Observational/Hydrographic data of the South Atlantic Ocean published as LOD

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Abstract. This article describes the publication of occurrences of Southern Elephant Seals Mirounga leonina (Linnaeus, 1758) as Linked Open Data in two environments (marine and coastal). The data constitutes hydrographic measurements of instrumented animals and observation data collected during censuses between 1990 and 2017. The data scheme is based on the previously developed ontology BiGe-Onto and the new version of the Semantic Sensor Network ontology (SSN). We introduce the network of ontologies used to organize the data and the transformation process to publish the dataset. In the use case, we develop an application to access and analyze the dataset. The linked open dataset and the related visualization tool turned data into a resource that can be located by the international community and thus increase the commitment to its sustainability. The data, coming from Península Valdés (UNESCO World Heritage), is available for interdisciplinary studies of management and conservation of marine and coastal protected areas which demand reliable and updated data.

Keywords: Hidrographic & Observational Data, Linked Open Data, Semantic Sensor Network, BiGe-Onto

1. Introduction

In the ecology domain, research teams collect and store biological and environmental information over the years/decades in database systems to answer their own queries. However, this information is isolated from other datasets for interoperating with and, in addition, is not ready to be accessed by machines. Particularly, in marine science the data collection is a process of cumulative logistic complexity, which makes it important to work on the curation and sustainability of the database, in both the short and long term. It is of great benefit for scientific institutions to publish their datasets following the Linked Data principles [1] not only for interlinking and easy cross-referencing but also for other purposes that are not foreseen at the moment of publication. The state of the art in the last decade shows that together with technology to collect data, semantic interoperability has further grown in importance [2]. To meet Linked Data requirements, datasets must be described with rich metadata such as controlled vocabularies in a particular form - RDF - and published as a findable resource with a unique identifier.

This paper integrates observational and hydrographic datasets based on the SOSA/SSN ontology [3, 4] and...
2. SES Database

Data are recorded from measurements of physical variables and locations obtained in two different stages. First stage involves an annual census, which takes place during the breeding season of SES. The second stage starts at the end of the breeding season, when SES go back at sea for foraging purposes. Below we briefly describe how data are generated and recorded in each stage. During the breeding season, the SES haul out to the beach to breed. Annual census on foot along the coast of the colony is an arduous but indispensable work to know distribution and trend of the population. The objective is to count each of the harems scattered on the beaches of the PV to determine the number of offspring born in a season. Counts carried out during 2-3 days at peak of the breeding season (October 3-7), when most of the population is ashore. All the breeding groups were counted and located along 200 km of coastline, divided into sections and each census taker is assigned to a route. The census taker must count for the number of animals and classify them by sex and age males, females, and pups. Hereinafter, we will call the procedure of counting individuals in a certain place Occurrence. Each occurrence was georeferenced (latitude and longitude) and demographic data included date and time, group size and substrate where the SES is located. All information about these censuses is recorded in a field book and then uploaded into a MySQL database. Table 1 summarizes the most relevant fields for the conducted censuses.

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observer</td>
<td>Person in charge</td>
</tr>
<tr>
<td>Date</td>
<td>Date of observations</td>
</tr>
<tr>
<td>Start time</td>
<td>Census’ starting hour</td>
</tr>
<tr>
<td>End time</td>
<td>Census’ finalizing hour</td>
</tr>
<tr>
<td>Location</td>
<td>Latitude and longitude of the occurrence</td>
</tr>
<tr>
<td>Weather</td>
<td>Cloudy, windy, rainy, clear</td>
</tr>
<tr>
<td>Tide</td>
<td>High/low</td>
</tr>
<tr>
<td>Category</td>
<td>Seals’ stage (adult, yeraling, pups, etc.)</td>
</tr>
<tr>
<td>Sex</td>
<td>Female, male, not determined</td>
</tr>
<tr>
<td>Count</td>
<td>Amount of SES observed</td>
</tr>
</tbody>
</table>

At the end of breeding, SES go back at sea for foraging. The trip is monitored by small computers designed and built by Wildlife Computers Inc. with sensors to take measurements about their location and immediate environment. The instrument is deployed when the

1 http://www.w3id.org/ceanpat-gilia/bigeonto

2 https://wildlifecomputers.com/
seal is on land before the migration into the sea begins. Time

Depth Recorder (TDR) records, time, depth, and temperature every 30 minutes during round foraging trip. The position is also registered when the seal ascends to the surface. Table 2 summarizes the fields that are most relevant in diving.

