STREAM ECOLOGY

Stream vegetation and flow regimes

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What influences the growth of plant beds in streams? Surveys and experiments are helping to identify and quantify the important factors.

Teachers: this article can be used for Biology L7 A.O. 7.1(a) and NCEA AS 2.5, 3.4. See other curriculum connections at www.niwa.co.nz/pubs/wa/resources

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Beds of water plants are a familiar sight in many lowland streams. These plants play a very important role as they influence nutrients, light, sediment stability, hydraulic conditions, and the abundance of micro-organisms, invertebrates and fish. Submerged vegetation creates environments that are very different from those in streams without plants.

But why do some streams have little or no submerged vegetation, while others have huge amounts? Almost certainly the most important factor is the stream's flow regime – how fast the water flows and how often floods occur. However, if we want to predict changes in vegetation when the flow regime changes – for example if water is taken out for irrigation – then it is important to be able to quantify these effects.

In this article, we describe a study on stream vegetation in relation to floods and water flows, based on plant abundance and composition in 15 lowland streams in the South Island.

Vegetation in flood-disturbed streams

We first investigated the relationship between the percentage of the streambed covered by plants (% cover) and the frequency of **floods** (see panel right).

Percentage cover by water plants was lower in streams regularly disturbed by floods than in streams with no or rare flood events. The data suggest that plants are unlikely to grow in streams with an average of more than 13 floods per year (see top graph, opposite page). A logical conclusion from this is that plants are removed during floods. Removal could happen in two ways: either whole plants are uprooted and washed away, or plant stems break in the force of the water.

Our experimental work strongly suggests that uprooting rather than stem breakage causes plant removal. During a flood, bed sediments in streams often become mobile. Erosion then causes plant roots to detach from the sediment and the plants get washed downstream.

To investigate whether the water force during floods causes plant stems to break, we recorded the loss of plant material caused by stem breakage in eight different stream plants in increasing water velocities. For all species we found that less than 1% of the total biomass

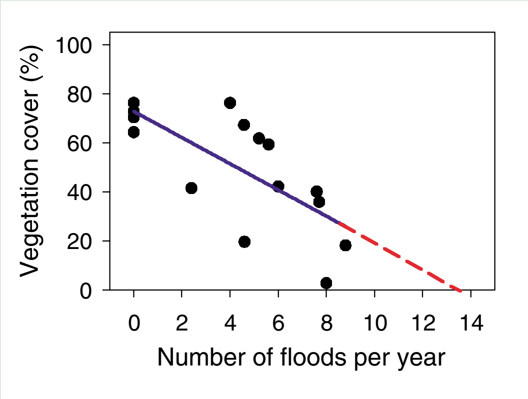
Floods

In this study we defined a flood as an event in which the daily flow was at least 7 times higher than the median daily flow calculated from data over the 5 years prior to the survey.

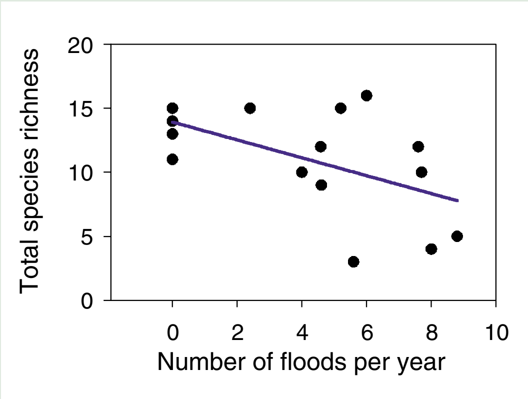
Rich beds of submerged plants in Spring Creek, near Blenheim.

was lost by stem breakage in water velocities up to 1.5 m/sec – a much faster flow than will ever occur in most lowland streams.

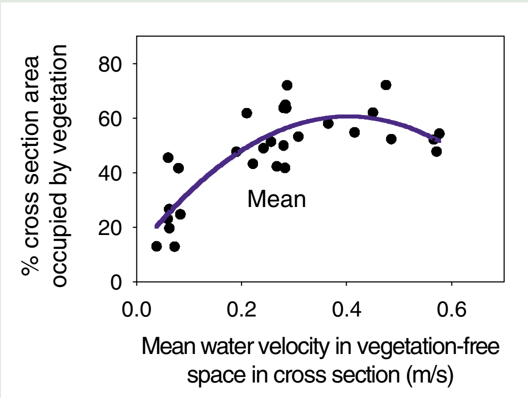
In general then, if the streambed becomes mobile during a flood, then sediment erosion could uproot plants; but if the bed is stable, only insignificant amounts of plants will be removed by stem breakage.



The relationship between the number of floods in a year and vegetation cover in 15 lowland streams. By extending the model line (blue) we estimated that in streams with more than 13 floods on average per year no plants are present (red).



The number of plant species in the study streams decreased as the number of floods per year increased.



The proportion of the area of cross-sections of streams occupied by plants increased as velocity increased, up to about 0.4 m/s, then decreased.

How fast do plants recolonise?

We also found that fewer plants were present when floods occurred more frequently, and this can be explained by the rate of plant recolonisation after a flood.

