Tethys, Antioch mosaic, 3rd century from Baltimore Museum of Art

http://tethys.sdsu.edu v 2.5

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1 Overview

Tethys is a temporal-spatial database for metadata related to acoustic recordings. The database is intended to house the metadata from marine mammal detection and localization studies, allowing the user to perform meta analyses or to aggregate data from many experimental efforts based on a common attribute. This resulting database can then be queried based on time, space, or any desired attribute and the results can be integrated with external datasets such as NASA's Ocean Color, lunar illumination, etc. in a consistent manner. While Tethys is designed primarily for acoustic metadata from marine mammals, the design is general enough to permit use in other areas as well.

Tethys provides a scientific workbench to the practitioner. Consequently, rather than providing a stand-alone graphical interface, Tethys provides methods, or subroutines, that can be called from programming environments that practitioners use to conduct their analysis. Currently, Tethys supports Matlab, Java, and Python. The R programming language will be included in the next major release. These methods allow practitioners to access the metadata associated with a specific laboratory or project. Additionally, the tools provide access to environmental data based on spatial location and selected temporal boundaries from a wide variety of online sources.

To run Tethys, a Windows machine is required (porting to other platforms is possible with a little work). To access Tethys from other machines, the network will need to permit communication between machines. In most cases, this will require a modification of a machine's firewall rules.

This manual is divided into several major parts and you need not read it all to use Tethys effectively. Section 2 contains information about installing and administering Tethys, while section 3 provides information for practitioners who wish to use it. Users may wish to begin by reading about data organization (section 3.1), the various types of XML documents (section 3.4) and then section of the manual that is appropriate for the language that they will be using to conduct their queries. Queries can either be written in the XQuery language (section 3.5) or the user can invoke specialized functions that construct common queries. The richest set of common queries is available for Matlab (sections 3.7 and 7).

2 Installation and Administration

2.1 Installation

The initial distribution of Tethys is designed to be executed on a Microsoft Windows platform, and a Windows installer program TethysInstaller.exe is provided. The user will need a Windows machine to be used as the server[1] for creating and housing the database. The same machine can be used for querying data and using the associated Tethys methods or additional client machines can be used. It is recommended that there be ample disk space for the database and that plans be put in place for routine backup of the database. As an example, in early 2014 the database used at the Scripps Whale Acoustics

[1] In this context, "server" means that Tethys will be providing services to other machines. The Windows Server operating system is *not required*.

Lab contained over four million detections and used a bit over 18 GB of storage. The majority of the space was used for the database records themselves (5 GB) and sample audio and images associated with detections that were stored at analyst request (11 GB).

During the installation process, the user is first asked what type of installation should be performed (Table 1). The server code only need be installed on the machine that will be storing the Tethys database, and it is recommended to do a complete install on the server machine, which will also initialize a skeleton database for the user. By convention, the installer will place the database in a subdirectory of C:\Users\Tethys, but this can be overridden this if desired

Installation choice	Components installed
Complete Install	Server, Client, initialize a database
Server and database instance	Server, initialize an empty database, and a populated sample database.
Server only	Server
Server update	Updates the Tethys project portion of the server code. This can be used to update to a new version of the server without having to reinstall Python or Berkeley DBXML provided that no changes are needed to those programs (nearly always the case).
Client only	Client
Empty database	Create a new database instance.
Demonstration database	Create a new database instance that is populated with sample data.
Empty and demonstration database	Create both databases.

Table 1 - Types of installations available

Individual Windows machines that will be accessing the database can simply install the client software. Any time the client software is installed, the user will be prompted for the default server. This takes the form of an Internet machine name (e.g. dataserver.myorg.edu) and a port. Port numbers are a method of specifying to which service a client should connect. By default, Tethys executed on port 9779, but a server administrator can change this.

The installer will connect to the Tethys software repository and download and install only the components that are needed. All of the components are installed as subdirectories of the selected installation directory.

2.1.1 Quick-start install for the impatient

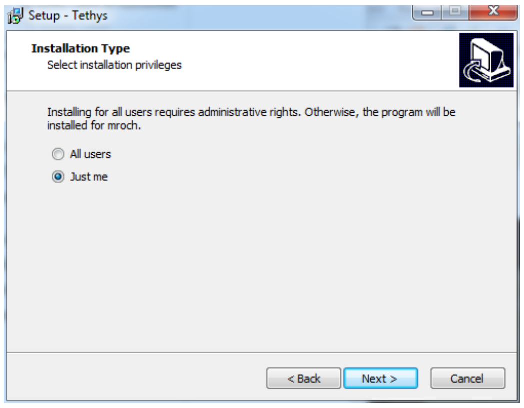
Tethys requires a 64 bit version of the Microsoft Windows operating system. If you wish to import data from Microsoft Office data sources (e.g. Excel, Access) and need to use Microsoft Office on the machine that you will be running the server on, you *must be using a 64 bit version of Office*. See section 2.5 for details on how to verify that you are using a 64 bit Office.

If you wish to import data from Microsoft office applications (e.g. Excel, Access), see section 2.1.6 after you complete the install.

The installer can be started by double clicking on the TethysInstaller executable that can be downloaded from tethys.sdsu.edu.

Should you encounter any problems, please start the installer from the command prompt by changing directory to the location where the installer was downloaded. Throughout this section, we will assume that your login is “Marmam.” Consequently, if you downloaded to C:\Users\Marmam\Downloads, type “cd C:\Users\Marmam\Downloads”). Then type the installer name followed by the argument /log=log.txt, e.g. “TethysInstaller-x64-2.4 /log=log.txt”. This will create a log file that will help you (or us) understand what happened during the installation process.

The Tethys installer will present the following series of prompts. The first dialog requests if you want to install Tethys just for yourself or for all users. Installing for all users requires administrative privileges. Installing for yourself places all of the code in your account. If you run the server, you can still provide services to other users subject to the permissions governing Internet access on your machine (see firewall rules, 2.1.5).

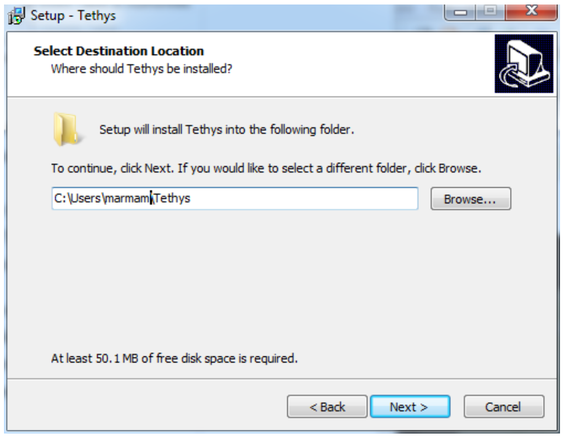


Installation Type
Select installation privileges

Installing for all users requires administrative rights. Otherwise, the program will be installed for mroch.

All users [✓ Just me]

Throughout the rest of this example, we will assume that we want a “Just me” installation that can be done by anyone. You are next asked where to would like to install Tethys. The default will either be in your account or in Program Files depending on whether you are installing for all users or just yourself.


Setup - Tethys
Select Destination Location
Where should Tethys be installed?
Browse...
< Back
Next >
Cancel

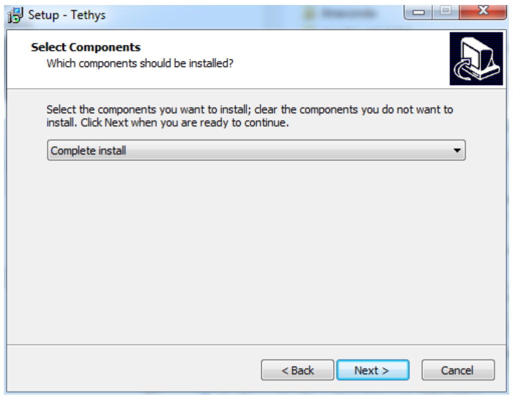
Setup will install Tethys into the following folder.

To continue, click Next. If you would like to select a different folder, click Browse.

C:\Users\marmam\Tethys

At least 50.1 MB of free disk space is required.

Afterwards, the user will be asked which parts of Tethys should be installed. The default is a complete install which includes the server, clients, an empty database ready for your data, and a sample database. This is the appropriate choice when examining Tethys for the first time. Subsets of this can be selected from the dropdown menu if so desired.

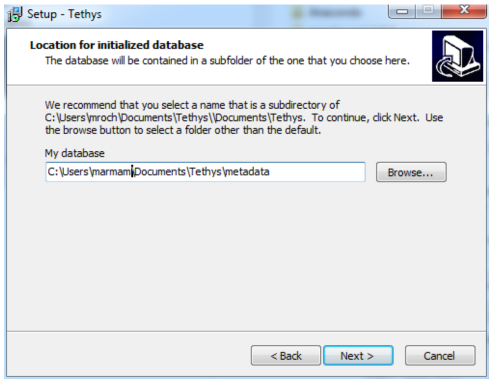


Select the components you want to install; clear the components you do not want to install. Click Next when you are ready to continue.

Complete install

When a database instance is to be installed, you are prompted for the location where data is to be stored. Defaults for “Just me” installations are in Documents\Tethys and C:\Users\Tethys for “All

Users," but these can be modified. The name of the database for your information defaults to metadata and the demonstration database defaults to demodb. Demodb contains a small subset of the Scripps Marine Acoustic Group's database. Regardless of the database type, a dialog similar to this one will appear, and the data locations and names can be overridden.


Setup - Tethys

Location for initialized database

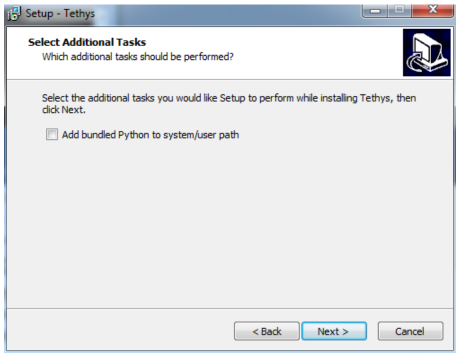
The database will be contained in a subfolder of the one that you choose here.

We recommend that you select a name that is a subdirectory of C:\Users\mroch\Documents\Tethys\\Documents\Tethys. To continue, click Next. Use the browse button to select a folder other than the default.

My database

C:\Users\marmam\Documents\Tethys\metadata

When installing the Server or the Python client, a version of Python will be installed in the Tethys code directory. If you wish to have your path modified so that this version is on the path environment variable, select the checkbox in the next dialog. If you do not know what a path variable is, you probably want to leave this unchecked.


Setup - Tethys

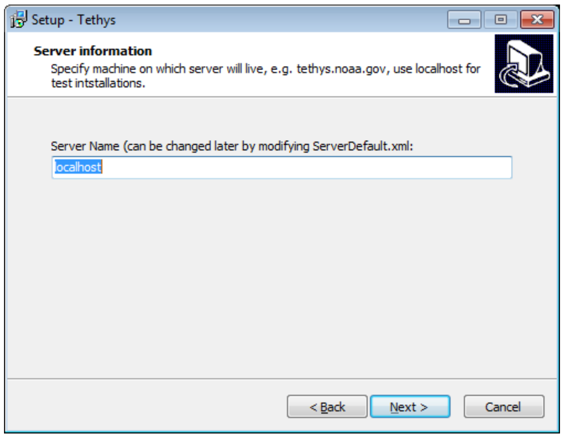
Select Additional Tasks

Which additional tasks should be performed?

Select the additional tasks you would like Setup to perform while installing Tethys, then click Next.

☐ Add bundled Python to system/user path

When clients communicate with the server, the server name is required which is either specified when the server session is started or allowed to default to a standard value. The next dialog allows one to specify the default server name. If a domain name system (DNS) entry or fixed internet protocol (IP) address has not been established for the machine that will be used as a server, the name localhost may be used to indicate that by default the client and server are on the same computer. This is the default value.



Server information

Specify machine on which server will live, e.g. tethys.noaa.gov, use localhost for test intstallations.

Server Name (can be changed later by modifying ServerDefault.xml:

localhost

A "Ready to Install" dialog will appear summarizing your choices. Press the Install button. Software will be downloaded and installed based on your choices. For people who wish to archive the code, you can download the software manually from the Tethys web site. The installer looks in the current directory to determin if products are already present before installing them.

Finally, a summary is produced and pressing install will start the installation process. The process consists of downloading the needed files, executing separate installers for the dependent programs (use the default installation values), and unarchiving the remaining programs. Note that the archive managers may take a minute or two to complete. They will show a blank window and will not show progress. Some of the archives will take a little while to decompress and you will see a window called unzip. Be patient.

SECURITY NOTE: As the installer cannot know which account will be starting the database, the database files (not the code) are made writable to any user that can log into the machine on which the database is running. If this is not acceptable, change the Windows permissions so that only the appropriate account can modify or access the database.

2.1.1.1 R data export installation (optional)

To configure your Tethys server to provide query results in R format you will first need to install R 4.x. on your server machine. The following link provides details on that installation. Download R-4.0.3 for Windows. The R-project for statistical computing. (r-project.org)

After you have R 4.x installed you will need to set an environment variable called R_HOME to the path of the R install, for example: `"C:/Program Files/R/R-4.0.0".`

Now you must install a python package for python to be able to talk to R. It is called rpy2 and must be installed using the rpy2-2.7.8-cp27-none-win_amd64.whl wheel file included in the distribution. To install it you can move the file to where your pip application lives, usually in Python2.7\Scripts and use pip at a DOS prompt to install like the following:

```
> pip install rpy2-2.7.8-cp27-none-win_amd64.whl
```

Now you must set an environment variable called R_USER to the path where rpy2 was installed, usually in the site-packages folder for Python.

To finish installing the R capabilities you need to find out where the library directory is for R. You can do this by typing the following at the R console:

```
> .libPaths()
```

Set an environmental variable called R_LIBS to the path presented in the output from the above command.

2.1.2 Server

The server is implemented using two open source technologies: the Python programming language, and Oracle's Berkeley DBXML which provides the extended markup language (XML) database engine. The installer will check to see if the correct version of Python is installed on the machine. If it is missing, it is downloaded and installed using Python's own installer. Once the correct version is present on the machine, add-on libraries are installed and the bindings that permit Python to access the database are created. Note that if you decide to uninstall Tethys, Python and the Python addons (EGenix, PyWin32, PyODBC, PyBSDDB, and PyDBXML) will need to be uninstalled separately. If you have another software package using Python (ArcGIS for example) you should install the Python for use by Tethys in a different folder than your existing Python folder and may need to.

If data is to be imported into the database from formats other than XML, other programs may need to be installed. Further details on this can be found in section 3.2.

2.1.3 Client

The client software will be installed as a subdirectory of the selected application directory. Subdirectories are available for different languages, and currently there are interfaces that permit the user to interface with the following languages:

- Java
- Python
- Matlab

Support for R is scheduled to be implemented in the future.

When installing a client without a server component, the user will be prompted for a default server. If the default of “localhost” is used, it assumes that the client will be executed on the same machine as the server. If this is not the case, specify an Internet DNS address (e.g. tethys.nwfsc.noaa.gov) or internet protocol (IP) address.

2.1.4 Database instance

Selecting the database instance can be used to either add a new database or reinitialize an existing one (deleting existing entries). Database initialization will create a directory of the user’s choosing, and several subdirectories and files:

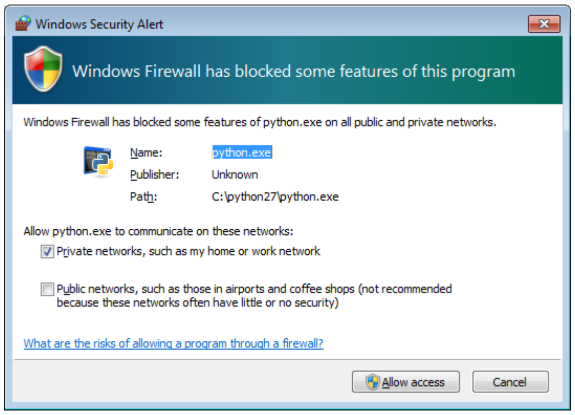
Directory/file	Description
db	Contains files used by the Berkely DB XML database.
source-docs	A copy of the source documents added to Tethys are stored in this directory. This is useful should there ever be a catastrophic failure and the database need be reconstructed from source material.
DeletedArchive	A copy of source documents that have been deleted from the repository. Note that multiple versions are not currently maintained.
lib	XQuery library modules and XML schema
logs	Logs detailing server activity.
TemporaryFiles	workspace
tethys.bat	A batch file that will launch the Tethys server with the default options.
tethys-ssl.bat	A batch file to launch Tethys with secure socket layer encryption enabled. Note that you must obtain a certificate and a public/private key pair before you can start Tethys in this mode. Directions on doing this are in the Tethys secure socket layer manual that can be found in Tethys/docs folder relative to your install folder or on the Tethys web site: tethys.sdsu.edu.

Table 2 - Contents of a database instance

The database can be started by double-clicking on the tethys.bat file located in the root directory of the database or manually as specified in section 2.2

2.1.5 Providing remote access - firewalls

To access your database, you must provide permission for the clients to use the port (9779 by default). Recent versions of Windows have a built in firewall which must be modified to allow local and/or network traffic. The first time you run Tethys, you may see a dialog similar to Figure 1. To permit connections, click *Allow access*. Note that this will permit connections from any machine, although your organization's firewall may block external access.



Windows Firewall has blocked some features of python.exe on all public and private networks.

Name: python.exe
Publisher: Unknown
Path: C:\python27\python.exe

Allow python.exe to communicate on these networks:
[✓] Private networks, such as my home or work network
[ ] Public networks, such as those in airports and coffee shops (not recommended because these networks often have little or no security)

What are the risks of allowing a program through a firewall?
Allow access
Cancel

Figure 1 – Sample windows firewall dialog (Windows 7) requesting the use to allow connections to the Tethys server.

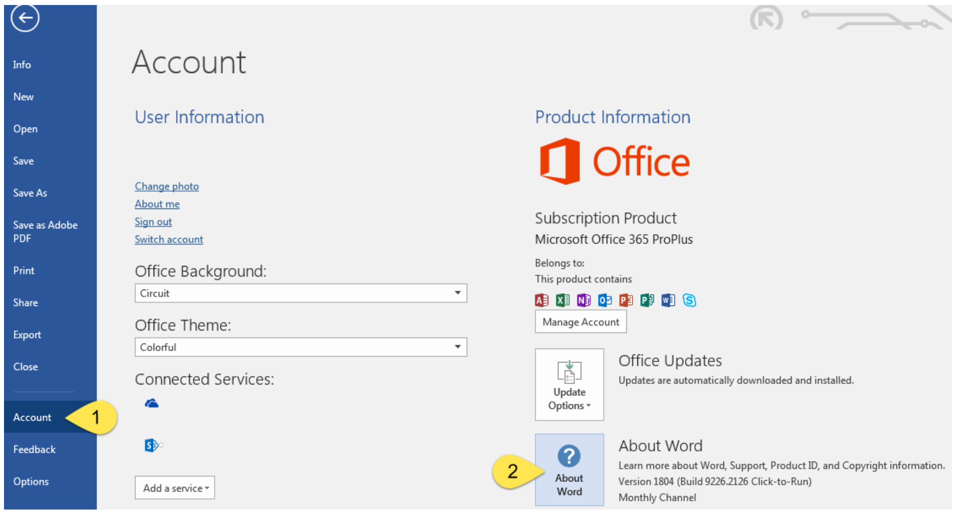
A tutorial article by Hoffman (2012, also placed in the documentation directory) explains how to set up Windows firewall rules. The firewall can be configured to provide more selective filtering, such as only allowing access from specific machines or subnetworks.

2.1.6 Installing support for importing from spreadsheets and databases

In order to import non-XML information into Tethys, we need to have the 64 bit version of Microsoft's open database connectivity (ODBC) driver installed. This will allow imports from Microsoft family products and comma separated value files. To support non-Microsoft databases, additional vendor-specific ODBC interfaces may need to be installed (e.g. the MySQL driver for MySQL databases). Note that while Tethys can be installed without administrative privileges, you will need to ask your system administrator to install these drivers if you do not have administrative privileges.

You should be able to tell if the ODBC driver is installed by attempting to import data from a spreadsheet, database, or other source (see appendix 6 for details on how to do this). If an error message indicates that the ODBC default driver could not be found, you will need to install it. As of this writing, we recommend installing the 2016 version or later, which is currently available here. Microsoft changes links frequently, and you may need to search for it. See Microsoft knowledge base article 2874601 if you have any problems, but note that on our system we did not require the /quiet switch that is discussed in that article.

If you are running a 64-bit version of Office that is not Office 365, you may already have the ODBC driver. Tethys cannot access the 64-bit ODBC driver that comes with Microsoft Office 365 which uses a container technology called click-to-run to isolate services from other applications, and you will need to install the ODBC driver. The 64-bit ODBC driver cannot be run when 32 bit versions of Office are installed. To determine if a recent version of Office is 32- or 64-bit, open an office document (e.g. Word) then click on the File icon on the ribbon, resulting in the following after you click on Account (arrow 1 below):



Office Background: Circuit

Office Theme: Colorful

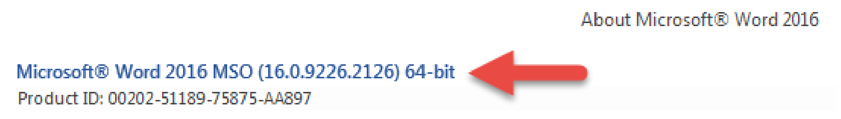
Connected Services:

Subscription Product
Microsoft Office 365 ProPlus
Belongs to:
This product contains

Office Updates
Updates are automatically downloaded and installed.

About Word
Learn more about Word, Support, Product ID, and Copyright information.
Version 1804 (Build 9226.2126 Click-to-Run)
Monthly Channel

Figure 2 - File tab in Microsoft Word. We see that this version is click-to-run (arrow 2) and we will need to install the Access ODBC driver. Clicking on About Word, it will show whether this is a 32 or 64 bit version (Figure 5).



About Microsoft® Word 2016

Microsoft® Word 2016 MSO (16.0.9226.2126) 64-bit
Product ID: 00202-51189-75875-AA897

Figure 3 - About Word dialog. Note arrow pointing to information indicating this installation of Office is 64-bit.

2.2 Starting the server manually

The database can be started by double-clicking or running dbXMLserver from the command line. The batch file sets a variable indicating where the Tethys sources were installed and then starts dbxmlServer.py with the appropriate options.

Several options are available. This list can be seen by using the --help flag on the command line:

```
c:\Program Files (x86)\Tethys\server> dbXMLserver.py --help
Welcome to Tethys - Server starting...
Usage: dbXMLserver.py - XML Database Server
    Default values for choices are marked by an *

Options:
  -h, --help            show this help message and exit
  -s SECURE_SOCKET_LAYER, --secure-socket-layer=SECURE_SOCKET_LAYER
                        Use encrypted communication (true/false*)?
                        encrypted-->https:// unencrypted-->http://
  --port=PORT           port to run on (default=9779)
  -t TRANSACTIONAL, --transactional=TRANSACTIONAL
                        Use transaction processing (true*/false)?
  -d DATABASE, --database=DATABASE
                        Directory (folder) name where the XML database will be
                        stored (must exist). Most users wishing to specify -d
                        should probably use the -r switch instead.
  -r RESOURCEDIR, --resourcedir=RESOURCEDIR
                        Set Tethys's resource directory (folder).  This is the
                        parent directory for all data used by Tethys including
                        the XML database.
```

Each option has a long name that is preceded by two dashes, and sometime a short name which is preceded by a single dash. Either one may be used.

Setting **secure socket layer** to true enables encrypted transmission. It requires the generation of certificates and keys. While the secure socket layer is currently functioning, for this initial manual we will focus on unencrypted communication as it is much simpler.

Computers communicate across networks by specifying an address and a **port**. The address is the Internet protocol (IP) address of the computer running the server and is not settable. The port can be thought of as a service address at the computer. By default, Tethys uses port 9779, but this can be overridden.

Many databases are capable of performing operations "atomically." This means that an operation is either not performed or is completed, but will never fail in a partially executed way. Should a failure occur part way through an operation (e.g. a power failure), a log is used to either undo the operation or complete it. This is known as **transactional** processing and is enabled by default in Tethys.

Files for the database are by default stored in C:/Users/Tethys, but this can be overridden with the **resourcedir** option. Several subdirectories are stored relative to the resource directory:

- db – The database itself. The name can be overridden with the **database** option. When the database flag is used, the folder will be relative to the resource directory unless it contains a path separator (e.g. –database %USERPROFILE%/Documents/testbed).
- DeletedArchive – When files are overwritten, the previous copy is stored here.
- lib – Library directory containing schema and database modules
- logs – Logs of failure operations.

- source-docs - An archive of source material added to the library that can be used for regenerating the database in case of failure. It also contains any images or short audio clips that are referenced from the database but not stored directly within it.
- TemporaryFiles – Working directory.

Other files may be stored in the resource directory as well. Currently, the file Detection_Effort_Template.xls is expected to be in the directory.

2.3 Manual shutdown of the server

To shutdown the server, send a terminate command (CTRL+Break, on most keyboards, the break key is in the row of function keys) and the server will shutdown and the command prompt will close. If users are using the database, they may lose some data, but the database will not be corrupted.

2.4 Running the server as a service

The server can also be run as an operating system service, although this requires the download of additional software. The server is started automatically and restarted if the server process unexpectedly dies or the server machine is restarted. We recommend using the NSSM service manager developed by Iain Patterson. Source code and executable files can be downloaded from http://iain.cx/src/nssm/ .

Complete details on NSSM can be found in the NSSM documentation, but to set Tethys as a service you may need to determine if you are using a 32 or 64 bit version of Windows. This can be seen by clicking on the system properties from the Computer window in Windows 7, other versions of Windows have similar methods of finding the computer's properties:

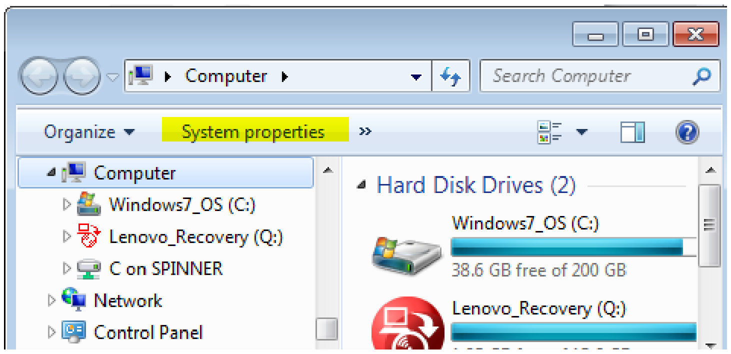
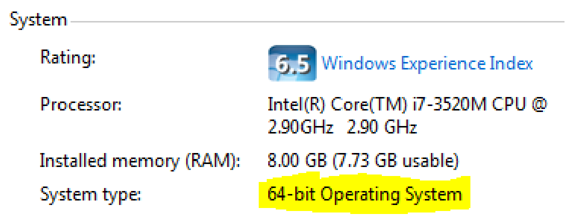


Figure 4 - Accessing system properties on a Windows 7 operating system.

Pressing on System Properties will display a new window that describes the hardware and operating system. On 64 bit systems, a 64 bit message will be shown:



System	
Rating:	6,5 Windows Experience Index
Processor:	Intel(R) Core(TM) i7-3520M CPU @ 2.90GHz 2.90 GHz
Installed memory (RAM):	8.00 GB (7.73 GB usable)
System type:	64-bit Operating System

Figure 5 - The Windows operating system is a 64 bit system if the system type message is present and indicates 64 bits.

Open a command window and type the following for Windows XP systems:

```
[path-to-nssm]\nssm install Tethys c:\users\Tethys\metadata\tethys.bat start=auto
```

For Windows Vista and later, change start=auto to start=delayed-auto. Replace [path-to-nssm] with the folder path to the nssm executable (32 or 64 bit) and change c:\users\Tethys\metadata\tethys.bat if you have customized where your database resides.

