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SUPPLEMENT

Providing web based diagnostics for the Barrow Island baseline survey

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ABSTRACT – During the years of 2005 to 2007, an extensive baseline study of the Barrow Island invertebrate fauna was conducted. This survey included more than 50 sample sites across the island and multiple collecting techniques were used at each site. Over 14,000 specimens were collected during this survey. Taxonomic specialist who examined this material nominated over 2,000 morphospecies of which about 300 could be placed to species rank. Having done all of this collecting and identification, the question then was how best to access and use this valuable resource. All of the specimens were stored in two institutions in Perth – several thousand kilometres south of Barrow Island. Manual access to these specimens was slow which hindered the decision making processes needed when a suspected non-indigenous species was found on the island. The decision was made to digitise the diagnostic characters for representative of each morphospecies. These images were to be made available through a website called PaDIL (Pests and Diseases Image Library). Each species was to have its own webpage containing at least 4 diagnostic images of each species and all of the species collection points to be displayed on an interactive Google Map. Species, as well as higher ranks, could be queried alone or against sample localities or against Indigenous or Non-Indigenous status. Individual species pages could be opened and comparative images tables could be pre-defined and presented or users could build their own comparative image tables in real time. The development of the Barrow Island PaDIL website made the results of the entire Baseline Study accessible to anyone with a web browser from anywhere with an internet connection. The Barrow Island PaDIL website is a major part of the Quarantine efforts of Chevron on Barrow Island.

KEYWORDS: online resource, terrestrial invertebrates, PaDIL, diagnostic photographs

BACKGROUND

The Barrow Island Baseline study, from the years 2005 to 2007, was a wonderful project from both a Quarantine and Biodiversity point of view. Indeed, this study is one of first in the world that attempted to document an entire island's fauna. The results speak for themselves. Over 14,000 specimens collected, at 50 sampling sites resulting in over 2,000 identified species. Many of these species are new to science and these results further enhanced the conservation value and status of Barrow Island.

However, the Barrow Island Baseline Survey project presented Chevron with a dilemma. The value of specimens to Chevron was to allow the rapid identification of insects found on Barrow Island – in particular one suspected of being new non-indigenous species to the island. If a specimen was found on Barrow Island today, decisions need to be as to whether it has been previously recorded on Barrow Island during the Baseline survey or is it a new quarantine and invasive to the island. The Baseline Survey provided a wealth of information to answer these questions – but not in a format that was easy to access or easy to use.

The specimens from the Baseline Survey are stored several thousand kilometres south of Barrow Island in Entomology collection at Curtin University, the Entomology Department at the Western Australian Museum and Entomology collection at the Western Australian Department of Fisheries and Agriculture (DAFWA) in Perth. To access these collections is no easy task. Initially, it requires special permission to enter the "behind the scenes" of these three institutions. The person wishing to access the collection then requires bench space and a microscope and scientific literature. Many of the Barrow Island Baseline Survey specimens are stored in alcohol filled glass vials. These specimens need to be removed from these vials for examination and then returned to the vial and have the alcohol replaced – a time consuming process. There is also the time component of transporting specimen collected on Barrow Island down to Perth and then waiting for someone to allocate time to access the collection. The normal process of an identification is complicated by the fact that most specimens have only been identified the morphospecies (i.e. Genus sp. 1; Genus sp. 2 etc). This means there are no descriptions or keys available to assist with identification. Each morphospecies needs to be examined and compared with the queried specimen.

The solution to this problem was to go digital.

DEVELOPMENT OF THE IMAGE LIBRARY

Several years earlier, the Commonwealth Department of Fisheries and Forestry (DAFF) had invested heavily in online quarantine diagnostics. Australia has pest species lists of invertebrates (both terrestrial and marine) that we wish to keep out of Australia. The AQIS (but now known as DAFF) quarantine staff have these pests lists – but, because these species are exotic, there are few if any representatives of these species in any Australian Museum, let alone in the working collections of AQIS at the major ports. How can they identify a specimen on the pest list without a having ever seen a representative of the pest species.

At first, DAFF tried to purchase from overseas Museums and Herbaria 25 specimens for each of the top priority exotic pest species to lodge specimens in individual collections around Australia. However, none of the overseas collections were willing to sell their specimens. So DAFF decided to experiment with new emerging digital technology and the internet. They approached me and a colleague of mine, Mike Grimm, at DAFWA, with a scoping project to see if digital photography of exotic pest species could prove to be an aid to identification at the Australian border. The project was called PaDIL – Pests and Diseases Image Library. They chose a Museum taxonomists and a front line quarantine worker to develop this project. I, as a Museum based taxonomist, have many contacts with other Museums around the world from where I could borrow specimens of pest species for image capture. Being a trained morphological taxonomist, I can read and understand scientific literature, in particular species descriptions and binominal keys, to discover the diagnostic characters pertinent to identify and determine each species. By photographing these diagnostic characters, I would be interpreting and converting the scientific literature and keys into digital imagery. Mike, as the front line quarantine worker, had a lot of technical and pest species knowledge to bring to the project.

