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PREVENTIVE CONSERVATION

Trends in effective communication of integrated pest management data

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ABSTRACT

Preventing heritage objects from being damaged by pests is a major challenge of collection care. Integrated pest management (IPM) programmes are currently the preferred option within the heritage sector for protecting collections from insect pests. One essential feature of IPM is monitoring and recording, resulting in large amounts of data processing. While there is a considerable body of literature on the identification of common pests and the implementation and maintenance of an IPM programme, including the collection of pest activity data, little guidance exists on how to communicate these data most effectively. This paper reviews current, and suggests future, solutions for data visualisation and advocates for more effective communication by adopting novel graphical representations. By offering options which are dynamic, visually attractive and meaningful, such as Dorling cartograms and Malthusian growth pyramids, the authors propose new tools to enhance IPM data communication. These tools contribute to improvements in communication, which remains an under-researched aspect of collection care.

IPM CHALLENGES

In recent years heritage organisations changed their response to insect pest infestations from treatment to preventive measures. This development was accompanied by a new emphasis on evidence-based risk management, as knowledge of the risks posed is crucial to the success of pest management. External independent factors, such as climate change or legislative frameworks, are linked to the successful management of pests, as are internal factors, such as patterns of funding impacting on staff or equipment. Between institutions, the mechanics of loans, such as their frequency and turnaround time, may lead to changes in pest occurrences. Each of these economic, political, climate or managerial changes involve considering dynamic data to inform collection care practice (Xavier-Rowe and Lauder 2011). Data may be used to validate the effectiveness of an integrated pest management (IPM) programme by asking whether a pest population within an organisation is increasing or spreading with time. Strang (1999) argued that pest migration patterns may only be detected by monitoring programmes if measures exist of their movement within collections. He compared museum collections to open, non-equilibrium systems, requiring the explicit incorporation of dispersal and spatial effects into theoretical models (cf. Onstad 1988). Pinniger (2013) made the case for improved communication of new pest management tools, which is here extended to improving the communication of findings.

DATA COMMUNICATION AND INFLUENCE

Answering IPM questions requires the monitoring of complex and dynamic data. The findings often demand action which impacts on collection use or the deployment of resources. Data collection is only of value if results are interpreted and communicated effectively. Successful presentation of evidence should result in the conclusion that an IPM programme and a preventive approach to collection care is the most resource-efficient approach. A challenge in communicating pest data to decision makers is to enable understanding of what the numbers mean for the collection in a way that inspires action or at least permission to act.

DATA COLLECTION AND REPRESENTATION: CURRENT PRACTICE

There is a lack of concern within the IPM community about the mode of data representation best suited for putting forward persuasive arguments in support of collection care. Improved communication of new pest management tools (Pinniger 2013) should go hand in hand with improvements to the communication of data. Lack of data does not appear to be a limitation. Heritage organisations amass large amounts of data on pest species in rooms, collections, buildings, regions and countries (for example, Querner et al. 2013). Data are recorded on presence/absence of species, species identity, density, distribution, and information on building integrity and maintenance. Tabulation in digital format offers the potential for analysis and graphical representation.

Conventionally, IPM data in the heritage sector are communicated with spreadsheets, bar charts and building plans. Each method has its own distinct advantages and disadvantages. Counts of insect populations are displayed as a bar or pie chart. This familiar graph may indicate a simple two-factor trend but no further detail without additional text or further graphs. Another commonly used representation is the building plan with insect pest catches plotted geographically by density, such as risk zone plans.

Limitations of current practice

The authors hypothesize that these representations are used frequently because of the ubiquitous availability and widespread familiarity in the use of software such as Microsoft Excel, and because they once were the most effective means of communicating data. The use of spreadsheets was adopted across the heritage sector with little significant adaptation for different applications and contexts. This offers benefits in terms of efficacy, familiarity and uniformity; at the same time, this practice may also have become habitual and non-reflective. Line graphs or building plans with superimposed pest data are sufficient for conservators assessing the effectiveness of their IPM strategy (for example, Ryder et al. 2014), but not necessarily influential when persuading museum management of the need to continue an IPM programme. While such graphical aids may communicate risk levels and population sizes to a degree, frequently they lack contextual information, are uninteresting visually, assume prior knowledge of buildings and collections and do not demonstrate temporal changes effectively. Many of the challenges of representing dynamic data, whether the migration of new species through a geographical area or the spread of pests through a collection, are linked to the changing demographics of pest occurrences, for which there is currently no commonly used effective graphical representation.