3 Using Tethys

At this point, it is assumed that you have an operational Tethys metadata database. Your database administrator should be able to tell you the name and port of the machine where Tethys is running. Tethys uses the extended markup language remote procedure call interface (XMLRPC) to transfer data between Tethys and the client programming language used for analysis. For common queries, you do not need to learn XQuery, the language that Tethys's database uses to access records. A number of templates for common queries have already been predefined and can be accessed using function calls from one of the Tethys clients. Currently, Matlab has the richest set of queries. For advanced queries, it is helpful to know XQuery. There is a XQuery tutorial later in this manual. Regardless of whether you use predefined queries or write your own, it is helpful to understand the structure of how data is stored in Tethys.

3.1 Data organization in Tethys

Data in Tethys are organized into documents that are placed into containers.

For most of the containers that you are likely to use, a *schema* is used to define what type of extended markup language (XML) data can be placed in the container. Parts of the schema are very well defined, and may require values for certain fields, other parts are loose and allow the user to define new types of information to be added to the database.

While there are a number of metadata containers in Tethys, the four that we will discuss here are D*eployment*, *Detections, Localizations,* and *Ensemble*. Each container contains one or more documents.

- The Deployments container is used to represent information about the deployment of instruments used to collect the data analyzed for detection and localization. It contains information such as the number of channels, sample rate, duty cycle, etc.

- The Detections collection describes when events have been detected within a specific deployment and can be of varying scale. An example of a fine scale detection might be reporting individual echolocation clicks produces by a Risso's dolphin while a medium scale detection might indicate that there was an acoustic encounter of Risso's dolphins between some start and end time. Finally, one can report binned presence/absence (e.g. hourly) information. In addition to the detection events, attachments can be added. These attachments include audio files and images related to the detections events. Note that a maximum of 500 files can be attached to a given detection document (this limitation will be removed in a future release).

- The Localizations collection denotes the source location of a sound source using either relative or absolute coordinates and permits the user to reference a detection in the Detections container if appropriate.

- The Ensemble collection allows multiple instruments to be referenced as a single one, which is useful when performing beamforming or localization on a large aperture array that contains separate instruments.

- The Events collection is used to specify events that may be of interest in the analysis. One such example might be a planned activity with possible consequences such as oil exploration. Individual detections of anthropogenic events such as airguns would be recorded in the Detections collection, but the knowledge that oil exploration was being conducted over a given time and location could be denoted in the Events collection.

Containers are used as needed, for example a set of detections without localizations from a single instrument would add a document to the Detections and possibly to the Deployment collections, but would not contribute new entries to the other collections.

Each document is written in extended markup language (XML) which is a language used for structuring data. The core of XML is quite simple, data is contained within elements that provide structure. The start of each element is denoted by its name enclosed in < > and the end by the element name within </ >. A small XML fragment is shown below:

```
<Deployment>
    <Project> Socal </Project>
    <Deployment> 32 </Deployment>
    <Site> A </Site>
    <Cruise> SocalInstrument </Cruise>
    <Platform> Mooring </Platform>
    other entries...
</Deployment>
```

Units are standardized when recorded in the database. All times follow the ISO 8601:2004 standard and are recorded in universal coordinated time (UTC). As an example, January 30th, at 6:22:30 PM UTC would be written 2013-01-30T18:22:30Z. Latitudes and longitudes are recorded in decimal form from 90 degrees (N) to -90 degrees (S) and 0 to 360 degrees (E).

3.2 Adding data to Tethys

Data can be added to the database with XML documents that conform to the schema (p. 56). Ideally, tools used by researchers will use the Nilus application programming interface to generate XML directly, but many existing tools generate data in other formats. Consequently, Tethys provides data import support for the following data sources:

- Microsoft Excel workbooks
- Comma separated value lists (text files with commas between entries)
- Microsoft Access
- MySQL open source relational database (www.mysql.com)

Data import services are provided using industry standard open database connectivity (ODBC), and hence other databases including but not limited to Oracle, Visual Fox Pro, PostgreSQL, etc. should function, but have not yet been tested. For data sources such as Excel and comma separated value lists, it is assumed that the first row contains the names of each field. Filenames can contain numbers, letters, dashes, and periods. Commas in filenames are not supported at this time, and ampersands (&) are disallowed.

3.2.1 Importing Data to Tethys

The Python utility import.py provides data import services, and can be run from any machine that has network connectivity to the server. Assuming that we wanted to add a set of detections from a spreadsheet in folder C:/Users/Eloise/SOCAL33M-BeakedWhales.xlsx located on the server machine tethys.sdsu.edu, with source map SIO.SWAL.Detections.Analyst.v1, we would type at a command prompt:

```
import.py --file C:/Users/Eloise/SOCAL33M-BeakedWhales.xlsx --server
tethys.your.org --sourcemap SIO.SWAL.Detections.Analyst.v1 Detections
```

where

--file indicates the file to be uploaded
--server indicates the server hosting the database. The server name you provided at installation will be used this option is omitted.
--sourcemap SIO.SWAL.Detections.Analyst.v1 is a translation map, and
Detections is the name of the collection to which we will add C:/…/…BeakedWhales.xlsx

XML translation maps are used to convert between field names used in the data source and names used in the database. The translators are defined in detail in section 6 (p. 67) but will be briefly introduced in this section. Each translation map consists of an XML element called Mapping with three children:

Name – Unique name used to specify which mapping should be used. In our example, the map Name is "SIO.SWAL.Detections.Analyst.v1," but any name may be used.

DocumentAttributes – This section contains information that will be added to the document so that the database knows which schema should be used to validate the document. In most cases, this section should just be copied from one of the existing examples.

Directives – This element contains children that specify how the translation is to be done. Within the Directives elements, one can specify sheets of a workbook to use or sequential query language (SQL) queries to databases. Each row of these data sources is then processed according to the instructions.

The following example is a portion of a Directives element from SIO.SWAL.Detections.Analyst.v1 which is included in the sample database:

```
<Map>
  <Name> SIO.SWAL.Detections.Analyst.v1 </Name>
  <DocumentAttributes> … omissions … </DocumentAttributes>
  <Directives>
    <Detections>
      … omissions …
      <OnEffort>
       <Sheet name="Detections">
         <Detection>
           <Entry>
             <Source> [Input file] </Source>
             <Dest> Input_file </Dest>
           </Entry>
           <Entry>
             <Source> [Start time] </Source>
             <Kind> DateTime </Kind>
             <Dest> Start </Dest>
           </Entry>
           <Entry>
             <Source> [End time] </Source>
             <Kind> DateTime </Kind>
             <Dest> End </Dest>
           </Entry>
           … omissions …
      </OffEffort>
    </Detections>
  </Directives>
</Map>
```

For each row in the Detections sheet of a workbook, a Detection element will be produced as shown below with many of the elements omitted:

```
<ty:Detections …attributes…>
  … many omissions, only Start shown for each Detection …
  <OnEffort>
    <Detection> … <Start> 2012-06-01T14:50:22.52Z </Start> … </Detection>
    <Detection> … <Start> 2012-06-01T14:50:23.9Z </Start> … </Detection>
    <Detection> … <Start> 2012-06-01T14:50:41.32Z </Start> … </Detection>
    … other rows …
  </OnEffort>
</ty:Detections>
```

Elements nested within a <Directives> element are simply copied with the exception of the following processing elements:

- <Sheet> and <Table>: Both of these elements are used to specify data from the current data source. The <Sheet> directive should be used with spreadsheets and expects the attribute *name* to indicate which sheet of the workbook will be used. For Table, the *query* attribute is used and may be any valid SQL query for the database. Table also works on Microsoft Excel spreadsheets, treating sheets as tables. Note that Microsoft's libraries append a dollar sign ($) to sheet names when they are treated as database tables.
- <Entry>: Specifies how fields in the spreadsheet or database will be transformed to an element expected by Tethys. <Entry> elements are always children of <Sheet> or <Table> elements and contain children describing the translation:
  - <Source>: One or more field names enclosed in square brackets [ ]. Multiple fields can be specified and will be merged together.
  - <Kind>: Specifies the data format. For text fields this is not needed. Valid kinds are: LongLat, DateTime, Integer, Number, and SpeciesCode. See the appendix for details.
  - <Default>: Value to use in cases of missing data. If no default is provided, no value is produced. Defaults may be strings, numbers, or the special value {id} which indicates that the document identifier is to be used.
  - <Dest>: Name of the output element.

3.2.2 Updating existing documents

We do not encourage modifying existing data by modifying the database. Rather, modify the document that was submitted and import it again with overwrite enabled (see previous section).

The rationale for this is that a copy of each source document submitted to Tethys is saved in addition to submitting the database. The documents are stored in the subfolder of the database's source-docs folder[2] that corresponds to the collection name. This makes is possible to rebuild the entire database should there be a case of catastrophic failure.

To rebuild a collection, use the Python client program update_documents.py.   The following is an example where any document that was inadvertently removed from SourceMaps is re-added:

```
update_documents.py SourceMaps
```

In general, any number of collections can be listed to be updated. Alternatively,

```
update_documents.py --update=true all
```

can be used to update all collections. The –update=true flag indicates that existing documents should be replaced by their sourcedocs collection document. This is not usually needed unless one has done a global search and replace across source documents and wishes to incorporate the modified documents into the database. Finally, the optional --clear flag will have the same effect as running the clear_documents.py command prior to update_documents.py (see the following section).

3.3 Removing data from Tethys

Individual documents may be removed as outlined in section 3.8.1.4 (p. 46). An entire collection can be emptied using the clear_documents.py command executed from the command line.   The syntax is as follows:

```
clear_documents.py collection1 collection2 ...
    Clear documents in the specified collections.
    This will not remove any source documents used to build the collection,
    but it will remove ALL documents from the specified collections and
    should be used with caution.

Options:
  -h, --help            show this help message and exit
  -s SECURE_SOCKET_LAYER, --secure-socket-layer=SECURE_SOCKET_LAYER
                        Use encrypted communication (true*/false)?
                        encrypted-->https:// unencrypted-->http://
  --port=PORT           port to run on (default=9779)
  --server=SERVER       Server name (defaults to 132.239.122.177
                        (beluga.ucsd.edu))
```

The primary use for this is prior to updating a collection whose contents come from an external database. As an example, at the Scripps Whale Acoustics Lab, a MySQL database is used to track the deployments of our instruments.   Rather than trying to determine which deployments have been added to Tethys, and only add the new ones, we simply empty the Deployments container:

```
clear_documents.py Deployments
```

[2] An exception to this is when the source material comes from a database.

followed by an import of the Deployments:

```
import.py --file HarpDB --sourcemap SIO.SWAL.Deployments.v1 --server
   tethys.my.org --connectionstring "Server=harp.my.org;Port=3306;User=harp-
   user;Password=*" Deployments
```

where the MySQL database is running on machine harp.my.org on port 3306, and Tethys is running on tethys.my.org. MySQL will be accessed with account harp-user. Setting Password to * will result in import.py prompting for a password. Data will be imported to the Deployments collection from database HarpDB using the SIO.SWAL.Deployments.v1 sourcemap.

When there are a very large number of documents to remove or add, the system may take longer than the amount of time that is allowed for a web services request. When the system knows that this is likely to happen, a message is returned that tells you that the operation is in progress and provides a web address that you can visit to determine the outcome of your request once it is finished. See the section on batch logs for details.

For more information on ODBC imports, see open database connectivity in section 6.2.

3.4 XML Document types

The Tethys schema support several types of documents that are described at a high level in this section. The goal is to describe the types of information contained in the documents rather than every last detail. More detailed descriptions can be found in appendix 5 which describe the schema that structures each document type.

Where possible, we use concepts from ISO 19115 or OpenGIS SensorML[3], but our emphasis is on meeting the needs of the marine mammal community in the most user-friendly way possible. As a consequence, we deviate from these standards. In addition, there are many concepts that are not covered in these standards such as recording detection effort.

3.4.1 ITIS

The itis collection contains one document, which is a subset of the integrated taxonomic information system (ITIS, www.itis.gov). While the Python tool update_documents.py is capable of converting any subset of the ITIS database to XML, the default database contains an ITIS subset suitable for oceanographic work. It contains marine mammals from the order *Cetacea* (whales and dolphins) and the suborder *Caniformia* (sealions and seals). Fish from families *Sciaenidae* (drums or croakers), *Cottidae* (sculpin), *Sebastidae* (rockfishes, rockcods and thornyheads), class *Actinopterygii* (ray-finned fishes), and superclass *Osteichthyes* (bony-fishes) are also included. Note that while only a subset of ITIS

[3] http://www.iso.org/iso/catalogue_detail.htm?csnumber=26020 and http://www.opengeospatial.org/standards/sensorml respectively

has been included, it is possible to add any species represented by ITIS[4]. Each entry has a taxonomic serial number (TSN), completename (scientific name), and vernacular entries.

Tethys's XML representation of ITIS supports physical phenomena by defining them with negative taxonomic serial numbers. Currently, there is a single TSN entry, Other, for physical phenomena. Due to the structure of the Tethys schema, the other category is represented as a Kingdom which is of course incorrect.

3.4.2 Deployment documents

Each document in the Deployments collection describes a deployment of an instrument. As many instrument designers have existing databases for their instruments, the goal in the deployment documents is to provide enough information to access an instrument database and then to describe how the instrument was used. Information such as how and where an instrument was deployed, references to tracklines for moving platforms, sensor packages and configuration are all described here. While the emphasis is on acoustic data (e.g. sampling rates, duty cycles, quantization), the schema permit the description of arbitrary instrumentation.

3.4.3 Detection Documents

Detection documents record information about the process used to perform the detections, the source data, and the effort which indicates which species and calls were searched for in the detection process. Recording effort is essential as the lack of detections for a specific species/call type is not relevant unless one was actually looking for them.

An essential element for being able to conduct metastudies is to use consistent naming conventions. To that end, we have adopted the integrated taxonomic information system (ITIS, www.itis.gov) for describing species. As the taxonomic serial numbers (TSNs) used by ITIS are not user friendly (180514 is the TSN for Stejneger's beaked whale, *Mesoplodon stejnegeri*), library functions permit the translation between TSNs and common or scientific names. In addition, a SpeciesAbbreviations collection permits labs to use their own set of local names or abbreviations (see 6.3.5 for details). Like the translation maps described in section 3.2, these are XML documents that provide mappings between a local name or abbreviation and the Latin species name which permits automatic bidirectional translation. Details on the translation are described in section

A list of call types has is being established based on the literature[5]. The DetectionEffortTemplate spreadsheet found in the root folder of the sample database contains a list of the species and call types. We do not currently enforce the use of these names in Tethys, but rather recommend doing so in any detection software that is used to generate detections to be stored in Tethys.

When possible, we recommend that detectors generate XML conforming to the Tethys schema (section 5), however it is not uncommon to want to import detections from an already established format. Most

[4] Doing so requires running a copy of the ITIS database on your machine and making modifications to the last few lines of the itis_order.py Python program.
[5] This process has been completed for mysticetes and is in progress for odontocetes.

such formats can be thought of as tables and facilities exist to import them from comma separated value lists, spreadsheet workbooks, and a wide variety of database products. Regardless of the data source, a common issue is how the data source, with its own organization and field names, can be translated into the XML required by Tethys. Section 3.2 describes data import at a high level and section 6 describes how to specify the mapping between a row oriented data source and XML documents.

3.4.4 Localization documents

Localization documents provide location information in the form of absolute locations or bearings. Localizations can be derived from data sources consisting of a single instrument deployment or an ensemble of multiple instrument deployments.

Like detection documents, localization documents begin with a description of the localization process followed by identification of the data source, the algorithm and its parameters as well as the user who submitted the localizations. This is followed by a description of the zero location. All localizations are made relative to this point which may be in absolute coordinates (e.g. UTM or longitude and latitude) or relative to the deployment or ensemble.

Each localization has a set of metadata about the localization. An event identifier uniquely identifies the event within the current document. A selection element permits the localization to be related to a specific detection or to a time-frequency bounding box relative to one of the channels. Finally, a list of sensors is provided that indicates which of the available sensors were used in this specific localization.

The localization data itself consists of either a bearing or a location. Bearings consist of a horizontal and optional vertical angle, specified in degrees. Locations are x, y, and optional z distances, specified in meters relative to the zero location. For either type of localization, standard error may be specified in the same units. Finally, when a location is a result of several crossed bearings, an optional list of bearings (event identifiers from previous localizations) may be provided to link the position to the bearings used to produce it.

3.4.5 Events

The events collection is designed to denote phenomena or events that are derived from other knowledge sources. Examples of this include planned Naval exercises, whale watching cruises, pile driving, oil exploration, earthquakes, etc. This collection is experimental and requires more community input before a definitive schema is designed.

3.4.6 External document types

Tethys provides the ability to access external data sources which are represented as collections prefixed with the name *ext:* followed by a collection name. Tethys provides what is known as a mediation service, providing a consistent way of accessing these external data sources. These are returned as XML documents that can be manipulated like any other data that Tethys returns.

Data access is constructed in a manner that looks similar to XML document navigation. The user specifies the collection they want followed by a set of slash (/) separated parameters and terminated with an exclamation point:

```
collection("ext:MediatorServiceName")/parameter1/.../parameterN!
```

Currently, mediation is provided for several types of external container types described in the following sections.

When Tethys accesses an external collection, it caches the results for approximately seven days (default) on the Tethys server. Consequently, if the same data is requested multiple times, subsequent queries are faster. This is particularly helpful when developing routines to analyze data where the same query may be executed dozens of times as the analysis routine is written. The cached results are stored in collection *mediator_cache*. In rare cases, one may wish to disable this behavior. Examples of this include services that provide different results for the same parameters (e.g. report current conditions) and when one knows that a service has been recently corrected.

There are two ways to ensure that mediated services retrieve values directly from the Internet. The first is simply to add a colon followed by cacheupdate after the mediation service name, e.g.

```
collection("ext:MediatorServiceName:cacheupdate")/parameter1/.../parameterN!
```

Data are retrieved from the mediator service and the mediator cache will be updated with the new results. A second and more drastic way to clear the cache is to empty the *mediator_cache* collection using one of the client programs such as the Python client's clear_documents.py . Both methods will work, but emptying the mediator_cache clears the cache of all documents for every user, so the cacheupdate parameter is usually the preferred mechanism for ensuring a fresh copy of the data.

3.4.6.1 *Ephemeris data*

Ephemeris, information about astronomical objects, can be obtained through an interface to NASA JPL's Horizons Web Service (Giorgini et al., 1996). While NASA's system provides information on a variety of astronomical objects, the mediator interface has been primarily tested for solar and lunar information.

The Horizons service is accessed via the ext:horizons collection. An example query might look like this:

```
collection("ext:horizons")/target="sol"/latitude=32.8/longitude=243.8/start="2009-10-01T00:00-
    08:00"/stop="2009-10-04T00:00-08:00"/interval="5m tvh"!
```

The arguments may appear in any order and are as follows:

- target – Celestial body. The horizons mediator knows the names "sol" and "sun" for the sun, "moon" and "luna" for the moon.
- latitude and longitude – Position of the location in degrees for which the ephemerides are to be computed. Latitude must be in the interval between 90° (N) and -90° (S), and longitude must be between 0 and 360° E. Note that this is the format in which Tethys stores latitude and longitude and no conversion is needed.
- start and stop – Time in ISO8601 format (YYYY-MM-DDTHH:MM:SS). All times are assumed to be in universal coordinate time (UTC) which again is the Tethys default.

- interval – How often should the ephemeris be computed. When determining transit (rise/set), this should be in intervals of 5 m with the tvh flags set as in the example above.

Tethys will return XML describing the ephemerides. The document consists of a set of entries describing information about the celestial object in question. The result of the query above with manually added comments is:

```xml
<?xml version="1.0" encoding="utf-8"?>
<ephemeris>
   <entry>
      <date>2009-10-01 01:35:00</date>
      <sun type="civil">day</sun>   <!-- Civil sunset -->
      <moon>set</moon>
   </entry>
   <entry>
      <date>2009-10-01 13:44:00</date>
      <sun>day</sun>
      <moon>rise</moon>
   </entry>
   <entry>
      <date>2009-10-01 19:38:00</date>
      <sun>day</sun>
      <moon>transit</moon>
   </entry>
   <entry>
      <date>2009-10-02 01:32:00</date>
      <sun type="civil">night</sun>  <!-- Civil sunrise -->
      <moon>set</moon>
   </entry>
   <entry>
      <date>2009-10-02 13:41:00</date>
      <sun>day</sun>
      <moon>rise</moon>
   </entry>
   <entry>
      <date>2009-10-02 19:35:00</date>
      <sun>day</sun>
      <moon>transit</moon>
   </entry>
   <entry>
      <date>2009-10-03 01:29:00</date>
      <sun type="civil">night</sun>
      <moon>set</moon>
   </entry>
   <entry>
      <date>2009-10-03 13:43:00</date>
      <sun>day</sun>
      <moon>rise</moon>
   </entry>
   <entry>
      <date>2009-10-03 19:37:00</date>
      <sun>day</sun>
      <moon>transit</moon>
   </entry>
</ephemeris>
```

Note that in most cases, information about the moon is returned as well.

3.4.6.2 Timezone data

The time zone collection can provide time zone for a specific longitude and latitude based on nautical time zones that consist of 15° gores centered on the prime meridian or based on civil boundaries. In general, the nautical gores are preferred as the civil boundaries are from a community effort maintained at earthtools.org and may be subject to error. An example of a nautical time zone query (the default) is:

```
collection("ext:timezone")/latitude=32.8/longitude=243.8!
```

Arguments can appear in any order and are:

- longitude and latitude – Position of the location in degrees for which the timezone is to be computed. Latitude must be in the interval between 90° (N) and -90° (S), and longitude should be between 0 and 360° E although the mediator will also take degrees west as a negative number. Note that this is the format in which Tethys stores latitude and longitude and no conversion is needed.
- tztype – Must be "nautical" or "civil," nautical is the default if omitted. Use civil with extreme caution as it has not been well verified.

The query above produces the following XML.

```
<?xml version="1.0" encoding="utf-8"?>
<timezone xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:noNamespaceSchemaLocation="http://www.earthtools.org/timezone-1.1.xsd">
   <version>1.1</version>
   <location>
      <latitude>32.800000</latitude>
      <longitude>-116.200000</longitude>
   </location>
   <offset>-8</offset>
   <suffix>U</suffix>
   <localtime/>
   <isotime/>
   <utctime/>
   <dst>Unknown</dst>
</timezone>
```

In most cases, the element of interest in a timezone query is the offset which in this case is -8 hours from UTC.

3.4.6.3 NOAA ERDDAP data

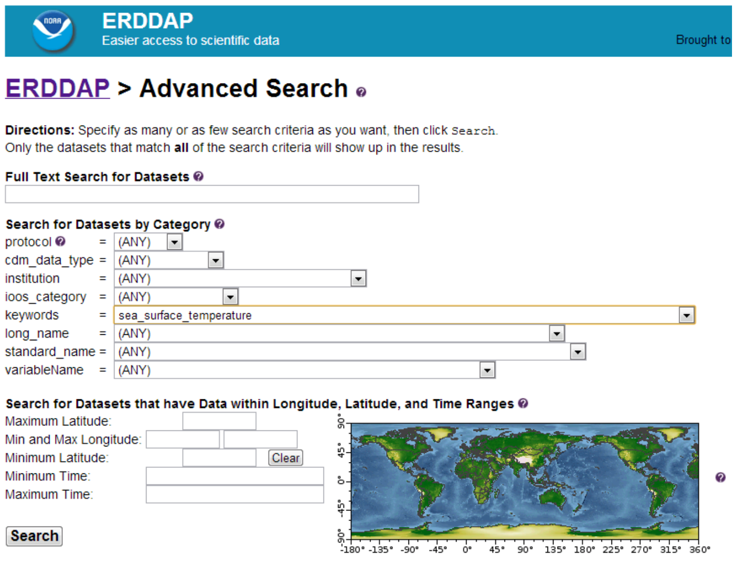
NOAA's Environmental Research Division Data Acccess Program (ERDDAP) provides a method of accessing a wide variety of environmental and biological data. ERDAP provides code to access most environmental data directly, but using the Tethys interface permits the queries to be driven by results of other queries. In addition, the next release of Tethys will support caching of external queries at the server. The impact of this is that during development of research code, users frequently make the same query over and over again. By maintaining a cache at the server which in most cases is on the local area network, the retrieval time is likely to be significantly faster on subsequent queries. In addition, it reduces the load on remote servers.

ERDAP organizes data either as a grid or a table and uses data access protocols named Griddap and Tabledap respectively. Latitude and longitudes follow the same conventions as Tethys, latitude is expressed in degrees North and longitude in degrees East.

The first step in using ERDDAP is to decide what type of data is to be used and then to find an appropriate data set. We will begin by looking for sea surface temperature. Throughout this section, we will use examples from the Matlab client (section 3.7). In this example, we will begin by looking for sea surface temperature and assume that we do not know anything about ERDDAP's naming conventions. Consequently, we begin by invoking dbERDDAPSearch with no search parameters:

```
dbERDDAPSearch(queryH);  % Assumes that queryH = dbInit() has been executed
```

This function returns the URL of the ERDDAP search page, but more importantly opens a web browser that allows one to search for a desired dataset. The ERDDAP search page allows full text search as well as search by a number of categories as well as by geo-temporal constraints. In our case, we will use the keywords category to search for sea_surface_temperature:


ERDDAP
Easier access to scientific data
Brought to

ERDDAP > Advanced Search

Directions: Specify as many or as few search criteria as you want, then click `Search`.
Only the datasets that match **all** of the search criteria will show up in the results.

Full Text Search for Datasets

Search for Datasets by Category

protocol	=	(ANY)
cdm_data_type	=	(ANY)
institution	=	(ANY)
ioos_category	=	(ANY)
keywords	=	sea_surface_temperature
long_name	=	(ANY)
standard_name	=	(ANY)
variableName	=	(ANY)

Search for Datasets that have Data within Longitude, Latitude, and Time Ranges

Maximum Latitude:
Min and Max Longitude:
Minimum Latitude:
Minimum Time:
Maximum Time:

Figure 6 - The ERDDAP search web interface allows one to search for data by specifying multiple criteria.

Geographic constraints can be found by specifying a bounding box either in the boxes or by dragging a rectangle on the map. Time constraints are specified in the ISO 8601:2004 time format used by Tethys (e.g. 2013-01-30T18:22:30Z). After pressing the Search button, the results will show a list of datasets meeting the specified criteria.

Each dataset has a unique identifier (ID) that will be used in all queries involving that dataset. In this case, we will select NOAA Coastwatch's one day SST composite: erdGRssta1day.

As one learns the search vocabulary, it becomes relatively simple to search for specific datasets from the command line. Each of the search parameters are joined by ampersand (&). The following Matlab and XQuery statements both find the URL for a region within approximately 5 km of an instrument deployed on the south east side of the Santa Cruz Basin in the Southern California Bight:

```
dbERDDAPSearch(queries, 'keywords=sea_surface_temperature&minLat=33.47&maxLat=33.56&
    minLong=240.71&maxLong=240.80')
```

Although not covered until the section on the XQuery language, it is worth noting that this Matlab function simply translates the search to an XQuery which returns a URL that is then opened by the Matlab function:

```
collection("ext:erddap_search)/keywords=sea_surface_temperature&minLat=33.47&maxLat=33.56&
    minLong=240.71&maxLong=240.80!
```

Once the ERDDAP data set has been identified, it can be queried to retrieve the data. In this example, we will assume that a one day composite sea surface temperature would suffice and will use the NOAA Coastwatch eight day composite sea surface temperature dataset from the Aqua MODIS satellite which has the dataset identifiier erdMBsstd1day. When we locate this dataset in the web page, we see that the data is listed in the Griddap column indicating that we should expect gridded data to be returned (Figure 5).

