EFFECTS OF RESERVOIR INUNDATION ON BREEDING CANADA GEESE NEAR DIEFENBAKER LAKE, SASK.

by

DANIEL J. NIEMAN
and
ALEX X. DZUBIN

Canadian Wildlife Service

1979

P&Y 166

Effects of reservoir inundation on breeding Canada geese near Diefenbaker Lake, Saskatchewan.

Daniel J. Nieman and Alex X. Dzubin
Canadian Wildlife Service, 115 Perimeter Road, Saskatoon, Sask. S7N 0X4

Periodic aerial surveys, 1958 to 1979, of segments of the South Saskatchewan River, before and after inundation by Diefenbaker Lake, confirmed the expected elimination of about 40 pairs of breeding, large Canada geese (Branta canadensis maxima) on over 200 km of reservoir. Post impoundment counts from the unflooded portion of the river, 90 km east of the Alberta border, showed a doubling or tripling of the pre-impoundment nesting population, from 40 to 75 indicated pairs to 107 to 199 pairs. Numbers have fluctuated annually but have not shown the massive increases paralleling those of the Hi-Line Plains Population to which geese showed affinity. Numbers of suitable islands and few brood feeding grounds on the unflooded river segment places limits on numerical expansion. In those years when ice melt on Diefenbaker Lake is delayed to mid-May nesting by geese is deterred on adjacent uplands and cliffs. Wide annual fluctuations in water levels on the reservoir prevents establishment of emergent vegetation suitable for grazing geese or their broods. Associated with droughts on surrounding grassland lakes, immigration onto river areas aids in short-term survival of flocks.

Key Words: Giant Canada goose, Branta canadensis maxima, South

Saskatchewan River, reservoir flooding, island nesting, population abundance, distribution, impact dam, ice effects, mitigation, Saskatchewan.

Water is a high demand commodity in prairie Canada but is distributed unevenly both in time and space. High quality runoff waters are captured by dams during peak periods and stored for subsequent use. A number of significant, quantifiable benefits have accrued to peoples and industries in this water deficient area of the southern prairies from such reservoirs. One of the obvious and undesirable side effects of impounding waters on a grand scale is the disbenefits accruing to those species which use bottomland habitats during their annual cycle. For example, large Canada geese, as regular insular nesters on rivers, are profoundly effected by inundation of their preferred nesting islands. This paper focuses on inundation effects on nesting geese in Saskatchewan.

Canada geese were apparently common nesters in southwestern Saskatchewan at the turn of the century (Bent 1907; Caldwell 1963; Knight 1967). Immediately thereafter, associated with land breaking and advent of grain farming, numbers decreased. The severe droughts of 1917 to 1921 and of 1929 to 1937 virtually eliminated upland lakes and associated breeding geese. During the latter period, Goldman (1932) noted the extreme aridity of southern Saskatchewan. After spending the period June 8 to 12, 1932 investigating lakes between Regina and Maple Creek he reported seeing only one flock of 14 Canada geese on Big Stick Lake. Two years later the Canada goose was apparently so reduced in numbers that a hunters

organization, the Saskatchewan Fish and Game League, passed a resolution recommending no open hunting season for two years (Goldman and Aldous 1934). Droughts affect breeders by drying shallow lakes used for nesting and brood sites and leave flightless adults and goslings more vulnerable to predation (Gillespie 1977). Emmigration, increased nest and brood mortality and lowered replacement rates lead to decreases in abundance or virtual extinction of local flocks.

Based on anecdotal evidence of local residents, R.T. Sterling, Ducks Unlimited biologist (unpubl. rep. July 1958) noted that few if any geese nested on the river islands between Empress, Alberta and Saskatoon, before the drought of the thirties. With the drought the few breeders retreated to the river which provided a center of dispersion for repopulation of the surrounding plains when favourable water conditions returned. He concluded that the river served as a nucleus of dispersion during the ebb and flow of xeric conditions. Thus, geese show breeding adaptations analogous to those of non-aquatic upland nesting species (Wiens 1974). They are able to survive in "river refugia" and reinvade the surrounding runoff lakes after mesic intervals.

