Modifications envisaged and supplemental comments in 2nd version of the manuscript, following 1st referee (Diego Fontaneto) suggestions:

For the major suggestion you evidenced, we substantially agree with you and we provided the extended name of each parameter observed by adding a column to the table 2 as you propose. Moreover, we added another, more comprehensive table in paragraph 6, reporting the extended name of all the observed and accessory parameters (such as date time, sensors name, coordinates).

For the minor issues you reported:

- we corrected the manuscript explaining all the acronyms in the order they appear in the revised version of the manuscript that we will upload after the discussion phase;

- we corrected english wording, as you suggested;

- lines in the water in figure 1 and 3 are territorial water limits (continuous violet lines) and navigation routes (dotted violet lines) contained in the original Open Street Map layer we used as a basemap. Since they are not relevant to the figures or the context, we provided a cleaned image (without these lines) in the revised version of the manuscript;

- for the Senigallia - Telesenigallia ambiguity in Figure 1: the transect is called "Senigallia-Susak", so there is an error in the figure that we corrected (Telesenigallia Pylon instead is a pylon belonging to the CNR fixed sensors observation network that records data in continuous, near Senigallia);

- in the database salinity is dimensionless, for pH we used the pH units. So, the "-" for pH record in the Table 2 has been changed to "pH Units";

- effectively there is a difference between the caption of the database (Figure 4) and the description in lines 215-221. We uploaded a corrected version of the Figure 4 complying with the description provided in the revised version of the manuscript;

- we corrected factor/parameter ambiguity using only "parameter" term.

Modifications envisaged and supplemental comments in 2nd version of the manuscript, following 2nd referee (Johan Wikner) suggestions:

- r. 19: We modified line 17 as follows:

"In this paper, we describe a 50 years (1965-2015) ecological database containing data collected in the Northern Adriatic Sea (NAS)"

- r. 46-47: We modified the paragraph as follows, adding some references:

"From the researcher point of view, open practices have been reported to give advantage, first of all, to open new frontiers in science (Science|Business network's cloud consultation group, 2019) and provide solutions to urgent societal problems (Palen et al., 2015; Tai and Robinson, 2018); moreover, it allows gaining more citations, media attention, potential collaborators, and funding opportunities (Eisenbach, 2006; McKiernan et al., 2016, Tennant et al., 2019) and it is vital for leaving a heritage to future generations."

References added:

- Science|Business Network's Cloud Consultation Group (2019). Why Open Science is the Future (and how to make it happen). Science|Business. Brussels. Report available here: https://sciencebusiness.net/report/why-open-science-future-and-how-make-it-happen
- Palen, L., Soden, R., Anderson, T. J., & Barrenechea, M. (2015, April). Success & scale in a data-producing organization: The socio-technical evolution of OpenStreetMap in response to humanitarian events. In Proceedings of the 33rd annual ACM conference on human factors in computing systems (pp. 4113-4122). ACM.
- Tai, T., & Robinson, J. (2018). Enhancing climate change research with open science. Frontiers in Environmental Science, 6, 115.
- Eysenbach, G. (2006). Citation advantage of open access articles. PLoS biology, 4(5), e157. DOI: 10.1371/journal.pbio.0040157
- Tennant JP, Crane H, Crick T, Davila J, Enkhbayar A, Havemann J, Kramer B, Martin R, Masuzzo P, Nobes A, Rice C, Rivera-López BS, Ross-Hellauer T, Sattler S, Thacker P, Vanholsbeeck M. 2019. Ten myths around open scholarly publishing. PeerJ Preprints 7:e27580v1 DOI: 10.7287/peerj.preprints.27580v1

- r. 97: Yes, of course the Adriatic Sea is part of the Mediterranean area, we modified the sentence as follows:

"and the notable sea-level range, relatively to the rest of the Mediterranean area…"

- r. 102-103: We modified the text, better specifying the periods of trophic changes and the references:

"The basin has undergone overfishing (Fortibuoni et al., 2010), marked eutrophication (during the 70s; Giani et al., 2012), followed by a phase of oligotrophication (years 2000s; Mozetič et al., 2010) and by a recent increase of nutrient concentrations (since 2007; Totti et al., 2019). The NAS has also been subjected to frequent development of mucilage aggregates (Giani et al., 2005; De Lazzari et al., 2008), until the first decade of the 2000s."

Reference added:

Giani et al., 2012. Recent changes in the marine ecosystems of the northern Adriatic Sea, Estuarine, Coastal, and Shelf Science, Volume 115, 2012, Pages 1-13, ISSN 0272-7714, https://doi.org/10.1016/j.ecss.2012.08.023.

- r. 108-109: The authors agree in referencing Table 2 here since it gives a complete overview of all the parameters examined. We modified the sentence as follows:

"The LTER-Italy parent site NAS includes four research sites (Gulf of Trieste, Gulf of Venice, Po Delta and Romagna Coast, Senigallia-Susak Transect; Figure 1), where meteo-oceanographic and biological data, mainly on plankton (Table 2), are gathered both during oceanographic cruises and at fixed point observatories."

- r. 110 -111: The dataset we describe here refers to the whole NAS, which includes also the 4 LTER research sites but is a much wider area, described in detail in the text (lines 93-112). The Authors believe that additional descriptions only of the four research sites could be a little bit misleading.

- r. 119: We better explained the level of metadatation and accessibility of data by adding the following sentence after line 130:

"In particular, methodological protocols and associated documentation changed through time. Several sensors are described and extensively documented through the GET-IT platform (see Section 5), where it is possible to visualize all the observations related to a specific instrument or method. Other protocols have undergone a deep metadatation process by analyzing ancillary historical metadata (Scovacricchi, 2017). In this case, it is not immediately possible to obtain data related to a specific protocol, but it is still possible to filter data by method by importing the .csv file in a spreadsheet."

ps: the partial upload of data through GET-IT platform is justified in rows 270-288.

- Tab. 2:
  - We added to the table the name of pH sensors (pH glass membrane and pH electrode) and Oxygen sensor (Oxygen Polarographic sensor).
  - For the indication of depth coverage and sampling frequency range we added this sentence in paragraph 3 (rows 121-123):
    "Sampling frequency: e.g., data coming from CTD (Conductivity, Temperature, Depth), such as temperature, oxygen, and pH, are registered in real-time at each meter in depth; other parameters, like nutrients and phytoplankton, are sampled at a much lowest time-frequency and at variable depths. The depth coverage ranged between 0-63 m, the sampling frequency from monthly to seasonal"
  - We changed the measurement unit (μm dm^{-3}) of nutrients as requested

- Tab. 1: We changed the caption as follow:

"Operation periods of the different research vessels between 1965 and 2015 and number of observations"

- r. 182: We added the following sentence at rows 182-183 in order to clarify the level of quality assurance of data:

"Samples collected during each cruise, whatever the station, were then analyzed in the laboratory by means of diverse techniques. Since 2000 analytical quality of nutrients and chlorophyll analyses is assessed through participation to the Quality Assurance of Information for Marine Environmental

Monitoring In Europe (QUASIMEME; http://www.quasimeme.org) international laboratory proficiency-testing."

- r. 204: We modified the sentence as follows:

"To deal with this issue, internal education and recurring calibration of taxonomic competence were carefully considered, with training periods and intercalibrations phases."

- r. 206: Here we added the following sentence in order to complete the list of taxonomic references we adopted:

"Since 2006 the taxonomic revision of the phytoplankton species has been made according to the global algal database of taxonomic, nomenclatural and distributional information "Algaebase" (www.algaebase.org), the global algal database of taxonomic, nomenclatural and distributional information, for the zooplankton the Marine Planktonic Copepods catalog (https://copepodes.obs-banyuls.fr/en/links.php, Razolus et al., 2005-2019) has been used. In the past, for phyto- and zooplankton analyses several texts and monographs were used (Berard-Therriault et al., 1999; Harris et al., 2000; Heimdal, 1993; Hendey, 1964; Hustedt, 1930-1966; Pascher, 1915; Peragallo and Peragallo, 1897-1908; Rampi and Bernhardt, 1980; Schiller, 1931-37; Throndsen, 1993; Tomas, 1997)"

References added:

