Inferring status changes of three widespread British reptiles from NBN Atlas records

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ABSTRACT - Records from the UK's NBN Atlas for three widespread reptiles (the slow-worm, *Anguis fragilis*, the northern viper, *Vipera berus* and the viviparous lizard, *Zootoca vivipara*) from 1970 to 2017 were investigated to assess relative trends in population trajectories. Unique 1 km^2 (U1KM) records for slow-worms and viviparous lizards increased over time whereas after the 1970s those for vipers did not. Viviparous lizard U1KM records increased concordantly in southern England and northern Scotland suggesting that climate warming has not influenced population trends for this species in recent decades. In southern and eastern English vice counties with high proportions of arable farming, U1KM records for slow-worms and vipers trended downwards since the 1990s. These declines were not seen in the less intensively farmed west and north of Britain. Problems and limitations of using NBN Atlas records are discussed.

INTRODUCTION

Declines of the widespread British reptiles (slow-worms *Anguis fragilis*, viviparous lizards *Zootoca vivipara*, northern vipers *Vipera berus* and grass snakes *Natrix helvetica*) have been widely investigated since the mid-late 20th century (e.g. Cooke & Scorgie, 1983; Swan & Oldham, 1993; Wilkinson & Arnell, 2013). Two of these species have attracted particular concern. Some observers have noted local disappearances of viviparous lizards, especially in southern England, and this is the only reptile to have declined significantly in the Netherlands since 1994 (Creemers & van Delft, 2009). Vipers have attracted attention in Britain because of increasing evidence that this snake has declined more than any other widespread reptile, an issue discussed at a dedicated conference,'The Vanishing Viper: Priorities for Adder Conservation', in autumn 2016.

In this paper we report analyses of records from the NBN Atlas (https://nbnatlas.org), a repository for records of all taxonomic groups in UK that extends over several centuries, to assess whether national trends can be identified from this huge data set. For reasons mentioned above we were particularly interested in vipers and viviparous lizards, but included slow-worms as a comparator with less indication of national decline. Grass snakes were excluded because, unlike the other three, their distribution is not Britain-wide and excludes almost all of Scotland. The main problem with using NBN Atlas data for trend analysis is well known; record numbers for most species have increased over time simply because ever more people are submitting their observations. Various methods to compensate for increased recorder effort have been proposed. One uses data from a large number of related species and identifies outliers showing increases or decreases relative to a concordant majority. Species that follow a common trend are attributed to increased recorder effort (Telfer et al., 2002). This could not be applied sensibly to a situation with only three species. Other approaches include random resampling of recent record sets to make numbers comparable with earlier submissions, but these are primarily designed to detect directional range shifts (Hassall & Thompson, 2010) rather than local changes and are therefore not appropriate for the present study. Our major assumption, based on evidence indicated above, is that there has been no true increase in abundance or distribution of any of the three reptiles investigated here, irrespective of increases in records. This is impossible to prove but forms a starting point for interspecies comparisons. The analyses addressed three hypotheses: (1) Vipers have fared less well than slow-worms or viviparous lizards since the 1970s; (2) Viviparous lizard records have increased less in southern rather than northern Britain as a result of climate change; and (3) records of all three species have increased less in the predominantly arable vice counties, mostly in southern and eastern England, compared with the rest of Britain.

METHODS

We downloaded all occurrence records for the three species (northern viper, viviparous lizard and slow-worm) from the NBN Atlas (NBN Atlas occurrence download at https://nbnatlas.org accessed on Sat Dec 09 12:37:17 UTC 2017).The NBN Atlas data resource citations are listed in supplementary material. The data included the Ordnance Survey grid reference and vice county for each record. We aggregated the data, for each species, as the total number of records per time period (1970s, 1980s, 1990s, 2000s and 2010s, up to and including 2017) in each vice county. One hundred and nine vice counties recognised by the NBN

Atlas and with common reptile records are listed in the Appendix. In addition, for each species we calculated the number of unique 1 km (U1KM) grid reference squares with records in each vice county in each decade, where records were available at that resolution. Unique squares were those that were included only once in the analysis, in each decade, even if there was more than one record from that square in a decade. This editing removed about 80% of the total records for each species, which included not only 1 km^2 duplicates but also all the many records at lower resolution. Although 1 km squares could include more than one locality for a species, this level of resolution was the most accurate basis available for determining record trends over time.

For climate change analysis we compared data from vice counties approximately south of a line between the Severn and Thames estuaries with those north of the Central Belt in Scotland, running approximately between Glasgow and Edinburgh, all as listed in the Appendix. Vice counties with large areas of intensive arable farming were subjectively assessed (no quantitative estimates were available) based on the CEH Land Cover map of 2007 (https://www.ceh.ac.uk/services/land-cover-map-2007) and these are also listed in the Appendix.

