SPATIO-TEMPORAL WEB MAPPING OF SCIENTIFIC DATA – APPROACHES FOR EFFECTIVE USER EXPERIENCES

Andrew Cowie, David Medyckyj-Scott, Tim Heuer
Manaaki Whenua – Landcare Research

(CowieA@landcareresearch.co.nz, Medyckyj-ScottD@landcareresearch.co.nz, HeuerT@landcareresearch.co.nz)

Spatio-temporal visualization, environmental data, web cartography, open source

1. INTRODUCTION

With ever increasing amounts of spatio-temporal data being collected, related to topics such as climate models and weather patterns, population movement of flora and fauna or airborne viruses, efficient and novel ways to analyse and visualise these data are required.

Generally speaking, spatio-temporal data are big data. These data can be difficult to visualise in a web browser due to the large data payload size. This becomes apparent to the user as poor rendering times when they try to view and explore the data dynamically at different scales and for different geographic extents. As a result, many web applications that display spatio-temporal data do so at only one geographic scale.

In this presentation we describe three investigations, conducted over several years, to identify technical approaches to enable dynamic exploration of spatio-temporal data in a web application at differing geographic scales. The approaches reflect the evolution of the technologies.

2. NATIONAL POSSUM MODEL (2011–12)

The audience for this experimental application was animal health specialists and local government analysts who wanted to understand how possum numbers potentially grow and decline over time.

2.1 The data

Manaaki Whenua has modelled New Zealand potential possum population growth over a 30-year period, from 2008 to 2038 (Shepherd et al., forthcoming 2018). The output data are a set of layers showing likely numbers of possums per 50-m cell resolution for the whole country under different management intervention scenarios.

2.2 The technology

Services like WMS and WMTS, delivered by technologies such as MapServer[1] and GeoServer[2], tile up spatial data into image tiles that the web application requests and displays. Manaaki Whenua extended this idea employing a custom web service, WMS-V, to serve animated web maps as "video tiles" instead of static images.

Using possum numbers data as a test, an automated process was developed to request map tiles for a given geographic extent, set scale, and time period and stitch them together into a standard video format. These videos were cached in a file/directory structure readable by the map serving software (34,000 video files, cache size 24Gb). A request from the application for a spatial extent was sent to the server and the associated video files sent back to the browser to be displayed.