- Razouls C., de Bovée F., Kouwenberg J. and Desreumaux N., 2005-2019. - Diversity and Geographic Distribution of Marine Planktonic Copepods. Sorbonne University, CNRS. Available at http://copepodes.obs-banyuls.fr/en [Accessed September 24, 2019]
- Berard-Therriault L., Poulin M., Bossé L. 1999. Guide d'identification du phytoplancton marin de l'estuaire et du golfe du Saint-Laurent. NRC Research Press, 387 pp.
- Harris, R.P., Wiebe, P.H., Lenz, J., Skjoldal, H.R. and M. Huntley. 2000. ICES Zooplankton Methodology Manual, Academic Press, USA. pp. 684
- Heimdal B. R., 1993 Modern Coccolithophorids in: Marine phytoplankton a guide to naked flagellates and coccolithophorids. Tanos editors, Academic Press: 147- 248.
- Hendey, N. I., 1964. An introductory account of the smaller algae of British coastal waters. Part V: Bacillariophyceae, Diatoms. Fishery Invest. Lond. Ser. IV 5, 317 pp.
- Hustedt F., 1930-1966. Die Kiesealgen von Deutschland, Österreichs und der Schweiz mit Berusichtigung der übrigen Länder Europas sowie der angrenzender Mehresgebiete. In : Rabenhorst's Kriptogamen-Flora von Deutschland, Österreichs und der Schweiz. Akad; Verlag. m. b. H. Leipzig. 7 : Tl. 2. 920 pp. : Tl., 2 845 pp. ; Tl. 3, 816 pp.
- Pascher A. 1915. Clorophyceae. In: Die Susswasser Flora Deutschlands, Osterreichs und der Schweiz. Verlags von Gustav Fisher, Jena, Heft 5, 250 pp.
- Peragallo H, Peragallo M., 1897-1908. Diatomees Marine de France et des Districts Maritimes Voisins. Micrographe Editeur Grez sur Loing (S. et M.), 419 pp.
- Rampi L., Bernhardt M., 1980. Chiave per la determinazione tassonomica delle Peridinee Pelagiche Mediterranee: C.N.E.N., Roma (RT/B10 (81)13): 1-98.
- Schiller J., 1931-37. Dinoflagellatae (Peridineae) Monografischer Behandlung. In : Rabenhorst Kriptogamen-Flora von Deutschland, Österreichs und der Schweiz. Verlag. m. b. H. Leipzig. 10 (3) -1, 1-617, (1931-1933), (10) 3-2, 1-590, (1933-1937).
- Sournia A., 1993. Atlas du phytoplancton marin. Editions du Centre National de la recerche Scientifique. (1), 1-219, (2) 1-297.
- Throndsen J., 1993. The planktonic marine flagellates in: Marine phytoplankton a guide to naked flagellates and coccolithophorids. Tanos editors, Academic Press: 7- 131.

- Tomas, C. R., 1997. Identifying Marine Phytoplankton. Academic Press, Arcourt Brace & Company.

- r. 215: We decided not to add coordinates of standard sampling stations to the database because the substantial validity of these stations is limited to the period prior to the advent of GPS on board. In fact, after 90s standard sampling stations started to lose their significance since station names were no more related to the name of the station but to coordinates themselves. Furthermore, the coordinates of standard sampling stations used as a reference in sampling until 90s are available as "stationsAll.csv" file via GitHub at the following link: https://github.com/CNR-ISMAR/econaos/tree/master/sampleData

- r. 227-228: In the updated version of the data paper, we added a graph to Figure 5 indicating the trend over the 50 years of abiotic (nutrients, alkalinity, and transparency) and biotic parameters (chlorophyll, phytoplankton, and zooplankton).

- r. 301-302: We deleted the link to the dataset at row 116, but the link to the database is mandatory for the journal both in the abstract and in the "data availability" section. This prescription is reported in the ESSD guidelines for authors.

- r. 316-317 e r335-337: We added some sentences to evidence the importance to collect metadata to document the methodological changes occurred across the years, in particular:

- r. 322: "..in the development of water quality indicators. However, these potential uses appear constrained by issues that are intrinsic to long-term series and that are related to the obvious variations, across the years, of sampling coverage and frequency and of analytical methodologies. In this respect, it is crucial to appropriately document the data, collecting and making available most ancillary information as possible on the changes occurred in time for each parameter measurement. This process was thoroughly carried for the 50 years NAS dataset so that the potential users might know which could be the proper application and the limitations of the dataset."
- r. 336 "..to identify and compare reliable trends. The consistency and the coherence of the dataset require careful efforts in supplying the proper metadata, which could document the methodological changes that occurred through the years, thus allowing the potential users to evaluate the restrictions as well as the most suitable uses of the dataset."

- r. 340-341: For the limitation to data access we modified and add a sentence in the "data availability" section (r. 310) :
"Thanks to an agreement between the eLTER Research Infrastructure and the EUDAT Collaborative Data Infrastructure (CDI), the dataset is automatically available also in the B2Share catalogue (http://hdl.handle.net/21.11125/4672def7-4aeb-47e0-a325-311d02860967)(https://b2share.fz-juelich.de/) and, through this, in the EOSC (European Open Science Cloud) and GEOSS (Global Earth Observation System of Systems) catalogues. Since we opted for CC-BY license our data are immediately fully available for download and reuse upon citation, without embargo rules or any further limitations."

For new data entry, we described in the conclusions paragraph a possible envisaged approach as follows (r-341):
"Currently, a dynamic update and integration of the published dataset is not yet supported by specific tools nor integrated in automatic procedures; anyway, it is foreseen to go on with the

promotion of a full open science approach to LTER also in the coming years and extend the dataset through the publication of updates and possibly through the integration of different long-term datasets."

Comments in the marked-up manuscript lost in conversion to .pdf format:

[1] We had to change the DOI reference since we published a new version of the database: in the first version, a column resulted to be duplicated, in the new version we deleted that column.
[2] Table added
[3] Table deleted
[4] We had to change the DOI reference since we published a new version of the database: in the first version, a column resulted to be duplicated, in the new version we deleted that column.

A long term (1965-2015) ecological marine database from the LTER-Italy site Northern Adriatic Sea: plankton and oceanographic observations

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Abstract

In this paper we describe a 50 years (1965-2015) ecological database containing data collected in the Northern Adriatic Sea (NAS), one of the 25 research parent sites belonging to the Italian Long Term Ecological Research Network (LTER-Italy, http://www.lteritalia.it). LTER-Italy is a formal member of the international (https://www.ilter.network) and European (http://www.lter-europe.net/) LTER networks. The NAS is undergoing a process, led by different research institutions and projects, for the establishment of a marine ecological observatory, building on the existing facilities, infrastructures, and long-term ecological data. Along this process, the implementation of the Open Access and Open Science principles has started, by creating an open research lifecycle that involves sharing ideas and results (scientific papers), data (raw and processed), metadata, methods, and software. The present data paper is framed within this wider context. The database is composed of observations on abiotic parameters, phyto- and zooplankton abundances, collected during 299 cruises in different sampling stations, in particular in the Gulf of Venice: we describe here the sampling and analytical activities, the parameters, and the structure of the database. The database is available at http://doi.org/10.5281/zenodo.3465097~~10.5281/zenodo.3266246~~[1] (Acri et al., 2019), it was also uploaded in the DEIMS-SDR repository (Dynamic Ecological Information Management System - Site and Dataset Registry, https://deims.org/), which is the official sites and data registry for LTER International network.

1. Introduction

We describe in this paper a 50 years (1965-2015) ecological database containing data on plankton communities and related abiotic parameters~~factors~~, collected in the Northern Adriatic Sea (NAS). Plankton communities, which are at the base of aquatic ecosystem functioning, have a broad and diversified range of seasonal patterns, multi-annual trends, and shifts across different marine ecosystems: making available long term series of plankton and oceanographic observations provides unique and precious tools for depicting reliable patterns of average annual cycles and for detecting significant changes and trends in response to global or local pressures and impacts.

Open Data is nowadays considered a crucial issue in both scientific research and public administration and management. Wilkinson et al. (2016) conceived the "FAIR" data management principles, which states that data must be "Findable, Accessible, Interoperable and Reusable". The open access to data is one crucial step of Open Science (http://www.budapestopenaccessinitiative.org/read, European Commission, 2016), which is a wider approach embracing transparency at all stages of the research process, from research ideas to papers, open access to data, codes, and software. Open Science is actually a democratic way of making freely available, for every researcher and stakeholder, research ideas, data, metadata, tools, and outcomes. From the researcher point of view, open practices have been reported to give advantage, first of all, to open new frontiers in science (Science|Business network's cloud consultation group, 2019) and provide solutions to urgent societal problems (Palen et al., 2015; Tai and Robinson, 2018); moreover, it allows gaining more citations, media attention, potential collaborators, and funding opportunities (Eisenbach, 2006; McKiernan et al., 2016, Tennant et al., 2019) and it is vital for leaving a heritage to future generations.

~~From the researcher point of view, open practices can give advantage, first of all, to open new frontiers in science and provide solutions to urgent societal problems; moreover, it allows gaining more citations, media attention, potential collaborators, and funding opportunities (McKiernan et al., 2016) and it is vital for leaving a heritage to future generations.~~

Ecology, being a multidisciplinary science, can surely benefit from the Open Science approach, which is, however, a matter of interest and discussion among ecologists only since the last decade (Reichman et al., 2011). Yet, the cultural shift from "data ownership to data stewardship" is not widely accomplished and data sharing standards, both from a technical and ethical point of view, have just started to be established (Hampton et al., 2015).

