both blocks, and length of wooded fringe declined by 13% on Block I. Since only 53% of wetland perimeters were open on Block I in 1964, compared to 26% open on Block II, there was probably more intensive pothole clearing on Block I prior to 1964.

Some complex shifts in cover classes occurred. Losses in cultivated land on Block I were chiefly related to changes in areas of woodland and grassland, but wetlands exerted secondary effects. On Block II, declines in woodland and grassland areas accounted for most of the increase in cultivated land. Despite the net increase in wetland areas, the quantitative reduction in grassland cover on wetland margins has probably reduced potential duck nesting habitat.

Résumé
Nous avons cherché à évaluer les répercussions de l'utilisation des terres sur deux types d'habitat de la sauvagine. Pour ce faire, nous avons recueilli des renseignements concernant les variations spatiales qui sont intervenues dans les terres humides et dans le couvert végétal entre 1964 et 1974. Nous avons sélectionné des secteurs d'étude de 124 km² dans des terres de classe 1 pour les possibilités de la sauvagine (Bloc I) près de Minnedosa et de Rapid City, et dans des terres de classe 3 (Bloc II) près d'Hamiota. Nous avons interprété des photographies aériennes prises en 1964–1965 et en 1974; puis nous avons préparé des cartes détaillées du couvert végétal de 36 parcelles de 65 hectares chacune, choisies au hasard dans les deux blocs. Nous avons codifié les cartes numériquement et nous avons attribué des données spatiales à cinq classes d'utilisation des terres pour établir des comparaisons entre 1964–1965 et 1974.

Dans le bloc I, la densité et la surface du couvert dans les terres humides se sont révélées plus grandes. Dans le bloc II, les terres humides étaient plus permanentes, mais la terre cultivée représentait une superficie proportionnellement plus grande. Dans les deux blocs, on a enregistré des diminutions nettes de la prairie et des zones boisées et des augmentations nettes de la superficie des terres humides. Dans le bloc II, la superficie de la prairie a diminué de 31 pour cent et celle des terres cultivées a augmenté de quatre pour cent. En 1974, les précipitations qui ont presque atteint un niveau record dans le bloc I ont provoqué l'inondation de la prairie et fait diminuer la superficie des terres agricoles disponibles. La superficie des terres humides s'est accrue de 20 pour cent dans le bloc I et de 31 pour cent dans le bloc II. L'inondation de 1974 a entraîné un gain de 49 terres humides temporaires; 49 terres humides repérées en 1964 ont disparu par suite d'activités de culture, de drainage et de comblement. Le drainage partiel a touché 15 pour cent des 424 terres humides du bloc I, mais 20 pour cent ont été modifiées par le drainage et l'enlèvement de la végétation et sept pour cent ont été perdues au cours de la décennie. Le périmètre des zones marécageuses à eau libre s'est accru de 24 pour cent dans le bloc I, mais le périmètre total des terres humides n'a augmenté que légèrement. Les périmètres de 49 terres humides ont été complètement dégarnis dans les deux blocs et la longueur de la frange boisée a diminué de 13 pour cent dans le bloc I. Comme 53 pour cent seulement des périmètres de terres humides étaient libres de végétation dans le bloc I en 1964, comparativement à 26 pour cent dans le bloc II, il est probable qu'il y a eu un enlèvement plus important de la végétation dans les cuvettes du bloc I avant 1964.

Les classes de couverture ont connu certaines transformations complexes. Les pertes de terres cultivées dans le bloc I ont été principalement liées aux modifications intervenues dans la superficie des terres boisées et de la prairie, mais les terres humides ont eu des effets secondaires. Dans le bloc II, c'est la réduction de la superficie des terres boisées et de la prairie qui explique, pour la majeure partie, l'accroissement des terres cultivées. Malgré l'accroissement net de la superficie des terres humides, la réduction quantitative du couvert de prairie sur les bordures marécageuses a probablement réduit la superficie de l'habitat où les canards peuvent faire leurs nids.

Introduction

The Newdale Plain (Ehrlich, Pratt, and Poyser 1956) contains the largest contiguous area of high quality waterfowl habitat in Manitoba (Kiel 1949; Hawkins and Cooch 1948; Rose and Morgan 1964), and is one of the finest waterfowl breeding areas in North America (Smith, Stoudt, and Gollop 1964). According to Kiel, Hawkins, and Perret (1972) "the Minnedosa district (which is largely encompassed by the Newdale Plain) is important to the continental waterfowl picture due to the high density of breeding ducks and the consistency of production". The relative drought resistance of the habitat (Hawkins and Cooch 1948) is due to the higher mean July pond retention rates exhibited in southwestern Manitoba compared to southern Saskatchewan or Alberta (Henny, Anderson, and Pospahala 1972). Pospahala, Anderson, and Henny (1974) demonstrated that the mean pond occupancy rates for breeding ducks and the density of duck broods were lowest in southwestern Manitoba; and mean brood indices have shown a declining trend, especially during 1969 to 1973. Breeding populations of mallards (*Anas platyrhynchos*) on the Newdale Plain in 1974 comprised 50% or less of the populations surveyed in 1964 (Stoudt 1974) and in 1959–60 (Hawkins 1974). Mallard production in southwestern Manitoba has not recovered to the levels shown in 1957 and 1958 (Pospahala *et al.* 1974), despite generally improving water conditions from 1969 to 1972, and in 1974. This has led to the assumption that deteriorating nesting habitat conditions caused by intensifying land use have been an important limiting factor (Stoudt 1967; Kiel *et al.* 1972; Sellers 1973; Fritzell 1975). We have attempted to document these changes in waterfowl habitat on the Newdale Plain by measuring the spatial changes in land use that have occurred between 1964 and 1974.

Comparisons of more recent habitat conditions discussed by Stoudt (1967, 1974), Dwyer (1970), Sellers (1973), Fritzell (1975), and Kiel *et al.* (1972), with conditions present from 1947 to 1955 (Hawkins and Cooch 1948; Kiel 1949; Evans, Hawkins, and Marshall 1952; Dzubin 1969) have raised concerns about deteriorating habitat affected by land-use changes in the Minnedosa district. Long term appraisals were conducted by Goodman and Pryor (1972) and Kiel *et al.* (1972). More recently, Rakowski, Nero, and Hutchison (1974) have updated habitat trend data from the Kiel *et al.* (1972) transects for the 1964 to 1974 period. Surveys by Stoudt (1974) and others furnished continuous records of habitat changes since 1964; and Hawkins (1974) resumed surveys of transects in 1974 to compare results with conditions monitored in 1964 or earlier.

These previous studies have evaluated changes in density and quality of wetlands as affected by land use. However, they have not interpreted land-use interactions in relation to spatial changes in wetlands and upland vegetative cover. Also areas were not stratified and analyzed according to differing habitat types. Using photomeasurements we evaluated and compared quantitative changes in land-use parameters on two land types described as classes 1 and 3 for waterfowl production capability (Perret 1970; Adams and Hutchison 1976).