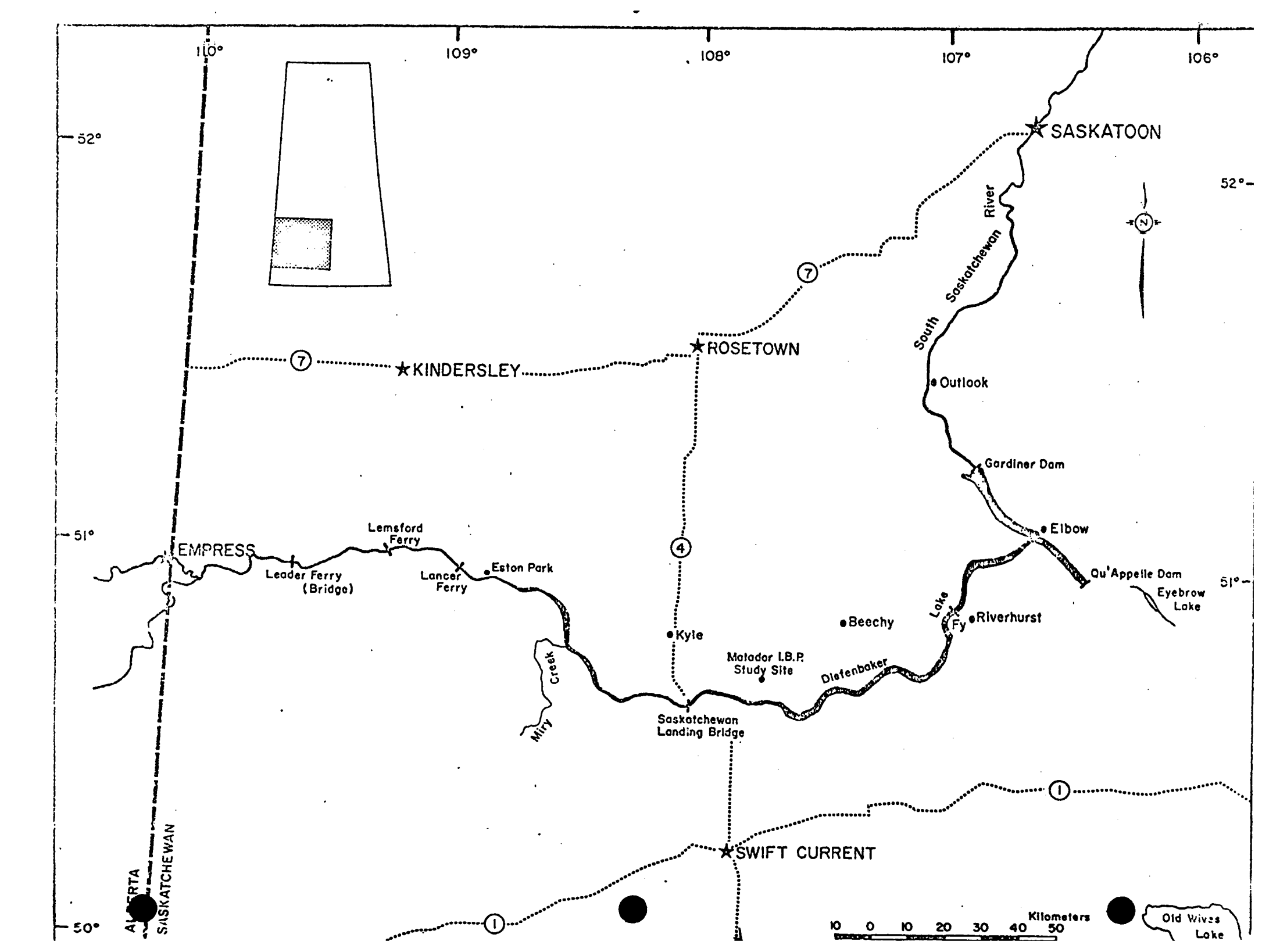
With return of wetter, cooler climatic patterns and more mesic conditions in the late forties numbers again expanded onto the surrounding lakes. Godfrey (1950) found them breeding on the larger bodies of water of the short grass plains and the Cypress Hills. Surveys by biologists of Ducks Unlimited (Canada) between 1954-1960, confirmed the spread onto their projects. In 1960, Nelson (1962) estimated over 500 breeding adults and 1,000 goslings in the area south of the South Saskatchewan River to the

49° latitude and west of Highway 4 to the Alberta border (Figure 1). However, with advent of increasing aridity in the 1959-1962 period many upland lakes again dried, decreased numbers of broods were enumerated but contrary to previous droughts Canada geese were able to sustain themselves on small man-made impoundments and further on the South Saskatchewan River (Caldwell 1963; T. Sterling, personal communication). Thus, riverine habitats had been recognized as important stable components for the periodic survival of geese in the southern part of the province.