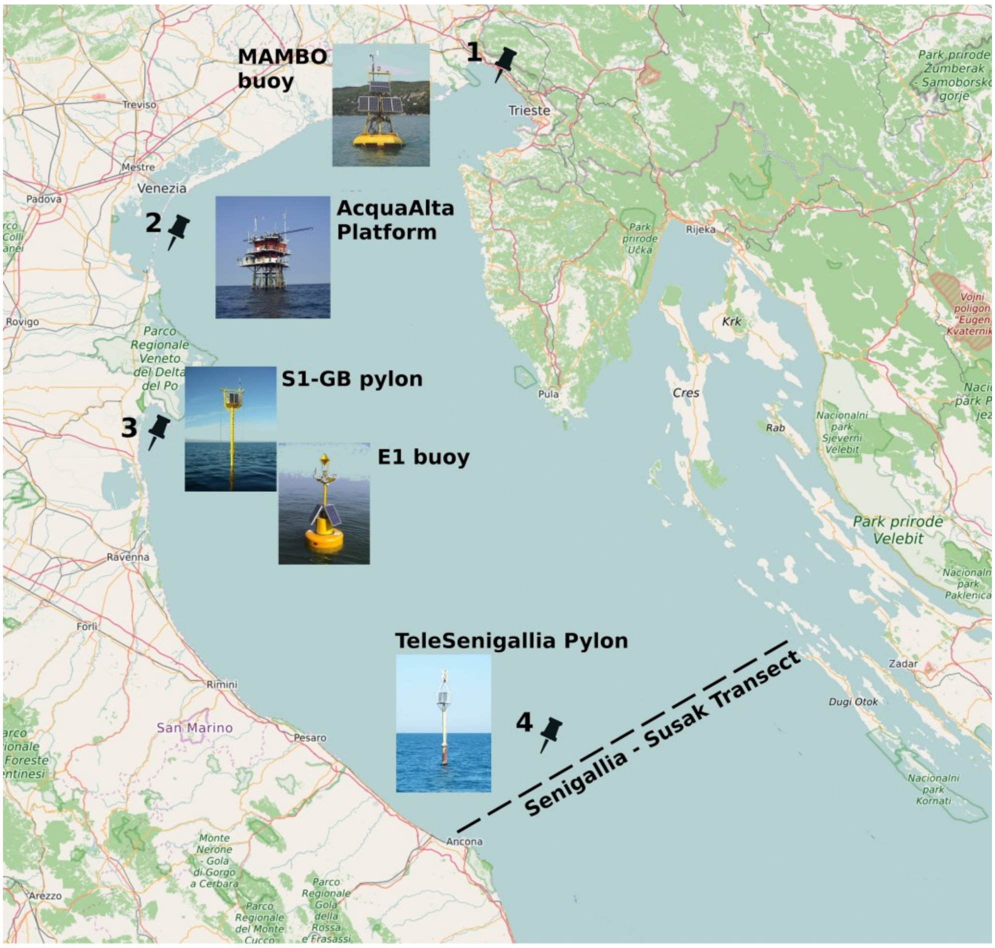
The Open Science approach is fostered in the data management plans of the Long Term Ecological Research (LTER) networks, at the national, European (LTER-Europe: http://www.lter-europe.net/) and global level (International LTER, ILTER: https://www.ilter.network), being considered a crucial step to advance socio-ecological research and education (Mirtl et al., 2018). ILTER provides a globally distributed network of long-term research sites for multiple purposes and uses in the fields of ecosystem, biodiversity, and socio-ecological research, it currently consists of 44 national networks, managing more than 700 sites worldwide (Haase et al., 2018; Mirtl et al., 2018). LTER-Italy (www.lteritalia.it), a formal component of ILTER and LTER Europe since 2006, consists of 79 research sites, organized in 25 parent sites, which include terrestrial, freshwater, transitional and marine ecosystems, managed and coordinated by public research, monitoring Institutions and Universities (Bergami et al., 2019).

The LTER marine component, which represents around 10% of global ILTER sites, focuses mainly on ecosystem structure and function, in response to a wide range of environmental forcing factors, using long-term, site-based research. As a result of the wide range and of the exceptional rate and intensity of human impacts, the scientific value of long-term ecological observations is more crucial than ever for effective assessment, management, and prediction of the state and pressure in the marine environment. The creation and maintenance of marine ecological observatories, able to arrange and maintain integrated, harmonized and coherent long-term ecological observations, is actually stressed as a relevant step at the European level, for sustaining European marine policies (Benedetti-Cecchi et al., 2018; European marine Board 2019).

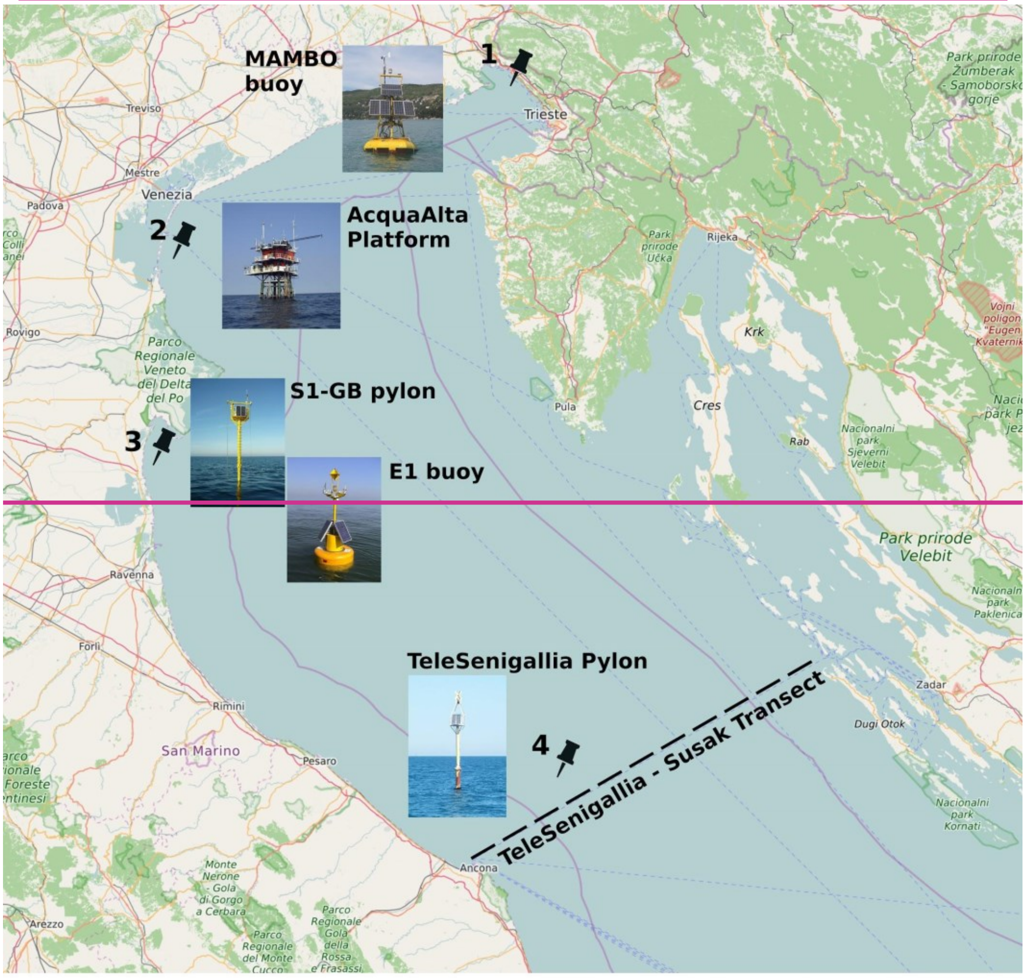
The marine component of LTER-Italy is made up of eight parent sites, mainly representing transitional and coastal ecosystems. Among them, the NAS is a significant geographical zone for the establishment of a marine ecological observatory, due to the concomitant presence of sensitive habitats, numerous ongoing monitoring, and research activities, as well as of heavy and diversified human pressures and economic interests. For these main reasons, during the years 2017-18, the Italian national flagship project RITMARE ("Italian research for the sea", http://www.ritmare.it/), funded by the Italian Ministry of University and Research, dedicated a Research Line to the establishment of a marine ecological observatory in the NAS. Building on the existing facilities, infrastructures and long-term ecological data, it aims at enhancing the marine observational capacities and at activating synergies among the main conservation management questions and key ecological and oceanographic variables. Along this process, it appeared crucial to start applying ~~of~~ the Open Science principles, by creating an open research lifecycle, which foresees sharing each step of the process, from ideas and results (scientific papers) to data (raw and processed), from metadata to methods and software. The ideas and plans for the development of the Open Science principles to the NAS ecological observatory, which we named project "EcoNAOS" (Ecological Northern Adriatic Open Science Observatory System), are thoroughly described by Minelli et al. (2018).

This data paper represents one relevant step of this wider activity. The database that we present is composed of observations on abiotic (physical and chemical) parameters and phyto- and zooplankton abundances, collected in 50 years (from 1965 to 2015), during cruises which interested different sampling stations across the NAS, in particular in the Gulf of Venice. Here we describe the sampling and analytical activities, the parameters, and the structure of the database.

2. **The LTER-Italy parent site Northern Adriatic Sea**



Created on Inkatlas. © OpenStreetMap contributors (openstreetmap.org). Map data Oct 27, 2017. 1:2000000



Created on Inkatlas. © OpenStreetMap contributors (openstreetmap.org). Map data Oct 27, 2017. 1:2000000

Figure 1 - The LTER-Italy parent site Northern Adriatic Sea, with its four research sites. 1: Gulf of Trieste; 2: Gulf of Venice; 3: Po Delta and Romagna Coast; 4: Senigallia-Susak Transect. The fixed point observatories at each research site are evidenced (see Ravaioli et al., 2016 for a full description). Base map credits: © OpenStreetMap contributors 2019. Distributed under a Creative Commons BY-SA License.

