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An indicator system for identification of sites of high conservation value for saproxylic oak (*Quercus* spp.) beetles in southern Sweden

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Abstract. The saproxylic beetle fauna on old oaks was sampled in four regions of southern Sweden using two methods: window and pitfall trapping. The aim was to test a way of finding indicator species which can be used to identify sites with high species number or that scored high on a conservation priority species index, based on occurrence of red-listed species. From 92 sites surveyed, in total 164 species of saproxylic beetles were identified. Different sets of indicator species were selected based upon 22 sites from a centrally located region. Predictions of species number and the index for 30 other sites from the same province were made. The correlation between observed and predicted species number and the index increased with increasing number of indicators. When comparing different treatment of species in data, the explanatory power of predictions was strongest for presence/absence data. Indicator sets of species effectively caught with pitfall traps gave overall the best predictions of both species number and the index. Predictions of species number and the index worked well within the same regions but gave varied result for the three other regions which shows that transferability of indicators between regions may be doubtful.

Keywords: coleoptera, beetles, saproxylic, *Quercus robur*, indicator, species density, prediction, transferability

Introduction

Among conservation practitioners, it is generally thought that protection of sites with high species richness is an efficient way of conserving overall biological diversity and an important key to preserving ecological functions (Scott *et al.* 1987; Myers *et al.* 2000). Therefore, it is important, when selecting sites for protection, to know which have the highest species richness or most rare species (Ratcliffe 1977; Usher 1986). There is also a demand for simple reliable methods that can be used in site selection with regard to protection, management and restoration (Simberloff 1998; Maes and Van Dyck 2005). Several authors have asked for an increased use of invertebrates as indicators in conservation biology (Collins and Thomas 1991; Alexander 1996; Kotze and Samways 1998, Taylor and Doran 2001). In habitats with old trees and dead wood, the saproxylic beetles form a great part of the species richness and also represent many functional groups. They have earlier been proposed as indicators for sites with high conservation interest (Speight 1989; Harding and Alexander 1994; Nilsson *et al.* 2001). Various considerations are important when selecting indicator species (Pearson 1995; McGeoch 1998). A good indicator should save time and expense by being easy to find and identify (Oliver and Beattie 1996; Jonsell and Eriksson 2002; Ranius and Jansson 2002). Among the invertebrates, there are cryptic taxonomic groups and groups that are time consuming if surveying the whole assemblages of species. Consequently, by searching for a subset of species, observers can save time and money (Gustafsson 2000; Pressey *et al.* 2000; Faith *et al.* 2001). If so, however, it is important to carefully evaluate their performance.

With their associations to important forest microhabitats such as trunk hollows, invertebrates are suggested to be especially useful indicators in habitats of old-growth forests

(Gibbons and Lindenmayer 1996). One of the most species-rich forest habitats in Europe is the remnant woodlands of ancient oaks (*Quercus* spp.), often situated in agricultural landscapes (Speight 1989; Warren and Key 1989). Many species dependent on large, old and hollow trees have survived in these small remnants. Although the conservation value of these sites is appreciated today, they are still under threat. A combination of, on one hand, intense use of some part of the land by agriculture, forestry industry or urban development and on the other hand reforestation of abandoned pasture woodlands, has caused an urgent need to restore and initiate management (Ranius and Jansson 2000; Kirby 2001). To be able to make cost-efficient use of the limited resources allocated to conservation it is important to rank the conservation value of these remaining oak patches. A suitable set of invertebrate indicators would make site selection more cost-effective. Old oaks harbour the most diverse fauna of beetles associated with old trees in Sweden (Palm, 1959) including a large proportion of the red-listed saproxylic insect species of which beetles constitute the main part (Jonsell *et al.*, 1998; Gärdenfors 2000; Ranius & Jansson 2000). These species are living in microhabitats like fungal fruit bodies, dead wood outside the tree (in branches or parts of the trunk) or inside the tree in hollows (Palm 1959; Speight 1989; Dajoz 2000). A species-rich saproxylic fauna can probably also be found, in this habitat, among Diptera and Hymenoptera, but information is currently limited.

The aim with this study was to test a way of finding sets of indicators among saproxylic beetle species living on old oaks, to be able to predict the conservation value of individual oak patches defined through the presence of species of high conservation priority or species number in this group of insects. A number of questions was addressed: (i) Is it possible to predict the conservation value of individual oak patches with sets of indicator species associated with old oaks with regard to presence of species of conservation interest (as manifested in an index) and species number? (ii) Which sampling method, of the two most commonly used, is the best for catching the set of indicator species: pitfall or window trapping? (iii) Is there a benefit in using abundance data in the selection rather than just presence/absence data? (iv) How does the number

of indicator species selected affect the result? (v) To what extent are selected sets of indicator species transferable from one region to another? The approach was that of cross validation, using one exploratory data set to identify potentially useful indicator species and a validation data set to evaluate their performance (cf. Hallgren *et al.* 1999).

