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A database for traditional knowledge of weather and climate in the Pacific

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ABSTRACT: Growing interest in traditional knowledge (TK), particularly in relation to the prediction of weather or climate extremes, raises issues concerning the appropriate storage and management of the information collected. The Traditional Knowledge Database (TK Database) for the storage and use of TK associated with weather and climate prediction in the Pacific was designed with the following principles in mind: (1) preservation of the knowledge, maintaining cultural context wherever possible; (2) respect for intellectual property and cultural sensitivities around data sharing and use; (3) appropriate system design, accounting for ongoing costs of system maintenance and often intermittent Internet access; and (4) moving beyond data preservation to ensure continued use and growth of the TK. The TK Database was successfully deployed to four countries in the south Pacific and is regularly used by their national meteorological services, and partner organizations, both to preserve TK related to weather and climate and as a tool to assist in monitoring the TK indicators. As the first database of its kind, the TK Database fills a critical gap in the appropriate storage and application of TK and provides an important foundation for future developments.

KEY WORDS Oceania; indigenous knowledge; Vanuatu; Samoa; Niue; Solomon Islands; digital rights management; environmental monitoring; database management

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1. Introduction

By closely observing the environment in which they live, communities have developed skills that enable them to survive extreme weather and climate events. In regions where warnings from national meteorological services (NMSs) are difficult to obtain, not understood and/or are not fully accepted by the community, there is a greater reliance on traditional knowledge (TK). This is based on observations that include the behaviour of plants and animals, astronomical indicators (e.g. the Sun and Moon) and meteorological variables (e.g. the direction and strength of winds: King *et al*., 2008; Lefale, 2010; Orlove *et al*., 2010). Although use of these methods has been largely successful in the past, concerns have been raised about the continued value of traditional forecast methods in the face of rapid knowledge loss, climate and environmental change (e.g. Brahy, 2006; Ziervogel and Opere, 2010; Gyampoh and Asante, 2011; Berkes, 2012; Kaniaha *et al*., 2012). Increasing recognition that traditional methods continue to play a key role both in building community resilience to extreme climate events and in the preservation of cultural traditions has led to the need for appropriate ways to facilitate sharing and storage of TK (Brahy, 2006; Pennesi, 2012; Seuseu *et al*., 2013).

Electronic storage of TK driven by requests from indigenous communities can bring with it a number of challenges. For example, databases are generally designed for a specific purpose and can therefore impose assumptions on the nature of the knowledge, including what it is and how it should be preserved (Christie, 2004). In addition, the knowledge itself may not be static and can be embedded in practice and belief, leading to an increased potential for the knowledge to be distorted (Van Der Velden, 2010; Pulsifer *et al*., 2012; McCarter *et al*., 2014).

Whenever TK databases are created and maintained by people other than the knowledge holders, careful consideration needs to be paid to the protection of the rights of the knowledge holders, including both intellectual property and cultural sensitivities (Schnarch, 2004; Brahy, 2006; Zaman and Wee, 2014). This can be challenging as legal protection of intellectual property typically applies to individuals rather than the groups or communities that may own the knowledge (McCarter *et al*., 2014).

There have been many discussions in the literature as to the most appropriate term to cover knowledge held by those living on the land (e.g. Nadasdy, 1999; McCarter *et al*., 2014). The present authors and our Pacific Island (indigenous) partners prefer the term ‘traditional knowledge’, as defined by Brahy (2006), as it covers both indigenous and non-indigenous peoples, but it is recognized that this knowledge is not static and can evolve over time.

Here the region Oceania, which covers Australia, Micronesia, Melanesia and Polynesia and contains a diverse range of cultures, was the focus. Concern over the rapid loss of TK related to weather and climate in the region (e.g. King *et al*., 2008; Kaniaha *et al*., 2012) led to a request from a number of Pacific NMSs and their partners in their respective cultural centres for support to preserve, understand and use this knowledge better,

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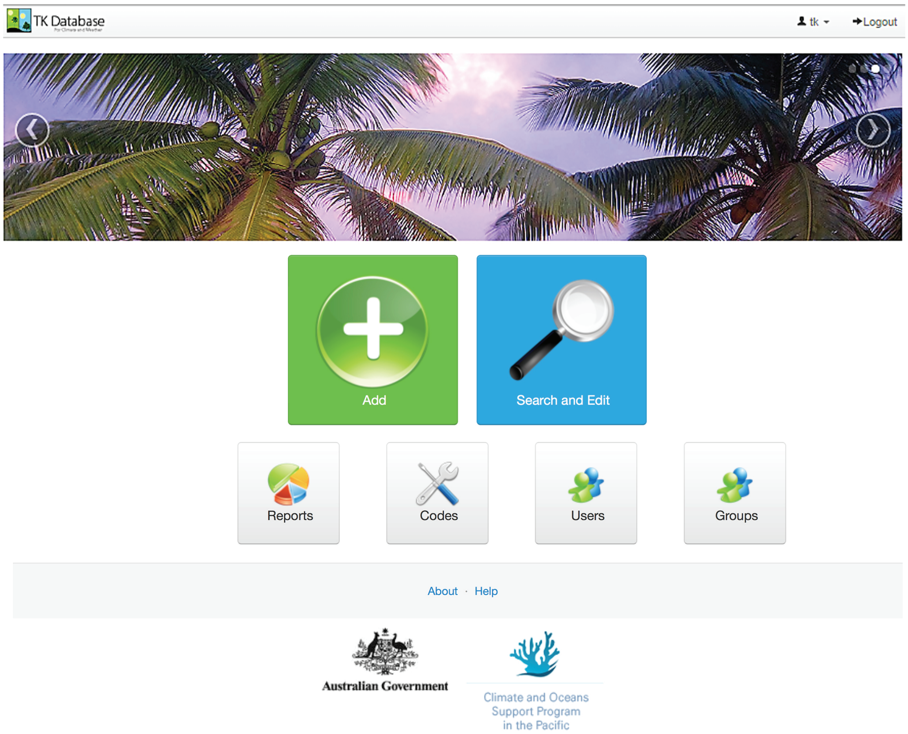


Figure 1. TK Database main menu illustrating one of the customized banners.

particularly components related to forecasting hazardous events such as cyclones, drought or flooding, with the potential to increase community resilience to these events. As part of this, it became apparent that a database could help, the design and implementation of which is the focus of this paper. The paper is structured as follows. First, details are provided on why the database was needed, including its role in a broader project on traditional weather and climate knowledge in the Pacific and the involvement of project partners and the community in the database development and trials. Then the database requirements and considerations that came out of the consultation process with project partners and the community are examined and are discussed more fully in terms of the database structure that was developed. Additional benefits that the TK Database provides are also considered, beyond what it was originally designed for. Finally, as few TK databases are available for guidance and a community of practice is yet to emerge, recommendations are provided for others involved in the development of TK databases. Throughout, the term TK Database refers to both data storage and the application designed to interact with it.

