

# Long-term silviculture experiments contribute to science-based forest management in British Columbia's public forests

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## Abstract

Protests over clearcutting public forestlands have been a part of British Columbia's forest policy scene for the last two decades. Pressure to modify silvicultural systems has resulted in the installation of a number of long-term silviculture experiments in British Columbia. In this paper we focus on how two of these experiments (MASS, Sicamous Creek) are being used to compare silvicultural systems, and to test hypotheses related to the retention of forest structure and the long-term influence of edges, aggregates and single trees on ecological processes. Results have shown that a given silvicultural treatment can have both negative and positive impacts depending on the values (e.g. regeneration, biodiversity, nutrient cycling) under consideration. The management influence of these experimental results are less obvious. The MASS project, as an operational demonstration, has had a substantial impact on the practices of one major company in coastal British Columbia, but the Sicamous Creek project has yet to have any major direct impact. We comment on the reasons for such differences, the prospects for continued funding, and lessons learned from conducting long-term projects such as these.

Keywords: silvicultural systems, clearcut, partial cutting, edges, patch size, variable retention

## 1 Introduction

Protests over clearcutting public forestlands have been a part of British Columbia's forest policy scene for the last two decades. Recent publications such as "A cut above: Ecological principles for sustainable forestry on BC's coast" (DREVER 2000) from the Suzuki Foundation and "British Columbia's Endangered Forests: what government and industry aren't telling you" (ForestEthics 2003) indicate that the controversy continues. Responses have ranged from a major overhaul of legislation, to more careful planning of opening sizes and shapes in visually sensitive areas, to jail sentences for protesters.

The public ownership of 95% of forest lands in British Columbia is unique in the developed world. This brings a special set of problems for regulating forestry practices. The public has brought considerable pressure to bear for the diversification of silvicultural systems. Government has responded by introducing a results-based forest practices code. Passed in

1994, the code contains provisions for further limiting the impact and extent of clearcutting and provides a context for testing the feasibility of partial cutting and retention silvicultural systems. However, little is known about the impacts such systems will have on growth and yield, timber supply and environmental values or if the restrictions are having any effect.

Pressure to modify silvicultural systems has also resulted in the installation of a number of large-scale experiments to test changes in forest structure in British Columbia (DAIGLE 1995; PUTONEN and MURPHY 1997). These include Date Creek (COATES *et al.* 1997), Quesnel Highlands (ARMLER and STEVENSON 1994), Lucille Mountain (EASTHAM and JULL 1999), Opax Mountain (KLENNER and VYSE 1998), Sicamous Creek (VYSE 1999) and the Montane Alternative Silvicultural Systems (MASS) Project (ARNOTT *et al.* 1995), in which the operational, economic and ecological impacts of alternatives to clearcutting are being investigated.

A premise common to all these trials is that the amount and the arrangement of retained forest structure will affect ecological values. By retaining diverse structures representative of the pre-harvest stand condition, including dead trees and coarse woody debris, diverse habitats will be conserved for the variety of organisms that underpin ecosystem functions (FRANKLIN *et al.* 1997, BURGESS *et al.* 2001). However, the links between forest structures and ecosystem attributes have seldom been investigated (SPENCE 2001). These attributes form the foundation of ecologically based silvicultural systems as advocated by FRANKLIN *et al.* (1997) and LINDENMAYER and FRANKLIN (2002). Of particular interest is the comparison of ecological values under different silvicultural systems that create edges and patches with a variety of orientations and sizes, and varying amounts of dispersed (single tree) and aggregated (groups of trees) retention.

Because managing public forests for multiple ecological, social and economic values will require trade-offs, it would be desirable to make decisions based on measurements of the impacts of different silvicultural alternatives on those values. This type of science-informed approach has been taken by Weyerhaeuser, British Columbia, in their coastal operations, where research on the operational and economic feasibility of silvicultural alternatives to clearcutting conducted at MASS in part gave the confidence to proceed with a plan to phase out clearcutting and move toward retention forestry. As the pressure for third-party certification of forestry practices increases, the demand for ecologically based criteria for making decisions about the amount and pattern of overstorey retention will likely become more acute. This knowledge is presently quite scanty for most of British Columbia's forest types.