The NAS (Figure 1) is the northernmost basin of the Mediterranean Sea and one of its most productive areas. It is characterized by a shallow depth and by a dominant cyclonic circulation. The oceanographic and meteorological parameters show a marked seasonal and interannual variability. The major forcings of the system are represented by the remarkable river inputs along the Italian coast, the Eastern Adriatic Current-EAC, which brings high salinity and oligotrophic waters from the southern basin, and the notable sea-level range, relatively to the rest of Mediterranean area. The urban and industrial inputs and the hydrodynamic exchange between the NAS and the lagoons located along the Italian coast are also elements of ecological relevance. A trophic gradient, decreasing from northwest to southeast, is typically observed in the basin, in which the nutrient-rich waters coming from the rivers are mainly spread southward and eastward from the Italian coast (Bernardi Aubry et al., 2006; Solidoro et al., 2009). The NAS is subject to multiple anthropogenic impacts (e.g., nutrient inputs, coastal urbanization, fishing activity, tourism, and maritime trade). The basin has undergone overfishing (Fortibuoni et al., 2010), marked eutrophication (during the 70s; Giani et al., 2012), followed by a phase of oligotrophication (years 2000s; Mozetič et al., 2010) and by a recent increase of nutrient concentrations (since 2007; Totti et al., 2019). The NAS has also been subjected to frequent development of mucilage aggregates (Giani et al., 2005; De Lazzari et al., 2008), until the first decade of the 2000s. The basin has undergone overfishing (Fortibuoni et al., 2010), marked eutrophication (Lotze et al., 2011) followed by a phase of oligotrophication (Mozetic et al., 2010) and then by a recent increase in nutrient concentrations (Totti et al., 2019). The NAS has also been subjected to frequent development of mucilage aggregates (Giani et al., 2005; De Lazzari et al., 2008), until the first decade of the 2000s.

The LTER-Italy parent site NAS includes four research sites (Gulf of Trieste, Gulf of Venice, Po Delta and Romagna Coast, Senigallia-Susak Transect; Figure 1), where meteo-oceanographic and biological data, mainly on plankton (Table 2), are gathered both during oceanographic cruises and at fixed point observatories (Ravaioli et al., 2016). Detailed information can be found in the ILTER Dynamic Ecological Information Management System Site and Dataset Registry, DEIMS-SDR (https://deims.org/92fd6fad-99cd-4972-93bd-c491f0be1301) (Wohner et al., 2019). The database we describe here refers to an area of about 40000 km^2, ranging between 43.7° and 45.8° North and 12.2° and 14.3° East (coordinate reference system: WGS84).

3. Description of the database

The database described in this data paper (reachable at http://doi.org/10.5281/zenodo.3266246) is composed of 108687 records. Each record is intended as a timestamped and georeferenced set of information, individuated by a row in the database. These observations belong to 22 datasets coming from 299 oceanographic cruises, carried out from 1965 to 2015.

Due to the long time coverage, the collection and analysis system for many parameters changed in time, thus making the database very heterogeneous for what concerns data management and organization. The heterogeneity is mainly due to:

- Sampling frequency: e.g., data coming from CTD (Conductivity, Temperature, Depth) sensors, such as temperature, oxygen, and pH, are registered in real-time at each meter in depth; other parameters, like nutrients and phytoplankton, are sampled at a lower time-frequency and at variable depths. The overall depth coverage ranged between 0-63 m, the sampling frequency from monthly to seasonal;Sampling frequency: e.g., data coming from CTD, such as temperature, oxygen, and pH, are registered in real-time at each meter in depth; other parameters, like nutrients and phytoplankton, are sampled at a much lowest time-frequency and at variable depths;
- Data treatment: some data are basically raw, e.g., data registered by CTD are reported into the database as they are delivered from the instrument; other data need some elaboration to obtain specific parameters' value (e.g., nutrients, chlorophyll-*a*, plankton abundance);
- Methodologies and units of measurements: e.g., changes of methodologies due to the introduction of CTD measurements; change of the units of measure of salinity, which passed from g l^{-1} to a dimensionless parameter.
- Data format: data collected between 1965 and 1990 were registered only on paper archives, while those from 1990 onwards on spreadsheets.

In particular, methodological protocols and associated documentation changed through time. Several sensors are described and extensively documented through the GET-IT platform (Geoinformation Enabling ToolkIT starterkit®, see Section 5), where it is possible to visualize all the observations related to a specific instrument or method. Other protocols have undergone a deep metadatation process by analyzing ancillary historical metadata (Scovacricchi, 2017). In this case, it is not immediately possible to obtain data related to a specific protocol, but it is still possible to filter data by method by importing the .csv file in a spreadsheet.

3.1 Data sources and geographical coverage

Data sources for this database come mainly from oceanographic cruises thatwhich were carried out on 12 different research vessels, at the basin scale (Table 1). The other observations come from sampling stations located next to the fixed automatic sensors: in this case the cruises are named as the nearby sensor, i.e.: 576 observations at the Paloma buoy (Gulf of Trieste), 1284 at the Acqua Alta oceanographic tower (Gulf of Venice), 138 at the S1 buoy (Po Delta). The data were gathered in the frame of many different projects thatwhich are all mentioned in the database:

Operation period	Research Vessel (R/V)	Nr. of observations
1965-1966	Vercelli	861
1966	Sea Quinn	60
1966-1990	Bannock	997
1968-2002	D'Ancona	45357
1977	Marsili	23
1979-1980	Mysis	48
1979-1990	Vila Vilebita	139
1986-1988	Minerva	737
2003	Boreana	2158
2003-2015	Dallaporta	43689
2007-2015	Litus	1900
2012-2014	Urania	12718

Table 1 – Operation periods of the different research vessels between 1965 and 2015 and number of observations.

~~Table 1 – Oceanographic cruises carried out from 1965 to 2015~~

Until the early 1990s, GPS systems were not usually on board of research vessels. For this reason, oceanographers used to refer to a fixed grid covering the entire research area and identified the sampling positions (stations) with the nodes of this grid. An example of grids used for this purpose is reported in Figure 2 (Franco, 1972).

In Figure 3a, the geographical coverage of the entire database is shown. Red dots represent the real observation points, while the nodes of the grid are evidenced with black crosses. Observations referring to a specific station were assigned to the coordinates of the corresponding node on the grid even if the real position was not precisely located on the grid node. This resulted in a cloud of points in the nearby of each sampling station. Since our main aim was to preserve most of the information for each observation, we decided not to "correct" the position of these points (see an example in Figure 3b for the station 09/0E).

In the following years, when the GPS allowed a better precision of the sampling position, researchers often continued referring to the nodes of the grid for the station names and they adopted a nomenclature coherent with the one of the original grid also for new sampling stations. For example, the new sampling point located eastward of the "09/2E" station is named "10/2E", since it is located at the same longitude (2E), but different latitude of "09/2E" station (Figure 3b). In Figure 3c, a 3D view of the entire database is shown.

Due to transcription errors occurred during the oldest cruises, some data were misplaced, falling on land or outside the NAS. A Python script (available under GNU GPL v.3 license here: https://github.com/CNR-ISMAR/econaos/tree/master) has been written in order to correct this kind of errors. The same script implemented also a routine to homogenize different names of the same sampling station (e.g. station “020D” could appear as well as station “02-0D” or “02/0D” or “020D_07/07/1968). We selected the name reported on the original stations’ network grid (Figure 2) and we created from these stations a vector layer (black crosses in Figure 3). Finally, since some stations changed their name through time, in order to maintain coherence with the same sampling point, we appointed them with the last, most recently used name.

