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# General factors that regulate survival among ectotherms at northern latitudes: a study of sand lizard, Lacerta agilis, habitat in southern Sweden

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# General factors that regulate survival among ectotherms at northern latitudes: a study of sand lizard, *Lacerta agilis,* habitat in southern Sweden.

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## Abstract

Open sand habitats in Sweden has been declining for the past century and this is mirrored by the increasing fragmentation and attenuation of species bound to these habitats. Many threatened species coexist in the same habitats as sand lizards, habitats best described as warm sites with a long continuity. Often with a sand-based substrate and a mosaic landscape of heather *Calluna vulgaris*, herbs, and patches of grass. Generally, areas with open sand are one of the keys for species bound to these habitats considering many of the species use south-facing sand slopes as nesting sites since it holds a warmer microhabitat that is beneficial for incubation of eggs and thus is essential for the whole lifecycle. This study investigates four current sand lizard (Lacerta agilis) localities in the county of Skåne and compares them to four empty localities in Southern Halland with similar character. The data collected from the study sites were analyzed to see if there were any significant differences between the populated and empty localities and thus could give information if key structures in the habitat are missing**.** The result from the analysis clearly shows that both the study sites Vapnö and Långenäsudden have the key structures that are essential for the sand lizard and could be considered as suitable habitats for potential new sand lizard populations. Information about both recreational pressure and predator abundance in these study sites would be an essential step in the final evaluation of the adequacy of the habitat as a whole.

## Sammanfattning

Öppna sandmiljöer i Sverige har försvunnit allt mer under det senaste århundradet, detta avspeglar sig genom den ökade fragmenteringen and minskningen i de arter som är knutna till dessa miljöer, en av dessa arter är sandödlan *Lacerta agilis*. Många andra hotade arter samexisterar i dessa miljöer, som bäst kan beskrivas som varma miljöer med lång kontinuitet. Dessa miljöer har ofta ett sand-baserat substrat och en mosaikartad flora bestående av områden med ljung, örter och gräs. Men också sydvända sandblottor, vilka är nyckeln-strukturer för många av de arter som lever i dessa miljöer då där skapas ett varmare mikrohabitat som är gynnsamt för äggläggares inkubation, bland annat sandödlans. Denna studien undersökte fyra nuvarande lokaler för sandödla i Skåne län, vilka jämfördes med fyra lokaler i södra Halland som har liknande karaktär men där sandödlan inte finns. Den insamlade datan från dessa lokaler analyserades sedan för att se om det fanns signifikanta skillnader mellan lokalerna, och därigenom visa om nyckelstrukturer i habitatet saknas. Resultatet från dessa analyser visar klart att både lokalerna i Vapnö samt Långenäsudden har de viktiga nyckel-strukturer som är avgörande för sandödlor. De kan därför anses som lämpliga habitat för eventuella nya populationer av sandödla. Sandödlan är dock känslig för både trycket från mänskliga friluftsaktiviteter och från predatorer som exempelvis tamkatter. Dessa ämnen bör därför undersökas och utvärderas innan den totala lämpligheten för sandödla på nämnda lokalerna kan fastslås.

## Introduction

The sand lizard *Lacerta agilis* (Linne 1758) has a large but fragmented distribution ranging from Siberia and Mongolia in the east to the middle and south parts of Europe (Nicholas et al. 2007). At northern latitudes, the distribution of the sand lizard becomes more scarce and fragmented as latitude increases. The northern limit of distribution in Sweden is at latitude 61° outside the city of Mora (Artportalen, 2019), all populations above latitude 58° could be considered isolated relict populations from the mid to late Holocene warm period that occurred 7000-500 B.C (Gullberg et.al 1998).

