

Habitat use and mobility of two threatened coastal dune insects: implications for conservation

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Abstract

We studied the habitat use and mobility of the Grayling butterfly (*Hipparchia semele*) and the Blue-Winged Grasshopper (*Oedipoda caerulescens*), two threatened insects within spatially structured blond and grey dunes in a nature reserve along the Belgian coast. Although both species occur in the same biotope, *H. semele* were more abundant in open, dynamic sites with a relatively high amount of bare sand, while *O. caerulescens* preferred sheltered, more stable environments with a lower amount of bare sand. Unlike *H. semele*, substrate use varied in accordance to body colouration in *O. caerulescens*, especially on cold days, with light-coloured animals being more abundant on sand and dark-coloured animals more abundant on moss. During a mark-recapture-study, we marked 493 Grayling butterflies and 1289 Blue-Winged Grasshoppers. On average, both sexes of *H. semele* were equally mobile (about 150 m/day; maximum recorded distance of about 1700 m) while male *O. caerulescens* were significantly more mobile than females (daily average 47 vs. 5 m; maximum distances observed for *O. caerulescens* were about 800 m). The importance of habitat heterogeneity (within and among patches) and the consequences of habitat use and mobility of both species for the conservation of typical coastal dune habitats are discussed. The complementary use of species-specific information to site-based management measures is advocated.

Introduction

Nature management of large sites is often a systems-approach in which the restoration of ecological processes is the objective (e.g., nutrient cycles, hydrology). Several authors have shown that species can go extinct under such ecosystem-based nature management (Pickett et al. 1992; Simberloff 1998) and the incorporation of species requirements into management measures is, to date, rather uncommon (Maes and Van Dyck 2005). The com-

plementary nature of simultaneous species and ecosystem conservation, however, can render nature conservation considerably more efficient through the use of species as tools for site selection, management evaluation and/or the evaluation of nature conservancy policy (Lawton 1997). An interesting short-cut is to incorporate so called indicator species into biotope restoration plans and/or nature management (e.g., Rubinoff 2001; Ranius 2002). Such species should represent the ecological demands of many other species in the same biotope

(Fleishman et al. 2001). But, different species in the same biotope type do not necessarily have the same resource demands and can differ in habitat use within that biotope type (Dennis et al. 2003). Furthermore, reactions to the same management measure can differ among species. Therefore, use of a single species rarely covers the ecological demands of all other species in that biotope (Landres et al. 1988; Simberloff 1998; Andelman and Fagan 2000). The use of more than one species is therefore preferable to a single-species approach because it results in complementary information for conservation and management purposes (e.g., Noss 1990; Lambeck 1997; Simberloff 1998; Kotze and Samways 1999). Combining a systems-approach (i.e., natural dynamics, grazing) with a species-approach (i.e., the application of autecological research) is advocated to be the best way to tackle conservation and management problems (Noss 1990).

Coastal dune grasslands have been dramatically reduced in area in most NW European countries, mainly due to building activities for tourism (De Ruyck et al. 2001). In Belgium, for example, the coastal dune area decreased from about 6000 to 3800 ha during the 20th century (Provoost and Bonte 2004). In addition to stabilization of the seaside dunes with *Ammophila arenaria*, dune dynamics has been adversely affected owing to the reduction of aeolian input from the beach and dune fragmentation (Provoost and Bonte 2004). This has resulted in a stagnation of dune dynamics and a shift from an open dynamic system towards a closed, stabilised landscape. Additionally, open dune habitats (e.g., blond and grey dunes) have suffered from shrub and grass encroachment (van Til et al. 2002) because of the cessation of livestock grazing (mainly pony), the collapse of rabbit populations after the viral diseases at the beginning of the 1950s (Ranwell 1960) and 1990s and from atmospheric nitrogen deposition (Kooijman et al. 1998). Internal fragmentation and decreases in the total area of dynamic (blond) dunes and open sparsely vegetated (grey) dunes has resulted in a decrease of both habitat quantity and quality for many thermophilous invertebrates. Many of them have subsequently become rare and now have their strongholds in the coastal dunes (Desender et al. 1995; Maelfait et al. 1998). Present nature management in dune systems aims at restoring the former species richness (both flora and fauna) by using low intensity grazing, the

traditional farming technique in the Belgian coastal dunes (Termote 1992). Most of these grazing projects only started recently and conservation biologists are only beginning to evaluate the results for typical dune species (Bonte et al. 2000, 2002; WallisDeVries and Ramaekers 2001). Since grazing is a 'systems-approach', it will not necessarily meet the demands of every single specialised species of open dune habitat (grazing may fail to create a sufficient area of high quality patches) and additional species specific management measures may be appropriate.

