Forest Hydrology and Watershed Management - Hydrologie Forestière et Aménagement des Bassins Hydrologiques
(Proceedings of the Vancouver Symposium, August 1987; Actes du Colloque de Vancouver, Août 1987):IAHS-AISH Publ.no.167,1987.

Carnation Creek, Canada — review of a west coast fish/forestry watershed impact project

E. D. HETHERINGTON
Pacific Forestry Centre, Canadian Forestry Service, 506 West Burnside Road, Victoria, British Columbia, Canada

ABSTRACT Carnation Creek is a small, rainforest salmon stream located on the west coast of Vancouver Island, British Columbia. In 1970, a 16-year multi-agency and multi-disciplinary project was initiated to evaluate the effects of logging and silvicultural activities on the Carnation Creek watershed and communicate the results to managers of forests and fish. This paper reviews the nature and results of the project and discusses the transfer of research findings, their application by resource managers, and the significance of the project for fishery and forestry management in coastal British Columbia. Peak flows and water yield increased in a small tributary, groundwater levels were higher and there were minor changes in water quality. There were also major changes in stream channel and organic debris structure, deterioration of fish habitat and spawning gravel quality and a complex variety of effects on fish growth and survival.

Le ruisseau Carnation, Canada - revue d'un projet sur la côte ouest traitant des impacts pêcherie/foresterie sur le bassin

RESUME Le ruisseau Carnation est un petit cours d'eau à saumon dans la forêt pluviale de la côte ouest de l'île de Vancouver en Columbie Britannique. En 1970, un projet de 16 ans, multi-disciplinaire et regroupant plusieurs agences gouvernementales, fut mis en place avec pour buts d'évaluer les effets de l'exploitation forestière et des activités sylvicoles sur la faune aquatique, et de communiquer les résultats aux gestionnaires des forêts et des pêcheries. Cet article résume la nature du projet et les résultats obtenus et discute de la transmission de ces résultats, de leur application par les gestionnaires, et de l'importance du projet pour la gestion des forêts et des pêcheries dans la région littorale de la Columbie Britannique. Les débits de pointes et l'écoulement annuel ont augmentés dans un petit tributaire, les niveaux des nappes souterraines furent plus élevés et il y a eu des petits changements dans la qualité des eaux. Il y a aussi eu des changements importantes dans la structure du lit du ruisseau et des débris organiques,

une détérioration de l'habitat aquatique et des frayères et un variété complexe d'effets sur la croissance et la survie des poissons.

INTRODUCTION

Coastal British Columbia is endowed with major fish and forest resources, both of which are of vital importance to the economy. The Carnation Creek Experimental Watershed Project was initiated in 1970 to meet a need for local information to help minimize conflicts in the management of these two resources. The main objective of this paper is to describe the project and pass on our experience in the transfer and application of research results. The project was scheduled for completion in 1986 but has been extended under a revised format.

STUDY AREA

Carnation Creek is a salmon stream that drains a 10 km^2 mountainous watershed located on the west coast of Vancouver Island, British Columbia, Canada (Fig.1). The basin slopes are steep with shallow, highly permeable, coarse colluvial soils, watertight volcanic bedrock, and mature coniferous rainforest vegetation.