2. Why create a database?

The Pacific NMSs and other regional organizations, including cultural centres and community groups, have long been interested in preserving TK narratives but did not have anywhere secure to store the often culturally sensitive data for preservation purposes and/or for making it available for later analysis and community use (e.g. Kaniaha *et al.*, 2012). The TK Database was designed as one way to contribute to filling that gap.

The development of the TK Database is part of a wider project concerned with working with communities in the Pacific to increase their resilience to extreme weather and climate events (Kaniaha *et al.*, 2012; Seuseu *et al.*, 2013; Chand *et al.*, 2014). This involved many aspects: documenting methods of TK forecasting specifically related to weather and climate; determining the geographical extent that these methods apply and if/how they have been impacted by climate or land-based environmental change; the development of ways to incorporate TK forecasts into routine climate forecasts produced by the NMSs; and developing improved climate communication products for local communities.

The primary roles of the database are the preservation of TK narratives related to weather and climate forecasting and ensuring that as much information as possible is captured to enable others, including community members, to produce weather or climate forecasts, collected using a TK Survey form, developed in partnership with the Pacific NMSs and their in-country partners including cultural centres and community members (Kaniaha *et al.*, 2012; Seuseu *et al.*, 2013) and using the principles of free, prior and informed consent (Zaman and Wee, 2014). However, access to particular narratives/information also needed to be restricted according to the storage and dissemination wishes of the original knowledge holder, particularly in cases where access to the knowledge may be associated with tribal position and therefore power. In addition to the stories, the database holds information collected through routine monitoring of the traditional indicators of weather or climate events, collected using a TK Monitoring form by community members trained by their NMS and/or cultural centre representative; see Section 4.2 for further details. A more structured database than that of many other TK databases concerned with archiving and storage alone is therefore required, while maintaining enough flexibility to capture additional information as required by the partner countries, e.g. TK narratives not collected as part of the TK Survey form or biological records of TK weather/climate indicator species.

The TK Database was developed under a partnership between the Pacific Meteorological Services, local stakeholders and the Climate and Oceans Support Program in the Pacific

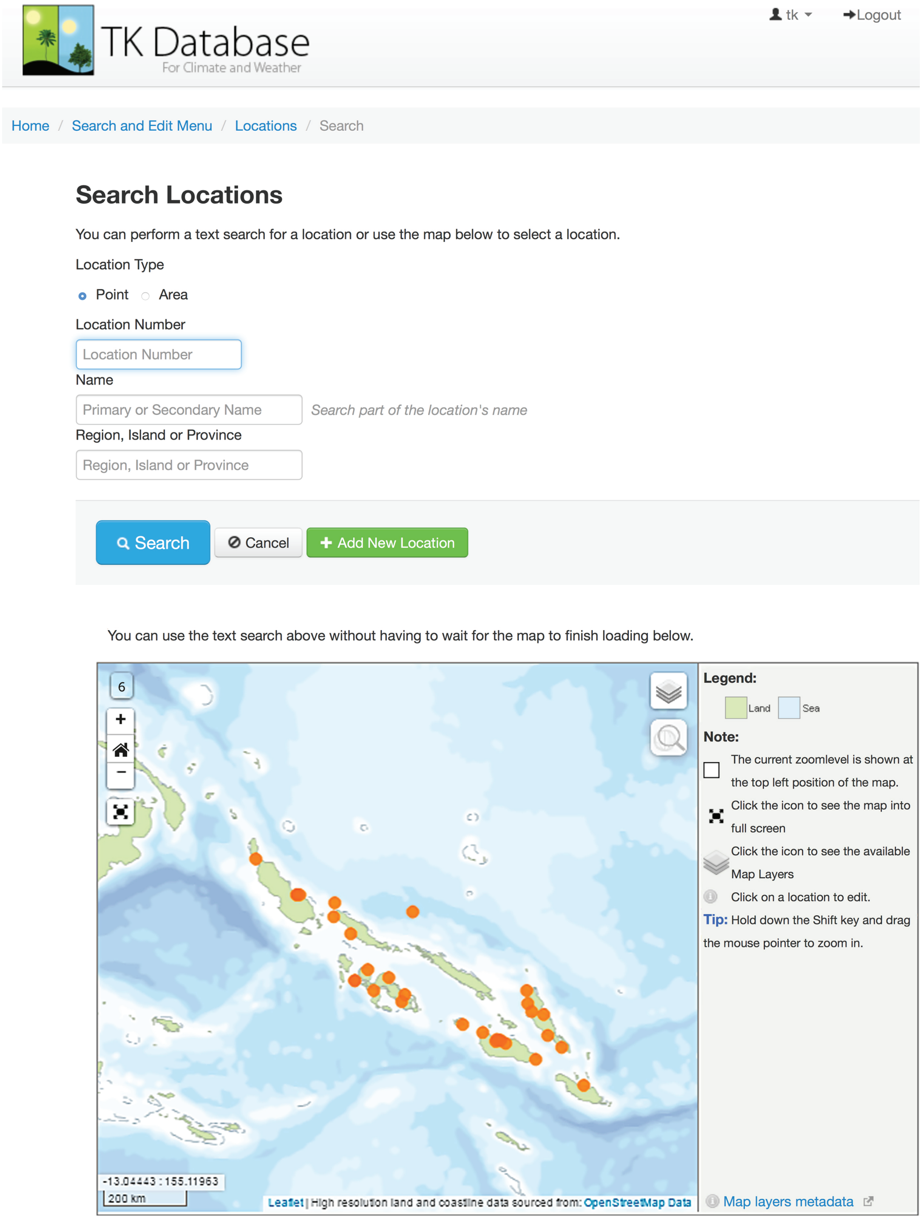


Figure 2. Location search and mapping function, using the Solomon Islands as an example. Note that the map functionality is customized for the Solomon Islands.