In this paper we focus on how two interdisciplinary long-term silvicultural experiments, one in the coastal mountains of Vancouver Island (MASS) and the other in the south central mountains of the province (Sicamous Creek), are contributing to the knowledge base for forest management decisions relating to clearcutting and other silvicultural practices.

## 2 The montane alternative silvicultural systems project (MASS)

Located in a coastal montane forest (850 m a.s.l.) on Vancouver Island, the Montane Alternative Silvicultural Systems (MASS) project tests three silvicultural alternatives (Green Tree Retention, Patch Cut, and Shelterwood) and compares them with a Clearcut in a previously uncut forest dominated by *Tsuga heterophylla* and *Abies amabilis* (ARNOTT *et al.* 1995; ARNOTT and BEESE 1997). The study began in 1993, using a factorial design with three 9-ha replicates of each of three silvicultural systems treatments and a large clearcut for comparison (Fig. 1).

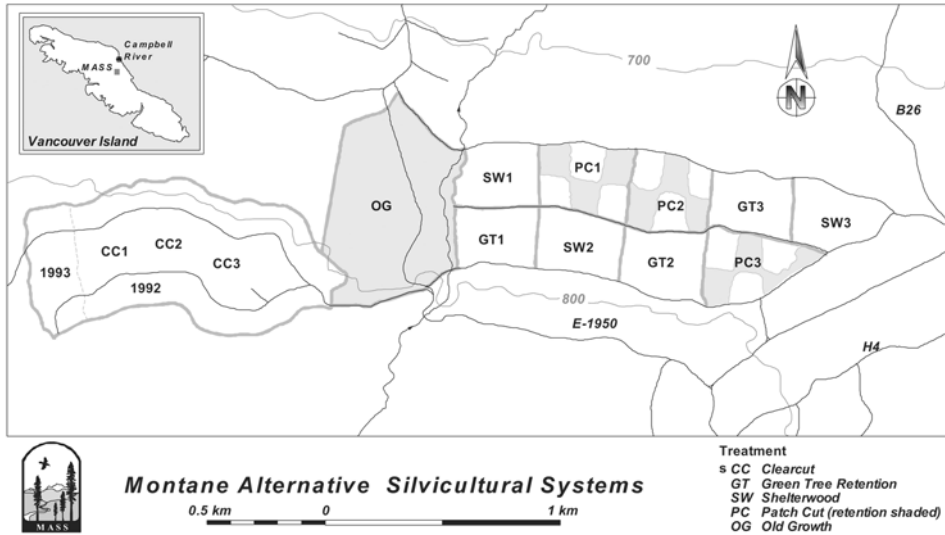


Fig. 1. The Montane Alternative Silviculture Systems (MASS) Project. Layout of silvicultural systems treatments. (From ARNOTT and BEESE 1997).

The silvicultural systems treatments were: 1) Clearcut – A 69-ha opening made using conventional clearcutting methods. Within the opening, three 9-ha treatment “blocks” were selected for parity with the experimental design used in the other treatments; 2) Patch Cut – Three 1.5-ha clearcut openings within each 9-ha treatment block; 3) Green Tree Retention –  $\geq 25$  trees  $ha^{-1}$  retained within each 9-ha treatment block; and 4) Shelterwood – 200 trees  $ha^{-1}$ , (ca. 30% of the original stand basal area) were retained within each 9-ha treatment block.

### 3 Sicamous creek research project

Located in the British Columbia interior in a subalpine forest (1550–1850 m a.s.l.), the Sicamous Creek Research Project focuses on comparisons of opening size and the effects of forest edge (VYSE 1999). The experiment tests different opening sizes (0.1 ha, 1.0 ha and 10.0 ha, and individual tree selection) in a cold, wet, previously uncut forest dominated by *Picea engelmanni* and *Abies lasiocarpa* (HUGGARD and VYSE 2002b).

Five harvest treatments were applied to three 30-ha replicate units at the Sicamous Creek site (Fig. 2): 1) 10-ha clearcut with 20 ha of leave strips, 2) nine 1-ha openings with 100-m leave strips, 3) sixty-five 0.1-ha patch cuts with 30-m leave strips, 4) uniform individual tree selection (ITS) removing 20% of the trees across the size distribution, and 5) uncut controls. With roads and skid trails, each of the four harvest treatments removed approximately one-third of the trees, representing the first pass of a three-pass system.

