Amphibian and Reptile Conservation
RESEARCH REPORT 16/01

Ten Years of Jersey Toadwatch: Analysis & Recommendations

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ACKNOWLEDGEMENTS

We thank Environment Department staff, those at Durrell who helped with *Toadwatch* in its early days, Jersey Biodiversity Centre for hosting the new on-line system and everyone who has reported crapauds to *Toadwatch!*

SUGGESTED CITATION: Wilkinson, J.W. & Starnes, T.S. (2016) Ten Years of Jersey Toadwatch: Analysis & Recommendations. *ARC Research Report* **16/01.**

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EXECUTIVE SUMMARY

The main document contains much technical information which will allow the modelling approaches described here to be repeated in future. This Summary is provided to allow easier interpretation of the main findings.

Jersey Toadwatch has been operating since 2005. This report uses “citizen science” data reported by Jersey residents to:

- Create a toad distribution map
- Model suitable habitat and suggest opportunities for pond/habitat creation
- Refine how *Toadwatch* data should be collected and used going forward.

Records of Jersey toads were received from 281 locations between 2005 and 2014 and used to create a distribution map (Fig. 2.1; page 8). The same data were used to create a GIS model indicating which features of the Jersey landscape are most important for toads. Ponds and gardens were most important, along with other man-made habitats like parks, golf courses and recreational fields (Table 2.1; page 12), indicating the reliance of toads on anthropogenic features in the modern Jersey landscape.

Further modelling combined with an analysis of barriers to connectivity between populations (roads) revealed that many toad populations in the centre and north of the island, especially, are isolated from the larger clusters of breeding ponds found in St. Brelade and St. Helier - St. Saviour (Fig. 2.11; page 17). This can be used to suggest areas where creation of new breeding ponds and other habitat will be most effective as a tool for toad conservation in the island – specifically:

1. Between La Crabière and Les Landes, and between St. Ouen’s Village and Grève de Lecq, as well as La Crabière and St Peter’s Village (to link populations in the west of the island);
2. Approximately between Beaumont and Sorel, and along almost any north-south valleys (to link the St. Mary – St. John population cluster to other populations);
3. Eastern Trinity, St. Martin, south-east to Gorey and through Grouville (to restore connectivity in the east of the island);
4. Approximately between Beaumont and Bellozane (reconnects the southern population clusters to one-another);
5. Between Noirmont, Woodbine Corner and Ouaisne (the latter population not currently recorded as part of *Toadwatch*) (to connect Noirmont with other populations and improve population robustness in this key area).

These areas are highlighted by the red-coloured pathways shown in Fig 4.1 (page 23).

(cont.)

EXECUTIVE SUMMARY CONT.

Analyses of the *Toadwatch* monitoring data showed that timing of toad breeding was very variable (starting usually any time between early January and early March) but there was no discernible trend towards earlier breeding. Analysis of any population trends 2005 – 2014 is difficult due to inconsistencies by recorders, however the average number of spawn strings per pond was <4, indicating generally small populations. The majority of ponds (81%) also had <30 toads in any one year.

A breakdown of the types of ponds used for toad breeding in Jersey (Table 3.3; page 21) overwhelmingly supports the suggestion that man-made habitats are critical for the species' survival in the island. Nevertheless, almost half of the reporters recorded toads being killed on nearby roads – a consequence of their dependence on urban habitats.

Toadwatch has not yet provided much data on other key species (such as grass snakes), though some islanders have begun to record these species. The adoption of an on-line recording system, hosted by Jersey Biodiversity Centre (see http://jerseybiodiversitycentre.org.je/get-involved/toadwatch/) will help improve collection of these data, improve consistency of reporting and allow for more revealing future analyses of e.g. population trends.

Summary of Key Recommendations

- Create new breeding ponds in the areas suggested to improve population resilience
- Continue to support collection of *Toadwatch* data on-line as a key component of monitoring the species' status in the island
- Use signage and patrols, where likely effective, to reduce road mortality
- Update the available information on creating toad habitat/ponds.

1. INTRODUCTION

In 2005, as part of a PhD research project funded by the Jersey Ecology Fund (see Wilkinson, 2007a), Jersey residents were asked to take part in *Toadwatch* through reporting sightings of toads (*Bufo spinosus*, at the time known as *B. bufo;* Fig. 1.1) in Jersey, in order to generate data to inform the species' conservation in the island. Records were collected initially through a paper recording form (see Appendix 1), and dedicated e-mail address and phone number set up by Durrell Wildlife Trust. Information and links were also placed on the Environment Department and Durrell websites. In 2015 it was possible to submit data on a pdf form that could be completed electronically (Appendix 2). *Toadwatch* data has now been collected over 10 years (2005-2014), with residents reporting toads to volunteers (and/or staff) from Durrell and/or Jersey Environment Department.

The aims of the present investigation were to:

- Utilize existing *Toadwatch* data to create a species distribution map for Jersey toads, highlighting suitable habitat and identifying opportunities in the landscape for new pond and habitat creation through connectivity analysis;

- Explore existing *Toadwatch* data, and assess its quality and usefulness for long-term monitoring of the species in Jersey;

- Refine *Toadwatch* recording protocols and resources (e.g. the recording form) for re-launch in 2016.

Figure 1.1. The Jersey toad, Western common toad or crapaud (*Bufo spinosus*). (JWW)

2. TOAD HABITAT AND POPULATION CONNECTIVITY

Jersey *Toadwatch* data (n = 281 unique record locations), collected between 2005 and 2014, were saved in CSV format using MS Excel and imported into ArcMap 10.2. They were then converted to a shapefile for spatial management in GIS and plotted on a map of Jersey (Fig. 2.1).

In order to avoid spatial autocorrelation (over-emphasis on locations where many records are clustered), which can be a danger when modelling habitat suitability from continuous environmental predictor variables, the ArcMap 'Create Random Points' tool was used with *Toadwatch* points as a constraining feature and a minimum allowed distance of 500 m in order to spatially rarefy the data. This tool was run 10 times to generate 10 random point feature classes, and the one with the highest number of random points was selected for use in the model. The spatially rarefied random point class with the greatest number of points after 10 runs (n = 120) was selected and converted back to CSV format for use in Maxent modelling (Fig. 2.2).

An Excel pivot table was used to create a breakdown of the age structure of *Toadwatch* records (Fig. 2.3).

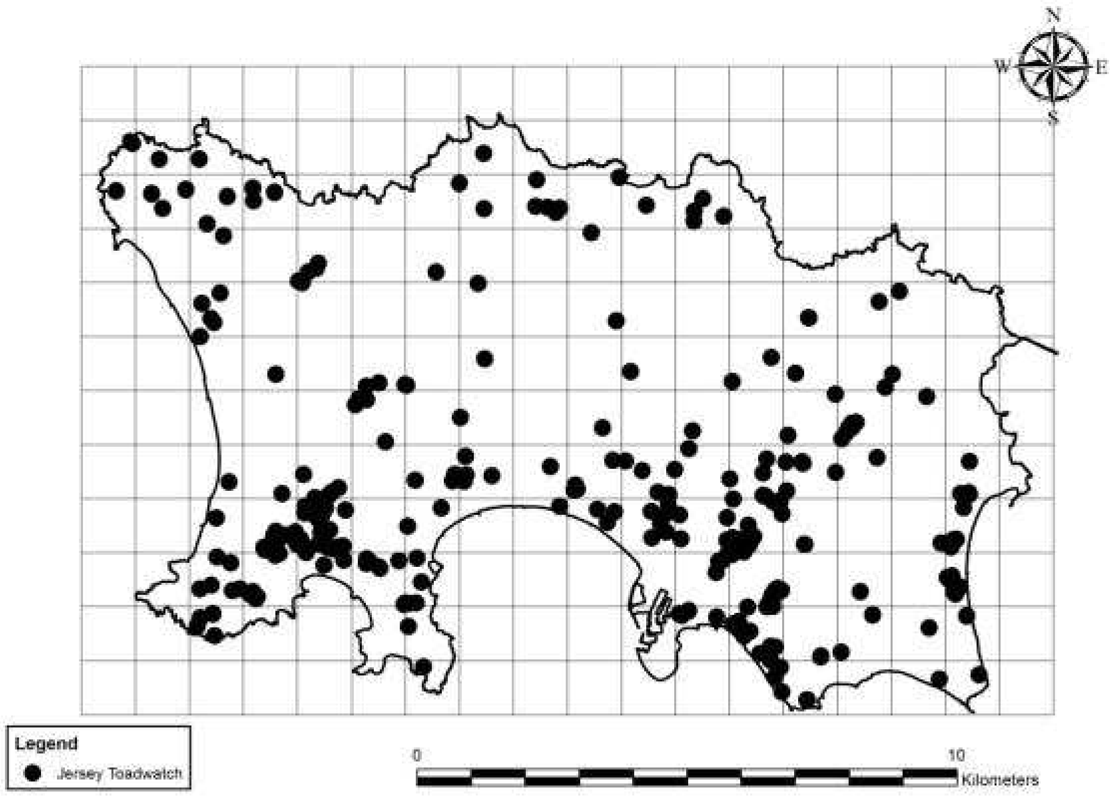

Figure 2.2. All *Toadwatch* record locations 2005 – 2014 plotted on Jersey 1 km grid.