(COSPPac), administered through the Australian Bureau of Meteorology and funded by the Department of Foreign Affairs and Trade. The database was initially developed and trialled according to requirements identified in Vanuatu (by the Vanuatu Meteorological and Geo-Hazards Department) as part of a joint project between the Vanuatu Meteorological and Geo-Hazards Department, the Secretariat of the Pacific Community, Deutsche Gesellschaft für Internationale Zusammenarbeit, the Vanuatu Cultural Centre and the Vanuatu Red Cross, with feedback leading to improvements in subsequent releases. Additional requirements were identified through trials of the database in Samoa, the Solomon Islands and Niue (through partnership with the respective NMSs and cultural centres). All trials included in-country training in the use of the TK Database by COSPPac TK Officers to members of the Pacific NMSs and key stakeholders, as selected by the NMS, who likewise provided training to the COSPPac TK Officers on related TK matters. All community consultations surrounding the collection and storage of TK were undertaken by the NMSs and their in-country partners using local language (e.g. Seuseu *et al*., 2013). The processes, including governance, surrounding this are described more fully in Malsale *et al.* (in preparation).

3. Database requirements and considerations

At the time of development, few examples of similar databases existed in the literature (Pennesi, 2012) and, unlike other climate databases (e.g. Martin *et al*., 2015), there is an absence of relevant international guidelines and standards (Pulsifer *et al*., 2012). Therefore, in addition to several critical components, such as respecting intellectual property and cultural sensitivities (covered in Section 4), the TK Database was designed with the following principles in mind: free and open source software; portability; sustainability; ease of use; and ability to be operated smoothly in

Table 1. Examples of the types of information contained within the TK Database.

Information on	Examples	Relates to
Biological objects	Plant and animal types and behaviour	Survey forms (TK narratives), monitoring forms ('validation', environmental monitoring), biological resource, seasonal calendars
Physical objects	Clouds, winds, astronomical	Survey forms, monitoring forms
Expected outcomes	Drought, rainfall, cyclone	Survey forms, monitoring forms
Interview details	Who, when, where, by whom	Survey forms, rights management
Time series data	Historical observations on biological or physical objects (e.g. flowering records) or expected outcomes (e.g. climate data)	Biological resource
Media files	Photos, audio, video, pdfs	Survey forms, biological resource
Access restrictions	Level of data sensitivity	Survey forms, rights management

environments with limited technical expertise. This was due to limitations identified during the development and maintenance of Climate Data for the Environment (CliDE), a climate data management system for the western Pacific Islands that provides countries with a central database for their meteorological records (http://www.bom.gov.au/climate/pacific/about-clide.shtml; Martin *et al*., 2015). That is:

- the system must be able to cater for several nations leading to the development of foundation capabilities that can be used by all;
- the skill set of the database operators and resources available to them vary and may be limited. Therefore, the complexity of the software needed to be minimized for basic functions while maintaining enough flexibility for more complex use by experienced users;
- costs associated with maintaining the system, such as software licensing, needed to be minimal or zero, due to limited operational budgets in partner countries;
- to prevent the potential overload of the system and/or office administrators, a simple browser-based user interface was developed;
- a continuous power supply can be an issue in many of the partner countries and needed to be factored into the design to ensure data integrity;
- it could not be assumed that a reliable Internet connection would always be available and the system needed to be able to operate without Internet access, and
- the system needed to be sustainable beyond the life of the COSPPac project and therefore was built to be independent of specific choices of operating system and hardware.

As a result of the above limitations, the main emphasis was on simplicity over complex functionality for the base product. The system's main aims were recording weather and climate related TK information and providing basic outputs. More complex outputs were left to be delivered as a part of later phases of the project or developed by the Pacific Island countries themselves.

Partner NMSs are responsible for the TK projects within their countries, deciding on which aspects of the overall COSPPac project they would like to incorporate and how. This meant that there needed to be some flexibility in the type of information stored, be it from survey forms or free format. The same design framework was used for the TK Database in all countries, with separate, customized databases and custom features including country-specific banner images and maps being deployed to each country. This also ensured that the TK collected was kept in-country rather than being stored at a regional level.

TK information can be sacred and can have varying degrees of cultural sensitivity (typically referred to as tabu or tapu in the Pacific) and so it was important that the TK Database incorporated this into its design (see Section 4.2 for further details), including the ability to store multiple media formats, such as video, so that the narratives were better able to retain their cultural context. In addition, intellectual property around the knowledge provided also needed to be considered.

Many of the points raised above are listed as 'requirements of indigenous knowledge management software' (Van Der Velden, 2010) and are discussed more fully in the following sections.

4. Database structure

4.1. Software and hardware

The TK Database was designed as a web application for the following reasons (see also Martin *et al*. (2015) who developed a climate database for the same region and were familiar with the software and hardware requirements needed):

- anywhere from 1 to over 100 users can access the system without needing to change the application, install extra software or pay additional licence fees. All use web browser software that is commonly available and standards compliant, as well as a local network link to the TK Database server;
- mainstream web development languages and tools are used that conform to international standards. Therefore, the skills required to expand, enhance or alter any logic are easily available and relatively cheap;
- single Internet connected server locations for the application software (the TK Database server) mean that deployment and upgrades are easier;
- a high level of TK data security is ensured through total control over access to it by database administrators and owners;
- separating the application into client (web front end) and server (back end) is a more maintainable structure than stand-alone desktop software. Additional interfaces can be built for the same back-end database, which should make implementing more advanced inputs and outputs easier, cheaper and safer;
- the central database system can be accessed from a variety of web browsers, independent of the client's operating system. All that is required to access the TK Database is compatible web browser software, and
- if required, it is possible to run a 'stand-alone' application on a single desktop computer or laptop, by installing the TK Database and its associated software on a single computer with no network connection.