Table 2

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SES identifier</td>
<td>4-character identifier (e.g. ABVM)</td>
</tr>
<tr>
<td>Dive number</td>
<td>Total dives in one journey</td>
</tr>
<tr>
<td>Start time</td>
<td>Dive starting time and date</td>
</tr>
<tr>
<td>End time</td>
<td>Dive finalizing time and date</td>
</tr>
<tr>
<td>Drive depth</td>
<td>Average (in meters)</td>
</tr>
<tr>
<td>Temperature</td>
<td>Average (in Celsius degrees)</td>
</tr>
<tr>
<td>Location</td>
<td>Latitude and longitude recorded</td>
</tr>
</tbody>
</table>

The census and the deployments of the instruments are carried out by the research team belonging to Centre for the Study of Marine Systems hosted in Puerto Madryn, Patagonia Argentina (CESIMAR-CENPAT-CONICET).

3. Ontologies used to model observations and hydrographic profiles

In this section, we briefly summarize these ontologies used for the publication of our dataset, indicating the reuse of concepts.

The core of our ontologies network is composed by SOSA/SSN [3] and BiGe-Onto [5], which can be jointly used for both hydrographic profiles and observational data. These ontologies are linked to other ones describing different sub-domains, and thus creating such network. Therefore, the resulting network is composed mainly by the following:

- an ontology to describe the locations and places of interest
- an ontology to describe temporality of events
- an ontology to describe scientific publications

We reuse only the elements from these ontologies that are necessary for modeling our data, adopting a soft reuse strategy [12] instead of importing the whole ontologies.

A list of prefixes and their corresponding URIs are listed in Table 3.

Semantic Sensor Network (SSN) Ontology

The Semantic Sensor Network (SSN) is a generic ontology related to sensor observations. This ontology has been updated to become a W3C recommendation, and currently it is a lightweight one dedicated to sensor and actuator descriptions. It has been called Sensor, Observation, Sample, and Actuator (SOSA) pattern. The link between SSN and SOSA is described in [3]. The classes we have reused from SOSA/SSN ontology are:

- sosa:Observation to describe the measurements context.
- sosa:FeatureOfInterest to specify the observed phenomena. In our case, the sample of water column registered by the SES during diving.
- sosa:ObservableProperty to specify the measured property of the observed phenomena (average temperature, average depth and location).
- sosa:Platform to represent the platform hosting a sensor. In our cases, the platform is always the SES.
- sosa:Sensor to describe sensors hosted by platform (e.g. TDR).
- sosa:Result to represent the measurement values from the sensors.

We have also reused the main properties associated with these classes: sosa:observedProperty, sosa:hosts, sosa:hasFeatureOfInterest sosa:madeBySensor, and sosa:hasResult.

BiGe-Onto Ontology

BiGe-Onto is an ontology designed for modeling biodiversity and marine biogeography data [5]. Its main concept is an occurrence. Given that each census is a set of occurrences of SES at a specific time and place, we consider BiGe-Onto fits the nature of our data. At the same time, it reuses different vocabularies such as Darwin Core (DwC) [13], which is the core one in BiGe-Onto. Main