Impact of trap numbers

A further consideration is the number of pest traps used to collect the data. Where charts focus on a count of pest occurrences, decoupling the relationship of total pests from the density of traps is necessary to avoid the distortion caused by a greater number of traps. It is a common strategy to increase the density of pest traps in an area where an infestation is suspected to help the IPM manager target the source of a pest problem, such as a chimney, food source or travel route. Any reporting system that relies on total counts and cross references this to locations will inevitably show density patterns that correlate as much to the density of the traps as to the frequency of individual pest organisms. Made without careful consideration, density mapping may best represent the concentration of traps rather than that of pests. Presenting such skewed data without reflection reduces their value.

WHAT IPM REPRESENTATION DO WE NEED?

None of the default charts are suited to communicating in an easily understandable format: complex answers are required when responding to many IPM challenges. Therefore, information should be communicated more effectively to ensure questions are, in fact, answered and the correct conclusions are drawn. With this approach comes a need for novel ways of data visualisation.

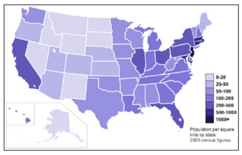
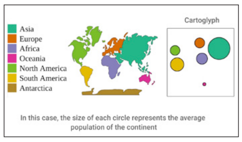
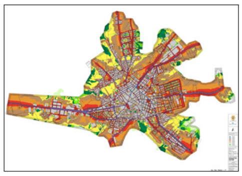
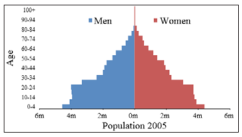
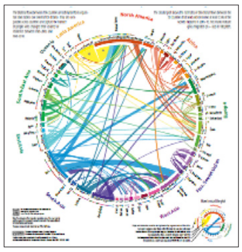
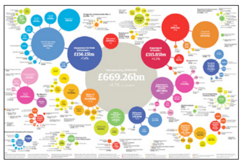
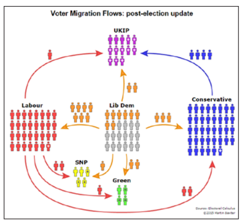
Properties of good data communication

The aim of data presentation is to match data visualisation to the research question and the communication goal. The quality of visualisations plays a vital role in this because the effective use of illustrations is an important facet of message design. Improvements in the communication of data would: enhance understanding of the risks posed by insect pests; identify issues and patterns on an organisational, national and international level; and contribute to attaining support and resources. Any good data visualisation addresses specific questions, is easy to understand and indicates the effect of an increase or decrease in pest numbers. The purpose of each visualisation should be clear before it is produced. This includes consideration of the limitations of graphical visualisations and the decision to include supplementary information or additional charts for important elements or data not represented in the main visualisation.

NEW OPTIONS FOR DATA REPRESENTATION

Recently, the creation of innovative, illustrative and interactive infographics has increased the options for illustrating and communicating complex data sets in a meaningful and accessible manner (Massironi 2001). Infographics are visual interpretations of information or data in an easily understandable way (Oxford Dictionaries 2015) and gained popularity quickly in a multitude of disciplines. For the purpose of this work, the term infographic is herewith used to represent any form of effective data visualisation. Infographics rely on the ‘picture superiority effect’: people are able to learn and recall information more clearly and effectively when presented as images than in other forms (Hockley 2008, Medina 2008). This is because a large proportion of the human brain is committed to visual processing (Krum 2013). Infographics employ patterns and colour to augment communication by holding attention and aiding memory (Medina 2008), although poor colour choice may result in a graphic that is neither effective nor appealing to the user. The use of colour in graphics has to consider the possibility of colour blindness and, therefore, the potential for misinterpretation. Principles of good visual communication using infographics include: having a clear purpose, avoiding distortion, encouraging comparison and focussing on the information rather than the methodology (Tufte 2001). A number of infographics may be considered potentially useful in the context of displaying pest management data effectively and these are summarised in Table 1.

