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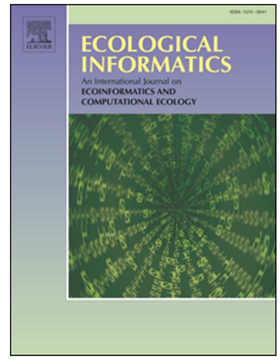

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A thesaurus for phytoplankton trait-based approaches: development and applicability

Ilaria Rosati[a,b,c*], Caterina Bergami[a,b,d], Elena Stanca[c], Leonilde Roselli[e], Paolo Tagliolato[a,f,g], Alessandro Oggioni[a,f], Nicola Fiore[a,c], Alessandra Pugnetti[a,g], Adriana Zingone[a,h], Angela Boggero[a,i], Alberto Basset[a,c]

[a] LifeWatch Italy
[b] National Research Council, Institute of Agro-environmental and Forest Biology (CNR - IBAF), Via Salaria Km 29,300, 00015 Monterotondo Stazione, Roma, Italy
[c] Department of Biological and Environmental Sciences and Technologies, University of the Salento, prov.le Lecce-Monteroni, 73100 Lecce, Italy
[d] National Research Council, Institute of Marine Sciences (CNR - ISMAR), Via Gobetti 101, 40129 Bologna, Italy
[e] Environmental Protection Agency of Puglia Region, Department of Lecce, via Miglietta 2, 73100 Lecce, Italy
[f] National Research Council, Institute for Electromagnetic Sensing of the Environment (CNR - IREA), Via Bassini, 15, 20133 Milano, Italy
[g] National Research Council, Institute of Marine Sciences (CNR - ISMAR), Arsenale - Tesa 104, Castello 2737/F, 30122 Venezia, Italy
[h] Department of Integrative Marine Ecology, Stazione Zoologica Anton Dohrn, Villa Comunale 80121 Napoli,Italy
[i] National Research Council, Institute of Ecosystem Study (CNR - ISE), Largo Tonolli 50/52, I-28922 Verbania Pallanza, Italy

* Corresponding author
E-mail address: ilaria.rosati@cnr.it

Abstract

In the last few decades, functional trait-based approaches have undergone an extraordinary expansion in phytoplankton ecology, due to the relative simplicity and the well-defined traits that determine the ecological niche of these organisms. A large quantity of heterogeneous and distributed data has been produced on phytoplankton traits and their use could be made more effective and efficient if data harmonization and interoperability would be improved.

The use of controlled vocabularies and thesauri is an acknowledged good practice to establish the foundation for semantic interoperability, a critical requirement for reuse and sharing of data. In fact, thesauri, collectively constructed, bypass ambiguity issues in natural language, facilitating the identification and integration of the information available in multiple data sources and allowing both scientists and computer applications to interpret more effectively the meaning of data.

Here we present a semantic resource on phytoplankton functional traits: the PhytoTraits thesaurus (http://thesauri.lifewatchitaly.eu/PhytoTraits/index.php). PhytoTraits is the result of the interdisciplinary collaboration of experts both from the phytoplankton functional domain and from information and communication technologies, working together within LifeWatch Italy, the Italian node of the e-science European infrastructure for biodiversity and ecosystem research. PhytoTraits is the first initiative to deal with the semantics of phytoplankton functional traits, focusing on morpho-functional traits towards standardized bio-volume assessment. It reflects the agreement of a scientific expert community to fix semantic properties (*e.g.* label, definition) of approximately 120 traits.

Following semantic web standard technologies, the thesaurus was implemented in Simple Knowledge Organization System (SKOS), a common data model based on the Resource Description Framework (RDF). PhytoTraits is freely available online, it can be queried through a SPARQL endpoint (http://thesauri.lifewatchitaly.eu/PhytoTraits/sparql.php) and is also accessible via API (http://thesauri.lifewatchitaly.eu/PhytoTraits/services.php) for integration with other systems. If adopted as a standard and rigorously applied and enriched by the scientific community, PhytoTraits, providing harmonized concepts with associated unique and resolvable URIs, has the potential to significantly reduce the barriers to data discovery, integration, and exchange.

Keywords

Functional diversity; Phytoplankton trait; Thesaurus; SKOS; Sematic interoperability

1. Introduction

In the last few years, ecological sciences have increasingly included trait-based approaches covering a diversity of topics, including functional ecology (Violle et al., 2007), community ecology (McGill et al., 2006; Edwards et al., 2013; Pey et al., 2014), biogeography (Barton et al., 2013; Violle et al., 2014), ecological risk assessment and ecological health/status assessment of aquatic ecosystems (Baird et al., 2010; Van den Brink et al., 2011; Basset et al., 2012; Lugoli et al., 2012).

As functional traits are any behavioural, morphological, phenological, or physiological traits measurable at the level of individual, which impact phytoplankton fitness (Violle et al., 2007), functional trait-based approach provides a framework to link organism functional response and effect traits to environmental filtering, community assembly and ecosystem structure and function (McGill et al., 2006; Reiss et al., 2009; Webb et al. 2010).

Although such approaches have been extensively developed in terrestrial plant ecology, aided by the development of standardized protocols and methodologies (Kattge et al. 2011; Garnier and Navas, 2012; Violle et al., 2014), only recently they are also used in plankton ecology (see Salmaso et al., 2015 for a review).

Phytoplankton are an extremely diverse group of microscopic photosynthetic organisms that are important because they account for half of global primary production and affect biogeochemical processes (Rousseaux and Gregg, 2013). They also can impact the global climate (Falkowski et al. 1998), the trophic dynamics of aquatic ecosystems (Sterner and Elser 2002) and water quality (Carvalho et al., 2013; Vadrucci et al., 2013). Phytoplankton provides a good model system to test trait-based approaches since their relative simplicity and the well-defined traits determine their ecological niche (Litchman and Klausmeier, 2008).

Over the last few decades, various attempts by using functional traits have been made to predict the structure and dynamics of phytoplankton communities along environmental gradients (Margalef, 1978; Reynolds, 1988; Vadrucci et al., 2007; Morabito et al., 2007; Litchman and Klausmeier, 2008; Sabetta et al., 2008; Kruk et al., 2010; Naselli-Flores and Barone, 2011; Stanca et al., 2012; Salmaso et al., 2015; Bernardi Aubry et al., 2017; Roselli et al., 2017).

Different phytoplankton traits have been described and measured by research groups, including morphological, physiological, behavioural and life history traits (Litchman and Klausmeier, 2008) but the effort to univocally define these traits and the whole process of trait measurement has been limited, so far. The absence of a standard terminology for traits produces impediments to data integration, which is increasingly required in ecology, but might also generate obstacles for the interpretation of data (Laporte et al., 2012). Terminological ambiguity slows down scientific progress, leads to redundant research efforts, and ultimately impedes advances towards a unified foundation for ecological science (Madin et al., 2007).

