Ecology and Northern Development

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No attribute of man exceeds in importance his capacity to alter his environment. During the long history of his social evolution from hunter-food-gatherer to twentieth century technological man his capacity for environmental change has been dramatic.

There have been two facets to this change. By direct attack on the vital problems of human mortality man equipped himself to lengthen his life span. At the same time his technological skills and his appetite for energy equipped him, in the industrialized parts of the world, with the means and the incentive to attack the environment in increasingly sophisticated ways and to bend it to his immediate interest. All too frequently the long-term consequences of these actions have been ignored.

There is every likelihood that through the 1970's millions of people will starve as a direct outcome of man's failure to understand the basic ecological parameters from which he cannot escape or, understanding them, his failure to act appropriately.

Population in an ecological sense is a relative concept and even in parts of the Arctic death from starvation has overtaken a distressingly large number of people in the last decade (Vallee 1967); this has been a direct consequence of dramatic man-induced changes in the environment.

While the crisis of numbers haunts the unindustrialized sectors of the human species, advanced peoples are pursuing a course equally at odds with ecological prudence, a course that can only lead to impoverishment and misery to man and catastrophe to a large part of the world's living organisms.

The most obvious symptom of the approaching catastrophe is the rate of our chemical and physical alteration of the air, water and land with waste products. I refer not only to sewage and industrial wastes in our rivers, lakes and inshore marine waters, to noxious gases, aerosol biocides and fission products cast into the air; but also to the cacophony, rapidly increasing in variety and volume as it invades the remaining silent places; to the sprawling chaos that reaches out from many of our cities; to the shack towns where the poor and unfortunate live in filth and distress; to the needless invasion of scarce farmlands by expanding cities; to the defilement and desecration of landscape by strip mines, automobile graveyards, and industrial and military junk; and to so many other activities that reflect a callous disinterest in maintaining a sensitive and effective relationship between man and the living world.

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But surely in Alaska, the Yukon, and the Northwest Territories, the last frontiers of the continent, where human populations average about 1 per 150 square miles, these forces cannot be at work. Surely with the mistakes made elsewhere as our lesson, we can proceed to avoid these errors and at least be original in the mistakes we make.

The natural communities of the continent fall roughly into two categories, first the pioneering associations of plants and animals that invade areas where catastrophe has struck by fire, flood or human clearing. These pioneering associations slowly evolve until there arises the second category, an assortment of plants that is relatively self-perpetuating — the climax state of the ecologist. For instance, the fire weed-willow-aspen community proceeds to the spruce forest climax. In each of these associations the classical biological energy cycle is proceeding, with the plants trapping solar energy and taking minerals and water from the soil. All other forms of life live either directly or indirectly upon the plants.

However, the passage from pioneer stage to climax is also a transition from an unstable state to a stable state. In the highly unstable early stages there is rapid change in the total mass of biological material. There is equally rapid change in the species composition. At the other extreme of the time scale there is relatively little change in the amount of living material from year to year, and though the proportions of the constituent species may change, the fluctuations are less extreme. The great surges in numbers of field mice, rabbits, lynx and moose take place generally in the early phase of the arctic-subarctic ecosystems.

Agricultural man survives on his capacity to create and maintain the unstable stages of the ecological cycle. By preference his aim is an annual cycle from plowed field to harvested crop. At the same time he strives to eliminate any competitors for his chosen plants and to assure that he is the only animal user. So he fences out competing animals, he hoes and cultivates and destroys pests with biocide sprays. A prodigious input of energy is needed to maintain the unstable state, in fact it has been calculated that the energy required to produce 1 calorie of metabolizable energy in an Iowa cornfield is 5 times the yield. In the ecological sense then man the cultivator is a natural catastrophe.

In the far north of the continent we have watched the impact of our agricultural technological culture, with its strong economic orientation, on that of the indigenous peoples. At its best it has been a dramatic social and biological revolution — too often however it has been tragic both in the short-term impact on the indigenes and in its long-term portent even for ourselves. The native peoples were a dynamic element in the balanced ecosystem. By ingenious techniques they lived on the contact zones between land and water removing annually some of the biological increase from each. Theirs was not a culture based on surpluses, and storage was limited and local. The causes of mortality were those of the wild living predator, starvation, accident and parasitic disease. Mortality was specially high among the young. Their mortality rate was apparently from 5 to 10 times that experienced by *southern* Canadians today.

