ASSESSING MANAGEMENT OPTIONS FOR A RAPIDLY EXPANDING MUSKOX POPULATION

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ABSTRACT

One of the current problems facing wildlife managers in the Northwest Territories, Canada, is how to manage rapidly increasing muskox (Ovibos moschatus) populations. Muskoxen were reduced to near-extinction at the turn of the century and numbers remained low for many decades thereafter. Tener (1965) estimated the Canadian population at 10,000 in 1965, and 17 years later Urquhart (1982) estimated 45,000. Most populations have grown rapidly in the past decade, and there is now concern for local over-population and future declines.

This report is based on a discussion paper presented at a workshop on management of expanding muskox populations convened during the Second International Muskox Symposium held 4-7 October, 1987 in Saskatoon, Saskatchewan. It is presented as an example of the sort of practical planning process wildlife managers can undertake when confronting difficult decisions. It explicitly treats the muskoxen of Banks Island, Northwest Territories, but the principles outlined are broadly applicable. The judgments and conclusions are my own and do not represent policies of the Government of the Northwest Territories.

EDITORIAL NOTE: The information used as the basis for this report was that available during 1987. Although additional data on muskox abundance are now available, the validity of this paper as an examination of management planning technique remains the same.

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INTRODUCTION

Before assessing the spectrum of available actions, the nature of the problem must be understood clearly. There are three questions to be asked:

1) What is the current situation?
2) What is the situation to be sought?
3) What is the situation to be avoided?

The current situation

1) There are ca. 26,000 muskoxen spread over the 70,000 km^2 island (McLean et al. 1986) concentrated primarily in the North. The Inuvialuit community of Sachs Harbour (pop. 165) is the only settlement on the island and is located in the extreme southwest corner.
2) The muskox population has been expanding at a rate of 10-16% per year (McLean et al. 1986).
3) The population is entering the "initial stabilization" phase (Caughley 1970) characterized by increasing juvenile mortality. (A. Gunn pers. comm.)
4) The caribou (Rangifer tarandus pearyi) population is declining (McLean et al. 1986). Local hunters maintain that muskoxen are outcompeting caribou.
5) Local people prefer to eat caribou but take 100-500 muskoxen per year for domestic consumption, sport hunts, and commercial

harvest.

What is the situation to be sought?

1) Population numbers stable within certain limits.
2) A population small enough that there is no concern for overpopulation.
3) A population large enough to provide for the needs of Sachs Harbour residents.

What is the situation to be avoided?

1) Population crash with possible population depression to a level at which access to the resource is lost to local people.

By the ambiguous term "crash", I refer to a dramatic density dependent decline. In fact, any decline will have both density independent and dependent factors operative and, consequently, it will be impossible to label the type of an observed die-off clearly. I will operationally define a crash as a "decline in population numbers of >50% with a downward trend extending over 2 years." This is an imperfect attempt to differentiate a crash from two other types of population decline. The first of these is a slow decline over a period of many years. This may be an acceptable situation but, if not, the longer time scale allows time for effective intervention. The second is a density independent catastrophe such as bad, winter icing conditions acting over a single year. Such an event is as undesirable as a crash but is wholly outside the realm of effective management action.

EVALUATING THE OPTIONS

Given an understanding of what is happening and what we would like to see happen, thought experiments can be conducted to determine and evaluate the results of various courses of action. To be thorough, decisions are presented in the approximate chronological order in which they must be addressed. The complete decision framework is presented as Figure 1.

Is action justifiable?

The most fundamental question to be addressed is whether or not to take any action at all. Wildlife managers approach their work with the tacit assumption that action should be undertaken only when it is reasonably certain that tangible benefits will accrue to the resource and its users. There are two aspects to this: there is no reason to fix what is not broken, or to attempt futilely to fix what is irreparable.

There are a number of reasons for deciding to take no action. First, it might be argued that the Banks Island muskox population will just cycle with dampening oscillations and perhaps some acceptable adjustment in mean numbers. Consequently, there is no requirement for action. Second, it might be argued that population numbers will be determined eventually by weather conditions in a density independent manner. If so, management actions cannot be effective and are, therefore, unnecessary.