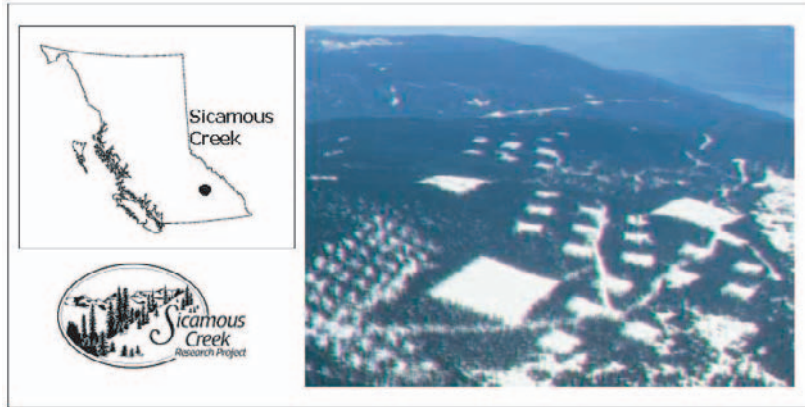


Fig. 2. Aerial view and location of the Sicamous Creek Silvicultural Systems Project.

#### 4 Applying knowledge for science-informed management of ecological values

To facilitate science-informed forest management, the ecosystem attributes under investigation should be considered as values just as social attributes such as visual quality and recreation potential are considered as values. The MASS and Sicamous Creek projects have begun to quantify the short- and long-term effects of silvicultural alternatives on ecological values related to regeneration, nutrient cycling and biodiversity. Although the silvicultural treatments are different, they share common characteristics with respect to the creation of edges and the influence of retained overstory in the form of single trees or groups of trees.

The idea of forest influence is at the core of retention silvicultural systems (KEENAN and KIMMINS 1993; MITCHELL and BEESE 2002). Most commonly this is thought of as the extent of the influence of the retained trees or stand, but the inverse concept in which the opening has influence on the retained stand also has relevance. In other words, any opening creates an edge and the edge effect extends into and away from the opening. The edge influence can be measured in terms of both abiotic and biotic values. Scientific information on forest influence could be applied to address the questions of how large a patch of trees must be to have conditions representative of the unharvested stand, and what size and shape of opening can be made and still conserve forest influence over the harvested area.

Results from MASS and Sicamous Creek have shown that a given silvicultural treatment can have both negative and positive impacts depending on the ecosystem attributes (values) under consideration. Following are some examples of those impacts on regeneration, nutrient cycling and biodiversity, and the silvicultural recommendations that would result from the findings. These examples have been greatly simplified. They are intended as examples of how management decisions about silvicultural systems, if based on scientific information, could differ depending on which values are considered.

## 5 Clearcuts versus retention systems

Aggregated and dispersed retention are two partial cutting systems that are being advocated as alternatives to clearcutting, particularly in coastal British Columbia. Information collected at the MASS site indicates that the preferred system will change depending on which set of values (e.g. regeneration, nutrient cycling, and biodiversity) are considered.

### 5.1 Regeneration

Some indicators of regeneration success can be favoured by aggregated retention and clearcut systems (PC, CC) or by dispersed systems (GT, SW), while others are favoured by a combination of the two (Table 1). Dispersed retention systems (GT, SW) or aggregated retention with small openings (PC) are more favourable for the establishment of natural regeneration than large clearcuts. Although the high level of dispersed retention in the SW promotes seedfall for natural regeneration, seedling growth rates are reduced unless shelter trees are removed as in the traditional approach. At MASS, some or all of the SW trees will be retained as long-term reserves, which will continue to affect growth rates. In contrast, artificial regeneration can be successful over a wider range of approaches, including aggregated retention, clearcuts or low levels of dispersed retention (GT). For these indicators of regeneration at MASS, aggregated and clearcut systems would be recommended for management based on artificial regeneration, and dispersed systems would be recommended for management decisions based on natural regeneration.

Table 1. Overstory retention effects on regeneration indicators at MASS (CC, clearcut; PC, patch cut; GT, green tree retention; SW, shelterwood), combining data for the dominant tree species (*Abies amabilis*; *Tsuga heterophylla*). Shaded cells show silvicultural systems of choice for each indicator. Source: Beese, W.J., Sandford, J.S., Andersen, T.G. and Martin, N.J., 2000. Natural Regeneration and Vegetation Dynamics in Coastal Montane Forests at MASS. Contract report to Forest Renewal BC, 41 p.

