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Sand pits as habitat for ground beetles (Carabidae): does the area affect species number and composition?

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Abstract

Sand pits are a valuable habitat which can hold many sand living species including several endangered ones. As many sand habitats with exposed sand are declining, sand pits have a potential as a substitute habitat.

This study was conducted to see what effect the area of a sand pit has on species number and composition of ground beetles (Coleoptera: Carabidae). Also, the effects of other environmental variables were tested, for example the proportion open sand, vegetation cover, sun exposure and tree cover. The study was conducted in the county of Uppsala in 2008 and included 13 sand pits with areas between 200 and 180,000 m^2. Pitfall traps were used as sampling method.

The study showed that the area of the sand pit affected the number of sand living species, which increased with an increasing area. The medium sized sand pits (~5,000 m^2) had the highest number of sand living species, while the largest sites (~100,000 m^2) had slightly less species probably because the large sites had a more homogeneous habitat. In smaller sand pits the proportion of sand living species was lower which indicate an edge effect.

The species composition was quite similar between most sites irrespective to its area. However, some of the small sand pits had a deviating composition due to the edge effect. Still, this suggest that a wide range of areas of the sand pits seems not important to preserve to include all sand living ground beetle species, even if some variation always is preferable. The species composition is however influenced by proportion open sand.

Based on this study, the recommendation is that sand pits preserved should have an area of more than 2,500 m^2. A recommendation of an optimum area cannot be given as large sites with a heterogeneous habitat might be as species rich as medium sized ones. However, as smaller areas are more cost efficient to preserve the main focus is recommended to be on medium sized sand pits.

Populärvetenskaplig sammanfattning

Sandtäkter är ett värdefullt habitat för många sandmarksarter, även för flera sällsynta och rödlistade sådana. Stora ytor exponerad sand har öppnats upp av den mänskliga aktiviteten och skapat varma och torra miljöer som många sandmarksarter behöver. Sandtäkter är ett relativt nytt habitat i landskapet då brytning av sand hade sin början för omkring 100 år sedan. Övriga sandmarker, så kallade ”naturliga”, minskar i utbredning och kvalité. Detta beror främst på utebliven störning vilket leder till igenväxning av den exponerade sanden. Sandtäkter kan därmed fungera som ett substituthabitat för dessa försvinnande sandmarker. Många sandtäkter har nyligen lagts ner eller kommer att läggas ned, så det är nu det finns möjlighet att bevara dessa habitat.

Alla sandtäkter är inte lika artrika och antalet arter borde bero på flera faktorer. En sådan är arean på sandtäkten och det är främst den som undersökts i den här studien. Antagandet bygger på den välkända ö-biogeografiteorin som säger att större habitat har fler arter. Att veta vilken area som hyser flest arter är viktig kunskap för att kunna göra prioriteringar i arbetet med bevarande av områden.

I studien, som utfördes i Uppsala län 2008, inventerades jordlöpare med hjälp av fallfällor i 13 sandtäkter med olika area (200–180 000 m^2). Totalt hittades 892 individer av 58 arter jordlöpare, varav 20 var typiska sandmarksarter. Förutom arean så undersöktes även en rad andra miljövariabler såsom andel sand, trädtäckning, trädhöjd, vegetationstäckning, solexponering och omkringliggande områden. Dessa variabler kunde dock inte visas ha något samband med artantalet i denna studie.

Arean på sandtäkten visade sig dock påverka antalet sandmarksarter positivt. Men det var de medelstora täkterna (~5 000 m^2) som hade allra flest sandmarksarter. De största täkterna (~100 000 m^2) hade något färre arter vilket kan bero på att de täkterna var ganska enformiga som habitat med stora plana ytor och lite vegetation.

Det är inte bara viktigt att titta på artantal vid prioritering av områden utan även på artsammansättningen. Om sammansättningen är olika beroende på arean så skulle olika areor behöva vara representerade för att alla arter ska kunna bevaras. Det visade sig dock att artsammansättningen inte var beroende av täktens area. En avvikande sammansättning kunde dock urskiljas i vissa av de minsta täkter, men de avvikande arterna var inga sandmarksarter. Däremot visade det sig att andelen sand i täkten påverkar artsammansättningen.

Kanteffekter kan påverka ett habitat och dess arter på flera olika sätt, t. ex. att mikroklimatet påverkas eller att arter från omkringliggande habitat vandrar in. Andelen sandmarksarter var lägre i de mindre täkterna, vilket troligen är orsakat av en kanteffekt. I de mindre täkterna hade fler skogsarter vandrat in vilket påverkade andelen sandmarksarter. De invandrade arterna kan tänkas konkurrera ut sandmarksarterna och detta kan vara en orsak till att små täkter har färre arter. Det är även troligt att större habitat har fler mikrohabitat vilket gör att de kan hysa fler arter.

Sammanfattningsvis så är sandtäkter viktigt att bevara eftersom andra sandmarker försvinner och eftersom täkterna kan fungera som ett substitut för arterna som är beroende av sandmarker med exponerad sand. Täkter med en area på mindre än 2 500 m^2 borde inte prioriteras vid naturvårdssatsningar eftersom de hyser färre arter och påverkas av kanteffekten. Utifrån studien går det inte att ge en rekommendation om den optimala arean eftersom stora täkter med en annan utformning skulle kunna hysa lika många arter som de medelstora. Däremot kan det ändå rekommenderas att prioritera de medelstora täkterna eftersom de har visat sig vara artrika och eftersom de är mer kostnadseffektiva att bevara. Dock är det alltid viktigt med en viss variation.

Introduction

Habitats on sandy soil

Sand habitats with exposed sand are important for many species. The insect fauna is especially rich, foremost when it comes to beetles (Ljungberg 2002) and stinging wasps, Aculeata (Abenius 2006; Hallin 2005). A dry and warm microclimate is typical for these habitats and the sandy soil makes it possible for the insects to easily dig burrows and galleries in the exposed sand.

Open sand habitats have never been a common element in the landscape in Scandinavia. Their distribution is restricted to areas with both sand and disturbance. The occurrence of sandy soil in the earth-layer is mostly concentrated as eskers and sometimes as plane deltas, formed by deposits from the ice rivers (Clason & Granström 1992; Sjögren 1999). To keep the habitat open and sand exposed a disturbance is also necessary. In plant ecology, disturbance is defined as “the mechanisms which limit the plant biomass by causing its partial or total destruction” (Grime 2001). As a result of the disturbance, the habitat is kept at an early succession stage and overgrowing is prevented. Examples of disturbance are grazing, trampling, fire and erosion. As sand habitats are nutrient poor the rate of overgrowing is relatively slow (Svedlund 2000) and it usually takes 20-40 years before most of the sand is covered with vegetation (Bergsten 2007).

The sand habitats have decreased in distribution and quality as a consequence of cease or decline in different disturbance regimes. Grazing on poor sandy soil has been moved to more fertile grazing-grounds (Gärdenfors 2000). Forest fires have effectively been fought since the beginning of 2000th century and slash-and-burn agriculture have ceased (Berglind 2005). The heathland, which need burning and grazing, have decline from 500,000 ha to less than 2,500 ha the last 100 years (Stenström & Forshed 2004). Landslide and erosion processes are prevented e.g. by planting (Bernes 2001), as was the case for many sand dunes (Persson 2008; Sohlman 2008). In addition, the sand habitats are threatened by fertilizing and an increase in nitrogen deposit which leads to a faster rate of overgrowing even on sites with disturbance (Ljungberg 2002; Sörensson 2006).

The consequence of the decrease of sand habitat was evident as a large number of species depended on the habitat was brought to the red-list or was lifted to a higher category of threat in 2000. In addition to the insects, a number of plants and fungi were included (Gärdenfors 2000). The situation was no different according to the 2005 red-list (Gärdenfors 2005).