Here, we investigate habitat use and mobility of two specialised species of blond and grey dunes, the Grayling butterfly *Hipparchia semele* and the Blue-Winged Grasshopper *Oedipoda caerulescens*. We discuss the differences between these two species and the implications for the conservation and management of blond and grey dunes in Belgium.

Material and methods

Studied species

The two specialist dune insects, *Hipparchia semele* (Linnaeus 1758) and *Oedipoda caerulescens* (Linnaeus 1758), have a discontinuous distribution in Flanders (north Belgium) with populations in the Campine region in the northeast and along the coast in the west. In the Campine region they mainly occur in dry heathlands, spoil heaps and railroad yards while along the coast they are restricted to dune grasslands. Both *H. semele* and *O. caerulescens* are listed as Vulnerable in Flanders (Declerck et al. 2000; Maes and Van Dyck 2001).

Study area

The study was carried out in the Westhoek Nature Reserve (De Panne, Belgium) close to the French border (Figure 1). The nature reserve is owned by the Flemish Ministry of Nature Conservation and covers about 340 ha. Within the Westhoek, we gathered data at three sites for *H. semele*: 'Voor-duinen', 'Centrale duinen' and 'Binnenduinen' (Figure 1a) and at three sites within the Binnenduinen for *O. caerulescens*: 'West', 'Centraal' and 'Oost' (Figure 1b). The area of and distances between the different sites are given in Table 1. The maximum possible distance detectable at the study

sites was 2050 m for *H. semele* and 1175 m for *O. caerulescens*. Voorduinen and Centrale duinen are separated by fairly dense scrub (*Hippophae rhamnoides*, *Ligustrum vulgare* and *Salix repens*), while Centrale Duinen and Binnenduinen are separated by a large band of bare sand (± 400 m) and scrubland (*H. rhamnoides*, *L. vulgaris* and *S. repens*). Within Binnenduinen, West and Centraal are separated by trees (*Populus* spp.) and mixed dense scrub while Centraal and Oost are only separated by a sand depression about 20 m wide. We calculated the surface of the main habitat types (moss, sand, grassland and shrub) within all study sites with a normalised vegetation index (i.e., (near infra-red – red)/(near infra-red + red), Lillesand and Kiefer 2000) from digitised false colour near infra-red aerial photographs (Table 1). The percentage of south facing slopes (exposition SW, S and SE of slopes $\pm 5^\circ$) within the study sites was calculated from a digital elevation model (Table 1).

Methods

We collected data on movements for both species by capturing all encountered individuals by hand net

(0.3 m diameter) on 35 days between 12 July and 30 August 2001 for *H. semele* and on 43 days between 12 July and 5 October 2001 for *O. caerulescens*. All individuals were marked with a unique number on the left hind-wing (*H. semele*) or on the left fore-wing (*O. caerulescens*) with a permanent lightfast marker (Staedtler Lumocolor 313 S). All capture points were marked on detailed infra-red aerial photographs (1:1000) and digitalised in a GIS. All individuals were sexed and wing lengths were measured. In addition, we distinguished four colour classes for *H. semele*: light coloured-contrasting, light coloured-uniform, dark coloured-contrasting and dark coloured-uniform (light coloured animals have light grey ventral wings, while dark coloured animals have dark brown under wings; contrasting animals have a wide white band, while uniform individuals have either a very narrow white band on the underside of the hind-wing or no band at all) and three for *O. caerulescens*: light (grey), medium (brown) and dark (dark grey or black). We also noted the resting substrates used (moss, sand, other vegetation) and the behaviour (only for *H. semele*: resting, basking, territorial behaviour, feeding). Additionally, temperatures

Table 1. Area of, distance between and percentage vegetation cover in the Grayling study areas (a) and in the Blue-winged Grasshopper study sites (b) within the Westhoek Nature Reserve. n.a. = data not available.