Methods and study area

Study area and tree characteristics

During 1994-2000, we collected saproxylic beetles in four different regions in southern Sweden (Figure 1). In total 92 sites were studied (52, 17, 16 and 7 sites in the county of Östergötland, Uppsala-Stockholm, Örebro and Halland, respectively). All trees studied were old, hollow oaks (*Quercus robur*, but in Halland also some *Quercus petraea*) potentially sustaining a species-rich fauna.. The studied beetle species lives in rotten wood, wood living fungi and wood mould in cavities in mainly old broad leaved deciduous trees. At the sites, *Quercus* spp. was the dominating (>80%) tree with these characters, but in some sites there were also old or dead trees from other species as *Betula* spp and *Picea abies* but their saproxylic fauna could to a large extent be identified and excluded. In total 380 oaks were studied. The age of the examined trees was not known but in a survey of a part (N=73) of the studied trees from Östergötland, it varied from about 200 to 500 years (unpublished data).

Sampling methods

The beetles were collected using two methods – window trapping and pitfall trapping. At every site, four (in some five) oaks were examined and one trap of each type was set in each of the trees. The maximum distance between two traps belonging to the same site was 250 m and the minimum distance between two traps belonging to different sites was 1500 m. The trees were randomly selected among those with a cavity with wood mould large enough to put a pit-fall in. Window traps consisted of a 30 x 50 cm wide transparent plastic plate with a tray underneath (Jansson and Lundberg, 2000). They were placed near the trunk (within 1 m), beside or in front of

a hollow entrance. Their positions were 1.5-7 m above the ground, depending on where the hollow entrance was situated on the studied tree. Pitfall traps were plastic cups with a top diameter of 6.5 cm. They were placed in the wood mould in the bottom of a cavity, with the opening on level with the wood mould surface. Both types of traps were partially (about ½ of the volume) filled with ethylene glycol and water (50:50 v/v), adding some detergent to reduce surface tension. The traps were placed in the trees in mid May, were emptied three to four times and eventually removed in the middle of August. As the sampling did not cover the entire flight period for all species, some early and late species may not have been represented, or were underrepresented, in the material. In a study by Ranius and Jansson (2002), a trapping effort of five window and five pitfall traps caught 56% of a specified part of the saproxylic beetle species known to exist at the studied site from intensive trap studies (20 window and 20 pit-fall traps).

Figure 1. The four regions in southern Sweden where the sampled sites were located. A = the county of Östergötland, B = the counties of Uppsala and Stockholm, C = the county of Örebro and D = the county of Halland.

Analyses

Identification of beetles

Most of the saproxylic beetles, based on the definition by Speight (1989), were identified to species level by NJ or MJ, but some species were identified by other experts (see acknowledgements). Beetles from families or genus with no saproxylic members were not identified to species. The nomenclature follows Lundberg (1995). We decided to leave out the following taxa because they require large resources for identification and/or because of limited autecological information on them: Anaspidae, Corticaridae, Dasytinae, Nitidulidae, Ptiliidae, Salpingidae, Scolytinae, Staphylinidae (except *Velleius dilatatus*, *Quedius* spp, *Hapalaraea pygmea*, *Batrissodes* spp and *Plectrophloeus nitidus*) and Throscidae.

For 22 sites in Östergötland, we used data on number of individuals for each species, whereas only presence/absence was used for the other sites. The former data set was called “Östergötland 1”.

Conservation priority species index

For each site, a conservation priority index (CPSI) was constructed. The index is based on presence of saproxylic beetle species of a former Swedish Red List (Gärdenfors 2000). Each threat category was assigned a value (Table 1) and the sum of all values made up the CPSI. The values originate from Jansson (2006). We did not use the most recent version of the red-list (Gärdenfors 2005), which contains fewer species due to a more strict application of IUCN rules. Most of the relevant species present in the 2000 list but not in the 2005 list are demanding species often only found in oak areas with very old trees (personal observations, NJ), even though they do not fulfil the new standards of the red list. When the red lists from 2000 and 2005 were compared on a beetle material from old oaks, there was a strong correlation in number of red-listed species per site between the two versions, but the average number of red-listed species per site (n=15) decreased by 73% (from 15 to 4; Jonsell 2005).

Table 1. Threat categories of the Swedish Red List from year 2000 (Gärdenfors, 2000) with the contributed score used for each category in this study to calculate CPSI (Conservation Priority Species Index).

Category	Contribution to CPSI
Near threatened (NT)	1
Vulnerable (VU)	3
Endangered (EN)	5
Critically endangered (CR)	5

Comparison of the sites from the different regions

To make a comparison between different sites and regions a Detrended Correspondence Analysis (DCA) was conducted on presence/absence data from all sites. The purpose was to illustrate similarities in species composition, using CANOCO 4.5 (ter Braak & Smilauer 2002).

Importance of type and number of indicator species and abundance data

The analysis procedures, described below, involved several steps, and was conducted independently for the two target variables (CPSI and species number). The overall purpose was to identify sets of indicators, and to evaluate their performance through cross-validation on independent data.

For each target variable, all steps were repeated for three types of data for Östergötland 1: (i) abundance data (ii) square-root-transformed abundance data and (iii) presence/absence data, but only the procedure for abundance data is described below.

