The 2017 Status of the Lulworth Skipper Butterfly

Fiona Bell (PTES Intern), Rachel Jones, Nigel Bourn

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CONTENTS

1. EXECUTIVE SUMMARY:

From June to August 2017, a survey was carried out for the Lulworth Skipper Butterfly across its known range in Dorset to determine its presence and abundance where possible, to relate these findings to habitat properties, and past distributions and population sizes.

The Lulworth Skipper is a geographically restricted butterfly and a species of Principal Importance under Section 41 of the NERC Act (2006), due to its being threatened by land use change and loss of its only larval hostplant, tor-grass, over a sward height of 10cm. As the last dedicated study was carried out in 2010, a more up-to-date report was needed to determine any significant changes in numbers or distribution, and to ensure that land management prescriptions remain accurate.

The survey and subsequent analyses found no observable change in distribution between 1997 and 2017, but did find an approximate 20% decline in the number of sites found to contain the Lulworth Skipper during that time period. As the nature of the declines within this time frame is unclear, further investigation is needed to understand current population trajectories and risk to the butterfly.

Interactions of population density and size with proxies of habitat suitability (e.g. sward height) were also explored. As expected, sward height and tor-grass frequency were positively linked with population density, suggesting that existing land management recommendations for the Lulworth Skipper continue to be relevant. While the index for grazing intensity used in this study was found to have no significant interaction with population density, greater insight may be provided by a more detailed categorisation of grazing types and seasonality in future research.

There were also found to be no significant interactions between Sites of Special Scientific Interest designation or Environmental Stewardship Scheme level, and habitat properties or population density. However, the broad landscape scale of these programs, and the subsequent range of management approaches, habitat types and landowners will complicate any investigations of their impact on an individual species. Further investigation with larger amounts of historic data, and more detailed analysis, may elucidate more of these impacts.

The Lulworth Skipper continues to be threatened by lowered habitat quality and site isolation related to grazing intensification from domestic stock and rabbit populations. This is particularly concerning in light of declines in 'core' sites and decreases in total population numbers reported in this study. Loss of presence in individual sites is likely to destabilise the population network, and limits its ability to withstand and recover from increasingly frequent and intense climate events. Further research, in parallel with strategic evidence-based land management, and consistent population monitoring, is crucial for improving the long-term outlook for this vulnerable species.

2. INTRODUCTION

The Lulworth Skipper (*Thymelicus acteon*) has been in long term decline since the mid-20th century (Fox *et al*., 2015) and is consequently a Section 41 Species of Principal Importance in the NERC Act of 2006. Widespread population declines in its European range have also caused the species to be deemed 'Vulnerable' (Fox *et al.*, 2006)**.** The species is of particular concern because it is sensitive to changes in grazing and is highly restricted with low dispersal ability (Thomas *et al.*, 1983a), reaching its northern limit in the south coasts of Dorset in England. Its vulnerability is also linked to the closed populations it forms, with low exchange of individuals (Louy *et al.*, 2007).

The habitat preferences of the Lulworth Skipper are highly specific, sufficiently so that the species' presence can be an indicator of vegetation successional stages. It requires an abundance of its larval food plant, tor-grass (*Brachypodium pinnatum*), of at least 10cm in height, predominantly on south-facing slopes of unimproved calcareous grassland. Populations reside on coastal and inland habitats, such as chalk downland and undercliffs, preferring where there is little to no grazing pressure; the female Lulworth Skipper prefers mature flowering spikes of between 30-50cm height tor-grass (Thomas *et al.*, 1983a)**.**

Given its low capacity for dispersal and sensitivity to turf height, the main threats to Lulworth Skipper are understood to be changes in grazing or cutting regimes and site isolation (Bourn & Warren, 1997). Both of these threats are compounded by the challenges posed by climate change. Landscape scale management, assisted by Countryside Stewardship Schemes (CSS) and Sites of Special Scientific Interest (SSSI) designations, could be effective means of addressing the threats, if well-implemented. Grazing pressures increased in the late 20th-century, particularly in CSS, partly in response to dramatic declines of short-turf preferring species such as the Adonis Blue, and lower plant biodiversity associated with stands of tor-grass. The recovery of rabbit populations from myxomatosis also increased non-domestic grazing intensity.

Detailed surveys have been conducted at regular intervals prior to this study, in 1978, 1997 and 2010. Although the 1998 report concluded that the status and distribution of the Lulworth Skipper has remained largely unchanged since 1978, findings from Botham *et al.* (2008) indicated that the majority of populations subsequently declined in abundance. However, despite dramatic long-term declines in abundance, the distribution of the Lulworth Skipper has remained largely unchanged since surveys in the 1970s, occurring along the coast between Weymouth and Swanage and inland to the Purbeck Ridge, in addition to an isolated colony at Burton Bradstock.

This study aims to provide an updated knowledge of the status and distribution of the Lulworth Skipper in 2017, and an insight into the role of habitat management and vegetation structure in observed population sizes. The data will be provided by visits to sites surveyed in previous investigations, and will be used to investigate whether the requirements of the Lulworth Skipper have changed since in the years following previous studies.

3. AIMS AND OBJECTIVES

The aim of this report is to outline the 2017 status of the Lulworth Skipper, highlighting areas where populations have changed since 1997.

This aim will be addressed through the following objectives:

- Conducting transect counts on all known Lulworth Skipper colonies, including those from previous studies, to determine population size, and distribution of the species.
- Analyse data on relevant habitat attributes, such as sward height and tor-grass frequency to assess links between habitat and population changes.
- Investigate the cause of any discovered changes in distribution.

4. METHODOLOGY

4.1 SPECIES COUNTS

For detailed methodology, refer to the 1998 report by Pearman *et al.* The primary aim was to re-visit every site visited in 1997 and 1978, and survey additional suitable habitat to identify new colonisations. Data was collected from 16 June 2017 to 10 August 2017 to span the peak flight period for Lulworth Skipper. The peak flight period was calculated using weekly transect data from permanent transects at Bindon Hill, Durlston Country Park and Ballard Down.

Count data was collected by walking transect routes as similar as possible to those walked in 1997, which crossed the middle of the flight area on most sites. Flight area was defined as areas of tor-grass taller than 10cm (Pearman *et al.*, 1998). Flight area was later mapped in QGIS, based on maps annotated in the field. All Lulworth Skippers two metres either side of the transect path were counted, as per the Pollard Method (Pollard & Yates, 1993).

Sites found to be absent of Lulworth Skipper were re-surveyed later in the season to increase the confidence of an ‘Absent’ finding. When revisiting sites, amendments to original transect routes were made where necessary to ensure that suitable habitat was surveyed. Some older transects used were made unsuitable for surveying Lulworth Skipper by populations too small to be detected, or shifts and contractions of the area occupied to under-cliffs, or similarly inaccessible areas. Sites initially recorded as ‘Absent’ were extensively searched beyond established transect routes during revisits to determine presence or absence of Lulworth Skipper, rather than estimates of abundance.