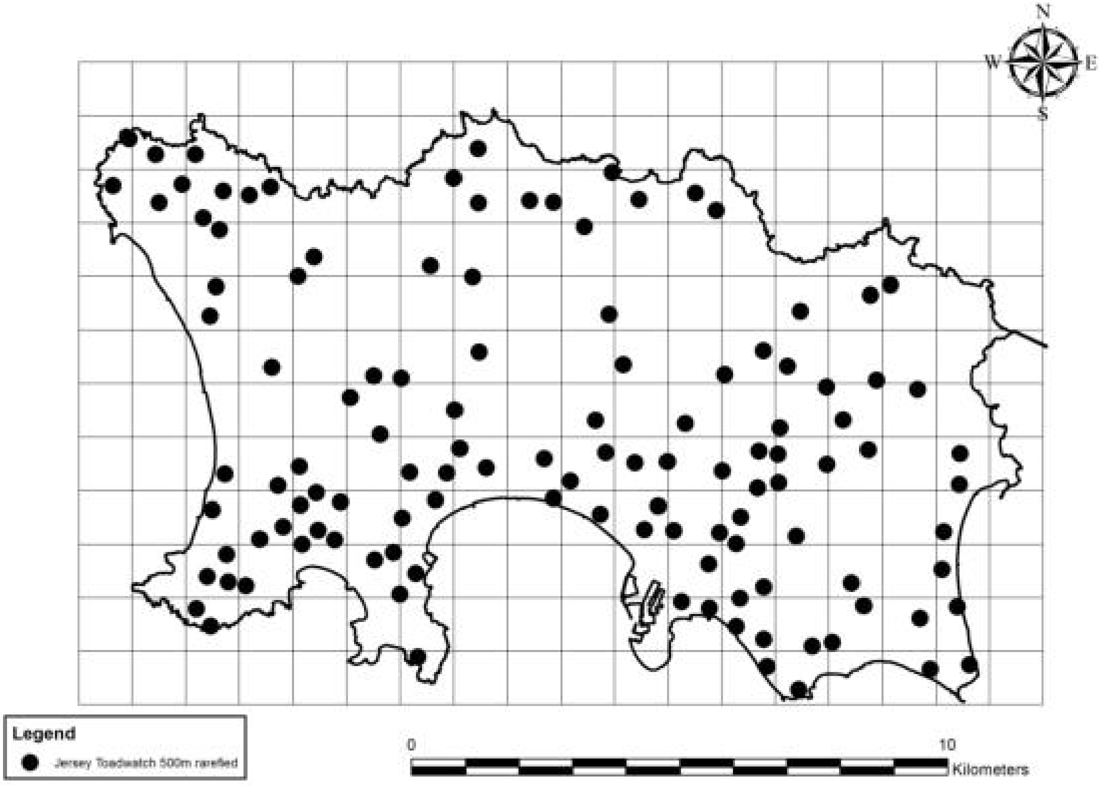

Figure 2.2. *Toadwatch* data spatially rarefied to 500 m for model creation.

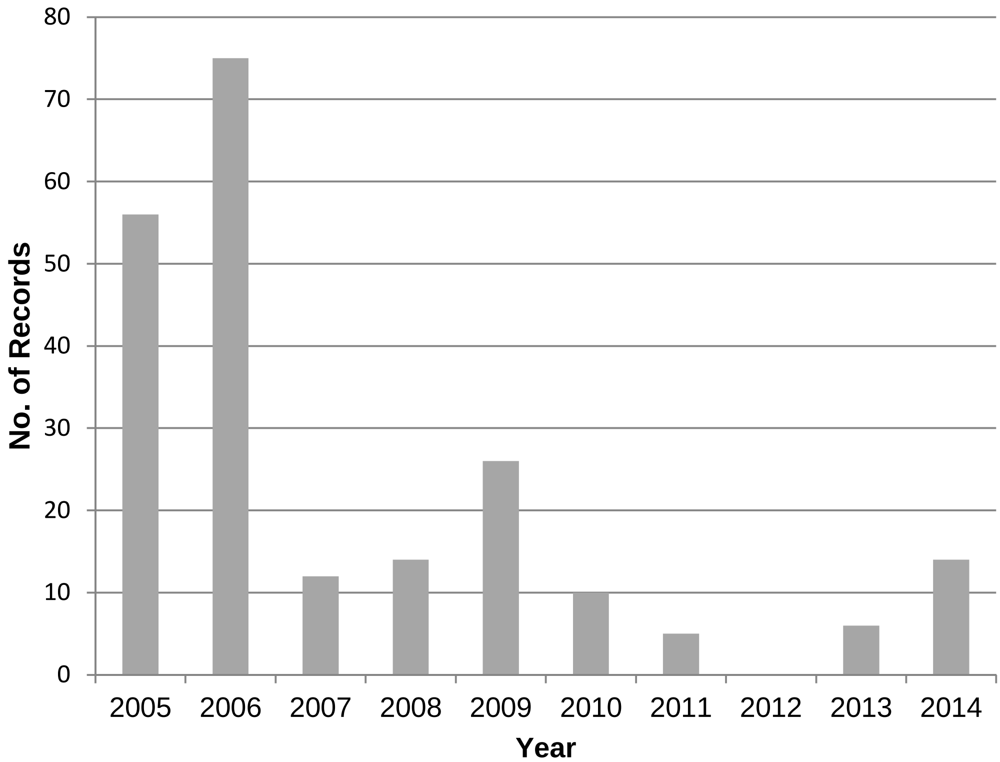

Figure 2.3. Recording chronology for *Toadwatch*: number of record per year 2005 - 2014.

2.1. Habitat suitability model extent

Land cover data from the Jersey Island Map (known as "JERP") were obtained from the Department of the Environment as a polygon shapefile. This shapefile was clipped to the mask of the Jersey high water line, thereby removing land feature classes such as 'sand' and 'rock outcrop' which extend seaward beyond this boundary (Fig. 2.4).

The clipped JERP shapefile was converted to raster grid format for further processing and modelling. The Jersey 1 km^2 grid was used as the processing extent so that all raster file outputs line up within this grid system. The JERP land cover data were converted to a 25 m^2 resolution raster using the 'Maximum combined area' cell assignment type. This means that each 25 m^2 was assigned a value corresponding to the dominant land feature class inside the area of that cell.

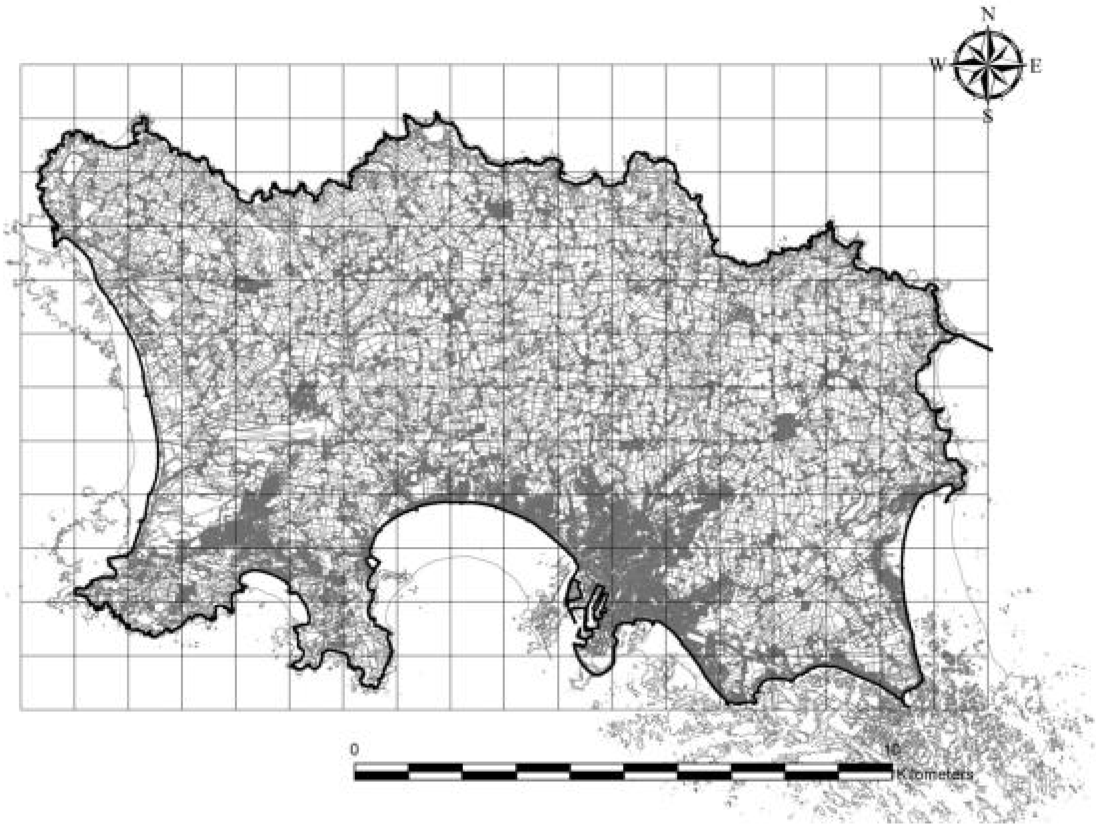

Figure 2.4. Jersey Island Map land cover, showing mean high water mark (extent of the study area).