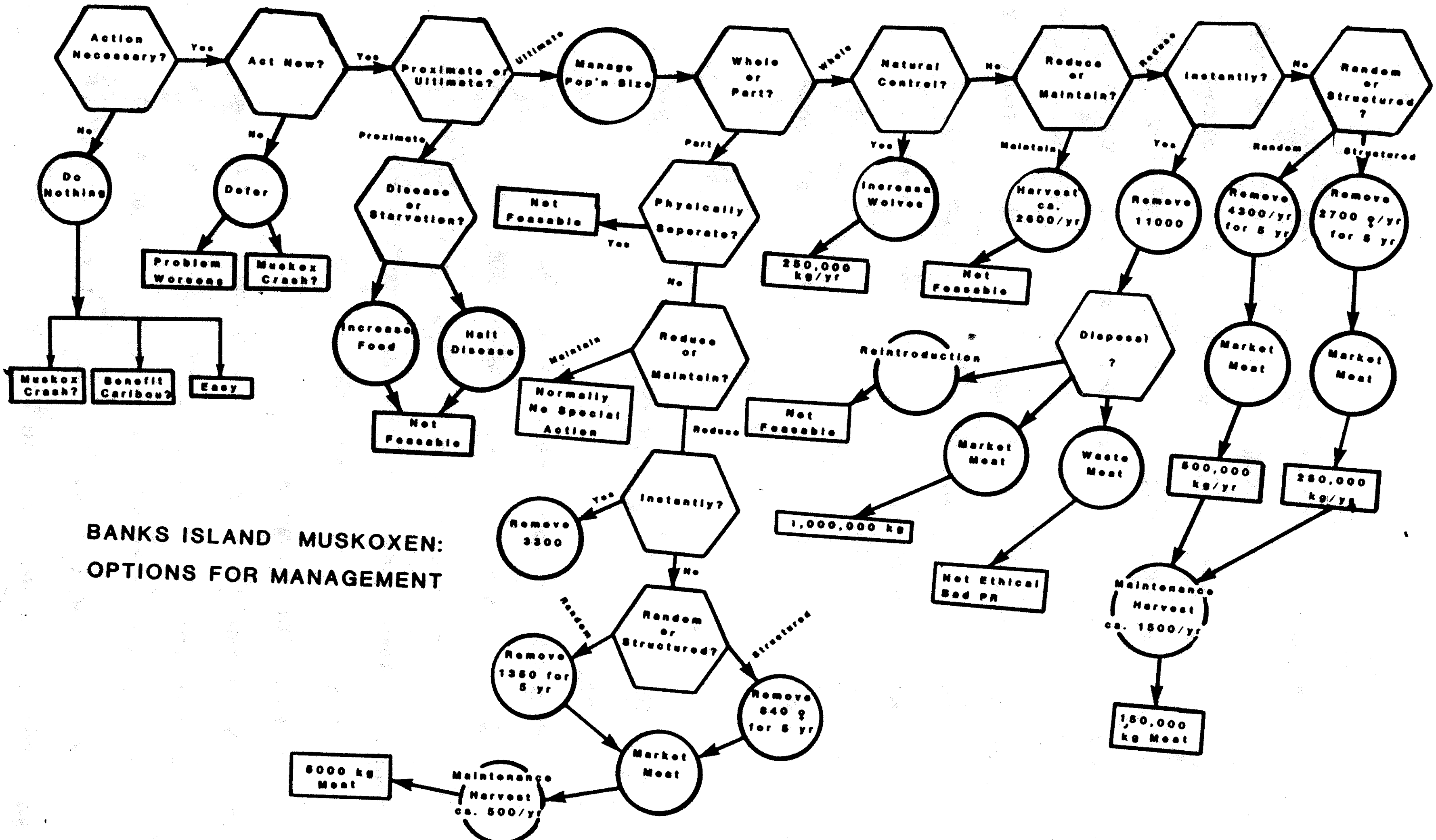

Figure 1. The decision framework of possible actions for managing muskoxen on Banks Island.

Third, the planning process may not identify logistically and economically feasible actions capable of averting a population crash. Fourth, "no action" may represent the tactic most likely to produce acceptable results in an uncertain planning environment. Doing nothing may not yield handsome rewards, but, on the other hand, it does not cost anything. And last, a muskox population crash may be considered a desirable outcome. Banks Island hunters have long contended that muskoxen are driving caribou numbers down. A critical test of this hypothesis requires a radical reduction in muskox numbers.

Assume for the sake of this exercise that some action is desirable.

Act now or later?

The next question to address is whether to act immediately or to wait until our understanding is more complete. There are major gaps in our knowledge of muskox biology on Banks Island, and, consequently, management actions undertaken now would be based largely on intuition, extrapolation, and craft rather than scientific wildlife management.

It is very tempting to defer action; the easiest solution to difficult questions is to procrastinate. In this case, however, deferring action is not only the simplest solution, it is also the most dangerous. The first danger is that the longer that action is delayed, the larger the problem becomes. The second is the loss in confidence felt by local people as managers commit themselves to action and then appear ineffectual when the crisis occurs during the delay period.

A decision to defer action should only be taken if there is some discrete bit of easily obtainable research required upon which the course of management action depends. Otherwise, the best course is to take the most reasonable action available or to decide *a priori* to take no action.

Treat proximate or ultimate causes?

The next decision concerns the level of causality to be targeted. Is it best to ameliorate the proximate mortality factors causing the possible decline or to approach the root problem, overpopulation?

The most obvious proximate factors leading to catastrophic population decline are disease and lack of food resources. Manipulation of either seems impractical. It is beyond our capacity to feed muskoxen during the winter, to fertilize sedge meadows, to fence off quarantine areas, or to inoculate animals. Even if such actions were feasible, they would not represent a solution to the problem. At best, treatment of proximate factors ultimately exacerbates the basic problem; overpopulation. Management action must be targeted upon the ultimate problem.

Treat all or part of island?

The entire population can be managed as a single unit or a subpopulation might be delineated and managed while nature took its course with the remainder of the population. I will first treat scenarios for managing the whole island and return to options for managing part of the population.

Natural or artificial mortality?

Overpopulation can be treated by increasing natural or human-induced mortality or by decreasing fecundity. The most reasonable way to increase natural mortality is to increase wolf predation. Few wolves (*Canis lupus*) are currently found on Banks Island for reasons that are not clear. Some biologists suspect that a disease vector operative through the very large arctic fox (*Alopex lagopus*) population is responsible. If wolves could be induced to increase at the maximal rate from their current number of about 20, a simple simulation model shows that the muskox population would increase to over 100,000 before there would be enough wolves to begin to reduce muskox numbers. Another mortality factor would doubtlessly become operative before muskoxen reached such a level. Even if it were possible to allow wolves to limit muskox populations, it would be too little and too late.

Reduce population or maintain current number?

A decision must be made whether to maintain current population numbers or to reduce them. If current numbers are to be maintained, it will require removing ca. 2,600 animals each year, for an indefinite period, with the effort spread over the island proportionately to population density.

A major problem lies in how to dispose of the removed animals. The preferable solution would be to capture and reintroduce them at locations where muskoxen no longer exist. Unfortunately, there is a shortage of suitable locations and the costs would be excessive; several million dollars each year.