Statistical tests including regression and comparisons of regression lines were carried out using the programme STATISTIX 7 (Tallahassee, USA).

RESULTS

The NBN Atlas accumulated totals of 25,165 records for slow-worms, 16,942 for vipers and 36,213 for viviparous lizards between 1970 and 2017. As expected, total record numbers for all three species increased over time (Fig. 1A). For each of the three reptiles, regression of number against time (1970s – 2010s) was significant (all with rsp<0.002) but the rate of record increases for vipers was less than 60% or 38% of the rates for slow worms and viviparous lizards respectively. In the case of U1KM squares (Fig. 1B) the difference was more dramatic, with no detectable net increase in viper records since the 1970s. However, a majority of records from the 2010s (62% for slow-worms, 56% for vipers and 69% for viviparous lizards) were from U1KM squares not recorded in any of the four previous decades.

U1KM square records of viviparous lizards increased concordantly in the climatically different regions of southern England and northern Scotland (Fig. 2). Regression slopes for the two areas were not significantly different (F = 0.47, df = 1,6, p=0.518). However, U1KM square records from vice counties with large areas of arable farming showed very different patterns of change over time compared with vice counties having generally smaller areas of arable land (Fig. 3). Slow-worms and vipers shared a similar pattern of fewer records since the 1990s in the "arable" vice counties, whereas in less intensively farmed parts of western and northern Britain the records of all three species increased continuously between the 1970s and 2010s.

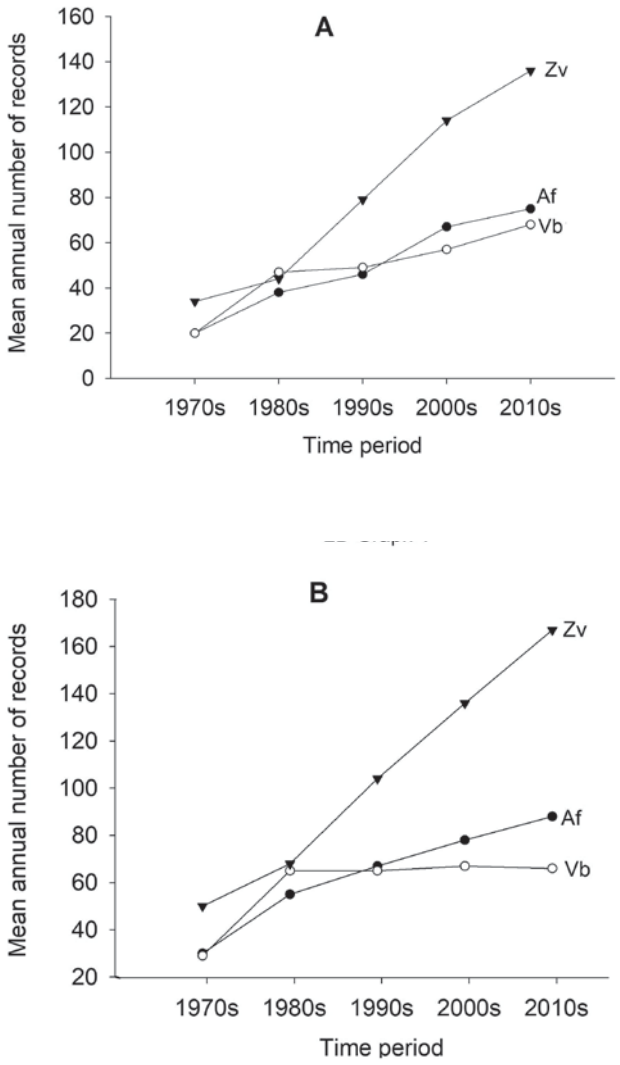

Figure 1. Reptile record increases over time. **(A)** = based on all records; **(B)** = based on U1KM square records. ●, Slow-worm (Af); O, viper (Vb); ▼, viviparous lizard (Zv)

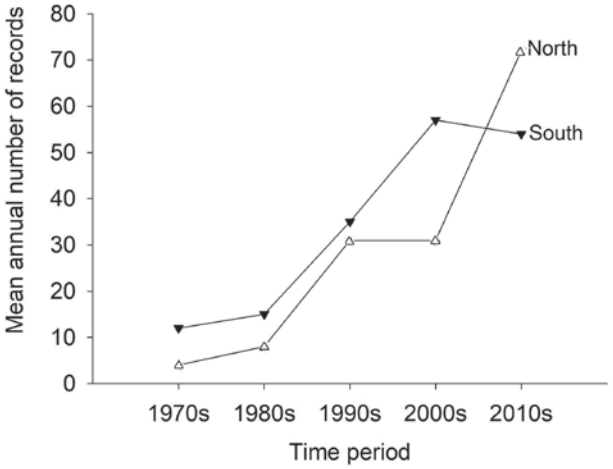

Figure 2. Latitudinal variation in increases of viviparous lizard U1KM square records. ▼ , Southern counties, total records = 1,729; Δ, north Scottish counties, total records = 1,468