The study area

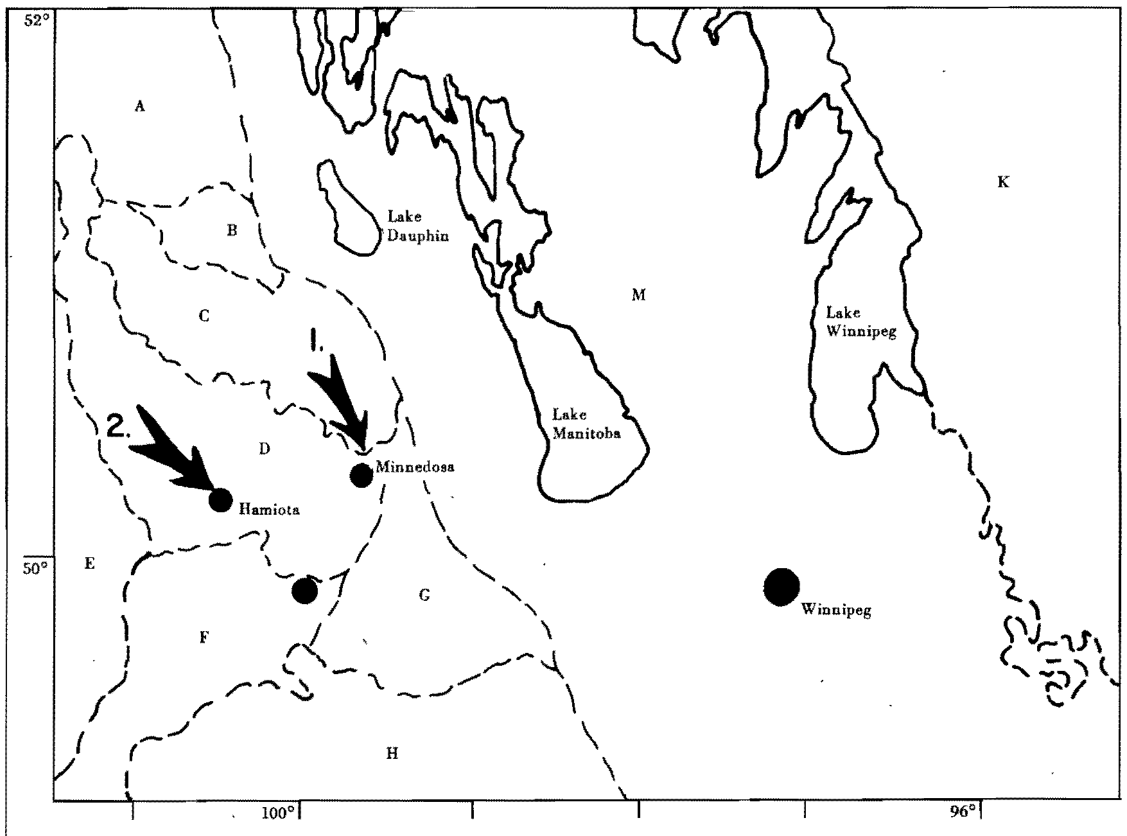
The Newdale Plain (Fig. 1) is 9065 km^2 in extent, bounded on the west and south by the Assiniboine River and the basin of the post-glacial Lake Souris, merging on the north with the Riding Mountain Upland, and extending east to the Manitoba escarpment (Ehrlich *et al.* 1956). Klassen (1966) classified the dominant surface materials of the plain as irregular and undulating recessional moraine, interspersed with belts of knob-and-kettle topography exhibiting displacements in relief of 3–8 m. The plain varies in elevation from 396 m to 580 m, with a perceptible slope from north to south. Most surface drainage is poorly integrated, and is furnished by several south-trending glacial meltwater channels, including small rivers such as the Minnedosa, Oak, and Birdtail. Soils are black or degrading black chernozems developed upon calcareous clay loam or loam till of the Newdale and Erickson soil associations (Ehrlich *et al.* 1956).

The natural vegetation of the Newdale Plain is parkland, containing stands of trembling aspen (*Populus tremuloides* Michx.), balsam poplar (P. *balsamifera L.*) and scattered bur oak (*Quercus macrocarpa* Michx.) (Bird 1961, Rowe 1972). Much of the plain has been cleared for agriculture, but aspen and willows (*Salix* spp.) ring undisturbed natural depressions. The plain presently supports a cereal grain economy with spring wheat (*Triticum* sp.), barley (*Hordeum* sp.), rapeseed (*Brassica* spp.), and some rye (*Secale* spp.) and flax (*Linum* sp.) interspersed with forage crops and small grazing units, especially on the rougher terrain or more saline soils. Pressures to intensify arable agriculture on the plain are partly justified by the high soil capability classes for agriculture as determined by the Canada Land Inventory. About 70% of the plain has an agricultural capability of class 2, whereas 30% of the landscape, predominantly wetlands, is assigned to class 6 (Ehrlich *et al.* 1966).

One study area block of 124 km^2 was located in each of two land capability classes for waterfowl. Block I, on class 1 land, was subdivided into three portions: (1) 36 km^2 north of Basswood, (2) 31 km^2 south of Minnedosa, and (3) 57 km^2 northwest of Rapid City (Fig. 2). Block II was on class 3 land near the towns of Hamiota and Oak River (Fig. 2). Class 1 land occupies about 4.7% and class 3 land about 34.0% of the Newdale Plain.

Figure 1
Major physiographic divisions of southern Manitoba showing locations of Newdale Plain and study blocks

Figure 1



Physiographic divisions

A — Duck Mountain
B — Valley River Plain
C — Riding Mountain
D — Newdale Plain
E — Oxbow Till Plain
F — Lake Souris Plain
G — Upper Assiniboine Delta
H — Waskada Plain–Tiger Hills
M — Manitoba Lowlands
K — Precambrian Shield

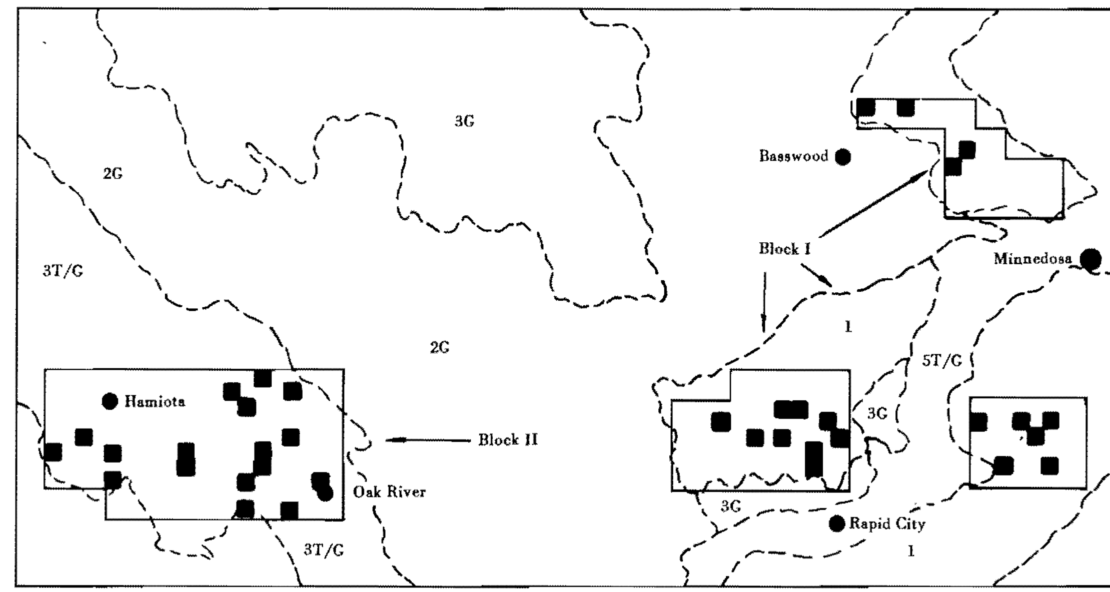
Study areas

1 — Block I
2 — Block II

0 40 80 Kilometres

Figure 2
Locations of study plots and study area blocks within mapped Canada Land Inventory (CLI) classes for waterfowl production

Figure 2



■ Study plot (65 ha)
- - - - - Area of each numbered CLI class
T — Limitations due to topography
G — Limitations due to interspersion of land forms or water

0 4 8 Kilometres

Methods

We treated each block as a stratum within which we randomly allocated 20 sample plots of 65 ha representing 10.4% of the block area (Fig. 2). Four of the samples were deleted from this study due to substandard aerial photography, leaving coverage of 19 plots on Block I and 17 plots on Block II.

