EFFECTS OF SELECTIVE LOGGING ON PHYSICAL WATER QUALITY IN SMALL STREAMS, OKARITO FOREST

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ABSTRACT

No change in suspended solids concentration, temperature, pH, or electrical conductivity was detected at four sample sites during normal flow or in storm runoff while 25% selective logging was in progress in Okarito Forest. No differences in physical water quality were found between unprotected streams and a stream where a 20 m to 50 m-wide protection zone was left undisturbed beside the channel.

INTRODUCTION

Selective logging in Okarito Forest has been the centre of controversy concerning impacts of logging and disturbance on the lagoon ecosystem. One much-discussed possible impact for which no data have been available is the effect of logging on the water quality of small streams draining the forest and entering either Okarito River or Okarito Lagoon. The aspect of physical water quality which has received most discussion is that of sediment concentration (and sediment yield), with changes in dissolved solids and in pH as secondary concerns. Data on these apects of physical water quality in either the undisturbed state, or after disturbance by logging, have not previously been available for lowland podocarp forests, or for many other forest areas in New Zealand. In this note, we present data on concentrations of suspended sediment, temperature, pH, and electrical conductivity collected on three streams over a six-month period during selective logging in part of northern Okarito Forest.

THE SAMPLING SITES AND METHODS OF DATA COLLECTION

The sampling sites were on small streams on the north side of Okarito River in Sale Area 385 (Fig. 1). The sale area covers 58.5 ha and was logged during the period from early April 1978 to mid-October 1978. The area is considered typical of north Okarito Forest, being underlain by a complex of till and outwash deposits of the last and penultimate glaciations (Okarito Formation, Warren, 1967). The forest is a high density, stable, semi-mature podocarp stand; 98% of the standing volume is rimu (*Dacrydium cupressinum*). Standing volume in the sale area assessed by 10% appraisal was 19,290 m^3 or 330 m^3/ha, of which 25% was marked for logging. Felled trees were hauled along narrow hauler lanes in a modified radial pattern (Fig. 1) to two landings. A modified high-lead cable system operating from a 20 m log spar was used; the maximum haul distance was approximately 500 m. Logs were hauled