https://cenpat.conicet.gov.ar/cesimar/
### Table 3

**Ontology/Vocabulary name** | **Prefix** | **URI**
---|---|---
BiGe-Onto ontology | bigeonto | http://www.w3id.org/cenpat-gilia/bigeonto/
Semantic Sensor Network Ontology | ssn | http://www.w3.org/ns/ssn/
Sensor, Observation, Sample, and Actuator Ontology | sosa | http://www.w3.org/ns/sosa/
Darwin Core (literal values) | dwc | http://rs.tdwg.org/dwc/terms/
Darwin Core (IRI values) | dwciri | http://rs.tdwg.org/dwc/iri/
GeoSPARQL ontology | geosparql | http://www.opengis.net/ont/geosparql#
W3C Time Ontology | time | http://www.w3.org/2006/time#
FRBR-aligned Bibliographic Ontology | fabio | http://purl.org/spar/fabio#
NERC vocabulary server (measured phenomena) | P01 | http://vocab.nerc.ac.uk/collection/P01/current/
NERC vocabulary server (biological entity sex) | S10 | http://vocab.nerc.ac.uk/collection/S10/current/
Quantities, Units, Dimensions and Types Ontology (v1.1) vocabulary | qudt | http://qudt.org/1.1/vocab/unit
Quantities, Units, Dimensions and Types Ontology (version 1.1) schema | qudts | http://qudt.org/1.1/schema/qudt
GoodRelations (v1.0) | gr | http://purl.org/goodrelations/v1#
Simple Knowledge Organization System | skos | http://www.w3.org/2004/02/skos/core#

**Reused vocabularies and ontologies.**

The **Quantity, Unit, Dimension and Type (QUDT) Ontologies** QUDT is a collection of OWL ontologies and vocabularies [14]. The QUDT schema defines the base classes, properties, and restrictions used for modeling physical quantities, units of measure, and their dimensions in various measurement systems. QUDT also contains a set of vocabularies to define units for different domains. We have reused the unit vocabulary that categorizes units in different classes. This vocabulary also provides individuals to identify units such as qudt:M for meter and qudt:DEG_C for Celsius degree.

**GeoSPARQL Ontology** GeoSPARQL [15] is an Open Geospatial Consortium (OGC) standard for supporting the representation and querying of geospatial data on the Semantic Web. As such, it is based on the OGC’s Simple Features model, with some adaptations for RDF. GeoSPARQL designates a vocabulary for representing geospatial data in RDF, and it defines an extension to the SPARQL query language for processing them, together with both a small ontology for representing features and geometries, and a number of SPARQL query predicates and functions. All these definitions are derived from other OGC standards so that they are well grounded and documented. Using the new standard should ensure two things: (1) if a data provider uses the spatial ontology in combination with the new standard should ensure two things: (1) if a data provider uses the spatial ontology in combination with the existing standard, the new vocabulary should be used in conjunction with the existing vocabulary. This would allow for interoperability with existing systems. (2) If a data provider uses the spatial ontology in combination with the new standard, the new vocabulary should be used in conjunction with the existing vocabulary. This would allow for interoperability with existing systems.

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4https://github.com/oborel/obo-relations

5https://www.w3.org/TR/sparql11-query/

6A feature is simply any entity in the real world with some spatial location.

7A geometry is any geometric shape, such as a point, polygon, or line, and is used as a representation of a feature’s spatial location.
with an ontology of their domain, these data can be properly indexed and queried in spatial RDF stores; and (2) RDF-compliant triple stores should be able to properly process the majority of spatial RDF data. This ontology is used to describe the location of each occurrence, and the beaches involved. We reuse the classes geos:Feature and geos:Geometry, and the associated properties, like geos:hasGeometry and geos:asWKT.

The W3C Time Ontology The W3C Time ontology [16] enables the description of time instants and intervals. Hence it may be useful when we need to describe the timestamp, or the time associated with the measurements made by the observers of the SES. We reuse the classes time:Interval and time:Instant, and their associated properties, such as time:hasBeginning, time:hasEnd, and time:inXSDDateTimeStamp.

FRBR-aligned Bibliographic Ontology (FaBiO) The aim of FaBiO [17] is recording and publishing descriptions of entities that are published or potentially publisable, and that contain or are referred to by bibliographic references. Its classes are structured according to the FRBR schema of Works, Expressions, Manifestations and Items. Additional properties have been added to extends the FRBR data model by linking works and manifestations. Considering that both census observations and measurements of physical variables have been used to publish results in diverse scientific journals, we have chosen the ontology FaBiO for modeling the relationships between platforms and such publications. Our choice is based on the fact that FaBiO is one of the ontologies involved in the OpenCitations initiative, which promotes the use of open bibliographic data by the use of Semantic Web technologies. We reuse several classes to identify the kind of published document, for example fabio:JournalArticle, fabio:Book, fabio:BookChapter and fabio:Dataset. We also reuse some of their associated properties, like prism:doi and prism:publicationDate.