(a) Grayling	Voorduinen	Centrale Duinen	Binnenduinen
Area (in ha)	5.714	3.629	3.465
Distances between the study areas (in m)			
Centrale Duinen	447	–	
Binnenduinen	1381	724	–
Vegetation cover of the four main vegetation types (in ha)			
Bare sand	2.354 (41%)	1.325 (37%)	0.648 (19%)
Moss	1.957 (34%)	0.699 (19%)	0.742 (21%)
Grassland	0.330 (6%)	0.311 (9%)	0.323 (9%)
Shrubs and trees	0.726 (13%)	0.680 (19%)	1.261 (36%)
South facing slopes (SW, S and SE and $\pm 5^\circ$)	n.a.	26%	34%
(b) Blue-winged Grasshopper			
Area (in ha)	West 0.775	Centraal 3.789	Oost 2.161
Distances between the study sites (in m)			
Centraal	74	–	
Oost	670	17	–
Vegetation cover of the four main vegetation types (in ha)			
Bare sand	0.168 (22%)	1.012 (27%)	0.327 (15%)
Moss	0.143 (18%)	0.689 (18%)	0.624 (29%)
Grassland	0.083 (11%)	0.364 (10%)	0.249 (12%)
Shrub	0.301 (39%)	1.201 (32%)	0.576 (27%)
South facing slopes (SW, S and SE and $\pm 5^\circ$)	25%	29%	30%

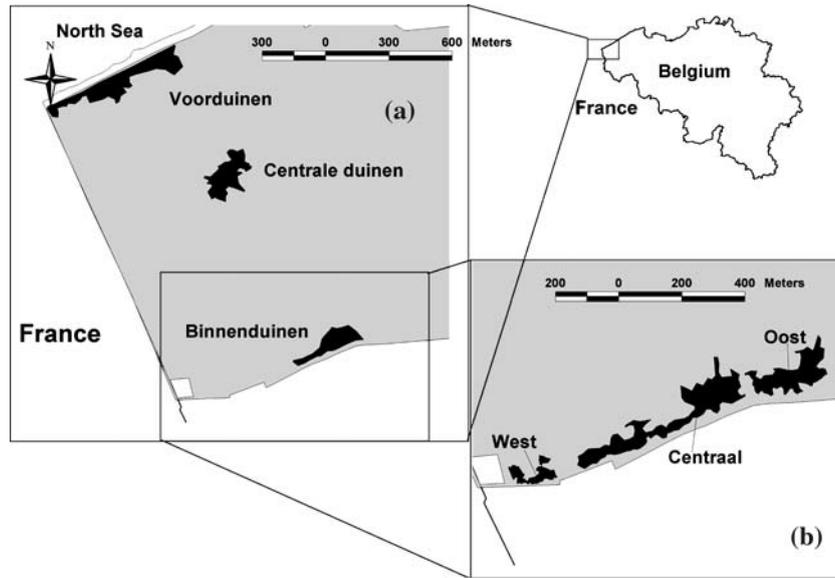


Figure 1. Location of the Westhoek Nature reserve (grey) in Belgium and the three study sites for (a) *H. semele* and (b) *O. caeruleascens*.

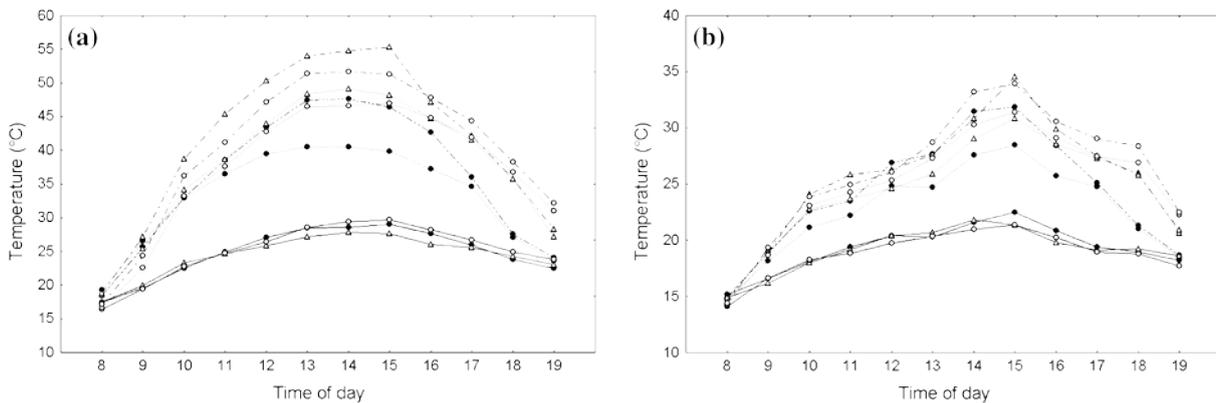


Figure 2. Temperature differences between the three Grayling study sites on warm days (a) and cold days (b): solid dots: Voorduinen; triangles: Centrale Duinen; circles: Binnenduinen; solid lines: shade temperature; dotted lines: sand temperature; dashed lines: moss temperature. Lines are drawn through hourly means.

