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LifeWatch Italy Thesauri Documentation

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Introduction

A major challenge in ecological information management concerns the provision of effective approaches for the discovery and integration of heterogeneous data sets. For instance, locating and combining relevant observational data are often critical and time-consuming steps for researchers studying phenomena at broad spatial, temporal, and biological scales. The data sets used within such studies frequently differ in subtle and complex ways, partly due to the protocols used for data collection, the types of observations made, the experimental and other contextual information associated with the data set. These differences in turn can lead to structural and semantic heterogeneity among data sets that make them hard to discover using current data management approaches and require a considerable manual effort by researchers needing to combine data sets.

A number of recent efforts within the biological and ecological informatics communities are adopting the semantic technologies, which provide a promising way to properly describe and interrelate these different data sources, in ways that reduce barriers to data discovery and integration. A major goal of these approaches is to enable interoperability and uniform access to data by providing the underlying representation details, the lack of which often impede integration across scientific data sets. The same strategy is also followed by the E-Biodiversity Research Institute of LifeWatch Italy (hereafter LW-ITA), the Italian node of the European e-Science Research Infrastructure on Biodiversity and Ecosystems, which aims at supporting the scientific research on biodiversity and its relationships with ecosystems services and societal benefits, through the development of thesauri and ontologies that foster data interoperability.

This document provides a comprehensive introduction to thesauri and insights on how LW-ITA pursues their construction following international standards and best practices.

By definition, a thesaurus is a: 'controlled and structured vocabulary in which concepts are represented by terms, organised so that relationships between concepts are made explicit, and preferred terms are accompanied by lead-in entries for synonyms or quasi-synonyms' (International Organization for Standardization 2011, 2013).

The LW-ITA thesauri presented here and developed through an open and collaborative process, provide standardised terms covering a broad spectrum of disciplines of relevance to biological sciences communities with a focus on the aquatic organisms. Using standardised sets of terms with associated unique and resolvable URIs in metadata and data schema definition solves the

problem of ambiguities associated with data mark-up, and also enables records to be interpreted by computers. This opens up data sets to a whole world of possibilities for computer aided manipulation, distribution and long-term reuse.

Terminology

- API - An Application Programming Interface is a set of commands, functions, protocols, and objects that programmers can use to create software or interact with an external system. It provides developers with standard commands for performing common operations so they do not have to write the code from scratch (https://techterms.com/definition/api).
- Concept - Unit of thought (ISO 25964-1).
- Concept Scheme – A concept scheme is the aggregation of one or more SKOS concepts, generally used to represent and identify thesauri or classification schemes. A concept scheme may have one or more top concepts, which head the hierarchical structures within the concept scheme itself. These are usually the start point for search and navigation tasks for users (Pastor-Sanchez et al., 2009).
- JSON - JavaScript Object Notation is a text-based data interchange format designed for transmitting structured data. It is most commonly used for transferring data between web applications and web servers (https://techterms.com/definition/json).
- JSON-LD - JavaScript Object Notation for Linked Data is a lightweight Linked Data format. It is easy for humans to read and write. It is based on the already successful JSON format and provides a way to help JSON data interoperate at Web-scale (https://json-ld.org/).
- RDF - The Resource Description Framework is a specification that defines how metadata, or descriptive information, should be formatted. The RDF model uses a subject-predicate-object format, known as triples, which is a standardised way of describing something (https://techterms.com/definition/rdf).
- SKOS - The Simple Knowledge Organization System (SKOS) is a common data model for sharing and linking knowledge organisation systems via the Semantic Web (https://www.w3.org/2009/08/skos-reference/skos.html).
- SPARQL - is an RDF query language, that is, a semantic query language for databases, able to retrieve and manipulate data stored in the Resource Description Framework (RDF)

format. It is a standard of the World Wide Web Consortium, and is recognised as one of the key technologies of the semantic web (https://en.wikipedia.org/wiki/SPARQL).

- Term - Word or phrase used to label a concept (ISO 25964-1).
- W3C - The World Wide Web Consortium is an international community that includes a full-time staff, industry experts, and several member organisations. These groups work together to develop standards for the World Wide Web (https://techterms.com/definition/w3c).
- XML – eXtensible Markup Language is a "metalanguage" that can be used to create markup languages for specific applications. It is used to define documents with a standard format that can be read by any XML-compatible application (https://techterms.com/definition/xml).
- URI – Uniform Resource Identifier; dereferenceable URI. It "is a compact string of characters for identifying an abstract or physical resource." (Berners-Lee et al. 2005). A URI follows the general form "scheme:[//[user[:password]@]host[:port]][/path][?query][#fragment]". A subset of URI, presenting "http" as the "scheme" are called HTTP URIs and they can be "dereferenced", so that they can be looked up following the http protocol, making it possible to retrieve the identified resource on the web.

