STREAM ECOSYSTEMS

Is wood in streams a dammed nuisance?

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Large amounts of wood can enter stream channels during pine forest harvesting, but their effects on stream ecosystems are poorly understood. NIWA is carrying out a suite of studies in collaboration with the forestry industry to provide a more informed basis for managing post-harvest woody debris in streams.

TREES THAT FALL into stream channels might look unsightly to the casual observer but they play an important role in the way stream ecosystems function. Overseas work has demonstrated that woody debris can increase habitat diversity by providing cover for fish and a substrate for aquatic invertebrates. Also, wood can slow down the speed with which nutrients and organic matter are flushed from the stream so that they remain available to aquatic life for longer. Logs lying across the channel can form dams which trap sediment upstream, create pools downstream and deflect flowing water into banks causing localised erosion.

The volume of wood in native forest streams is generally low in New Zealand compared with that measured in North America. But what happens when catchments are planted in production pine forests? Wood can enter pine forest streams as windthrow or during pruning and thinning, but by far the greatest amount enters stream channels during harvesting if logs are felled or pulled over waterways.

In many parts of New Zealand, forestry companies deploy Best Management Practices which require felling away from waterways and the removal of logging debris from stream channels following harvesting. The benefits associated with removing logging debris and what happens to aquatic life if this debris is left undisturbed following harvest have not previously been quantified. NIWA is working on a project jointly funded by forestry companies and the Foundation for Research, Science and Technology (FRST) that aims to understand more fully the effects of logging debris on stream ecosystems, and to provide a more informed basis for managing post-harvest woody debris in streams.

Studies are underway to address four questions:

- how much wood enters stream channels during logging?
- how long does woody material take to break down in streams?
- how important is wood as a place to live for invertebrates?
- what are the effects of different wood management scenarios on streams?

An important issue for the forestry industry is knowing when the volume of wood in the stream can be helpful (e.g., by providing shade, water temperature control, habitat and food for biota), and when it can become harmful (e.g., by blocking up streams, lowering oxygen levels and forming debris dams).

How much wood enters stream channels?

The forestry industry uses a wide range of machinery and work practices to harvest along stream edges, resulting in varying amounts of woody debris in the stream channel. To determine exactly how much wood is entering stream channels during harvesting, Liro Ltd (formerly the Logging Industry Research Organisation) has established 21 study sites in five regions around New Zealand (Auckland / Coromandel, central North Island, Hawkes Bay, Nelson and Southland). At each site the amount of woody debris in the stream channel is measured before and after harvesting. Wood 1–9 cm in diameter is measured using randomly orientated transect lines spaced 5 m apart along a 100-m section of stream. Large wood (10 cm or greater) is measured for length, large end diameter and small end diameter. These measurements are converted to wood volumes per hectare of stream channel using a mathematical formula.

So far, pre-harvest measurements have been completed at 19 sites. The amount of wood in the streams ranged from 2 to 182 m^3/ha. Post-harvest measurement of wood has been completed at nine sites. Initial results indicate that streams in ground-based operations have much lower post-harvest wood volumes than those in hauler operations (see photo below). Ground-based operations use tracked and wheeled machines to harvest trees on flat to rolling land. Hauler operations use a stationary winch located on a landing, to haul fully or partially suspended trees from the surrounding

right: *Harvesting across a waterway using a hauler system.*

above: *Assessing the decay state of wood along stream banks* (top) *and submerged in the stream channel* (bottom).

below: *Introducing woody substrates (cones, sawn wood and sticks) into a stream in Pokairoa Forest.*

steep terrain. It is a lot easier to control the direction and movement of logs around streams on flat terrain. On steep hillsides, the physical environment, access limitations, safety issues and machine capability can make it difficult and often impossible to keep harvested material out of the streams.

How long does wood take to break down?

Wood doesn't last forever. Different tree species break down at different rates, and less durable types such as pine are often treated before being used for exterior building. In nature, once a tree falls the wood is subject to decay and attack by fungi and insects. It is not known how long pine wood in streams takes to break down and therefore how long any advantages or disadvantages of submerged logging debris might persist.

The length of time that wood stays at a site is also a function of flow regime. To factor out the effects of floods, we focused our studies of wood breakdown in spring-fed central North Island streams where flows are stable and the loss of wood at a site should be largely due to decay (assuming it has not been removed by humans). Different types of logging debris (e.g., cones, sticks) probably break down at different rates; for sticks this might be a short-term process (months to years) while for cones and logs it is likely to occur over the longer term (several years to decades).

