



Clarifying the ambiguous invasion of *Pelophylax ridibundus*

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Introduction:

- The **marsh frog** (*Pelophylax ridibundus*) is a **large** species of water frog with natural distribution across predominantly **Europe** and some parts of Asia (Kuzmin *et al.*, 2020).
- They prefer **wetland** habitats but are **highly adaptable** (Ivanova & Berzin, 2019).
- They are **invasive** in the UK due to:
 - This species **large size**
 - outcompetes** native species
 - predates** native species
 - Tolerance** of brackish water and salinity
 - Hybridisation** with native pool frog (*P. lessonae*) to produce the edible frog (*P. esculentus*).
 - Chytrid** threat from pet trade imports.

- Edward P Smith released **12 frogs** into the **Romney/Walland marsh** area (Kent) in 1935 for ornamental reasons (Smith, 1939).
- Geographic profiling** (a statistical technique) was used to identify secondary invasions or places the frog were spending a lot of time in.

Methods:

- Spatial data (latitude and longitude coordinates) were obtained from **NBN Atlas** and **ARG UK**.
- Data was filtered by **verified entries**.
- Data was separated into **pre-2000s** and then in 3 year intervals from **2002 - 2022** to account for sexual maturity and splitting data into equal subsets.
- Google map overlay** was also created.
- List of **golf courses, nature reserves and fisheries** were located from the map overlay.
- Spatial data** from these and the Romney/Walland marsh was generated.
- The **Dirichlet Process Mixture model** of geographic profiling was used to generate geoprofiles, hit scores and sigma using spatial data.