DISCUSSION

There are obvious caveats to analysing and interpreting NBN Atlas record data in the way that we have attempted to do. The continuous increase in recorder effort means that in most cases it is impossible to quantify absolute changes in abundance, and interpretation is necessarily restricted to relative variations among species or circumstances. Focusing on the most geographically precise (1 km^2) records came at the cost of ignoring the remaining 80%, the hope being that the most geographically accurate data provide a realistic view of overall trends. There are also some differences among the three reptiles with respect to survey methods. Viviparous lizards are mostly seen basking, slow-worms are usually under refugia while vipers are found by both methods but most often when out basking. The snake, being higher up the food chain than the lizards, is likely to be inherently the rarest of the three species. A notable preliminary result of the analysis was a substantial turnover of records, with many previously unrecorded U1KM squares appearing in the 2010s commensurate with overall declines. This implies probable heavy losses from previously documented U1KMs during the recording period.

How, then, do the three starting hypotheses stand up in the face of the NBN Atlas data analysis? In the first instance, is there evidence of vipers faring worse than the other two reptiles? The answer seems to be yes. In the 1970s and 1980s total numbers of records for all three species were quite similar, as shown in Figure 1A. After that, despite a general increase in recorder effort, viper records increased more slowly than those for either of the lizards. Trends based on the U1KM square records (Fig. 1B) reinforced evidence of the viper's special predicament, with numbers flat-lining since the 1970s. This result is concordant with field-based studies of vipers (e.g. Gleed-Owen & Langham, 2012). In a wide-ranging synopsis of viper monitoring across Britain, more than 90% of over 100 populations studied for at least three years were in decline (Gardner & Baker, 2018). The NBN Atlas data therefore support the viper decline hypothesis.

Local declines of viviparous lizards have been noticed by several observers. Experiments in enclosures subjected to differing temperature regimes have suggested that an overall average increase of 2 °C, within the range predicted by some models of climate change, would dramatically increase mortality rates of adult viviparous lizards ultimately leading to local extinctions (Bestion et al., 2015). However, the second hypothesis, that climate warming might be causing viviparous lizard declines in Britain, was not supported. U1KM square record increases between the 1970s and 2010s were essentially identical at the two extremes of latitude in Britain, notably southern England and northern Scotland (Fig. 2). It may be too soon to expect climatic effects on viviparous lizards, even in southern Britain. Such warming as has occurred in recent decades has mostly been manifest in winter, with much smaller effects in summer (Beebee, in press). Local viviparous lizard declines are perhaps more likely due to factors such as habitat change or destruction.

Comparing records from heavily arabilised vice counties with those from western and northern Britain broadly

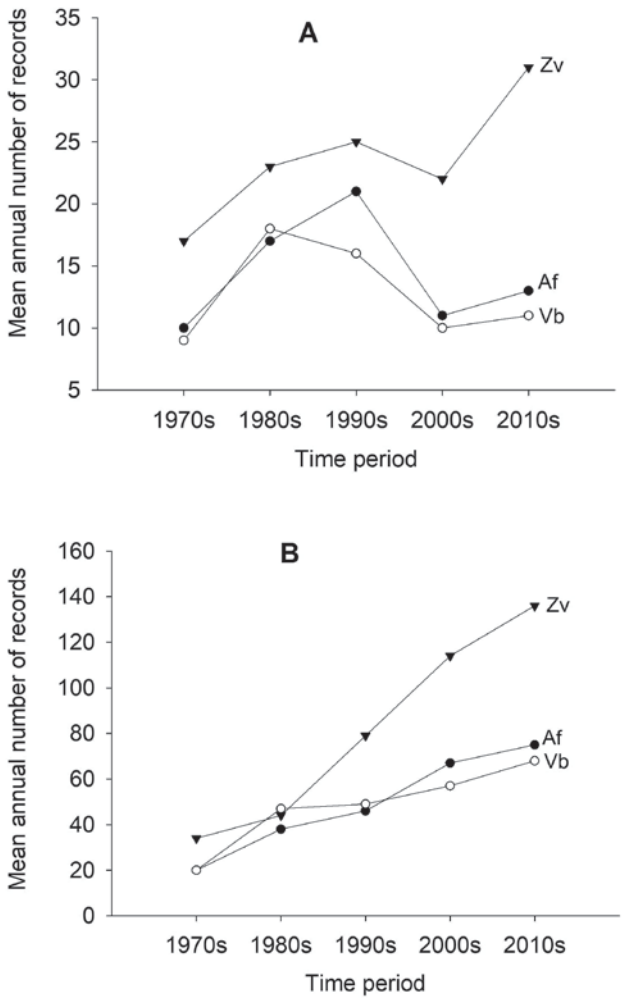

Figure 3. Reptile U1KM records and land use. **(A)** = trends in 35 "arable" vice-counties, total records = 2,538; **(B)** = trends in 74 "non-arable" vice counties, total records = 8,939.●, Slow-worm (Af); O, viper (Vb); ▼, viviparous lizard (Zv)

