Citizen Science in meadow studies: population dynamics in *Fritillaria meleagris* on North Meadow (Wiltshire, UK)

Irina Tatarenko, Mike Dodd, Emma Rothero, David Gowing
Open University, Milton Keynes, UK

Interest in scientific observations and discoveries in natural history is deeply rooted in British society. Communities of volunteers and individual naturalists have been contributing to data collection across various groups of organisms, weather, habitats and landscape since the early 19th century. In recent years, a rapid increase in the number of citizen-science projects has been observed which could be due to the increasing availability of digital cameras and mobile connection to the internet. Electronic resources allowed development of large and interactive databases that are easily accessible to thousands of individuals, e.g. iSpot (www.iSpot.org.uk). There are a number of small citizen-led projects in local communities as well as scientist-led initiatives on a bigger scale. Special guidebooks have been published in order to help various governmental and educational organisations with design and management of citizen science projects (e.g. Tweddle et al., 2012). Since 1999, ecologists from the Open University have been running a survey program on the dynamics of a large population of the rare species *Fritillaria meleagris,* in the North Meadow National Nature Reserve (Wiltshire, United Kingdom).

F. meleagris is a rare species growing in old meadows that have not been ploughed or improved for several hundred years. In total, 27 known populations are considered to be wild across the UK. The population of the species on North Meadow is the largest and contains approximately 80% of the UK population *of F. meleagris.* The very spectacular flowering display attracts a lot of public interest, and the number of visitors on North Meadow in April, during the flowering period of *F. meleagris* has increased dramatically over the last decade. North Meadow is an ancient floodplain hay meadow lying in the upper river Thames valley near the Saxon town of Cricklade. Floods are common during the winter months and can last from a few days up to 2 months. Several ancient river channels and drainage ditches cross the meadow (Fig. 1). The main vegetation type is *Alopecurus pratensis – Sanguisorba officinalis* floodplain meadow, a community classified by the UK National Vegetation Classification (NVC; Rodwell, 1992) as mesotrophic grassland number 4 (MG4.) . Annual botanical surveys are conducted on 320 permanent quadrats each June, 200 of these are also monitored for *F, meleagris* in April.

The *F, meleagris* population survey is conducted in the second half of April when most individuals are in flower. One metre by one metre quadrats are divided into cells 10 square centimetres across for convenience of counting. The location of the individual plant, whether it is flowering, its height, number of leaves and flowers (if more than 1) as well as flower colour are recorded on the recording sheets provided. Before recording, volunteers are given detailed instructions and an explanation about counting and measurement along with basic plant identification skills allowing the volunteers to distinguish non-flowering individuals of *F. meleagris* from similar looking species like small sedges, seedlings of *Tragopogon* and *Plantago lanceolata.*

Fig.1. place

Fig.1. The Block of observation quadrats on the North Meadow overlaid on the lidar image (courtesy of …) showing ancient channel across the meadow. The different intensity of colour in the squares represents the density of plants per square metre from 0 up to 50.

The question "How viable is data collection by voluntary groups?" is one of the central questions in citizen science. In order to assess this, 15% of quadrats were randomly re-counted by professional botanists in 2012 on the same day as the main survey was done by volunteers. As expected, there were some disagreements between surveys especially with the quadrats having large numbers of vegetative individuals, however difference was not statistically significant (p-value<0.05). This result supports the validity of data collected by volunteers and confidence with using them in subsequent analyses.

The dataset collected by volunteers led by professional botanists from the Open University has substantial potential for further analysis because various other ecological measurements have been made at the same locations. These include groundwater levels measured in tubewells with automatic pressure-transducer loggers (Schlumberger, NL), orthometric heights measured with differential GPS, vegetation composition surveyed by professional botanists, soil nutrients (N, P, K, Ca, Mg, Na, and pH), and meteorological data. Plot locations were recorded initially using a Total Station (Leica T705, Switzerland accurate to 5 cm) and from 2004 with a differential GPS (Leica R1200; accurate to 3 cm). This ensures that the counts are carried out in the same

quadrats through the whole period of observations. Analyses of the dataset have just started, with some preliminary results on the dynamics of the population age structure and presence/absence of plants on the quadrats presented in this paper. The data indicate that this species has been steadily increasing on North Meadow since 2001 (Fig.2). The dramatic increase in vegetative plants in 2002 and 2008 may suggest that fritillaries benefit from summer flooding in the preceeding year, which appears to depress the overall species richness of the meadow.

The number of leaves on each plant allows an estimate of its growth stage and by grouping them into 4 stages: juvenile (1 leaf), sub-adult (2-3 leaves), adult vegetative (4 leaves and more), adult flowering (plants with >4 leaves plus a flower) we can allocate them to age groups such as those suggested for this species studied in Moscow Region (Rotov, 1976) and The Netherlands (Corporaal *et al*, 1993).