High-altitude aerial photographs (1:60 000 scale) of the study blocks in 230 mm black-and-white and Aerochrome infrared were taken in July 1973 by the Airborne Operations Section of the Canada Centre for Remote Sensing, Ottawa. These photographs were used as photomaps for pond enumeration and as navigational aids for locating study plots. We interpreted information on 1964 habitat conditions from 230 mm black-and-white photographs (1:15 000 scale) taken from 8–14 September 1964. Additional coverage of six plots on Block II was furnished from similar photography flown on 6 August 1965. These photographs were obtained from the National Air Photo Library, Ottawa. We obtained 1:20 000 photographic coverage of the plots on 18 July 1974 using two Hasselblad cameras, which were operated simultaneously in a vertical camera mount in a Piper Apache aircraft equipped with a camera hatch. We used 70 mm Aerochrome infrared 2443 film exposed with W12 and CCM 20 filters, and 70 mm Ektachrome 2448 exposed with an HZ skylight filter. The films were processed by the National Air Photo Library.

Cover maps were prepared from the 1974 imagery using a photographic enlarger to project and trace an enlarged image onto a 1: 6000 grid. We rectified the resultant maps by tilting the enlarger lens and registering the intersecting field lines of the plots to the grid co-ordinates. Using photocopies of a portion of the original prints, we prepared 1964–65 plot maps on enlargements to approximately 1:6000. Stereomatched contact prints were interpreted and cover classes identified and transferred to the traced or photomap base (Fig. 3).

We adjusted individual plot scales on the 1964–65 photomaps to account for irregularities in scale from flight-line coverage and photocopy techniques. We assumed that one east–west dimension of the plot as depicted by field boundaries (0.5 miles) was equivalent to 805 m. The actual scale of each photomap was determined by dividing 805 m by the square root in centimetres of the digitized plot area. A factor of 1.03 as determined by a ratio of mean plot size in 1974 to mean size in 1964 was used to adjust the 1964–65 digitized data to match 1974 map scales.

Simplified cover maps as described by De Vos and Mosby (1969) were prepared using differences in photo tones and textures to differentiate cover types (Leedy 1948; Cowardin and Meyers 1974). Identification of 1974 cover areas was facilitated by correlating photo-image characteristics to cover classes and wetlands mapped on 10 ground plots. We prepared base maps of these plots using 1:6000–230 mm black-and-white prints of photography flown on 1 June 1974. The minimum unit area mapped was 0.02 ha, corresponding to a circular area 15 m in diameter. A lack of chronological ground truth data in 1964–65 restricted the level of interpretation to seven broad cover and surface water classes: (1) cultivated land, (2) grassland (grazed and ungrazed) including low shrubs and wet meadow, (3) woodland comprised of trees and tall shrubs (> 1.5 m), (4) closed wetlands including sedge (*Carex* spp.) meadows, (5) open water marshes including tree-bordered ponds, where central pools exceeded 25% of the basin diameter, (6) habitations or farmsteads, and (7) excavations or denuded land. We delineated, coded, and digitized these cover class units using a programmed Hewlett–Packard calculator and digitizer.

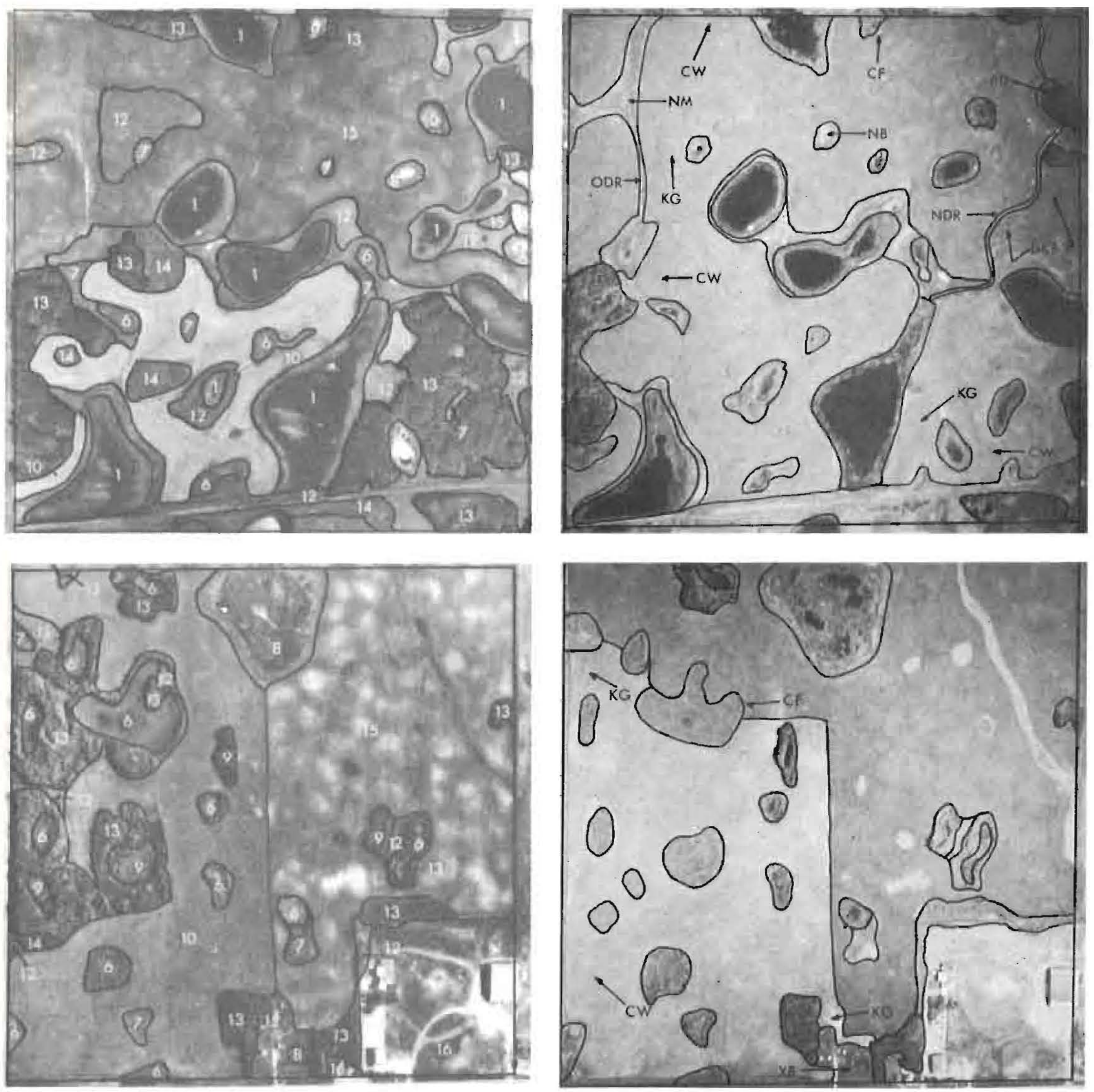
To treat situations where pond basins crossed plot boundary lines, we decided to incorporate the segments of ponds enclosed within the boundary. We also measured the entire area of an extralimital pond not exceeding 4 ha where at least 50% of the basin lay within the plot boundary. The extralimital areas and boundary line segments bisecting ponds larger than 4 ha were deleted from calculations, leaving shorelines unclosed. The same pond segments were measured consistently in both photographic periods. Changes in areas of included extralimital pond segments altered somewhat the total areas of plots from 1964 to 1974, but had no effect on comparisons of cover classes.