There were probably as many people living in arctic North America as the biological resources could support and this capacity was unbelievably low. Evidence arising from recent studies of a human population west of Hudson Bay

(Vallee 1967) suggests a mean carrying capacity of 1 person per 250 square miles. Away from the coast caribou was the major source of food and it was a nomadic species imposing on its predators (wolves and men alike) unpredictable changes in its presence and abundance. The total system was essentially closed in as much as there was neither import nor export by the native peoples. The only exchange occurred through the annual migration from the Arctic of the entire new generation of birds reared on the summer surplus there.

Technological man introduced massive disturbances within the northern ecosystems. Not the least of these was an entirely new, economic, strategy of approach to the natural resources. This involved import and export along with novel techniques for the use of energy in man's interest. The advent of the fur economy led to the need for more extensive travel. This in many parts of the North necessitated more dogs. In the Arctic dogs and men share the same food resources, thus more dogs were, in this sense, the ecological equivalent of more men. Lengthy trap lines encouraged the establishment of temporary food caches (caribou) in areas remote from the base village. Provident men would attempt to have a surplus at each site — a surplus that could not be carried over from year to year. This revolution would have been impossible without the accompanying changes that came with the rifle.

We know now that the caribou and musk ox, the only native large ungulates of the high North, were unable to sustain the increased demands on their numbers and the great decline began.

The details of this decline have been studied now for twenty years. We have no accurate figure on the original population of the 600,000 square miles of range between the Mackenzie River and Hudson Bay, but one million would seem to be a reasonable approximation. Everything we have discovered points to the barren ground caribou as an animal in delicate balance with its environment and highly vulnerable to the vicissitudes of weather during the calving season. Consequently for several successive years there may be a net decline in numbers without the impact of man. The net loss is balanced by periodic *good* years when reproductive input greatly exceeds output. This is a form of production with which we have little experience. In essence it means that if there is to be sustained use of caribou by man for food, the base population of animals must be large enough to permit successive years upon which the breeding herd suffers draw-down without sinking to a level from which the good years cannot restore it. The biological *capital* required in this situation greatly exceeds that wherein an annual surplus can be anticipated, as with our domestic livestock.

In this kind of ecological situation short-term assessment of stock is meaningless, only assessment made over ten-year periods or longer will yield a true picture of the trends in numbers and provide a guide to the possible tolerable use by man. We can only assume that neolithic man entered this equation after the caribou population was fully established. We have no evidence as to the limiting factor operating upon those early men — it may not have been the presence or absence of caribou. We do know, however, that the caribou was over-harvested in the years that followed the advent of economics and the population collapsed in the 1950's to a low point, only 10 to 20 per cent of the primitive herd. At this point

it certainly became the limiting factor in human population and many communities and nomadic bands would have perished entirely without the importation of food from *outside*.

The musk ox had preceded the caribou into the status of a resource no longer useful in the indigenous survival of man in the north.

But these are only isolated examples presented to illustrate the concept that in the ecology of the North we are dealing with an environment where the biological ground rules often depart widely from those with which we are familiar.

Our success in establishing permanent settlements in the middle and high North of this continent will depend in large measure upon our effectiveness in managing the natural resources. The resources of this vast area have been considered in detail in two recent studies. Turner (1959) sees little hope that agriculture can be a profitable venture as a base for permanent settlement in the area except in small exceptional localities. Forests, on the other hand, will contribute importantly, and wildlife and fisheries will continue to provide support for native peoples in non-urban areas. Turner is more pessimistic than some would be regarding the long-term contributions of mining to the existence of strong permanent settlement.

In general Dunbar (1962) concurs with these views of the terrestrial resources but is more optimistic about possible yields from the sea.

It is safe to say that we have still to solve the problems of successful use of the living resources of Arctic Canada and Arctic Alaska in the support of human populations much in excess of the primitive ones. In fact our impact over the first three to four centuries has generally reduced the resource base and its productivity.

Following is a brief review of some of the major ecological factors that must be considered in taking decisions on strategy in northern development. A first principle would be that at our stage of social evolution our biological resources should be managed so that their capacity to produce future crops is undiminished.

I shall not deal with the role of forests as timber or as cellulose for manufacture. The elements in this equation are reasonably well known.

Meat Production

There are three potentially important large meat animals of the Arctic: caribou, moose, and musk oxen.