Climate and Oceans Support Program in the Pacific

Traditional Knowledge Survey

DATABASE RECORD #:	
FORM VERSION #:	4.0

PLEASE NOTE: The Project Information and Protocol form must be provided and a statement of prior informed consent completed and signed by the participant before commencing interview!

INTERVIEW / MEETING INFORMATION (please write down or circle where possible):						
Date(d/m/y):			Time:		am	pm
Place of Interview:	Village:		Province:		Island	
Interview Language:						
ExtraRecords:	Audio	Video	Photo	None	Other (write here):	

INTERVIEWER / OBSERVER INFORMATION:			
Name of Interviewer:		Contact Details:	

PARTICIPANT INFORMATION:						
Participant's Name:					Male	Female
Position in Community:			What tribe do they belong to:			
Age Group:	< 20	21-30	31-40	41-50	51-70	> 70
First Language:						
Where is their Home:	Village:		Province:		Island:	
Contact Details:						

TRADITIONAL KNOWLEDGE (TK) LOCATION INFORMATION AND ACCESS:						
Where is this TK story found?	Around Participant's Home	If not, please specify where?	Village(s):	Province(s):	Island(s):	
Who is allowed access to your TK story?	LOW TABU: Public–everyone	MEDIUM TABU: Managers, Public with permission	HIGH TABU: Project Managers Only	Are there any other access Restrictions? Circle: Yes / No	Gender: …………. Other: …………………………	Religion: …..……..

Figure 3. The cover sheet for the Traditional Knowledge Survey form. Information is collected on the person providing the knowledge (participant) to ensure that 1) the knowledge is attributed to this person/tribe and, 2) the project managers are able to contact the participant should permission be required to share the story (generally applied to TK stories assigned a medium level of sensitivity/tabu). Note this cover sheet is designed to incorporate project partner logos in the header – illustrated here with the COSPPac logo only. [Colour figure can be viewed at wileyonlinelibrary .com].

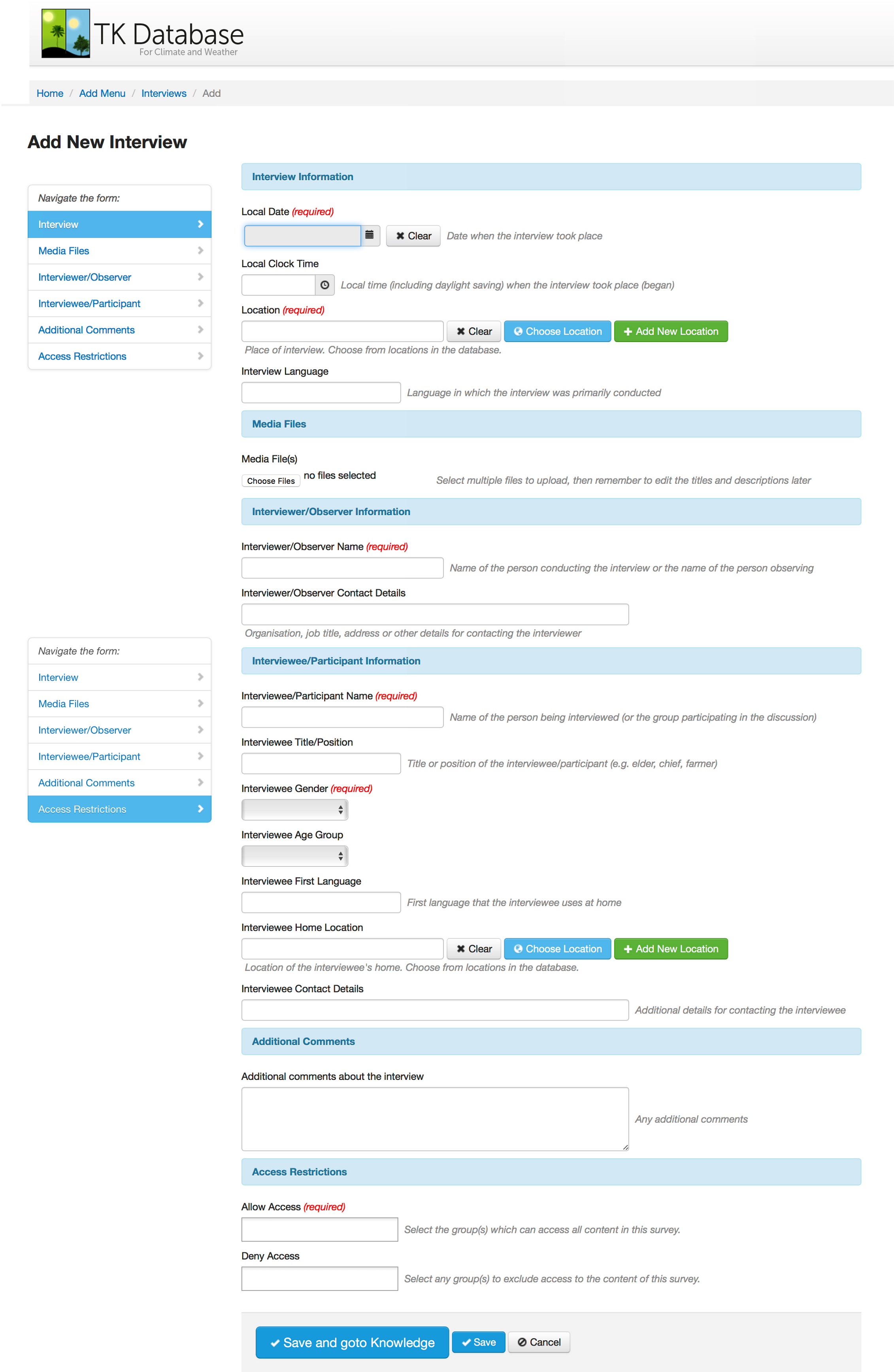
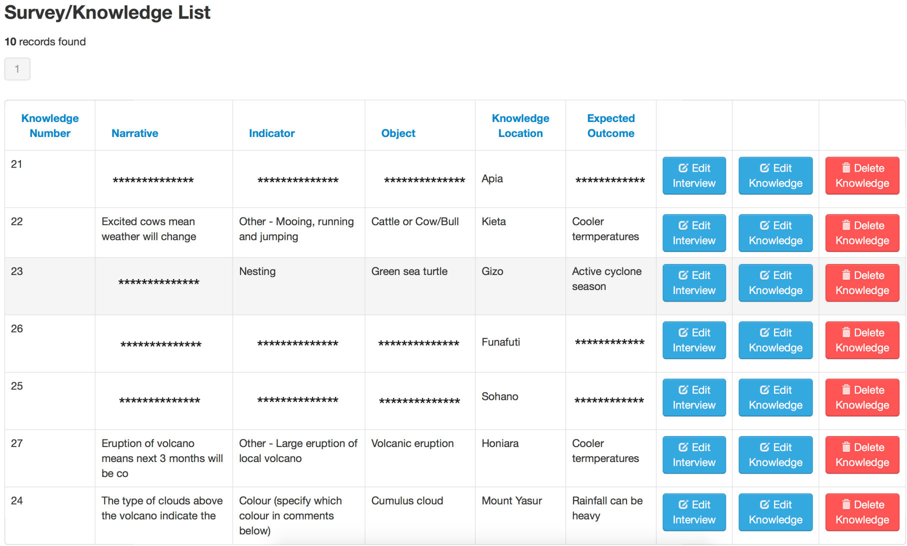