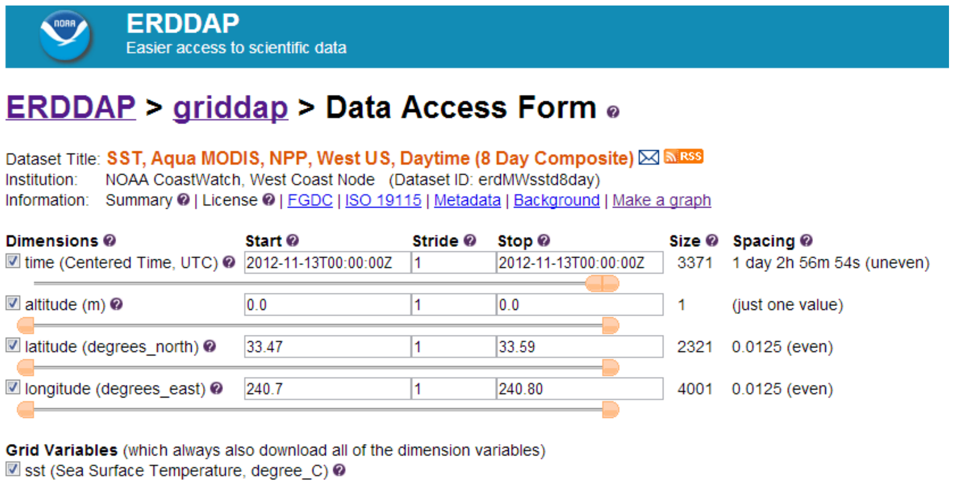
GridDAP Data	Sub-set	Table DAP Data	Make A Graph	WMS	Title	Summary	FGDC,ISO,Metadata	Background Info	RSS	E-mail	Institution	Dataset ID

data			graph	M	SST, Aqua MODIS, NPP, West US, Daytime (8 Day Composite)		F I M	background	R	✉	NOAA CoastWatch	erdMWsstd8day

Figure 7 - Row from an ERDDAP data search for sea surface temperature.

Other sources, such as buoys, might be expected to return tabular or vector data as shown in the Tabledap column.

Clicking on the data link (Figure 5) exposes more information about the dataset (Figure 6). It shows the dimensions of the dataset indices. To query this dataset, we need to specify four sets of indices: time, altitude, latitude, and longitude. The minimum and maximum values of the dataset can be seen by moving the cursor over the dimension or in the more detailed data attribute structure which is shown beneath the sliders although it has not been reproduced here.


ERDDAP
Easier access to scientific data

ERDDAP > griddap > Data Access Form

Dataset Title: SST, Aqua MODIS, NPP, West US, Daytime (8 Day Composite) RSS
Institution: NOAA CoastWatch, West Coast Node (Dataset ID: erdMWsstd8day)
Information: Summary | License | FGDC | ISO 19115 | Metadata | Background | Make a graph

Dimensions	Start	Stride	Stop	Size	Spacing
✓ time (Centered Time, UTC)	2012-11-13T00:00:00Z	1	2012-11-13T00:00:00Z	3371	1 day 2h 56m 54s (uneven)
✓ altitude (m)	0.0	1	0.0	1	(just one value)
✓ latitude (degrees_north)	33.47	1	33.59	2321	0.0125 (even)
✓ longitude (degrees_east)	240.7	1	240.80	4001	0.0125 (even)

Grid Variables (which always also download all of the dimension variables)
✓ sst (Sea Surface Temperature, degree_C)

Figure 8 - ERDDAPAqua Modis 8 day sea surface temperature composite. This dataset is accessed using four dimensions: time, altitude, latitude, and longitude. Positioning the cursor (mouse pointer) over any one of these will show the possible values and the resolution of the data.

The sea surface temperature variable is called sst as shown in the Grid Variables section (Figure 6). To construct a query, we need to specify the following:

- dataset identifier, erdMWsstd8day in this example
- the variable(s) to be returned, sst,
- and a list of dimensions.

Each dimension is enclosed in square brackets, [ ], and this dataset will require four sets of these. Each set of brackets has the following syntax: [StartValue:StrideValue:StopValue] The values may either be indices from 1 to the number of grid points, or in the units associated with the grid axis (e.g. time, longitude, etc.). When values are specified in units as opposed to indices, they must be enclosed in parentheses ( ). The StrideValue indicates how often data should be returned. A stride of one indicates that all data points are returned, two would be every other one, etc.

Continuing our example, we would have the following values:

- time: [(2012-11-13T00:00:00Z):1:(2012-11-13T00:00:00Z)]
- altitude: [(0.0):1:(0.0)]'
- latitude: [(33.47):1:(33.59)]
- longitude: [(240.7):1:(240.80)]

These are all assembled as follows in an XQuery:

```
collection("ext:erddap")/erdMWsstd8day?sst[(2012-11-13T00:00:00Z):1:(2012-11-
    13T00:00:00Z)][(0.0):1:(0.0)][(33.47):1:(33.59)][(240.7):1:(240.80)]!
```

Tethys will return an XML document with the data:

```
<?xml version="1.0" encoding="utf-8"?>
<table>
   <header>
      <time units="UTC" type="String"/>
      <altitude units="m" type="double"/>
      <latitude units="degrees_north" type="double"/>
      <longitude units="degrees_east" type="double"/>
      <sst units="degree_C" type="float"/>
   </header>
   <row>
      <time>2012-11-13T00:00:00Z</time>
      <altitude>0.0</altitude>
      <latitude>33.475</latitude>
      <longitude>240.7</longitude>
      <sst>16.83</sst>
   </row>
   <row>
      <time>2012-11-13T00:00:00Z</time>
      <altitude>0.0</altitude>
      <latitude>33.475</latitude>
      <longitude>240.7125</longitude>
      <sst>16.77</sst>
   </row>
   … more entries
</table>
```

which consists of a header element describing the data and the units in which they are represented. Following the header is a series of row elements, where each element describes a grid point.

Language specific interfaces will parse this information into a usable format. As an example, the Matlab command dbERDDAP expects a query handler and the portion of the query string between collection("ext:erddap)/ and the exclamation point (!):

```
data = dbERDDAP(queries, 'erdMWsstd8day?sst[(2012-11-13T00:00:00Z):1:(2012-11-
    13T00:00:00Z)][(0.0):1:(0.0)][(33.47):1:(33.59)][(240.7):1:(240.80)]')

data = 

          hdr: [5x1 struct]
         time: {90x1 cell}
     altitude: [90x1 double]
     latitude: [90x1 double]
    longitude: [90x1 double]
          sst: [90x1 double]
```

When requesting ERDDAP data, it is currently returned as columnar data regardless of whether the dataset was produced by GRIDDAP or TABLEDAP. This can be reshaped into matrix format by using the Matlab dbERDDAPReshape function. Future releases will do this automatically. The user must specify the number of axes in the dataset:

```
grid4D = dbERDDAPReshape(data, 4)

grid4D = 

          hdr: [5x1 struct]
         time: {4-D cell}
     altitude: [4-D double]
     latitude: [4-D double]
    longitude: [4-D double]
          sst: [4-D double]
       labels: [1x1 struct]
```

If we wished to see sea surface temperature from the first day, `grid4D.sst(1,1,:,:)` could be used. Unfortunately, Matlab remembers that this is the third and fourth dimension of a four dimensional matrix, and using the data in this format is difficult. The data can be reduced to a standard matrix with the squeeze command:

```
squeeze(grid4D.sst(1,1,:,:))
```

which removes singleton dimensions.

3.5 XQuery

XQuery is a language used to query XML databases. Walmsley's (2006) book on XQuery provides an excellent and complete introduction to XQuery and is recommend reading for people who wish to become experts in XQuery. Many useful queries can be performed using the Matlab client with no knowledge of XQuery whatsoever. However, for users who wish to create complicated custom queries, investing the time to learn XQuery will be beneficial. Our goal in this section is to provide a gentle and incomplete introduction to XQuery, deferring advanced materials to other sources such as Walmsley's book.

3.5.1 Our first query

It is helpful to run queries interactively when designing them, and the Matlab interface provides a good way to do this. The Matlab client is described in section 3.7, and the Matlab function dbRunQueryFile() is particularly helpful. We begin with a query to find all deployments where effort has been put into finding Pacific white-sided dolphin clicks:

```
import schema namespace ty="http://tethys.sdsu.edu/schema/1.0" at "tethys.xsd";

<ty:Result xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
{
for $detections in collection("Detections")/ty:Detections
  (: 180444 is the Pacific white-sided dolphin :)
  (: We'll see how to find this automatically later :)
  where $detections/Effort/Kind/SpeciesID = 180444
  return
     <Effort>
     {$detections/DataSource}
     </Effort>
}
</ty:Result>
```

The query begins with an import statement. This is required for nearly every Tethys query and defines what is known as a namespace. Namespaces can be thought of as prefixes that can distinguish elements with the same name. As an example, the first element in a Tethys detections document is Detections. To distinguish this from other possible Detections documents established by other groups, we associate it with a namespace. The namespace used by Tethys is http://tethys.sdsu.edu/schema/1.0. The first import statement:

```
import schema namespace ty="http://tethys.sdsu.edu/schema/1.0" at "tethys.xsd";
```

states that we will abbreviate the namespace as "ty," and provides a hint to the XML database as to where the schema definition will reside (at file tethys.xsd on the server). Top-level elements within the Tethys schema can now be denoted with a ty: prefix, e.g. <ty:Detections>. Note that there is nothing special about the choice of the abbreviation ty, it is the namespace itself, http://tethys.sdsu.edu/schema/1.0, that is important.

XQueries return XML documents. One strategy in designing XQueries is to design a document skeleton and have XQuery fill in portions of it. Tethys provides a generic document element called `<Result>` whose schema permits any valid XML, and we note that the XML is bracketed by:

```
<ty:Result xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
…
</ty:Result>
```

The xsi namespace declared in <ty:Result> is not mandatory, but it will prevent the children of <ty:Result> from having the xsi namespace in each element. The namespace is present in Tethys documents as they reference a schema which is part of the http://www.w3.org/2001/XMLSchema-instance namespace. To distinguish the XQuery code from the XML document, curly braces { } are used and we see that { } brackets the XQuery code in our query.

Let us turn our attention to the XML code itself which we number for convenience:

```
1. for $detections in collection("Detections")/ty:Detections
2.   (: 180444 is the Pacific white-sided dolphin :)
3.   (: We'll see how to find this automatically later :)
4.   where $detections/Effort/Kind/SpeciesID = 180444
5.   return
6.    $detections/DataSource
```

Let us begin by examining portions of line 1. The path expression (referred to as an XPath), `collection("Detections")/ty:Detections`, returns a list of documents in the collections detection whose top-level element is <ty:Detections>. This should be every document in the Detections collection, but if there were documents in the Detections collection that started with a different element, they would not be included. The `for` loop will assign the variable `$detections` to each one of these documents at the `<ty:Detections>` level. Note that all XQuery variables start with the dollar sign ($).

If we wished to access the Description element for a group of detections, we could do so with `$detections/Description`. The optional `where` clause allows us to restrict, or filter, the selection of documents based on their contents. In this case, we are looking for Pacific white-sided dolphins, TSN 180444 and will see later how we could write a query for something less obscure, such as using the common name "Pacific White-sided Dolphin" or the scientific name "Lagenorhynchus obliquidens." This is also noted in the comments of lines 2 and 3. Any text between a (: and :) are interpreted as comments. In any case, to find effort where analysts or algorithms were searching for any type of call associated with this species, we construct an *XPath* from `$detections` to the species identifier. The path is based on the structure of the schema (see section 5), `$detections/Effort/Kind/SpeciesID`, and has a check for equality (line 4).

For each document that remains after our filter for Pacific white-sided dolphins, we wish to return information about the data source. This is indicated by the return statement on line 5 which is followed by either an XQuery expression or XML. In the above example, it is followed by an XQuery expression that states that the DataSource element and its children which specify the project, deployment, and site should be returned. A sample output might look like the following:

```
<?xml version="1.0" encoding="utf-8"?>
<ty:Result xmlns:ty="http://tethys.sdsu.edu/schema/1.0"
           xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
<DataSource>
      <Project>SOCAL</Project>
      <Deployment>40</Deployment>
      <Site>M</Site>
   </DataSource>
   many entries omitted…
   <DataSource>
```

```
      <Project>SOCAL</Project>
      <Deployment>44</Deployment>
      <Site>N</Site>
   </DataSource>
</ty:Result>
```

Alternatively, we could have placed XML in the return statement and line 5 could have read:

```
<Effort>
{$detections/DataSource}
</Effort>
```

where the XPath element `$detections/DataSource` is enclosed in { } to indicate that it is XQuery code rather than part of the XML document. The result would be similar, except each `<DataSource>` element would be enclosed within an `<Effort>` element.

3.5.2 Let statements and modules

We extend our simple query with the introduction of other variables and a library function call to eliminate the need to know the TSN for Pacific white-sided dolphins. Variables can be introduced with the let statement. Here, we use a library function to look up the TSN from the Latin species name and assign it to a variable:

```
1.  import schema namespace ty="http://tethys.sdsu.edu/schema/1.0" at "tethys.xsd";
2.  import module namespace lib="http://tethys.sdsu.edu/XQueryFns" at "Tethys.xq";

3.  <ty:Result xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
4.  {
5.    (: Find TSN from species name :)
6.    let $id := lib:completename2tsn("Lagenorhynchus obliquidens")
7.    for $detections in collection("Detections")/ty:Detections
8.    where $detections/Effort/Kind/SpeciesID = $id
9.    return
10.     $detections/DataSource
11. }
12. </ty:Result>
```

This XQuery returns the same values as the previous ones, but adds an additional import to access the library module in the namespace http://tethys.sdsu.edu/XQueryFns (line 2) which is given the abbreviated name *lib*. The lookup is performed by function completename2tsn in line 6 which will map the species name to a TSN if it is in the itis collection (all cetaceans and pinnipeds as well as many fishes are in the ITIS subset that are distributed with ITIS). The value is then substituted into the equality of line 8. The results from this query will be identical to the previous one.

A description of the other functions in the module can be found in section 8. Most of the functions are useful for translating back and forth between TSNs and species names, common names, or local abbreviations.

3.5.3 Nested loops and conditional statements

We continue this with a slightly more complicated query which finds the detections themselves in documents where we know that we are looking for Pacific white-sided echolocation clicks. Note that we could have looked for detections in *every* Detection document, but it is more efficient to restrict our search to places where detection effort has been made as there should not be any on-effort detections in any document where no effort has been placed in finding them.

```
1.  import schema namespace ty="http://tethys.sdsu.edu/schema/1.0" at "tethys.xsd";
2.  import module namespace lib="http://tethys.sdsu.edu/XQueryFns" at "Tethys.xq";
3.
4.  <ty:Result xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
5.  {
6.  let $id := lib:completename2tsn("Lagenorhynchus obliquidens")
7.  for $detections in collection("Detections")/ty:Detections
8.  where $detections/Effort/Kind/SpeciesID = $id
9.  return
10. for $d in $detections/OnEffort/Detection
11.     where $d/SpeciesID = $id and $d/Call = "Clicks"
12.     return if ($d/Parameters/Subtype)
13.         then $d
14.         else ()
15. }
16. </ty:Result>
```

This example begins in a similar manner to the first one, but begins to differ in what is returned starting at line 10. The return value is actually a nested XQuery. Once we have identified a document where there was effort for Pacific white-sided echolocation clicks, we look through the on-effort detections (line 10), and then filter out all calls that were not Pacific white-sided echolocation clicks (line 11). As this is a nested XQuery, it also needs a return value. Rather than returning every detection, we wish to only return echolocation clicks that have a subtype associated with them. In Soldevilla et al. (2008), we identified two types of echolocation clicks which we called subtypes A and B. We store this distinction in Tethys by adding a `<Subtype>` element as a child of `<Parameters>`.

The if statement on line 12 is true if there is a Parameters/Subtype element relative to the current detection, $d. When this is true, the detection is returned, otherwise the empty sequence is returned which does not change the output. The following shows a sample output from this query:

```
<?xml version="1.0" encoding="utf-8"?>
<ty:Result xmlns:ty="http://tethys.sdsu.edu/schema/1.0"
           xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  … many detections omitted …
  <Detection>
      <Input_file>H:\SOCAL44N_disk06\SOCAL44N_disk06_5s_100Hz.ltsa</Input_file>
      <Start>2011-08-17T02:58:12.500Z</Start>
      <End>2011-08-17T03:18:02.500Z</End>
      <Event>02/28/12 13:05:56</Event>
      <SpeciesID>180444</SpeciesID>
      <Call>Clicks</Call>
      <Parameters>
         <Subtype>A</Subtype>
      </Parameters>
   </Detection>
   <Detection>
      <Input_file>H:\SOCAL44N_disk07\SOCAL44N_disk07_5s_100Hz.ltsa</Input_file>
      <Start>2011-09-15T02:49:27.500Z</Start>
      <End>2011-09-15T03:18:17.500Z</End>
      <Event>03/02/12 10:58:35</Event>
      <SpeciesID>180444</SpeciesID>
      <Call>Clicks</Call>
      <Parameters>
         <Subtype>A</Subtype>
         <UserDefined>
            <peak_1_low>21700.0</peak_1_low>
            <peak_2>27700.0</peak_2>
            <peak_3_high>38400.0</peak_3_high>
         </UserDefined>
      </Parameters>
   </Detection>
</ty:Result>
```

Although not shown here, the order by clause can be used to sort results and typically follows the where clause. Due to the keywords *for*, *let, order by*, where, and *return*, queries in the XQuery language are frequently referred to as FLOWRs (pronounced flowers).

3.6 Java client

The Java client provides basic functionality and consists of two Java classes. The Client class represents client information about the Tethys server, and the Queries class provides an interface to the server.

The Client constructor has a single argument, a URL which will be used to communicate with the Tethys server. This can either be an instance of the java.net.URL or java.lang.String classes. Once the client is created, one can create a Queries instance which takes an instance of Client as the argument to its constructor:

```
import dbxml.Client;
import dbmxl.Queries;

// Initialize connection to Tethys on port 9779 (the default port).
// Substitute an appropriate domain, use https:// for a secure socket layer connection
// The java.net.URL class can also be used.
Client client = new Client("http://tethys.nwfsc.noaa.gov:9779");
Queries queryHandler = new Queries(client);
```

We refer to instances of the Queries class as query handlers. Once a query handler has been constructed, the Client instance is no longer needed. The query handler provides the following methods:

String Query(String query) – Executes the XQuery contained in query and returns the result in a string.

String QueryTethys(String query) – Similar to the Query method, except that the following namespace declarations are prepended to the query:

```
import schema namespace ty="http://tethys.sdsu.edu/schema/1.0" at "tethys.xsd";
import module namespace lib="http://tethys.sdsu.edu/XQueryFns" at "Tethys.xq";
```

These imports load in the schema and library module for Tethys and are required for many Tethys queries. The primary purpose of this method is to let interactive users perform short queries without the need to declare namespaces. In most production code, the user should use Query or QueryReturnDoc.

Document QueryReturnDoc(String query) – Executes the XQuery contained in query and returns the result as a document object model (DOM) object. DOM is an in-memory graph representation of an XML document and provides a standard interface to access the various elements of the XML document. The Document class is defined in `org.w3c.dom.Document`. There are numerous tutorials on the DOM interface that can be found on the web and books on XML.

String xmlpp(String xmldoc) – Given a serialized XML document (one represented as a string), format it to be aesthetically pleasing with proper indentation. Note that this can be slow for large documents. As an example if xmldoc contains:

```
<Detection><Input_file>H:\SOCAL44N_disk06\SOCAL44N_disk06_5s_100Hz.ltsa<
/Input_file><Start>2011-08-17T02:58:12.500Z</Start><End>2011-08-
17T03:18:02.500Z</End><Event>02/28/1213:05:56</Event><SpeciesID>180444</
SpeciesID><Call>Clicks</Call><Parameters><Subtype>A</Subtype></Parameter
s></Detection>
```

it will be transformed to:

```
<Detection>
  <Input_file>H:\SOCAL44N_disk06\SOCAL44N_disk06_5s_100Hz.ltsa</Input_file>
  <Start>2011-08-17T02:58:12.500Z</Start>
  <End>2011-08-17T03:18:02.500Z</End>
  <Event>02/28/12 13:05:56</Event>
  <SpeciesID>180444</SpeciesID>
  <Call>Clicks</Call>
  <Parameters>
    <Subtype>A</Subtype>
  </Parameters>
</Detection>
```

URL getURL() – Returns the URL to which the query handler is associated.

String getURLString() – Returns a string representation of the URL returned by getURL().

3.7 Matlab client

The Matlab client can be used to add data to the database and to use the Tethys methods for querying the database. The installer will have copied several files to the MatlabClient directory which is located in the Tethys\MatlabClient relative to the root folder of the installation. For “Just me” (non-administrative installs), this is relative to your account directory, which is usually c:\Users\YourLoginName. For “All users” (administrative installs), this is usually in C:\Program Files\Tethys. If you or the person who installed Tethys chose a different location, you will need to modify appropriately.

These are collected into subfolders: db, db\c and vis. The functions under db are related to accessing the database while the functions in the vis directory provide support for visualizing data.

Once Matlab has started, add the db, db\c and vis directories to your path. This can be done using Matlab's pathtool or addpath commands. The pathtool command allows you to save the path for the next time you start Matlab. Alternatively, addpath commands can be put in the startup.m file which is executed when Matlab starts. See the Matlab documentation for details.

Once the path is set, dbInit() to create a database query handler:

```
% Any variable name is fine, but we will use query_h throughout this chapter
>> query_h = dbInit();
```

The database query handler is the first step in using Tethys in Matlab, and will allow the user to query the Tethys metadata database that has been created on the server and to use the Tethys methods to perform spatial and temporal analyses. While the Tethys interface to Matlab permits the user to query the Tethys server using XQuery, Matlab functions for a number of common queries have been written to generate the queries and parse the results into structures that are easily usable within Matlab.

For any function, one can type "help" or "doc" followed by the function name. As an example, in the Matlab command window, typing

doc dbInit

brings up the help browser with the following text:

```
dbInit(optional_args)
Create a connection to the Tethys database.
With no arguments, a connection is created to the default server
defined within this function.

Optional args:
'Server', NameString - name of server or IP address
        Use 'localhost' if the server is running the
        same machine as where the client is executing.
'Port', N - port number on which server is running
'Secure', false|true - make connection over a secure socket

Returns a handle to a query object through which Tethys queries
are served.
```

If you were running your server in unencrypted mode (secure-socket-layer=false) on the same computer as your Matlab client, you would type:

```
query_h = dbInit('Server', 'localhost', 'Secure', false);
```

to obtain the query handler. Many functions in the Tethys Matlab client take optional arguments that are specified by keyword (e.g. 'Secure') and value pairs. Again, one can see the optional arguments by using help or doc followed by the function name in the Matlab command window.

Once the query handle has been created, it is possible to perform a variety of tasks.

3.7.1 Uploading data

Detection data to be added to your Tethys metadata database from source materials. These source materials are typically generated by an analyst or automated detector. The description can be in XML matching the Detection schema (see Appendix for details) or in a variety of other formats. Tethys provides a facility to specify a data source and import row oriented data from that source. The sample database provides an example of importing from a spreadsheet and from a MySQL relational database.

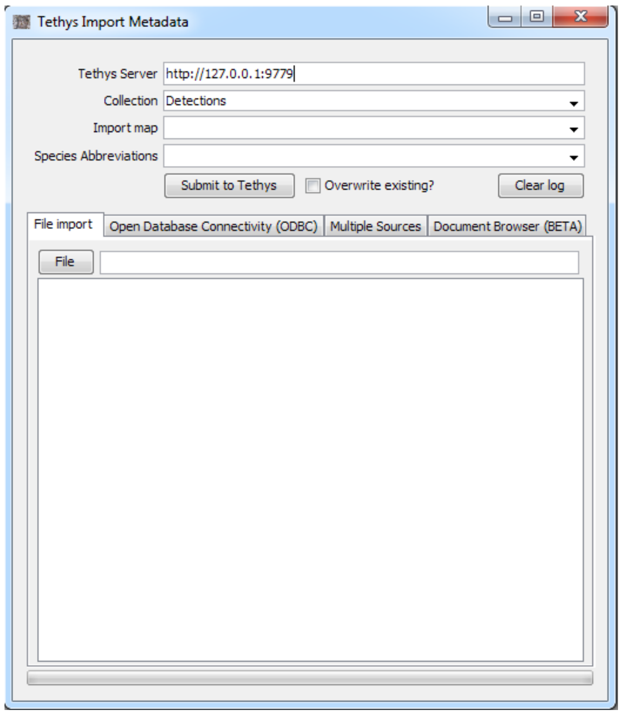
It is important that the data source have the mandatory information for each collection to which it is to add. Detections can be added by generating XML matching uploaded from Matlab using a spreadsheet format such as Excel. The uploader program will upload any image and audio files listed in the image and audio columns. These are expected to be in directories with the same name as the spreadsheet with –image and –audio appended. As an example, if the spreadsheet is Socal36Odontocetes-SilbidoDetector the image and audio directories would be *Socal36Odontocetes-SilbidoDetector-image* and *Socal36Odontocetes-SilbidoDetector-audio.* A maximum of 500 files can be attached to any detections document.

This information is converted into XML and uploaded into the database using the Matlab dbSubmit function from the Tethys methods. The uploader will prompt for a spreadsheet to upload to the database. As will be seen later in the XQuery section, a name is associated with each XML document. In most cases, we will never need to know the name of the document, but it must be unique. We use the name of the spreadsheet without the spreadsheet extension as the document name. This has the advantage that the document names can be meaningful (e.g. Socal36Odonotocetes-SilbidoDetector), but it also means that the spreadsheet names must be unique.

Suppose we wanted to upload a set of detections from the spreadsheet SOCAL41N_Minke_ajc.xls. From Matlab, we would type one of the following:

```
dbSubmit() % default behavior
dbSubmit('Server', 'localhost') % server is on same machine
dbSubmit('QueryHandler', query_h) % query handler already setup
```

Regardless of how you invoke dbSubmit, a dialog similar to the following will appear:



Tethys Server: http://127.0.0.1:9779
Collection: Detections

Figure 9 Detection submission for Matlab client

You can browse for a detections spreadsheet by pressing the File button and then press the Upload button. The event log will report success or provide some diagnostic of problems associated with your spreadsheet. Most problems are related to bad data entry.

The overwrite check box allows replacement of existing files and the secure socket layer checkbox will use an encrypted channel to submit data. Note that the client and server must both be operating in the same state (unencrypted or encrypted).

For more information on uploading data, refer to the Appendix.

3.7.2 Querying the database

All Matlab queries to the database using the Tethys methods require a query handler to be created (see the beginning of section 3.2). While the query handler is capable of querying XML directly using the XQuery language, a number of common queries have been packaged into functions that can be used without any knowledge of XQuery.

Functions to access the database start with the prefix db. Most of these functions require the query handler returned from dbInit as their first argument. Optional arguments let users specify criteria such as spatial or temporal information, species or call types of interest, etc. Queries can be made using a single value ('Site', 'M') or using a list ('Site', {'M', 'N'}) as desired.

Deployments:

- dbDeploymentInfo() – Retrieves information about deployments.

Detections:

- Effort information: dbGetEffort() – Retrieves information about effort to detect species.
- Detections: dbGetDetections() – Retrieves start and end times of detections meeting the specified criteria. As of v2.3, we use a pre-compiled C++ extension (Windows) to format the detection data into Matlab variables. We include the source files for compilation in Linux, however it is currently not actively supported. dbGetDetectionsMatlab() can be used instead, which was the standard of prior versions.

Environmental data

- Diel: dbDiel() – Provides information about sunrise and sunset.
- dbGetLunar() – Provides information about lunar rise and set as well as illumination (without taking into account cloud cover).
- dbERDDAPSearch() – Searches NOAA's Environmental Research Division Data Acccess Program (ERDDAP) servers to find an appropriate server for various oceanographic data such as ice coverage over a specified spatial-temporal range.
- dbERDDAP() – Retrieves oceanographic data from a specific server.

3.7.3 Visualization

Note: visPresence uses a drawing technology called OpenGL. A bug has been observed in some cases where saving figures rendered with OpenGL appear entirely black. Postings in Matlab forums attribute this to a bug in the operating system video driver, and indicate that updating your video driver and rebooting the machine will frequently remedy the problem. Contact your system administrator to help you upgrade your video driver if you do not know how to do this.

3.8 Python client

The Python client is designed primarily for administrative purposes and to provide low level access (e.g. users writing their own XQueries). All of the supplied Python programs can be invoked from the command line. They all have the following options in common:

-h or --help	Show a help message and exit
--port	Specify a port number. Defaults to 9779.
--servertype	Server transport layer type, do not set.
--server	Server address. Defaults to the name specified for the server during the installation of clients.