NERC and GoodRelations ontologies Additionally, we reuse the vocabulary for Oceanography known as Natural Environment Research Council (NERC) Vocabulary Server [18] developed by the British Oceanographic Data Center (BODC)9, which provides access to lists of standardized terms that cover a broad spectrum of disciplines relevant to Oceanography. In particular, we use the category P01 whose terms are used to describe individual measured phenomena and S10 category to describe the sex of biological entities. We also reuse the GoodRelations ontology [19] to model sensor brands, serial numbers and models.

It is important to highlight that the previous ontologies were chosen because many of them are W3C standards (such as SOSA/SSN and OWL Time) or standards of the Open Geospatial Consortium (OGC) such as GeoSPARQL and vocabularies that are widely used by the user community involved in the domain. (e.g. Darwin Core or NERC). In the absence of a standard ontology for a specific domain, we decided to use those that according to our knowledge, are the ones that are currently under development, provide support and the documentation is adequate, such as FaBiO and GoodRelations.

4. Data model and URIs

Based on the network of ontologies described in the previous section, we are now able to create a dataset containing all the individuals describing hydrographic profiles and occurrences taken during the censuses. Now we explain the decisions taken to create resource URIs and we provide examples of resource descriptions.

4.1. Resource URIs for hydrographic profiles

This subsection presents the main URI design decisions and conventions used. Table 4 provides a summary of the main types of URIs that we generate. The first column presents the type of resources. The second column indicates the associated class which types the resources. The last column contains the name pattern used to generate the resource URIs. The base URI for our dataset is http://linkeddata.cenpat-conicet.gob.ar/resource/. Its prefix is base. Our generic name pattern to produce URIs for each object is baseURI +"/+ nameOfClass +"/+ objectIdentifier.

4.1.1. Platform and Sensor

We consider SES as an oceanographic sampling platform. The individual that represents the platform is an instance of the sos:Platform class. Each sensor hosted by the SES is represented by an instance
Table 4

<table>
<thead>
<tr>
<th>Object Class</th>
<th>URI pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>SES Platform</td>
<td>sosa:Platform base:platform/{sesID}</td>
</tr>
<tr>
<td>TDR</td>
<td>sosa:Sensor base:sensor/{Sensor type}/id-{serialNumber}</td>
</tr>
<tr>
<td>Feature of Interest</td>
<td>sosa:FeatureOfInterest base:featureOfInterest/sampleOfWaterColumn/id-{DiveID}</td>
</tr>
<tr>
<td>Observable property</td>
<td>sosa:ObservableProperty base:observableProperty/id-{DiveID}/avg_temp</td>
</tr>
<tr>
<td>Instant</td>
<td>time:Instant base:instant/{beginDive}/T{beginTime}</td>
</tr>
<tr>
<td>Duration</td>
<td>time:Duration base:duration/sampleID-{DiveID}</td>
</tr>
<tr>
<td>Interval</td>
<td>time:Interval base:interval/sampleID-{DiveID}</td>
</tr>
<tr>
<td>Observation</td>
<td>sosa:Observation base:observation/id-{DiveID}/avg_temp</td>
</tr>
<tr>
<td>Result value</td>
<td>sosa:Result base:result/id-{DiveID}/avg_temp</td>
</tr>
<tr>
<td>Dive location</td>
<td>geo:Geometry base:geometry/point_{longitude}_{latitude}</td>
</tr>
<tr>
<td>Census observation</td>
<td>dwc:Occurrence base:occurrence/ID-{ObservationID}</td>
</tr>
<tr>
<td>Observation event</td>
<td>bigeonto:BioEvent base:bioevent/ID-{ObservationID}</td>
</tr>
<tr>
<td>Location</td>
<td>dc:Location base:geometry/geometryType_{longitude}_{latitude}</td>
</tr>
<tr>
<td>Observer</td>
<td>foaf:Person base:person/{personID}</td>
</tr>
<tr>
<td>SES category</td>
<td>vocab:Category base:category/{categoryCode}</td>
</tr>
<tr>
<td>Taxon</td>
<td>dwc:Taxon base:taxon/mirounga_leonina</td>
</tr>
<tr>
<td>Related paper</td>
<td>fabio:Expression base:paper/ID-{paperID}</td>
</tr>
</tbody>
</table>