All wetland basins were delineated according to vegetative features, regardless of the presence or absence of surface water. The waterline boundary was considered to be an unreliable marker of the basin perimeter, due to seasonal fluctuations in water levels. We took the wetland boundary to represent the landward edge of the sedge meadow or shallow marsh zones as defined by Stewart and Kantrud (1971) and Millar (1969, 1976). This boundary usually corresponded with the inner edge of the willow fringe, if present. Exceptions were made where wet meadow vegetation occupied the centre of well defined and uncultivated basins, and where the shallow marsh zone was missing. In the latter case the outer border of the deep marsh (Millar 1976) formed the wetland boundary. In small wet basins dominated by willows, the outer extent of the tall shrub border was the only practical boundary to be determined on aerial photographs. In 1974 the surface water edge often closely coincided with the wetland vegetative boundary, since many large wetlands were still flooded at capacity in July. Conversely, in 1964 more water drawdown was apparent because of the later date, but the edges of the peripheral dry marsh zones were recognizable on photographs.

We grouped wetlands into two cover categories based upon the radial extent of open surface water or seasonal drawdown. Open water marshes were distinguished from closed wetlands in July or August by the presence of central pools or barren drawdown zones occupying more than 25% of the short-axis diameter of the wetland basin. This type corresponds to semipermanent and permanent wetland classes (Stewart and Kantrud 1971) and some seasonal transitional open water types (Millar 1976). Wet and dry vegetated wetlands with more than 75% diameter vegetation coverage were grouped in the closed marsh category. We included wet meadows occupying defined basin centres with the latter. The proportion of the linear wetland perimeter occupied by tree or tall shrub cover was estimated from stereoscopic examination of photographs, using a superimposed scale and calipers for measurements. We then calculated the total length of the wooded fringe by multiplying this estimated proportion by the total digitized perimeter.

Figure 3
Aerial photo cover maps depicting habitat changes from 1964 to 1974 on plot 11 in Block I (upper pair) and plot 36 in Block II (lower pair)

Figure 3



Cover classes

1 — Open reed marsh
6 — Sedge meadow
7 — Wet meadow
8 — Closed reed marsh
9 — Carr or shrub wetland
10 — Cropland
12 — Grassland
13 — Woodland
14 — Low shrubs
15 — Fallow
16 — Urban or habitation

Change modifiers

F — Wooded fringe
R — Ditch
G — Grassland
W — Woodland
C — Cleared
P — Partial
D — Drained
K — Cultivated
B — Basin
M — Meadow
X — Filled
N — New
O — Old

Results

1. Accuracy of map measurements

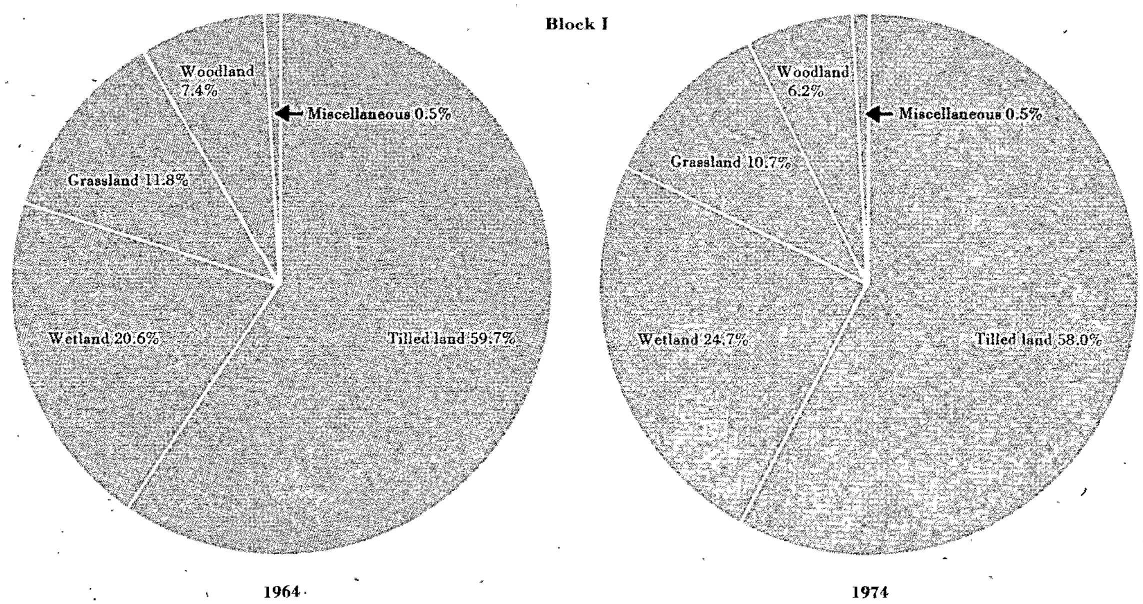
We tested the accuracy of the digitizer by running periodic checks on known areas and taking repetitive measurements. The tests indicated that errors were compensatory and well within $\pm 5\%$ of the mean. Since we were making comparisons, a potential source of error was indicated by the area deviations between the 1964 and 1974 sets of cover maps. These deviations were tested by comparing the accumulated totals of class units for each plot between 1964 and 1974. Mean deviations of -0.27 and $+0.19$ ha for blocks I and II were not significant between the years ($P < 0.05$). The largest deviations of -3.82 and -2.28 ha were found to correspond to those plots having extralimital pond segments which changed in relative sizes between the photo coverages undertaken in 1964 and 1974.

2. Comparison of study blocks

The study blocks were considered typical of class 1 and class 3 waterfowl habitat on the Newdale Plain. Class 3 land was distinguished from class 1 land on the basis of smoother topography, fewer permanent ponds, and a lower density of potholes (Adams and Hutchison 1976). Total wet July ponds in 1973 were enumerated on 192 plots comprising the entire block area. Using 1973 Aerochrome infrared photography (scale 1:60 000), we obtained mean counts of 12.16 ± 0.54 (standard error) July ponds per km^2 in Block I, and 1.59 ± 0.29 July ponds per km^2 in Block II. Ground counts in 1974 of total wetlands, including dry types, on the 20 sample plots in each block gave estimates of 13.63 ± 1.29 wetlands per km^2 on Block I, and 2.39 ± 0.54 wetlands per km^2 on Block II. The wetland density data appear to support the differential in waterfowl capability classification between the two blocks.

Figure 4
Proportions of total plot areas occupied by land-use classes, Block I, 1964 and 1974