Nowadays, modern technologies, such as Internet and electronic data catalogues, enable researchers to exchange understandable information with greater rapidity and more easily than ever before. However, locating useful information for a specific study and then integrating it for analysis requires seamless access to datasets and improved mechanisms for clearly explicating and exploring basic semantic notions within and across data sets (e.g., that biomass is a weight and that “dry weight” is a biomass and a weight) (Jones et al., 2006; Madin et al., 2008).

The solution is a strategy (cfr. Haslhoefer and Klas, 2010) exploiting the semantic web, which is primarily based on the key principles of metadata, controlled vocabularies, thesauri or even ontologies, which should be considered complementary. A thesaurus is a controlled and structured vocabulary in which concepts are represented by terms, organized so that relationships between concepts are made explicit, and preferred terms are accompanied by lead-in entries for synonyms or “quasi-synonyms” (ISO 2011, 2013). Thesauri, bypassing ambiguity issues in natural language, are vital and valuable tools in content discovery, and in information organization and retrieval. They allow representing contents in a consistent manner and enabling researchers, employees and the public to find them easily and quickly.

In this paper, we present the thesaurus on phytoplankton functional traits (e.g. shape, volume, surface area, linear dimensions) and describe the methodology applied to its development.

The paper is structured as follow: section 2, which briefly reviews the state of the art in thesauri development methodologies showing examples on thesauri related to functional ecology domain; section 3, which presents the PhytoTraits (Phytoplankton Traits) thesaurus focusing on the methodology used to implement it; section 4, which presents possible use cases of the established semantic resource; and finally, section 5, which discusses the usefulness of the thesaurus and of its future developments.

2. State of Art in the Process of Construction of Thesauri

The construction of a thesaurus is a complex process in which terms used in a knowledge domain are collected, analysed and linked together into a model that can be used for classification of resources in the same domain. Throughout the years, different standards have been created to normalise the structure and properties of monolingual and multilingual thesauri (BSI, 2005; ANSI/NISO, 2010; ISO, 2011; 2013). ISO 25964, the most recent international standard for the creation of thesauri, provides a data model and derived XML schema (http://www.niso.org/schemas/iso25964/), which sets out five basic classes: *Thesaurus*, *ThesaurusConcept*, *ThesaurusTerm*, *ThesaurusArray* and *Note*, as well as the relationships that exist between the concepts. The data model makes explicit the distinction between "*terms*" and "*concepts*" and also contains information on other potential elements of a thesaurus, including *ConceptGroup*, a special grouping for terms relating to a particular domain, theme or other categories, which can be brought together from different hierarchies and sits parallel to the thesaurus itself (ISO 2011, 2013). However, the ISO 25964, as its precursors, does not propose a detailed construction methodology, but it mostly gives recommendations on the development and maintenance of thesauri.

The Simple Knowledge Organization System (SKOS) (W3C, 2009) is the World Wide Web Consortium (W3C) recommendation for a common data model for "sharing and linking knowledge organization systems" i.e. thesauri. It grounds its definition on the aforementioned ISO standards and it can be considered an evolution that enables porting thesauri to the semantic web (Berners-Lee et al., 2001). Formally, W3C defines SKOS as an OWL Full (W3C, 2004) ontology and encoding schema. The use of SKOS for sharing vocabularies on the web is an expanding practice and an up-do-date strategy to enable data and metadata interoperability.

Latre et al. (2012) suggest that there are four common steps in the process of thesaurus construction, though each of these steps can be approached in a variety of ways:

1. The first step is to review existing thesauri in order to avoid the creation of a new thesaurus from zero and the proliferation of redundant thesauri if an existent one can be valid or adapted;
2. In the second step, developers select the desired structure, format and final display of the thesaurus;
3. third step expects that the candidate terms to be included in the thesaurus are selected and related;
4. finally, the fourth is a validation step, during which candidate terms are reviewed to select only those that fulfil the agreement of an expert community of the knowledge domain (Latre et al., 2012).

In recent years, several vocabularies have been produced in the environmental and ecological domain following this approach but most of them are highly generic or do not contain specific concepts of functional ecology. The General Multilingual Environmental Thesaurus (GEMET) is a compilation of several multilingual vocabularies and was designed as a general thesaurus, aiming at defining a general core terminology for the environment (Albertoni et al., 2013). The Environmental Application Reference Thesaurus (Earth) extended GEMET with more than 9000 concepts and revised its categorical and thematic structure.

The Environmental Thesaurus (EnvThes) is a domain specific thesaurus, which provides a list of significant terms and their definitions used in the domain of long-term ecological research, monitoring and experiments. It uses the US LTER Controlled Vocabulary (http://im.lternet.edu/VocabTOR) as stable backbone and it is based on existing controlled vocabularies of the ecological domain, including GEMET (Schentz et al., 2013).

Up to now, few initiatives have been dedicated to the development of thesauri on the specific domain of functional ecology. Laporte et al. (2012) describe the work conducted by a community of plant functional ecologists to produce the Thesaurus Of Plant characteristics (TOP; http://www.top-thesaurus.org/). They firstly focused on the development of a web-based tool, Thesauform, for the collaborative construction of thesauri providing a flexible and user-friendly environment. Successively, they involved a group of experts in the thesaurus construction through different phases such as editing, validation and supervision (Laporte et al., 2012; 2013; Garnier et al. 2016).

The same approach was also used by Pey et al. (2014) to construct the Thesaurus for Soil Invertebrate Trait-based Approaches (T-SITA).

3. PhytoTraits thesaurus development

In agreement with Latre et al. (2012), we decided to create a new thesaurus (PhytoTraits), since neither of existent vocabularies fulfilled the needs of the phytoplankton community. To date, PhytoTraits is focused on size, which is a key morpho-functional trait of phytoplankton cells with cascading effects on several other functional traits (e.g., cell light and nutrient absorption, cell sinking rates). Moreover, different measures and methodologies are in use in order to quantify cell size and they require unequivocal definition to ensure standardisation and comparability of measurements. The resulting thesaurus contains 120 terms organised hierarchically and focusing on morpho-functional traits._The process of PhytoTraits implementation was a collaborative process involving different working groups with specific roles: editors, ICT and validators (Fig.1).

Figure 1. Diagram showing the three working groups involved in the different phases of PhytoTraits thesaurus implementation. The same and contemporary action from different working group is represented in the same colour (adapted from Rosati et al., 2017).

