Conserving solitary bees in active quarries.

Sydenham, Markus.

Final report for the Quarry Life Awards (QLA) contest.

September 2012.

Abstract

- Current land use patterns have caused several species to go extinct and is threatening many more. This may threaten the integrity of ecosystems and the services they provide.
- One important ecosystem service is pollination by feral pollinators. Bees are the most important animal pollinators and landscape management should aim to sustain local bee populations.
- However, during the past century populations of wild bees have declined in both the Netherlands and in the United Kingdom. The decline is seemingly caused by habitats loss. The same seems to be the case for Norwegian populations. However other habitats may have been made available through the exposure of sandy banks during the opening of sand pits.
- The aim of this study was to create a table of guidelines to assists quarry management in protecting and promoting high quality bee habitats in sand pits. I used the Nenset quarry in Norway as a model system.
- I created a table of guidelines by combining information based on the literature and an exhaustive species list already compiled by Norwegian bee specialist Frode Ødegaard with my own field work.
- To preserve nesting resources site managers should locate all sun-exposed banks with an angle >20 degrees, and a substrate mixture of sand and clay, within the quarry. These should not be disturbed.
- Further, when depositing and refilling material in the quarry, this should be aligned in a manor that maximizes sun-exposure. The material should then be covered with a layer of a sand and clay mixture to create new nesting grounds for bees.
- To preserve forage resources site managers should locate all patches of high plant diversity and abundance and avoid disturbing these. Also *Salix* species already present should be left intact and should be promoted when not within 200 m of nest sites.

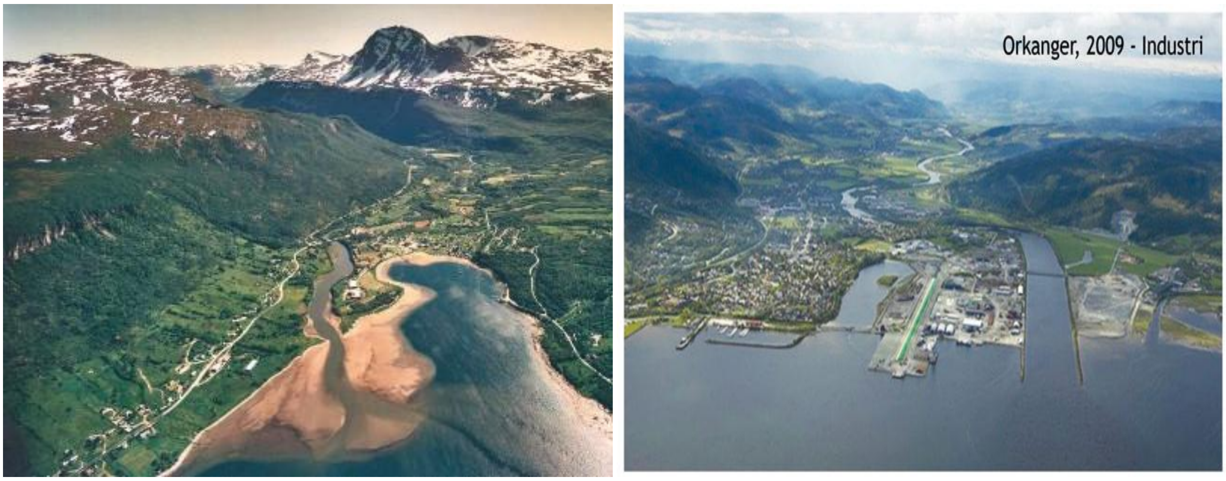

Figure 1a-b shows how sandy deltas apear in relatively undisturbed and developed states respectively. Photo (a); Fjellanger Widerøe Foto AS, (b); Orkanger municipality.

Introduction

As the anthropogenic footprint on the earths ecosystems increased during the past century, we have become the most important driver of changes in the biosphere. The alteration of landscapes and ecosystems and the following extinctions of species has made nature conservation a public matter and the center of several transnational treaties and legislations (Secretariat of the Convention on Biological Diversity 2010). Concerns have been risen over how current patterns of species extinctions may affects the integrity of ecosystems and the services they provide.

One ecosystem service is the pollination of plants. Of the worlds 250.000 flowering plants more than 90% depend to some degree on pollination. Moreover, the value of crop pollination has been estimated to 153 billion euroes (Gallai et al. 2009). The bees (Hymenoptera: Apiformes) are the most important pollinators (Klein et al. 2007). However, as a result of modern land use the distribution of specialized solitary bees and the plants they pollinate has decreased during the past century in both the Netherlands and the UK (Biesmeijer et al. 2006). The same seems to be the case in Norway where about one third of all bee species are currently found in the national IUCN red list (Hansen et al 2010).

