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CHANGES IN DISSOLVED NITROGEN CONCENTRATIONS IN TRIBUTARIES OF THE BELLA COOLA RIVER AFTER FOREST FERTILIZATION WITH UREA

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SUMMARY

The effect of forest fertilization with urea on concentrations of dissolved nitrogen was measured in the Salloompt River and a first order tributary of the Nusatsum River. These rivers are tributaries of the Bella Coola River which empties into the North Bentinck Arm of Burke Channel at the community of Bella Coola on the central coast of British Columbia. The study was included as part of the fertilization of 18 forest blocks near Bella Coola ranging in size from 10 to 64 ha. Fertilized areas that were monitored included a 25 and 53 ha block on the Nusatsum and Salloopmt drainages respectively. Water samples were collected from a site upstream (control) and downstream (treatment) of each block before, during, and after the fertilization. The Nusatsum block was 12.2% of the total drainage area of the Nusatsum tributary; that on the Salloompt was 1.4%. Forest stands in the fertilized areas included a mix of second growth hemlock, amabilis fir, cedar, and Douglas fir ranging in age from 25 to 30 years. Alder dominated the riparian zone in the Salloompt but was less common along the Nusatsum tributary. Soils were generally characterized by a thin forest floor overlying colluvial material. The forest blocks were fertilized with urea at a rate of 435 $kg \cdot ha^{-1}$ (200 $kg\ N \cdot ha^{-1}$) and the treatment of both sites was completed on October 24, 1992. 30m fertilizer free zones (FFZ) were maintained around the Salloompt River but because of its small size, no FFZ was placed around the Nusatsum tributary. There was no change in urea or ammonia concentrations due to fertilization. Concentrations of both were mostly near the detectable limit of 5 $\mu g \cdot L^{-1}$ except in mid-November when peak levels of 18 $\mu g \cdot L^{-1}$ of urea and 16 $\mu g \cdot L^{-1}$ of ammonia were recorded and these occurred during high rainfall events. Fertilizer additions increased nitrate levels in the Nusatsum by 7 times immediately after fertilization to reach 46 $\mu g \cdot L^{-1}$. The difference declined to about 2 times within the first week after treatment and within two weeks there was no difference between the control and treatment sites. A peak NO_3^--N concentration of 88 $\mu g \cdot L^{-1}$ was later measured in association with heavy rainfall in November and no recovery to control levels was found by the time of the last sample collection in mid-January. In the Salloompt River, nitrate-N levels were variable but generally increased at both control and treatment sites, likley in relation to N-fixation from the abundant alder in the riparian zone. After the heavy rain in November control levels generally declined but treatment concentrations increased to a peak of 210 $\mu g \cdot L^{-1}$ and remained greater than control levels even by the end of sampling in January. These changes in dissolved nitrogen are some of the lowest reported from studies in coastal B.C., Washington, Oregon, and Alaska. High dilution of the added fertilizer (relatively low ratio of area fertilized to drainage area) was considered the most important factor contributing to such a low response. Nitrate mobilization from the fertilizer additions was attributed mainly to increased surface and subsurface water flow rates associated with high rainfall. Aqueous input of nitrate fixed by riparian alder potentially confounded differences between control and treatment sites, particularly on the Salloompt River. A comparison of the nitrate concentrations with federal water quality guidelines indicated that the forest fertilization did not affect the quality of water for domestic consumption or fish.

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1.0 INTRODUCTION

Foliar analyses of second growth stands in the Bella Coola valley have suggested that growth of Douglas fir is limited by deficiencies of nitrogen and boron (N. McCrea, Ministry of Forests, Hagensborg; R. Carter, Fletcher Challenge Ltd. Vancouver). These fir stands are found with hemlock, amabilis fir, and some cedar and spruce in transition from the coastal western hemlock to mountain hemlock biogeoclimatic zones. In this transition zone some of the Douglas fir has been selectively removed in favour of hemlock and amabilis fir as part of juvenile spacing activities. In these areas, acute boron deficiency is pronounced in the fir but not in the other species. However, where second growth Douglas fir has demonstrated adequate growth responses, it has been retained.

In 1991, 18 mixed stands that had been previously spaced were selected for fertilization with urea fertilizer. These areas included small blocks (10 to 64 ha) on the east slope of the Salloompt River, east and west slopes of the Nusatsum River, the west slope of the Talchako River, and selected locations adjacent to the Bella Coola River (Figure 1). These treatments were part of a coast wide plan of second growth enhancement over several years using nitrogen fertilization.

As part of the fertilization initiative, data have been collected at several coastal locations to document changes in the concentrations of several forms of nitrogen in streams that drain the fertilized sites. These data have been used to compile information on aqueous losses of applied fertilizer and to describe effects of the treatments on stream and in some cases lake water chemistry. Most of these data have been collected by LIMNOTEK personnel over the past 13 years and are available in several reports (eg. Perrin et al 1984, Perrin 1987, 1988, 1989, 1990a, 1990b).