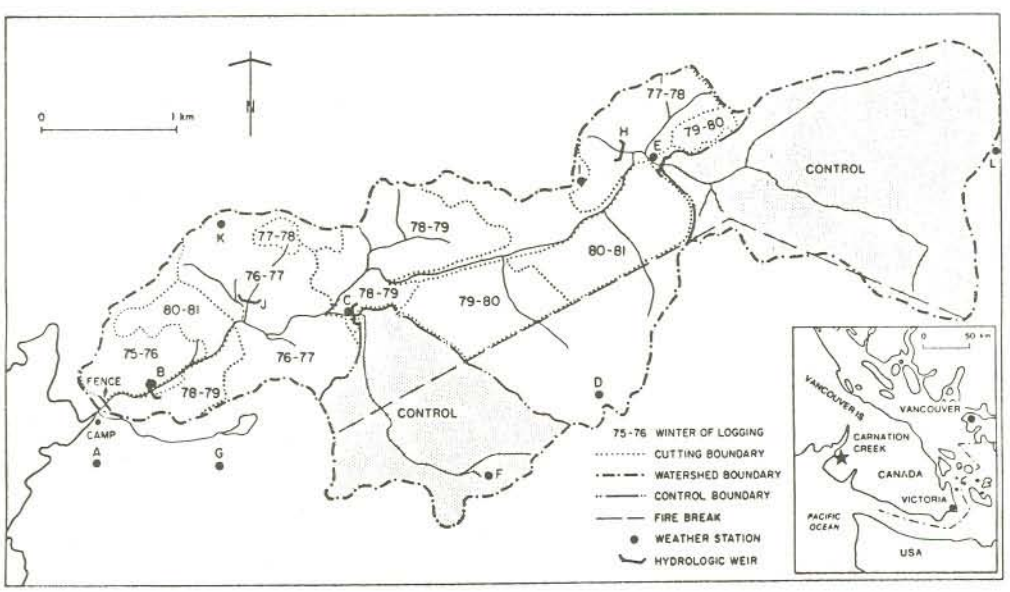

FIG.1 Carnation Creek Experimental Watershed showing location of hydrometeorological stations and clearcut logging boundaries.

The climate features mild, wet winters with frequent rainstorms, mild summers, and annual precipitation (mostly rain) of 2100 to over

5000 mm. Runoff is rapid with measured flows ranging from 0.02 to over 60 m^3s^{-1}. Streamflow was measured at five weirs, precipitation at 10 sites and groundwater levels at a number of locations (Fig.1).

NATURE OF THE CARNATION CREEK PROJECT

Objectives

The original objectives of the project (Hartman *et al.*, in press 1987b) were: (1) to develop a better understanding of undisturbed coastal rainforest-salmon ecosystems; (2) to explain and quantify impacts of forest management activities on stream environments and their capacity to produce salmonid fishes; and (3) to provide continuous input to the development of integrated resource management guidelines for watershed ecosystems. An emphasis has been placed on understanding processes to maximize the transferability and application of results.

Organization

The project is multi-agency and multi-disciplinary in nature. The initiating and lead agency was Fisheries and Oceans Canada (federal government) which provided continuity of leadership and most of the funding for field operations. A steering committee comprised of up to 10 senior representatives of participating agencies was formed to review progress and provide appropriate direction and support. The operation of the project was supervised by a project coordinator from Fisheries and Oceans Canada with the support of a working group composed of 15-20 principals conducting component studies or lending technical or advisory support. Participating organizations included both federal and provincial fisheries, forestry and water resource agencies, industry and universities. Forestry operations were carried out by MacMillan Bloedel Ltd.

Study design

The study included three phases: 5 years pre-logging (1971-1975), 6 years active logging (1976-1981) and 5 years post-logging (1982-1986). A total of 41% of the watershed area was clearcut in patches ranging from 7 to 64 ha using high-lead and grapple cable yarding techniques. Silvicultural treatments included prescribed burning of slash, reforestation, some scarification and use of herbicides. The experiment was designed to evaluate the impacts of three streamside forest management treatments (Hartman *et al.*, 1987a): (1) a leave strip of variable width, (2) a careful treatment keeping debris from the stream, and (3) an intensive treatment where the stream channel was disturbed by debris and yarding. The impacts of forestry operations were evaluated by studies focussing on both terrestrial (soil, vegetation, water) and stream (physical, chemical and biological) processes (Hartman, 1982). Major week-long simulation modelling workshops (Walters, 1974) were held in 1973 and 1979

to identify research needs and ensure that adequate data were being collected. Two unlogged tributaries served as hydrological controls (Fig.1). Additional facilities included a major weather station, an automatic sediment sampler at B weir, a permanent fish counting fence and a permanent field camp.

REVIEW OF RESEARCH FINDINGS

Hydrology

Post-logging changes in streamflow have been assessed for the main stream at B weir (41% clearcut) and the 12-ha tributary watershed at H weir (90% clearcut) (Hetherington, 1982). At H weir, peak flows increased by 20%, summer low flows increased by 78% and annual water yield increased by 14% during the first 3 years after treatment. In the main stream, there were no detectable changes in peak flows, while gravel conditions and the nature of B weir precluded accurate assessment of changes in low flows or annual water yields.

Transient peak groundwater levels during rainstorms were lower at one hillslope site below a road after road construction but were higher at another steeply sloped site above a road after harvesting. In the alluvial valley bottom of Carnation Creek, summer groundwater levels were higher after harvesting.

Erosion has been minimal in the Carnation Creek watershed. Some minor surface erosion occurred from roads. A few small landslides and debris torrents occurred during major storms after logging in both clearcut and uncut areas. A relatively broad flood plain has prevented most of these hillslope erosion events from causing noticeable sedimentation of the main stream. Most of the sediment observed in the stream has come from erosion of the stream banks themselves.