As with other "vegetatively-annual" plants, which renew the entire plant structure each year (e.g. orchids of tribe *Orchideae*), the changes in plant numbers within a population can be quite dramatic. The mortality rate for juveniles is relatively high, transition to the dormancy is regular in all age groups, transitions of flowering plants back into the "adult vegetative" stage are frequent, the mortality rate after first flowering is also high (Vakhrameeva, Hutchings,). In the fritillary population on the North Meadow, the biggest fluctuations in the number of individuals appearing above the ground were recorded in juvenile and adult vegetative age groups (Fig.2). This can be explained by the high mortality and/or dormancy rate in juvenile group in 2009 and 2011, which followed big germination peaks in 2008 and 2010 accordingly. It has been reported that this species can occasionally propagate vegetatively by forming bulbils (Petrić *et al*., 2011), so that factor must be further investigated in wild populations in order to estimate the role of bulbils, if any, in the appearance of juvenile plants within the population.

The data identify some opposing trends: in some years the numbers of flowering plants increases whilst the number of adult vegetative plants decreases (as seen in Fig. 2 for the years 2004, 2009, 2011) and vice-versa in years 2005, 2008 and 2012 This is likely to be as a result of flowering plants transitioning into the adult vegetative group and back. Low but steady number of sub-adult plants indicates the stable rate of transformation of juveniles to the adult vegetative stage, and also a relatively high speed of this transformation (1-3 years). This can be considered as a sign of the population being stable and well-established in the meadow community.

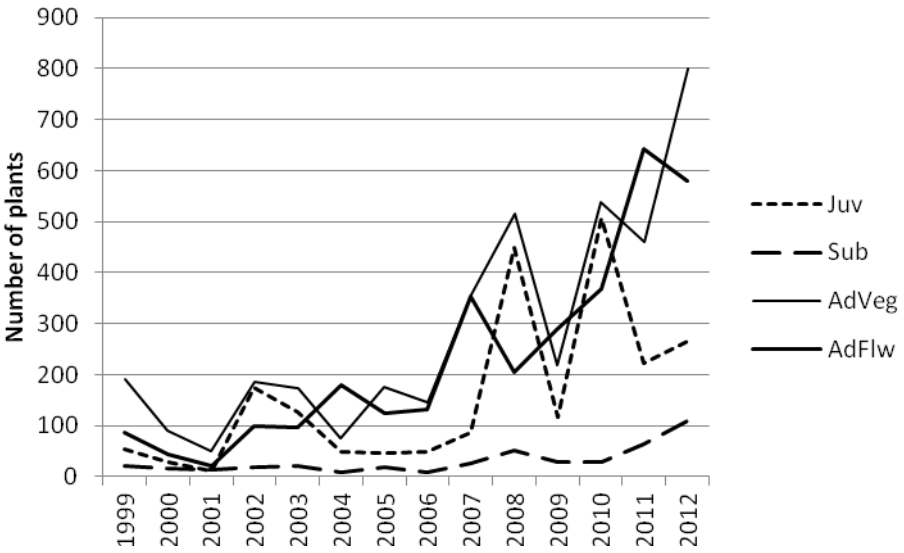
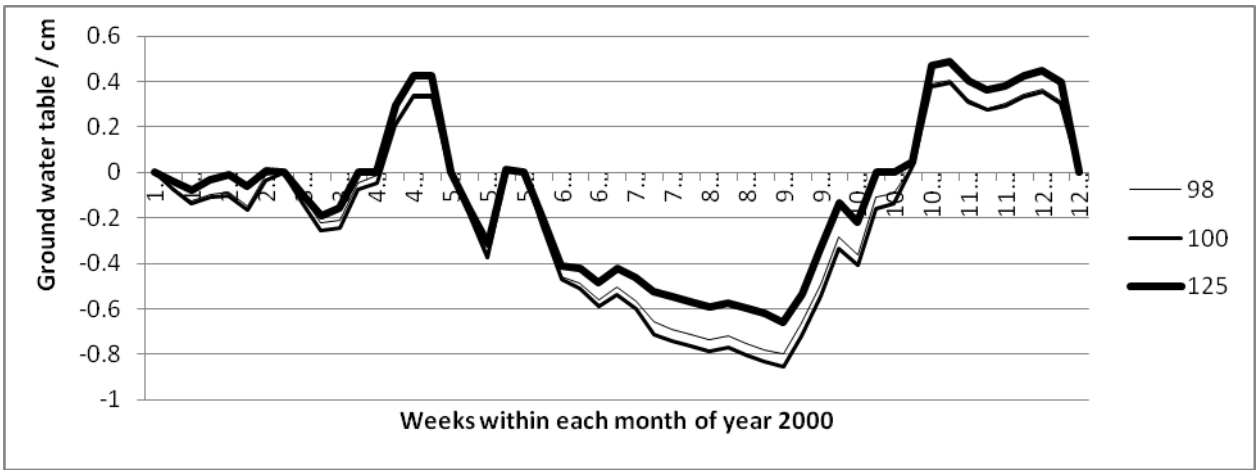


Fig.2. *Fritillaria meleagris* population dynamics on North Meadow in 1999-2012: Juv – juveniles, Sub – sub-adults, AdVeg – adult vegetative, AdFlw – adult flowering age groups.

