CANADIAN WILDLIFE SERVICE

Ecological Effects of Diverting Water from the Mackenzie River Basin to the Saskatchewan-Nelson Basin

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THE 711,000 SQUARE MILE MACKENZIE DRAINAGE SYSTEM

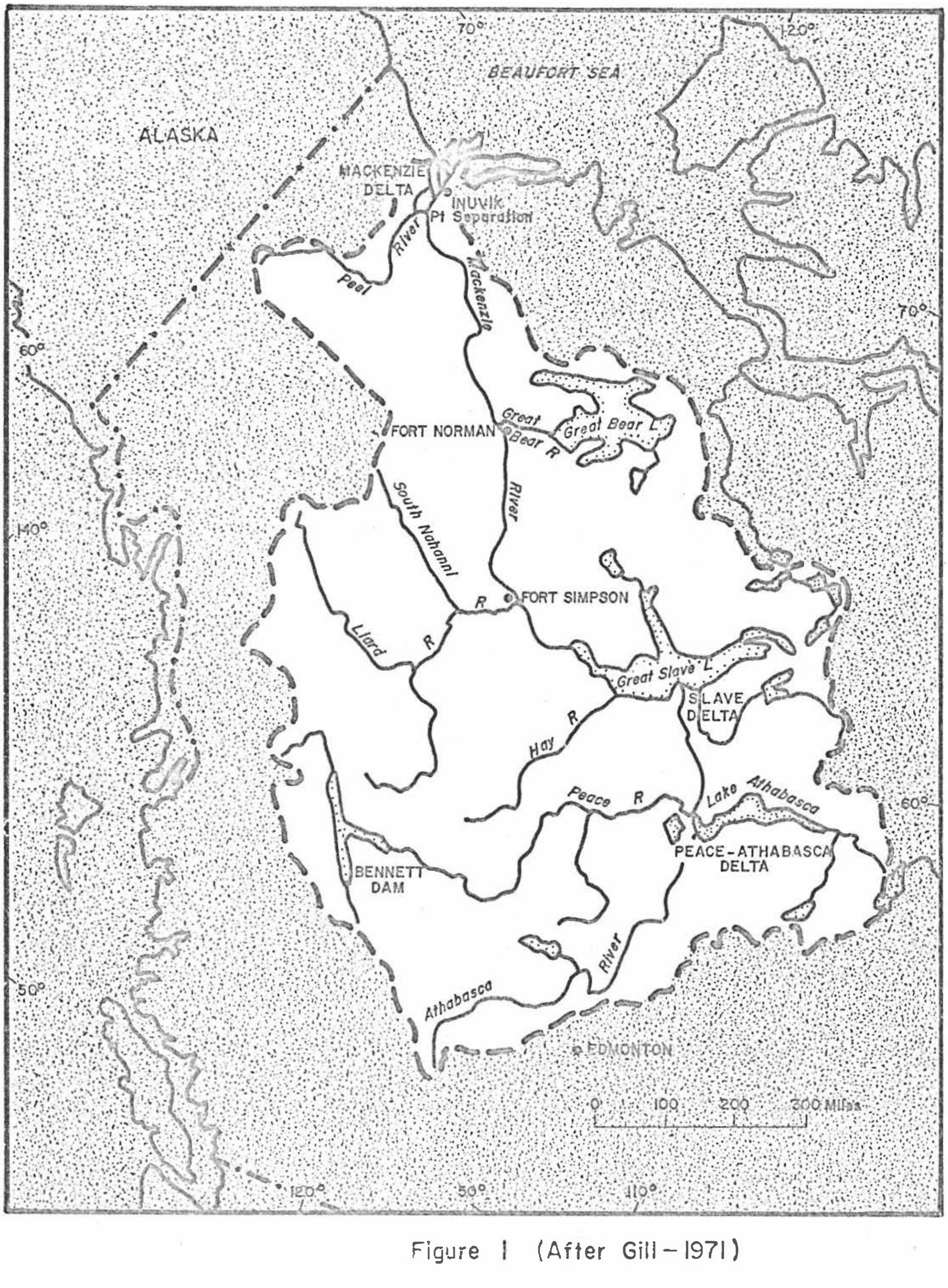

Figure 1 (After Gill - 1971)

INTRODUCTION

The Grand Replenishment and Northern Development Canal was proposed by T.W. Kierans of Sudbury, Ontario in 1959 (see Western States Water Council-1969). That was not the first diversion of Canadian water resources proposed; several are listed by Quinn (1970), but it appeared to bring in its train other proposals of various sorts, culminating in the massive engineering works that the Parson's Company of Los Angeles envisaged to move Alaskan and Yukon water to California.

Because of the magnitude of the concept and the international aspects thereof, a great deal of public interest was engendered. A former member of the International Joint Commission A.G.L. McNaughton (1967) blasted it as "a monstrous concept - a diabolical thesis", whereas W.R.D. Sewell (1967) called the NAWAPA scheme exciting and imaginative saying that "It illustrates the twentieth century emphasis on the application of technology on a massive scale to solve human problems".

The appearance of those water management schemes in the news media brought forth similar schemes that had been in gestation for various periods of time, and were of varying technological excellence and public acceptability. The Alberta Prairie Rivers Improvement and Management Evaluation (PRIME) program was only one of a number of schemes which sought to employ technology on a massive scale to solve human problems. The Alberta Water Resources Division (1969) did a valuable service by collating and publishing details of a number of water diversion schemes that would move water through massive engineering works from Canada to the United States, and even to Mexico. Central in most such schemes was the thesis that water flowing northward is wasted water because fewer people live in the north country (See Quinn, 1970). If somehow the flows could be reversed the deserts could be made to blossom and all manner of pollutants could be diluted.

Untoward ecological effects of river diversions are latterly of considerable public concern. A recent example of failure to appreciate public attitudes in the water resources sector was the confrontation between the Manitoba Hydro Commission and the public of that province over the proposal to raise the level of South Indian Lake in order to store water for power generation.

Perhaps the other most cogent example of one-sided planning was the construction of the Bennett dam on the Peace River, and the effects that the alteration of riverine flows have had upon the Peace-Athabasca Delta in Alberta, and adjacent portions of Lake Athabasca in Saskatchewan. Many of the conflicts of resource use that have ensued are set forth in the Proceedings of the Peace-Athabasca Delta Symposium published by the University of Alberta (1971). Additional studies to clarify some of the residual problems still are being conducted under the aegis of a federal "Task Force". No doubt its proposals and recommendations will be useful in predicting the ecological effects of some of the engineering projects being studied by the Saskatchewan-Nelson Basin Board.

The Saskatchewan-Nelson Basin Board is conducting engineering feasibility studies for the following diversions from the Mackenzie basin, through several water resource agencies, as indicated.

Diversion	Project	Method
2,000 cfs	Upper Athabasca (Dams and diversions on Pembina at Evansburg, McLeod at Peers, and Athabasca at Old Man Creek). Engineering site studies done by Alberta Water Resources.	Water removed from Pembina replaced from McLeod, water from McLeod replaced from Athabasca, water from Athabasca not replaced.
4,000 cfs	Upper Athabasca Engineering site studies done by Alberta Water Resources Division.	Same structure but removing twice as much water (2,896,000 ac.ft./yr.)
5,000 cfs	Lower Athabasca Diversion Moose Portage Site near Smith. Engineering site studies by P.F.R.A.	Dam for diversion by canal to N. Saskatchewan River.
10,000 cfs	Lower Athabasca Diversion Moose Portage Site (P.F.R.A.)	Same structure but twice as much removed from Athabasca River.
10,000 cfs	Smoky River Diversion near Watino. Engineering site studies by P.F.R.A.	High dam with gravity flow or low dam with pumping. Canal to Lesser Slave Lake.
10,000 cfs	Peace River Diversion at Dunvegan. Engineering site studies by P.F.R.A.	Dam with pumping only. Canal to Lesser Slave Lake.

* cfs. - cubic feet per second

Total diversions as outlined = 34,000 cfs or 24,616,000 ac.ft./year.

A thorough ecological understanding of the impact of massive water diversions on the biotic environment downstream on the Mackenzie River system is beyond the scope of a brief report such as this. It is strongly recommended that new resources be allocated to thorough ecological appraisals prior to any further reduction of Mackenzie River system flows.

WILDLIFE OF THE MACKENZIE BASIN

There are a number of useful reference books available wherein one may read what plants, forest trees, insects, fishes birds and mammals are to be found in the Mackenzie basin. Not only is there a thriving resident population of wild species but there is a spectacular influx of summer visitors that ranges from humming birds to whooping cranes.

There has not been a census made of the wildlife species within the whole of the Mackenzie basin. British Columbia (1964) once made some useful estimates but other jurisdictions have been more cautious in providing total figures, except in a few instances. For the sake of this discussion, a tally of the total numbers of animals, birds and fishes is less important than a consideration of the ecological framework within which they exist. Because parts of that framework may be altered by any significant water diversion, the ecological aspects will take precedence over questions of total animal populations and biomass. It is felt that the time long since is past when alternatives that involve environmental quality can be discussed adequately in terms of dollars, kilowatt hours, or horsepower. As requested however, at least a preliminary assessment of wildlife values in dollars will be given for 1962-63, a year when comparative data are available.

One expression of the wildlife potential of any area is the extent of use made of it by trappers and hunters. Data for the total use in any one year are not easily forthcoming, especially within provincial jurisdictions, because no record of hunter success is maintained. For management purposes however, a sampling technique is employed which generally gives adequate data.

Table 1 and Table 2 provide a comparison for 1962-63 of the units of fur and large game taken by hunters and trappers within Alberta, B.C. and Mackenzie District of N.W.T. In Alberta most of the fur caught is in the region north of Highway 16 which corresponds roughly with the present Big Game Zone 1. In the B.C. sources, the data are not broken down by districts. In the N.W.T. most of the fur is taken from the Mackenzie basin because most of the settlements are along the river.

The data for big game species are in each case adjusted to include only the Mackenzie drainage basin.

For fur bearers the number of units trapped within the three jurisdictional areas in 1962-63 was 1,528,000 (Table 1). In Alberta, that was reputed to have a market value of $1,825,000, in B.C. $830,000 and in Mackenzie District $695,000; for a total of $3,350,000.

If we assume that half of the fur in B.C. was taken from the Liard River and Peace River drainages then the actual value was $415,000, reducing our total to $2,935,000.

If we evaluate each moose as worth $170, as Pattison (1970) proposed, and each deer or caribou at half that amount, the value of the big game resource was $1,720,000. Thus in 1962-63 the commercial value for the big game and fur resource in the Mackenzie basin was of the order of $4,655,000. It is admitted that the figures could be added together in different ways and different totals might be achieved. In addition to that fact, no data are available for the numbers of waterfowl, and upland

Table 1 - Yield of wild furs from the Mackenzie Basin in 1962-63.

