

# Miniature Farmers on a Massive! SCALE

## Do scale insects regulate the productivity of beech forest?

- What regulates ecosystem productivity? In wet ecosystems like streams and oceans, productivity is often regulated from the top down, by large herbivores or predators. In terrestrial ecosystems, control is usually from the bottom up, and is regulated by photosynthesising plants. This is an important question for ecological researchers, because ecosystem productivity underpins the response of forests to global climate change.
- Beech trees in New Zealand are parasitized by scale insects that live in the bark of tree trunks and branches. Insects insert their mouth-parts into the wood, feed on the sugary sap, and excrete the sugar they don't need through waxy tubes. This forms droplets of honeydew, which is a vital food source for native birds and insects (Figure 1).
- This interaction offers the fascinating possibility that productivity of 1 million hectares of forest is controlled by insects' feeding; a rare and exciting example of widespread top-down control in a forest ecosystem.
- Day-to-day tree growth is regulated by the balance between carbon sources (*i.e.* photosynthesis) and sinks (parts of the plant with strong demand for energy). We hypothesise that scale insects alter source-sink balance of beech trees, stimulating extra photosynthesis which enables infested trees to compensate for the sugars lost via insect feeding.



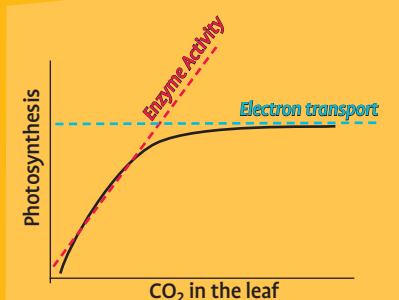
Figure 1. (Clockwise from left). Trees covered with the hair-like wax tubes produced by scale insects are a distinctive part of lowland beech forest. The small apricot-coloured insects settle in cracks in the bark, and produce hard waxy covers for protection. Mature insects have no hard exoskeleton and few distinguishing features.

## Photosynthesis: a balance of sources and sinks

- We quantified the size of the carbon source in trees with and without insects using a computer model that scales-up a biochemical model of photosynthesis to the whole canopy. Model parameters were derived from a year of field measurements (Figure 2).
- The size of the extra sink of scale insect feeding was estimated with a newly-developed computer model of honeydew production that accounts for seasonal as well as tree-to-tree variability in honeydew production.
- Trees with and without insects were partially shaded. This increases the demand for sugar production, stimulating extra photosynthesis in unshaded leaves. If our hypothesis is right, we should see less extra production in trees with insects, because the insects had already stimulated photosynthesis



Figure 2. (Clockwise from left) Measurements of photosynthesis were made on leaves at the tops of mature trees, accessed with a cherry picker. Parameters were used in a model of canopy photosynthesis that is driven by enzyme activity and electron transport in chloroplasts.



## Insects 'farming' trees for sugar

- The model estimated that trees with insects were losing 520 kg of carbon per hectare to honeydew.
- This carbon loss was balanced by extra photosynthesis. Trees with scale insects had 5% more annual photosynthesis than trees without insects, equivalent to 450 kg carbon per hectare.
- Our shading experiment showed that trees with insects had little extra capacity for photosynthesis, suggesting the insects were already stimulating photosynthesis (Figure 3).
- Our results suggest that scale insects are inducing extra photosynthesis in the trees they feed on. This is a unique example of widespread top-down regulation of forest ecosystem productivity, and shows that scale insects are effectively farming sugar from 1 million hectares of beech forest!
- This research is making an important contribution to our understanding of the productivity of native forests. This is improving models of the national carbon budget, which are an important part of New Zealand's Kyoto Protocol response. It is also giving important new insights into a keystone interaction in beech forests that is vitally important for the conservation of threatened native birds and insects that depend on honeydew for food.

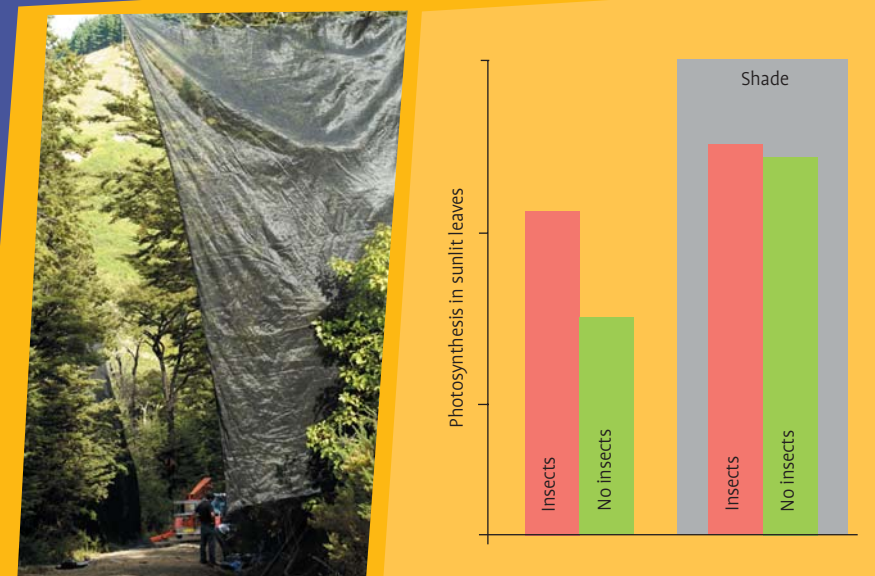


Figure 3. Trees with and without insects were partially shaded, and changes in the photosynthetic capacity of the unshaded leaves measured. Trees with insects showed less upregulation than trees without insects. This suggests their production was already increased by the scale insects.