Even though most disturbance regimes have declined, the disturbance caused by human activity has increased and have created new sand habitats. These manmade habitats seem to function as substitute for several sand living species (Eversham *et al.* 1996; Ljungberg 2002; Svedlund 2000; Sörensson 2004). A few examples of these habitats are artillery ranges (Jonsell 2004; Eriksson *et al.* 2005), road verges (Vermeulen 1993) and not least sand pits (e.g. Berglind 2005; Johansson 2006; Sörensson 1983; Fig. 1). The term sand pits, as used in this paper, include of both sand- and gravel pits.

Figure 1. This sand pit in Korsbacken is a manmade sand habitat with large areas of exposed sand which can harbour several sand living species. This habitat can substitute the declining “natural” sand habitats.

Sand pits and its biological values

Sand pits have been shown to be a valuable habitat for many sand living species (Fig. 2), for example among beetles (Ljungberg 2001; Molander 2007; Sörensson 1983), stinging wasps (Bergsten 2007; Johansson 2006; Sörensson 2006), butterflies, vertebrates (Frycklund 2003) and plants (Andersson 1995; Widgren 2005). Several of the species found in sand pits are rare or endangered (Bernes 2001; Eversham 1996; Frycklund 2003). For ground beetles, as much as 50 % of the red-listed species have been found in sand pits (Ljungberg 2002).

Figure 2. Examples of species found in sand pits in the county of Uppsala. From the top left: *Apalus bimaculatus* (bibagge), *Philanthus triangulum* (bivarg), Sand martin nests *Riparia riparia* (backsvala), *Sphecodes albilabris* (stort blodbi), Ortolan *Emberiza hortulana* (ortolansparv), *Cicindela campestris* (grön sandjägare), *Harpalus rufipes* (åkerfrölöpare), *Notiophilus sp.* (ögonlöpare sp.).

Even so, within nature conservation attention to the biological value of the sand pits has just recently been paid. The former negative attitude towards sand pits originate in the destruction of the beautiful esker environment and therefore the pits were seen as a wound in the landscape. The former attitude still lives on, for example with the bylaw required after-treatment of the sand pits. The change in attitude now seen is probably connected with the decrease of sand habitats, as was the case in Western Europe (Sörensson 2006).

Entomologists have for a longer time been aware of the high values of sand pits as a habitat where interesting and rare species could be found. In a summary of the beetle fauna of Omberget, Palm (1931) mentioned several sand pits and in the book of Swedish ground beetles by Lindroth (1961), sand pits were included as habitat for several species.

One of the first inventories of sand pits, initiated by a county administrative board, was conducted in Gotland by Sörensson (1983), where a rich insect fauna was found including several rare species. Since then sand pits have been included in some inventories (e.g. Björklund *et al.* 2004; Johansson 2006; Sörensson 2004) but only a few inventories have had the focus on the sand pits. In a study of one sand pit in Trelleborg, three solitary bees (*Apoidea*) new to Scandinavia was found together with several red-listed or rare species of insects (Sörensson 2006). In the county of Skåne the beetle fauna was studied in five sand pits and 16 red-listed species were found (Molander 2007). In the county of Uppsala four red-listed butterflies and Sand-martin *Riparia riparia* (backsvala) were inventoried in sand pits in

Uppsalaåsen and a summarize was made which included all red-listed species noted in sand pits in the county of Uppsala (Frycklund 2003). In the county of Stockholm an extensive inventory were conducted in 2006, including 50 sand pits. The result showed that red-listed species was found in almost all sand pits inventoried (Bergsten 2007).

The biological value of sand pits has more recently been included in several informative publications, e.g. from the National Environment Protection Board (Bernes 2001), the Board of Agriculture (Appelqvist & Svedlund 1998), the county administrative board of Östergötland (Karlsson 2008) and the municipality administrative board of Borås (Pleym 2000). Also popular science articles have been published about the subject (Lönnell & Ljungberg 2006; Svedlund 2000).

In 2006 there were 1,110 licensed sand pits in Sweden and the trend is that they become fewer but larger. The extraction of sand and gravel started in a larger scale about one hundred years ago and reached its top in the 1970's. Since then the production have decline and have started to be replaced by crushed bedrock (aggregates) from stone pits (Anonymous 2007).

Environmental variables affecting species numbers and composition

Sand pits, as any other habitat, differ in species number and species composition between sites depending on a number of different variables. In species conservation it is important to understand which factors influences the species number and composition and how, to be able to prioritize within nature conservation when preserving sites. One factor which probably influences this is the area of the sand pit.

The species-area relationship is well known and originates from the island biogeography theory which states that large islands harbour more species than small ones. The theory could also be applied for different habitats, which can be seen as islands in the landscape (MacArthur & Wilson 1967). Several studies have shown a positive species-area relationship in sand habitats e.g. ground beetles in *Calluna* heathlands (Gunnarsson & Götmark 1998; de Vries *et al.* 1996), beetles in artillery ranges (Jonsell 2004) and beetles in sand pits (Molander 2007).

Another aspect of how the area of a habitat could affect its species is the edge effect, which is the effect the surrounding area has on the habitat and its species. Small habitats have a more pronounced edge effect because of their larger proportion of edge habitat (Ries *et al.* 2004).

In addition to the area of the sand pit, several other environmental variables can affect the species number and species composition. A rich flora is important for several insects as food resource, and more plant species enables the presence of more specialists (Bergsten 2007; Frycklund 2003; Sörensson 2004). The cover of trees and bushes need to be low, not to shade the sand. However, a few trees and bushes give shelter from the wind and contribute to a warmer microclimate, which is important for many of the sand living species (Bergsten 2007). That is also why the southern slope is described as an important element (Bergsten 2007; Johansson 2006; Molander 2007; Sörensson 2004). Few studies have been conducted to test how the different environmental variables affect species number and composition, so most of the knowledge comes from more anecdotal experience.

To study ground beetles

The beetle family Carabidae, ground beetles, is a well known group, both ecologically and taxonomically, with a relatively high species number, about 330 species in Sweden (Lundberg 1995). The ground beetles are interesting to use in nature conservation studies because many of them are threatened, 68 were red-listed in 2005 (Gärdenfors 2005). The ground beetle fauna in sand pits is special, composing of species from many different habitats, with species which otherwise rarely coexist (Ljungberg 2002). As most of the species are polyphagous carnivores (Fig. 3), omnivores or seedeaters they are not dependent on certain host plants (Ljungberg 2001).

Ground beetles are most commonly studied with pitfall traps, which is a time and cost efficient method. Catches from pitfall traps can estimate ground beetle density between similar habitats, but cannot be used in comparison between species because the catch frequency depends on the activity and size of the species (Desender & Maelfait 1986; Spence & Niemelä 1994).

Figure 3. Many of the ground beetles are carnivores as this species, *Cicindela campestris*. Notice its powerful jaws.

When studying species richness it would be too time consuming to include all species groups. A better option would be to find one group that can be used as a biodiversity indicator to indicate the total species richness. It is important to choose the right group as indicator but there are no perfect indicators which correlate with all other groups (Vessby *et al.* 2002). In open habitats at an early succession stage and in sand habitats, ground beetles are suggested as suitable indicators (Björklund *et al.* 2004; Ljungberg 2001). However, only a few studies have tested ground beetles as biodiversity indicators and the results vary. Positive correlations have been found between ground beetles and other beetles, and between ground beetles and other insect groups (Rainio & Niemelä 2003).

The aim of this study

This study aim to help choose which kind or kinds of sand pits should be prioritized within nature conservation to preserve the sand living ground beetles.

The main question was how the area of a sand pit affects the number of sand living ground beetle species present. In addition, a few other environmental variables were tested: Cover open ground, Proportion open sand, Tree cover, Tree height, Lower vegetation cover, Sun exposure and Surroundings.

It was also tested if the species composition differed between the sites and if any of the variables above had an effect on species composition. Difference in species composition would lead to a need of variation in the habitats preserved instead of aiming towards one optimum kind.

