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AN ANNOTATED BIBLIOGRAPHY OF THE CARNATION CREEK FISH-FORESTRY PROJECT - 1970 TO 1988.

by

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ABSTRACT

Poulin, V.A. and J.C. Scrivener. 1988. An annotated bibliography of the Carnation Creek fish-forestry project - 1970 to 1988. Can. Tech. Rep. Fish. Aquat. Sci. 1640: 35 p. (Contrib. No. 146.)

This bibliography contains 147 articles and research papers produced by participants in the Carnation Creek fish-forestry project. Article citations are listed in alphabetical order and include abstracts where available. Contribution numbers have been assigned. In addition, manuscripts approved for publication to the date of this document are listed by contribution number in an appendix.

RÉSUMÉ

Cette bibliographie contient 147 articles et comptes rendus de recherche écrits par les participantsau projet d'étude forestière et halieutique du ruisseau Carnation. Les citations tirées des articles sont données par ordre alphabétique et comprennent des résumés, le cas échéant. Des numéros de contribution ont été assignés. En outre, les manuscrits dont la publication a été autorisée à la date de parution du document sont énumérés en appendice, dans l'ordre de leur numéro de contribution.

PREFACE

In the late 1960's, forestry and fishery managers were becoming increasingly concerned about the impact of clearcut logging on salmonid stocks throughout the Pacific Northwest. In British Columbia, little detailed information was available from cedar-hemlock watersheds where much of the Province's coastal wood and salmonid production originates. In 1970, Carnation Creek, a small west coast watershed located on Vancouver Island was selected for an interagency study. Objectives of the project were to assess the effects of forest practices including logging, prescribed burning, reforestation and herbicide use on salmonid production and to partition these effects from natural variability caused by factors such as climate, streamflow and nutrient availability. The project continues to the present, thus distinguishing it as one of the longest continuous watershed studies conducted in North America. The study has been undertaken in three phases. Watershed processes were calibrated in a pre-logging phase from 1970 to 1975, followed by active logging in 1976 to 1981, and post-logging monitoring from 1982 to present.

Results to date have been reported in 147 articles and research papers. Three major workshops have been held (February 24-26, 1982; January 13-15, 1987; and December 8-10, 1987). Proceedings from these workshops contain research papers and panel discussions bridging topics from watershed processes to management implications. Articles have appeared in scientific journals, symposia and in the popular media.

This document was produced in response to the need for a compendium of the many technical articles and publications arising from Carnation Creek research. To improve reader access to results of current research and otherwise out-of-print information abstracts are provided where available. Contribution numbers have also been assigned to establish a permanent chronological record of source listings. Article citations are listed in the bibliography in alphabetical order. Citations of manuscripts that have been approved for publication are appendicized.

Reprints of the more recent papers are available from the senior authors or the Pacific Biological Station, Nanaimo, British Columbia.

ACKNOWLEDGEMENTS

During the past 18 years many individuals have contributed to the Carnation Creek Project. Years of field assistance was provided by B.C. Andersen, T.G. Brown, R.K. King, P.E. Neaves, J. Lamb, R.M. Leahy, L.H. Powell and R. Rowswell. Previous project coordinators were Drs. D.W. Narver, P.K.E. Symons, G.F. Hartman and V.A. Poulin. Data analysis has been improved by Dr. L.B. Holtby. The workshops were organized and proceedings edited by G.F. Hartman, T.W. Chamberlin and P.E. Reynolds. We are also eternally grateful to the many scientists that are cited in the bibliography.

Annotated Bibliography

Andersen, B.C. 1978. Fish populations of Carnation Creek and other Barkley Sound streams 1975-1977. Fish. Mar. Serv. Data Rep. 89: 118 p. (Contrib. No. 20.)

Andersen, B.C. 1981. Fish populations of Carnation Creek and other Barkley Sound streams 1978-1980. Can. Data Rep. Fish. Aquat. Sci. 302: 150 p. (Contrib. No. 33.)

Andersen, B.C. 1983. Fish populations of Carnation Creek and other Barkley Sound streams 1970-1980. Can. Data Rep. Fish. Aquat. Sci. 415: 267 p. (Contrib. No. 60.)

Andersen, B.C. 1984. Fish populations of Carnation Creek and other Barkley Sound streams 1981-1982. Can. Data Rep. Fish. Aquat. Sci. 435: 63 p. (Contrib. No. 68.)

Andersen, B.C. 1985. Fish populations of Carnation Creek and other Barkley Sound streams 1983-1984. Can. Data Rep. Fish. Aquat. Sci. 553: 62 p. (Contrib. No. 75.)

Andersen, B.C. 1987. Fish populations of Carnation Creek and other Barkley Sound streams 1985-1986. Can. Data Rep. Fish. Aquat. Sci. 657: 59 p. (Contrib. No. 86.)

ABSTRACT

Summaries of fish population data, collected as part of the Carnation Creek Experimental Watershed Project, are presented. The time period covered is from 1978 to December 1986.

Andersen, B.C. and D.W. Narver. 1975. Fish populations of Carnation Creek and other Barkley Sound streams - 1974: data record and progress report. Fish. Res. Board Can. MS Rep. 1351: 73 p. (Contrib. No. 10.)

Anon. 1973. Carnation Creek watershed project. Typed MS prepared by Carnation Creek Working Group. Pacific Biological Station, Nanaimo, British Columbia. 26 p. Contrib. No. 1.)

Anon. 1979. Carnation Creek modelling workshop, Inst. of Anim. Res. Ecol., University of British Columbia, July 9-13, 1979. Typed MS. 49 p. (Contrib. No. 25.)

Anon. 1979. Carnation Creek experimental watershed project. Information Forestry, 6: 1-4. Can. For. Serv. Pac. For. Res. Cent., Victoria, B.C. (Contrib. No. 26.)

Anon. 1984. Massive outdoor laboratory Carnation Creek. MB Journal, 4: 4-5. (Contrib. No. 69.)

Aquafor Consulting Ltd. 1986. An investigation of the effects of logging on instream debris and stream channel morphology in Carnation Creek, British Columbia. Prepared for Fisheries and Oceans Canada, Vancouver, British Columbia, p. 149 and appendices. (Contrib. No. 80.)

ABSTRACT

The Ritherdon Road extension project on the west coast of Vancouver Island was used in 1975 to study the relationship between logging road design and construction tasks, and stream sedimentation. A method of determining least cost logging road design and construction prescriptions to meet stream sedimentation standards is described using sample data.

Berg, L. 1982. The effect of exposure to short-term pulses of suspended sediment on the behavior of juvenile salmonids, p. 177-196. *In:* G.F. Hartman [ed.] Proceedings of the Carnation Creek Workshop: A 10 year review. Pacific Biological Station, Nanaimo, British Columbia. 404 p. (Contrib. No. 41.)

ABSTRACT

The behavior of juvenile coho salmon *(Oncorhynchus kisutch)*, in response to exposure to short-term pulses of suspended sediment, was monitored in a laboratory donut channel. Results indicate a breakdown of social organization, a change in the form of aggression elicited, an increase in activity, and a decrease in feeding ability in response to suspended sediment. The data suggest the potential for decreased fish production in streams affected

by short-term pulses of suspended sediment.

Berg, L. and T.G. Northcote. 1985. Changes in territorial, gill-flaring, and feeding behavior in juvenile coho salmon (*Oncorhynchus kisutch*) following short-term pulses of suspended sediment. Can. J. Fish. Aquat. Sci. 42: 1410-1417. (Contrib. No. 76.)

ABSRACT

The territorial, gill-flaring and feeding behavior of juvenile coho salmon (*Oncorhynchus kisutch*) in a laboratory stream was disrupted by short-term exposure to suspended sediment pulses. At the higher turbidities tested (30 and 60 nephelometric turbidity units (NTU)), dominance hierachies broke down, territories were not defended, and gill flaring occurred more frequently. Only after to lower turbidities (0-20 NTU) was social organization reestablished. The reaction distance of the capture success per strike and the percentage of prey ingested. Implications of these behavioral modifications suggest that the fitness of salmonid populations exposed to short-term pulses of suspended sediment may be impaired.

Beschta, R.L. , R.E. Bilby, G.W. Brown, L.B. Holtby, and T.D. Hofstra. 1987. Stream temperature and aquatic habitat: Fisheries and forestry interactions, p. 191-232. *In:* E.O. Salo and T.W. Cundy [eds.] Streamside management: Forestry and fishery interactions. Contrib. No. 57 of the Institute of Forest Resources, University of Washington, AR-10,Seattle, WA. (Contrib. No. 87.)

ABSTRACT

The temperature of water entering a forest stream system typically resembles that of the watershed's subsoil environment. As this water continues to flow down the stream system, seasonal and diurnal water temperatures are strongly influenced by solar radiation. Pronounced differences in stream temperature patterns are evident for streams draining watersheds throughout the Pacific Northwest. Seasonal and diurnal patterns of stream temperature influence a wide range of responses by instream biota. Further more, logging activities can initiate pronounced temperature changes by the removal of forest vegetation along channels. Buffer strips of forest vegetation are an effective means of minimizing stream temperature impacts associated with logging. Although direct mortality of fish is probably not a major concern throughout the Pacific Northwest when stream temperatures are altered by management activities, temperature changes can influence rates of egg development, rearing success, species competition, and other factors.

Brown, T.G. 1985. The role of abandoned stream channels as over-wintering habitat for juvenile salmonids. M.S. Thesis, Faculty of Graduate Studies, Department of Forestry, University of British Columbia, Vancouver, B.C. 134 p. (Contrib. No. 77.)

ABSTRACT

The role of ephemeral and intermittent tributaries (off-stream habitat) located on the flood-plain of a west coast Vancouver Island stream (Carnation Creek), as over-wintering habitat, was examined for two winters. All trout (*Salmo gairdneri* and *S. clarki clarki*) and juvenile coho salmon (*Oncorhynchus kisutch*) off-stream habitat was identified and characterized. Within this habitat: seasonal movement of salmonids was noted, coho growth rates were measured, salmonid populations were enumerated and contribution of off-stream habitat to the total coho smolt production was estimated.

Coho and trout did not occupy all winter flooded land. Trout occupied intermittent tributaries, while coho occupied both intermittent tributaries and ephemeral swamps. Salmonid use of flooded meadows was negligible. The contribution of off- stream habitat to the watershed's total smolt production was at least 23% and more than 15% came from sites devoid of water in summer.

Seasonal movement of juvenile coho followed a distinct pattern and appeared dependent upon climatic conditions such as magnitude and timing of the first fall (Oct.-Nov.) freshet. Climatic conditions in spring (March-May) appeared to influence both growth and survival of coho within one small ephemeral swamp.

Brown, T.G. 1987. Characterization of salmonid over-wintering habitat within seasonally flooded land on the Carnation Creek flood-plain. B. C. Min. For. Land Manage. Rep. No. 44: 42 p. (Contrib. No. 88.)

ABSTRACT

Seasonally flooded land (ephemeral swamps and intermittent tributaries) located on the flood-plain of a west coast Vancouver Island stream (Carnation Creek) was examined for two winters. Seven distinct map units were identified by discriminant analysis, based on environmental and biotic factors. These seven map units were further grouped into three habitat units based on their ability to support over-wintering coho (*Oncorhynchus kisutch*) and trout (*Salmo gairdneri* and *S. clarki clarki*). The use of these habitat units to identify salmonid off-stream winter habitat was shown to be valid for the watershed in which it was developed.

Brown, T.G. and McMahon, T. 1988. Winter ecology of juvenile coho salmon in Carnation Creek: summery of findings and management implications, p. 108-117. *In:* T. W. Chamberlin [ed.] Proceedings of the workshop: Applying 15 years of Carnation Creek results. Pacific Biological Station, Nanaimo, B.C. (Contrib. No. 102.)

Brown, T.G., I. V. Williams, and B.C. Andersen. 1987 Fish survey of Barkley Sound Streams, Vancouver Island. Can. MS Rep. Fish. Aquat. Sci. 1953: 61. p. (Contrib. No. 89)

ABSTRACT

Minnow traps were used to capture juvenile salmonids from five locations in each of twenty-one Barkley Sound Streams. At each location the environmental features were noted,the length and weight of all captured juvenile coho were recorded, and scales were obtained for salmonid age determination. Juvenile coho catch/effort, mean length of one year old coho, and percent two year olds were calculated for each stream surveyed. The mean catch at each location was correlated to various environmental features such as: dominant biogeoclimatic variant, gradient, stream order, stream orientation and stream location. The mean catch at each location was also correlated with vegetation type, vegetation age, percentage in-stream cover, cover type, and substrate type. Few results were statistically significant because catches and age compositions were highly variable and sample sizes were small.

Bustard, D.R. 1973. Some aspects of the winter ecology of juvenile salmonids with reference to possible habitat alteration by logging in Carnation Creek, Vancouver Island. Fish. Res. Board Can. MS Rep. 1277: 85 p. (Contrib. No. 4.)

ABSTRACT

Juvenile coho, steelhead, and cutthroat trout commonly spend from one to three or more years in coastal streams before migrating to the sea. Much of this time is spent in streams during the winter, making a study of these fish winter habitat requirements, distribution, behavior, and the possible influences of stream habitat alteration on them a useful undertaking. Some physical characteristics of areas selected by juvenile coho and steelhead were observed by snorkeling in a small west coast of Vancouver Island stream between September 1972 and April 1973. Observations revealed that with lowering water temperatures from 9° C to 2° C coho and older steelhead tended to move into deeper water while most steelhead fry remained in shallow, marginal sections of the stream. As water temperatures dropped in the winter, juvenile fish fed less and moved closer to areas offering low water velocities and cover. Steelhead fry were most often found under rubble while coho and older steelhead were most often found within upturned roots and under logs.

Results from fish traps located on the lower ends of two small tributary streams indicated that juvenile coho, steelhead and cutthroat trout moved upstream into these tributaries in the late fall. Overwinter survival of coho in one tributary was 3-6 times as great as the estimated survival of coho in the main stream. Together the two tributaries contributed between 15 and 25 per cent to the total coho smolt production of the larger system.

A series of experiments comparing coho and cutthroat preference for alternative habitat types in side pool areas as may occur before and after stream disturbance were carried out during the winter. Both coho and cutthroat demonstrated a strong preference for bay areas offering overhanging bank cover as opposed to bays without cover, and for bays offering clean rubble

substrate as opposed to silted rubble substrate.

The impacts of timber harvesting on overwintering fish as suggested by the results from the underwater observations, winter movements, and the side pool experiments are discussed and management recommendations are made.

Bustard, D.R., and D.W. Narver. 1975. Aspects of the winter ecology of juvenile coho salmon *(Oncorhynchus kisutch)* and steelhead trout *(Salmo gairdneri)*. J. Fish. Res. Board Can. 32: 667-680. (Contrib. No. 11.)

ABSTRACT

The major physical characteristics of overwintering areas for juvenile coho salmon *(Oncorhynchus kisutch)* and steelhead trout *(Salmo gairdneri)* are described for a small, unlogged, west coast Vancouver Island stream. During the winter months age 1+ coho and steelhead were found at a range of depths mainly greater than 45 cm and in deeper water than age 0 of either species. About 45% of age 0 steelhead observed were in water <15 cm deep. The depth occupied by coho and age 1+ steelhead was negatively correlated with water temperature below 8.5 C. Coho were associated less closely with the bottom than were steelhead. At 7°C or less most fish were associated with water velocities of <15 cm/s. Velocities in which steelhead occurred were positively correlated with rising temperature above 4 C. As water temperature decreased from 9 to 2°C, coho and steelhead moved closer to cover. Cover used by coho and age 1+ steelhead most frequently was logs and upturned tree roots, although debris accumulations and overhanging banks were also used. Both age-groups of coho used overhanging brush but steelhead did not. Over 50% of age 0 steelhead were associated with rocks 10-25 cm in diameter. Side pools and quiet back channels that contained water only in the winter and that had combinations of the above cover types were populated by coho during the winter. A series of unused beaver ponds, dry in the summer, was an important overwintering area for coho with a survival rate about twice as high as the 35% estimated for the entire stream system.

Bustard, D.R. and D.W. Narver. 1975. Preferences of juvenile coho salmon *(Oncorhynchus kisutch)* and cutthroat trout *(Salmo clarki)* relative to simulated alteration of winter habitat. J. Fish. Res. Board Can. 32: 681-687. (Contrib. No. 12.)