2.3 Cartography and visualizations

A simple green to red colour ramp was used to signify density of possum numbers. Each frame of each video tile represented a year. Using video synchronisation technology developed by Manaaki Whenua, despite the fact a large number of video tiles were running in the application at the same time, the user could interact with the application as if the map were a single video.
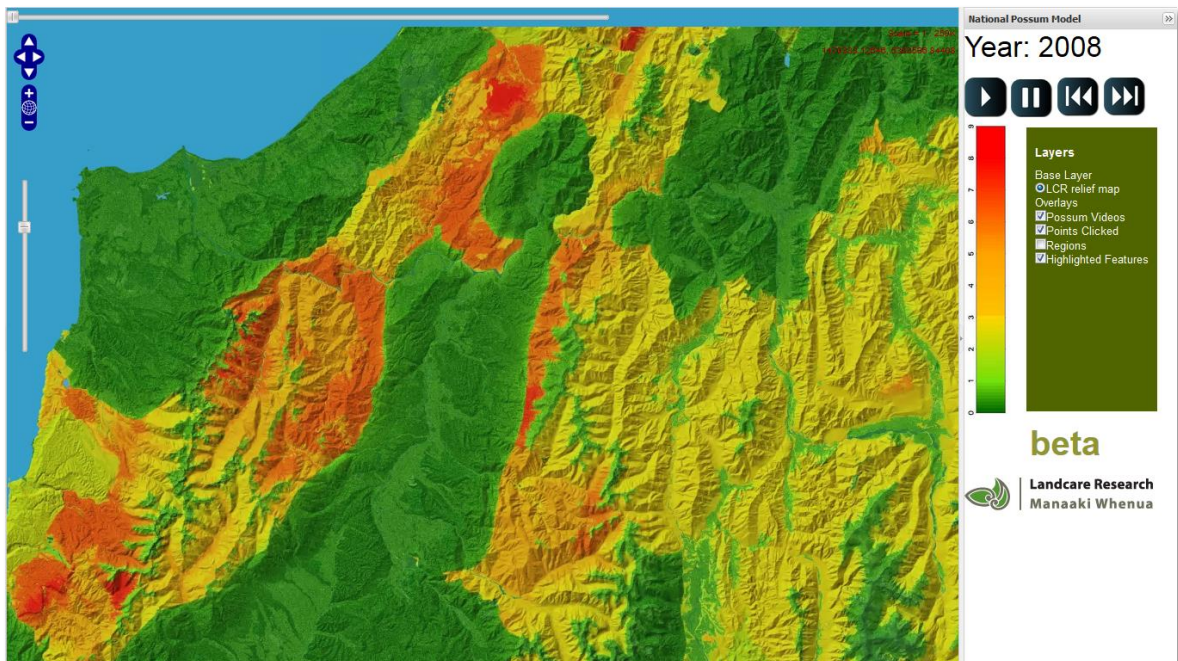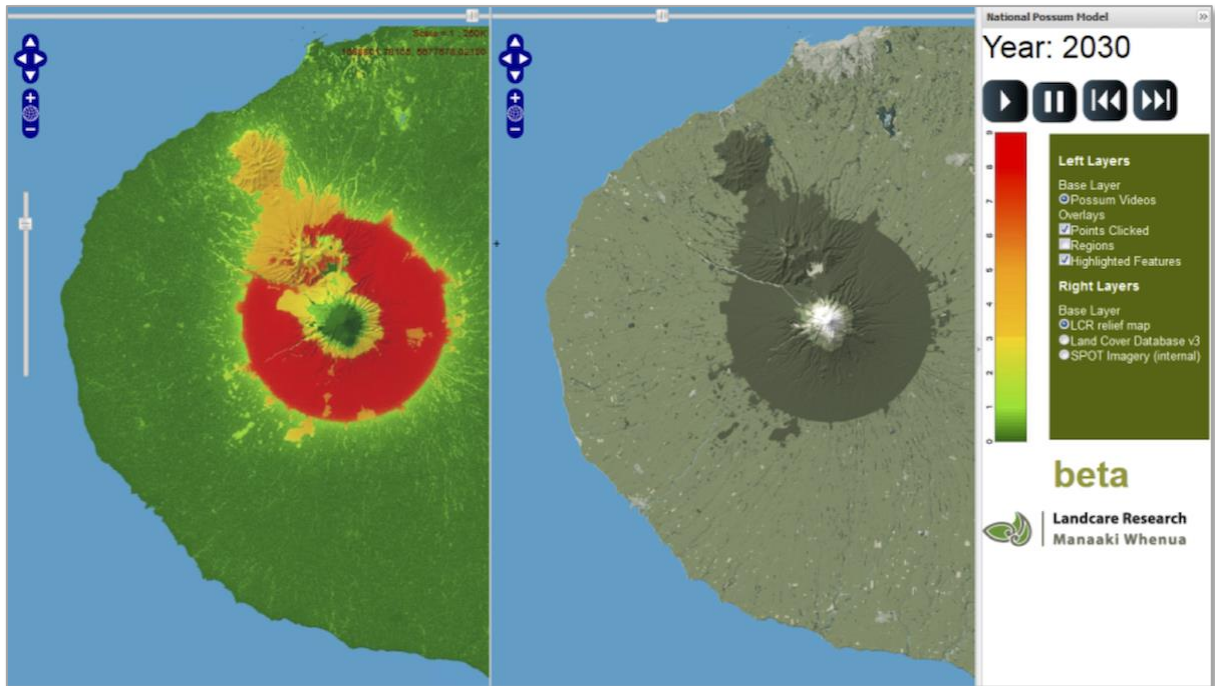

Figure 1 Possum Density Viewer

---

[1] http://mapserver.org/uk/index.html

[2] http://geoserver.org/

Figure 2 Possum Density Viewer – Side-by-side thematic comparison.

2.4 The UX

The web application was built using a forked version of OpenLayers[3] (Figures 1 and 2). OpenLayers was extended to request video tiles instead of static images, and a standard HTML5 video element used to play the videos in the browser. The application consisted of a "slippy" map, related navigation controls and the type of controls one would find on a web video player. Using these, the user could "play" the map data, over a time period of 30 years, zooming and panning the map to study the data.