The next best solution would be to increase the current harvest. Despite the quota of 2,000, hunters from Sachs Harbour only take about 100/yr for domestic consumption and a maximum of 400 (usually <200) for commercial purposes. It is not reasonable to expect this harvest to increase to required levels.

Increasing the commercial harvest through governmental assistance is perhaps the most feasible solution. However, an annual cull of 2,600 animals would produce over 250,000 kg of meat each year and would require an annual outlay of $1,000,000 (exclusive of abattoir and freezer facilities) just to get the meat to Inuvik, the nearest roadhead. Establishing a long-term commercial operation of this scale entails thorny problems including precedents for large-scale commercialization of wildlife, opposition from the beef lobby, establishment of feasible federal field-dressing and inspection protocols, and heavy capitalization, all overlain with uncertainties inherent in natural instability of arctic animal populations. However, local people could profit handsomely from their natural resources in a manner not often realized in the Arctic.

The last alternative is to leave the carcasses to rot. This would entail a huge public relations problem, would contravene wastage laws, and would be distasteful to everyone involved. Wastage is a viable option only when it represents the sole solution to a certain problem of devastating consequences. Neither the likelihood nor the outcome of a muskox crash are fully understood and consequently wasting the meat cannot be accepted.

The effectiveness of management action involving maintenance of current numbers is uncertain. Juvenile mortality is currently increasing indicating that a crash could occur at present population levels. Maintaining current numbers over the whole island would be both costly in its implementation and uncertain in its results.

Achieve goal population level instantly or gradually?

If it is decided to reduce the population, the optimal population size must be established. For the sake of example, I suggest a 40% reduction to 1980 levels of 15,000; probably comfortably below ecological carrying capacity.

If an instantaneous reduction is to be effected, 11,000 animals must be removed in 1 year. Commercially harvesting the requisite number of animals would result in over a million kg of meat to be sold to a one-time-only market. The needed infrastructure and capital equipment do not exist and acquisition could not be justified for a single venture.

The alternative to an instantaneous reduction is to spread the harvest over a period of years. The implications are that the total number of individuals killed would be greater because of continuing, and perhaps compensatory, natality over the cull period, but the number of animals killed per year would be less. The practical results would be the need for less capital equipment, work crews would be of a more manageable size, costs would be spread over several years, and more stable outside markets could be developed.

There are two ways to achieve a gradual approach to target level. The kill could be a random one in which the age-sex composition approximates that of the population or, alternatively, breeding females could be killed preferentially. The advantage of the latter alternative is to slow the natality rate by reducing the proportion of breeders.

A simple simulation model indicates that a random kill, needed to reduce the population to 15,000 in 5 years, would amount to ca. 4,300 per year or 21,500 animals over 5 years (Figure 2). Marketing the meat is still a major task involving around 400,000 kg/yr.