Resident Canada geese generally arrive in southwestern Saskatchewan from March 10 to 30 and begin nesting activities on islands of the South Saskatchewan River about April 5, at the time of ice break-up (Nelson 1963; Caldwell 1967). The preferred nesting locations are islands. Caldwell (1967) found only one of 140 nests on the river bank. Island nesting is a characteristic attribute of Canada geese on rivers, lakes and marshes throughout the southern prairies (Vermeer 1970; Ewaschuk and Boag 1972; McDonald 1975; Cole 1976; Gillespie 1977), and northern Great Plains (Johnsgard 1979). Fitness of individuals is enhanced by nesting on islands and is probably an anti-predator adaptation. It may also be an adaptation to fires. The influence of fire on species inhabitating northern grasslands has been examined by Nelson (1976) while Hanson (1965:168) suggested that fire may have been a population depressive factor for geese in presettlement times.

This paper is a "before and after" study involving empirical and observational evaluation of the biological aspects of flooding on riverine

Figure 1. Location of Diefenbaker Lake and census segments along the South Saskatchewan River.


110°
109°
108°
107°
106°
52°
51°
50°
SASKATOON
ROSETOWN
KINDERSLEY
EMPRESS
South Saskatchewan River
Outlook
Gardiner Dam
Elbow
Qu'Appelle Dam
Eyebrow Lake
Lemsford Ferry
Leader Ferry (Bridge)
Lancer Ferry
Eston Park
Kyle
Beechy
Lake Fy
Riverhurst
Matador I.B.P. Study Site
Diefenbaker
Creek
Miry
Saskatchewan Landing Bridge
SWIFT CURRENT
ALBERTA
SASKATCHEWAN
Old Wives Lake
Kilometers
10 0 10 20 30 40 50
7
4
1
N

nesting populations of the Giant Canada Goose. Counts were fortuitously available in the pre-impoundment period. It is not an impact statement as it lacks a multi disciplinary approach. We were not in a position to weigh the broader and more complex social, environmental or political ramifications. However, it should aid managers to identify emerging use conflicts by documenting one case history. More refined predictive models may then be possible for an expanded species list. Our specific objectives were to (1) provide a temporal analysis of effects on nesting geese, a decade after a part of the river basin was flooded; (2) confirm or reject predictions enunciated in pre-impoundment times; (3) compare effects of reservoir filling with other Great Basin impoundments, and (4) identify areas where mitigation strategies would likely increase nesting abundance.

Methods

Surveys

Various portions of the South Saskatchewan River between Saskatoon and the Alberta border had been monitored on an intermittent basis since spring, 1957. One or two aerial counts were made annually. These irregular, surveys provided data of sufficient precision, when corroborated with boat surveys, to satisfy the then current demands for abundance and distribution data of waterfowl species. To conduct counts, various types of high winged aircraft were flown at speeds of 160-200 Kph and at heights of 50-100 m. Two experienced observers, one on each side of the aircraft recorded location of lone geese, pairs and flocks of 3 or more. The first

two categories were pooled to estimate indicated breeding pairs. On occasion, a knowledgeable pilot and only one observer was used. Surveys were conducted down the center of the river generally from east to west under high visibility and low wind conditions. Counts were made primarily in the prenoon hours.

Because river width varied from several hundred meters to well over 1 km, and as the river was braided and interspersed with wooded islands, absolute counts of all birds present were impossible to make. We assumed that the same biases and sampling errors were operative with each survey. Counts were thus broadly comparable. Certain assumptions are examined below.