Figure 4



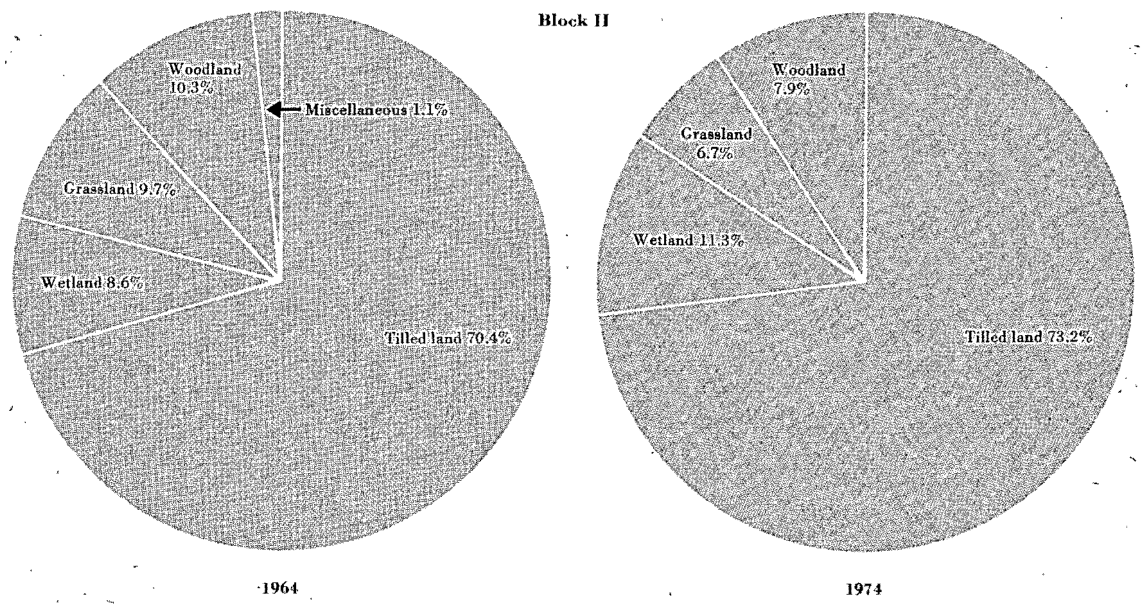
The magnitude of the habitat differences between study blocks I and II is also shown by the wetland areas and relative permanence of surface water (Table 1). Areas of wetlands on Block I in 1974 occupied more than twice the areas of Block II wetlands. The relative permanence of 1974 wetlands as indicated by the ratio in hectares of open water marshes to total wetlands was 77% on Block I, compared to 33% on Block II. This ratio changed between 1964 and 1974, showing an increase of 5% on Block I and a decrease of 11% on Block II.

Relative differences in land use and vegetation cover occurred between the two blocks (Figs. 4 and 5). The greater proportion of the landscape under cultivation on Block II may be related to differences in total wetland area coverage. Grassland occupied a slightly greater percentage of the area on Block I, but a greater portion of the landscape was wooded on Block II. Although changes in hectares of cover classes occurred between 1964 and 1974, the relative class proportions remained similar.

Land-use changes were assessed for four basic land-use classes: cultivated, grassland, woodland, and wetland. On Block I there was a decrease of 1.7% in the proportion of land cultivated, whereas Block II showed an increase of

Figure 5
Proportions of total plot areas occupied by land-use classes, Block II, 1964 and 1974

Figure 5



2.8% during the decade. On Block II the land occupied by grassland declined by 3.0%, whereas a 1.1% decline occurred on Block I (Figs. 4 and 5). The proportions of woodland showed net losses of 2.4% on Block II plots and of 1.2% on Block I. Conversely the proportion of land occupied by wetlands increased by 4.1% on Block I and 2.7% on Block II.

3. Land-use changes within blocks

Although most cover classes showed declines in area of cover, there was considerable variation among individual sample plots. On Block I, 11 plots lost 52.61 ha and 8 plots gained 32.48 ha, for a net loss of 3% of cultivated land (Table 2). One reason for the unexpected loss of tilled land between 1964 and 1974 was the retirement of 30.73 ha of cropland to seeded pasture on two plots. Conversely, 23.45 ha of cropland were gained on two plots from conversion of grassland and woodland. Total hectares of wetlands increased on 16 plots, showing significant net changes of 20%; open water marshes increased significantly in area by 54.14 ha (Table 1). Areas of natural vegetation (grassland and woodland) showed a decline of 29.61 ha, whereas cultivated land decreased by 20.13 ha. On Block I, tilled land and grassland were the only classes not

Table 1
Changes in areas (ha) of wetland classes, 1964–74

Block	Wetland class	Area 1964	Area 1974	Change	% change
I	Closed marsh	73.09	70.89	− 2.20	− 3
	*Open water marsh	186.43	240.57	+54.14†	+29
	Total	259.52	311.46	+51.94†	+20
II	Closed marsh	53.82	84.86	+27.79†	+58
	*Open water marsh	42.16	41.24	− 0.92	− 2
	Total	95.98	126.10	+30.12†	+31

*Open water marsh — a wetland in July having central open water or barren draw-down zone occupying more than 25% of basin diameter.
†Significant at $P < 0.01$.

Table 2
Net changes (ha) of land-use classes on blocks I and II, 1964, 1965–74

Block	Effect	Cult.	Wooded	Grass	Wetland	Misc.	Total
I	Loss	52.61	20.66	43.16	0.58	1.41	118.42
	Gain	32.48	5.01	29.20	52.52	1.09	120.30
	Change	−20.13	−15.65*	−13.96	+51.94‡	− 0.32	+ 1.88§
	% Change	− 3	−16	− 9	+20	−23	—
II	Loss	11.74	37.25	37.36	0.71	2.88	89.94
	Gain	43.65	10.57	4.34	30.83	1.27	90.66
	Change	+31.91†	−26.68*	−33.02‡	+30.12‡	− 1.61	+ 0.72§
	% Change	+ 4	−23	−31	+31	−56	—

*Significant at $P < 0.10$.
†Significant at $P < 0.05$.
‡Significant at $P < 0.01$.
§Accumulative measurement error.

Table 3
Accumulated precipitation* (cm) for 12-month period preceding dates of aerial photography on blocks I and II; 1963–64, 1964–65, and 1973–74

Block	Year	Fall 1 Aug. or 1 Sep. to 31 Oct.	Winter 1 Nov. to 31 Mar.	Spring–Summer 1 Apr. to July or 31 Aug.	Total 12 months
I	1963–64	2.74	9.57	29.61	41.92
	1973–74	25.50	12.58	21.14	59.22
II	1963–64	2.89	13.65	26.76	43.30
	1964–65	8.94	10.12	21.84	40.90
	1973–74	17.96	13.54	17.48	48.98

*Dep. Transp. weather records for the stations of Rivers and Minnedosa (Block I) and Hamiota and Birtle (Block II).

showing significant changes between 1964 and 1974 (Table 2).

Land-use changes on Block II were more pronounced. Thirteen plots gained 43.65 ha and only four plots lost 11.74 ha of cultivated land (Table 2). Of 17 plots, 14 lost 37.36 ha of grassland, representing a loss of 31%. Similarly 12 plots lost 37.25 ha, contributing to a net loss of 23% of woodland area. Wetland areas increased by 31% on 15 plots. Changes in areas of cultivated land, grassland, and wetland were significant, but woodland changes were only slightly significant. Cultivated land showed a net gain of about 4% despite the large increase in flooded land in 1974.

4. Wetland gains and losses

Changes in wetland numbers over a chronological period may be influenced by yearly variations in precipitation. Precipitation in 1974 exceeded 1964 levels by 17.30 cm at Rivers (Block I) and 5.68 cm at Hamiota (Block II) (Table 3). In 1964–65 accumulated precipitation at Hamiota fell below 1963–64 levels by only 2.40 cm. However, the spring–summer rainfall was higher on both blocks during 1964 and 1965, whereas more precipitation occurred during the fall in 1973.

There was little change in wetland densities on Block I despite more favorable precipitation in 1973–74 (Table 3). The net loss of four wetland basins was the result of a gain of 27 on eight plots and a loss of 31 from 12 plots. In attempting to trace the fate of these individual wetland basins, we discovered that 23 were cultivated as of 1974, two merged with a larger pond, and the remaining six wetlands had succeeded to upland vegetation or were undetected in 1974 (Table 4).

In Block II, 22 wetlands were gained on 10 plots by 1974, whereas seven plots lost 18 wetlands (Table 5). Of the 18 wetlands that disappeared, 16 were cultivated, one was captured due to flooding, and one succeeded to an aspen stand. New wetlands present in 1974 represented seasonal or tillage types (Stewart and Kantrud 1971). Other wetlands changed little in size or configuration from 1964 to 1974.