However, human land-use may in some cases promote the local species richness and abundance of wild bees, as in the case of pastoral lands (Morandin et al. 2007) or even agriculture in forested areas (Winfree et al. 2007). In addition, secondary habitats such as sand pits and limestone quarries among others, provide many species, including bees, with important habitats (reviewed in Krauss et al. 2009). However, the contribution to species richness and abundance depends on the amount of high quality habitat. This may be reduced through habitat degradation, as in the case of the development on sandy deltas (Fig. 1a-b).

Figure 2a-b, (a); A female of fhe solitary bee *Andrena vaga* carying willow (*Salix sp.*) pollen to her nest. (b); a *Nomada* female leaving the nest of a host species. Her larvae will then steal the pollen intended for the hosts larvae. Photos; M. Sydenham.

Objectives

The majority of Norwegian solitary bee species build their nests in the ground. Preferred nest sites are often sandy banks and deltas (as in Fig. 1a). Moreover, sandy areas have been classified as hot-spot habitats in the Norwegian landscape since they contain many endangered species (Ødegaard et al. 2009). Parallel to the loss of habitats found in deltas, other sandy habitats become available as sand deposits are opened for quarrying. This may mitigate habitat loss or at least provide increased habitats for ground nesting solitary bees if proper measures are taken. In turn this may invigorate the populations of bees in quarries and increase the pollination of commercial and wild plants in the surrounding landscape.

In addition to contributing positively to the pollination service, increasing the populations of solitary bees may also contribute to the integrity of the ecosystem by providing their predators with prey and their cuckoo bees with hosts (Fig. 2a-b).

The aim of this study was to produce a template of simple guidelines to guide quarry activities in sand/gravel-pits so that nest sites of ground nesting bees may be protected or created. For this purpose the Nenset quarry provided an fitting model system. There were two main reasons for this; The quarry is to be further developed so that my findings might be relevant, and that an exhaustive list of the bee species present in the area had already been compiled (Ødegaard et al. 2009), making inferences of the bee community’s habitat requirements possible.

Figure 3a-b, (a); Aerial photo of the Nenset quarry. Photo; Eniro Norge AS. The 14 transects surveyed are marked in red lines. Note that the quarry has undergone changes after the photos were taken. The map should therefore be viewed as an indicator rather than an explicit depiction of the study area. (b); showing the scale of the landscape. Photo: M. Sydenham.

Methods

I conducted field work on May 2nd.-3rd.. I selected 14 transects from aerial photos (Fig. 3a) ranging in length from 50-200 m. This range was set to increase the possibility of finding nests in unsuitable areas. Since changes in the quarry had occurred after the photos were taken I adapted the transects to the current situation during the field work. I followed the transects and stopped every five metres to note environmental variables and counted the number of bees displaying nest seeking activity within four square meters (site). I noted insect burrows as “nests” if bees where seen entering or leaving them. Bees that left the four square metres without entering or leaving a nest were noted as “nest seeking bees”. I included cuckoo bees in this survey since their nest seeking activity would be linked to the presence of potential hosts. I noted if sites were: sun-exposure, level/angular, the substrate quality (clay, sand, soil and gravel), % vegetation and area of similar characteristics surrounding the site. Sun-exposure and substrate types were all coded as dummy variables (i.e. 1 vs. 0). I then conducted a multiple regression analysis using a step-wise selection to find the variables that best explained the presence of nest seeking bees and bee nests. Analysis were run using Minitab16.

I compiled a species list of solitary bees present at Nenset based on the findings of Ødegaard et al. (2009) and noted the nesting preferences of individual species as described by Westrich (1990). In this process I excluded all cuckoo bees since their nesting preferences are linked to those of their hosts. I then classified nesting preferences hierarchically according to how many species displayed them.

Figure 4a-b showing two of the banks with the most bee activity during the survey in early May. Both sloped at an angle between 20-45 degrees and were sun exposed. (a); consisted of a mixture of clay and sand, (b); consisted of sand. Photos; M. Sydenham

Results

The number of nest sites and nest seeking bees where highly correlated (R^2 = 0.67, P <0.001). I therefore focused on nest seeking bees throughout the analysis since these were more readily detected in the field. I found most activity, both in the form of active nests and nest seeking bees in banks with an angle of 30-50 degrees. Figure 4 shows two bee banks with high bee activity. A step-wise regression analysis showed that sun-exposed banks with a substrate mixture of clay and sand harbored most nest seeking bees (Fig. 5). The large amount of variation at on the left site of the graph was caused by the fact that many bees were observed in areas with either sand or clay substrate. I define these areas as of intermediate quality.