supported the hypothesis that intensive agriculture has damaged reptile populations. Remarkably, from the 1990s onwards U1KM square records for slow-worms and vipers actually decreased substantially in arable regions (Fig. 3A) despite the overall increases in recorder effort documented earlier. In sharp contrast, U1KM square records for all three reptiles, including the viper, increased continuously in western and northern vice counties (Fig. 3B). "Arable" vice counties constituted about 32% of the UK total vice county area, whereas they had only about 22% of the widespread reptile records since 1970 (almost identical percentages for all three species) despite having some of the warmest summers in Britain. The "arable" region records just since 2010 were even lower, averaging about 15% of the UK total. Reptile fates therefore matched those of many other declining species of British wildlife for which agricultural intensification stands out as the major cause (Burns et al., 2016). Nevertheless, it would be wrong to attribute all the widespread reptiles' problems to arable farming. The differences between arable and non-arable regions could be coincidental, perhaps due to factors other than farming practices. Vipers, for example, have declined dramatically

in much of central England and even pastures have widely been 'improved' to the detriment of wildlife. Among other things, urbanisation and increasing disturbance by walkers in the countryside have also impacted adversely on this snake (Gardner & Baker, 2018). However, albeit with the limitations alluded to earlier, it seems that the NBN Atlas records can be useful as providers of evidence about the recent fate of wildlife despite complications from increased recorder effort.

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APPENDIX

The vice counties of Great Britain that were the origin for the NBN Atlas reptile records in this study, indicating those used in climate change analysis (Southern England v. Northern Scotland) and those used for assessing the impacts of a high incidence of arable land (Arable v. the rest)

	Listings for specific analyses		
Vice County	Southern England	Northen Scotland	Arable
Anglesey			
Ayrshire			
Banff		X	
Bedfordshire			X
Berkshire	X		
Berwickshire			
Brecon			
Buckinghamshire			X
Caernarvon			
Caithness		X	
Cambridgeshire			X
Cardiganshire			
Carmarthenshire			
Cheshire			
Cheviotland			
Clyde Islands			
Cumberland			
Denbighshire			
Derbyshire			
Dorset	X		
Dumfrieshire			
Dunbarton			
Durham			
East Cornwall	X		
East Gloucestershire			X
East Kent	X		X
East Norfolk			X
East Perth		X	
East Ross		X	
East Suffolk			X
East Sussex	X		X
East Sutherland		X	
Easterness		X	
Edinburgh			X
Elgin		X	
Fife		X	
Flintshire			
Forfar		X	
Glamorgan			
Haddington			X
Herefordshire			X
Hertfordshire			X
Huntingdonshire			X
Isle of Man			
Isle of Wight	X		
Kincardine		X	X
Kintyre			
Kirkudbrightshire			
Lanarkshire			
Leicestershire			X
Main Argyl		X	
Merionethshire			
Mid Ebudes		X	
Mid Perth		X	
Mid-west Yorkshire			X
Middlesex			X
Monmouthshire			
Montgomeryshire			
North Aberdeen		X	
North Devon	X		
North Ebudes		X	
North Essex			X
North Hampshire	X		X
North Lincolnshire			X
North Somerset	X		
North Wiltshire	X		X
North-east Yorkshire			X
North-west Yorkshire			X
Northampton			X
Northumberland			
Nottinghamshire			X
Outer Hebrides		X	
Oxfordshire			X
Peebles			
Pembrokeshire			
Radnorshire			
Renfrewshire			
Roxburgh			
Selkirk			
Shropshire			
South Aberdeen		X	
South Devon	X		
South Ebudes		X	
South Essex			X
South Hampshire	X		
South Lancashire			
South Lincolnshire			X
South Somerset	X		
South Wiltshire	X		X
South-east Yorkshire			X
South-west Yorkshire			X
Stafford			
Stirling			
Surrey	X		
Warwickshire			
West Cornwall	X		
West Gloucestershire			
West Kent	X		X
West Lancashire			
West Norfolk			X
West Perth		X	
West Ross		X	
West Suffolk			X
West Sussex	X		
West Sutherland		X	
Westerness		X	
Westmorland			
Wigtownshire			
Worcestershire			X

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