Except for the loss of 39 wetlands to cultivation, drainage had little influence on wetland loss. In 1974, ditches provided incomplete drainage of 72 wetlands representing 10.2% of the wetlands present in 1964 (Table 4), and 28 or 4% were improved by inflow. On at least five plots, wetlands were replenished by ditches importing water from outside sources. High precipitation in the summer of 1974 (Table 3) caused flooding of recipient basins and surface water was retained longer in partially drained wetlands. In total, wetlands were altered by ditching on 16 plots on Block I, and on five plots on Block II. The effects were more severe on Block I, where cumulative drainage to 1974 had affected about 15% of 1964 wetlands, and an additional 7% of wetlands had disappeared through various causes (Table 4).

5. Changes in wetland perimeters

Total perimeters of all wet and dry wetlands showed only slight increases between 1964–65 and 1974, and these increases were significant only on Block I (Table 6). However, since the amount of surface water fluctuates yearly, a comparison of the changes in the more permanent open water marshes may be more indicative of land-use trends. On Block I, perimeter length of open water marshes increased by a significant 17.44 km or 24% between 1964 and 1974 (Table 6). Conversely, Block II plots showed a decline of 2.34 km or 8% in open water marsh perimeter.

Changes in lengths of wooded wetland perimeters occurred between 1964 and 1974 (Table 6). On Block I, a decline of 13% was significant ($P < 0.10$), but a decline of 9% in wooded peri-

Table 4
Land-use and successional changes to wetland basins and perimeters, 1964–74

Block	Perimeter		No. of wetland basins					Total	
	[a]New fringe	[b]Cleared fringe	[c]Imp'd	[d]Drained	[e]Cult.	[f]Flood	[g]Dryland	[h]Alt'd	[i]Lost
I	26	23	4	62	23	2	6	85	31
II	14	26	3	10	16	1	1	36	18
VI (%)	6	5	1	15	5	<1	1	20	7
VII (%)	5	9	<1	4	6	<1	<1	13	6
Total	40	49	7	72	39	3	7	121	49

[a] Open-fringe wetlands in 1964–65 showing regrowth of wooded fringes during 1964–74 on more than 5% of perimeter.
[b] Completely cleared of wooded fringe, but not cultivated.
[c] Created by clearing small wooded depressions.
[d] Partly drained with outlet ditches.
[e] Altered by clearing or filling and subsequently tilled.
[f] Basins captured by larger ponds due to raised water levels.
[g] Wetland vegetation succeeding to dryland grasses or low shrubs due to natural filling or changes in moisture regime.
[h] Including all intact wetland basins that have been cleared or partly drained but not cultivated, or lost to succession.
[i] Including basins eradicated by filling, cultivation, pond capture, or plant succession.

Table 5
Net changes in numbers and perimeter cover of wetlands, 1964–74

Block		No. of wetlands				
		*Wood.	†Part wood.	‡Open-fringe	% open	Total
I	Total 1964	98	101	225	53	424
	Loss	27	5	22	—	31
	Gain	0	30	20	—	27
	Total 1974	71	126	223	53	420
	Net Change	−27	+25	−2	0	−4
II	Total 1964	144	66	73	26	283
	Loss	31	12	16	—	18
	Gain	4	22	37	—	22
	Total 1974	117	76	94	33	287
	Net Change	−27	+10	+21	+7	+4

* Wooded fringes occupying > 90% of wetland perimeter. The fringe includes trees or tall shrubs > 1.5m high.
† Wooded fringes occupying 5 – 90% of wetland perimeter.
‡ Wetlands with 0–5% of perimeter wooded.

Table 6
Changes in length of wetland perimeters and wooded fringes, 1964–74

Wetlands	Year	Block I (perim. lgth./km)			Block II (perim. lgth./km)		
		Wooded	Open water	Total	Wooded	Open water	Total
Identified	1964	32.60	73.05	126.06	42.18	20.17	69.13
Persisting*	1974	26.00	90.49	130.66	36.48	18.49	66.79
Change	64–74	−6.60	+17.44	+4.60	−5.70	−1.68	−2.34
New Gains†	1974	2.31	—	4.70	1.36	—	3.46
Eradicated‡	1974	5.23	—	5.85	5.35	—	3.40
Totals	1974	28.31	90.49	135.36	37.84	18.49	70.25
Net change‖	64–74	−4.29#	+17.44¶	+9.30¶	−4.34	−1.68	+1.12
% change	64–74	−13	+24	+7	−9	−8	+2

* Mapped in 1964 and identified in 1974, but excluding wetland gains during 1964–74.
† Perimeters of entire wetlands mapped as new entities in 1974.
‡ Perimeters of entire wetlands present in 1964, that were lost to agricultural practices or succession.
‖ Total perimeter changes between wetlands present in 1964–65 and in 1974.
Significant at $P < 0.10$.
¶ Significant at $P < 0.01$.

meter on Block II was not significant. Decreases in wooded perimeters occurred on 13 and 10 plots on Block I and Block II respectively, resulting in wooded wetland fringes comprising 21% and 54% of total wetland perimeters in 1974. Of wetlands present in 1964 and 1974, total wooded perimeters decreased by 6.6 km on Block I and 5.7 km on Block II (Table 6). Eradicated wetlands accounted for the disappearance of 5.2 and 5.4 km of wooded fringes on blocks I and II respectively. Gains in perimeter length of wetlands or wooded fringes related to recently flooded wetlands or wooded growth not present in 1964.

Shifts in the frequency of open-fringe, partly wooded and completely wooded wetlands occurred during 1964–74, but the changes were more pronounced on Block II (Table 5). Here a loss of 31 wooded and 12 partly wooded wetlands contributed to a gain of 37 open-fringe types, but this was offset by a loss of 16. On Block I there was an increase of 20 and a loss of 22 open-fringe wetlands between 1964 and 1974. Of wooded wetlands present in 1964, 23 or 5% were completely cleared on Block I, and 26 or 9% were cleared on Block II (Table 4). Regrowth of wooded margins took place on 26 wetlands on Block I and 14 wetlands on Block II. These latter wetlands were classed as open-fringe types in 1964. The net effect was virtually no change in the proportion of open-fringe wetlands on Block I, and an increase by 7% on Block II (Table 5).

6. Land-use interactions

We tested the interactions of the four land-use classes by a multiple regression, using deviations in cultivated land as the dependent variable (Table 7). Since the interactions of other variables, including residual effects, can mask the correlation between a pair of variables, we tested various combinations of land-use classes by sequentially eliminating other interactions. Partial correlation coefficients were derived from correlation coefficients in the matrix in Table 7. On Block I, the highest partial correlations with the remaining two variables eliminated were shown between the following paired variables: (1) tilled land x grassland and (2) tilled land x woodland (Table 8). Tilled land and wetland also showed moderate correlations with the effects of grassland removed. Some relationship was also shown in the net reaction of grassland and woodland.

On Block II, generally higher partial coefficients were shown for all interactions eliminating both remaining variables. The strongest relationships occurred between (1) tilled land x woodland, (2) tilled land x grassland, and (3) grassland x woodland (Table 8). The interactions between changes in woodland and other land-use classes were stronger on Block II than on Block I. Although there were high correlations between cultivated land and each of the other variables, considerable interaction occurred among the land-use classes.

Table 7
Correlation matrix showing simple correlations with changes in land-use classes on blocks I and II, 1964–65 to 1974

Block	Class	Tilled	Grass	Wood	Wetland	Mult. R	F ratio
I	Tilled	1.0000	—	—	—	—	—
	Grass	−0.8178	1.0000	—	—	—	—
	Wood	−0.6212	+0.2109	1.0000	—	—	—
	Wetland	−0.3243	−0.1552	+0.3601	1.0000	0.9668	1.4573
II	Tilled	1.0000	—	—	—	—	—
	Grass	−0.3239	1.0000	—	—	—	—
	Wood	−0.6032	−0.3154	1.0000	—	—	—
	Wetland	−0.2793	−0.0069	−0.2648	1.0000	0.9188	4.9058*

*Significant at $P < 0.05$.