During 14 years of observations at North Meadow, about 35 % of surveyed quadrats stayed "empty", with no fritillaries appearing in any year; whilst 8% have had fritillaries present throughout the whole period. The majority of sampled locations (57%) however have contained fritillaries in some but not all years, demonstrating the dynamism of the population. The absence and/or low frequency of fritillaries is significantly correlated ($p<0.05$) with the elevation of the quadrat. Low densities occur along an paleochannel running through the centre of the site which regularly retains floodwater (Fig.1). Such locations with regular soil waterlogging were shown to be unfavorable for fritillary growth (Zhang *et al*., 1985). However, some of "empty" or low density quadrats are also located on higher ground, in between the areas densely occupied by

fritillaries (Fig.1). That suggests that long-term flooding observed in the paleochannel, may not be the only hydrological factor influencing fritillary distribution on the site. To test that, a model calculating groundwater depth that has been validated aginst tubewell observations across the site (Gowing et al., 1998) was run weekly, for each sampled location over the period 2000-2005. The locations with and without fritillaries were then inspected separately. The example of an annual output is shown in Fig. 3 for the year 2000. The patterns displayed on these graphs were representative of all the quadrats in each category.

a)



b)

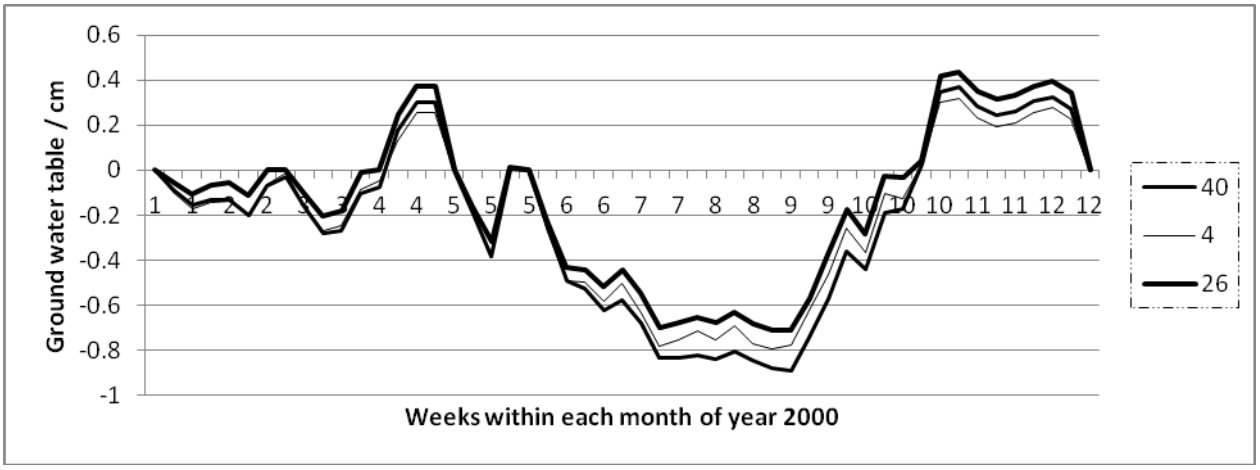


Fig.3. Hydrographs of water-tables depths a) in the locations of "empty" quadrats (nos 98, 100 and 125) and b) in the locations of "constantly occupied" quadrats (nos 40, 4 and 26.)

Two hydrographs presented on Fig.3 are very similar in timing of water-table rise and fall, in the duration of flood events, showing only difference between water levels depending on quadrat location. The only noticeable difference in the graphs pattern happens in summer, when the water table is at its lowest: the water table dropped in both categories until mid July, but after that it stayed almost constant beneath the "empty" quadrats, whilst steadily decreasing beneath the "constantly occupied" quadrats until rainfall started to raise water levels at the beginning of September (Fig.5). The linear regressions are highly significant for both groups of locations (R^2=0.94, $p<0.001$). All other years from our runs of the hydrological model showed similar patterns specifically for the drier period in summer months for the two categories of quadrats. The slow decrease in water-table depth during the dry season, observed in the "constantly occupied" locations, may be explained by the nature of the soil profile, which consists of fine-textured alluvial deposits (silty-clays) above a much coarser textured river-terrace deposit (sands and gravels). Additional investigation of profile composition is needed for confirmation of this hypothesis.