LifeWatch Italy thesauri

LW-ITA implemented thesauri on functional traits of several groups of aquatic organism and on alien species. In detail, three thesauri on mostly morphological functional traits of phytoplankton, fishes and zooplankton were produced, plus a thesaurus on alien species and another one on general concepts inherent to aquatic organisms. They are all available online and, being defined through the SKOS (Simple Knowledge Organization System) standard (Kempf and Neubert 2016), they serve as a stable reference resource, specifically when available as linked data on the web.

- Aquatic Organisms Thesaurus (http://thesauri.lifewatchitaly.eu/AquaticOrganisms/index.php): 20 generic terms on aquatic organisms;

- Phytoplankton Traits Thesaurus (http://thesauri.lifewatchitaly.eu/PhytoTraits/index.php): 83 terms on functional traits of phytoplankton;
- Fish Traits Thesaurus (http://thesauri.lifewatchitaly.eu/fishTraits/index.php): 211 terms on functional traits of fishes;
- Zooplankton Traits Thesaurus (http://thesauri.lifewatchitaly.eu/zooplanktonTraits/index.php): 63 terms on functional traits of zooplankton;
- Alien Species Thesaurus (http://thesauri.lifewatchitaly.eu/AlienSpecies/): 327 terms on the alien traits, modes of arrival, impacts, management and control.

The next steps will be:

- Improve and expand the existing thesauri with other functional traits (physiological, phenological and behavioural traits);
- Implement and publish thesauri on other taxonomic groups such as macrozoobenthos and macroalgae;
- Implement and publish a thesaurus on the endemisms and one on genomics and barcoding.

Planning and implementation workflow of LifeWatch Italy thesauri

A thesaurus is a long-term project, which requires a significant planning, with a number of aspects to be considered before the construction begins (Ryan, 2014). ISO 25964-1 recommends planning the objectives and features of the thesaurus as well as the resources available for the thesaurus, deciding who will be responsible for different aspects of the thesaurus construction and maintenance, and choosing the software for the thesaurus (International Organization for Standardization 2011).

The process of LW-ITA thesauri implementation was initially established by the Interactions Thematic Centre with the implementation of thesauri on functional traits of aquatic organisms, and then extended to the knowledge domains of the other LW-ITA Thematic Centres. It is a collaborative process involving different working groups with specific roles: editors, ICT experts and validators.

Editors are experts of the specific knowledge domain and they have the responsibility of each aspect of the thesaurus construction and management, from planning to design, dissemination and maintenance.

The ICT group supervises the technological aspects of thesauri modelling, advising on semantic technology and modelling, and giving technical support to the editor team in the selection, use and maintenance of the most suitable tools for the development of thesauri and their linking. They collaborate with the editor team for defining relationships between concepts and data type properties for defining attributes (or qualities) of concepts.

Validators are domain experts who review the constructed thesaurus and highlight any question about the terms chosen, any gap, missing or redundant feature, as well as any usability issue.

The LW-ITA thesauri implementation envisages four phases: (i) terms research and selection, (ii) formalisation, (iii) edition, and (iv) validation of the thesaurus (Figure 1).