The barren ground caribou is intensely social and migratory. Furthermore its food preferences are met in the climax plant communities, the lichen tundra and the mature taiga or broken forest of spruce and tamarack where lichen is an important element. The tundra proper is relatively fire-resistant but the taiga is highly inflammable and huge areas totalling thousands of square miles have been returned to the disturbed early stages with, in the Northwest Territories, a greatly reduced capacity for caribou production. Experience in Newfoundland, however, suggests that under certain conditions burning does not make tundra range useless to caribou. We do not yet understand the circumstances. Biological succession proceeds much more slowly in the Arctic than farther south and it may well take half a century to restore the tundra lichen-range following serious fire.

The moose, on the other hand, is a creature of the disturbed forests. It flourishes on the abundant second growth of deciduous plants that follow disturbance by fire, flood, avalanche or man (Spencer and Chatelain 1953). Thus as the caribou range has decreased, the moose range has increased, but potential yields do not seem to be equated. Furthermore, the moose is less migratory and thus more dependent on the appropriate mix of environment locally to provide its year round needs. It is also solitary and thus all major elements in the strategy of moose management differ from those of caribou management.

The musk ox in the wild has a low rate of productivity. In general it finds its ecological requirements north of the tree line and extends successfully to the frigideserts of northernmost Ellesmere Island. It is only locally a migrant and except for the low energy yield of its habitat could be an important animal in the production of meat and wool. Captive rearing experiments by Teal in Alaska and Oeming in Alberta (personal communications) confirm a capacity for growth and production almost the equivalent of less specialized breeds of domestic cattle.

The success of the reindeer cultures of equivalent latitudes in Europe and Asia led naturally to attempts to use this semi-domesticated caribou as a substitute for the vanishing wild herds of our Arctic. The history of these trials both in Alaska and Canada have been reported in detail (Krebs 1961, Roberts 1942). At their maximum the Alaskan population numbered some 600,000 animals. Porsild's (1929) study of the range potential of the tundra between the Mackenzie and Coppermine Rivers suggested a capacity of about half a million animals. In addition to the trials made on the mainland of Alaska the reindeer was introduced to St. Matthew Island, Nunivak Island and St. Paul and St. George islands of the Pribiloff group.

The history of those trials, in terms of economic or social impact on the North, can only be summarized as failures. In western Alaska and on some of the islands they have also been most destructive of the natural vegetation. The reasons for failure have been varied but the overriding ones are political bungling and failure of the northern population either indigenous or immigrant to grasp the potential, understand the ecological strictures, and make the social adaptations requisite for success.

The island introductions have now become classic textbook models for the population behavior of a herbivore with no predators in an environment with limited food supply. (Scheffer 1951, Klein and Whisenhaut 1958). There was no attempt at management and in ecological terms these introductions can only be regarded as irresponsible acts with far reaching consequences to the biota of the islands.

These failures then are best regarded as socio-political, the ecological potential remains even if now somewhat reduced. On the basis of studies by Porsild (1929), Palmer and Rouse (1945) and the experience in U.S.S.R. (Flerov 1952), it is possible to predict that managed herds of reindeer numbering perhaps a million head could be supported in the Arctic from the Alaskan coast to the Coppermine River and that these could yield as much as 34 million pounds of meat a year. These would in part displace existing caribou herds and arrangements for the continued survival of the wild herds would probably reduce the domesticated

potential somewhat. The meat yield from the combination would not be proportionately lowered.

The dispersed characteristic of moose distribution makes this an unsatisfactory animal for the production of a wild-taken harvest for the use of arctic communities. It is almost impossible to take an effective harvest even where the local politicians have overcome their sex bias and arranged for the removal of both sexes. The consequence of under-harvest is local surpluses that eat out the food supply and perish.

Great care should be taken that our quasi religious presence before the shrine of the musk ox does not lead to the same unfortunate consequence as has befallen the St. Matthew Island reindeer. This is of special significance on its island habitats, especially where the musk ox has been introduced to areas not previously inhabited.

It is becoming certain that the burgeoning human population of the world will demand first priority of all plant foods usable directly by man. The loss of energy that results from the conversion of human plant food into the meat of herbivores will not be tolerated. It follows therefore that we should be devoting ourselves to a search among the wild herbivores for species that we can culture as human food on acres, and plant forms that cannot be used for the primary production of human comestibles. In the U.S.S.R. there are several Institutes devoted to reindeer research and at least one at which the domestication of the moose is a primary objective. We, on this continent, have given almost no attention to the various possibilities of adapting the three arctic herbivores for domestic or semi-domestic culture. These might involve animal breeding experiments devoted to changing the physical and behavioural characteristics of the animals as well as attempts to adapt mid-arctic lands to the production of shrub or herb pastures suitable for the culture of these creatures. Such culture may be facilitated by the addition to the diet of low bulk, high energy chemical supplements imported for the purpose.

