Recapture rates and habitat associations of White-faced Darter *Leucorhinnia dubia* on Fenn's and Whixall Moss, Shropshire, UK

Rachel Davies, Achaz von Hardenberg & Matthew Geary

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Abstract

Introduction

There has been a marked decline in global biodiversity in the last several decades and this has been largely attributed to changes in land-use activities (Foley et al, 2005). Land-use activities include agriculture, forestry, creation of urban areas, and use of natural resources (Foley et al, 2005). These activities have a huge impact on the environment, including having an impact on soil quality, water quality and air quality (Foley et al, 2005). Land-use change is often negative and can impact on habitats by causing habitat loss and habitat fragmentation, contributing largely to the decline in global species diversity (Foley et al, 2005; Holloway, Griffiths, & Richardson, 2003). As such management and protection of habitats and populations is vital at both a local and global scale (Foley et al, 2005; Holloway et al, 2003).

A bias exists in conservation research towards charismatic vertebrates (REF). Although Odonata are charismatic invertebrates they are not immune to this bias (REF). In addition much research into Odonata focuses on physiology, evolution and behaviour and, unlike butterflies (REF), they have rarely been the focus of conservation research (REF). Basic ecological research into demogrpahy, survival and habitat use is essential for effective protection of species and habitats (REF). For any taxa this requires detailed ecological and life history data collected in the field. These are often difficult to obtain, particularly on large scales (REF). Integrating large scale data such as presence-only distribution datasets with more detailed local information is a current challenge in conservation ecology (REF).

Methods to analyse habitat preferences are varied depending on the data available. The current 'gold standard' is the use of occupancy models which take into account the detectability of a species as well as it's presence or absence at a site (REF). Models using this framework help us to avoid the age-old problem of not always seeing what is there (REF). However, these models require repeated surveys where both presence and absence are recorded; these data are not always available to us. On larger scales a number of methods exist which can use only presence records along with environmental covariates (REF). These can tell us about habitat use but are constrained to giving us a relative importance of habitats (REF) and are limited by the environmental data available. At very small scales, such as individual protected areas, data on habitats and landcover can be difficult to obtain. Datasets such as the UK lancover map (LCM2015), although the resolution is 15m, is too crude for local studies. Simpler methods which indicate preferred habitat such as selection indices (REF) have fewer assumptions and can be revealing even at small scales (REF).

Investigating survival and movement requires individual recognition (REF) and methods using a capture mark-recapture approach are well established. Such analyses can tell us about the longevity of individuals, the use of different sites or habitats and how this changes over time or the likelihood of encountering individuals again in the future (REF). High quality data of this type can give us good indications of population size. Mark-recapture methods have been used on Odonata populations in the past (REF) and have been used to monitor rare species as well as to track individuals (REF) and as a model species for mark-recpature research (REF).

The White-faced Darter, is a specialist of lowland peatbogs where it breeds in bog pools containing sphagnum mosses (Smallshire & Swash, 2010). The White-faced Darter has a life cycle that includes a 1-3-year larval period, followed by an adult flight period (Smallshire & Swash, 2010). Emergence is weather dependant and will typically start in either May or June each year. Tenerals are thought to disperse to low scrub following emergence, staying there whilst they mature. Following this, the adults return to breeding pools, with males returning sooner than females so they can hold breeding territories (Smallshire & Swash, 2010). The adult flight period typically ends in either late July or August. The White-faced Darter has a scattered distribution and its populations have been declining in Britain over the past several decades. Despite being classified as a species of least concern on the IUCN Red Data List (Clausnitzer, 2009), this decline in Britain has resulted in a classification of Endangered on the Odonata Red Data List for Britain (Daguet, French, & Taylor, 2008). This decline is largely attributed to habitat loss and the resulting habitat fragmentation (Daguet et al, 2008); as over 90% of England's peatbogs have been lost or substantially damaged to date (English Nature, 2002). There are currently only three stable historical populations of White-faced Darter in England, along with two recently reintroduced populations, one in Cumbria and one in Cheshire (Clarke, 2014; Meredith, 2017).

