FIRE IN THE MANAGEMENT OF CANADA'S NATIONAL PARKS: PHILOSOPHY AND STRATEGY

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ABSTRACT

This paper deals with the question of whether fire has a place in the management of national parks. It takes as given the basic parks' philosophy that large-scale artificial techniques or treatments are out of place in park management.

The paper begins with a discussion of ecological principles: that the concept of stability is quite appropriate to an ecosystem that depends on fire for periodic recycling, that the temporary post-fire transformation of the site is necessary for such an ecosystem's survival, and that the same age-class distribution found in self-perpetuating forests among individual trees is likely to be found also in fire-dependent forests among communities or stands. The paper goes on to discuss:

- the ecological role of fire and its impact on the site;
- renewal rate and age-class distribution;
- fire behaviour and its importance;
- fire regimes and fire history;
- choice of vegetation and wildlife;
- classification of vegetation;
- lightning, man-caused, and prescribed fire;
- scale in time and space.

The paper stops short of questions about individual parks or problems of tactical, day-to-day fire management. It concludes that three options are open to large parks whose vegetation is largely fire-dependent:

- include fire in park management;
- permit artificial means of vegetative renewal;
- accept pronounced changes in park vegetation and wildlife with time.

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I. INTRODUCTION

Rational and successful land management has four prerequisites: (1) a statement of objectives and principles, (2) a good conceptual grasp of regional ecology and landscape evolution, (3) a management strategy compatible with both of (1) and (2), and (4) an operational plan.

This paper about fire in the national parks takes as given the broad objectives of Parks Canada, but stops short of considering the operational details and problems of carrying them out. It deals rather with certain aspects of ecosystem ecology and management strategy, namely points (2) and (3) above. The principle underlying the entire discussion is the importance of compatibility between objectives, ecosystem function, and management strategy. In other words, management should be directed towards goals that recognize the realities of nature and can actually be attained by the means allowed.

In 1979 appeared a new "Parks Canada Policy" stating in comprehensive unequivocal terms the objective of the national parks:

- "*To protect for all time representative natural areas of Canadian significance in a system of national parks, and to encourage public understanding, appreciation, and enjoyment of this heritage so as to leave it unimpaired for future generations.*" (p. 38)

Several further short quotations from this Policy are also worth listing:

- "*Ecological and historical integrity are Parks Canada;s first considerations ...*" (p. 12)

- *"... national parks are ecological benchmarks for research into natural processes and into the relative effects of man on lands outside national parks."* (p. 37)

- *"Natural resources within national parks will be protected and managed with minimal interference to natural processes to ensure the perpetuation of naturally-evolving land and water environments and their associated species."* (p. 41)

Of special interest to the question of fire, the Policy provides that:

- *"Manipulation of naturally occurring processes such as fire, insects, and disease may take place only after monitoring has shown that:*

  (i) there may be serious adverse effects on neighbouring lands; or

  (ii) public health or safety is threatened; or

  (iii) major park facilities are threatened; or

  (iv) natural processes have been altered by man and manipulation is required to store the natural balance, or

  (v) a major natural control is absent from the park, or ..." (p. 41)

and also that

- *"Where active resource management is necessary, techniques will duplicate natural processes as closely as possible."* (p. 41)

These statements of policy set the stage for an open-minded discussion of fire in the national parks. The "natural resources" referred to above are in many cases assemblages of plant and animal species that are maintained in nature by continued flux and change. If so, then preservation must allow for these dynamics; it may require active management rather than simple custody. The nature of the forces involved and their effects must be understood for management to be successful. Furthermore, Parks Canada Policy imposes a severe limitation, clearly providing that management should involve natural processes as a rule, only resorting to artificial techniques in certain highly-limited circumstances.

There are no references quoted in this paper. This is because it is hardly possible in a few pages to trace each idea and fact about fire in Nature to its source and to give all credit where credit is due. This paper is, therefore, a discussion of what might be done about fire in the national parks as the authors see it, with due acknowledgement to the many authors on this broad subject over the years.

II. CONCEPTS

The nature and direction of ecosystem change are a product of evolution, species adaptations, and the conditions of the environment. Since park management will have no influence on evolution and species adaptations, at least in the short term, there remain only the factors of the environment that can be manipulated to influence ecosystem dynamics, the direction of change, and the type of ecosystem present. It is, in fact, within the power of parks management to choose within limits the kind of vegetation and wildlife that will inhabit a given national park. With this in mind, it is worthwhile to take a broader look at ecosystems and their functioning before tackling the particular subject of fire.

1. Ecosystems, disturbance, and stability

To elucidate basic principles of ecosystem behaviour properly requires that a global overview be taken, and that extremes be examined.

To concentrate on a limited range of ecosystems or a limited geographic area could lead to a failure to recognize the universal principles that ought to be the basis of any management strategy. This is particularly true of fire, which plays an important role in the ecology of every continent except Antarctica. However, to concentrate only on ecosystems in which fire plays a role would be to sacrifice the universality of principle which should be the objective of any science and the resource management based upon it. In an effort to retain both universality and simplicity, the following discussion employs as examples two quite geographically and environmentally different ecosystems, the tropical rainforest and the boreal forest.