Each client is invoked by opening a command console, changing to the folder where the client was installed (e.g. C:/Program Files/Tethys/client-python) and typing the name of the command followed by any needed arguments.

3.8.1 Administrative clients

3.8.1.1 checkpoint.py

checkpoint.py is used for creating a checkpoint in the database. Checkpoints verify that any changes to the database are in a stable state. The database automatically checkpoints itself each time it starts. See section 4.1 for details on checkpoints.

3.8.1.2 clear_documents.py

clear_documents.py removes all documents from a collection. A list of collection names to be cleared are given, e.g.

```
clear_documents.py Deployments SpeciesAbbreviations
```

Use with caution. The primary use for this command is when importing from a database. As an example, the Scripps Whale Acoustics Lab stores instrument deployments in a MySQL database. To update the Deployments collection, the collection is first cleared, then import.py is used to import all of the deployments.

3.8.1.3 import.py

import.py provides a mechanism to import documents into a collection. Use of this client is described in section 3.2.1 on data import.

3.8.1.4 remove.py

remove.py is used to remove a specific document from a specified collection. Document names are either based on:

- the filename of the submitted data (without the extension) or
- a database name followed by an _ and a number. As an example, the Scripps Whale Acoustics Lab imports deployments from database HarpDB and the deployments are named HarpDB_1, HarpDB_2, etc.

Example: remove.py Deployments HarpDB_235

3.8.1.5 shutdown.py

shutdown.py requests the server to exit. Queries in progress are handled and then the server will stop. Example:

```
shutdown.py
Connecting to server:  http://127.0.0.1:9779 plain text (UNSECURED)...
<Tethys> exiting </Tethys>
```

3.8.1.6 update.py

update.py is used for rebuilding collections from source documents that have already been submitted. See section 3.2.2 for details.

3.8.1.7 Low level access – client.py

client.py provides an example of how to use an XQuery from Python. Its purpose is to provide an example for users who wish to write XQueries against the server without the need for Matlab or Java.

3.9 Extending representation – Case study: Northeast Fisheries Science Center Minke Boing analysis

NOAA's NEFSC conducted an analysis of Minke boing calls where received levels were estimated for individual pulses near the beginning, middle and end of each call (Table 3). The Detection element in the Detections schema (set of rules indicating valid syntax) has methods to support recording nonstandard data. In the Parameters section, there is an element called UserDefined. We can generate arbitrary XML as a child of this element (see the appendix on data import, specifically section 6.3 on source maps).

This is where XML can shine by allowing both standard and non-standard elements to be mixed. The schema for detections indicates that any set of elements are permitted under UserDefined, permitting extensibility where it is needed while preserving consistency elsewhere.

The source material contains multiple lines, and some of the information is associated with the entire call (average received level) while other parts are pulse specific. This can be represented via XML with the following structure which describes the first Boing in the table:

```
<Detection>
       <Start> … [field values represented by …] </Start>
       <End> … </End>
       <SpeciesID> … </SpeciesID>
       <Call> Boing </Call>
       <Parameters>
            <ReceivedLevel_dB> 101.841103727 </ReceivedLevel_dB>
            <MinFreq_Hz> 45.6 </<MinFreq_Hz>
            <MaxFreq_Hz> 169.1 </MaxFreq_Hz>
            <UserDefined>
              <pulse>
```

```
                <number> 1.0 </number>  <!-- Call number -->
                <signal>
                    <Selection> 5.0 </Selection>
                    <end_s> 36988.673 </end_s>
                    <rms_amp_dBre1uPa> 103.684142949 </rms_amp_dBre1uPa>
                    <f_rms_amp_u> 139.1 </f_rms_amp_u>
                    <tag> pt1_A </tag>
                    <start_s> 36988.374 </start_s>
                    <Channel> 2.0
                    </Channel>
                <ambient>
                    <low_Hz> 47.6 </low_Hz>
                    <Selection> 2.0 </Selection>
                    <end_s> 37010.763 </end_s>
                    <rms_amp_dBre1uPa> 99.0726664225 </rms_amp_dBre1uPa>
                    <f_rms_amp_u> 81.8 </f_rms_amp_u>
                    <tag> pt1_A </tag>
                    <high_Hz> 171.1 </high_Hz>
                    <start_s> 37010.463 </start_s>
                    <Channel> 2.0 </Channel>
                </ambient>
              </pulse>
              <!-- Other pulses omitted for brevity -->
           </UserDefined>
        </Parameters>
    </Detection>
```

The UserDefined elemnt allows embedding arbitrary information such as whistle contour tracks, etc.

Selection	Original/ Ambient	Channel	Begin Time (s)	End Time (s)	Low Freq (Hz)	High Freq (Hz)	Tag	F-RMS Amp (u)	RMS Amplitude (dB re 1 µPa)	Subtracted RMS Amp (dB re 1 µPa)	Pulse train	Average RL
2	A	2	37010.463	37010.763	47.6	171.1	pt1_A	81.8	99.1	101.8	1	98.7
5	O	2	36988.374	36988.673	45.6	169.1	pt1_A	139.1	103.7			
4	A	2	37011.004	37011.293	46.7	195.4	pt1_B	87.4	99.6	97.1		
6	O	2	36998.247	36998.535	47	195.8	pt1_B	109.2	101.6			
6	A	2	37011.471	37011.737	52.5	164.7	pt1_C	78.7	98.7	97.1		
7	O	2	37009.577	37009.843	51.2	163.5	pt1_C	102.1	101.0			
8	A	5	37294.504	37294.748	50	171.7	pt2_A	70.3	97.8	96.5	2	96.4
8	O	5	37276.193	37276.437	49.7	171.3	pt2_A	93	100.2			
10	A	5	37294.914	37295.18	47.7	168	pt2_B	57.8	96.1	95.4		
9	O	5	37283.932	37284.198	46.9	167.1	pt2_B	78.8	98.7			
11	A	5	37293.887	37294.142	45.7	153.4	pt2_C	65.3	97.1	97.4		
10	O	5	37293.255	37293.51	45.5	153.1	pt2_C	93.8	100.3			

Table 3 - NOAA NEFSC Minke boing source level information. Information from pulse trains are measured near the beginning, middle, and end of each boing. Alternating lines show measurements of energy during the pulse (original) and ambient background. The estimated received levels are given along with the average received level.

3.10 Query

Tethys allows the user to both create and query a metadata database. The user can choose to use XQuery for advanced queries, or the user can take advantage of many standard queries within the Tethys methods.

XQuery from within Matlab

Here we show an example using the XQuery methods in the Matlab environment. From the Matlab command window, first we need to start a query handler.

```
query_h = dbInit('Server', 'localhost');
```

Now that a query handler exists, we can query our metadata database. For example, we might be interested in the OffEffort detections for a portion of the database. In a database of humpback whale detections, we might have detected other species in addition to the humpbacks even though our main objective was to detect humpbacks.

To do this, we must first define our namespace for the query, in this example, called ty.

```
query_h.Query('import schema namespace ty="http://tethys.sdsu.edu/schema/1.0"
at "tethys.xsd";
```

where:

query_h is the already defined query handler

ty is the name of our new namespace

http://tethys.sdsu.edu/schema/1.0 is the string specifying the location of the schema used

tethys.xsd is the name of our database

Now we have not only created a query handler, but we have also created a namespace. We can go on to querying our data. In this example, we want to return the number of OffEffort detections.

```
count(collection("Detections")/ty:Detections/OffEffort/Detection)')
```

Where

Detections is the data to query

ty is our namespace

OffEffort is the element of interest

Detection is the attribute of the element to find

Another common query is to list all of the species that have effort. Again, we first need to have a query handler. Next, we create a namespace, and then perform the query.

```
query_h.Query('import schema namespace ty="http://tethys.sdsu.edu/schema/1.0" at
"tethys.xsd";
distinctvalues(collection("Detections")/ty:Detections/Effort/Kind/SpeciesID)')
```

where:

query_h is the already defined query handler

ty is the name of our new namespace

http://tethys.sdsu.edu/schema/1.0 is the string specifying the location of the schema used

tethys.xsd is the name of our database

Detections is the data to query

Effort is the element of interest

Kind/SpeciesID is the attribute of the element to find

In addition to the simple queries described above, complex queries are possible using Tethys. In this example, we would like a list of scientific names for all of the species for which we have effort. However, our Detections documents encode species names as an ITIS taxonomic serial number (TSN). Fortunately, the ITIS collection can let us associate the scientific name with the TSN.

We could write a FLOWR expression to match the TSN with the species name, but Tethys has a number of library functions that will let us do this with minimal effort.

First we will import our namespace.

```
import schema namespace ty="http://tethys.sdsu.edu/schema/1.0" at "tethys.xsd";
```

Next we need to import the software library containing the function that will map from a TSN to a Latin species name which the ITIS database refers to as a *completename*.

```
import module namespace lib="http://tethys.sdsu.edu/XQueryFns" at "Tethys.xq";
```

In the previous examples, the results of our queries were displayed on the screen. Here we will instead save the query returns as a variable, called $tsns.

```
let $tsns := distinct-values(collection("Detections")/ty:Detections/Effort/Kind/SpeciesID)
```

$tsns will be the list of each SpeciesID for which we have effort. Next, we loop through each of the TSNs stored in $tsns and use the function tsn2completename to perform the mapping. We prefix tsn2completename with the namespace abbreviation lib that we defined in our module import.

```
for $tsn in $tsns
   return lib:tsn2completename($tsn)
```

where:

$tsn is a variable consisting of the scientific names

$tsns is the output of our previous query

lib refers to the software library created containing the scientific names for all species

tsn2completename is the Tethys method to match Species ID or other species format with scientific names.

The final query is as follows:

```
import schema namespace ty="http://tethys.sdsu.edu/schema/1.0" at "tethys.xsd";
import module namespace lib="http://tethys.sdsu.edu/XQueryFns" at "Tethys.xq";
let $tsns := distinct-values(collection("Detections")/ty:Detections/Effort/Kind/SpeciesID)
for $tsn in $tsns
   return lib:tsn2completename($tsn)
```

3.11 Shutting down a Tethys server

There are numerous ways to shutdown a Tethys server. The cleanest way is to use the PythonClient's shutdown script. If you added Python to your system path during the installation, you can open a command window, and navigate to the Tethys\PythonClient\src folder. Then type:

shutdown.py –server ServerName –port PortNumber

where ServerName is replaced with the name of the computer running the server (e.g. localhost if it is on the same machine) and PortNumber is the port on which the server was started. If you did not change the default port, this can be omitted. If Python is not on the system path, you will need to preface shutdown with the path to Python. For a user install to user WingedWhale with the default settings, it would be:

C:\Users\WingedWhale\Tethys\Python27\python.exe shutdown.py –server ServerName …

You can also simply kill the process, but if someone is in the middle of inserting data, it may not complete (it will not hurt the database).

4 Care and feeding of your database

4.1 Checkpoints

All database operations are made as transactions, which means that if the database dies in the middle of an operation, it should not corrupt itself. A series of transaction log files are made as changes are conducted. These can be found in the database directory. When an instance of Tethys is started, it examines the log files. If anything is amiss, it uses the log files to restore the database to a stable state with the last modification instructions either omitted or applied successfully. Once this is done, the database is checkpointed, which means that only logs created after this point are used.

The database itself is stored in a set of files with the same names as the containers and a set of files that start with __db. followed by a number. The __db files are a relational database decomposition of the XML. This is handled automatically.

Currently, there is no automatic cleanup of the log files which over time can grow to be quite large. After a checkpoint, old log files **except for the very last one can be removed** (they are numbered, e.g. log.0000000768) although this should not be done before backing up.

4.2 Backups

Your database should be backed up from time to time. The location of the database files is reported when the server first starts and may have been overridden with the resource directory (–resourcedir) startup option. Here's an example:

```
C:\Program Files\dbXMLServer\src> dbXMLserver.py
     --resourcedir=C:/Users/Tethys/metadata --secure-socket-layer false
Welcome to Tethys - Server starting...
Set cache size 1.000000 GB
Reset cache size to 524288000.000000 MB
BSDDB environment initialized
Starting DB XML in transactional mode
Checkpointing database c:/Users/Tethys/metadata/db... Checkpoint complete
Serving database c:/Users/Tethys/metadata/db via http://0.0.0.0:9779 plain text
(UNSECURED)
```

In addition to backing up the database itself, the source material used to construct the database should be backed up. This consists of spreadsheets, XML documents, and any media files that are referenced from the XML. Tethys keeps a copy of everything that you have submitted that is not from a database in the source-docs folder contained in the resource directory. It is assumed that other databases have their own backups. **Backing up source material is critical.** Should the database ever become completely corrupted or undergo major revisions, this will allow you to regenerate it with very little effort.

4.3 Help! My database has fallen and cannot get up!

4.3.1 Server will not start / Server window disappears

Double clicking on the Tethys batch file should start the server. However, if the server fails, the window will disappear. The first step in troubleshooting is to open a command window and change directory to the folder where the server was started. With the default database location, this would be as follows:

```
cd c:\Users\Tethys\metadata
```

Then start Tethys using the batch file in the directory:

```
tethys.bat
```

This will let you see the error. See below how to handle "database corrupted" messages. If there are permission problems, the account executing Tethys may not have write privileges for the folders containing the database.

4.3.2 Database is not responsive

If you are running the database from a Windows command line terminal, and if you press a key in the window, all input/output to the database may be paused, effectively blocking all operations. Making the window active by clicking on it and pressing escape will remedy this situation. When you run the database as a service this is not an issue.

Very large queries to external services take time to process. There are three components that drive how fast local data queries are processed:

1. Whether or not the data have been indexed. (We are not currently building any indices but will do so within the next couple releases.)
2. The speed and congestion of the network over which they are being transported.
3. The amount of time needed to parse the XML into a usable format at the database client. This amount of time can be greatly reduced by having queries only return the information that is needed rather than everything in a record.

4.3.3 Database is corrupted

IMPORTANT: If for some reason you start a second instance of the database on the same port, you will receive a message that the database is corrupted even though everything is fine. In this case, simply kill both processes and restart.

In many cases, restarting the database will allow the automatic recovery of the database. However, if things should become damaged beyond repair (we have yet to see this), you can use the dbxml recovery program dbrecover which is in the Tethys/dbxml-2.5.16/bin folder. Open a console window and cd to the appropriate Tethys directory, then run it (you may need to change this):

```
cd C:Users\Tethys\metadata\db
```

```
“C:\Program Files (x86)\Tethys\dbxml-2.5.16\bin\dbrecover”
```

The dbrecover program can also be run with a –c option for “catastrophic” database recovery. Finally, should all else fail, remember that Tethys retains the source documents submitted to the database in the source-docs directory and the update_documents.py program (section 3.2.2) can be used to reinsert them into a blank database. Documents derived from an external database such as MySQL or Access are not stored, it is assumed that you can use the import.py program (section 3.2.1) to reinsert these.

4.3.4 Warning for Cygwin users

Cygwin is a UNIX emulation package that people who prefer UNIX often use when running programs on Microsoft Windows. Please be aware that the Python used with the distribution can exhibit problems when running in a window other than a Microsoft Window “cmd” terminal. In particular, the mintty terminal emulator will freeze when Python sends certain character sequences, and X11 terminal emulators such as xterm have not been tested. It is possible to execute the bash shell in Windows’ cmd terminal. Simply execute bash.exe rather the terminal emulator mintty/xterm etc.

Cygwin users should also be aware that Cygwin has its own version of Python. If that python is used when invoking the server, it will not work as the bindings to Berkeley DBXML and other add-on packages will not have been installed for it.

5 Appendix: XML Schema Diagrams

The following sections of this manual provide an overview of the types of data that appear in each collection. Frequent use is made of XML schema diagrams which show the structure of the XML data. While most of the details of the XML schema need not be understood by the casual reader, a few notations are worth describing:

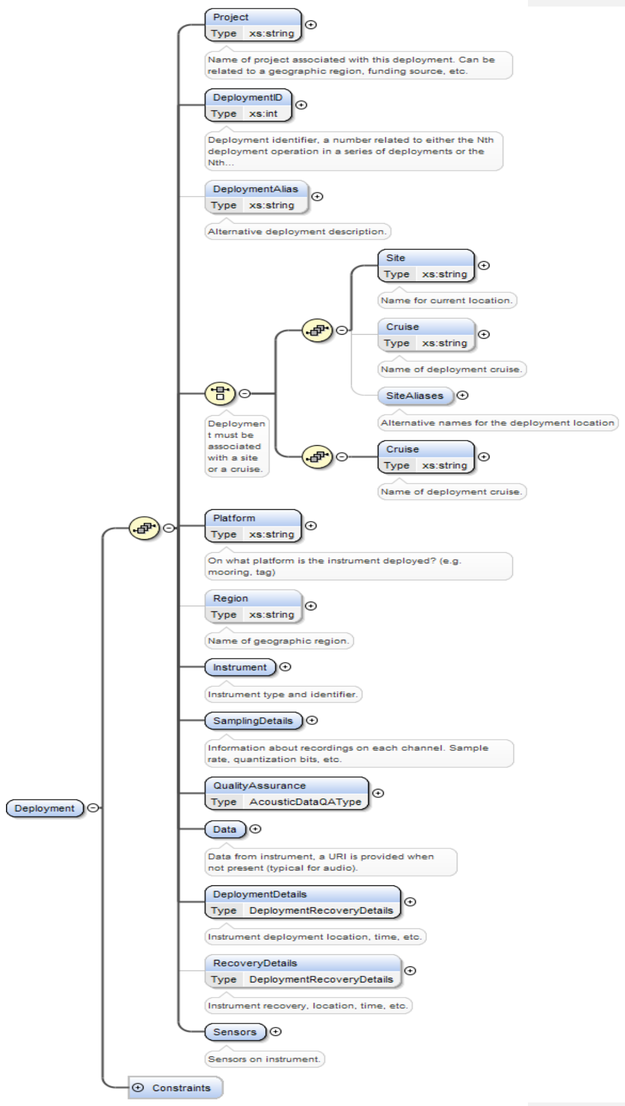
denotes a sequence of elements that must appear in the order that they appear,

is used to represent a choice, only one of the child elements (or groups of elements) can be used.

Mandatory elements are denoted by dark lines whereas optional elements have light lines. Elements that may be repeated are indicated by labels indicating how many times they can be repeated. As an example, 1 … ∞, indicates that an element must at least one time.

5.1 Deployment

Deployment records are used to track how an instrument is configured during the time that it is deployed. If the instrument is not fixed to a single point, a trackline is added showing the instrument's position at various points during the deployment. Note that while deployments describe the current configuration of the equipment, the deployment record is not designed to describe the instrument itself. It does however provide sufficient information to identify the instrument whose characteristics may be stored in a separate database.



Project
Type xs:string
Name of project associated with this deployment. Can be related to a geographic region, funding source, etc.
DeploymentID
Type xs:int
Deployment identifier, a number related to either the Nth deployment operation in a series of deployments or the Nth…
DeploymentAlias
Type xs:string
Alternative deployment description.
Site
Type xs:string
Name for current location.
Cruise
Type xs:string
Name of deployment cruise.
SiteAliases
Alternative names for the deployment location
Deploymen t must be associated with a site or a cruise.
Cruise
Type xs:string
Name of deployment cruise.
Platform
Type xs:string
On what platform is the instrument deployed? (e.g. mooring, tag)
Region
Type xs:string
Name of geographic region.
Instrument
Instrument type and identifier.
SamplingDetails
Information about recordings on each channel. Sample rate, quantization bits, etc.
QualityAssurance
Type AcousticDataQAType
Deployment
Data
Data from instrument, a URI is provided when not present (typical for audio).
DeploymentDetails
Type DeploymentRecoveryDetails
Instrument deployment location, time, etc.
RecoveryDetails
Type DeploymentRecoveryDetails
Instrument recovery, location, time, etc.
Sensors
Sensors on instrument.
Constraints

Figure 10– Top level of deployment schema. Light lines indicate optional items. Many of the items contain subinformation. XML datatypes for each element are denoted in the Type field, and the constraints indicate elements that are used to form a unique key for a deployment record.

All Tethys schema and diagrams may be retrieved at: http://tethys.sdsu.edu/schema & http://tethys.sdsu.edu/schema/diagrams respectively.

Each record associated with a specific data set within the Deployment collection is called a document. The structure of the top level of a record contains information that identifies the project and location of the deployment, the instrument, and the trackline along which the instrument traveled if appropriate.

- The Project field is a string that identifies a series of deployments, typically in the same geographic region. As an example, at the Scripps Whale Acoustics Lab, we use SOCAL for our high frequency acoustic recording package (HARP) deployments in Southern California.

- The Deployment is an integer used to identify the n^{th} deployment with respect to a project (or if you prefer with respect to a site or cruise).

- The site is a string which permits a name to be associated with the area in which the instrument is deployed (e.g. Tanner Banks, A, Palmyra west terrace) and cruise can be used to identify the expedition that deployed the instrument.

- SiteAliases is a string that permits alternate names for the same site.

- Platform is a string that describes the platform on which the instrument is deployed. Instrument contains subfields that identify the instrument type (e.g. HARP, POPUP, BURP, EAR, D-Tag) and serial number or other identifier.

- As most cruises have automated systems to collect trackline information, rather than storing the trackline directly, the trackline field contains a string that provides enough information for the user to access the trackline. Assuming that the trackline system provides a way to access the information via a uniform resource identifier (URI; e.g. http://, ftp:// address), theURI should be used.

Details about the acoustic data are provided in the SamplingDetails, QualityAssurance, and DeploymentDetails fields.

SamplingDetails permits the user to specify how each channel was collected. A reference to the acoustic sensor within the Sensors element identifies which hydrophone was used for this channel, and start and end dates specify the recording interval:

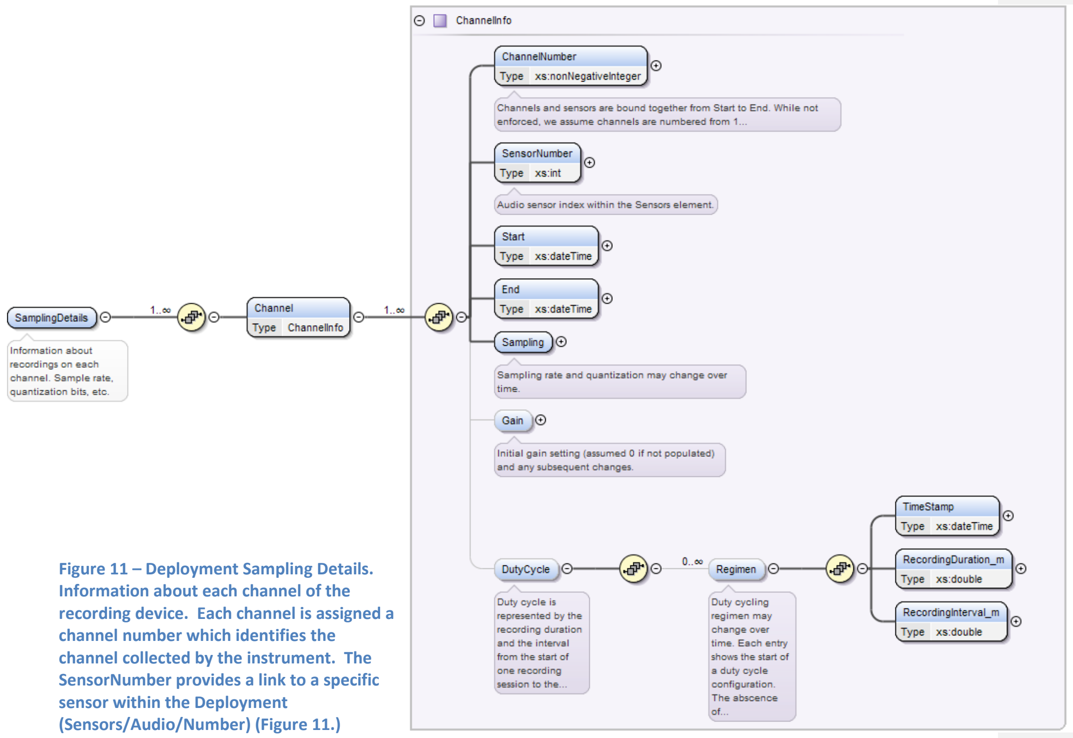

ChannelInfo
ChannelNumber
Type xs:nonNegativeInteger
Channels and sensors are bound together from Start to End. While not enforced, we assume channels are numbered from 1...
SensorNumber
Type xs:int
Audio sensor index within the Sensors element.
Start
Type xs:dateTime
End
Type xs:dateTime
Sampling
Sampling rate and quantization may change over time.
Gain
Initial gain setting (assumed 0 if not populated) and any subsequent changes.
SamplingDetails
Information about recordings on each channel. Sample rate, quantization bits, etc.
1..∞
Channel
Type ChannelInfo
1..∞
TimeStamp
Type xs:dateTime
RecordingDuration_m
Type xs:double
RecordingInterval_m
Type xs:double
DutyCycle
0..∞
Regimen
Duty cycle is represented by the recording duration and the interval from the start of one recording session to the...
Duty cycling regimen may change over time. Each entry shows the start of a duty cycle configuration. The abscence of...

Figure 11 – Deployment Sampling Details. Information about each channel of the recording device. Each channel is assigned a channel number which identifies the channel collected by the instrument. The SensorNumber provides a link to a specific sensor within the Deployment (Sensors/Audio/Number) (Figure 11.)

- Channel is a non-negative integer that refers to the channel number used. This refers to the channel of the data, which does not necessarily correspond to sensor position within an array.

- SensorNumber is an integer describing the sensor used to collect the channel data. This could refer to a serial number, to the position within the array, or another identifying number

- Start and End are dateTime formatted fields for the time that the instrument was recording. dateTime format conforms to the ISO8601 standard and consists of YYYY-MM-DDThh:mm:ss, where YYYY is year, MM is month, DD is day, T is the character between date and time, hh is hour, mm is minute, and ss is second. Additional precision can be obtained by following ss with a decimal and the fractional number of seconds. .
  For example, January 5, 2012 at 10:30:00 am would be 2012-01-05T10:30:00. Note that all times in Tethys are GMT.

- DutyCycling of recording can be expressed, and changes in gain or sample rate are expressed by time stamped entries in the Sampling and Gain elements (details in the online schema).

QualityAssurance allows for the specification of data quality. In most cases, all data retrieved should begin with a single Quality element. The category should be "unverified" until the data has been examined, and the Start and End elements would specify the entire deployment.

Later, once the data has been inspected, quality assurance can be specified for different time and/or frequency ranges, marked with their respective categories: good, compromised or unusable.

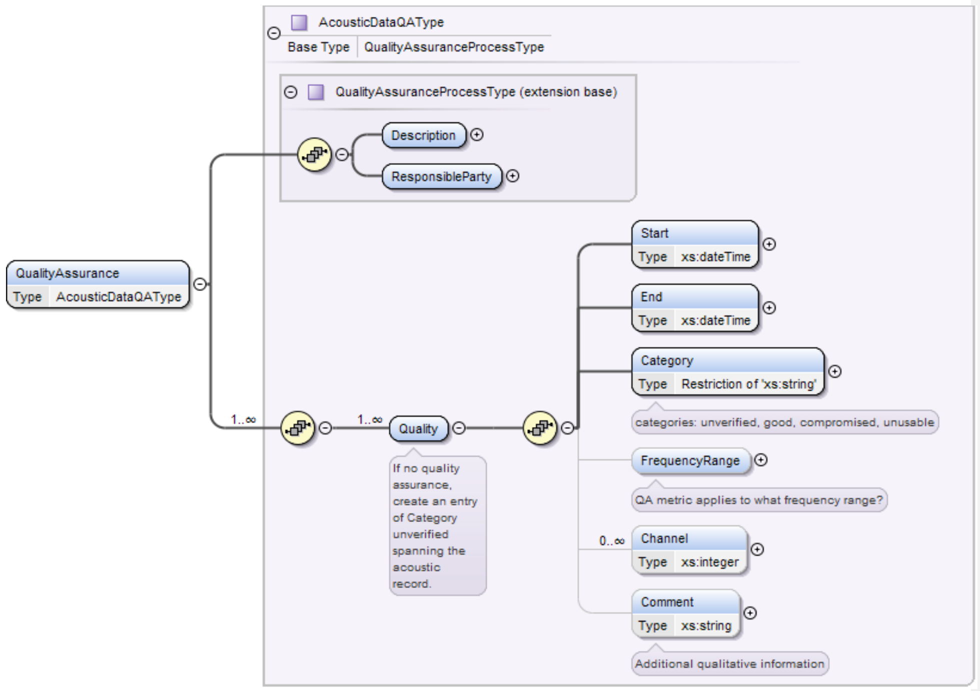

AcousticDataQAType
Base Type QualityAssuranceProcessType
QualityAssuranceProcessType (extension base)
Description
ResponsibleParty
QualityAssurance
Type AcousticDataQAType
1..∞
1..∞
Quality
If no quality assurance, create an entry of Category unverified spanning the acoustic record.
Start
Type xs:dateTime
End
Type xs:dateTime
Category
Type Restriction of 'xs:string'
categories: unverified, good, compromised, unusable
FrequencyRange
QA metric applies to what frequency range?
0..∞
Channel
Type xs:integer
Comment
Type xs:string
Additional qualitative information

Figure 12 QualityAssurance element. QualityAssurance permits the annotation of data quality: unverified, good, compromised, unusable. These can be specified over different times, frequencies and/or channels. ResponsibleParty represents the person or party to contact regarding the quality assurance.