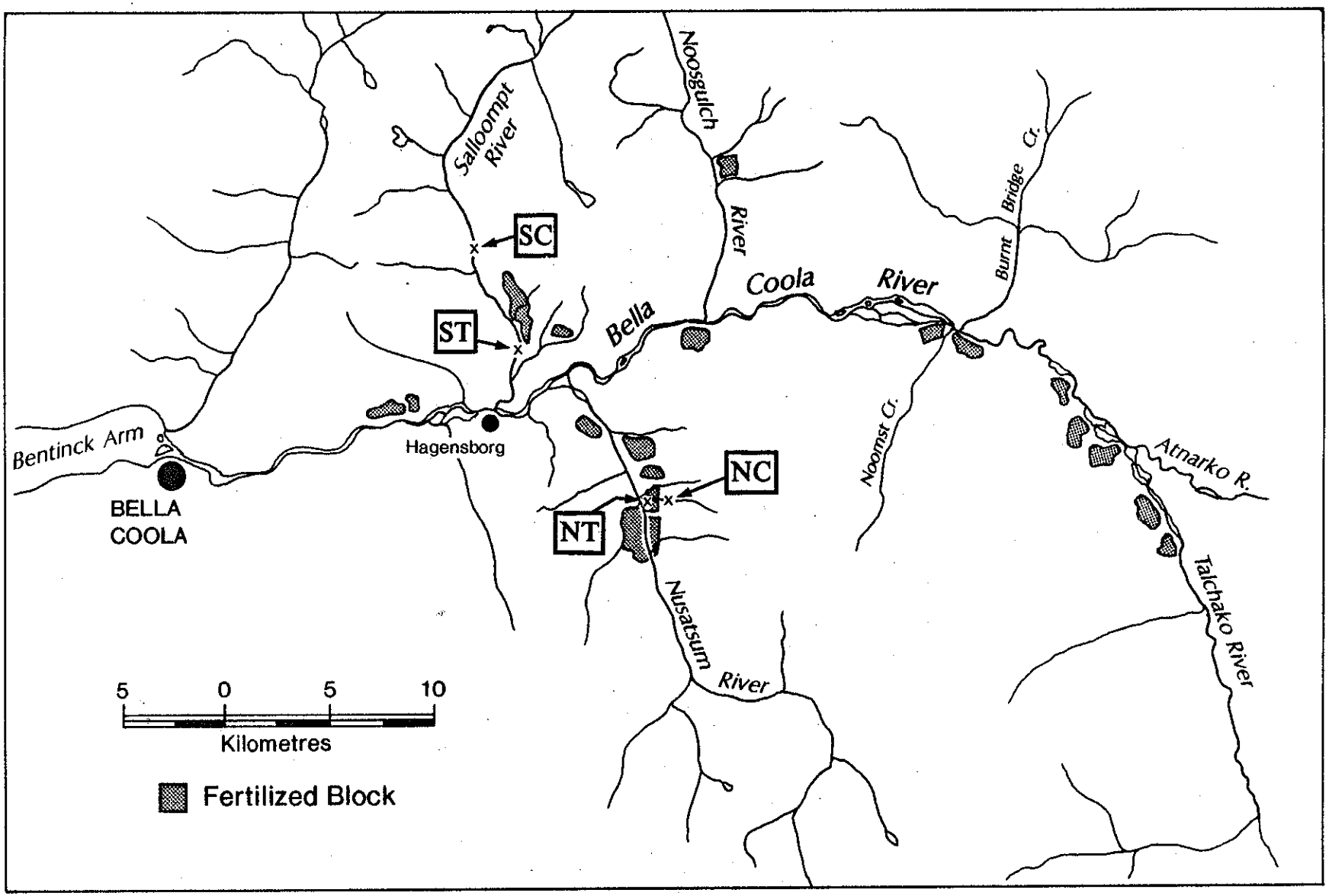

Figure 1. Study site location showing the distribution of fertilized sites in the Bella Coola valley and sampling sites located in the Salloompt and Nusatsum drainages.

The fertilization treatments in the Bella Coola valley provided another opportunity to add to this database. A control and treatment site was selected around two blocks, one adjacent to the Salloompt River and another on a tributary to the Nusatsum River. At each block, the control site was established upstream of the fertilization boundary and the treatment site was located downstream (Figure 1). With this design, the effects of fertilization on streamwater nitrogen concentrations were measured.

2.0 STUDY SITE

The study area included drainages of the Salloompt and Nusatsum Rivers, each of which are major tributaries to the Bella Coola River (Figure 1). Headwaters of both rivers originate in steep mountainous terrain reaching more than 1500 m in elevation. The Salloompt and Nusatsum flow south and north respectively and discharge to the Bella Coola River near the community of Hagensborg, approximately 18 km east of Bella Coola. Both rivers drain steep U-shaped valleys and have an average gradient of 5%. The small tributary of the Nusatsum River that drained the fertilized forest block had an average gradient of 30%.

Forest stands in the Nusatsum included a mix of second growth hemlock, amabilis fir, and Douglas fir associations. Stand age ranged between 25 and 30 years and stand density after thinning was 1000 to 1200 stems$\cdot$ha^{-1}. In the Salloompt, the forest included a mix of second growth cedar, Douglas fir, and hemlock having an average age of 26 years. Average stand density was 725 stems$\cdot$ha^{-1}. The riparian zone along the Salloompt included an extensive growth of alder. From general observations during the site reconnaissance in September, 1991, and from observations during previous surveys (N. McCrea, Ministry of Forests, Hagensborg, Pers comm.) the density of alder was estimated to be not less than 150 stems$\cdot$ha^{-1} but may have been much higher in localized patches adjacent to the river. Alder did not dominate the riparian zone of the drainage that was fertilized in the Nusatsum.

Soils in the area generally consisted of a thin forest floor overlying coarse colluvium. The forest floors were approximately 15 cm thick containing relatively little humus. The colluvium probably originated at higher elevations and was reworked angular talus, likely not derived from till. Given the shallow forest floor, the rooting zone would have penetrated this colluvial material.