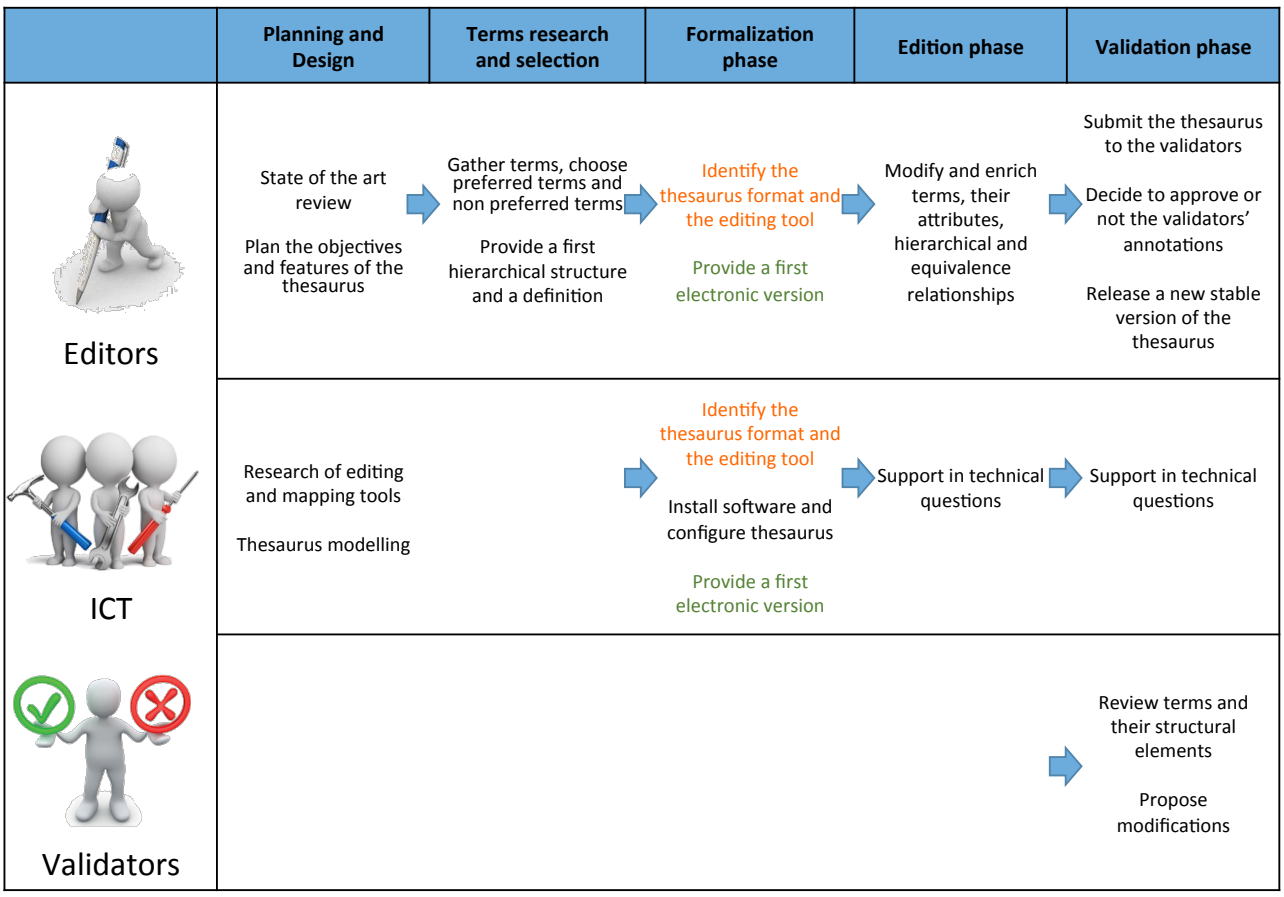

FIgure 1. Diagram showing the three working groups involved in the different phases of the LW-ITA thesauri implementation. The same and contemporary action from different working group is represented in the same colour.

i) Terms research and selection phase

The decision to create new thesauri stemmed from the consideration that no existent vocabulary did fulfil the needs of the LW-ITA community. The first step in the construction of the thesauri was to perform a content audit gathering terms from existing vocabularies and ontologies, published works, reference tools such as indexes and databases, and internal team sources. In this way, a first list representative of the knowledge domain was produced. All terms with similar meanings were grouped and a preferred term was chosen, while synonyms, variant spellings and abbreviations were included as non-preferred terms. Terms were organised into a first hierarchical structure and provided with a definition taking into account relevant literature and pre-existent thesauri and ontologies, to avoid redefinitions.

ii) Formalisation phase

After the selection process, editors and the ICT group identified the thesaurus structure and the editing tool that was more suitable to an electronic version. As the main objective was to facilitate reuse, the choice fell on the SKOS format, which covers all requirements for easy and complete data publication and exchange (Kempf and Neubert 2016). SKOS is a common data model which is based on the Resource Description Framework (RDF) (Cyganiak et al., 2014) with predefined object properties for defining relationships between concepts and data type properties for defining attributes (or qualities) of concepts. These properties (e.g. *skos:prefLabel*, *skos:altLabel*, *skos:Definition, skos:broader*, *skos:narrower*, *skos:related*) allow users to set up hierarchical and associative relationships among terms within a thesaurus and assign essential attributes to each term (e.g., Pastor-Sanchez et al., 2009).