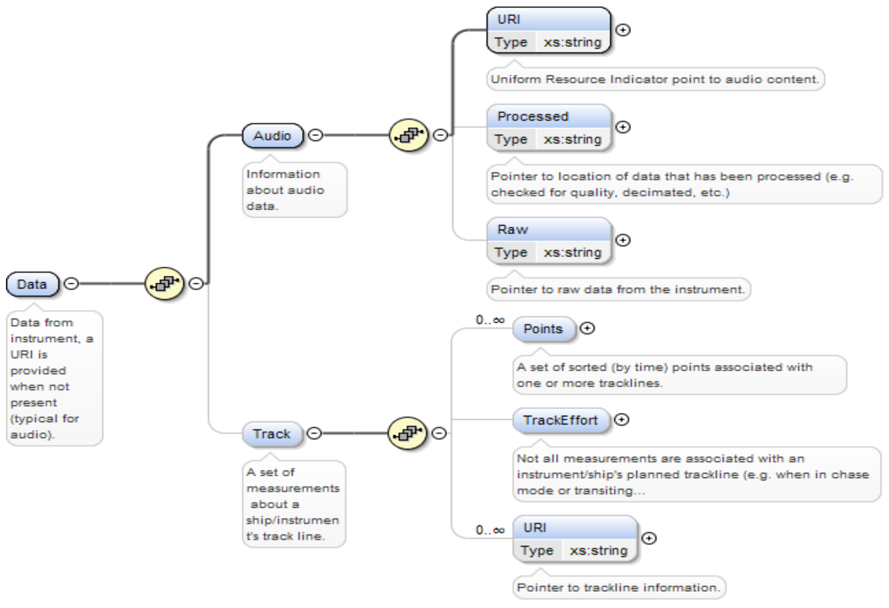

URI
Type xs:string
Uniform Resource Indicator point to audio content.
Processed
Type xs:string
Pointer to location of data that has been processed (e.g. checked for quality, decimated, etc.)
Raw
Type xs:string
Pointer to raw data from the instrument.
Audio
Information about audio data.
Data
Data from instrument, a URI is provided when not present (typical for audio).
0..∞
Points
A set of sorted (by time) points associated with one or more tracklines.
TrackEffort
Not all measurements are associated with an instrument/ship's planned trackline (e.g. when in chase mode or transiting...
Track
A set of measurements about a ship/instrument's track line.
0..∞
URI
Type xs:string
Pointer to trackline information.

Figure 13 - Data element. The Data element indicates where audio information can be found, as well as any points associated with a Track Line

The Data element references where to find the data itself, as well as Track line information. The Audio Uniform Resource Indicator (URI) can be any sort of string indicator as to where the physical data resides, such as a serial number or filing code, for example. The Track section contains a list of points describing the track location, and TrackEffort can be specified for different types of Effort during surveys.

The Sensors field describes information about the types of sensors that are associated with the deployment. There are currently elements to describe Audio and Depth sensors as well as an extendable generic sensor to accommodate other sensor types. Each sensor has a geometry relative to the platform, a name and description, and sensor identifiers that can be used to identify specific pieces of equipment. This information can be used to retrieve information such as calibration data for equipment from a separate instrument database which would be exterior to Tethys.

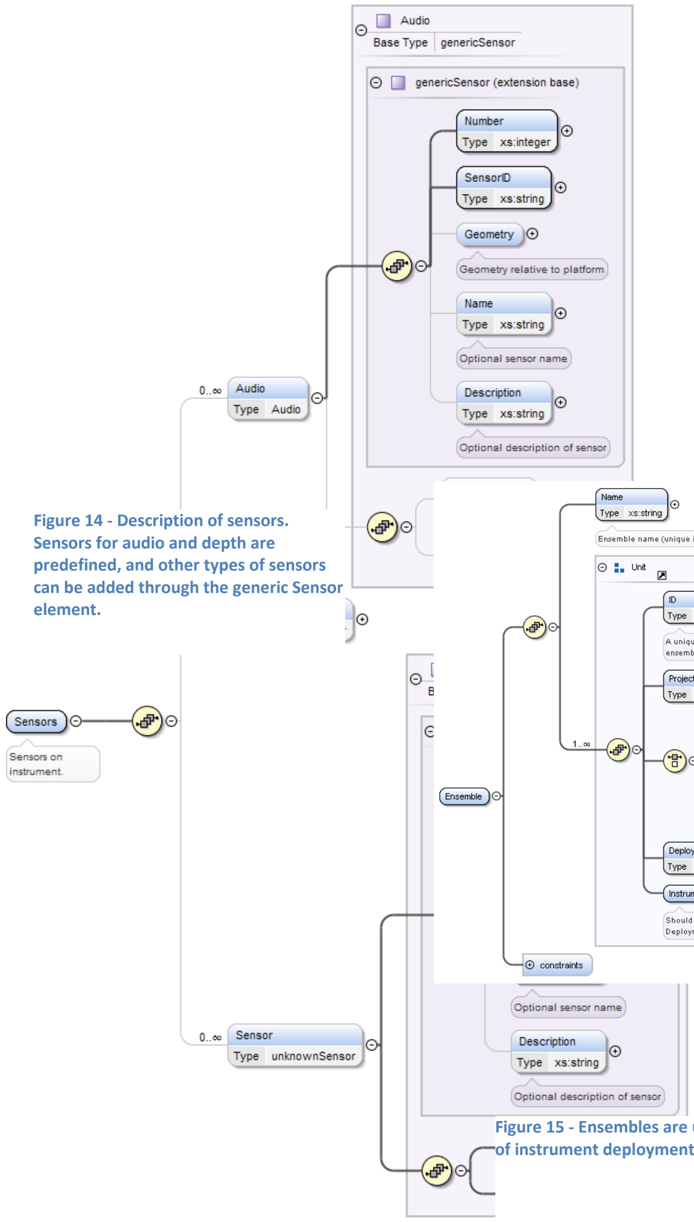


Figure 14 - Description of sensors. Sensors for audio and depth are predefined, and other types of sensors can be added through the generic Sensor element.

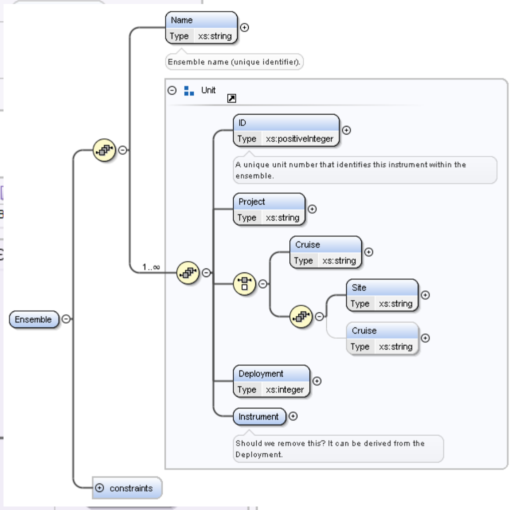


Figure 15 - Ensembles are used to create logical groupings of instrument deployments.

5.2 Ensemble

Ensembles provide a logical grouping of instrument deployments. This is most useful for large aperture localization where separate instruments may be deployed individually, but the data within them are to be treated as if they originated from a single instrument. Ensemble records are relatively simple, they consist of a unique name for the Ensemble and a sequence of Unit elements that describe each instrument in the ensemble (Figure 12). Each Unit consists of a unit number that is unique within the ensemble and other information necessary to determine the deployment associated with the unit.

5.3 Detections

Documents within the Detections collection can be characterized by three types of information: information describing the detection process and data on which the process was performed, a specification of the effort, and the detections themselves.

The Description elements provide a high-level textual overview of the detection process, consisting of

- the Objectives (e.g. find every call produced by a rare species),
- Abstract, and
- Method elements. These can be text or URLs .

The DataSource identifies a specific deployment or a set of employments that have been grouped together in a logical manner which is referred to as an Ensemble (Figure 13).

The Algorithm element provides details on the algorithm that is used to perform the detections. To be able to compare or reproduce results, it is important that its sub-elements be populated accurately.

- The Method provides a text identifier for the element. When possible, including a citation to a published method is a good way to populate this element.
- The Software element provides the name of the software algorithm performing the detection, and is coupled with a Version string
- The Version string is to identify differences in the algorithm that might evolve over time. Note that even if detections were made manually, there is still an algorithm. A person may be examining data in long-term spectrograms, or perhaps looking through time-series data. A description of this along with parameters (e.g. examine 1 h of data at a time) can still be provided when a human analyst is performing the detections.
- The Parameters describe any user-settable parameters of the algorithm. This is denoted in the schema (detail not shown) by the #any keyword in that allow arbitrary elements be nested within a <Parameters> element.
- The final element of the AlgorithmType is SupportSoftware. This allows the user to describe other software that might be required for the algorithm to execute. For instance, if the detection algorithm was a plug-in module for PamGuard (www.pamguard.org), the PamGuard version might be included.

Two possible examples for an energy-based click detector:

```
<Parameters>
   <CommandArguments>
   -thresh 6 –lowcut 10000 –highcut 8000
   </CommandArguments>
</Parameters>
```

or

```
<Parameters>
  <Thresh_dB>   6  </Thresh_dB>
  <Cutoff_low_Hz>  10000 </Cutoff_low_Hz>
   <Cutoff_high_Hz> 80000 </Cutoff_high_Hz>
</Parameters>
```

Both forms convey information about the band on which the detector should operate as well as the signal to noise ratio threshold. We recommend that one put in whatever parameter format the algorithm expects. We would also advocate that algorithm designers consider using XML arguments as they can be more descriptive and also let the user query the parameters. With the latter representation, it would be easy to find all detection efforts with this algorithm where the threshold was set to 6 dB or higher.

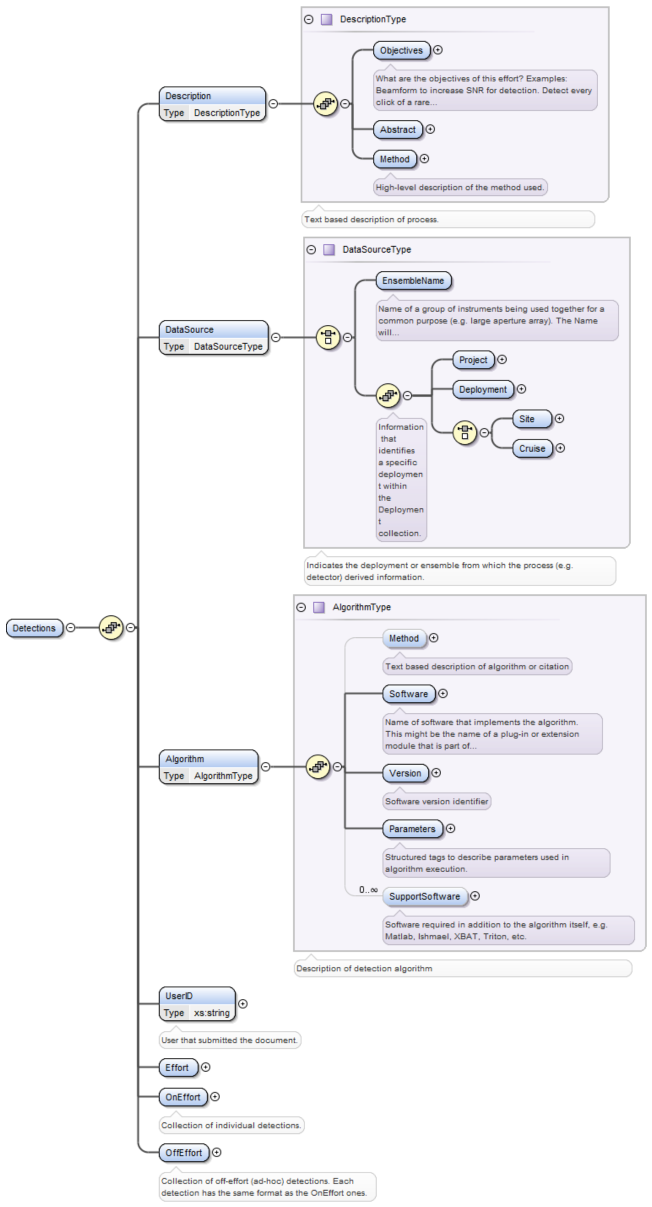

Detections
Description
Type DescriptionType
DescriptionType
Objectives
What are the objectives of this effort? Examples: Beamform to increase SNR for detection. Detect every click of a rare...
Abstract
Method
High-level description of the method used.
Text based description of process.
DataSource
Type DataSourceType
DataSourceType
EnsembleName
Name of a group of instruments being used together for a common purpose (e.g. large aperture array). The Name will...
Project
Deployment
Site
Cruise
Information that identifies a specific deployment within the Deployment collection.
Indicates the deployment or ensemble from which the process (e.g. detector) derived information.
Algorithm
Type AlgorithmType
AlgorithmType
Method
Text based description of algorithm or citation
Software
Name of software that implements the algorithm. This might be the name of a plug-in or extension module that is part of...
Version
Software version identifier
Parameters
Structured tags to describe parameters used in algorithm execution.
0..∞
SupportSoftware
Software required in addition to the algorithm itself, e.g. Matlab, Ishmael, XBAT, Triton, etc.
Description of detection algorithm
UserID
Type xs:string
User that submitted the document.
Effort
OnEffort
Collection of individual detections.
OffEffort
Collection of off-effort (ad-hoc) detections. Each detection has the same format as the OnEffort ones.

Figure 16- Detection schema. Top level description of how acoustic detections are represented within the system.

The Effort element describes the span of time over which events were searched for in the specified deployment or ensemble and what kinds of events are of interest.

Each type of event is denoted by a Kind which indicates a species, call type, and granularity of call.

- The species identifier is taken from the Integrated Taxonomic Information System (ITIS; www.itis.gov). For anthropogenic events such as ship noise, we typically attribute the species as *Homo sapiens*. To denote calls when the species is not well known, a higher order label can be used. As an example, if an echolocation click could not be contributed to a specific species, one could record the SpeciesId using the order label of *Odontoceti*.
- The Call indicates the type of call detected.
- Granularity is used to indicate how often detections are recorded. Valid parameters are call, encounter, and binned, representing the annotation of specific calls, the beginning and end of a set of calls, and presence of calls within a given time interval respectively. When binned is selected, the attribute binsize_m is used to indicate how often the presence is reported.

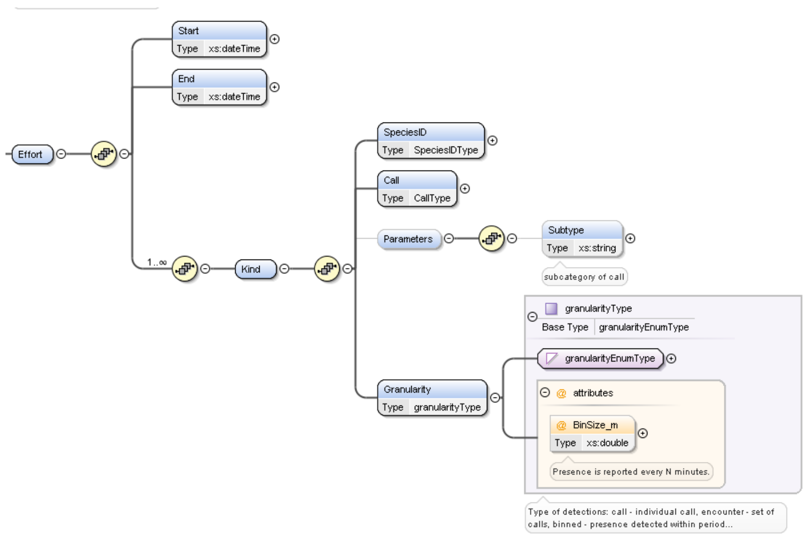


Figure 17- Detection effort is described by the elements that capture the timespan and types of events that were investigated.

The final elements describe the detections themselves. These are divided into on and off-effort sections. Anything detected event that was not included in the Effort specification must be placed on the OffEffort element. Within the OnEffort and OffEffort elements, a sequence of 0 or more Detection elements are used to specify events.

Most of the elements within a detection element are well described by the comments in the schema which are displayed in the figure. Several of the elements are worth discussing in further detail. When the effort is binned, the Start time may be any time within the time span covered by the bin and the End time of the observed call may be included or omitted. The Parameters element can be used to describe characteristics of the call. A number of common parameters are included, as in Figure 15, but Tethys users can define their own parameters as well in a UserDefined section.

The Image and Audio elements permit the user to store an image or audio sample of the event. These samples are submitted with the Detections document and can be retrieved from the database.

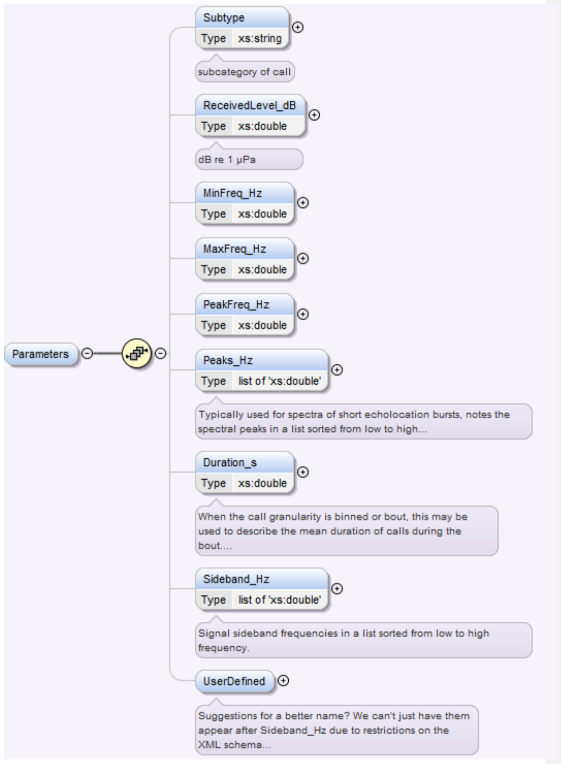

Parameters
Subtype
Type xs:string
subcategory of call
ReceivedLevel_dB
Type xs:double
dB re 1 µPa
MinFreq_Hz
Type xs:double
MaxFreq_Hz
Type xs:double
PeakFreq_Hz
Type xs:double
Peaks_Hz
Type list of 'xs:double'
Typically used for spectra of short echolocation bursts, notes the spectral peaks in a list sorted from low to high...
Duration_s
Type xs:double
When the call granularity is binned or bout, this may be used to describe the mean duration of calls during the bout....
Sideband_Hz
Type list of 'xs:double'
Signal sideband frequencies in a list sorted from low to high frequency.
UserDefined
Suggestions for a better name? We can't just have them appear after Sideband_Hz due to restrictions on the XML schema...

Figure 18 - Detection elements are repeated within the OnEffort or OffEffort (not shown) elements of a Detection document to describe observed phenomena.

5.4 Localizations

The Localizations collection is designed to organize information about localizations derived from multiple hydrophones.

6 Appendix: Data Import

As discussed in sections 3.2, 3.2.2, and 3.7.1, data can be imported into Tethys in a variety of formats. When the data being imported is not stored in XML, a translator needs to be used to map the row-oriented data to XML. Such sources can come from comma separated value files, spreadsheet workbooks, databases, and anything else that supports the open database connectivity protocol.

The following sections provide additional details and examples for the different methods of importing, as well as an in depth description of various strategies for creating source maps – XML files that translate data from their source into Tethys fields. As of version 2.3, data from multiple sources of different formats can be imported as a single document.

6.1 Java Graphical Interface for uploads

A graphical user interface is also provided by the Java client to handle document submission. Submission can be done via a single file resource, an ODBC connection, or a multiple-file resource. The GUI is typically executed from Matlab, using the **dbSubmit()** command provided by the Matlab client.

The style of submission can be changed with the corresponding tabs:

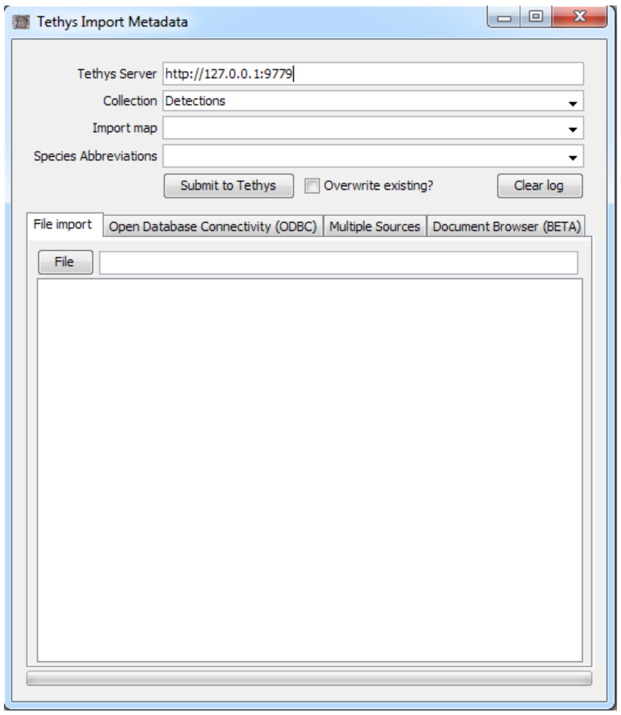
Commented [MR1]: This needs expansion, I've started adding some of the content, but - please finish up.

- File import – Used when submitting one or more files where each file will be submitted to Tethys as a separate document. Spreadsheets and comma separated file values may be used.
- Open Database Connectivity – Interface for asking the Tethys server use Microsoft open database connectivity (ODBC) technology to access foreign databases. Users can specify files (similarly to file import) or connect to a networked resource such as a database server.
- Multiple Sources – On occasion, multiple files may be needed to construct a document such as for a deployment that has a separate trackline file. This tab permits multiple document sources to be included. See section 6.3.5 for details.
- Document Browser – This pane allows for tree view of submitted XML documents by name. Simply specify the collection of the target document, enter its name and hit Retrieve Document. XML elements can be expanded and their values examined.

Commented [MR2]: We probably need some concrete examples for this in a separate section.

Commented [s3R2]: See 6.2.

Commented [s4]: I had shown you this earlier in the year and you decided while neat, it wasn't something that should be developed, so I did no further development---however, it works fine, and is easily implemented, so I kept it in. I think for beginners it is useful, I prefer peace of mind knowing that what I submitted has the proper information (without having to do any REST commands or queries via a separate program).



Tethys Server: http://127.0.0.1:9779
Collection: Detections

Figure 19 – Data submission interface. User specifies the Tethys server and collection to which data will be submitted. Import map specifies data field name translation (see section Source Maps) and when species names are being provided, the user may specify a set of local abbreviations that are used. Tabs indicate where the imported data will be taken from (see text for details).

Available Import and Species Abbreviation maps can be retrieved from the server by opening the drop down menu and selecting the appropriate action.

6.2 Open Database Connectivity (ODBC)

Tethys can interact with any database with ODBC capabilities (MySQL, Oracle, PostgreSQL, MSAccess, etc.). Data can be imported directly from the database as long as a network connection can be made and a 64-bit ODBC driver for that database has been installed (refer to your database documentation on which driver should be installed).

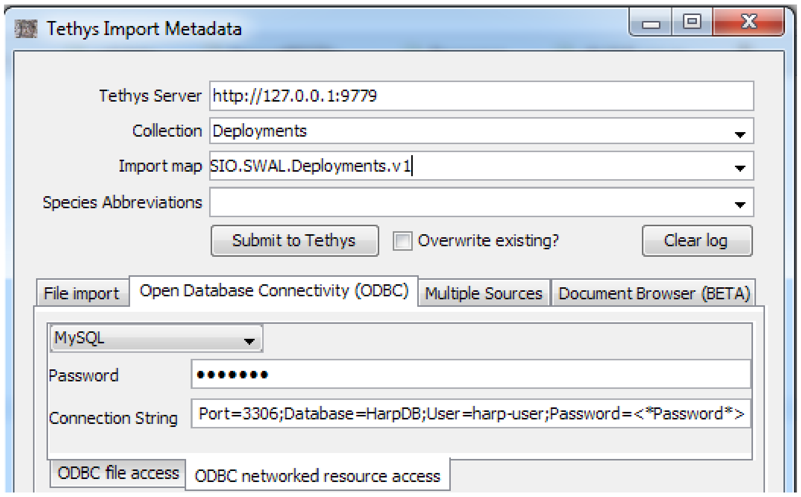
Data can be imported using ODBC with either the Java Graphical Interface (above) or the Python client's import.py. In either case, a Connection String must be supplied which allows communication between both databases.

Here is an example of a command line ODBC import into the Deployment container:

```
import.py --sourcemap SIO.SWAL.Deployments.v1 --server tethys.my.org --
   ConnectionString "Driver={MySQL ODBC 5.1 Driver};Server=harp.my.org;
   Port=3306;Database=HarpDB;User=harp-user;Password=<*Password*>"
   Deployments
```

The MySQL database is running on machine harp.my.org on port 3306, and Tethys is running on 69ethys.my.org. MySQL will be accessed with account harp-user. Setting Password to <*Password*> will result in import.py prompting for a password. The ODBC driver is specified in {curly braces} and if not supplied, will default to the above. Data will be imported to the Deployments collection from database HarpDB using the SIO.SWAL.Deployments.v1 sourcemap.

Similarly, when using the graphical interface, switch to the ODBC tab and the "ODBC networked resource access" sub-tab. Here you can use the drop down menu to select what sort of database you're trying to connect to (MySQL, MSAccess) which will provide a template for the connection string. The ODBC option allows for any string to be used. To omit the password from the string and use the encrypted field instead, use Password=<*Password*> in the Connection String, and enter the password in the field above.



Tethys Server http://127.0.0.1:9779
Collection Deployments
Import map SIO.SWAL.Deployments.v1
Species Abbreviations
MySQL
Password •••••••
Connection String Port=3306;Database=HarpDB;User=harp-user;Password=<*Password*>

Figure 20 – ODBC data import using the Graphical Interface. The password is supplied in the encrypted field by using <*Password*> in the connection string.