If it is decided to institute a sex-structured harvest, fewer

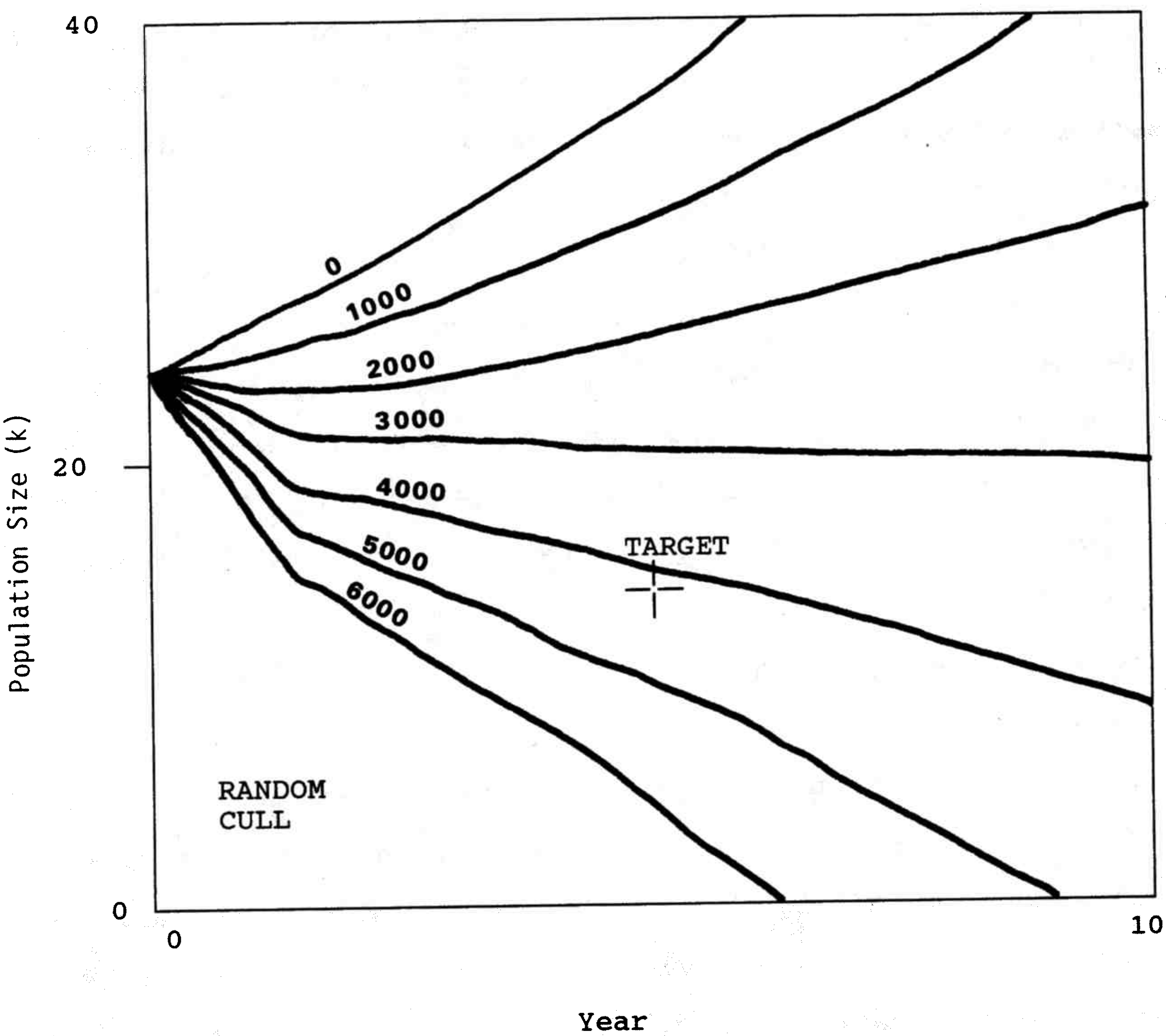

Figure 2. Results of a computer simulation showing population size after 0-10 years of random harvest. The size of cull is denoted on the relevant trajectory. The cross represents the goal of 15,000 animals in 5 years.

individuals would have to be killed but much more effort would be expended in selective hunting. Female kill would be 2,700/yr for 5 years (Figure 3), producing 250,000 kg of meat per year. Annual outlays to process the meat and get it to Inuvik would be well over $2,000,000 exclusive of capital equipment. With effective marketing, annual profits to the Inuvialuit might amount to $1,000,000.

Once the population has been reduced, it must be maintained at a low level through regular culling. The size of this cull will depend upon the age and sex structure of the population and could vary from 300-700/yr. Reducing the population over the entire island would require a massive effort but would probably be very effective in averting a population crash.

Managing part of the Banks Island population

A more workable alternative might be made to manage only part of the Banks Island muskox population, implying that the managed subpopulation must in itself meet the desirable objectives. The subpopulation must be kept at robust stability, provide for the needs of Sachs Harbour hunters, and be within snowmobile range of the community. The managed subpopulation must, therefore, be in the southern half of the island.

The first problem is whether or not to try to delineate the managed subpopulation physically. A fence is not feasible, but it would be possible to maintain a wide removal zone around the managed

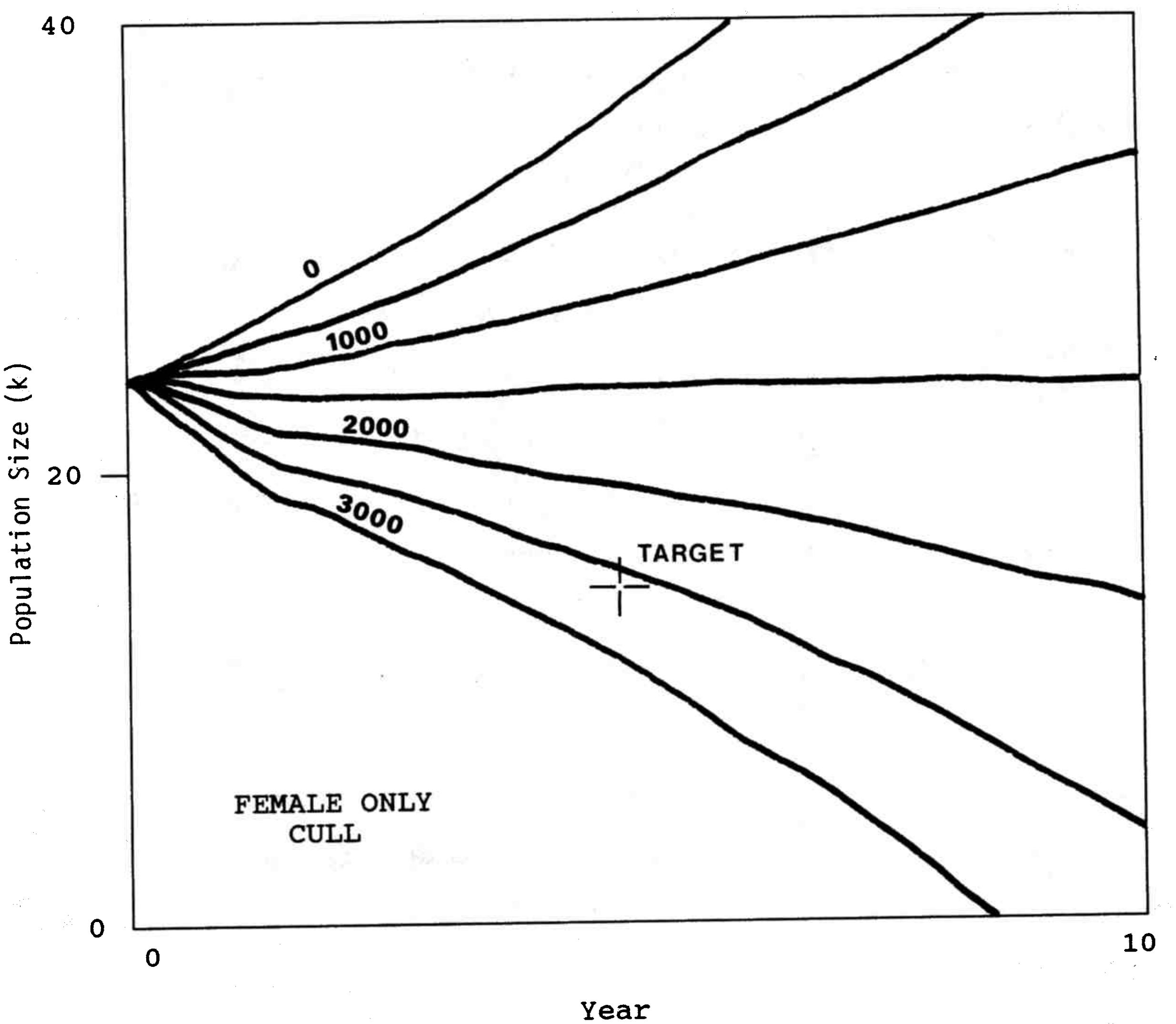

Figure 3. Results of a computer simulation showing population size after 0-10 years of female-only harvest. The size of the cull is denoted on the relevant trajectory. The cross represents the goal of 15,000 animals in 5 years.