The warmer climate during this period made it possible for thermophilic organisms like the sand lizard to migrate northward through a temporary land bridge from the European mainland up to higher latitudes in the Baltics and Scandinavia. When the climate changed and became cooler. The sand lizards, therefore, could only survive in favorable environments, in the north most localities in Sweden, these environments mainly consist of pine forests with a high content of glaciofluvial sand deposits and relative warm microhabitats, requirements in these latitudes for the sand lizard thermoregulation and overall life cycle (Gullberg et.al 1998).

The sand lizard has during the last decades experienced severe declines in many countries in its northwestern range (Edgar & Bird 2006). Declining trends have also been observed in other "sand bound" heat dependent species such as *Apiformes* spp. *Eurolion nostras* and *Podalonia luffii* (Hochkirch et al. 2007, Gärdenfors 2010). The above species coexist in the same habitat as sand lizards and are likely to benefit from the same directed conservation measures that is implemented in sand lizard habitat restoration (Berglind 2003).

In Southern Halland, the sand lizard has been locally extinct since 1995-2005 (Fritz et al 2012). The last known locality was in Brogård just outside the city of Halmstad (Administrative county board, Threatened species list). It is plausible that in past times the sand lizards were more widespread along the coasts of Halland since historical literature describes Halland as a heather landscape with large problems from fly sand blowing inland from the coastal dunes (Hallandia antiqua et Hodierna, Rosquist 2018)

The reason for the disappearance of the sand lizard in Southern Halland is likely to be habitat degradation from increased plantation to bind sand, overgrowing and changes in agricultural practices thus making areas with a mosaic of open sand rare, ironically in a region known for its sand dunes (Berglind 2004a). Sand dunes alone could therefore not be considered an optimal habitat for the sand lizard, and most of the localities in southern Sweden where sand lizards appear are in fact not on coastal sand dunes. For the habitat to be suitable for sand lizards the landscape needs a heterogenic character with patches of sand preferably in an area dominated with heath and herbs (House & Spellerberg 1983b, Edgar & Bird 2006), this mosaic patterned ground in localities that sand lizards inhabit generally has a rich fauna of invertebrates upon which the sand lizard feeds. Sand lizards are opportunistic feeders and no key species of prey is recognized (Strijbosch 1986). Monitoring of restored areas dominated by sand has shown that invertebrates reinhabit the areas in a short time period (Fritz m.fl. 2012). In the south of Sweden, sand lizards have a wider tolerance of suitable habitats and with increasing latitude, their habitat demands narrow down to sandy pine forests. This could probably be explained by the narrower array of suitable warm microhabitats and continuity of the habitat in the most northern localities (Berglind 2004a). Today these landscapes are rare and often associated with labor-intensive reserves and recently restored areas.

The Sand life project (Rosquist 2018) and other similar conservation actions have restored areas along southern Swedish coasts, it is possible that some of these areas will be suitable for sand lizards. Since much of the dense pine forests is being cleared and replaced mosaic of sand and heath. Dead wood from the loggings also helps to create a suitable habitat for both invertebrates and sand lizards (Edgar & Bird 2006, Jonsell et al 1998). There is also interesting ecological similarities in these habitats, for example, the distribution of the spotted ant lion *Eurolion nostras,* correlates very well with the distribution of the sand lizard in southern Sweden (Artportalen 2019).

The sand lizard could also have an important role as an umbrella species in these types of habitats since vertebrates generally address a greater public interest than invertebrates (Simberloff 1998, Berglind 2004a). One of the national and international action plan goals regarding sand lizards is to stop the decline and secure the viability of these species (Edgar & Bird 2006). Sand lizards are relatively stationary with a dispersal distance of only 500-2000m in suitable habitats (Strijbosch & van Gelder 1997). Studies made on the genetic variation shows that Swedish sand lizards have low heterozygosity which could be explained by a possible bottleneck event in the historical northward migration that took place after the last ice age (Gullberg et al 1998). Their heavily fragmented distribution in Sweden thereby makes the chance of them repopulating restored suitable areas unlikely (Ohlsson et al 1997, Berglind 2000).