Table 1. This – by no means exhaustive – summary illustrates the diversity of visualisations that may be useful for the depiction of pest monitoring data . For this illustrative purpose it is not possible to use the same data for all visualisations because each format uses a different approach. Certain applications are therefore suitable for different data sets

Type	Shows	Useful because	Limitations	Example graphic
Choropleth map	Represents average values (or density) of a variable within a defined area, usually geo-political.	Depicts gradients of a characteristic with a spatial component. Often used to indicate population density in a specific area.	Shows average density for a specific space and masks local variables (i.e. distribution in a room). May give false impression of change at boundary.	 https://zh.wikipedia.org/wiki/File:USA_states_population_density_map.PNG
Dorling cartogram	Quantitative information mapped on an outline geography.	The size of the representation is dependent on the quantified data and not the size of the geographical areas, thus it represents a factor such as population density and its geographical relation without the potential confusion of the area.	Not suitable for more than two dimensions. Geographical details may not be a relevant factor.	 http://i.vimeocdn.com/video/592054613_1280x720.jpg
Isopleth map	Plots density of a factor by space, such as density of earthquake or population.	Connects areas or similar density with lines or shading. Indicates 'hot spots' and is not constrained by geography.	Requires a lot of data for accuracy.	 https://en.wikipedia.org/wiki/Noise_map#/media/File:Mapa_de_ruido.jpg
Malthusian growth pyramid	Demographic population data, often organised by sex and age. Traditionally used for displaying segmented age groups within populations.	Shows the distribution of a population assisting in predictions of population change. Large amount of data communicated in a single graphic showing of, in essence, three axes and colour coding.	Does not communicate geographical relationships.	 https://en.wikipedia.org/wiki/Demographic_trap#/media/File:Egypt_population_pyramid_2005.svg
Migration model	Circular plot depicts flows between spaces.	Appealing visually and ground breaking through interactivity, which gives opportunity to interrogate data in detail.	Migration flows are not suitable for the ecological spread of pest species where a new population may be started by a single individual.	 Abel and Sander (2014)
Radial circle relationship infographic	Variation of the Dorling cartogram without geography.	Text in each circle may contain additional information such as the number of pest traps and occurrences per floor area. Graphic would also make sense in greyscale. Available from Excel.	Lacks a temporal component and precise geographical information.	 https://www.theguardian.com/news/datablog/2010/oct/18/government-spending-department-2009-10
Voter migration flow model	Shows the flow of several variables over a series of events s between spaces.	Easy to read and visually appealing. Captures shifting population very clearly.	Assumes a fixed total population and that flow from one zone must arrive from another or that each individual leaving one space arrives in a different space.	 Baxter 2015

Infographic options

Geopolitical information is often displayed using choropleth maps that depict gradients of a single characteristic, such as life expectancy, with a spatial component (Table 1). In pest monitoring, this may be the population size of individual species mapped across a building floor plan, indicating the effectiveness of barriers, or the spreading route of an infestation. A sharp change at a physical boundary would indicate the successful containment of a pest. Pockets of high concentrations of a pest emerging without spatial adjacency would suggest a potential additional human agency, such as infested objects being moved from stores to a study area. To be entirely meaningful such a map would require additional contextual information, such as risk zones, collection areas and access routes. As with all density maps, consideration of the number of pest traps per unit area in a given space is of utmost importance.

Isopleth maps connect areas with matching concentration and show a more accurate indication of distribution than choropleth maps. Not being governed by geographical nor structural boundaries such as political regions or room divisions, they do not give a false impression of abrupt changes at a boundary. An isopleth map would require a great deal of pest monitoring data collected in a uniform manner to connect lines of similar density, but if available the growth of a population from a point of origin may be obvious (Bryant et al. 2014). Assuming the presence of sufficient amounts of data, the spread of a newly identified pest across a country, for example, as a result of climate change, may be illustrated. Isopleth maps would be less suitable than choropleth maps where data are inconsistent, or where the growth of a population is not connected geographically. While isopleths show density changes such as population growth independent of geographical boundaries, choropleths may highlight the impact of those boundaries.

