COAT CASE STORY

# Critical transitions in ecotone forests driven by pest outbreaks

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Pest insect outbreaks in the sub-arctic birch forest of northern Norway have been described as among the most abrupt and large-scale ecosystem disturbances attributed to recent climate change in Northern Europe. But outbreaks and forest damage inflicted by moth larvae are not a new phenomenon in the north. They have occurred at regular intervals as far back as historical records go. So, what is new and why may moth outbreaks be a cause of concern for the future of the northern birch forest?

## LONGER OUTBREAKS IN A WARMER CLIMATE

The outbreak ranges of the moth species are changing in response to a milder climate. Historically, moth outbreaks in northern Fennoscandia were mainly caused by the autumnal moth – a relatively cold adapted species. The less cold adapted winter moth was not recorded north of Tromsø until early 20th century. Since then both species have spread into more northern and continental areas. During massive outbreaks during the 2000's, the winter moth reached outbreak densities over most of the region, far inland and all the way to the low arctic tree line in eastern Finnmark. The scarce umber moth, has expanded its range northwards in Troms during the last decades, and is now an important pest in coastal forests. Because the different moth species tend to reach their population peaks with a time lag of a few years, more species means longer outbreaks. This is bad news for the birch forest.

## FOREST DYNAMICS AND DISTURBANCE

Forests are dynamical systems able to withstand a certain amount of disturbance by for instance drought, storms, insect outbreaks or wild fires. Disturbances are followed by recovery back towards a similar state as before the disturbance. This ability of an ecosystem to maintain its structure and function despite disturbances is referred to as resilience. However, if disturbances become more severe or more frequent, the ecosystem may no longer be able to recover; the system has reached

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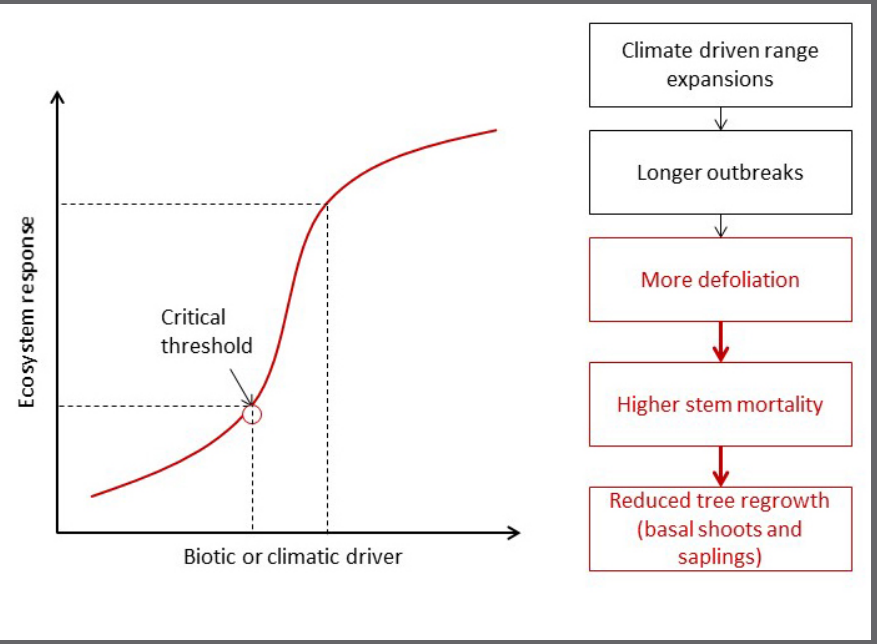
The leaf eating larvae of three species of moth are doing all the damage. From left to right: the winter moth (*Operophtera brumata*), the autumnal moth (*Epirrita autumnata*), and the scarce umber moth (*Agriopis aurantiaria*). The scarce umber moth has so far not been found in Finnmark, but is expanding its range in Troms. All three species hatch in synchrony with budburst of their host tree the mountain birch, and feed for 4-6 weeks before pupating in the soil. The adult moths emerge in autumn, mate, and lay eggs on the trunks and branches of birch.

a critical threshold. In such cases even gradual and small changes in disturbance level, may results in disproportionally large and sudden impacts on the forest ecosystem. In the northern birch forest, we have found several indications that such thresholds exist.

## A GLOOMY FUTURE FOR THE NORTHERN BIRCH FOREST?

The intensified outbreaks and the presence of critical thresholds in the response of the forest raise concern for the future of the affected areas. Relatively small changes in defoliation pressure caused by continued moth range expansions under climate warming, can cause very large increases in forest mortality and subsequent recruitment failure. This will drive a transition from forest towards more open or treeless states. However, the behavior of ecosystems that exhibit non-linear responses, as observed here, is notoriously difficult to predict. Therefore, focused long-term monitoring of both moth outbreaks and forest responses are needed to understand the implications of insect pest disturbances on the northern birch forest ecosystem. Such monitoring is currently being developed as part of COAT.




Critical ecosystem thresholds. Non-linear relationships between the level of disturbance by a biotic or climatic driver (for instance duration of insect outbreaks), and the response of the ecosystem (for instance tree mortality) indicates the presence of a critical threshold. Beyond the threshold a small increase in disturbance will result in a large change in the ecosystem. For the birch forest, such non-linear relationships have been identified both in the relationship between defoliation (the amount of leaves consumed by insect larvae) and stem mortality, and between stem mortality and regeneration from basal shoots and saplings (red sections of the figure). First, the forest can tolerate defoliation up to a certain level, but exceeding this threshold results in rapid mass-mortality of birch. Second, there is threshold behavior also in the potential for forest regrowth, as the recruitment of both saplings and basal sprouts becomes very poor if the mature tree layer is too severely damaged.

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