ABSTRACT

Winter habitat preferences of juvenile coho salmon *(Oncorhynchus kisutch)* and cutthroat trout *(Salmo clarki)* were tested by simulating conditions before and after stream disturbance such as might result from logging: (1) side pools with or without an overhanging bank and roots, and (2) side pools with clean or silted rubble substrate. Both coho and cutthroat demonstrated a strong preference for side pools offering overhanging bank cover as opposed to those without bank cover. Similarly they preferred side pools with clean rubble substrate as opposed to silted rubble. In both the bank and rubble tests, when given the option of either remaining in the side pools or of moving into the stream, a greater percentage of the total number of coho and cutthroat originally in the side pools remained in the pools with cover as opposed to those without cover. Coho utilized bank cover more readily than rubble cover whereas cutthroat used both bank and rubble cover.

Chamberlin, T.W. [ed.] 1988. Proceedings of the workshop: Applying 15 years of Carnation Creek results. Pacific Biological Station, Nanaimo, B.C. 239p. (Contrib. No. 101.)

Cowell, D. 1981. 15-year study at Carnation Creek. British Columbia Lumberman. p. 19-22. (Contrib.No. 34.)

Culp, J.M. 1986. Experimental evidence that stream macroinvertebrate community structure is unaffected by different densities of coho salmon fry. J. N. Am. Benthol. Soc. 5: 140-149. (Contrib. No. 81.)

ABSTRACT

Manipulative field enclosure/exclosure experiments were carried out in Carnation Creek, British Columbia to determine if patch-restricted coho fry *(Oncorhynchus kisutch)* affected the distribution and abundance of macroinvertebrates in the drift or benthos. Enclosures/

exclosures with standardized substrate, detritus, and current velocity were buried in the streambed during the low discharge period, and four treatments used: no fish, double ambient fish, and quadruple ambient fish densities. Density, biomass, and size distribution of macroinvertebrates in the drift were not significantly affected by fish density treatment. Additionally, with the exception of large swimming larvae of *Ameletus* sp. and *Baetis tricaudatus*, macroinvertebrate density, size distribution, and biomass in the benthos were also not significantly affected by fish density treatments. Thus, despite fish densities being increased from two to four times above ambient patch levels, patch-restricted coho fry had little measureable effect on macroinvertebrate distribution and abundance in Carnation Creek during the low discharge period of August to September.

Culp, J.M. and R.W. Davies. 1982. Effect of substrate and detritus manipulation on macroinvertebrate density and biomass: Implications for forest clearcutting, p. 210-218. *In:* G.F. Hartman [ed.] Proceedings of the Carnation Creek Workshop: A 10 year review. Pacific Biological Station, Nanaimo, British Columbia. 404 p. (Contrib. No. 42.)

Culp, J.M. and R.W. Davies. 1983. An assessment of the effects of streambank clear-cutting on macroinvertebrate communities in a managed watershed. Can. Tech. Rep. Fish. Aquat. Sci. 1208: 115 p. (Contrib. No. 61.)

ABSTRACT

Three macroinvertebrate sampling sites were established on Carnation Creek, Vancouver Island, British Columbia, and sampled from 1974-1980 to determine the effects of logging, with or without buffer zones, on macroinvertebrate communities. Logging without a buffer zone increased streambank erosion and the resulting sedimentation of streambank material caused a significant increase in the proportion of <9 mm sediment particles in the substrate. Although logging opened the forest canopy and increased the light available for primary production, algal biomass did not increase after logging because phosphorus remained the limiting factor. Allochthonous litter input to the stream was significantly reduced at both logged sites, but the site with a buffer zone provided greater amounts of leaf litter to the stream, and had a higher post-logging benthic standing crop than the site without a buffer zone.

Culp, J.M. and R.W. Davies. 1985. Responses of benthic macroinvertebrate species to manipulation of interstitial detritus in Carnation Creek, British Columbia. Can. J. Fish. Aquat. Sci. 42: 139-146. (Contrib. No. 78.)

ABSTRACT

Experimental manipulations were conducted in Carnation Creek, British Columbia, to determine the response of macroinvertebrates distribution and abundance to differences in detritus source and quantity. Four treatments (no detrius, low hemlock (*Tsuga heterophylla*), low alder (*Alnus rubra*), high alder) with a standardized substrate were established in a riffle and left for 28 d. Densities and/or biomasses of 12 of the 20 colonizing macroinvertebrate taxa were significantly different among the detritus treatments. Microbial activity, detritus processing, and macroinvertebrate abundances were highest in the substrate patches with alder detritus. Compared with the no detritus and low hemlock treatments, the low alder treatment increased the abundances of nine taxa and decreased three taxa, while the high alder treatment increased the abundances of six taxa and decreased six taxa. Thus, detritus source and quantity strongly influenced macroinvertebrate community composition within the streambed. Although most of the macroinvertebrates in all treatments were either collector-gatherer or shredder detritivores, these macroinvertebrates responded to changes in detritus in species-specific manner. Therefore, the Carnation Creek experiments emphasize the importance of interstitial detritus in the substrate as a factor that influences the microdistribution of the benthos at the species, rather than trophic feeding, assemblage.

Culp, J.M., S.J. Walde, and R.W. Davies. 1983. Relative importance of substrate particle size and detritus to stream benthic macroinvertebrate microdistribution. Can. J. Fish. Aquat. Sci. 40: 1568-1574. (Contrib. No. 62.)

ABSTRACT

Manipulative field experiments were conducted in Carnation Creek, British Columbia, to determine whether particle-size composition of the stony substrate influenced macroinvertebrate microdistribution if substrate detritus was standardized. A standardized quantity of alder (*Alnus rubra*) detritus was added to five substrate mixtures ranging from homogeneous gravel to a heterogeneous gravel, pebble, and cobble mixture, and the substrates imbedded in a riffle to allow macroinvertebrate colonization. Densities and biomasses of most macroinvertebrate taxa (16 of 19) were not significantly different among the wide range of substrate types containing the standardized alder detritus, even though surface area, intrasubstrate current velocity, and interstitial space varied significantly between treatments. However, in the treatment that did not have the standardized detritus, the biomasses and densities of nine taxa, and the totals of all taxa combined, were significantly lower than in an identical substrate mixture that contained the detritus. We concluded that the differential colonization of substrates demonstrated for many macroinvertebrate taxa in previous studies was more likely related to differences in organic sedimentation. Although detritus is a major determinant of detritivore microdistribution, substrate composition may be an important factor to other trophic groups such as filter-feeders.

Culp, J.M., F.J. Wrona, and R.W. Davies. 1986. Response of stream benthos and drift to fine sediment deposition versus transport. Can. J. Zool. 64: 1345-1351. (Contrib. No. 82.)

ABSTRACT

Field experiments were conducted to investigate the responses of benthic macroinvertebrate communities to experimental additions of fine sediments into riffles having a flow with either low tractive force so the sediments were deposited or sufficient tractive force to transport the added sediments. Sediment deposition had no measurable impact on most taxa, the only negative effects being significantly higher drift rates and lower benthic densities for *Paraleptophlebia*. Sediment transport by saltation created a physical disturbance that reduced total benthic densities by >50% in 24 h and significantly influenced macroinvertebrate community composition. Changes in the benthic community were the result of catastrophic drift, and distinct immediate and delayed responses of diurnal drift to the saltating sediments were evident. Taxa with the immediate drift response resided predominantly at the substrate surface and were instantaneously exposed to scouring as sediments were added. Macroinvertebrates showing the delayed response initially avoided the saltating sediments because of their deeper distribution, but an apparent diel shift in vertical distribution exposed these taxa to saltating sediments 6-9 h after additions. Thus, even when tractive forces were insufficient to suspend fine sediments, catastrophic drift was initiated by fine sediments that slid and bounced along the stony substrate. Sediment saltation, therefore, has the potential to act as a community-level disturbance early in the storm hydrograph or at lower discharge magnitudes than required to suspend sediments.

Culp, J. M., 1988. Effect of streambank clearcutting on the benthic invertebrates of Carnation Creek, British Columbia,p. 87-92. *In:* T. W. Chamberlin [ed]. Proceedings of the workshop: Applying 15 years of Carnation Creek results Pacific Biological Station, Nanaimo, British Columbia. (Contrib. No. 103.)

Davies, R.W. and J.M. Culp. 1979. The effects of logging on the macroinvertebrate community of Carnation Creek. Progr. Rep. to Fish. Mar. Serv. 5427. Dept. of Biol., University of Calgary, Calgary, Alberta. Typed MS. 28 p. (Contrib. No. 27.)

de Leeuw, A.D. 1981. The effect of logging on benthic invertebrate stream drift and trout growth rates in two small west coast Vancouver Island streams. M.S. Thesis, Department of Biology, University of Victoria, Victoria, B.C. 353 p. (Contrib. No. 35.)

ABSTRACT

A study was conducted during the summer and fall of 1976 and 1977 on Carnation, Dick, and Ritherdon creeks and in the Barkley Sound area on the west coast of Vancouver Island to document the effects of logging on the density and behavior of drifting stream invertebrates and trout growth rates.

In the logged areas, daily light intensities reached a maximum of 1200 foot candles (fc), whereas in the unlogged areas, maximum light intensities were only 200 fc and generally less than 10 fc. At night, however, all light intensities dropped to less than 0.002 fc in all sample sites, regardless of whether or not they were logged. Duration of low light intensity usually lasted from one hour after sunset until approximately one hour before sunrise.

Although results were variable, no consistent differences in total drift densities and behavior of all drift invertebrates could be detected between pre and postlogging and logged and unlogged samples on Ritherdon and Carnation creeks. Differences in drift behavior, as ascertained by recording temporal patterns of peak stream drift rates, were also not apparent between logged and unlogged stream sections. The latter was attributed mainly to low nighttime light intensities in all stream sections.

In the experimental situation, increasing (in late evening to midnight) light intensities from 0.002 to 0.009 fc failed to produce a response in drift behavior. Decreasing light intensities also failed to produce a response in drift rates of all species and was attributed to identical low nocturnal light intensities within treated and control sections.

Growth rates of rainbow trout fry were greatest in the logged areas and were attributed to higher temperatures in these areas compared to the unlogged sections. Increasing evening light intensities, in an attempt to make drift more available as a food source to trout, failed to show an effect on growth rates. It is likely that the use of large fish and little available drift accounted for this result. Decreasing overall light intensities also failed to show a response in trout growth rates. Trout fry grew equally well in both treated (illumination decreased) and control stream sections.

de Leeuw, A.D. 1982. The effect of logging on benthic invertebrate stream drift and trout growth rates in two small west coast Vancouver Island streams, p. 240-256. *In:* G.F. Hartman [ed.] Proceedings of the Carnation Creek Workshop: A 10 year review. Pacific Biological Station, Nanaimo, British Columbia. 404 p. (Contrib. No. 43.)

Dryburgh, J.G. 1982. Carnation Creek logging and silvicultural treatment program, p. 36-44. *In:* G.F. Hartman [ed.] Proceedings of the Carnation Creek Workshop: A 10 year review. Pacific Biological Station, Nanaimo, British Columbia. 404 p. (Contrib. No. 44.)

ABSTRACT

Logging and silvicultural activities in the Carnation Creek Watershed Study were monitored to aid researchers in the analysis of results of these treatments on aquatic environments and fish populations. Over the period 1975 to 1981, 41% of the watershed was logged with a range of streamside treatments.

Western hemlock (Tsuga heterophylla) western red cedar *(Thuja plicata)* , and amabilis fir *(Abies amabilis)* along with a lesser volume of Douglas-fir *(Pseudotsuga menziesii)* on southerly aspects, western white pine *(Pinus monticola)* around Mount Blenheim, Sitka spruce *(Picea sitchensis)* along alluvial flood plains, and a narrow band of red alder *(Alnus rubra)* along the creek.

MacMillan Bloedel became involved with the Carnation creek project in 1970 with the selection of the watershed to do an in-depth study on the effects of logging and forestry practices on a west coast salmonid stream.

There are three phases to the project:

1. 1970 to 1975-prelogging baseline study.
2. 1975 to 1981-six winters of logging activities.
3. 1981 to 1984-postlogging recovery period.

The Carnation Creek watershed is a small west coast British Columbia watershed that is subject to rapid flushing of heavy precipitation (260 to 350 cm/year). Mature trees present were predominantly western hemlock.

Eastwood, G.E.P. 1975. Geological field works: A summary of field activities of the geological division, Mineral Resources Branch. Southern Vancouver Island, p. 33- 40. Ann. Rep. Dept. Mines and Petroleum Resources, Gov. of British Columbia, Victoria, B.C. (Contrib. No. 13.)

Everest, F.H., R.L. Beschta, J.C. Scrivener, K V. Koski, J.R. Sedell, and. C.J. Cederholm, 1987. Fine sediment and salmonid production: a paradox, p. 98-142.. *In:* E.O. Salo and T.W. Cundy [eds.] Streamside management: Forestry and fishery interactions. Contrib. No. 57 of the Institute of Forest Resources. University of Washington, AR-10, Seattle, WA. (Contrib. No. 90.)

ABSTRACT

The term "sediment," as commonly used by fishery biologists, means fine sediment and excludes up to 90% of sedimentary material in streams. In mountainous terrain, hillslope erosion (primarily mass soil movements) provides periodic inputs of sediment into stream systems, often during periods of high flow when two major sediment transport mechanisms are active: (1) suspended sediment transport and (2) bedload transport. Suspended sediment consists primarily of silt and clay-size particles that may be rapidly transported downstream and locally deposited on floodplains and overbank storage locations or that may infiltrate into gravel interstices of the bed. Bedload transport, consisting primarily of coarse sands or larger particles, is complex and sporadic, and has major implications regarding channel morphology and the quality of spawning gravels. It is greatly affected by large roughness elements (logs, boulders, bedrock outcrops, etc.). Hence the impacts of sediment on fish habitat are influenced by both sediment availability and the subsequent routing of these materials through the channel system.

The effects of fine sediment on aquatic life have been studied intensively for more than three decades, both in situ and in the laboratory. Laboratory studies have demonstrated potential negative effects of fine sediment on macroinvertebrates, on survival and emergence of salmonid embryos and alevins, and on growth of salmonid fry. But there are significant difficulties in extrapolating these findings to the field. Nearly all laboratory survival studies have used simplified unnatural gravel mixtures to test incubation and emergence of salmonid fry. Also, mitigating factors in streams, such as structural roughness elements and spawning behavior of female salmonids, complicate direct field application of laboratory studies. Nevertheless, forest practice rules designed to minimize fine sediment and turbidity in streams have resulted primarily from laboratory studies. The relatively few studies dealing with the effects of sediment from forest management in natural environments have been less conclusive. Some negative effects observed in the laboratory also occur from acute or chronic sedimentation in the field. The problem with interpreting the results of field studies is that increased fine sediment from forest management is almost always accompanied by other environmental effects. Also, field studies have shown both increases and decreases in salmonid populations associated with forest management. The studies have generally failed to isolate the effects of fine sediment from other habitat changes.

A more holistic view of the role of sediment in stream ecosystems is needed. Undisturbed streams in forests have stored abundant sediments in their channels and maintained an equilibrium between sediment input and sediment routing. An abundance of large organic debris and other roughness elements played an important role in the storage and routing of sediments. Forest management has broadly changed sediment storage and equilibrium in streams throughout much of the western United States. The general result has been a concurrent loss of roughness elements and accelerated routing of sediment through fluvial systems. There is evidence that stable channels containing stored sediment and large organic debris are more productive at every trophic level than either degraded channels mainly devoid of sediment or channels that are aggraded and unstable. Thus there seems to be a broad middle ground between too much and too little sediment in salmonid habitats.

Forest practice rules designed to minimize introduction of fine sediment into streams are justified, but in themselves do not ensure protection of salmonid habitats. These rules might result in improved water quality and a reduction in fine sediment in gravels, but they do not ensure protection of the physical structure of salmonid habitats. In fact, large losses of productive habitat have occurred while these rules were in force. The long-term emphasis of forest practice rules on control of water quality and fine sediment must be expanded to a more

holistic view of salmonid habitat. Protection of streamside vegetation and physical structure of rearing habitat for juvenile salmonids must be given equal emphasis.