We have taken a two-pronged approach to understanding the rates at which woody debris breaks down.

Firstly, with the assistance of staff from Carter Holt Harvey Ltd, we selected stream sites in Kinleith Forest which had been harvested between 1 and 20 years ago. Using a qualitative scale ranging from 1 (fresh) to 7 (severe decay) we measured the state of decay of large pieces of wood (>10 cm diameter) found in the streams and on the banks, to compare long-term breakdown rates in these two environments and to relate this to time since harvest (see photos, left).

The second approach was to assess short-term breakdown rates of different types of woody material (sticks <1 cm diameter, cones, sawn wood – see photo, lower left) in streams in Pokairoa Forest (Fletcher Challenge Forests Ltd) using pre-weighed material tied to stakes in the stream.

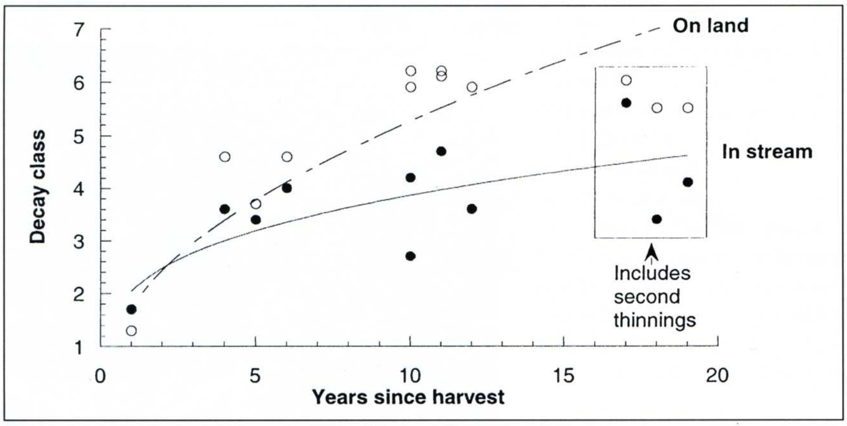
The work in Kinleith Forest was carried out in December 1996, and preliminary analysis of the data indicates that large woody debris on land becomes highly decomposed (equivalent to a score of 6) within 10 years of harvesting. Submerged wood breaks down much more slowly and is only moderately decomposed 10 years after harvesting as shown in Figure 1. Although our preliminary analysis of data from sites harvested more than 16 years ago includes second thinnings, it was nevertheless clear that most submerged harvesting material was at an advanced stage of decay after this time. The streams sampled in this survey had cool water temperatures (11–14°C) and it is likely that decay processes are faster where water temperatures are higher.

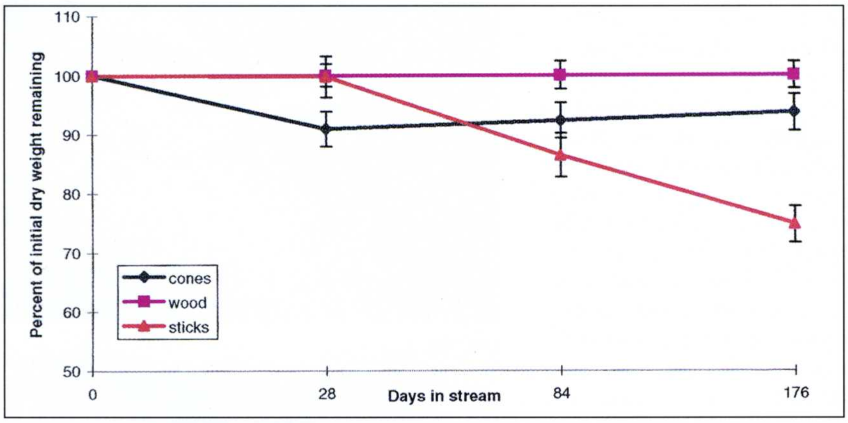
Initial data from the introduced woody-substrate study show that weight loss (an indicator of decay) was negligible for sawn wood and cones after 176 days in the stream, while around 25% of the initial weight of sticks had been lost by this time – probably due to the loss of bark – as shown in Figure 2. This part of the study will continue for at least another two years, during which time any short-term weight losses of cones and sawn wood should become evident.