In field studies on large-type Canada geese the proportions of breeders in spring censused flocks has ranged from 38 percent to 65 percent (Miller and Collins 1953; Steele, Dalke and Bizeau 1957; Dimmick 1968; and Culbertson, Caldwell and Buss 1971). Generally, most estimates have shown the proportion of non-breeders to be 45 to 55 percent of the observed spring flocks. Hanson (1965) estimated that spring populations consisted of 40% breeders and 60% non-breeders. On the South Saskatchewan River there appears to be a tendency for grouped, subadult geese to spend portions of each day away feeding in surrounding fields and they are thus not available to be counted. After mid-May, flocked birds generally make up 52% of all geese counted, e.g., 102 of 197 geese on May 25, 1962 (Nelson 1963) but prior to that less than 30%. The high mobility of "unemployed" geese, less than 3 years of age, and the difficulties in achieving absolute counts were stressed by Hanson and Eberhardt (1971).

These authors reported that only 63% of nesting geese were seen from the air when compared with an intensive ground census. Other confounding factors to censusing are the sibling or temporary pair associations of subadults (Raveling 1969; 1979) which erroneously may be assigned breeding pair status. Age structure of the local flock, previous hunting season mortality of cohorts, reproductive outputs of young, homing tendencies, harassments by man or predators and shifts of birds due to droughts all influence river segment counts and indicated abundance. Replicate censuses were unavailable for evaluation of such factors.

Study Area

The area lies primarily in the mixed prairie region south of the Aspen Parklands (Bird 1961). An aspen outlier is situated along the north-south axis between the Gardiner and Qu'Appelle Dams (Rowe 1972). On the uplands beyond the river valley a number of closed depressions fill with runoff water and form intermittant lakes of varying salinity. Descriptions of soils, climate and land use can be found in the Atlas of Saskatchewan (Richards and Fung 1969). A wealth of background information is available from the IBP Grassland Zone study site at Matador (Figure 1) which lies just north of the river breaks halfway along the reservoir (Abouguendia 1974).

Along the river floodplain, lines of cottonwood (Populus sargenti), aspen (Populus tremuloides), willow (Salix sp.), were found. Uplands, intermittent streams and coullees contained clumped shrubs, snowberry (Symphoricarpus occidentalis), wolfberry (Elaeagnus commutata) and rose

(Rosa woodsii). Much like the east to west river courses of the Great Plains (Johnsgard 1979) the treed floodplain habitats of the South Saskatchewan River were probably important corridors linking woodland species of the eastern aspen-oak parkland belt (Rowe 1972) with the montane forest to the west. Hybrid indices of passerine birds using the corridor remain unstudied.

The river itself flows in a valley which varies in height from 50 m near the Alberta border to near 150 m elevation at the dam. The shoreline types of the reservoir are varied from gentle underwater slopes with sand and silt to shorelines deep in the valley with a 400'-450' wall of exposed shale above (Baker 1960a). In the area of the Coteau between Riverhurst Ferry and Saskatchewan Landing numerous small harbours occur but their steep slopes are subject to erosion and slumping.

Work on Gardiner Dam was officially begun on May 27, 1959 with Lake Diefenbaker being created by the closure of a base dam on February 14, 1964 (Spence 1967). Two more years were required to complete the 210 foot earthen dam. Within the impoundment area partial clearing, cutting and burning of trees and shrubs on islands and shorelines was accomplished. By summer, 1966 the reservoir extended westward approximately 65 km to the Riverhurst Ferry (Figure 1). The lake was completely filled by autumn 1969 when it extended to near Eston Park. Thereafter, each spring all islands from Gardiner Dam to the vicinity of Miry Creek were permanently inundated. Associated with hydroelectric generation, drawdowns of up to 12 feet occur during the winter months. Stranded ice blocks cover islands on the west end until early May.

The latent heat within the reservoir keeps portions ice free until late December or even January. Depending on spring phenology the main lake is rarely free of ice before April 20 and may contain landfast ice to early May. When full, the reservoir extends westward some 225 km, is generally 5 km or less in width and has a surface area at FSL of 445,000 ha. It fulfills a number of expressed needs for water for irrigation, power, industrial and municipal uses and recreation.