	British Columbia [1]	Alberta [2]	Mackenzie District [3]
Red squirrel	n.d.	799,531	12,199
Beaver	26,529	50,462	8,691
Muskrat	39,811	204,532	193,460
Weasel	10,821	36,547	6,903
Mink	11,896	9,563	9,832
Fisher	605	478	18
Otter	1,363	38	195
Marten	8,099	538	14,414
Wolverine	40	18	33
Coyote	n.d.*	5,086	19
Red Fox	826	509	267
Wolf	n.d.	200	102
Bears	n.d.	108	21
Lynx	12,570	11,251	4,761
Varying hare	n.d.	45,761	n.d.
Skunk	n.d.	18	0
Totals	112,560	1,164,640	250,815

* - no data

1. British Columbia (1964) - Inventory of Natural Resources

2. Data from J. Stelfox (pers. comm.)

3. N.W.T. Fur Export Tax Returns (courtesy H.J. Mann)

Table 2 - Yield of Moose, Deer and Woodland Caribou from the Mackenzie Basin in 1962-63.

	Deer	Moose	W. Caribou
B.C. - Peace River Area [1]	4527	3378	
Alberta - Zone 1 [2]	1281	1993	30
N.W.T. - Mackenzie Dist. [3]	0	1678	300 (est.)
Totals	5808	7049	330

1. B.C. (1964) - Inventory of Natural Resources
2. Data from J. Stelfox (pers. comm.)
3. N.W.T. Hunting License returns (courtesy H.J. Mann)

game birds taken for sport and for food, nor is there information about the moose, deer, and caribou used for food by those northern residents who are not included within the samples of licensed sport hunters. Given time and a satisfactory framework for collecting and analyzing the data, more accurate figures could be arrived at. Such figures would indicate that the partial cost estimates presented here for 1962-63 are too low. Although all provincial jurisdictions maintain wild life statistics their frame of reference often is different for each, so comparisons become difficult. The Northwest Territories collects royalties on furs exported, but Alberta and B.C. do not. Provincial jurisdictions require residents as well as visitors to purchase licenses to hunt and fish. The same practice is not universal in the Northwest Territories.

In the British Columbia sources quoted the statement is made that nowhere in the province have hunters been able to harvest the annual increase in the stocks of big game (page 566). The same conclusion was reached by Pattison for moose in the northern half of Alberta. Probably a similar situation exists with regard to the fur on registered trap-lines in the two provinces. It is well known that although the fur potential of the Mackenzie District is heavily utilized near the settlements, large areas away from the major waterways are seldom visited.

The wild life resource now contributes importantly to the northern economy and has the potential to provide a great deal more, given greater effort on the part of the trappers and hunters. Obviously it is a resource with a great deal of potential for the future. It is a resource worth managing and cultivating for the variety and interest that it can contribute to the northern landscape, as well as for the economic values that are more usually regarded as paramount.

There are some useful conclusions to be drawn from provincial government sources with regard to the value of the major water courses to big game species in Alberta. Stelfox (1966) compared the numbers of moose seen on straight line flight transects with those seen along valley bottoms in winter. In flying wildlife transects over 80,000 square miles in north-western Alberta he saw an average of 1.3 moose per square mile, with a density range of 1.0 to 2.5 per square mile. When he followed valley bottoms the incidence of animals increased four-fold as follows:

Peace River	7.5	moose per square mile
Clear and Notekewin Rivers	4.3	" " " "
Big Smoky River	4.0	" " " "
Wapiti, Narraway and Kakwa Rivers	5.5	" " " "
Simonette and Little Smoky Rivers	3.1	" " " "
Average	4.9	moose per square mile

On other straight line transect flights in which moose, elk, and deer collectively were counted the average was 3.5 animals per square mile, compared with 11.8 animals per square mile in selected valley habitat on the Pembina, Brazeau and Elk Rivers. Those data are convincing evidence of the value of the valley floodplains in supporting the larger ungulates, especially in winter. The animals resort to those areas for shelter and for the less onerous snow conditions, but especially for the shrub and hardwood browse species to to be found growing there. The browse species usually are associated with an early seral stage of plant succession.

Another important contribution of river valleys to wildlife is their use as migration routes by wild fowl. A river represents an avenue of continuous habitat for waterfowl, and in addition, by showing some of the earliest open water in spring, provides safe resting habitat for migrating flocks. The sandbars and mudbars are especially important to swans, geese, and shorebirds, as may be noted in the appropriate maps and booklets of the Arctic Ecology Map series (1971) published by the Canadian Wildlife Service. Geese and swans resort to mudbars for the grasses and horsetails that constitute an important food; other species are attracted by the protection provided by the open space. On northward flowing rivers like the Peace, Athabasca, Slave and Mackenzie whose courses are aligned with migration routes for many species of bird life, the production of new mudbars and gravel flats by late spring floods renews the kinds of habitat on which the birds depend. Should a situation arise wherein spring floods are greatly reduced or eliminated such habitat would rapidly be overtaken by copses of willows and poplars, and eventually by spruce forest. That kind of habitat is not attractive to aquatic bird life.

Although habitat requirements of beavers will be discussed under sections dealing with the large deltas in the Mackenzie River system it may be mentioned here that beavers are creatures of floodplains in our northern regions because rivers represent not only a pathway for travel but have abundant food in the form of aspen, poplars and willows. Beavers inhabit the Mackenzie basin from its headwaters to its terminus, although they probably have been displaced from the 680 square mile Williston Reservoir in B.C. because of the extreme variation in water levels and the flooding out of food sources.

This last problem is considered by Welch et. al. (1966). Those authors state (page 23) that muskrats and beavers are placed at an extreme disadvantage by fluctuating water levels, particularly where drawdown occurs in late winter and spring, when the already scarce food sources are destroyed and lodges marooned. Although they were speaking of the situation that could develop on the South Indian Lake Reservoir in Manitoba, the problem is no less real for other areas of Canada. Of special interest is the water regimen that is created below impoundments, or along diversion channels, wherein water levels continue to increase from early winter until spring as water is released, for power generation as on the Peace River, or for industrial and domestic use.

In a northern climate aquatic animals are suddenly confined to a particular habitat by a layer of ice. Whether that habitat represents a secure haven or a prison depends upon how generously the requirements for space and food are provided for. Beavers often build dams to maintain water levels in the lakes or streams they occupy, constructing therein a lodge or bank den and sinking into the mud a store of tree branches to serve as food over winter.

Muskrats also build houses or bank dens and although they do not store food they have developed their ingenious feeding lodges on the ice to make the food growing on the lake bottom more easily available to them. Beaver lodges, feed-beds and dams are completed by late autumn to accord with the low water conditions that usually prevail at "freeze-up". Muskrat lodges and bank dens also are constructed under the influence of slack water conditions of September and October, but muskrats have no means of influencing water levels by dams so they are more at the mercy of water fluctuations. In either case, the rise in water levels after freeze-up drowns the animals caught under the ice, or forces them to escape. Being aquatic animals they cannot survive the rigours of our northern winters and once out of their usual environment they quickly freeze or fall prey to predators. Rising water levels then can be just as damaging to aquatic fur resources as the falling levels that Welch spoke about.

There is another phenomenon in northern areas that is known to local people as "overflow" and to glaciologists as "aufeis". It is the extrusion of water from below an existing ice surface and its mixture with snow layers to form a slush that quickly freezes. In many alpine and northern streams the depths of ice that can be built up by this method are quite impressive, and often their persistence into summer attests to their mass. The formation of aufeis depends in part upon streams freezing to their beds at some point and then the unfrozen water behind spilling out over the surface and freezing in successive layers.

To the trapper or northern traveller the presence of overflow on lakes and rivers is a great inconvenience because it adheres as ice to the webs of snowshoes, the running surface of sleds or the tracks of oversnow vehicles. It also freezes shut the plunge-holes in muskrat push-ups and makes trapping activities much more difficult, if any muskrats survive.

In as much as the regulation of northern rivers is a stated intention of several hydropower and water management agencies the effects of significantly increasing winter flows in northern rivers should be investigated, not only for the deleterious effects to wildlife and fish resources but also for the impact on northern transportation, ice thickness and on the dates of break-up of the river ice. That these problems are not always fully appreciated is shown by the statement of Coulson (1969) that increased winter flows are beneficial.

DELTAS OF THE MACKENZIE BASIN

It is axiomatic that wild animals cannot persist outside the protection and sustenance of a suitable habitat. Changes in wildlife habitat may be dramatic, as outlined by Dirschl (1970), but more usually they are gradual and it takes time to observe their effects upon the wildlife involved. Most studies of individual species in the boreal forests of the Mackenzie basin have been done under the natural regimen of soil, climate and waterflow that was established after removal of the last Pleistocene ice sheet. Anticipating trends in the accommodation of plant and animal communities to new sets of conditions can be tentative at best, and calls for the kinds of speculation that usually are frowned upon in scientific endeavor. To make what follows in this report scientifically respectable would require the inclusion of much more data, which only can be collected over time. Yet when faced with problems which are new and unique in our northern climate, some conclusions have to be drawn from too few data. We may never have all the data we need, but the present dearth of biological information clearly indicates that more study must be done if the ecological consequences of turning Mackenzie River water southward to the heavily populated heart of the North American continent are to be predicted.

Hydrological data available are insufficient to make valid judgements about the extent and duration of flooding on the floodplains of the Peace, Athabasca, Slave and Mackenzie Rivers. A few clues to the timing of the floods are available in published and unpublished literature but more needs to be learned by the establishment of more gauging stations. There are no data available for the lower Slave River, the lower Liard River, nor the Mackenzie River beyond Ft. Norman. As will be pointed out hereunder, the exceptional high water situations are valuable to the northern eco-system, not only to fill basins and flush out the products of organic decay, but also to add a vital layer of calcareous silt to lakes and floodplains.

In the published literature there are few studies that report on the withdrawal of significant amounts of water from river basins. Curiously, the studies done of the proposed diversions from the Churchill River in Manitoba were almost entirely concerned with the delterious effects of flooding South Indian Lake on the fish and wildlife, and the trapping economy of the local people. Only passing mention was made of the drastic decline in flows of the Churchill River below the dam at Missi Falls.

Because deltas are the portions of a watershed having the richest and most varied flora and fauna, the following portions of this report will deal specifically with the three largest deltas in the Mackenzie basin; the Slave Delta, the Mackenzie Delta and the Peace-Athabasca Delta. Information about conditions on floodplains of northern rivers, such as the Peace and Liard Rivers, will be referred to in order to clarify and amplify ecological conditions to be encountered in those deltas.