Table 8
Partial correlation analysis of interactions in land-use changes, 1964–1974

		Partial correlations–coefficients of determination Effects of class or combination eliminated				
Block	Correlation	Cult.	Grass	Wood	Wetland	Both variables
I	Cult. x Grass	—	—	0.8039	0.8629	0.9448
	Cult. x Wood	—	0.6363	—	0.3267	0.7295
	Cult. x Wetland	—	0.6300	0.0189	—	0.2387
	Grass x Wood	0.4340	—	—	0.0838	0.6317
	Grass x Wetland	0.5963	—	0.0076	—	0.2298
	Wood x Wetland	0.0458	0.1655	—	—	0.3807
II	Cult. x Grass	—	—	0.4614	0.1151	0.8109
	Cult. x Wood	—	0.6173	—	0.5349	0.9006
	Cult. x Wetland	—	0.0886	0.3258	—	0.7632
	Grass x Wood	0.4582	—	—	0.1082	0.8095
	Grass x Wetland	0.0115	—	0.0098	—	0.6521
	Wood x Wetland	0.3201	0.0792	—	—	0.7607

Discussion

Land use in relation to wildlife habitat connotes two differing interpretations which are often confused. The term "land use" usually reflects seasonal physical modification to plant communities caused by agricultural practices such as burning, crop rotation, mowing, and grazing. These practices are reversible, they fluctuate yearly and exert temporary effects on habitat, because the plant communities usually recover quickly when the practices are removed. The other aspect of land use concerns the changing patterns of water and vegetation cover, and the long term effects of structural and spatial alterations caused by the more irreversible practices including drainage, land clearing, and cultivation. We are concerned primarily in this paper with the latter changes in water and vegetation cover.

1. Nesting cover

The literature on land use–waterfowl relationships emphasizes the reversible practices and the influence of vegetation cover on waterfowl nesting success. Martz (1967) documented lower duck nesting success in mowed and burned grassland, and Kirsch (1969) showed inverse relationships between the degree of grazing and nesting success. Milonski (1958) documented nesting success in various cover types in Manitoba, finding that 57% and 41% of Pintail (*Anas acuta*) nests were destroyed by farming operations in 1956 and 1957. Duebbert (1969), Jarvis and Harris (1971), and Nelson and Duebbert (1973) demonstrated that large blocks of dense residual herbaceous cover in proximity to wetlands attracted higher densities of nesting waterfowl. Also, upland nesting ducks showed significantly higher nesting success rates in undisturbed grass–legume cover on retired fields compared to land modified by arable agriculture (Duebbert 1969).

Most available nesting cover in the parklands is confined to idle and grazed bands of grassland peripheral to wetlands, as shown on the study blocks. On the Roseneath area near Minnedosa, upland nesting ducks usually initiated nesting within 50 m of the nearest water (Dzubin and Gollop 1972). If not altered by tillage, many of these wetlands margins were burnt each year, resulting in reduced residual nesting cover available during the succeeding spring (Stoudt 1967, Fritzell 1975). However, the absence of residual cover does not necessarily restrict nesting rates of late nesting species (Fritzell 1975). Therefore, the assurance of continued waterfowl production in the parkland is dependent upon the area, distribution, and condition of these grassland margins.

2. Historical changes in land use

Considerable upland and over-water nesting cover was available on a 3.9 km² study area near Minnedosa in 1949. Evan *et al.* (1952) reported that 57% of this area was cultivated, 14% was in pasture, and 17% consisted of idle land including grassland and stands of trees. On an area of 130.5 km², also on the Newdale Plain, Kiel *et al.* (1972) determined that cleared and cultivated land increased from 58.6% in 1948 to 68.9% in 1964. Rakowski *et al.* (1974) resurveyed the same study transects and estimated that cleared and cultivated land had increased to 82.8% of the area in 1970 and to 84.7% in 1974. However, grassland contributes an unknown proportion of this percentage. We found that the combined area of grassland and cultivated land was about 71% of the Block I area in 1964, decreasing to 69% in 1974 (Fig. 4). On Block II, combined tilled land and grassland comprised about 80% of the plots in 1964 and 1974 (Fig. 5). Except for Block II, the 1974 results are not in close agreement with data from Rakowski *et al.* (1974).

The differences in study area size and location, the variations in land use, and the lack of stratification in the Kiel *et al.* (1972) data may explain the discrepancies. However, these studies do demonstrate a definite trend towards increases in cultivated land on the Newdale Plain. The relative amounts of and changes in vegetative cover on the study blocks indicate historical and district differences in the rate of land clearing between the two blocks, despite their geographic proximity (Figs. 4 and 5). The percentage of grassland and woodland lost was higher on Block II, although the 23% decrease in woodland was marginally significant due to small sample size (Table 2). On Block I, wooded cover also showed some slightly significant changes, but other vegetative cover did not change significantly. A high rate of woodland clearing took place on Block I prior to 1964, leaving only about 6% of the land in residual woodland. Kiel *et al.* (1972) recorded a 4.6% reduction in woodlots between 1958 and 1964 to occupy 21.4% of the study area. However, Rakowski *et al.* (1974) observed that woodlots declined to 9.6% of the area, which represents a rate of reduction of 45% in woodland between 1964 and 1974.

In 1974, we found that woodland on blocks I and II occupied slightly lower percentages of area compared to data shown by Rakowski *et al.* (1974); but the rates of changes between 1964 and 1974 were widely divergent. Since only four of the 12 Kiel *et al.* (1972) transects are close to our study blocks, it is possible that the remaining eight-transect sample areas were subjected to more intensive land use than those represented by blocks I and II. Also the two capability classes only comprise about 39% of the plain. Therefore considerable variation in land-use practices may occur throughout the Newdale Plain.

3. Surface water changes

Wetland changes probably had some effect on areas of adjoining upland cover. On Block I, the combined losses of tilled land, grassland, woodland and miscellaneous were nearly offset by the gain of 52 ha in wetlands (Table 2). Also, the changes in tilled land showed high negative correlations with changes in grassland and woodland (Table 8). On Block II, almost 60 ha of grassland and woodland were probably converted to cultivated land or wetlands, which together showed gains of about 62 ha. High precipitation levels in 1974 (Table 3) caused wetlands to flood adjoining areas, thus displacing some grassland and tilled land; but there was no simple replacement of an entire cover class unit by another. On Block I, the increase in wetland areas probably temporarily offset the trend to more intensive land use.

Whereas wetland numbers showed no appreciable change between the two years (Table 5), wetland areas increased significantly (Table 1) and perimeters increased (Table 6) without appreciably influencing density of wetlands. The loss of wetlands present on both blocks in 1964–65 was offset by the gain of temporary or seasonal wetlands in 1974 (Table 5). The number of wetlands holding surface water in August or September 1964–65 could not be determined accurately from aerial photographs, but the area of open water marsh increased by 29% on Block I in 1974 (Table 1). Hence this raises the question whether the parameter of pond density is a valid index for measuring change in waterfowl habitat, or consequently for predicting trends in waterfowl use or production (Cooch 1969, Henny *et al.* 1972). Thus the parameters of wetland area, perimeter and permanency appear to be more reliable than wetland density for indicating changes in waterfowl habitat.