In the first step, species were ranked according to how much their number or occurrence correlated with the target variables. This was done with Redundancy Analysis (RDA; CANOCO 4.5) and with the data set Östergötland 1 (number of sites = 22, with abundance data). From the two ranking lists (CPSI and species number), we then chose three different sets of indicator species, each including the nine highest ranked species that met one of the following criteria: (1)

large species (>4mm) easy to identify, (2) species effectively caught by window traps, (3) species effectively caught by pit-fall traps. The classification of the species and the frequency of the species when using different survey methods were based on Ranius and Jansson (2002) and how effectively the species are caught with the different sampling methods and how difficult the species are to identify was based on NJ's own experience. In the second step we built models (one for each indicator set) describing the relationship between the number of indicator species on a site and the target variables. This was done with regression and the number of indicator species was used as the independent variable. The number of the nine indicator species found per site was used as independent variables and target variables as dependent). In the third step, the estimated regression parameters from the exploratory data set (second step) were used to calculate predicted CPSI and species number values for sites in a confirmatory data set (Östergötland 2, 30 sites). In the fourth step, the correlations between observed and predicted CPSI and species number for Östergötland 2 were calculated.

For both target variables, all of the above steps were repeated also for different numbers of indicators, from three to nine. In total, this generated 126 regressions (3 criteria x 7 different numbers of indicator species x 3 data treatments x 2 target variables) based on Östergötland 1 and 2. To get an overview of the performance of the many combinations of methods and species data, correlation coefficients (R) and slope values, were compared. The correlation coefficients and slope values were ranked, and according to ranking scores were given (3, 2, 1 and 0 for comparisons of the type of indicator sets and 2, 1 and 0 for comparisons of the treatment of the data). Two types of scores were calculated: the highest R and slope closest to one. The scores were then summed and reported as percentage of sum of total score.

Transferability of indicators to other regions

To evaluate the transferability of the sets of indicator species to other regions, we used the regression equation based on Östergötland 1 to predict CPSI and species number for the sites in

the provinces of Uppsala-Stockholm (N=17), Örebro (N=16) and Halland (N=7). We used the regression equation based on nine indicator species in the sets and presence/absence data.

Results

Overview of the data

A total of 164 species of saproxylic species were identified at the 92 sites. Of these, 22 species were on the Swedish red list for 2005 (Gärdefors 2005) and 41 were used to calculate CPSI, i.e. on the 2000 list (Gärdenfors 2000). The number of saproxylic beetle species found at the sites varied from nine to 62 and the number of red-listed species from one to 13.

The DCA showed a large overlap between Östergötland and Örebro but for Uppsala/Stockholm and Halland the overlap with the other regions was small or non-existing (Figure 2). Östergötland 1 and 2, the exploratory and confirmatory data sets, overlapped well.

There was a strong correlation between the CPSI and species number for the 92 sites (Figure 3).

Selection of indicators

The RDA ranked species according to how well their abundance, or presence, explained the variation in CPSI or species number (species score in Table 2). The species that had the highest species score in the RDA for presence/absence data (>0.65) and thus were most related to the target variable were, for CPSI, *Cryptophagus micaceus* Rey, *Osmoderma eremita* Scopoli, *Allecula moria* Fabricius, *Mycetophagus piceus* Fabricius and *Scraptia fuscula* Müller (Table 2). Corresponding species for species number were *Osmoderma eremita*, *Cryptophagus micaceus*, *Scraptia fuscula*, *Globicornis nigripes* Fabricius and *Allecula morio* (Table 2). CPSI and species number resulted in relatively similar ranking of species (Table 2) and several of the chosen indicators species were common for the different sample methods (Table 3).

The (formerly) red-listed species contributed both to the response variable and the explanatory variables in the present RDAs, and this means that a certain degree of autocorrelation

is present. Such autocorrelation should be most pronounced for CPSI and nearly negligible for species number. Therefore, the similar ranking might suggest that autocorrelation is of minor importance.

Figure 2. Sample scores from a DCA of the saproxylic beetle fauna from 92 sites with old oaks in four different regions in Sweden (Östergötland represented by two data sets; see text for explanation). Eigenvalues for axis 1 and 2 were 0.179 and 0.110, respectively and total inertia 2.785.

Validation

Importance of type of indicators

The best regression model was selected based on which predictions performed best in

Östergötland 2, considering both R and slope (close to 1; Table 4). If taking both the correlation coefficient and the slope of the correlation curves in consideration, the indicator species set

“species best caught with pit-fall traps” gave the best result for the prediction of CPSI and species number.

Figure 3. The correlation between species number and CPSI (Conservation Priority Species Index) for the saproxylic beetle species from 92 sites with old oaks in southern Sweden.

Importance of abundance data

The analyses using square-root-transformed abundance data and presence/absence data gave similar or better results than untransformed abundance data for prediction of both CPSI and species number. If also taking the slope of the curves into consideration, presence/absence data worked best for CPSI while the abundance data gave best results for species number (Table 5).

Table 2. Species scores for the species in six different RDA (Redundancy Analysis) of saproxylic beetles from 22 sites with old oaks in the county Östergötland, Sweden, using three types of species frequency data, and two types of response variables (CPSI and species number). The species are sorted after species score from the RDA for species number and presence/absence data. Species names written in bold type are the selected indicator species from analysis of presence/absence data. Figures in parenthesis are in the order the indicators (pit-fall traps) were used. R1 = Red list category in Swedish red list 2000 (Gärdenfors 2000) and R2 = Red list category in Swedish red list 2005 (Gärdefors 2005).