Many wildlife studies to date have been done in deltas because of the concentrations of animals there. Some particularly valuable and pertinent studies currently are being done in the Peace-Athabasca Delta, and some preliminary results already are available and will be referred to. The concentration of investigative effort there in the past few months should be looked upon as a measure of the scale of effort that needs to be expended to understand the dynamic processes of complex ecosystems, even in a comparatively small part of a major river basin.

Slave River Delta

Following the removal of the last Keewatin ice sheet a long arm of Great Slave Lake extended southward almost to the present site of Ft. Smith on the southern boundary of the Northwest Territories (Raup 1946). Since that time water levels in Great Slave Lake have fallen from the 700 foot level that Raup quoted, to the present summer level of about 515 feet. The long lacustrine estuary that stretched almost 200 miles southward has been filled in by water-borne sediments, and the Slave River has now encroached upon the lake, where it is rapidly laying down a typical delta. Although the present delta is only about 60 square miles in size, adding thereto its antecedent portions would make it almost comparable in area to the Peace-Athabasca Delta to the south.

Law (1950), who spent the summer of 1949 in the Slave Delta studying the biology and habitat requirements of the muskrats, provides a description of the plant communities there. Preble (1908) previously had recorded a traveller's view of the waterway from Ft. Smith and noted that "the narrow channels through which Slave River enters the lake are disposed along a distance of over 20 miles of its coast line. Many of these channels are so shallow in times of low water as to be almost unnavigable even for canoes, and even in the main channel the 6 feet of water necessary for the passage of the Wrigley is sometimes found with difficulty. The alluvial islands which are inclosed by these channels are low, and are mainly covered with grasses and willows. Toward the head of the delta the islands are older and higher, and have become clothed with willows, poplars and spruces, in varying degrees of combination, according to the age of the island."

Law (op. cit.) also noted that within the more recent and active portions of the delta no spruce were to be found. Soper (1957) who, as a migratory birds officer, made several visits to the delta over 20 years, recorded similar observations about the unforested nature of the lower delta. One general conclusion to be drawn from these observations is that the process of delta building is proceeding very rapidly, and that natural plant succession is able to clothe the land with forest only as conditions for spruce regeneration become suitable. In Law's report is a sketch map of the changes in delta configuration between the years 1942 and 1949. Without base data as to water levels during these two years, it is difficult to judge whether Law's extensions of mudbars by a mile into the lake are valid, but generally Great Slave Lake levels are stable, so some credence must be given to his observations.

Like the other major deltas along the Peace-Mackenzie waterway the Slave Delta is a dynamic system and supports a varied fauna and flora. Raup (op. cit.) provided a listing of the major plants in successional growth on the alluvial flats, starting with willows (Salix) and commencing through alders (Alnus tenuifolia) to balsam poplars (Populus balsamifera).

The poplars in turn provide shade and protection for the establishment of white spruce (Picea glauca), which eventually emerges as the dominant species. Others who have made similar studies in the region in question include Lacate, Horton and Blyth (1958), Jeffrey (1961, 1964) and Wagg (1964). Although they mainly were interested in forest growth on the rich alluvial floodplains of the Mackenzie lowlands, they all agreed that the major route whereby boreal spruce forests became established is through the primary successional stages that Raup outlined. Once established, fire, lumbering and windthrow might exert a major influence on forest replacement, but that was another problem. Wagg especially described the role that alluvial deposits played in forest regeneration, and Robinson (1967) was of the opinion that viable spruce forests could persist on floodplains and grow to maturity only if periodic flooding and siltation occurred. Such flooding removed the insulating layer of mosses (especially Hylocomium), that raised permafrost levels beneath the spruce canopy. Flooding also provided a layer of mineral soil whereon spruce seeds could germinate and become established. Wagg (op. cit.) commented that primary invaders on alluvium, notably the horsetails (Equisetum), played an important role by protecting white spruce seedlings from insolation. He stressed that one reason species like spruce, willows and horsetails are able to resist burial by successive alluvial deposits is their ability to produce adventitious roots further up the stem. He noted that jackpine (Pinus banksiana), occupied only the drier sites because it grew from a tap root, and did not have such flexibility of growth pattern.

It was Robinson's contention that, in the northern boreal areas, forest sites will naturally degrade to poorer growing conditions, unless such natural events as fires or flooding interpose to stop or to reverse normal succession. His ideas are in part supported by Benninghoff (1952) and Viereck (1970) in Alaska and certainly require more study, if only to develop better forest management methods.

It is unfortunate that actual figures for flows and stages within the Slave Delta are not available at this time. At Fort Fitzgerald it is suggested that the control of flow by the Bennett dam, coupled with the proposed diversions of 30,000 cfs out of the Mackenzie basin would reduce the mean monthly stage level by only 2 feet, from 25 to 23 feet in June. Although Fort Fitzgerald is the nearest gauging station to the Slave Delta such average figures are difficult to evaluate because they provide no indication of the timing or amounts of maximum flows by year, nor over time. As Brown (1971) has stated, river channels are carved and structured by periods of peak flow of high frequency, not by average or low flows. Floods with their quickened current and high sediment loads represent the vitality of rivers; the yearly renewal to their life systems.

Assume for the sake of argument that a combination of water control structures on the Peace River either store or divert most of the flood waters that normally impinge upon the Slave River Delta. Simultaneously, a situation can be envisaged wherein most of the Athabasca River flood waters were being stored in Lake Athabasca and adjacent delta water bodies to restore their depleted levels. As a consequence only a minor rise of the Slave River above the winter stage levels would be allowed. Experience in other places indicates a few trends that might develop in the flora and its associated fauna as a consequence. Law's (1950) study of muskrats will provide a few clues, as will Soper's (1957) observations on birds.

Like the muskrats of the Mackenzie Delta, those in the Slave Delta do not build winter lodges of vegetation. Whether there is a lack of suitable plant material or whether some behavioral cause is paramount, all animals live in dens dug into the banks of lakes and channels. The food they eat yearlong must be found in the vicinity of a suitable den, and the water must be deep enough to preserve the right kinds of food over winter, when ice forms on lakes and channels. Law suggested that water bodies less than five feet in depth were not suitable for muskrats, and that there was a definite relationship between water levels and muskrat populations. He said that "moderately high and stable levels over the fall and winter make the maximum amount of food available and prevent freezing to the bottom". Although muskrats lived in slack channels, they also lived in lakes on the delta islands so unless water levels were raised sufficiently to flood such sites they would present insecure habitat, and likely would change markedly in chemical composition and floral structure over time.

Soper (1957) observed that the Slave Delta, being the largest such habitat between the Peace-Athabasca Delta and the Mackenzie Delta, was attractive for thousands of wild fowl that fed and rested there on migration. Although some birds stayed to nest, the majority moved on northward. Those spring migrants included not only ducks but also thousands of geese that fanned out from that dispersal point as far west as the Mackenzie Delta and Yukon coast, and as far east as the Perry River.

Most of them funnelled back through the delta in the fall. According to Soper the feeding and resting sites for geese "are not in the wooded depths of the area along the streams, but spectacular concourses assemble on the mudflats and sandspits from Nagle Bay northeast to Stony Island and beyond".

For both muskrats and waterfowl the preferred habitat in the Slave Delta is the newer habitat at the primary levels of succession; habitat that is maintained at such early stages by flooding and sediment deposition. Similar situations obtain on the other large deltas and will be expanded upon later. It seems safe to say however, that if yearly flooding were reduced significantly, or if high flows were eliminated, there would be a bolting of the ecological complex toward a white spruce forest that eventually might be replaced by black spruce muskeg, as Robinson (1967) suggested.

Although there is little timber extraction along the Slave River currently, there were several saw mills operating there at one time, and they would operate there again. Earlier Robinson (1960) had suggested a reservoir of 85 million f.b.m. of spruce along the Slave River, admitting that as a commercial product it lacked a ready market. However, much local lumber was used in the construction of Inuvik, and larger demands could be placed upon timber resources in any scheme to build major railroads or pipelines in the north to transport minerals and petroleum products.

At the time of Law's study, trapping was the important source of income for the people of Fort Resolution. Aquatic furs such as beaver, mink and muskrats represented a major portion of the catch, with muskrats sales varying from a high of 75,000 pelts, to as few as 5,000. Although trapping generally has declined in importance since 1950 it still represents an alternative to welfare subsistence for people without wage employment. It still has a place in northern communities.

Mackenzie River Delta

Just as the Mackenzie River is the longest in Canada so is its delta the largest. If one considers the outer islands as forming a part of the delta then the total area is 4,700 square miles. Probably no area in northern Canada has received so much study as the Mackenzie Delta, considering that continuous European residence there dates only from the establishment of the fur trading post at Ft. McPherson in 1872. Aklavik was established in 1924 and Inuvik in 1961. A recent bibliography of the delta by Jones (1969) runs to 478 titles and like all such publications it already is out of date. Aside from the fur trade, which has waxed and waned over the years, there have been specific events of news that have focussed attention on the region, and may thus have contributed to the increase in research activity there. A few might be mentioned: the gold rush of 1898 which brought people to the delta enroute to the Yukon, the Stefansson-Anderson western arctic expedition of 1908-1911, the hunt for the "mad trapper" Johnson on the Rat River in 1931, the establishment of a government reindeer herd in 1935, the establishment of a Loran navigational station in 1947 and construction of the Distant Early Warning line in the 1950's. Those and other events are outlined in publications by Bissett (1967), Mackay (1963) and many others. There now is a northern research laboratory at the new town of Inuvik, a settlement that has become increasingly important to the exploration activities of oil companies.

The waters of the Liard and Mackenzie Rivers join at Ft. Simpson and with additional flows from minor distributaries spread out at Point Separation into a vast delta that is a maze of channels, lakes, islands, and marshes. Because of the rich alluvial deposits, and because of the ameliorating influence of the river in an otherwise severe climate, the upper two-thirds of the delta is clothed by white spruce and balsam poplar. The whole of the delta however is overgrown to the Arctic Ocean with willows and alder, in association with numerous heath species and aquatic plants. Porsild (1943, 1955, 1957) Cody (1965) and Hulten (1968) have all provided authoritative information about the botany, and additional work has been done by others. Mackay (1963) has provided an excellent account of the physical geography of the delta and its vicinity and his studies have formed the basis for additional work by such of his students as Stager (1956), and Gill (1971a).

Mackay (1963) stated that the growth of white spruce is confined to the levees along the delta channels. Where the elevation of such levees is less than 10 feet above low water, spruce do not find conditions suitable. In the upper half of the delta the floodplains are 20-30 feet above low water but levees as such are lower. All of the delta is subject to flooding and the amount of silt laid down during especially high water levels can be of the order of several feet, though usually it is less. Ice jams at break-up in spring are partially to blame for the unusually high water levels. Henoch (1960) observed that maximum flood heights of 20 feet had been observed on the Peel Channel in the upper delta, grading to 22 feet on the Husky Channel near Aklavik and 8-12 feet in the lower delta. The flood waters are distributed more effectively by the many channels near the ocean, and the lakes have lower shorelines.