Before doing so, however, a word should be said about disturbance and stability, because both concepts are associated with a great deal of confusion and controversy within the ecological literature. "To disturb" means to throw into disorder. The starting point must obviously be a definition of normal behaviour; then, only an environmental factor that throws an ecosystem's normal behaviour into disorder can be called a disturbance.

The term "stability" has been used in the ecological literature to include such concepts or meanings as constancy, homeostasis, degree of fluctuation, resilience and persistence. Here it will be used quite simply to mean persistence in the long-term general sense.

Although ecosystems are integrated entities, each can be imagined as having two interacting parts, a biological community and a physical environment. It is then useful to classify ecosystems according to their physical environment, and how the biological community accommodates to it. Two contrasting types then emerge, joined of course by a complete spectrum of intervening types.

The one type occupies a constant benign physical environment, relatively free from physiological stress. Adaptations here are controlled primarily by biological interaction and competition, resulting in a large number of species each adapted to a narrow range of conditions. This type is well characterized by the tropical rainforest.

The other type occupies a harsh, fluctuating environment, which may include sudden severe physical stresses such as fire or strong wind. Adaptations here are primarily to the physical environment, resulting in a smaller number of species, each adapted to a wide range of conditions. An excellent example of this type is the boreal forest.

As succession or development proceeds and an autotrophic (photosynthetic) organism or community matures, biomass will accumulate as a result of positive net photosynthesis, and the biomass supported per unit energy flow will increase until a persistent maximum is reached. In the tropical rainforest community this maximum will be maintained through the continual replacement and recycling of the individual organisms, and evolution has provided the appropriate regeneration mechanism for each species. Stability is maintained through a dynamic equilibrium at the maximum persistent biomass.

In the boreal forest community on the other hand regeneration mechanisms at the individual organism level are ineffective; evolution instead has resulted in renewal at the community level. Stability is maintained through a continual fluctuation between a very low and a maximum biomass. Figure 1 is an attempt to portray this contrast in stability styles in terms of biomass fluctuations on an area of, say, 100 to 1,000 times the area occupied by an individual tree.

The agent of renewal in the tropical rainforest is decadence

[illegible] with adaptation to [illegible] ment while the agent of renewal in the boreal forest is fire, associated with adaptation to the physical environment. At first glance it appears that both systems behave entirely differently, and this is true at the community level of organization. However, if the space scale is expanded to the landscape level, and the time scale to a duration many times the life of the individual tree species, then a quite different picture emerges. The boreal forest is then seen to exist in the same dynamic equilibrium as the tropical rainforest. Stability is maintained by cycling at the community level with fire as the agent, and biomass is again maintained at the maximum persistent level.

The universal principle emerges therefore of ecosystem stability being expressed through a dynamic equilibrium at the maximum persistent biomass, by pulses or oscillations of renewal occurring at various organizational levels.

Another related principle emerges from the intimate association between energy flow and age structure. A multi-aged community such as found in the tropical rainforest will possess a certain expected distribution of individual tree ages, with frequencies highest at young age and gradually decreasing with maturity.

An even-aged community, such as occurs in the boreal forest, has no significant age-class distribution; however, if the scale is expanded once again to the landscape level, then one finds the same expected age-class distribution among separate communities as is found at the individual tree level in the tropical rainforest (more about this subject later).

From the above two ecological principles we can derive the following management principle; that while management operations or tactics must concern themselves with the community level of organization, management strategy must be based on ecosystem ecology as expressed at the whole landscape level.

Finally, it can be seen that fire, far from being a disturbance, is in fact an agent of renewal that is essential to the stability of fire-adapted ecosystems.

2. The ecological role of fire

Fire has been associated with many if not most of the plant communities of the Canadian landscape on an evolutionary time scale, and remains a normal and pervasive component of the environment. As developed in the previous section, this characterizes fire, not as a perturbation or disturbance, but as a recycling agent and an ecosystem stabilizer. In other words, fire is essential to the stability of most Canadian ecosystems.

This stabilizing function is effected through halting development and/or succession before instability becomes irreversible, (i.e. before the community is radically altered), creating the conditions necessary for a new cycle to be initiated, and maintaining an optimum landscape age-class distribution in terms of energy flow and stability.

In other words, the primary function of fire in most Canadian fire-dependent vegetation, especially forests, is to set up the proper conditions for the regeneration of a new stand. However, besides this primary cycling or regeneration function, fire has a secondary role in some parts of the world which may be termed a maintenance function. For example, the pines of the southeastern United States, and the dry sclerophyll eucalypts of Australia require gentle fire every few years to prevent a buildup of surface fuel that would result in a fire intensive enough to eliminate the species or community from the site. No Canadian forest types are entirely dependent on this type of maintenance fire, but some, such as red and white pine, benefit from gentle fires at short intervals that control competing vegetation and make regeneration easier when the proper time for it does arrive.