of the class sosa:Sensor. Figure 1 presents the description of the TDR sensor. The TDR is identified by an URI generated using the sensor type, e.g. TDR plus the manufacturing number 19793. This URI is typed by the class sosa:Sensor. The sosa:host property links the sosa:Platform instance to the TDR URI. The sosa:observes property links the TDR URI to an instance of sosa:ObservableProperty; in this case it corresponds to depth. Additionally, the gr:ProductOrServiceModel class is used to model the sensor, and the gr:hasBrand property relates the sensor to its manufacturer, which is an instance of the gr:Brand class. Other properties such as gr:serialNumber and gr:category were reused to describe the type of sensor and its serial number. The link http://linkeddata.cenpat-conicet.gob.ar/resource/sensor/TDR/id-19793 can be used to explore visually the sensor URI.

4.1.2. Observation

An observation describes the context of a measurement made by a sensor. In the case of TDRs, the measurements are location, time, depth and temperature. Properties sosa:hasFeatureOfInterest, sosa:hasResult, sosa:observableProperty and sosa:madeBySensor link our specific observation with its corresponding observed property, location, sensor, and measurement value. We create an instance of sosa:FeatureOfInterest class that represents the sample of water column during dive. GeoSPARQL is used to describe the precise location of the SES during the dive. As shown in Figure 2, the geometry of the trip made by the SES is a set of points expressed by a WKT string. This string is linked to a geo:Geometry instance by the geo:asWKT property. The geo:hasGeometry property links the sosa:Result instance to an instance of the geo:Geometry class. Visually exploring the observation URI can be done through http://linkeddata.cenpat-conicet.gob.ar/page/observation/id-233/location.

4.1.3. Phenomenon Time

Figure 3 presents an observation produced by the TDR. Sometimes a measurement is related to a period of time. For example, the TDR measures the duration of a dive during an immersion. The property sosa:phenomenonTime links an instance of sosa:Observation to an instance of the class time:Interval. The properties time:hasEnd and time:hasBeginning point to an instance of the class time:Interval. To connect an instance of time:Instant with a xsd:dateTime
value we use the \textit{time:inXSDDateTimeStamp} property. The duration of the interval is described as instances of the class \textit{time:Duration}. To explore the phenomenon time URI visually use the link \texttt{http://linkeddata.cenpat-conicet.gob.ar/page/interval/sampleID-233}.

\subsection*{4.1.4. Occurrence}

It is true that we can model the SES census using SOSA/SSN because \textit{sosa:Sensor} can be an observation made by a human instead of an electronic equipment. Thus, we decided not to use SOSA/SSN, and instead we used BiGe-Onto since it was created to model species occurrences by means of the DwC. We believe that if we want to share the results in an interdisciplinary way, it is necessary to respect the standard adopted by biodiversity community. Using DwC will also allow the reuse of this part of the dataset to perform more complex analyses such as marine spatial planning. We use the class \textit{dwc:Occurrence} to represent the SES observations made during a census. In Figure 4 you can see the observation of two female pups on October 3, 2001. To represent gender we use the nerc’s URI (S10:S106). The property \textit{bigeonto:has_event} connects the instance of occurrence with the instance of the event \textit{bigeonto:BioEvent}. In the same way, each event instance is related to an instance of the \textit{geo:Geometry} class through the \textit{bigeonto:has_location} relationship. On the other hand, the \textit{dwciri:recordedBy} property relates the instance of the occurrence to instances of the \textit{foaf:person} class that perform the observation. Finally, the occurrence is associated with an instance of the class \textit{dwc:Organism} through the \textit{bigeonto:associated} property and the organism belongs to a specific taxon (\textit{dwc:Taxon}) whose scientific name is \textit{Mirounga leonina}. The red rectangles represent the links generated for the taxon in DBPedia and Wikidata, as well as the identifier of the person in ORCID. The link \texttt{http://linkeddata.cenpat-conicet.gob.ar/page/occurrence/ID-36202} can be used to explore visually the occurrence URI.