Mackay differentiated 5 kinds of lakes in the Mackenzie Delta, but categorized 90 per cent of them as floodplain lakes. Such lakes were formed behind channel levees. Because levee deposition went on more quickly than infilling of the adjacent lakes, the floodplain lakes could become fairly deep, most having connections to the channels, but others having none. The incidence of such lakes in the Mackenzie Delta must be seen to be appreciated. Measurements by Mackay showed that 30 to 50 per cent of the surface of the delta was comprised of lakes.

Although the process of channel shifting appears to be rapid, being accomplished not only by flood waters but also by the melting of permafrost in the banks, observations by Giddings (1947) showed that spruce trees could grow to 300 to 500 years of age. Stands of 200-300 years on both sides of a channel attest to the age of some of the waterways. Deposition of sediment may be largely local, with the material deposited on point bars being carried from the upstream side of the meander curve. This requires high water levels to accomplish because for most of the ice-free period the sediment load of the Mackenzie River is reasonably low.

The aquatic habitats of the Mackenzie Delta are the most productive areas for wild life. Although the region lies one hundred and fifty miles north of the polar circle the climate is such that species of animals occur there that could not persist at those latitudes were it not for the protection they received from the water in which they live. As already stated, coniferous trees and hardwood trees like poplar also are able to flourish within the deep incursion of temperate conditions represented by the Mackenzie Valley.

Two aquatic fur species will be dealt with in detail to indicate how they are dependent for their existence on particular components of their habitat, and how their numbers would be seriously reduced if conditions changed appreciably. These two species are the northwestern muskrat (<u>Ondatra zibethicus spatulatus</u>) and the northern beaver (<u>Castor canadensis</u>).

<u>Muskrats</u>: Preble (1908) noted on his descent of the Mackenzie River that muskrats were excessively abundant on the lower reaches of that river and the Arctic Red River. Thousands were traded at that time at Ft. McPherson and the Eskimos were very skillful in taking them with throwing darts and bows and arrows. Anderson (1937) said that the best muskrat areas in the Northwest Territories were the Slave Delta and Mackenzie Delta, and that their furs formed an important component of the fur trade in those districts. Porsild (1945) was able to make more extensive observations in the delta during the time he was resident at the Reindeer Station between 1927 and 1935. His observations formed the background for later studies by Banfield (1946), Cowan (1947) and Stevens (1953, 1955). During Porsild's stay in the area the local people had few other sources of income, so trapping was a major occupation with them.* Muskrats represented not only a cash income but, together with the returning waterfowl, a very important food item at a time of year when everyone was heartily sick of subsisting on snowshoe hares. For a long time the delta people have made excellent parkas from muskrat skins and more recently their experience has been turned to commercial use with the establishment of a

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* In 1945-46 sales were 344,000 pelts when the average price was nearly $3.00; by contrast, in 1968-69 sales of muskrats pelts in the Mackenzie Delta were 221,000; average price about $1.00.

fur garment industry at Inuvik and Tuktoyaktuk.

Porsild observed that the distribution of muskrats was closely tied to food supply, and that only lakes with abundant aquatic vegetation and depths of over 12 feet of water could support muskrats over winter. Subsequent studies by Stevens (1955) confirmed the need for a plentiful food supply but demonstrated that a lesser water depth was required because for most years ice depths on delta lakes correlated inversely with snow cover, and seldom exceeded three feet. Enough water had to be available beneath the ice to allow the muskrats to move about and to protect their food supply from freezing. If the water in lakes was too shallow, the muskrats were either forced out, starved, or had a very thin time of it over winter. Rodents are extremely adaptable and tenacious but some of the miserable specimens trapped from shallow lakes by trappers during April and May showed the effects of a poor winter environment. Such muskrats were called "paper rats" by the local people because their pelts were so thin and under-prime as to be unsaleable.

Stevens (1953) suggested that ideal water depths for muskrats were in the range of 6 to 10 feet in late summer. He found that portions of lakes deeper than 10 feet did not produce enough of the preferred plant foods to support muskrats during winter. Because most of the lakes froze over in October and did not thaw until June (8 months) the winter food supply represented the critical factor in muskrat survival. All muskrats lived in bank dens and constructed small feeding lodges on the ice. Those feeding lodges, called push-ups were used as a sanctuary where the animals could feed on the stems and roots of submerged plants that they had retrieved from the lake bottom. Those plants included several species of pond-weeds (Potamogeton), water-milfoil (Myriophyllum exalbescens), with lesser amounts of duckweeds (Lemna) and water arum (Calla).

Food plants used in summer were in part a reflection of availability, and in part a matter of preference. By far the greatest use was made of lakeside stands of horsetail (Equisetum fluviatile) that flourished in all alluvial situations, and was one of the earliest species available to muskrats. Sedges (Carex), water oats (Arctophila fulva) and bur reed (Sparganium hyperboreum) also constituted important items of summer diet.

Cowan (1948) noted that in lakes that flooded regularly an alluvial type of plant succession occurred. Pond-weeds and water-milfoil were co-dominants in deeper water and bur reed, horsetail and water oats grew in shoal areas. In lakes that did not flood the shorelines were sparsely vegetated, with Carex aquatilis being most abundant in shallow areas, and bog species such as marestail (Hippurus), buckbean (Menyanthes) and water arum (Calla) replacing the pond-weeds and duckweeds in deeper water.

Studies by Stevens (1955) and Hawley (1970) have shown the unflooded lakes to be less productive of muskrats than the alluvial lakes. There are several reasons, but the chief ones are that the former provide less food in summer and winter, break-up later in the spring, and because of their steep banks, are less preferred for the tunnelling that is entailed in muskrat den construction.

Gill (1971a) has shown that the most abundant species of horsetail (Equisetum fluviatile) grows only on silty loam or loamy soils and that those soils are produced by current sorting of the sediment load.

Such soils are to be found most commonly behind point bars on shifting channels, and beyond channel levees in flooded lakes. Two factors favoring the growth of horsetails are their requirement for an alkaline soil, and their marked ability to survive burial by alluvium.

The Mackenzie Delta is the most northerly area of muskrat abundance in Canada. Stevens (1955) found that the animals were physiologically capable of breeding in spring almost a month before the ice cover was removed by the floods of late May. As a consequence, only one litter of young was produced by most females, although older animals which had bred the previous year might produce two litters. Delay in break-up by decreased water flows of the Mackenzie River or by cold and overcast weather could delay the breeding season, and perhaps eliminate the second litter. It was also found that young muskrats from late litters had a lower survival rate, and that any animals weighing less than 300 gm. in September probably did not survive until spring.

Buckley (1954) noted that low fall water levels in Alaska provided less initial habitat and thus crowded more muskrat together to subsist on a reduced food supply over winter. Stevens (1953) observed that a late break-up of the Mackenzie River and the associated delta lakes reduced the availability of muskrats to the local trappers, who shoot most of their muskrats after open water appears.

Gill (1971b) has postulated that spring floods remove the ice cover from lakes and channels in the Mackenzie Delta and provide a flush of warm water which removes the snow and rapidly reduces the albedo of the whole delta, allowing it to warm up quickly. Anyone who has experienced the phenomenon realizes the dramatic changes that take place at break-up of the winter ice. Gill postulated rather dire consequences to the delta if water control structures should delay the rush of the spring floods. He concluded that:

1. The Delta's mesoclimate during spring and early summer would be cooler.
2. Soil temperatures in the delta would be lowered.
3. Permafrost conditions would spread over a larger area.
4. Plants which tolerate cold, wet and acidic soil conditions would succeed the mesophytic species that now dominate.
5. Wildlife species such as waterfowl, beaver and muskrats would lose much of their preferred habitats.

Plant succession as described by Gill proceeds from horsetails and willows (Salix alaxensis) on new point bars, through alders (Alnus crispa) to balsam poplar (Populus balsamifera) and eventually white spruce (Picea glauca). Because succession of woody plants is especially important to beavers, it will be referred to in the following section.

Beavers: During the period that he was in the Mackenzie Delta area (1927-1935) Porsild (1945) saw few beavers, despite the fact that the species was being given rigid protection. He postulated that eventually the region should be able to support a fairly large population of beaver, and that situation has come about. Studies by Hawley (1968) suggested that there were between 1,600 and 2,000 colonies of beaver in the delta and a yearly trapping quota of 4,000 animals has been allowed. In 1968 there were 907 beaver taken from the delta and in 1969 there were 1,181, at an average return of $13 per pelt. Most of the animals taken were shot after break-up because few people understood how to trap them, and as a consequence, the dollar return was lower than it might have been otherwise.

Aleksiuk (1968) studied the energy requirements of beavers from the Mackenzie Delta. He found that their food consisted of willow, poplar and alder in that order. Willow predominated because of its abundance in the habitat, but poplar was heavily utilized where it was available. Gill (1971c) stated that the coarse-grained deposits on point bars in the delta have a lower water content and a higher soil temperature than other deltaic surfaces, and that nearly every point bar is colonized by a distinct ecosystem dominated by balsam poplar. Behind the point bars are current-initiated meander scroll depressions, usually much grown up to willow and alder. Those sites are colonized by beavers which dam up the outlet, construct a lodge, and use the available poplar and willow for food. The colony persists until food supplies dwindle, after which it finds a new meander scroll depression.

Although Hawley believed that the available habitats in the delta were becoming fully utilized by beavers, the creation of new habitats by yearly floods, and a realistic trapping program to prevent over-population should maintain a valuable source of income for the local people. The important variable in the life equation that produces beavers at these latitudes is the continued renewal of their primary habitat by river flooding.

Waterfowl: The many species of wild fowl that migrate yearly to the arctic regions do so in order to rear their young and certainly some of the largest and most diverse habitats for migratory waterfowl are the deltas of the Mackenzie River drainage. Smith (1964) considered the large northern deltas of Canada especially productive for waterfowl at times when more southerly regions suffered lessened habitat because of drought. Porsild (1935) provided some of the first quantitative assessments of the value of Mackenzie Delta as a breeding ground for waterfowl. He also noted the value of the delta as a resting and feeding area for geese and swans enroute to and from more northerly breeding grounds. To one who has been in the delta, there is no more oustanding harbinger of summer than the seemingly endless skeins of whistling swans against a cloudless sky.