Indicator	CC	PC	GT	SW	Recommendation
Seedfall (seeds/square m)	306	2218	2199	6661	<b>SW</b>
Natural regeneration (% survival year 3)	95	89	88	87	<b>CC</b>
Natural regeneration height (cm at year 5)	52	51	52	39	<b>CC, PC, GT</b>
Planted seedling survival (% over 5 years)	90	97	94	80	<b>CC, PC, GT</b>
Planted seedling height (cm at 7 years)	158	159	164	115	<b>CC, PC, GT</b>

### 5.2 Nutrient cycling

Nutrient cycling processes that underpin site productivity could be changed in the short term and perhaps in the long term by different retention systems. However, there is no indication from physiological measures of stress in regenerating seedlings at MASS that there were major differences in stress levels among the clearcut, aggregated or dispersed systems (Table 2). Although seedling growth was reduced in the dispersed (SW) system, there was no indication that nutrient cycling processes were detrimentally affected resulting in seedling stress. For these indicators, aggregated retention or clearcut systems would be recommended, perhaps mixed with low levels of dispersed retention, for management decisions based on nutrient cycling values.

Table 2. Overstorey retention effects on regeneration physiology at MASS (CC, clearcut; PC, patch cut; GT, green tree retention; SW, shelterwood), combining data for the dominant tree species (*Abies amabilis*; *Tsuga heterophylla*). Shaded cells show silvicultural systems of choice for each indicator. Modified from: MITCHELL 2001.

Indicator	CC	PC	GT	SW	Recommendation
Light use (Fv/Fm, year 3)	0.74	0.74	0.73	0.74	<b>CC, PC, GT, SW</b>
Photosynthesis (Amax, year 3)	8.4	7.6	8.1	8.5	<b>CC, SW</b>
Tree water stress (MPa, year 3)	-1.6	-1.6	-1.6	-1.6	<b>CC, PC, GT, SW</b>

### 5.3 Biodiversity

Using indicators of species richness and abundance, from studies of plant communities at MASS, the dispersed SW system would be chosen for biodiversity conservation (Table 3). Overall species diversity may increase after harvesting due to common invasive native and non-native plants; therefore, species losses from the pre-harvest forest condition or changes to species groups that are sensitive to disturbance may be more important indicators for biodiversity conservation. The SW system at MASS had the fewest species losses and maintained the greatest cover of bryophytes among treatments. The data for the patch cuts (PC) in Table 3, however, includes only the harvested portion. If the retained aggregates were included as long-term retention, the PC would equal or exceed the SW for maintenance of understory plant diversity.

Table 3. Overstorey retention effects on indicators of plant diversity at MASS (CC, clearcut; PC, patch cut; GT, green tree retention; SW, shelterwood). ns = no effect. Shaded cells show silvicultural systems of choice for each indicator. Modified from Beese, W.J., Sandford, J.S., Andersen, T.G. and Martin, N.J. 2000. Natural Regeneration and Vegetation Dynamics in Coastal Montane Forests at MASS. Contract report to Forest Renewal BC, 41 p.

Indicator	CC	PC	GT	SW	Recommendation
Richness (number of species)	ns	ns	ns	greater	<b>SW (PC**)</b>
Abundance (frequency of species)	ns	ns	ns	greater	<b>SW (PC)</b>
Species losses*	17	27	17	9	<b>SW (PC)</b>
Bryophyte cover (%)*	9	9	11	62	<b>SW (PC)</b>

\* percent of pre-harvest at year 5

\*\* when PC retained aggregates are included.

## 6 Opening size

In the interior of British Columbia, particularly at high elevations, foresters have focused more on reducing clearcut size than retention. Information collected at the Sicamous Creek research site showed a diverse range of responses to 10-ha, 1.0-ha or 0.1-ha openings, or to individual tree selection (ITS) when three different values – regeneration, nutrient cycling, and biodiversity – are considered.

## 6.1 Regeneration

Opening size can significantly affect different indicators of regeneration. Opening sizes of 10 ha or 1 ha tend to favour artificial regeneration, and small openings (0.1 ha) or single tree selection systems tend to favour natural regeneration (Table 4). Results also show that seedlings grew more slowly under the canopy of retained trees and within one tree height of the North facing edge in openings.