Feng, J.C. and D.G. Thompson. 1989. Persistence and dissipation of glyphosate in foliage and soils of a Canadian coastal forest watershed. Presented at the Dec. 8 -10, 1987, Herbicide Workshop. *In:* P.E. Reynolds [ed]. Proceedings of the Carnation Creek Herbicide Workshop. Can./B.C. Econ. Develop. Agree. FRDA. Rep. (in press). (Contrib. No. 127.)

ABSTRACT

The environmental fate and persistence of glyphosate and its major metabolite(AMPA) in terrestrial components of a Canadian coastal forest watershed was investigated in a one-year study, following aerial application of "Round-up" herbicide. The uniformity of herbicide deposition was assessed through analyses of deposit collectors and initial residues at three sampling sites throughout the watershed. Soil and foliage of two brush species, salmonberry (*Rubus spectabilis*) and red alder (*Alunus rubra* Bong) were monitored for chemical residues throughout the study.

Average initial deposition differed depending on the method of determination. Both the deposit collector estimate (2.5 Kg/ha) and soil residue estimate (1.92 Kg/ha) of average deposition were reasonably close to the nominal application rate of 2.0 Kg/ha. However, both systems indicated high variability in deposition rates between different spray blocks and different sites, ranging from a low of 0.63 Kg/ha to a high of 3.39 Kg/ha. Time of application and site location were correlated with the amount of chemical deposited

Analyses of foliage and leaf-litter samples also indicated variable initial deposits on the target species . Residues dissipated rapidly from leaf litter with <1% and <0.1% remaining 29 and 75 days post-application respectively. The data indicated that leaf-litter residues would be an insignificant, transient source of chemical combination.

Feng, J.C., D. G.Thompson, and P.E. Reynolds. 1989. Fate of gylphosate in a Canadian forest stream ecosystem. Presented at the Dec. 8 -10, 1987, Herbicide Workshop, Nanaimo. *In:* P.E.Reynolds [ed]. Proceeding of the Carnation Creek Herbicide Workshop. Can./B.C. Econ. Develop. Agree. FRDA. Rep. (in press). (Contrib. No. 137.)

ABSTRACT

Residues of glyphosate and its major metabolite aminomethyl phosphonic acid (AMPA) were monitored for a one-year period post application in the Carnation Creek watershed of Vancouver Island, British Columbia. The main stream channel and two tributaries were protected by a 10-m wide vegetation strip, while two other tributaries received direct chemical application at a rate of 2 Kg/ha. Deposits of glyphosate declined rapidly with distance off-target, such that 1% of the full rate was found 2-3 m. from the target, area. Off-target deposit extinction rates were not significantly different between alder and salmonberry vegetation areas ($p<0.05$), however the alder vegetation did appear to limit the deposition off-target to a greater degree than did the salmonberry vegetation.

Dissipation of residues in the two tributaries receiving direct chemical application differed depending on stream flow and degree of exposure. Glyphosate concentration in stream water 2 h after application were 100-fold greater in the rapid-flowing 1600 tributary than those in the slow-flowing 750 tributary which was covered with dense vegetation. Gylphosate concentrations decreased rapidly to 37 ug/L and less than 0.1 ug/L respectively, 16 h post application. No detectable residues were observed in water samples taken 150 days to 365 days post application. AMPA concentrations in individual water samples did not exceed 1% of the corresponding gylphosate concentrations.

Although no glyphosate residues were detected in samples of stream bottom sediment from buffered tributaries, those of directly over-sprayed tributaries contained concentrations exceeding those in corresponding water samples. Residues in bottom sediments persisted until the end of the one year monitoring period. Suspended sediment samples collected from the main stream channel, contained glyphosate during the first five storm events (23-26 days post application).

No detectable residues of either glyphosate or AMPA were found in the buffered tributaries during the monitoring period, thus indicating that the vegetation barrier effectively prevented stream contamination from drift or subsequent runoff input.

Graeme, I. 1985. Analysis of a small debris slide on coastal Vancouver Island. B.S.F. Thesis, Department of Forestry, University of British Columbia, Vancouver, B.C. 57 p. (Contrib. No. 79.)

Harris, C.D. 1984. Organic debris complexity and its effect on small scale distribution and abundance of coho *(Oncorhynchus kisutch)* fry populations in Carnation Creek, British Columbia. B.S.F. Thesis, Department of Forestry, University of British Columbia, Vancouver, B.C. 49 p. (Contrib. No. 70.)

ABSTRACT

The importance of large organic debris as a rearing habitat for juvenile coho salmon (*Oncorhynchus kisutch*) was examined in Carnation Creek, British Columbia, a small coastal watershed subject to a detailed study of logging impacts. Specifically, this thesis attempted to categorize instream debris and develop an index of debris complexity. Snorkel observation was used to determine juvenile coho density and abundance associated with different levels of debris complexity. There was a highly positive linear correlation between the number of juvenile coho salmon and the index of debris complexity during the summer months. Winter observations indicated that all coho were absent from the mainstem of the creek possibly because of high flows during October. Furthermore, no juvenile coho were seen during low flow levels in the mainstem creek in January suggesting that they permanently move away from such areas during the winter months. This finding is very important to fisheries-forestry interactions. Not only should areas of large, complex, organic debris in streams be maintained and protected for summer rearing habitat of juvenile coho salmon , but also the side channels away from the mainstem require careful protection during logging practices.

Harris, C.D. 1988. A summary of the effects of streamside logging treatments on organic debris in Carnation Creek, p. 26-30. *In:* T.W. Chamberlin [ed.]. Proceeding of the Workshop: Applying 15 years of Carnation Creek results. Pacific Biological Station, Nanaimo, B.C. (Contrib. No. 104.)

Hartman, G.F. [ed.] 1980. The Carnation Creek experimental watershed project: A perspective prepared for the director of the Resource Services Branch. Pacific Biological Station, Nanaimo, British Columbia. Typed MS. 32 p. (Contrib. No. 30.)

Hartman, G.F. [ed.] 1980. A summary of the November 14 meeting of the Carnation Creek Project. Pacific Biological Station, Nanaimo, British Columbia, Typed MS. 12 p. (Contrib. No. 31.)

Hartman, G.F. [ed.] 1981. Carnation Creek project report for 1979 and 1980. Pacific Biological Station, Nanaimo, British Columbia 21 p. (Contrib. No. 36.)

Hartman, G.F. 1982. The study area: An initial description, p. 15. *In:* G.F. Hartman [ed]. Proceedings of the Carnation Creek Workshop: A 10 year review. Pacific Biological Station, Nanaimo, British Columbia. 404 p. (Contrib. No. 45.)

Hartman, G.F. [ed.] 1983. Carnation Creek project report for 1981 and 1982. Pacific Biological Station, Nanaimo, British Columbia. 20 p. (Contrib. No. 63.)

Hartman, G.F. 1984. Creek project presents some surprising results. B.C. Sportsman, Fall Issue: 7-8. (Contrib. No. 71.)

Hartman, G.F. 1988. Some preliminary comments on results of studies of trout biology and logging impacts in Carnation Creek, p 175-180. *In*: T. W. Chamberlin [ed.] Proceedings of the workshop: Applying 15 years of Carnation Creek results. Pacific Biological Station, Nanaimo, B.C. (Contrib. No. 105.)

Hartman, G. F., 1988. Carnation Creek, 15 years of fisheries-forestry work, bridges from research to management, p. 189-204. *In:* T. W. Chamberlin [ed.] Proceedings of the workshop: Applying 15 years of Carnation Creek results. Pacific Biological Station, Nanaimo, B.C. (Contrib. No. 106.)

Hartman, G.F. 1988. Research and forestry fisheries management: Institutional voids in technology transfer, p. 225-227. *In:* T.W. Chamberlin [ed]. Proceedings of the Workshop: Applying 15 years of Carnation Creek results. Pacific Biological Station, Nanaimo, B.C. (Contrib. No. 119.)

Hartman, G.F., B.C. Andersen, and J.C. Scrivener. 1982. Seaward movement of coho salmon *(Oncorhynchus kisutch)* fry in Carnation Creek, an unstable coastal stream in British Columbia. Can. J. Fish. Aquat. Sci. 39: 588-597. (Contrib. No. 39.)

ABSTRACT

The seaward movement of coho *(Oncorhynchus kisutch)* fry was monitored over a 10-year period as a part of a major watershed study. The time period over which downstream movement took place varied widely during different years of study. Coho fry moved seaward earlier, and terminated the main period of movement earlier, following winters in which stream temperatures were warmer. It is presumed that they underwent more rapid development during winters in which stream temperatures were relatively high. Winter stream temperatures were primarily dependent on air temperatures. During seaward movement daily numbers fluctuated widely. Peaks of movement were coincident with or slightly before freshet peaks. In 94 of 122 cases (77%) the number of fry moving seaward during the night of peak discharge, or during the night before, was higher than in any of the three preceding nights. Movement in these cases may have been initiated by rainfall or falling water temperature or a combination of both. Aggressive behavior among coho fry is considered to be an underlying cause of seaward movement. In Carnation Creek, particularly in the early part of the period of seaward movement, the effects of such social behavior on movement patterns may be masked by the effect of freshets and related conditions. By autumn the number of fry remaining in the stream ranged from 9,000 to 13,000 over the 10-yr. study. Much of the downward adjustment to this resident fry population size occurred after the most active period of seaward movement.

Hartman, G.F. and T.G. Brown. 1988. Forestry-fisheries planning considerations on coastal floodplains. The Forestry Chronicle 64(February): 47-51. (Contrib. No. 97.)

ABSTRACT

Minor drainages (ephemeral swamps and intermittent tributaries) located on coastal floodplains are utilized by trout *(Salmo sp.)* and juvenile coho *(Oncorhynchus kisutch)* as over-wintering habitat. This paper describes salmonid habitat associated with these minor drainages, lists the possible impacts of forestry activities on this habitat, and discusses various measures that may be taken to protect these areas. The importance of careful surveys to identify and evaluate potential over-wintering habitat, prior to logging planning, is emphasized.

Hartman, G.F. and L.B. Holtby. 1982. An overview of some biophysical determinants of fish production and fish population responses to logging in Carnation Creek, British Columbia, p. 348-374. *In:* G.F. Hartman [ed.] Proceedings of the Carnation Creek Workshop: A 10 year review. Pacific Biological Station, Nanaimo, British Columbia. 404 p. (Contrib. No. 46.)

Hartman, G.F. and R.M. Leahy, 1983. Some temperature characteristics of stream and intra-gravel water in Carnation Creek, British Columbia. Can. MS Rep. Fish. Aquat. Sci. 173l: 36 p. (Contrib. No. 64.)

ABSTRACT

Twenty series of measurements of stream and intra-gravel water temperatures were made in Carnation Creek above the zone of tidal influence during a one year period. Four series were made in the part of the stream that was within the zone of tidal influence. Intra-gravel temperatures within a series were more variable than those of the stream and tended to be lower than those of the stream in summer and higher, in winter. In several of the series of measurements taken during the summer stream temperatures were relatively low in the areas where the intra-gravel temperatures were low. In such temperature series taken in summer stream temperatures were progressively lower from upstream, at such sites, to downstream. During series of measurements taken in winter and early spring the stream appeared to warm along the length within the reach were temperatures were taken. In the zone of tidal influence summer intra-gravel temperatures, apparently influenced by warm incoming tide water, were higher than those of the stream.

The paper discusses the fact that measurements of stream temperatures at specific sites may not indicate very well what the intra-gravel temperatures, at egg incubation depth, may be.

Where artificial egg introductions are made and there is a desire to know or control the time of emergence this should be kept in mind. Secondly, the paper discusses the fact that during summer, in a clear-cut area of the stream, water temperatures become progressively lower downstream. The fact that this may occur in some situations should be recognized by fisheries people, evaluating forest harvest impacts.

Hartman, G.F., J.C. Scrivener, M.J. Brownlee, and D.C. Morrison. 1983. Fish habitat protection and planning for forest harvesting in coastal streams of British Columbia: Some research and management implications. Can. Ind. Rep. Fish. Aquat. Sci. 143: 73 p. (Contrib. No. 65.)

ABSTRACT

The first of the two parts of this report reviews some of the major results emerging from the Carnation Creek Watershed Study. The paper considers the implication of research results of the British Columbia Coast Forest Planning Guidelines and Protection Clauses. The second part of this report reviews those salient elements of the stream protections clauses, outlines the purpose of these elements and suggests areas for revision. The Appendices include copies of the protection clauses and related management correspondence.

Hartman, G.F., L.B. Holtby, and J.C. Scrivener. 1984. Some effects of natural and logging-related winter stream temperature changes on the early life history of coho salmon *(Oncorhynchus kisutch)* in Carnation Creek, British Columbia, p. 141-149. *In:* W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley [eds.] Fish and wildlife relationships in old-growth forests: Proceedings of a symposium held in Juneau, Alaska 12-15 April 1982. Published by the American Institute of Fishery Research Biologists. Available from John W. Reintjes, Rt. 4, Box 85, Morehead City, NC. 425 p.
(Contrib. No. 72.)

ABSTRACT

Carnation Creek is a small rain-forest stream located on Barkley Sound, Vancouver Island, British Columbia. It is the site of a 15-year watershed study concerned with the impact of logging on anadromous and resident salmonids. This paper deals with some of the effects of natural and logging-induced stream temperature changes in winter on juvenile coho salmon. Extensive logging began in the winter of 1976-77 and continued until 1980-81, by which time 41% of the watershed had been clearcut. Stream temperatures in early winter from 1976-77 through 1980-81 were higher than they had been prior to logging. Temperature increases resulted from climatic amelioration, which began in 1976, and from the effects of logging. As a result of higher temperatures, coho salmon fry emerged earlier in the spring than they had prior to logging. Early emergent fish that did not move downstream during spring freshets began growing sooner. In 1981, the year of highest winter temperatures, fry emerged 47 days earlier than in the prelogging years and this, coupled with faster growth in late spring, led to the fish entering their first winter at a larger size. Consequently, survival through the winter was greater, leading to increased numbers and size of 1-year smolts and an increased proportion of 1-year versus 2-year smolts. Brief speculation is offered about processes that may have affected stream temperatures during winter.

Hartman, G.F. and J.C. Scrivener. 1986. Some strategy considerations for small stream restoration and enhancement with special emphasis on high rainfall area streams such as Carnation Creek, p. 69-84. *In:* J.M. Patterson [ed.] Proceedings of the workshop on habitat improvements , Whistler, B.C., May 8-10, 1984. Can. Tech. Rep. Fish. Aquat. Sci. 1483: 219 p. (Contrib. No. 83.)

Hartman, G.F. and T.G. Brown. 1987. Use of small, temporary, floodplain tributaries by juvenile salmonids in a west coast rain-forest drainage basin; Carnation Creek, British Columbia. Can. J. Fish. Aquat. Sci. 44:262-270. (Contrib. No. 91.)

ABSTRACT

Seasonal movement of trout *(Salmo clarki* and *S. gairdneri)* into and out of three tributaries which drain areas ranging from 15 to 100 ha within the lower Carnation Creek catchment basin were monitored periodically from 1972 to 1985. The number of trout entering the three tributaries relative to total trout was as high as the number of coho salmon *(Oncorhynchus kisutch)* entering these tributaries relative to total coho. The percentage of the salmonid population represented by trout was highest in the two largest tributaries and lowest in the

smallest. Trout were most clearly associated with nonvegetated sand and gravel bottom portions of the three tributaries. Coho were associated with this habitat too, but they also frequented portions of the tributaries that were vegetated and had a mud substrate. In the two largest tributaries, trout were represented by more age classes than were coho salmon. The paper considers some of the implications of use of small drainages by trout to habitat managers.

Hartman, G.F., J.C. Scrivener, L.B. Holtby, and L. Powell. 1987. Some effects of different streamside treatments on physical conditions and fish population processes in Carnation Creek, a coastal rain-forest stream in British Columbia, p. 330-372. *In:* E.O. Salo and T.W. Cundy [eds.] Streamside Management: Forestry and Fishery Interactions. Contrib. No. 57 of the Institute of Forest Resources. University of Washington, AR-10, Seattle, WA. 471 p. (Contrib. No. 92.)