Figure 4. Extract of the interview section of the TK Database, designed to match the TK Survey form (see Figure 3). [Colour figure can be viewed at wileyonlinelibrary.com].



Survey/Knowledge List

10 records found

1

Knowledge Number	Narrative	Indicator	Object	Knowledge Location	Expected Outcome			
21	**************	**************	**************	Apia	************	Edit Interview	Edit Knowledge	Delete Knowledge
22	Excited cows mean weather will change	Other - Mooing, running and jumping	Cattle or Cow/Bull	Kieta	Cooler termperatures	Edit Interview	Edit Knowledge	Delete Knowledge
23	**************	Nesting	Green sea turtle	Gizo	Active cyclone season	Edit Interview	Edit Knowledge	Delete Knowledge
26	**************	**************	**************	Funafuti	************	Edit Interview	Edit Knowledge	Delete Knowledge
25	**************	**************	**************	Sohano	************	Edit Interview	Edit Knowledge	Delete Knowledge
27	Eruption of volcano means next 3 months will be co	Other - Large eruption of local volcano	Volcanic eruption	Honiara	Cooler termperatures	Edit Interview	Edit Knowledge	Delete Knowledge
24	The type of clouds above the volcano indicate the	Colour (specify which colour in comments below)	Cumulus cloud	Mount Yasur	Rainfall can be heavy	Edit Interview	Edit Knowledge	Delete Knowledge

Figure 5. Illustration of the digital rights management implemented in the TK Database based on fictitious data. Note that this user (a female elder) is not able to view or edit records 21, 23 and 25–26 due to sensitivity settings (as indicated by the entries with asterisks). [Colour figure can be viewed at wileyonlinelibrary.com].

The TK Database was designed to be independent of any particular operating system, provided it can run the chosen database management system, programming language and web server software. The application was written in the HTML, JavaScript and Python programming languages.

A relational database management system was most suited to the TK Database because of the need to report and combine it with data from other sources, such as the CliDE climate database (Martin *et al.*, 2015) and numerical weather and seasonal forecasts. Using this approach, the data are stored in 'tables' and the system allows for multi-user sharing of data (subject to individual users meeting the access criteria – see Section 4.2), search and retrieval, observations to be linked to particular locations, and the data to be accessed in a consistent way *via* a standard interface. This was achieved through use of the open source database management system PostgreSQL (PostgreSQL, 2015), with PostGIS supporting the storage of locations for an interactive mapping interface.

Although the TK Database could run on any platform, it was more cost effective to develop it in Linux, with the option of using a virtual environment for non-Linux machines. Linux was also desirable as Microsoft Windows-based machines run a greater risk of virus/Trojan infection (Martin *et al.*, 2015). It was installed on the high-end workstation hardware that was deployed to the partner countries, together with an uninterruptible power supply to reduce the impact of power anomalies and interruptions. Ubuntu and CentOS (CentOS, 2015; free and open source implementation of RedHat Enterprise Linux) were the chosen Linux distributions. The software was generally installed prior to shipment to avoid large and expensive Internet downloads while in-country as well as to minimize the risk of problems occurring during installation. The TK Database was customized for each country through, for example, banner images representing cultural events and detailed country maps and locations (Figures 1 and 2). Following the installation, in-country training was provided to the NMS staff and other local partners, building on personal relationships and trust and allowing them to further refine the database development to ensure it was fit for purpose. As the TK Database was developed outside of the country in which it was to be used and the database developers had no access to culturally sensitive narratives but had a predetermined information structure through consultation with the NMSs, the initially installed TK Database contained no narratives. The software running on the application system is kept up to date *via* a continuous deployment service based on an Ansible (Ansible is a free software platform for configuring and managing computers; https://en.wikipedia.org/wiki/Ansible_(software)) that allows the developers to install or update the software without needing to access the database and its culturally sensitive data directly. Thus, the system is low maintenance and cost effective to maintain while respecting cultural sensitivities.

Additional security measures for the TK Database included the database being housed behind the firewall of the climate services in each country with restricted access to registered users. The database design added another level of security to culturally sensitive information through limiting access according to restrictions imposed by the TK expert who initially provided the narrative (see Section 4.2 for further details).

4.2. TK Database content

The TK Database was designed to store a variety of types of information (Table 1). On gaining access to the TK Database system, the user is presented with a number of options (Figure 1). They can add new data, search or edit existing data, run reports, view, edit or add new codes or, subject to their permission status, manage user accounts.