The timing of the pilot project was excellent. Leica has recently brought out the most powerful binocular microscope on the market (the MZ16) and had added a motor drive to the microscope's column. They had also released a new colour digital camera (DC500). Together, this microscope/camera hardware interfaced with new Leica software that controlled the motor drive on the microscope and operated the shutter on the camera. The system worked liked this: The user would place a specimen under the microscope. Using the LAS-Leica software installed, the user could see on a PC monitor screen the specimen under the microscope and move the microscope up or down to focus on the specimen. The user moved the focus of the microscope to the top of the specimen and, by software, marked that point. They then moved the microscope to the bottom focus of the specimen and, by software, marked that point as well. They then instructed the software to take a prescribed number of images between the two marked points and clicked "Go". The software then moved the microscope, with attached camera, to the top marked point of the focus and took a picture. It then divided the distance between the two marked focal points and moved the microscope and camera in incremental, equally measured steps throughout the distance between the two marked places. The individual images were captured as high resolution TIFF images and stored in a newly created folder. Together, the images in this folder are called an "Image Stack" which typically contained between 40 to 60 images, all as high resolution 15MB TIFF images – almost 1GB of data.

The other, almost simultaneous, occurrence at the time of the Leica microscope development was the release of a new montaging program called Automontage. It was an expensive piece of software at $7,000 for a single user licence but it was magic. Within a few minutes, Automontage would load all images in the image stack and begin to process them. This process entailed creating a new, single image from the 60 or so original images. It did this by taking only the pixels in focus and adding them to the new image and discarding the remaining out of focus pixels. The resultant single image, complied from 1GB of 60 or so images, created a single 3D image with all parts of the image in focus. The problem with photography under a microscope has always been the shallow depth of field of the image when taken through a microscope lens.. Automontage turned this disadvantage into an advantage and the better the microscopes resolution to capture thinner and more detailed image slices the better – the smaller the in-focus focal plane for each image, the more precise and in-focus the final montaged image.

The final montaged image is not quite ready yet for public display. The montaged images must be post-process in Photoshop using a technique we developed which includes adjusting Levels, Curves, Brightness, Contrast and Filters with two different settings in Unsharpen mask. The resultant Photoshop post-processing turns a good image into an excellent image. The post-processing technique creates a "Polaroid" image similar to one we used to take using an old Polaroid Instamatic – the image literally jumps out at you. Once the TIFF image has been post-processed, it is converted to a lower resolution JPEG file which is then ready to be used on a website. The entire process, from putting a specimen under the microscope to having a web ready JPEG image, can be done in about 15 minutes. Since the initial PaDIL Pilot study, many more montaging software packages have now entered the market and at dramatically lower prices. The current montaging software program we use is Helicon Focus whose license costs about $100 – a lot different to $7,000.

The PaDIL Pilot project was a success which led to DAFF significantly funding the development of PaDIL website between 2004 and 2011 which incorporated web pages and diagnostic image for over 2,000 species, including all of the species on the High priority Exotic pest lists. The PaDIL website now has the enviable statistics of over 1.5 million visitors per year from over 180 countries around the world and the users open over 16 million images each year. Basically, almost every country has mostly the same pest insect problems as Australia so our PaDIL images are in great demand internationally for this precision and diagnostic value. The only alternative is to seek images on Google which has no quality controls of its data.

CHEVRON AND PADIL

The CRC Plant Biosecurity proposed to Chevron to use the PaDIL exotic pest model and experienced staff to provide a reliable and diagnostic access pathway to the Barrow Island Baseline Survey resources. Chevron accepted this recommendation and then funded the Barrow Island PaDIL project. To Chevron's credit, two early decisions were made about the Barrow Island PaDIL project. One – Chevron could have restricted the digital capture to only species collected in the survey that were non-indigenous to the island. Two – Chevron could have decided to restrict access to this dataset. However, Chevron decided to image capture all species collected during the survey and to make all of these resources (images and species checklist) publicly available – these decisions were massive to the Biodiversity knowledge of the island's invertebrate fauna.

The Barrow Island PaDIL library proved to be quite a challenge. With Chevron funding we purchased an additional microscope/camera setup and hired a full time image capture project officer. After 2 years, we had almost 90% of the target Baseline Survey species on the Barrow Island PaDIL website accompanied with almost 10,000 montaged habitus and diagnostic images. The diagnostic image set always contained the standard dorsal and lateral habitus images and then we often added head front and side images, for flies and wasps we added wings, for beetles we added close up images of the elytra, for ants we added antennal and petiole images etc. For each major taxon group, we decided on what addition diagnostic images to add apart from the standard habitus images.