The influence of the edge effect, measured as proportion sand living species, was studied to see if there was a noticeable effect which was influenced by the area of the sand pit. The species found in the study could also assess the suitability of sand pits as a substitute habitat for sand living species.

Materials and methods

The study sites

The study was conducted in the county of Uppsala, Sweden, in 2008 and included 13 study sites located in Enköpingsåsen north of Enköping (5), Vattholmaåsen (1) and Uppsalaåsen between Uppsala and Mehedeby (7). Three additional study sites were intended to be in the study but had to be excluded, due to sampling problems at the sites (Fig. 4). The study sites consisted of sand pits, both abandoned and those with low activity. In this report, the term sand pit is used as a generic term for both sand- and gravel pits. The area of the sites range from 200 m^2 to 180,000 m^2.

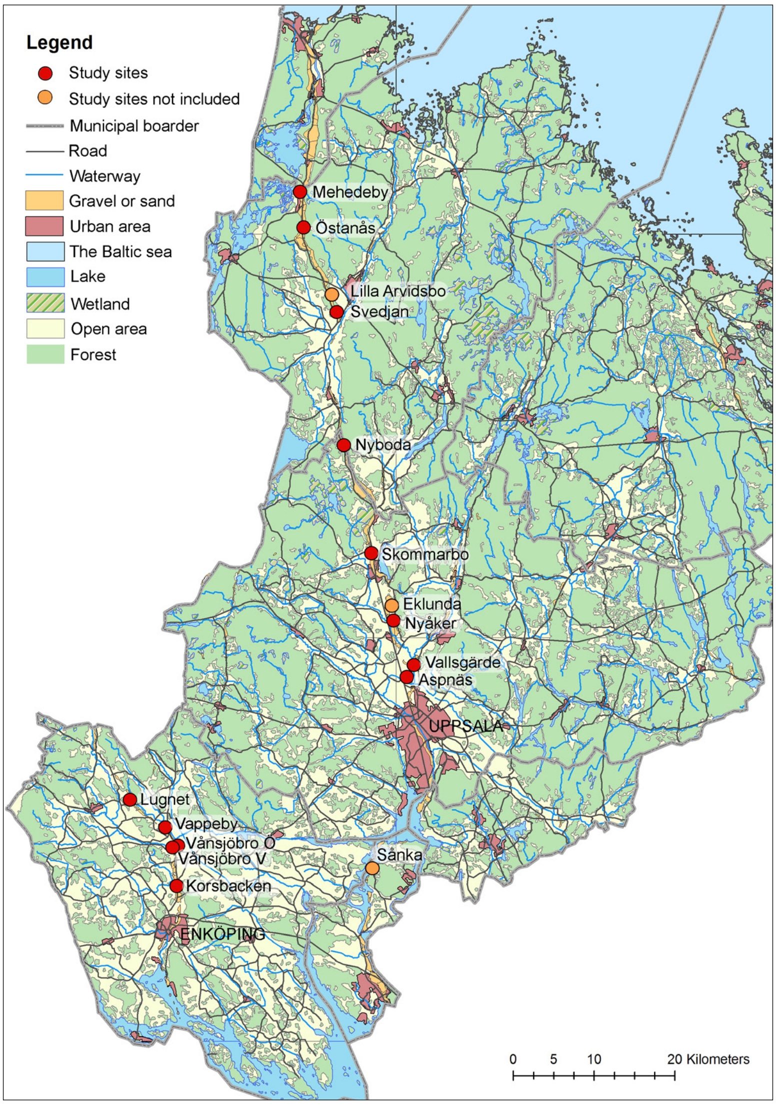

Figure 4. The location of the 13 study sites in the county of Uppsala, and the three study sites not included in the analysis. Descriptions of the sites are found in Appendix 2. © Lantmäteriet Gävle 2009. Medgivande I 2008/1959.

Records of all the sand pits, both active and abandoned, in the county of Uppsala (Heby municipality excluded) was used, to avoid a bias towards the localities well known among biologists. From the county administrative board of Uppsala data base records of 133 sand pits (36 active commercial, 23 for private use and 74 abandoned) were collected. To complement with earlier records a series of gravel inventories, conducted during the 1970's and 80's, were used (Anonymous 1977, 1978, 1979; Dahlberg & Grånäs 1991). In these inventories all active sand pits were marked on paper maps, a total number of 291, some of which overlap with the data base records. Together, these records gathered do not include all sand pits in this study region, but, it could be considered adequate enough to make a random selection of the study sites.

In the selection of the study sites, the aim was to get an even distribution of site areas and to get an even geographical distribution. Most of the sand pits consisted of soils with gravel but to the greatest possible extent sites with high proportions of sand material were chosen. Sites were not chosen if they were too overgrown, leaving only small patches of open sand, or if there was a high level of disturbance, often by motocross riding, which could disturb the traps.

To overview the sand pit records the GIS (geographical information system) program ArcGIS 9.2 was used. The analogous records from the early inventories were digitalized using "länsstyrelsens GIS-tjänst" (Lönnberg 2007).

To reduce the number of sites visited in the field a remote sensing analysis with aerial photos was conducted to sort out the sites which had been overgrown. Sites with open sand could be detected as lighter areas whereas closed vegetation is depicted as darker areas (Lönnberg 2008). The remote sensing was limited to Enköpingsåsen, Uppsalaåsen and Vattholmaåsen from Uppsala to Vattholma. About 70 sites were visited in the field. Among them 16 study sites were chosen and 13 of them could be used in the analysis.

Environmental variables registered

The environmental variables registered at each study site were Total area, Cover open ground, Proportion open sand, Tree cover, Tree height, Lower vegetation cover, Sun exposure and Surroundings. Two additional environmental variables were calculated: Area open sand and Area open ground (Tab. 1).

The Total area of the study sites were defined as the original area of the sand pit, but excluding areas with a total cover of trees along the edges. However, small clumps of trees could be included when located in the sand pit away from the edges. To measure the total area of the sand pits, GPS points were taken while walking around the edge of it. The total area was then calculated in the GIS program. For two of the largest sites, walking around the edges was not possible, and there areas were calculated from aerial photos. The two methods were compared for the other study sites with a good correspondence, especially for the larger sites.

Cover open ground, Lower vegetation cover, Tree cover and Proportion open sand were all estimated in the field in 5 % intervals. The variable Cover open ground could include some scarce vegetation, but only as long as the ground could be seen through it. The area not classified as open ground was included in lower vegetation. The Tree cover included trees of all sizes and was estimated as the area covered by the crown when seen from above. Proportion open sand was estimated as the proportion of the open area where sand was the dominant material. What was considered to be sand material was estimated based on my prior knowledge and might lie somewhat outside the definition of 0.2-2 mm (Clason & Granström 1992).

Table 1. Definition of measured environmental variables at the study sites.

Environmental variables	**Definition**	
Total area	Calculated using GPS measurement or using aerial photos	m^2
Cover open ground	The area were the ground can be seen, estimated in the field	%
Proportion open sand	The proportion of the open ground that consists largely of sand material, estimated in the field	%
Tree cover	The area covered by tree crowns as seen from above, estimated in the field	%
Tree height	Mean height of the oldest trees, estimated in the field	m
Lower vegetation cover	The area with total cover of non woody plants and small bushes, estimated in the field	%
Sun exposure	Estimated in three categories: low, medium and high	
Surroundings	Categorized as forest, open area or a mixture of both	
Area open sand	The area calculated from the Proportion open sand	m^2
Area open ground	The area calculated from the Cover open ground	m^2

Table 2. Values of the environmental variables registered at the study sites.