6.3 Source Maps

The SourceMaps collection consists of XML documents that provide detailed information on how to translate from a non-XML data source and the XML document structure to Tethys XML schemata. As introduced in section 3.2.1, source map documents have the following structure:

```
<Mapping>
        <Name> MyMap </Name>
        <DocumentAttributes>
                List of <Attribute> elements that will be applied to the document
        </DocumentAttributes>
        <Directives>
                Elements that provide document structure and specify how
                fields in the source spreadsheet, database, etc. correspond to elements in the
                resulting XML document.
        </Directives>
</Mapping>
```

The value of the <Name> attribute must be unique and is used to identify the source map. The Attributes define the XML namespace. In most cases, one will simply copy the following Attributes:

```
  <DocumentAttributes>
    <Attribute>
      <Name>xmlns:ty</Name>
      <Value>http://tethys.sdsu.edu/schema/1.0</Value>
    </Attribute>
    <Attribute>
      <Name>xmlns:xsi</Name>
      <Value>http://www.w3.org/2001/XMLSchema-instance</Value>
    </Attribute>
    <Attribute>
      <Name>xsi:schemaLocation </Name>
      <Value>http://tethys.sdsu.edu/schema/1.0 tethys.xsd</Value>
    </Attribute>
  </DocumentAttributes>
```

Each attribute Name/Value pair will be appended to the first element of the resulting document. As an example, if the map creates a Detections document, the above DocumentAttributes will create the following:

```
<ty:Detections xmlns:ty="http://tethys.sdsu.edu/schema/1.0"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsiSchemaLocation="http://tethys.sdsu.edu/schema/1.0 tethys.xsd">
        …
</ty:Detections>
```

The <Directives> element allows one to actually perform the data translation. Most elements are simply copied. For example,

```
<Directives>
      <Deployment>
            <Project> SOCAL </Project>
            <DeploymentID> 34 </DeploymentID>
      </Deployment>
</Directives>
```

would produce the following XML document:

```
<ty:Deployment xmlns:ty="http://tethys.sdsu.edu/schema/1.0" [other attributes…]>
      <Project> SOCAL </Project>
      <DeploymentID> 34 </DeploymentID>
</ty:Deployment>
```

6.3.1 Accessing the data

In most cases however, we would like the element values to be populated with values from our source document. The ***Table*** and ***Sheet*** elements allow this to occur. When a Table or Sheet element is encountered in the Directives section, the element ***Entry*** can be introduced to allow data to be mapped from the source document to XML.

The Sheet document is used for spreadsheet workbooks and comma separated value sources. When used with a workbook, the attribute **name** is expected and specifies the name of the workbook page. By default, Excel uses Sheet1 as the name for the first sheet, Sheet2 for the second, etc., but users can rename these.

```
<Directives>
      <Sheet name="Deployments">
            <Deployment>
                  <Entry>
                        <Source> [Project Label] </Source>
                        <Dest> Project </Dest>
                  </Entry>
                  <Entry>
                        <Source> [Project #] </Source>
                        <Dest> DeploymentID </Dest>
                  </Entry>
            </Deployment>
      </Sheet>
</Directives>
```

As Sheet is the very first element after Directives, an XML document will be produced for each row of the workbook's Deployments sheet. For workbooks, the first row must contain column headers with subsequent rows providing data. The ***Source*** element indicates the name of row header and the ***Dest*** element indicates the name to which it will be mapped. ***Note that the Source element field name is enclosed in square brackets [ ].***

If our workbook contained:

Project Label	Project #
SOCAL	32
SOCAL	33

two XML documents would be produced (note that these do not conform to the Deployment schema as there are missing mandatory elements):

```
<ty:Deployment …> <Project>SOCAL</Project> <DeploymentID>32</DeploymentID> </ty:Deployment>
```
and
```
<ty:Deployment …> <Project>SOCAL</Project> <DeploymentID>33</DeploymentID> </ty:Deployment>
```

Alternatively, if we change the order of Deployment and Sheet, one document with two entries is produced as Sheet is a child of Deployment. This is not what we want as our schema defines each Deployment as a separate entity, but there are other situations where having multiple "rows" is useful, such as in a Detections or Localizations document.

```
<ty:Deployment …>
       <Project>SOCAL</Project> <DeploymentID>32</DeploymentID>
       <Project>SOCAL</Project> <DeploymentID>33</DeploymentID>
</ty:Deployment>
```

When importing from a relational database, the Table directive is used. The Table directive requires an attribute, ***query***, which will be a database query in sequential query language (SQL). SQL is beyond the scope of this manual, but *SAMS Teach Yourself SQL in 10 Minutes* (Forta, 2016) is a recommended introductory primer. Table can be used with spreadsheets as well, but Microsoft Excel appends a dollar sign to sheet names. The following Directives section would be equivalent to the Sheet syntax:

```
<Directives>
```

```
      <!-- Note $ at end of Deployments as from a spreadsheet -->
      <Table query="select * from Deployments$;">
            <Deployment>
                  <Entry>
                        <Source> [Project Label] </Source>
                        <Dest> Project </Dest>
                  </Entry>
                  <Entry>
                        <Source> [Project #] </Source>
                        <Dest> DeploymentID </Dest>
                  </Entry>
            </Deployment>
      </Table>
</Directives>
```

6.3.2 More on Entry directives

Entry directives have several other features. Multiple source fields can be combined simply by placing them in the same Source element. If a ***Default*** element is provided, its value is used when the source field is absent or has no value present. Finally, a ***Kind*** element can be used to specify special formats.

The following are the currently valid Kinds:

DateTime – Date and time from a number of standard formats. When multiple fields are included in the Source element, they are combined. For instance, if the data source broke a timestamp into day and hour, specifying <Source> [day] [hour] </Source> could be used to combine the two.

Integer- Value is converted to an integer.

LatLong – Value is interpreted as a latitude or longitude. Latitudes and longitudes and are stored internally in degrees ([-90,90] south/north and [0, 360] east respectively). The following formats are accepted:

- Number in the range [-90,90] or [0, 360] representing degrees north/south or east. This is the format in which Tethys stores latitude and longitudes.
- Degrees minutes seconds (DMS) followed by an optional directional indicator: N, S, W, E. Numbers in the DMS can be separated by anything that is not a number, the strings "36 24 02.5 W" and "36° 24' 2.5 W", and "36 degrees, 24 minutes 2.5 seconds w" will all be converted to a longitude of approximately 323.5993 degrees east.

Number – Value is converted to a number.

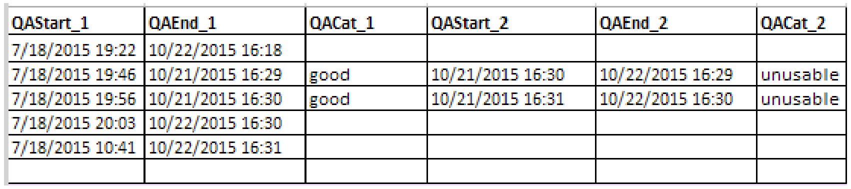
SpeciesCode – The field is to be treated as a species identifier. This invokes the lookup routines to convert from the selected species map to an ITIS taxonomic serial number.

CallType – The field will be interpreted as a call type. When the data in the field contains a forward slash “/”, anything after the / will be interpreted as a call subtype and will automatically be mapped to a Subtype element of Parameters if the user specifies a *Parameters section as described in section 6.3.3.

6.3.3 Conditional Entries

There may be times where certain XML elements should be created only when certain conditions are true in the source data. Consider a spreadsheet containing several rows of Deployment information, which will be translated into several Deployment documents for Tethys. Some of these deployments have had two distinct quality assurance tests ran on them. These are represented by the columns QAStart_1, QAEnd_1, QACategory_1, QAStart_2, and so on, in the spreadsheet. These deployments would require two Entries for the Quality element.

However, most of the deployments were only quality tested once. In which case, their QAStart_2, QAEnd_2, etc, cells are empty. Creating empty <Quality/> elements for these would result in an error, as <Quality> has mandatory children. The source data for such a case might look like:



QAStart_1	QAEnd_1	QACat_1	QAStart_2	QAEnd_2	QACat_2
7/18/2015 19:22	10/22/2015 16:18				
7/18/2015 19:46	10/21/2015 16:29	good	10/21/2015 16:30	10/22/2015 16:29	unusable
7/18/2015 19:56	10/21/2015 16:30	good	10/21/2015 16:31	10/22/2015 16:30	unusable
7/18/2015 20:03	10/22/2015 16:30				
7/18/2015 10:41	10/22/2015 16:31				

Conditional entries allow us to create the elements *only when certain conditions are true*. This is done within the sourcemap with a <Condition> element. <Condition> should encapsulate the element of interest, and contain a <Predicate> which specifies the condition. Using the example we have above, an excerpt from the source map might look like:

```
<Condition>
      <Predicate>
            <Operand>[QAStart_2]</Operand>
            <Operation op="empty" retain="iffalse"/>
      </Predicate>
      <Quality>
            <Entry>
                  <Source> [QAStart_2] </Source>
                  <Kind> DateTime </Kind>
                  <Dest> Start </Dest>
            </Entry>
            <Entry>
                  <Source> [QAEnd_2] </Source>
                  <Kind> DateTime </Kind>
                  <Dest> End </Dest>
            </Entry>
            <Entry>
```

```
                  <Source> [QACat_2] </Source>
                  <Dest> Category </Dest>
                  <Default>unverified</Default>
            </Entry>
      </Quality>
</Condition>
```

We specify the column name to check in the <Operand> element. The actual condition we are checking is specified by the @op attribute of the Operation element. Valid operations are:

- empty - checks if cell contents are empty
- matches - checks if the cell contents match the value of the Operation element. For example to only make note of compromised data:
  ```
  <Predicate>
        <Operand>[QACat_1]</Operand>
        <Operation op="matches" retain="iftrue">compromised</Operand>
  </Predicate>
  ```
- matchesregexp - checks the contents for the regular expression contained in the value of Operation. Regular expressions must follow Python's re module syntax (https://docs.python.org/2/library/re.html). For example, to import only deployments with projects that begin with TET
  ```
  <Predicate>
        <Operand>[Project]</Operand>
        <Operation op="matchesregexp" retain="iftrue">^TET.*</Operation>
  </Predicate>
  ```

@retain is used to specify whether to include the element if the condition was true or false, designated by "iftrue" or "iffalse".

6.3.4 Specifying attributes

Sourcemaps can specify attributes of elements as well. As an example for effort that is binned, it is necessary to specify an attribute indicating the bin size in minutes. An Entry can have additional fields marked Attribute that permit the specification of an attribute. Each Attribute supports the same Source, Default, and Dest tags as entries. The following provides an example that looks for the granularity in a source field called Granularity and then populates the BinSize_m attribute if it exists:

```
<Entry>
      <Source> [Granularity] </Source>
      <Default> binned </Default>
      <Dest> Granularity </Dest>
      <Attribute>
            <Source> [BinSize_m] </Source>
            <Dest> BinSize_m </Dest>
      </Attribute>
</Entry>
```

Optionally, we could have provided a Default, but if this sourcemap were used for anything that was not binned data, the BinSize_m attribute would be set to the default value which would be inappropriate as the other granularity specifications (encounter, call) are not binned.

6.3.5 Handling parameters

Data sources that have optional parameters are difficult to represent in tabular format, and we recommend generating XML directly using Nilus or other means when feasible. However, there are times that importing from a non XML source is required and Tethys provides a method to handle data specific parameters. We currently assume that parameters are defined on a per species/call type basis, permitting one to measure call-specific parameters. For example, one can examine the Detection_Effort_Template spreadsheet in the sample database. On the Effort sheet, for each species and call, there is a list of parameters as shown in the following excerpt:

Common Name	Species Code	Call	Parameter 1	Parameter 2
Sei Whale	Bb	Downsweep	Start_Hz	End_Hz
Sei Whale	Bb	LF Downsweep	Start_Hz	End_Hz
Sei Whale	Bb	All		
Sei Whale	Bb	Unspecified	Start_Hz	End_Hz
…				
Killer Whale	Oo	HFM	High_Hz	Low_Hz

The case-sensitive parameter columns are numbered, and indicate that for Sei Whale downsweeps, the starting frequency will be the first parameter to be recorded. Similarly, for killer whales, the maximum frequency in Hz will be recorded as parameter 1. This definition of parameter positions is created by specifying the Sheet or Table directive and adding the attribute **parameters="define"**. Within the Sheet/Table, an entry with a Source of **[*Parameters]** and a destination of **Parameters** is required as in this excerpt from SIO.SWAL.Detections.v1 source map from the sample database.

```
<Sheet name="Effort" parameters="define">
…<Entry>
    <Source> [*Parameters] </Source>
    <Dest> Parameters </Dest>
  </Entry> …
</Sheet>
```

To associate data with these parameters, values are placed in a subsequent Sheet or Table that has columns named Parameter 1, Parameter 2, etc. and contains an entry mapping [*Parameters] to Parameters. For the above data, suppose one had a workbook with a sheet called Detections. If the SourceMap had the following entry:

```
<Sheet name="Detections">
…<Entry>
    <Source> [*Parameters] </Source>
```

```
        <Dest> Parameters </Dest>
      </Entry> …
    </Sheet>
```

with the following entries on the Detections sheet (start/end times and other fields not shown):

Species Code	Call	Parameter 1	Parameter 2
Oo	HFM	20000	38000
Oo	HFM	22000	39000

the values in the Parameter 1 column (20000 and 22000 shown here) would be associated with the element High_Hz of each entry for all killer whale HFM calls. Similarly, if a sei whale downsweep detection was present, any value in the Parameter 1 column would be associated with Start_Hz.

A full example of this can be seen in the SourceMap SIO.SWAL.Detections.Analyst.v1.xml. This map was designed to work with workbooks that follow the format of the Detection_Effort_Template.xlsx workbook located in the base folder of the database (C:/Users/Tethys by default).

<u>Deployment data format for input to database</u>

The deployment input data should be available in one of the formats supported by the import utility (e.g. a spreadsheet, comma separated value file, or database). In the case of spreadsheets and comma separated value files, the data importer assumes that the first row consists of header information. Just as in workbooks, the header information need not have the same names as Tethys fields, but must be specified in the SourceMap's Source element with square brackets [ ]. Listed here are some of the general fields that should be included on a spreadsheet or database:

- Project – A text string indicating the overall scope of a set of deployments. This is typically the name of a region or body of water, but can be anything that helps the user separate out different projects.
- DeploymentID – A number indicating the Nth deployment. This may be the Nth deployment to the same site, the Nth cruise, etc. The important thing is to be able to distinguish multiple deployments to the same site.
- Site or Cruise – A text string related to where the deployment was made, e.g. “Tanner Banks”, “M”, “17”, or the name of the cruise carrying out the deployment.
- Platform – A text string indicating the sort of platform on which the instrument is deployed, e.g. mooring, tag.
- Instrument Information – Text strings describing the type of instrument used and an identifier for the instrument, e.g. serial number.

- Channel Information – Various fields containing information about the recordings on each channel, including start and end of recording, the duty cycle regimen, sample rate and bits, and serialized identifiers for the channel and sensors, see the deployment schema for specifics.
- Longitude – A number indicating degrees east from the prime meridian [0, 360) or [-180, 180) or a string with hours and minutes HH:MM. Minutes may be fractional.
- Latitude - A number or string indicating degrees South/North of the equator [-90,90]. May also be in HH:MM form.
- DepthInstrument_m – Depth of deployed instrument. This is expected to be a negative number to be compatible with other GIS systems that measure altitude relative to sea level.
- TimeStamp – The start or end of deployment in Excel format (assumed UTC) or as an ISO 8601 string: YYYY-MM-DDTHH:MM:SSZ (Z for UTC) or YYYY-MM-DDTHH:MM:SS±HH:MM to specify a date in local time where ±HH:MM is the offset from UTC.

Additional Tethys fields may be added as needed, according to the Schema. As different groups have different naming conventions, a separate file can be used to translate between local field names and the standard ones as well as to specify which fields will be included. When a name appears without a translation it is used as is. Here is an example developed for NOAA's Pacific Islands Fisheries Science Center for their work with high-frequency recorders around Hawaiian seamounts:

```
Project,
DeploymentID,
DeploymentAlias,
Site,
Region,
Instrument_Type, Type
Data_ID, ID
Data_Start_Date Data_Start_Time_GMT,Start
Data_End_Date Data_End_Time_GMT, End
Data_Start_Date Data_Start_Time_GMT, TimeStamp
Sample_Rate_kHz, SampleRate_kHz
Recording_Duration_min_1, RecordingDuration_m
Recording_Interval_min_1, RecordingInterval_m
DutyCycle_StartDate_2 DutyCycle_StartTime_2, TimeStamp
Data_ID, URI
Deployment_Longitude, Longitude
Deployment_Latitude, Latitude
Deployment_Depth_m, DepthInstrument_m
Recorvery_Date Data_End_Time_GMT, TimeStamp
Data_ID, SensorID
PreAmp_ID, PreampID
```

Important note: These names are used as XML elements and must obey certain rules. Specifically, they must start with a letter or underscore and cannot contain any spaces, special characters, or punctuation (e.g. # $ . ...).

Detections Input sheet format

The detections input data should be saved as a spreadsheet, such as Excel form, and will consist of several sheets within the Excel workbook.

The first two sheets are *Detections* and *AdhocDetections*. These permit us to specify the detections. Both sheets have a similar structure, the difference being that AdhocDetections should be used to specify detections that are off-effort. An off-effort detection is one found where the analysis intent was detection of a different species. Note that all detections must be put into one of the categories defined by a master spreadsheet that is stored in the database directory.

The following fields are available in the Detections/AdhocDetections worksheets, mandatory fields are in **bold face**:

- Input file – This defines the acoustic record in which the call/phenomena was detected. The term file is used loosely here and can contain site-specific methods to identify the data source.
- Event number – A unique identifier for the event within this set of detections. We typically use the detection time, but other fields such as an XBAT event are equally viable.
- **Species Code** – Local abbreviation for the species/phenomena.
- **Call** – Type of call/phenomena.
- **Start time**/End time – If both start and end time are present, this defines the time span covered by the event. If only the Start time is present, it is assumed to be the time of an example detection within a fixed period. Currently, we have hard coded this period to be hourly bins starting at midnight, but this will be expanded in future releases.
- ReceivedLevel_dB – The received level of the call in dB re 1 µPa.
- Parameter 1 – Parameter 6 – User definable parameters associated with calls. See the discussion above for how these are defined in the effort sheet.
- Comments – Any analyst/program comments about the detection.
- Image – The name of an image file (typically a spectrogram) documenting the event.
- Audio – The name of an audio file documenting the event.

The third sheet is the *Effort sheet* The Effort Sheet lets the user track the effort made to find specific species and call types. Without effort specification, it is impossible to know if a lack of detections means that it was unlikely that animals were present or if we simply have not looked for them. Important columns in this sheet are the common name, species code, and call. For example, if one were searching for blue whale B and D calls, the following rows would occur in the table:

Common Name	**Species Code**	**Call**
Blue Whale	Bm	B
Blue Whale	Bm	D

The species code is a local abbreviation and at a later date will be expanded to use the Integrated Taxonomic Information System(IT IS; www.itis.gov). In addition, it is possible to note information about specific calls types. By providing column headers labeled Param N where N is a digit, additional information can be associated with specific parameter columns in the detections:

Common Name	Species Code	Call	Parameter 1	Parameter 2	Parameter 3
Sperm Whale	Pm	Clicks	min Hz	peak Hz	max Hz
Sperm Whale	Pm	Creaks	min Hz	peak Hz	max Hz

In this example, whenever a number was placed in the parameter 1 column of a detection associated with a sperm whale creak, it would be interpreted as the minimum frequency of the creak specified in Hertz.

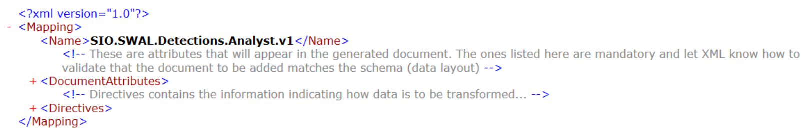
The fourth sheet, the *Metadata sheet*, provides information that lets the detections be linked to the deployment of a specific instrument group. Typical parameters include a project name, site identifier, and deployment number.

The metadata sheet can include any image and audio files, which should be listed in the image and audio columns. These are expected to be in directories with the same name as the spreadsheet with –image and –audio appended. As an example, if the spreadsheet is Socal36Odontocetes-SilbidoDetector the image and audio directories would be *Socal36Odontocetes-SilbidoDetector-image* and *Socal36Odontocetes-SilbidoDetector-audio.*

Detections Data Maps

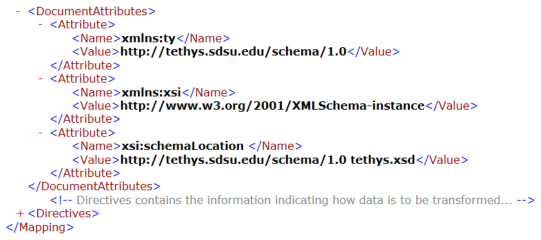
In order to parse user's detection data into the Tethys database so that the result corresponds to the Tethys data schema (shown in the appendix) a data map is used. There are two options: have the user's data match an existing data map as described below, or create a data map that translates the user's format to that of the Tethys schema. This example is for importing an excel spreadsheet into the database.

Example of a detections SourceMap:



```
  <?xml version="1.0"?>
- <Mapping>
    <Name>SIO.SWAL.Detections.Analyst.v1</Name>
      <!-- These are attributes that will appear in the generated document. The ones listed here are mandatory and let XML know how to
      validate that the document to be added matches the schema (data layout) -->
  + <DocumentAttributes>
      <!-- Directives contains the information indicating how data is to be transformed... -->
  + <Directives>
  </Mapping>
```

First we have the name of the Map, which we will call when adding data to the Tethys database. In this example, the map name is SIO.SWAL.Detections.Analyst.v1. The rest of the map document consists of two parts, the Document Attributes and the Directives.

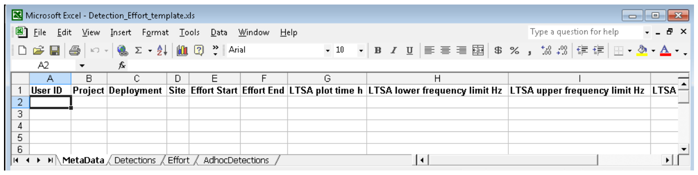


```
- <DocumentAttributes>
  - <Attribute>
        <Name>xmlns:ty</Name>
        <Value>http://tethys.sdsu.edu/schema/1.0</Value>
    </Attribute>
  - <Attribute>
        <Name>xmlns:xsi</Name>
        <Value>http://www.w3.org/2001/XMLSchema-instance</Value>
    </Attribute>
  - <Attribute>
        <Name>xsi:schemaLocation </Name>
        <Value>http://tethys.sdsu.edu/schema/1.0 tethys.xsd</Value>
    </Attribute>
  </DocumentAttributes>
    <!-- Directives contains the information indicating how data is to be transformed... -->
+ <Directives>
</Mapping>
```

The document attributes include which data schema matches with this document map and the location of this schema. There are three portions. First, we set the namespace for the schema. It is called "ty" and is preceded by "xmlns". Then the value for the namespace is on the next line.

Second, we have the schema instance. Finally we have the schema location as the name and then the value.

The Document Attributes are the portion of the map document that contains the information for Tethys to transform the user data into the Tethys database format using the specified schema. This is done using a series of directives. In our example, we have and excel file with several sheets.

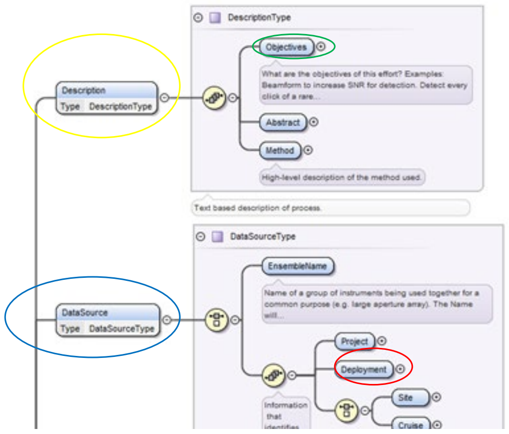

Microsoft Excel - Detection_Effort_template.xls
File Edit View Insert Format Tools Data Window Help
Type a question for help
Arial
10
A2
MetaData
Detections
Effort
AdhocDetections

	A	B	C	D	E	F	G	H	I	
1	User ID	Project	Deployment	Site	Effort Start	Effort End	LTSA plot time h	LTSA lower frequency limit Hz	LTSA upper frequency limit Hz	LTSA
2										
3										
4										
5										
6										

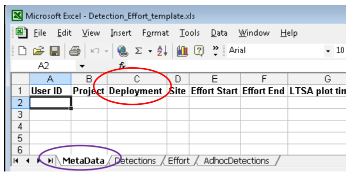
The sheets above are: Metadata, Detectors, Effort, and AdHocDetectors. To match the schema, we will need to specify the name and location of each element in the source or input data, and specify the name and location of each element in the schema. The terminology used in our xml data map is "Source" and "Dest". Since we expect to use our data map for many files, we also include default values specific to our data.

Since our map is to match our data with a schema, we need to refer to the data schema. Seven main data entries are expected for a Detection document. Description, DataSource, Algorithm, UserID, Effort, OnEffort, and OffEffort. These are described in detail in section 5 of the appendix.

Schema:

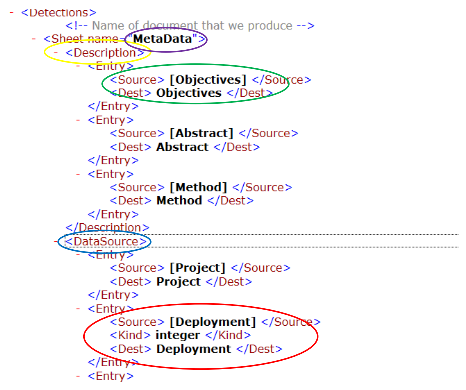

DescriptionType
Objectives
What are the objectives of this effort? Examples: Beamform to increase SNR for detection. Detect every click of a rare...
Abstract
Method
High-level description of the method used.
Description
Type DescriptionType
Text based description of process.
DataSourceType
EnsembleName
Name of a group of instruments being used together for a common purpose (e.g. large aperture array). The Name will...
DataSource
Type DataSourceType
Project
Deployment
Site
Cruise
Information that identifies...

Source (input) data from Excel:


Microsoft Excel - Detection_Effort_template.xls

	A	B	C	D	E	F	G
1	User ID	Project	Deployment	Site	Effort Start	Effort End	LTSA plot tim
2							
3							
4							
5							
6							

<u>Data map:</u>



```
- <Detections>
      <!-- Name of document that we produce -->
  - <Sheet name="MetaData">
    - <Description>
      - <Entry>
          <Source> [Objectives] </Source>
          <Dest> Objectives </Dest>
        </Entry>
      - <Entry>
          <Source> [Abstract] </Source>
          <Dest> Abstract </Dest>
        </Entry>
      - <Entry>
          <Source> [Method] </Source>
          <Dest> Method </Dest>
        </Entry>
      </Description>
    - <DataSource>
      - <Entry>
          <Source> [Project] </Source>
          <Dest> Project </Dest>
        </Entry>
      - <Entry>
          <Source> [Deployment] </Source>
          <Kind> integer </Kind>
          <Dest> Deployment </Dest>
        </Entry>
      - <Entry>
```

Above is a portion of the data schema. Note that the first listed is called “Description”. The yellow ellipse shows “Description” in the data schema in the top panel, and shows the same “Description” in our data map. All required portion of the data schema must be in the data map.