This makes human-assisted translocation the only reasonable way to establish populations on new or previous populated localities. The area needed to sustain sand lizards in the long term need to be at least 5-10 hectare to have a good chance of survival within 50 years (Berglind 2004a). In Sweden, the sand lizard is classified as vulnerable, and internationally as least concern but decreasing. The Swedish metapopulation of sand lizards is estimated to consist of between 7700-14700 adult animals. In the past 20 years, there has been a decline of 20-40% in sand lizard numbers (IUCN, Gärdefors 2010).

This study will, therefore, investigate what structures are of greatest importance for the sand lizard in Sweden's southern populations and if there are suitable habitats for sand lizards in southern Halland. Localities in Skåne where sand lizards are found in great numbers will be compared to restored localities in southern Halland where sand lizards are missing.

## Materials and methods

### Data sources

When choosing localities in Skåne I used Artportalen to find localities where the sand lizards have a stable population and were found consistently during the years 2000-2019 (Artportalen 2019). The localities in Southern Halland were chosen in collaboration with the county Administrative board of Hallands län which helped me find suitable localities and reserves that could have the potential to become sustainable long term sand lizard habitats. Four localities with a known and lasting population of sand lizards were chosen in the county of Skåne. These are Stenshuvud, Sundvik, Vitabäckshällorna, and Västerleden. Four empty localities in the county of Halland were chosen, these are Tönnsera, Långenäsudden, Vapnö, and Skogsgård. The localities are presented in figure 1.

The specific squares investigated were primarily chosen on terrain that had areas with south-facing sand slopes thus this is one of the preferred microhabitats for sand lizards (Strijbosch 1986, as well as one of the key elements for their life cycle/egg incubation (Berglind 1988, Moulton & Corbett 1999). The squares were measured out with a measuring tape.

Vegetation/habitat data was obtained from on-site surveys done between 2019-04-30 and 2019-05-15. The recording unit for each locality of the surveys was done in three samples, each sample, a square of 10x10m. In each square, the variables such as sand, grass/moss, brush, etc. were measured. A total of 10 broad vegetation types were identified and used as variables since the types were present in the sample squares. The variables found and used were sand, heath, grass/moss, rock, dead wood, trees, brushes, south-facing sand, water, and leaf litter. All variables were not present in all sample squares.

Table 1. In every locality, three sample squares of 10x10m were chosen. The coordinates were measured in the middle of each site.

| Names of localities | Square | Gps Sweref | Status |
|---|---|---|---|
| **Stenshuvud, Simrishamn** | 1. | 6168437.635, 454463.662 | Populated |
| | 2. | 6168394.62, 454390.311 | |
| | 3. | 6168221.523, 454337.693 | |
| **Sundvik, Landskrona** | 4. | 6200995.205, 361817.604 | Populated |
| | 5. | 6201011.471, 361854.199 | |
| | 6. | 6201064.205, 361887.677 | |
| **Vitabäckshällorna, Sjöbo** | 7. | 6161004.291, 423167.768 | Populated |
| | 8. | 6160997.993, 423180.509 | |
| | 9. | 6160973.309, 423202.565 | |
| **Västerleden, Ystad** | 10. | 6142695.644, 422186.713 | Populated |
| | 11. | 6142700.246, 422275.136 | |
| | 12. | 6142714.088, 422331.661 | |
| **Tönnersa Halmstad** | 13. | 6271058.495, 373733.485 | Empty |
| | 14. | 6271231.388, 373749.93 | |
| | 15. | 6271210.225, 373745.285 | |
| **Långenäsudden, Halmstad** | 16. | 6271210.225, 373745.285 | Empty |
| | 17. | 6279872.587, 364494.934 | |
| | 18. | 6279866.115, 364518.61 | |
| **Vapnö, Halmstad** | 19. | 6285240.743, 367142.795 | Empty |
| | 20. | 6285377.957, 367187.104 | |
| | 21. | 6285396.57, 367208.339 | |
| **Skogsgård, Laholm** | 22. | 6273209.073, 384822.952 | Empty |

| | |
|---|---|
| 23. | 6273220.191, 384861.493 |
| 24. | 6273250.645, 384722.231 |

**Statistical analyses**

Since the data collected was not normally distributed I used Mann-Whitney U-test. I tested the current sand lizard localities against the empty localities in southern Halland to investigate if there were significant differences between the variables in the populated and empty localities. Differences between the populated and empty localities could indicate that essential structures (vegetation types) in the empty localities are missing, which in turn could render the locality unsuitable for sand lizards.