Frontal storm activity and associated rainfall is frequent in the Bella Coola area in fall and winter. Confirmed precipitation records (to date available only to November 30, 1991), collected by Environment Canada at the Bella Coola airport (3 km west of Hagensborg) indicated a rising frequency of storms and increasing amounts of rainfall associated with those storms over three months ending November 30 (Figure 2). In September there were 13 days of no measurable rainfall, but this number declined to 12 and then to 2 days in October and November respectively. December and January continued to be wet and relatively warm months. The study areas were always accessible during the study, which was unusual because of coastal warming from the El Nino ocean current. Snow accumulations which otherwise would have restricted access in a non-El Nino year, were relatively small and did not restrict vehicle traffic for sample collections.

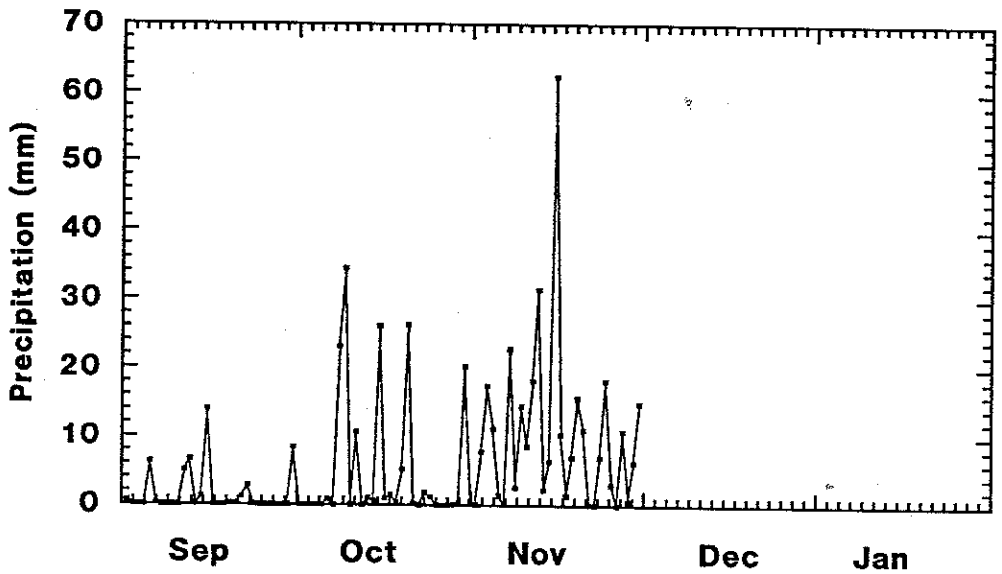

Figure 2. Total daily precipitation measured at the Bella Coola airport as part of the Environment Canada network of weather data collections. Confirmed data were available only to the end of November, 1991.

3.0 MATERIALS AND METHODS

Of the 18 forest blocks that were fertilized, effects of fertilizer additions on streamwater nitrogen concentrations were measured in one 25 ha block in the Nusatsum drainage and a 53 ha block in the Salloompt (Figure 1). At each block a control sampling site was established upstream of the treatment boundary (SC on the Salloompt and NC on the Nusatsum) and a treatment site was located downslope of the fertilized area (ST on the Salloompt and NT on the Nusatsum).

The two areas were different with respect to potential dilution rates of the transported fertilizer. The Salloompt treatment was monitored on the mainstem Salloompt River which produced relatively high dilution of any fertilizer losses. The treated area was only 1.4% of the total drainage area, which in this case included the entire Salloompt watershed down to the elevation of ST. The treatment area on the Nusatsum tributary was 12.2% of the drainage area which would have resulted in less dilution of the added fertilzer compared to that in the Salloompt. Hence, it was hypothesized that change in dissolved nitrogen concentrations in the Nusatsum tributary should be greater than those in the Salloompt River.

Urea fertilizer (46-0-0) was applied at a rate of 435 $kg \cdot ha^{-1}$ (200 kg $N \cdot ha^{-1}$). The fertilizer was spread from a centrifugal-deploying bucket slung beneath a Bell 205 helicopter that was equipped with a navigational system known as a Del Norte MS 12 Flying Flagman. The guidance system used transponders as markers for an on-board computer to continuously calculate the position of the machine on a real time basis. This system maintained accurate flight lines within the treatment boundaries. A 30 m fertilizer free zone (FFZ) was maintained along the Salloompt and Nusatsum Rivers, but no FFZ was established around the Nusatsum tributary.

Water sampling at each of the four locations was designed to cover the period before and after fertilization, including the time for concentrations of N to return to pretreatment levels. Without knowing the actual recovery time, the design was largely empirical, resulting in sample collections in irregular intervals for 119 days; 32 days before the day of treatment and 87 days thereafter. Pretreatment sampling started on September 21 and continued in weekly or biweekly intervals until October 24, the day of fertilization. Daily sampling was initiated immediately after fertilization but within the first week the frequency declined to once every 2, 3 and then 5 days for the next month, weekly for three weeks, biweekly for the next month, and a one month interval before the final sample collection. This approach accommodated intensive data collections during the time when N concentrations usually change rapidly after fertilization and less intensive collections when rate of change usually declines (ie. with increasing time from the day of treatment).

All samples were filtered in the field through 0.45 μm membrane filters and air shipped on the day of sample collection to Vancouver for analysis within 48 h. Analyses for dissolved inorganic nitrogen included total ammonia ($NH_4^+ + NH_3$-N) and nitrate plus nitrite ($NO_3^- + NO_2^-$-N). The analysis for nitrite was routinely combined with nitrate since nitrite is rarely detectable in coastal freshwater and its levels are always several orders of magnitude less than those known to produce toxic effects. Changes in nitrite levels are not considered to be a water quality issue in relation to forest fertilization. All these laboratory analyses followed procedures in APHA (1985). Since the N source in the fertilizer was urea and rapid transport of lost fertilizer was expected, all water samples were also analyzed for urea concentrations. The procedure followed that reported by Kluckner et al (1980) modified for a manual apparatus.