2.2. Creating a bioclimatic envelope for Jersey

Gridded interpolated climatological data coverages for Jersey were created to a spatial resolution of 25 m^2. Climate data are based on the world gridded climate dataset at 1 km^2 resolution (Hijmans *et al.*, 2005). This dataset is itself interpolated from global weather station data. The Worldclim dataset was first clipped to the extent of the Jersey high water level and point values were extracted from the centroid of each 1 km^2 cell. Kriging was applied to interpolate a climate surface from these 203 points. Kriging is the method most used for interpolating temperature data (Dobesch *et al.*, 2007), one primary advantage being that interpolated values are limited to within the range of the input data. As the base data are themselves interpolated, it seemed prudent not to project outside the range of values provided.

2.3. Species distribution model output

Runs of 29 models were performed with Maxent species distribution modelling (SDM) software, each using different combinations of land cover and bioclimatic variables. Each combination of model variables was run 15 times, creating 15 replicates of each model. Each replicate was divided into 'folds' (different combinations of training and test data), used to test the model, and these were crossvalidated in the final output. A number of parameters remained constant throughout the modelling process. The maximum number of iterations was set to 1,000 and a threshold rule of 'equal training sensitivity and specificity' (EQSS) was set. All models were evaluated using the ENMTools model selection function in ARCMap. Suitability of models was assessed on their corrected Aikake's Information Criteria (AICc) scores. AICc indicates model performance similarly to AIC but corrected for relatively small sample sizes. Lower AICc scores indicate preferable models (Burnham & Anderson, 2002; Burnham & Anderson, 2004). For each run, the AICc score was averaged using the arithmetic mean of the 15 replicates' scores. These averaged scores were then used to compare model performance. AIC (Akaike, 1974) is an information-theoretic criterion designed to select for parsimony between complex models with higher uncertainty ('overfitting') and simple models with greater bias ('underfitting') (Aho *et al.,* 2014). The model with the lowest score (i.e. the most suitable model) was *Run 4*, in which the sole variable was the JERP land classification (see Fig. 2.5 and Table 2.1).

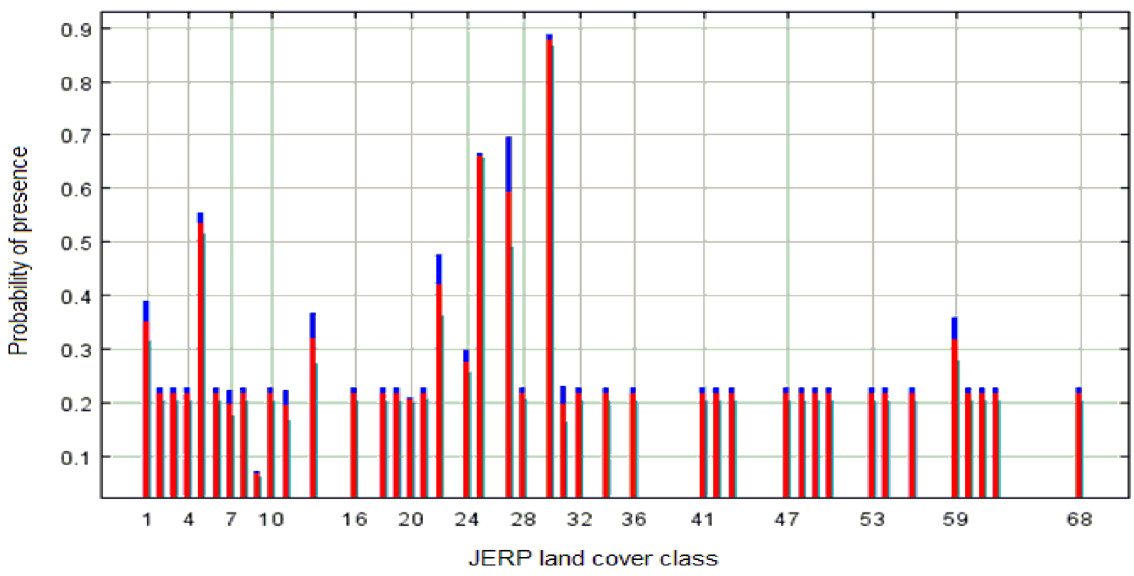

Figure 2.5. Maxent response of *Bufo spinosus* (n = 120) to JERP 25 m land cover raster; higher bars indicate variables influencing toad presence, see Table 2.1, below (for full list of variables, see Appendix 3). Red bars = average response to variable from 15 model replicates; blue bars = average response +/- 1 S.D.

Table 2.1. Top nine (logistic output >0.25) land cover variables influencing presence of *Bufo spinosus* in Jersey.

Cover class No.	Variable Name	Rank
30	pond	1
25	garden	2
27	slope*	3
5	major building	4
22	park	5
1	rock outcrop	6
13	road	7
59	golf course	8
24	recreation field	9

* see text

The two single most important variables influencing toad distribution in Jersey were ponds and gardens. Land cover variable 27 was identified to be the third best predictor of *B. spinosus* presence, corresponding to 'slope'. We suggest that slope in itself is not a useful land cover type for two reasons: (i) the precise degree of slope can be easily calculated from digital elevation models, such as the topographical position index (tpi) value derived from slope index in this study, (ii) slope is not a land cover type in itself; areas of sloping ground also have an associated land cover type such as rock outcrop or woodland.

The majority of variables influencing toad presence in the modern Jersey landscape are anthropogenic in origin – a clear signal that toads are essentially dependant on artificial and semi-natural habitats as traditional ones (e.g. agricultural reservoirs) have become less suitable over time with chemical use and the falling water table.

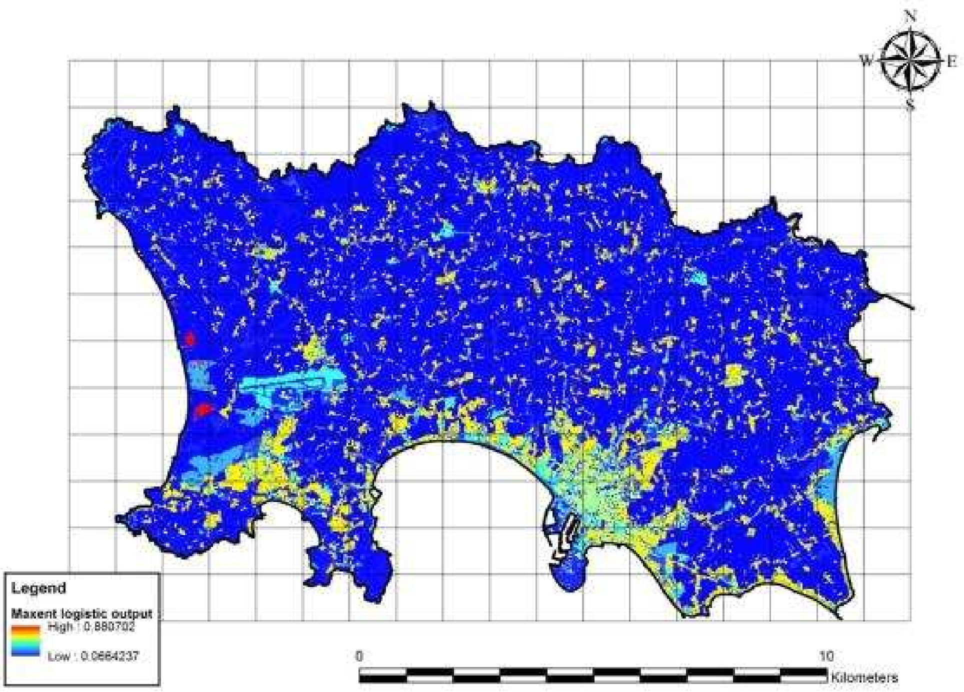

Figure 2.6. Maxent logistic output for the Jersey *Bufo spinosus* model (*Run 4*). Warmer colours indicate relatively more suitable habitat, least suitable habitat shows as dark blue.

2.4. Landscape resistance and analysis of connectivity

Landscape resistance is a measure of how easy (or otherwise) it is for organisms to move through different habitats and disperse across barriers such as roads. The Maxent habitat suitability model as in Fig. 2.6, was inverted and converted from a probability scale (0-1) to create a resistance layer using the calculation **((1-[MaxEnt_output])*100)+1**. This process assumes that areas modelled to be less suitable for the species have a higher resistance to dispersal. Connectivity between breeding populations is therefore lower in high resistance areas (Fig. 2.7).