4. LANDCOVER OF NEW ZEALAND CHANGE VIEWER (2014)

4.1 The data

The Landcover Database of New Zealand (LCDB)[4] contains data for four time periods – 1996/97, 2001/02, 2008/09, 2012/13. This investigation looked at whether a web application could be built that allowed anyone interested in landcover within New Zealand, to view how landcover changes.

4.2 The technology

On the server side, a vector tile map cache was created, using the Tilestache software[5]. Vector tiles are similar to normal map image tiles; however, they store chunks of vector data instead of storing a map image. The geometries and attributes of the data were cached in tiled chunks and served to the client in manageable payloads.

---

[3] Javascript web mapping library (v2): http://openlayers.org/two/

[4] http://www.lcdb.scinfo.org.nz/
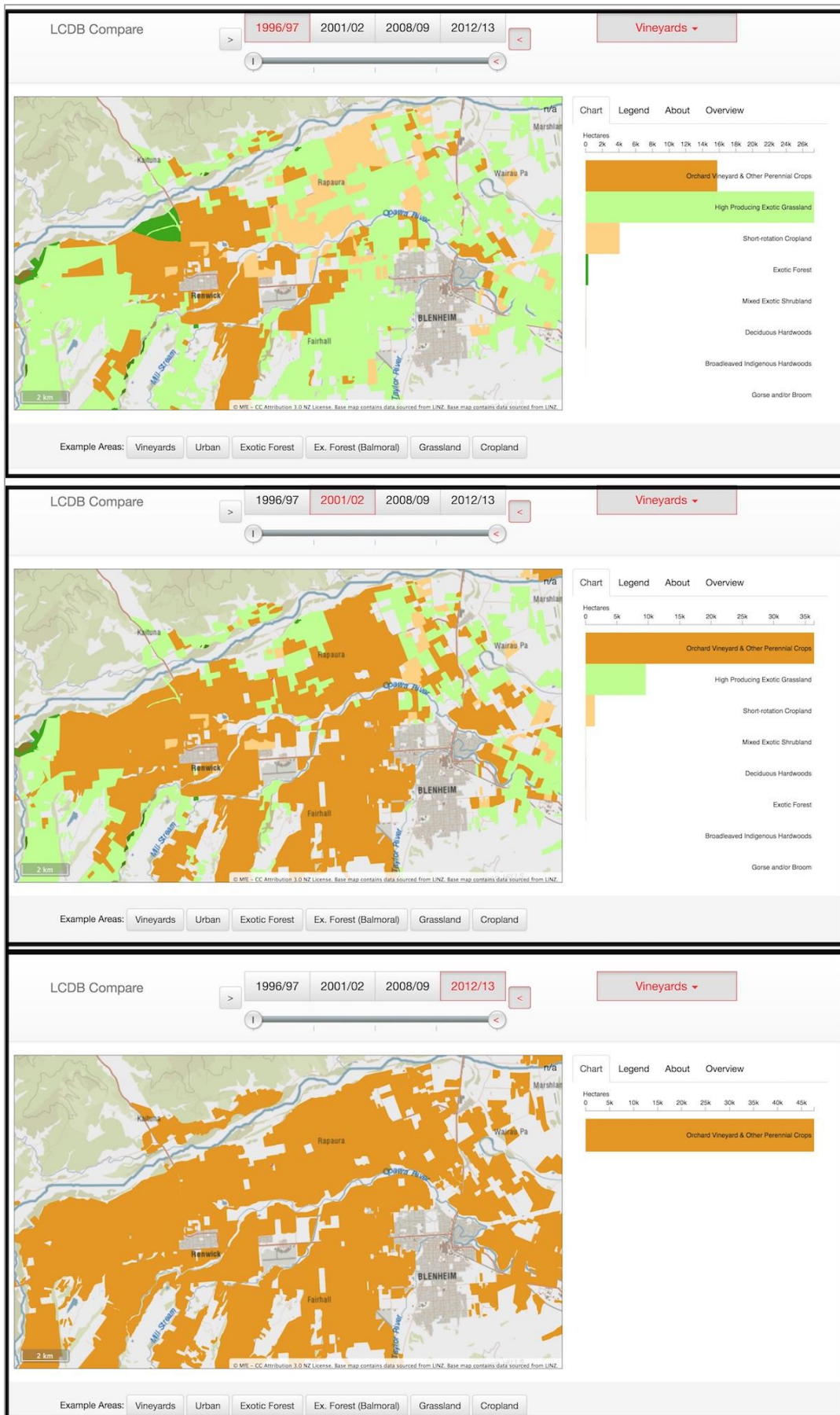
[5]:http://tilestache.org/.