Species	R1	R2	Number of sites	Number of specimens	CPSI			Species number		
					Abundance	Square of abundance	Presence/absence	Abundance	Square of abundance	Presence/absence
					Spec score	Spec score	Spec score	Spec score	Spec score	Spec score
Osmoderma eremita	VU	NT	11	65	0.30	0.54	0.72 (2)	0.17	0.43	0.74 (1)
Cryptophagus micaceus	NT		16	89	0.51	0.70	0.79 (1)	0.48	0.64	0.71 (2)
Scaptia fuscula	NT		15	188	0.38	0.52	0.66 (5)	0.57	0.67	0.69 (3)
Globicornis nigripes	VU	VU	7	19	0.56	0.61	0.64	0.64	0.68	0.68
Allecula morio	VU	NT	16	195	0.36	0.54	0.71 (3)	0.34	0.53	0.68 (4)
Plegaderus caeseus	NT		6	17	0.38	0.42	0.43	0.58	0.64	0.63
Mycetophagus piceus	NT		16	110	0.20	0.39	0.66 (4)	0.22	0.38	0.62 (5)
Cryptophagus populi			6	13	0.21	0.21	0.19	0.43	0.51	0.55
Anobium nitidum			11	23	0.46	0.54	0.50	0.39	0.51	0.55
Mycetochara axillaris	NT		7	20	0.23	0.36	0.48	0.25	0.41	0.54
Calambus bipustulatus	VU	NT	9	11	0.48	0.51	0.53	0.61	0.58	0.53
Euglenes oculatus			18	184	0.00	0.21	0.61	0.03	0.22	0.53
Quedius cruentus			8	27	0.19	0.23	0.23	0.39	0.48	0.53
Megatoma undata			16	36	0.32	0.41	0.46	0.38	0.48	0.51
Hedobia imperialis			6	8	0.34	0.38	0.39	0.52	0.54	0.51
Dorcatoma flavicornis	NT		14	228	0.02	0.22	0.50 (9)	0.08	0.27	0.49 (6)
Pseudocistela ceramboides			21	122	-0.27	-0.14	0.39	-0.15	0.00	0.49 (7)
Nemadus colonoides	NT		7	13	0.31	0.41	0.48	0.45	0.49	0.49
Lymexylon navale	VU	NT	7	16	0.43	0.48	0.50	0.45	0.47	0.48
Gastrallus immarginatus	NT		9	19	0.44	0.52	0.58	0.41	0.44	0.46 (8)
Procræus tibialis	VU	NT	9	25	0.41	0.50	0.59 (7)	0.44	0.47	0.46 (9)
Ampedus cardinalis	VU	NT	14	26	0.14	0.28	0.40	0.18	0.32	0.45
Agrilus laticornis	NT	NT	3	3	0.44	0.44	0.44	0.45	0.45	0.45
Tenebrio opacus	VU	VU	5	15	0.56	0.61	0.61 (6)	0.36	0.41	0.44
Atomaria morio			13	78	0.37	0.41	0.32	0.47	0.52	0.41
Dendrophilus corticalis			20	206	0.12	0.23	0.41	0.19	0.32	0.40
Prionychus ater			18	77	0.48	0.56	0.52 (8)	0.59	0.59	0.39
Ptinus rufipes			20	253	0.10	0.20	0.41	0.45	0.51	0.39
Quedius scitus			8	13	0.15	0.17	0.20	0.36	0.38	0.38
Palorus depressus			3	3	0.07	0.07	0.07	0.37	0.37	0.37
Quedius brevicollis			6	14	0.26	0.27	0.24	0.44	0.43	0.36
Cryptophagus scanicus			19	229	0.07	0.14	0.34	0.26	0.27	0.35
Ptinus sexpunctatus	VU	NT	1	1	0.16	0.16	0.16	0.35	0.35	0.35
Velleius dilatatus	VU		15	93	0.30	0.39	0.51	0.32	0.34	0.34
Conopalpus testaceus	NT		7	25	0.63	0.64	0.60	0.39	0.38	0.33
Cryptophagus dentatus			9	48	0.25	0.28	0.25	0.53	0.51	0.33
Anoobium rufipes			2	2	0.30	0.30	0.30	0.33	0.33	0.33
Batrisodes delaporti	EN	VU	2	2	0.30	0.30	0.30	0.33	0.33	0.33
Batrisodes venustus			1	6	0.10	0.10	0.10	0.32	0.32	0.32
Rhizophagus cribratus			1	1	0.10	0.10	0.10	0.32	0.32	0.32
Scydmaenus hellwigi			6	8	-0.04	-0.01	0.02	0.26	0.29	0.32
Agrilus sulcicollis			4	17	0.15	0.23	0.29	0.36	0.38	0.31
Ptinus fur			21	300	0.32	0.38	0.38	0.44	0.49	0.31