ABSTRACT

Carnation Creek is a small (10 km^2) drainage in a high rainfall, coastal western hemlock (CWH) biogeoclimatic zone on the west coast of Vancouver Island, British Columbia. The stream and its fish populations have been studied continuously since 1971, including a period in which 41% of the watershed was logged (1976-81). Three different kinds of streamside treatments, set largely in an alluvial floodplain portion of the stream valley, were evaluated: (1) an intensive treatment involved clearcutting to the streambank, felling of streambank alder, and some yarding of felled trees and merchantable blow down from the stream, (2) a careful treatment involved clearcutting to the margin of the stream and the felling of streambank alder, with virtually no in-channel activity, and (3) a leave strip treatment in which a variable width strip of vegetation was left along the stream.

Stream thermal regimes increased as a result of logging. The concentration of a wide range of ions in the water also increased with logging. Volume and stability of large woody debris decreased immediately in the most intensive treatment area, but decreased a few years after logging in the careful treatment area. Woody debris remained most stable in the area in which streamside trees and other vegetation were left.

The decrease in volume and stability of large debris was accompanied by erosion of the streambanks and straightening of the channel. Changes in gravel quality, particularly the increase in medium and coarse sand in the lower sections of the stream, are considered to be the result of streambank erosion and channel change that occurred in upstream sections subsequent to logging.

Population changes among young salmonids were positive to some components of forest harvest and were negative to others. They reflected different responses to different streamside treatments. Population changes also reflected responses to interannual climatic changes.

Coho *(Oncorhynchus kisutch)* and chum *(O. keta)* salmon egg-to-fry survival has been variable but lower since the first major storm event following logging. The numbers of trout *(Salmo gairdneri)* smolts declined coincident with logging, while the numbers of coho smolts were about 76% greater between 1978 and 1983. They have since declined to within the prelogging range. Within the system the best data available are for coho production. These data showed that the compensatory effects of lower coho fry density, earlier emergence, longer period of growth, and higher first winter survival have offset the increased egg-to-fry mortality up to 1984. The effects of forest harvest and different streamside treatments were a complex of positive and negative impacts that occurred at different times and had different effects on different species and on different life stages of the same species. Since logging, the physical conditions and the coho population in Carnation Creek have shown greater annual variations.

The Carnation Creek work indicates that the existing P.1 Clauses and the Coast Forest Planning Guidelines, where they are involved with streamside management, should be applied in a fashion that ensures not only the maintenance of the physical integrity of the stream but also that there will be a future source of large woody debris at the stream channel margin. This study has also indicated that different kinds of tributaries and different sections of the main stem respond differently to logging impacts. The work supports the desire on the

part of the management agencies to establish a stream classification system and apply protection clauses and planning guidelines with specific reference to stream classes and to upper watershed areas.

Hartman, G.F., J.C. Scrivener, and T.E. McMahon. 1987. Saying that logging is either 'good' or 'bad' for fish doesn't tell you how to manage the system. The Forestry Chronicle 63(June): 159-164. (Contrib. No. 93.)

ABSTRACT

A 16-year multi-disciplinary watershed study at Carnation Creek, British Columbia, revealed that different activities in a forest harvest program had different impacts on the physical and biological components of the system. Changes in stream temperature, as a result of logging and a climatic warming trend, and changes in the distribution and volume of woody debris in the channel caused complex sequences of processes to influence salmonid production in both a positive and negative manner. The influence depended on the type of physical change, the fish species and its life history stage, and on the elapsed time after the logging activity. Some direct implications of the research to the problems of managing in the face of complexity are discussed.

Hetherington, E.D. 1982. A first look at logging effects on the hydrologic regime of Carnation Creek experimental watershed, p. 45-63. *In:* G.F. Hartman [ed.] Proceedings of the Carnation Creek Workshop: A 10 year review. Pacific Biological Station, Nanaimo, British Columbia. 404 p. (Contrib. No. 47.)

Hetherington, E.D. 1982. Effects of forest harvesting on the hydrologic regime of Carnation Creek Experimental Watershed: a preliminary assessment, p. 247-267. *In:* Proceedings Canadian Hydrology Symposium: 82. National Research Council of Canada, Ottawa. (Contrib. No. 40.)

ABSTRACT

Preliminary results are given for two small, west coast watersheds characterized by rugged terrain, an old growth coniferous forest, heavy rainfall and flashy runoff. Following successive clearcuts covering 40% and prescribed burning on 20% of Carnation Creek watershed, there was no clear evidence of changes in storm runoff but annual water yield and summer low flows apparently decreased in some years. Valley bottom groundwater levels were higher. In a smaller tributary watershed which was 90% clearcut and 35% burned, annual water yield, summer low flows, and peak flows increased, while the time-to-peak hydrograph characteristics decreased. On steep side slopes, peak groundwater levels changed after both road construction and harvesting.

Hetherington, E.D. 1987. Carnation Creek, Canada-review of a west coast fish/forestry watershed impact study. Proceedings of Forest Hydrology and Watershed Management Symposium. August 1987. IAHS-AISH Publ. No. 167, 1987: 531-538. (Contrib. No. 95.)

ABSTRACT

Carnation Creek is a small, rain forest 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.

Hetherington, E.D. 1988. Hydrology and logging in the Carnation Creek watershed - what we have learned p. 11-15. *In* : T.W. Chamberlin [ed]. Proceedings of the.Workshop: Applying 15 years of Carnation Creek results. Pacific Biological Station, Nanaimo, B.C. (Contrib. No. 107.)

Hetherington, E.D. 1989. Carnation Creek floodplain hydrology: September 1984-September 1985. Presented at the Dec. 8 -10, 1987, Herbicide Workshop. *In:* P.E. Reynolds [ed]. Proceedings Carnation Creek Herbicide Workshop. Can./B. C. Econ. Reg. Develop. Agree. FRDA. Rep. (in press). (Contrib. No. 126.)

ABSTRACT

The precipitation, streamflow and groundwater regimes in the lower Carnation Creek floodplain are described for the one-year period encompassing the application and monitoring of the environmental behavior of the herbicide glyphosate. Rainfall just prior to the first herbicide application on the floodplain moistened the soil on well drained areas and initiated ponding and flow of water in side channel depressions and swamps. The next rainfall on blocks containing monitored tributaries and seasonally flooded soil residue sampling sites came within 24 hours after herbicide application. Rainfall during the next 10 weeks was above average, providing ample opportunity for off-site movement and leaching of any mobile herbicide residue. However, precipitation then remained below average for the rest of the study period. Surface water was continuously present in floodplain depressions and side channels until the following summer, with groundwater levels rising and falling in response to rainfall events. Surface soil layers on well drained soil sampling sites would have remained moist but unsaturated and above the groundwater table throughout most of the study period. Of the three seasonally flooded soil sampling sites, two remained saturated and were frequently flooded until the following summer, while the other experienced unsaturated periods, particularly during the first 3 weeks after herbicide application, and only occasional flooding. The implications of these soil water regimes are that herbicide residues would have leached vertically downward on well drained sites and under non-saturated soil conditions, but would have tended to move laterally from seasonally flooded plots during flooding and saturated conditions.

Holtby, L.B. 1988. Effects of logging on stream temperatures in Carnation Creek, British Colunbia, and associated impacts on the coho salmon *(Oncorhynchus kisutch).* Can. J. Fish. Aquat. Sci. 45:502-515. (Contrib. No. 98.)

ABSTRACT

Clear-cut logging of 41% of the basin of Carnation Creek, British Columbia, resulted in increased stream temperatures in all months of the year. Increases above prelogging temperatures ranged from 0.7°C in December to 3.2°C August. Earlier emergence of coho salmon (*Oncorhynchus kisutch*) fry associated with the temperature increases lengthened their summer growing season by up to 6 weeks. Fingerlings were significantly larger by the fall in the years after logging compared with the years before logging. The increased size of fingerlings was associated with improved overwinter survival. Following logging, yearling smolt numbers doubled, although 2-yr old smolt numbers decreased. Warmer spring temperatures were also associated with earlier seaward migration of smolts, probably resulting in decreased smolt-to-adult survivals. A linked series of models that first predict logging effects on stream temperatures and then the effects of those temperatures on critical coho life history events are developed. The life history model is used to quantify the effects of stream temperature changes related to logging on the population size of adult coho salmon. The predicted effect of those temperature changes was a 9% increase in adult coho numbers prior to the fishery, an increase considerably less than the observed 47% increase in smolt numbers.

Holtby, L. B. 1988. The effects of logging on stream temperatures at Carnation Creek, p. 118-122. *In:* T.W. Chamberlin [ed]. Proceeding of the Workshop: Applying 15 years of Carnation Creek results. Pacific Biological Station, Nanaimo, B. C. (Contrib. No. 108.)

Holtby, L. B. 1988. The effects of logging on the coho salmon *(Oncorhynchus kisutch)* of Carnation Creek, British Columbia, p. 159-174. *In:* T. W. Chamberlin [ed.]. Proceedings of the workshop: Applying 15 years of Carnation Creek results. Pacific Biological Station, Nanaimo, B.C. (Contrib. No. 109.)

Holtby, L.B. 1989. Changes in the temperature regime of a permanent side-channel over-sprayed with the herbicide "Roundup". Presented at the Dec. 8 -10, 1987, Herbicide Workshop. *In:* P. E.

Reynolds [ed]. Proceedings of the Carnation Creek Herbicide Workshop. Can./B.C. Econ. Reg. Develop. Agree. FRDA. Rep. (in press). (Contrib. No. 130.)

ABSTRACT

The temperature of a permanent side-channel of Carnation Creek was monitored for 2-yr. following the aereal application of the herbicide "Roundup" to the entire length of the riparian vegetation over the side-channel. Temperature changes were assessed by comparing water temperatures in the side-channel with temperatures in the main-stem of Carnation Creek at 1600 m. Significant increases in mean daily temperatures of 0.7°C were observed during the summer following spraying. Daily maximum temperatures increased by 2.7°C in the first summer after spraying and by 1.4°C in the second summer. The increased temperatures observed after herbicide application were associated with the de-foliation of riparian alder. Although no adverse effects of the temperature changes were observed on resident salmonids in the side-channel, the additive effects of numerous herbicide treatments in a larger river could be of some concern, as would a similar treatment at a warmer site.

Holtby, L.B. and S.J. Baille. 1989. Litter-fall and detrital decomposition rates in a side-channel of Carnation Creek, over-sprayed with the herbicide "Roundup". Presented at the Dec. 8 -10, 1987, Herbicide Workshop. *In:* P.E. Reynolds [ed]. Proceedings of the Carnation Creek Herbicide Workshop. Can./B.C. Econ. Reg. Develop. Agree. FRDA Rep. (in press). (Contrib. No. 131.)

ABSTRACT

Litter-fall was measured in the riparian zone of a side-channel over-sprayed with the herbicide "Roundup" for 18 months after application. Defoliation of the riparian zone of the side-channel reduced deciduous litter-fall to approx. 6% of the expected total deposition of 300 $g.m^{-2}.d^{-1}$. Coniferous litter was a minor component of all treatment and control sites, averaging less than 1% of the total. At the three control sites coniferous litter-fall increased by an average of 296% in the year after spraying compared to the year before, but in the treatment area the increase was only 36%. Litter decomposition rates in water were available in the three summers during which measurements were made. Decomposition rates were greatest in the over-sprayed side-channel and lowest in the control side-channel. Between-site differences in decomposition rates were probably the result of differences in their macro-invertebrate communities. Most of the between-year variability in decomposition rates was accounted for by differences in stream temperatures. The herbicide had no measurable effects on macro-invertebrate abundance or community composition. Decomposition rates and the activity levels of macro-invertebrates in the over-sprayed side-channel increased in the summers after spraying, probably as a result of increased summer temperatures that resulted from defoliation of the riparian zone.

Holtby, L.B. and S.J. Baille. 1989 Effects of the herbicide "Roundup" on periphyton in Carnation Creek, British Columbia. Presented at the Dec. 8 -10, 1987, Herbicide Workshop. *In*: P.E. Reynolds [ed]. Proceedings of the Carnation Creek Herbicide Workshop. Can./B.C. Econ. Reg. Develop. Agree. FRDA. Rep. (in press). (Contrib. No. 132.)

ABSTRACT

Periphyton standing crops and accumulation rates were monitored at several sites in the main-stem and side-channels of Carnation Creek for 18 months after the herbicide "Roundup" was applied at a rate of 2.2 kg. glyphosate.ha--1to much of the valley floor of the watershed. One side-channel was over-sprayed. There is evidence of direct toxicity of some herbicide component two weeks after the mid-Sept. application. In the year following spraying there was some localized enhancement of production as the periphyton responded to increased levels of phosphorus immediately downstream of the over-sprayed side-channel.

Holtby, L.B. and S.J. Baille. 1989. Effects of the herbicide "Roundup" on coho salmon fingerlings in an over-sprayed side-channel of Carnation Creek, British Columbia . Presented at the Dec. 8 -10,1987, Herbicide Workshop. *In:* P.E. Reynolds (ed). Proceedings of the Carnation Creek Herbicide Workshop. Can./B.C. Econ. Reg. Develop. Agree. FRDA. Rep. (in press). (Contrib. No. 133.)

ABSTRACT

The responses of coho salmon fingerlings are described, following the over-spraying of a permanent side-channel of Carnation Creek with the herbicide "Roundup". Qualitative observations of caged coho fingerlings at exposed sites in the over-sprayed side-channel indicated some stress 2 hr. after application and subsequently some mortality (2.6%) of those fish was observed. Caged fish at other sites showed no similar signs of stress and no mortality immediately after application. We observed no unusual mortality of the approximately 300 coho fingerlings estimated to be resident in the side-channel at the time of the application. In comparison with unaffected sites, trapping efficiencies in the side-channel did decline after the application and remained depressed for at least 4 months, suggesting that coho fingerlings were less active in the over-sprayed side-channel. In comparison with 1-3 years of pre-spray data, no changes in over-winter mortality, growth rates, or the probabilities of entering and leaving the side-channel were observed for two years following application.

Holtby, L.B. and G.F. Hartman. 1982. The population dynamics of coho salmon *(Oncorhynchus kisutch)* in a west coast rain forest stream subjected to logging, p. 308-347. *In:* G.F. Hartman [ed.] Proceedings of the Carnation Creek Workshop: A 10 year review. Pacific Biological Station, Nanaimo, British Columbia. 404 p. (Contrib. No. 48.)

Holtby, L.B. G.F. Hartman, and J.C. Scrivener. 1984. Stream indexing from the perspective of the Carnation Creek experience, p.89-112. *In:* P.E.K. Symons and M. Waldichuk [eds.] Proceedings of the workshop on stream indexing for salmon escapement estimation, West Vancouver, B.C., 2-3 February, 1984. Can. Tech. Rep. Fish. Aquat. Sci. 1326: 258 p. (Contrib. No. 78.)

Holtby, L.B. and C.P. Newcombe. 1982. A preliminary analysis of logging-related temperature changes in Carnation Creek, British Columbia, p. 81-99. *In:* G.F. Hartman [ed]. Proceedings of the Carnation Creek Workshop: A 10 year review. Pacific Biological Station, Nanaimo, British Columbia. 404 p. (Contrib. No. 49.)

Holtby, L.B. and M.C. Healey. 1986. Selection for adult size in female coho salmon *(Oncorhynchus kisutch)*. Can. J. Fish. Aquat. Sci. 43: 1946-1959. (Contrib. No. 84.)

ABSTRACT

Several recent studies have presented evidence that large size confers a selective advantage to female Pacific salmon. Nevertheless, a wide range of female sizes is normally present in any spawning population. Two possible explanations exist for the observed range in female size. First, average female size might be determined by an optimizing process with variation around the optimum due to individual differences in success at obtaining food. Second, various sizes of females might coexist as a mixed evolutionary stable strategy. Under the first explanation, females of sizes other than the optimum would display lower fitness whereas, under the second explanation, females of all sizes would be equally fit. We investigated factors affecting survival of eggs, fry, and smolts of coho salmon *(Oncorhynchus kisutch)* in Carnation Creek on Vancouver Island with a view to determining the relative fitness of different sized females. Egg-to-fry mortality was best explained by a model that included only the effects of stream bed scour and gravel quality. Including an effect of female size, expressed through depth of egg burying, worsened the model's predictive capability. We could find no evidence that the eggs of large females consistently survived better during incubation than those of small females. In fact, we observed three instances in which it appeared that the eggs of small females survived better. In Carnation Creek, large 1- and 2-yr-old smolts did not consistently survive better in the marine environment than small smolts. Thus, we were unable to demonstrate that the reproductive success of large females was consistently higher than that of small females, contrary to the hypothesis that female size is the result of an optimizing process. In Carnation Creek, the observed range of female sizes probably represents an evolutionary stable strategy in which all sizes have equal fitness. We propose a model that predicts female size based on the conflicting selective effects of gravel quality, scour, and competition for nest sites.