Past statistics (Hammer, 2015) was used for an NmDS (Non-metric Multidimensional Scaling) analysis to plot what empty localities best matched the populated localities in Skåne. I used my collected data from all 8 localities to verify the habitat overlap between localities inhabited by the sand lizards and those without the species, using Non-metric Multidimensional Scaling through the software Past v.3.06 (Hammer, 2015). The analysis groups the localities based on the variables (sand, dead wood, heath, grass/moss, rock, trees, shrubs, south-facing sand, water, and leaf litter). This analysis then indicates if any of the empty habitats fall within the range of the inhabited sand lizard localities and therethrough giving a strong indication of whether an empty locality has the right qualities/variables for a future sand lizard population.

**Study sites**

The study sites in Skåne are different from each other in a lot of aspects, from Stenshuvud coastal habitat with heath, *juniperus* and parts with oak trees (Figure 1:1 in appendix 1) in contrast to Vitabäckshällorna edge zone between an agricultural landscape and a mountain slope with deciduous trees. Though all study sites in Skåne have south facing sand slopes incommon. The study sites in Halland have a shorter continuity than in Skåne. They also have a substantial difference in character, Vapnö is an inland former Sand excavation site whilst Lånenäsudden is a coastal heath and juniperus habitat (Figure 1:2 and 1:3 in appendix 1)

## Results

The U-tests showed significant differences between the amount of dead wood and sand between the populated and empty localities (Table 2). For the other variables, no significant differences could be found.

Table 2, Showing grouped median, total range and p< in the different variables between populated and empty localities.

| Variable | Grouped Median, Populated localities | Grouped Median, Empty localities | Range | p< 0,05 |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Sand | 4,44 | 9,00 | 0-40m2 | **0,045** |
| Dead wood | 0,63 | 3,60 | 0-25m2 | **0,008** |
| Heath | 5,45 | 1,25 | 0-49m2 | 0,478 |
| Grass/moss | 35,00 | 31,00 | 4-68,5m2 | 0,443 |
| Rock | 0,44 | 0,85 | 0-51m2 | 0,319 |
| Trees | 0,75 | 0,36 | 0-6 | 0,242 |
| Shrubs | 10,50 | 9,50 | 0-50m2 | 0,630 |
| South-facing sand | 18,66 | 15,00 | 0-82m2 | 0,590 |
| Water | 1,67 | 0,0 | 0-20m2 | 0,755 |
| Leaf litter | 1,55 | 0,30 | 0-40m2 | 0,590 |