<i>Tenebrio molitor</i>			10	52	0.32	0.36	0.38	0.33	0.33	0.30
<i>Stenichnus godarti</i>			8	10	0.26	0.26	0.24	0.43	0.37	0.30
<i>Hapalaraea pygmea</i>	NT		4	31	0.48	0.47	0.42	0.27	0.27	0.25
<i>Orchesia micans</i>			2	2	0.15	0.15	0.15	0.25	0.25	0.25
<i>Liocola marmorata</i>	VU		9	61	0.12	0.18	0.18	0.35	0.39	0.24
<i>Mycetochara linearis</i>			7	62	0.17	0.33	0.52	0.07	0.15	0.24
<i>Cerylon ferrugineum</i>			9	31	0.14	0.14	0.07	0.42	0.41	0.24
<i>Leipus nebulosus</i>			5	7	0.14	0.11	0.07	0.28	0.26	0.23
<i>Ctesias serra</i>			21	214	0.26	0.39	0.23	0.50	0.60	0.22
<i>Dorcatoma chrysomelina</i>			21	704	-0.16	-0.11	0.23	-0.01	0.07	0.22
<i>Ampedus balteatus</i>			18	55	-0.37	-0.29	-0.08	-0.23	-0.07	0.22
<i>Anthrenus scrophilarie</i>			7	26	0.01	0.04	0.04	0.04	0.12	0.21
<i>Ampedus hjorti</i>	NT		14	41	0.02	0.16	0.23	0.03	0.15	0.19
<i>Cryptophagus labilis</i>	NT	NT	1	1	0.20	0.20	0.20	0.19	0.19	0.19
<i>Uloma rufa</i>			1	1	0.20	0.20	0.20	0.19	0.19	0.19
<i>Hypebaeus flavipes</i>	VU	VU	5	9	0.32	0.37	0.39	0.20	0.20	0.19
<i>Mycetophagus quadriguttatus</i>	EN	VU	2	2	0.14	0.14	0.14	0.18	0.18	0.18
<i>Triplax aenea</i>			2	4	0.11	0.11	0.11	0.29	0.25	0.18
<i>Lyctus linearis</i>	VU	VU	1	1	0.28	0.28	0.28	0.17	0.17	0.17
<i>Elater ferrugineus</i>	VU	EN	4	5	0.31	0.34	0.36	0.12	0.15	0.17
<i>Corticeus fasciatus</i>	EN	VU	3	3	0.39	0.39	0.39	0.17	0.17	0.17
<i>Phymatodes testaceus</i>			14	39	-0.16	-0.13	-0.08	-0.02	0.06	0.17
<i>Cryptophagus quercinus</i>	NT		10	83	-0.07	-0.10	0.07	0.03	0.03	0.16
<i>Sinodendron cylindricum</i>			5	8	-0.11	-0.09	-0.07	0.12	0.14	0.15
<i>Uloma culinaris</i>	NT	NT	1	1	0.39	0.39	0.39	0.15	0.15	0.15
<i>Cerylon histeroideus</i>			18	38	0.06	0.06	0.01	0.36	0.33	0.14
<i>Dermestes lardarius</i>			8	9	-0.05	-0.02	0.00	0.04	0.10	0.14
<i>Anthrenus museorum</i>			13	35	0.37	0.32	0.18	0.27	0.23	0.13
<i>Mycetophagus populi</i>	NT		2	3	0.30	0.29	0.27	0.15	0.14	0.12
<i>Triplax russica</i>			5	12	-0.12	-0.07	0.02	-0.15	-0.04	0.12
<i>Xyletinus pectinicornis</i>			5	9	0.17	0.22	0.27	0.12	0.12	0.12
<i>Trichocele memnonia</i>	NT		13	35	0.61	0.66	0.28	0.40	0.44	0.12
<i>Mycetochara flavipes</i>			5	9	0.10	0.04	-0.03	0.27	0.21	0.11
<i>Pentaphyllus testaceus</i>	VU	NT	2	11	0.15	0.16	0.18	0.05	0.08	0.11
<i>Grammotera ustulata</i>	VU	NT	6	7	0.24	0.23	0.21	0.15	0.12	0.09
<i>Cryptophagus badius</i>			15	135	-0.19	-0.21	-0.10	-0.15	-0.08	0.09
<i>Diaperis boleti</i>			17	73	-0.31	-0.30	-0.03	-0.08	-0.11	0.09
<i>Eledona agaricola</i>			6	92	0.08	0.06	-0.05	0.06	0.05	0.07
<i>Paromalus flavicornis</i>			5	11	-0.02	-0.08	-0.13	0.23	0.15	0.06
<i>Attagenus pelli</i>			5	11	0.08	0.12	0.02	0.17	0.20	0.05
<i>Alosterna tabacicolor</i>			16	38	-0.05	-0.10	-0.12	-0.01	0.00	0.04
<i>Atomaria bella</i>			1	1	-0.21	-0.21	-0.21	0.02	0.02	0.02
<i>Rhyncolus ater</i>			7	9	-0.17	-0.11	-0.04	-0.05	-0.02	0.02
<i>Melanotus castanipes/villosus</i>			14	65	-0.52	-0.48	-0.30	-0.24	-0.17	0.00
<i>Xestobium rufovillosum</i>			22	211	-0.18	-0.18	0.00	0.01	-0.03	0.00
<i>Endomychus coccinea</i>			1	1	0.10	0.10	0.10	0.00	0.00	0.00
<i>Cryptophagus confusus</i>	NT		10	26	-0.27	-0.27	-0.20	-0.25	-0.17	-0.01
<i>Tillus elongatus</i>			3	5	-0.02	-0.05	-0.08	-0.05	-0.04	-0.03
<i>Ampedus pomorum</i>			5	7	-0.20	-0.19	-0.17	-0.02	-0.03	-0.04
<i>Hadrobregmus pertinax</i>			2	2	0.12	0.12	0.12	-0.05	-0.05	-0.05
<i>Myceiochara humeralis</i>	NT	NT	10	49	0.05	0.00	-0.06	0.07	0.00	-0.06
<i>Trox scaber</i>			11	49	0.43	0.33	0.07	0.28	0.17	-0.06
<i>Ptinus subpilosus</i>			20	398	-0.06	-0.01	-0.07	-0.07	-0.01	-0.09
<i>Gnathoncus spp</i>			21	103	0.26	0.24	-0.15	0.45	0.43	-0.15
<i>Ampedus nigroflavus</i>	NT	NT	4	5	-0.12	-0.10	-0.08	-0.20	-0.19	-0.16
<i>Xyletinus longitarsis</i>			2	2	-0.30	-0.30	-0.30	-0.16	-0.16	-0.16
<i>Grynocharis oblonga</i>	VU		12	41	-0.14	-0.15	-0.12	-0.15	-0.18	-0.18
<i>Atomaria umbrellae</i>			1	1	-0.15	-0.15	-0.15	-0.20	-0.20	-0.20

