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Species richness of orthopteroid insects and incidence of a rare moth on an island nature reserve threatened by sea level rise in the Walton Backwaters in eastern England

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Abstract

The species richness of orthopteroid insects (grasshoppers/bush-crickets and earwigs) and the incidence of *Gortyna borelii lunata* (Freyer) on an island nature reserve were compared with mainland sites to determine the value of offshore habitats in the Walton Backwaters in eastern England. The species richness of orthopteroid insects was significantly different between Skippers Island and the mainland study sites. The flightless *Leptophyes punctatissima* (Bosc) and the nationally scarce *Forficula lesnei* (Finot) were restricted to offshore habitats. The favourability of Skippers Island for orthopteroids may be due to the absence of intensive agricultural management and livestock grazing, which has led to the development of tussocky grassland and scrub. Despite a high density of its larval foodplant, *Peucedanum officinale* (L.), there was not a significantly greater incidence of larval feeding signs of *G. borelii lunata* on Skippers Island. Insects reliant on the island (such as *F. lesnei*) may be susceptible to the loss of coastal populations due to sea level rise, particularly as the sea wall flood defence on Skippers Island is poorly maintained and eroding quickly.

Keywords: bush-crickets, climate change, coastal habitats, dispersal, earwigs, grasshoppers.

Introduction

Islands may be important for Orthoptera (grasshoppers and crickets) and Dermaptera (earwigs), particularly flightless species such as the rare *Motuweta isolata* (Johns) (Orthoptera: Anostostomatidae) (Stringer & Chappell, 2008). Wetas may require translocation of individuals to islands where they are free of predation or habitat destruction (Watts *et al*., 2008). The flightless *Dryococelus australis* (Montrouzier) is affected by inbreeding and was believed to be extinct on its last island refuge until it was rediscovered in 2001 (Honan, 2008). The lack of wings may be extremely important in the survival of orthopteroids on islands, rendering dispersal virtually impossible where they are isolated by any distance from the mainland. Island size may also be crucial, with large islands

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having a greater range of habitats and species than smaller ones, although this is not the only factor (Dapporto & Dennis, 2008).

The Essex coast in eastern England is rich in Orthoptera with 18 species (including the allied insects Dermaptera and Dictyoptera) being recorded on a regular basis (Gardiner & Benton, 2009 in press). Several nationally scarce species have been recorded, including *Platycleis albopunctata* (Goeze), *Forficula lesnei* (Finot) and *Ectobius panzeri* (Stephens). The coast is also important for Essex rarities, such as *Tettigonia viridissima* (Linnaeus) and *Myrmeleotettix maculatus* (Thunberg) (Gardiner & Harvey, 2004). Coastal spits such as Colne Point are the only known Essex sites for *P. albopunctata* and *E. panzeri* (Harvey & Gardiner, 2006), which is a concern as low level habitats are extremely threatened by sea level rise induced by climate change (Gardiner & Benton, 2009 in press). It is not known how valuable islands are for Orthoptera or Dermaptera in the county and the fauna has not been compared with mainland sites to assess the relative importance of offshore refuges. However, populations of island insects are likely to be highly threatened by sea level rise, particularly if they are flightless and unable to disperse to higher ground.

The Essex coast is also nationally important for its populations of the rare moth *Gortyna borelii lunata* (Freyer), the larva of which feeds on *Peucedanum officinale* (L.), a scarce plant in the U.K. *Gortyna borelii lunata* is listed as vulnerable (Category 2) in the British Red Data Book (Shirt, 1987) and is afforded protection by its inclusion in Schedule 5 of the Wildlife & Countryside Act (1981) (Gibson, 2000). The moth occurs in low-lying coastal areas of north-east Essex in the Walton Backwaters and is significantly threatened by sea level rise (Ringwood *et al*., 2002; Ringwood, Hill & Gibson, 2004).

This paper describes the importance of an island nature reserve in the Walton Backwaters in north-east Essex and relates the species richness of orthopteroid insects and abundance of *G. borelii lunata* and its larval foodplant, *P. officinale*, to mainland sites. Conservation implications for island insect assemblages are discussed. The Walton Backwaters is a shallow tidal bay located on the north-east Essex coast in eastern England. The area is situated between Walton-on-the-Naze and Dovercourt/Harwich. Much of the area forms the Hamford Water National Nature Reserve, an internationally important bay for its wintering birdlife (Gunton, 2008). Habitats in Hamford Water include grassy sea walls, salt marsh, scrub and cliff vegetation at the Naze. The climate of the Backwaters is dry (approximately 550 mm annual rainfall) and temperate (mean annual air temperature 11°C). There are several large islands in the bay; these include Horsey Island and Skippers Island (Fig. 1). Skippers Island formed the basis of this study.