Revised transects incorporated more of the under-cliffs on coastal sites than in 1997, for example, by conducting transect routes on the beach along the cliff base on sites such as Osmington Bay and Ringstead Bay.

Count data was converted into an index of population size comparable between years though use of the quick method (Thomas, 1983b). The size of the flight area (A; ha) was calculated using QGIS (Nodebo, 2.16.1). The transect length (L; metres) and butterfly count (N) were used to determine abundance per 100m, providing a comparable measure of butterfly numbers between sites. Abundance per 100m was then multiplied by the flight area to give a population index (P) for each colony; see formula below.

Population Index: P = 100N/L x A

4.2 SITE CHARACTERISTICS

Vegetation height was recorded at intervals along the transect walk using a 30cm diameter drop-disc; for full drop-disc methodology see Stewart *et al.* (2001). Intervals were dependent on transect length to allow for approximately 50, and no less than 30, measurements of sward height per site, which were then used to calculate a mean sward height of the flight area of each site.

Table 1. Transect length and corresponding interval distance

Transect Length	Interval Distance
X=<300m	5m
300m<X=<600m	10m
600m<X	20m

Presence or absence of tor-grass within $50cm^2$ of the drop disc was recorded at each measurement and converted to tor-grass frequency per transect. Sward height and tor-grass frequency were used as indicators of habitat quality for the Lulworth Skipper. During surveys, notes on habitat condition, site characteristics, and evidence of management were recorded (e.g. grazing, scrub cover).

4.3 DATA ANALYSIS

For investigation of distribution and abundance trends between years, only sites that had been surveyed in 1997 and 2017 were included for more reliable comparison. For analysing interactions of 2017 population densities and indices with habitat attributes and management strategies, sites with no 2017 occurrences recorded were excluded for expediency. All analysis was conducted, and all graphs created, in R Studio (1.0.136). Maps were made in QGIS (Nodebo, 2.16.1). All values are reported to 3 decimal places, or 3 significant figures when less than 0.1.

The correlations of population density and indices with sward height, tor-grass frequency and flight area were tested for significance of association using Spearman's Test of correlation for paired samples. Spearman's test was deemed more suitable for this purpose than Pearson's because of the non-linearity of the relationships, and Spearman's test can more reliably interpret all monotonic correlations.

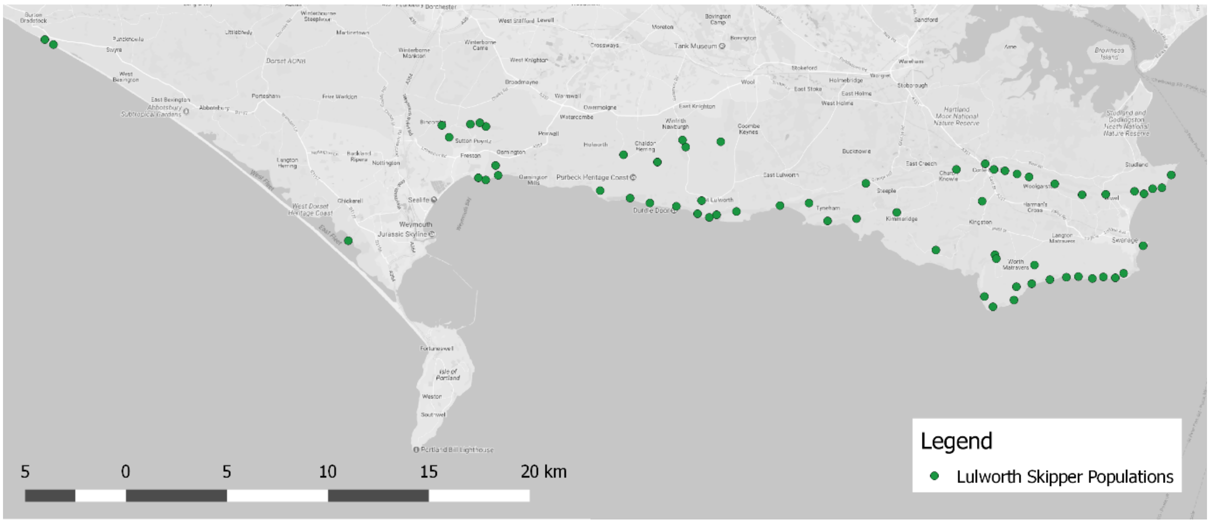
Comparisons of the median sward height, tor-grass frequency and flight area between 'small' and 'medium' populations were made using Wilcoxon Rank Sum Non-paired tests.

Kruskal Wallis Rank Sum tests were used to test for differences in median habitat attributes and population densities/indices dependent on; grazing level, management scheme, SSSI designation, and ownership. Wilcoxon Rank Sum tests were inappropriate in these cases because of there being more than two ordinal categories (e.g. Grazed, Mixed, Ungrazed).