In order to ease the edition of SKOS formatted thesauri, the open source and web-based thesaurus management software TemaTres was chosen (Gonzales-Aguilar et al., 2012). The relative simplicity of TemaTres and the web accessibility of its interface, while maintaining a rich set of underlying capabilities, made it a suitable choice for the development of LW-ITA thesauri. More specifically, TemaTres includes, a simple but functional user interface for editing concepts (Figure 2), sophisticated search capabilities (Figure 3), options for linking to external concepts and also the ability to export all, or part, of a thesaurus in a number of standardised forms (e.g. SKOS-Core, JSON, JSON-LD). TemaTres also supports a more rudimentary input capability for taxonomies in tab-indented files or SKOS documents encoded in RDF-XML (Beckett, 2004).

A SPARQL endpoint is also available (e.g. for Phytoplankton terms http://thesauri.lifewatchitaly.eu/PhytoTraits/sparql.php), enabling users (human or other) to query the thesaurus via the SPARQL language (Prud'hommeaux et al., 2008). Results are returned in one or more machine-processable formats. The SPARQL endpoint is conceived as a machine-friendly interface towards a thesaurus. Both the formulation of the queries and the human-readable presentation of the results should typically be implemented by the calling software, and not be done manually by human users.

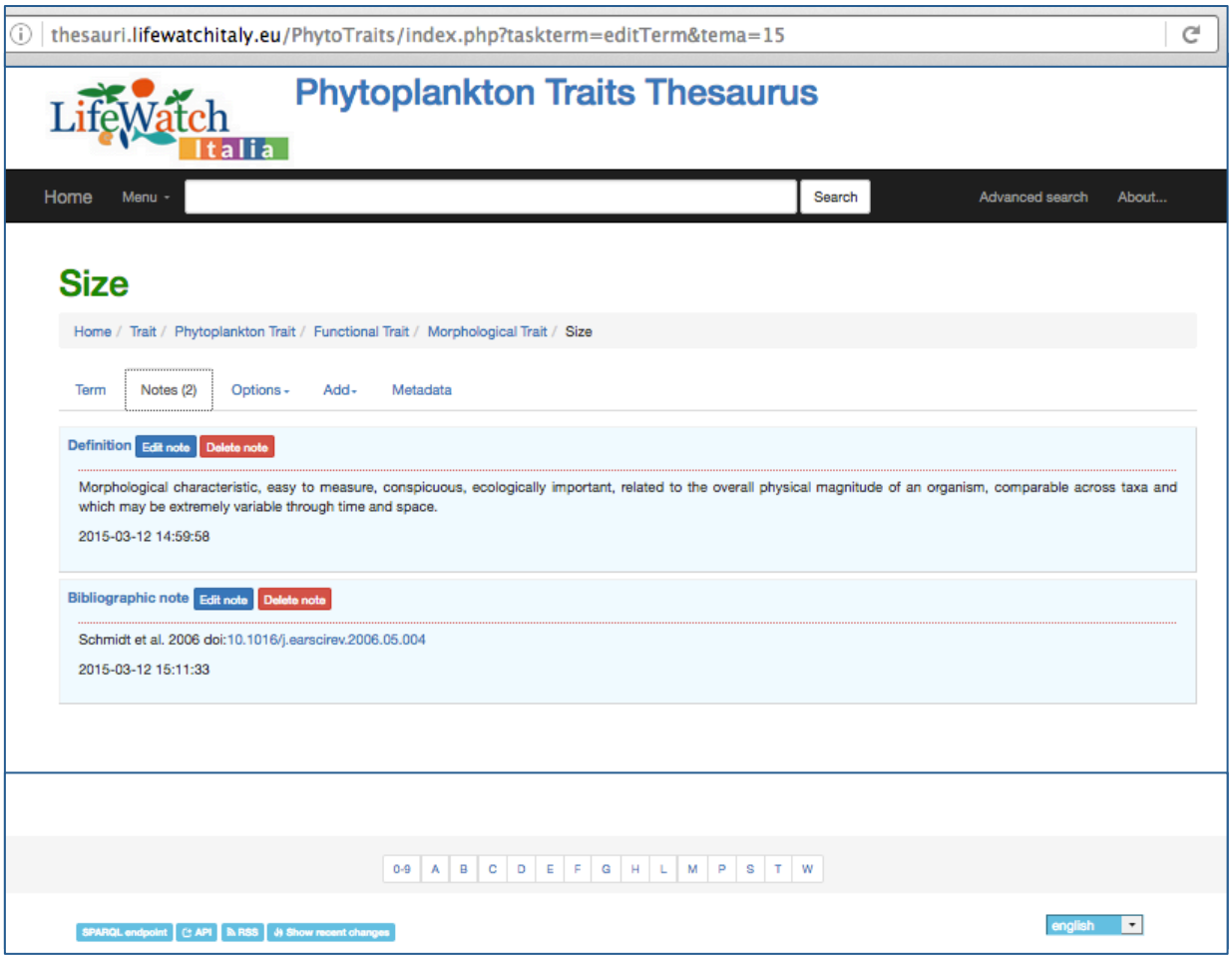

Figure 2. Screenshot of the user interface for editing concepts in TemaTres showing different tabs (Term, Notes, Options, Add, and Metadata), URI, hierarchy, definition, bibliographic note, preferred unit and last change date for the selected concept. We show as example the PhytoTraits thesaurus.

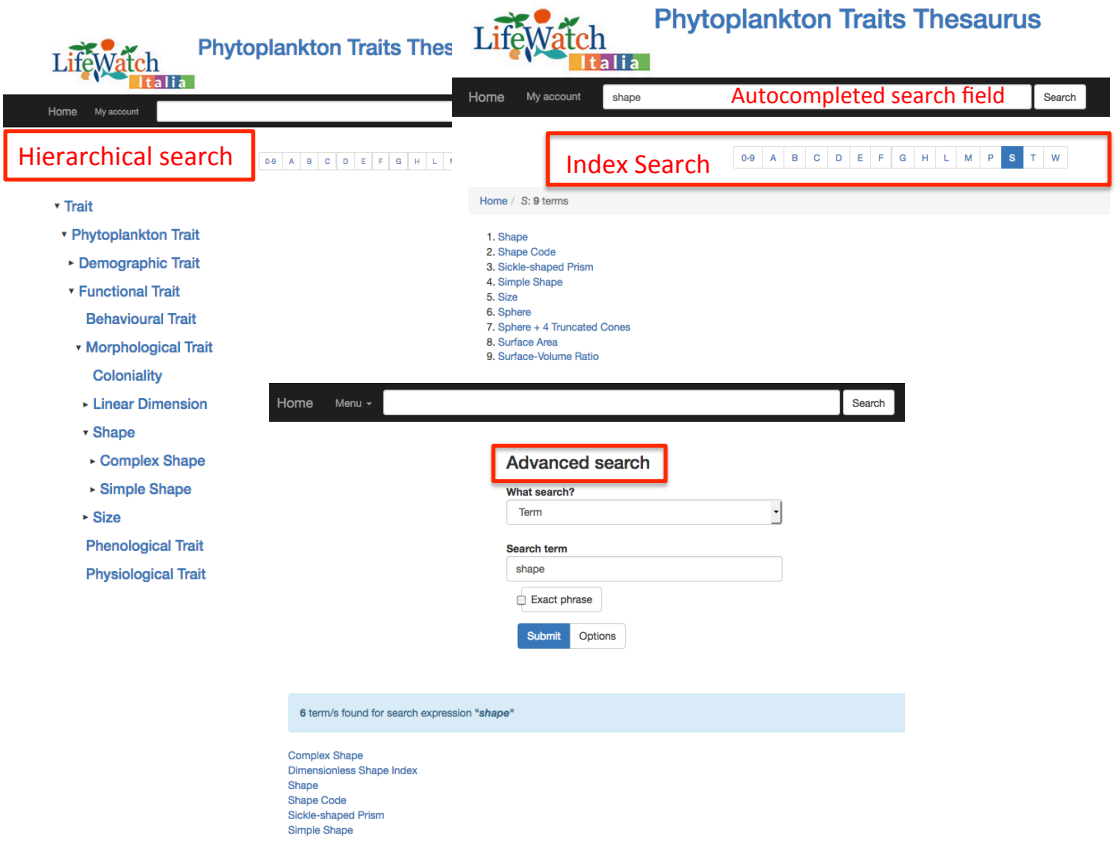

Figure 3. Screenshot of the different user-friendly search engines provided by TemaTres: hierarchical search; auto-completed field search; alphabetic letters search; and finally advanced research where it is possible to search for term or note, note type, created date, and level. We show as example the PhytoTraits thesaurus.