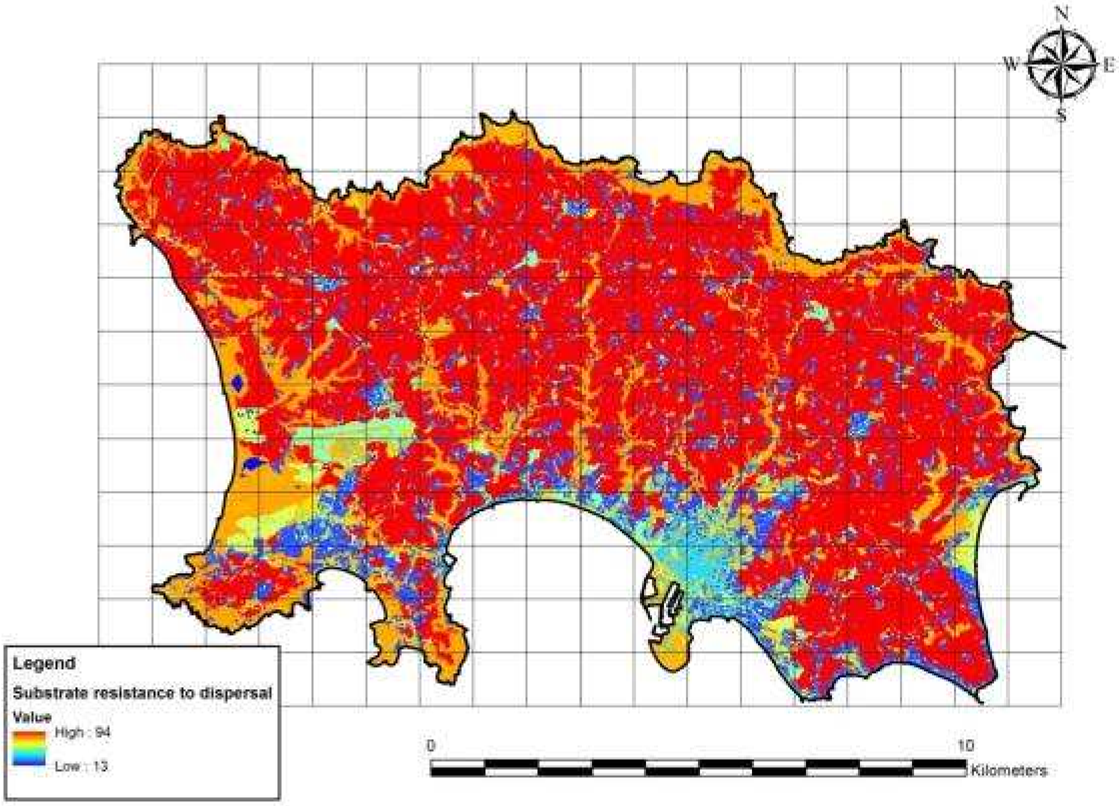

Figure 2.7. *Bufo spinosus* resistance to dispersal in the Jersey landscape. Warmer colours represent areas that are of relatively higher resistance, the most inimical areas showing as red.

In addition to different land cover types, roads (Fig 2.8) pose a significant barrier to toad dispersal due (1) simply to the physically greater effort involved in crossing a dry open space offering no shelter and (2) because of the effects of traffic mortality on migrating adult toads and dispersing juveniles. Road polygons were extracted from the Jersey Island Map and assigned resistance values to reflect the relative effectiveness of a given road as a barrier to toad dispersal. Values were assigned as per Table 2.2. The roads polygon feature class was then buffered by 17.7 metres and converted to 25 m x 25 m raster format before adding to the previously generated Maxent-derived resistance raster. The 17.7 metre buffer ensures that, when the roads are converted to raster grid format, there are no ‘gaps’ in the dispersal barrier which the model would interpret as potential dispersal pathways.

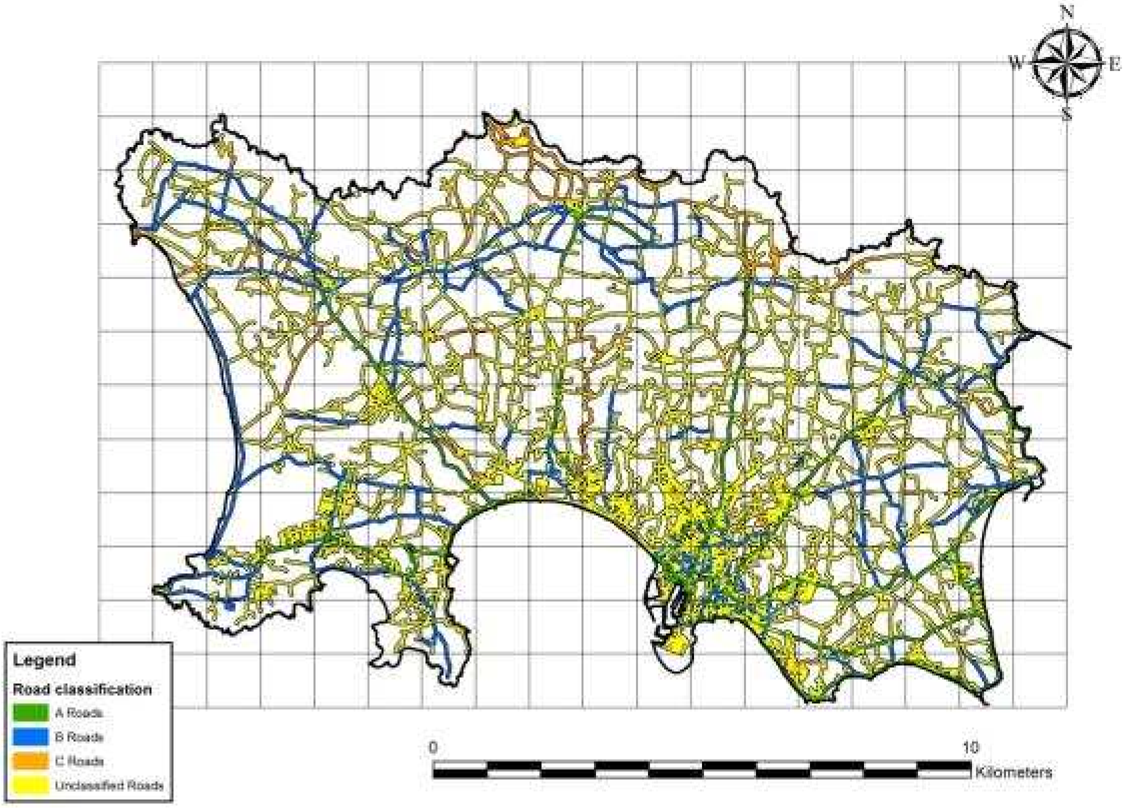

Figure 2.8. Road classifications in Jersey.

Table 2.2. Road classifications and resistance values (actual values are meaningless; values indicate relative strength of each type of road as a barrier).

Road classification	Resistance value
A Road	533
B Road	400
C Road	267
Unclassified Road	133

The Maxent-derived resistance surface and rasterized roads layer were combined using a sum function. This means that for each 25 m x 25 m square in the final resistance raster (Fig. 2.9), the resistance value is the sum of the two input layers. This is the final resistance surface which was used in the connectivity analysis.