All data graphics in this report were produced using SYGRAPH application software (Wilkinson 1988).

4.0 RESULTS

The general temporal pattern of rainfall has been described above (section 2.0) but it is also important to note from Figure 2 that with the declining number of days without measurable rainfall, the intensity of rainfall events increased. In September, the highest peak amount of rainfall was only 14 mm. In October, three peaks of 34.4, 26.0, and 26.2 mm occurred within two weeks before treatment. A week after fertilization a minor peak of 20.2 mm was recorded. In November, a series of intense storms passed the area producing several peaks between 10 and 25 mm. Heaviest rainfall occurred between November 10 and 15 when peaks of 31.4 and 62.4 mm were measured. These major events linked with continuous but lower amounts of rainfall on other days produced stream flows that were observed to be considerably higher than those in October and September.

Concentrations of urea and ammonium were similar between the control and treatment sites at both locations, thus indicating no change as a function of the fertilization. Ammonium-N levels were usually $<5\ \mu g \cdot L^{-1}$. There were only 4 samples from ST in which ammonium concentrations were $>10\ \mu g \cdot L^{-1}$ but even in these, the concentrations never exceeded 16 $\mu g \cdot L^{-1}$. One of these peaks occurred before fertilization and the other three occurred in November during heavy rainfall. Urea-N concentrations in the Salloompt River were always $<10\ \mu g \cdot L^{-1}$, with the exception of one measurement on November 7 when a peak of 18 $\mu g \cdot L^{-1}$ was recorded (Figure 4). This spike occurred at both SC and ST thus indicating that it was not related to fertilization. Since it coincided with a large increase in rainfall (change from trace amounts to 22.8 mm in 24 h), the response was likely related to urea mobility caused by rapid water transport through the coarse colluvial soils. Similarly, in the Nusatsum, there were urea spikes from background levels near 5 $\mu gN \cdot L^{-1}$ but they occurred at both the control and treatment sites (Figure 3) and were closely associated with heavy precipitation events (compare Figure 2 and 3). Again these data indicate no treatment effect, but do indicate mobility of urea associated with water transport.