iii) Edition phase

During the edition phase, the initial list of terms, their attributes and hierarchical and associative relationships were subjected to different modifications. Editors: (i) modified and enriched the structural elements of each term through TemaTres user interface (preferred term, non-preferred term, definition, associated bibliographic note, etc.), (ii) modified the hierarchical structure, or (iii) added or deleted a term. For each preferred term, a definition often associated to a bibliographic reference and a hierarchical relationship are provided. In some cases, synonyms and abbreviations were included as non preferred terms when their use is popular, related terms were also specified as well as a preferred unit. Some concepts have also been linked to external sources by exactMatch, closeMatch and relatedMatch properties.

iv) Validation Phase

Once the thesaurus was constructed, editors submitted it to the validators, who reviewed terms and their structural elements, approved or rejected them and proposed modifications to the editors team by using the element private note of TemaTres. Editors decided whether to approve or not the validators' annotations and finally they released a new stable version of the thesaurus. Each concept and its Uniform Resource Identifier (URI, a unique and persistent identifier in the World Wide Web) are published and its change history will be tracked.

Elements and semantic relationships of the LW-ITA thesauri

The LW-ITA thesauri are concept schemes comprising a set of concepts identified unambiguously by a URI. A concept represents an idea, a notion, or a unit of thought, and it is labelled with a term, which is defined by one or more lexical strings. Terms are selected from natural language and each term is used to represent only one concept. Actually, the LW-ITA thesauri are edited in English and contain the following information for each concept:

- Uniform Resource Identifier (URI)
- Preferred term/Preferred label
- Non preferred term/Alternative label
- Notes
- Semantic Relationships

Uniform Resource Identifier (URI)

A unique and persistent identifier for the term designed for computer storage rather than human readability. In SKOS, concepts are formalised as *skos:Concept* and identified by dereferenceable URIs, e.g. http://thesauri.lifewatchitaly.eu/PhytoTraits/?tema=21 is the URI of the concept biovolume. When search for a URI, this address provides information about the concept and links to other ones through defined relationships.

Preferred term/Preferred label

The preferred label is represented by one or more lexical strings in human readable form and used to name a concept in any given language. Only one preferred label per language could be related to a concept. In SKOS, a preferred label is formalised as *skos:prefLabel*.

Non preferred term/Alternative label

Alternative labels are alternative lexical strings used to assign multiple labels to a concept. This is helpful in representing synonyms, acronyms and abbreviations of the same concept. For example, Ash Free Dry Weight is the preferred term, while AFDW and Ash Free Dry Mass are the non preferred terms. In SKOS, a non preferred label is formalised as *skos:altLabel*, e.g. AFDW and Ash Free Dry Mass are alternative labels of Ash Fee Dry Weight. The alternative labels enrich the vocabulary offering various access routes to a concept and increasing the chances of success in indexing and search process.

Notes

Notes are descriptive elements associated to a term, which can include definition, bibliographic note, preferred unit and scope note. Additional notes, such as cataloguer's note, historic note and private note, describing the administrative aspects of a term or reporting comments from editors and validators, may also be created, but not necessarily formalised in SKOS.

The definition is a complete explanation of the intended meaning of a concept, based on relevant literature and other sources (e.g.: journal articles, books, other thesauri, ontologies) that can be reported in the bibliographic note. In SKOS, definition and bibliographic note are formalized as *skos:definition* and *skos:note*, respectively. When possible, the concept could be enriched with information about the preferred unit of measure, formalized as *skos:scopeNote*. The scope note is a short note that describes how and when the term should be used and when it should not be used. These notes are used extensively to help disambiguate terms and ensure consistency across the thesaurus. A scope note is used to:

- restrict or expand the application of a term,
- distinguish between terms that have overlapping meanings in natural language, or
- provide other advice on term usage to either the indexer or the searcher.

The historic note, formalized as *skos:historyNote*, provides a short description of the history and evolution of the term over time. These notes provide important guidance for researchers who are interested in a topic covering many decades. It is especially important to indicate when and how a term has changed over time.

Semantic Relationships

Semantic relationships among concepts are distinguished in inter-thesaurus and cross-thesauri relationships (mapping relationships). Properties of the first set express relationships within the same thesaurus. The Simple Knowledge Organization Scheme accounts for two main relationships of this kind, the first is a generic reflexive relation between two concepts, with the second hierarchies can be expressed among concepts.