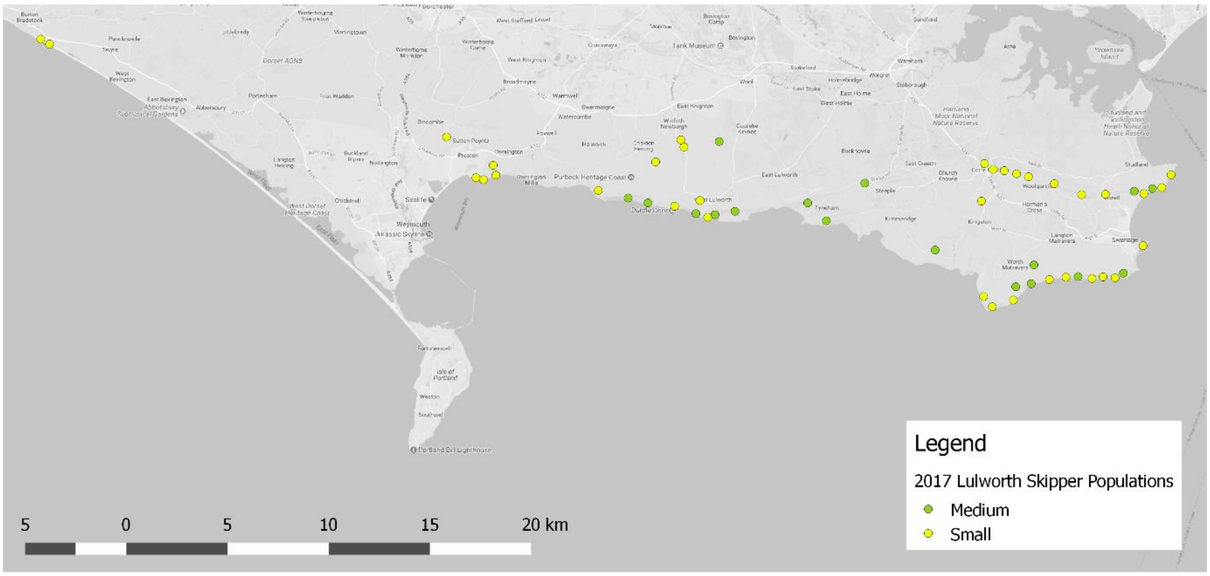
5. RESULTS

5.1 DISTRIBUTION OF COLONIES

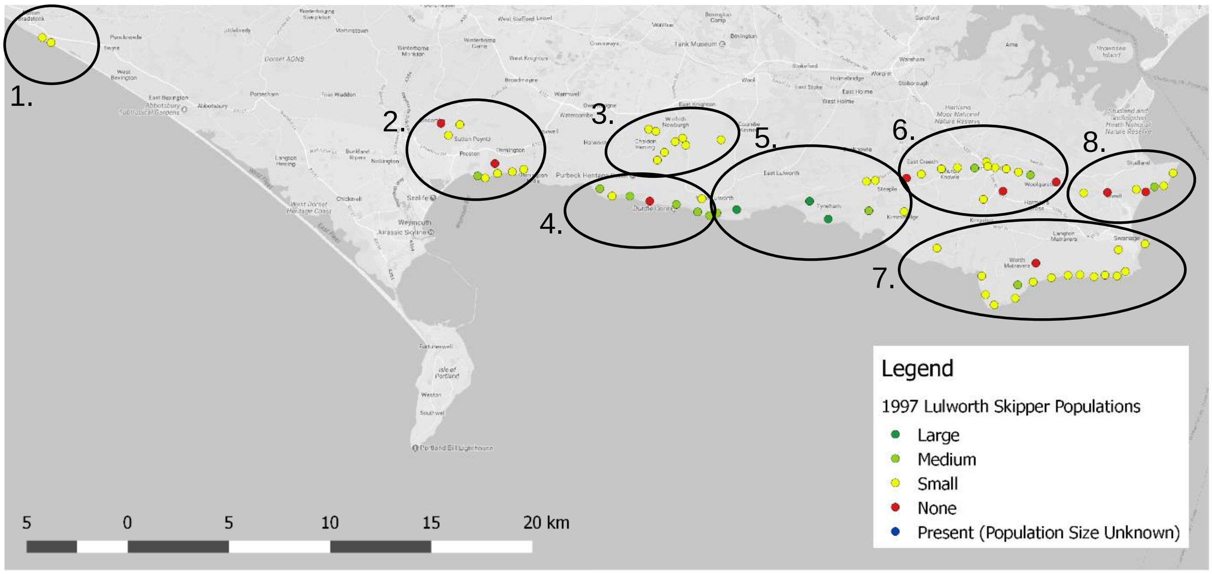
Map 1.i. All sites with recorded occurrences in 2017 (Total number = 64), represented by individual points. Black circles indicate geographical groupings of populations within a larger network.



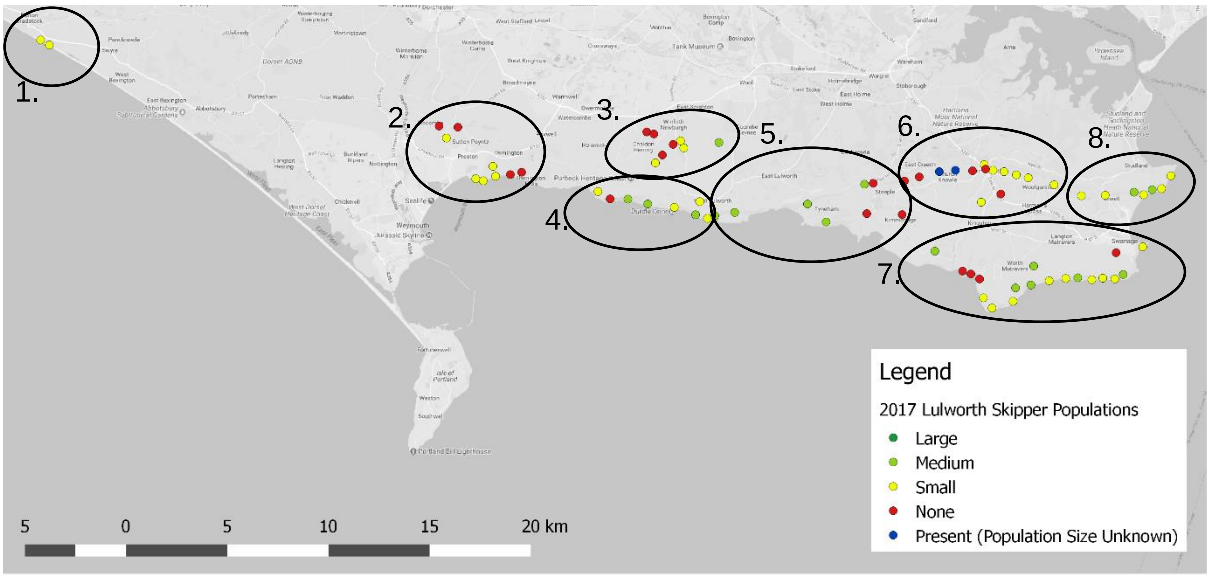
Map 1.ii. All sites with recorded occurrences in 2017 and basis for estimation of population size, as above (Map 1.i). Points are colour coded according to size category of the population at respective sites, see legend for more details. Black circles indicate geographical groupings of populations within a larger network.



Map 2.i. Sizes of populations as recorded in 1997, of sites surveyed in both 1997 and 2017, represented by individual points. Black circles indicate geographical groupings of populations within a larger network and are numbered for ease of reference.



Map 2.ii. Sizes of populations as recorded in 2017, of sites surveyed in both 1997 and 2017, represented by individual points. Black circles indicate geographical groupings of populations within a larger network and are numbered for ease of reference.



Sites were categorised by population index as a surrogate measure for colony size that allows for comparison of populations between surveys. The range of values for colony size were established by Bourn and Warren (1997), and the equivalent values for population index were calculated using the regression equation for estimated colony size determined by Thomas (1983b), given below. The category sizes are large to account for natural fluctuations in population sizes.