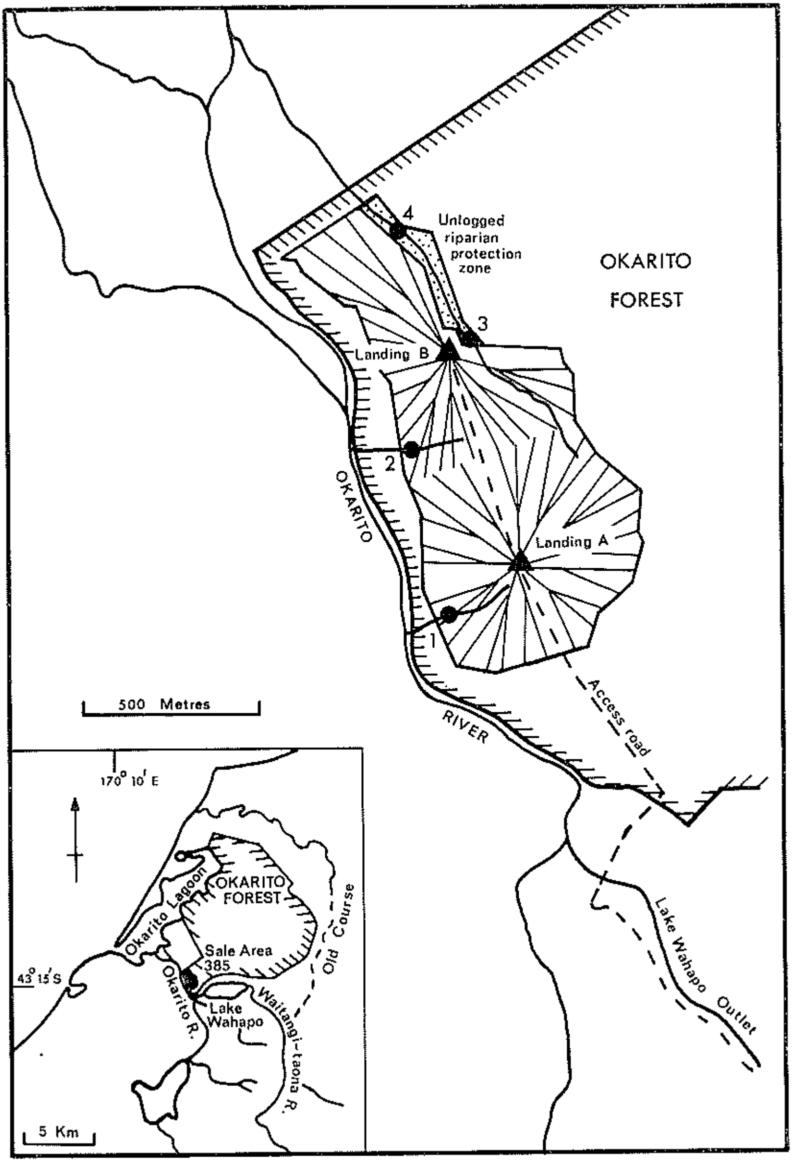

FIG. 1—Location of stream sampling sites 1 to 4 (●) in relation to hauler lanes (———) and log landings (▲) in Sale Area 385, Okarito State Forest.

to Landing B from 3.4.78 to 13.10.78, and to Landing A from 30.7.78 to 13.10.78.

The largest of the streams draining the area was considered large enough to warrant setting aside a riparian protection zone along part of its length. The protection zone boundaries were marked by N.Z. Forest Service staff after consultation with Westland Catchment Board staff. The zone (see Fig. 1) is nominally 20 m either side of the stream but extends in places to 50 m in width on one or other side of the stream; the full width ranges from about 30 m to about 70 m. Of the approximately 1 km of this stream within the logged area, approximately 500 m were without riparian protection, and one hauler lane crossed the unprotected part of the stream. This stream was sampled just downstream of the unprotected channel reach, and near the downstream end of the protection zone. Two much smaller streams draining into the main stem of the Okarito river were also sampled at sites near the edge of the logged area, downstream of several hauler lane crossings on each stream. The headwater ends of both of these channels are poorly defined even at low and medium flows, so additional sampling sites on these streams could not be found within the logged area. At each site a temporary staff gauge enabled an estimate of relative discharge at different sampling times. One litre samples of water were collected at approximately weekly intervals from March 31 1978 to October 25 1978. Water stage (depth) and stream temperature were recorded at the time of sampling. Laboratory measurements of pH, electrical conductivity, and turbidity were made using a Corning pH meter, a Toa combined pH/turbidity meter, and a Radiometer conductivity meter. Conductivity measurements were corrected to standard temperature (25°C). Samples with visible suspended solids were to be analysed by vacuum filtration. (Analysis of many hundreds of samples from North Westland has shown that samples without visible suspended sediment have suspended solids concentrations < 10 ppm, which is the lower limit of reliable measurements using this technique.) Turbidity measurements were made on samples without visible suspended solids.

Samples were also collected at 30 minute intervals for several hours during two heavy rainstorms in April and August. Laboratory measurements on these samples were made using the same methods as for the weekly samples.

RESULTS

Weekly samples

Samples collected at approximately weekly intervals were at flow depths ranging from less than 10 cm at site 4 and 15-20 cm at site 1 to depths of 40 cm at site 4 and 75 cm at site 1. The higher discharges sampled are probably between four and eight times the lower discharges sampled. The lower discharges were during lengthy dry periods, and the higher flows were during periods of light or moderate rainfalls. Water temperatures ranged from 15°C in March and April to between 7° and 11° between May and October. On two observation days in June during fine frosty weather, temperatures were as low as 4° on the larger stream and 5.5° on the smaller streams. Except during this very cold period, the range of temperatures between sampling sites was normally less than 0.5°C. The larger stream, with less complete canopy cover over the channel, recorded marginally the warmest temperatures in warm weather, and in the coldest weather, was 1.0-1.5°C colder than the smaller streams. Differences in temperature between the unprotected and protected sections of the larger stream were typically 0.0 to 0.2°C, but occasional differences of 0.5°C were recorded. No consistent pattern is apparent in the larger temperature differences between the protected and unprotected reaches.

The streams are moderately acid, with weekly measurements ranging from about 4.0 pH to 5.0 pH. The portable pH meters used in this study have a precision of about ±0.5 pH, and differences between sampling sites were within this range for all weekly samples. Within the precision of the measurements made, no seasonal or other trend in pH was apparent.

Electrical conductivity provides an integrated measure of the dissolved ionic constituents and on the weekly samples ranged from 50-85 microsiemens/cm (µS/cm) at lower flows to 30/50 µS/cm at higher flows and during the winter months. These values are comparable to conductivity data for undisturbed beech-podocarp-hardwood forests in both north Westland and south Nelson (O'Loughlin, 1979). Site 1 frequently had conductivities about 25% lower than the other sampling sites; this relationship did not change during the progression of logging from other parts of the sale area towards site 1. Differences between the other three sites were typically in the order of 5 µS/cm, without any consistent trends.