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

ICT group supervises the technological aspects of thesauri modelling, providing advice 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 for 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 questions about terms chosen, any gap, any missing or redundant feature as well as any usability issue (Rosati et al., 2017).

Thesaurus implementation envisages the aforementioned phases: (i) terms research and selection, (ii) formalization, (iii) editing, and (iv) validation of the thesaurus (Fig. 1).

3.1 Terms research and selection phase

The initial phase was the selection of terms following a bottom-up, deductive approach, where all the terms requiring description are identified and their relationships subsequently defined. A first list of terms was produced gathering terms from a phytoplankton relational database and from an Atlas of Phytoplankton Shapes (http://phytoplankton.lifewatch.unisalento.it), which had previously been produced by national and international experts in the field of phytoplankton ecology (Stanca et al., in preparation). Subsequently, related terms in well-known sources, such as existing vocabularies and ontologies, published works and internal team sources, were also searched and added, as recommended by ISO 25964-1, in order to provide a first list representative of the knowledge domain (Table 1).

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 organized into a first hierarchical structure (Fig. 2) and provided with a definition taking into account relevant literature and pre-existent thesauri and ontologies, to avoid redefinitions.

3.2 Formalization phase

As the main objective was to facilitate reuse, the choice fell on the SKOS (Simple Knowledge Organization System) model, which covers all requirements for easy and complete data publication and exchange (Kempf and Neubert 2016). SKOS is a common data model based on the Resource Description Framework (RDF) (Cyganiak et al., 2014) with predefined object properties for defining relationships between concepts (e.g., *skos:broader, skos:narrower, skos:related*) and data type properties (e.g., *skos:prefLabel*, *skos:altLabel*, *skos:definition*) for defining literal values as attributes (or qualities) of concepts. These properties allow users to set up hierarchical and associative relationships between terms within a thesaurus, and assign essential attributes to each term (e.g. Pastor-Sanchez et al., 2009).

Table 1. A subset of the terms extracted and initially present in the phytoplankton trait thesaurus, together with their definition and associated reference.

Figure 2. Example of hierarchical structure with narrower terms and broader terms for “Morphological Trait” and “Complex Shape” respectively.

In order to ease the editing of SKOS formatted thesaurus, the open-source and web-based thesaurus management software TemaTres (http://www.vocabularyserver.com/) was chosen (Gonzales-Aguilar et al., 2012). The relative simplicity of TemaTres and the availability of its web interface, while maintaining a rich set of underlying capabilities, made it a suitable choice for the development of PhytoTraits thesaurus. More specifically, TemaTres user interface includes a simple but effective functionality for editing concepts (Fig. 3), sophisticated search capabilities (Fig. 4), options for linking to external concepts and also the ability to export all, or part, of the thesaurus in a number of standardized formats (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).

Figure 3. Edition interface of PhytoTraits thesaurus showing different tabs (Term, Notes, Options Add, and Metadata), hierarchy, definition, bibliographic note, preferred unit and last change date for the selected concept.

A SPARQL endpoint is also available, which enables users (human or other) to query the thesaurus via the SPARQL language (W3C, 2008). Results are returned in one or more machine-processable formats. On top of the SPARQL interface, TemaTres exposes in its web-based user interface a form to query the thesaurus using SPARQL (Fig. 5), exploitable by ICT experts: For unskilled users, both the formulation of the queries and the human-readable presentation of the results should typically be implemented by other ad-hoc user interfaces and softwares.

Figure 4. Different user-friendly search engines provided in PhytoTraits: 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.

Figure 5. SPARQL endpoint interface with an example of query for the concept "Shape" and result in HTML table format.

3.3 Editing phase

During the editing 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 the TemaTres[1] user interface (preferred term, non-preferred term, definition, associated bibliographic note, etc.), (ii) modified the hierarchical structure, and/or (iii) added or deleted a term. For each preferred term, a definition often associated to a bibliographic reference and a hierarchical relationship were provided. In some cases, synonyms and abbreviations were included as non-preferred terms when their use is common, related terms were also specified as well as a preferred unit. Some concepts have also been linked to internal and external sources by *exactMatch*, *closeMatch* and *relatedMatch* properties. For example, the widely used trait “Size” is defined as “Morphological characteristic, easy to measure, conspicuous, ecologically important, related to …” in Schmidt et al. 2006. In the thesaurus, this trait is linked to other different traits: it falls under the broader concept of “Morphological Trait”; has different

[1] TemaTres interface adopts a different terminology than that of SKOS with respect to data type properties: preferred term stands for *skos:prefLabel*, non-preferred term for *skos:altLabel*.

narrower terms such as "Biovolume", "Cell Carbon Content" and "Dimensionless Shape Index"; and it is related to other external concepts such as "Body Size" by *exactMatch* (Fig. 6).

is

3.4 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 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 is tracked.

4. Use case of the PhytoTraits Thesaurus in the LifeWatch Italy Data Portal

PhytoTraits is freely available on the web at the URL http://thesauri.lifewatchitaly.eu/PhytoTraits/index.ph[2] and it could be utilised for different purposes. We use PhytoTraits as well as other existing controlled vocabularies for metadata and data annotation in the LifeWatch Italy Data Portal (http://www.servicecentrelifewatch.eu/catalogue-of-resources) in order to manage biodiversity and ecosystem data, including species traits data with grain size from individual to species, and to support semantic interoperability.

Figure 6. A combination of screenshots of different information provided for the concept "Size".

The LifeWatch Italy Metadata Schema, related to the dataset description, follows the INSPIRE metadata regulation (Drafting Team Metadata and European Commission Joint Research Centre, 2013) and the ISO 19115:2003 metadata standard. PhytoTraits thesaurus has been incorporated into the "Dataset Metadata" user interface, which provides authorised users with entry forms to create metadata description for datasets in accordance with LifeWatch Italy Metadata Schema. In particular, PhytoTraits can be used for metadata annotations, to select terms to insert in the mandatory metadata element "*Keyword"* for the description of datasets on phytoplankton functional diversity or related domains[3]. The population of a field in a metadata schema with unambiguous terms selected from shared thesauri eases data discovery and retrieval.

[2] https://creativecommons.org/licenses/by-sa/4.0/

[3] The metadata is downloadable as JSON file.

Additionally, PhytoTraits is used by the portal system for data annotation, along with Darwin Core (http://rs.tdwg.org/dwc) standard terms, other thesauri and controlled vocabularies relevant to LifeWatch Italy community (e.g. PhytoTraits, EnvThes (Schentz et al., 2013) and NERC Vocabularies[4] (Leadbetter et al., 2012). When data contributors share their data resources through the Portal data ingestion web-interface, they have to map fields of their dataset (column names) with URIs corresponding to concepts in the selected thesauri. The extensible set of these concepts constitutes the "LifeWatch Data Schema".