\subsection*{4.1.5. Publication}

Each publication is represented as an instance of \textit{fabio:Expression}. These expressions are also split by type of publication, thus using the respective subclasses of \textit{fabio:Expression}. For instance, published books are represented with the class \textit{fabio:Book} and so on. The shared properties for all the publications include date of publication.
Fig. 3. Example of an interval representing a dive of 10.94 seconds duration.

Fig. 4. Representation of an observation (dwc:occurrence) made during a census. The occurrence of an SES is performed by a person at a location and time. Links to Geonames, DBPedia, Wikidata, and ORCID are shown highlighted.

Fig. 5. Representation of a publication associated with the AAPR platform, the DOI is described using prism:doi and the external link (owl:sameAs) to OpenCitations was shortened for simplicity.

5. Data Transformation Process

To create Linked Open Data, a conversion needs to take place from the data contained in SES database into RDF. As explained in section 2, measurements produced by sensors, and census data are stored in MySQL server. Fields that are no longer used or that contain confidential data are excluded, for example data that is still being processed. Transformation process is done by D2RQ Platform\(^\text{10}\), which consists of the D2RQ Mapping Language, used to write mappings between database tables and RDF vocabularies or OWL ontologies; the D2RQ Engine, a SPARQL-to-SQL rewriter that can evaluate SPARQL queries over your mapped database; and the D2R Server, a web application that provides access to the database via the SPARQL protocol, as Linked Data, and via a simple HTML interface. In order to see the complete mapping, one can use the link https://bitbucket.org/arglod/southern-elephant-seals/src/master/mappings/buceos.ttl to the project repository.

D2RQ runs at http://linkeddata.cenpat-conicet.gob.ar in back-end to browse structured data. It also has a SPARQL endpoint to be accessed from other ap-

\(^{10}\)http://d2rq.org/d2r-server
applications, and a SPARQL explorer to query our own database in a friendly manner. One of the advantages that D2RQ provides is that after mapping, if the database is updated, it is not necessary to rewrite the mapping. Key statistics are presented in Table 5, and were computed in December 2020.

Table 5
Dataset key statistics

<table>
<thead>
<tr>
<th>Category</th>
<th>Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Nr. of Triples</td>
<td>742k</td>
</tr>
<tr>
<td>Nr. of classes</td>
<td>22</td>
</tr>
<tr>
<td>Nr. of properties</td>
<td>50</td>
</tr>
<tr>
<td>Nr. of platforms</td>
<td>9</td>
</tr>
<tr>
<td>Nr. of sensors</td>
<td>9</td>
</tr>
<tr>
<td>Nr. of observations</td>
<td>9,543</td>
</tr>
<tr>
<td>Nr. links to DBPedia</td>
<td>1</td>
</tr>
<tr>
<td>Nr. links to Wikidata</td>
<td>1</td>
</tr>
<tr>
<td>Nr. links to GeoNames</td>
<td>10</td>
</tr>
<tr>
<td>Nr. links to NERC</td>
<td>2</td>
</tr>
<tr>
<td>Nr. links to ORCID</td>
<td>7</td>
</tr>
<tr>
<td>Nr. links to OpenCitations</td>
<td>13</td>
</tr>
</tbody>
</table>

5.1. Interlinking

The external links were generated manually, using a MySQL table specifically created for this purpose, which is then mapped using D2RQ. This table has in one column the URI of some concept belonging to our data set, and in another column the equivalent URI that references the external dataset. For example, http://linkeddata.cenpat-conicet.gob.ar/resource/person/MZA in one column, and in the other the equivalent URI (https://orcid.org/0000-0001-8851-8602) that represents the same person in Open Researcher and Contributor Identifiers (ORCID).

When possible, in the case of publications, the instances of fabio:Expression class were linked to OpenCitation dataset [20] as Figure 5 shows. The relationship between these URIs is done using owl:sameAs property. The instances of observable properties were linked to their corresponding URI in NERC through the skos:broader property. For example, average depth is related to http://vocab.nerc.ac.uk/collection/P01/current/ADEPZZ01, as shown in Figure 1.