$Y = (0.013x + 5.394)$, Where Y = Population Index, x = Estimated Colony Size

Table 2. Definitions of colony size according to population index, converted from categories parameterised by Thomas (1983b)

POPULATION INDEX	ESTIMATED POPULATION SIZE	COLONY SIZE
5.394- 18.393	1 – 999 adults	Small
18.394- 135.393	1000 – 9999 adults	Medium
>135.394	>10000 adults	Large

Network Status Summary:

1. Two ‘small’ populations were recorded in 1997 in Burton Bradstock which have remained as such in 2017.
2. ‘Small’/’medium’ populations in 1997, four ‘small’ populations found in 2017.
3. Majority 2017 populations present are ‘small’, with only four colonies compared to the previous eight in 1997 but Lulworth Common has increased to become a ‘medium’ population.
4. Previously supported seven sites, including five ‘medium’ populations, though one absent site (Middle Bottom/Bat’s Head) was recorded. In 2017, Whitenothe is the only absent site with seven of eight sites are present, including Middle Bottom/Bat’s Head, though only three are ‘medium’ populations.
5. Three ‘large’ populations in 1997 have been reduced to ‘medium’ size, and one population that was ‘medium’ in 1997 in South Egliston appears to have become absent.
6. Only one out of 14 sites were not present in 1997. In 2017, four sites were not present, generally clustered towards the western edge of the area. It should be noted that two sites in this area (Cocknowle and West Hill East) were observed outside of timed counts, so a population size could not be determined, but presence has been confirmed.
7. Populations were predominantly ‘small’ in 1997, but four of those had increased to ‘medium’ size, and one site (Worth Matravers) was colonised, by 2017.
8. Five colonies of ‘small’ to ‘medium’ populations were present in 1997. However, all seven sites had occurrences in 2017, with two new ‘small’ populations, and one previously ‘small’ population in Ballard Down increasing to ‘medium’.

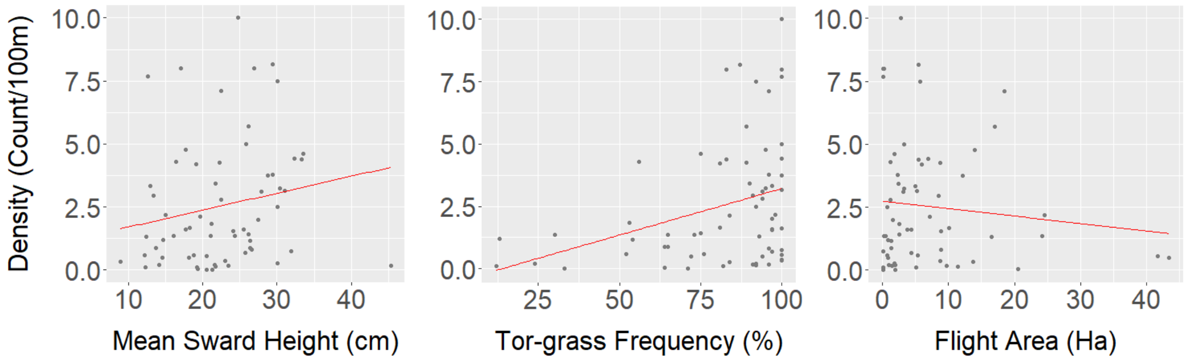
Table 3. Summary of population totals according to size determined from population index in 1997 and 2017

YEAR	NOT PRESENT	SMALL	MEDIUM	LARGE	TOTAL SURVEYED
1997	11	51	12	3	77
2017	24	36	17	0	77

Of the sites which were surveyed in all years, the number of sites where Lulworth Skippers were observed decreased by approximately 20% from 66 in 1997 to 53 in 2017, and all three ‘large’ populations decreased in size to ‘medium’ populations, though there has been a slight increase in the number of ‘medium’ populations (5) not wholly accounted for by the reduction of ‘large’ populations.

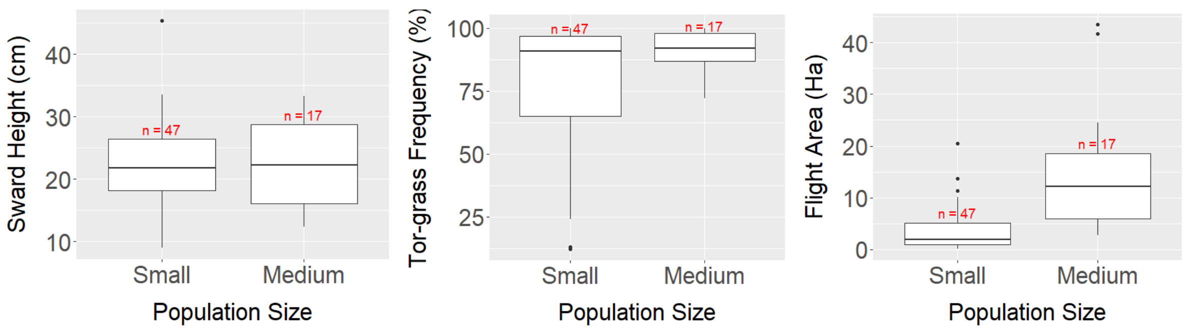
5.2 HABITAT CHARACTERISTICS AND POPULATION SIZE

Chart 1. Linear regression of sward height/frequency/flight area and population size/density. The red line represents the line of best fit. Sample size of 64 sites.



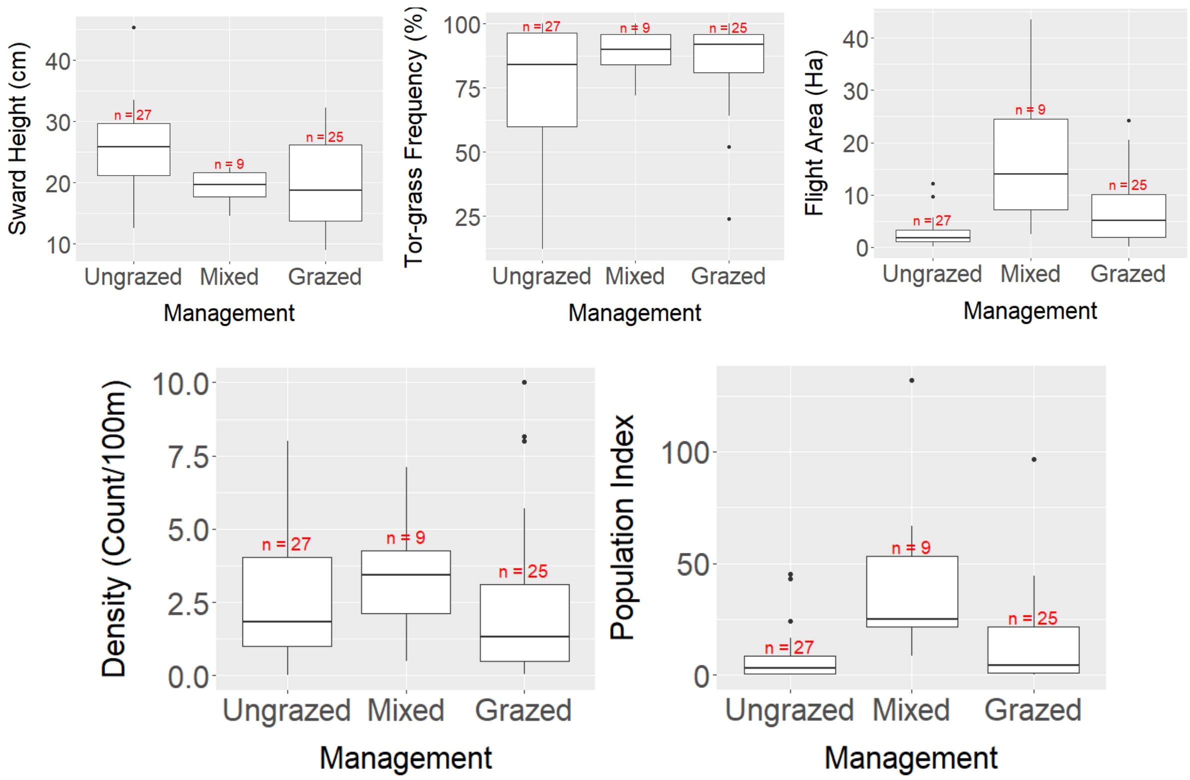
Population density was significantly positively correlated with both sward height (rho = 0.263, p = 0.0358, n = 64) and frequency of tor-grass (rho = 0.325, p = 0.00872, n = 64), though these relationships may not be linear. Frequency of tor-grass in particular appears to have an exponential relationship with population density, suggesting a potential threshold level of tor-grass cover, below which population density is limited. In contrast, flight area was not linked to density (rho = 0.0408, p = 0.749, n = 64), which could indicate that the relationship between absolute population size and flight area is linear, simplifying estimation of colony size from counts and measurement of flight area.