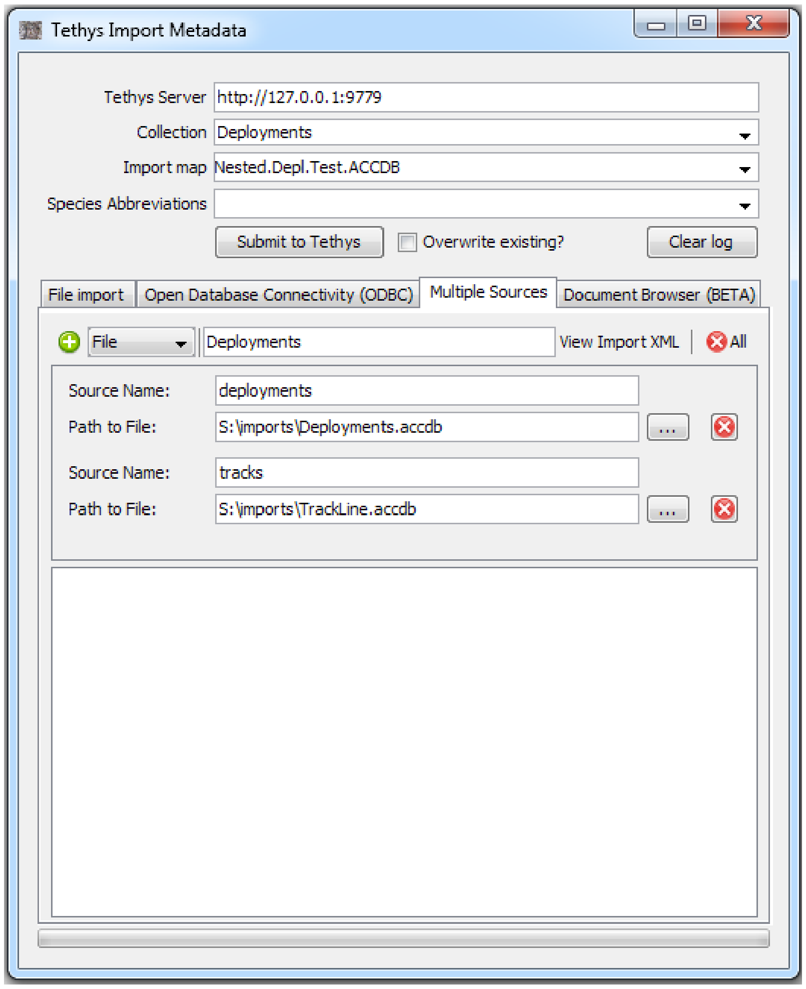
To parse out the data, we now need to specify where in the source data to find the elements of “Description” from the schema. Specifying the source (input) data sheet is a required portion of the data map. The purple ellipses show the name of the excel sheet (“Metadata”) and the name of the source data sheet in the source map.   The next portion of the map is the locations of the data entries. From our data schema, we see “Objectives” (green ellipse) under “Descriptions”. In our specified excel sheet, we should also have a column for “Objective” – but it may have a different name than specified in the schema. In the map, we will specify the column name from the “Source” (input) data and its corresponding name in the schema as the “Dest” shown in the green ellipse.

A second example, also under the “Metadata” sheet (purple) is the element “Deployment” below “Data Source”. We now need to specify where in the source data to find the elements of “Data Source” from the schema. This is also under the excel sheet (“Metadata”) shown in the purple ellipse. The next portion of the map is the locations of the data entries. From our data schema, we see “Deployments” (red ellipse) under “DataSource” (blue ellipse) and we will need to specify this location in the map. In our specified excel sheet, we have a column for “Deployments” (red ellipse) – we specify the column name from the “Source” (input) data and its corresponding name in the schema as the “Dest” shown in the red ellipse with the data type described in the schema. The data type from the schema is listed under “kind” in the map.

6.3.6 Multiple Sources and Nested Queries

It is possible to add data to Tethys from multiple sources. Suppose that a set of towed array deployments is maintained by passive acoustic monitoring staff and a separate ship-wide database contains ship position information. To construct a deployment document which contains information about the deployment such as sampling regime as well as trackline information, these two sources must be accessed together. Furthermore, if the trackline was for the entire voyage, one would need to begin processing the deployment and then query the portion of the trackline relevant to the deployment.

As with the other import methods specified above, sourcemaps are used to provide direction on how data are to be translated. These use the open database connectivity (ODBC) syntax, where data are queries using “select” commands (these are sequential query language (SQL) queries and people with knowledge of SQL may write more sophisticated queries). When the data are submitted, each data source is given a name that will be used to reference the data source from within the sourcemap.



Tethys Server: http://127.0.0.1:9779
Collection: Deployments
Import map: Nested.Depl.Test.ACCDB
Species Abbreviations:

Deployments

Source Name: deployments
Path to File: S:\imports\Deployments.accdb

Source Name: tracks
Path to File: S:\imports\TrackLine.accdb

In general, the <*Table*> element is used to begin accessing data; even for spreadsheets. Attributes are used to indicate which source the query is to be taken from and what is to be retrieved:

- source – The name given to the data source. As an example, if we were taking data from the PAM team and a ship-wide database, we might call one source "PAM" and the other "SHIP". What we elect to call these is not important as long as source names provided to the submission tool match those in the sourcemap.
- query – A SQL query. The simplest SQL queries have the format: "select * from [table]" where table is the name of the table. For spreadhseets, each tab is treated as a table, and the Microsoft ODBC appends a $ to the sheet name.

The same general rules for sourcemaps apply when sourcing multiple documents, except regardless of the source format, the <Table> element is used to specify the source data.

Example Table entries:

```
<Table source="deployments" query="select * from Deployments">
…
</Table>

<Table source="ship" query="select * from trackline">
…
</Table>

<Table source="PAM" query="select * from [MetaData$]">
…
</Table>
```

This is the basic method of referencing multiple sources on a single document submission.

When an import using multiple sources is submitted, a specification is sent to the server indicating the sources, import map, and species abbreviations (if needed) along with the data that are to be added. For the curious, a button at the top of the Multiple Source tab marked "View Import XML" will permit viewing of the specification that is sent.

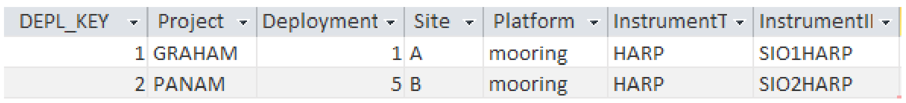
There are different ways to link more sources together. In general, we need a way of determining which data subset (e.g. trackline entries) correspond to the parent (e.g. deployment entries). In the sourcemap's <Table> element, we add a WHERE clause to the SQL query which restricts the sub-data in some way, like the start and end of a deployment:

```
<Table  source="tracks"
        query="SELECT *
        FROM TrackPoints
        WHERE START_DATE >= {DEPL_START_DATE}
        AND END_DATE <= {DEPL_END_DATE};">
```

This would pull entries from the table called TrackPoints, residing between the parent row's Start and End dates, denoted by the columns DEPL_START_DATE and DEPL_END_DATE. The new lines within the attribute query are added for readability, but are not necessary.

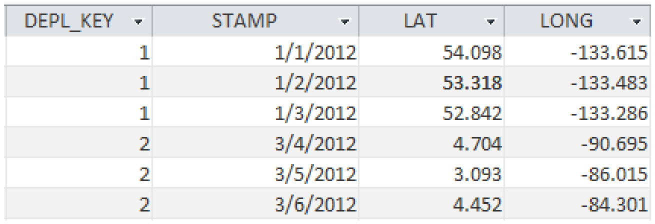
Another strategy is to assign keys to the data:

Deployments.accdb (many omitted fields):



DEPL_KEY	Project	Deployment	Site	Platform	InstrumentT	InstrumentII
1	GRAHAM	1	A	mooring	HARP	SIO1HARP
2	PANAM	5	B	mooring	HARP	SIO2HARP

TrackLine.accdb:



DEPL_KEY	STAMP	LAT	LONG
1	1/1/2012	54.098	-133.615
1	1/2/2012	53.318	-133.483
1	1/3/2012	52.842	-133.286
2	3/4/2012	4.704	-90.695
2	3/5/2012	3.093	-86.015
2	3/6/2012	4.452	-84.301

Now, in the source map, we begin with a <Table> element for the Deployment source as usual:

```
<Table  source="deployments"
        query="select * from Deployments">
```

And continue filling in the <Entry>'s for each field. As each row of the Deployments table is processed, the field DEPL_KEY will hold the value associated with that row and can be used to write a second query that only retrieves trackline entries for that deployment. Once we reach the <Point> section, where the track line coordinates would go, we wrap another <Table> element around it. This time, we specify the key:

```
        <Table source="tracks"
              query="SELECT *
                    FROM TrackPoints
                    WHERE DEPL_KEY = {DEPL_KEY};">
```

We have now linked the two tables together, and three <Point> elements will be generated for each of the deployments in the screenshot above. Any number of sources and keys can be specified. The curly braces around DEPL KEY indicate that the current value of DEPL KEY should be used in the query.

The above are just a couple examples, the main thing to remember is that there must be a way of determining which entries belong to which, and that should be put into the WHERE clause

6.4 Species Abbreviations

Detections are attributed to entries in the ITIS collection. They are stored as taxonomic serial numbers which are not conducive to human interpretation. The ITIS collection itself provides mapping to vernacular names in several languages as well as scientific names for each species. However, many research organizations have their own set of names, or abbreviations used for each species. As an example, at the Scripps Whale Acoustics Lab, it is common to use abbreviations based on the genus and species names, such as Zc to denote *Ziphius cavirostris*, or Cuvier's beaked whale.

Unfortunately, the California sea lion, *Zalophus californianus*, would also be abbreviated Zc, and consequently it is very difficult to develop an abbreviation/local name list that would work for all groups. The SpeciesAbbreviations collection provides a method for labs to

6.5 Localization format

The data format for localizations is currently in its preliminary stage and based largely on work done at NEFSC with a custom module developed for XBAT. An example of a spreadsheet produced by the detector and augmented by the analyst can be found in the documentation directory: location_output.xlsx. It contains four tabs:

- Localization – Information about the localizations themselves. This includes an event id that should ideally be linked to the event id in the detection log to determine information about the call although there is no such link at this time. Localization is currently planar with x and y locations, and there is currently no mechanism for finding the reference.
- Metadata – Contains the user who conducted the anlaysis, the algorithm used and its version.
- Parameters – User settable parameters used in the localization algorithm.
- Sensors – A list of Projects, Sites, and Deployments of the instruments used in the localization.
- Storing the parameters, algorithm and version number are necessary to make results reproducible.

7 Appendix: Matlab functions in Tethys

See the Matlab cookbook document for examples of using the Matlab client.

dbCannedReports(queries, detector, bycall, statfile)

```
% summary = dbCannedReports(queries, detector)
% Generate reports from Tethys database
% detector - one of 'human', 'sbp_rule', 'hr_click'
% bycall - false: species level only, true: break down by call type
```

% statfile - [] or filename where summary statistics are written
When working with large amounts of data, it is often useful to have a summary of the data of interest. dbCannedReports allows the user to quickly create a summary of the data returned in a query. First the user supplies the method of detector used for the data set. This can be done for all data returned for each species (use false as the bycall) or separated out by call type. The output is a file of summary statistics. dbCanned Reports differs from dbCannedReportsLoSubtype in that summary statistics are included.

dbCannedReportsLoSubtype(queries)

```
% dbCannedReports(queries, detector)
% Generate reports from Tethys database
% detector - one of 'human', 'sbp_rule', 'hr_click'
% bycall - false: species level only, true: break down by call type
```

dbCannedReportsLoSubtype allows the user to quickly create a summary of the data returned in a query. First the user supplies the method of detector used for the data set. This can be done for all data returned for each species (use false as the bycall) or separated out by call type.

dbDateToOffsets(serdate, resolution_m, varargin)

```
% [day, m, originalIndices] = dbDateToOffsets(serdate, resolution_m,
%     OptionalArguments)
% Given one or two columns of serial dates, convert to
% day numbers and resolution_m m bins.
%
% For one column data, the a second column will be added that
% is resolution_m minutes after the start time.
%
% For two column data, the second column is rounded up to the
% start of the next bin
%
% Returns Nx2 matrices for days and minutes showing the timespan
% of contiguous detections within each day.
%
% The optional output originalIndices shows which row of serdate
% is associated with each entry in day and m.
%
% Optional arguments
% 'Debug', true|false - Output information about the conversion.
%                 Default: false
% 'Merge', true|false - Combine adjacent resolution_m periods.
%                 Warning:  Only the first index of original
%                 indices will be reported for merged segments.
%                 Default: true
%
% For row k, time span is from:
%   day(k,1), m(k,1) minutes into the day to day(k,2) m(k,2)
```

dbDemo(example, debug)

```
% Examples of using the Tethys database.
%
% example - example N, see switch statement for details.
% debug - turn on debugging mode, functions supporting debugging
%   flags will have them enabled.
```

For a demonstration of some common uses of the Tethys database and tools, use dbDemo. Several examples are buit in to dbDemo. The examples can be used to confirm that the software is installed and configured correctly, or as a template for the user's metadata analyses. Example 1 uses sample data included with the Tethys download, and queries for all unidentified whale detections associated with a specific deployment and site. Example 2 queries the sample database for three types of whale calls. Example 3 displays information on the project, deployment, and site for the data used in a query. Example 4 uses the entire database, rather than a query subset, to create a summary of effort for the entire database. In example 5, a diel plot of detections for a given species, deployment, and site is produced. Example 6 returns a list of all species detected at a specific site. Example 7 lists all of the species and all of the call types found in the database.   Example 8 uses the output of a detection query to create a diel plot, including calculating the times of sunrise and sunset for the query output data. In example 9 we plot lunar illumination for a query output rather than the sunrise and sunset data shown in example 8. Finally, example 10 we have an example query written in XQuery - all other examples are matlab based.

dbDeploymentInfo(query_eng, varargin)

```
% [deployments, dom] = dbDeploymentInfo(query_eng, OptArgs)
% Returns an array where each element is a structure
% with fields about fixed deployments.  Records are selected
% based on the following optional arguments which fall into two
% categories
%
% Equality checks:  Specified value must be equal (case independent)
% to the string provided
% 'Project', string
% 'Region', string
% 'Site', string
%
% Floating point comparisions:
% 'DeploymentId', Comparison
% 'Geotime/Latitude', Comparison
% 'Geotime/Longitude', Comparison
% 'Geotime/Depth_m', Comparison
% Comparison consists of either a:
%   scalar - queries for equality
%   cell array {operator, scalar} - Operator is a relational
%       operator in {'=', '<', '<=', '>', '>='} which is compared
%       to the specified scalar.
```

To find the information on the deployment of the instruments used to collect the data in your database, dbDeployment can be used from the command window of Matlab. Any combination Project,Re gion, Site, DeploymentId, Latitude, Longitude, and Depth_m can be included in the arguments. To see the possible values for Project, Region, and Site refer to the detections input data. Note that the string provided to Matlab must match the string in the input data exactly. The comparison arguments can be a value equal to a scalar (for example, Geotime/Depth_m = 1000) or a relational operator such as greater than or less than (Geotime/Depth_m > 1000) a specific value.

dbDeployments2kml(query_h, kmlfile, varargin)

```
% dbDeployments2kml(query_h, kmlfile, Optional Args)
% Write a KML file with all deployments meeting the criteria
% and display them in Google Earth.
%
% See dbDeploymentInfo() for optional arguments, the same arguments
% are supported and permit selection criteria for deployments.
%
% Example:
% q = dbInit();  % set up query handler
% dbDeployments2kml(q, 'socal.kml', 'Project', 'SOCAL');
```

dbDetections2XML(EffStart, EffEnd, Kinds, DetectionTimes)

```
% xml = dbDetections2XML(EffStart, EffEnd, Kinds)
% Generate XML from a set of detections
%
% Kinds should be a structure array where each element has:
%  .SpeciesID (a taxonomic serial number from the ITIS collection)
%  .Call (a call type)
%  .Granularity - granularity type
%  .BinSize_m - bin size in minutes
% Note that every element of the structure must have the same fields.
% If some things are not needed set them to [] (e.g. BinSize_m for
% effort of granularity "encounter".
%
```

dbDiel(query_eng, lat, long, start, stop, varargin)

```
% night = dbDiel(query_eng, lat, long, start, stop, Optional)
% Return information from database about when sunrise and sunset occur
% across the specified interval between start and stop which are UTC
% serial dates (see datenum).  Sunrise and Sunset information are
% given as serial dates in UTC time in columns 1 and 2 respecitvely of
% sunrise_sunset.
%
% Position is specified as decimal longitude [0-360) and latitude [-90 90].
% Negative latitudes indicate the southern hempisphere.
% Longitudes > 180 degrees are west.
%
% Optional arguments:
%  'type', SunsetType - default civil, not well tested with other
%    types:  nautical, astronomical
%  'UTCOffset', N - Return values are offset by N hours (e.g. -4.5
%    four and a half hours before UTC).  The start and stop times
%    are still assumed to be UTC.
```

dbDiel returns the sunrise and sunset times for a specific location on a specific date range. Note that all times are in UTC, not local times.

dbEffort(queries, detector)

Calls dbGetEffort, this can be used as an example for building a query to find all species for which there is effort given the Site, Deployment, Project, and Detector. dbGetEffort is the preferred function for this type of analysis.

dbERDDAP(queryH, Query, squeezeP)

```
% result = dbERDDAP(queryH, Query, squeezeP)
% Return the results of an ERDDAP query.
% ERDDAP returns data as either a table or grid.  Some
% grids have singleton dimensions.  Setting the optional squeezeP
% will remove any singleton dimensions for grid data and has no
% effect on table data.
%
% result is a structure with the following structure:
%
% For grids -------------------------------------------------------------
%   dims - Vector of grid dimensions
%   Axes - Structure with information about the axes, fields:
%      names - Cell array with axis names
%      units - Cell array of units associated with type
%      types - Cell array of data type of axis values:
%            datenum, String, numeric type
%            Note that numeric types are stored as doubles in Matlab,
%            but their original precision (e.g. float, double, int)
%            can be determined from this field.
%      values - Cell array of grid axis labels
%   Data - Structure with grid data
%      names - Cell array with data variable names
%      units - Cell array with data units
%      types - Cell array of data types:
%            datenum, String, double
%       values - Cell array of data values.
%          Each cell entry is one variable
%
% Grid example:
% r = dbERDDAP(q, 'erdGAssta1day?sst[(2009-07-24T00:00:00Z):1:(2009-09-
16T00:00:00Z)][(0.0):1:(0.0)][(32.559):1:(32.759)][(240.423):1:(240.623)]');
%
% r.Axes.names:  'time'    'altitude'    'latitude'    'longitude'
% r.Axes.units:  'UTC'    'm'    'degrees_north'    'degrees_east'
% r.Axes.types:  'datenum'    'double'    'double'    'double'
% r.Axes.values{1} contains datenums indicating the sampling points on the
%   time axis, r.Axes.units(Joint W3C/IEFT URI Planning Interest Group) contains latitudes, etc.
% r.Data.names:  'sst'
% r.Data.units:  'degree_C'
% r.Data.types:  'float'
% r.Data.values{1} contains sea surface temperature (SST) measurements
%
% If mulitple varaibles were requested (not possible with this specific
% dataset), then r.Data.values would contain additional cells.
%
% Removing singleton axes (squeeze predicate)
% Note that the altitude is constant as the altitude of the sea surface
% is always zero, making for r.Data.values matrices that have a only
% one value along the altitude axis.  (In this example, a 55 x 1 x 5 x 5
% matrix).  To remove the singleton axis, set the optional squeeze predicate
% (squeezeP) to true.
%
% Squeeze exmaple:
% r = dbERDDAP(q, 'erdGAssta1day?sst[(2009-07-24T00:00:00Z):1:(2009-09-
16T00:00:00Z)][(0.0):1:(0.0)][(32.559):1:(32.759)][(240.423):1:(240.623)]', true);
%
% Ouput will be similar, the Axes and Data fields will have the same
% structure except elements that contain only a single value will be
% removed.  Hence, in this example, altitude will be removed and
% results.Data.values{1} will be 55 x 5 x 5 instead of 55 x 1 x 5 x 5.
%
% A new constants field shows the singleton axes that were "squeezed" out.
% r.Constants:
%     names: {'altitude'}
%     units: {'m'}
%     types: {'double'}
%    values: {[0]}
%
% for Tables --------------------------------------------------------------
%   rows - Number of rows in table
%   Columns - Structure containing information about each table
%       names - Cell array of column names
%       types - Cell array of column types
%            datenum, String, numeric type
%            Note that numeric types are stored as doubles in Matlab,
%            but their original precision (e.g. float, double, int)
%            can be determined from this field.
%      units - Cell array of units of measure if applicable ([] if not)
%   Data
%      fields corresponding to the names.  Each field is a cell array
%      or vector depending upon its data type.
%
% Example:
% r = dbERDDAP(q,...
%'erdCalcofiBio?line_station,line,station,longitude,latitude,depth,...
%time,occupy,obsCommon,obsScientific,obsValue,...
%obsUnits&time>=2004-11-12T00:00:00Z&time<=2004-11-19T08:32:00Z');
% r
%      Columns: [1x1 struct]
%      Data: [1x1 struct]
%      rows: 296
% r.Columns.names'
%    'line_station' 'line' 'station' 'longitude' 'latitude' 'depth'
%    'time' 'occupy' 'obsCommon' 'obsScientific' 'obsValue' 'obsUnits'
%     7
% datestr(r.Data.time)  OR using a technique that can be applied to loops
%      fieldname = 'time';
%      datestr(r.Data.(fieldname))  % .(variable) use contents as name
% returns
%   18-Nov-2004 11:57:00
%   18-Nov-2004 11:57:00
%   18-Nov-2004 11:57:00
%   ...
```

dbERDDAPSearch(queryH, SearchParams, Open)

```
% url = dbERDDAPSearch(queryH, SearchParams, Open)
% Search NOAA's Environmental Research Division Data Access Program
% (ERDDAP) catalog for datasets matching desired parameters.
% SearchParams arguments are any valid set of ERDDAP keywords.  Each
% keyword is followed by an = sign with a search value.  Multiple keywords
% are joined by &.
% queryH is the qeury handler, see dbInit()
%
% If the optional Open argument (default true) is true, a web browser
% will display the search results.  The return value url is the url that
% is returned.
%
% ERDDAP's web services discussion gives a couple of examples and contains
% a pointer to a GUI which will let people observe all settable parameters:
```

```
% http://coastwatch.pfeg.noaa.gov/erddap/rest.html
%
%
% Search parameters as of this writing:
%       searchFor - search terms separated by +, e.g. night+modis
%       protocol
%       cdm_data_type
%       institution
%       ioos_category
%       long_name
%       standard_name
%       minLat  - Latitude is in degrees North
%       maxLat
%       minLon  - Longitude is in degrees East
%       MaxLon
%       minTime - Time is in the ISO 8601:2004 format
%       maxTime   e.g. 2012-01-01T18:34:22Z
%
%
% Examples:
% dbERDDAPSearch(queryH, 'ioos_category=ice_distribution')
%
% dbERDDAPSearch(queries, ...
%'keywords=sea_surface_temperature&minLat=33.47&maxLat=33.56&minLong=240.71&maxLong=240.80')
```

To add environmental data, use dbERDDAPSearch. For a given set of ERDDAP keywords (some common keywords are: bathymetry, calcofi, chlorophyll-a, goes, ice, noaa, ocean-color) with a search value, Tethys will go to the ERDDAP website and dowload the desired environmental data.

For a full list of keywords go to http://coastwatch.pfeg.noaa.gov/erddap/categorize/keywords/index.html?page=1&itemsPerPage=1000

dbFindFiles(SearchFileMask, SearchPathMask, SearchRecursiv)

```
% Find Files regarding a search mask
%
%  This function searches for files in the current directory /
%  a given directory: The serach can be recursively, depending
%  on the provided parameters.
%  The search mask is relatively simple (just '*' as wildcard).
%
```

dbGetCalltypes(queryEng, MetaDataPred, DetectionPred)

```
% calltypes = dbGetCalltypes(queryEng, MetaDataPred, DetectionPred)
% Given a database query engine,
% Return a list of calltypes meeting the associated meta data
% and detection data predicates.
%
% Examples:  Return all call types for anthropogenic calls detected
% at sites M and N.
% dbGetCalltypes('Deployment/Site = "M" or Deployment/Site = "N"', ...
%       'Species = 'Anthro')
```

dbGetCannedQuery(querynm)

```
% query_text = dbGetCannedQuery(query)
% Return a canned query with printf style strings
% to set criteria.
%
% Query are defined in the xqueries directory relative to this function
```

dbGetDetections(queryEngine, varargin)

```
% [timestamps, endPredicate, deploymentIdx, deployments] = dbGetDetections(queryEngine,
Optional Args)
% Retrieve detections meeting criteria from database.  Detections
% are returned as a timestamps matrix of Matlab serial dates (see
% datenum).  The timestamps will either be single times that represent
% a detection within a binned interval, or span a time interval.  If the
% bin interval time is desired, sue the 'Duration' parameter that is
% documented below.
%
% The optional endP return value allows callers to distinguish between
% interval and instantaneous detections.  Its usage is described at the
% example at the end of this help.
%
% The optional output info is a structure variable.  If requested, it
% contains the following fields:
%   deployments - An array of structures that can be used to identify
%      the deployments associated with the retrieved detections.
%   deploymentIdx - A vector with the same number of rows as detections
%      returned (number of rows in timestamps).  Each item is an index
%      into the deployments array indicating which deployment the
%      detection originated from.
%   Other fields may be populated based on parameters passed to the
%      optional input 'Return'
%
% Inputs:
% queryEngine must be a Tethys database query object, see dbDemo() for an
% example of how to create one.
%
% To query for specific types of detections, use any combination of the
% following keyword/value pairs:
%
% Attributes associated with project metadata:
% 'Project', string - Name of project data is associated with
% 'Site', string - name of location where data was collected
% 'Deployment', comparison - Which deployment of sensor at a given location
%
% Attributes associated with how detections were made:
% 'Method', string - Method of detection
%          e.g. analyst, Spectrogram Correlation
% 'Software', string - Name of detector, e.g. analyst, silbido
% 'Version', string - What version of the detector
% 'Parameters', string - Parameters given to the detector, for humans,
%   we use the individual's user id.
% 'UserID', string - User responsible for the analysis
%
% Attributes associated with detections
% 'SpeciesID', string  - species or category of sound
% 'Group', string - species group e.g. BW43
% 'Call_type', string - type of call/sound
% 'Call_type/@Subtype', string - subtype of call
%
% Comparison consists of either a:
%   scalar - queries for equality
%   cell array {operator, scalar} - Operator is a relational
%      operator in {'=', '<', '<=', '>', '>='} which is compared
%      to the specified scalar.
%
% Other optional arguments:
% 'Return', string - Return an additional field, e.g.
%   'Return', 'File'
% 'Duration', N - When present, detections without a stop time
%    are interpreted as having fixed duration, and the end
%    time is set to start time + N.  (Default N=0)
%    Example:  60 m duration:  'Duration', datenum([0 0 0 1 0 0])
%    Note that when duration is set, two columns will always be
%    returned, even if there are no end times in the requested
%    detections.
%
% Example:  Retrieve all detections for Pacific white-sided dolphins
% from Southern California regardless of project.  Note that when
% multiple attirbutes are specified, all criterai must be satisfied.
% [detections, endP] = dbGetDetections(qengine, ...
%                       'Project', 'SOCAL', 'Species', 'Lo');
%
% Output is a one or two column matrix of start and (if available) end
% times of detections.  If the result contains instantaneous detections
% and two columns are returned due to interval detections also being
% present, the time end predicate (endP) can be used to determine
% which is which.  Where endP(row_idx) = 1, detections(row_idx, :) will
% be an interval detection.  Accordingly, a 0 indicates an instantaneous
% detection.
% Example: [detections, endP] = dbGetDetections(...);
% Interval detections: detections(endP, :)
% Instantaneous detections:  detections(~endP, 1)
```

dbGetEffort(queryEng, varargin)

```
% [Effort Characteristics] = dbGetDetections(queryEngine, Arguments)
% Retrieve effort information from Tethys detection effort records.
% Effort is a matrix of Matlab serial dates containing the start and
% end times in each row.  Characteristics is a structure array whose
% elements correspond to each row of the Effort matrix and characterize
% the effort (i.e. which species, site, etc.)
%
% queryEngine must be a Tethys database query object, see dbDemo() for an
% example of how to create one.
%
% To query for specific types of effort, use one of the following
% keywords as a string followed by the desired value to be queried:
% species is the desired species.
%
% Attributes associate with project metadata:
% 'Project', string - Name of project data is associated with, e.g. SOCAL
% 'Site', string - name of location where data was collected
% 'Deployment', comparison - Which deployment of sensor at a given location
% 'UserID', string - User that prepared data
% Attributes associated with how detections were made:
% 'Detector', string - Name of detector, e.g. human
% 'Version', string - What version of the detector
% 'Parameters', string - Parameters given to the detector, for humans,
%   we use the individual's user id.
% Attributes associated with species effort
% 'SpeciesID' - species/family/order/... name.  Format depends on the last
%    call to dbSpeciesIDFmt.
% 'Call'
% 'Subtype'
% 'Group' - Species Group
% 'Granularity' - Type of effort
% 'BinSize_m' - Binsize in minutes
%
% Attributes whose argument is comparison can either be a:
%   scalar - queries for equality
%   cell array {operator, scalar} - Operator is a relational
%      operator in {'=', '<', '<=', '>', '>='} which is compared
%      to the specified scalar.
%
% One can also query for a specific document by using the document id
% in the detections collection:
```

```
% 'Document', DocID - DocId is 'dbxml:///Detections/document_name'
%     At the time of this writing, document names are derived from the
%     source spreadsheet name.  Document names can also be obtained
%     from the results of this function, by inspecting the XML_Document
%     field of the Characteristics array.
%
% Examples:  Retrieve effort to detect Pacific white-sided dolphins
% from Southern California regardless of project.  Note that when
% multiple attirbutes are specified, all criterai must be satisfied.
%
% dbGetEffort(qengine, 'Region', 'SOCAL', 'SpeciesID', 'Lo')
%
% The same query could be run for the 35th deployment by adding:
%      'Deployment', 35
% or for deployments >= 35 with
%      'Deployment', {'>=', 35}
%
% Retrieve the effort associated with the submitted document
% SOCAL41N_Humpback_ajc
% dbGetEffort(qengine, ...
%    'Document', 'dbxml:///Detections/SOCAL41N_Humpback_ajc')
```