Results

Numbers of goose breeding pairs and broods were annually variable both prior to and in the post-impoundment period (Table 1). In part, such variability may reflect the phenologically changing census dates and constrains application of statistical tests. The mean number of breeding pairs prior to flooding, east of Saskatchewan Landing, based on two counts, was 17 while west to the Alberta border, based on 7 counts, the average was 68. The low numbers found east of Saskatchewan Landing is consistent with previous anecdotal observations. It also corroborates the study of Kaminski and Price (1977) who concluded that slope of island relief and density of vegetation were key parameters affecting island use. On the eastern segment of the river many islands were overgrown with dense stands of willow (Salix sp.). The slightly wider valley, less restricted stream bed, and shallower water between shoreline and islands made access easier by potential predators. Predation and flooding were key factors controlling breeding success west of the Landing (Caldwell 1967).

In 1966, during partial filling of the reservoir, some 22 pairs were

seen east and 77 pairs west (average of 72 and 82). The mean number of pairs west of the Landing had risen to 142 in the post-impoundment period 1974-1979 (Table 1). Nearly all of the pairs were located west of Miry Creek at the upper end of the reservoir.

The increase in pairs is consistent with a massive increase in the Hi-Line Plains Canada Goose Population to which the birds show affinity (Bellrose 1976, D. Witt, personal communication). This stock has shown an 11-fold increase from 7,000 in January, 1961 to nearly 78,000 in 1978. It is also consistent with two hypothesis, (1) a shift of displaced pairs westward from the flooded reservoir, (2) a shift of displaced pairs into the river from drying upland marshes associated with droughts of 1977. We were unable to separate the relative contributions of the three factors to the magnitude of the flock increase.

East of the Landing on the reservoir only two counts are available, one on April 20, 1978 which showed 43 pairs scattered along the lake shoreline primarily on the reservoir between the Gardiner and Qu'Appelle Dams. These indicated pairs may have shifted to the lake area from the surplus of birds at the Saskatchewan Department of Tourism and Renewable Resources Niska Project at Eyebrow Lake (Figure 1). Here geese are artificially raised for release into unoccupied habitats. In 1978, such "floaters" may have been attracted to the reservoir but did not nest there. In the delayed spring of 1979, no pairs of geese were observed over the entire reservoir shoreline. All parts were covered with landfast ice east of the Landing, until the second week of May.

From Saskatchewan Landing to the Alberta border in the 1962-1964

Table 1. Number of indicated breeding pairs and broods of Canada geese counted on the South Saskatchewan River before and after impoundment.

Breeding Pairs

	Pre-impoundment								Filling			Post-impoundment		
Year	1960	1961	1962	1962	1963	1963	1964	Mean	1966	1966	1974	1978	1979	Mean
Count Date	5/31	5/16	4/17	5/25	4/17	5/25	4/17		5/4	5/12	5/15	4/20	4/30	
East[a]	18	16	-	-	-	-	-	17	22	23	-	43	0	
West[b]	27	59	72	52	119	64	85	68	72	82	107	199	121	142

Broods

Year	1958	1960	1961	1962	1962	1963	1963	1964	Mean	1966	1974	1975
Count Date	7/4	6/29	7/4	5/25	6/29	5/25	7/29	7/10		7/7	5/17	6/10
East[a]	1	5	5	-	-	-	-	-	4	13	-	1[c]
West[b]	15	10	26	14	23	28	50	27	24	44	27	

[a]East of Saskatchewan Landing to the Gardiner Dam or Elbow.

[b]West of Saskatchewan Landing to the Alberta Border.

[c]Partial count Gardiner Dam to Riverhurst Ferry.

pre-impoundment period, Nelson (1963) and Caldwell (1967) enumerated a maximum of 74 nests (1963) on some 70 semi-permanent islands. A comparable survey conducted by Donald (1974) in the post-impoundment period showed 45 nests on 24 islands from the Alberta border to Eston Riverside Resort. Forty-five islands between Eston Resort and Saskatchewan Landing, on 75 km of river, supported no nesting geese that year. That portion of the reservoir is subject to varying degrees of flooding from marginal to near total submersion depending on magnitude of spring inflows.