1. Hierarchical relationships

Hierarchical arrangements are common in thesauri and are represented using the broader and narrower relationships (*skos:broader* and *skos:narrower*). These terms denote relationships between the concepts in a thesaurus and indicate whether a concept contains or is contained by another concept. In TemaTres, broader (BT) and narrower term (NT) relationships correspond to the terms 'superordinate' and 'subordinate' used in classification. BT relationships are used to direct users to a concept that is higher up in the thesaurus hierarchy, and therefore a broader or more general concept than the one users were seeking. Likewise, NT relationships direct users further down the hierarchy to more specific terms. In SKOS thesauri poly-hierarchies are allowed, but at the moment the convention adopted in LW-ITA thesauri is to follow a single hierarchy.

2. Equivalence relationships

Equivalence relationships are used to denote equivalence between terms and distinguish among preferred label and alternative label (synonyms, acronyms and abbreviations). These relationships in TemaTres interface can be added as non preferred term, using Use For (UF), Use For Abbreviation (UFAB) and are formalized in SKOS as *skos:altLabel*.

3. Linking relationships

Linking relationships in Tematres as narrowMatch, broadMatch, closeMatch, relatedMatch, and exactMatch. They are used to establish correspondence among concepts included in different conceptual schemes (thesauri, glossaries, ontologies). It can be declared that an exact correspondence exists between two concepts, that one is more generic or specific than the other, or otherwise a correspondence association may be established. These relationships are

formalized in SKOS as *skos:narrowMatch*, *skos:broadMatch*, *skos:closeMatch*, *skos:relatedMatch*, and *skos:exactMatch*.

Mapping of thesauri

The mapping is the process of identifying the semantic correspondence or equivalence among concepts of two or more thesauri. There are a number of reasons for mapping one thesaurus to another. These include identifying relationships and enhancing the search capabilities of a discovery interface, as the thesauri used are then interoperable since terms from separate thesauri are interchangeable and a search for one term will bring up content indexed with the equivalent term from another thesaurus.

However, one of the main reasons given for mapping thesauri is the benefit gained in the long-term as part of the Semantic Web. If thesauri are published and mapped through the Semantic Web standards, this will provide better and more effective services, as more and more resources are introduced into the network environment (see also: Abecker et al., 2014; Binding & Tudhope, 2016).

Mapping between thesauri is to be performed programmatically by string comparison of terms and subsequently validated by intellectual review, taking into account the hierarchical and associative relationships of the corresponding concepts. There are a number of tools, which can help in the mapping process.

LW-ITA thesauri were mapped using Silk Link Discovery Framework (http://silkframework.org/). SILK is an open source framework for integrating heterogeneous data sources and is based on the Linked Data paradigm, which is built on two simple ideas: first, RDF provides an expressive data model for representing structured information; second, RDF links are set between entities in different data sources. Using the declarative *Silk - Link Specification Language* (Silk-LSL), developers can specify which types of RDF links should be discovered between data sources, as well as which conditions data items must fulfil in order to be interlinked. Silk accesses the data sources that should be interlinked via the SPARQL protocol, and can thus be used against local, as well as remote, SPARQL endpoints. Link Specifications can be created using the Silk Workbench graphical user interface, which guides the user through the process of interlinking different data sources.

In order to find out a complete connection among LW-ITA thesauri, a two-step process has been put in place: first, SILK has been applied by comparing preferred terms from two separate thesauri using the Token-wise distance algorithm to discover new links (Fig 4); then the SILK results have been validated by editors in order to verify the accuracy of the links and identify the most suitable types of interlinking property (i.e., *skos:exactMatch* or *skos:closeMatch*). In particular, about 116 links have been discovered connecting concepts in different LW-ITA thesauri.