Non-metric Multidimensional Scaling analysis

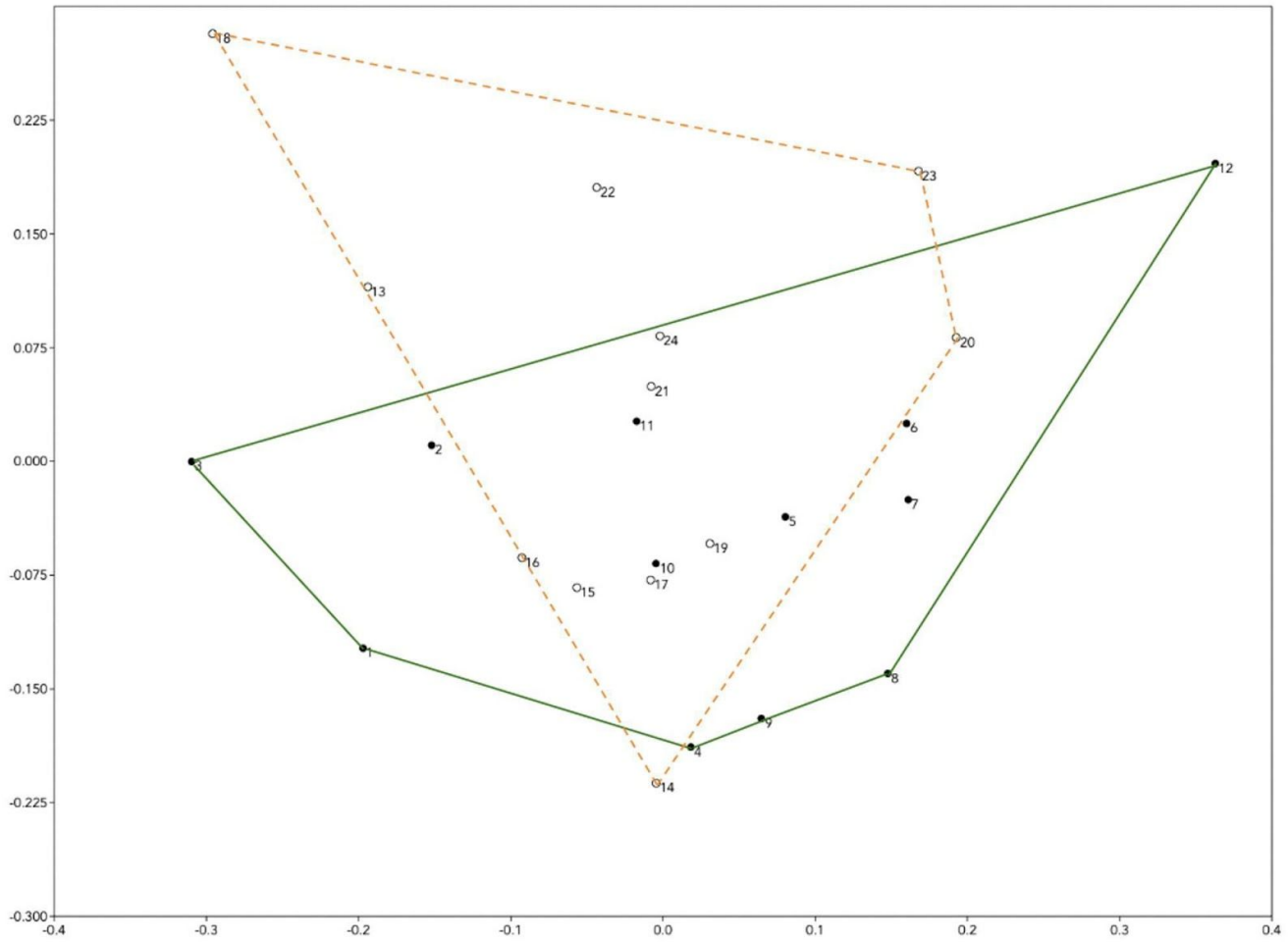


Figure 1, Open circles shows empty test squares, Filled circles figure show populated squares. The empty localities inside the green polygon share the most similarities with the populated localities.

The NmDS analysis result show that there is an evident overlap between the variables in the populated localities in Skåne and th empty test squares 15,16,17,19, 20, 21, 24 in southern Halland.