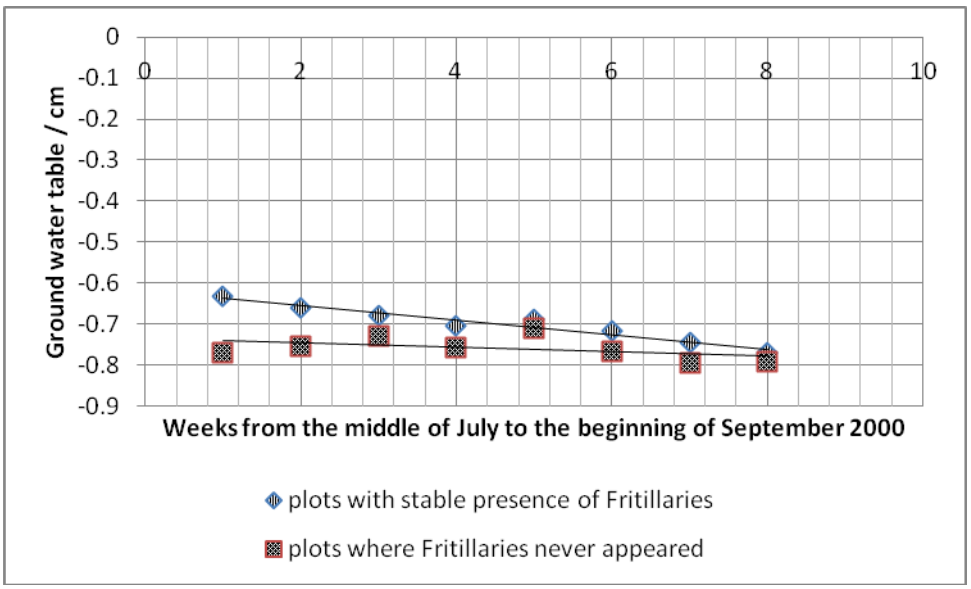


Fig.5. Groundwater tables in the locations with and without fritillaries on the North meadow during the dry period of summer from the middle of July to the beginning of September.

Conclusion

Citizen science provides a valuable means of combining environmental research with environmental education and wildlife recording. Public involvement in data collection has been proved to be a success. Data obtained by volunteers in monitoring of the rare species *Fritillaria meleagris* at North Meadow have been used for both research and teaching projects at the Open University as well as for public outreach and education events relating to plant conservation. The data analyses presented here indicate a stable population with a significant increase in the total number of the individuals over the last decade. The results indicate a possibility that alluvium thickness is a driving factor controlling the species distribution across the meadow; further investigation is needed to confirm that. The value of such long-term data sets is increasing from year to year giving more opportunities for the data analyses both on local and on large geographical climatic scale. Data management and analyses may still require the involvement of professional scientists, but building up the volunteers' expertise might result in more public engagement with experimental design and data analyses.

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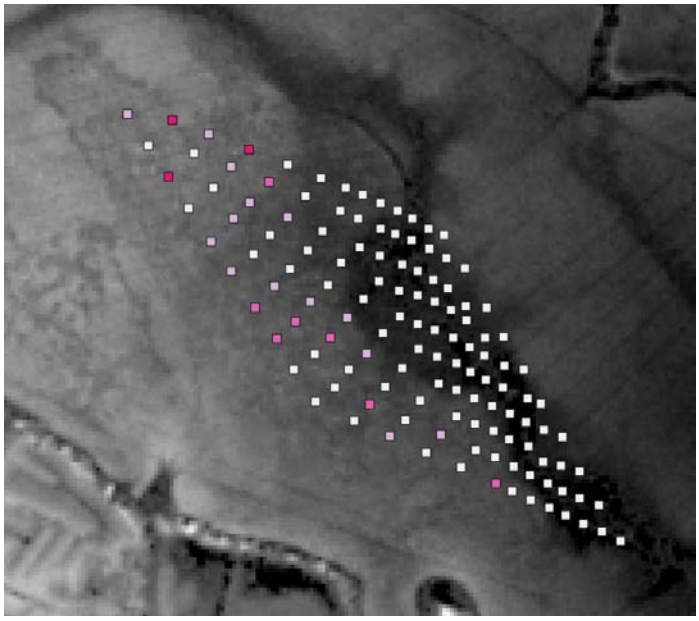

Fig.1. The Block of observation quadrats on the North Meadow overlaid on a ground-suface-radar image (cortesy of …) showing the route of a paleochannel across the meadow (darker zones are of lower elevation.) The different intensity of colour in the squares represents the density of plants per square metre from 0 up to 50.