Holtby, L.B. and J.C. Scrivener, 1988. Observed and simulated effects of climatic variability, clear-cut logging and fishing on the numbers of chum salmon *(Oncorhynchus keta)* and coho salmon *(O. kisutch)* returning to Carnation Creek, British Columbia. In: C.D. Levings, L.B. Holtby, and M.A.

Henderson [eds]. Effects of habitat alterations on salmonid stocks. Can. Spec. Publ. Fish. Aquat. Sci. 105. (in press) (Contrib. No. 124.)

ABSTRACT

The population dynamics of coho and chum salmon have been studied at Carnation Creek since 1970 as part of a multi-disciplinary study of the effects of logging on a small salmon stream in a coastal rain forest. We have developed models that predict the numbers of chum and coho salmon from correlative relationships between survival and growth at various life stages and 1) climatic, hydrologic and physical variables, 2) indices of those features of the stream habitat that were affected by logging and, 3) exploitation rates in the fishery. The models were used to partition the variability in adult returns between the effects of climatic variability in the stream and the ocean, changes in stream conditions caused by logging and variations in fishing mortality. For both species, most of the observed variation in adult numbers resulted from climatic variability in the stream and the ocean, and in roughly equal measure. Variation of the fishing mortality over realistic ranges did not change variability in adult abundance, except at very high exploitation rates where variability was increased. Coho salmon were unaffected by observed and simulated logging activity but chum salmon were adversely affected. We suggest that overall variability in the salmon abundance will tend to increase in the wake of land-use activities, particularly when accompanied by high levels of exploitation and adverse environmental conditions.

King, R.K. and E.T. Oswald. 1982. Revegetation of Carnation Creek watershed, p. 110-128. *In:* G.F. Hartman [ed.] Proceedings of the Carnation Creek Workshop: A 10 year review. Pacific Biological Station, Nanaimo, British Columbia. 404 p. (Contrib. No. 50)

ABSTRACT

A study was established to monitor the recolonization by vegetation following logging and burning in the Carnation Creek watershed. To date, a total of 255 plots have been located along predetermined transects in 10 settings that have been logged and burned for slash removal. Vegetation analyses were conducted according to a schedule of year 1, 2, 3, 5, 10, and 15-with year 1 being the spring following the last disturbance. The data were processed into a computer system for storage, analyses, and retrieval. A preliminary indication of the vegetation succession is given for only one setting in which the vegetation assessments have been conducted for three consecutive years. *Rubus spectabilis, Blechnum spicant* and *Polystichum munitum* were most common on wetter sites, while *Gaultheria shallon* and *Vaccinium ovatum* were more common on drier sites. The setting was planted with a variety of tree species on the floodplain and with *Pseudotsuga menziesii* on upland areas. Initial indications are that seedling survival is low, possibly due to desiccation.

Kreutzweisser, D.P. and P.D. Kingsbury. 1989. Drift responses of stream invertebrates to a glyphosate application. Presented at the Dec. 8 -10, 1987, Herbicide Workshop. *In:* P.E. Reynolds [ed]. Proceedings of the Carnation Creek Herbicide Workshop. Can./B.C. Econ. Reg. Develop. Agree. FRDA. Rep. (in press). (Contrib. No. 136.)

ABSTRACT

The application of glyphosate to or adjacent to small tributaries of Carnation Creek did not result in undue disturbance of stream invertebrates. The drift response of two particular organisms, *Gammarus* sp. and *Paralepthlebia* sp., suggests a slight and ephemeral effect of the herbicide in and downstream of the treatment areas. None of the post-spray drift levels were significantly higher than pre-spray densities ($p>0.05$) but a measurable alteration in the drift patterns of these genera, especially of *Paraletophlebia*, was demonstrated.

The lack of significant difference in drift levels does not entirely negate an indication of impact since the variation in factors not included in the statistics, such as stream flow, light intensity, and insect morphology, greatly influence stream invertebrate drift. Interpretation of relative drift levels must include a consideration of these integral parameters.

The apparent effects of the glyphosate applications on *Paraleptophlebia* mayflies suggest a particular susceptibility of this genus to the herbicide. The magnitude of the disturbance was not great enough to ecologically impact on the organism in terms of density or distribution in

benthos, but may have provided evidence of a particular mayfly useful as an indicator of glyphosate effects on aquatic insects. Further investigation of the toxicity of glyphosate effects on aquatic insects (two *Paraleptophlebia* sp.) would be appropriate.

Lill, A.F. and P. Sookachoff. 1974. Carnation Creek counting fence. Fish. Mar. Serv. Tech. Rep. Ser. No. PAC-T-74-2: 32 p. (Contrib. No. 5.)

MacMillan Bloedel Limited. 1979. MacMillan Bloedel Limited logging operations in Carnation Creek watershed 1975-1978. Fish. Mar. Serv. Data Rep. 157: 22 p. (Contrib. No. 28.)

McMahon, T.E. and G.F. Hartman. 1988. Variation in degree of silvering of wild coho salmon, *Oncorhynchus kisutch,* smolts migrating seaward from Carnation Creek, British Columbia. J. Fish. Biol. 32: 825-833. (Contrib. No. 99.)

ABSTRACT

Degree of silvering (coloration) is often used as an index of the degree of smoltification in salmonids. To judge the reliability of silvering as an indicator of migratory readiness, we examined the silvering of wild coho salmon, *Oncorhynchus kisutch* , smolts upon entry into the Carnation Creek, British Columbia, estuary. Silvering of migrants was greater in larger fish and increased over the course of the migratory period. Photoperiod appeared to account for most of the observed increase in silvering over time; increased silvering was not correlated with temperature or lunar phase. Overall, 50% of seaward migrants were completely silvered, 45% were in a transitional phase, and 5% still retained coloration characteristics of parr. Coloration thus appears to have limited utility as a reliable indicator of migratory readiness. Our findings suggest that estuarine residence is important for completion of parr-smolt transformation and that acclimation of hatchery smolts in brackish waters prior to seawater entry may enhance their survival.

Narver, D.W. [ed.] 1974. Carnation Creek experimental watershed project annual report for 1973. Pacific Biological Station, Nanaimo, British Columbia. 24 p. (Contrib. No. 6.)

ABSTRACT

The purpose of this report is to formalize the rationale, objectives, design, progress and status of the Carnation Creek Experimental Watershed Project. It is not a repository of scientific and operational results but is a useful reference document. Since this is the first Annual Report, the entire development and progress since 1970 was included.

Narver, D.W., and B.C. Andersen. 1974. Fish populations of Carnation Creek and other Barkley Sound streams - 1970-1973: data record and progress report. Fish. Res. Board Can. MS Rep. 1303: 115 p. (Contrib. No. 7)

Narver, D.W. and T.W. Chamberlin. 1976. Carnation Creek - an experiment towards integrated resource management. Fish. Mar. Serv. Pac. Biol. Sta. Circ. 104: 20 p. (Contrib. No. 17.)

ABSTRACT

The rationale, objectives, design, progress and limitations of the Carnation Creek Experimental Watershed Project on the west coast of Vancouver Island are described. Six agencies in the federal and provincial governments and the forest industry are the principle cooperators in the studies designed to develop sound, practicable integrated-resource-management guidelines for the coastal forest-stream ecosystem. The project evolved due to serious conflicts between approaches to the management of fisheries and forest resources. Five years of prelogging calibration has been completed and the project is entering the 5-yr road building-logging phase. It is anticipated that results will have substantial application to watershed management in coastal British Columbia.

Neaves, P.I. 1978. Litter fall, export, decomposition, and retention in Carnation Creek, Vancouver Island. Fish. Mar. Serv. Tech. Rep. 809: 43 p. (Contrib. No. 21.)

ABSTRACT

The Carnation Creek Experimental Watershed Project is a long-term ecosystem study being conducted by a number of federal and provincial agencies in cooperation with private industry

in order to determine the effects of logging on a typical British Columbia west coast salmon and trout nursery stream.

The basic design of the project includes continuous studies during 5 yr. of prelogging calibration (1970-1974), 6 yr. of active logging (1975-1980), and a period of 2-3 yr following logging. A more detailed treatment of the experimental design and logging plans is given in the Annual Report for 1973 (Narver 1974).

This report deals with the floral litter fall from the major riparian plant species to the streambeds in the watershed, its export from the watershed by the stream, and its decomposition and retention in the stream substrate.

Litter retained in a streambed forms the basis of the decomposer food chain which leads to benthic invertebrate and fish production (Egglishaw 1964; Kaushik and Hynes 1968). At present it is suspected that 95% of the aquatic insect production in Carnation Creek is based on forest litter that is incorporated in the stream substrate (Narver 1974).

Oswald, E.T. 1973. Vegetation and soils in Carnation Creek watershed. Can. For. Serv., Pac. For. Res. Center, Internal Rep. BC-43: 38 p. (Contrib. No. 2.)

ABSTRACT

An intensive investigation of the effects of timber management on stream flow, water quality and fish populations of a coastal watershed was initiated by the Fisheries Service of the Department of the Environment. The watershed selected for study was Carnation Creek, which empties into Trevor Channel of Barkley Sound on the west coast of Vancouver Island (Fig. 1). The watershed contains approximately 10 square kilometers of over-mature western hemlock-amabilis fir-western red cedar forest and is drained by a creek approximately six kilometers long. The project was established on a multidisciplinary framework and currently involves members of Fisheries Research Board and the Resource Development Branch of Fisheries Service, with some inputs by Canadian Forestry Service, B.C. Forest Service, B.D. Water Resources Branch, MacMillan Bloedel Ltd., and the University of British Columbia Institute of Fisheries.

The Canadian Forestry Service undertook to classify and map the soils and vegetation of the watershed. This report records progress made in 1972 when the western half of the watershed was surveyed.

Oswald, E.T. 1974. Vegetation and soils of Carnation Creek watershed (upper section). Can. For. Serv., Pac. For. Res. Center, BC-P-11-74: 15 p. (Contrib. No. 8.)

ABSTRACT

Carnation Creek Watershed was selected by Fisheries Service for an intensive investigation of the effects of forest harvesting operations on salmonid fish populations. The creek is located north of Sarita River and empties into Trevor Channel of Barkley Sound, on the west coast of Vancouver Island. The Canadian Forestry Service undertook the classification and mapping of soils and vegetation of the watershed.

A survey of soils and vegetation of the watershed was initiated in 1972. During this period, the lower or western portion was completed (Oswald, 1973). The survey was extended to the upper portion of the watershed during 1973 and the results are hereby presented. The report is intended as a working document and much of the background material has been presented in the 1973 report.

Oswald, E.T. 1975. Vegetation of Carnation Creek streambed. Can. For. Serv., Pac. For. Res. Center, BC-P-12: 8 p. (Contrib. No. 14.)

ABSTRACT

Carnation Creek watershed was selected by the Fisheries Service of Environment Canada for an intensive investigation into the effects of forest harvesting operations on salmonid fish populations. The creek, located north of Sarita River, empties into Trevor Channel of Barkley Sound, on the west coast of Vancouver Island. The Canadian Forestry service undertook the classification and mapping of vegetation and soils of the watershed.

A survey of vegetation and soils of the lower or western portion of the watershed was initiated and completed in 1972 (Oswald, 1973), and was extended to the upper portion of the watershed during 1973 (Oswald, 1974). Because of the importance of vegetation along the stream channel for supplying food and cover for fish, a more intensive survey of the stream-side vegetation was undertaken than that conducted on the upland areas. Results of this investigation are hereby presented as a preliminary report.

Oswald, E.T. 1982. Preharvest vegetation and soils of Carnation Creek watershed, p. 17-35. *In:* G.F. Hartman [ed.]. Proceedings of the Carnation Creek Workshop: A 10 year review. Pacific Biological Station, Nanaimo, British Columbia. 404 p. (Contrib. No. 51.)

ABSTRACT

Vegetation and soil surveys of Carnation Creek watershed were conducted prior to forest harvesting. These surveys formed part of the baseline data on a coastal watershed of a multidisciplinary, interagency project to investigate the effects of forest harvesting on salmonid fish populations. Five plant associations and three subassociations are described and a map presented showing the distribution of these, mostly in complexes. The watershed occurs in a mature coastal western hemlock forest and the described associations are considered stable. The streamside vegetation, because of its potential in providing food, shade, and cover to fish populations, was mapped separately and in more detail. A graph indicating the percentage of the stream channel covered by vegetation at 10 m intervals is given. Deciduous trees and shrubs are considered the most important plant species in the food chain of fish. Landform, soils, and ecosite maps are presented to indicate the relationship of vegetation to the terrain. The vegetation is most closely associated to site moisture regimes, as inferred through aspect, slope, soil depth, and texture. Most materials are of volcanic origin, and soils are mostly coarse-textured. Shallow soils, bedrock outcrops, and steep slopes are common. These physical site components have implications to forest harvesting, site preparation, and reforestation.

Ottens, J. and J. Rudd. 1977. Environmental protection costs in logging road design and construction to prevent increased sedimentation in the Carnation Creek watershed. Can. For. Serv. Rep. BC-X-155, Victoria, B.C. 28 p. (Contrib. No. 19)

ABSTRACT

The Ritherdon Road extension project on the west coast of Vancouver Island was used in 1975 to study the relationship between logging road design and construction tasks, and stream sedimentation. A method of determining least cost logging road design and construction prescriptions to meet stream sedimentation standards is described using sample data.

Powell, L. H. 1988. Stream morphology changes since logging, p. 16-25. *In:* T. W. Chamberlin [ed.] Proceedings of the Workshop: Applying 15 years of Carnation Creek results. Pacific Biological Station, Nanaimo, B.C. (Contrib. No. 110.)

Poulin, V.A. and J.C. Scrivener. 1988. An annotated bibliography of the Carnation Creek fish-forestry project 1970 to 1988. Can. Tech. Rep. Fish. Aquat. Sci. 1640: 35p. (Contrib. No. 146.)

ABSTRACT

This bibliography contains 147 articles and research papers produced by participants in the Carnation Creek fish-forestry project. Article citations are listed in alphabetical order and include abstracts were available. Contribution numbers have been assigned. In addition, manuscripts approved for publication to the date of this document are listed by contribution number in an appendix.

Reynolds, P.E. 1985. Progress Report 184, British Columbia cooperative herbicide research trials. Forest Pest Management Institute, Sault Ste. Marie, Ontario. 31 p. (Contrib. No. 120.)

Reynolds, P.E. [ed.] 1989. Proceedings of the Carnation Creek Herbicide Workshop. Can./B.C. Econ. Reg. Develop. Agree. RFDA. Rep. (in press). (Contrib. No. 125.)

Reynolds, P.E., K. King, R. Whitehead, and T. MacKay. 1987. One year results for a coastal British Columbia glyphosate conifer release trial. Forest Pest Management Institute, Sault Ste. Marie, Ontario. 15 p. (Contrib. No. 121.)

Reynolds,P.E., J.C. Scrivener, L.B.Holtby, and P.D.Kingsbury. 1989. An overview of the Carnation Creek herbicide study: Historical perspective, experimental protocols, and spray operations. Presented at the Dec. 8 -10,1987, Herbicide Workshop. *In:* P.E. Reynolds [ed]. Proceedings of the Carnation Creek Herbicide Workshop. Can./B.C. Econ. Reg. Develop. Agree.FRDA. Rep. (in press). (Contrib. No. 134.)