Rhyncoilus sculptratus		2	3	-0.32	-0.29	-0.24	-0.32	-0.30	-0.28
Orchesia undulata		1	3	-0.38	-0.38	-0.38	-0.29	-0.29	-0.29
Dacne bipustulata		13	155	-0.56	-0.64	-0.73	-0.40	-0.42	-0.49
Korynetes caeruleus		6	7	-0.45	-0.50	-0.53	-0.45	-0.51	-0.54
Quedius microps	NT	2	2	-0.56	-0.56	-0.56	-0.58	-0.58	-0.58

Table 3. Indicator species effectively observed with different sampling methods for prediction of CPSI (Conservation Priority Species Index) and species number. The figures are the rank they got from repeated RDA analysis only using presence/absence data.

species	large & easy		pit-fall		window	
	CPSI	species number	CPSI	species number	CPSI	species number
Allecula morio	2	2	3	4	2	4
Osmoderma eremita	1	1	2	1		
Cryptophagus micaceus			1	2	1	1
Scraptia fuscata			5	3	4	2
Mycetophagus piceus			4	5	3	5
Procraterus tibialis	5	8	7	8		
Calambus bipustulatus	6	3				
Tenebrio opacus	3		6			
Pseudocistela cerambyoides		6		7		
Globicornis nigripes					5	3
Prionychus ater	7		8		9	
Conopalpus testaceus	4				7	
Megatoma undata		4				8
Ampedus cardinalis		9		9		
Dorcatoma flavicornis			9	6		9
Dendrophilus corticalis						
Hedobia imperialis		5				
Euglenus oculatus					6	
Lymexylon navale	9	7				
Anobium nitidum						6
Quedius cruentus						7
Gastrallus immarginatus					8	
Velleius dilatatus	8					

Table 4. Results from comparisons of three different indicator sets, with species effectively observed with different sampling methods and after three different methods of treating the data. Regressions were made between observed and predicted CPSI (Conservation Priority Species Index) and species number for a confirmatory dataset (Östergötland 2) after analysis of an exploratory data set (Östergötland 1). Comparisons of correlation coefficients (corr) and slopes of the curves from these regressions were made between different numbers (3-9) of indicator species. The figures are percentage of sum of total points from these comparisons of correlation coefficients and slopes respectively.

CPSI	abundance		sqrt transformed		presence/absence	
sampling method	corr	slope	corr	slope	corr	slope
large & easy	17	19	10	48	19	52
pit-fall	57	43	62	14	62	19
window	26	38	29	38	19	29
Species number						
sampling method	corr	slope	corr	slope	corr	slope
large & easy	33	28	32	29	57	14
pit-fall	22	44	32	38	38	64
window	44	28	36	33	5	23

Table 5. Results from comparisons of three different methods of treating the data. The comparisons were made for three different indicator set of species effectively observed with different sampling methods. Regressions were made between observed and predicted CPSI (Conservation Priority Species Index) and species number for a confirmatory dataset (Östergötland 2) after analysis of an exploratory data set (Östergötland 1). Comparisons of correlation coefficients (corr) and slopes of the curves from these regressions were made between for different numbers (3-9) of indicator species. The figures are percentage of sum of total points from these comparisons of correlation coefficients and slopes respectively.

CPSI	large & easy		pit-fall		window	
data treatment	corr	slope	corr	slope	corr	slope
abundance	10	19	10	52	22	44
sqrt transformed	24	33	33	9	33	32
presence/absence	67	48	57	39	44	24
species number						
data treatment						
abundance	11	16	0	29	0	14
sqrt transformed	26	47	33	38	36	41
presence/absence	63	42	67	33	64	45

Number of indicator species

The correlation coefficient (R) increased with number of indicator species in many cases, independent of indicator set (method for effectively detecting the beetle fauna) and for data with or without abundance (presence/absence; Figure 4). The correlation was generally higher for the analysis of data without abundance.