Study site	Total area	Cover open ground	Proportion open sand	Tree cover	Tree height	Lower vegetation cover	Sun exposure	Surroundings
	m^2	%	%	%	m	%		
Vånsjöbro V	200	80	0	5	1	20	medium	mixture
Vånsjöbro Ö	1,500	90	100	0	0	10	low	forest
Lugnet	2,000	80	65	10	2	20	low	forest
Nyboda	2,050	60	15	10	3	40	medium	forest
Vallsgärde	2,300	40	50	20	5	60	high	open area
Mehedeby	3,600	90	100	20	3	10	medium	forest
Östanås	5,000	90	15	15	1	10	high	forest
Aspnäs	6,600	50	100	30	5	50	medium	mixture
Nyåker	7,000	95	100	40	6	5	medium	open area
Vappeby	50,000	90	5	15	1	10	high	open area
Svedjan	74,000	95	5	65	2	5	medium	forest
Korsbacken	95,000	95	70	5	4	5	high	mixture
Skommarbo	180,000	95	5	5	1	5	high	forest

The height of the oldest tree, estimated in a 0.5 m interval, could be seen as a reflection on how long ago the sand pit was abandoned and the disturbance ceased or reduced. Sun exposure was estimated as low, medium or high according to the area which is sun exposed a large proportion of the day. The Surroundings was categorized are forest, open area such as arable land or urban areas or a mixture of both open and forested areas.

Table 2 lists the values of the environmental variables registered in each study site and in Appendix 2 there is a written description of each site.

Sampling method

The ground beetle fauna were sampled using pitfall traps. Five to six traps were used per site giving a total of 72 traps in the 13 sites analysed. Six traps were placed at the study sites where there was risk of disturbance. The sampling period lasted for four month, from mid April to mid August in 2008.

The pitfall trap consisted of a plastic cup, 9.5 cm deep and with an 8.3 cm opening in diameter. The cup was dug into the ground with the top of the cup in line with the ground surface. The cup was half filled with a 50 % propylene glycol solution, which preserve the sample and remove the surface tension (Fig. 5). A roof was placed above, raised a few cm with stones or sticks. The roofs consisted of Masonite boards or things alike found in the area.

Figure 5. Pitfall traps, with a solution of propylene glycol, were used to sample the ground beetles.

At the sites the pitfall traps were placed in open areas and, if possible, with a high sun exposure. As far as possible the areas with sand material were chosen. The traps were placed no closer than two meters apart and placement close to the edge were avoided when possible.

The traps were placed in the field between the 8th and 20th of April, a period when snow fall made the ground beetles inactive. The sampling start is therefore roughly the same for all study sites. The traps were emptied three times and brought in between the 11th and 13th of August. The period of catch, reaching from spring to late summer, enabled the representation of species developed both early and late in the season.

When emptying the pitfall traps, broken traps were replaced and put at the same or a close by location and blown off roofs were fixed with a stone on top. If the trap had been filled with sand, the top layer was removed and the rest collected.

Species determination

All ground beetles were determined to species, using the key by Lindroth (1961). The determination was conducted by the author with support from Mats Jonsell. Some difficult species were determined by Håkan Ljungberg, at ArtDatabanken, who also verified the species determination of parts of the sampling. The nomenclature follows Catalogus coleopterorum Sueciae (Lundberg 1995).

Statistical analysis

The data from the pitfall traps were pooled for each of the 13 study sites. All species and number of individuals from these sites were included in the analysis. Rare faction was avoided not to lose any data.

The species found were classified into three categories of habitat preference: open sand, other open areas and forest (Jonsell 2004; Jonsell pers. com.; Lindroth 1961).

The effect of the environmental variables on number of species, number of sand living species and proportion sand living species was analyzed by linear regression. The variables were tested both individually and in multiple regressions. In the multiple regression forward selection was conducted until there was no significant variable.

In the analysis of species-area relationship, the area variables and number of species was $\log_{10}$-transformed. The number of sand living species was $\log_{10}(n+1)$-transformed since it include zero-values. The regressions including area variables were also tested in a quadratic power function, $S = 10^{\wedge} (b_0 + b_1 \log A + b_2 (\log A)^2)$ (Dengler 2009).

In the regressions including proportion sand living species, the study site Nyboda was excluded. The low total species value of two gave a misleading value for proportion sand living species of 100 %.

Ordination was used for analyzing species composition. Ordination is a multivariate analysis used to recognize patterns in community data. Of the many different techniques available, correspondence analysis (CA) was used because of the intermediate length of the gradient, which had an eigenvalue of 2.3 (Heidi Paltto pers. com.). In a CA the study sites are arranged in a multi dimensional diagram according to their similarity in species composition. Sites with similar species composition lie near each other in the diagram. Also, the species can be included in the diagram and are arranged according to their presence at the study sites. Species close to each other are more likely to be found at the same site. Only species present in more than one site were used in the analysis (n=25). A CCA (canonical correspondence analysis) was also conducted. In addition to CA, it includes environmental variables and describes their effects on species composition, displayed in the diagram as arrows. The significance of the environmental variables was tested with a Monte Carlo permutation test (499 permutations) and only the significant environmental variables were included. As the

CCA is a combination of ordination and multiple regression it also considers a combination of environmental variables (Krebs 1989; Jongman *et al.* 1995; Quinn & Keough 2002).

The statistical analyses were performed using the programs Minitab 15 (regressions), SAS for Macintosh 6.12 (multiple regressions) and Canoco for Windows 4.5 (ordination).

Results

The ground beetle catch

In the 13 sand pits 892 ground beetles of 58 species were found. Out of the 58 species there were 20 typical sand living species, 24 open area species and 14 forest species.

In the three study sites excluded from the analysis 26 additional individuals were found, including one additional sand living species. See appendix 3 for a total species list together with the classification according to habitat preference.

Catch per study site

The highest number of sand living species at a site was 8, which was found in Nyåker and Mehedeby (Tab. 3). The number ranged down to 0 in Vallsgärde and Vånsjöbro V. The highest total species number of 14 was found in Nyåker. The lowest species number of 2, found in Nyboda, was quite deviant as the second lowest number was 6 species.

The number of individuals varied a lot between sites, from 165 individuals in Vappeby to 18 in Svedjan. This variation was foremost caused by a few numerous species. There was a near significant positive correlation between number of species and individuals ($n=13$, $p=0.054$, $R^2=29.7$ %) but the relationship was weak. For example, two sites with 11 species each had 165 and 29 individuals respectively.

The catch intensity differed between sites due to disturbance and destruction of the traps. Catch intensity was calculated as the number of days the trap was left undisturbed in the field. If there had been a disturbance, such as the trap being filled with sand or flooded, only half of

Table 3. The ground beetle catch of the 13 study sites, arranged according to highest numbers of sand living species.

Study site	Number of sand living species	Total number of species	Number of individuals	Proportion sand living species
Nyåker	8	14	79	0.6
Mehedeby	8	11	56	0.7
Östanås	6	13	113	0.5
Korsbacken	6	12	112	0.5
Vappeby	6	11	165	0.5
Skommarbo	6	10	49	0.6
Aspnäs	6	8	55	0.8
Lugnet	4	13	118	0.3
Svedjan	4	8	18	0.5
Nyboda	2	2	24	1.0
Vånsjöbro Ö	1	12	34	0.1
Vallsgärde	0	11	29	0.0
Vånsjöbro V	0	6	40	0.0

the days of that period were calculated. Approximately 20 % of the traps were destroyed or were missing and approximately 30 % of the traps had been disturbed due to problems with the roof or human activity. The catch intensity ranged from 382 catch days (Östanås) to 708 (Skommarbo). The data showed no patterns between catch intensity and number of species or individuals.

The species

There was a low evenness in species abundance with a few highly dominant species. Approximately 50 % of the species caught was represented by only one individual and an additional 25 % had less than five individuals. This could indicate a sampling effect caused by insufficient sampling. Nine species was found in a higher abundance, with more than ten individuals. The most numerous species was *Lionychus quadrillum* with 386 individuals (Fig. 6). Subsequently follows *Calathus erratus* (166), *Broscus cephalotes* (77), *Harpalus rufipes* (54) and *Amara quenseli* (40). The species represented at most study sites was *Calathus erratus* (11 sites), *Bembidion lampros* (8) and *Harpalus rufipes* (8).