Chart 2. Whisker plots comparing medians and quartiles of sward height, tor-grass frequency and flight area between small and medium populations. Sample size for each group included in figure. Outliers included as individual points.



Population size is determined from population index and flight area, and broadly categorised into 'small', 'medium' and 'large' populations. Within this study, higher tor-grass frequency was not associated with 'medium' or 'small' populations (W = 318, p = 0.216), nor was median sward height significantly greater at sites with 'medium' populations (W = 407, p = 0.916). 'Medium' populations were however linked to greater flight areas (W = 86, p = 2.02e-07).

Chart 3. Whisker plots comparing medians and quartiles of habitat attributes and proxies of population size between sites grouped by grazing intensity. Sample size for each group included in figure. Outliers included as individual points.

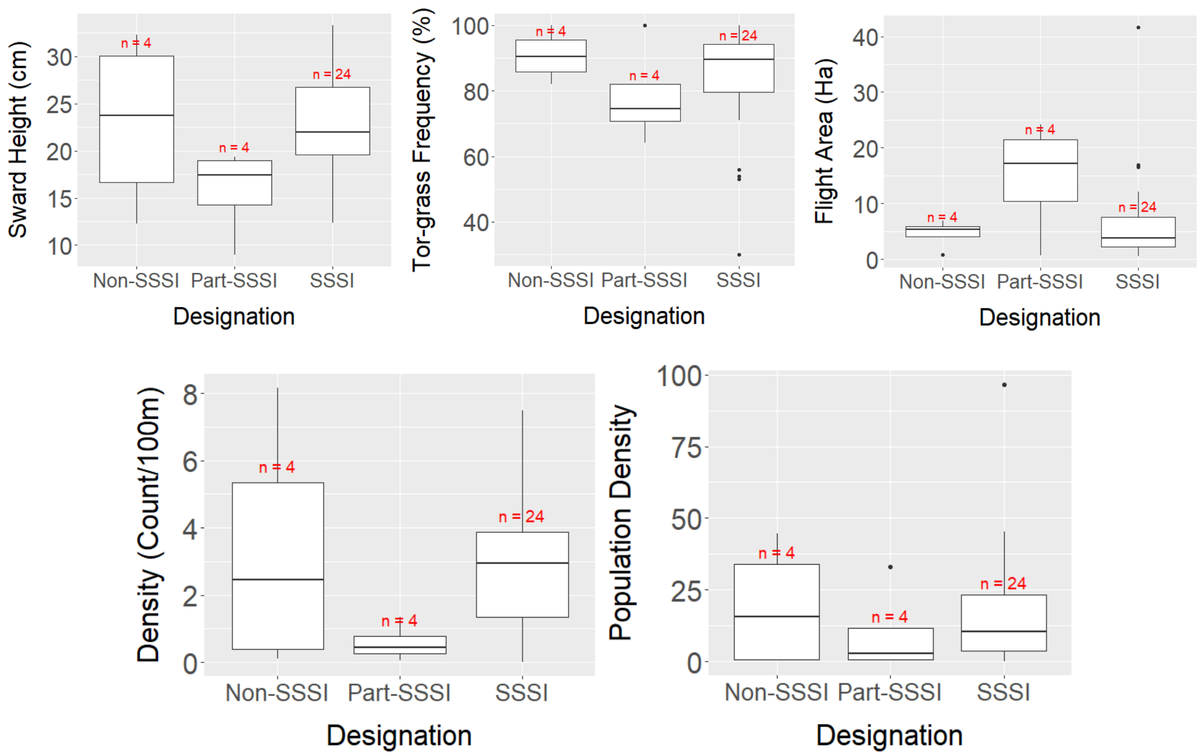


Sward height (K = 9.443, df = 2, p = 0.0089) was significantly linked to grazing strategy, while tor-grass frequency was not (K = 0.861, df = 2, p = 0.65). However, flight area did significantly interact with level of grazing (K = 18.293, df = 2, p = 1.066e-04), with greater flight area in ‘mixed’ grazed sites. It should be noted that this may be an artefact of sites with larger land areas housing a mixture of grazing strategies.

Grazing level did not appear to impact on population density (K = 2.072, df = 2, p = 0.355), though its interaction with population index was significant (K = 13.197, df = 2, p= 0.001362), with mixed sites having a higher index. As population indices are products of flight area, the near significantly higher index in mixed sites is likely a consequence of higher flight area in those sites.