This stabilizing, regenerative, and/or maintenance role of fire is effected through some or all of the following specific consequences.

A) Partial or complete removal of the overhead canopy, resulting in increased radiation at the ground surface that in turn results in:
   i) release of dormant vegetative buds (stump, root-collar, roots);
   ii) stimulation of roots, rhizomes, and buried seeds through increased soil temperature; and
   iii) optimum light intensity for growth and energy accumulation.

B) Consumption of duff and humus that results in:
   i) increase in soil reaction (pH);
   ii) increased supply of bases;
   iii) increased soil temperature and lowering of permafrost; and
   iv) improvement of seedbed characteristics.

C) Control of competing or late successional vegetation that would exclude fire adapted communities.

D) Prevention of fuel accumulations (live and/or dead) to levels that endanger the survival of particular communities.

E) Maintenance of a stable mix of communities and age-classes by differential recycling that prevents large buildups of pathogenic organisms, and that provides a mosaic of habitats for a thriving and varied wildlife population.

3. <u>The impact of fire on the site</u>

The immediate impact of fire on the site is a reduction of the organic material covering the mineral soil. This is necessary for the health and survival of fire-adapted ecosystems for the reasons listed in the previous section. However, in spite of the normality and necessity of this impact or consequence of fire it has given rise to two major concerns; erosion and nutrient loss.

Erosion is the sculptor of our landscape, and there is hardly a more natural force on earth. Presumably, then, under a policy of naturalness, erosion following a fire should be accepted as part of normal landscape evolution. Furthermore, it is reasonable to suppose that the entire area now occupied by fire-dependent vegetation has burned in the order of, say, 100 times since the revegetation that followed the last glaciation. It can then be argued that most of the potential fire-associated erosion of glacial and post-glacial deposits has long since taken place, and that the landscape is now fairly well stabilized against further post-fire erosion. For example, fire often removes the mossy organic cover on otherwise bare rock; the visual effect, especially from the air, is startling. However, no erosion has occurred and the organic cover gradually reforms in the ensuing decades. In fact, true erosion following fire in natural undisturbed vegetation is the rare exception rather than the rule, and only occurs under a combination of severe drought, steep slopes, and immediate heavy post-fire rain. Normally, some organic surface cover remains and revegetation is rapid.

There is no doubt that fire will result in some nutrient loss through volatilization and leaching of ashed minerals. This loss is rarely significant in terms of site nutrient capital, and income from atmospheric and geochemical sources generally replenishes this loss well before the next fire. Furthermore, nutrient loss is merely one component in a complex of effects that as a whole are beneficial and even necessary to fire-adapted ecosystems. These effects include improvement of seedbed characteristics, release of mineral nutrients from a bound organic form, increased surface supply and concentration of nutrients for limited root systems of developing seedlings, increased base saturation, increased soil reaction (pH), decreased solubility of potentially toxic elements such as aluminum (Al), iron (Fe), and manganese (Mn), increased availability of phosphorus due to reduced formation of insoluble complexes with Al, Fe, and Mn, reduced leaching of potassium, and increased microorganismal activity and nitrification. There is a fairly radical difference therefore in the nutrient picture before and after fire, but this difference is ideally suited to the nature of the vegetation and animal life occupying the site at these times. Immediately before fire the function of the site is to support a more mature, slow-growing or even decadent forest in which the nutrient dynamics are largely closed and possibly limiting. After fire, however, the sole function of the site is to support a rapidly-growing complex of seedlings and young plants in which nutrient dynamics are largely open and accumulative.

In short, where fire is a normal and prevalent feature of their environment, ecosystems have adapted to take advantage of the changed nutrient status after fire through rapid revegetation and growth. The temporary post-fire transformation of the site is necessary for their survival.

4. Renewal rate and the fire cycle

Fire-dependent variation is cyclic. That is, it must be renewed at more or less regular intervals. The renewal rate can be expressed as an average annual proportion; furthermore, for each fire-dependent vegetation type there will be an optimum renewal rate that maintains the type in the best possible ecological state with respect to vigour and competition with other vegetation that might tend to supplant it in case of either too much fire or too little.

If the average annual renewal rate is inverted, one obtains the renewal cycle, or, since we are dealing with fire, the fire cycle. The fire cycle is defined as the number of years required to burn an area equal to the whole area of the vegetation type in question. Thus, in the more or less random natural environment, some stands may burn more than once within one cycle and others not at all.

5. Age-class distribution

Any cyclic vegetation type has many faces, from newly-regenerated through healthy maturity to decadence. Only when all these faces are present within the reference area, in the form of distinct stands, is the vegetation type truly represented. The distribution or frequency of each age-class as a proportion of the total, namely the age-class distribution, is a major feature of the forest landscape.

The renewal rate fixes the age-class distribution (ACD) to some extent, in defining what proportion of the total type area should always be in the youngest age class. Beyond this point, the ACD may take one of several different forms, three of which are worthy of description. See also Figure 2.

A) The rectangular distribution. In this ACD each stand is renewed only when it reaches an age equal to the renewal cycle or rotation age. Each age-class occupies an equal area, and no stands are allowed to exceed the rotation age. This ACD is the ideal goal of managers of production forests.