On the average, in the pre-impoundment period, fewer broods like pairs were also observed east of the Landing than west, 4 vs. 24 (Table 1). A partial count of the river from the Riverhurst Ferry to the Leader Ferry, on June 28, 1957, showed 65 goslings and 34 adults, 23 of which were located west of Saskatchewan Landing. Caldwell (in Knight 1967) reported at least 10 broods between Riverhurst Ferry and Saskatchewan Landing in July 1963. A single count in 1966 showed 13 east and 44 west of the Landing. One count in the latter area in 1974 showed 27 broods. On June 10, 1975 in aerial surveys along the shorelines of the eastern portion of Diefenbaker Lake from the Gardiner Dam to the Riverhurst Ferry (Figure 1) only 1 pair with 3 goslings were noted plus two groups of 8 and 20. In a comparable survey on July 30, 1975 no Canada geese were observed on the approximately 185 km of lake shoreline. The latter survey coincided with the peak period of recreational boating. Anecdotal and observational evidence from Saskatchewan Conservation Officers does not substantiate that the main, east-west reservoir holds more than a few

broods except for that portion west of Saskatchewan Landing. The north-south reservoir between the two high dams may also hold a few annually. The observations are consistent with the lack of low flat grazing areas for goslings. Although Nelson (1963) had earlier recorded maximum brood movements of 16 miles downstream on the flowing river and Caldwell (1967) one of 30 miles after banding, broods or accompanying adults were not attracted to the area east of the Landing on the reservoir proper. Along the Bow River of Alberta McDonald (1975) noted that the principal brooding areas were located on large, open river flats or on the inside bend of a river meander where the land sloped gently toward the river. The flats were generally covered with short grasses or pastureland and were closely associated with nesting areas.

On April 16, 1961, 1,225 ducks, probably migrants, were counted on the South Saskatchewan River from the Alberta border to Elbow. In order of abundance the species were mallard (Anas platyrhynchos), pintail (A. acuta), red-breasted merganser (Mergus serrator), American goldeneye (Bucephala clangula), baldpate (A. americana) and green-winged teal (A. crecca). On April 17, 1961 J.B. Gollop (personal communication) counted 150 ducks on a 65 km portion of the river from Lancer Ferry to Leader Bridge (see Figure 1). It is unknown if all of the ducks observed were migrating or breeding. T. Sterling (personal communication) reported 2 broods of mallards at Eston Park in July, 1958 while three broods of red-breasted mergansers were noted from the Alberta border to Saskatchewan Landing during the same airboat survey. No empirical evidence was obtained on non-waterfowl species use of upland or floodplain habitat. The relative abundance of such species in parts of the flooded river basin has been described by Roy (1964).

Discussion

Predicted impacts

Historically, prior to 1965, most prairie reservoirs were constructed without detailed ecological impact statements. Wildlife is not listed as one of the resources of the South Saskatchewan Basin during the early hearings of the Royal Commission which weighed economic and social returns of the development (Hogg, Gaherty and Widtsoe 1952). Nor was it listed among those topics where basic data deficiencies occurred in evaluation. In ancillary studies designed to determine potential recreation benefits wildlife is only casually noted. Cited as a long term economic and social benefit, increases in bird populations were predicted (Boan, undated). Sewell (1968) indicated that the only potential conflict between wildlife and the project would be one of fish resources versus the production of power. Baker (1960a) concluded that inundation of the valley would undoubtedly destroy some of the "favorite haunts" used by natural scientists. He acknowledged that the dam would cause losses to some wildlife species but predicted a general improvement within as much as a 100 mile radius would follow inundation and irrigation. Baker (1960b) recommended a complete inventory be accomplished so that effective programs could be designed to ameliorate the destructive effects upon wildlife which could result from flooding.

As early as July, 1958, R.T. Sterling, Ducks Unlimited Biologist (unpubl. rep.) noted that the proposed dam would have little direct affect on the breeding population of geese found between Empress, Alberta and Saskatoon, Saskatchewan. The main nesting population was believed to be

upriver from the Saskatchewan Landing Bridge above the area to be flooded by the proposed reservoir. Caldwell (1964) speculated that "the loss of island nesting sites could result in a shift in population or a change in nesting habitat, i.e., use of shorelines or elevated nesting sites". He subsequently suggested that the most significant loss due to the dam construction would be the loss of islands and sandbars and displacement of geese westward (Caldwell 1967). We attempted to confirm or reject the above projected impacts. Assessments of impacts for waterfowl species other than breeding Canada geese remain imperfect as the necessary historical data bases are lacking.