None of the species found are threatened according to the red-list 2005 or 2000. An interesting finding however was *Cymindis angularis* which is quite unusual to find this far north (Jonsell 2004).

Figure 6. From the left: The most numerous species *Lionychus quadrillum*; the species found at most sites *Calathus erratus*; the locally rare species *Cymindis angularis*.

Effects of the area of the sand pit

The Total area positively influenced the number of sand living species (n=13, p=0.020, R^2=40.4 %; Tab. 4). The Area open ground also positively influenced the number of sand living species with an even higher significance when analyzed with a quadratic power function (n=13, p=0.003, R^2=69.1 %; Fig. 7). The Area open sand was significant as well (n=13, p=0.004, R^2=53.9 %) but this result was influenced by an outlier. By excluding the outlier the p-value raised to 0.052 (n=12, R^2=32.7 %). The three measurements of area (total, open ground and open sand) were highly correlated with each other.

The Total area was positively correlated with the proportion sand living species (n=12, p=0.033, R^2=37.8 %). Area open ground also gave a positive correlation in a quadratic power function with a higher significance (n=12, p=0.024, R^2=56.3 %; Fig. 8).

The total number of species could not be significantly explained by the area (Tab. 4).

Table 4. Results from the regression analysis including area variables.

Response variable	Area variable	Function	n	p-value	R^2 (%)
Number of sand living species	Total area	Linear	13	0.020	40.4
Number of sand living species	Area open ground	Linear	13	0.013	44.2
Number of sand living species	Area open ground	Quadratic	13	0.003	69.1
Number of sand living species	Area open sand (with outlier)	Linear	13	*0.004*	*53.9*
Number of sand living species	Area open sand	Linear	12	0.052	32.7
Total number of species	Total area	Linear	13	0.102	6.5
Total number of species	Area open ground	Quadratic	13	0.472	13.9

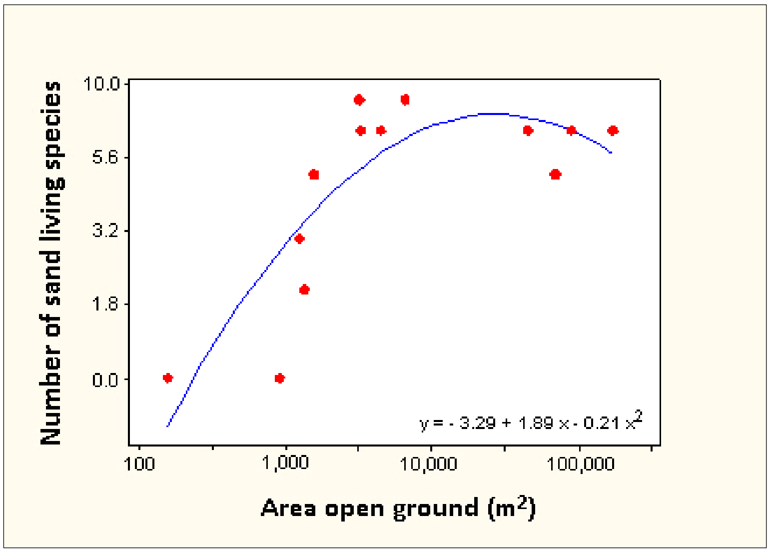

Figure 7. The species-area relationship. A regression with number of sand living species and Area open ground in a quadratic power function (n=13, p=0.003, R^2=69.1 %).

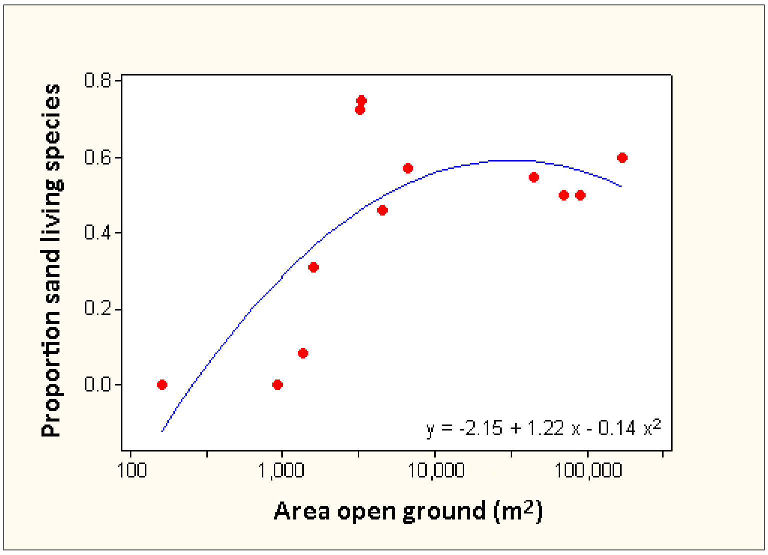

Figure 8. The proportion sand living species increases with an increasing area open ground, up to a certain level (n=12, p=0.024, R^2=56.3 %).

Effects of other environmental variables

There is an indication that Proportion open sand positively affects number of sand living species (p=0.114) when analyzed in a multiple regression together with Area open ground (n=13, p=0.015, R^2=57.0 %). The significance was higher compared to the single regression with Proportion open sand (n=13, p=0.456, R^2=5.1 %). Including Proportion open sand in the model also help explain some additional variation of Area open sand (p=0.006) compared to the single regression (n=13, p=0.013, R^2=44.2).

There is an indication that the cover of lower vegetation could influence the number of sand living species negatively but the regression is not significant (n=13, p=0.093, R^2=23.5 %). As Cover lower vegetation equals the inverted value of Cover open ground, the result is true for this variable as well but with a positive influence.

None of the other environmental variables could explain the total number of species, number of sand living species or proportion sand living species.

Species composition

The species compositions are similar between most of the study sites, which is shown as a cluster in figure 9. This cluster consists of small, medium and large sized sand pits. The study sites which lie outside the cluster can be split into two groups, one consisting of small pits and the other of medium sized pits with high proportion open sand. Figure 10 shows how the species are distributed between the sites and consequently how they contribute to the difference in species composition. The distances between the species indicate their degree of coexistence.

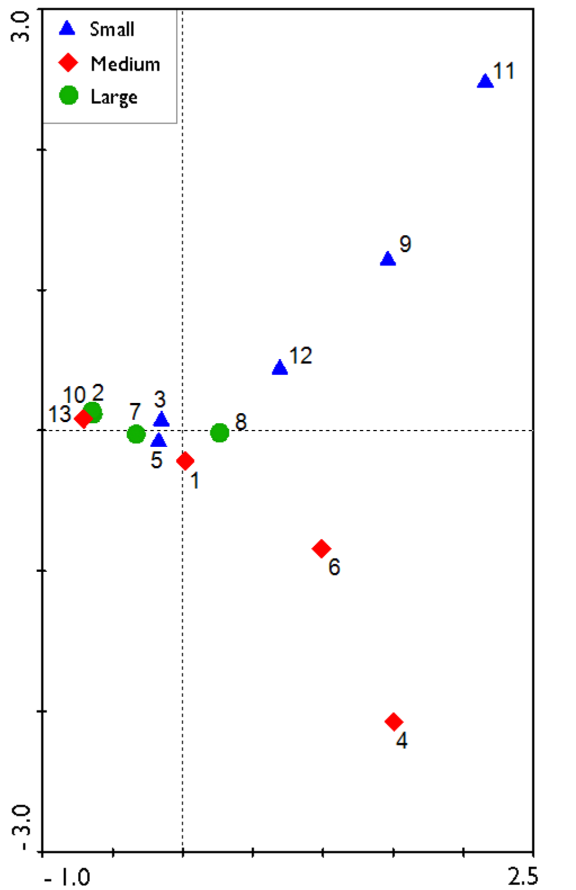

Figure 9. Correspondence Analysis (CA) biplots of the study sites. The distance between the plots indicates the differences in species composition between the study sites. The sites are categorized by area as small, medium or large. Axis 1 and 2 explains 60 % of the variance.