B) The negative exponential distribution. In this ACD, the frequency of the successive age-classes gradually decreases with age, as described by a descending straight line on semilog paper. Such an ACD results when stands are selected for renewal at random without regard for age. In theory, this is the basic ACD to be expected in the natural fire-dependent forest. About one-third of the stands live longer than the cycle age and there is no sharp cut-off point.

C) The bell-shaped distribution. This ACD can only exist if the renewal rate was greater in the past than at present. It is typical of natural forests from which fire has been excluded for some time. Probably the original distribution was the negative exponential described above. The bell-shaped distribution is by definition a transient distribution that cannot be maintained indefinitely.

6. <u>Fire behaviour and the variability of fire</u>

Fire behaviour is not an absolute or a constant, but a highly variable phenomenon both in space and time, a fact that has great ecological significance. Three features of the variability of forest fires are important from the ecological viewpoint.

A) Frontal intensity. This is the rate of energy output per unit length of the fire front, best expressed in kilowatts per metre. Flame size is its main visual manifestation. Tree mortality and damage are mainly dependent on frontal intensity.

B) Depth of burn. Fires remove varying proportions of the organic layer overlaying the mineral soil, the amount mainly depending on its moisture content at the time of fire. Some of this material contributes directly to the frontal intensity, some smoulders away after the fire front passes. The quality of the resultant seedbed and the fate of plants whose underground regenerating parts occur at different depths are both highly dependent on the depth of burn.

C) Fire interval. The average interval between fires at a given point is essentially the same quantity as the fire cycle (the reciprocal of the renewal rate), already discussed above. The vegetation type itself may influence the fire interval through the amount and flammability of combustible material it produces. In any event, for long-term stability, the average fire interval must lie somewhere between the minimum and maximum ages at which reproduction after fire is possible. Also relevant is the potential effect of repeated fires at short intervals on the reproductive organs of the various plants. Fire interval and its variability thus exerts a considerable selective pressure on both the presence and the proportional amounts of the available plant species.

Furthermore, all fires can be divided into three relative intensity classes in terms of their effect on the forest.

A) Fires so gentle as to leave no direct trace of their passing in the tree stand.

B) Fires intense enough to scar some trees but not kill them; some trees may be killed.

C) Fires intense enough to kill all the trees over a substantial area.

Large fires may contain areas of all three intensity classes as a result of the direction of travel relative to the wind, topographic variation, changes in fuel character, and differences in weather over time, particularly from day to night.

The complex of intensity, depth of burn, and fire interval constitutes a fire regime, and for each vegetation type to be perpetuated by periodic fire, there will exist an optimum fire regime that best fulfills the ecological requirements of that vegetation type.

7. Fire regimes and fire history

Fire leaves direct physical evidence of its occurrence in the form of fire scars and as charcoal deposits in the organic soil layers and in lake beds. Indirect evidence can be obtained from the forest age-class distribution which may be an excellent indication of the renewal rate or fire cycle throughout the past two or more centuries. This is especially true in forest types that are generally killed outright and completely renewed by fire. The negative exponential model of age-class distribution can often be used to estimate the recent fire cycle of such forests. In combination with fire records for the most recent past, this evidence enables a fire history to be constructed for a given geographic area. However there are several possible reasons for treating such a fire history with some caution, because of the limited nature of the data and the difficulty associated with their interpretation.

A) The past century or two may be anomalous. The period of white settlement generally resulted in more than the normal amount of fire, and the recent decades of fire suppression less than normal.

B) The problem of securing a large enough sample is serious. The randomness and variability of nature with respect to both weather and ignition may produce wide swings, and a very large area and time period may be needed to average these out.

C) The locations of fire-scarred trees may not be unbiased, i.e. they may be sites of generally low fire intensity or frequency as a result of topography and prevailing wind direction.

D) Later fires, especially intense ones, have a tendency to obliterate evidence of previous fires. The record of actual fires will therefore be less complete with receding time.

E) Fire may be so gentle as not to kill or even scar the trees, and thus no record will be left.

The study of fire history in the field provides positive evidence of the presence of periodic fire, sometimes far into the past. It also provides educational material especially valuable in a park's interpretive program. Because of the above limitations, however, it would be unwise to base a planned future fire regime on field history data alone. Rather, the ecology and longevity of the main vegetation species should be considered jointly with the present age-class distribution and the known fire history.

III. MANAGEMENT STRATEGY

1. Broad implications

Fire management in the national parks implies nothing short of complete vegetation management. This is because, of all possible techniques and tools available for large-scale vegetation management, fire is the only one that is compatible with the Parks Canada philosophy. As long as chainsaws, bulldozers, and chemical sprays are prohibited or reserved for small, developed parks or areas within large parks, vegetation can only be managed by manipulating natural forces. Of these, wind for instance is uncontrollable. Insects and disease are directly controllable in the negative sense, but cannot be positively applied and confined in time and place. Flooding can be controlled artificially, at least in valley bottoms and lowlands, but fire is the only natural force that both affects the landscape at large and can be applied within a chosen area at a chosen time. Before a fire management plan can be formulated, therefore, it follows that there must be a vegetation plan. Furthermore, such a vegetation plan must be ecologically compatible with what can be achieved by managing fire, either through its application or its exclusion. This leads to the following questions and considerations.