Studies on reservoir impacts on nesting Canada geese have been conducted along the Snake and Palouse Rivers of Washington (Buss and Wing 1966; Culbertson, Cadwell and Buss 1971; Allen, Fast, Langstaff, Tomrdle and Troutman 1978) and also along the Columbia River (Hanson and Eberhardt 1971). These studies like the one on the South Saskatchewan River confirm that flooding associated with impoundment negatively influences overall reproductive outputs, generally on a permanent basis. Massive seasonal drawdowns tend also to deter establishment of emergent plant species which can be grazed by geese. Hydro-electric and irrigation developments along many of the water courses of the Pacific Population of western Canada geese, (B.c. moffitti), which stretches from central British Columbia to northern California, have destroyed historical habitats (C. Kebbe, personal communication). Efforts to mitigate for these losses have met with both success and failure. McDonald (1975) concluded that a proposed dam on the Bow-Highwood Rivers of southern Alberta and the

resultant impoundment would likely eliminate a nesting population of 50 pairs of Canada geese unless specified ameliorative measures were implemented.

Strategies for mitigation of nesting islands irreplaceably lost to permanent inundation, might include provision of artificial nest structures akin to those described by Will and Crawford (1970) or Atkins and Fuller (1979). Although various races nest in trees, (Yocum 1951) tubs (Brakage 1965) and nest platforms (Cooper 1978) the "tradition" does not appear regularly in geese on the South Saskatchewan River. Thirty-nine nesting structures placed in trees in 1962 were unused by geese in subsequent years (Nelson 1963; Caldwell 1967). However, in April 1974 along the South Saskatchewan River of Alberta, immediately west of the border, H. Armbruster (personal communication) noted 3 of 35 "washtubs", placed in cotton wood trees to attract golden eagles (Aquila chrysaëtos) were used by nesting geese. Sealy (1967) documented two, tree nests of Canada geese on the North Saskatchewan River near Battleford.

Although mitigation through creation of predator proof nesting structures could potentially increase numbers of nesting pairs, the necessary shoreline grazing areas for goslings may be limiting. The entire southern and northern shore of the reservoir contains a few wind free bays with sloping shores. As broods are invariably associated with open level grazing areas (Hanson 1965:194) their lack may negate any enhancement of the nesting flock around the reservoir. Further it may be necessary to restrict boat activity along sections of shoreline for the brood period to prevent undue harassment. Loss of water-based recreation

would result.

To alleviate impacts caused by inundation, creation of subimpoundment marshes on the deltaic west end may be possible. Such intensively managed units have shown promise in both increasing breeding flocks and dust abatement on a Montana reservoir (Childress and Eng 1979). In Manitoba, subimpoundments, have been used to reduce duck nest losses from flooding at the Grand Rapids Hydroelectric Project on the Saskatchewan River (White and Malaher 1964).

Canada geese are known to use cliff nesting sites associated with reservoirs in Washington state (Hanson and Browning 1959; Culbertson, Caldwell and Buss 1971) and also in southern Alberta. During an April 25, 1974 raptor survey of portions of the Old Man, Bow, South Saskatchewan and Red Deer Rivers, Armbruster (personal communication) observed 46 of 269 indicating pairs of Canada geese associated with river cliffs. At least 10 geese were noted on cliff nests. In Alberta, R. Fyfe (personal communication) has undertaken an active program for creation of artificial nest ledges on cliffs through digging and blasting. Prairie falcons (Falco mexicanus) nest readily in holes where none existed before. Such cliff sites, may also be shared or used by nesting geese. Oliphant and Donald (1974) proposed a similar management program for the South Saskatchewan River. The delayed ice melt on Diefenbaker Lake proper might preclude use of such sites by geese east of the Saskatchewan Landing Bridge but not to the west.

Reservoir impacts on waterfowl. Depending on location, size, method of operation and adjacent land use, reservoirs may have beneficial,

adverse or insignificant effects on waterfowl (White and Malaher 1964). Also such effects may be local, regional or international in scope. Further, depending on the perceptions and prejudices of the observer, reservoirs, at the extremes, can be viewed as environmental and social insults or as positive developments leading only to the common good (Prosser, Martin and Stroud 1979).