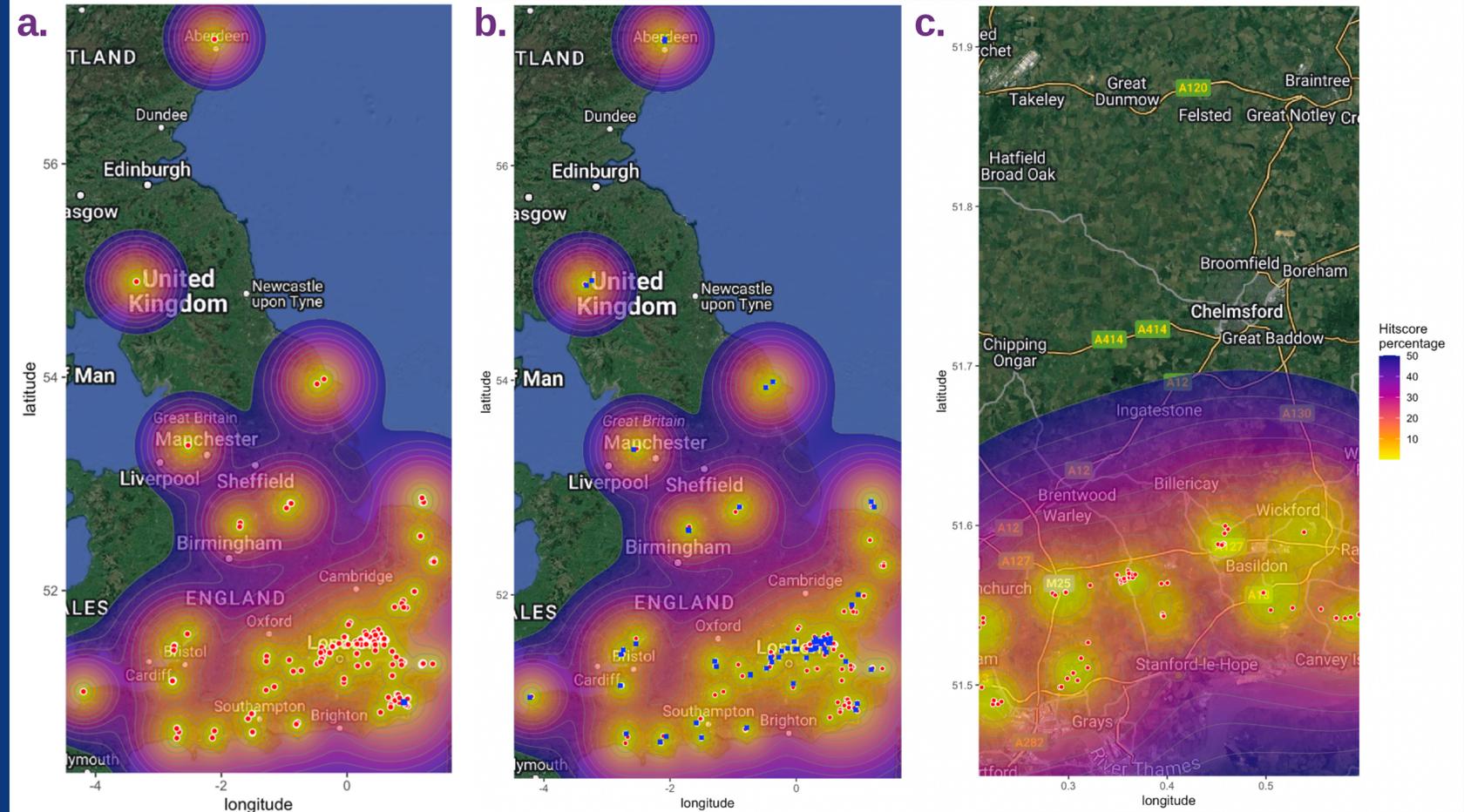


Figure 2: a. geoprofiles of all collated marsh frog data from 1951-2022 with Romney and Walland marsh as the release source, b. hit score geoprofile for golf courses, nature reserves, fisheries, farms and parks next to or near marsh frog sightings. Red dots show frog sightings and blue squares show a possible source location, c. a zoomed in geoprofile of the London/Essex cluster as seen in figure 2.a.

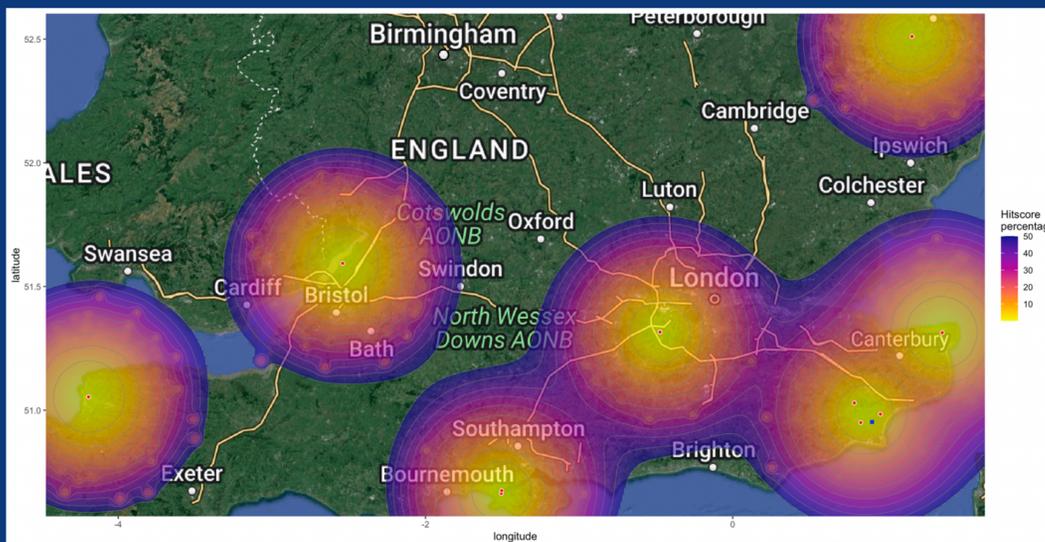


Figure 1: geoprofile of all pre-2000s (1951, 1953, 1954, 1959, 1966, 1981, 1984, 1993 and 1999) marsh frog sightings with Romney and Walland marsh as the release source. Red dots show frog sightings and blue squares show a source location.

Hit score: Lower hit scores mean a greater chance that the source location has marsh frogs present or is an origin site.

Sigma: Used as a proxy for estimating dispersal; how far frogs are moving in an area.

Discussion:

- Pre-2000s geoprofile** (fig 1) shows that Romney/Walland marsh is the origin site as expected (low hit score of 0.2236).
- Isolated sightings could show **human mediated dispersal** e.g via a car from the origin site.
- Collated geoprofile (fig 2.a) has clusters around Romney/Walland marsh (0.5536) - frogs still spending time here.

London/Essex cluster (fig 2.c):

- Source locations with sightings along the **Mardyke River** (golf courses, a fishery and a nature reserve) with low hit scores (see results section - areas of interest).
- Slow current of the Mardyke could be **sweeping frog spawn** along the river and into the **River Thames**.
- Could facilitate **further dispersal** as River Thames spans across nearly the whole of England and **salinity is not an issue**.