None of the samples collected at weekly intervals contained visible suspended sediment, and thus had sediment concentrations less than 10 ppm. The samples were all compared with domestic-supply tap water using the turbidity scale of a Toa "Aquamate" water quality meter, with the meter calibrated to 0.0 ppm turbidty using Harihari tap water. None of the weekly samples exceeded a reading of 1 ppm on this scale, and the bulk of samples had readings of less than 0.5 ppm. These values almost certainly cannot be compared with sediment concentrations determined by filtration, and are of doubtful precision. They nevertheless help confirm the clarity of the water samples as not greatly different from that of the normal Harihari domestic water supply, and have limited value in comparing the clarity of storm samples with those collected during low-flow periods. Data from other undisturbed forests in Westland (Pearce *et al.*, 1976; O'Loughlin *et al.*, 1978) show that forest streams typically have very low sediment concentrations except for short periods during storm runoff. The Okarito Forest streams conform to this behaviour. No differences in suspended sediment concentrations were detected between streams without riparian protection and the reach with a riparian protection zone.

Storm-period samples

Two sets of samples were collected during storm runoff following heavy rain. The first set were collected at 30 minute intervals between 1000 hours and 1500 hours on 14 April during the latter part of a rainstorm from late on 13 April to the afternoon of the 14th. During this storm 171 mm of rain fell. This storm would have a return period of about two years (Tomlinson, 1980). The flow depth at sites 3 and 4 rose from 10 cm at 1430 hours on the 13th to 110 and 90 cm respectively (a 10-fold to 30-fold increase in flow) in the late morning of April 14. Flow depths at sites 1 and 2 rose from 17 cm and 11 cm respectively to 85 and 78 cm (a 6- to 15-fold increase in flow). The maximum flow depths measured were probably somewhat after the peak flow on the smaller streams but near the peak on the larger stream. At these depths of flow, surface runoff was not confined to the stream channel, but flow at depths ranging from 5 cm to 50 cm was widespread over the forest floor. The influx of fresh rainwater caused a decrease in conductivity from 40-45 μS/cm during low flow on the morning of the 13th, to 25-35 μS/cm during the latter part of the storm runoff. No significant differences in conductivity were apparent between sites, although site 1 was the only site not influenced by logging at this time. No difference in pH was found between sites or between low flow before the storm and runoff during the storm; all measurements were approximately pH 4.0. None of the 31 samples collected during this high flow event contained visible suspended sediment; measurements on the turbidity scale of the Toa meter ranged from 0.2 ppm to 0.6 ppm, i.e. in the same very limited range as samples collected during low flow.

A second set of storm samples was collected during a major storm on the 9th and 10th of August. The rainfall total for this storm at Okarito is not known, but at least 300 mm of rain fell. The return period of this rainfall amount in 48 hours is between 5 years and 10 years (Tomlinson, 1980). Samples from the four sites were collected at 30 minute intervals between 1000 hours and 1400 hours on August 10th. Again flow depths were large, ranging from 85 cm to 90 cm at sites 1 and 2 to 135 cm on site 3; the stage height marker at site 4 (max. height 1.85 m) was overtopped by the flow. In this storm also, flow was not confined to the stream channels, but was widespread over the forest floor. Flow was about 75 cm above the channel banks near site 3, and at least 1.15 m above the channel banks near site 4. Flow rates at sites 1 and 2 were probably 10-25 times low-flow discharges, and at sites 3 and 4 were 15-75 times low-flow discharges. Conductivities of storm runoff were in the 25-35 μS/cm range, whereas during the preceding and following low flow periods conductivities were 40-45 μS/cm. Conductivities at site 1 were consistently about 5 μS/cm lower than for the other three sites. At sites 2, 3 and 4, pH values were all close to 4.0, and not different from values measured in preceding or following low flow periods. At site 1, however, some dilution from the rainfall is apparent and pH during storm runoff was between 4.5 and 5.0 in the earlier samples, but had declined to 4.0 by the end of the sample series. Visible suspended sediment was absent from all samples, and turbidity measurements were all in the range 0.1 ppm to 0.5 ppm, i.e. not different from the samples collected during lower flow.

DISCUSSION AND CONCLUSIONS

The physical water quality data collected in this study cover a wide range of flow rates. Samples were collected without regard for the timing of events such as logs being hauled across stream channels; some of the samples were collected within a few minutes of such events occurring in the channel reach upstream of the sampling sites. Nevertheless, the outstanding feature of the data is that differences were not found between the physical quality of water during low flows and that during storm runoff, between those parts of the stream with riparian protection and those without, nor between those parts of the study area that were unlogged at the beginning of the study and those that were then being logged. Suspended sediment was not detected in any of the samples collected. Within the limits of the methods used to collect and analyse the field data, then, no detectable change in physical water quality occurred during the selective logging in sale area 385.