2. <u>What kind of vegetation?</u>

This question is posed if only to demonstrate that some degree of choice exists. One obvious answer is that the kinds of vegetation now present in a national park are the ones worthy of perpetuation. However, it may be known that the vegetation in times past differed from that present now, either in terms of species present or their proportional amounts. The difference may be due to a history of logging and, at different times, periods of both "too much" or "too little" fire. Perhaps the ideal answer is "that native vegetation in the best long-term equilibrium with the natural regional environment". At any rate, consideration of this question is the first logical step in the chain of reasoning leading to a fire management plan.

3. <u>What kind of wildlife?</u>

The visible presence of wildlife is an important essential feature of the national parks. No doubt any individual park management plan will have a great deal to say about the kinds and numbers of animals and birds that should be maintained within it. The principle worth emphasizing here is that, in order to manage wildlife, one must first manage vegetation; furthermore, that any wildlife plan must be compatible with a feasible and appropriate vegetation plan. The question "What kind of vegetation?" may well be asked with wildlife in mind, as long as the principle of "vegetation first" is not violated. For example, the choice of whether to maintain a certain area in grassland or allow it to revert to forest may be made with wildlife in mind; or, the average age at which a certain forest type is maintained may be influenced by the kinds of wildlife desired.

4. <u>Classification of vegetation</u>

Fire being the only positive management tool, all vegetation must presumably be classified with respect to it. The first broad breakdown is:

A) Vegetation dependent on periodic fire.

B) Vegetation not dependent on periodic fire.

Vegetation types of the second category are, by implication, able to perpetuate themselves without periodic renewal by fire. In certain cases perhaps some other natural recycling mechanism is involved. Barring a relaxation of park philosophy, however, vegetation types not ecologically dependent on periodic fire will presumably be protected from fire and otherwise left to Nature. Fire-dependent vegetation would, of course, need further sub-classification in ways that will become apparent.

5. <u>What renewal rate, fire cycle, and age-class distribution?</u>

For national park purposes, the renewal rate and fire cycle of any particular fire-dependent vegetation are best determined from a knowledge of its ecology, especially with respect to the function of fire and the longevity of the main species, together with the known fire history. The optimum fire cycle will be the one that maintains the forest in the best ecological state from the viewpoint of competition with other vegetation types that would tend to supplant it in the case of either too much or too little fire. Historical evidence and present age-class distribution (if unaffected by white settlement) can be used as secondary indications of how Nature has tended the forest in the most recent past.

To complete the vegetation plan, once the renewal rate and fire cycle have been chosen, a desired age-class distribution must also be specified to match them. The form must be either the rectangular or negative exponential or something in between. The rectangular is only attainable with perfect control, and in any case does not allow any stands to grow beyond a set maximum age. The negative exponential permits greater flexibility in the selection of stands for renewal (perhaps by accident) and displays better the full potential age range of the vegetation type, even to the point of its disappearance. For a given vegetation type, the age-class distribution could well be chosen to suit certain wildlife goals, depending on whether the desired animal species favours a younger or older phase of the vegetation cycle. The bell-shaped age-class distribution is, of course, impossible as a stable long-term goal, even though, perhaps, a substantial proportion of the present park forests may fit this distribution as a result of fire exclusion.

6. <u>What kind of fire?</u>

There is an understandable tendency to distinguish between man-caused and lightning fires when drawing up guidelines for fire suppression in large parks, on grounds that lightning fires, ignited by a "natural" agent, are philosophically more acceptable and desirable for ecological purposes. There are three reasons why this idea may confuse the issue and hinder rather than help the development of a rational fire policy.

The first reason is that the effect of any fire is quite independent of how it started; the forest certainly cannot tell the difference. The second reason is that the concept of "natural" fire involves much more than just mode of ignition. It includes also the idea that lightning fire be allowed to run with complete freedom whenever or wherever it chooses at any intensity, at the same time in the total absence of "unnatural" fire. Once such a natural fire regime is modified at all, then the distinction between lightning and man-caused fire becomes meaningless. What the park managers really desire, presumably, is not the natural fire regime *per se*, but rather the vegetation complex that the natural fire regime would have created. The only worthwhile distinction is then between wanted and unwanted fire, the ignition agent being irrelevant. The criterion is the vegetation plan.

The third reason is that in many cases operational fire control does not allow the time for determining whether a fire is lightning-caused or man-caused. Decisions have to be made rapidly, so the only possible operational question is whether the fire is wanted or unwanted. Furthermore, a particular park presumably desires reasonably smooth performance in vegetation renewal within its limited boundaries. This will not be likely with a random process as erratic as lightning fire, implying that man-caused fire, perhaps both accidental and prescribed, may have to be used to achieve the desired efficiency.