Reynolds, P.E., D.G. Pitt, R. Whitehead, and K. King. 1989. Three year weed efficacy, crop tolerance and crop growth response results for a 1984 glyphosate conifer-release trial at Carnation Creek,British Columbia. Presented at the Dec. 8 -10,1987, Herbicide Workshop. *In:* P.E. Reynolds [ed]. Proceeding of the Carnation Creek Herbicide Workshop. Can./B.C. Econ. Reg. Develop. Agree. FRDA. Rep. (in press). (Contrib. No. 135)

ABSTRACT

In early September 1984, portions of the Carnation Creek Watershed, located on the west coast of Vancouver Island (48°54'N, 125°01'W), were aerially treated with 2 kg/ha of glyphosate [N-(phosphonomethyl) glycine] using a Bell-47 helicopter equipped with a MICROFOIL BOOM to minimize herbicide drift into an adjoining salmon-bearing stream. Since 1970, the watershed has been a focal point for interagency cooperative research designed to assess the effects of forest practices (ie., harvesting, prescribed burning herbicide use) on resident salmonid fish populations. The present herbicide study was undertaken in support of this overall objective.

Prior to glyphosate treatment, major weed competition consisted of red alder (*Alnus rubra*) and salmonberry (*Rubus* species). Weed efficacy following glyphosate treatment was species dependent, for most species present. Although salmonberry control was quite satisfactory after one post-spray growing season, control of red alder was quite variable, ranging from no control (i.e., completely healthy) to total control (i.e., totally dead). Salal (*Gaultheria shallon*) was uncontrolled by the herbicide treatment. Control of all weed species declined two and three years after treatment.

Some minor crop tree injury resulted following glyphosate treatment for western hemlock and to a lesser extent for western cedar. Initial injury consisted of death or dieback of the primary leader and was unobserved for other crop trees (i.e., sitka spruce, amablis fir and Douglas fir) present. After one year, trees exhibiting initial injury showed full recovery.

Following glyphosate treatment, sitka spruce and hemlock root-collar diameter and diameter increment increased significantly for trees treated with glyphosate. Had optimal weed control been achieved, even greater growth increases would have likely resulted from the herbicide treatment. In the context of the present environmental impact study, glyphosate is seen to have performed the job it was to do and to have provided better than expected silvicultural performance.

Ringstad, N.R. 1974. Food competition between freshwater sculpins (Genus *Cottus)* and juvenile coho salmon *(Oncorhynchus kisutch):* an experimental and ecological study in a British Columbia coastal stream. Fish. Mar. Serv. Tech. Rep. 457: 88 p. (Contrib. No. 9.)

ABSTRACT

A system of experimental troughs was designed to examine food competition between sculpins and juvenile coho. Manipulation of sculpin densities showed that sculpins at higher than stream densities were able to crop down the benthos sufficiently to significantly reduce drift densities and thus coho growth. At close to natural stream densities sculpins did not limit coho growth. A detailed study of the autecology of the two sculpins (*Cottus asper* and *Cottus aleuticus)* occurring in Carnation Creek did not alter this conclusion. Juveniles of both sculpin species are found in the estuary. This results from either estuarine spawning or upstream spawning combined with downstream movement from March to July to the estuary, and subsequent metamorphosis of larvae. Upstream migration of young cottids takes place a year later from August to December. In the lowest 1500 m of the stream *C. asper* tends to occupy

areas with good cover and low current velocity, whereas *C. aleuticus* is restricted to the peripheral areas of *C. asper* habitat and riffles. In the lowest reaches of the stream the ratio of *C. aleuticus* to *C. asper* is 4:1. Above 1500 m, in the absence of *C. asper, C. aleuticus* occupies all available habitat. *C. aleuticus* is smaller per age group than *C. asper* and the life span of both species is up to seven years. Both species are primarily bottom foragers feeding on aquatic insect larvae. Feeding increases throughout the night with maximal activity at or just before dawn. Some sexually mature adults of both species undertake a downstream spawning migration in the spring. Most *C. asper* spawn in the estuary while *C. aleuticus* may undergo only local migrations and spawns primarily in freshwater.

Ringstad, N.R. 1982. Carnation Creek Watershed Project, freshwater sculpins genus (*Cottus):* a review, p. 219-239. *In:* G.F. Hartman [ed.] Proceedings of the Carnation Creek Workshop: A 10 year review. Pacific Biological Station, Nanaimo, British Columbia. 404 p. (Contrib. No. 52.)

ABSTRACT

Extensive information on population dynamics, migratory movements, growth, and food habits of *Cottus asper* and *C. aleuticus.* in Carnation Creek are given. Field observations and controlled experiments indicate that sculpins do not, through competition, produce adverse effects on young coho salmon at the population densities normally encountered in the stream.

Data from the study do not demonstrate impacts of logging treatments on sculpin populations. Population estimates and counts of migrating fish were not sensitive or reliable enough to reveal impacts of logging on fish populations if such impacts had occurred.

Ringstad, N.R. and D.W. Narver. 1973. Some aspects of the ecology of two species of sculpin *(Cottus)* in a west coast Vancouver Island stream. Fish. Res. Board Can. MS Rep. 1267: 69 p. (Contrib. No. 3.)

ABSTRACT

This study was part of an investigation of the impact of logging on the production of salmonid fishes in Carnation Creek, a small coastal stream on the west coast of Vancouver Island. The Aleutian sculpin, (*Cottus aleuticus*), and the prickly sculpin, (*C. asper*), both occur commonly in streams of coastal British Columbia. In Carnation Creek sculpins comprise from 33 to 66% of the total late summer fish biomass with the greatest abundance in the lowest part of the stream.

Both species undertake downstream migrations in the early spring prior to spawning in April to early June. *C. asper* spawns mainly in the upper estuary where the adhesive egg cluster is placed on the underside of logs and rocks. *C. aleuticus* apparently spawns in the stream above tide water. Upon hatching the larvae of both species are pelagic and all drift to the estuary where they settle and metamorphose to the juvenile form. Adults of both species begin to migrate upstream after the spawning season, but young of the year remain in the estuary for more than one year, moving upstream the following fall as yearlings. In late summer *C. aleuticus* occur under rocks in moving water from the high tide level to a barrier falls about 3,100 m upstream. At the same time *C. asper* occur in quiet water under cover such as roots and cutbanks in the lowest 1,000 m of the stream. The ratio of *C. aleuticus* to *C. asper* was 4:1 in a study section 300 m from the mouth in late summer. In the upstream area where *C. asper* is absent, *C. aleuticus* occurs in both pool and riffle areas.

C. aleuticus are shorter per age group than *C. asper.* The life span of each species is up to seven years. Both species feed mainly on benthic insect larvae. Feeding activity is maximum at dawn.

Schultz International Limited. 1981. An analysis and summary of data on changes in debris and channel morphology in Carnation Creek, 1971-1980. Prepared for Fisheries and Oceans Canada, Vancouver, British Columbia. 26 p. (Contrib.No. 32.)

Scrivener, J.C. 1975. Water, water chemistry and hydrochemical balance of dissolved ions in Carnation Creek watershed, Vancouver Island, July 1971-May 1974. Fish. Mar. Serv. Tech. Rep. 564: 141 p. (Contrib.No. 15.)

ABSTRACT

Loss of water by runoff from the watershed was 308 and 271 cm. during water-years 1971-72 and 1972-73, respectively. Evapotranspiration was calculated at 25 cm. during both years, which is less than half that reported for areas receiving more than 90 cm. annual precipitation.

Precipitation in the area was weakly acidic (pH 5.0- 5.5) of sulphate, chloride, and sodium (75% of TDS). Average annual concentrations (mg/L) were 0.9 sulphate, 0.6 chloride, and 0.4 sodium which was half the range of their weighed average monthly concetrations in the twice monthly rain-water samples.

Ionic concentrations in the stream samples were low, but total dissolved solids (TDS), conductivity, and concentrations of the major ions (bicarbonate, calcium, sulphate, chloride, sodium, silicate, magnesium, potassium, and nitrate) were inversely related to stream discharge on an annual basis and during most freshets. These inverse relationships showed seasonal patterns which were dependent on the previous hydrological flux. Concentrations were higher during autumn, lower during winter and higher again during spring freshets than concentrations from the twice monthly samples that produced the average annual inverse relationship with discharge. These relationships probably occurred because the watershed channel network expanded during storms and intercepted soil water farther upslope. The result was a progressively shorter time period for soil water to leach ions from the soil before it was channelized and output in the stream. Ionic concentrations declined during the winter because hydrologic flux rates increased.

Scrivener, J.C. 1982. Logging impacts on the concentration patterns of dissolved ions in Carnation Creek, British Columbia, p. 64-80. *In:* G.F. Hartman [ed.] Proceedings of the Carnation Creek Workshop: A 10 year review. Pacific Biological Station, Nanaimo, British Columbia. 404 p. (Contrib.No. 53.)

Scrivener, J.C. 1988 Two devices to assess incubation survival and emergence of salmon fry in an estuary streambed. N. Am. J. Fish. Manage. 8: 283-311. (Contrib.No. 100.)

ABSTRACT

Survival of eggs of chum salmon *(Oncorhynchus keta)* was determined at Carnation Creek, British Columbia, with two devices that were designed to assess factors influencing incubation and to cause minimum disturbance of natural stream gravels. Three variations of the incubation technique were assessed with perforated plastic cylinders (incubation capsules). Survival rates of 0 - 47%were obtained when: (1) water exchange through the capsules was adequate, (2) egg density was limited to 30 eggs/capsule, (3) eggs were distributed throughout the capsules, and (4) eggs were planted within an hour of fertilization. Variation in survival was partially attributed to differences among stations in salinity, substrate composition, and dissolved oxygen concentrations. The technique was simple and inexpensive, so many replicates could be used. A capped and inverted plastic pipe (intra-gravel fry releaser) was developed to introduce alevins into the streambed. From 0% - 69% of them emerged. No differences in timing and pattern of emergence were observed between wild and experimental fry. Results compared favorably with other techniques that had been designed to enhance instream survival of salmonid eggs, but these techniques required extensive gravel disturbance during installation.

Scrivener, J.C. 1989. A comparison of three techniques used to determine the incubation quality of salmonid spawning gravels from streambed cores. N. Am. J. Fish. Manage. (in press). (Contrib.No. 122.)

ABSTRACT

Three techniques for describing the size composition of salmonid spawning gravel were assessed using data from 772 freeze-cores and annual incubation survivals of coho *(Oncorhynchus kisutch)* and chum salmon *(O. keta)* from Carnation Creek, British Columbia. Cumulative distributions of particle sizes in the cores could be described accurately by lsonormal regression equations that could also be used to predict the proportion of particles of any size smaller than 25 mm in diameter. 1) Mean particle size (Dg-) was a normally distributed index of substrate composition, but it was sensitive only to changes in the

proportion of particles that were larger than 1 mm in diameter. 2) The fredle index (Fi-) was not normally distributed, but it was sensitive to changes among fines smaller than 1 mm in diameter. 3) Equation graphics indices from Carnation Creek frozen cores indicated that particles smaller than 0.85 mm increased in proportion to those smaller than 9.50 mm, unlike the substrates used to develop this index. The equations from laboratory studies that were used to validate these indices of substrate composition predicted only half of the next change in egg incubation survival that was observed in a natural stream.

Scrivener, J.C. 1988. Carnation Creek experimental watershed: A description and history from 1970 to 1986, p. 1-10. *In:* T. W. Chamberlin [ed.] Proceedings of the workshop: Applying 15 years of Carnation Creek results. Pacific Biological Station, Nanaimo, B.C. (Contrib.No. 111.)

Scrivener, J.C. 1988. Changes in concentration of dissolved ions during 16 years at Carnation Creek, British Columbia, p. 75-80. *In:* T.W. Chamberlin [ed.]. Proceedings of the Workshop: Applying 15 years of Carnation Creek results. Pacific Biological station, Nanaimo, B.C. (Contrib.No. 112.)

Scrivener, J.C. 1989. Comparative changes in concentration of dissolved ions in the stream following logging, slash burning, and herbicide application (glyphosate) at Carnation Creek, British Columbia. Presented at the Dec. 8 -10, 1987, Herbicide Workshop. *In:* P.E. Reynolds [ed]. Proceedings of the Carnation Creek Herbicide Workshop. Can./B.C. Econ. Reg. Develop. Agree. FRDA. Rep. (in press). (Contrib.No. 128.)

ABSTRACT

The patterns of dissolved ions were studied in the main channel, in two pristine tributaries, and in two tributary swamps (1600-trib, 2600-trib) for 14 years prior to and for 2 years after aerial applications of the herbicide "Round-Up" (glyphosate). Four percent (41.7 ha) of the main watershed and half of the watershed including the stream channel of tributary 1600 were sprayed with the herbicide. In all the streams electrical conductivity and the concentration of dissolved nitrate-N were negatively correlated with stream flow. After herbicide treatment these values were unchanged at minimum to median stream flow, but conductivity increased 21% and nitrate concentrations increased 3-fold during periods of freshet. Increases that were 4 times as large had been observed when these watersheds were logged and the logging slash was burned. Phosphate-P concentration was not correlated with stream flow and it increased 2-fold after herbicide application. No changes in dissolved phosphate concentration had been observed after logging and slash burning.

Scrivener, J. C. 1988. Changes in composition of the streambed between 1973 and 1985 and the impacts on salmonids in Carnation Creek, p. 59-65. *In:* T.W. Chamberlin [ed]. Proceedings of the Workshop : Applying 15 years of Carnation Creek results . Pacific Biological Station , Nanaimo, B. C. (Contrib.No. 113.)

Scrivener, J. C. 1988. Summary of the population responses of chum salmon to logging in Carnation Creek, B. C. between 1970 and 1986, p. 150-158. *In*: T.W. Chamberlin [ed]. Proceedings of the Workshop: Applying 15 years of Carnation Creek results. Pacific Biological Station , Nanaimo, B. C. (Contrib.No. 114.)

Scrivener, J.C. and B.C. Andersen. 1982. Logging impacts and some mechanisms which determine the size of spring and summer population of coho fry in Carnation Creek, p. 257-272. *In*: G.F. Hartman [ed]. Proceedings of the Carnation Creek Workshop, a 10 year review. Pacific Biological Station, Nanaimo, B.C. 404 p. (Contrib.No. 54.)

Scrivener, J.C. and B.C. Andersen. 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: 1097-1105. (Contrib.No. 74.)

ABSTRACT

Natural patterns in emergence times, seaward movements, instream distributions, densities, and growth of coho salmon fry *(Oncorhynchus kisutch)* between March and September are contrasted with patterns observed during and after logging in the Carnation Creek watershed. After streamside logging in 1976-77, fry emerged up to 6 wk earlier and moved seaward more quickly than during years before logging. These observations are attributed to higher water

temperatures during the winter and to emergence during a period of more frequent freshets. Increased fry movement from the stream could result in habitat being underutilized. In sections affected by intense streamside logging, the deposition of "fine" logging debris led to increased fry densities during the summers of 1977 and 1978. After major freshets in November 1978, which removed this fine debris and affected channel morphology in these sections, fry densities declined below those observed prior to logging. Growth rates, after correction for density, tended to be greater in all sections after the adjacent streamside was logged. Larger fry and more variable numbers of fry remained in the stream in September after logging than before logging. Their increased size is attributed to the longer growing season afforded by earlier emergence. This complex of interacting factors determines the number and size of fry in autumn and it can influence the production of smolts the following spring.

Scrivener, J.C. and M.J. Brownlee. 1981. A preliminary analysis of Carnation Creek gravel quality data, 1973-1980, p. 195-226. *In:* Proceedings from the conference salmon-spawning gravel: A renewable resource in the Pacific Northwest? State of Washington Water Research Center, Rep. 39. Washington State University, Pullman, WA. 285 p. (Contrib.No. 37.)