In this way, data associated to a particular concept but labelled with different terms can be integrated. For example the same trait concept (e.g. "Morphological characteristic related to the overall physical magnitude of an organism") could be represented by different terms (e.g. "Size", "Cell Size" or "Body Size") from data contributors, but linking these terms with the preferred term reported in PhytoTraits thesaurus, data inserted from these terms will be identified in the database as belonging to the same trait concept. These linkings constitute the data annotation exposed by the dataportal within data assets obtained through APIs, as exemplified in the excerpt in figure 7 (JSON format).

Figure 7. Excerpt of data structure description exposing semantic annotation of fields with thesauri concepts.

As a consequence, a data query concerning this trait concept will return data from all these terms. Standardized sets of terms with associated unique and resolvable URIs solves the problem of ambiguities associated with data mark-up and enables records to be interpreted by computers. This opens up datasets to a whole world of possibilities for computer aided manipulation, distribution and long-term reuse.

5. Discussion and conclusion

The thesaurus presented here provides the characterization of concepts widely used in phytoplankton morpho-functional ecology and it is the result of a joint effort to insure its wide acceptance and future reuse (Laporte et al., 2012). The first objective, in developing PhytoTraits, was that it should solve the ambiguity issues of natural language by formalizing the construction of the terms themselves, their definitions and how terms are inter-related.

[4] http://vocab.nerc.ac.uk

To our knowledge PhytoTraits is the first coordinated action to provide a comprehensive thesaurus of concepts frequently used in this field. Starting from trait-based community ecology of phytoplankton (Litchman & Klausmeier, 2008), it fills a gap by providing accurate descriptions of key concepts of phytoplankton morpho-functional diversity, which are currently poorly described in existing terminological standards (see Walls et al. 2014 for a review and Pey et al. 2014 and Garnier et al., 2016 for comparable initiatives as applied to soil invertebrates and plants, respectively). If widely used, it could become a standard terminological resource available to the functional ecology community.

Besides its role as a terminological resource, PhytoTraits may contribute to resource discovery, interpretation, integration and analysis in the context of a "*data intensive*" science, which relies on massive amounts of data collected by an array of sources (Michener and Jones, 2012). Ecologists increasingly address complex questions of both scientific and societal relevance needing available data from sources ranging from small-scale experiments to regional and global researches (Worm et al., 2006; Madin et al. 2007). A common approach is to leverage the growing amounts of data available through internet but their discovery is particularly problematic as often they are flat files or spreadsheets with minimal formal structure and little to no metadata documentation. Moreover, these data often have variables and concepts with different meanings not only across disciplines and levels of organization but also among researchers of the same field (Garnier et al., 2016). Such incompleteness and heterogeneity can be due, in part, to methodological specialization to address specific scientific hypotheses but also to a lack of standard protocols for acquiring, organizing and describing data (Michener and Jones, 2012).

Consequently, the development of semantic resources such as PhytoTraits and their use for the annotation of data and compilation of metadata from data providers is fundamental for fostering the discovery and the exchange of existing and new knowledge and for achieving a major understanding within the specific domain and in a wider context.

Annotation of datasets with thesauri is a first step towards semantic interoperability, following the vision of semantic web (Berners-Lee et al. 2001). LifeWatch, as well as other ecological research infrastructures, are planning to exploit upper ontologies like OBOE, (Extensible Observation Model; Madin et al., 2007), for interoperable data sharing. OBOE has been designed to capture the semantics of generic ecological observations and measurements, and follows a pattern easily mappable to other conceptual models (Cox, 2017) widely used for data representation, like ISO/OGC Observations and Measurements standard (ISO/TC 211, 2013), suggested by INSPIRE guidelines (INSPIRE Temporary MIG subgroup for action MIPW7a, 2016). Using the upper ontology for data general structure, mapping it with other ontologies and schemas to obtain reconciliation (Haslhofer et al., 2010), and complementing and linking it with other, domain-specific semantic resources, will enable both syntactic and semantic interoperability, on top of the technical interoperability level ensured by the usage of standard technologies of the semantic web – like RDF served as Linked Data and through SPARQL endpoints.

In this perspective the development of PhytoTraits, in compliance with Semantic Web standards, “provides a standard set of structures that will enable computers to operate in ways that more precisely assist data users in locating (data discovery) and processing the data of interest” (Garnier et al., 2016). Moreover PhytoTraits, adhering to Web standards, enhances interoperability and effectiveness of automated data exchange among different sources. Simultaneous queries on different data will thus become possible when different databases use PhytoTraits concepts for the semantic annotation of their data.

PhytoTraits is considered as a first step toward the construction of domain ontology for phytoplankton ecology. In a review presenting different approaches to the construction of ontologies, Pinto and Martins (2004) actually recommend building ontologies from thesauri. In this perspective, PhytoTraits will be used with OBOE, providing functional ecologists with a semantic framework, enabling scientists to produce new knowledge sets from large information systems (Laporte et al., 2012; Vanderbilt et al., 2016; Garnier et al., 2016).