A map does not necessarily need to include the underlying geography or structure such as a building. If the purpose of the communication is to relay information about collection risk to people without knowledge of a building, geographic detail may be a distraction. Hence, the base map may be disregarded altogether. In a Dorling cartogram, proportionally sized circles arranged in a broadly geographic pattern communicate quantities, focussing attention on the size of population while maintaining spatial relationships without the use of maps (Dorling 1996). In an IPM context, a Dorling cartogram draws attention to population counts and the relationship of adjacency between each unit (for example, rooms within a building). Only spaces with pests present would be displayed in the infographic, focussing attention on problem areas and conveying a sense of urgency to act. Radial circle relationship graphics go a step further than Dorling cartograms and abandon geographies altogether. This allows the depiction of pest populations even across separate floors within a building, with connected radial circles outlining the relative sizes of the component species contributing towards the total in each space. This representation lacks the temporal component, but the characterisation of pest populations for individual collections is more detailed than in other visualisations. In both options, additional text in each population circle may contain such information as the room name, number of pest traps or occurrences per floor area. Within the figure it may also be possible to represent the composition of a total pest count by species in the form of a pie chart within the circle. While the use of colour enables easier interpretation, the graphic would also make sense in greyscale.

A model representing human migration routes produced by Abel and Sander (2014) operates both as a fixed and as an interactive diagram. A visually appealing circular plot, sometimes known as a radial table, describes flows between spaces. This graphic is particularly interesting due to its interactivity, which allows interrogation of even small details in an online application, though not if printed in two dimensions on paper. This diagram allows both macro and micro population changes to be represented on a single graphic. Technically complex, it may be beyond the resources of most museums but might offer a well-resourced institution with several sites the chance to map large quantities of data in a clear and attractive format.

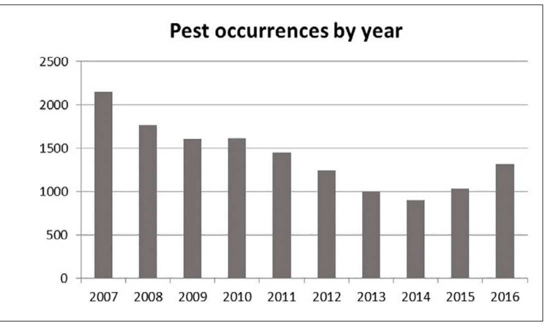


Figure 1. A bar chart indicates a trend of declining pest occurrences with time and a sudden increase in the last two years

Similar data are visualised in an entirely different way through voter migration flow charts (Baxter 2015), which may be useful to show the balance of pests within a fixed geography such as a building. For pest challenges it may help plan resource deployment, targeting the pest type posing the greatest risk.

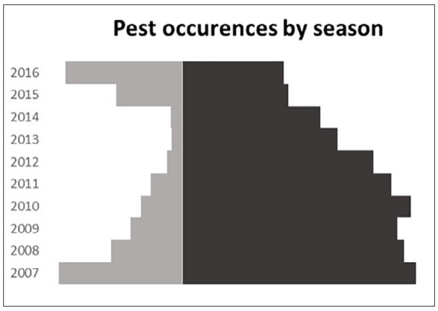


Figure 2. A Malthusian pyramid adds more detail than a simple bar chart while still being easy to interpret

Malthusian growth pyramids are used frequently to display population data (Ginn Daugherty and Kammeyer 1995), such as the distribution of males and females across different age ranges and at different points in time (*The Economist* online 2011). This appears inherently useful as a way of comparing pest populations in time, perhaps summer and winter populations, or larval vs adult growth stages (X axis), over a number of years (Y axis). A large amount of data communication in a single graphic is enabled through the use of, in essence, three axes and colour coding, although it is not possible to communicate any geographies with this style of chart.

SUGGESTION OF A PEST DATA VISUALISATION

The authors suggest a hypothetical scenario of pest monitoring data from a single museum in a historic building with multiple collection areas. A traditional bar chart (Figure 1) shows that cumulative pest occurrences in the building decrease over time, indicating that the IPM programme at this museum may have a positive effect. What this type of graphic cannot resolve is why the IPM programme appears to be working. A Malthusian pyramid (Figure 2) is more powerful as it includes more information in a similar format. It is now evident that there are a number of parallel trends in the data: a general decrease in pest occurrences during the winter months. The sharp increase of pest occurrences in the last two years was due to numbers increasing in winter, while summer numbers were still on the decline, as they had been for six years.