subpopulation resulting in inhibition of ingress. The attractiveness of the idea lies in the known sedentariness of muskoxen. The problem rests in our lack of knowledge about muskox colonization. Colonization probably occurs by relatively infrequent irruptions involving swift movement over long distance. Maintaining a removal zone seems an inordinate amount of effort for a very uncertain result. Physical separation of the subpopulations seems impractical.

The remainder of the decisions follow those made relative to the entire population; only the numbers are smaller (Figure 1). If a herd of 5,000 is to be maintained, about 500 muskoxen would need to be harvested each year, which is well within current capabilities. However, if current densities are too high for stability, this strategy could result in a crash of the managed subpopulation.

Reducing the subpopulation by 40% would entail delineating a management zone holding 8,300 animals, reducing them to 5,000, and maintaining the resulting density. The reduction could be instantaneous, involving the slaughter of 3,300 individuals, or a gradual approach to desired levels through an annual kill of 1,350 randomly selected animals or 840 females for 5 years. In all cases, the annual maintenance harvest would be about 500 randomly selected animals.

A major objection to managing part of the population without physical delimitation is concern over whether or not a decline in the unmanaged north will extend into the managed south. What is uncertain is whether or not lower population densities will result in sufficient vigour to resist density dependent mortality and fecundity factors originating under more crowded conditions. Therefore, managing part of the population is intrinsically of uncertain effectiveness.

COPING WITH UNCERTAINTY

The above discussion identified only five management actions as being feasible. We can decide to do nothing (Option 1), to maintain current numbers over part of the island (Option 2), to reduce the population over part of the island (Option 3), to maintain current numbers over the whole island (Option 4), or to reduce the entire population (Option 5). Each of these options has differing costs and effectiveness. What is clear, however, is that there is no solution which is simultaneously both inexpensive and effective. Such a solution would fall into the upper left corner of a graph plotting cost against effectiveness (Figure 4). Instead, the 5 solutions fall on a curve roughly sigmoidal in shape. "No action" costs nothing and has no effectiveness. Maintaining current population levels on part of the island costs little more but is not much more effective. Maintaining current numbers on the whole island would be very expensive and only modestly effective. Reducing the population over the entire island would cost vastly more for a disproportionately small increase in effectiveness. In general, increasing expenditures yield slowly increasing returns at both high and low cost levels.

Picking the best solution becomes a complex, optimization problem with poorly defined and probabilistic inputs. The best manner to analyze such complex decisions seems to be the classical "decision tree" (Lindley 1985). An example is provided as Figure 5. Each square represents a decision or management option and each