were measured on bare sand, moss and in the shade every 3 min using temperature data loggers in the three *H. semele* study areas between 9 August and 16 September 2001 (Figure 2).

Statistical analysis

Overall mobility was tested with mixed models using only individuals that were caught with at least one day interval between captures. Time interval between captures was included as a

covariate, while variation contributed by individuals and individual-time interactions were included as random effects. The significance of the latter were tested against the χ^2 distribution of the log-likelihood-difference between the models with and without random effects. Degrees of freedom were approximated using the Satterthwaite procedure (controlling for unbalanced sampling design).

We used a log-linear analysis to test for associations between substrate use and wing colour for both species separately; additionally, we applied a log-linear analysis to test whether substrate use

and colour were associated with day temperature ('warm' vs. 'cold' days), substrate use and wing colour per sex and per species separately. The nine 'warm' days had an average day temperature in the shade $>22^{\circ}\text{C}$ whereas the 'cold' days had an average day temperature in the shade $<20^{\circ}\text{C}$ (5 days for *H. semele* and 9 days for *O. caerulescens*).

Results

Grayling butterfly

Habitat and substrate use

Of all three sites, male density was by far the highest in Voorduinen; sex-ratios differed significantly in Voorduinen and in Centrale duinen (with significantly more males than females), but not in Binnenduinen (Table 2a). Voorduinen and Centrale duinen had more extensive areas of bare sand (ca 40%) and a low amount of shrub (ca 15%); female density was highest in Binnenduinen (but differences between sites are less marked than in males) which had the largest amount of shrub and the lowest amount of bare sand; about 1/3 of the sites consisted of south-facing slopes (Table 1a).

Male *H. semele* used significantly more sand than moss as resting substrate compared to the relative frequencies of both substrates (Table 2c; $v^2_1 = 12.89$, $p < 0.001$), which was not the case for females ($v^2_1 = 1.17$, $p = 0.28$). We found no significant association between colour and substrate use (crypsis) in either of the sexes (males: Log-linear analysis $v^2 = 4.562$, $p = 0.21$; females: Log-linear analysis $v^2 = 1.541$, $p = 0.67$; $df = 2$). This result did not depend on day temperature (males: Log-linear analysis $v^2 = 2.540$, $p = 0.47$; females: Log-linear analysis $v^2 = 6.613$, $p = 0.09$; $df = 3$). There was a highly significant association between behaviour and sex: males were observed flying more often than females ($v^2_1 = 13.838$, $p < 0.001$).

Mobility

The recapture ratio was significantly different between males and females in Voorduinen and in Binnenduinen but not in Centrale duinen (Table 2a). Observed dispersal distances were related to the time interval between two successive captures, longer distances occurring between captures sepa-

rated by longer time intervals ($F_{1,110} = 13.47$; $p < 0.001$). Overall mobility did not differ significantly between males and females ($F_{1,91.4} = 0.05$, $p = 0.83$; Table 2a); 54% of the males and 63% of the females did not move further than 100 m and only 10% of the males and 13% of the females moved distances longer than 800 m. The maximum distance covered between two captures was 1736 m for males and 1704 m for females. There was no significant difference in the proportion of males and females moving between sites ($v^2_1 = 0.01$, $p = 0.91$; Figure 3a).

Blue-winged grasshopper

Habitat use

Densities of *O. caerulescens* differed among patches and can be related to the difference in the proportion of bare sand: the area of bare sand was lowest in Oost (15% bare sand) resulting in lower densities of *O. caerulescens* than in West and Centraal (ca. 25% bare sand). In all patches, we captured significantly more males than females (Table 2). All *O. caerulescens* sites were sheltered by shrubs surrounding the patches (27–39%). About 27% of the habitat consisted of south-facing slopes (Table 1b).