Wood as a place to live

Aquatic invertebrates are usually associated with stones on the streambed, but in many central North Island streams the unstable, pumice bottoms are not suitable for most aquatic life. Large pieces of submerged wood in these streams may represent a stable substrate for invertebrate colonisation. We are investigating this potentially

below, upper:
Figure 1. The state of decay of large pieces of woody debris on the land or submerged in the stream at different times since harvest. For decay class, 1 = fresh and 7 = severe decay.
below, lower:
Figure 2. Short-term weight losses of pine cones, sawn wood and sticks kept in a Pokairoa Forest stream for up to 176 days.





Submerged wood at an advanced stage of decay with many openings provided good habitat for aquatic insects in Kinleith Forest streams (note stonefly in centre).

beneficial role of wood by surveying stream invertebrate faunas on pumice beds and on large pieces of submerged wood in Kinleith Forest, and by investigating the colonisation of different types of woody material over time in Pokairoa Forest.

Although the data have not yet been analysed it is clear from our survey work that wood provides important habitat for aquatic invertebrates. Pieces of wood at an advanced stage of decomposition and with many crevices were often teeming with mayfly, stonefly and caddisfly larvae (see photo below), and there was some evidence of invertebrates feeding on wood at less advanced stages of decay. In contrast, very few animals were found in samples collected from pumice streambeds in Kinleith Forest.

The colonisation study is being conducted in association with the short-term decomposition work described above to assess the relative merits of different types of woody material for invertebrates, and to find out how this changes with time in the stream. After 176 days in the stream, densities of invertebrates were similar on the three types of wood material (3500–4500 per m^2), and were an order of magnitude higher than on the pumice bed. Furthermore, although it is difficult to compare the number of taxa on the different substrate types directly because of differences in surface area, it was clear that woody material provided habitat for a much wider range of species than the streambed (see Figure 3).

The invertebrate fauna on sticks submerged at one of the Pokairoa Forest sites for 176 days was dominated by stoneflies, particularly *Austroperla cyrene* which appeared to be feeding on the bark. Larvae of the caddisfly *Pycnocentria funerea* were also common on all types of woody material, and there was evidence that this species had been feeding directly on the sawn wood. In contrast, invertebrate faunas on the pumice streambed were dominated by worms and mayflies. As well as providing a stable place to live for many invertebrates in pumice-bed streams, the wood at these sites also seemed to be a potentially important food source.

Wood manipulation experiments

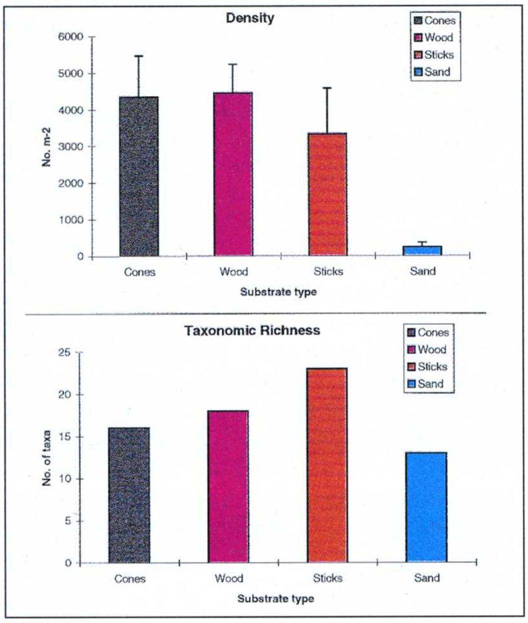
To evaluate the effects of different post-harvest management scenarios on streams we are conducting wood manipulation experiments in some Whirinaki Forest streams with relatively stable flows and pumice beds (in association with Fletcher Challenge Forests Ltd) and in a cobbly Coromandel stream with a more variable flow regime (with Ernslaw One Ltd). The post-harvest wood management scenarios being tested are:

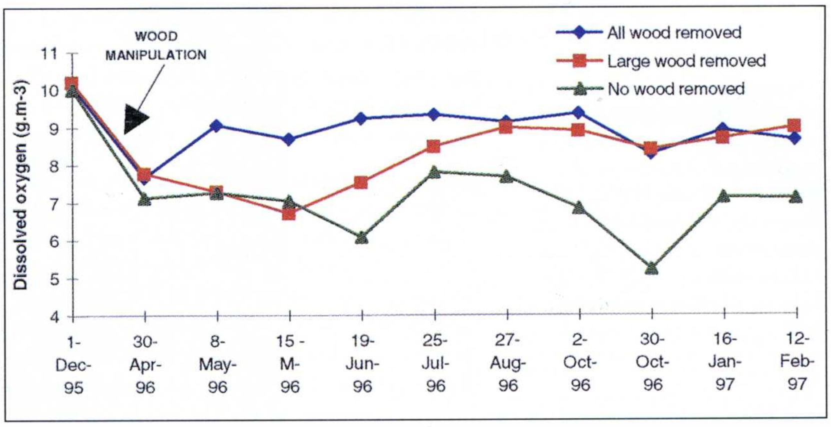
- removal of all wood from the stream channel
- removal of large merchantable pieces of wood only
- no removal of wood from the stream channel.

(See photographs, following page.)

Whirinaki experiment

For the Whirinaki Forest experiment, manipulations were carried out over entire catchments of small (0.7–0.9 m wide) streams. Measurements were made of water quality and invertebrate faunas before harvest, and are being made at various times after harvest and wood manipulation in three catchments. The data collected so far show that dissolved oxygen levels





above:
Figure 3. Aquatic invertebrate densities and number of taxa found on the sandy streambed and on cones, sawn wood and sticks after 176 days in a Pokairoa Forest stream.

above right:
Figure 4. Dissolved oxygen concentrations measured in three Whirinaki Forest streams before harvesting and following different post-harvest woody debris management.

dropped from around 10 g/m³ to 7–8 g/m³ following harvesting, but recovered to around 9 g/m³ within 15 weeks of harvest/wood manipulation where large wood or all wood was removed. Dissolved oxygen remains around 7 g/m³ at the "no wood removal" site where there was a large amount of submerged wood; this is not considered low enough to be particularly stressful to aquatic life (<5–6 g/m³) (see Figure 4).

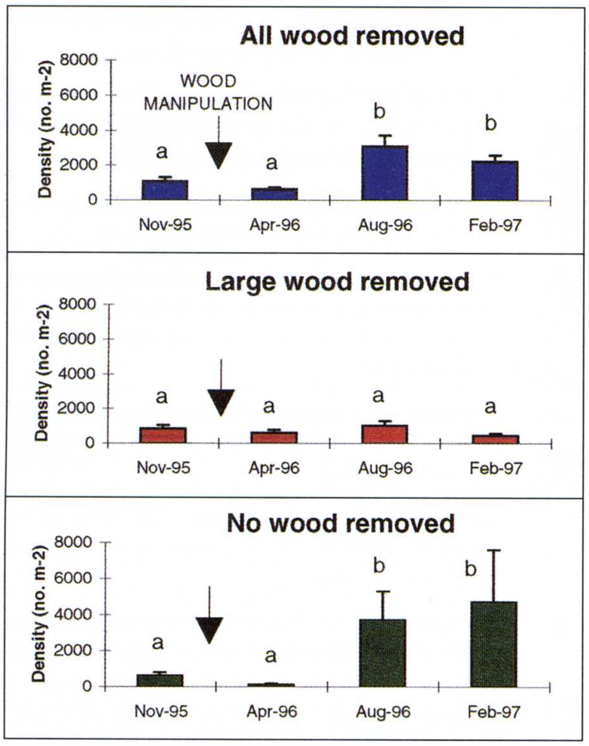
Invertebrate densities were not greatly impacted by removal of all wood or large wood only, most of which was suspended across the stream channel (see Figure 5). However, density declined markedly following harvesting where no wood was removed and there had been some channel damage. Our monitoring since then has indicated that recovery of densities has occurred quite quickly at this site as sand and small gravels filled in the spaces between the submerged wood (Figure 4). However, the invertebrate fauna at this site is still dominated numerically by worms rather than the stoneflies and caddisflies found at the other sites. The number of taxa found in the three study streams followed a similar pattern to densities.

Continued monitoring of these sites over the next two years will provide insights into the longer-term impacts of woody debris manipulation and the timescales associated with recovery to pre-harvest conditions in spring-fed, pumice-bed streams.