Figure 3 Land cover change that has become Vineyards around Blenheim.

4.3 Cartography and visualizations

The LCDB data were styled as a simple choropleth map, using Manaaki Whenua's standard styles for each landcover class. While the LCDB data were delivered to the web application as vector tiles, the information required on how to style each polygon was stored and applied in the application. Doing this in the application rather than on the server meant updating the map and charts as the time period was changed was very fast.

4.4 The UX

The vector tiles were visualised within an OpenLayers "slippy" map, overlaid on a topographic base map, served via cached WMS. A time slider enabled the user to click through different time periods of the LCDB data, select a specific landcover type, and see how that changed over the four time periods.

As the user panned about the country, a bar chart, built using D3,[6] dynamically displayed and updated the types and amounts of land cover classes within the extent of the map window for any given location and time (Figure 3).

5. ANTARCTIC TERRESTRIAL DATA ANALYSIS (2018)

This recent application is targeted at policy makers and scientists from the member countries of the Antarctic Treaty who want to make informed decisions when carrying out Environmental Impact Assessments.

5.1. The data

Regional-scale, terrestrial, spatio-temporal data, both modelled and measured, relating to the geology, climate, biodiversity, and human activity in Antarctica were assembled. The time periods covered are dataset dependent but in total spans from 1956 to 2100; for certain data, the user can see how a phenomenon may change in the future.

5.2 Technology, cartography and visualizations

A server side API service, which uses NodeJS,[7] allows querying of all the terrestrial data. The data sent to the client are used to create a report covering four aspects: geology, climate, biodiversity, and human activity, over various time frames.

The technical approach used to visualise the data varies with the type of data. For example, a series of hexbin[8] maps (Figure 4) display the human activity data. They are created dynamically (per zoom scale and per year) in the application using OpenLayers as the user interacts with the map with a time slider.

---

[6] Javascript visualization library https://d3js.org/
[7] https://nodejs.org/en/
[8] http://pro.arcgis.com/en/pro-app/tool-reference/spatial-statistics/h-whyhexagons.htm
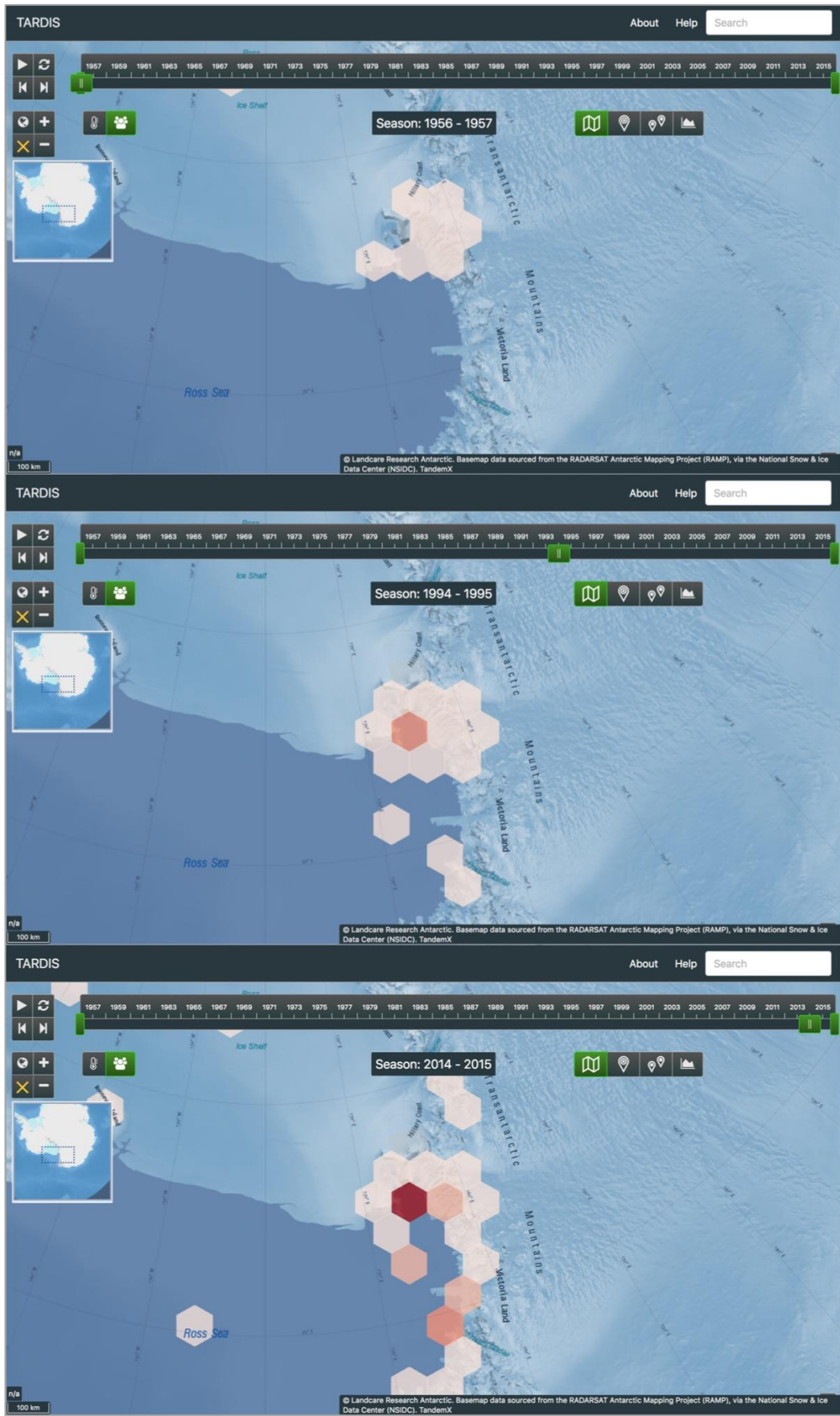
Figure 4 Hexbin map showing human activity over three time periods of the 60-year dataset. Time period is selected via the slider at the top.