There was no significant difference in substrate use for either males or females in *O. caerulescens* (Table 2d; males: $v^2_1 = 0.06$, $p = 0.81$; females: $v^2_1 = 0.00$, $p = 1.00$). Light-coloured individuals significantly used more sand than dark-coloured individuals that were mainly found on moss (males: Log-linear analysis $v^2 = 56.433$, $p < 0.001$; females: Log-linear analysis $v^2 = 33.582$, $p < 0.001$, $df = 2$ – Figure 4). In both sexes, background matching (homochromy) was more pronounced on cold days than on warm days (males: Log-linear analysis $v^2 = 4.227$, $p = 0.040$; females Log-linear analysis $v^2 = 6.247$, $p = 0.044$, $df = 3$) with especially medium and dark-coloured animals using more moss on cold days than on warm days.

Mobility

The recapture ratio was not significantly different between males and females (Table 2b). Observed dispersal distances were significantly related to the time interval between successive captures ($F_{1,203} = 14.18$; $p < 0.001$). Overall mean mobility differed significantly between sexes with males moving

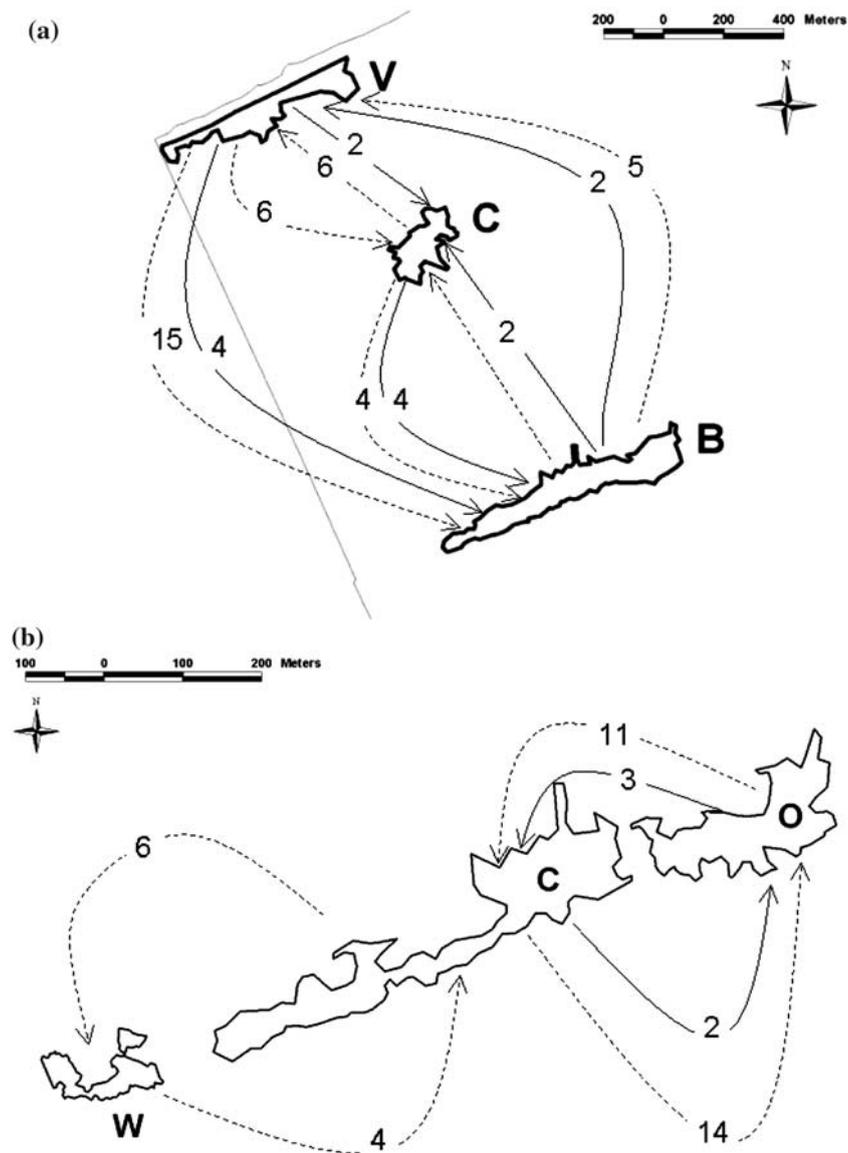


Figure 3. Number of males (dashed lines) and females (solid lines) exchanging between sites for (a) *H. semele* (V = Voorduinen, C = Centraal and B = Binnenduinen) and (b) *O. caerulescens* (W = West, C = Centraal and O = Oost).

longer distances than females ($F_{1,129} = 13.28$, $p < 0.001$; Table 2b). About 68% of the males and 87% of the females did not move further than 50 m and only 4% of the males and less than 1% of the females moved distances greater than 400 m. The maximum distance covered between two captures was 790 m for males and 833 m for females. The proportion of males moving between sites was significantly higher than that of females ($\chi^2_1 = 7.92$, $p = 0.002$; Figure 3b).