Table 4. Patch size effects on some indicators of regeneration at Sicamous Creek. (ITS, individual tree selection). Shaded cells show silvicultural systems of choice for each indicator. Source: HUGGARD and VYSE 2002b.

Indicator	10 ha	1 ha	0.1 ha	ITS	Recommendation
Seedfall (/m <sup>2</sup> /yr)	30	29	41	73	<b>ITS</b>
Natural regeneration (seedlings/ha)	500	200	2600	2400	<b>0.1, ITS</b>
Seedling survival (% over 4 years)	88	81	77	75	<b>10</b>
Seedling height growth (cm at 4 years)	46	46	51	40	<b>0.1</b>

## 6.2 Nutrient cycling

In the short term, nutrient cycling was strongly influenced by opening size with significant reductions in litterfall and increases in mineral nitrogen when the opening size reached 0.1 ha or more. Decomposition was favoured in the individual tree selection system (Table 5).

Table 5. Patch size effects on some indicators of nutrient cycling at Sicamous Creek (ITS, individual tree selection). Shaded cells show silvicultural systems of choice for each indicator. Modified from: HUGGARD and VYSE 2002b.

Indicator	10 ha	1 ha	0.1 ha	ITS	Recommendation
Mineral nitrogen ( $\mu\text{g N/g soil}$ )	21	22	20	10	<b>10, 1.0, 0.1</b>
Decomposition – needles (% loss/5 years)	51	49	52	56	<b>ITS</b>
Litterfall (kg/ha/year)	36	34	85	415	<b>ITS</b>

## 6.3 Biodiversity

Different components of biodiversity can be significantly affected by opening size. For example, woodpeckers or snail-eating ground beetles were favoured by all the opening sizes markedly more than by individual tree selection. In contrast, voles and millipedes were favoured in small (0.1-ha) openings compared with large and intermediate (10-ha or 1.0-ha) opening sizes or individual tree selection (Table 6). Many other species studied at Sicamous Creek benefited from small openings, but this contrasted with the better results for planted regeneration in larger openings. Therefore, management options for maintaining stand-level biodiversity could conflict with regeneration goals.

Table 6. Patch size effects on some indicators of biodiversity at Sicamous Creek. Abundances as a percent of abundance in controls (ITS, single tree selection). Shaded cells show silvicultural systems of choice for each indicator. Modified from HUGGARD and VYSE 2002b.

Indicator	10 ha	1 ha	0.1 ha	ITS	Recommendation
Three-toed woodpeckers	122	114	101	22	10, 1.0, 0.1
Red-backed voles	80	80	91	77	0.1
Millipedes	62	80	99	76	0.1
Snail-eating ground beetle	81	84	88	54	10, 1.0, 0.1

## 7 Forest influence

Retention silvicultural systems are predicated in part on the idea that the influence of the uncut stand extends one or two tree lengths into the harvested area (FRANKLIN *et al.* 1997; MITCHELL and BEESE 2002). Based on post-harvest microclimatic data from Sicamous Creek, forest influence can be detected 25 m to 50 m (one to two tree lengths) into the forest and into the harvested area (Fig. 3). However, forest influence on other values such as nutrients may extend only very short distances (less than 10 m) into the cutblock (Fig. 4). This is also the case for most components of biodiversity, such as abundance of plant species, where forest influence is also restricted to a narrow band on either side adjacent to the stand edge (Fig. 5).

The results also show that some of the attributes of nutrient cycling and biodiversity can be negatively affected while others are positively influenced. For example, some soil nutrients such as nitrate increase dramatically at the stand edge, while others such as potassium decrease dramatically. Similarly, plant abundance can be increased, as in the case of herbs, or negatively affected, as in the case of bryophytes. Therefore, forest influence could extend two tree-heights or it could extend almost no distance at all, and silvicultural systems that create abundant edges could have negative or positive effects, depending on the values under consideration.