Baxter (1977) has reviewed some of the environmental consequences of creating reservoirs in all continents. More biological surprises were associated with tropical than temporate impoundments. Effects in high latitude regions have been less dramatic and more time was available to reverse some of the undesirable effects, e.g., Peace-Athabasca Delta. There, environmental changes which occurred in response to lower water levels below the Bennett Dam were expected to decrease waterfowl production by 20-25% (Townsend 1975; the Peace Athabasca Delta Project Group, 1973). Weirs, which stabilized water regimes have ameliorated some of the negative impacts. The environmental, and social consequences of developing hydro power on boreal rivers of Manitoba were examined by Newbury and Malaher (1972). On Lake Baikal, U.S.S.R., Skryabin (1965) noted how the rise in lake levels by dams on the Irkutsk and Angara Rivers in 1956 and 1959, caused flooding of 60,000-70,000 ha of littoral lowlands. Annually, rising levels inundated more lowlands and flooded waterfowl clutches. Secondarily, flooding led to increased nest densities on the remaining favorable habitats and high levels of nest parasitism. In another global overview, Berry (1978) discussed a number of benefits to wildlife species from new water development projects in dryland habitats.

Generally most benefits have accrued to transient and migrant waterfowl (Mills and MacIver 1964) but in one case, breeding ducks also showed a four fold rise the first year after reservoir flooding of the Ottawa River but little change thereafter (Munro 1967). In Oklahoma, large multi-purpose reservoirs have created extensive areas of new habitat now being used by over one million ducks and geese annually during the migration and wintering periods (Barclay 1976). Generally, precise measures of the long-term, environmental costs or accruing benefits of main stem impoundments on waterfowl and other avian resources have yet to be established.

Conclusions

Most large impoundments have a galaxy of associated ecological costs and benefits. Diefenbaker Lake ensures a steady supply of quality water to communities and industries in central Saskatchewan. With reservoir filling some negative effects on breeding geese were apparent. Damming the South Saskatchewan River in 1964 and reservoir filling to 1969 has inundated bottomland islands on over 200 km of the river basin. A maximum of 40, island-nesting pairs of Canada geese were forced from the reservoir area. Pre-impoundment predictions of adverse effects were thus confirmed. In the post-impoundment period, thick ice cover and delayed spring melt on the reservoir itself, has deterred geese from consistently settling on cliff or bank sites. The action of ice, wind, and waves leads to slumping of the steep shorelines. Summer recharge from cordilleran snow melt and winter drawdowns of up to 12 feet, are not conducive to emergent growth on

the periodically exposed shorelines. Necessary brood feeding areas are now lacking around the main body of the lake. Recreation boating and man-induced harassment may also displace broods from the few remaining bays and low relief areas. Experimental mitigation strategies, e.g., building elevated nesting structures on the silted west end of the lake and creation of cliff sites for both geese and peregrine falcons might be initiated west of Saskatchewan Landing.

The number of nesting pairs on the island-riverine habitat above the west end of Diefenbaker Lake to the Alberta border appears to vary annually between 100-200 pairs, a level twice that found before damming of the river. Thus, some possible shifting of pairs westward may have occurred after full inundation in 1969. However, in light of the 11-fold increase in wintering numbers between 1961-1978 in the Hi-Line Plains Population to which this breeding subunit belongs, some habitat component on the unflooded river may be lacking or the island nesting birds have reached carrying capacity because of social or environmental factors. Annual estimates of breeding numbers may also be confounded by influxes of pairs or sibling groups during drought periods. A much expanded monitoring system is required to validly assess present status of pairs and broods.

The significance of the 200 km flooded portion of the South Saskatchewan River for nesting geese has diminished drastically with reservoir filling. On balance, the use by autumn migrating geese has increased on the deltaic west end of the reservoir. The increase has been at the expense of a concommitant decrease on small saline lakes lying 150 km to

the north (Dzubin and Nieman, unpubl.).

Acknowledgements

We thank our many colleagues from the Canadian Wildlife Service, Ducks Unlimited (Canada), and Saskatchewan Department of Tourism and Renewable Resources for provision of unpublished counts or for participating in surveys. Mr. Jack Smith, Wildlife Technician aided in data analyses and drafting.

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