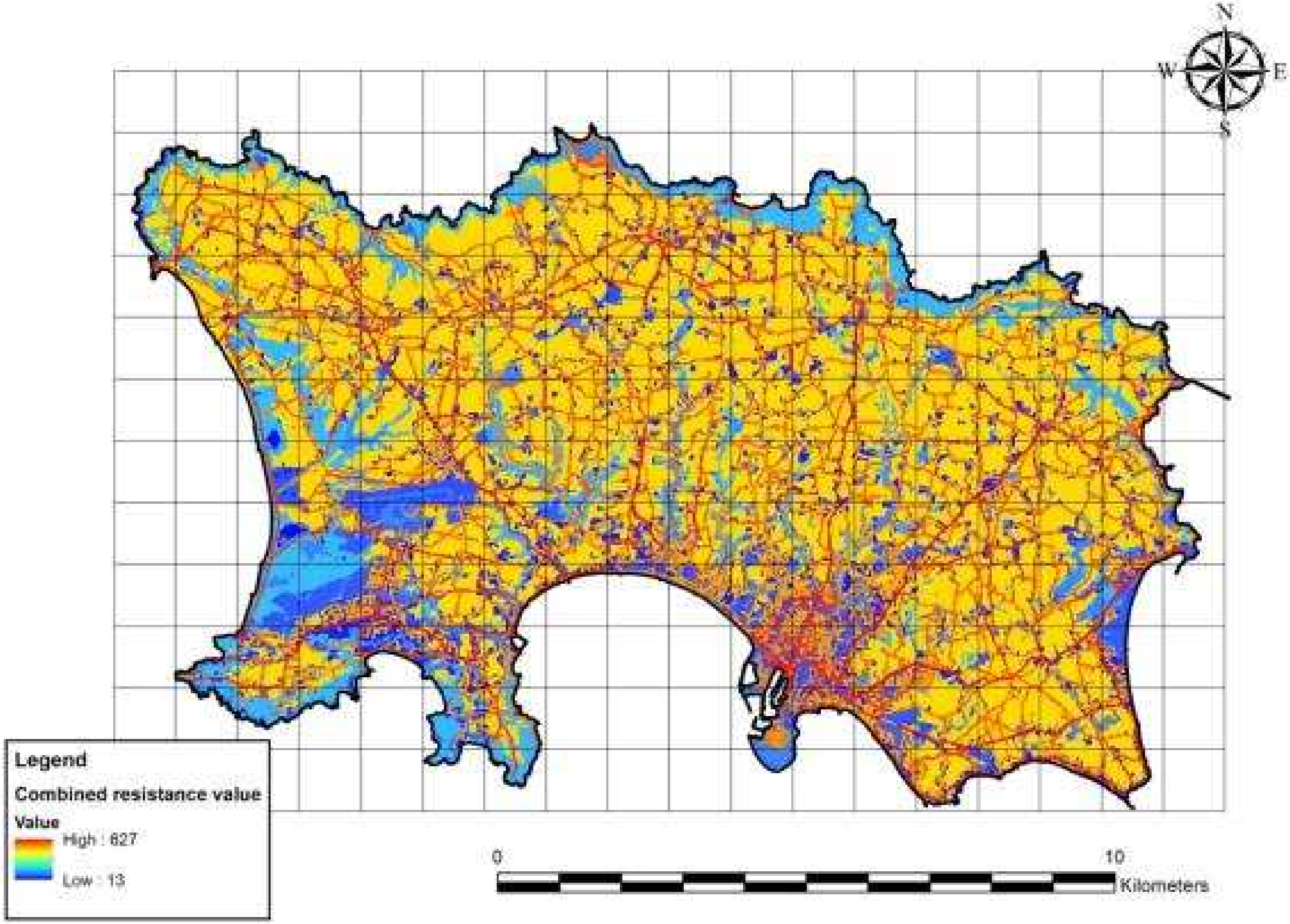

Figure 2.9. Histogram equalized map of combined resistance surface (land cover plus barriers) for *Bufo spinosus* in Jersey. Warmer colours represent areas that are of relatively higher resistance, the highest resistance showing as major roads (red).

Linkage Mapper connectivity analysis software (McRae *at el.,* 2012) was then used with the resistance surface and original *Toadwatch* record locations to identify least cost paths between populations, i.e. which breeding populations are connected to one-another. Two levels of potential toad dispersal ability were examined, 2 km and 1 km, these distances equating to distances toads could theoretically travel between breeding sites (see Discussion). A least cost path is a path of least resistance across a cost weighted distance (CWD) surface (Euclidian and CWD thresholds can be set independently). The cost weighted distance surface is the cumulative hypothetical distance between known toad populations. The results are shown in Figs, 2.10 and 2.11.

With a dispersal ability of up to 2km from breeding sites, toad populations in Jersey are theoretically connected to one-another across the island, albeit with few connectivity pathways through the more agricultural areas. With a dispersal ability of just 1km, however, (which is likely more realistic) populations are more clustered, with many of those found in agricultural areas effectively isolated from all but their nearest breeding ponds (Fig. 2.11). The implications of this for toad conservation in Jersey are discussed below.

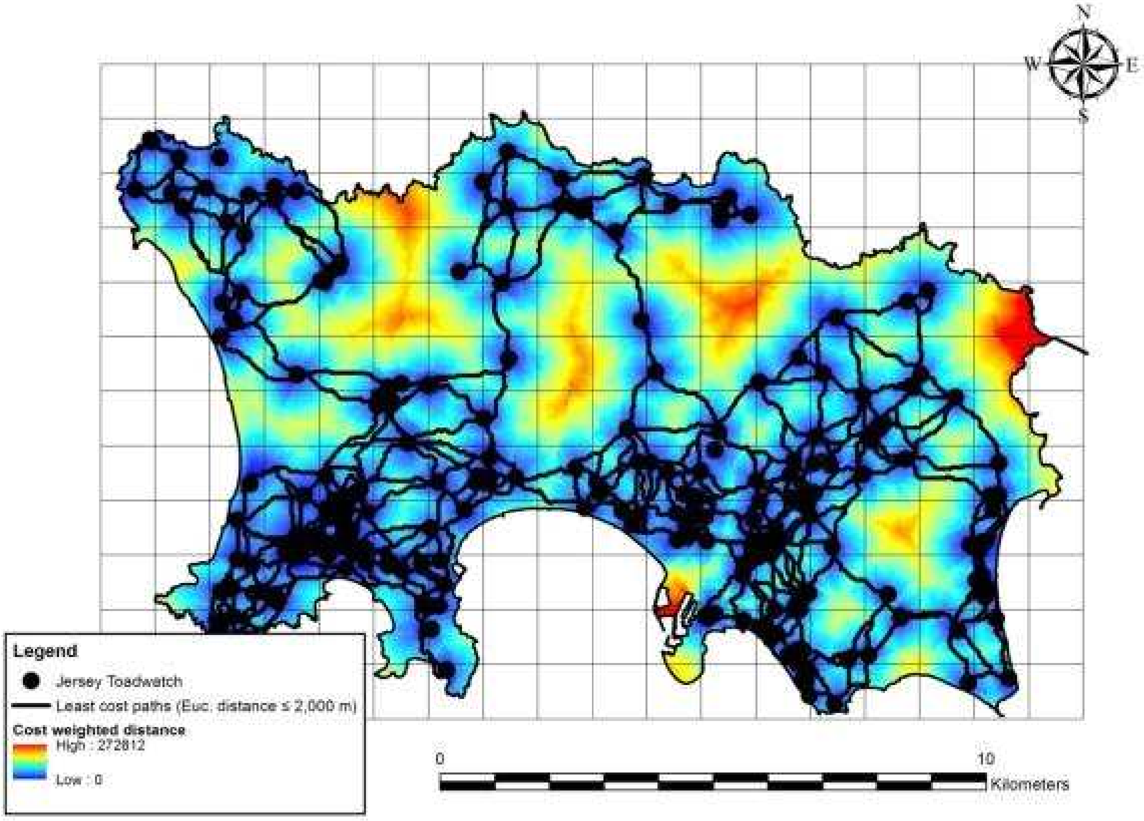

Figure 2.10. Least cost paths between recorded toad populations in Jersey (assuming potential toad dispersal distance of 2 km).

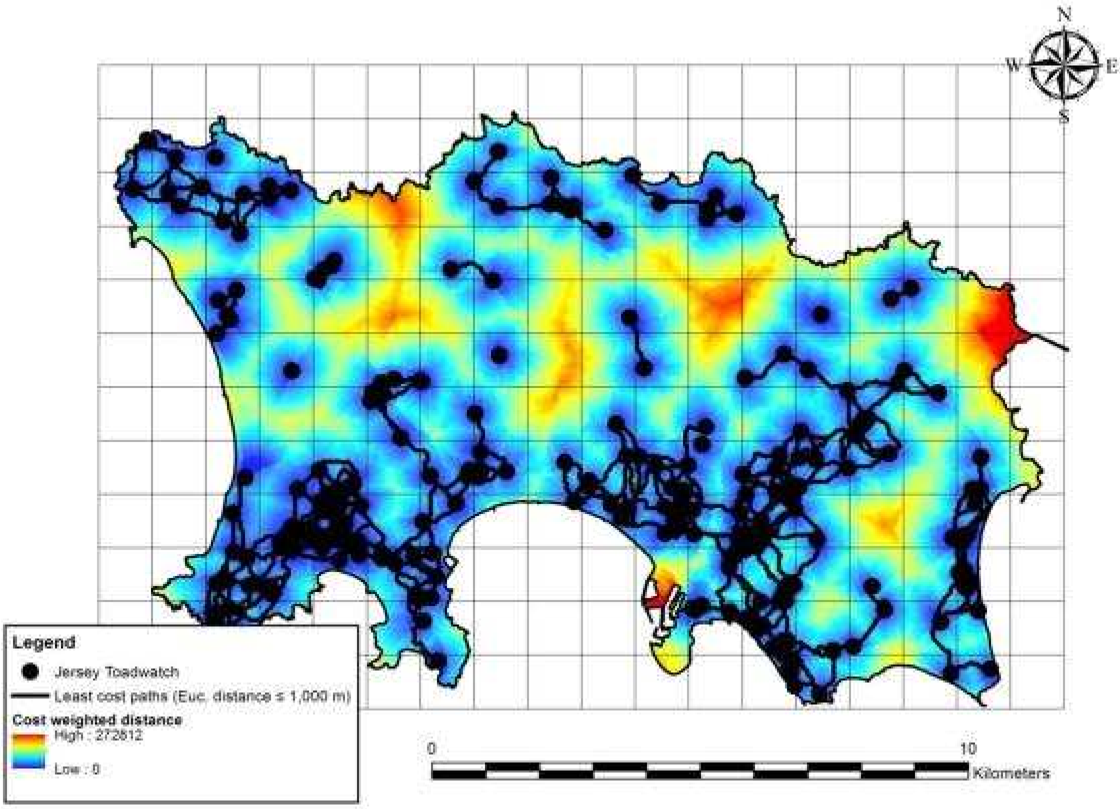

Figure 2.11. Least cost paths between recorded toad populations in Jersey (assuming potential toad dispersal distance of 1 km).