Legend: 1-Aspnäs , 2-Korsbacken , 3-Lugnet, 4-Mehedeby, 5-Nyboda, 6-Nyåker, 7-Skommarbo, 8-Svedjan, 9-Vallsgärde, 10-Vappeby, 11-Vånsjöbro V, 12-Vånsjöbro Ö, 13-Östanås.

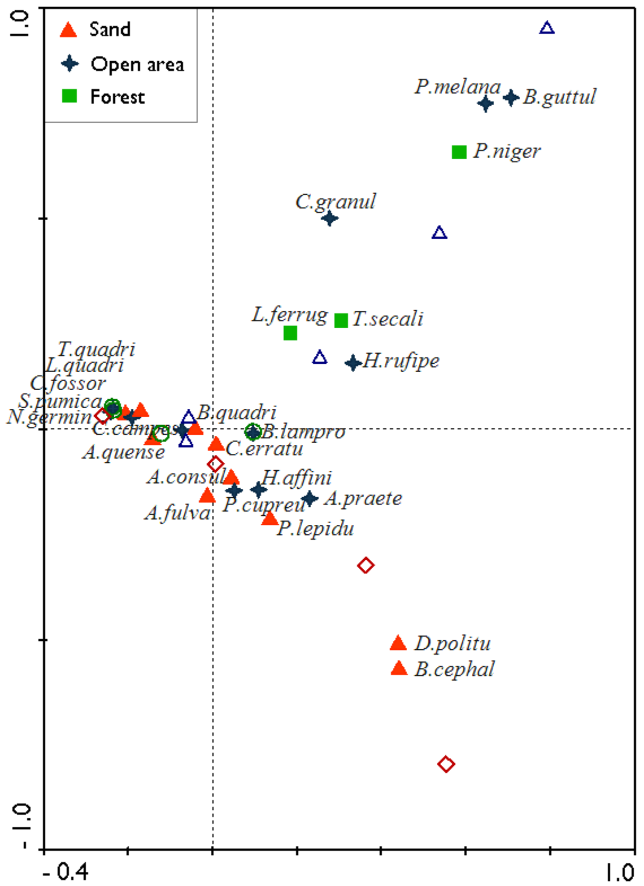

Figure 10. Correspondence Analysis (CA) biplots of the species, with the positions of the study sites from figure 9 present in the background. The names consist of the first letter in the genus name and the six first letters in the species name. The species are categorized according to their habitat preference. Axis 1 and 2 explains 60 % of the variance.

Two environmental variables significantly explained the species composition: Area open sand (p=0.046, F-ratio=2.27) and Proportion open sand (p=0.01, F-ratio=2.96) according to the Monte Carlo simulation in the CCA (Fig. 11). Figure 11 is a compliment to figure 10 and the position of the species has shifted as the data is forced to maximize the explanation of the variables. The species are arranged along the arrows according to their association with each environmental variable, the arrows pointing towards a higher value. The plot illustrates that most species occur at intermediate area open sand and the only species associated with small area sand are forest species and open ground species also occurring in open forest habitats. Most species are associated with a high proportion of open sand, *Dyschirius politus* and *Broscus cephalotes* being the most pronounced.

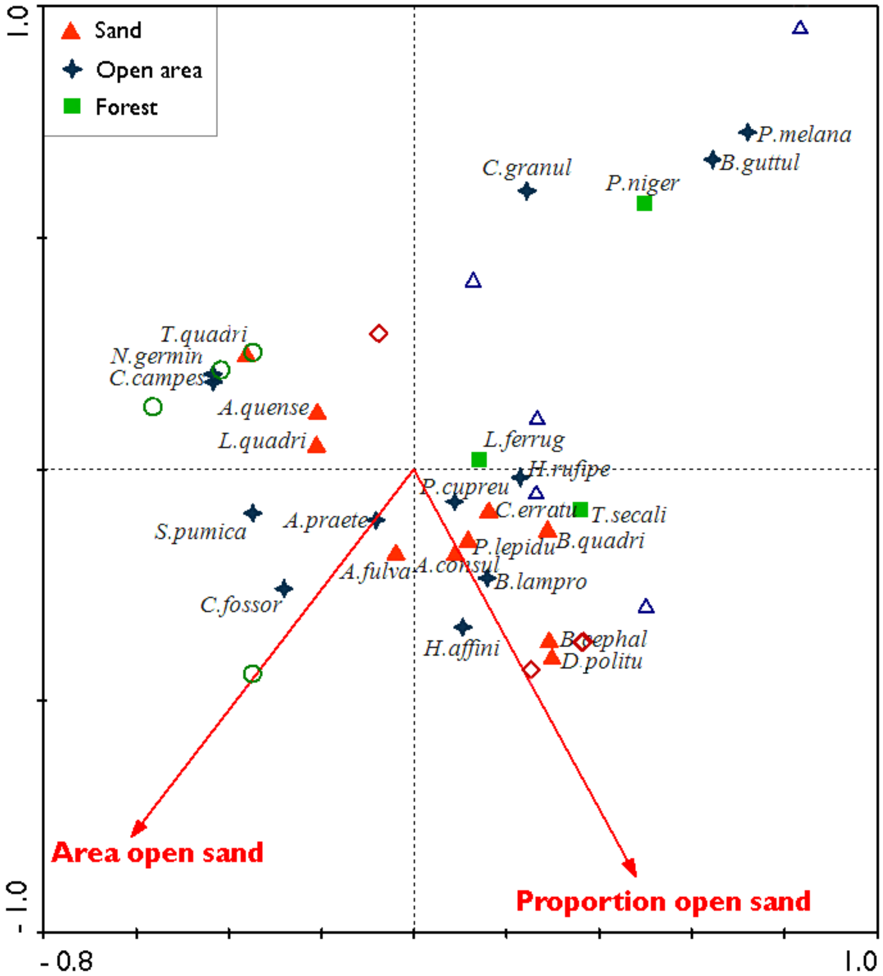

Figure 11. Canonical Correspondence Analysis (CCA) biplots of the species, with the positions of the study sites present in the background. Axis 1 and 2 explains all variance of species-environmental relation and 36.1 % of the variance of the species data.

Discussion

Effects of the area of the sand pit

This study has shown that the area of a sand pit affects the number of sand living ground beetle species present. Sand pits with a larger area have a higher number of sand living species than a smaller one, which is according to the island biogeography theory (MacArthur & Wilson 1967) and several studies (e.g. Gunnarsson & Götmark 1998; de Vries *et al.* 1996; Jonsell 2004; Molander 2007). However, as the area increase, the number of sand living species levels out and even drops, giving a curved relationship instead of a linier one. As a mean, the large sites (50,000-180,000 m^2) had somewhat less sand living species than the medium sized ones (3,600-7,000 m^2). Because there is a gap in area between the medium and the large sized sand pits it is not possible to give a suggestion of which area could be the optimum one.

There are several theories which can help explain the species-area relationship. For example, large areas could have a higher chance of being colonized and can contain more individuals which means a lower risk of extinction of species. A large area also contains a higher proportion "core" area which is not influenced by edge effects (Stiling 2002). An explanation, which could be applied for sand habitats, is that a larger area is more probable to have had a longer continuity of exposed sand because disturbance can occur sporadically (Berglind 2004). A theory which I believe have a high explanatory value is that a larger area could contain more microhabitats and consequently harbour more species. This might also explain why the largest sand pits in this study had somewhat lower species number than the medium sized ones, because those four large sites had a quite homogeneous habitat both in topology and vegetation (Fig. 12). A broken ground in contrary to a plane ground contributes to a more diverse habitat (Bergsten 2007). A homogeneous topology also makes the largest sand pits more wind exposed which could lead to a colder microclimate. However, more research is needed to better understand what effect a homogeneous habitat has on species number.

Another important aspect of what affects species number at a site is the distribution of the habitat in the landscape. The species number is limited by occurrence of species in the nearby area which can disperse to the patch. This aspect has not been included in this study but should be considered when prioritizing between sites.