Discussion

Although both *H. semele* and *O. caerulescens* are typical species of blond and grey dunes, our results demonstrate that they differ in microhabitat preferences and mobility. Appropriate conservation of typical dune habitats along the Belgian coast should, as a result, take into account these differences in suggested management measures.

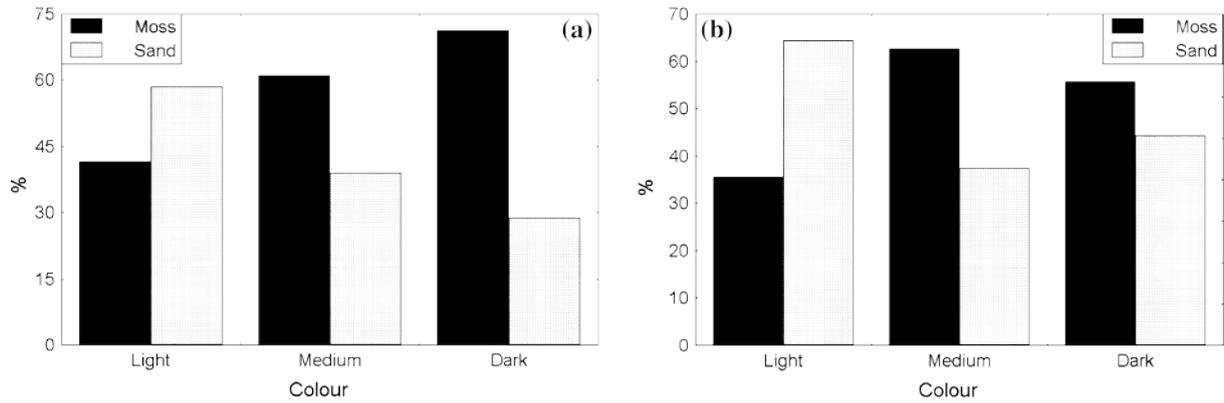


Figure 4. Differences in substrate use by differently coloured individuals of *O. caerulea* (a) males and (b) females.

Habitat use and behaviour

H. semele needs, certainly in Belgium, fairly large sites (>16 ha – Bink 1992) comprising essential resources (male territories, female egg-laying sites and nectar sources). Male *H. semele* defend territories on bare sand patches while females prefer more sheltered and vegetation-covered sites for egg-

laying (Shreeve 1990; García-Barros 2000). The importance of bare sand for males is confirmed by the difference in sex-ratio in Voorduinen and Centrale duinen (largest area of bare sand) compared to Binnenduinen (smallest area of bare sand) and by the significantly larger number of males found on sand patches. The preference for sand patches, however, was not related to day tempera-

Table 2. Numbers of males (M) and females (F) marked, recaptured per study site, density (number of marked individuals/ha) and estimated daily movement distance (\pm s.e; covariate time was set to one in full model) and maximum distance moved between two successive captures for (a) the Grayling and (b) the Blue-winged Grasshopper. Substrate use in the different study sites for male and female Graylings (c) and Blue-winged Grasshoppers (d).