It would seem to be quite possible, for instance, to develop techniques for converting aspen and willow into pelleted feeds for big game being raised in semi-confinement. Technological and economic changes will be needed before such uses will be practicable. However we should be exploring the possibilities.

The fur resource of the arctic and subarctic areas has been a major contribution to this resource in North America. At the same time I must point to some of the Banks Island white fox trappers as the most affluent practitioners of the trapper's art anywhere in the world. It is a fickle component in the regional economy however because of very large fluctuations in the harvestable crop as well as rapid changes in demand based upon the social attitude toward different kinds of fur and the development of fur substitutes. The recent changes in the market for sealskins have made this particularly emphatic. The vagaries of supply can be predicted with reasonable assurance, not so the changes in demand.

The extensive marshlands of such areas as the delta of the Mackenzie River, the delta of the Athabasca, the area adjacent to Old Crow and other great river Deltas of the North have the capacity to provide a sustained harvest of muskrat fur of considerable volume.

The muskrat crop could be increased and stabilized by some relatively simple alterations in the habitat that would deepen the water remaining through the winter in many productive but temporary lakes. At the same time the institution of more refined management regulations, based upon a comprehension of the ecological opportunities and constraints could also improve the long-term yield.

So far the meat potential of this species has been ignored, probably because of a bias arising from the common name. I can give personal assurance that fresh muskrat properly handled is far superior to rabbit both in flavour and nutritive content. It has enjoyed a limited market elsewhere under a trade name and I can see an opportunity for the promotion of a specialty market in Canada.

I should not leave the subject of meat production from the arctic ecosystems without referring to the fishery potential. Recent studies by biologists of the Fisheries Research Board of Canada (personal communication) have revealed char stocks as high as 5 lbs. per acre in landlocked waters and stocks of migratory and marine fishes of some 3 lbs. per acre in the western Arctic and ten times that in the eastern Arctic. These stocks may be able to tolerate annual harvests of 20 per cent or higher on a sustained basis. The potential tonnage of high quality protein is immense when economic constraints are overcome.

The Role of the Far North as a Nursery Area for Migratory Birds:

So far human activity in the North has had little influence on the hosts of migratory birds that swarm into its vast reaches each spring to make use of the energy surpluses available each summer. Countless millions of birds of some species annually raise their young on the teeming insects and the abundant crop of vegetation, seeds and fruits that characterize the arctic summer.

The majority of these species will remain relatively immune to normal human alterations to the environment. However, to an increasing extent we are searching for oil and minerals over vast regions and our leasing regulations completely ignore the ecology of the areas being assigned for *development*. The Arctic occupies a unique position with respect to many important migratory species of wildlife. Among the rare and vanishing species of birds the very localized and extremely vulnerable nesting grounds of the whooping crane have received wide publicity. No similar concern has been centred on the even rarer Eskimo curlew that may be making its last stand somewhere along the lower reaches of the Anderson River. The Tule goose, Ross's goose, of the lower Perry River, the Aleutian Canada goose of Amchitka Island, the greater snow goose on Bylot Island are just examples of large and valuable species, with small to very small world populations based exclusively upon very circumscribed arctic nesting grounds. A number of other species of Alaska and Northern Canada could be mentioned as almost as vulnerable.

My purpose in naming these few examples is to emphasize the ecological problems they present, and to urge modification of our regulations governing alienation of tracts of arctic land so that concern for proper ecological behaviour becomes an essential condition of the development.

Pesticides and Other Pollutants

The establishment of human communities in the Arctic sometimes leads to the demand for aerial distribution of DDT and other pesticides over adjacent areas. As a former and potential meal for millions of mosquitos, black flies and tabanids that blight the short arctic summer I can sympathize with the demand. However, decisions to spray and choice of the chemical should not be taken without adequate consideration of ecological consequences. The appropriate biologists of the wildlife services should always be involved in reaching decisions on where, when and how to use eradicants and which ones to apply.

Pruitt has shown that the arctic caribou acquire a heavier load of radioactive fallout products than any other known species. It has been shown also that even on the isolated arctic slope of the Brooks Range the aquatic insects are carrying their quota of DDT. True no harmful consequences have yet been demonstrated for these two situations but then we have not looked for any. These examples, however, do serve to emphasize that caution must be observed even in such remote habitats. We cannot assume that a species is safe from such contacts with damaging chemicals merely because its nesting ground is remote.