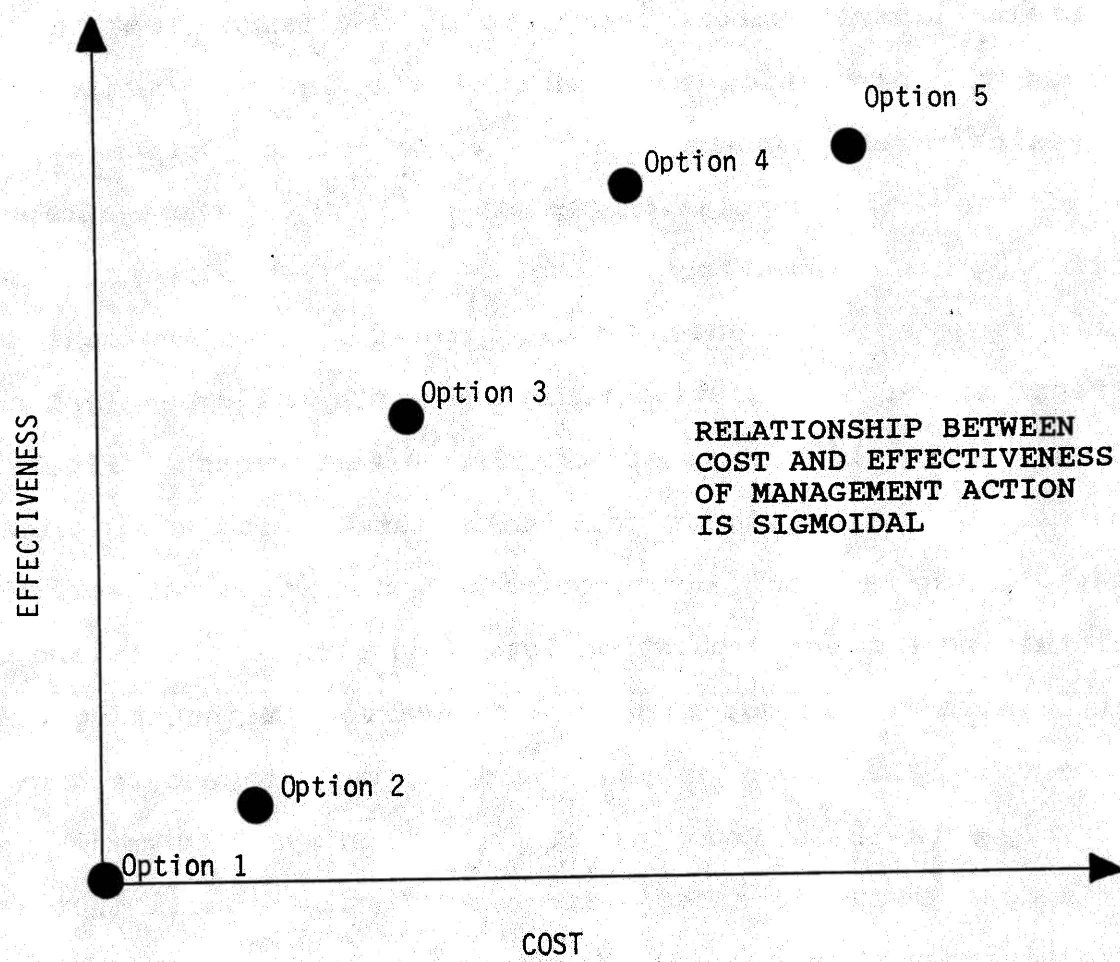

Figure 4. The relative values of cost and effectiveness of the five possible management actions.

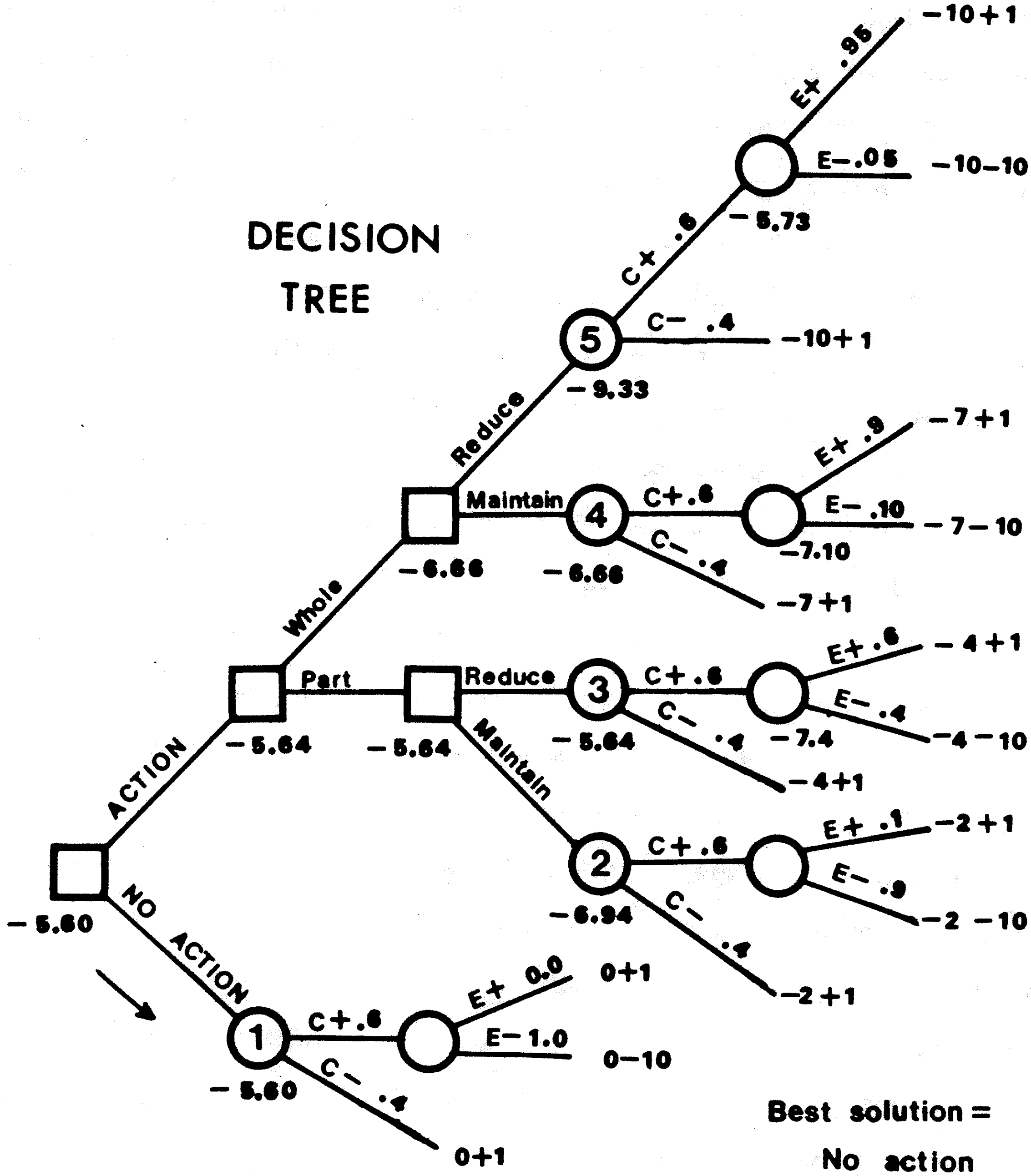

Figure 5. A sample decision tree. Boxes represent decisions and circles probabilistic events. Numbers to the right are utilities representing payoffs for management costs and effects. See text for details.

circle represents a probabilistic event over which managers have no control given the previous decisions. The upper right branch treats the decision to reduce the population over the whole island (Option 5). The intrinsic probability of a population crash is denoted C+ and is given a probability of 0.6. The alternative is the intrinsic probability of no crash which is denoted C- and has a value of 0.4. Management action of this intensity is assumed to be effective in averting a crash with a probability of E+ = 0.95. The probability of our actions failing is E- = 0.05. Utilities or pay-offs are assigned to each possible outcome on the extreme right. Costs are assigned negative values and benefits positive ones. Option 5 involves a management cost of -10 units but a gain of +1 unit if a crash is avoided. If Option 5 fails to avoid the crash, the total loss is large; -10 for management costs and -10 for cost of the crash. The end utilities are multiplied by the probabilities of uncertain events and the resulting modified utilities from all the converging branches are added together. At each decision node, one accepts the branch providing the highest payoff; in this case the lowest cost. In the example, the lowest cost option is "no action" (Option 5) although Option 3 leads to almost identical costs. See Lindley (1985) for more details on evaluating decision trees.