Transferability of indicators to other regions

The predictions of the CPSI based on data from Östergötland 1 worked well in Uppsala-Stockholm (comparable R with Östergötland 2) but were poor in Örebro and Halland (Figure 5a). For predictions of species number, Uppsala-Stockholm and Örebro were comparable with Östergötland 2, while it was poor for Halland (Figure 5b).

Discussion

We conclude that it is possible to predict the conservation value of saproxylic beetles in individual oak patches with sets of indicator species with regard to the presence of conservation priority species (CPSI) and species number associated with old oaks. This makes it possible to save time and money by searching for a subset of species instead of surveying all species in the

Figure 4. Correlations (R) of the observed and the predicted (4A) CPSI – Conservation Priority Species Index and (4B) species number with different number of beetle indicator species for the sites (n=30) with old oaks in Östergötland 2. Results from analyses of data from all three indicator sets (from three different methods for sampling the fauna) with abundance data and only presence/absence data.

assemblages. It might, in our case, seem easier to estimate the quality of suitable habitat (e.g. count number of hollow oaks). For example Grove (2002) used tree basal area and dead wood volume, instead of using species as indicators. However, results from earlier studies are

Figure 5. Correlation of observed and predicted (5A) CPSI (Conservation Priority Species Index) and (5B) species number for sites from four regions in southern Sweden (the counties of Östergötland, Uppsala-Stockholm, Örebro and Halland). The indicator species used are nine species effectively observed when sampling with pit-fall traps inside hollow oaks: Both species sets are from the analysis of data when only presence/absence data were used.

conflicting. On one hand, Siitonen (1994), Økland *et al.* (1996) and Franc *et al.* (2007) have shown that habitat quality (local amount of dead wood) have weak relationships with species

number of saproxylic beetles. In the study by Franc *et al.* (2007), it was instead suggested that the amount of dead wood at the regional scale and the area of oak dominated woodland key habitats within one km of sites were the main (and strong) predictors of variation in local species richness of oak beetles. On the other hand, Martikainen *et al.* (2000) and Penttilä *et al.* (2004) showed a positive relationship between the amount of dead wood and the number of saproxylic species. Also Ranius (2002) found a positive correlation between species richness and stand size. The reasons for the conflicting results with regard to the correlation between substrate and number of saproxylic beetles species may be a result of the history of the studied areas. Speight (1989) points out that British forests lacking continuity in time are species-poor even though there are trees 200-300 years old, i.e., tree ages known to be enough to create suitable substrates for saproxylic beetles. The other way around, Hanski and Ovaskainen (2002) show that small forests fragments in southern Finland are more species rich than expected probably due to an extinction debt. By searching for a limited number of indicator species and get an estimation of the number of conservation priority species, a better decision base for site-selection for conservation may be gained by combining area, substrate quality and indicator species at a reasonable cost.

Insect indicators have successfully been used to predict species richness for the same taxon (Eyre and Luff 2002; Ranius 2002) as in this study. It is less clear to what extent insect indicators show strong correlation with other taxonomic groups and if they can be used for diversity/richness estimations. Some studies report success (e.g. Nilsson *et al.* 1995; Lambeck 1997; Jonsson and Jonsell 1999; Pearson 1999; Kerr *et al.* 2000; Fleishman *et al.* 2005) while others report poor performance (Faith and Walker 1996; Dufrêne and Legendre 1997; Duelli and Obrist 1998; Grand *et al.* 2002; Kotze and Samways 1999; Sverdrup-Thygeson A 2001, Vessby *et al.* 2002; Weibull *et al.* 2003). However, in remnant woodlands with ancient oaks, as in this study, saproxylic beetles constitute a large part of the total biodiversity on their own and using indicator species from this group will probably give a good estimation of the conservation value of the site.

The correlation between CPSI and species number for the 92 sites was strong. Parallel to this, there were large similarities between our chosen indicator species for CPSI and species number (six species out of nine; Table 2). High species number in sites rich in rare or red-listed species has also been shown for butterflies and plants (Patterson and Atmar 1986, Wright *et al.* 1998, Pearman and Weber 2007, Wittig *et al.* 2007). However, the ability to predict CPSI was weaker than the ability to predict species number. This may result from the high degree of stochastic occurrence or patchy distribution that often characterise rare species (Mouna 1999; Thomson *et al.* 2007) or the fact that they are so rare that catching them is largely dictated by chance (Martikainen and Kouki 2003).

Rare and threatened species have sometimes been identified as useful indicators (Lawler *et al.* 2003, Warman *et al.* 2004, Tognelli 2005). Their usefulness, however, decreases with increasing rarity (Mouna 1999; Martikainen and Kouki 2003). The species in our indicator sets were a mixture of species, both common and rare species (Table 2), which to some extent should buffer for such chance effects. Furthermore, Larsen *et al.* (2007) found positive effects when adding rare, endemic and range-restricted species in indicator groups mainly consisting of large-bodied and widespread species.