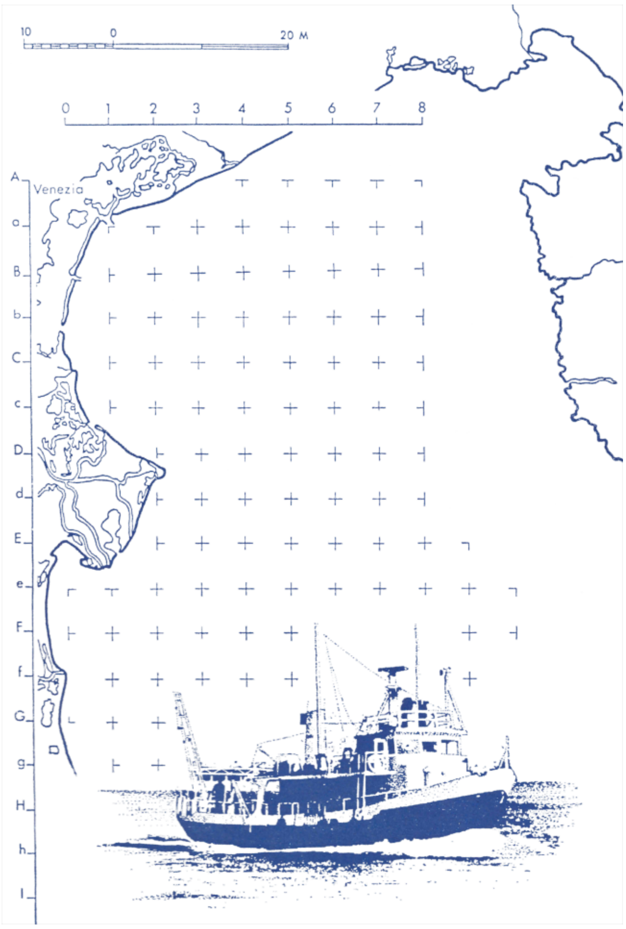
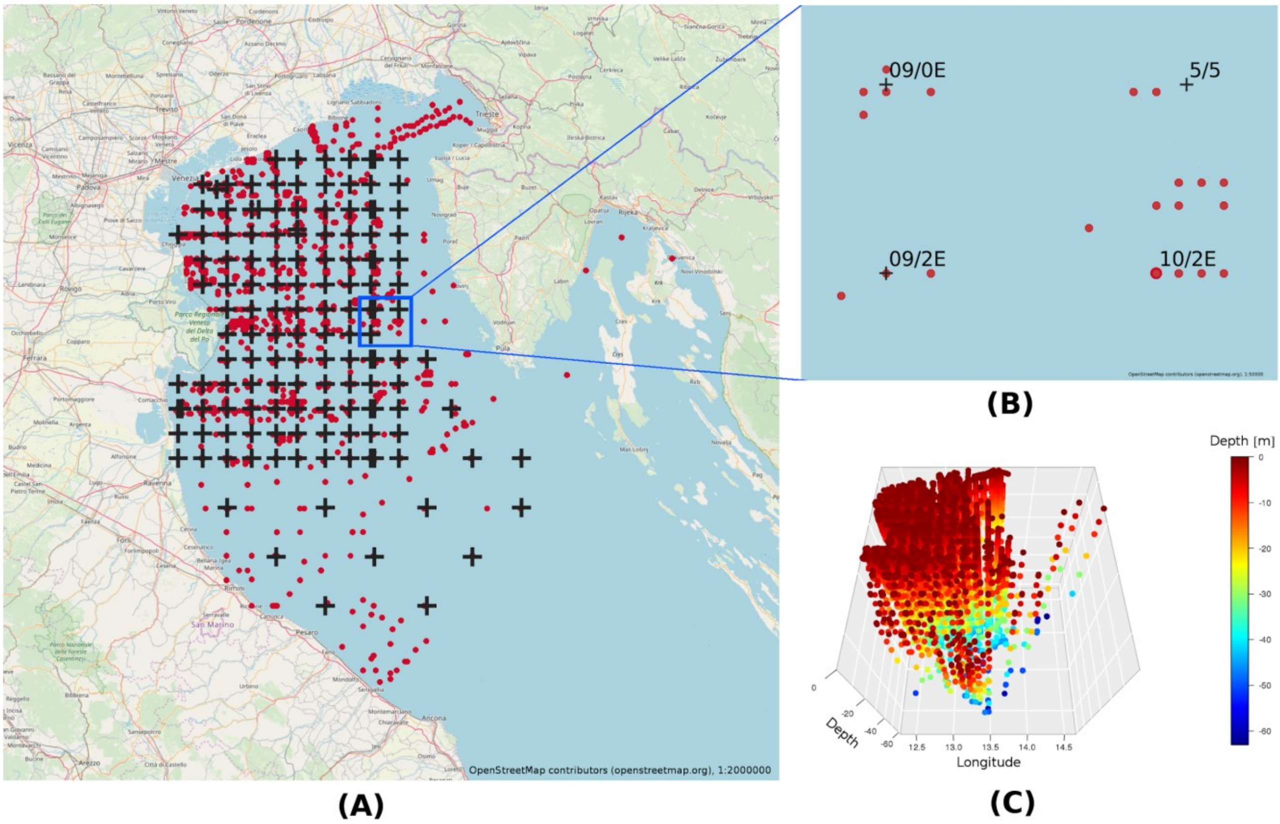


Figure 2 - An example of sampling stations based on the regular grid created in the NAS for the cruises from 1966 to 1980 (from Franco, 1972).



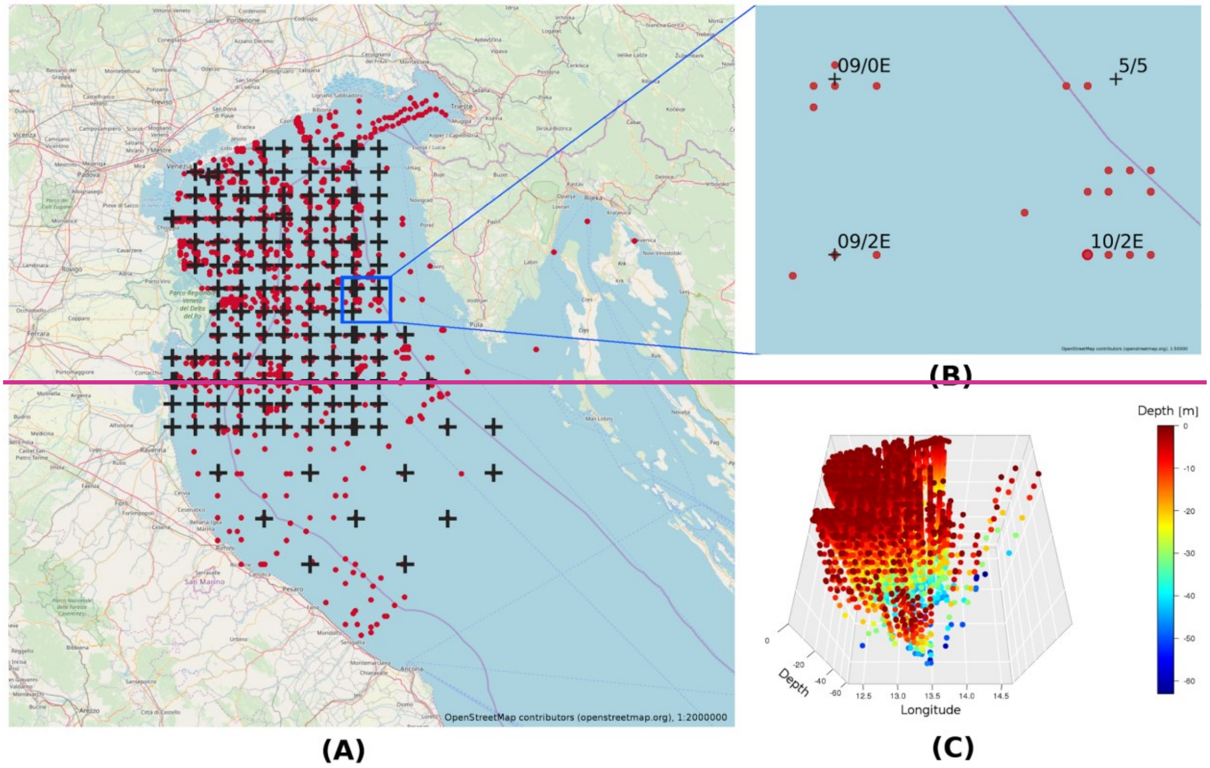


Figure 3 - (A) Geographical distribution of the observations: red dots for observations; black crosses for nodes of the grid. (B) Example of cloud distribution of observations around sampling station 09/2E and the naming of new sampling station 10/2E. (C) 3D view of the database. Base map credits: © OpenStreetMap contributors 2019. Distributed under a Creative Commons BY-SA License.

3.2 Parameters: history, time coverage, and sensors

Samples collected during each cruise, whatever the station of collection, were then analyzed in the laboratory by means of diverse techniques. Since 2000 analytical quality of nutrients and chlorophyll analyses is assessed through participation to the

Quality Assurance of Information for Marine Environmental Monitoring In Europe (QUASIMEME; http://www.quasimeme.org) international laboratory proficiency-testing. The complete list of the parameters of the database is reported in Table 2, together with some descriptive elements, i.e.:

- Total number of observations,
- Temporal coverage (from the first to the last record),
- Method or sensor currently used,
- Current unit of measure.