A choropleth map (Figure 3) of the building shows that the areas with the most significant pest problems are the galleries, one office and the reception area. Within the exhibition space the greatest population density is in the natural history gallery. Rooms on either side of this gallery have a lesser pest occurrence, indicating that the natural history gallery is the source of the problem. A correspondingly large population density detected in isolation within the curator's office suggests human transference rather than pest migration. The density (pest count per m^2) in the reception indicates that pests may be arriving with deliveries but are contained effectively by the quarantine arrangements. The focus on population density with boundary helps to highlight the success or failure of control systems. In contrast, the radial circle diagram (Figure 4) places more focus on absolute populations and the need to act. From a risk management point of view, the radial circle diagram is a powerful illustration of which areas need to be investigated further and perhaps warrant the provision of further resources to counteract emerging negative trends before problems get out of hand. It may divert attention from areas where current success must be maintained. For either diagram, there is additional potential to offer a breakdown by pest type within a circle, offering further clarification of the problem.

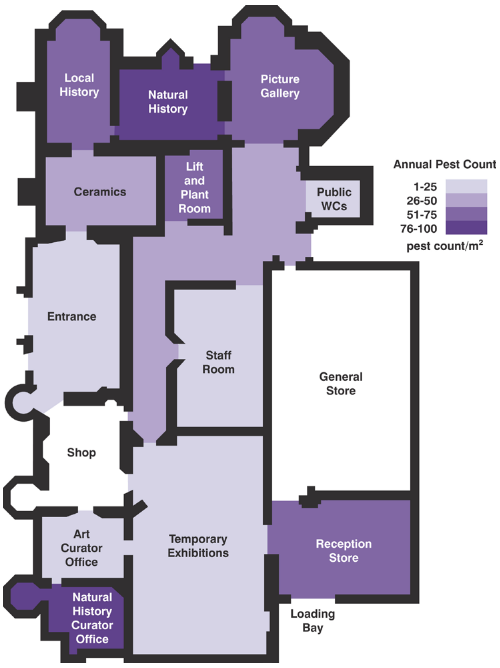


Figure 3. A choropleth map highlights the pest density in different parts of the building, focussing on the impact of boundaries

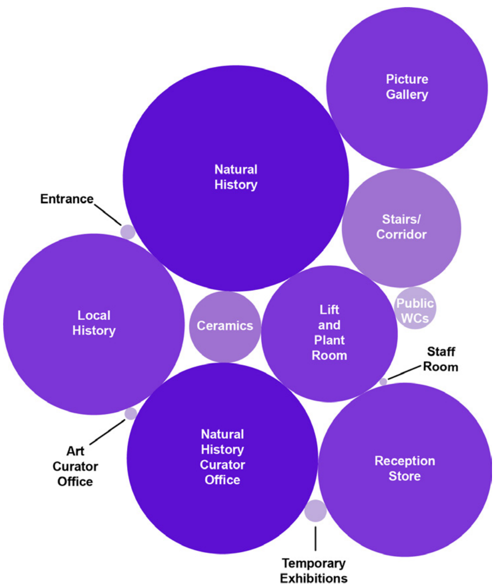


Figure 4. A radial circle diagram showing the same data as Figure 3 offers a greater emphasis on population than location

CONCLUSION

Ultimately, the aim of improvements in the communication of pest monitoring data is to reduce future pest damage to collections. Effective data communication is therefore part of successful collection care. Data inform collection care practice. IPM generates a significant amount of data; consideration of how it is represented may make data collection and sharing more effective. Whilst representations used traditionally in the heritage sector offer uniformity, they do little to capture and communicate the dynamic data underlying many of the current challenges of effective pest management. A review of graphical representations used within the heritage sector and comparison with those used in other disciplines shows that the heritage sector utilises only a narrow range of the options available. Novel ways of graphical data summary and representation may be suited better to communicate pest data. Benefits include enhanced data comprehension and easier recognition of underlying patterns. In addition, collection care staff would be able to inform decision makers more effectively of risks to collections, and perhaps even to raise public awareness of conservation challenges. Powerfully persuasive and illustrative graphical representations of pest monitoring data can be created by populating infographics with pest monitoring data to illustrate their potential future use in the heritage sector. The suitability of each type of visualisation depends very much on the questions asked and the target audience. Some visualisations may work better in an online context, but a discussion of joint data collection and data sharing is beyond the scope of this paper. The next step in this work will now be to explore individual models in more detail for their usefulness as pest data communication tools. By focussing on how we communicate in one aspect of collection care, we may highlight the more general aspiration for collection care professionals to develop communication skills as part of a broader skill set to achieve greater influence and to become effective agents of change.

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