Habitat thresholds as guidance for forest management and conservation

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Studies of habitat thresholds have been used to estimate the risk to biodiversity and ecological function in BC,[2] Canada[3] and elsewhere.[4] Thresholds are built into reports describing planetary change.[5] The literature examining habitat thresholds has grown considerably in the 15 years since the approach was first applied in BC.[6] This summary updates evidence for habitat thresholds, describes considerations for using thresholds to guide conservation and compares the existing approach used in BC to published literature.

What are habitat thresholds?

Ecological thresholds are points of rapid change (also called "tipping points" or "regime shifts") in ecological condition in response to small changes in external factors.[7] Extensive experimental, observational and modelling evidence supports the occurrence of ecological thresholds in a variety of ecosystems.[8]

Habitat thresholds are a sub-set of ecological thresholds, identifying a habitat amount (where habitat is defined at an appropriate scale and ecosystem type for a species) associated with rapid changes in biodiversity (e.g., species richness), population size (e.g., extinction, abundance), or behaviour (e.g., patch occupancy, pollination).[9] Habitat amount influences landscape pattern; as amount declines, patches of suitable habitat become smaller and/or further apart.[10] When studies tease apart the effects of amount and pattern, habitat amount matters most.[11]

Why do habitat thresholds matter?

Habitat loss is the principal factor driving the global biodiversity crisis, as populations decline towards extirpation.[12] Habitat thresholds can indicate points of irreversible change.[13] In turn, biodiversity loss impacts ecosystem function and services (e.g., productivity, decomposition, pollination, disease spread, resilience).[14] Species, and combinations of species, play complementary roles in stabilising ecosystem function through disturbance and under variable conditions; species loss can destabilise function.[15]

Habitat thresholds matter for forest management and conservation because they provide guidance about where small changes in habitat amount may lead to important ecological change.[16]

Evidence for habitat thresholds

Studies agree that habitat thresholds are common in diverse species and regions around the globe.[17] While most studies focus on birds, habitat thresholds have been documented in mammals, amphibians, invertebrates and plants.[18] Unsurprisingly, there is no single "magic" threshold; threshold amount varies widely by study, species and region, with factors including life history (e.g., habitat specialists have higher thresholds than generalists), dispersal ability, scale, type of threshold (e.g., reproductive, population, community) and landscape context (e.g., high quality matrix habitat mitigates habitat loss; forest degradation causes population declines even with constant total amount).[19] Relevant to BC's forest management, old forest specialists will be more sensitive to loss of old growth than either generalists or young forest specialists.[20]

Sufficient evidence for habitat thresholds existed in the early 1990s to allow a meta-analysis of more than 30 studies, which found that most thresholds, where detected, occurred between 10 and 30% habitat.[21] This is the first well-cited paper that summarises evidence across species and communities for increased risk below 30% habitat. As statistical methodology and data availability improved, and projects considered larger spatial and temporal scales, subsequent studies found thresholds at higher habitat amounts, with many occurring between 30% and 60% habitat, and some above 70%.[22]

Studies of probability of extinction at different habitat levels provide additional evidence that retaining 30% of habitat threatens persistence of some species (e.g., 13/25 bird species have below a 50% probability of persistence with 30% habitat, 8/25 with 50% habitat and 3/25 with 70% habitat).[23] In the tropics, conserving 30% of the area reduces combined probability of extinction across thousands of species by 50%; conserving 50% of the area reduces extinction probability by more than 70%.[24]

As well as empirical studies, modeling studies offer guidance. For example, in modeled landscapes, habitat patches start to separate from each other at about 60% of a landscape, and become fully fragmented below 30%,[25] suggesting thresholds in landscape structure at 30% and 60%.[26]

Studies of stand-level retention find similar thresholds to those documented at the landscape scale. For example, forest bird communities in stands with low retention (about 20%) change, while those in stands with high retention (above 40 – 60%) are similar to those in mature forest.[27] Similar patterns exist in bryophytes and late-successional plants.[28] Soil communities are similar to unharvested stands at above 60 – 70% retention, and decline below 50% retention.[29]

Several lines of evidence suggest that some habitat thresholds may be higher than detected. First, poorly-studied organisms, apex predators and rare species may experience thresholds at higher habitat amounts than the birds and small mammals studied most often.[30] Unfortunately, the most sensitive species may be hardest to study, and some may already be lost.[31] Second, studies rarely consider long-enough time periods to capture time lags ("extinction debt") in response to habitat loss.[32] Third, thresholds in species richness are extreme measures, representing the endpoint of many extirpations; they may be difficult to detect because generalist species may compensate for the loss of specialists.[33]

Using habitat thresholds to guide forest management and conservation

Because quantitative targets for representing ecosystems underpin planning,[34] habitat thresholds have long been recognised as an important management tool.[35] Targets informed by thresholds have been implemented in a range of contexts, including forest management and restoration.[36] Caution is required to ensure that thresholds are applied to appropriate, representative ecosystems (i.e., "forest cover" is insufficient as a metric; thresholds must apply to different forest ecosystems).[37]

Most approaches define a minimum habitat amount that avoids high risk to biodiversity within representative ecosystems. **The evidence for high risk below 30% habitat is sufficiently incontrovertible that it inspired a global agreement for 30% conservation of representative ecosystems by 2030**.[38] Thirty percent, however, is insufficient to maintain all species: evidence for higher thresholds, up to at least 70% (see above), coupled with uncertainty, has led to concerns about choosing a single target percent.[39] Natural disturbances continue in retained old forest, meaning that realised habitat decreases over time. Setting targets based on extinction thresholds will not ensure persistence over time: managing to the high-risk precipice is a dangerous strategy.[40]

Options to address uncertainty include using precaution (i.e., setting higher targets), gathering more data or defining a range of risk with associated probabilities.