In the literature, there are various ways to select indicators and differing ambition in evaluating them. Most previous authors have, based on expert knowledge, suggested different saproxylic beetle species as indicators for different valuable phenomenon, like areas with high significance for conservation aspects (Speight 1989; Müller *et al.* 2005), areas with hollow trees (Niklasson and Nilsson 2005), sites with continuity of saproxylic habitats (Alexander 2004), sites with continuity of large trees (Martin 1989; Nilsson and Baranowski 1994) or many red-listed species (Nilsson *et al.* 2001). Other authors have evaluated the candidate proposed through their expert judgement: e.g. Ranius (2002) showed that *Osmoderma eremita* Scopoli was associated with species richness of beetles in tree hollows, and Buse *et al.* (2008) that *Cerambyx cerdo* was associated with high species richness of saproxylic beetles on old oaks.

Some authors have used statistical methods to select indicators from data on species assemblages. For example, Jonsell and Nordlander (2002) suggested that among the polypore-inhabiting insects, *Oplocephala haemorrhoidalis* might indicate forests of high conservation value (long continuous supply of dead wood). In the present study, we also used a statistical tool (RDA) to select indicators from a species assemblage, but we then also thoroughly evaluated the indicators through cross validation, i.e. applying them on an independent dataset. In addition, we also applied them to data from other regions, to evaluate their spatial transferability (c.f. Buse et al. 2007).

It is interesting to note that some of the suggested, but unconfirmed, indicators from the studies mentioned above, also had a high explanation degree in our analysis (Table 2). For example: *Tenebrio opacus* Duftschmidt was suggested as an indicator of primeval forests structures and features (Müller *et al.* 2005); *Allecula morio* Fabricius as an indicator of valuable areas with hollow trees (Niklasson and Nilsson 2005) or many red-listed species (Nilsson *et al.* 2001); *Ampedus cardinalis* as an indicator of forests of international importance to nature conservation (Speight 1989) and together with *Procræus tibialis* Lacordaire, as indicators of valuable sites with continuity of large trees (Martin 1989; Nilsson and Baranowski 1994).

In the present study, correlations between CPSI/species number increase with and a higher number of indicator species (Figure 4). However, the increase in correlation was surprisingly modest. Therefore, it may be possible to use a smaller set of indicator species with good results. Ranius (2002) suggest the presence of a single species, *Osmoderma eremita*, as an indicator of species richness of beetles in tree hollows. However, a problem with using presence/absence of single species as indicators is the categorical classification of the evaluation. With a higher number of indicators, it also becomes possible to rank sites. Another consequence of using a higher number of indicator species relates to the geographical transfer of protocol: more species meant that the selected species could better predict species number in distant areas (data not shown).

Sample methods and whether abundance or only presence/absence is used influence the cost of a survey. In the current analysis, there was only a small added value from the abundance data, so the much simpler and cheaper presence/absence records is preferable.

In the current study, the indicators best caught with pit-fall sampling gave the best predictions in most of the cases (Table 4). The sample size has earlier been discussed in Ranius and Jansson (2002) and calculations showed that pit-fall traps in ten hollow oaks captured 75% (18 of 24) of the saproxylic beetle species living in hollows on old oaks caught with a large trapping effort of 20 window traps and 20 pitfall traps. The cheapest sampling method, when comparing full scale inventories, has earlier been showed to be wood mould sampling, as it involves only one field visit (Ranius and Jansson 2002) but in this case, when using pitfall traps and only searching for a low number of indicator species, the difference in time/cost for the methods becomes smaller. If the wood mould is dry and old one probably gets a picture of the fauna from the past 10-20 years until the present. On the other hand, if one compares sites sampled with window and pitfall traps in only one year, there is an unknown degree of fluctuation between the years that might give you different outcome. Insects in general have large population fluctuations. But many of the species living on old oaks, like in this study, uses substrate types that can be more or less stable for many decades on a specific tree. Of course their populations fluctuate too, of different reasons, but they are generally more stable (Ranius 2007). Another reason for getting fluctuations in the number of caught individuals by the traps is the weather conditions during the season of a specific year. But as long as you are not working with abundance it will only be a serious problem for rare species with low population sizes. It is expected that the quality of the predictions would decrease when geographically moving away from the origin of the model and the inevitable change in species composition or other factors. Kalwij et al. (2005) showed that the lichen *Lobaria pulmonaria* used as an indicator of ecological continuity in many countries, did not work in Switzerland.

The predictions were weakest in Halland, the most species-poor region. A problem with the indicator sets selected based on the Östergötland material is the lack of parts of the species in the other provinces. Probably, our selected indicator sets work best in regions with high species richness and with many red-listed species. Dahlberg and Stokland (2004) and Franc *et al.* (2007), showed that both species richness and number of red-listed oak beetles increase in Sweden from west to east. Our data show a similar pattern. This gives an indication that geographic direction may influence transferability.

In conclusion, our results indicated that the most efficient way to identify oak areas of high conservation value is to use pitfall traps and the generated indicator set. Our two indicator sets could be used to predict the conservation priority species index and number of species. A reasonable selection of indicators can be achieved using only presence/absence data. As little as three indicator species seemed to work well, but the result improved with higher numbers, especially when working in species poor regions or regions far from where the indicators originating from.

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