Water quality

Stream water quality changed following harvesting and prescribed burning. Water temperatures increased in the summer (Holtby & Newcombe, 1982) and also in the winter (Hartman *et al.*, in press 1987b). Concentrations of several nutrients (calcium, magnesium, sodium, and nitrate) increased, but they remained low in this nutrient poor stream (Hartman *et al.*, in press 1987b; Scrivener, 1982). Suspended sediment at B weir showed little change.

Stream channel

The morphology and structure of the stream channel changed significantly following streamside logging (Hartman *et al.*, 1987a; Scrivener & Andersen, 1984; Toews & Moore, 1982). Deterioration of stream banks after tree removal, destabilization and removal of instream logs and introduction of small organic debris during logging and from the flood plain after logging have destabilized the

channel. Changes have included increased bank erosion, straightening of the channel and major shifting of gravel. Sand deposition in the lower reaches of the stream has deteriorated the quality of spawning gravel (Scrivener & Andersen, 1984; Scrivener & Brownlee, 1982).

Stream biology and fish

The biological consequences of changes in the physical aspects of the system have been a major focus. Studies have been conducted on basic stream productivity, including aquatic insects, detritus and algae as well as fish (Hartman, 1982). The research has revealed a complex variety of both positive and negative impacts on fish in relation to different life stages of the fish, different time scales and differences among species (Hartman et al. in press 1987b, Scrivener & Andersen, 1984). Reductions in salmon egg-to-fry survival have been offset by compensatory effects of lower fry density, earlier emergence of fry in the spring, higher growth rates and higher first winter survival of the young salmon. The importance of side-channels as overwinter habitat for young salmon has been a major finding (Tschaplinski & Hartman, 1983). The specific importance of large woody debris in stabilizing the stream channel and providing diversified fish habitat has also been documented.

TRANSFER OF RESEARCH INFORMATION

Ongoing communication of research findings to fishery and forestry managers and other potential users has been a major goal of the project. Almost 100 articles have been produced to date in a variety of publications, including scientific journals, symposium and workshop proceedings, agency and project reports and university theses. A short information film was produced to explain the project. Working group members passed on information directly through numerous presentations and talks to organizations such as federal and provincial government agencies, professional fishery and forestry associations, public groups, and university classes. Field tours of the watershed have been an important means of transferring research findings. After 1980, several evening seminars combined with field tours the next day were arranged for groups of operational fishery and forestry personnel from government and industry. Personal contact with working group members in the field or at meetings has been the most effective method of information transfer.

Major 3-day workshops were given in 1982 and 1987 to provide comprehensive summaries of results. An emphasis was placed on management implications and applications of the results and on participation of fishery and forestry managers in the workshops. The 1982 workshop was instrumental in initiating a major revision of coastal forestry and fishery guidelines for stream protection, in which Carnation Creek results and working group members played an important role.

APPLICATION OF RESEARCH INFORMATION

Carnation Creek research findings have been widely used in coastal British Columbia as a basis for on-site fish-forestry interaction evaluations and for assessment and planning of forestry development proposals. These applications have been mostly qualitative in that they have served as a guide for constructive preservation of fish and their stream habitat. The input to the revision of coastal logging guidelines is a good example.

The long-term, detailed hydrometeorological measurements in the Carnation Creek watershed have provided a unique data base for the coastal region. These data have been used to estimate the frequency and magnitude of peak flows in other watersheds and to test and calibrate several computer simulation models. Information on the importance of subsurface flow and the effects of roads in intercepting and diverting this flow have resulted in modifications to road drainage procedures by at least one company.

Other information which has been particularly useful to operational fishery and forestry personnel includes: the value of side-channels as overwinter fish habitat; the relative importance of specific streamside management treatments in relation to stream protection; the role and impact of changes in woody debris in the stream channel; documentation of changes in morphology and stability of the stream channel and its banks; cumulative degradation of spawning gravels in such a high-energy stream; and the differences in impacts on the various life stages and species of fish.

SIGNIFICANCE OF THE PROJECT FOR FISH-FORESTRY MANAGEMENT

The Carnation Creek project has succeeded in heightening the sensitivity of both forestry and fishery personnel to hydrological concerns, and in breaking down barriers of communication between the two groups. It has definitely influenced those responsible for the planning and operational management of fish and forests. The emphasis on the understanding of processes and provision of a comprehensive perspective of the impacts of forestry operations on fish and streams has been particularly valuable in this regard.