	# Marked			# Recaptured			Density		Mean dist (m)		Max dist (m)	
	M	F	χ^2	M	F	χ^2	M	F	M	F	M	F
(a) Grayling												
Voorduinen	177	78	19.2***	68	19	4.2*	31	14				
Centrale Duinen	70	38	4.3*	32	11	2.2 ^{n.s.}	19	11				
Binnenduinen	69	61	0.1 ^{n.s.}	60	38	9.3**	20	18				
Total	316	177		160	55				146.4 \pm 38.8	158.4 \pm 53.3	1736	1704
(b) Blue-winged Grasshopper												
West	107	47	11.4***	33	13	0.1 ^{n.s.}	138	61				
Centraal	598	245	76.5***	183	64	1.5 ^{n.s.}	158	65				
Oost	221	71	40.2***	33	12	0.1 ^{n.s.}	102	33				
Total	926	363		249	89				46.6 \pm 9.8	5.0 \pm 11.8	790	833
(c) Substrate use Grayling												
	Males						Females					
	Moss	Sand	Other	Moss	Sand	Other						
Voorduinen	29	110	38	14	36	28						
Centrale Duinen	14	36	20	10	19	9						
Binnenduinen	23	38	8	20	26	15						
Total	66	184	66	44	81	52						
(d) Substrate use Blue-winged Grasshopper												
West	52	54	1	25	22	–						
Centraal	287	267	44	107	110	28						
Oost	116	101	4	37	28	6						
Total	455	422	49	169	160	34						

*** $p < 0.001$; * $p < 0.05$; n.s. not significant

ture or body colouration (Findlay et al. 1983; Shreeve 1990). This lack of crypsis may be due to the fact that ground temperatures were fairly similar on both substrate types (Figure 2). Furthermore, we only rarely visited the study sites in early morning, evening or under bad weather conditions, when crypsis might have been more pronounced to minimize predation. As shown by Findlay et al. (1983) and Shreeve (1990), crypsis will become secondary to territorial behaviour once body temperature is sufficiently high.

O. caerulescens populations are able to persist in fairly small habitat patches (0.2–0.3 ha – Appelt 1996; Kuhn and Kleyer 1999–2000). As in *H. semele*, the presence of bare sand is an important habitat characteristic, but here for egg-laying *O. caerulescens* females (Cherrill and Brown 1990; Kurstjens et al. 1999). Temperatures are sufficiently high and well-buffered beneath sand for the hibernation and development of eggs in the next spring (van Wingerden et al. 1991b). *O. caerulescens* clearly showed homochromy (Ergene 1953; Levita 1970) which was even more pronounced on cold than on warm days. According to Whitman (1988), maximisation of homochromy on cold days will lower predation risks, because body temperature will be too low to ensure sufficient activity to escape from predators.

Mobility

H. semele is a fairly mobile butterfly species with recorded dispersal distances of up to 15–20 km (Dennis et al. 1998). Such distances are only covered by a small proportion of the population and the actual number of long distance movements greatly depends on the number of individuals in source populations (Dennis et al. 1998). No differences were found in the average or maximum distance moved by males and females. This enables both sexes or single fertilized females to colonize suitable habitat patches at substantial distances from existing populations (Nieminen 1996).

O. caerulescens is far more sedentary than *H. semele* with clear differences in mobility between males and females (Appelt 1996; Appelt and Poethke 1997; Wollny 1997). With an average daily distance between two consecutive captures of ca. 5 m, female *O. caerulescens* can be regarded as very sedentary. This sexual difference appears be a

general pattern in grasshoppers (e.g., *Stenobothrus lineatus* – Samietz et al. 1996, *Oedipoda germanica* – Zöller 1995). Only a small percentage of individuals (mainly males) covered long distances (up to 800 m, cf. Appelt 1996) which is consistent with previous mobility research on grasshoppers in general (e.g., Zöller 1995; Samietz et al. 1996; Altmoos 2000). Individuals moving between Centraal and West (6 males and 1 female, Figure 3b) had to cross a distance of about 75 m of dense shrubs and trees.

O. caerulescens has been observed flying distances of up to 100 m, which probably enables it to cross such barriers (Detzel 1998). Observations of *O. caerulescens* away from existing populations, usually concern males and the limited mobility of females hampers the colonization of suitable habitat patches at greater distances.

Implications for conservation

Combining the above findings reveals that both the butterfly and the grasshopper depend on bare sand (i.e., *H. semele* territories and *O. caerulescens* egg-laying sites) but also on vegetated patches (i.e., *H. semele* egg-laying sites and *O. caerulescens* food). Variation in the coverage of both is equally important for thermoregulation and for predator avoidance. The higher mobility of *H. semele* probably enables it to access most of the (larger) grey and blond dune patches along the western part of the Belgian coast and its conservation should focus on enlargement and on quality improvement of dune patches (Thomas et al. 2001b). The limited mobility of *O. caerulescens*, especially females, accentuates the need to restore and adequately manage actually occupied patches (that may be relatively small) in the vicinity of existing populations (Kuhn and Kleyer 1999–2000).