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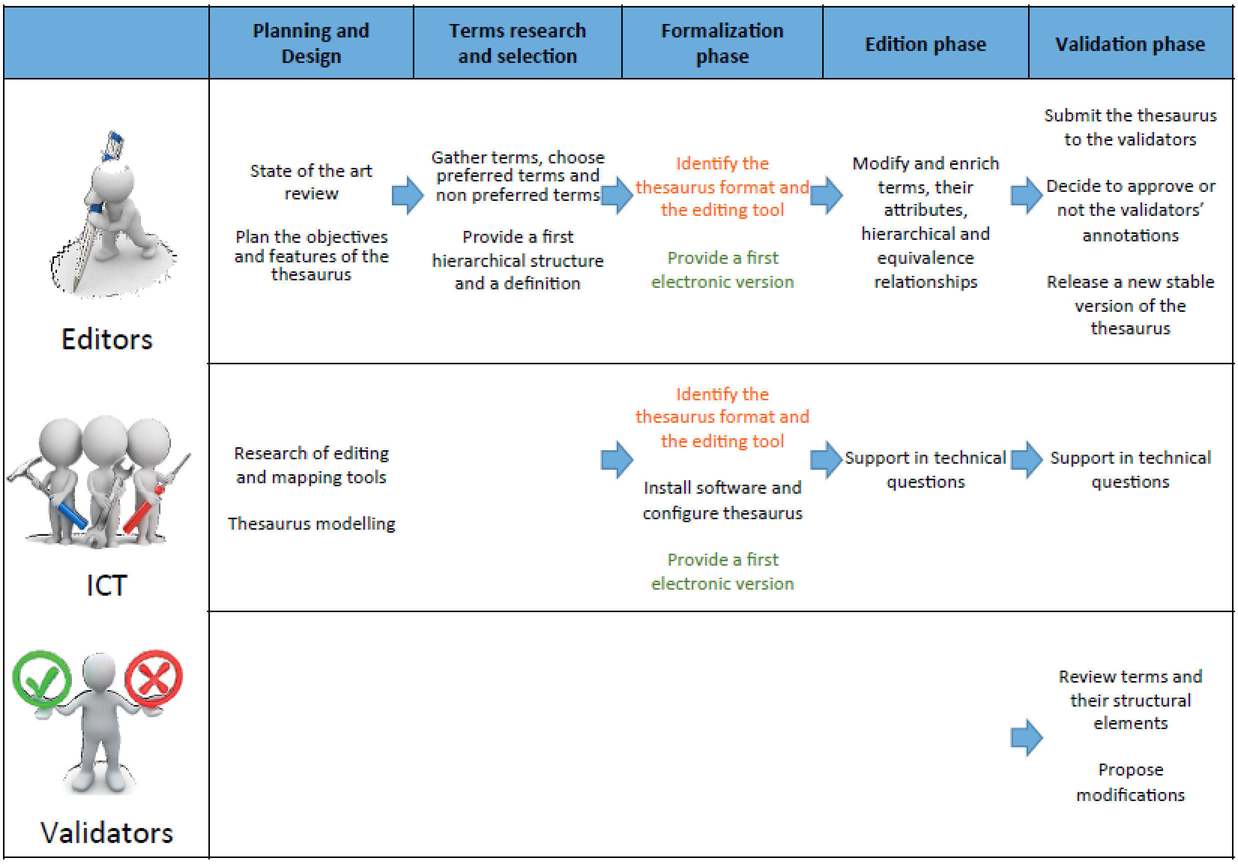


Planning and Design
Terms research and selection
Formalization phase
Edition phase
Validation phase
Editors
State of the art review
Plan the objectives and features of the thesaurus
Gather terms, choose preferred terms and non preferred terms
Provide a first hierarchical structure and a definition
Identify the thesaurus format and the editing tool
Provide a first electronic version
Modify and enrich terms, their attributes, hierarchical and equivalence relationships
Submit the thesaurus to the validators
Decide to approve or not the validators' annotations
Release a new stable version of the thesaurus
ICT
Research of editing and mapping tools
Thesaurus modelling
Identify the thesaurus format and the editing tool
Install software and configure thesaurus
Provide a first electronic version
Support in technical questions
Support in technical questions
Validators
Review terms and their structural elements
Propose modifications

Fig. 1

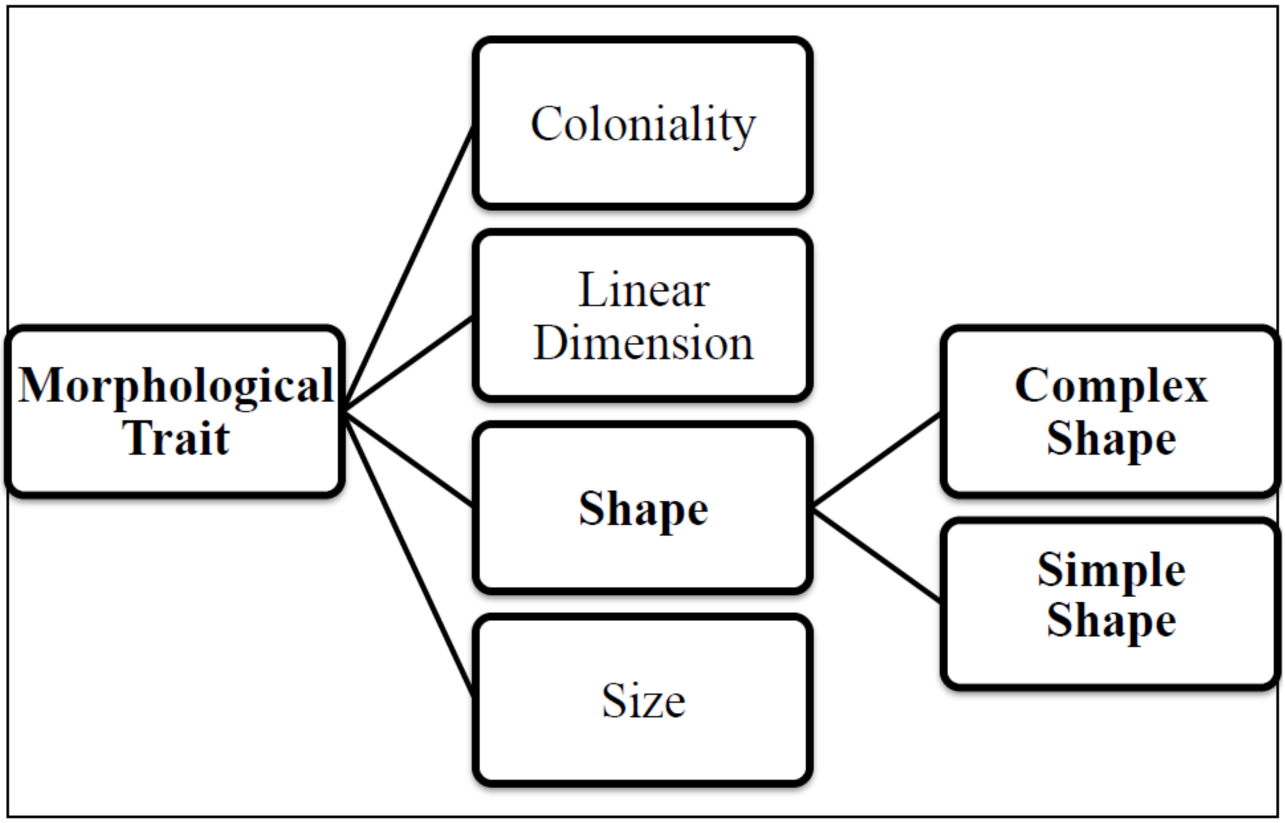
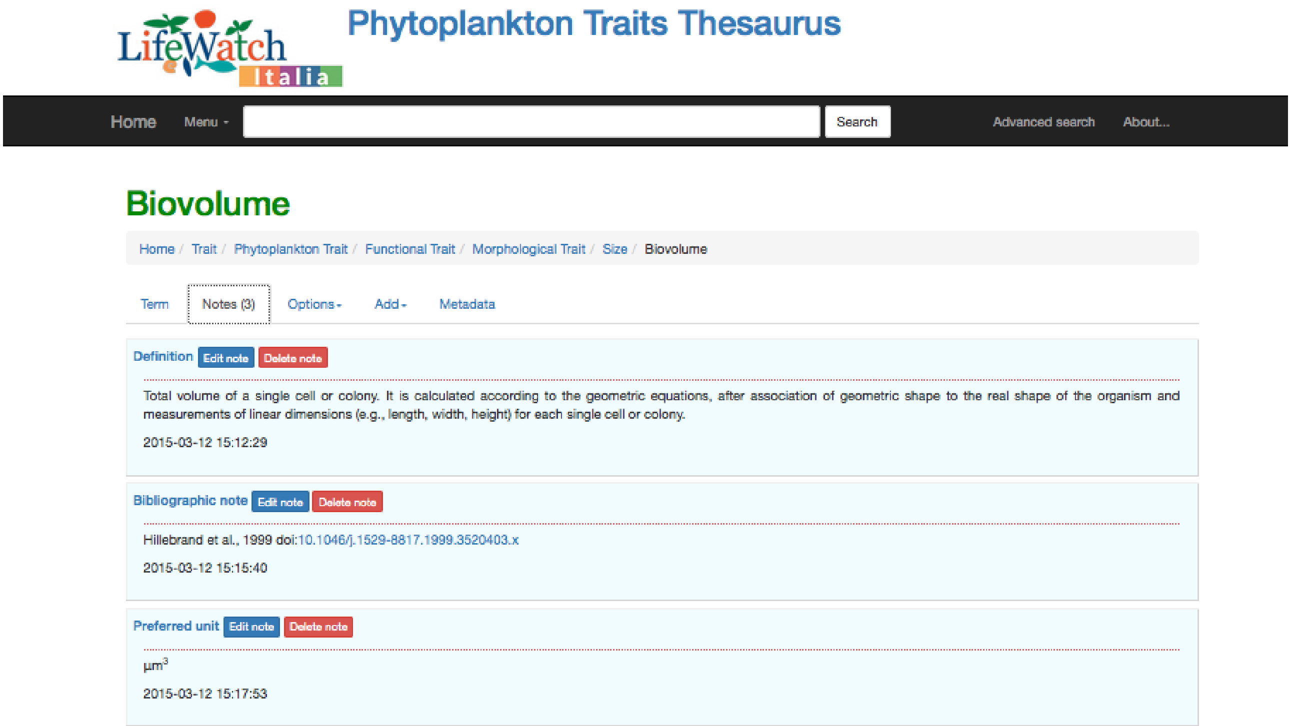

