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Framework for building models for species habitat suitability assessment in the biodiversity module of Heureka system

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Among different tools assisting biodiversity planning in forest management, habitat suitability models quantifying relationships between species and their habitats are gaining increased attention (Edenius & Mikusiński 2006). To be efficient planning tools, habitat suitability models should aim at covering a wide ecological range of potential responses of species to forest management (Rempel et al. 2004). The goal of the biodiversity module in the Heureka analysis and planning system is to provide a coherent framework based on habitat suitability modelling for assessing biodiversity scores in a changing forest landscape. Our approach is based on the focal species concept, which focuses on factors limiting species occurrence (Lambeck 1997). By addressing the needs of species representing different limiting factors our approach aims at bridging the gap between fine- and coarse filter approaches to forest management planning (Carignan & Villard 2002). The models derive habitat statistics relevant to the life requirements of species, and therefore primarily belong to landscape indices approach to conservation planning (Vos et al. 2001).

In Heureka, we have evaluated Swedish forests in respect to number of characteristics relevant for biodiversity management. We selected six forest organisms that represent a wide range of species' ecologies with respect to forest type, substrate/habitat requirement, space use and movement capability (Table 1) and simultaneously their habitat requirements may be described with commonly available forest data. Most of the species are already used as indicators and has broad geographic distribution in Sweden (Table 2). The models are intended to be used primarily at landscape scale (>1000 ha), which means that they are most applicable for large forest holdings.

Each species is classified with respect to the forest type within it mostly occurs and factor/s within that habitat most crucial for providing conditions for occurrence. These factors are then translated into model variables compatible with traditional forest data. Model variables at the stand scale are based on tree species proportions and forest age. Particular stands (or pixels in raster data representing forest variables e.g. kNN-data (Reese et al. 2003)) are scored as unsuitable, moderately good or suitable habitat. These scores correspond to habitat suitability index (HSI) of 0, 0.5 and 1, respectively. Two units of HSI = 0.5 is equal to one unit HSI = 1. Habitat suitability indices may be assessed either at pixel scale or stand scale, dependent on the data sources available and the ecology of the species in question.

Pixels with habitat scores >0 are summarized to yield a gross habitat suitability index for the whole planning area, one for each species. Alternatively, dependent on the user's interest, a combined suitability index for many species may be produced. This is done at pixel or stand scale and the joint suitability score for the whole planning area is calculated as above[1]. For species with area requirements larger than individual pixels (fine-grained species), a species-specific measure of neighbourhood quality (e.g. moving window of certain size or Minimum Linked Area concept) is applied to weigh individual pixel/stand scores by the neighbour's pixel scores before summarizing individual pixel scores (Gurnell et al. 2002;).

The models yield a habitat suitability index (or indices) for a specific forest state, i.e. a static representation of the planning area's present forest condition. For changes in the forest state (which could be done e.g. by forecasting or applying alternative forest management simulators) new landscape suitability scores must be calculated. For species where spatial context is considered of lower importance (e.g. without area requirements), the habitat suitability score may be calculated using tabular data only. For species with larger area requirements where both the size and juxtaposition of potential habitat in the landscape are of importance, the use of GIS-software may be needed in calculating habitat scores. Our approach provides possibilities to evaluate and rank different management scenarios with respect to their potential impact on the biota.

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Table 1. Ecological characteristics of focal species in HEUREKA Biodiversity Module.

Species	Species type	Forest type	Primary limitation	Model variables	References
Alectoria sarmentosa	tree living lichen	coniferous	dispersal, location	old trees	Esseen & Rehorn 1998; Esseen 2006
Harminius undulatus	predatory saproxylic beetle	all managed forest types	substrate	forest age	Schroeder et al. 2007
Lesser spotted woodpecker	resident bird	deciduous, mixed	area	dying deciduous trees	Olsson et al. 1992; Wiktander et al. 1992; Wiktander et al. 2001; Angelstam et al. 2004; Manton et al. 2005
Siberian jay	territorial resident bird	coniferous	area, dispersal	closed coniferous forest	Angelstam et al. 2004, Edenius et al. 2004, Ekman et al. 2001
Hazel grouse	territorial resident bird	mixed	area, dispersal	moist closed forest	Swenson 1993; Swenson & Angelstam 1993; Åberg et al. 1995; Åberg et al. 2000; Åberg et al. 2003; Jansson et al. 2004; Angelstam et al. 2004, Manton et al. 2005
Red squirrel	small mammal	coniferous, spruce	area, dispersal	closed coniferous forest	Andrén & Delin 1994; Delin & Andrén 1999; Gurnell et al. 2002; Rodriguez & Andrén 1999

Table 2. Focal species in HEUREKA Biodiversity Module; distribution; status and use as indicators.