7. What fire intensity and depth of burn?

The appropriate intensity of fire, for a given vegetation type, is that which best fulfills the ecological needs of its various species. This means that a very wide range of fire intensities may be called for throughout the national park system, all the way from surface fires in grassland or forest litter to crown fires in mature conifer stands. With respect to fire-dependent forest, the main tree species can be separated into two classes:

A) Those species able to regenerate even though all individuals are killed (at least above ground) over a wide area, e.g. aspen, jack pine, black spruce, countless minor plant species.

B) Those species of which some individuals must survive in order to provide seed for the next generation, e.g. red pine, white spruce, Douglas-fir.

A species normally cycled by intense fire, perhaps to open serotinous cones and/or provide maximum light for the new growth, will not do well in a regime of gentle fire. Conversely, a widespread intense fire would eliminate from the burned area any tree species that depend on live individual survivors for seed.

Depth of burn, that is the quantity of forest floor organic matter consumed by fire, is a characteristic of fire bearing directly on the nature of the resulting seedbed. Being mainly a function of dryness in depth, it is somewhat independent of fire intensity, which is a compound function of both rate of spread and fuel consumption. Associated with each tree species regenerating from seed will be some optimum depth of burn.

The depth of burn has ecological consequences for all sprouting and suckering species as well. Thus, certain herbs and shrubs whose rhizomes or sprouting organs commonly lie in the duff layer may be severely set back by deep burning. This may be desirable from the viewpoint of reducing competition for conifer seedlings, without by any means eliminating these species from the site. A shallow burn may, on the other hand, favour the suckering or sprouting hardwoods such as aspen or birch, simply by failing to provide adequate seedbed for the conifers. The vegetative complex on any given area may therefore vary from generation to generation as a result of variation in depth of burn alone.

A complete specification for the fire regime in a particular forest (or other vegetation type) would, then, include:

A) The chosen renewal rate.

B) The appropriate fire intensity.

C) The appropriate depth of burn.

The latter two factors would also be quoted in terms of the relevant codes and indexes of the Canadian Forest Fire Danger Rating System at which they would be best achieved.

The selection of stands to be renewed would be governed by the desired age-class distribution for each forest or vegetation type, the means being either prescribed fire or allowing accidental ignitions to spread.

8. How many fires and what size?

The question of scale arises, both in space and time. The park, being of limited size, may be only a sample of the regional landscape, vegetation associations and wildlife. Furthermore, the existence of the park boundary, with different management objectives on the other side, limits the extent to which natural forces such as fire can be allowed to run their course. The park, therefore, may have to be managed as a microcosm of the real world, in which very large fires such as normally occur in Nature would be considered quite undesirable.

Fortunately, the renewal rate or fire cycle specifies only what proportion of a given forest or vegetation type should be renewed annually, but nothing about numbers or sizes of the actual fires. The required burned area could thus be achieved by one large fire or by any number of smaller ones. Given the proportion of area to be burned annually, several considerations could affect the desired fire size:

A) The total park area.

B) The spatial arrangement of the vegetation type in question throughout the park.

C) The pattern of park use.

D) The arrangement of topographic fire barriers.

E) The optimum vegetation mosaic for wildlife.

With respect to time, it would, of course, be next to impossible to manage fire in the parks perfectly enough that the desired total area and particular stands were burned every year by fire of the required intensity and depth of burn. Annual weather variation, the unpredictability of fire starts, and the general difficulty of controlling fire, especially accidental intense ones, will no doubt continue to produce sizeable swings in annual burned areas as they have in the past. Some averaging procedure, based on say 10 or 20% of the fire cycle, would be needed for reasonable periodic assessment of the program. Furthermore, a present badly-balanced age-class distribution cannot be corrected quickly, but only gradually within one or more whole fire cycles.

9. <u>What about fire exclusion or artificial forest renewal?</u>

Suppose that fire could be completely eliminated from the national parks; what vegetation would ultimately prevail in the fire-dependent ecosystems? This is a fair question to which there are no authoritative answers, and the experiment would be a long one. Throughout the Canadian boreal forest, for example, it is difficult to find an upland stand in which the first generation of trees following the last fire is not still present forming a substantial part of the crown canopy. There is no suggestion that any tree species would become extinct. Probably the average density of the forest would decrease greatly, occasional windthrow being the only source of mineral seedbed. A tolerant species like balsam fir might achieve greater distribution, and some brush species might be much more prevalent. It is only certain that such fire-free vegetation complexes would be quite different from the present ones.

With respect to artificial renewal, there is no doubt that new stands of any desired tree species could be produced by logging and planting. Special harvesting methods might be devised to reduce unsightly logging slash and interference with visitor activity. However, it would be most difficult to produce all the variations in stand density and tree species composition that characterize the natural forest, and the minor vegetation would probably alter considerably. Various ecological complications and problems might ensue. In either case, fire exclusion or artificial forest renewal, the parks' purpose of perpetuating Canadian ecosystems in their natural state would have to be set aside.