Figure 12. One of the large sites, Svedjan, is quite homogeneous and consists largely of a plane ground. To the right is the medium sized sand pit, Nyåker, which is a more diverse habitat. In Svedjan 4 sand living species was found and in Nyåker 8.

Edge effect

The proportion of sand living species was lower in small sand pits. This can be explained by an edge effect (Jonsell 2004) which is more pronounced in smaller habitats. The edge habitat often has a different microclimate, which is influenced by the surroundings, and some species avoid it (Ewers & Didham 2006). Also, species from the surroundings often move into the edge habitat and compete with the species characteristic to the habitat (Ries *et al.* 2004). A competitive interaction might result in fewer sand living ground beetles and if so, the edge effect can help explain a species-area relationship. However, in a review of interspecific competitive of ground beetles, a competitive exclusion had not been showed in any of the studies included, even though competitive interactions were shown (Niemelä 1993).

An inflow of species from the surroundings can lead to a higher number of species towards the edges as there is a mixture of species from different habitats (Báldi & Kisbenedek 1994; Ewers & Didham 2006). As a consequence a negative species-area relationship can sometime be seen (Webb & Hopkins 1984). This effect of the edge habitat is probably why no correlation was found between area of the sand pits and total number of species.

Effects of other environmental variables

Together with the Total area, the Proportion open sand was indicated to help explain the increase of number of sand living species with an increasing area. It is said among entomologists that areas with sand material is more species rich than where the material consists of gravel, but I have not found any empirical data supporting this.

It was also indicated that the lower vegetation is of less importance for ground beetles in contrary to areas open ground with no or scarce vegetation. The Area open ground, and not Total area (which include lower vegetation), best explained the number of sand living species and also, the Lower vegetation cover showed a weak negative relation with the number of sand living species. However, this does not mean that the vegetation itself have a negative effect on the ground beetles but show that a rich flora is not essential. In a study of beetles in an artillery ranges, the vegetation cover did not affect the proportion of sand living species or the number of red-listed species (Jonsell 2004). For many other insects, on the other hand, a rich flora is very important for a rich fauna.

The lack of significant relations with the remaining environmental variables should not be interpreted as they having no affect on the number of sand living ground beetles. The study sites were chosen to study the effect of the area and were therefore not an optimal selection to study the other environmental variables.

Species composition

Most of the study sites have a similar species composition irrespective of the area of the sand pit. However, two groups of outliers had a different species composition. One was composed of small pits, in which the edge effect could explain the divergence. There, species from surrounding habitats have influenced the species composition and the sites are characterized by forest species and open area species which also occur in open forest habitats. These species largely contribute to the findings that Area open sand affects species composition. The second group of outliers was composed of medium sized sand pits with high proportion of open sand. They were mostly influenced by two sand living species, *Dyschirius politus* and *Broscus cephalotes*. *D. politus* were found only at these two sites and *B. cephalotes* was found in higher numbers at these sites but was also present at other sites.

The proportion open sand in a sand pit has an effect on its species composition. As the occurrence of sand was one criterion in the selection of study sites, all but one site had areas with sand material. Sand pits with no sand could then have a different species composition.

The future of sand pits

The extraction of sand and gravel from sand pits has rapidly declined from a yearly production of 70 million ton to 20 million ton between the years 1990 and 2006 (Anonymous 2007). A further decline is expected as the Government's environment quality objectives state that in 2010 the delivery of sand and gravel must not exceed 12 million ton per year (Anonymous 2000). This means that many sand pits have recently been and will be abandoned in a few years. Approximately 300 red-listed species are affected by what will happen with the sand pits (Bernes 2001).

When a sand pit is abandoned an after-treatment is required. When carried out in the traditional way of levelling out the pit, filling it with soil and planting of trees, it usually destroys the biological values of the sand pits. However, there are alternative after-treatments, one of them aiming to conserve the biological values, as mentioned in a guideline-document (Anonymous 2006). The biological values are rarely prioritized, but one example is the abandoned sand pit Vappeby (included in this study) bought by Upplandsstiftelsen (Fig. 13). The after-treatment has included adding of sand material, the construction of a pond and a management plan to avoid overgrowing (Gillis Aronsson pers. com.). There are also plans to include the pit in a nature reserve, something which is quite unusual (Björklund *et al.* 2004).

An abandoned sand pit, where the biological values have been preserved, then has to have some kind of disturbance to keep the area in an early succession stage. What kind of disturbance regime is most suitable is not clear but any disturbance is better than none. Many sand pits are kept open by motocross or horseback riding, but there are divergent opinions whether they have a positive (Johansson 2006; Molander 2007) or negative (Anonymous 2006) effect. The problem is that the disturbance easily can get too intense and unevenly distributed. A more controlled management where part of the ground is scraped to expose the sand and shading trees removed is probably more optimal for the species (Berglind 2005). On the other hand, there is a cost for active management, and it has to be repeated even if not so often. Most of the sites in this study were kept open by motocross riding and occasional extractions of material.

Figure 13. In the after-treatment of the sand pit Vappeby the biological values are being prioritized.

Sand pit as a substitute habitat

Almost one fifth of the ground beetle fauna of Sweden was found in this study, which is quite impressive when only one specific habitat was studied. Most of the species found occur in sand habitats regularly and several species have sand habitats as their main habitat (Appendix 3). This indicates that the manmade habitat of sand pits can substitute the "natural" sand habitats, which is supported by several other studies (e.g. Berglind 2005; Eversham *et al.* 1996; Johansson 2006; Sörensson 1983).

Sand pits are an important habitat for sand living ground beetle species and should be preserved. Now is the time to act to be able to preserve them and their habitants as many sand pits have recently been and are being abandoned.

Conclusions

Small sized sand pits, with an area less than about 2,500 m^2, should not be prioritized as they contain less sand living species and are influenced by species from the surrounding habitats. Medium sized sand pits contained the most species of sand living ground beetles but larger sand pits might contain as much species if their habitat is not homogeneous. An optimum area, where species number is the highest, cannot be given but as it is more cost efficient to preserve medium sized sites these should be the main focus.

To preserve a wide range of sand pits of different areas seems not of great importance because the species composition do not differ much in sites larger than 2,500 m^2. Even so, there should always be some variation although smaller sand pits should not be the main target. In the selection of sand pits to preserve it should be considered that the species composition is influenced by the proportion of sand.

Ground beetles have been proposed to be indicators for the total species richness (Björklund *et al.* 2004; Ljungberg 2001) and therefore the result from this study can to some extent be applied to other species groups. However, more similar studies including other species groups are needed to be able to give more broadly valid recommendations. More knowledge is also required to be able to establish the best plan of management to preserve the biological values long-term.

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Appendix 1 – Descriptions of the study sites

Mehedeby

An abandoned and probably levelled sand pit in connection to the town. The open area consists of a northern slope and run out into several jogging and riding tracks. The site consists of only sand material. The surrounding area is relatively open but the low pine forest in the south limits the sun exposure somewhat. A few small trees grow in the open area and there is very little lower vegetation. Many bees were observed in the western corner where the human activity is lower.

Östanås

A shallow pit with a mixture of gravel and sand. The bottom consists only of gravel and a clump of small pines. Except for a pile of clay covered with lower vegetation the pit is without vegetation. There is a high sun exposure even though there is a forest in the south. The clear cut in the north are likely to make the pit wind exposed. The pit is easily accessed so some material might still be extracted and some motocross riding occurs.

Svedjan

A large sand pit which have been levelled out and planted with pines, now 0.5-3 m high. Still, the pines are planted thin and there is almost no lower vegetation so large parts are still open. Most parts consist of gravel but a few areas consist of sand, i. e. the southwest edge. *Apalus bimaculatus* (bibagge) and *Colletes cunicularius* (vårsidenbi) have been found earlier years.