ABSTRACT

A project to study the effects of logging on a small salmonid nursery stream commenced in 1970 at Carnation creek on the west coast of Vancouver Island, British Columbia. The project is designed for five years of prelogging calibration (1970 to 1975), six years of logging (1975 to 1981), and five years of postlogging assessment (1981 to 1986). A component study of this multidisciplinary project is the assessment of spawning gravel quality. More than 1200 gravel cores, intergravel-dissolved oxygen, and intergravel permeabilities have been obtained since 1973 to assess changes in the quality of the gravel and the corresponding changes to survival and condition of salmon embryos. Cores were split and analyzed as three layers. Fines less than 9.55 mm were found to increase with depth. A seasonal trend was exhibited in the top and middle layers, as particles less than 0.297 mm decrease between early autumn and the following spring. After logging commenced, fines less than 9.55 mm increased in the top layer over pre-logging levels. Major accumulations of particles between 9.55 mm and 0.297 mm occurred in the top layer of the lower 2 km of stream after the first major postlogging freshet. Concurrently, fines decreased in the bottom layer and intergravel permeability and dissolved oxygen declined. The addition of data from August 1980 to September 1981 indicated that all classes of fines were still accumulating in the streambed. Marked reductions in chum and coho salmon egg-to-fry survival were noted. All studies are continuing until project completion.

Scrivener, J.C. and M.J. Brownlee. 1982. An analysis of Carnation Creek gravel-quality data, 1973 to 1981, p. 154-176. *In:* G.F. Hartman [ed.] Proceedings of the Carnation Creek Workshop: A 10 year review. Pacific Biological Station, Nanaimo, British Columbia. 404 p. (Contrib.No. 55.)

Scrivener, J.C. and M.C. Brownlee, 1989. Effects of forest harvesting on spawning gravel, and incubation survival of chum (*Oncorhynchus keta)* and coho salmon *(O. kisutch)* in Carnation Creek, British Columbia. Can. J. Fish. Aquat. Sci. 46 (4). (Contrib.No. 123.)

ABSTRACT

Following logging, pea gravel and sand (ie. fines) in the streambed of Carnation Creek increased 4.6% and 5.%, respectively. The quantity of fines was greater in the bottom layer, while the frequency and magnitude of changes in composition were greater in the top layer of streambed cores. Changes in streambed fines depended on the timing and type of streamside logging and on the timing of large freshets. Accumulating fines appeared to originate from erosion of streambanks or from upstream storage areas and they were transported as bedload. Suspended sediment (11.4 to 44.5 $t \cdot km^{-2} \cdot yr^{-1}$) did not increase after road construction and logging. Deposition and scour rates of pea gravel and sand in the streambed were inversely related to particle size, and to their depth in the bed. Following logging, survival to emergence declined from 29.1% to 16.4% for coho salmon salmon *(Oncorhynchus kisutch)* and from 22.2% to 11.5% for chum salmon *(O. keta)* . Annual survival to emergence and size of fry of both species were positively related to two indices of substrate composition. Annual changes in substrate composition and peak flows explained

60% and 73% of the variability in survival to emergence for chum and coho salmon, respectively.

Scrivener, J.D. and S. Carruthers, 1989. Changes in the invertebrate populations of the main stream and back channels of Carnation Creek, British Columbia following spraying with the herbicide "Round-Up" (gylphosate). Presented at the Dec. 8 -10, 1987, Herbicide Workshop, Nanaimo. *In:* P.E. Reynolds [ed]. Proceedings of the Carnation Creek Herbicide Workshop. Can./B.C. Econ. Reg. Develop. Agree. FRDA. Rep. (in press). (Contrib.No. 129.)

ABSTRACT

Populations of macroinvertebrates were monitored at two sites in the main stream and at sites with bare mud and mud with rooted vegetation substrates in four tributary swamps. Three tributary swamps (750-trib. 1500-trib, 1600-trib) and one site in the main stream were influenced by the herbicide "Round-Up' (glyphosate) after aerial application. Any impacts from the herbicide were not easily detectable because macroinvertebrate densities varied with substrate types, with the seasons and with previous hydrological conditions. In the main stream, a negative relationship between density and stream flow indicated that after frequent freshets macroinvertebrate densities were 42% lower at the treated versus untreated site, although the difference was not statistically significant ($p=0.09$). In the swamps, density of organisms on the surface of the substrate was related to stream flow with a cubic polynomial ($r^2 = 0.45$). Density maxima occurred during median flows, while density minima occurred during periods with extremes of flow. During periods of freshet, densities in the treated swamp were half those of the untreated swamp.

Shephard, B.G., G.F. Hartman, and W.J. Wilson. 1986. Relationships between stream and intragravel temperatures in coastal drainages, and some implications for fisheries workers. Can. J. Fish. Aquat. Sci. 43: 1818-1822. (Contrib.No. 85.)

ABSTRACT

By a depth of 10 cm. into the streambed, water temperatures are likely to be different from those in the open water of the stream. Combined results from three independent studies on disparate streams on the Pacific Northwest coast indicated that there are widespread similarities in the thermal behavior of intragravel water. In general, the thermal mass of the substrate causes parallel but lagged and buffered heating and cooling trends in infiltration-source intragravel water compared with surface water. Intragravel mean daily temperatures were generally 0.5-1.0°C warmer in winter and 0.5-1.5°C cooler in summer, with cross-overs around March and October; intragravel daily maximum temperatures could be up to 6°C different in summer (a difference of 4°C was common). The degree of difference showed considerable site-specific variation, and potentially can be affected by several factors. Such intragravel temperature differences have implications for those involved in salmonid egg incubation and fry emergence studies, enhancement projects, benthic invertebrate research, and environmental impact assessments.

Shortreed, K.S. and J.G. Stockner. 1982. The impact of logging on periphyton biomass and species composition in Carnation Creek: a coastal rain-forest stream on Vancouver Island, British Columbia, p. 197-209. *In:* G.F. Hartman [ed.] Proceedings of the Carnation Creek Workshop: A 10 year review. Pacific Biological Station, Nanaimo, British Columbia. 404 p. (Contrib.No. 56.)

ABSTRACT

Periphyton biomass, species composition, and accumulation rates on plexiglass substrates were determined from 1974 to 1979 in Carnation Creek. During the first three years of the study, the watershed was unlogged. Clear-cut logging in the remainder of the study resulted in increases in light intensity of over 100% at some sites, slight increases in stream temperature 2° to 3° in summer), and increases in some dissolved nutrient concentrations. Diatoms were the most common class of algae throughout the study, and *Achnanthes minutissima* and *Synedra rumpens* were the most common diatoms. Filamentous chlorophytes *(Draparnaldia* sp., *Mougeotia* sp., *Spirogyra* sp., and *Zygema* sp.) occurred sporadically throughout the study but were more common after logging.

Highest recorded periphyton biomass and accumulation rates occurred after logging,

although post-logging values were not consistently higher than those recorded prior to logging.

Shortreed, K.S. and J.G. Stockner. 1983. Periphyton biomass and species composition in a coastal rain-forest stream in British Columbia: Effects of environmental changes caused by logging. Can. J. Fish. Aquat. Sci. 40: 1887-1895. (Contrib.No. 66.)

ABSTRACT

Periphyton biomass, species composition, and accumulation rates on Plexiglass substrates were determined in a 6-yr. study from 1974 to 1979 in Carnation Creek, Vancouver Island, B.C. During the first 2 yr. of the study, the watershed was unlogged. Clearcut logging during the remainder of the study resulted in increases in light intensity of over 100% at some sites, slight increases in stream temperature (2-3°C in summer) and increases in some dissolved ion concentrations. Phosphorus concentrations were similar throughout the study. Diatoms were the most common class of algae, and *Achnanthes minutissma* and *Synedra rumpens* were the most common diatoms. Filamentous chlorophytes (predominantly *Mougeotia* sp. with some *Draparnaldia* sp., *Spirogyra* sp., and *Zygnema* sp.) occurred sporadically throughout the study but were more common after logging, primarily as a result of increased light intensity. Although highest recorded periphyton biomass and accumulation rates occurred after logging, post-logging values were generally similar to those recorded prior to logging. We attributed this to the lack of increase in phosphorus concentrations after logging.

Smith, R.B., W. Hays, and R.K. King. 1988. Some implications of vegetative changes induced by forest management, p. 93-98. *In:* T.W. Chamberlin [ed]. Proceedings of the Workshop: Applying 15 years of Carnation Creek results. Pacific Biological Station, Nanaimo, British Columbia. (Contrib.No. 115.)

Smith, R.B. and E.F. Wass. 1982. Changes in ground-surface characteristics and vegetative cover associated with logging and prescribed broadcast burning, p. 100-109. *In:* G.F. Hartman [ed.] Proceedings of the Carnation Creek Workshop: A 10 year review. Pacific Biological Station, Nanaimo, British Columbia. 404 p. (Contrib.No. 57.)

ABSTRACT

Surveys of ground-surface conditions were conducted on six clear-cut blocks (cutblocks) within and on one cutblock immediately adjacent to the Carnation Creek Experimental Watershed. Surveys were done before clear-cutting, after felling and yarding, after broadcast burning, and after up to three additional years following logging or broadcast burning. Areas of haul roads were measured on aerial photographs, the coverage amounting to an average of 9.5% for all cutblocks. For interroad areas, data collected at points and milacre plots along transects showed that unlogged stands had little ground disturbance and nearly 100% vegetative cover. Logging reduced vegetative cover to 24% and increased mineral soil exposure to 16% and slash cover to 50%. Burning increased mineral soil exposure to 26%, decreased slash cover by half, and reduced vegetative cover to less than 5%. By two years after burning, vegetative cover recovered to about 30%. Erosion was noticeable only on burned cutblocks, occurring primarily after the first rainy season following the burn. These results and subsequent surveys and data from other investigators will facilitate comparisons of ground-surface changes with changes occurring in the stream.

Stockner, J.G. and K.R.S. Shortreed. 1975. Attached algae growth in Carnation Creek: A coastal rain forest stream on Vancouver Island, British Columbia. Fish. Mar. Serv. Res. Div. Tech. Rep. 558: 64 p. (Contrib.No. 16.)

Stockner, J.G. and K.R.S. Shortreed. 1976. Autotrophic production in Carnation Creek, a coastal rain-forest stream on Vancouver Island, British Columbia. J. Fish. Res.. Board Can. 33: 1553-1563. (Contrib.No. 18.)

ABSTRACT

Attached algal growth in Carnation Creek and its estuary were monitored in 1974 and 1975 as part of the Carnation Creek Experimental Watershed Project. Net production on the estuary was 17.8 ug organic matter (org)·cm^{-2}·day^{-1}, and in Carnation Creek the average was 3.4

org.•cm^{-2}•day^{-1}. Algal growth in Ritherdon Creek, located in an adjacent logged watershed, was slightly higher (4.6 ug org.•cm^{-2}•day^{-1}) than the Carnation Creek average. In a streamside nutrient enrichment experiment, nitrate and phosphate concentrations in one trough were increased to twice the normal Carnation Creek values present in the control. In 35 days the nutrient-enriched trough had a total algal volume 3 times that of the control. It is suggested that extremely low nutrient concentrations (especially phosphate), and secondarily, poor light conditions under the canopy, are responsible for the paucity of algal growth in the Carnation Creek. Major loss of algae from the system was caused by periodic freshets which scour the stream bed. Losses by grazing herbivorous insects were considered negligible. Dominant diatoms in Carnation Creek were *Achnanthes minutissima*, *Synedra ulna*, *Hannaea arcus*, *Diatomia hiemale*, and *Eunotia pectinalis*. *Ulothrix* sp. *Drapaarnaldia* sp. and *Mougeotia* sp. were the dominant filamentous green algae. Net production and Algal biomass (chlorophyll a) in Carnation Creek are among the lowest ever reported in the literature.

Stockner, J.G. and K.R.S. Shortreed. 1978. Enhancement of autotrophic production by nutrient addition in a coastal rain-forest stream on Vancouver Island. J. Fish. Res. Board Can. 35: 28-34. (Contrib.No. 22.)

ABSTRACT

In 1976 streamside nutrient-enrichment experiments were conducted using wooden troughs. Tripling of the PO_4-P concentration, with or without a similar increase of NO_3-N, increased algal biomass on the troughs by 8 times after 35 days. Increasing NO_3-N alone had no appreciable effect on algal growth. A sloughing of algal biomass in August 1976 is believed to have been due to the instability of the heavy algal mat on the troughs and to the very poor light conditions that prevailed throughout August. Visual observation indicated that the relatively heavy algal population in Carnation Creek rapidly declined concurrent with the decline in the troughs. The percentage of diatoms in the algal assemblage remained the same in a troughs. The percentage of diatoms in the algal assemblage remained the same in all troughs, and *Fragilaria vaucheriae* replaced *Achnanthes minutissima* as dominant assemblages occurred despite alteration of the N:P ratio. The dynamics of species succession, distribution, and growth, with and without nutrient addition, are discussed.

Stockner, J.G. and K.R.S. Shortreed. 1988. The autotrophic community response to logging in Carnation Creek, British Columbia, p. 81-86. *In:* T.W. Chamberlin [ed.]. Proceedings of the Workshop: Applying 15 years of Carnation Creek results. Pacific Biological Station, Nanaimo, B.C. (Contrib.No. 116.)

Symons, P.E.K. [ed.] 1978. Carnation Creek Project annual report for 1976, Pacific Biological Station, Nanaimo, British Columbia. 14 p. (Contrib.No. 23.)

Symons, P.E.K. [ed.] 1978. Carnation Creek Project annual report for 1977, Pacific Biological Station, Nanaimo, British Columbia. 12 p. (Contrib.No. 24.)

Symons, P.E.K. [ed.] 1979. Carnation Creek Project annual report for 1978, Pacific Biological Station, Nanaimo, British Columbia. 14 p. (Contrib.No. 29.)

Tassone, B. L. 1988. Sediment loads from 1973 to 1984 08HB048 Carnation Creek at the mouth, British Columbia, p 46-58. *In:* T. W. Chamberlin [ed.] Proceedings of the Workshop: Applying 15 years of Carnation Creek results. Pacific Biological Station, Nanaimo, B.C. (Contrib.No. 117.)

Toews, D.A. and M.K. Moore, 1982. The effects of streamside logging on large organic debris in Carnation Creek. B.C. Min. For., Land Manage. Rep. No. 11: 29 p. (Contrib.No.38.)

ABSTRACT

The stability and volume characteristics of large organic debris in undisturbed and logged reaches of Carnation Creek were studied by comparing large scale maps prepared annually for four years before logging and two years following logging. Three reaches that were logged were compared to two that remained unlogged throughout the study. The results showed that the debris is less stable, the debris volumes are similar or lower, the number of pieces is greater, and the average piece size is smaller following logging. These changes are the result

of the removal and breaking up of stable instream debris and the addition of unstable debris during logging. The report presents preliminary data which indicates that coho fry populations initially increase as a result of the fine debris added immediately following logging but decrease with time as a consequence of channel alternations that resulted from the removal of stable debris. Streamside logging recommendations are presented that are directed towards maintaining the prelogging distribution and stability of organic debris.

Toews, D.A. and M.K. Moore. 1982. The effects of three streamside logging treatments on organic debris and channel morphology in Carnation Creek, p. 129-153. *In:* G.F. Hartman [ed.]. Proceedings of the Carnation Creek Workshop: A 10 year review. Pacific Biological Station, Nanaimo, British Columbia. 404 p. (Contrib.No. 58.)

Tschaplinski, P.J. 1982. Aspects of the population biology of estuary-reared and stream-reared juvenile coho salmon in Carnation Creek: A summary of current research, p. 289-307. *In:* G.F. Hartman [ed.] Proceedings of the Carnation Creek Workshop: A 10 year review. Pacific Biological Station, Nanaimo, British Columbia. 404 p. (Contrib.No. 59.)

ABSTRACT

Juvenile coho salmon inhabit a large number of small coastal streams (e.g. , ≤20 km long) in northwestern North America. Thousands of newly emerged coho fry emigrate from these streams in spring and early summer each year. In Carnation Creek (Vancouver Island), some of these emigrants inhabit the estuary from March to October-November. Coho inhabit main-channel and side-channel habitats in the uppermost 250 m of the estuary. Coho habitat requirements were identical to those of their stream-dwelling siblings. Most of the coho inhabited low-velocity sites, including deep pools. The largest number of fish in the main channel occurred in areas where midstream water velocities at low tide were ≤ 40 cm/s. Little or no water movement occurred in the side channels. Areas preferred by coho contained cover in the form of undercut banks, overhanging vegetation, and large debris (e.g., root masses, fallen trees). Coho occurred in waters ranging in salinity from 0 to 19 ‰ during periods of maximum high tide in summer.