IV. CONCLUSIONS

The stability of many ecosystems is dependent on cyclic behaviour at the community level induced or regulated by fire. Many forests and other vegetation within our national parks belong to this category. If it is desired to maintain and stabilize them in their natural state, then fire must be allowed to play its role as recycling agent.

Since parks are surrounded by boundaries that separate them from areas of different uses, are of limited area, and must protect their visitors from uncontrolled fire, a totally natural fire regime is neither possible nor desirable. The objective of perpetuating certain ecosystems within the parks would therefore have to be met by a planned fire regime, probably involving prescribed as well as controlled accidental fire. The renewal rates and fire cycles would best be set according to the ecology and longevity of the main species, in conjunction with the present age-class distribution and the evidence of fire history. Actual locations, numbers, and sizes of fires would be subject to many practical considerations.

It is one thing to study the ecology and fire history of park vegetation and to design hypothetical schemes for managing it with fire; it is quite another thing altogether to carry them out. Certainly the amount of fire required for managing park vegetation under pseudo-natural fire regimes would be many times what the national parks are presently used to. Many practical problems of policy, public education, and public safety immediately spring to mind. To implement such new fire regimes would take a great deal of skill and organization. These could, of course, be built up slowly over many years; the time scale of most Canadian ecosystems would permit a careful, gradual approach to this new form of management. At the same time, the alternatives are fairly clear. Their major fire-dependent ecosystems must either be managed with fire, or else the parks must permit artificial means of renewal. Without either fire or a change in Parks Canada philosophy, these ecosystems will eventually alter drastically or be replaced by others.

V. ACKNOWLEDGEMENT

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The original draft was much revised as a result of this process, and we believe and hope there are no major points of difference remaining. At the same time we do not present this paper as a complete consensus, necessarily representing the combined views of all Canadian Forestry Service staff active in this field. The subject of how to manage forest fire in parks is still, in our opinion, wide open for further information and discussion.