The difficulty with this sort of analysis is in assigning values to probabilistic inputs and in objectively defining payoff utilities. It seems possible to overcome this problem partially and derive some qualitative conclusions by means of simple sensitivity analysis in which important variables are scaled continuously.

The key unknown is the probability of a crash. Figure 6 represents the solutions of a number of decision trees varying the probability of a crash. The vertical axis represents the calculated pay-offs for each of the 5 suggested management actions. Because these are represented as costs, the lowest one is the most acceptable. When the probability of a crash is less than about one-half, it is best to do nothing. If a crash is thought to be very likely, it is preferable to make a moderate effort; i.e., reduce the population over part of the island. It is important to note that there is no point in making a small, token effort or a major, intense effort. The conclusion is to do nothing or take moderate action.

This conclusion is based on the sigmoidal relationship between cost and effectiveness alluded to earlier. The exact nature of this relationship will have an effect on results of decision tree analysis. A linear relationship between cost and effectiveness makes "no action" the best decision over the entire range of crash probabilities whereas a monotonically increasing relationship makes lower cost solutions more viable but does not alter the general conclusion stated above; do nothing or act moderately.

Another factor influencing these decisions is how disastrous a crash is perceived to be relative to management costs. It might be decided that a population crash is unacceptable and must be avoided at all costs. Figure 7 shows the cost of a crash varying from 0 to

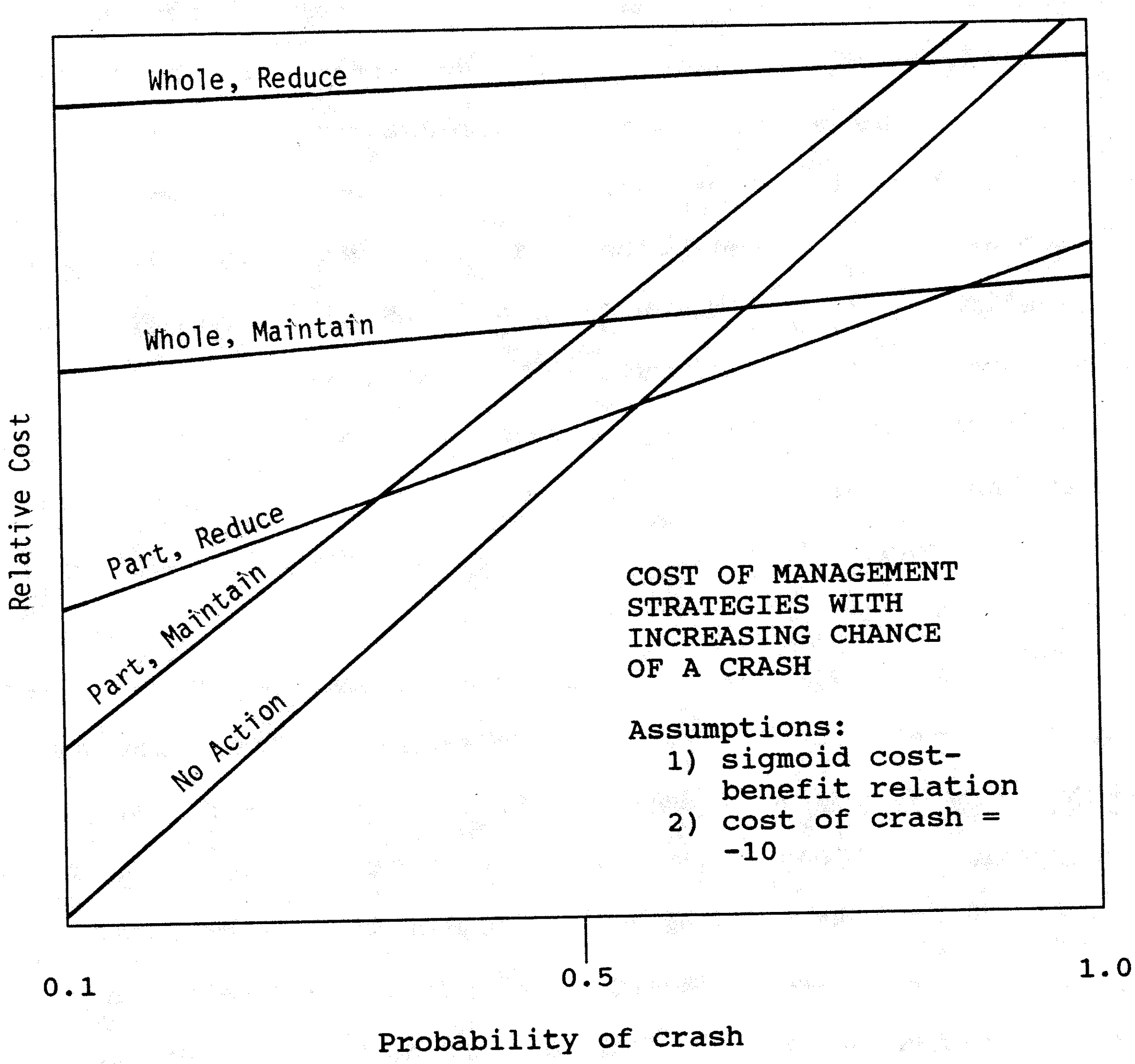

Figure 6. Sensitivity analysis representing maximum utilities (minimum costs) resulting from the 5 possible management actions under varying probabilities of a population crash. Assumes a sigmoid cost-benefit relationship.