Here we use two methods to investigate important ecological characteristics of White-faced darter on Fenn's and Whixall moss in Shropshire. We use mark-recapture methods to investigate survival and movements of adults during the flight period and a selection index method to investigate habitat use. These methods can both contribute to our understaonding of the spatial use of habitat by White-faced darter and can help us to prioritise future research for this species.

Methods

Study area

Fenn's, Whixall and Bettisfield Mosses (FWB Mosses) are located within Shropshire and they support a large, long-established population of White-faced Darter. FWB Mosses are a lowland raised bog complex, stretching nearly 1000 hectares (Meredith, 2017). Historically, the mosses were used for peat cutting and in the 19 th century they were drained to allow larger-scale operations to take place (Meredith, 2017). Eventually, in 1990, the mosses were taken over by English Nature (now Natural England) and long-term restoration began, benefitting a whole host of mossland species, including the White-faced Darter. (Meredith, 2017). Restoration continues today.

Field methods

The site was surveyed twice per week between the 22nd of May and 6th of July 2017. This encompassed the peak flight period of White-faced Darters (Smallshire & Swash, 2010). Two separate breeding pools within FWB Mosses were sampled simultaneously, along with a variety of scrub and other potentially suitable habitat. On each sampling occasion, the full sampling area was searched for any White-faced Darter individuals. Different routes were walked on each occasion to allow different areas within the sampling area to be searched at different times of the day. Sampling sessions lasting between 5-10 hours, being carried out between 10am and 4pm, as this is the favoured flight period for adult dragonflies (Smallshire & Benyon, 2010). Sampling days were weather dependant (Chin & Taylor, 2009) and weather conditions were recorded on all sampling days.

Capture-Mark-Recapture
Where possible, mature adults were caught using an invertebrate net and marked with a unique number on their wing (Chin & Taylor, 2009), using an Edding 404 permanent marker pen (Plate.1). The insects were then released at point of capture and any behavioural observations recorded. Not all observed individuals were captured and tenerals were excluded from the CMR survey as during this life stage they are fragile and handling may cause wing damage (Allen & Thompson, 2014). Tenerals are easily identified by their pale green colouration, a lack of their full adult colouration and by their shiny wings (Smallshire & Swash, 2010). Insects recaptured on day of marking were not re-counted (Foster & Soluk, 2006). Following an initial marking, recapture on successive days was only necessary when relevant information could not be collected from re-sighting individuals (Lettink & Armstrong, 2003).

Selection index White-faced darter presence was recorded while searching the site during the capture-mark-recapture study. This included captured individuals as well as those seen on survey routes but not captured. On each occasion the location of the individual was recorded with a hand-held GPS unit. Additionally, a phase 1 habitat survey (REF) was conducted across the study site to produce a habitat map using 100 x 100 m grid cells. The proportion of six habitat types were recorded in each square: moss (DEFINITION?), scrub (DEFINITION?), scrub-moss (DEFINITION?), water (DEFINITION?) and woodland (DEFINITION?). From this the dominat habitat in each square was calculated. Of these, onyl water was not used in analyses as adult individuals tended to be sighted over terrestrial habitat.