3. MONITORING JERSEY TOADS THROUGH *TOADWATCH*

Toadwatch records 2005-2014 were imported into MS Excel and likely breeding population locations were identified using the “possible toad breeding site” field of the *Toadwatch* database. Duplicate locations from different time indices were excluded by checking for records where both the X *and* Y coordinates of the record were duplicated. A further six entries stated “no pond”, resulting in a redacted dataset indicating a possible 275 toad breeding sites in the island (based on existing information). These data also represent the most up to date distributional information for toads in Jersey since 2007 (Wilkinson, 2007) (see Fig. 2.1, above).

Though annual record submission was initially high, with 75 records being submitted in 2006 alone, records dropped away after this point (Fig. 2.3). This coincides with a reduction in toad publicity (the PhD study having finished) and possibly reluctance by individual observers to keep submitting records in instances where garden pond toads had been reported in the previous year. Though this provides good data on distribution over a medium-term timescale, it has not resulted in sufficient population-level data to determine fluctuations or declines in population sizes over the relevant demographic period. The ten years of *Toadwatch* is equivalent to ca. three generations of toads and is also the approximate likely lifespan of a fairly long-lived wild toad. Obtaining comparative demographic data is particularly important in light of the fact that many of Jersey’s most urban toad populations are sustained each year by just two to three breeding females (see Wilkinson *et al.,* 2007). It is not, therefore, reasonable to attempt to discern real change in the number of populations between (e.g.) two equal, arbitrary time periods: 2005-2009 and 2010-2014 (70% of records came from the first time period). Nevertheless, certain comparisons within the data can be made:

1. Phenology;
2. Population information;
3. Toad breeding pond characteristics;
4. Road mortality;
5. Presence of other species.

3.1. Phenology

The earliest and mean "day of year" on which toads and spawn were seen is shown in table 3.1. In some years, few accurate date records were submitted, so range values are not directly comparable (e.g. some means are based on <10 observations and others on >30); however, the day of year on which spawn was first seen 2005-2014 corresponds generally with the pattern of first observations of toads (Fig. 3.1).

Table 3.1. Earliest and mean day of year on which toads and spawn were first observed, by year.

Year	Earliest day toads seen	Mean day toads seen	Range*	Earliest day spawn seen	Mean day spawn seen	Range*
2005	7	18	43	15	53	65
2006	17	57	67	63	79	33
2007	8	38	53	52	55	6
2008	8	44	78	33	51	40
2009	25	51	33	51	56	13
2010	6	59	108	51	71	41
2011	26	47	48	44	50	16
2012	No records received			No records received		
2013	3	54	99	33	67	72
2014	10	51	67	42	61	33

* = number of days between first and last reported observations.

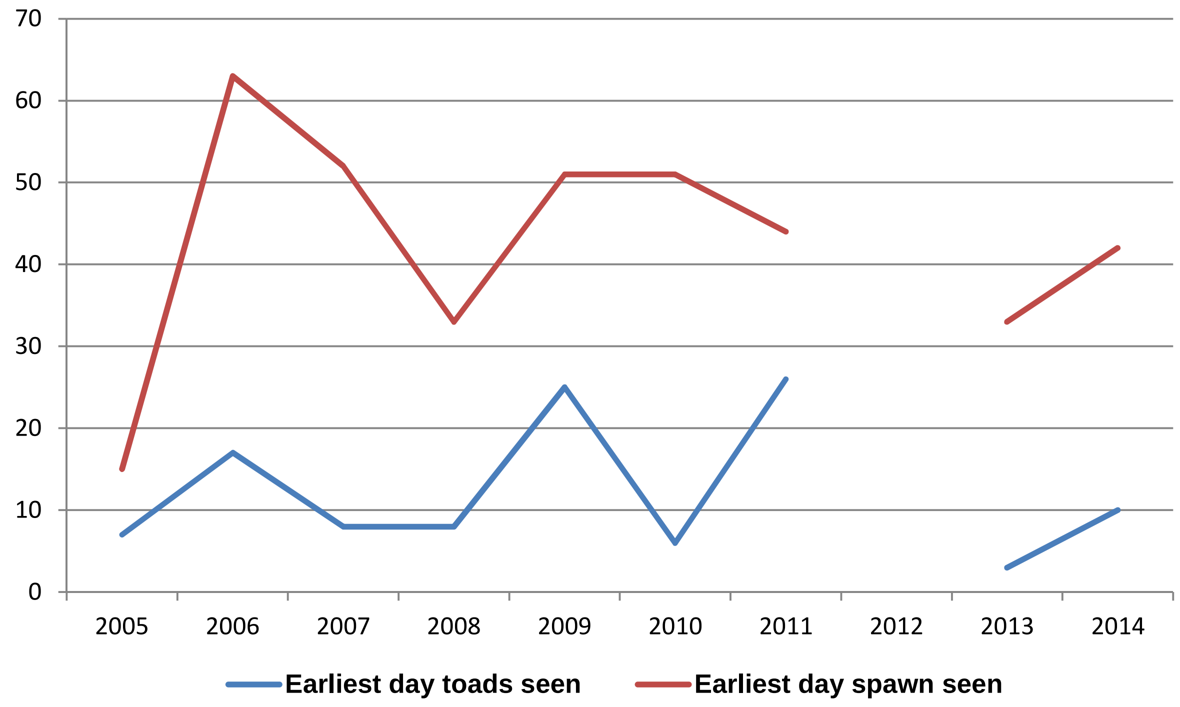

Figure 3.1 Earliest observations (day of year) of toads and spawn, by year.

3.2 Population information

3.2.1. Numbers of spawn strings

This variable should help monitor population trends at garden sites, where mortality and connectivity factors can have a variable effect on breeding success from year to year. One-hundred and twenty-seven observations were recorded under “number of spawn strings” over nine years of *Toadwatch* data collection (the parameter was not recorded in 2007), however 31 of these were recorded as text (e.g. “lots”, “several”) and are not possible to analyse. Of the remaining 96 records, the number of records per year varied from 1 to 42 (mean 14) so an examination of trends would be extremely misleading. Nevertheless, the average number of strings per (garden) pond over this period (based on n=96) was 3.74 (range 0-30), indicating generally low effective population sizes in Jersey garden ponds.

3.2.2. Total toad numbers

Sex ratios in toads are usually highly biased towards males. So whilst numbers of spawn strings equates to the number of breeding female toads, total toad numbers may be very much more than simply double that number. Maximum number of toads recorded by *Toadwatch* are shown in Table 3.2 (n=68); this parameter has only been recorded since 2013.

Table 3.2. Total toad numbers seen (max in any one year).

<10	11-30	30-100	>100
43%	38%	12%	7%

3.2.3. Other parameters

Recent *Toadwatch* recording has also included questions on whether spawn hatched successfully and when tadpoles were first seen to hatch. Few respondents have as yet submitted these data but ten people from 2013-2014 did report that their spawn did not hatch. In both those years, no tadpoles were reported as having hatched prior to March (and in one case as late as May; n=28 records).

3.3 Toad breeding pond characteristics

Information submitted regarding the characteristics of toad breeding ponds recorded through *Toadwatch* (almost exclusively in private gardens) was highly variable in terms of numbers of responses to different questions. These data are therefore presented here as percentages (Table 3.2). Two factors (“pond depth” [no longer recorded] and “how many years have toads been present”) had insufficient data to draw meaningful conclusions and so are omitted here.

Table 3.3. Characteristics of toad breeding ponds recorded through *Toadwatch.*

Pond type	*Formal garden pond* 9%	*"Wild" garden pond* 9%	*Fish pond* 30%	*Garden pond unspecified* 52%	*Farm pond* <1%
Pond construction	*Liner* 40%	*Preformed plastic* 19%	*Concrete* 29%	*Other* 12%	
Habitat around pond	*Formal garden* 54%	*"Wild" garden* 21%	*Garden unspecified* 22%	*Farmland* 2%	*Woodland* 1%
Pond max length	<2 m 47%	2-5 m 37%	5-8 m 9%	>8 m 7%	
Age of pond	<10 years 22%	10-20 years 31%	20-30 years 31%	>30 years 16%	

3.4. Mortality factors

The number of responses to questions about toad mortality factors was again variable, however 47% of n=97 respondents had seen toads killed at least once on roads ranging from between 1 and 50 m away from their toad observations (mean 16.5 m away). All but a few roads were estate or minor roads, reflecting the toads' association with private garden ponds. Thirty-six percent of n=71 respondents had also seen one or more dead toads in their gardens at some point (often in the pond itself).