Description of the island and mainland sites

Skippers Island (east and west islands)

A fairly large island (93 ha in size) that is owned and managed by the Essex Wildlife Trust (EWT) as a nature reserve (Table 1). The island is important

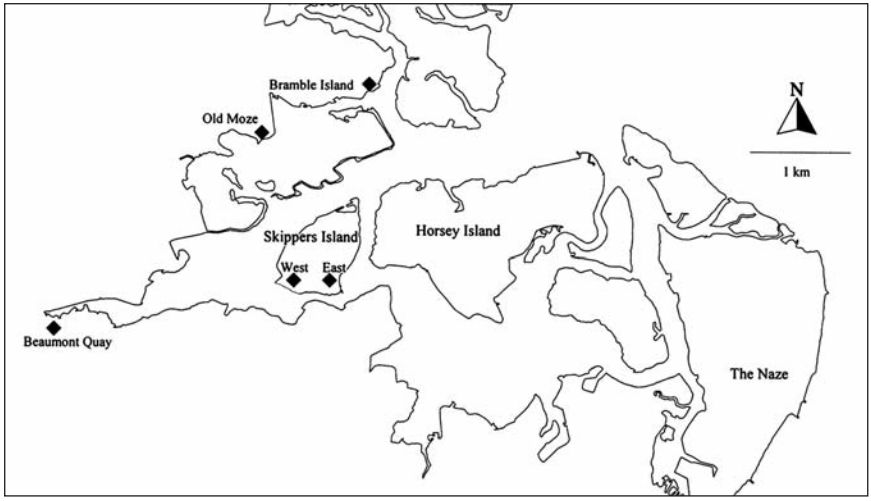

Fig. 1. Location of the two island (Skippers Island East and West) and three mainland study sites (marked with black diamond symbols) in the Walton Backwaters.

primarily for its population of the nationally rare *G. borelii lunata* (Ringwood, Hill & Gibson, 2004), which is largely restricted to the Walton Backwaters in the U.K. The island is divided into two major areas (east and west islands; Table 1; Fig. 1) that are connected by a grassy sea wall and salt marsh. The west island contains a large area of *Prunus spinosa* (L.) scrub, and the remains of a heronry containing a large number of dead *Ulmus* (L.) sp. There is also a large swathe of unimproved, coarse grassland dominated by *Elytrigia atherica* (Link), with large stands of *P. officinale* (foodplant of *G. borelii lunata*; Ringwood *et al.*, 2002) and *Genista tinctoria* (L.). The island used to be grazed by livestock in the 1800s and was connected to the mainland by a causeway (now gone) to allow access. The grassland is no longer grazed and has become tall and rank, with significant scrub encroachment that threatens the survival of *G. borelii lunata* and grassland Orthoptera.

Mainland sites

Two of the mainland sites are sea wall flood defences (Beaumont Quay and Old Moze), and the remaining site at Bramble Island is an industrial 'brownfield' grassland (Table 1; Fig. 1)

Orthopteroid sampling

All study sites were visited on three separate occasions in 2001 (a visit lasted approximately 4 hours) and once in 2004. A range of sampling techniques was used to record the Orthoptera (grasshoppers and bush-crickets) and Dermaptera (earwigs) species present on each island (e.g. sweep netting, visual searching, acoustic monitoring by ear, and beating) (Gardiner, Hill & Chesmore, 2005). No data on abundance were collected. All sampling was

conducted in sunny weather conditions with air temperatures >17°C. Nomenclature used follows Haes & Harding (1997).

Vegetation and *Gortyna borelii lunata* larval sampling

The five study sites were surveyed between 25 June and 10 July 2001. Ten 1 m^2 quadrats were placed randomly within the area of the main stands of *P. officinale* at each of the five sites. The number of *P. officinale* plants and height of the grass sward were measured in each of the quadrats. The other vegetation species (including grasses) were recorded in each quadrat. Nomenclature follows Stace (1997), with only the first author listed for each species where appropriate for reasons of brevity. In addition to the quadrat surveys, 50 *P. officinale* plants were examined for the presence of *G. borelii lunata* larval feeding signs (bore holes and/or frass piles within the stems, stem axils or at the base of the plant). This was conducted to obtain an indication of the abundance of this moth at each of the study sites. The larval feeding signs of this species are distinctive and therefore cannot be confused with that of any other species of Lepidoptera.