Data analysis

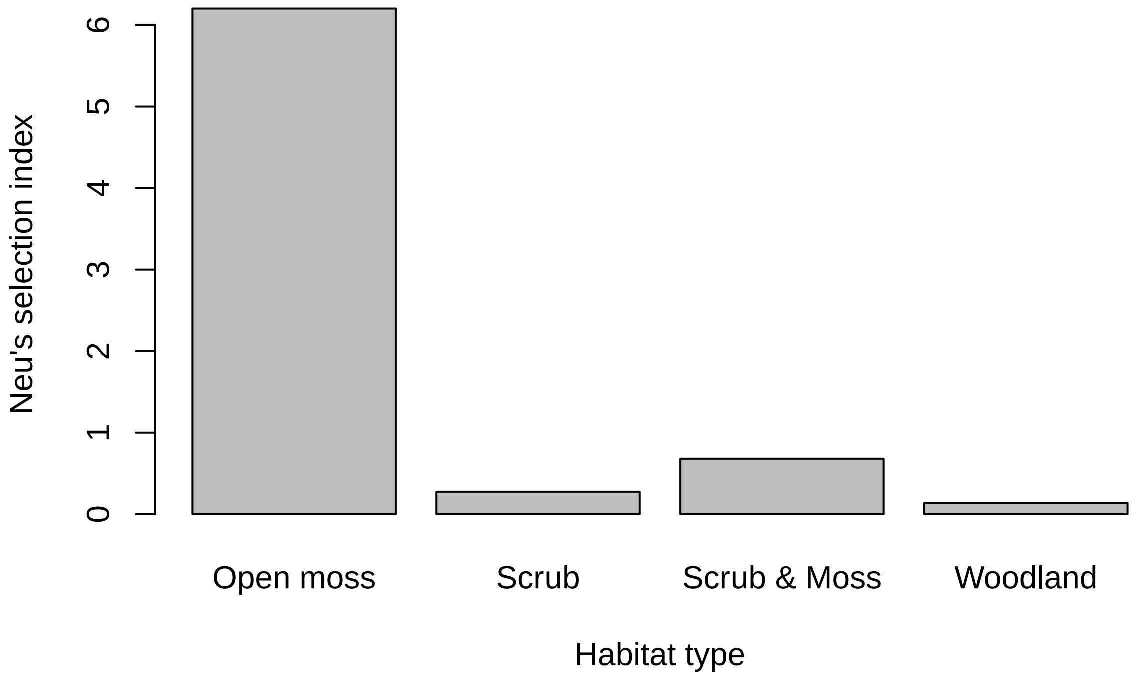
Capture-mark-recapture
A Capture-Mark-Recapture, single-season The Cormack-Jolly-Seber model (Citation!) was used to determine to probability of survival between sampling days and the probability of capture on sampling days for the capture-mark-recapture data. Capture-mark-recapture analysis was carried out in the RMARK package version 2.2.2, in R version 3.3.2. (R Core Team, 2016).

Selection index
Selection indices calculate habitat use as a ratio between habitat where a species is recorded compared to the proportion of each habitat within the study area (REF). Although relatively simple they can be effective in indicating habitat use (REF). Selection indices can be sensitive to the scale used in calculating habitat use (REF) however Neu's index is relatively robust to changes in scale (REF). For this reason we used Neu's index which calculates $w_i = \frac{u_i}{\pi_i}$ where w_i is the proportion of squares of each dominant habitat type among all of the squares wiht White-faced darter records and π_i is the proportion of each dominat habitat type among all of the squares in the stufy area (REF). Values of thsi index > 1 indicate use of a habitat type in greater proportions than it is generally available in the study area. Selection index analysis was performed in R version 3.4.4 (REF - R Core Team 2018).

Results

Capture-Mark-Recapture Model
A total of 13 sampling days were carried out at FWB Mosses from the 22nd May 2017 until the 7th July 2017. During these sampling days, a total of 50 adult White-faced Darters were marked (Figure!!!) (41 males, 9 females), and a total of 6 recaptures were made. We fitted a Capture-Mark-Recapture single season Cormack-Jolly-Seber model (Cormack, 1964; Jolly, 1965; Seber, 1965) investigating the probability of survival between each sampling day (Phi) and the probability of capture on each sampling day (p). Phi was estimated at 0.25 (SE = 0.67, 95% confidence intervals: 0.08, 0.57). p was estimated at 0.39 (SE = 0.76, 95% confidence intervals: 0.06, 0.86). Further models using a range of co-variates were unsuitable as the models became over parameterised due to the lack of recaptures.

Selection Index
A further 304 individual White-faced darter were observed during the fieldwork, 234 of which were not captured (Figure!!!). White-faced darter show a clear preference (SI > 1) for 'moss' habitats while scrub and woodland (smallest SI) appear to be avoided (Figure!!!).