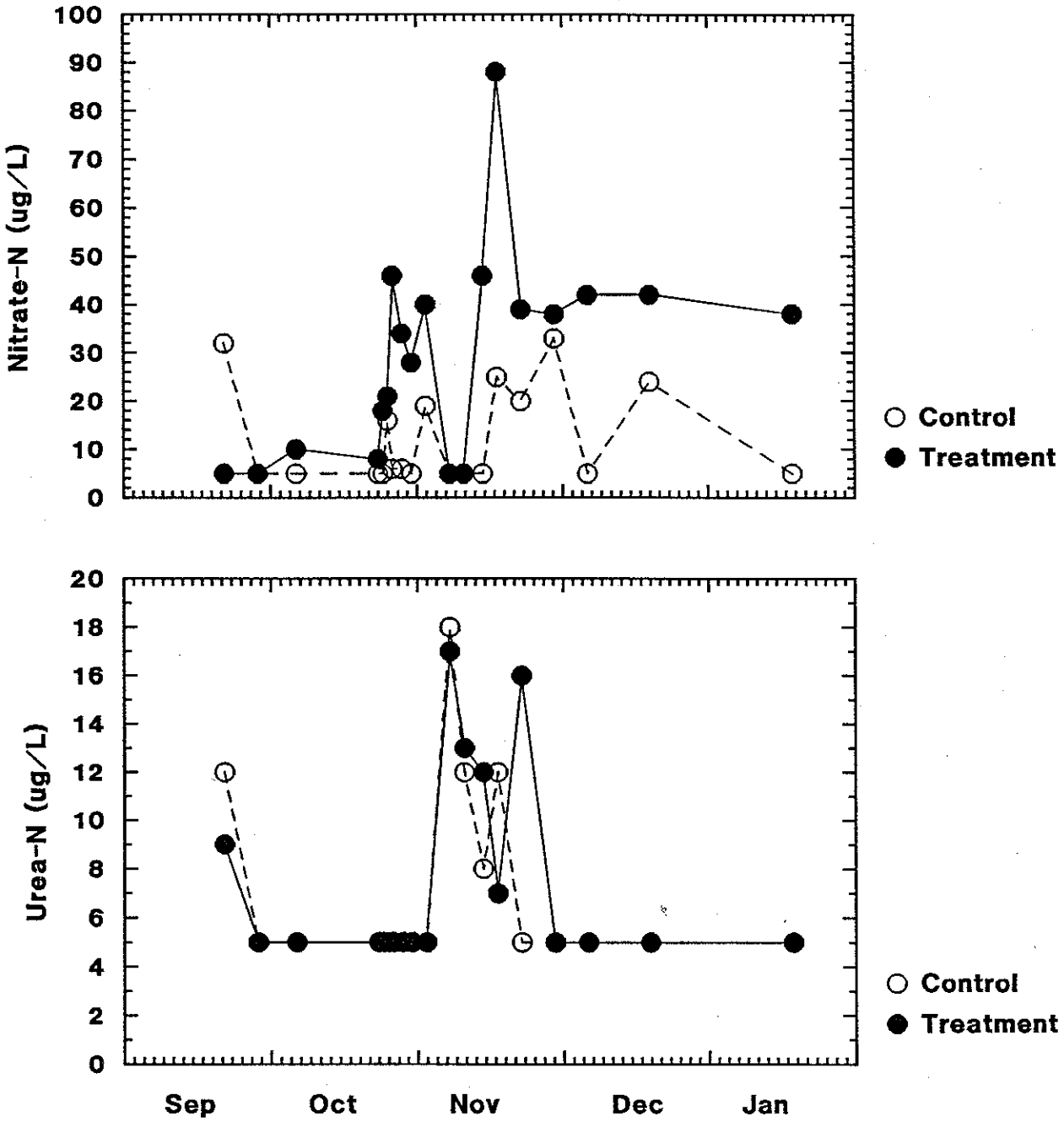

Figure 3. Time course changes in nitrate and urea concentrations in the Nusatsum tributary before, during, and after forest fertilization with urea. The site was fertilized on October 24. Note differences in scales on the Y axis.

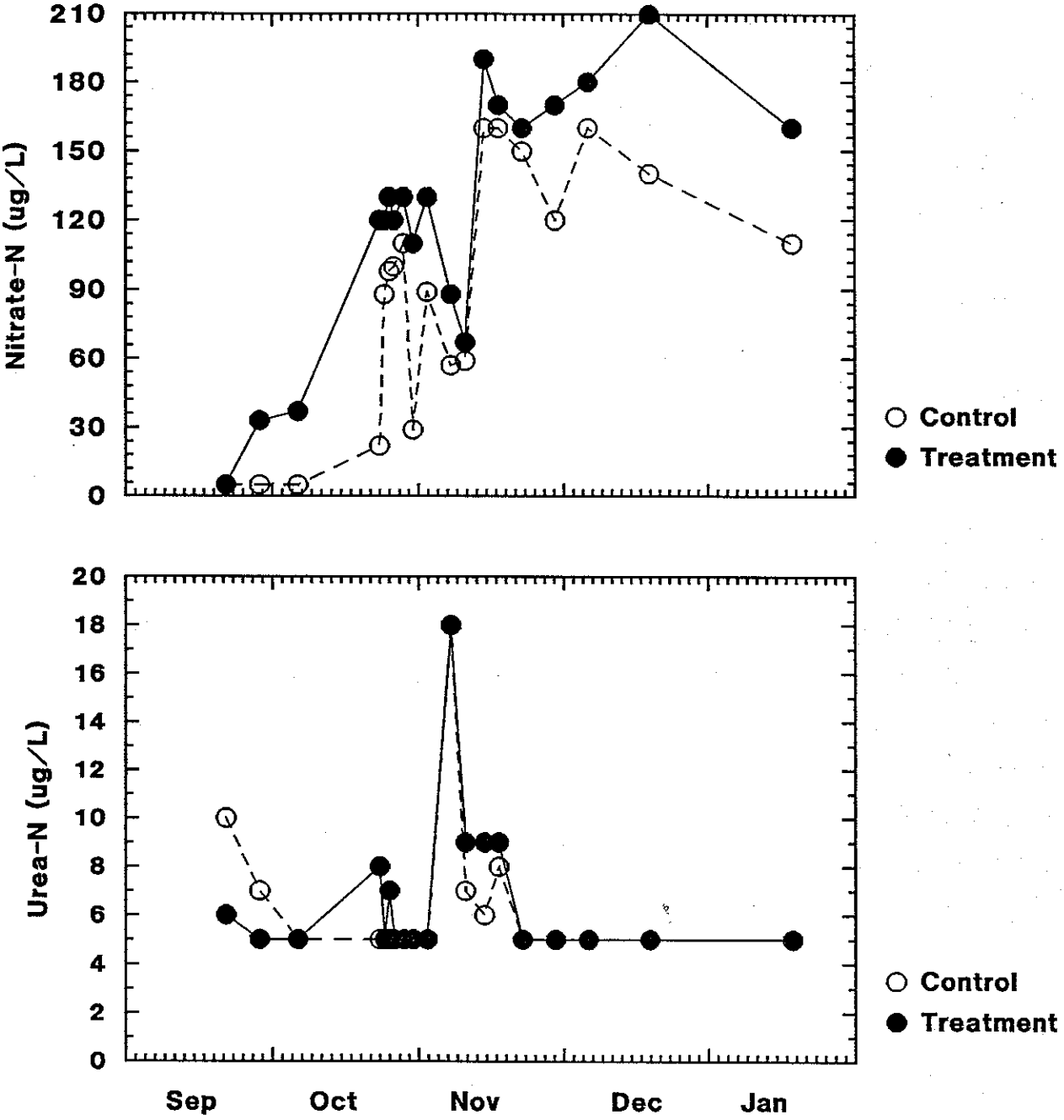

Figure 4. Time course changes in nitrate and urea concentrations in the Salloompt River before, during, and after forest fertilization with urea. The site was fertilized on October 24. Note differences in scales on the Y axis.

Nitrate was the only form of nitrogen for which a treatment effect was apparent (Figure 3 and 4) at the Nusatsum location (Figure 3). Nitrate concentrations at both sites were similar before fertilization but after treatment those at NT increased to 7 times those at NC, reaching 46 $\mu g \cdot L^{-1}$. After this initial pulse the levels at NT oscillated between 26 and 40 $\mu g \cdot L^{-1}$ before declining to <5 $\mu g \cdot L^{-1}$, the same level as at NC. With the onset of heavy rain on November 15 (Figure 2), NO_3^--N concentrations again increased, reaching 88 $\mu g \cdot L^{-1}$. This change was more than double the levels at NC ($<$ 35 $\mu g \cdot L^{-1}$) at the same time. After this peak storm event, NO_3^--N concentrations declined by about 50% at NT but remained near 40 $\mu g \cdot L^{-1}$. This level was consistently higher that at NC which was mainly <25 $\mu g \cdot L^{-1}$. No recovery to control levels was found by the last sample collection on January 18.