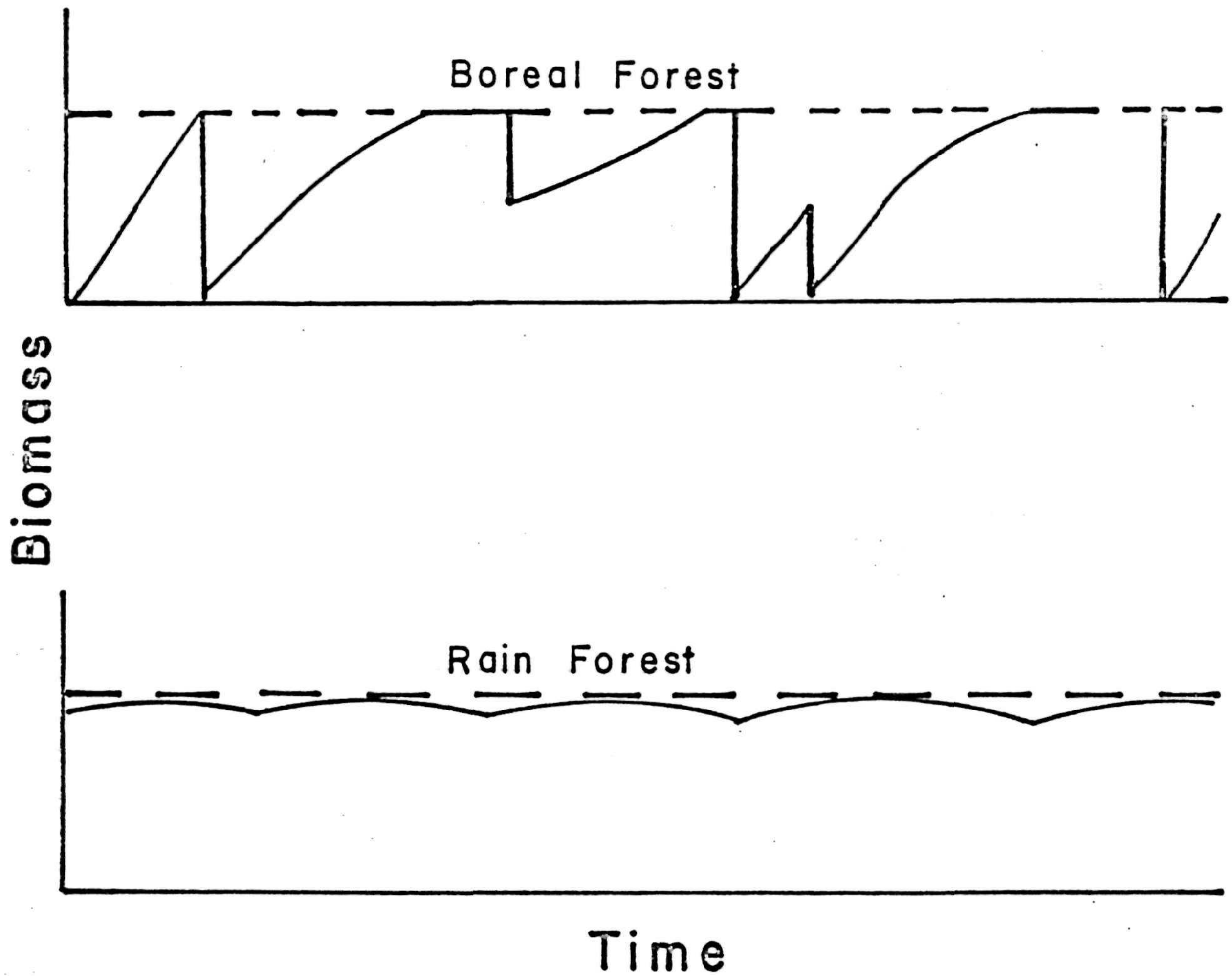

Fig. 1. Diagram of contrasting stability styles for boreal forest and tropical rainforest. Horizontal dotted lines represent maximum persistent biomass. Time period long enough for several tree generations on area large enough for say 100 to 1000 trees. Fires at random intervals in boreal forest represented by vertical lines; partial mortality portrayed in one case.

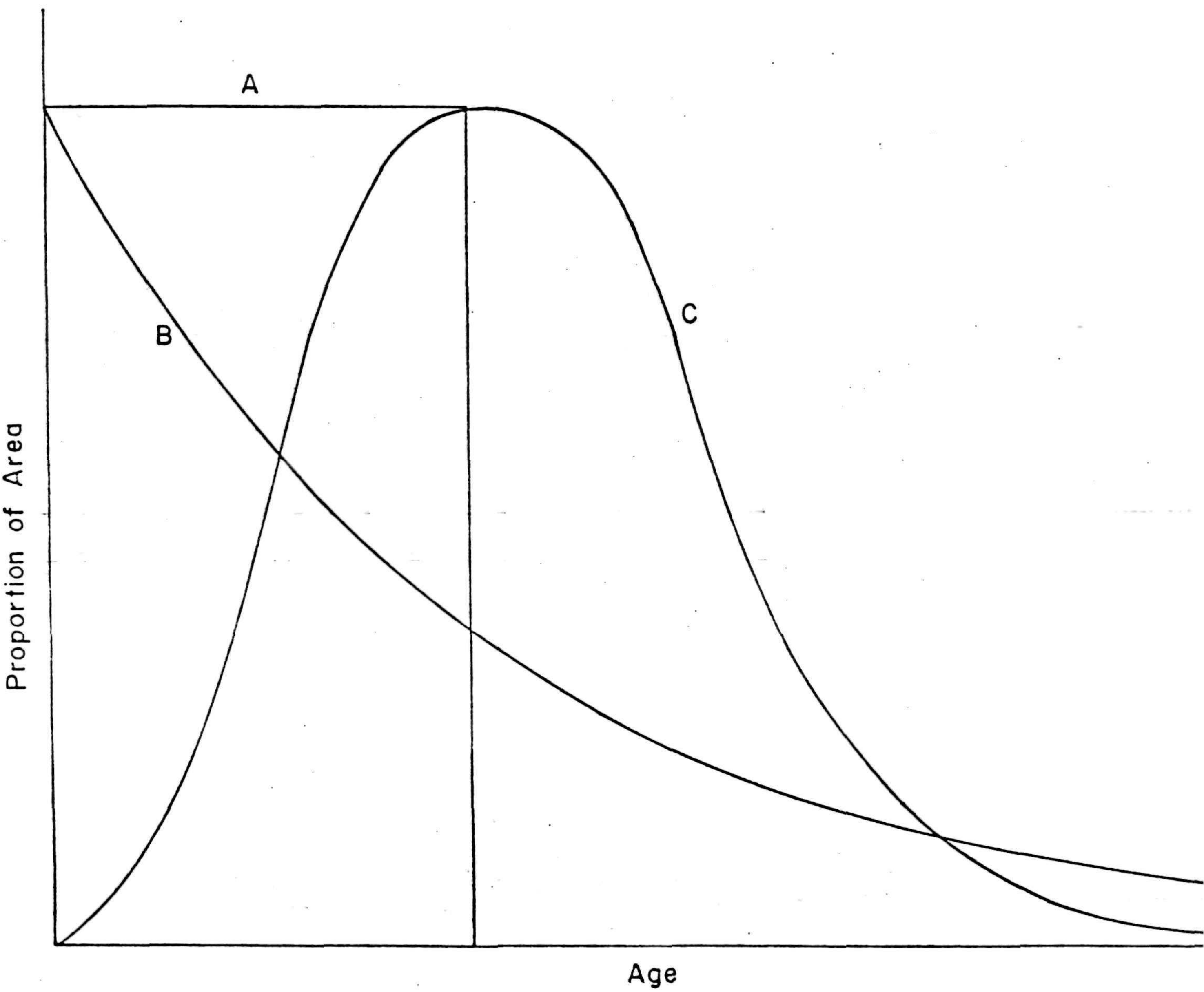

Fig. 1 Three idealized forms of age-class distribution:
A. Rectangular
B. Negative exponential
C. Bell-shaped