Discussion

The capture-mark-recapture model suggested that the survival rate of adult White-faced darter was 25% from day to day, however, the confidence intervals around this estiamte were very wide. Similarly, we estimated a 40% chance of each individual being captured by our methods but with very wide confidence intervals. The reason for the wide confidence intervals around these estimates was the very low recapture rate (only 6 recaptures in 13 survey days). Although low capture rates might be expected in a large invertebrate population (REF) and have been noted before in Odonata (REF), this was lower than expected. Although male White-faced darter hold territories (REF) they are less tied to these sites than species such as Four-spotted chaser (LATIN) and so are less predictable in their movements. We suggest that in future capture-mark-recapture approaches for this species, and otther similarly cryptic species, need a greater number of capture days and more researchers in the field making captures. This increase in effort is likely to increase the capture rate (REF) and increase the accuracy of estimates (REF).

Many more White-faced darter were seen than were captured and the selecting index calculated using these data suggest that they prefer the 'moss' habitat among those available. Although this habitat is the most common habitat in the study area, the seleciton index suggests that they use this habitat in proportions greater than those present across the site. The 'moss' habitat consists of peat with low heather vegetation and wet flushes and is the habitat most commonly found at pool edges. This is the habitat described in previous research on White-faced darter (REF) and described in Boudot & Kalman (REF) including "peat moss, rushes and sedges". Locally on this site, White-faced darter appear to avoid vegetation, including scrub and woodland. However, White-faced darter sites, especially those in Scotland which represents the stronghold for this species in Britain, are often forested (REF). Breeding pools within these sites are likely to be in open areas but the association with woodland, particularly ancient woodland (REF), is suggestive of some associations between White-faced darter and these habitats at larger scales.

Although a preference for open 'moss' habitats might be expected for this species, coupled with the low capture and recpature rate from the capture-mark-recapture portion of this study there is another possible explanation. White-faced darter are well camouflaged within their habitats and like to remain amongst vegetation where possible (IS this true? REF). As such, their is a good chance of not seeing White-faced darter because of habitat complexity. This is referred to as low detectability (REF). Unfotunatley, our field methods, did not allow us to estimate detectability on this occasion but in future we siggest that survey methods are designed so that detectability can be incorporated into analyses. In this case we are left unable to confidently suggest whether White-faced darter are avoiding more complex vegetation or whether they are harder to see and therefore record in these habitats.

Data which allows the calculation of detectability can easily be collected with just a few minor changes to currently common survey methods. In fact, the majority of these suggestions are already being requested by the BDS to provide data for the upcoming State of the Nation's Dragonflies in 2020 (REF - Darter mag?). We would like to add our voice to these calls to record complete lists and to repeat site visits. Complete lists are records of all of the Odonata species detected on a single visit and allow absence to be inferred where species are not recorded (REF). This requires recorders to note very common species as well as rarities. Unfortunatley, there is a tendency in biological recordings to note only the rare or exciting species (REF) and this can affect our inferences about population change amongst more common species (REF). Repeated site visists allow us to estimate the detectability of aa species (REF), something which would have been extremely useful in this case, because we can start to build a picture about how often we might not see a species which is actually there (REF). We would also like to suggest that where possible recorders include some measure of effort in their surveys (e.g. time spent surveying or distance walked). However, this suggestion is less vital because this could potentially be crudely estimated through list-length analysis (REF) provided that multiple visits are made to the same sites.

We present the results in this paper as an indication of what can be done in terms of conservation research in Odonata. Although we have been unable to make firm inferences regarding White-faced darter survival and habitat preference at this stage this study can provide valuable information which can contribute to the design of future studies. We suggest that research into the conservation ecology of White-faced darter along with other Odonata species threatedned with declining ranges (e.g. REF), declining populations (e.g. REF) or habitat loss (e.g. REF) is essential to the long-term conservation of these species. Methods for such studies can be well informed by current practices used with other taxa. In particular, the analytical advances made in ornithology, research on Lepidoptera and work related to the use of data collected through citizen science provide a fantastic opportunity to advance our knowledge on the conservation ecology of Odonata.