Parameter	**Number of observations**	**Temporal coverage**	**Current sensor**	**Unit of measure**	**Acronym in the database**
[2]Transparency	2322	1965-2015	Secchi Disk	m	Secchi
Temperature	107648	1965-2015	CTD	C	Temp
Salinity	107655	1965-2015	CTD	dimensionless	Sal
Density anomaly	99961	1965-2015	Derived from temperature and salinity	kg m^{-3}	Dens
pH	70376	1965-2011	pH glass membrane and pH electrode	pH unit	pH
Alkalinity	492	1965-2002	Titrino titration	meq l^{-1}	Alky
Oxygen	12791	1965-2012	Oxygen Polarographic sensor	cc l^{-1}	Oxyg (ml/l)
N-NH3	11154	1965-2015	Automated nutrient analysis	µm dm^{-3}	NH3 (microMol)
N-NO2	11232	1965-2015	Automated nutrient analysis	µm dm^{-3}	NO2 (microMol)
N-NO3	11299	1965-2015	Automated nutrient analysis	µm dm^{-3}	NO3 (microMol)
P-PO4	11191	1965-2015	Automated nutrient analysis	µm dm^{-3}	PO4 (microMol)
Si-SiO4	11420	1965-2015	Automated nutrient analysis	µm dm^{-3}	Si (microMol)
Chlorophyll-*a*	11541	1965-2015	Spectrofluorimeter	µg l^{-1}	Chla (ug/l)
Pheopygments	6352	1979-2015	Spectrofluorimeter	µg l^{-1}	Pheo (ug/l)
Total Phytoplankton	3463	1977-2015	Inverted microscope	Cells l^{-1}	Phyto TOT (cell/ml)
Diatoms	3070	1977-2015	Inverted microscope	Cells l^{-1}	Diato (cell/ml)
Dinoflagellates	3070	1977-2015	Inverted microscope	Cells l^{-1}	Dino (cell/ml)
Coccolithophores	3070	1977-2015	Inverted microscope	Cells l^{-1}	Cocco (cell/ml)

Others	3070	1977-2015	Inverted microscope	Cells l^{-1}	Flag (cell/ml)
Total Zooplankton	372	1987-2015	Stereo microscope	Ind. m^{-3}	Zoo (ind/m^3)

~~Parameter~~	~~Number of observations~~	~~Temporal coverage~~	~~Current sensor~~	~~Unit of measure~~
[3]~~Transparency~~	~~2322~~	~~1965-2015~~	~~Secchi Disk~~	~~m~~
~~Temperature~~	~~107648~~	~~1965-2015~~	~~CTD~~	~~C~~
~~Salinity~~	~~107655~~	~~1965-2015~~	~~CTD~~	~~dimensionless~~
~~Density~~	~~99961~~	~~1965-2015~~	~~Derived from temperature and salinity~~	~~kg m^{-3}~~
~~pH~~	~~70376~~	~~1965-2011~~	~~CTD~~	~~-~~
~~Alkalinity~~	~~492~~	~~1965-2002~~	~~Titrino titration~~	~~meq l^{-1}~~
~~Oxygen~~	~~12791~~	~~1965-2012~~	~~CTD~~	~~cc l^{-1}~~
~~N-NH3~~	~~11154~~	~~1965-2015~~	~~Automated nutrient analysis~~	~~µM~~
~~N-NO2~~	~~11232~~	~~1965-2015~~	~~Automated nutrient analysis~~	~~µM~~
~~N-NO3~~	~~11299~~	~~1965-2015~~	~~Automated nutrient analysis~~	~~µM~~
~~P-PO4~~	~~11191~~	~~1965-2015~~	~~Automated nutrient analysis~~	~~µM~~
~~Si-SiO4~~	~~11420~~	~~1965-2015~~	~~Automated nutrient analysis~~	~~µM~~
~~Chlorophyll-*a*~~	~~11541~~	~~1965-2015~~	~~Spectrofluorimeter~~	~~µg l^{-1}~~
~~Pheopygments~~	~~6352~~	~~1979-2015~~	~~Spectrofluorimeter~~	~~µg l^{-1}~~
~~Total Phytoplankton~~	~~3463~~	~~1977-2015~~	~~Inverted microscope~~	~~Cells l^{-1}~~
~~Diatoms~~	~~3070~~	~~1977-2015~~	~~Inverted microscope~~	~~Cells l^{-1}~~
~~Dinoflagellates~~	~~3070~~	~~1977-2015~~	~~Inverted microscope~~	~~Cells l^{-1}~~
~~Coccolithophores~~	~~3070~~	~~1977-2015~~	~~Inverted microscope~~	~~Cells l^{-1}~~
~~Others~~	~~3070~~	~~1977-2015~~	~~Inverted microscope~~	~~Cells l^{-1}~~
~~Total Zooplankton~~	~~372~~	~~1987-2015~~	~~Stereo microscope~~	~~Ind. m^{-3}~~

Table 2 - Database parameters and main descriptive information.

Instruments and sensors changed over the 50 year period, due to technological and scientific progress. Furthermore, instruments are also subject to degradation and need to be replaced. It is essential to preserve the information about these instrument changes and upgrading, to track the reliability of the measurements.

In order to appropriately document data and guarantee the consistency of data within the database, we collected most ancillary information as possible on the changes occurred in time for each parameter measurement. To this purpose, a thorough review of historical sources (e.g. logbooks and manual transcription in spreadsheets) was carried out (Scovacricchi, 2017), working in cooperation with some researchers - now retired - who participated to the first cruises and referring as well to papers by Franco (1970, 1972 and 1982), which describe methods and instruments during a number of oceanographic cruises in the NAS from 1965 to 1979.

Plankton data are particularly sensitive to the skill of the operators, in particular during the microscope analyses of the samples. The change of the operators, which necessarily occurred during 50 years, actually could hamper the data comparison across time. To deal with this issue, internal education and recurring calibration of taxonomic competence were carefully considered, with training periods and intercalibrations phases.

~~To deal with this issue, the handing down of the expertise was carefully considered, with training periods and intercalibrations phases.~~

Since 2006 the taxonomic revision of the phytoplankton species has been made according to "Algaebase" (www.algaebase.org), the global algal database of taxonomic, nomenclatural and distributional information for the zooplankton the Marine Planktonic Copepods catalog (https://copepodes.obs-banyuls.fr/en/links.php, Razolus et al., 2005-2019) has been used. In the past, for phyto- and zooplankton analyses several texts and monographs were used (Berard-Therriault et al., 1999; Harris et al., 2000; Heimdal, 1993; Hendey, 1964; Hustedt, 1930-1966; Pascher, 1915; Peragallo and Peragallo, 1897-1908; Rampi and Bernhardt, 1980; Schiller, 1931-37; Throndsen, 1993; Tomas, 1997).

The phytoplankton was gathered and analyzed with the same method (Utermohl, 1958) across the years. In the database we report the total phytoplankton abundances and the following main groups: diatoms, dinoflagellates (naked and armoured cells), coccolithophorids and "others", which include the sum of cells belonging to cryptophyceans, crysophyceans, prymnesiophyceans (except coccolithophorids), prasinophyceans and chlorophyceans, whose sizes lie between 4 and 20 µm and often remain undetermined. Mesozooplankton was always identified under a stereo-microscope and expressed as the total number of organisms per cubic meter. Compared to phytoplankton, the mesozooplankton data are much fragmented over time: they cover a 28 year period, from 1987 to 2015, for a total of 372 observations.

4. Database structure and analysis

The present version of the database is recorded in a unique spreadsheet (Figure 4), carrying information, for each record, about:

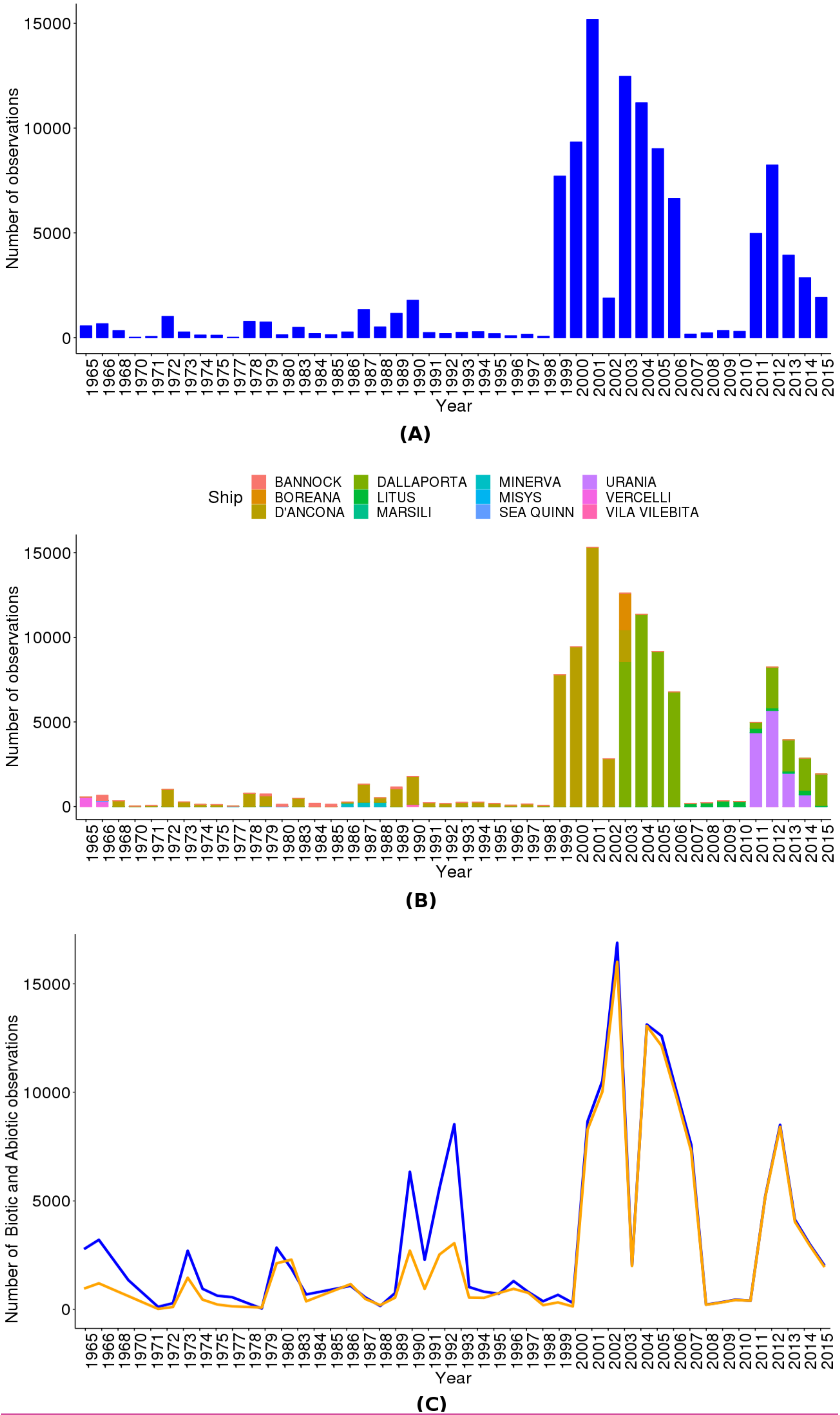
- Coordinates (longitude-latitude) of the sampling station;
- Sampling depth;
- Sampling~~Original~~ station name~~ and updated name~~;
- Cruise and R/V (Ship) name;
- Sampling date and time;
- Water column depth (Bot. Depth);
- Instrument/method used for each measurement and relative parameter value.