Soil samples were taken to a depth of 25 cm from every study site in the survey and analysed for available phosphorus, potassium, magnesium and texture according to MAFF (1986).

Statistical analysis

Before analysis, all data were square root transformed to correct for non-normality (Gardiner, Hill & Chesmore, 2005). To compare species richness of orthopteroid insects, plant species richness, density of *P. officinale* and percentage incidence of *G. borelii lunata* between island and mainland sites, an unmatched samples t-test was used for each variable. The mean grass height and available phosphorus, potassium and magnesium content of the soil samples were all analysed using an unmatched samples t-test. The data were analysed using SPSS software (SPSS, 2007).

Results and discussion

Grass height and soil characteristics

The mean grass height was not significantly different between Skippers Island and the mainland sites (Table 2), despite the fact that island swards have been ungrazed for *ca* 100 years. However, although the difference was not statistically significant ($t = -2.28$, $P = 0.11$), the available phosphorus content of the soil was lower on the islands, indicating that the absence of agricultural improvement on Skippers Island, due to difficulty in accessing the grasslands with machinery, has led to impoverishment of a key nutrient in the soil. Most inorganic fertilisers that are used on the mainland include phosphorus and it is highly likely that drift may occur during applications; the two sea walls, with adjacent arable fields, may be particularly susceptible to this. A chemical plant was present at the Bramble Island site during the course of the study and the historical usage of the site as an explosives factory may have led to the enhanced phosphorus content of the soil. The clay loams present at two of the

Table 1. Details of the island and mainland study sites.

Island / mainland	Status	Site Description	Altitude (m)	Management	Threats
Island					
Skippers East	National Nature Reserve	Coastal grassland located between the sea wall and scrub	< 2	None	Flooding and scrub encroachment
Skippers West	National Nature Reserve	Coastal grassland located between eroding sea defence and scrub	< 2	None	Flooding and scrub encroachment
Mainland					
Beaumont Quay	National Nature Reserve	Long, rank, unimproved grassland on and behind a sea defence wall	1–3	Mown annually	None perceived
Bramble Island	Privately owned	Grassland within an industrial area	4–5	Mown regularly	Intensive mowing (every 2–3 weeks)
Old Moze	Privately owned	Coarse, unimproved grassland on and behind a steep, well maintained sea wall	1–4	None	None perceived

Table 2. Grass height and soil nutrient status/texture for the five study sites.

Island / mainland study sites	Mean grass height (cm)	Soil P (mg/l)	Soil Mg (mg/l)	Soil K (mg/l)	Texture
Island					
Skippers East	81 ± 6	9.2	324	638	Sandy silt loam
Skippers West	72 ± 10	10.0	334	865	Clay loam
Mean ± SE	77 ± 5	9.6 ± 0.4	329 ± 5	752 ± 114	–
Mainland					
Beaumont Quay	101 ± 3	20.6	321	451	Clay loam
Bramble Island	62 ± 4	23.4	399	732	Clay loam
Old Moze	94 ± 3	12.0	212	313	Sandy silt loam
Mean ± SE	86 ± 12	18.7 ± 3.4	311 ± 54	499 ± 123	–
T-test value*	–0.52	–2.28	0.32	1.39	–

* all means in each column are not statistically different

mainland sites were also fairly fertile and able to retain soil nutrients. However, none of the other soil nutrients was markedly different between Skippers Island and the mainland (Table 2).

Table 3. Species richness of orthopteroids and plants (herbaceous species, grasses and rushes recorded, total number of species in brackets), and the density of the endangered *Peucedanum officinale* and percentage of this plant with larval feeding signs for *Gortyna borelii lunata* on two island replicates and three mainland sites.

Island / mainland study sites	Orthopteroid sp. richness	Plant sp. richness m^{-2}	*P. officinale* density m^{-2}	*G. borelii lunata* larval feeding signs (%)
Island				
Skippers East	8	2.5 (9)	2.7	54
Skippers West	9	3.7 (12)	3.0	22
Mean ± SE	8.5 ± 0.5	3.1 ± 0.6	2.9 ± 0.2	38 ± 16
Mainland				
Beaumont Quay	5	5.9 (21)	0.6	30
Bramble Island	6	7.1 (19)	3.3	4
Old Moze	6	4.9 (10)	1.2	30
Mean ± SE	5.7 ± 0.3	6.0 ± 0.6	1.7 ± 0.8	21 ± 9
T-test value*	4.98*	–3.13*	1.08	0.93