For the land surface temperature data, an embedded, pre-generated video is used, effectively a single-tiled version of the idea used in the Possum viewer, with each video frame being a month. This was created by stitching together multiple images, initially requested from a Mapserver WMS, to form a video.

5.3 The UX

The map provides the focus of the application, supplemented by controls that enable querying at a single location, comparison between two locations (Figure 5), or along a transect line (Figure 6).

A time slider and set of associated controls allow the data to be "played". Stepping through each month/year allows the user to build a picture of the trends and change, both current and modelled, of the various datasets – both on the map and within the charts. Using the slider handles, the data can be filtered for a selected time frame that dynamically updates the relevant charts and graphs, built using D3.

Figure 5 Comparing land surface temperature between two points across a range of years.

Figure 6 Transect query, showing land surface temperature for a single month and year

6. Reflections

From our investigations, we concluded there is no one-size-fits-all solution to delivering spatio-temporal data to a web browser. The best solution will depend upon the resolution and size of the dataset and what and how information is required to be presented. For example, the high-resolution nature of the possum model data required a custom WMS-V tiled video solution. This allowed acceptable quality images to be rendered within the browser at all zoom scales without overloading the application. The WMS-V approach would be unsuitable if extended to responding in real-time to a user defined bounding box.

The use of vector tiles in the LCDB application identified issues arising from the nature of the data. For example, large, complex polygons were not well suited for delivery to the application at all zoom scales. New and more efficient encoding techniques, such as the Topojson[9], could allow better handling of these geometries. Generalised versions of the dataset could be created for each zoom level. However, to do this properly could involve a significant investment of time.

The Antarctic site learnt from the previous two projects, selecting different technologies that took account of the nature of the data and the visualization requirements.

All the approaches encountered problems in their ability to function properly across all web browsers. While this is not uncommon in web development, it's exaggerated when making use of cutting-edge libraries and techniques, and may be a challenge if the goal is production versions of the applications.

---

[9] https://github.com/topojson/topojson

Acknowledgements

References

Shepherd, J. D., Gillingham, S., Heuer, T., Barron, M. C., Byrom, A. E. and Pech, R. P. (2018). Multi-scale dynamic maps for the management of invading and established wildlife populations: brushtail possums in New Zealand. Wildlife Research (in press).