Cowan (1948) found that the number of waterfowl had decreased markedly from the period fifteen years earlier that Porsild had described. The following year (1948) the U.S. Fish and Wildlife Service extended its breeding ground surveys to the delta region and for the first time factual counts on aerial transects gave data for assessing breeding success of the migrant waterfowl. Those counts have been continued since that date and form a valuable record of waterfowl populations and their dependence upon the far northern breeding grounds. Smith (1964) reported that aerial surveys revealed breeding populations as high as 335 thousand ducks in the Mackenzie Delta, with additional nesting colonies of snow geese and whistling swans. One snow goose colony now is protected from disturbance by the Kendall Island migratory bird sanctuary at the foot of the delta. Ducks resort to the delta because of the rich food supply represented by an abundant insect fauna for the young and high energy foods like the pond-weeds for the adults. Concentrations of birds in migration are to be found on the mudflats and river bars or in the lakes with preferred foods. As pointed out previously, those foods flourish only in lakes which flood periodically and possess an alluvial basin. There is no doubt that changes in plant succession caused by reduced water flows would hasten the growth of willows on the mud banks and spruce on the levees, with the result that food and habitat would be reduced for the migrant species. For many species of waterfowl that breed in the delta, especially the ducks, a change in lake chemistry from eutrophic to dystrophic conditions would make lake habitat much less appealing. It would however, favour species such as loons and grebes.

Other Species: As Gill (1971b) mentioned, alteration in riverine flow rates could benefit some wildlife species such as lynx, foxes and moose; but it would not be of benefit to muskrats and beavers. Nor would it benefit the mink, an important fur resource, that depends for its food upon muskrats, meadow voles and fish, as studies by Burns (1964) in the Yukon Delta of Alaska have shown. Mink are one of the more important fur resources of the Mackenzie District and 2,647 were shipped as fur from the delta in 1969-70. The habitat and food of mink are found on lake shores, most often associated with the early successional sere comprised of horsetails, carices and grasses. Their dens are usually dug under the root systems of willows where there is a deeper active permafrost layer than under spruce cover. Maturing of the vegetational complex would be to the disadvantage of mink, because few animals are to be found away from the active river channels.

Moose and hares depend for their winter food upon willow twigs, and inasmuch as the lower third of the Mackenzie Delta contains vast willow flats, they find conditions there especially suitable. Hares however, exhibit cyclic populations and when they are numerous they strip the bark from willows over large areas. Historically they were the staple winter food for the Indian communities along the Mackenzie River system, and that dependence is expressed in the naming of the Hare Indians of the Ft. Good Hope region. Moose and hares are abundant on floodplains of the Mackenzie River but find suitable habitat elsewhere, especially in the mixed forest that grows up following fires.

Additional Considerations: Because the Mackenzie Delta lies within the arctic circle, climatic limitations for many life forms are especially critical. Wellstead (1968) in addressing the 19th Alaska Science Conference summarized the observations made by Robinson (1967) in part as follows:

1. The establishment and maintenance of spruce stands on the alluvial flats appears to require periodic flooding. It is probably necessary to have a severe flood to provide a good seed bed, followed by a good seed year.
2. Because decay of surface litter is very slow and bacterial action is limited by the cool northern climate, it is quite likely that most northern soils lack nutrients in available forms.
3. The key to northern forestry may be the establishment of mixed forests because hardwood litter may help to prevent

moss development (which raises permafrost levels) and will also provide necessary nutrients to the soil.

In regard to the first point Mikola (1970) spoke of the difficulty of obtaining a sufficient seed fall in northern forests of Europe and says that:

> "Since the maturing of seed depends only on summer temperatures, the continuous existence of forests in the northern timber-line region is determined by how often summers recur which are sufficiently warm for seeds to reach maturity. Consequently even slight climatic fluctuations may cause an advance or retreat of the forest limit."

Although this matter has not been investigated in northern Canada, the effects of cooling of the mesoclimate by water control structures such as Gill (1971b) spoke of, must be considered.

Also of particular importance in Wellstead's second statement is the need for <u>severe</u> flooding. A complete inundation with the deposit of alluvium, the dilution of acidic organic compounds and the filling of perched basins is required to maintain the fertility of floodplains and prevent the establishment of muskeg conditions.

Mixed forests may be established following harvesting or burning, but the route by way of natural succession is the most usual one in northern regions. In as much as trees of merchantable dimensions are confined to floodplains in the Mackenzie lowlands, the value of the latter method of maintaining mixed stands becomes apparent.

To anyone who has lived along the Mackenzie waterway one of the most dramatic natural phenomena is "break-up"; the flushing out of the winter ice cover. Although many people have watched the process it has been only recently that someone has studied it in any detail. Henoch (1960) made observations of the interaction of the Mackenzie and Peel Rivers at break-up. He noted that the height and extent of flooding is related to the spring break-up of river ice; rather than to precipitation, and that ice jams are important in producing high flood levels. A peculiarity of the arctic flowing rivers is that their headwaters and tributaries break up first, and this accumulated flow raises the river ice downstream and flushes it seaward almost a month before the adjacent lakes are free of ice. Mackay (1963) and Abrahamsson (1966) have recorded the progress of break-up of the Mackenzie River system, noting that the process involves nearly a month in time from the headwaters to the Arctic Ocean. Because Great Slave Lake represents a sump of cold water in spring the real input of energy into the system must come from the Liard River which not only contributes as much water at that time of year, but also contributes water at a higher temperature (Mackay 1970). One conclusion that may be drawn from that phenomenon is that the Liard River controls the date of break-up in the Mackenzie River and any significant alteration in its flow pattern, such as by damming or diversion, could seriously alter the climate of the Mackenzie Delta. The extent of that alteration should be predictable, following adequate hydrological studies. The northern ecosystem is in delicate balance with the physical components of climate and topography, and the quickest way to upset that system is to seriously alter those components. The major rivers represent an infusion of energy into a climatic region that does not capture and store much energy. If we purposely go about changing that energy flow we must be aware of the consequences, and the costs.

The Peace-Athabasca Delta

There has been a good deal written about the Peace-Athabasca Delta within the last year or two. A public symposium was held in Edmonton in January 1971 to discuss some of the problems associated with lowered water levels in the area subsequent to storage of some of the Peace River waters in Lake Williston behind the W.A.C. Bennett dam in order to turn the generators of the Gordon Shrum power station. The proceedings of that symposium have been published.

The curious hydrological relationship existing between the Peace River and the Athabasca River at the delta was known long ago. Prof. J. Macoun was in the area as early as 1875, and presented as evidence before a Senate Committee considering the Great Mackenzie Basin the following observations (page 37):

> "the Peace River proper does not enter Lake Athabasca, but a large river about 100 yards wide or more, called the Quatre Fourches, connecting the Peace River, does. In spring of the year, when the Peace is high, the water runs out of it via the Quatre Fourches into Lake Athabasca, but when the water is low, the flow is from Lake Athabasca, via the Grand Fourches into the Peace River. There would be no difficulty in a steamboat passing from the Peace to Lake Athabasca via the Quatre Fourches. The real mouth of the Peace is about twenty-five miles below, where it falls into the Slave River. For 200 miles from its

mouth the Peace is a mighty river, 1,000 yards wide, with no bars."

The history of Ft. Chipewyan on Athabasca Lake is presented by Fuller and LaRoi (1971) and will not be enlarged upon here, except to say that the settlement is probably the oldest one in Alberta, dating from 1788. As an outpost of trade and civilization during its early years it became well known and numerous expeditions passed through it, including Alexander Mackenzie's and John Franklin's.

Macoun (op. cit. p. 40) noted that:

> "There is an abundance of timber in the vicinity of Fort Chipewyan on Lake Athabasca. There are as fine spruce in the Athabasca Delta as are to be found in any part of the Northwest. I have measured trees on the Embarras River that were two feet and a half in diameter and very tall. On the Peace River, likewise, especially on islands, there are many large groves of spruce and poplar, which attain extraordinary dimensions."

He made other useful observations about the biology of the area as did Preble (1908), but it was not until Wood Buffalo National Park was established in 1922 that more serious investigations were undertaken, by Raup (1933, 1935, 1946) and Soper (1941, 1942). Since 1947 the federal government has maintained a biologist at Ft. Smith, the headquarters for Wood Buffalo National Park, and studies by Fuller (1951, 1966) and others have been published. In 1967 Novakowski prepared a report of the anticipated ecological effects on the delta following damming of the Peace River.

His conclusions anticipated most of the ecological changes later investigated by Dirschl (1970), Fuller and LaRoi (1971) and Dabbs (1971). Additional field work was conducted in the summer of 1970 by McCourt, and continued over winter by E. Kuyt,,the resident biologist at Ft. Smith, in order to establish the distribution and food requirements of bison. Because the amount of information about the Peace-Athabasca Delta region is becoming voluminous only summary information will be provided here, with the expectation that the original sources will be referred to for more details.

Some preliminary forest surveys were conducted along the lower Peace River in the late 1940's which disclosed very significant stands of white spruce saw-timber on the floodplains. Perhaps because the Peace River ran through Wood Buffalo National Park those stands had been sancrosanct in the past, but during the expansionist era after the war the decision was made to allow sawmills to become established. Lacate, Horton and Blyth (1958) studied forest succession and forest yield on the islands and adjacent terraces along the Peace River. Highest productivity was found on the alluvial floodplains with progressively less timber volume as one progressed away from the river. Decrease in productivity was related first to soil moisture conditions and secondly to the build up of a moss layer on the soil surface. Moss, acting as an insulating blanket, allowed the rise of permafrost under spruce cover, thus inhibiting tree growth and reproduction. Wagg (1964) later demonstrated that most spruce seedlings were dependent upon fresh alluvial deposits or decaying wood for their establishment.

Jeffrey (1961) also had been in the lower Peace River area and his conclusions about forest succession agreed with Raup's (1946), namely, that the forest was established through a vegetative progression, starting with willows on channel point bars progressing through a balsam poplar-alder forest to white spruce-balsam poplar forest and finally to white spruce forest. Lacate and his associates had suggested that fire and windthrow were instrumental in sculpturing the forest complex once it had become established. Fire was most frequent on the older river terraces and produced relatively even-aged stands.

Later Jeffrey (1964) extended his investigations to the Liard River valley and postulated the same route of forest establishment there, commencing with a riparian shrub component followed eventually by an uneven-aged mature white spruce forest, unless fire had intervened in the process.

As has been stated previously, point bars on rivers are laid down during periods of high flow, so we must conclude that without floods there would be a gradual senility of the riparian forests, the only ones that perpetuate themselves without the intercession of fires.