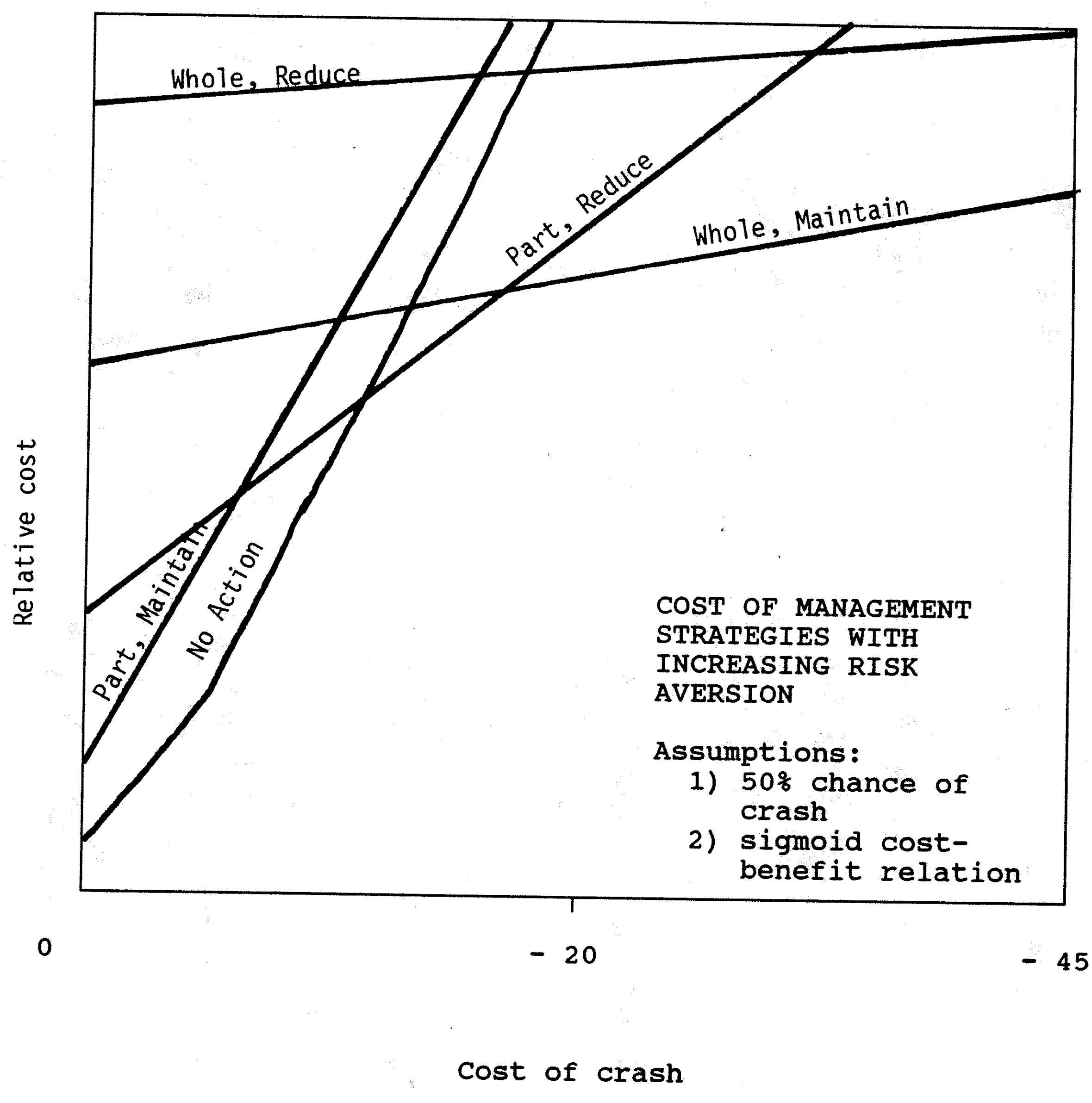

Figure 7. Sensitivity analysis representing maximum utilities (minimum cost) resulting from 5 possible management actions under varying perceived costs of a crash. Assumes a sigmoid cost-benefit relationship.

-45 relative to management costs varying from 0 to -10. The interesting point is that the same general patterns emerge. It is never the best decision to take high or low cost management actions; better to intervene moderately or not at all.

CONCLUSIONS

The conclusions from these analyses are: _if_ the best estimate of the probability of a population crash occurring is <ca. 0.5 _and_ a population crash is not intolerable, _then_ no action should be taken. If action is to be taken, the best is one of moderate intensity; probably to reduce the population over part of the island. This conclusion is modifiable as decision makers and management experts evaluate the framework's inputs and evaluations.

Research needs have not been mentioned because they are irrelevant to the decisions which must be made immediately. However, if future decisions are to be better informed, then integrated research must be undertaken to provide the specific information required.

SUMMARY

An assessment of options for managing an expanding muskox population on Banks Island, NWT, is presented as an example of a procedure wildlife managers can use to assist them in making difficult decisions. The problem is bounded by making explicit the current, desirable, and intolerable situations. Thought experiments are done on all conceivable management options to assess them for feasibility and effectiveness. Those which are ineffective or impossible are discarded. Remaining options are scaled by relative cost and effectiveness. On the basis of these data, multiple decision trees are evaluated with varying values for important input variables. Qualitative statements can then be made regarding the best action to choose under various conditions.

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Anne Gunn provided the initial impetus for me to consider this problem carefully. Earlier drafts of this paper were reviewed by K. Poole, R. Case, and A. Gunn. G. Caughley encouraged me to publish the report.

PERSONAL COMMUNICATIONS

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