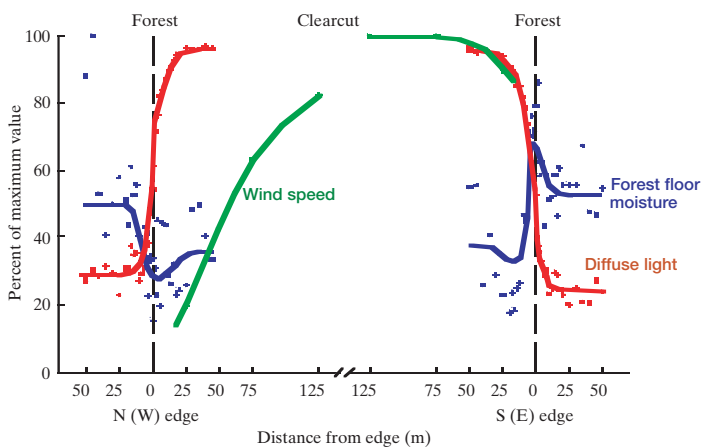


Fig. 3. Wind speed, diffuse light, and forest floor moisture across edges. Wind speed measured across west and east edges. Maximum value is the maximum individual point recorded along the transect (from HUGGARD and VYSE 2002a).



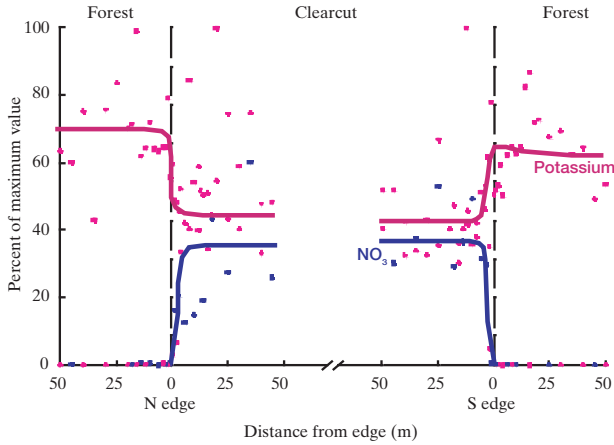


Fig. 4. Net soil nitrate and soil potassium across edges. Maximum value is the maximum individual point recorded along the transect (from HUGGARD and VYSE 2002a).

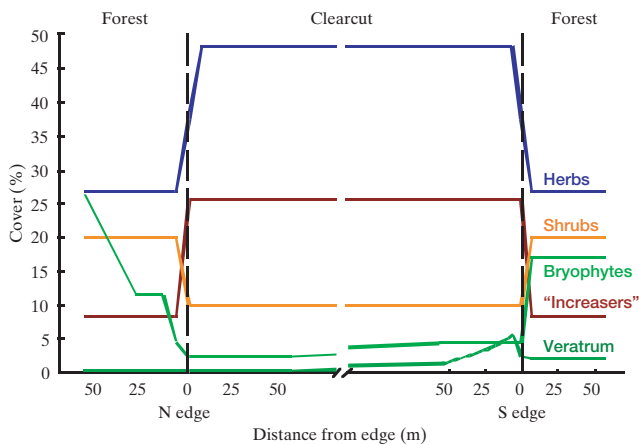


Fig. 5. Plant response to forest-clearcut edges 5 years after harvest (from HUGGARD and VYSE 2002a).

## 8 Making a difference

MASS, Sicamous Creek and several other similar projects in British Columbia have provided extensive information on how management options affect many values in the short term at the stand level. This information clearly forms the basis of science-informed management. It is less clear that these experiments have actually affected management. The MASS project has had a substantial impact on practices of one major company in coastal British Columbia, but mostly as an operational demonstration of alternative practices, while the Sicamous project has yet to have any major direct impact. This may have to do with differences in the economic, social and ecological issues in coastal and interior forests. Clearcutting has been

ongoing on the coast for forty years, and on southeastern Vancouver Island, stands containing old trees have largely been replaced with young managed stands. This has resulted in growing controversy, with highly active public groups in the nearby urban centres of Vancouver and Victoria questioning the sustainability of even-aged management and demanding that the practice of clearcutting be stopped. This threat to the social licence for harvesting on public lands was recognized by MacMillan Bloedel (now Weyerhaeuser) and prompted the announcement that the company would phase out clearcutting on their coastal operations in favour of retention silvicultural systems. The role of the MASS Project in that decision was to provide confidence that such systems could be used in coastal forests. Of primary importance were the findings that the systems tested at MASS could be safely and economically implemented (BEESE and PHILLIPS 1998). The question of whether those systems are ecologically sound has been more difficult to address.