The disposal of the waste products of our culture are a continuing problem in the Arctic. Human sewage is usually dumped into a local river if one is available. In this the north differs little from many more southerly areas. However, rates of decomposition are much slower and we know almost nothing of the impact of such action on arctic rivers. Research is urgent. The beaches of some of our most remote Arctic Islands are littered with plastic bags of human excrement grounded ashore after drifting miles from some northern outpost of our culture!

In the Far North where the number of polluters is small and the cost of better planning correspondingly low, we must face the reality that the assumption of dilution, where biologically active wastes are at issue, is frequently false. The assumption is an attractive one. It seems so obvious that if a relatively small amount of a biologically active toxicant is discharged into a large body of water it will rapidly dilute below the level of toxicity. The evidence from study of radioactive wastes (Woodwell 1968) and from DDT is that the assumption is false and that biological concentration is a frequent sequel. Unfortunately this false assumption is so much part of our philosophy that we accept its corollary, the right to pollute until detailed scientific proof of damage to man is produced. It would be far more valid to adopt here the principle behind the licensing of drugs for use on man — that permission be refused until there is detailed scientific proof that the pollutant will do no damage to the biosystem.

Military and industrial activity in the Far North has shown widespread disregard for the environment. Anyone who has visited the sites has been appalled at the litter that is left behind. In almost every instance government involvement or control was intrinsic and it becomes the responsibility of government to insure a clean-up of each such project in the north.

Mining is one of our most productive uses of the natural resources of the Far North. In most instances it is an activity with high waste residues. In land as heavily glacier-tilled as much of the western Arctic is, the physical wastes of sub-

surface mining may be relatively unimportant except where they occur in areas of special value in their original state. The discharge of chemical pollutants, however, is a different matter and should be carefully studied and controlled where ecological changes may arise.

The rates of recovery from all forms of exploitation are much slower in the Arctic than in the more southerly areas where we have been forming our procedures. This is a fact of the greatest significance as we pattern our attitudes and behaviour.

The Protection Movement

One of the most significant developments of the last forty years has been the rapid growth in the number of people who look to the natural environment for a large part of their recreation and enjoyment. This segment of our population is not generally antagonistic to economic development and to the use of the natural resources for human enrichment. They realize fully that to a very large extent the many advantages we enjoy stem directly and indirectly from our ingenuity in resource use. They agree that man cannot expand his use or improve his lot without greatly altering many areas of land.

However, these developments do demand that we develop patterns of use that are consistent with the maintenance of natural ecological conditions wherever possible. They also require total proscription in some areas of unique quality or biological importance.

There are many excellent reasons for seeking special immunity from environmental alteration in some areas. One of these is aesthetic. Many people attain a refreshment of the spirit in wildlife and unspoiled wilderness that needs no explanation or justification. A host of others, while not actively participating in the enjoyment of nature in remote places, find their lives richer for the knowledge that the opportunities exist.

Furthermore, the world's store of genetic material may well prove to be exceedingly valuable as we seek to put our new-found knowledge of genetic processes to work. The Arctic includes many species that have acquired unique heritable capacities to survive and prosper under northern climatic circumstances during millions of years of evolution. These qualities are in theory available for our use when we reach the stage in our knowledge that makes it possible. But each genotype lost, before evolution has replaced it, is another step in the degradation of our environment, another potential opportunity irretrievably lost.

The participants in the conservation movement regard the Arctic as of very special interest. It is a part of the continent where we have not yet made the plethora of mistakes that face us with unfortunate consequences farther south. It is a land where vast areas remain essentially as they have always been. It is a land rich in a unique flora, where plants and animals alike have evolved highly specialized attributes of behaviour, anatomy and physiology, much of this still unexplored. Conservationists therefore will increasingly appear as the conscience of our society to demand that the conversion of wild lands and their products into marketable form in the least expensive way is not the sole, nor perhaps the most important goal of this society.

In the northern lands knowledge of the appropriate ecological facts is indispensable if we are quickly to recognize the alternative opportunities for resource development and the constraints within which we must conduct our activities. Here, even more than further south, man will continue to live in the closest contact with the natural environment. His success will depend as much upon the sophistication of his ecological knowledge as upon his technological competence to respond.

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