* significant difference between both means in column at $P<0.05$

Plant species richness

Despite the low fertility of the unimproved grassland on Skippers Island, plant species richness was significantly lower than on the mainland (Table 3). Indicators of fertility such as *Anthriscus sylvestris* (L.) and *Urtica dioica* (L.) were present on the mainland but not on Skippers Island (Table 4), perhaps reflecting the higher nutrient status of the sea wall and industrial swards. The low plant species richness is probably due to the tussocky nature of the island swards (with a high amount of litter), due to an absence of grazing management for *ca* 100 years. The resultant dominance of *Dactylis glomerata* (L.) and *E. atherica* (Table 4), has led to the loss of low-growing plants such as *Lotus corniculatus* (L.) and *Trifolium pratense* (L.) that persist under the mowing regimes at mainland sites such as Bramble Island (mown every 2–3 weeks in summer) and the sea wall at Beaumont Quay (mown once annually) respectively.

Orthopteroid species richness and moth incidence

However, the importance of tussocky, ungrazed swards for orthopteroid insects is confirmed by this study (Tables 3 and 5). Gardiner & Haines (2008) found that ungrazed horse pastures in the south of the county had a higher species richness of Orthoptera than heavily grazed pasture, and a higher abundance of six out of seven species including *Metrioptera roeselii* (Hagenbach) and *Pholidoptera griseoaptera* (DeGeer), which were both recorded in the ungrazed pastures of Skippers Island in this study (Table 5). Two of the mainland sites were mown in July and August (Beaumont Quay and Bramble Island), thus restricting the development of scrub, which is important for *F. lesnei* and

Table 4. Plant species recorded in quadrat surveys on the islands and the mainland (× indicates presence).

Species	Island site		Mainland site		
	Skippers East	Skippers West	Beaumont Quay	Bramble Island	Old Moze
Agrostis capillaris (L.)	×	×	×	×	×
Anthoxanthum odoratum (L.)					×
Anthriscus sylvestris (L.)			×		
Arrhenatherum elatius (L.)	×	×	×	×	×
Atriplex prostrata (Boucher)		×			
Carex spp. (L.)				×	
Cirsium arvense (L.)	×	×	×	×	×
Cirsium vulgare (Savi)		×			
Convolvulus arvensis (L.)			×		
Cynosurus cristatus (L.)			×		
Dactylis glomerata (L.)			×	×	×
Elytrigia spp. (Desv.)	×	×	×		×
Festuca rubra (L.)	×	×	×	×	×
Galium aparine (L.)			×	×	
Genista tinctoria (L.)	×			×	
Holcus lanatus (L.)	×	×	×	×	×
Hordeum secalinum (Schreb.)			×		
Juncus spp. (L.)				×	
Lathyrus pratensis (L.)				×	
Lolium perenne (L.)			×		
Lotus corniculatus (L.)				×	
Peucedanum officinale (L.)	×	×	×	×	×
Phleum bertolonii (DC.)			×		
Phragmites australis (Cav.)			×		
Plantago lanceolata (L.)			×		
Potentilla anserina (L.)				×	
Prunus spinosa (L.)		×	×		
Ranunculus repens (L.)				×	
Rumex crispus (L.)		×		×	
Senecio viscosus (L.)		×			
Sonchus spp. (L.)	×				
Stellaria graminea (L.)				×	
Trifolium pratense (L.)			×		
Trifolium repens (L.)			×		
Urtica dioica (L.)				×	
Vicia cracca (L.)			×		
Vicia hirsuta (L.)				×	
Vicia sativa (L.)					×

Leptophyes punctatissima (Bosc), two species that were recorded on Skippers Island but not at any of the mainland sites (Table 5).

The overall orthopteroid species richness of Skippers Island (93 ha in size) compares favourably with larger islands (> 100 ha) in the U.K. For example, the species richness of Skippers West Island (9 orthopteroid species) was

higher than Lundy (4 species), Skokholm (3 species) and Skomer (6 species) (Marshall & Haes, 1988), indicating that it is nationally important for its orthopteroid assemblages, particularly for *F. lesnei* and *L. punctatissima*, which are rare offshore (Haes & Harding, 1997).

Skippers Island was managed as a nature reserve and was free from the adverse effects of intensive arable farming and had large areas of coarse grassland and scrub that earwigs, such as *F. lesnei*, inhabit (Marshall & Haes, 1988). What is of concern is the poor dispersal capacity of *F. lesnei* and *L. punctatissima* (species recorded only on the islands), which means that any loss of their island habitats through sea level rise and salt marsh encroachment could threaten their survival in the area. However, both species have been found further inland than the surveyed sites (*L. punctatissima* is particularly widespread; Wake (1997)) and are not in any imminent danger of extinction in the county.