The value of the long duration of the project cannot be too highly stressed. It has served as a focus of attention for long enough to become an effective agent for change. Credibility has been one of the key elements. The project itself has achieved credibility because of the openness and unbiased approach of the researchers in willingly sharing their information with all potential users. The local documentation of changes and impacts has given valuable support and credibility to recommendations for stream protection measures by fisheries officers and other resource planners and advisors. This includes more confidence in extrapolation of results from elsewhere based on a better understanding of processes relevant to local conditions. The involvement of the forest industry in the project has resulted in greater awareness and acceptance of the Carnation Creek findings. This in turn has given the companies greater credibility with government agencies in terms of acceptance of forestry management plans.

ACHIEVEMENT OF PROJECT OBJECTIVES

The Carnation Creek project has achieved and perhaps surpassed its original objectives. The communication of its message to those responsible for resolving conflicts between the fishery and forestry resources has been particularly effective. The project has helped focus attention on important fish-forestry issues and influenced day- to-day planning and selection of stream protection measures in coastal British Columbia.

REFERENCES

Hartman, G. Ed. (1982) *Proc. Carnation Creek Workshop, a 10-Year Review.* Pacific Biological Station, Dept. Fisheries & Oceans, Nanaimo, British Columbia, Canada.

Hartman, G., Scrivener, J.C., Holtby, L.B., & Powell, L. (1987a) Some effects of different streamside treatments on physical conditions and fish population processes in Carnation Creek, a coastal rain forest stream in British Columbia. In: *Proc. Symp. Streamside Management: Forestry and Fisheries Interactions,* Feb. 1986 (ed by E.Salo and T.Cundy), 330-372. University of Washington, Seattle, Washington, USA.

Hartman, G.F., Scrivener, J.C., & McMahon, T.E. (in press 1987b) Fisheries-forestry research at Carnation Creek: Saying that logging is either "good" or "bad" for fish doesn't tell you how to manage the system. *For. Chronicle.*

Hetherington, E.D. (1982) Effects of forest harvesting on the hydrologic regime of Carnation Creek Experimental Watershed: a preliminary assessment. In: *Canadian Hydrology Symposium: 82,* 247- 267. National Research Council of Canada, Ottawa.

Holtby, B. & Newcombe, C.P. (1982) A preliminary analysis of logging-related temperature changes in Carnation Creek, British Columbia. In: *Proc. Carnation Creek Workshop, A 10-Year Review* (ed. by G.Hartman), 81-99. Pacific Biological Station, Dept. Fisheries and Oceans, Nanaimo, British Columbia, Canada.

Scrivener, J.C. (1982) Logging impacts on the concentration patterns of dissolved ions in Carnation Creek, British Columbia. In: *Proc. Carnation Creek Workshop, A 10-Year Review* (ed. by G.Hartman), 64-80. Pacific Biological Station, Dept. Fisheries & Oceans, Nanaimo, British Columbia, Canada.

Scrivener, J.C. & Andersen, B.C. (1984) Logging impacts and some mechanisms that determine the size of spring and summer populations of coho salmon fry (*Oncorhynchus kisutch*) in Carnation Creek, British Columbia. *Can. J. Fish. Aquat. Sci.* 41(7), 1097-1105.

Scrivener, J.C. & Brownlee, M.J. (1982) An analysis of Carnation Creek gravel-quality data 1973-1981. In: *Proc. Carnation Creek Workshop, a 10-Year Review* (ed. by G.Hartman), 154-176. Pacific Biological Station, Dept. Fisheries & Oceans, Nanaimo, British Columbia, Canada.

Toews, D.A. & Moore, M.K. (1982) The effects of three streamside logging treatments on organic debris and channel morphology of Carnation Creek. In: *Proc. Carnation Workshop, a 10-Year Review*

(ed. by G.Hartman), 129-153. Pacific Biological Station, Dept. Fisheries & Oceans, Nanaimo, British Columbia, Canada.

Tschaplinski, P.J. & Hartman, G.F. (1983) Winter distribution of juvenile coho salmon (*Oncorhynchus kisutch*) before and after logging in Carnation Creek, British Columbia, and some implications for overwinter survival. *Can. J. Fish. Aquat. Sci.* 40, 452-461.

Walters, C. (1974) An interdisciplinary approach to development of watershed simulation models. *Technological Forecasting and Social Change* 6, 299-323.