5.3 STATUS, SCHEMES AND OWNERSHIP

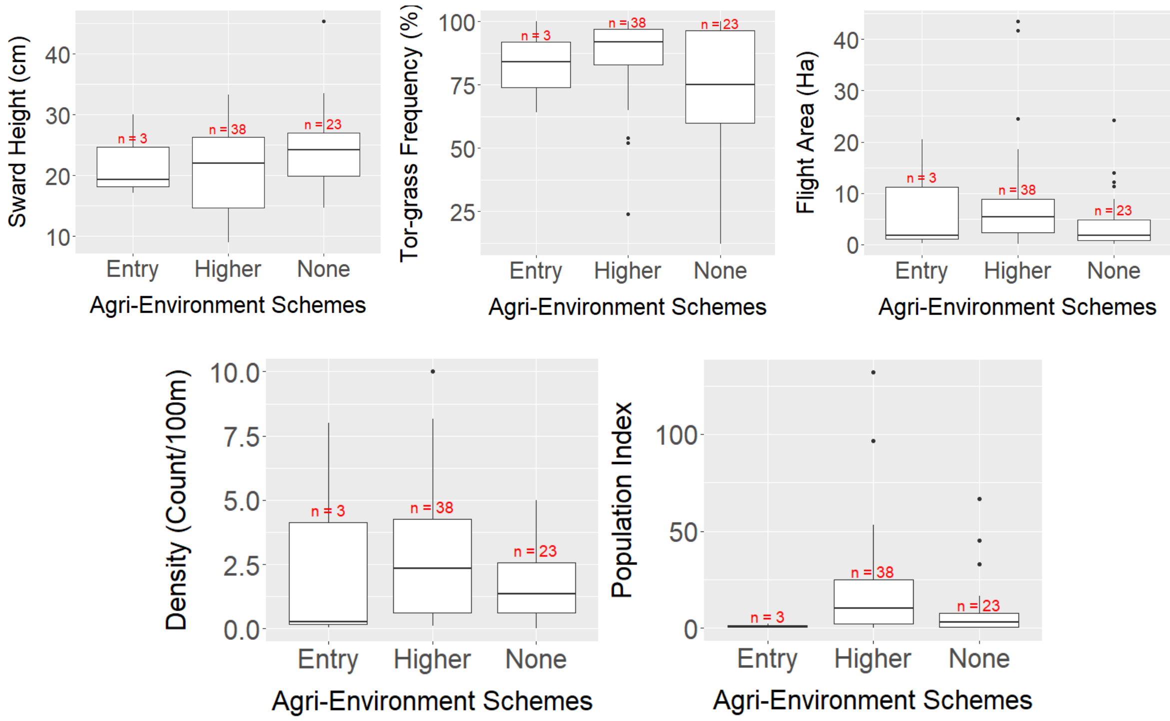
Chart 4. Whisker plots comparing medians and quartiles of habitat attributes and proxies of population size between sites grouped by SSSI designation. Sample size for each group included in figure. Outliers included as individual points.



SSSI status of sites were not significantly associated with tor-grass frequency (K = 1.197, df = 2, p = 0.549), flight area (K = 1.892, df = 2, p = 0.549) or sward height, although sward height was approaching significance (K = 4.481, df = 2, p = 0.106), being greatest in non-SSSI sites. There are many factors that play into management strategy, so no obvious conclusion can immediately be drawn from this finding, but implications will be discussed later in this report.

Similarly, neither population density (K = 4.695, df = 2, p = 0.0956) nor index (K = 0.977, df = 2, p = 0.614) were significantly associated with SSSI status, although the interaction between population density and SSSI status approached significance.

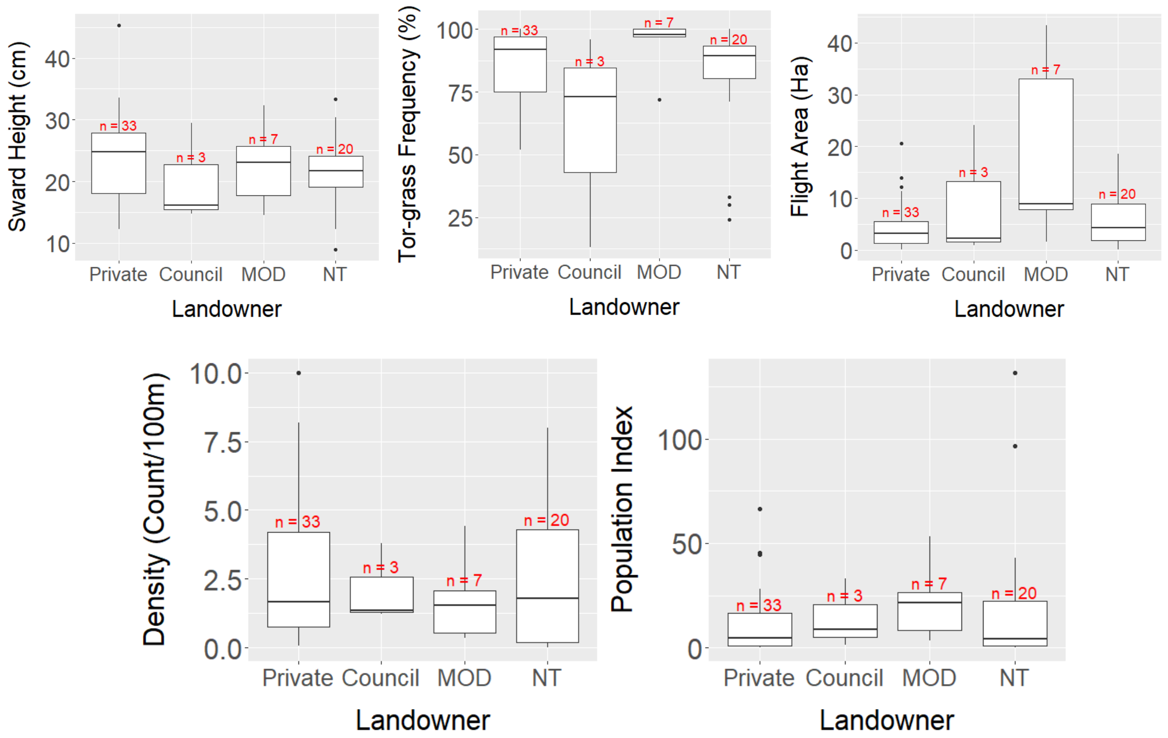
Chart 5. Whisker plots comparing medians and quartiles of habitat attributes and proxies of population size between sites grouped by status in agri-environment schemes. Sample size for each group included in figure. Outliers included as individual points.



Environmental Stewardship Scheme (ESS) involvement had no significant associations with sward height (K = 1.868, df = 2, p = 0.393), tor-grass frequency (K = 1.55, df = 2, p = 0.461), or flight area (K = 4.891, df = 2, p = 0.0867). Although only approaching significance, sites in Higher tier ESS prescriptions appear to have greater flight areas. Again, the complexity of land management prescriptions and implementation prevents conclusions being taken from the non-significant results, but the role of agri-environment schemes will be discussed in greater detail.

Similarly, population density had no significant associations with agri-environment schemes (K = 2.828, df = 2, p = 0.243). However, population index was linked to agri-environment scheme (K = 7.35, df = 2, p = 0.0254), with higher indices in higher tier sites.

Chart 6. Whisker plots comparing medians and quartiles of habitat attributes and proxies of population size between sites grouped by landowner. Sample size for each group included in figure. Outliers included as individual points.



Sward height does not significantly differ between owners (K = 1.154, df = 3, p = 0.764) but the interaction between ownership and tor-grass frequency approaches significance (K = 7.412, df = 3, p = 0.0599); council owned sites appear to have lower tor-grass cover. Flight area does not differ significantly between owners (K = 7.639, df = 3, p = 0.0541), though the greatest median flight area appears to be in MOD sites. This may be an artefact of MOD owning larger land areas.