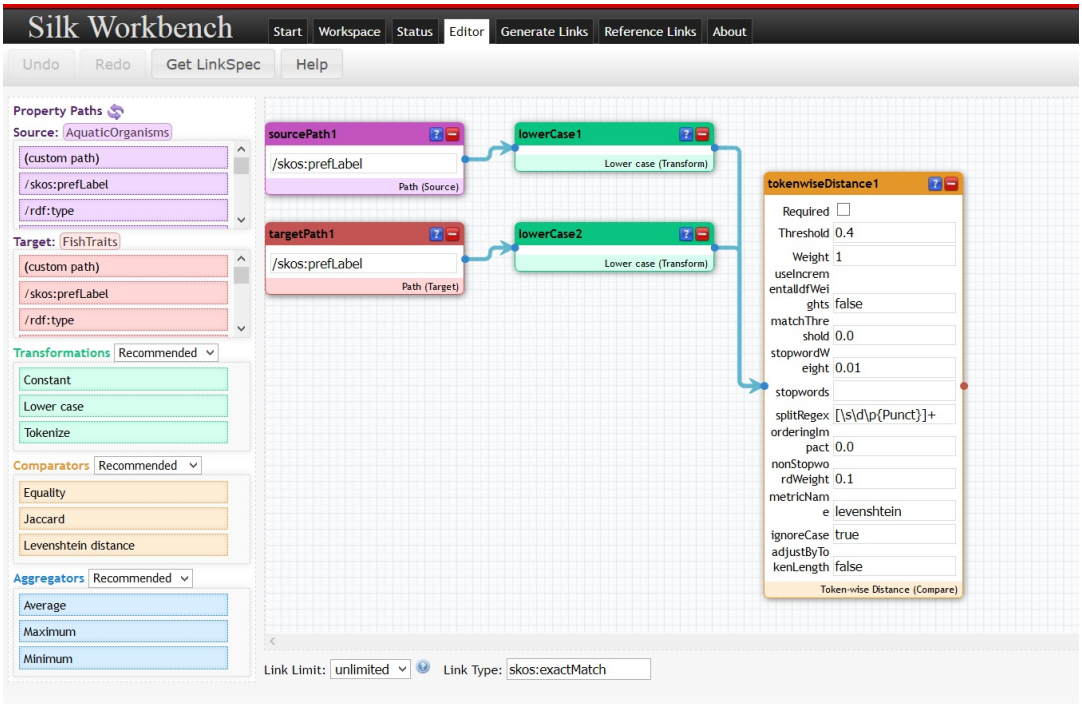

Figure 4. Silk Workbench graphical user interface showing the workflow for linking LW-ITA thesauri. We show as example the linking between Aquatic Organisms and FishTraits thesauri.

SPARQL and API

Concepts of LW-ITA thesauri are accessible as linked data following their http URI, or can be retrieved through SPARQL queries at the following endpoints:

- Aquatic Organisms Thesaurus (http://thesauri.lifewatchitaly.eu/AquaticOrganisms/sparql.php);
- Phytoplankton Traits Thesaurus (http://thesauri.lifewatchitaly.eu/PhytoTraits/sparql.php);
- Fish Traits Thesaurus (http://thesauri.lifewatchitaly.eu/fishTraits/sparql.php);

- Zooplankton traits Thesaurus (http://thesauri.lifewatchitaly.eu/zooplanktonTraits/sparql.php);
- Alien Species Thesaurus (http://thesauri.lifewatchitaly.eu/AlienSpecies/sparql.php).

In the first case, the resolution of the http URI lends to a document describing the concept. LodView (http://en.lodlive.it), a RDF viewer, provides a demonstration of the use of Linked Data standards to browse thesauri, glossaries, ontologies. In the case of LW-ITA thesauri, starting by URI of terms (e.g. http://thesauri.lifewatchitaly.eu/PhytoTraits/?tema=4) is possible to surf around the linked concepts.

The SPARQL access enables finer selections of thesauri concepts in different output format (HTML, JSON, Turtle, RDF/XML, XML, etc.). A simple example of query SPARQL is:

```
1    PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
2    SELECT * WHERE {
3     GRAPH ?g { ?s ?p ?o . }
4    }
5    LIMIT 50
```

This query gives first fifty terms of a thesaurus, distinguishing subject (s), predicate (p) and object (o).

All the concepts are also accessible via API for integration with other systems, such as a thesaurus publishing interface. The example of use of the different implemented web services are available to the following links:

- Aquatic Organisms Thesaurus (http://thesauri.lifewatchitaly.eu/AquaticOrganisms/services.php);
- Phytoplankton Traits Thesaurus (http://thesauri.lifewatchitaly.eu/PhytoTraits/services.php);
- Fish Traits Thesaurus (http://thesauri.lifewatchitaly.eu/fishTraits/services.php);
- Zooplankton traits Thesaurus (http://thesauri.lifewatchitaly.eu/zooplanktonTraits/services.php);
- Alien Species Thesaurus (http://thesauri.lifewatchitaly.eu/AlienSpecies/services.php).

The APIs give the possibility for example to retrieve data about vocabulary (http://thesauri.lifewatchitaly.eu/AquaticOrganisms/services.php?task=fetchVocabularyData) or to search and retrieve terms (http://thesauri.lifewatchitaly.eu/PhytoTraits/services.php?task=search&arg=trait).

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