4.2.1. Details

The TK Database was originally designed around the TK Survey form, which collects traditional information on the 'interview' details (who provided the narrative, when and where and any media formats used to record the narrative), the associated TK weather and climate narrative, the sensitivity of the data (access restrictions), location information (where the interview took place and where the story applies to), information on the object used to forecast weather and climate and expected weather/climate outcome (Figure 3). The TK Database preserves

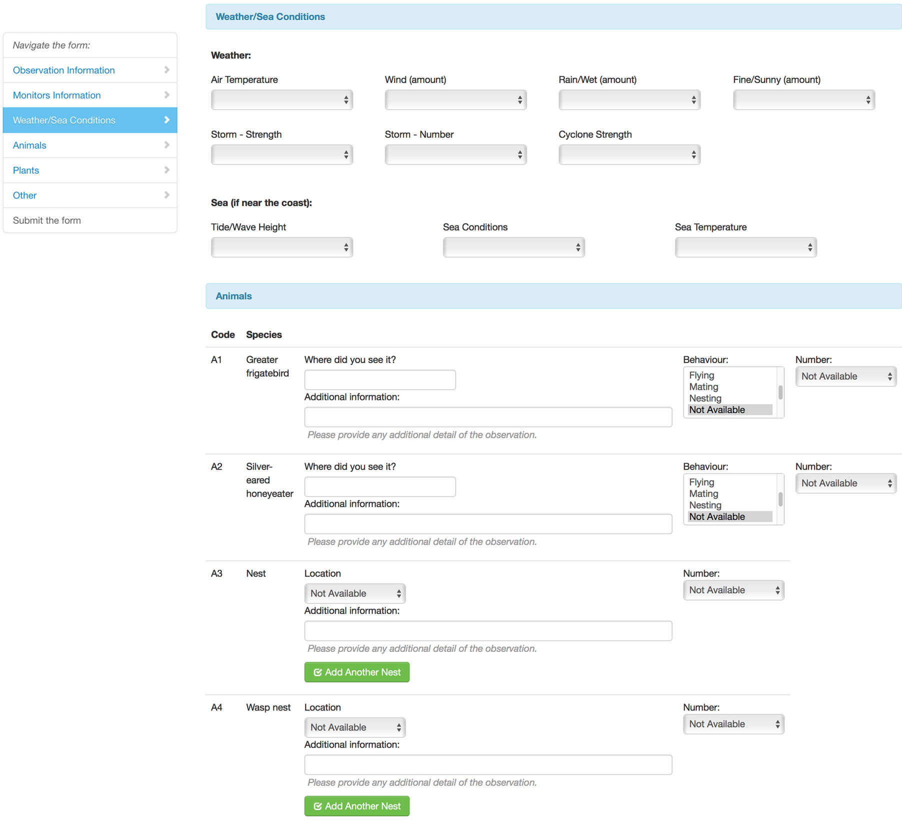


Figure 6. Extract from the Monitoring entry form. [Colour figure can be viewed at wileyonlinelibrary.com].

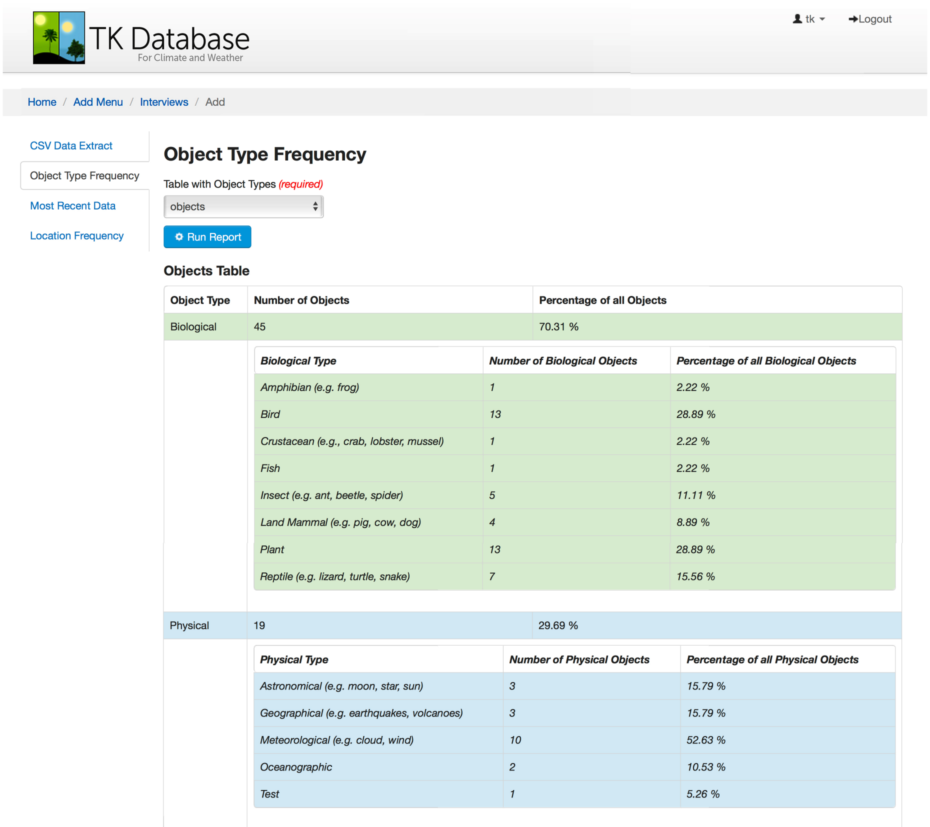


Figure 7. Basic reports available include a frequency listing of the types of objects within the TK Database. [Colour figure can be viewed at wileyonlinelibrary.com].