Ownership is not significantly linked to population density (K = 0.722, df 3, p = 0.868) or index (K = 3.491, df = 3, p = 0.322). While no conclusive trends have emerged from the data collected in this study, the role of land ownership in maintaining Lulworth Skipper habitat will be explored in greater detail later in this report.

6. DISCUSSION

6.1 POPULATION DISTRIBUTION AND TRENDS

Peak abundance of the Lulworth Skipper in Dorset was recorded in the 20th century (Thomas *et al.*, 1983a) but long term declines of in abundance and occurrence have since been reported (Botham *et al.*, 2008) (Fox *et al*., 2015). Population declines for *T. acteon* have been widely linked to habitat loss (Thomas *et al.*, 1983a) (Bourn & Thomas, 2002) as grazing intensification has reduced occurrence of tor-grass of sufficient sward height to serve as breeding habitat.

However, more recent data indicate that populations may have stabilised, though not recovered (Fox *et al*., 2015). While there are a number of possible factors contributing to the recent change in trend that merit further investigation, such as site isolation and climate, this report will focus predominantly on vegetation structure.

Despite declines in number, this study mirrors previous findings that the distribution of the Lulworth Skipper in Dorset have remained largely stable since populations were surveyed in 1997 (Maps 2.i-ii.) (Jones *et al.*, 2013). Significant range expansion was unlikely for this species considering their specific habitat requirements and short dispersal distance, but this persistence across the Lulworth Skipper's historic range suggests that the extent of tall tor-grass hasn't decreased, and that their range currently remains climatically suitable within the UK.

Of sites surveyed in 1997 and 2017, the number of 'Present' sites has declined from 66 to 53 (Table 3). However, the decline is unlikely to be linear so it is unclear when the bulk of this decline took place within the 20-year time frame. Further research into the status of the butterfly in the past decade would help to elucidate the nature of the decline. This understanding is crucial to better gauge efficacy of any efforts to manage land more sympathetically for the Lulworth Skipper. Besides this, no geographic pattern is immediately observable for recorded changes in occupancy status or population size since 1997.

While the total range within the parameters of the survey appears to be unchanged, extinctions within the range still have the potential to disrupt site connectivity. In the 'Corfe' area (Map 2.ii., Circle 6), the majority of sites in the western half of the ridge had no occurrences during transect counts in 2017. It should be noted that these sites contained only 'small' populations in previous surveys, so absences in 2017 could result from temporary extinctions as part of a dynamic system (Thomas *et al.*, 1992), or populations too small to be detected and so require additional search effort (e.g. additional visits, or exploration of a greater proportion of the area). However, potential long-term extinctions in this region could be of particular significance, as these sites may serve as 'stepping stones' for recolonisations of inland colonies (Thomas *et* *al.*, 1992)**,** though their role in exchange of individuals between populations may be limited (Louy *et al.*, 2007).

The likelihood of long-term Lulworth Skipper persistence is also reduced by declines in 'core' sites, such as Tyneham and Gad Hill (Pearman *et al.*, 1998) as indicated by the shrinking of upper population sizes. 'Core' sites can act as refuges during disturbance events, and facilitate recolonisation as 'source-populations' provided sufficient connectivity in the surrounding habitat. Small populations can be more vulnerable in an unstable environment, as local extinctions have been found to predominantly occur in small habitat patches for some butterfly species (Thomas & Harrison, 1992). While this trend was not found to be significant specifically for Lulworth Skippers, possibly as a consequence of recording biases, it was reported that the smallest occupied patches recorded were close to neighbouring populations, so a loss of larger sites may have to be compensated for by increased network connectivity.

No 'large' populations were recorded in 2017, raising questions over whether efforts to restore the suitability of previously identified 'core' sites, or opportunistically manage growing sites, would be the most practical and effective use of resources. While it is possible that 'core' sites have shifted to areas not included in this survey, the potential loss of 'large' populations may limit Lulworth Skipper robustness and resilience to potential disturbance events, which are likely to increase with climate change (Pachauri *et al*., 2014).

6.2 HABITAT INTERACTIONS WITH POPULATIONS

Vegetation structure components such as sward height and tor-grass cover have been identified as key determinants in observed trends of Lulworth Skipper abundance and distribution (Thomas *et al.*, 1983a), because of their role in the species' egg-laying and larval development.

One of the aims of this study was to investigate whether assumptions based on previously established associations between habitat and Lulworth Skipper population size (Bourn & Thomas, 2002) remain relevant and accurate for the species today. An up-to-date understanding of Lulworth Skipper habitat requirements, and those of other species, is necessary to maintain the effectiveness of land management advice.

As might be expected, higher frequency of tor-grass was found to be correlated with population density (Chart 1), likely due to the greater availability of egg-laying sites. However, there were sites, such as Ailwood Down, with high tor-grass frequency that had relatively low density. This site did however have an average sward height of less than 10cm, which may lower the availability of egg laying sites. Sward height has been identified as a key determinant of

Lulworth Skipper density, but other habitat features such as topography (e.g. land slope and aspect), availability of nectar sources, and local weather may limit density.

Established requirements of Lulworth Skipper for taller turfs of tor-grass (Bourn & Thomas, 2002)**,** (Thomas *et al.*, 1983a) are supported by the data from this study given a positive relationship between population density and sward height (Chart 1). It has been speculated that Lulworth Skippers may adapt to use shorter tor-grass for reproduction, and while sward height appears to remain a density limiting factor, there were outlying populations such as those in Ballard Down and Ridgeway Hills with high densities at relatively low mean turf height (>10cm).

Some of these outliers may be an artefact of vegetation measurements that were not representative of the entire flight area; specifically, in Ridgeway Hills where MOD safety restrictions prevented transecting optimum habitat. Sites that were more thoroughly sampled (e.g. Ailwood Down) may however provide evidence for local adaptation and merit further investigation and comparison of relationships between years.

The results of this study indicate that our understanding of tor-grass structure's impact on Lulworth Skipper populations, and subsequent land management prescriptions remain relevant in 2017. However, the role of vegetation structure in observed extinctions and colonisations over time should be further investigated beyond proxies such as frequency and sward height so as to improve site specific recommendations. Additionally, the increasing pressures of a changing environment strengthen the argument for future return surveys to monitor any changes in habitat requirements.

Average UK temperatures have increased since the start of the 20th century, along with the frequency and intensity of extreme weather events (Pachauri *et al*., 2014). Changes in climate have been linked to shifts in species' range and timing of seasonal events (Parmesan *et al*., 1999) (Roy & Sparks, 2000), with more negative impacts on species with narrow habitat niches and low dispersal ability, such as the Lulworth Skipper (Fox *et al*., 2015). The direct and indirect effects of climate change and its interactions with other pressures (e.g. disease, land use change) are frequently difficult to predict, so there is an increasing need to maintain a variety of habitats within well connected networks to provide resilience from loss of individual populations during, for example, extreme weather events (e.g. drought) (Thomas *et al.*, 1992) (Scriven *et al.*, 2015).