Although the operating schedule of the W.A.C. Bennett dam has not been divulged, it is reasonable to suppose that it will be operated entirely for electrical power generation, as was its original intention. That will mean that the crests will be taken off the Peace River floods to the extent of about 120,000 cfs (Coulson 1970). At Peace Point that will decrease maximum stage levels by 6 to 12 feet, according to Coulson's 1962 report. It also will help to eliminate the profound channel flooding that carves meanders, deposits point bars, lays down levees and forms new habitat. The proposals being evaluated by the Saskatchewan-Nelson Basin Board, to remove an additional 20,000 cfs by diversion, will serve to aggravate the problem even more. Water will have to be stored in order to be diverted and that adds a new dimension in time and flow rates. Average flow rates at each gauging station mean little in ecological terms. The existing environment of northern river basins and associated wild life has developed in response to rather marked fluctuations about a mean, and unless such fluctuations can continue, there will be rapid and profound changes, as has been demonstrated in the Peace-Athabasca Delta since 1967.

The result of the Bennett dam has been to effectively isolate the Peace-Athabasca Delta from the periodic inflows of the Peace River that John Macoun, and many people since that time, have remarked upon. Coulson and Adamcyk (1969) have stated that once the Gordon Shrum power station is in full operation, the overall effects (to the Peace River system) promise to be beneficial because of reductions in flood peaks and increases in low flows. As previously stated, this view is questionable from the environmental point of view.

The vegetational complex in the Peace-Athabasca Delta has been structured in response to soil types and water levels. Although the climatic conditions are severe at those latitudes the overriding consideration in maintaining an early successional stage of plant growth has been the periodic inflow by silt laden flood waters from the Athabasca and Peace Rivers. As Fuller and LaRoi (1971) have pointed out, the biological resources of the area are the result of two opposing forces. The first is the tendency for aquatic plant communities to build toward terrestrial communities by filling in habitat with organic material as water levels decrease through drainage and evaporation. Opposing that ageing tendency is the fact of periodic spring flooding which pushes plant associations back toward early successional stages. Without such a rejuvenating process, the eventual plant association would be mature forest and muskeg.

Dirschl (1970) defined several broad landform-vegetation categories for the delta commencing with open water, and progressing through mudflats to fen, shrub and forest. Through air surveys and ground comparisons Dabbs (1971) was able to define those categories more critically and to designate the plant species growing within each one. He produced detailed maps of the vegetational complex and developed methods of aerial photography whereby those maps could be revised as the composition of plant communities changed. He has defined the short term trends and the long term trends in vegetational changes, using for background the pioneer work by Raup (1946).

The short term changes, as might be expected, have been in direct response to lowered water levels and the general drying out of the habitat. Land once under water has become mudflats and has been colonized by pioneer species such as spikerush (Eleocharis), ragwort (Senecio) and sedges (Carex), with a rapid influx of willow seedlings after the first year. Areas of wet fen, that previously were grown to sedges (C. atherodes) are being replaced by reedgrass (Calamagrostis canadensis). Long term trends more often reflected changes in landform such as the silting in of backswamps and the building of levees. Many of the low-lying areas mapped by Raup as fens of Carex atherodes in 1930 have been invaded by reedgrass and low willows. It was significant that the willows came to dominate nearly half of Raup's map area from which they previously had been absent.

Dabbs also identified several categories of aquatic habitat that would be affected by lowered water levels. Lakes and ponds with unrestricted outflow to channels would go dry in response to the significantly lower water levels in the delta. Lake Mamawi is such a lake. Water bodies with restricted outflow, which represent the majority of the backswamp areas, would usually be flooded in spring but would drain out only partially because of their protecting marginal levees. Their permanence, their vegetational complex and their use by wildlife would depend upon the depth and frequency of flood waters they received. Because the delta is a very flat area, two or three feet less water can make a tremendous difference in the amount of land surface exposed. Dirschl (1971) measured on air photographs the areas of eight of the larger delta lakes. He found that their water areas had decreased by 55 per cent between 1955 and 1970.

The effects of changes in the vegetational complex upon wildlife still are under active study, and will be reported through the aegis of the delta task force. The observations provided below, while tentative, are based upon field research already conducted to this time. Results will be reported in condensed form in order to form a general picture of what has occurred since 1968.

Bison: All the bison in the Peace-Athabasca Delta are in the Wood Buffalo Park portion thereof. Novakowski (1967) reported 7,000 to 8,500 to be present south of the Peace River, with 3,000 to 4,500 animals using the area in winter. He estimated that 24 square miles of the area between Lake Claire and the Embarras River was at that time in grassland comprised of reedgrass with some Scolochloa and Beckmannia, and that an additional 262 square miles of such habitat could be formed if the water table was lowered. Such grassland habitat would develop at the expense of the more aquatic sedges *Carex rostrata*, *C. aquatilis* and *C. atherodes*.

McCourt (1970) made detailed observations of bison feeding areas on the northeast side of Lake Claire during July and August of that year. He also recorded the numbers of bison to be found in the delta area. His conclusion was that awned sedge (*C. atherodes*) was the preferred summer food of the bison and that it made up nearly 90 per cent of their diet. Raup (1933) gave higher status to reedgrasses in the bison's diet, but listed the green winter buds of awned sedge with their rich store of nutrient, as one of the most important elements in the winter food. It is probable that reedgrass represents an important early summer food but there is no doubt that it becomes too rank and coarse to add much to the winter diet.

McCourt counted as many as 6,500 bison (calves excepted) in the delta area during the summer. The counts were continued throughout the winter by Kuyt (1971) who found some shift of population southward and eastward after freeze-up. His greatest count was 8,275 animals, which is in agreement with Novakowski's (1967) estimate of 7,000-8,500 animals. One is tempted to state that the population is remaining more or less static, but it is known that there is some seasonal movement north and south across the Peace River so such a statement might not be valid. Novakowski (1971) estimated that the carrying capacity of the delta in the mid 1960's to be about 19,000 animals, based upon conditions to be encountered then. Pringle (1971), upon preliminary examination of the area under late winter conditions, thought the carrying capacity to be nearer 30,000 bison. His data will be further analysed, but under the current conditions in the delta there seems to be no immediate dearth of year-long range. That situation could change rapidly, depending upon the rate of drying of the sedge meadows and their replacement by willows and reedgrass. Continuation of the present water regime in the Peace-Athabasca Delta will achieve that result, and further draw-down by water diversion will hasten the process.

Waterfowl: The Peace-Athabasca Delta has for long been renowned for the myriads of waterfowl that pass through on their spring and fall migrations, and for the significant numbers that stay to rear their young and to moult their flight feathers. Soper (1934) was obviously impressed by the numbers of ducks, geese and other wild fowl that he saw there in 1933. He ventured the opinion however, that because of drought on the prairies many waterfowl were seeking the better watered areas of the north in the Thirties. Smith (1964), after long association with waterfowl surveys in the North, was able to corroborate and quantify Soper's opinion. He found a quarter of a million ducks on the delta marshes in 1961, a year of drought on the prairies, but only 84 thousand in 1955 when more southerly areas were wet.

Whereas the delta normally has its greatest value as a feeding and resting area for migrant waterfowl, it also supports a fairly large breeding population. The size of that population in any year is dependent not only upon water conditions in the prairies, but also upon the absolute numbers of ducks that survive to nest in Canada. Nieman (1971) has provided information from the two years he studied the nesting success of mallard and canvasback ducks in the marshes of the Peace-Athabasca Delta. He recorded an increase of breeding ducks in 1970 over the previous year, but was unable to account for that change.

Information about breeding habitat proved most interesting. Both diving ducks (canvasbacks) and dabbling ducks (mallards) were found with their broods most frequently on water bodies that flooded in spring, but which had no egress thereafter. The deeper river channels and water courses also showed heavier use than normal. These observations were set forth by Nieman and Dirschl (1971) in a statement to the delta task force. The general trend was for breeding waterfowl to be concentrated in those portions of the delta unaffected by the current low waters in the large lake basins. Birds which had not nested in such permanent habitat later moved into it with their broods.

Moulting waterfowl increased in numbers by 25 per cent from 1969 to 1970 and were found most frequently in the deep stable ponds and channels containing adequate emergent vegetation for escape cover during the flightless period. Moulting birds no longer were found on the numerous lakes and streams which became very shallow or dried up during 1970.

In the autumn the number of migrants using the Peace-Athabasca Delta area decreased by half, as compared with 1969. Weather conditions could have been partly responsible for the decreased use, but on the other hand, the delta may have offered a less attractive milieu to the migrants and they went elsewhere.

Two observations are relevant here. Although the use by migratory waterfowl decreased, the breeding and moulting populations showed an increase. In as much as the latter sought out water bodies of a permanent nature, the drying of the large lakes did not prevent them from staying in the area. The useful water bodies were the "perched" basins which flood during high water, but have no normal drainage ways. Their success at supporting breeding and moulting waterfowl is entirely dependent upon their being recharged each year by spring freshets, which maintain their level and sustain the kinds of emergent and floating vegetation that serve as food and cover for the birds during summer. If the floods do not rise these basins soon will fill in with sedges and eventually with willows.

Migrant birds are attracted by the mudflats and relatively open areas of the delta during autumn. At that time of year birds travel in large flocks and so seek out areas where there is food available and where the flocks can be protected by open space. Lake Mamawi and other larger lakes which were nearly dry by autumn provided those conditions during 1970. Needless to say, however, any further drying of the delta and any further invasion of the mudflats by sedges and willows will render such extensive areas entirely useless for waterfowl. Nieman (1971) makes a strong plea for control structures to maintain the Peace-Athabasca Delta as a breeding area, a moulting area and a staging area for migratory waterfowl. He recognized the fact that "when the situation approaches a 'no-water' condition then all waterfowl species are adversely affected".

Smith (1964) stressed the necessity for maintaining the large northern deltas in Canada and Alaska for waterfowl use; and noted the rapidity of their passing. He recorded the flooding of 135 thousand acres of prime waterfowl habitat in the Saskatchewan River Delta for power generation by Manitoba Hydro. He noted the ever-increasing pace of exploration and development in the Mackenzie Delta and the adjacent Old Crow Delta of the Yukon. He mentioned the massive threat to the Yukon flats of Alaska by the impending construction of the Ramparts Canyon dam and reservoir project (which has been forestalled, at least temporarily), and he had not yet heard of the W.A.C. Bennett dam on the Peace River, nor the proposals to divert Mackenzie River water southward. Although the northern deltas comprise only 56 thousand square miles they represent breeding areas for 1 to 2 million ducks and 675 thousand geese. And of equal importance, they represent assured breeding habitat for many more birds when there is a dearth of water on the Canadian prairies.