The late summer (September) populations of estuary coho totalled 1205 and 2453 fry respectively in 1979 and 1980. These numbers comprised respectively 9.1% and 12.1% of the numbers of coho enumerated in Carnation creek for the 2 years. Coho emigrating to the estuary from the stream showed high rates of survival and growth. May to September survival rates of the spring (March to May) emigrants were respectively 33.9% and 26.0% for 1979 and 1980. These coho rapidly outgrew their stream-dwelling siblings and were 16.1 mm and 18.0 mm larger on the average by mid-to-late September respectively in the same 2 years. On the average, estuary coho grew from 1.8 to 2.3 times more rapidly than stream-dwelling fry on a monthly basis.

Stream fry emigrating into brackish estuaries gradually develop tolerance to waters of midrange salinities (e.g., 15 ‰) and increase their resistance to high salinity water (e.g., 30 ‰) as they grow during summer. This long-term adaptation allows fry to inhabit brackish estuaries efficiently. By autumn, about 50% of the estuarine fry are at least as large as 1-year-old smolts which leave Carnation Creek in spring. Most of these estuary coho disperse seaward into Barkley Sound in autumn with the onset of the first seasonal freshets. These fry are physiologically able to withstand the midsalinity, near-store, surface waters of Barkley Sound in winter. Large numbers of these estuary-reared fry must be marked to investigate the numbers which can potentially return to Carnation Creek to spawn.

Tschaplinski, P.J. 1987. A comparative ecology of stream and estuary populations of juvenile coho salmon *(Oncorhynchus kisutch)* in Carnation Creek, British Columbia. Ph.D. Thesis, Department of Biology, University of Victoria, Victoria, B.C. (Contrib.No. 96.)

ABSTRACT

Estuaries as well as coastal streams, can provide important rearing habitats for juvenile coho salmon but were previously unstudied. This investigation details the ecology of estuarine coho fry for the first time, and documents comparatively with stream coho, their period of estuarine residence and trophic dynamics, physiological adaptation to the estuarine

environment, food resources, and feeding behavior.

Estuary coho consist mainly of fry that emigrate annually in large numbers from coastal streams from early spring to mid-summer. Fry inhabited the upper intertidal zone of Carnation Creek from March to October-November when salinities ranged between 0 - 21.0 ‰ and temperatures after April averaged 13.7°C and spanned 8.9 - 19.0°C.

Habitat space limited the numbers and distribution of estuary fry. Coho numbers averaged seasonally 2.4 fry/m^2 (pool area) in favorable sites at low tide containing: low-velocity water averaging < 10 cm/s; pools usually ~ 45 - 225 cm deep; and structural cover consisting of undercut banks, vegetation overhanging the channels, and large, woody debris.

About 30.4% and 26.5% of all spring emigrants survived in the estuary by late September in 1979 and 1980, respectively. Late-summer populations totalled 1,205 and 2,453 fry respectively in those years, comprising 9.1% and 12.1% of the total numbers of fry rearing upstream. Estuary fry in 1979 and 1980 respectively (a) grew 1.8- and 2.3-fold more rapidly than stream fry and were 16.1 and 17.9 mm longer on average by mid-September, and (b) formed 19.8% and 23.8% of the total biomass and 26.0% and 38.0% of the seasonal net production quantified for coho upstream.

The feeding ecology of both stream and estuary coho was clarified by diel and seasonal diet studies, confirmed by direct observations of feeding behavior, and incorporated (a) simultaneous determinations of the species and quantities of potential prey from benthic, drift, and terrestrial sources, and (b) statistical correlations between diet and potential food resources. Estuary coho consumed diurnally 28 - 71% more prey than stream coho and outgrew fry upstream because benthic and drifting invertebrates were more available intertidally and exceeded numbers in the stream by as much as six fold or more. Drifting aquatic and terrestrial invertebrates were the most important immediate sources of food in both environments. Prey overlap (C_T) coefficients between the diet and drift were 0.77 - 0.87 for estuary coho and 0.59 - 0.95 for stream juveniles. Most values of the Linear Index of Food Selection were near zero for all coho, demonstrating that coho fed opportunistically upon most drifting species in direct proportion to prey abundance, and did not discriminate between species.

Laboratory studies confirmed that coho fry entering estuaries survive at high rates and adapt gradually to estuarine salinities. Estuary fry were able to fully osmoregulate in brackish water by August and simultaneously increased their physiological tolerance to seawater. Fry seasonally reduced their plasma sodium ion concentrations to (a) 166 - 172 mM when immersed fro 72 h in 15 ‰ brackish water, and (b) 186 - 188 mM when immersed for 24 h in 30 ‰ seawater. Stream fry without prior exposure to brackish water could neither osmoregulate in 15 ‰ water nor reduce their plasma sodium ion concentrations below 202 mM in seawater.

By autumn, ~ 50% of estuary fry are as large as 1-yr-old smolts which leave the stream in spring. Most of these estuary coho apparently disperse seaward in autumn with the onset of seasonal freshets. Nine of 300 estuary fry tagged in autumn returned as jacks in the following year, but large numbers of coho must be marked to establish the proportion of the spawning population formed by estuary-reared juveniles.

Tschaplinski, P. J. 1988. Use of estuaries as rearing habitats by juvenile coho salmon of Carnation Creek,British Columbia, p. 123-142. *In:* T. W. Chamberlin [ed.]. Proceedings of the Workshop: Applying 15 years of Carnation Creek results. Pacific Biological Station, Nanaimo, B.C. (Contrib.No. 118.)

Tschaplinski, P.J. and G.F. Hartman. 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. (Contrib.No. 67.)

ABSTRACT

Coho populations in streams are reduced substantially in winter compared to numbers which occur in summer. Most of this reduction occurs early in autumn with the onset of the first

seasonal freshets. Stream sections containing adequate winter habitat in the form of deep pools, logjams, and undercut banks with tree roots and debris lost fewer fish during freshets and maintained higher numbers of coho in winter than sections without these habitat characteristics. These features provide shelter and reduce stream velocities. Microhabitats occupied by coho juveniles in winter after logging were unchanged from those described before logging--all microhabitats were characterized by low water velocities ($\leq$ 0.3 m/s). Up to 48% of the coho population inhabiting stream sections with adequate shelter remained there by midwinter (January 3). This survival rate was typical of stream sections where at least some trees remained after logging. Streamside trees stabilized the banks and prevented their collapse. In contrast, 2 of 3 study sections which had been clear-cut logged had unstable banks which collapsed during winter freshets. Coho were almost eliminated from these sections in winter.

Concurrent with seasonally declining fish populations in Carnation creek, many coho emigrate from the main stream to seek the shelter of quiet tributaries and valley sloughs in autumn. This seasonal shift in distribution reverses in the spring when large numbers of coho reenter the main stream. Fish overwintering in these sites have a high survival rate. In the 750 m site before logging, a 4-year mean of 169 $\pm$ 44 coho entered in autumn; of these, 72.2% survived the winter. During logging, an annual mean of 288 coho entered the same site. The survival rate during logging was 67.4% essentially unchanged from the prelogging value. Logging has neither reduced the numbers of coho juveniles which enter such sites in autumn to overwinter nor reduced the numbers leaving these sites to reenter Carnation Creek in spring.

APPENDIX I. Manuscripts approved for publication listed by contribution number

138 McMahon, T.E. and G.F. Hartman. MS. An experimental analysis of winter cover requirements of juvenile coho salmon, *Oncorhynchus kisutch*. Accepted by Can. J. Fish. Aquat. Sci.

ABSTRACT

In freshet-prone coastal streams, woody debris provides an important source of cover for juvenile coho salmon *(Oncorhynchus kisutch)* during winter. To isolate the features that determine its suitability as winter cover, habitat selection by coho was examined in artificial stream channels offering various combinations of cover (none, low velocity, overhead shade, woody debris), flow levels, and fish density. Cover utilization and numbers of coho establishing residency in stream channels increased significantly as cover complexity increased, and only the most complex cover (low velocity, shade, woody debris combined) provided adequate shelter during a simulated freshet. There were no consistent size differences between residents and emigrants, and in all experiments, most emigration occurred coincident with the rapid decline in light levels during twilight. As in summer, aggressive behavior (in concert with habitat features also appeared to influence the number of coho that remain in specific stream habitats during winter, as the addition of coho to stream channels with established residents resulted in high emigration of introduced fish. These results emphasize the importance of protecting and/or enhancing the structural complexity of woody debris in designing management practices for protecting and/or enhancing winter-habitat for coho.

139 Brown, T.G. and G.F. Hartman. MS. The contribution of seasonally flooded lands and minor tributaries to coho *(Oncorhynchus kisutch)* salmon smolt production in Carnation Creek, a small coastal stream in British Columbia. Trans. Am. Fish. Soc. (accepted).

140 Holtby, L. B., T. E. McMahon, and J. C. Scrivener. MS. Stream temperatures and inter-annual variability in the emigration timing of coho salmon *(Oncorhynchus kisutch)* smolts and fry and chum salmon *(Oncorhynchus keta)* fry from Carnation Creek, British Columbia. Submitted to Can. J. Fish. Aquat. Sci.

ABSTRACT

Variability in average stream temperatures between peak spawning and fry emergence accounted for 82% and 77% of the variance in the median emigration date of fry of chum and coho salmon, respectively over a 9 to 10-yr period. These relationships mirrored laboratory models that predicted time to maximum alevin wet weight for both species. Variability in the stream temperatures during the spring accounted for 60% of the variability in the median date of coho smolt emigration. In response to a temperature variation of 3.6^0C (the historical range) emigration timing changed considerably less for coho salmon smolts (15 d), than for either coho or chum salmon fry (73 d and 58 d, respectively). The durations of the emigration period also differed among the groups: 50% of the chum salmon fry emigrating over a 1-wk period compared with a 2- to 3-wk period for coho fry and smolts. Only coho salmon demonstrated a near constant total thermal requirement for embryonic development. We speculate that the emigration timing - temperature relationships represent adaptions for synchronizing emigration with "windows of opportunity" in the ocean or stream. They differ in widths and in levels of predictability for coho and chum salmon fry and coho salmon smolts.

141 Hetherington, E.D. and J.C. Scrivener. MS. Carnation Creek experimental watershed-reflections on 18 years of experience with a west coast fish/forestry interaction project, *In*: Proceedings of the Canadian Hydrology Symposium, 1988. Canadian Research Basins: Successes, failures and the future. National Research Council of Canada, Ottawa.

ABSTRACT

Carnation Creek is a small salmon stream located on Vancouver Island, British Columbia. A long-term multi-agency project was initiated in 1970 to evaluate the effects of forestry operations on the stream and its fish production and communicate results to forestry and fishery managers. Hydrology was a supportive rather than primary focus of the project. Both

terrestrial and stream processes were emphasized. Objectives have been achieved despite funding shortages, changes in coordinator and research priorities, periodic lack of interest, missed opportunities, and difficult field conditions. Achievements include significant scientific findings, effective transfer of results to potential users, and a substantial influence on the resolution of fish/forestry conflicts in coastal British Columbia.

142 **Payne, N., J.C. Feng, and P.E. Reynolds. MS.** Off-target deposit measurements and buffers required around water for aerial glyphosate application. Presented at the Dec. 8 -10, 1987, Herbicide Workshop. *In:* P.E. Reynolds [ed]. Proceedings of the Carnation Creek Herbicide Workshop. Can./B.C. Econ. Reg. Develop. Agree. FRDA. Rep. (in press).

ABSTRACT

This study was conducted to compare off-target deposit from three types of forestry glyphosate application, and to design a scientific approach and gather data to estimate buffers required around water to protect fish and their food supply during such applications. Field measurements were made during aerial applications of "Round-up" using three different types of dispersal system, a MICROFOIL boom, through Valve boom and hydraulic nozzle D8-46. Off-target glyphosate deposits on water and foliar surfaces were measured at various downwind distances from several swaths overlaid on a crosswind track. Glyphosate area dose was also sampled. To overcome the problem of the multiplicity of buffers required under different conditions, e.g. windspeed, boundary-layer stability, active (a.i.) application rate, etc., a reasonable worst case scenario was chosen, and data collected for this case. Using these worst case field measurements, mathematical models were constructed to predict glyphosate deposits on water surfaces downwind of multiple swath applications. In conjunction with published measurements of the toxicity of glyphosate to fish and aquatic invertebrates, an estimate was made of buffers required around water to protect fish and their food supply from direct effects. In general measure off-target deposit was highest from the D8-46 application, and lowest from the MICROFOIL boom application. In all applications off-target deposit on water decreased rapidly with downwind distance. For any of the dispersal systems used the suggested buffer around water bodies during forestry glyphosate application is 10 m.

143 **Preston, C.M. and J.A. Trofymow. MS.** Effects of glyphosate on biological activity of two forest soils. Presented at the Dec. 8 -10, 1987, Herbicide Workshop. *In:* P.E. Reynolds [ed]. Proceedings of the Carnation Creek Herbicide Workshop. Can./B.C. Econ. Reg. Develop. Agree. FRDA. Rep. (in press).

ABSTRACT

The results from laboratory and field trials are presented. To examine possible effects of glyphosate on carbon dioxide evolution and nitrogen transformations, forest floor and mineral soil from a Douglas-fir site at Shawnigan Lake (Vancouver Island) were incubated with glyphosate (10 and 50 $ug \cdot g^{-1}$) with or without 15 N-labelled urea (200 $ug.g^{-1}$ N). No significant effects of glyphosate were found on carbon dioxide evolution, urea hydrolysis, immobilization of ammonium or nitrification, for either soil depth or level of glyphosate application. In field studies, soil fauna and microflora populations were monitored in surface organic layers prior to and following glyphosate application on alder covered sites at Carnation Creek (Vancouver Island). In a six month study, glyphosate had no significant long-term effects on soil fauna or microflora populations. Soil microflora populations in herbicide treated plots fluctuated and then returned to control levels during an intensive one month field sampling trial.

144 **Ritchie, D.C., A.S. Harestad, and R. Archibald. MS.** Glyphosate treatment and deer mice in clearcut and forest. Presented at the Dec. 8 -10, 1987, Herbicide Workshop. *In:* P.E. Reynolds [ed]. Proceedings of the Carnation Creek Herbicide Workshop. Can./B.C. Econ. Reg. Develop. Agree. FRDA. Rep. (in press).

ABSTRACT

Prior to planting conifers, herbicides are commonly used to reduce competition from deciduous trees and shrubs. Herbicides are usually not toxic to wildlife but do affect their

habitats. We examined deer mice (*Peromyscus maniculatus)* to assess the impact of herbicides on small mammals. Deer mice from adjacent untreated and glyphosate-treated clearcuts had similar body sizes and numbers of placental scars and foeti. In untreated clearcuts, deer mice were more abundant than in treated clearcut, but were less abundant than in surrounding old growth forest. Glyphosate altered vegetation and reduced density of deer mice in young seral stages. Habitat changes induced by glyphosate likely modified abundance and quality of food and cover for small mammals.

145 **Reynolds, P.E., J.C. Scrivener, L.B. Holtby, and P.D. Kingsbury. MS.** Summary of Carnation Creek herbicide study results. Presented at the Dec. 8 -10, 1987, Herbicide Workshop. *In:* P.E. Reynolds [ed]. Proceedings of the Carnation Creek Herbicide Workshop. Can./B.C. Econ. Reg. Develop. Agree. Rep. (in press).

146 **This Article**

147 **Holtby, L.B. and M.C. Healey. MS.** Sex specific life history tactics and risk taking in coho salmon *(Onchorhynchus kisutch).* Submitted to J. Behavioural Ecology and Socio-Biology. (submitted).

SUMMARY

In the coho salmon *(Onchorhynchus kisutch)* of Carnation Creek, British Columbia, males outnumbered females age .1 adults, females were generally larger than males, and the male/female sex ratio varied directly with the female/male size ratio. Absolute female size was constant over a 16-yr period while male size varied inversely with the male/female sex ratio. Evidence is presented that females had higher mortality rates than males and that the difference in mortality rates increased as the animals neared maturity. Sex- and size-ratio data from numerous other coho salmon poulations indicate that there are two general population "types": about half are, like Carnation Creek, while in the other type males and females are roughly equally abundant and equally sized. We propose a model that explains the observations by linking sex-specific foraging strategies and risk taking to the constraints imposed on body size by the breeding environment and the differing reproductive roles of the sexes.