Species	**Geographic distribution in Sweden***	**Conservation status in Sweden****	**Use as indicators**
Alectoria sarmentosa	HB, SB, MB, NB	-	• Natura 2000 species • Signal species
Harminius undulatus	HB, SB, MB, NB	-	-
Lesser spotted woodpecker	NE, HB, SB, MB, NB	NT	• Natura 2000 species • Indicator species in E. O. S. F.***
Siberian jay	MB, NB	NT	• Natura 2000 species • Indicator species in E. O. S. F.*** • SPEC 3 species
Hazel grouse	HB, SB, MB, NB	-	• Natura 2000 species • Indicator species in E. O. S. F.***
Red squirrel	NE, HB, SB, MB, NB	-	• NT (IUCN)

*** nemoral (NE), hemi-boreal (HB), syd- (SB), mellan- (MB), och nordboreal (NB)**
**** according to 2005 Red List of the Swedish Species**
***** Environmental Objective Sustainable Forests**

Appendix 1

Parameters of habitat suitability models

Alectoria sarmentosa (Swedish name: garnlav)

Stand scale requirements

Habitat score 1.0
- stand age ≥100 years
- spruce proportion ≥80% of standing timber volume
- **forest interior** located ≥50 m from non-forest land, clearcuts and stands with age ≤50 years or entire stands if surrounded only by forest of ≥50 years (Esseen 2006)

Habitat score 0.5
- stand age ≥100 years
- spruce proportion ≥80% of standing timber volume
- **forest edge** located within 50 m wide zone adjacent to non-forest land, clearcuts and stands with age ≤50 years (Esseen 2006)

Harminius undulatus (Swedish name: violettbandad knäppare)

Stand scale requirements
Habitat score 1.0
- stand age ≥60-100 years or 3-10 years

Habitat score 0.5
- stand age ≥100 years

Lesser spotted woodpecker *Dendrocopos minor* (Swedish name: mindre hackspett)

Stand scale requirements
Habitat score 1.0
- stand age ≥60 years (Manton et al. 2005)
- proportion of deciduous species ≥50% of standing timber volume (Wiktander et al. 1992)

Habitat score 0.5
- stand age ≥60 years (Manton et al. 2005)
- proportion of deciduous species ≥25-50% of standing timber volume

Landscape scale requirements
Only stands that create habitat network with ≥40 ha (Wiktander et al. 1992) effective area within 200 ha window.

Siberian jay *Perisoreus infaustus* **(**Swedish name: lavskrika)

Stand scale requirements
Habitat score 1.0
- stand age ≥60 years
- ≥70% coniferous trees (volume)
- ≥25% spruce (Edenius et al. 2004)

Habitat score 0.5
- stand age 30-60 years
- ≥70% coniferous trees (volume)

Landscape scale requirements
Only stands that create habitat network with ≥50 ha effective area with within 200 ha window. (Angelstam et al. 2004)

Hazel grouse *Bonasa bonasia* (Swedish name: järpe)

Stand scale requirements
Habitat score 1.0
- stand age ≥20 years (Åberg et al. 2003)
- spruce proportion ≥25% of standing timber volume (Åberg et al. 2003)

proportion of deciduous species >15-40 % of standing timber volume (Åberg et al. 2003)
Habitat score 0.5
- stand age ≥20 years (Åberg et al. 2003)
- spruce proportion ≥25% of standing timber volume (Åberg et al. 2003)
- proportion of deciduous species 5-15 % of standing timber volume (Åberg et al. 2003)

Landscape scale requirements
Only stands that create habitat network with ≥20 ha (Åberg et al. 1995, Jansson et al. 2004) effective area within 100 ha window (Jansson et al. 2004, Manton et al. 2005).

Red squirrel *Sciurus vulgaris* (Swedish name: ekorre)

Stand scale requirements
Habitat score 1.0
- stand age ≥70 years (Delin & Andrén 1999)
- spruce proportion >50% of standing timber volume (Delin & Andrén 1999)

Habitat score 0.5
- stand age ≥70 years (Delin & Andrén 1999)
- spruce proportion 25-50% of standing timber volume (Delin & Andrén 1999)

Landscape scale requirements
Only stands that create habitat network with ≥10 ha (after Rodriguez & Andrén 1999) effective area effective area within 200 ha window (after Gurnell et al. 2002).