In the Salloompt River, there was a general increase in NO_3^--N concentrations from September through mid-November at both SC and ST. Throughout this period, including the time before fertilization, NO_3^--N levels at ST were always greater than those at SC (Figure 4). There was considerable variation at both sites but the general trend was an increase in concentrations at both sites at the time of fertilization (90 to 130 $\mu g \cdot L^{-1}$), a decline in levels during the time of no rainfall within the week after fertilization (near 60 $\mu g \cdot L^{-1}$) and an abrupt increase to 150-200 $\mu g \cdot L^{-1}$ with the onset of heavy rain in early November. After this last increase at both sites, the concentrations at each site diverged; control levels declined to 110 $\mu g \cdot L^{-1}$ by January 18 but levels at ST never declined below 160 $\mu g \cdot L^{-1}$.

5.0 DISCUSSION

5.1 Dissolved Nitrogen Concentrations

Findings from this study are consistent with previous work showing an increase in dissolved nitrogen concentrations in streams after forest fertilization with urea. Peak

concentrations of the various forms of dissolved nitrogen are variable, but transient, and in previous studies they have been followed by periods of declining concentrations that are within the range of variability at control sites within one month to several months after treatment. The precise timing of peak concentrations and recovery appears to be site specific as there is no consistent temporal sequence among studies (Table 1). In the present study, the form of nitrogen that was mobilized, and the magnitude of responses were most similar to those studies listed in Table 1 in which dilution of mobilized nitrogen was high (<5% of total drainage area was fertilized).

A detectable increase in nitrate concentrations after fertilization indicates that hydrolysis of the urea and subsequent nitrification of the ammonium was active in the forest floors in both the Nusatsum and Salloompt drainages. When urea fertilizer contacts the forest floor, hydrolysis reactions yield ammonium, which can be effectively retained at cation exchange sites in the forest floor. Subsequent nitrification produces nitrate which is relatively mobile and can persist at elevated concentrations for weeks after fertilization.

Hydrolysis and nitrification reactions are temperature dependant and the potential transport of N species that result from the reactions can be influenced by physical factors. At Bella Coola, air temperatures during the study were 0 - 5 °C, which is in the range that can slow the rate of hydrolysis and nitrification. Hence, the reduced forms of N (urea and ammonium) may have persisted in aqueous solution for up to several weeks as was found at several other coastal sites in recent studies (eg. Perrin et al 1984, Perrin 1991). The combination of low temperatures with porous soils, and heavy rainfall, can result in the rapid transport of urea shortly after fertilization. Any ammonium produced from initial hydrolysis soon after fertilization and is not retained at exchange sites can also be mobilized, usually with water flow in macropores or other channelization that reduces the contact time with reactive organic matter in the forest floor. This mobilization of urea and ammonium can be detected as an increase in concentrations within days after treatment where high proportions of drainages have been fertilized (eg. Perrin 1991, Perrin et al 1984, Stay et al 1978 in Table 1).

Table 1. Peak concentrations (PC) and time for N concentrations to return to and remain at control levels (time to recover: TTR) in comparable studies of coastal British Columbia and the northwestern US. Forest types are distinguished as hemlock/spruce associations (HS), Douglas-fir (F), hemlock/cedar associations (HC), Douglas-fir/hemlock associations (FH), Hemlock/Balsam associations (HB), and cedar/Douglas fir/hemlock associations (CFH). Percent (%) total area refers to the proportion of the entire drainage or watershed that was fertilized.

Study	Forest Type	Area Fert. (ha)	% total area	Urea		Ammonium		Nitrate	
				PC (µg/L)	TTR (d)	PC (µg/L)	TTR (d)	PC (µg/L)	TTR (d)
This study: Nusatsum tributary	HB and HF	25	12.2	No effect detected				88	>61
This study: Salloompt R.	CFH	53	1.4	No effect detected				210	>31
Perrin 1991 Honna R. (QCI)	HS	691	16.5	296	11	42	3	No Effect	
Perrin 1991 Tarundl Cr.(QCI)	HS	247	36.7	614	8	590	22	No Effect	
Perrin 1991 Honna Tributary	HS	200	92.2	2430	?	471	22	130	>70
Perrin et al. 1984 Sayward Forest	F	960	91.4	265	144	215	136	190	27
Stay et al. 1978 Oregon	F	388	46.6	400	<5	10	<5	450	<5
Perrin (1989) Holberg	HC	146	30.3	not measured		570	30	71	6
Perrin (1988) Chilliwack	FH	71	0.8	No Effect Detected					
Perrin (1990a) Rosewall Cr.	F	43	2.4	No Effect Detected				57	116
Perrin (1990a) Qualicum R.	F	209	4.4	No Effect Detected				88	118
Perrin (1990b) Squamish	HC	21	0.6	No Effect Detected				37	9
Perrin (1987) Gold R.	F	140	<0.3	No Effect Detected				110	16

Given that mobilization of urea and ammonium soon after forest fertilization does occur at coastal sites in British Columbia, the lack of similar evidence in this study suggests that dilution rather than complete retention of urea and ammonium in the forest floor was most important. Obviously, the ability to detect ion mobilization will decline as treatment area relative to total drainage area is reduced. In previous studies where concentrations of urea and ammonium measured at a treatment site could not be distinguished from those at a control site, the proportion of the drainage area that was fertilized was $\leq 4.4\%$ (Table 1). Data from the Nusatsum tributary suggest that this critical value can be as high as 12%. The fact that a nitrate response was detected, albeit a weak one, is evidence that the loss rates of nitrate may have been greater than those for urea and ammonium to overcome those dilution effects.