The presence of brachypterous species such as *L. punctatissima* and *P. griseoaptera* on the islands (indeed, the former bush-cricket was not seen on the mainland) suggests that wingless Orthoptera can sustain populations offshore, although sea level rise may well threaten the future of these sedentary bush-crickets, which will be unlikely to disperse inland. The absence of *L. punctatissima* on the mainland is probably due to the lack of scrub/woodland on the sea wall flood defences and at Bramble Island. Species with macropterous (long-winged) forms such as *M. roeselii* may well be able to disperse between islands separated by narrow channels of water by drifting on air currents (Smith, 2007). The close proximity of Skippers Island to the mainland (*ca* 108 m at nearest point) may allow immigration and emigration of orthopteroids.

The incidence of *G. borelii lunata* and its larval foodplant, *P. officinale*, were not significantly different between mainland and island sites (Table 3). This suggests that the sea walls that support this moth at Beaumont Quay and Old Moze have populations that are important in the Walton Backwaters. Therefore, Environment Agency (EA) mowing regimes on sea walls are crucial in maintaining the viability of the Walton Backwater's metapopulation. To this end, the EA has implemented a system of rotational mowing at both sites to allow sections of both sea walls to remain uncut during the most sensitive times for this insect; mowing must also be conducted in a very tight time window (from 10–25 August) so that destructive impacts are avoided. The low incidence of larval feeding signs (4%) on Bramble Island may be due to the regular mowing of the site during the summer months having a negative impact on the species.

Much work has been undertaken into creating new sites for the moth, away from the dangers of rising sea levels. Following successful trials in 2004, *P. officinale* has been planted out on a large scale (approximately 1000–2000 plants per site) at eight secure sites on the north Essex coast. Four of these sites consist of established grassland, supporting an abundance of the long, coarse grasses the moth requires for egg laying, and the other four are located on agricultural land. It is envisaged that this work will facilitate the future survival of this moth in the U.K. if sea levels rise.

Table 5. Orthoptera and Dermaptera species recorded on the islands and on the mainland (× indicates presence).

Order / Species	Island site		Mainland site		
	Skippers East	Skippers West	Beaumont Quay	Bramble Island	Old Moze
Orthoptera					
Chorthippus albomarginatus (De Geer)	×	×	×	×	×
Chorthippus brunneus (Thunberg)	×	×	×	×	×
Chorthippus parallelus (Zetterstedt)	×	×	×	×	×
Conocephalus dorsalis (Latreille)	×	×		×	×
Leptophyes punctatissima (Bosc)	×	×			
Metrioptera roeselii (Hagenbach)	×	×	×	×	×
Pholidoptera griseoaptera (De Geer)	×	×		×	×
Dermaptera					
Forficula auricularia (Linnaeus)	×	×	×		
Forficula lesnei (Finot)		×			

However, despite the lack of significant differences in the abundance of the moth or foodplant between the islands and the mainland, Skippers Island still holds a very important population of *G. borelii lunata* because of the extensive stands of *P. officinale* present. This means that the overall moth population on Skippers Island is much greater than that found on the mainland, therefore establishment of colonies away from the coast, and the continuing favourable management of the sea wall sites, assume greater importance for the future survival of this insect in the U.K. if the Skippers Island colonies become extinct due to permanent tidal inundation of the grazing marsh. The current rate of sea level rise in the county (6 mm/yr net sea level rise; DEFRA, 2006), combined with the low-lying nature of the grazing marsh at Skippers Island (< 2 m OD; Table 1), means that the island will probably be permanently inundated, without major rebuilding works on the flood defences, in the next 100–200 years. The mainland sea walls are approximately 4 m in height and may allow the moth to migrate up the banks as the sea level rises.

Conclusions

The results from this small-scale study suggest that islands can be important refuges for Orthoptera and Dermaptera on the Essex coast due to

the absence of intensive agricultural practices and livestock grazing leading to scrub development. However, species found on islands (particularly those that are brachypterous) are at a high risk of extinction due to sea level rise. The abundance of the rare moth, *G. borelii lunata*, and its larval foodplant *P. officinale*, were not significantly different between the mainland sites and those on the islands. This moth may therefore have a greater chance of persisting in the Walton Backwaters when sea level rises as a result of climate change. The results of this paper should be viewed with some caution due to its small-scale and limited replication.

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