After plants have been washed away it takes a while for new plants to grow back in the empty streambed. Other researchers have found that in streams where there some vegetation remained recolonisation occurred within 3–4 months. However, we found that when all plants were removed (including seeds and underground parts) it took around 14 months before 90% of the vegetation had recovered. In this case all colonisation relies on dispersal organs (such as stem fragments and seeds) spreading in from upstream plant beds.

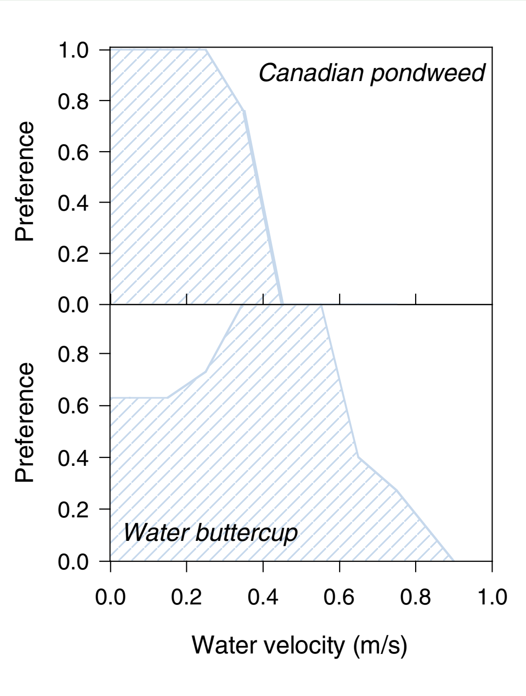
From this, we predict that streams that flood at least once every 3–4 months (with adjacent vegetation) or at least once every 14 months (with no adjacent vegetation) will have fewer plants than streams with longer periods between floods or no floods at all.

Flood frequency also affects plant species diversity in streams, with hydrologically stable streams having more species than streams that are frequently disturbed by floods (middle graph). This is because the fast-colonising species that dominate disturbed streams can also grow in stable streams. Other less efficient colonisers can persist only in stable streams. In other words, more species have the opportunity to grow in stable streams than in disturbed streams.

Vegetation in stable streams

In streams with few or no floods, vegetation can develop to maximum abundance. In these streams, water velocity in the plant-free area of the channel appears to control the maximum vegetation abundance in the stream. We calculated the percentage area of stream cross-sections occupied by vegetation along with the mean velocity in the plant-free area across the channel. We found that vegetation abundance increased with increasing velocity up to 0.4 m/s after which vegetation abundance decreased with increasing velocities (bottom graph).

The increase in abundance in the low-velocity range is most likely caused by an increase in plant growth: as water velocity increases, nutrients can diffuse more easily into the plant cells. However, some low-velocity streams can have almost 100% vegetation abundance (though none was included in our study), indicating that low abundance at lowest current velocities is not always the case. We need closer examination of species composition, nutrient concentrations and water velocities within plant beds to clarify the factors controlling plant abundance at low velocities.



Velocity preferences of Canadian pondweed and water buttercup. Preference is calculated as the proportion of observations of the species in each habitat. (In this case, habitats were defined as different water velocities.)

Hydrodynamic drag forces

Hydrodynamic drag forces are water forces acting on a submerged object in moving water. The hydrodynamic drag force is larger for an object with a large area turned towards the water current than for an object with a small area towards the water current. Imagine the strength required to keep a plate facing the water current steady, compared to the strength required to keep the plate in place if you turn the edge towards the water current. A higher drag force on the large area compared to the small area causes the difference. Plants experience different hydrodynamic drag force depending on their morphology (shape).

Water buttercup (*Ranunculus* sp.).

The decrease in plant cover at higher velocities (seen in the bottom graph, previous page) is probably caused by mobilisation of sediments in the plant-free area, which prevents plants from establishing. We found that the upper limit of mean velocity in the plant-free area in a cross-section is 0.80 m/s. Above this, we would expect no vegetation to be present. More work is required to test these ideas.

We also found that different plant species in stable streams have preferred ranges of current velocities and that the preference is correlated to the **hydrodynamic drag forces** of the plant (see panel). For example, Canadian pondweed (*Elodea canadensis*) preferred habitats with velocity less than 0.4 m/s and had relatively high drag forces. In contrast, the water buttercup (*Ranunculus trichophyllus*) tended to inhabit waters flowing at 0.3–0.6 m/s and had drag forces only 60% of that for Canadian pondweed. This suggests that plant species with lower drag (most streamlined morphology) might dominate faster flowing waters, and species with highest drag (least streamlined morphology) might only be present in slow-flowing water.

Contribution to improved predictions

Overall, this study has confirmed that flood frequency is a main controller of stream vegetation, and this explains why plants are absent from hill and mountain-fed streams where flood disturbances occur regularly. We have also shown that plant removal during floods is caused mainly by bed destabilisation rather than stem breakage. The study has gone some way towards quantifying both these effects.

Our investigations also show that in stable streams the water velocity in the plant-free area influences plant abundance and probably species composition, as different species were found to prefer different velocity ranges. Moreover, species prefer different stream velocities depending on the drag forces caused by their morphology. All these results will contribute to improving predictions of how changes in flow regimes might affect stream ecosystems. ■

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