There is however, an alternative explanation. Urea and ammonium mobilization may have occurred as in those previous studies, but the rates of transport may have been sufficiently high that immediate transport after fertilization could not be detected in the sampling design. Soils of the Bella Coola area are very different from those typical of other coastal sites by the unique dominance of very coarse colluvium. Water transport rates in this material can be extremely high. Thus, it is conceivable that ions originating in fertilizer could be carried through the entire drainage with the rising and declining limb of storm hydrographs within hours or even minutes, particularly in the small drainages. Sampling frequencies greater than those applied to this study would be required to record such short term changes. Hence, it is possible that urea and ammonium mobilization occurred before the first sample was collected after fertilization, particularly in the Nusatsum tributary where the slope gradient was relatively high (about 30%).

Rainfall events have been repeatedly mentioned as being potentially important in controlling nitrogen transport in both the Salloompt and Nusatsum drainages. The peak concentration of nitrate in the Nusatsum tributary occurred within hours of the highest amount of daily rainfall recorded in November. The second highest nitrate concentration measured in

the Salloompt was also recorded at that time. The peaks followed an increase of 140 $\mu gN \cdot L^{-1}$ in the Salloompt and 85 $\mu gN \cdot L^{-1}$ in the Nusatsum which occurred during heavy rainfall. These were the highest one-day increases in nitrate levels recorded during the study. Highest urea concentrations were also associated with the high rainfall in November. At both the control and treatment sites in both streams the urea-N concentrations increased from ≤ 5 $\mu g \cdot L^{-1}$ to 18 $\mu g \cdot L^{-1}$. These concentrations were within the range typically expected from forest soils unaffected by fertilizer additions (eg. Perrin 1991) but the coincidental increase with higher rainfall is further evidence suggesting a causal relationship between rate of water flow in soils and streams with concentrations of dissolved nitrogen.

Comparisons of time course changes in nitrate concentrations in Figure 3 and 4 indicate the presence of a nitrate source independent of the fertilizer additions affecting both the control and treatment sites in the Salloompt but not in the Nusatsum tributary. In the Salloompt, nitrate levels at both the control and treatment sites increased from September through November. Since increasing amounts of rainfall during this period would have increased river flows, this change must be related to nitrate augmentation at both sites, not a concentration effect associated with reduced flow. Given that the control sites were not affected by the fertilizer additions, the change had to be related to nitrogen fixation, the only possible source of ambient nitrate. During the field reconnaissance, Alder (*Alnus rubra*) was found in the riparian zones at both sites but stand densities in the Salloompt (ca. 150 - 200 stems/ha) were estimated to be more than double those near the Nusatsum tributary (ca. 75 stems/ha). Some reaches of the Salloompt were completely dominated by Alder and the riparian zones in those areas may have supported much higher densities. The association between Alder and the high and variable nitrate levels is not unusual. For example, nitrate levels in some streams of the Queen Charlotte Islands that were monitored as part of another forest fertilization study (Perrin 1991) were also found to be affected by riparian zones that were dominated by Alder.

5.2 Nitrogen Export

If differences in dissolved nitrogen concentrations were large between SC and ST, continuous flow data collected by Environment Canada at a flow monitoring site at ST could be used to roughly estimate the export of added fertilizer (eg. Perrin 1991). However, the small change in concentrations of only nitrate makes this calculation somewhat futile since estimates of variation in flows between SC and ST would introduce sufficient error to question the small value that would result (ie. the estimate would be within ambient variation and could not be used to unequivocally determine the amount of fertilizer lost in streamflow).

Loss rates reported from other studies range from 0.5% to 14.5% of the applied N. Perrin (1991) measured a loss of 0.62% of N applied to Hemlock/Spruce sites in the Queen Charlotte Islands. Losses from Douglas fir sites in the Sayward Forest, Vancouver Island ranged from 2.1% where FFZ's were present to 5.2% where they were absent (Perrin et al. 1984). Hetherington (1985) reported losses ranging from 5.9 - 14.5% of N applied near Cowichan Lake on Vancouver Island. In western Washington and Oregon, loss rates range from 0.5% (Fredriksen et al 1975) to 2-3% (Moore 1974).

5.3 Water Quality

Potential toxicity of urea fertilizer lost to streams has often been raised as an important concern in systems supporting highly valued fish resources. Toxicity is not a concern with respect to drinking water quality since there is no effect of low-level consumption of ammonium and urea and peak nitrate levels in this study were 48 times lower than the 10 $mg \cdot L^{-1}$ criterion that is established in both Provincial (Nordin and Pommen 1986) and Federal (CCREM 1990) water quality guidelines. Fish, however, can develop pathological symptoms under exposure to increased levels of unionized ammonia (NH_3), the form that exists in equilibrium with ionized ammonium (NH_4^+). The proportion of total ammonia ($NH_3 + NH_4^+$) that is unionized is a

function of pH and temperature (Emerson et al 1975). At ambient temperatures of about 5°C and circumneutral pH, which was probably typical in this study, the concentration of unionized ammonia will be $<0.2\%$ of measured ammonium levels. At the peak measured concentration of 16 $\mu gN \cdot L^{-1}$, the unionized ammonia level would have been 0.032 $\mu g \cdot L^{-1}$ which is four orders of magnitude less than levels known to produce pathological symptoms in trout (USEPA 1985). Obviously, ammonia toxicity was not a possibility in this study.