Hit score map (fig 2.b):

- Frogs choosing to spend time in **golf courses, nature reserves, fisheries** or similar.
- Ideal habitats with **little competition** from other native species.
- People could be **intentionally dumping frogs** here (unwanted pets - easy to purchase on reptile forums).
- People could be releasing frogs into **back garden ponds** and they disperse unintentionally via interconnected streams and rivers.
- Fisheries** release tadpoles to **fatten up carp**.
- Shows **mainly human mediated dispersal**.

Results:

- Highest number of sightings in **2018** (fig 3).
- Pre-2000s dispersal was around **4-10 km** (fig 4.a) with high sigma.
- London/Essex dispersal was around **2km** (fig 4.b).

Hit score values (release marsh):

- Romney and Walland marsh (collated data geoprofile) = **0.5536**.
- Romney and Walland marsh (pre-2000s geoprofile) = **0.2256**.

Hit score values (areas of interest near Mardyke River):

- Mean hit scores** for fig 2.b = 0.276.
- Essex Golf Course** = 0.0124.
- Essex Fishery** = 0.0536.
- Essex Nature Reserve** = 0.0020.

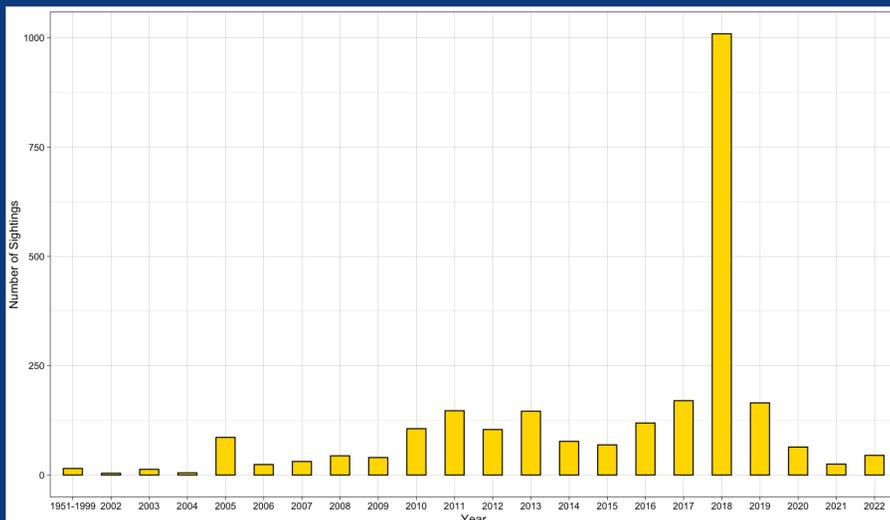


Figure 3: sightings per year.

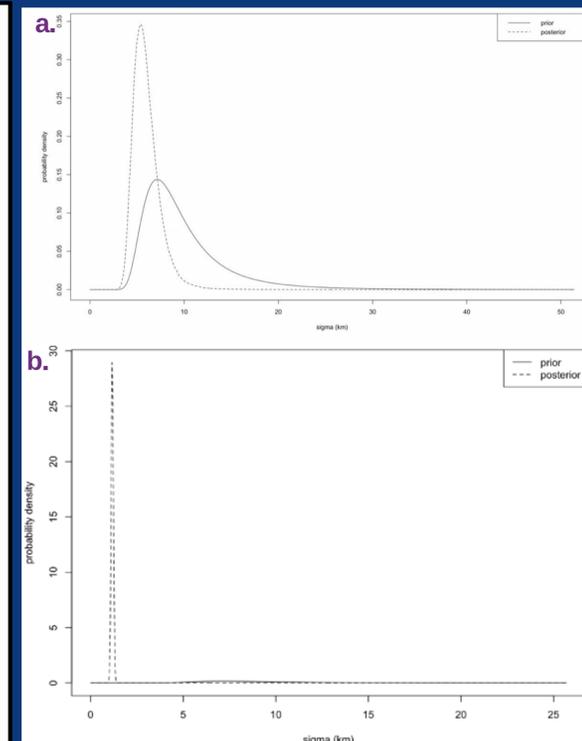


Figure 4: a) dispersion data of the pre-2000s geoprofile as seen in fig.1, b) dispersion data of the London/Essex cluster as seen in fig 2.c.