A number of deficiencies are present in the design of this study and in the methods of analysis that were used. We contend that changes undetectable by our study methods are unlikely to have significant impacts on the Okarito Lagoon ecosystem, in view of the large natural variations in physical water quality and recent natural changes in sediment and water inputs to the lagoon resulting from the diversion of the Waitangi-taona River into Lake Wahapo. The study deficiencies include:

—the small number of sampling sites;
—the limited degree of control-treatment comparison possible;
—the rather low precision of the pH measurements;
—the lack of an accurate, precise method of measuring sediment concentrations in the range 0-10 ppm;
—insufficient storm samples obtained during the rising limb and at or near the peak flow rate of large runoff events.

All except the last of these can have only a very limited effect on the validity of the conclusion that no significant changes in physical water quality have occurred compared with recent natural changes. The small number of sampling sites prevents useful statistical evaluation of differences between sampling sites, but all streams which were affected by logging in the sale area were studied. Comparison of data from sites unaffected by the early part of the logging with those that were being affected show no systematic differences, and similiarly, no systematic differences between sites are apparent when all had been affected by logging. This comparison simply reverses the more usual comparison of data before and after logging with continued measurements on an unlogged control set of sites. Measurements of pH to $\pm$ 0.1 pH unit may have enabled detection of systematic differences before and after logging of a few tenths of a pH unit. Such changes are unlikely to affect pH of Okarito Lagoon waters because of the buffering capacity of mixed fresh and saline waters, except in the upper basin (Macpherson, in press) after large floods, and when the entrance is closed (Knox *et al.*, 1976).

If sediment concentration measurements with precision of 1 or 2 ppm had enabled changes of $<$ 10 ppm to be detected in both low flows and storm runoff, these would be insignificant relative to natural variations in the other sediment inputs to the Okarito River and lagoon. Sediment inputs are dominated by the Waitangitoana River-Lake Wahapo catchment (Macpherson, in press); prior to 1976 the Waitangi-taona River did not flow into Okarito Lagoon. The outflow of Lake Wahapo has low-flow and flood-flow sediment concentrations of about 10 ppm and 100 ppm respectively (Macpherson, in press) and discharges that are typically more than an order of magnitude greater than the combined discharge of all the small streams draining from Okarito Forest (Macpherson, in press). The post-diversion sediment input from the Wahapo outflow is about two orders of magnitude greater than the combined sediment output of the forest streams would be if all the streams were to increase their sediment concentrations both permanently and simultaneously by the maximum amount undetected (10 ppm) by our methods of measurement.

The limited number of samples in the rising part of the flood hydrograph is a more serious concern. Studies in both undisturbed and logged forests in north Westland and Nelson have shown that peak sediment concentrations often occur slightly before the peak flow rate (O'Loughlin *et al.*, 1978) and that storm runoff is often lacking in sediment on the later part of the falling limb of the hydrograph. In two large events storm runoff samples lacked suspended sediment at or shortly after the peak flow and through the bulk of the falling limb of the hydrograph. Sediment concentrations in the earlier part of large events may, however, have increased above the undisturbed condition. The rising limbs of flood hydrographs occupy only a few per cent of the total flow duration (approximately 6%, for mean rise time of 10 hours and one event per week). If rising-limb sediment concentrations in all Okarito Forest streams reached about 1000 ppm after logging, the yield in the unsampled part of the flood hydrograph would be comparable to the post-diversion sediment outflow from Lake Wahapo. Increases of this magnitude after logging have been found only in studies of clearfelling on steep hill country, where access tracks for skidder extraction have been constructed (Pearce and O'Loughlin, 1978; O'Loughlin, 1979).

Studies in New Zealand and elsewhere have shown that increased sediment yield after logging declines to pre-logging levels within a few years (Brown, 1972; Graynoth, 1979). It is most unlikely that logging has increased peak sediment concentrations to more than a few hundred ppm, and if such effects lasted for five years after logging, about one quarter of Okarito Forest would be affected at any time. Increased sediment outputs from the Okarito Forest streams could equal about 10% of the present output from Lake Wahapo, if rising-limb sediment concentrations on logged streams averaged about 400 ppm over a five year post-logging period.

More sampling of sediment concentrations on the rising-limb and during peak flow is necessary in catchments that are being selectively logged, to fully evaluate the impact of selective logging relative to natural changes such as the diversion of the Waitangi-taona River. The results of this study, however, strongly suggest that logging-related increases in sediment yield are likely to be 1% to 10% of the increase in sediment supply to Okarito Lagoon caused by diversion of the Waitangi-taona River.

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