Although nitrogen is an important plant nutrient in streams, both nitrogen and phosphorus limit the growth and biomass accrual of periphytic algae in coastal streams of British Columbia. This phenomenon has been clearly established in bioassay experiments (Stockner and Shortreed 1978) and river enrichment studies (Perrin et al. 1987). While the additions of N to the Nusatsum tributary and to the Salloompt River (from fertilizer and alder) may produce a very small change in autotrophic production, as has been observed during controlled N additions to streams (Stockner and Shortreed 1978), a large increase in periphyton biomass is not possible without concomitant additions of phosphorus. Without an allochthonous source of phosphorus, it is not possible to change algal production or trophodynamics (fish food production) in these tributary streams of the Bella Coola River from the forest fertilization with urea.

6.0 LIST OF REFERENCES

APHA. 1985. Standard methods for the examination of water and wastewater. 16th Edition. Amer. Public Health Assoc. Washington, D.C.

CCREM. 1990. Canadian Water Quality Guidelines. Task force on water quality guidelines of the Canadian Council of Resource and Environment Ministers. Ottawa.

Emerson, K., R.C. Russo, R.E. Lund, and R.V. Thurston. 1975. Aqueous ammonia equilibrium calculations: effect of pH and temperature. J. Fish. Res. Bd. Can. 32(12):2379-2383.

Fredriksen, R.L., D.G. Moore, and L.A. Norris. 1975. The impact of timber harvest, fertilization, and herbicide treatment on stream water quality in the Douglas-fir region. *In* Forest soils and forest land management. Proceedings of the Fourth North American Forest Soils Conference. *Edited by* B. Bernier and C.H. Winget. Les Presses de l'Universite Laval, Quebec. pp 283-313.

Hetherington, E.D. 1985. Streamflow nitrogen loss following forest fertilization in a southern Vancouver Island watershed. Can. J. For. Res. 15:34-41.

Kluckner, P.D., K.D. Taylor, and P.P.M. Wong. 1980. Automated determination of urea in freshwater samples. B.C. ministry of Environment, project No. P9022. 16p.

Moore, D.G. 1974. Impact of forest fertilization on water quality in the Douglas-fir region-a summary of monitoring studies. *In* Proceedings of the National Convention, Society of American Foresters. 1974. pp. 209-219.

Nordin, R.N. and L.W. Pommen. 1986. Water quality criteria for nitrogen (nitrate, nitrite, and ammonia). B.C Ministry of Environment, Water Management Branch, Victoria, B.C.

Perrin, C.J. 1987. Change in nitrogen concentrations and periphyton accumulation rates due to forest fertilization with urea in a "sensitive" drainage on Vancouver Island. Limnotek Research and Development Inc. contract report to B.C. Ministry of Forests. 45p.

Perrin, C.J. 1988. The change in nitrogen and sulfur transport and acid neutralizing capacity in a tributary of the Chilliwack R. after forest fertilization with urea-sulfur. Limnotek Research and Development Inc. contract report to B.C. Ministry of Forests and Dept. Fisheries and Oceans. 35p.

Perrin, C.J. 1989. Change in N and P concentrations in drainage after forest fertilization with urea and ammonium phosphate: new data for coastal fisheries-forestry guidelines. Limnotek Research and Development Inc. contract report to Western Forest Products Ltd. 50p.

Perrin, C.J. 1990a. Change in inorganic nitrogen concentrations in Rosewall Creek and the upper Qualicum River after forest fertilization with urea. Limnotek Research and Development Inc. contract report to B.C. Ministry of Forests. 15p.

Perrin, C.J. 1990b. Change in inorganic nitrogen concentrations in Mashiter Creek, Squamish Forest District, after forest fertilization with urea. Limnotek Research and Development Inc. contract report to B.C. Ministry of Forests. 13p.

Perrin, C.J. 1991. Changes in dissolved nitrogen concentrations in Queen Charlotte Islands rivers after forest fertilization with urea. Limnotek Research and Development Inc. contract report to B.C. Ministry of Forests. 24p.

Perrin, C.J., M.L. Bothwell, and P.A. Slaney. 1987. Experimental enrichment of a coastal stream in British Columbia: effects of organic and inorganic additions on autotrophic periphyton production. Can. J. Fish Aquat. Sci. 44(6): 1247-1256.

Perrin, C.J., K.S. Shortreed, and J.G. Stockner. 1984. An Integration of forest and lake fertilization: transport and transformations of fertilizer elements. Can. J. Fish. Aquat. Sci. 41(2): 253-262.

Stay, F.S., K.W. Malueg, R.E. Austin, M.R. Crouse, A. Katko, and S.E. Dominguez. 1978. Ecological effects of forest fertilization with urea on small Western Cascade streams of Oregon, U.S.A. Verh. Internat. Verein. Limnol. 20:1347-1358.

Stockner, J.G. and K.S. Shortreed. 1978. Enhancement of autotrophic production by nutrient addition in a coastal rainforest stream on Vancouver Island. J. Fish. Res. Bd. Can. 35:28-34.

U.S.E.P.A. 1985. Ambient aquatic life water quality criteria for ammonia. Environmental Protection Agency, Washington, D.C.

Wilkinson, L. 1988. SYSTAT: The system for statistics. Evanston, IL: SYSTAT, Inc.