Muskrat: In the Mackenzie basin muskrats have been able to adapt to an environment that normally would prove much too severe for an aquatic animal. They adapt by seeking out areas of water that though ice-covered, do not freeze to the bottom each winter, and contain therein sufficient food of plant or animal origin to support them over winter. Fuller (1951) provided information about muskrats of the Peace-Athabasca Delta at a time when that area was recovering from a previous low-water period in 1944-46. He found that the animals built houses on the edge of marshes and that in winter radiating lines of push-ups were constructed on the ice, in which the animals fed. Houses usually were constructed of emergent vegetation such as cattails (Typha latifolia), bulrushes (Scirpus spp.) or sedges. Push-ups were made from submerged plants such as milfoil (Myriophyllum) and pond-weeds (Potamogeton). Stevens (1971) suggested that a depth of four feet of water was necessary for the survival of muskrats in northern regions. That figure was based upon experience in the Mackenzie Delta where muskrats do not build houses. Winter observations by Surrendi (1971) demonstrated that whereas an optimum depth of 4.75 feet may be postulated, muskrats were able to exist under conditions where there was much less water. In some places in the Peace-Athabasca Delta he found muskrats living under circumstances where there was no detectable water. At those minimal depths however, most of the houses and push-ups were no longer being used. The percentage of live houses and push-ups increased as water depths increased, up to the maximum depth of 4½ feet that Surrendi was able to discover on one lake. Fuller gave the average productivity of the delta as 43,000 muskrats. In 1970 only 5,000 animals were trapped*, which circumstance came about through lowered water levels and reduction of trapping effort. Trapping effort was reduced because of the really dispersed nature of the muskrat population, with the remnants hanging on to life wherever tolerable conditions could be encountered. Trappers quickly became discouraged by the lack of returns for the work involved in trapping muskrats, and expended little effort.

A small population of muskrats is able to survive even under the circumstances to be encountered in the delta now, but if additional restrictions on water inflow are imposed it is likely that their habitat situation will deteriorate even further.

<u>Other Species</u>: There have been a few additional studies of the wildlife resources of the area. Wood (1967) investigated the ecology of the northern red squirrel in Wood Buffalo National Park and found that,

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* Data from Alberta Fish and Wildlife office, Ft. Chipewyan

whereas the animals were generally distributed throughout the boreal forest areas of the Park, they achieved their highest populations in the white spruce timber stands on the floodplains of the Athabasca and Peace Rivers. He concluded that squirrel numbers were related to the production of a good seed cone crop of white spruce. Wagg (1964) had studied the relationship between white spruce reproduction and cone middens on the floodplains along the lower Peace River. He found one major red squirrel cache per acre, which he also felt was an expression of squirrel density, one squirrel being responsible for each cache.

Although squirrel pelts are low in price, they form collectively the most important fur trapped in northern Alberta (Table 1), and represent a very significant source of income. Because squirrelsare most numerous on floodplains, any changes to the spruce stands thereon could reduce their numbers. River control, and reduction in flood stages could have an adverse effect on red squirrel numbers.

Snowshoe hares form an important component of the diet of those northern people who depend for their livlihood upon the products of the land. Studies in Alberta by Keith (1971) and his students have shown that the willows on river floodplains are very important to the winter diet of snowshoe hares. In summer the hares disperse to more varied habitat on the uplands where a greater supply of herbaceous food is available to them, but in winter they are drawn in to the willow flats from as far away as five miles. Willows on floodplains are a pioneer species and persist only as long as new point bars and river bars are being formed by high water. Under the usual forest succession of northern regions willows are replaced by balsam poplar and white spruce.

It must not be forgotten that most of the Peace-Athabasca Delta lies within the boundaries of Wood Buffalo National Park. The National Parks Act, which is a federal statute, specifies that national parks are dedicated to the people of Canada for their education and enjoyment and must be left unimpaired for future generations. The original studies done by the federal Water Resources Branch (Coulson, 1962) considered the right of Canada to control navigation but did not consider the federal duty to protect the National Parks. Wood Buffalo Park was established for the propagation and preservation of the resident bison, which already have been discussed. Its value as a waterfowl sanctuary also has been referred to. One of the problems facing the existing task force is how to reverse changes in park ecosystems caused by the Bennett dam. Diverting more water from the Peace and Slave Rivers will give rise to similar problems.

NEED FOR ADDITIONAL STUDIES

The above review of our knowledge of the ecological requirements of Mackenzie River basin wildlife indicates how much still needs to be learned in connection with river basin planning. It is understood that some preliminary work is underway on the ecological ramifications of diverting water out of the Pembina River at Evansburg, as a part of Alberta's PRIME program.

In a brief to the Churchill river diversion hearings in Winnipeg in January 1969 Prof. C.C. Lindsey of the University of Manitoba stated that surveys of an ecological nature, to be of much value, must examine year to year changes induced by year-to-year variations in conditions.

Welch et al. (1966) stated that "experience suggests that 5 or 6 years are necessary for gathering data if biologists are to advise soundly on large and complex systems". They cite as a practical example, the fact that 6 - 8 years are required to see a change in fish productivity because it takes that long for fish to grow to a size to be caught in commercial nets. The Canadian Wildlife Service similarly has found that even well-supported ecological research programs take a number of years to yield useful results.

Scientists concerned professionally with the least altered of the world's ecosystems are naturally conscious of, and often emphasize, the importance of renewable resources to the indigenous people, whose use of these resources tends to be traditional and not easily mutable. The Mackenzie basin should not be thought of as a distant vista of snow and ice. It has an area of 711,000 square miles (Fig. 1), three times as large as Alberta, and has a population of more than 263,000 people distributed as follows:*

British Columbia	68,300
Alberta	174,250
Saskatchewan	2,450
Northwest Territories	18,300
Yukon Territory	200

Many of those people are of native and mixed blood, most live under or adjacent to frontier conditions, and all are dependent in large measure upon the resources of water, soil and forest for their sustenance. In that vast and sparsely settled region the largest settlement is Dawson

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* Figures based on the 1966 Census of Canada; Dom. Bureau of Statistics, Ottawa.

Creek, B.C., with a population of 12,400 people. Many of the older and more primitive settlements are located along the waterways because those originally represented the travel routes of the frontier. In addition, the valleys had a better climate and a more abundant resource base than the adjacent uplands. For such frontier communities Mackay and Fedoruk (1968) observed that "The depreciation of a resource base means a lost opportunity to benefit from the development, exploitation or enjoyment of a natural complex". Because many northern communities have a narrow resource base such disruption can be extremely unsettling. By tradition and preference people will try to persist in the same life style and social structure to which they have become accustomed. The community of Ft. Chipewyan presents a clear example of that tendency. Even though it may be said that such northern communities represent a dead-end life style, it is what the people know, and evolving into something different will take time. Northern citizens increasingly expect to have some input into decisions that affect them, and to make decisions at their own pace.

It may be trite to suggest it because the idea is not new, but there appears to be a real need for a multiple purpose plan to be developed for the region between Edmonton and the Arctic Ocean. Admittedly that kind of planning is difficult because it cuts across boundaries and responsibilities, but it would help toward an integrated natural resources policy, and would point up a number of alternative courses of action. Booy (1969) in addressing the public hearings on the Churchill River diversions in Manitoba expressed the opinion that "when we have to make a decision, we make it on the basis of the available information in a way that leaves as much as possible our options open for the future."

He also said that "our predictions of future development are not nearly as certain as the complicated calculations based on them would lead one to believe".

Koelzer (1970) was being realistic when he said that we should accept the concept of alternative futures requiring planning for a spectrum of policies. To date planning organizations attempt to forecast a single course that the future will follow, and then plan accordingly. Almost certainly the future will deviate from forecasts so planning will have to be continuous process, and planners and managers will have to make an endless series of judgements and decisions to meet new situations. On that basis it is folly to create rigid master plans that are expected to be good in perpetuity. Koelzer felt that "the need in long-range planning is to specify immediate steps that are best for the immediate future but which maintain maximum flexibility for selection of alternatives in the distant future steps". He also observed that multipurpose planning is seldom done and in its place multilayered planning is substituted. That approach stifles innovative thinking because the organizational structure limits professional staff to thinking only within the framework of agency fiat. Guidelines for water resource planning as set forth by the Water Resources Council (1970) are relevant because they adopt a multi-objective approach and consider not only environmental quality, but also regional development and social well-being.

Obviously, the aim of planning must be flexible, and flexibility can only be achieved by as wide a spectrum of information as possible. In addition, a major responsibility of the planning process must be to ensure that the collection of information is a continuous process. With regard to diverting Mackenzie River water there appears to be a requirement for a great deal more information of all sorts. The need is to start with an inventory of physical, biological and sociological parameters, and to then interpret them into such categories of useable resources as minerals, waterpower, forestry, fisheries, game and fur, agriculture, human skills, group interaction and so forth. Once those data are collected and collated alternative plans may be developed, using the multi-objective approach that Koelzer recommended. That would allow for a trade-off between alternatives but would require as imperatives public scrutiny (see Silcox 1968), and the frequent review and up-dating of plans.

It is recognized that some of these considerations are outside the scope of an essentially biological report, and no further attention will be devoted to them herein. What follows therefore is a framework whereby biological phenomena may be investigated. It will include reference to the use of the biological resources by residents of the Mackenzie basin, but will not go into that aspect in detail because socio-economic studies, while overwhemingly important, are within the special competence and responsibility of other disciplines and jurisdiction.

Biological Studies

A thorough study of an ecosystem, suitable for predictive purposes, requires a massive amount of information. For example, much can be learned from palynological studies which give clues as to the origin of the system and the limits within which it is maintained. Again, studies of present energy flow patterns indicate the relative importance to the maintenance of the ecosystem of its many biological components. Broadly-based inventory studies leading to an understanding of vegetative associations have been detailed by the Canadian Forestry Service (1969).

A national inventory of important wildlife habitats has been completed in part for southern Canada under the Canada Land Inventory. If the CLI boundaries could be extended northward on the same general basis a preliminary but useful overview of the wildlife capability could be achieved. Canada Land Inventory Report #7 (1970) sets forth a classification system for waterfowl and for wild ungulates. Although a portion of the Mackenzie basin is included within the boundaries for that study the work has not yet been made available in its entirety in published form. Experience with CLI has indicated that if a landform study can precede the wildlife study a great deal of time is saved, and duplication of effort avoided.

A preliminary compilation of known information was embodied in the Arctic Ecology Map series released in 1970 by the Canadian Wildlife Service. That exercise attempted to delineate areas that were known to be especially important as breeding areas, migration routes or wintering areas for a fairly wide spectrum of wildlife, including some anadromous fishes. It made no claim to be other than a first look at problems that might arise as a consequence of increased human activity in a natural setting, such as parts of northern Canada. In the face of such abrupt and imminent man-made alterations as pipelines, roads, railroads, water diversions, oil spills and mine development there is a great need to define those important and critical areas with much greater exactness. A more detailed inventory is underway in the Mackenzie valley and adjacent portions of the Yukon with respect to a transportation corridor for Alaskan gas and oil resources. It is expected that this inventory will be more complete and more detailed, but that much will still remain to be understood about the dynamics of the ecological systems delineated.