6.3 HABITAT MANAGEMENT STRATEGY AND SCHEMES

While management recommendations can improve circumstances for the Lulworth Skipper in the short-term given their rapid response to changes in vegetation structure (Bourn & Thomas, 2002), resources can be managed more effectively when considering the network of populations in the surrounding landscape.

Landscape-scale conservation coordinates conservation and management efforts with the aim of not just supporting persistent population networks of a target species, but for a range of species within a large natural area (Ellis *et al.*, 2012). Coordinated management over such a large spatial scale requires sustained monitoring efforts, shared vision between conservationists and landowners, evidence-based management prescriptions, and both long and short-term funding (Ellis *et al.*, 2012). Agri-environment schemes and special designation statuses are both useful tools for landscape scale management, and this study investigated the role of both in Lulworth Skipper habitat suitability and abundance.

Agri-environment schemes, such as the Countryside Stewardship Scheme (CSS) which replaced Environmental Stewardship (ESS) in 2015 (Natural England, 2014a), are government-run schemes that can provide funding to land managers to deliver beneficial environmental management. Variations of the scheme (e.g. Higher Tier, Organic) can offer higher levels of funding in return for more targeted management which will be of greater benefit to wildlife. When well-designed and combined with strong ground presence, these schemes are key delivery mechanisms for long-term funding to sustaining persistence of species such as the Lulworth Skipper (Ellis *et al.*, 2012).

An extension of Countryside Stewardship, the Farmland Butterfly and Moth Initiative (FBMI) is a collaboration begun in 2012 between Natural England and Butterfly Conservation that targets sites within the Higher tiers of CSS (Butterfly Conservation, 2017). The project collects data and provides site-tailored management prescriptions for ten of the most vulnerable butterfly species, including the Lulworth Skipper. The FBMI is a promising example of the potential applications of agri-environment schemes to efficiently manage effort and resources for conservation through shared partnership and science-based recommendations at a landscape scale.

Sites of Special Scientific Interest (SSSI), meanwhile, are areas that are notified by nature conservation agencies (under the amended Wildlife and Countryside Act, 1981) to contain flora, fauna, geological or physiogeographical features of special interest, such as lowland grassland habitat. When a site has been notified, suggestions will be given on land management and certain operations on the site will require consent from Natural England

(Natural England, 2017). SSSI status doesn’t inherently provide funding, but can qualify a site for grants and other sources of funding (Natural England, 2014b).

The data in this study did not reveal a significant association between SSSI status or agri-environment scheme level, and sward height, tor-grass frequency, or flight area. A lack of association between sward height and agri-environment schemes (Chart 5) is precedented (Pearman *et al.*, 1998), and may suggest similar average grazing intensity between sites regardless of scheme or designation. More specifically, vegetation structure within stands of tor-grass may not have been manipulated if policy were targeted to species not impacted by tor-grass condition. SSSI in particular had a greater range of sward heights than non- or part-SSSI (Chart 4), a possible consequence of site-tailored management prescriptions with varying levels of priority given to Lulworth Skippers over species with conflicting habitat requirements.

Agri-environment scheme levels were not linked to population density of the Lulworth skipper but the Higher level of the scheme was positively associated with population index (Chart 5), likely owing to non-significantly greater median flight areas in Higher level sites, as population index is a product of both population density and flight area. Neither population density and index were significantly linked to SSSI status, in accordance with an absence of interaction with vegetation structure (Chart 4). However, caution should be taken when interpreting these results, as the small sample sizes for non-SSSI and part-SSSI may limit the statistical significance of any observed associations. It has been suggested that NE management advice may lead to higher grazing intensity in SSSI, particularly for the benefit of the Adonis Blue and specialist short-turf flora (Pearman *et al.*, 1998). Other factors to investigate that may explain population differences between SSSI and non-SSSI include duration and timing of grazing, and scrub clearance strategy.

The Purbeck Ridges, previously ‘large’ ‘core’ sites, were being tightly grazed in 1997, both in and out of Countryside Stewardship, and scrub was controlled through rotational burning; both actions were predicted to encourage short-turf preferring Adonis Blue populations while negatively impacting Lulworth Skippers (Pearman *et al.*, 1998). The same report highlighted the need to include habitat diversity (e.g. taller tor-grass margins) within sites and at the landscape scale in land management prescriptions. Today, the Purbeck Ridges hold only ‘small’ to ‘medium’ populations (Map 2.ii), in line with predictions made in 1997, potentially associated with a loss of habitat to scrub encroachment.

However, a lack of significant interactions between Lulworth Skipper population density and schemes and designations does not necessarily negate the effectiveness of these schemes for creating habitat and benefiting wildlife. The relationship between schemes and designations, and habitat management is complex, and not necessarily captured by the basic analyses in this report. A better understanding may be gained, for example, through increasing sample size of sites with known designation, and a more detailed breakdown of management techniques (e.g. grazing, scrub clearance).

7. CONCLUSIONS

- The distribution of the Lulworth Skipper has remained largely unchanged from 1997. The potential for expansion is limited by the species' low capacity for dispersal, but the continued maintenance of its range is positive.
- In agreement with established relationships, sward height and tor-grass frequency is positively correlated with population density, indicating that habitat preferences have not significantly altered since 1997. Population density is not linked with flight area however.
- Proxies of grazing intensity used in this study were not associated with tor-grass frequency, but did interact with sward height and flight area. There was no interaction with population density or index. A more detailed categorisation of grazing may provide greater insight in future research.
- There were no significant interactions with level of Environmental Stewardship and habitat attributes or population density. However, habitat management prescriptions are generally aimed more at conserving biodiversity than individual species across the landscape, so gauging the efficacy of active management for Lulworth Skipper via the scheme will require more information.
- SSSI status were not significantly linked to vegetation structure or population densities and indices, though the confidence with which we can interpret the absence of interactions are limited by the sample sizes available.
- Ownership was not significantly linked to vegetation structure or population densities, though the degree to which sites owned by MOD had significantly greater flight area approached significance, most likely due to greater land area of the sites.
- Continued grazing intensification from domestic stock or fluctuations in rabbit populations and subsequent destabilisation of the network of Lulworth Skipper habitats through lowering of habitat quality and site isolation present the largest current threat to the species. Identification of and defence against future threats are further complicated by the instability introduced by climate change. To improve the robustness and resilience of a species vulnerable to rapid vegetation change and site isolation, it is necessary to strategically manage habitat at the landscape scale; 'bigger, better and more connected' habitats with evidence-based management and consistent population monitoring.

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