Precaution

To address evidence for higher thresholds, and uncertainty, a recent meta-analysis suggests retaining 40% as a minimum,[41] with higher areas in the tropics.[42] At the stand scale, biodiversity-friendly coffee certification uses the same threshold, requiring 40% canopy cover.[43] Several efforts have suggested that 50% of the earth should be conserved to ensure maintenance of biodiversity and ecosystem services on which we depend.[44]

Gathering more data

The variability in thresholds and concern that higher thresholds remain undetected has led to suggestions that thresholds should be regionally-defined for sensitive local species.[45] Unfortunately, while choosing regionally relevant targets might be ideal, the current crisis precludes the time for such research.[46] Management that ignores evidence due to variability and uncertainty risks damage and irreversible consequences.[47] Threshold science does not claim that a single value explains all patterns, but identifies reasonably consistent levels where risk to biodiversity is higher.[48]

Probability approach

Trying to capture the variation and uncertainty in thresholds has led to a more flexible probability-based approach that defines a region between low- and high-risk limits.[49] Meeting global conservation goals likely requires conserving somewhere between 25 – 75% of land and water.[50]

In BC[51] and Canada,[52] planning processes have used a risk curve, where risk to biodiversity is defined as the probability of crossing a habitat threshold (Figure 1). In this approach, risk is likely low with more than 70% of habitat remaining (i.e., low probability that species cross a threshold) and likely high with less than 30% remaining. Uncertainty is higher between these points, where risk will depend on species traits and landscape condition. The probability approach mirrors that used by the IPCC to define the likelihood of climate impacts.[53]

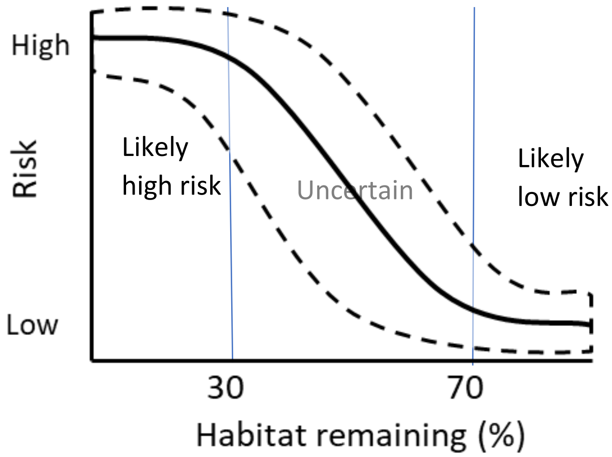

Figure 1. Habitat risk curve, based on studies of habitat thresholds and used in BC. Risk to biodiversity is likely low when more than 70% habitat remains, likely high when less than 30% remains, and less certain between.

Development of a planetary boundary framework uses a risk approach conceptually identical to that used in BC (Figure 2).[54] For a variety of factors, including biodiversity, climate change, land-use change and biochemical flows, the framework defines points for low- and high- risk, with uncertainty between, thus suggesting a "safe operating space". This safe operating space varies across factors: the biosphere integrity index suggests biodiversity intactness should be from 30 – 90% of pre-industrial values; the land-use change index (based on impacts to climate) suggests a range of 54 – 75% of original forest cover.[55]

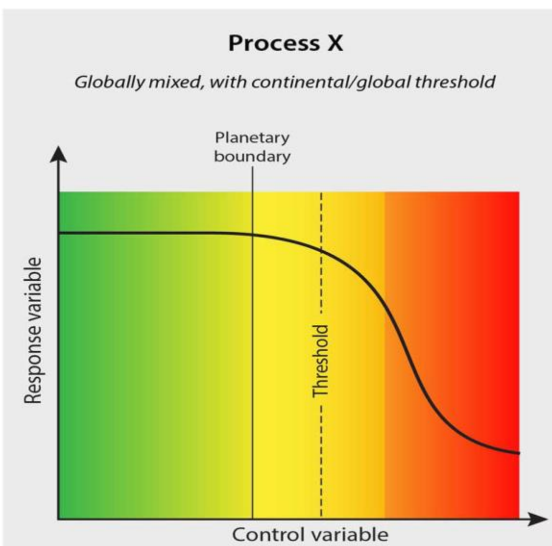

Figure 2. Copied from Fig. 1 in Steffen et al. 2015.[56] Showing a risk curve for planetary boundaries with areas of safe operating space (green), uncertainty (yellow) and high risk (red).

Conclusions

Recent evidence confirms that the approach used in BC to estimate risk to biodiversity (Figure 1) remains consistent with the best-available knowledge. The need to maintain more than 30% of representative ecosystems is incontrovertible; low-risk above 70% is less certain, but consistent with knowledge. This approach will be particularly useful if the province moves towards prioritising ecological integrity in forest management.[57]

Even when uncertainty prevents precise threshold location, awareness of the risks of crossing thresholds has led to cooperation elsewhere, in climate negotiations and avoidance of thresholds by resource extractors.[58] Multiple lines of evidence, including empirical studies, modeling studies, and traditional knowledge can reduce uncertainty, but residual uncertainty is unavoidable.[59] The approach used in BC captures uncertainty, allows flexibility in decision-making based on the acceptable level of risk, and can easily be updated as knowledge increases.[60]

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