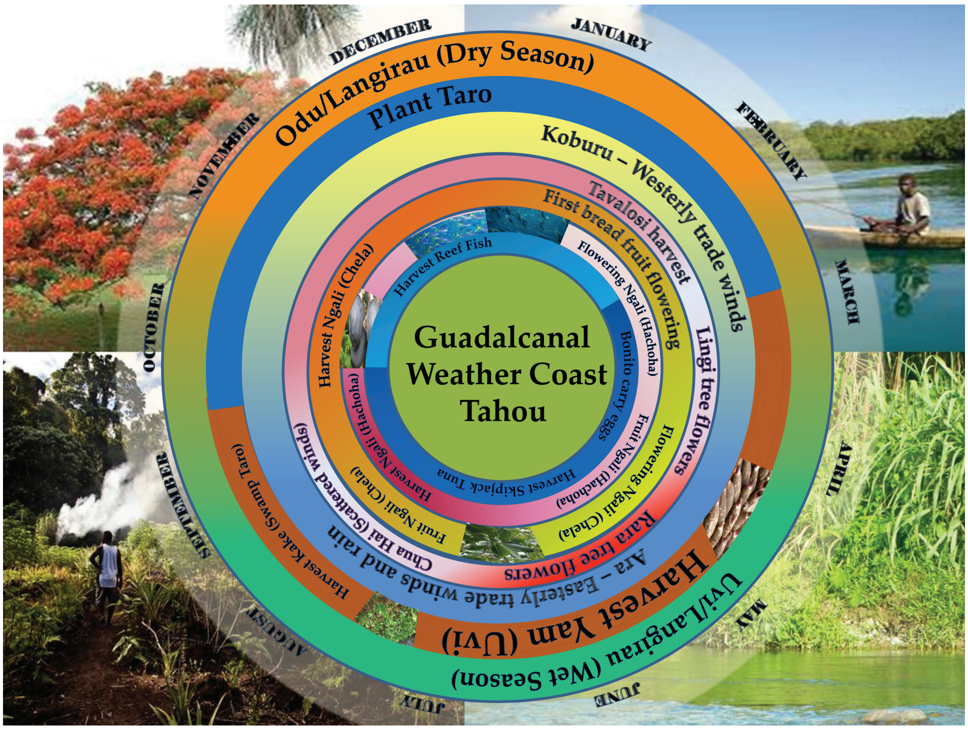


Figure 8. Example of a seasonal calendar for the Guadalcanal Weather Coast, Solomon Islands, that can be produced using information contained within the TK Database. Calendars such as this one are useful climate communications tools with regional communities (The Komu'valu Community contributed the information and the calendar and figure was produced by the Solomon Islands Meteorological Service).

and can later be used to recall this information with components specifically designed for that purpose (Figure 4).

4.2.2. Cultural context

Importantly, the narrative associated with the TK of weather and climate is stored and database users are able to upload associated media files, such as photos, audio and video, all of which provide additional cultural context, including the ability to capture the narrative in local language. Databases supporting the inclusion of narratives, and therefore aiming to preserve cultural context, can help to build and maintain healthy relationships between the project partners who collect and store the knowledge and the local communities (Pulsifer *et al.*, 2012). Linking the interview details with the narrative helps to ensure that appropriate recognition (and data sensitivity) is provided to those sharing their TK.

4.2.3. Intellectual property

Digital rights management was an important component of the TK Database development. TK by its very nature can have a variety of cultural sensitivities attached to it, including knowledge that can only be shared between particular members of a clan or tribe. Consideration of these issues is critical to maintaining trust between the TK expert and those with whom the TK has been shared. As part of the process, it is important that all parties are clear on who will have control of the TK information, including who can access it and how it will be used (ITK and NRI, 2007; Pulsifer *et al.*, 2012; Eicken *et al.*, 2014). At the end of each interview with a TK expert, the expert was asked to specify the level of sensitivity associated with the information, from low (everyone can access) to high (not to be shared). At this point, the TK expert was also able to specify particular groups of people with whom the information should not be shared. This meant that the TK Database needed to enable restrictions based on things such as:

- user's membership of a clan or tribe;
- user's status/role within the tribe;
- user's gender, and
- the context in which the resource will be reused or reproduced (Figure 5).

The restriction groups in the TK Database are deliberately flexible to allow the users to set restrictions appropriate to their individual needs. Recording information in this way recognizes that the knowledge provided may be owned by several people, be they selected members of a community, the full community or from multiple communities (Brahy, 2006).

4.2.4. Monitoring indicators over time

Representatives of some of the meteorological services were also interested in incorporating forecasts made using TK with their contemporary seasonal forecast products (e.g. Kaniaha *et al.*, 2012; Plotz *et al.*, 2013; Seuseu *et al.*, 2013; Chand *et al.*, 2014), subject to the TK component being classified by the provider as 'low' sensitivity and therefore permission being granted for public release. In order to build a reliable integrated forecast system, it was necessary to monitor the indicators used for the traditional forecasts to test the validity of the forecast model and to assess how wide an area the forecasts could be accurately applied to. As a consequence, the TK Database was adapted to manage observations on TK forecast indicators, e.g. bird or plant behaviour, astronomical signs, recorded on a regular basis by dedicated volunteer observers. In order to respect any cultural sensitivities or intellectual property issues associated with the TK weather or climate forecast narrative, the TK Monitoring