Table 3, The analysis shows that all test squares done in Vapnö Sand extraction site has the structural potential to inhabit sand lizards. Skogsgård and Långenäsudden both have 2 of 3 squares that show the same potential.

| Empty localities | Individual Square numbers # | Total of suitable squares (1-3) |
|---|---|---|
| Tönnersa | 15 | 1 |
| Långenäsudden | 16,17 | 2 |
| Vapnö | 19,20,21 | 3 |

| | | |
|---|---|---|
| Skogsgård | 21,24 | 2 |

## Discussion

The NmDS analysis showed that the empty localities in Halland could be well suited to inhabit sand lizards since multiple test squares were found well inside the suitability polygon and in Vapnö all test squares were placed inside. The suitability for a new sand lizard populations could be judged by several factors. I found that the habitat of the sand lizard in the southern parts of Sweden varies greatly but has some key structures in common. The habitat needs to be at least partly open for ground temperatures to be sufficient for thermoregulation, other important structures are areas with open sand, brushes/heath for cover, and a sufficient supply of invertebrates for food. I noticed that other structures seem less important since visited sand lizard localities in skåne varies greatly. (Lydänge & Berglind 2003, 2005, Lydänge 2005a, Norström & Westrin 2006, Niesel 2007).

The contemporary landscape is fragmented and if a new sand lizard locality is to become a reality in southern Halland it is my opinion that decision-makers needs to be aware of limits of dispersal from this locality especially if it is placed inland. I think that locality close to the coast could eventually spread along the coastline at least in stretches between larger cities if the habitat is somewhat habitable, making the population larger and more stable (Ryberg et al 2004, Ohlsson et al 1997). With this said isolated inland localities would not be negative but restricted to the area and more sensible to stochastic events (Berglind 2000). If there is aim and funding to create a large network of interconnected sand lizard habitats the study site Skogsgård in Laholms county could make a suitable area since there is multiple heath dominated nature reserves in close proximity to each other, restoration and improvements of heath habitats has been shown successful in multiple habitats both nationally and internationally (Corbett & Tamarind 1979, Berglind 1988, 2003, 2004a,2005a) .

The empty localities in southern Halland showed a significantly higher amount of sand in the squares than in the populated squares in Skåne (Table 2), this could be explained by a tendency to choose squares in areas that had open sand and that these areas are larger and not as mosaic patterned as the areas in Skåne. The open sand patches most sand lizards populations depend upon for incubation could be considered early successional habitats. The disturbance needed to keep these areas open could be from either abiotic factors like winds or fire. It could also come from biotic factors like grazing livestock or digging animals like rabbits (Edgar & Bird 2006). Today these habitats would most likely have to be managed to ensure that the habitat remains in the suitable early successional state since fire regimes and agricultural practices have changed dramatically the last century (Berglind 2004a, Forslund et al 2010).

There are also a significant difference in the amount of dead wood in the south Halland localities with more dead wood in the squares in Halland than in Skåne (see figure 2 and 5). This is possibly a good sign and could indicate a higher amount of invertebrates of which many are bound to dead and decomposing wood (Jonsell et al 1998, Kouki et al 2010). Another way to interpret the higher amount of dead wood is that the localities in southern Halland is more recently logged and has been “open” for a much shorter period of time.

The maturity and continuity of the habitat is important since it directly affects the density and abundance of suitable invertebrates for food and in turn is essential to establish a new population/locality (Beebee & Griffiths 2000, ). I would argue that a study to investigate this is important to acquire knowledge of the maturity of the food web. This could be crucial to make an educated decision on the adequacy of the prospective locality. I would argue that Långenäsudden has the longest continuity and maturity of my study sites since Vapnö, Skogsgård , and Tönnersa have undergone substantial shifts and restoration in the recent past and both Vapnö and Tönnersa has substantially more dead wood than the populated localities in Skåne (see table 2 and 5). Vapnö, Tönnersa , and Skogsgård also have a significantly higher amount of sand than the populated localities in Skåne. These differences in the amount of dead wood and sand support my argument that their habitat is younger and don't have the same continuity as Långenäsudden.