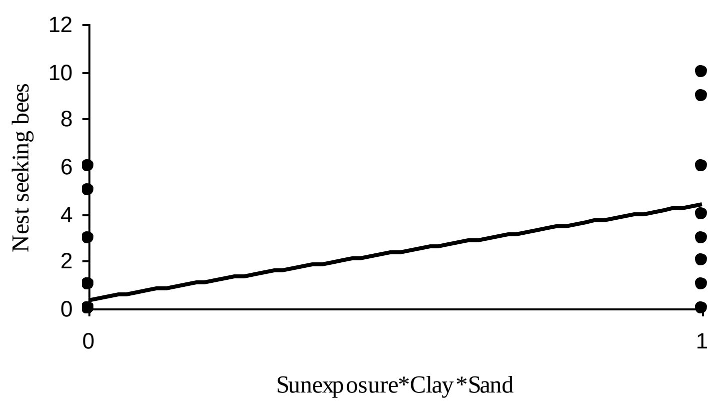

Figure 5. Nest seeking bees found in transects with Sun exposed slopes with a substrate mixture of clay and sand (1) as compared to transects without the pressence of all three variables (0). Linear regression; R^2 = 0.4, P <0.001.

Figure 6a-c, (a); The bee bank which hosted the most solitary bees. (b); a cuckoo bee of the genus *Sphecodes*, (c); a solitary bee of the genus *Andrena.* Photos; M. Sydenham.

Of the 56 species of solitary bees registered in the site (Ødegaard et al 2009) 13 were cuckoo bees of the genus' *Nomada* and *Sphecodes* (Fig. 6b). Of the 43 species that provide for their own larvae 35 build their nests below ground. The most species rich genus' were *Andrena* and *Lasioglossum*. Habitat requirements vary, some build nests in level grounds which is typical for *Lasioglossum* species while *Andrenas* typically build nests in sloping surfaces. Seven of the ten above ground nesting bee species registered in the area build nests in stems of *Rubus fruticosus*, among other substrates. *Anthidium puncatum* builds her nest in crevices between rocks and pebbles.

The majority of the species registered in the area are generalists, i.e. collect pollen from a wide array of unrelated plants whereas 12 species were specialists. The specialist species depend on pollen from plants within the families Asteraceae, Fabaceae and the genus *Salix*.

Twenty-four of the species only have one generation per year. 18 of the species can potentially have up to two generations per year. These include the social *Lasioglossum calceatum* (Westrich 1989). In total 35 species are active during the spring and 31 in the summer, note that several species are active in both time periods. The spring active species often rely on pollen from willow trees (*Salix caprea*).

I used the results from the field survey and the species list to create a table of guidelines to help site managers locate patches that may be of importance to solitary bees at the quarry (table 1).

Figure 5a-b. (a); deposition of asfalt and soil on a intermediate to high quality bee bank. (b); model bee bank to be recreated when building bee habitats. Photo; M. Sydenham.

Discussion

My findings correspond to those of Westrich (1996) who states that ground nesting bees often prefer south facing slopes with a sandy or clay/sandy substrate. However the nest requirements are often species specific and some species require level surfaces which may be found on food paths. I found no bees nesting in level areas. This suggests that more field work needs to be conducted to create a second template for level surfaces.

The bees found at Nenset vary in body size from 5-7 mm to 12-14 mm with important implications for foraging distances (Gathmann & Tscharnkte 2002). Since most bees stay within the lower bounds of their foraging range (Zurbuchen et al 2010) pollen sources should be within a 200 m radius of nest sites to satisfy all species. Conserving species through the season requires that floral resources are available during the entire activity period of the bee community.

Krauss et al (2009) found that quarry size and plant species richness, but not quarry age determined the species richness of wild bees in lime stone quarries in Germany. Their findings suggest more suitable habitats are found in large quarries compared to small ones. Moreover the authors suggest that activities such as refilling and flooding after abandonment should be avoided.

However, the negative impact of refilling quarries with soil and boulders may be mitigated or even reversed. By following the guidelines in table 1 site managers can point out areas of importance to bees and avoid destroying them by accident (as in Fig. 5a). In addition, the information in the table can be used to create new bee habitats. For instance, when depositing low quality substrate this could be aligned to maximize sun exposure and then covered in a mixture of clay and sand. The aim should be to create features as in figure 5b. By planting fast growing *Salix* species on top of the mounds the bee habitats would function as dust reducing screens which would benefit the working environment (pers. comm. Svein Tønnesen), at the same time as providing bees with pollen.

Locating Solitary bee nests in quarries

Table 1 shows the patch characteristics that should be assessed when locating areas of high conservation value to solitary bees in sand pits. The patch characteristics are listed in order of importance in the sense that whether an area is sun exposed or not should be assessed before classifying substrate quality *etc*. The first four characteristics must be assessed, the following four, marked in *italic*, are recommended. Plant species should be found within a 200 m radius of the sites. If an area is not sun exposed it is to be categorized as a low quality area disregarding it's other characteristics. By following the table site managers should be able to locate all intermediate and high quality areas. These areas should be left undisturbed.