Long	Lat	Depth	Station	Cruise	Ship	YYYY-MM-DD	hh:mm:ss	Bot. Depth	Temp_sensor	Temp	Sal_sensor	Sal
12.68	45.33	0.5	B	PP/1	VERCELLI	1965-04-12	9:33:00	23	Tilting thermometer	13.12	Morh Knudsen titration	29.61
12.68	45.33	5	B	PP/1	VERCELLI	1965-04-12	9:33:00	23	Tilting thermometer	12.35	Morh Knudsen titration	35.66
12.68	45.33	10	B	PP/1	VERCELLI	1965-04-12	9:33:00	23	Tilting thermometer	12.45	Morh Knudsen titration	35.43
12.68	45.33	20	B	PP/1	VERCELLI	1965-04-12	9:33:00	23	Tilting thermometer	12.14	Morh Knudsen titration	38.01
12.86	45.28	0.5	C	PP/1	VERCELLI	1965-04-12	12:20:00	29	Tilting thermometer	12.25	Morh Knudsen titration	35.44
12.86	45.28	5	C	PP/1	VERCELLI	1965-04-12	12:20:00	29	Tilting thermometer	12.24	Morh Knudsen titration	35.46
12.86	45.28	10	C	PP/1	VERCELLI	1965-04-12	12:20:00	29	Tilting thermometer	11.16	Morh Knudsen titration	37.79
12.86	45.28	20	C	PP/1	VERCELLI	1965-04-12	12:20:00	29	Tilting thermometer	12.3	Morh Knudsen titration	37.92
12.48	45.40	0.5	A	PP/2	VERCELLI	1965-04-28	6:42:00	16.4	Tilting thermometer	12.27	Morh Knudsen titration	33.04
12.48	45.40	1	A	PP/2	VERCELLI	1965-04-28	6:42:00	16.4	Tilting thermometer	12.37	Morh Knudsen titration	33.39
12.48	45.40	5	A	PP/2	VERCELLI	1965-04-28	6:42:00	16.4	Tilting thermometer	12.44	Morh Knudsen titration	35.39
12.48	45.40	10	A	PP/2	VERCELLI	1965-04-28	6:42:00	16.4	Tilting thermometer	12.23	Morh Knudsen titration	37.3
12.68	45.33	0.5	B	PP/2	VERCELLI	1965-04-28	9:10:00	22.3	Tilting thermometer	12.49	Morh Knudsen titration	32.9
12.68	45.33	5	B	PP/2	VERCELLI	1965-04-28	9:10:00	22.3	Tilting thermometer	12.43	Morh Knudsen titration	33.78
12.68	45.33	10	B	PP/2	VERCELLI	1965-04-28	9:10:00	22.3	Tilting thermometer	11.92	Morh Knudsen titration	37.21
12.68	45.33	20	B	PP/2	VERCELLI	1965-04-28	9:10:00	22.3	Tilting thermometer	10.5	Morh Knudsen titration	37.72
12.86	45.28	0.5	C	PP/2	VERCELLI	1965-04-28	11:20:00	31	Tilting thermometer	12.4	Morh Knudsen titration	34.2
12.86	45.28	5	C	PP/2	VERCELLI	1965-04-28	11:20:00	31	Tilting thermometer	12.09	Morh Knudsen titration	36.15
12.86	45.28	8	C	PP/2	VERCELLI	1965-04-28	11:20:00	31	Tilting thermometer	11.5	Morh Knudsen titration	37.38
12.86	45.28	20	C	PP/2	VERCELLI	1965-04-28	11:20:00	31	Tilting thermometer	10.42	Morh Knudsen titration	37.9
12.48	45.40	0.5	A	PP/3	VERCELLI	1965-05-13	6:47:00	16	Tilting thermometer	15.92	Morh Knudsen titration	33.66
12.48	45.40	1	A	PP/3	VERCELLI	1965-05-13	6:47:00	16	Tilting thermometer	15.8	Morh Knudsen titration	33.77
12.48	45.40	5	A	PP/3	VERCELLI	1965-05-13	6:47:00	16	Tilting thermometer	14.92	Morh Knudsen titration	33.51
12.48	45.40	10	A	PP/3	VERCELLI	1965-05-13	6:47:00	16	Tilting thermometer	11.34	Morh Knudsen titration	37.61
12.68	45.33	0.5	B	PP/3	VERCELLI	1965-05-13	9:23:00	21	Tilting thermometer	17.4	Morh Knudsen titration	33.84
12.68	45.33	5	B	PP/3	VERCELLI	1965-05-13	9:23:00	21	Tilting thermometer	15.66	Morh Knudsen titration	36.2
12.68	45.33	10	B	PP/3	VERCELLI	1965-05-13	9:23:00	21	Tilting thermometer	13.64	Morh Knudsen titration	37.3
12.68	45.33	20	B	PP/3	VERCELLI	1965-05-13	9:23:00	21	Tilting thermometer	11.83	Morh Knudsen titration	37.72
12.86	45.28	0.5	C	PP/3	VERCELLI	1965-05-13	12:15:00	31	Tilting thermometer	18.03	Morh Knudsen titration	33.01

Long	Lat	Depth	Station	Cruise	Ship	YYYY-MM-DD	hh:mm:ss	Temp_sensor	Temp	Sal_sensor	Sal	Dens
12.68	45.33	0.5	B	PP/1	VERCELLI	1965-04-12	9:33:00	Tilting thermometer	13.12	Morh Knudsen titration	29.61	22.22
12.68	45.33	5	B	PP/1	VERCELLI	1965-04-12	9:33:00	Tilting thermometer	12.35	Morh Knudsen titration	35.66	27.04
12.68	45.33	10	B	PP/1	VERCELLI	1965-04-12	9:33:00	Tilting thermometer	12.45	Morh Knudsen titration	35.43	26.85
12.68	45.33	20	B	PP/1	VERCELLI	1965-04-12	9:33:00	Tilting thermometer	12.14	Morh Knudsen titration	38.01	28.92
12.86	45.28	0.5	C	PP/1	VERCELLI	1965-04-12	12:20:00	Tilting thermometer	12.25	Morh Knudsen titration	35.44	26.89
12.86	45.28	5	C	PP/1	VERCELLI	1965-04-12	12:20:00	Tilting thermometer	12.24	Morh Knudsen titration	35.46	26.93
12.86	45.28	10	C	PP/1	VERCELLI	1965-04-12	12:20:00	Tilting thermometer	11.16	Morh Knudsen titration	37.79	28.95
12.86	45.28	20	C	PP/1	VERCELLI	1965-04-12	12:20:00	Tilting thermometer	12.3	Morh Knudsen titration	37.92	28.81
12.48	45.4	0.5	A	PP/2	VERCELLI	1965-04-28	6:42:00	Tilting thermometer	12.27	Morh Knudsen titration	33.04	25.03
12.48	45.4	1	A	PP/2	VERCELLI	1965-04-28	6:42:00	Tilting thermometer	12.37	Morh Knudsen titration	33.39	25.3
12.48	45.4	5	A	PP/2	VERCELLI	1965-04-28	6:42:00	Tilting thermometer	12.44	Morh Knudsen titration	35.39	26.98
12.48	45.4	10	A	PP/2	VERCELLI	1965-04-28	6:42:00	Tilting thermometer	12.23	Morh Knudsen titration	37.3	28.35
12.68	45.33	0.5	B	PP/2	VERCELLI	1965-04-28	9:10:00	Tilting thermometer	12.49	Morh Knudsen titration	32.9	24.89
~~12.68~~	~~45.33~~	~~5~~	~~B~~	~~PP/2~~	~~VERCELLI~~	~~1965-04-28~~	~~9:10:00~~	~~Tilting thermometer~~	~~12.43~~	~~Morh Knudsen titration~~	~~33.78~~	~~25.6~~
12.68	45.33	10	B	PP/2	VERCELLI	1965-04-28	9:10:00	Tilting thermometer	11.92	Morh Knudsen titration	37.21	28.34
12.68	45.33	20	B	PP/2	VERCELLI	1965-04-28	9:10:00	Tilting thermometer	10.5	Morh Knudsen titration	37.72	29
12.86	45.28	0.5	C	PP/2	VERCELLI	1965-04-28	11:20:00	Tilting thermometer	12.4	Morh Knudsen titration	34.2	25.91
12.86	45.28	5	C	PP/2	VERCELLI	1965-04-28	11:20:00	Tilting thermometer	12.09	Morh Knudsen titration	36.15	27.48
12.86	45.28	8	C	PP/2	VERCELLI	1965-04-28	11:20:00	Tilting thermometer	11.5	Morh Knudsen titration	37.38	28.56
12.86	45.28	20	C	PP/2	VERCELLI	1965-04-28	11:20:00	Tilting thermometer	10.42	Morh Knudsen titration	37.9	29.16
12.48	45.4	0.5	A	PP/3	VERCELLI	1965-05-13	6:47:00	Tilting thermometer	15.92	Morh Knudsen titration	33.66	24.76
12.48	45.4	1	A	PP/3	VERCELLI	1965-05-13	6:47:00	Tilting thermometer	15.8	Morh Knudsen titration	33.77	24.87
12.48	45.4	5	A	PP/3	VERCELLI	1965-05-13	6:47:00	Tilting thermometer	14.92	Morh Knudsen titration	33.51	24.86
12.48	45.4	10	A	PP/3	VERCELLI	1965-05-13	6:47:00	Tilting thermometer	11.34	Morh Knudsen titration	37.61	28.75
12.68	45.33	0.5	B	PP/3	VERCELLI	1965-05-13	9:23:00	Tilting thermometer	17.4	Morh Knudsen titration	33.84	24.55
12.68	45.33	5	B	PP/3	VERCELLI	1965-05-13	9:23:00	Tilting thermometer	15.66	Morh Knudsen titration	36.2	26.77
12.68	45.33	10	B	PP/3	VERCELLI	1965-05-13	9:23:00	Tilting thermometer	13.64	Morh Knudsen titration	37.3	28.06
12.68	45.33	20	B	PP/3	VERCELLI	1965-05-13	9:23:00	Tilting thermometer	11.83	Morh Knudsen titration	37.72	28.75