We use Geonames11, a geographical database that contains over 11.8 million geographical names, as a source of external links for places. The structure behind the data is the Geonames ontology v3.2 12, which closely resembles the flat-file structure. An individual in the database is an instance of type Feature and has a Feature Class (administrative divisions, populated places, etc.), a Feature Code (subcategories of Feature Class) along with latitude, longitude, etc. associated with it. For censuses where locations are recorded, for example a beach (instances of geo:Feature and dc:Location) the link to Geonanes is generated through skos:related property. An example of this can be seen in Figure 4, the location corresponds to a beach located in the PV called Punta Buenos Aires whose identifier is https://www.geonames.org/3863776.

To link instances of people (foaf:person) we use links to ORCiD [21]. They are intended to uniquely identify researchers so that those individuals can be correctly credited for their research work, and links can be provided to express their professional affiliations, as shown in Figure 4. By September 2020, 34 external links to different datasets have been created.

5.2. Dataset availability

The SES dataset can be downloaded, navigated and queried using a SPARQL endpoint, and they are published under Creative Commons Universal Public Domain Dedication (CC0 1.0)13 License. All the criteria for five star Linked Data as defined in [22] are met. There is a description of the data online, the data is available in RDF, there are many links to structured vocabularies, and metadata about the collection is made available. Our dataset characteristics are listed in Table 6.

Table 6
Technical details

<table>
<thead>
<tr>
<th>URL</th>
<th><a href="http://linkeddata.cenpat-conicet.gob.ar">http://linkeddata.cenpat-conicet.gob.ar</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>SPARQL</td>
<td><a href="http://linkeddata.cenpat-conicet.gob.ar/sparql">http://linkeddata.cenpat-conicet.gob.ar/sparql</a></td>
</tr>
<tr>
<td>SNORQL</td>
<td><a href="http://linkeddata.cenpat-conicet.gob.ar/snorql">http://linkeddata.cenpat-conicet.gob.ar/snorql</a></td>
</tr>
<tr>
<td>Dump Data</td>
<td><a href="http://dx.doi.org/10.17632/5nv5c7575w.3">http://dx.doi.org/10.17632/5nv5c7575w.3</a></td>
</tr>
<tr>
<td>VoID</td>
<td><a href="http://linkeddata.cenpat-conicet.gob.ar/dataset">http://linkeddata.cenpat-conicet.gob.ar/dataset</a></td>
</tr>
<tr>
<td>Licencing</td>
<td>CC0 1.0</td>
</tr>
</tbody>
</table>

To explore the dataset using the SPARQL endpoint, we have developed a set of queries to answer the most common questions that researchers need to answer. For

11https://www.geonames.org/
12http://www.geonames.org/ontology/documentation.html
13https://creativecommons.org/publicdomain/zero/1.0/
example, number of dives, trips, and values of certain environmental variables. Table 7 shows the developed queries and their corresponding links to the endpoint.

Table 7
Predefined queries to explore the data set.

<table>
<thead>
<tr>
<th>Query</th>
<th>Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensors associated with each platform</td>
<td>Query 1</td>
</tr>
<tr>
<td>Number of dives made by each platform</td>
<td>Query 2</td>
</tr>
<tr>
<td>Temperatures sampled by the ABVM platform</td>
<td>Query 3</td>
</tr>
<tr>
<td>Locations, depths and dates registered by ABVM</td>
<td>Query 4</td>
</tr>
<tr>
<td>Papers associated with each platform</td>
<td>Query 5</td>
</tr>
<tr>
<td>1990 census grouped by SES categories</td>
<td>Query 6</td>
</tr>
</tbody>
</table>

6. Use Case: Accessing and analyzing data from dives and censuses

One crucial aspect is how to access and analyze data, and especially how to get only that part of data which is of interest for a given research question. To show the exploitation of the dataset, we developed a dashboard 14 that allows querying the statistics of the dives and the taken routes. We use the R flexdashboard 15 package that allows generating web pages based on an R Markdown 16 document. To query our endpoint we use the SPARQL Package 17 that allows to import directly results of SPARQL SELECT queries into the statistical environment of R as a data frame. The following describes each module of the dashboard.

Diving statistics This module summarizes the diving statistics (maximum depths recorded, number of dives, maximum temperatures and number of platforms). The information for each of the sensors used is also detailed. For bar charts, the ggplot 18 library was used.