Coloniality
Linear Dimension
Morphological Trait
Shape
Complex Shape
Simple Shape
Size

Fig. 2


Phytoplankton Traits Thesaurus
LifeWatch Italia
Home
Menu
Search
Advanced search
About...
Biovolume
Home / Trait / Phytoplankton Trait / Functional Trait / Morphological Trait / Size / Biovolume
Term
Notes (3)
Options
Add
Metadata
Definition
Edit note
Delete note
Total volume of a single cell or colony. It is calculated according to the geometric equations, after association of geometric shape to the real shape of the organism and measurements of linear dimensions (e.g., length, width, height) for each single cell or colony.
2015-03-12 15:12:29
Bibliographic note
Edit note
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Hillebrand et al., 1999 doi:10.1046/j.1529-8817.1999.3520403.x
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Fig. 3

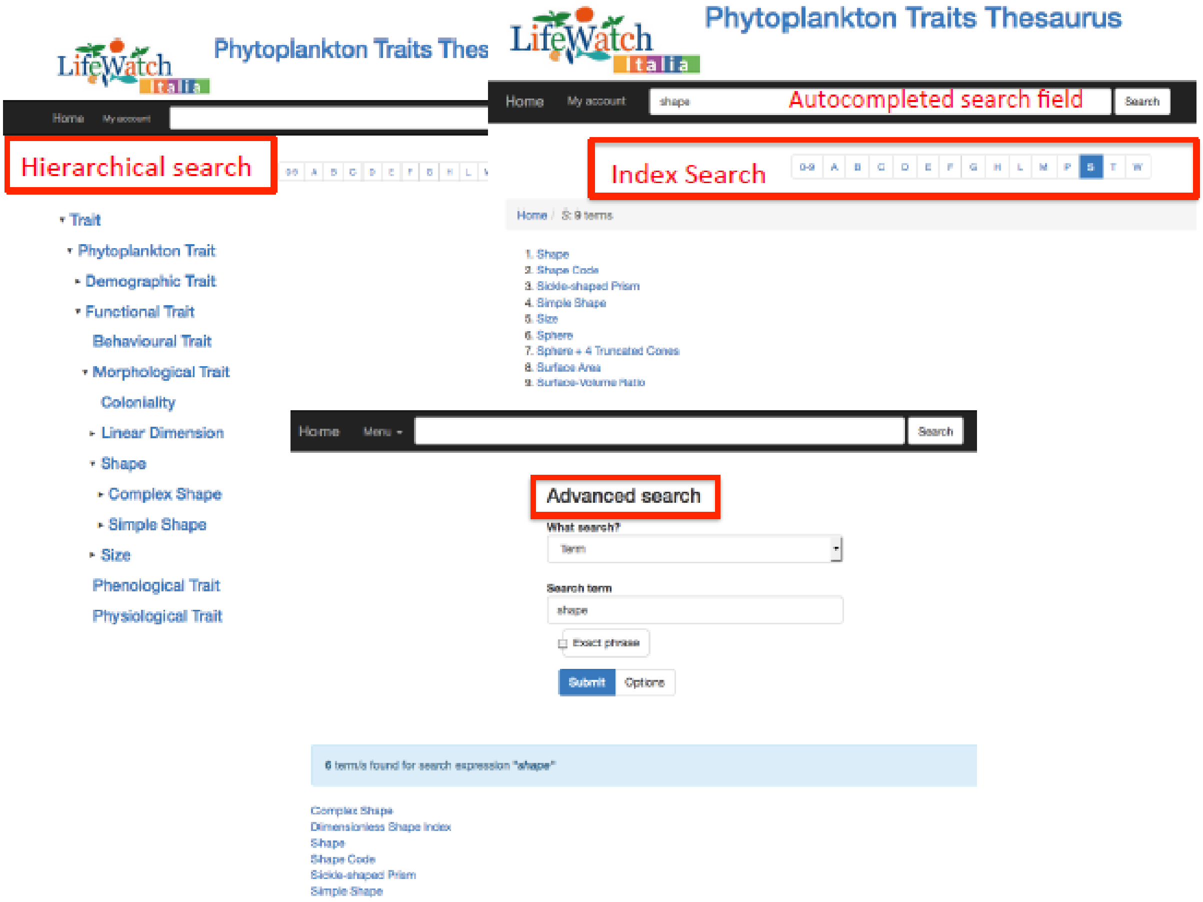

Phytoplankton Traits Thesaurus
Home
My account
shape
Autocompleted search field
Search
Hierarchical search
Index Search
0-9 A B C D E F G H L M P S T W
Home / S: 9 terms
1. Shape
2. Shape Code
3. Sickle-shaped Prism
4. Simple Shape
5. Size
6. Sphere
7. Sphere + 4 Truncated Cones
8. Surface Area
9. Surface-Volume Ratio
Trait
Phytoplankton Trait
Demographic Trait
Functional Trait
Behavioural Trait
Morphological Trait
Coloniality
Linear Dimension
Shape
Complex Shape
Simple Shape
Size
Phenological Trait
Physiological Trait
Home
Menu
Search
Advanced search
What search?
Term
Search term
shape
Exact phrase
Submit
Options
6 term/s found for search expression "shape"
Complex Shape
Dimensionless Shape Index
Shape
Shape Code
Sickle-shaped Prism
Simple Shape

Fig. 4

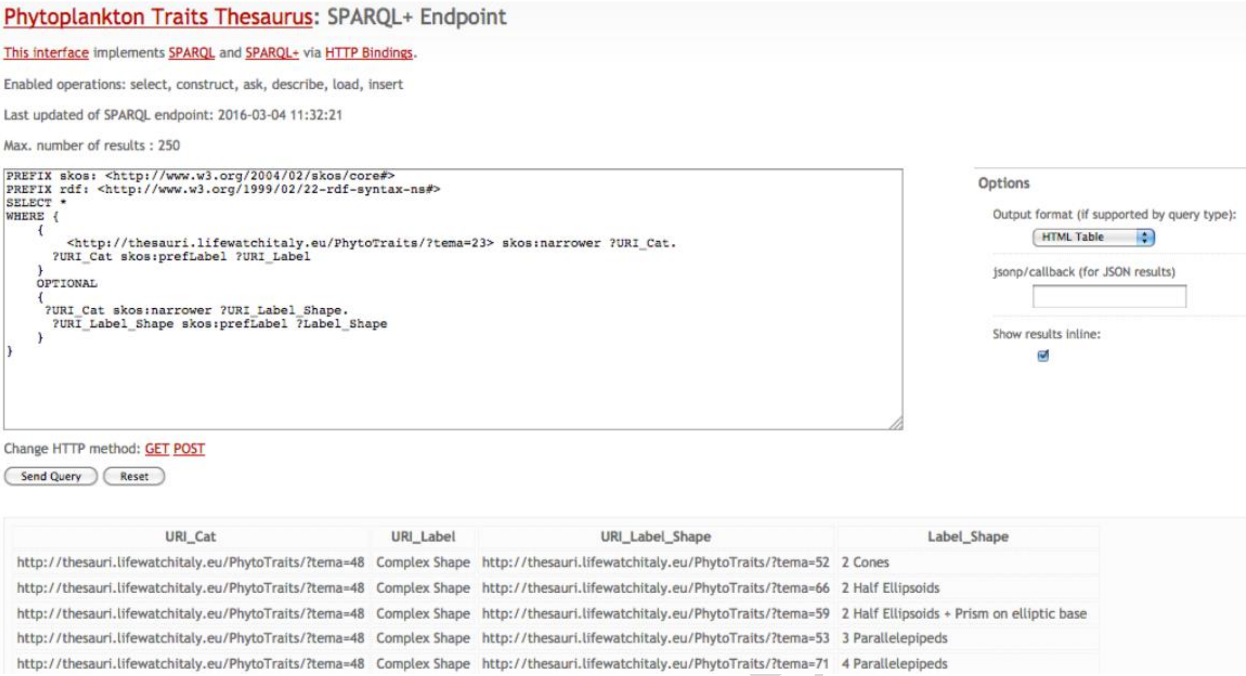
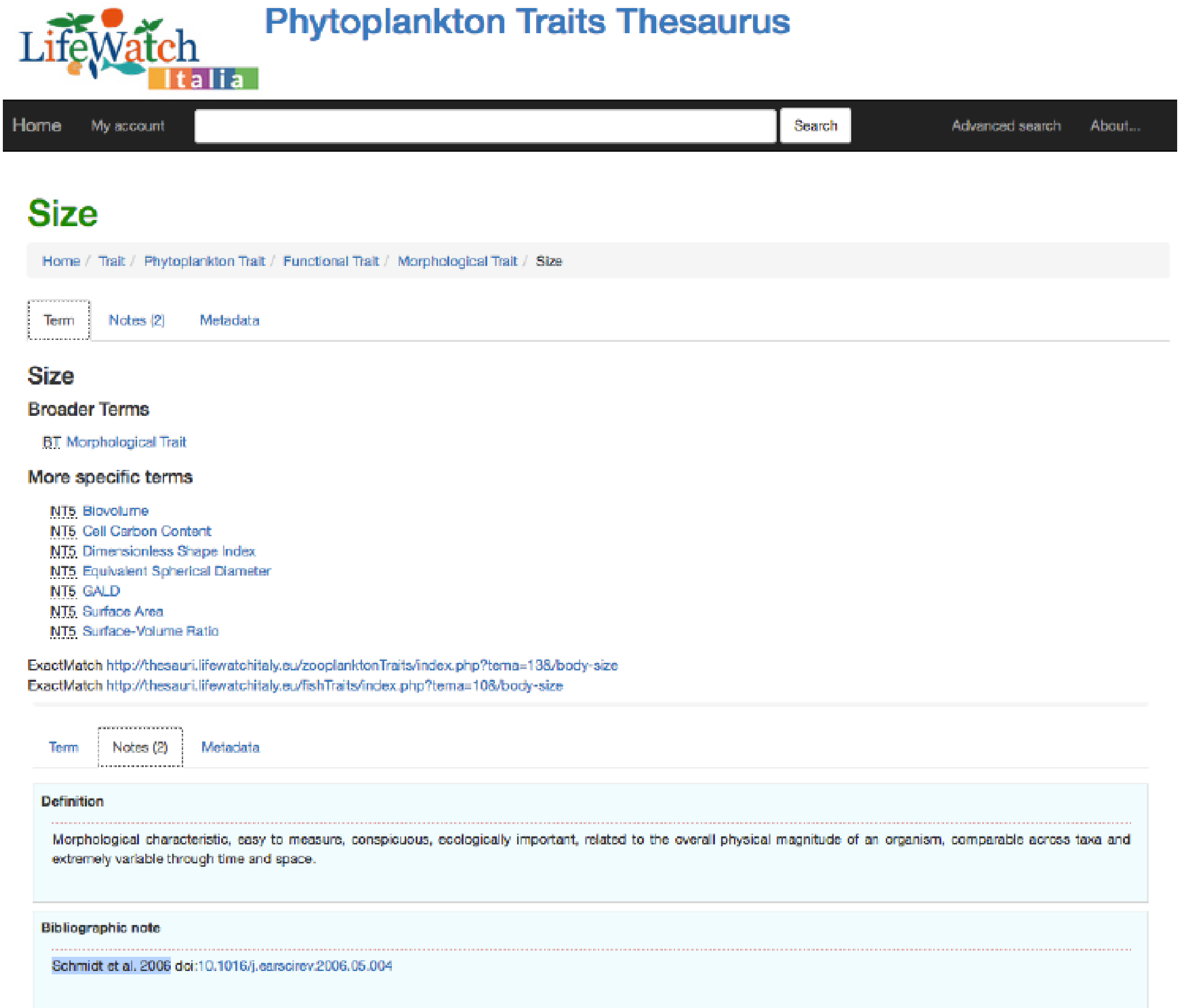