In the larger dune reserves along the Belgian coast, grazing is now used to introduce (secondary) dynamics in dunes and is generally recommended as a good management measure for invertebrates like butterflies (WallisDeVries and Ramaekers 2001), grasshoppers (van Wingerden et al. 1991a) and spiders (Bonte et al. 2002). Grazers are believed to increase habitat quality (soil trampling stimulates aeolian dynamics) and patch connectivity between current fragments (removal of dense vegetation within the matrix) for invertebrates restricted to blond and grey dune

habitats. However, detailed investigations on patch use of domestic grazers within this heterogeneous landscape demonstrated that they particularly use nutrient-rich grasslands (Lamoot et al. 2005). Scrub is avoided and open sparse vegetation is only occasionally used as corridors between grazing habitats. As a result, it is questionable whether the introduction of domestic grazers will enhance blond and grey dune connectivity without additional management effort, as the most important barriers for arthropod dispersal appear to be dense scrub-vegetation (Bonte et al. 2003).

Furthermore, because introduced, large grazers avoid scrubland and prefer open dune vegetation as corridors, trampling effects on the latter will be extremely high in stabilised dune landscapes characterised by scattered remnants of open vegetation (like all lime-rich dune landscapes along the North Sea). Apart from direct effects on below-ground egg-development, trampling will result in an immediate destruction of moss patches. As demonstrated here, and also by Cherrill and Brown (1990) and Kindvall (1996), habitat heterogeneity within and between habitat patches is essential for thermophilic arthropods that use different substrates under different weather conditions. Annual variation in weather conditions can lead to a shift in the use of different substrate types (e.g., for thermoregulation) making (meta)populations in heterogeneous habitats more likely to persist than those in homogeneous habitats (Kindvall 1995; Thomas et al. 2001a). Furthermore, homogenisation of open dune habitats due to stabilisation (all patches become grey dunes) or extreme dynamics (all patches become blond dunes) will induce bottlenecks on current genetically diverse populations, as reflected by the variance in genetically determined body colouration (Ergene 1953; Levita 1970). However, long-term monitoring research has yet to show whether the presently-used grazing intensity in scrub dominated dune landscapes conflicts with the ecological demands of *H. semele* and *O. caerulescens*.

In addition to an adequate management scheme, increasing connectivity among suitable patches is equally important for the maintenance of viable metapopulations of both species (Thomas et al. 2001b; Maes and Bonte unpublished data.). Connecting suitable dune grasslands is especially important for *O. caerulescens* and could be

achieved by cutting large swathes of shrub between suitable habitats, creating stepping-stones or corridors. The conservation and restoration of natural dynamics, however, is in our opinion the best way to maintain connectivity and patch quality for these and other typical coastal dune arthropods (Provoost and Bonte 2004). Dispersal of *O. caerulescens* between large dune entities only seems to be possible along the upper beach and seaside blond dunes, as assumed for the dune wolf spider *P. monticola* (Bonte and Maelfait 2001).

Although we did not investigate the habitat use and mobility of other typical dune species, we assume that the use of *H. semele* and *O. caerulescens* to model conservation measures may be beneficial for many other co-occurring species which share the dispersal capacities and habitat requirements of both studied species. More research on other typical blond and grey dune species can further extend the list of possible conservation indicators for coastal dune grasslands in Belgium, such as the wolf spider *Pardosa monticola* (Bonte and Maelfait 2001), the carabid beetle *Cicindela maritima* (Desender 1996) and the solitary wasp *Bembix rostrata* (Peeters et al. 2004). Detailed studies on the habitat use and mobility of these species will likely add complementary information to that of *H. semele* and *O. caerulescens*: *P. monticola*, for example, needs litter for hibernation (Bonte and Maelfait 2001), a resource that is not used by butterflies or grasshoppers. *C. maritima* or *B. rostrata*, on the other hand, have a partially burrowing life style, making them very vulnerable to trampling by large grazers and tourists (Bonte 2005).

In conclusion, in order to conserve specialized insect species, it is essential to understand their precise resource requirements, such as detailed habitat use and mobility. Incorporating these different requirements of a well chosen list of specialized species into management or restoration plans (the so called 'multi-species approach'), would greatly increase the chances of a successful conservation of a wider suite of co-existing species in blond and grey dunes (Kotze and Samways 1999; Maes and Van Dyck 2005).

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