Dive Analysis This module allows you to see by platform the most important variables registered during dives. Temperatures and depths, as well as duration can be displayed. The line chart was built using the plot_ly library 19.

Platforms trips This module retrieve the trips made by each platform and displays them on a map generated with the leaflet library 20, a filter can be made for each one if necessary. A spatial cluster analysis using the dbscan 21 algorithm is also provided to understand the distribution of SES at sea. The parameters can be configured by the user for their best adjustment.

Census statistics This module allows analyzing the data of the census carried out during 1990 to 2017. Two charts were developed with ggplot, the first shows the annual population of SES grouped by category, while the second shows the trend of the SES breeding population.

7. Discussion

This paper presents the publication as LOD of a biological and physical dataset, collected for more than 20 years, and stored with early objective of studying the environment influence on the foraging, reproductive performance, and population trend of the SES. This dataset was initially available for a small research group, and the aim is to make it available to a global community. Our development improves the discoverability of the content of the database and could be applied at new knowledge-building and cross-disciplinary research. For example, we expect the hydrographic profiles become a useful tool together with physical samples resulting from other science programs, to assess ocean changes associated with the climate change.

The dataset comes from PV a geographic region under conservation regulations by UNESCO and there is a continue demand of the governmental authorities to develop spatial planning. This requirement helps the sustainability of the database, because it needs a high level of accuracy for SES data, and access at other databases in a user-friendly manner. Coastal management Planning and Marine Spatial Planning (MSP) are concerned with the management of the distribution of human activities in space and time in and around seas and oceans to achieve ecological, economic and societal objectives and outcomes [23]. The next steps will be to promote the use vocabulary terms for discovery databases purposes of the institute CESIMAR, to allow the availability and suitability of data, to be used at

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14 https://cesimar.shanyapps.io/DiveAnalysisDashboard/
15 https://rmarkdown.rstudio.com/flexdashboard/
16 https://rmarkdown.rstudio.com/
17 http://cran.r-project.org/web/packages/SPARQL/index.html
18 https://cran.r-project.org/web/packages/ggplot2/index.html
19 https://cran.r-project.org/package=plotly
20 https://cran.r-project.org/web/packages/leaflet/leaflet.pdf
21 https://cran.r-project.org/package=dbscan
regular review cycles of the MSP process. In addition, it would be desirable to access to the physical dataset collected by tourist and commercial vessels that overlap the same range in the southwest Atlantic Ocean. These hydrographic profiles could cover changes of the environment in all influence area of the SES distribution.

 Particularly, this work shows the feasibility of using the SSN/SOSA ontology for modeling hydrographic measurements of instrumented animals and observation data collected during censuses. SSN/SOSA ontology is already a W3C standard, then we find this analysis as a valuable step towards the definition of the precise semantics of the ocean biodiversity systems, which requires of a collaborative effort.

 The research also provides us useful insights into the process of developing and publishing data as LOD. First of all, valuable raw data can be highly heterogeneous and, as it was in this case, stored in relational databases developed by third parties, and even no longer maintained. Therefore, understanding how these data have been structured is one of the first barriers. Automated processes for bootstrapping SPARQL-to-SQL mappings, as those provided by the very same D2RQ or related technologies, fail in their attempts to automatically generate such mappings based on the content of data sources. Thus, much of this work have to done manually.

 Ontology reusing is another challenging task, particularly in the context where standard ontologies have not been developed yet. Thus, our process required of a trade-off between the needed conceptualization (concerning the domain) and the availability of reused ontologies. As defined in [12], the strategy to reuse ontologies is another important obstacle, reusing concepts or properties from external ontologies (soft reuse) seems to be a good strategy to bootstrap LOD datasets from scratch, but it is limited for reasoning purposes. As a consequence and looking toward the future works, other strategies must be considered to increase the expressiveness of model without introducing unnecessary complexity.

 Acknowledgements

 This work could not have been possible if it were not for the immense task of digitizing and ordering the data carried out by the Computer Scientist Maria Rosa Marin (recently retired). We grateful to PhD Claudio Campagna founder of the program for his vision of long lasting studies that allowed to keep the collection of records.

 References