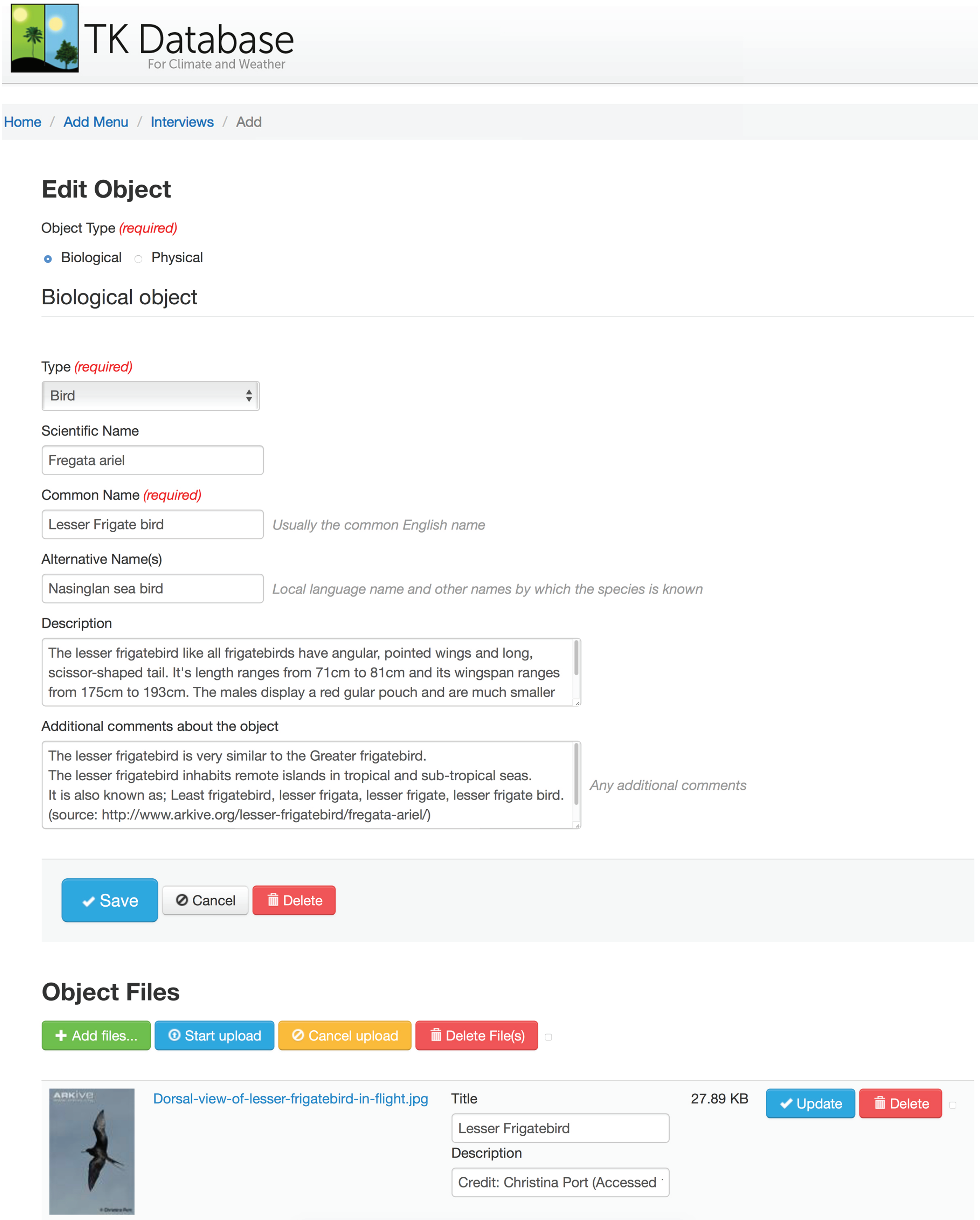


Figure 9. Example of biological information available in the TK Database. Partner countries are provided with some common species. Records of objects (in this case the Lesser Frigate bird) can be edited to add local names for the object (e.g. Nasinglan sea bird) or additional media files, or new objects can be added.

form and associated database fields do not provide detailed information on the object used to do the forecasting or how the forecast is made. Rather, the form indicates which objects should be observed and provides opportunities for the observers to record the behaviour of the object (if seen) and associated weather conditions (Figure 6).

4.2.5. Reporting

Currently, the reporting functions in the TK Database are limited to basic functions, such as extracting the data to CSV file format, generating frequency tables of the object types (e.g. biological (plant, bird, fish, reptile, land mammal) or physical (astronomical, such as the Moon, star, Sun, and meteorological, such as cloud, wind, waves); Figure 7), summaries of the most recent data entered or summaries of the location frequencies. As a number of NMSs pay their rainfall and TK observers, the reporting functions also include the ability to output the number and frequency of returns by each observer.

5. Additional benefits

Pacific NMSs are keen to increase their ability to communicate climate messages successfully with, often remote, community members. Seasonal calendars (Figure 8) are an engaging and easily understood tool for initiating meaningful community discussions on climate variability and climate extremes, particularly with those who live off the land or sea. Once sufficient records are available in the TK Database, seasonal calendars can be produced based around the indicators (e.g. behaviour of plants, animals, astronomical), when these are observed, and the associated weather and climate conditions. Seasonal calendar reports can be generated for the whole country, i.e. all data in the database, or for specific islands or regions for more localized calendars, such as has been produced for the Guadalcanal Province in the Solomon Islands (Figure 8) as part of the broader TK project.

The TK Database also forms an important biological data resource for the Pacific region, containing both detailed information on plant and animal species (Figure 9) and the start of long-term monitoring of TK climate indicator species. It is anticipated that this biological information will be of considerable interest to other agencies in the Pacific, particularly those associated with natural resource management and agriculture.

6. Conclusions

The Traditional Knowledge Database (TK Database) has been developed in partnership with four south Pacific countries and is regularly used by their national meteorological services, and partner organizations, to preserve traditional knowledge (TK) related to weather and climate and as a tool for monitoring the TK indicators. Feedback from the users has been positive with the TK Database clearly addressing local needs (e.g. ‘Future generations need this; TK is slowly dying out if not shared and documented’, workshop participant Niue 2014, unpublished workshop report). The TK Database’s design enables it to operate in environments where Internet access can be problematic, allowing multiple users to access the system *via* local area networks using web browsers while still maintaining the flexibility to operate *via* a stand-alone desktop, the Internet or Cloud.

Recognizing that user needs can change over time, the TK Database has been designed to be adaptable, with the system allowing for further developments, such as computer generated seasonal calendars or automated TK climate forecasts and verification based on the TK narratives and monitoring components.

To the authors’ knowledge, this is the first database of its kind and it helps to fill a critical gap in the appropriate storage and application of TK and provides an important foundation for future developments. The process of the development of the TK Database highlighted several important aspects that are recommended for consideration when developing databases for storage and use of TK. (1) Ensure sufficient time and resources are built into the project to involve project partners and the community effectively in the design and testing (of suitability) of the database. (2) As the database may contain culturally sensitive information, it is important to be aware of any potential information access constraints, such as restrictions according to gender or status, and to ensure that the database is designed to incorporate these. (3) Database design should incorporate intellectual property considerations. (4) The database development needs to consider the resource availability of the end users, e.g. use freely available open source code for low to middle income countries with limited financial resources.

The TK Database is recognized by the four Pacific countries in which it was trialled as an important tool for preserving and continued application of climate and weather related TK and is actively used towards this goal through strong partnerships and information flows between the Pacific NMSs, cultural centres, community members and other stakeholders.

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