Standardisation of image character, image type and image orientation is very import to the value and use of the final output. If a use is looking at individual species pages only, then the orientation or standardisation of the images is not that important. However, to me, the value of images is in the comparative mode. Imagine an image table for 6 species of the same genus (eg. The ant genus Camponotus) versus 8 image characters – Dorsal and Lateral views, Head front and Head side, Thorax and Propodeum, Petiole and Metasoma (apparent abdomen). This creates a matrix of 48 images. All of the Species image run Horizontally and all of the character images run Vertically. So, Dorsal images for all 6 species are on top of each other and the user can scroll down the Dorsal column and compare differences any 2 or more species – similarly for all other 7 characters. This provides the users an image rich, detailed and interactive experience with all members of the genus found on the island. As an aid to identification, it is invaluable. From within this table, the user can open the species page for any species and view the species' interactive Google distribution map as well as examining individual sample sites (eg. GP1). This is the power of placing all images, the species checklist and all of the specimen collection data into a single database and allowing the user to manipulate that dataset to answer their own questions. Compare the usefulness of this web format to the restricted value of presenting this data as hard-copy printed fact sheets – one per species. Users cannot concatenate the fact sheet data into user defined formats to answer user generated questions.

There is one other powerful feature available within the Barrow Island Survey PaDIL website. We were provided access to the GPS coordinates for all 50 sample sites on the island. We use this data to construct species distribution maps found within each species page. However, having these GPS coordinates opens the door to spatial querying and, in particular, User defined Spatial searching. We present a live, interactive and scalable Google Map. The user can scan, pan and scroll this map to enlarge to move to any part of Barrow Island. With some additional software added to the Google Map, the user can "drop" a shaded, spatial bounding box onto the Google Map – as an overlay. The user can now move and resize this overlaid spatial bounding box to cover any area they wish on the island. When queried, it returns any species which has GPS coordinates within the spatial area created by the user. The query can be further modified to include a taxon into the query. For example, show me all of the Coleoptera within the family Curculionidae (weevils) and subfamily Scoltyinae within the user defined spatial bounding box of around the island's central station. The results of this Spatial query can then be expressed as a Comparative Image table. This type of query ability puts the Barrow Island invertebrate fauna at the fingertips of the user.

In summary, the Barrow Island Baseline Survey PaDIL website presented each species as:

- Each species on its own webpage, usually with at least 5 images;
- Images always included: Dorsal and Lateral images;
- Images usually included: Head front, Head side, thorax and abdomen;
- Diagnostic images of characters pertinent to each species were taken.

The PaDIL software allows the user to:

- Query on Taxonomic Groups by Common or Scientific names (eg. Fly or Diptera);
- Query on Scientific species names or Baseline Survey nomenclature code name;
- View an individual page per species and to enlarge each image;
- Each specimen location point has full collecting details of trap code and date collected;
- User defined spatial queries – i.e. a user a drop a scalable query box onto a scalable Google Map of Barrow Island and decide which part of the island and how much of the island to query. The returned results combine all of the species collected within the user defined area;
- Users can build Comparative Image Tables. The user makes a query that returns 2 or more species. All images inside these two separate species pages can be combined into a Species Versus Image Character table. This allows the user to easily compare differences between species in one view rather than having to open each species page individually and to remember what each image looked like. Imagine using this technique to compare 20 or more species – impossible;
- Queries can also be made against each collecting location (e.g. GP1) and the all species collected at that station during the Baseline Survey will be returned;
- Queries can also be made for species considered to be endemic to Barrow Island and Non-indigenous to the island.

The combination of habitus and diagnostic images, extensive query ability and multiple ways to display the results provides the users with the results of the Barrow Island Baseline Survey at their fingertips. They can begin with a spatial mapping query combined with a taxon query and display the results as a Comparative Image table. They can produce checklists for every species collected at every sampled location. They can query for individual species.

Here is an excellent example of the full usage of this system. Someone collects an ant near the airport in the SE corner of the Barrow Island and wants to know if it is new species to the island or if it was present during the Baseline Survey. The user could begin by bringing up a Google Map of Barrow Island and enlarging the scale of the map to just incorporate the airport in the SE corner of the island. They could then drop a user defined spatial bounding box onto the scaled Google map and adjust the spatial bounding box corners to include or exclude any areas surrounding the airport. This query returns a species checklist for all species collected during the Baseline survey within the selected area. The user then queries for either "Ants" or "Formicidae" which reduces the Mapping query generated species checklist to just the ant species from within the selected spatial area. The user then generates a Comparative Image table for the ant species remaining in the Mapping query generated species checklist and is able to then scroll down the screen to compare Dorsal, Lateral, Head front and Head sides for all species returned to the query.

Take into account that this query can be instantaneously made by anyone on Barrow Island with an internet connection and using either a PC in the laboratory or an iPad with a WIFI connection in the field. The query uses specimens lodged in either the Western Australian Museum or DAFWA and is combined with a specimen dataset stored on computers at the Chevron Perth head office. So, the distance barrier between Barrow Island and their associated specimens and location data had been resolved. The magic of e-technology in full swing.

A total of 2,292 morphospecies were collected during the Baseline study. There are 1,634 of the morphospecies on PaDIL. The shortfall is due to a number of reasons including unprocessed mites, Collembola and beetles as well as researchers retaining singleton examples of new species they wish to describe and publish.

REFERENCE

The PaDIL Barrow Island Baseline Survey website address is: http://www.padil.gov.au/barrow-island/

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