Coromandel experiment

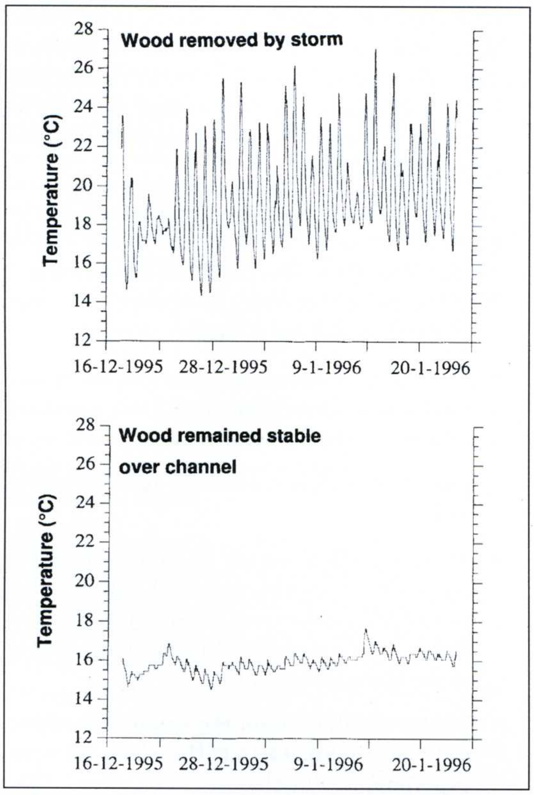
Amongst other things, this experiment aimed to determine what size of wood was stable in a small headwater catchment (<50 ha) in the Coromandel where surface runoff results in highly variable flows. An intense rainstorm (150 mm recorded overnight at a nearby site) shortly after detailed surveys of the size and position of woody debris showed that none was large enough to be stable in the long-term: all the channel wood was dislodged and accumulated in a few large aggregations at tight bends and above waterfalls

photographs, right:
Two of the Whirinaki wood manipulation sites showing all wood removed from the channel (top) *and large wood only removed* (bottom).



left:
Figure 5. Densities (means + 1 standard error) of aquatic invertebrates collected in the three Whirinaki Forest streams before and after harvesting and wood manipulations. Bars with the same letter above are not significantly different.

below:
Figure 6. Daily variations in water temperature recorded using data loggers in Coromandel streams where post-harvest wood was removed by a storm and where it remained stable over the channel of a smaller tributary stream.



and a culvert. This highlighted the over-riding effect that flow regime can have on wood stability in parts of New Zealand where the hydrology is dominated by runoff, rather than by groundwater inputs as occurs in the Whirinaki Forest streams and some other parts of the central North Island.

We were also able to capitalise on the effects of the flood by comparing summer water temperatures in the stream where the wood had been removed by the storm with those in a smaller tributary stream which was too small to have the wood washed away. The shading effect of the wood over the channel in the small tributary maintained water temperatures at around 15°C , similar to those in a mature pine forest stream nearby. At the larger site with no wood and minimal shade, water temperatures fluctuated widely during the day, often exceeding 22–25°C. Figure 6 illustrates the difference. Such levels are known to be stressful to sensitive aquatic life if they persist for long periods (e.g., 4 days) but the effects of daily falls and rises above these levels are not well understood. This experiment showed that wood over small streams can play an important role by providing shade and keeping summer water temperatures cool.

Where to from here?

The management of post-harvest woody debris in stream channels is a complex issue as it affects many different aspects of stream ecology. Our ongoing work has highlighted that wood can have both beneficial and adverse impacts in some streams, and that the timescales associated with these effects may differ. Also, issues relating to post-harvest wood management in streams relate not only to aquatic life but also to the safety of downstream users. Management of post-harvest wood in streams will need to address these issues, and will inevitably require tradeoffs between factors including short- and long-term ecological impacts and downstream safety.

The studies at Pokairoa and Whirinaki will provide information on the longer-term effects of woody debris deposited in pumice-bed streams with stable flow regimes and cool water temperatures that are typical of much of the central Volcanic Plateau area. Wood clearly provides significant habitat for invertebrates in these streams, but how important is it in cobbly streams? How important is the long-term provision of shade by wood covering the channel compared with short-term impacts on water quality? In what size of stream and under what hydrological regime does woody debris remain stable? How does wood movement affect bank and channel stability? Studies in other types of streams carried out in partnership with the forestry industry are needed to answer these questions and to formulate broadly applicable guidelines for managing post-harvest woody debris in stream channels. ■

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