The surface water conditions in 1964–65 and in 1974 tended to be related to precipitation patterns over the preceding 12 months (Table 3). Pospahala *et al.* (1974) demonstrated that accumulated precipitation from 1 August to 31 July was highly correlated with July pond numbers in the prairie–parkland region. The number of ponds in a given year appear to be a function of pond numbers present in the previous year and the accumulated 12-month precipitation. Accumulated precipitation levels in 1973–74 exceeded 1963–64 and 1964–65 levels at Rivers, Minnedosa, and Hamiota, and more precipitation fell in Block I than in Block II (Table 3). According to Hansen (1964) July pond habitat conditions were reported good, but below the 11-year coverage for southwestern Manitoba. Pospahala *et al.* (1974) present data showing that southwestern Manitoba had more water areas in May 1964 than in any previous year since 1956. Pond numbers dropped from 701 300 to 411 500 between May and July 1964; and in 1965, ponds declined from 732 900 in May to 350 700 in July. In comparison, the surface water conditions in May 1974 were near record high levels (US Fish and Wildlife Service 1974). On transects totalling 10.4 km² near Minnedosa, Stoudt (1974) recorded 40 water areas per km² in May, representing the highest count since 1967. Water areas declined to 20 per km² by 20 July. Similarly Hawkins (1974) tallied 2707 May ponds on the transects (Kiel *et al.* 1972). and considered 1974 to be one of the wettest years since 1949. These observations support the precipitation data (Table 3) and the changes in wetland area (Tables 1 and 2) on the study blocks.

4. Drainage and flooding

Large scale drainage on the study plots was not a significant factor in reducing wetland numbers or permanency during the 1964–74 period. The percentage of ponds drained on both blocks (10.2%) was higher than the 6.1% rate for ponds drained in the black soil belt of Manitoba between 1945 and 1970 (Goodman and Pryor 1972). On Block I during 1964–74 the partial drainage rate is similar to the 16% rate reported by Kiel *et al.* (1972) in a study of 120 potholes in the Minnedosa district between 1949 and 1964. If these results are representative of the Minnedosa district, there has been little change in drainage rates since 1964. However total alterations and losses of wetlands on Block I, including drainage and clearing, affected 27% of wetlands present in 1964. Although numbers of wetlands destroyed have been temporarily offset by a gain of wetlands in 1974 (Table 5), the latter are chiefly transitory wetlands with open perimeters. With the return of more normal water conditions, most of these wetlands will disappear or be eradicated by land-use practices. The periodic occurrence of abnormally high water levels subsequently leads to increased drainage and clearing activities by farmers when the water levels recede. These land-use alterations will ultimately affect the more permanent wetlands.

On Block I, the relative increases in perimeters of open water marshes and total wetlands, and the proportionate increase of open water marsh areas (Tables 1 and 6) were due to expansion in areas of wetlands and conversion of closed canopy wetlands to open water types due to the inundation and dieback of marsh vegetation. The relative increase in water permanence was caused by improved water retention as a result of heavy precipitation in the 1973–74 year (Table 3). Due to yearly fluctuations in water regimes, the permanency rating is not a consistent attribute of wetlands, and it makes their classification more difficult without long term water-level records.

5. Clearing

The clearing of woodland areas on Block I produced significant changes (Table 2), and the 13% loss of wooded wetland perimeter (Table 6) was also significant. In comparison, loss of wooded perimeter length on Block II was not significant, yet more wetlands were cleared of wooded fringes (Table 4). Compared to wetlands on Block I, most of the wooded wetlands on Block II were relatively small. The contrast between percentages of open wetland perimeters on Block I and Block II in 1964 suggests that more intensive clearing did occur on Block I prior to 1964.

According to Kiel *et al.* (1972) about 37% of 120 basins in the Minnedosa district were altered by clearing between 1949 and 1964, and most potholes were cleared during the 1961–64 period. At Lousana, Alberta, Smith (1971) documented a reduction by 55% of aspen-rimmed shorelines between 1953 and 1969, and open-fringe potholes had increased by 71%. In Alberta, Merriam (1975) recorded the elimination of wooded fringes from 123 sloughs or 31% of the total sampled between the years 1945–50 and 1974. Near Redvers, Saskatchewan, Stoudt (1971) observed fluctuations in open-fringe potholes from 46.4% open in 1952 to 56.6% open in 1964. The change from closed to open-fringe he attributed to clearing and dieback of the willow fringe due to excess flooding.

We found that open-fringe wetlands showed little net increase between 1964 and 1974 (Table 5). Although the entire perimeters of 49 wetlands were cleared (Table 4), some partial clearing or dieback of wooded fringes probably also took place. On Block I, 32 wetlands showed reductions in wooded fringes, leaving nine wetlands unaccounted for in the total cleared (Table 4). Similarly 26 wetlands were cleared on Block II compared to 43 wetlands affected by entire and partial perimeter losses. Therefore the rates for clearing on blocks I and II are probably underestimates since about 8% (Block I) and 15% (Block II) of all wetlands showed some reductions in wooded perimeters; but the causes cannot all be attributed to clearing. Regrowth of wooded fringes, which occurred on 40 wetlands, tended to offset these losses (Table 4), but there is an apparent accelerating trend in pothole clearing on Block II.

6. Interactions

Land-use changes may result in strong correlations among classes, but not all changes are unidirectional or reciprocal. Despite the high multiple correlation coefficient shown in Table 7, the interactions on Block I did not show a significant rectilinear relationship. Except for the correlations between tilled land, grassland, and woodland, the individual correlations were poor. This was due to the masking effects of the interactions of the four variables.

These interacting effects can be isolated and the relative contribution of each effect can be analyzed from the partial correlations (Table 8). On Block I the elimination of the effects of woodland and wetland showed that changes in tilled land and grassland were highly correlated, accounting for 94% of the variation. By calculating the differential between the R-square values derived from the correlation matrix (Table 7) and the partial correlation coefficients (Table 8), we determined the masking effects of the individual classes. About 11% of the variation caused by the association of tilled land and grassland on Block I was influenced by wetland changes; whereas woodland effects influenced 14% of the variation. Similarly on Block II, wetland effects masked 17% of the variation shown in the association of tilled land and woodland, and grassland influenced about 25%. About 36% of the variation between tilled land and grassland changes in Block II is explained by the interaction of woodland. Grassland affected 25% of the variation in the correlation of tilled land with woodland in Block I. All paired class combinations, with the effects of the remaining two variables removed, showed relatively high interactions on Block II (Table 8).

We attributed the relative decline in hectares of grassland and woodland on Block I to the effects of clearing, cultivation, and flooding, with the latter exerting most effect on grassland areas. On Block II, changes in grassland and woodland were highly correlated with each other, as well as with tillage and clearing. Therefore cultivation appeared to be the most important factor reducing grassland and woodland on Block II. In some cases woodland tracts were cleared but not cultivated, thereby succeeding to grassland; whereas, in contrast, examples of grassland succeeding to woodlots also occurred. Similarly wetland losses on Block II were correlated with the clearing of adjacent woodlands and the cultivation of dry basins.

In 1974, the relative increase in wetland perimeters may have improved habitat edge for waterfowl nesting cover, but the effects were counteracted by reductions in the width and quality of grassland margins. The agents responsible were primarily cultivation and flooding, although clearing contributed — the effects of burning were not assessed. On Block I, the 9% loss rate for grassland may be misleading due to the conversion of 31 ha of cropland to seeded pasture, which provides lower quality nesting cover. However, almost one-third of total grassland hectares were lost due to cultivation and clearing on Block II. Although yearly comparisons of habitat changes tend to be masked by dissimilar moisture regimes, there is a definite trend toward increasing cultivation and reduction of natural cover. The losses of temporary wetlands, the destruction of grassland, and the alteration of wetland margins have probably reduced the quantity and quality of available waterfowl nesting habitat.

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