Phytoplankton Traits Thesaurus: SPARQL+ Endpoint
This interface implements SPARQL and SPARQL+ via HTTP Bindings.
Enabled operations: select, construct, ask, describe, load, insert
Last updated of SPARQL endpoint: 2016-03-04 11:32:21
Max. number of results : 250
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
SELECT *
WHERE {
{
<http://thesauri.lifewatchitaly.eu/PhytoTraits/?tema=23> skos:narrower ?URI_Cat.
?URI_Cat skos:prefLabel ?URI_Label
}
OPTIONAL
{
?URI_Cat skos:narrower ?URI_Label_Shape.
?URI_Label_Shape skos:prefLabel ?Label_Shape
}
}
Options
Output format (if supported by query type):
HTML Table
jsonp/callback (for JSON results)
Show results inline:
Change HTTP method: GET POST
Send Query
Reset
URI_Cat
URI_Label
URI_Label_Shape
Label_Shape
http://thesauri.lifewatchitaly.eu/PhytoTraits/?tema=48 Complex Shape http://thesauri.lifewatchitaly.eu/PhytoTraits/?tema=52 2 Cones
http://thesauri.lifewatchitaly.eu/PhytoTraits/?tema=48 Complex Shape http://thesauri.lifewatchitaly.eu/PhytoTraits/?tema=66 2 Half Ellipsoids
http://thesauri.lifewatchitaly.eu/PhytoTraits/?tema=48 Complex Shape http://thesauri.lifewatchitaly.eu/PhytoTraits/?tema=59 2 Half Ellipsoids + Prism on elliptic base
http://thesauri.lifewatchitaly.eu/PhytoTraits/?tema=48 Complex Shape http://thesauri.lifewatchitaly.eu/PhytoTraits/?tema=53 3 Parallelepipeds
http://thesauri.lifewatchitaly.eu/PhytoTraits/?tema=48 Complex Shape http://thesauri.lifewatchitaly.eu/PhytoTraits/?tema=71 4 Parallelepipeds

Fig. 5



Phytoplankton Traits Thesaurus
LifeWatch Italia
Home
My account
Search
Advanced search
About...
Size
Home / Trait / Phytoplankton Trait / Functional Trait / Morphological Trait / Size
Term
Notes (2)
Metadata
Size
Broader Terms
BT Morphological Trait
More specific terms
NT5 Biovolume
NT5 Cell Carbon Content
NT5 Dimensionless Shape Index
NT5 Equivalent Spherical Diameter
NT5 GALD
NT5 Surface Area
NT5 Surface-Volume Ratio
ExactMatch http://thesauri.lifewatchitaly.eu/zooplanktonTraits/index.php?tema=13&/body-size
ExactMatch http://thesauri.lifewatchitaly.eu/fishTraits/index.php?tema=10&/body-size
Term
Notes (2)
Metadata
Definition
Morphological characteristic, easy to measure, conspicuous, ecologically important, related to the overall physical magnitude of an organism, comparable across taxa and extremely variable through time and space.
Bibliographic note
Schmidt et al. 2006 doi:10.1016/j.earscirev.2006.05.004

Fig. 6

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Fig. 7

Term	Initial definition	Reference of definition
Simple shape	A geometric model composed of a single geometric shape, requiring 3 linear measurements per cell	LifeWatch Editors
Cone	A cell shape that approximates a cone	http://eol.org/schema/terms/coneShapedCell
Prolate spheroid	A cell shape that approximates a prolate spheroid	LifeWatch Editors
Ellipsoid	A shape for a biological structure that approximates an ellipsoid	http://eol.org/schema/terms/ellipsoid
Cylinder	A cell shape that approximates a cylinder	http://eol.org/schema/terms/cylinder
Complex shape	Geometric model composed of a more than 1geometric shape, requiring up to 3 linear measurements per geometric shape	LifeWatch Editors
Cone + Cone	A cell shape that approximates 2 cones	http://eol.org/schema/terms/2cones
Cylinder + Cone	A cell shape that approximates a cylinder + cone.	LifeWatch Editors
Ellipsoid + Cone	A cell shape that approximates an ellipsoid + cone	LifeWatch Editors
Linear dimension	Each of the three dimensions that characterize a geometrical solid shape, both simple and complex.	LifeWatch Editors
Surface Area	Total surface area of a single cell or colony. It is determined by obtaining critical cell measurements or cell dimensions (e.g, length, width) for each single cell or colony, after association of geometric shape to the real shape of the organism	Hillebrand et al., 1999
Biovolume	Total volume of a single cell or colony. It is calculated according to the geometric equations, after association of geometric shape to the real shape of the organism and measurements of linear dimensions (e.g., length, width, height) for each single cell or colony	Hillebrand et al., 1999
Size	Morphological characteristic, easy to measure, conspicuous, ecologically important, related to the overall physical magnitude of an organism, comparable across taxa and which may be extremely variable through time and space	Schmidt et al. 2006

Table 1. A subset of the terms extracted and initially present in the phytoplankton trait thesaurus, together with their definition and associated reference.

Highlights

- Trait-based approaches have undergone an extraordinary expansion in recent years
- Here we present PhytoTraits: a thesaurus on phytoplankton functional traits.
- PhytoTraits is a SKOS thesaurus compliant with Semantic Web standards.
- PhytoTraits enhances interoperability and effectiveness of automated data exchange among different sources.