3.5. Presence of other species

Toadwatch respondents were also asked to note if they ever saw slow-worms or grass snakes in their gardens. Just 19 respondents reported seeing slow-worms and 15 saw grass snakes, though less than a third of people answered these questions. Some people also reported having newts through the free text "other information" box – from which it is currently difficult to quantify or draw consistent conclusions.

4. DISCUSSION

4.1. Toad Habitat and Population Connectivity

Over the ten years of *Toadwatch*, some 275 breeding ponds have been recorded – the vast majority (>95%) being in islanders' gardens or other man-made ponds. This dependence on anthropogenic habitats is reflected in the toad's species distribution model (section 2.3), which identified ponds and gardens as the most important habitat features for toads in Jersey. Other anthropogenic features (buildings, parks, golf courses and recreation fields) were also associated with the presence of toads. It is undoubtedly positive that *B. spinosus* has been able to adapt to Jersey's urbanizing landscape, but its current dependence on these habitats creates problems in terms of connectivity between populations and, often, effective population size (actual number of breeding females) that make individual colonies more prone to extinction. The chance of recolonization and/or recovery is relatively low when neighbouring breeding colonies are also dependent on few females and separated by roads or other barriers.

Knowledge of important habitat features for toads has enabled the creation of a resistance surface map (Fig. 2.9) and connectivity pathway maps (Figs. 2.10 and 2.11). Cooler colours (Fig. 2.9) show areas of lower resistance to dispersal for toads and in which pond creation should prove effective. These areas are located mainly in the south-west (especially Blanche Banques and around the south-west coast) and in a band running along the north coast. Other potentially suitable areas in and around St. Helier and on the east coast are largely separated from one-another by road networks and agricultural land.

Pond and other habitat creation can also be targeted specifically to increasing population linkage using the connectivity paths shown in Figs. 2.10 and 2.11. This approach would allow greater gene flow between breeding populations and facilitate pond recolonization following local extinctions. A theoretical dispersal distance of up to 2 km for Jersey toads results in population connectivity that shows (effectively) one large, connected population cluster of toads in the island (Fig. 2.10), whereas theoretical dispersal of only up to 1 km shows two large, relatively well-connected populations clusters in the south with several much smaller clusters and isolated ponds elsewhere in the island (Fig. 2.11). Wilkinson (2007) and Wilkinson *et al.* (2007) found low gene flow even between ponds <1 km apart in St. Brelade, and also found no movement of adult toads during the breeding season between two semi-natural populations <1 km apart at Les Landes (Grosnez and Canné de Squez). This suggests that Fig 2.11 (where maximum dispersal is set at 1 km) is likely more indicative of the "real" situation in Jersey; toad dispersal being restricted by certain habitat features and barriers. Fig. 2.10 can, nevertheless, be used to identify connectivity pathways that could be created or restored by the creation of new breeding ponds and habitat in the areas indicated by putative least cost paths. These are highlighted in Fig. 4.1.

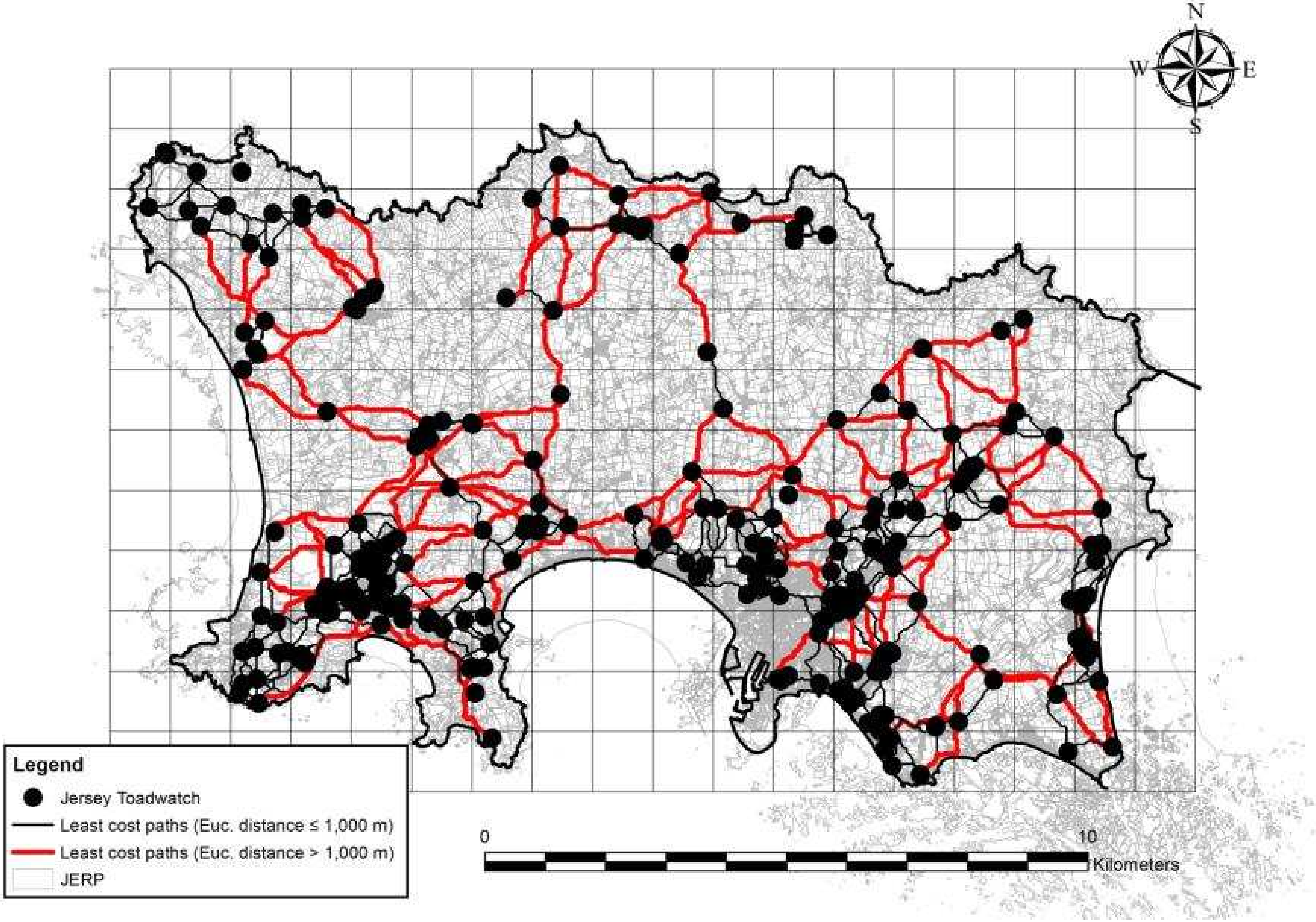

Fig. 4.1. Population linkage opportunities for Jersey toads. Red routes represent least cost paths that could restore connectivity through pond and habitat creation.

Priority pond conservation areas can therefore be identified as:

6. Between La Crabière and Les Landes, and between St. Ouen's Village and Grève de Lecq, as well as La Crabière and St Peter's Village (to link populations in the west of the island);
7. Approximately between Beaumont and Sorel, and along almost any north-south valleys (to link the St. Mary – St. John population cluster to other populations);
8. Eastern Trinity, St. Martin, south-east to Gorey and through Grouville (to restore connectivity in the east of the island);
9. Approximately between Beaumont and Bellozane (reconnects the southern population clusters to one-another);
10. Between Noirmont, Woodbine Corner and Ouaisne (the latter population not currently recorded as part of *Toadwatch*) (to connect Noirmont with other populations and improve population robustness in this key area).

Note that the routes of red least cost paths in Fig. 4.1 should not be interpreted literally – any pond creation along those general routes will decrease landscape resistance, allowing future models to identify other possible connectivity routes that emerge as a result. Nevertheless, some of these suggested pond creation areas represent a considerable challenge. Three weak putative connections can be seen (Fig. 4.1) that would link northern populations to those in the south (which are more numerous and better interconnected). The most challenging suggestion is probably creating opportunities to link the St. Mary – St. John population cluster to those along St. Aubin's Bay. The two routes identified there pass through Jersey's agricultural heartland, likely meaning both lack of opportunity to identify pond creation sites and potential problems with low water table and agricultural runoff. Some of the highest landscape resistance occurs in eastern St. Ouen and in central Trinity (Figs. 2.10 and 2.11) making population reconnection east to west extremely difficult (though at the same time new opportunities may emerge along the north coast as exemplified by the restoration of Plèmont). We therefore suggest that Jersey pond creation initiatives benefiiting the toad should begin with the goal of linking Red Houses/Quennevais – St. Peter – Les Landes and thus reconnecting some of the densest (but smaller) garden populations with those which have the highest numbers of individuals in Jersey but are relatively isolated. The west of the island is also more likely to provide better opportunities for pond creation at present.