Any large-scale wildlife inventory depends on knowledge of how wildlife abundance is related to physical or vegetational characteristics of the environment. Some satisfactory attempts have been undertaken for northern bison, for muskrats, for waterfowl, for moose and for beavers, as previously quoted. But such other important wild species as woodland caribou, black bear, mustelid fur-bearers (mink, marten, weasel etc.) and lynx await to be studied, as do the plant and animal species that they depend upon as food. Survival of wildlife in northern areas depends upon the development of behaviour patterns in response to a range of natural conditions. If those natural conditions suddenly are altered in an unusual manner, such as by unnatural changes in the timing and amounts of water flows, then the affected species are at a disadvantage until new patterns can be learned, or they are eliminated if adjustments cannot be made. Law (1951) wanted to exchange house dwelling muskrats from the Peace Delta with bank dwelling muskrats from the Slave Delta to ascertain whether house construction was a learned or an innate skill. Although the experiment was never done, the validity of his concern is pertinent and has been demonstrated with other species which depend upon learned behavior, such as large carnivores and many migrant species.

One area of study that requires magnification is the relationship between the wildlife resource base and the people who are dependent upon it for food, for income (fur), for by-products (babiche), for recreation (photography) or for sport (hunting and fishing). One recent study by Pattison (1970) is relevant in that regard. His study took place in that portion of Alberta north and east of the Athabasca River and was an attempt to measure the net social benefits derived from the moose resource through hunting activity. In 1968 he estimated that 26,000 moose hunters harvested 8,657 moose which had a total value to the region of 1.5 million dollars. It was his opinion that the resource was under-utilized.

Whereas Pattison's study involved sport hunting there are additional studies which have attempted to measure the value of wild land resources to people who hunt for subsistence. Macauley (1968) made a very useful appraisal of the utilization of waterfowl and other country food by the Slave Indian band at Habay in northwestern Alberta, and suggested that the need for such sources of food and other products should be considered as a local necessity in any management of the wild fowl resource. Klein (1966) made such an appraisal in central Alaska among the Eskimo people and noted that the use of waterfowl and their eggs occurred at a time when other sources of food were not available. Previously Brooks (1955) had computed that wildlife utilization was by far the most valuable among the four basic industries in Alaska.

In the Mackenzie Delta area Mary Carpenter (1967) was able to gather very relevant information about the place of waterfowl in the economy of the local Eskimo people. The fact that she was of Eskimo origin, helped her in getting factual answers to her interview questions. In that way her study was unique. Also in the Mackenzie Delta area economic surveys have been undertaken by Bissett (1967) and by Smith (1967).

All of those studies attempted to gauge the relationship between a people who are dependent to a variable extent upon a hunting and trapping economy, and the wildlife resource base available to them. In most cases it was found that the resource was being under-utilized because of the relatively small economic return for the effort expended in trapping. But other alternatives for making a living were often not available, with the possible exception of social assistance payments.

Basically then, three areas of investigation are required to improve the picture regarding the extent and value of the wildlife resource. The first area comprises inventories of wildlife habitats and populations, with associated research on the dynamic aspects of their existence. A second kind involves studies of individual species in order to assess their requirements for adequate space, for useful habitat and for necessary food. Such studies by their nature will assess interactions with other species, and as more species are studied those interrelationships will be clarified. A third kind is that designed to collect data on the use of the wildlife resource by area as an aid in determining the impact of withdrawal of portions of that resource by changing land use and water use patterns. Only by knowing how much we have and who uses it will we know how much we are in danger of losing.

CONCLUSIONS

Most of the conclusions about ecological disbenefits already have been stated under previous headings. It has been noted that hydrological data are not always in a form useful to ecologists in predicting the effects of changes in water regime. In addition, the scale and scope of data collection must be greatly increased in other fields of endeavor before intelligent decisions can be made. Such decisions furthermore, will have to be made in Canada using Canadian data, although experience at similar latitudes in the U.S.S.R. may be helpful. Some of the greatest blunders in renewable resource use in recent years have been made in water management, and although not all of those mistakes have been made in Canada, collective experience should provide enough warning to make us cautious of quick answers and one-sided planning exercises.

One of the questions posed by the Saskatchewan-Nelson Basin agency for consideration in this report was "In what way are present water level fluctuations along the Mackenzie River system undesirable for wildlife and in what way could they be improved?" It has been found that in some years the Peace-Athabasca Delta has limited value to nesting waterfowl because late flooding destroyed many nests. As intensified agriculture on the Prairies removes waterfowl habitat there, flood control on that delta may prove beneficial in the maintenance of continental waterfowl resources. The maintenance of productive habitat, however, would still depend on seasonal flooding, perhaps phased earlier in the year, and the maintenance of fur-bearer numbers might require careful attention to the maintenance of fairly high and stable levels over winter. The reduction of the head of water necessary for flooding, silting and rejuvenating riverine and deltaic habitats would be difficult, if not impossible, to effect while maintaining the ability to manage productively these delicately balanced but highly productive biotic associations.

It has been found in the past that the reservoir areas behind power dams are not of particular use to wildlife or recreation because fluctuating water levels make the establishment of plant and animal communities difficult. If fluctuations can be kept to a minimum it is possible that a water control regimen suitable to wildlife might be instituted. That would depend upon the control structures built and the purpose for which the water was being controlled.

If we knew how much less water would be flowing into the Mackenzie basin, and how that flow would reduce the flood crests over each island and sandbar; if we knew how many tons fewer of river silts would be spread over deltas and floodplains, how much break-up would be delayed, or how much freeze-up would be accelerated, then it might be possible to make more intelligent estimates of damages and disbenefits that will accrue from water diversions. Similarly, it should be recognized that the ecological study of the effects of changes in water regimes on wetlands in the North is only at a beginning, and that what these studies amount to are uncontrolled experiments. The resources have simply not been available for carrying out properly-designed studies of either effects or mitigation techniques.

<u>SUMMARY</u>

1. There has been a great deal of interest lately in water diversion schemes in North America and the engineering site studies undertaken for the Saskatchewan-Nelson Basin Board represent only part of those proposed.

2. It is estimated that the fur and big game resource of the Mackenzie basin produces an annual yield valued at five million dollars. That figure does not take into account expenditures by the public in hunting waterfowl and upland game, nor does it include the value of the wildlife resource for country food and by-products to the many people in frontier areas.
3. River valleys in the Mackenzie basin represent a valuable and preferred habitat for ungulates such as moose, elk and deer, and for fur species such as beavers, hares and squirrels. Those rivers also are routes for most of the birds that migrate to and from nesting grounds in northern regions.
4. Increasing the flow of northern rivers under winter conditions can have deleterious effects upon aquatic fur species, and may inhibit travel and the break-up of winter ice through the formation of overflow.
5. Deltas represent the richest portions of watersheds and the Mackenzie basin is favoured with three of them. The Slave Delta is the smallest of the three but is building rapidly into Great Slave Lake. It is especially important for the resident fur species and the migrating wild fowl that depend for food and habitat upon the pioneer plant communities on silt flats and river bars.
6. The spruce forest along the Slave River has become established through vegetative succession; from horsetails and willows on exposed river banks through balsam poplar to white spruce. Those

stands have been estimated to contain 85 million f.b.m. of saw timber.

7. The upper two-thirds of the Mackenzie Delta is forested with white spruce which is restricted to the channel levees. The whole of the region is underlain by permafrost which presents special problems in forest growth and regeneration.

8. Muskrats are the most valuable fur resource in the Mackenzie Delta and live in the floodplain lakes that occupy half the land surface of the area. Lakes which do not flood periodically do not grow an adequate food supply to support muskrats over winter.

9. Beavers in the Mackenzie Delta inhabit meander scroll depressions and floodplain lakes and are entirely dependent for food upon the willows and poplars that grow only upon recent delta alluvium. A harvest quota of 4,000 animals has been established for the delta.

10. The Mackenzie Delta is an important breeding and staging area for migratory waterfowl and shorebirds. Air surveys have shown breeding pair indices for ducks to be as high as 335 thousand.

11. Any interruption of the usual profound flooding of the Mackenzie Delta could direct plant succession towards muskeg conditions; could cool the climate, delay break-up and increase permafrost. In so doing it would eliminate much of the muskrat, beaver and waterfowl habitat.

12. It is suggested that the Liard River has a major influence upon the time of break-up in the Mackenzie River, and thus upon the climate of the lower Mackenzie basin.

13. The Peace-Athabasca Delta has been denied the flood waters of the Peace River as a consequence of riverine control by the Bennett Dam in B.C. Both the delta and adjacent Lake Athabasca have low average levels as a result.

14. Some of the best stands of saw timber in northern Alberta grow on the floodplains of the lower Peace and Athabasca Rivers, including those portions within Wood Buffalo National Park. As for other areas within the northern boreal forest zone, the establishment of such spruce forest may be dependent upon the germination of seedlings on recent alluvium.

15. The bison in the Peace-Athabasca Delta portion of Wood Buffalo National Park are dependent for most of the year upon edible sedges for their food. Those sedges are being replaced over large areas by reedgrass subsequent to the drawdown of water levels by the Bennett Dam in B.C. Reedgrasses are an inferior forage for bison, especially in winter. Sedges require flooding in spring with a gradual lowering of water levels during summer.

16. Breeding and moulting populations of waterfowl in the Peace-Athabasca Delta have become concentrated in permanent water basins that are filled by spring freshets. The northern deltas are especially important to the continental waterfowl resource during periods of drought on the prairies of Canada.

17. The number of muskrats traded from the Peace-Athabasca Delta decreased from 43,000 in 1967-68 to 4,900 in 1970-71, largely because of reduction in habitat following steadily decreasing water levels.

18. There is a very great need for high enough water levels periodically to fill the perched basins of the delta region which represent the permanent habitat for muskrats and waterfowl.

19. Much of the Peace-Athabasca Delta lies within the boundaries of Wood Buffalo National Park. National park values have been impaired by reduced flows in the Peace River and would be further impaired by the diversion of water from the Peace and Athabasca River systems. Mitigating the present damage to the national park will prove to be difficult enough.

20. The Mackenzie basin has a population of 263,000 people, many of whom are of native or mixed blood and live under frontier conditions wherein they are dependent to a significant degree upon the products of the land. Most of those people live along the major water courses.

21. Ecological studies in the Mackenzie basin must be accompanied by further physical and socio-economic studies in order to provide an adequate data base for the establishment of regional goals and objectives.

22. Additional hydrological studies in the Mackenzie basin are especially desirable in order for judgements to be made concerning the extent and duration of flood peaks on component streams in the system, the extent of winter flooding, and the impact of altered flows on northern climates.

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