Nyboda

A small sand pit which lies a bit secluded beside the old E4 (now road 600). The slopes in the east and north are steep and consist of sand with some stones. The bottom consists mainly of hard packed gravel and grass. Some material is still being extracted from the pit.

Skommarbo

A large sand pit which still have some activity. Some after treatment have been done, levelling of slopes and planting of pine in a few areas. A few temporary pools of water have been observed. The western slope consists to some extent of clay but mainly by gravel. The northern part is the interesting one and consists partly of sand and little lower vegetation. *Apalus bimaculatus* (bibagge), Sand martin *Riparia riparia* (backsvala) and *Colletes cunicularius* (vårsidenbi) have been found at the site.

Nyåker

The sand pit was abandoned in 1975 but has been keep open by motocross riding. This medium sized pit consists only of sand material and is surrounded by arable land. Some not fully grown pines grow in the southern part where there is low sun exposure. The northern part lies higher and there the shallow slopes have a high sun exposure. In March three *Apalus bimaculatus* (bibagge) was seen together with many bees of different species.

Aspnäs

A medium sized pit where some succession have taken place. The slopes in the north and south are covered with vegetation and the bottom in the west part is covered with grass. In the eastern part there is a clump of 2-5 m high trees, mostly pine, birch and goat willow. The eastern slopes are high and sleep, mostly open but party with trees. About half of the open area consists of sand material.

Vallsgärde

A small sand pit with low activity surrounded by arable land. The shape is of a two levelled pits, one shallow and one deep. In the middle of the pit there is an open southern slop. One third consists of open ground and the rest are covered with low vegetation. A few trees grow at the edges, mostly in the north which gives some wind shelter and still allows a high sun exposure. Half of the open area consists of sand.

Lugnet

The site lies in the northern part of Enköpingsåsen and is a part of a bigger sand pit which is overgrown at most parts. The open part is a small but deep pit with high forest surrounding it, shading the sun. This part is probably kept open by some extraction activity and motocross riding. The slopes are mostly overgrown but are open in the east where the activity is. The bottom is open and consists of both sand and gravel.

Vappeby

A large sand pit now owned by Upplandsstiftelsen. The pit consists of three levels, the deepest in the NW and with high slopes mainly in the west. The eastern slop has some part consisting of clay and is partly covered with lower vegetation. Some parts of the slopes consist of sand but the rest of the area consists of gravel. In the bottom trees have started to grow but are only 0.5-1 m high. The pit is surrounded by arable land but with a few trees along the edges. Sand martin *Riparia riparia* (backsvala) and Ortolan *Emberiza hortulana* (ortolansparv) have been seen at the site.

Vånsjöbro Ö

A very small sand pit with one steep slope in the south and a plane surface beneath. The pit is surrounded by a small forest and the sun exposure is low. The area consists of sand and there is no vegetation. The sand pit was thought to be abandoned but in June a big extraction was made altering the whole pit.

Vånsjöbro V

A very small sand pit consisting mostly of gravel and partly stones. The surrounding in the south are arable land and in the north forest. The slopes are low and have some lower vegetation. One extraction was made in June altering the whole pit.

Korsbacken

A large sand pit with two deep pits and with some surrounding sand areas. There is no visible activity but it is still registered as active. North lies a large active pit. Almost the whole pit consists of open ground and sand material. Species registered from the site are *Apalus bimaculatus* (bibagge) and Sand martin *Riparia riparia* (backsvala).

Study sites not included in the analysis

Sånka

The most southern study site at Skoklosterhalvön in Uppsalaåsen. The sand pit consists of one open, plane surface in the NE, one slope in the middle and motocross trails among about 4 m high pines and birches in the SW. The motocross trails are frequently used. The open part consists only of sand. *Apalus bimaculatus* (bibagge) have been seen at the site.

Eklunda

A plane, open area used as motocross trail. It is not certain that this area has been used as a sand pit but it lies close to a large active pit. The area consists of sand material and lies in a forest.

Lilla Arvidsbo

A small sand pit which lies close to a large active pit. There are open slopes in the west and in the south. In the bottom there is a clamp of 2-3 m high pines, birches and *Salix*. Half of the area is open and consists mainly of sand material. *Apalus bimaculatus* (bibagge) have been registered from the site.

Appendix 2 – Species list

	Habitat preference	Aspnäs	Eklunda	Korsbacken	Lilla Arvidsbo	Lugnet	Mehedeby	Nyboda	Nyåker	Skommarbo	Svedjan	Sånka	Vallsgärde	Vappeby	Vånsjöbro V	Vånsjöbro Ö	Östanås	Total
Acupalpus meridianus	open												1					**1**
Amara bifrons	sand																1	**1**
Amara communis	open					1												**1**
Amara consularis	sand	1							1					1				**3**
Amara cursitans	sand																2	**2**
Amara equestris	sand						1											**1**
Amara eurynota	open			1														**1**
Amara familiaris	open															1		**1**
Amara fulva	sand			2			1		1								2	**6**
Amara praetermissa	open								1		1							**2**
Amara quenseli	sand			4			2		2	3	3			12			14	**40**
Anchomenus dorsalis	open								1									**1**
Asaphidion flavipes flavipes	open					1												**1**
Asaphidion pallipes pallipes	sand						1											**1**
Badister bullatus	open						1											**1**
Bembidion femoratum	sand									1								**1**
Bembidion guttula	open											1	1		2			**4**
Bembidion lampros	open	5	2	2	1	1			3	1			2			1	1	**19**
Bembidion obtusum	open	1																**1**
Bembidion quadrimaculatum	sand	1				3						1						**5**
Broscus cephalotes	sand	3					44		27	2	1							**77**
Calathus erratus	sand	34		3	2	60	1	18	17	11	7	1		6		8	1	**169**
Carabus coriaceus	forest						1											**1**
Carabus granulatus	open													1	1			**2**
Carabus hortensis	forest					1												**1**
Carabus nemoralis	forest															3		**3**
Cicindela campestris	open									3	2	11					1	**17**
Clivina fossor	open		1	3													1	**5**
Cymindis angularis	sand			1														**1**
Dromius notatus	sand											1						**1**
Dromius sigma	open																1	**1**
Dyschirius politus	sand						2		3									**5**
Harpalus affinis	open			1		1			2			1						**5**
Harpalus distinguendus	sand								2									**2**
Harpalus quadripunctatus	forest															1		**1**
Harpalus rubripes	sand			1														**1**
Harpalus rufipes	open			4		1			17		2		13	5	7	5		**54**

	Habitat preference	Aspnäs	Eklunda	Korsbacken	Lilla Arvidsbo	Lugnet	Mehedeby	Nyboda	Nyåker	Skommarbo	Svedjan	Sånka	Vallsgärde	Vappeby	Vånsjöbro V	Vånsjöbro Ö	Östanås	Total
Harpalus smaragdinus	sand	1																**1**
Harpalus tardus	open												1					**1**
Leistus ferrugineus	forest												1	1		1		**3**
Leistus terminatus	forest																1	**1**
Lionychus quadrillum	sand	9		89		42		6		24				130			86	**386**
Loricera pilicornis	forest												1					**1**
Nebria brevicollis	forest						1											**1**
Notiophilus aestuans	sand													1				**1**
Notiophilus biguttatus	forest															4		**4**
Notiophilus germinyi	open									2				3				**5**
Notiophilus palustris	forest														2			**2**
Pterostichus cupreus	open								1								1	**2**
Pterostichus gracilis	open												1					**1**
Pterostichus lepidus	sand					2	1		1	1								**5**
Pterostichus melanarius	open		1			3						1	1		18	1		**25**
Pterostichus niger	forest					1				1	1		5		10			**18**
Pterostichus oblongopunctatus	forest															6		**6**
Pterostichus strenuus	forest											1				1		**2**
Pterostichus versicolor	open																1	**1**
Stomis pumicatus	open			1										1				**2**
Trechus quadristriatus	sand										1			4				**5**
Trechus secalis	forest					1							2			2		**5**