4.2. Monitoring Jersey toads through *Toadwatch*

Phenological data demonstrate that toad emergence from hibernation and spawning follow the same general pattern but are extremely variable from year to year. Toads were reported through *Toadwatch* as early as 3rd January (2013) and as late as 26th January (2011); spawn was reported as early as 15th January (2005) and as late as 4th March (2006) (Table 3.1). The ranges over which first observations were made in any given year is also highly variable (e.g. 72 days for first spawn in 2013, or over 10 weeks) indicating local variations within Jersey according to specific conditions. Collection of phenological data will likely prove valuable long-term with anticipated changes in climate that may have unpredictable influences on Jersey's temperature and rainfall patterns, and which may differentially influence toad breeding in different areas of the island.

The generally low average number of spawn strings at Jersey breeding sites is of concern, and is an additional indication that many garden populations are vulnerable to extinction because of small numbers of breeding female toads. Efforts to record this parameter more consistently will be valuable long-term to allow the detection of robust trends, as will collection of other data recently added to the *Toadwatch* recording form such as total toad numbers. So far the indications are that total number of toads per garden site is rather low, with 81% of respondents recording no more than 30 toads in total in any one year (Table 3.2).

The characteristics of recorded toad breeding ponds in Jersey match the habitat features predicted by the model (see Table 2.1). Some 99% of records came from garden ponds and at least 88% were constructed of artificial materials (liner/plastic/concrete); over half (54%) of ponds were in "formal" gardens with most of the rest being surrounded by garden habitats of some kind (including "wild" gardens; Table 3.2). Eighty-one percent of breeding ponds were less than 5 m in size, as may be expected from garden ponds, this possibly being a limiting factor in breeding population size in the long-term. Age of pond, however, did not seem to be related to the presence of breeding toads (Table 3.3), indicating that *B. spinosus* is able to relatively quickly exploit new ponds, once created, as breeding sites. This adaptability may be expected in a species well-used to unpredictable environments (for example in drier areas of Iberia and North Africa) and contrasts with the breeding behaviour of *B. bufo* in the UK, which is notoriously reluctant to establish in garden ponds (see e.g. Beebee, 1979; Zeisset & Beebee, 2013). In common with *B. spinosus*, however, UK *B. bufo* has smaller breeding populations in garden ponds than in other types of breeding site Cooke, 1975).

Many *Toadwatch* participants reported mortality of toads (either on nearby roads or in the pond/garden itself). In the current situation where survival of *B. spinosus* as a widespread species in Jersey is *dependent* on garden ponds, this will be difficult to prevent. Part of the issue is, no doubt, that, in ponds where the number of males exceeds the number of females by a factor of five, ten or even more, females can be killed by the simultaneous attention of several males. The male:female sex ratio in *Bufo bufo* is approximately 3:1 (Davies & Halliday, 1979), and is likely similar in *B. spinosus*; the effects are exacerbated in small garden ponds where males remain for an extended time but females tend to spawn and then leave.

Lastly, the inclusion of questions on other species on *Toadwatch* forms no doubt has the potential to prove informative over time – especially perhaps if regular respondents see (e.g.) a grass snake for the first time. We suggest that the palmate newt is included in future as the species is thought to be less ubiquitous in the island than it formerly was (Arntzen *et al.,* 2014).

5. RECOMMENDATIONS

- Resilience of Jersey toad populations to local extinction events should be improved through increasing connectivity (creation of new ponds and habitat in areas of lower landscape resistance and targeted to possible connectivity pathways;
- The information collected and method of recording *Toadwatch* data since its inception has changed (and been improved) over time. This has, however, resulted in some inconsistencies in the dataset that have made some analyses more difficult. These have now been addressed through the creation of an on-line form and reporting system hosted by Jersey Biodiversity Centre (see http://jerseybiodiversitycentre.org.je/get-involved/toadwatch/). This development will aid future analyses and help to prevent differences in interpretation between what “should” be recorded – as has happened in the past through recording by different volunteers.
- Address mortality issues by (1) erecting of signs and encouraging toad patrols at key locations/times, and (2) updating existing provision of advice on general habitat creation for toads (as well as ponds) in gardens, that will help reduce toad movements through the urban landscape by allowing them to exploit closer terrestrial habitat, and thus reduce exposure to traffic.

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APPENDIX 1. *Toadwatch* recording form from 2008.

Jersey Toadwatch

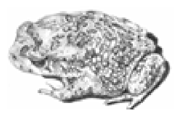
TOADWATCH 2008

Contact details	
Name	*Phone number / Email address*

Pond location
Parish
Pond address or nearby roads and landmarks

Site Type		
Type of pond (e.g. garden pond, farm pond)	*Estimate of pond length (at longest point)* m	*Habitat around pond (e.g. garden, farmland, woodland)*

Roads	
Do migrating toads get run over near the site? **Yes** **No**	*If yes, how near is the road?* m
	How busy is the road?

Adult toads	
	*First spotted this year on (date)*
	Approx. number of toads present in your garden
	Have you had any dead toads in your pond / garden? If yes, how many?
If toads are usually present in your garden during the breeding season, but you do not observe any this year, please let us know	*Last seen this year on (date)*

Toadspawn	
	*First spotted this year on (date)*
	Did tadpoles hatch from the spawn?

Other information (including how many years toads have been present in your garden, how old the pond is, etc.)

Please return to: Toadwatch, Durrell Wildlife Conservation Trust, Les Augres Manor, Trinity, JE3 5B
Email: toadwatch@durrell.org

durrell States of Jersey JARG

APPENDIX 2. The most recent *Toadwatch* recording form.

JARG Jersey Amphibian & Reptile Group "Working to save the Amphibians and Reptiles of Jersey"	durrell	States of Jersey

TOADWATCH 2015

Your contact details

Name

Tel

Email

Address

Pond location (if not home address)

Parish

Pond address or nearby roads and landmarks)

Pond Information (please select the closest answer)

Type of pond	Pond construction	Habitat around pond	Pond max length
No pond ☐	Liner ☐	Garden (formal) ☐	Up to 2m ☐
Formal garden pond ☐	Preformed plastic ☐	Garden (wild) ☐	2m – 5m ☐
Wild garden pond ☐	Concrete ☐	Farmland ☐	5m – 8m ☐
Fish pond ☐	Clay ☐	Woodland ☐	Over 8m ☐
Communal pond ☐	Other ☐	Paving ☐	
Farm pond ☐			
Restaurant pond ☐			
School pond ☐			
Golf course pond ☐			

Toad Breeding Information

How old is the pond?				
How many years have toads been present in the pond?				
First toads seen this year	Date		Month	
First spawn seen	Date		Month	
Approx. no. of strings of spawn				
Did tadpoles hatch from spawn?	Yes ☐		No ☐	
First tadpoles seen	Date		Month	
Total number of toads in garden (approx)				
Do you ever find dead toads in the garden?	Yes ☐	No ☐	If yes, how many?	

Toads and Roads

Do you find migrating toads killed on the road nearby?	Yes ☐	No ☐	
If yes, how near is the road?	Metres		
How would you describe the road?	Main road ☐	Minor road ☐	Private/Estate ☐

Other Information

Do you ever see grass snakes in your garden?		Yes ☐	No ☐
Do you ever see slow-worms in your garden?		Yes ☐	No ☐

Please use the space below to give us any other information that you feel may be useful to us:

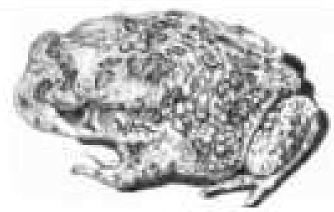
Please return completed form to:

Toadwatch, Durrell Wildlife Conservation Trust,

Les Augres Manor, Trinity. JE3 5BP

Or email to: toadwatch@durrell.org

Toadwatch line: 01534 860053



Appendix 3. Jersey Island Map land classifications.

Value	Feature	Value	Feature
1	Rock Outcrop	34	Reservoir
2	Cliff	36	Rock Defences
3	Misc. Road Feature	37	Pathway
4	Shingle	39	Boundary
5	Major Building	40	Slipway
6	Boulder Rock	41	Misc. Landform Feature
7	Scrub / Bush	42	Sloping Masonry
8	Minor Building	43	Woodland Coniferous
9	Cultivation	47	Sand
10	Quarry Slope	48	Orchard
11	Grassland	49	Cemetery
13	Road	50	Misc. Veg Feature
15	Tank	53	Marsh
16	Pavement	54	Multi Property
17	Track	56	Area Undergoing Change
18	Verge	59	Golf Course
19	Misc. Building Feature	60	Airport Taxiway
20	Driveway	61	Airport Runway
21	Woodland Mixed	62	Dunes and Dune Grass
22	Park	65	Waterfall / Weir
24	Recreation Field	68	Sea
25	Garden		
26	Swimming Pool		
27	Slope		
28	Car Park		
30	Pond		
31	Woodland Deciduous		
32	Glasshouse		
33	Ruin		