dbGetEvents(queryEngine, varargin)

```
% [timestamps, events, endPredicate] = dbGetEvents(queryEngine, Optional Args)
% Retrieve detections meeting criteria from database.  Detections
% are returned as a timestamps matrix of Matlab serial dates (see
% datenum).  The timestamps will either be instantaneous or span an
% intveral.  (Instantaneous events can be converted to fixed period
% events with the optional 'Duration' parameter (see below).  The
% optional endP return value allows callers to distinguish between
% intrval and instantaneous detections.  Its usage is described at the
% example at the end of this help.
%
% Inputs:
% queryEngine must be a Tethys database query object, see dbDemo() for an
% example of how to create one.
%
% To query for specific types of detections, use any combination of the
% following keyword/value pairs:
%
% 'Start', date - >= start as Matlab serial date (datenum)
% 'End', date - <= end as Matlab serial date
%
% Comparison consists of either a:
%   scalar - queries for equality (unless otherwise specified)
%   cell array {operator, scalar} - Operator is a relational
%       operator in {'=', '<', '<=', '>', '>='} which is compared
%       to the specified scalar.
```

```
%
%
% Example:  Retrieve events between
% from Southern California regardless of project.  Note that when
% multiple attirbutes are specified, all criteria must be satisfied.
% startd = datenum([2010 1 1]);
% endd = datenum([2010 12 31 23 59 59.999]);
% [events, endP] = dbGetEvents(qengine,
%                       'Start', startd, 'End', endd);
%
% Output is a one or two column matrix of start and (if available) end
% times of detections.  If the result contains instantaneous detections
% and two columns are returned due to interval detections also being
% present, the time end predicate (endP) can be used to determine
% which is which.  Where endP(row_idx) = 1, detections(row_idx, :) will
% be an interval detection.  Accordingly, a 0 indicates an instantaneous
% detection.
% Example: [detections, endP] = dbGetDetections(...);
% Interval detections: detections(endP, :)
% Instantaneous detections:  detections(~endP, 1)
```

dbGetLunarIllumination(query_eng, lat, long, start, stop, interval, varargin)

```
% illu = dbGetLunarIllumination(query_eng, lat, long, start, stop, interval, varargin)
% Return information from database about the lunar illumination percentage
% between the start and ennd UTC serial timestamps (datenums) in the
% specified interval.
%
% illu(:,1) contains serial dates (datenums)
% illu(:,2) contains the percentage of lunar illumination 0-100
% illu(:,3) contains the apparent azimuth
% illu(:,4) contains the apparent elevation
%
% Position is specified as decimal longitude [0-360) and latitude [-90 90].
% Negative latitudes indicate the southern hempisphere.
% Longitudes > 180 degrees are west.
%
% Optional arguments
% getDaylight true|false(default)
%   Return illumination during daylight hours as well?
% UTCOffset, N
%   Used to process queries and results in local time.  Specify the
%   offset from universal coordinated time.
%
% Example:  See dbLunarDemo.m
% Caveats:  Cloud cover is not taken into account
% See also:  datenum for converting date/time to serial timestamps.
```

dbGetSpecies(queries, expedition, site)
```
% species = dbGetSpecies(queries, expedition, site)
% Determine which species have been detected
% for a given expedition and site.
```

dbGetUsers(queries)
```
% users = dbGetUsers(queries)
% Return a cell array with users that have detection effort.
```

dbInit(varargin)
```
% dbInit(optional_args)
% Create a connection to the Tethys database.
% With no arguments, a connection is created to the default server
% defined within this function.
%
% Optional arguments:
% 'Server', NameString - name of server or IP address
%         Use 'localhost' if the server is running the
%         same machine as where the client is executing.
% 'Port', N - port number on which server is running
% 'Secure', false (default)|true - make connection over a secure socket
% 'TransportLayer', 'xmlrpc'|'REST'
%         Describes transport layer mechanism.  Default 'REST'
%         This must match the server transport layer mechanism.
%
% 'NAT', false (default) | true - Most users can ignore this switch.
%        It should only be used when communicating with a Tethys server
%        attached to a router providing network address translation and
%        clients will be connecting from both within the NAT network and
%        the wider network.  One possible sign of a NAT network is when
%        some of the clients have private network IP addresses:
%            10.x.x.x, 172.16.x.x:172.31.x.x, or 192.168.x.x
%        and other clients do not.  Contact your network administrator
%        if you are not sure.
%        In general, using a NAT network can create problem for
%        the Secure option as it may be harder to verify self-signed
%        certificates.
%
% Returns a handle to a query object through which Tethys queries
% are served.
```

dbISO8601toSerialDate(isodatesZ, offset)
```
% dates = dbISO8601toSerialDate(isodates, offset)
% Given a cell array of ISO8601 format dates:
%   YYYY-MM-DDTHH:MM:SS.FFFZ
%   e.g. 2010-02-09T07:39:22.325Z
% convert to Matlab serial dates.
% For now, we assume that all times are in UTC and do not
% parse the possible time zone indictator following the Z
%
% The optional parameter offset is a Matlab serial date that
% will be used as an offset.  This is useful for handling time
% zones or converting to Triton format serial dates, which are
% offset from a different date than the standard date.  To
% convert to Triton dates, use -dateoffset() as the offset parameter.
```

dbJavaPaths

```
% Make sure Java classes on path
```

dbNormDiel(detections, night, UTCoffset)

```
% Given a set of detections and diel informaiton specifying night time,
% renormalize detections to represent a 12 hour day/night period by
% linear interpolation.
%
% Assumptions:
% Both detections and night are sorted by timestamp and
%   converted to local time (or in UTC with a provided UTCoffset)
%   so that night fall is after sunrise each day.
% There are no detections outside of the night intervals except for
%   the day before and after the first and last night respectively.
```

dbParseDates(dom, varargin)

```
% [timestamps, missingP] = dbParseDates(records, OptionalArgs)
%
% Given a set of records returned from a dbXPathDOMQuery, parse timestamp
% fields and return them as a matrix of Matlab serial dates.  Each row
% corresponds to the timestamps associated with a single record.
%
% missingP is an indicator function. 1 indicates that the value was
% missing for the record and 0 indicates that a value was extracted.
%
% Optional arguments
%  'Elements', names - Cell array of element names that will be checked
%     Defaults to {'Start', 'End'}
%  'Record, str - Name of element containing the fields from which
%     dates will be extracted.  Defaults to 'Detection'
```

dbPresenceAbsence(presence, varargin)

```
% [counts, dayrng, eff] = dbPresenceAbsence(presence, Optional args...)
% Compute presence/absence in resolution_m increments
% Presence is a one or two column matrix giving starting (and
% possibly ending times) as Matlab serial dates.  If end time
% is unavailable, only the resolution_m segment containing the
% start time will be selected. Dates are assumed to be UTC and sorted.
%
% Outputs:
% counts - Output depend on the 'Output' optional argument, see
%         Optional arguments.
%   Matrix with 0/1 presence indicator.  Rows are days,
%   columns make up a day with the number of columns determiend by
%   the Resolution_m argument.
%   OR
%   Row vector with counts in each time period of the day.  Equivalent
%   to summing the matrix output across rows.
% dayrng - First and last day (serial dates, see datestr/datenum)
%   of period covered by analysis
% eff - Matrix or row (as with counts) showing where there was effort.
%
% Optional arguments:
%  'UTCOffset', N - Convert to local time using an offset of N (default 0)
%  'Effort', SerialDateMatrix - Indicates where effort to detect was
%     made.  Regions of the plot where there was no effort will be
%     displayed with a lighter version of the plot color.
%  'Resolution_m', M - Plot resolution (bin size) in minutes (default 60)
%  'Values', Nx1 - A vector of values with the same number of entries
%        as there are rows in presence.  Rather than populating each
%        entry with a 0/1 indicator value, the corresponding value
%        is used.
%  'Output', String -
%    'indicator' (default) - counts will be a matrix of indicator
%        functions where each row is a day and columns correspond
%        to bins of resolution_m minutes.
%
%    'counts' - Number of times indicator function was positive, suitable
%        for use in a histogram.  Equivalent to sum(counts) when output
%        is specified as indicator.
%    This option should not be used with the 'Values' option.
```

dbRelOp(Element, XPathFmt, Comparison, default)

```
% comparison = dbRelOp(Parameter, XPathFmt, RelOp, defaultcomp)
% Helper function for translating  numeric comparisons into XQuery
% fragments.  Not intended to be called directly by the user.
%
% Element is a the XML element name
% XPathFmt is the a format string that qualifies the element
%  within the query.
% Comparison consists of either a:
%   scalar - queries for equality
%   cell array {operator, scalar} - Operator is a relational
%      operator in {'=', '<', '<=', '>', '>='} which is compared
%      to the specified scalar.
% default - default comparison '='
```

dbRelOpChar(Element, XPathFmt, Comparison, default)

```
% comparison = dbRelOp(Parameter, XPathFmt, RelOp, defaultcomp)
% Helper function for translating  numeric comparisons into XQuery
% fragments.  Not intended to be called directly by the user.
%
% Element is a the XML element name
% XPathFmt is the a format string that qualifies the element
%  within the query.
% Comparison consists of either a:
%   scalar - queries for equality
%   cell array {operator, scalar} - Operator is a relational
%      operator in {'=', '<', '<=', '>', '>='} which is compared
%      to the specified scalar.
% default - default comparison '='
% Determine which operator will be used unless the user overrides
```

NOTE: The following command does not function in the current release. Use the Python client remove.py to delete a document.

dbRemoveDetectionDoc(queries, user, docid)

```
% result = dbRemoveDetectionDoc(queries, user, docid)
% Remove a specified database detection document for a user.
% queries - database query handle returned by dbInit()
% user - user id
% docid - XML document id
%
% Example:
%
% queries = dbInit();
% % find detections submitted by TestUser
% dbUserEffort(queries, 'TestUser')
%
% ans =
%
% dbxml:///Detections/SOCAL38N_MF_Minke_test
% .. others ...
% % document id follows dbxml:///Detections/
% dbRemoveDetectionDoc(queries, user, ...
%    'dbxml:///Detections/SOCAL38N_MF_Minke_test')
%
```

dbRemoveOverlap(timespans)

```
% [revised, removed] = dbRemoveOverlap(timespans)
% Given a matrix row oriented start and end dates,
% return a new matrix where overlapping rows have
% been removed.
%
```

```
% The optional output removed indicates which rows
% of the original matrix were deleted.
```

dbRunQuery(query_eng, query_txt, varargin)

```
% results = dbRunQuery(query_eng, query_txt, OptionalArgs)
% Run the query contained in the string query_txt.  Optional arguments
%
% 'AsDOM', true | false(default) - Return the results as a
%   document object model (DOM).
% 'FormatOutput', true | false(default) - Format XML results
%   to be more easily readable by humans.  Note that the output
%   must be a valid XML document to be formatted.
% 'FormatQuery', CellArrayOfArgs - When present, it is assumed
%   that the query file contains sprintf formatting symbols (e.g.
%   %s for string, %f for floating point).  The query is formatted
%   using the arguments in the cell array.  See Matlab's sprintf
%   for more details on formatting instructions.
% 'SaveTo', outputname - Write the results to the specified XML file
% 'TyNamespace' true | false(default) - Prefix the Tethys namespace
%   and libraries to the query
% Return the results as a text XML document unless the
% optional asdom parameter is true in which case a
% document object model representation of the
% results is returned.
```

dbRunQueryFile(query_eng, filename, varargin)

```
% results = dbRunQueryFile(query_eng, filename, OptionalArgs)
% Run the query contained in filename.  Optional arguments
%
% 'AsDOM', true | false(default) - Return the results as a
%   document object model (DOM).
% 'FormatOutput', true | false(default) - Format XML results
%   to be more easily readable by humans.  Note that the output
%   must be a valid XML document to be formatted.
% 'FormatQuery', CellArrayOfArgs - When present, it is assumed
%   that the query file contains sprintf formatting symbols (e.g.
%   %s for string, %f for floating point).  The query is formatted
%   using the arguments in the cell array.  See Matlab's sprintf
%   for more details on formatting instructions.
%  'SaveTo', outputname - Write the results to the specified XML file
% Return the results as a text XML document unless the
% optional asdom parameter is true in which case a
% document object model representation of the
% results is returned.
```

dbSerialDateToISO8601(serial)

```
% Convert a set of of Matlab serial dates to ISO8601 format
% It is assumed that the dates are in UTC.
```

dbSpeciesFmt(Type, Format, varargin)

```
% dbSpeciesFmt(Type, Format, Option)
% Sets the species naming format used for XQueries (tsn, Latin name,
% abbreviation) as well as how those results will be displayed.
%
% Type is 'Input' or 'Output' representing XQueries or Xquery results
% respectively
% Format indicates how the values are specified or reported, and is one of the following:
%  'tsn' - ITIS tsn
%  'Latin' - ITIS completename (Latin species/family/order/... name)
%  'Vernacular', Language - ITIS vernacular.  Language must be one of the
%     the following:  'English', 'French', 'Portugese', 'Spanish'.
%     Vernacular is only complete for English and will cause problems
%     for some queries when using other languages
%  'Abbrev', SpeciesAbbreviaitonMap - Use custom abbreviations based
%     on the specified abbreviaiton map
%
% To retrieve the current format, call with Type set to GetInput or
% GetOutput.
```

dbStats(queries, detector, bycall)

```
% dbStats(queries, detector, bycall)
% Generate statistics on daily and hourly bins with calls and percentage
% in regards to effort from Tethys database
% detector - one of 'human', 'sbp_rule', 'hr_click'
% bycall - false: species level only, true: break down by call type
```

dbSubmit(varargin)

```
% dbSubmit(OptionalArgs, Files)
% Submit files to the database.  Files may be a single filename,
% a cell array of filenames, or omitted in which case a GUI prompts
% for a single file submission
%
% OptionalArgs:
% 'QueryHandler', queryH - A handle to the Xquery interface.  If omitted
%         dbInit() will be called to produce one.
% The following optional arguments only apply when files are passed in:
% 'Collection', name - To which collection will these be added.
%         Default is 'Detections'.
% 'Overwrite', true|false - Overwrite spreadsheet if it is already
%         in the repository
%
% The Server, Port, and whether or not to use a secure socket layer
% can also be specified, see dbInit for details.
%
% Files may be:
%   omitted - A dialog requests a file to upload
%   a string - Single file upload
%   or multiple files as a cell array, all of which are uploaded
% When invoked from a GUI, the first two arguments contain the
% callback object and a reserved argument.
```

dbTimeZone(queries, longitude, latitude, method)

```
    % offset = dbTimeZone(queries, longitude, latitude, method)
    % Retrieve offset from UTC time for specified longitude and latitude
    %
    % Inputs:
    % queries - query engine handle
    % longitude - (-180, 180] or [0, 360)
    % latitude - [-90, 90]
    % method -  Optional
    %      nautical - Nautical 15 degree timezones centered on
    %          the prime meridean (default if not specified)
    %      civil - Geopolitcial timezone (experimental)
```

dbDetectionsForUser(queries, User)

```
    % documents = dbUserDocuments(User)
    % Return a list of documents submitted by the specified user
```

dbXPathDomQuery(doc, query, nodereturn)

```
    % Given a document object model representation of a document,
    % run an XPath query on it
    % nodereturn is an optional argument that controls the return type:
    %  'node' --> XPathConstants.NODE
    %  'nodeset' --> XPathConstants.NODESET (a sequence of nodes)
```

dbYearly(query_eng, varargin)

```
    % dbYearly(query_eng, Arguments)
    % Produce a long-term plot containing all data for a given sight
    % Arguments are keywords value pairs:
    %
    % Project, Site, Detector, Species, Call_type, Call_type/@Subtype
    % Each of these allows selections of detections.  See dbGetDetections
    % for details.
    %
    % 'Diel', true|false|night
    % Add a diel plot with sunrise/sunset information.  Returns the time spans
    % of darkness hours over the queried time period.  If called again for
    % the same area, passing in the night time as the argument to Diel
    % will result in a faster plot and avoid taxing the ephemeris server.
    %
    % 'TickSpacingDays, N
    % Default:  Ticks every 30 days
```

dbYearlyReport(queries, detector, bycall, statfile)

```
% dbCannedReports(queries, detector)
% Generate reports from Tethys database
% detector - one of 'human', 'sbp_rule', 'hr_click'
% bycall - false: species level only, true: break down by call type
```

visCyclic(PresenceI, Labels)

```
% Plot cyclic data in a polar plot with labels as specified
```

visLunarIllumination(illu, varargin)

```
% Parses an illumination query return and plots it on the given figure
% plot.
% Required arguments
%   illu: n x 2 cell array of datetime values in the first column, and
%   illumination percentages in the second column.
% Optional arguments
%   UTCOffset: integer of the offset from GMT
%   cGrad: color gradient of variable size
```

visPresence(presence, varargin)

```
% [BarH, presence_d, presence_dayfrace] = visPresence(presence, Optional args...)
% Show presence/absence plot
% Display presence/absence in resolution_m increments
% Presence is a one or two column matrix giving starting (and
% possibly ending times) as Matlab serial dates.  If end time
% is unavailable, only the resolution_m segment containing the
% start time will be selected. Dates are assumed to be UTC and sorted.
%
% BarH is a column vector where the first entry is a handle group
% containing the presence patches.  The second entry is a handle group
% for areas of no effort.  When no patches are plotted, the BarH entry is
% 0.  Handle groups are Matlab's way of treating groups of graphics objects
% (handle objects) as a unit.  Returning these groups allows the user
% to modify the presence/effort rectangles that have been plotted, changing
% color, outline, etc.  If you do not plan on modifying/removing the
% presence plots, you do not need to retain the variable.
%
% presence_d and presence_dayfrac are the presence matrix translated into days
% and fractions of days.
%
% Optional input arguments:
%  'UTCOffset', N - Convert to local time using an offset of N (default 0)
%  'Color' - Specify color as a string (e.g. 'g' or 'green') or as
%      a red, green, blue triplet.  Avoid using light colors as they
%      will be lightened to show areas without effort.  Default 'blue'.
%  'NoEffortColor' - Color for no effort, similar to color.  Defaults
%      to a transparent version of color which will not work well in
%     a legend.
%  'DateRange', [StartSerialDate, StopSerialDate] - Specify the range
%     over which the plot is to span.  If not given, the plot will span
%     from the earliest effort (or detection if effort not given) to
%     the latest effort (or last detection).
%  'DateTickInterval', N - Plot dates and ticks every N days (default 7)
%  'HourTickInterval', N - Plot hour ticks every N hours (default 3)
%  'Effort', SerialDateMatrix - Indicates where effort to detect was
%     made.  Regions of the plot where there was no effort will be
%     displayed with a lighter version of the plot color.
%
%  'Label', String - Uniform label for detections.  Label is displayed
%     when user clicks on a detection bar.  This is useful when
%     visPresence is called multiple times and each invocation is for a
%     different type of data.
%  'LabeledData', CellArray - Individual labels for region.  Labels
%     are displayed over the region and are only really useful for large
%     patches relative to the overall plot size (e.g. multiday event in
%     monthly plot, multiweek in yearly plot)
%
%  'ShowLabels', true|false - Display label in detection box
%  'Resolution_m', M - Plot resolution (bin size) in minutes (default 60)
%  'Title', String - Plot title
%  'BarHeight', N - Height relative to day row [0, 1] (default 1)
%  'BarOffset', N - Vertical offset into day [0, 1-BarHeight]]
%                 (default  0)
%  'LineStyle', String - Line style, i.e. '-', 'none' (default 'none')
%  'Transparency', N - [0=transparent, 1=opaque] alpha transparency value
%                  (default 1)
%  Unsupported:  'XLength_d', M - Length of X axis in days (default 1)
```

visPresenceAbsence(presence, varargin)

```
% visPresenceAbsence(presence, Optional args...)
% Show presence/absence plot
% Display presence/absence in resolution_m increments
% Presence is a one or two column matrix giving starting (and
% possibly ending times) as Matlab serial dates.  If end time
% is unavailable, only the resolution_m segment containing the
% start time will be selected.
```

8 Appendix – BatchLogs

Operations that take a long time (e.g. rebuilding part of the database) may be done as batch operations. When this occurs, a message is given providing a batch log url that can be used to access the log. To see any of the logs that are currently in the system, use a web browser (e.g. Chrome, Internet Explorer) or other tool to visit the Tethys URL with the path BatchLogs. For example, if the server is running Tethys.me.edu port 9779 (the default port), use http://Tethys.me.edu:9779/BatchLogs?html=true . The ?html=true is optional, but tells the browser to format the result for human reading.

For example, one might see the following:

```
<BatchLogs>
  <InProgress>None</InProgress>
  <Complete>
    <Log>2018-05-10T01.06.13Z-a5794435.xml</Log>
    <Log>2018-05-10T01.06.40Z-fd6ffd54.xml</Log>
    <Log>2018-05-10T01.08.11Z-3042c318.xml</Log>
  </Complete>
</BatchLogs>
```

This states that all tasks are complete (InProgress – None) and lists three different batch logs. To see the last one, we visit http://Tethys.me.edu:9779/BatchLogs/2018-05-10T01.08.11Z-3042c318.xml?html=true:

```
<UpdateDocuments>
  <Collection>Detections</Collection>
  <ClearBeforeUpdate>False</ClearBeforeUpdate>
  <ReplaceExistingDocuments>False</ReplaceExistingDocuments>
  <SummaryReport>
  </SummaryReport>
</UpdateDocuments>
```

This tells us that the batch job updated all Detections, existing documents were not removed first, and any existing documents were not replaced. The SummaryReport shows what documents were added, and if any documents that we attempted to add failed.

9 Appendix – Tethys.xq Module Functions

XQuery allows one to define subroutines that can be called from within an XQuery. Tethys has provided a set of such functions in a module called Tethys.xq. Currently, the main purpose of this module is to provide conversion between ITIS taxonomic serial numbers, Latin species names, common species names, and user-defined abbreviations. When converting to vernacular names, a language must be specified. Currrently, there are ITIS entries for the languages Afrikaans, Arabic, Chinese, Djuka, Dutch, English, French, Galibi, German, Greek, Hausa, Hawaiian, Hindi, Icelandic, Japanese, Portuguese, and Spanish. However, not all entries are supported equally, and English is by far the most complete with some languages having only a few entries. When a vernacular name does not exist, the Latin name is returned. In rare instances, ITIS contains multiple vernacular names for the same species. In such cases, the first name is returned. As an example, *Orcinus orca* has both Killer Whale and orca as English vernacular names, but the functions described here will always return Killer Whale for the English vernacular name.

In order to use these functions, an XQuery must include the following line of code prior to FLWR query:
```
import module namespace lib="http://tethys.sdsu.edu/XQueryFns" at "Tethys.xq";
```

The namespace indicates a prefix that will be used before each function. In the example above, to invoke function tsn2completename, one would write lib:tsn2completename.   The namespace could have been any valid label, for instance as most of the routines in this module deal with ITIS taxonomic serial number (TSN) translation, we might have used:

```
import module namespace tsn="http://tethys.sdsu.edu/XQueryFns" at "Tethys.xq";
```

Subroutines names are presented without a namespace, but some namespace is required. Note that we do not describe all functions in Tethys.xq, but rather the ones that Tethys users are most likely to find helpful. Many of the client queries wrap the results of queries in one of these functions to change TSNs into strings.

AbrrevationMapExists(abbrevmap) – Does a specified abbreviation map exist?
  e.g. lib:AbbreviationMapExists("NOAA.NMFS.v1") → true

abbrev2completename(abbrev, abbrevmap) – Convert an abbreviation to a Latin name
  The function accepts two strings, abbreviation and the abbreviation map that is to be used.
  e.g. lib: abbrev2completename("Oo", "NOAA.NMFS.v1") → *Orcinus orca*

abbrev2group(abbrev, abbrevmap) – Find the group associated with a specific abbreviation.
  Group is an attribute that is sometimes used with species to denote additional information. As an example, there are currently a number of echolocation clicks that we believe are produced by beaked whales, but it is unclear which species of beaked whale produced them. We set up an abbreviation map for each type, e.g. BWC for beaked whales observed at Cross SeaMount, and set the species to family Hyperoodontidae.

abbrev2tsn(abbrev, abbrevmap) – Conver an abbreviation to a TSN.
  The function accepts two strings, and abbreviation and the abbreviation map name.
  e.g. lib:abbrev2tsn("Oo", "NOAA.NMFS.v1") → 180469.

completename2tsn(name) – Translate a Latin name to a TSN
  e.g. completename2tsn("Orcinus orca") → 180469.

tsn2completename(tsnnodes) – Convert a TSN to a “complete” (Latin) name.
  tsnnodes must a list of tsn nodes that each have an integer value, e.g. a SpeciesID from a detection document.

tsn2vernacular(tsnnodes, language) – Convert a TSN to a vernacular name
  tsnnodes must a list of tsn nodes that each have an integer value, e.g. a SpeciesID from a detection document. The argument language must be a string for a language that is supported by ITIS.

tsn2abbrev(tsnnodes, abbrevmap) – Convert a TSN to a user defined abbreviation.
  tsnnodes must a list of tsn nodes that each have an integer value, e.g. a SpeciesID from a detection document. Parameter abbrevmap must be the name of an abbreviation map that species the set of

abbreviations to be used. Like tsn2vernacular, the Latin name is returned if no abbreviation is found.

vernacular2tsn(CommonName, Language) – Convert a common name to a TSN.
e.g. lib:vernacular2tsn("Killer Whale", "English") → 180469.

The following functions are intended to be called on result documents and can rewrite an entire XML document. They are used by the client libraries to reformat results in a human readable format.

SpeciesIDtsn2name(element) – Convert XML document from TSN species identifiers to Latin names.

SpeciesIDtsn2abbrev(element, abbrevmap) – Convert XML document from TSN species to the specified abbreviation map.

SpeciesIDtsn2vernacular(element, language) – Convert XML document from TSN species to vernacular names for the specified ITIS supported language.

10 References

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Walmsley, P. (2006). XQuery. Farnham, UK: O'Reilly.

11 Licenses

Tethys uses components from the following vendors:

11.1 Python

The Python programming language is used to bind various server components and is also used in the Python client. Several Python libraries that are used also fall under this license: Python for Windows extensions (pywin32),

PYTHON SOFTWARE FOUNDATION LICENSE VERSION 2

11.2 Berkeley DBXML

The server's database store is implemented using the freely redistributable BerkeleyDB XML which is subjec tot the following terms:

11.3 CherryPy Object oriented web framework

www.cherrypy.org - Copyright 2004-2011. The Tethys server uses CherryPy to implement its transport layer.

11.4 Libraries using the MIT License

The following libraries use the MIT License shown below:

1. py-dom-xdom: XML XPath queries for Python (c) 2009, used in Python client: https://code.google.com/p/py-dom-xpath/
2. pyodbc – Open database connectivity library (c) 2012, used in server: https://code.google.com/p/pyodbc/

11.5 Egenix.com Public License

Egenix’s Python libraries are used by the server code.