Patch characteristics	**Patch Quality**		
	Low	Intermediate	High
Sun exposed	No	Yes	Yes
Substrate	Gravel/soil	Sand/clay	Sand & clay
Slope >20 degrees	No	Yes	Yes
Bare patches of earth	No	Yes	Yes
Rubus sp. found nearby	*No*	*Uncertain*	*Yes/uncertain*
Salix sp. found nearby	*No*	*Uncertain*	*Yes/uncertain*
Fabaceae sp. found nearby	*No*	*Uncertain*	*Yes/uncertain*
Asterareae sp. found nearby	*No*	*Uncertain*	*Yes/uncertain*

Concluding remarks and acknowledgements

Even though more and more areas are set a side as nature conservation areas, this cannot compensate for the loss of pristine habitats being the most important factor threatening most species. Therefore it is of dire need that the extraction of resources from natural landscapes is conducted in a fashion that minimizes potential harmful effects on biodiversity. I am of the conviction that such best practices have to be simple and if possible benefit the people affected by them. The work on this report has been my attempt to satisfy both these goals.

However, the template should be further developed, which requires more field work to be conducted in collaboration with local site managers. With the expertise of site managers a functional design of “artificial” bee habitats could be produced. Also, more species than bees should be included. However, this was beyond the scope of this project.

I could not have written this report had it not been for the help of QHSE Manager Svein Tønnessen and operational manager Jarle Nygård, who kindly guided me around the quarry and assisted with their expertise on substrate types and gave their suggestions to how dust screens might improve the working environment in the quarry. All costs related to the field work was covered by Heidelberg Cement Sweden.

Also I would like to thank Christian B. Strømme for useful comments on the final draft of this report.

Litterature citet

- Biesmeijer, J. C., Roberts, S. P. M., Reemer, M., Ohlemuller, R., Edwards, M., Peeters, T., Schaffers, A. P., Potts, S. G., Kleukers, R., Thomas, C. D., Settele, J. & Kunin, W. E. (2006). Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. *Science*, **313**: 351-354.
- Gallai, N., Salles, J. M., Settele, J. & Vaissiere, B. E. (2009). Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. *Ecological Economics*, **68**: 810-821.
- Gathmann, A. & Tscharntke, T. (2002). Foraging ranges of solitary bees. *Journal of Animal Ecology* **71**: 757-764.
- Holzschuh, A., Steffan-Dewenter, I. & Tscharntke, T. (2010). How do landscape composition and configuration, organic farming and fallow strips affect the diversity of bees, wasps and their parasitoids? *Journal of Animal Ecology*, **79**: 491-500.
- Klein, A. M., Steffan-Dewenter, I. & Tscharntke, T. (2003) Fruit set of highland coffee increases with the diversity of pollinating bees. *Proceedings of the Royal Society of London Series B-Biological Sciences*, **270**: 955-961.
- Klein, A. M., Vaissiere, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C. & Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society Biological Sciences*, **274**: 303-313.
- Krauss, J., Alfert, T. & Steffan-Dewenter, I. (2009). Habitat area but not habitat age determines wild bee richness in limestone quarries. *Journal of Applied Ecology*, **46**: 194-202.
- Morandin, L. A., Winston, M. L., Abbott, V. A. & Franklin, M. T. (2007). Can pastureland increase wild bee abundance in agriculturally intense areas? *Basic and Applied Ecology*, **8**: 117-124.
- Secretariat of the Convention on Biological Diversity (2010). *Global Biodiversity Outlook 3*. Montréal, 94 pages.
- Westrich, P. (1989). Die Wildbienen Baden-Württembergs. Eugen Ulmer GmbH & Co. Germany.
- Westrich, P. (1996). Habitat requirements of central European bees and the problems of partial habitats. In Matheson, A., Buchmann, S. L., O`Toole, C., Westrich, P. & Williams, I. H. (eds) *The Conservation of bees*, London, Academic Press. 1-16 pp.
- Zurbuchen, A., Landert, L., Klaiber, J., Müller, A. & Dorn, S. (2010). Maximum foraging ranges in solitary bees: only few individuals have the capability to cover long foraging distances. *Biological Conservation*, **143**: 669-676.
- Ødegaard, F., Sverdrup-Thygeson, A., Hansen, L. O. & Öberg, S. (2009). Kartlegging av invertebrater i fem hotspot-habitattyper. Nye norske arter og rødlistearter 2004-2008 – NINA Rapport 500. 102 pages.