At Sicamous Creek, similar ecological information has been generated. However, in the absence of a nearby large urban population, public concern for the ecological effects of forestry is subdued, there is no international pressure, and the issue of stability for forestry-dependent communities appears to have a greater impact than biodiversity issues in debates about the management of public lands. Therefore, operations have changed little.

Acceptance of research results requires coincidence of ecological understanding, economic conditions and political realities (Fig. 6). Before research at MASS, industry economic concerns were well known. However, intense public concerns were not well connected with ecology or economics. Perhaps MASS contributed to a closer alignment of ecological and economic factors, helping to suggest a way for industry to respond to intense public pressure.

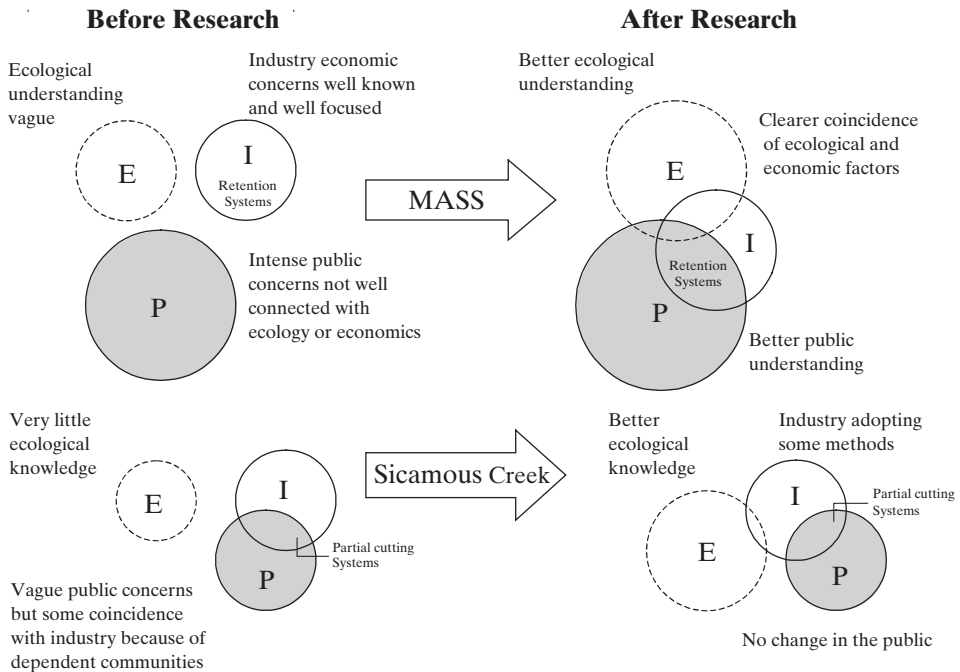


Fig. 6. Influence of research on the interface between public (P), industry (I) and ecological (E) values.

This resulted in an increased public acceptance of changes in forestry practices and created a niche for the application of scientific information to inform the debate on managing forests for multiple values.

Before research at Sicamous Creek, very little ecological knowledge of the impacts of silvicultural alternatives on subalpine forests was available. Public concern over forestry practices was limited and associated with industry-dependent communities. After research, ecological knowledge increased and industry adopted some methods where these coincided with industry concerns (e.g., regeneration). However, there was little or no change in public attitudes toward silvicultural alternatives.

## 9 Prospects for the future

Applied forest management is becoming more complex as concern over the management of public lands and the number of resources to be considered increases. Long-term interdisciplinary applied forest ecological experiments such as MASS and Sicamous Creek are providing information about complex responses of forest ecosystems to managed and natural disturbances. Both projects have been remarkably successful in this respect over the first ten years. Impressive lists of publications have been produced by the respective project collaborators through a combination of scientific cooperation, and common access to substantial funding and facilities. But is this enough to retain long-term funding? If the current trend toward results-based activities on publicly owned forests continues, research projects may be judged only on their short-term influence. On this criterion, only the MASS project would be judged a success. This would be difficult to accept since early results can often change in the long term. In conclusion, (1) success may depend less on the information value of applied ecological experiments and more on their short-term influence, and (2) the application of results depends as much or more on the coincidence of local economic and social pressures as on the quality of the research.

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