Table 4, Mean percentage of dead wood and sand.

| Mean value | Populated localities | Långenäsudden | Vapnö | Tönnersa | Skogsgård |
|---|---|---|---|---|---|
| Dead wood | 1,3% | 2,3% | 8,3% | 13,6% | 2,3% |
| Sand | 4,9% | 5% | 18,3% | 14,6% | 25% |

Vapnö is approximately 26,5 hectares. Thus making it a large suitable habitat for sand lizards and all of the study sites fell inside the suitability polygon (table 3, figure 1). Though connectivity wise it is isolated by agriculture and urban settlements, so for the area to work as a arc/hub for spreading to adjacent areas is not plausible.

Långenäsudden is approximately 22,8 hectares and is situated in along the coastline.
This fact makes it the only real possible locality for possible expansion from the locality, this since regulations in Sweden prohibit urban exploitation along coastlines.
The continuity in långenäsudden is “good” and it resembles partly Stenshuvud, Observations in the area show that common adders are abundant, this indicates a healthy ecosystem with nutrients moving up the food web. This is also a locality with a large flora of heather that is a preferred cover for sand lizards (House & Spellerberg 1983b, Edgar & Bird 2006).
Both Långenäsudden and Vapnö are regularly visited nature excursion/hiking destinations.

Skogsgård is approximately 8 hectares. The area also got two squares inside the suitability polygon is relatively newly created and lacked sufficient cover in terms of heather or other brushes (House & Spellerberg 1983b, Edgar & Bird 2006). If managed in an appropriate way I think that it could become a good habitat in the future.

Tönnersa is a 288 hectares large nature reserve that stretches along Hallands coastal dune habitat, The Sand life project have in recent years have done major restoration efforts in areas of the reserve and pine forests has been logged and the former dune landscape restored. this makes much of the habitat young and with low continuity. I argue that it could be a suitable habitat in a decade when the landscape has settled and matured, restoration efforts could possibly speed this process.

## Conclusions

Either Vapnö or Långenäsudden should make a suitable habitat since the habitat very well resembles the populated localities investigated in Skåne. They are both large enough and hold the essential structures. To make an informed decision on whether southern Halland localities are suitable for relocation of sand lizards research about the abundance of invertebrates/prey could help make successful decisions. Domestic cats and crows are known to specialize and predate and eradicate populations of sand lizards. Also here information about the abundance of these predators could be of utmost importance (Edgar & Bird 2006).
The effects from the human population should also be considered since sand lizards are known to be more sensitive by disturbance from recreational pressures such as mountain bikes, horse riding, and vegetation trampling than other reptile species in northern latitudes (Strijbosch 1988, Edgar 2002). To consider these factors is especially important if the habitat is small and the human presence is abundant (Moulton & Corbett 1999, Haskins 2000, Woodfine et al 2017). I would advise that information about previously mentioned topics should be gathered and evaluated so a decision about future creation of a sand lizard locality is as well founded and flaws could be foreseen.

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## Appendix 1

**Figure 1:1** Stenshuvud national park. Typical sand lizard habitat. Stenshuvud national park is 400 hectares big and is characterized by long term human presence, grazing livestock, old stone walls, and high biodiversity. Structures found here are deciduous lush forests, herb-rich meadows, heathlands with patches of bare sand, and a littoral stretch of sand and gravel deposits.

**Figure 1:2** Vapnö, Halmstad. Possible sand lizard habitat.
Vapnö is an former sand excavation site located just outside Halmstad. Characterised by large areas of bare sand and rich biodiveristy.  The area is still used by the military to some extent but the after-treatment of the sand excavation is since several years complete.

**Figure 1:3** Långenäsudden, Halmstad. Possible sand lizard habitat.
Långenäsudden is a coastal heathland with windswept vegetation, the area is a mosaic of junipers, round pebbles, bare sand , and shrubs. Sections of the area are grazed by sheep during parts of the year.

**Figure 1:4** Skogsgård, Veinge. Possible sand lizard habitat.
Skogsgård is a nature reserve 20km from the coast. The habitat is predominantly consisting of grass and herbs with some trenches and relatively recently dug sandpits and trenches., small patches of calluna and other brushes is found in around the edges of the reserve.

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