Figure 4 - An example of the database showing the fields for each observation.

Around 89% of the observations of the database refers to the years 1999-2015 and the remaining 11% covers the previous 33 years (see Figure 5a for details). This is mainly due to the adoption of CTD probes since 1999 for measuring abiotic parameters at each meter depth, leading to an imbalance between the observations before (e.g. 778 in 1978) and after 1999 (e.g. 11359 in 2004)In Figure 5b observations from oceanographic cruises onboard of the different research vessels are shown (see also Table 1). The number of observations on abiotic parameters (nutrients, alkalinity, and transparency) is higher than the biotic (chlorophyll-*a*, phytoplankton, and zooplankton abundances) ones up to the year 2000; since then, they become comparable (Figure 5c).


Number of observations
15000
10000
5000
0
Year
(A)
Ship
BANNOCK
BOREANA
D'ANCONA
DALLAPORTA
LITUS
MARSILI
MINERVA
MISYS
SEA QUINN
URANIA
VERCELLI
VILA VILEBITA
Number of observations
Year
(B)
Number of Biotic and Abiotic observations
Year
(C)

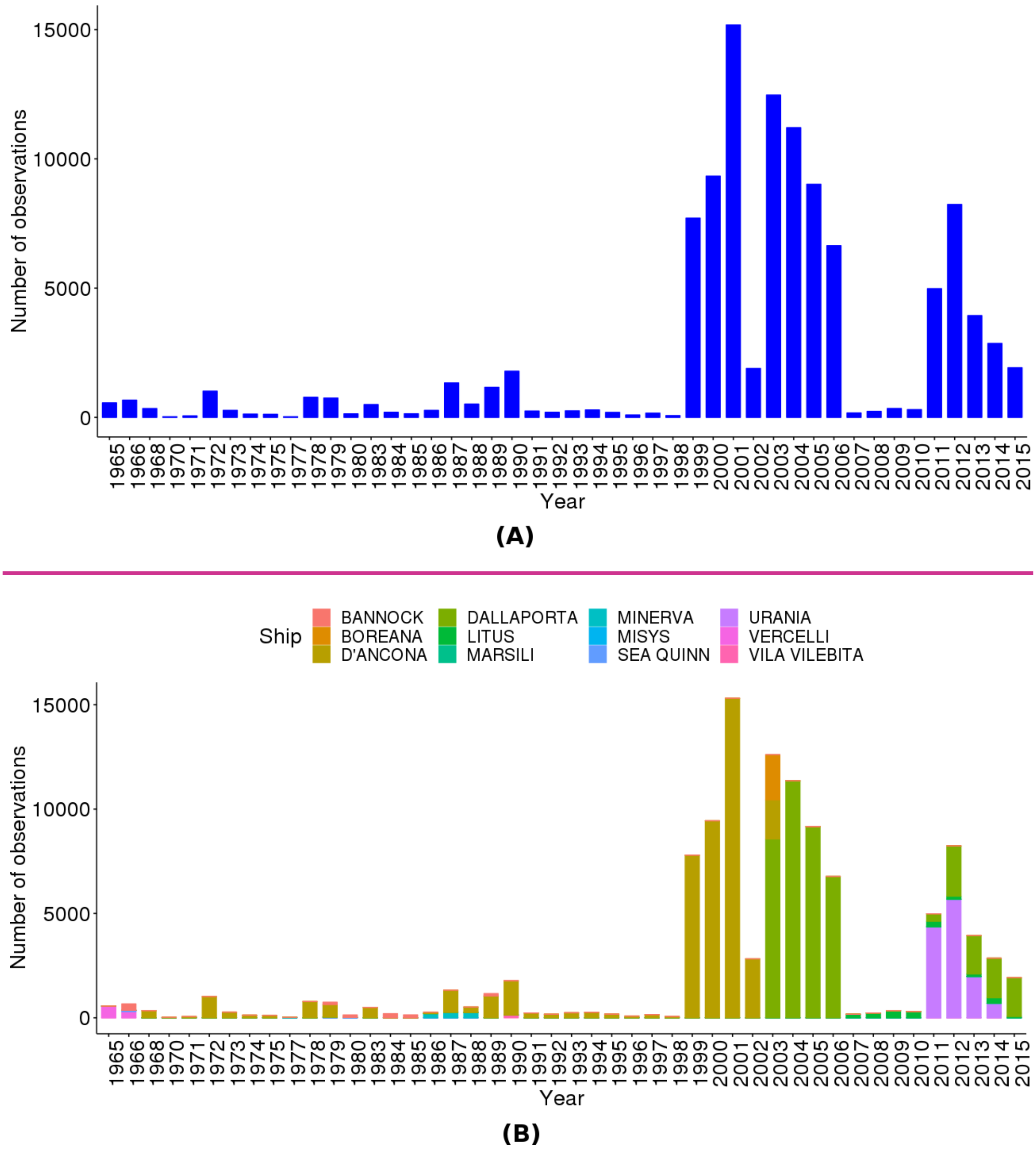
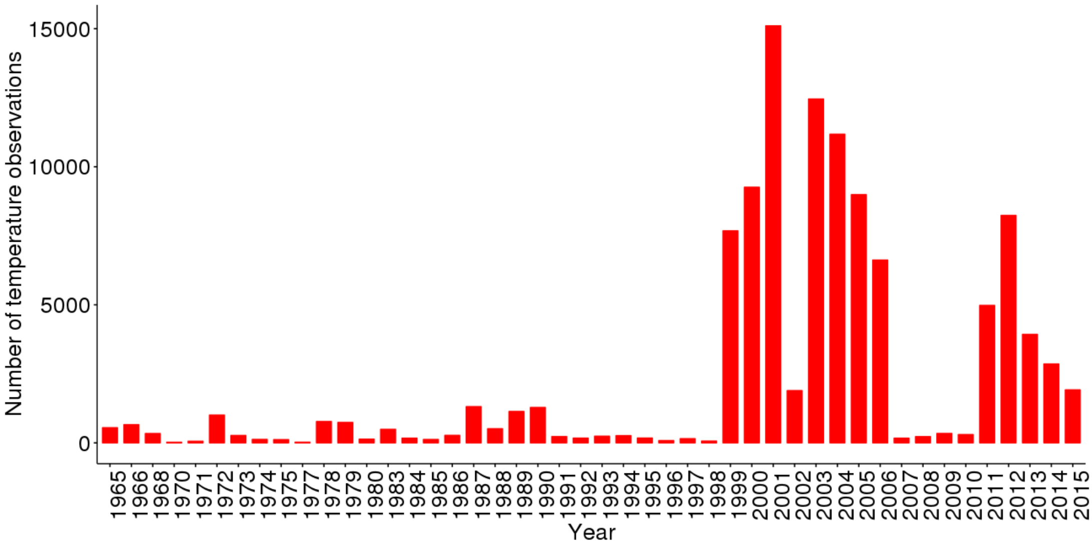
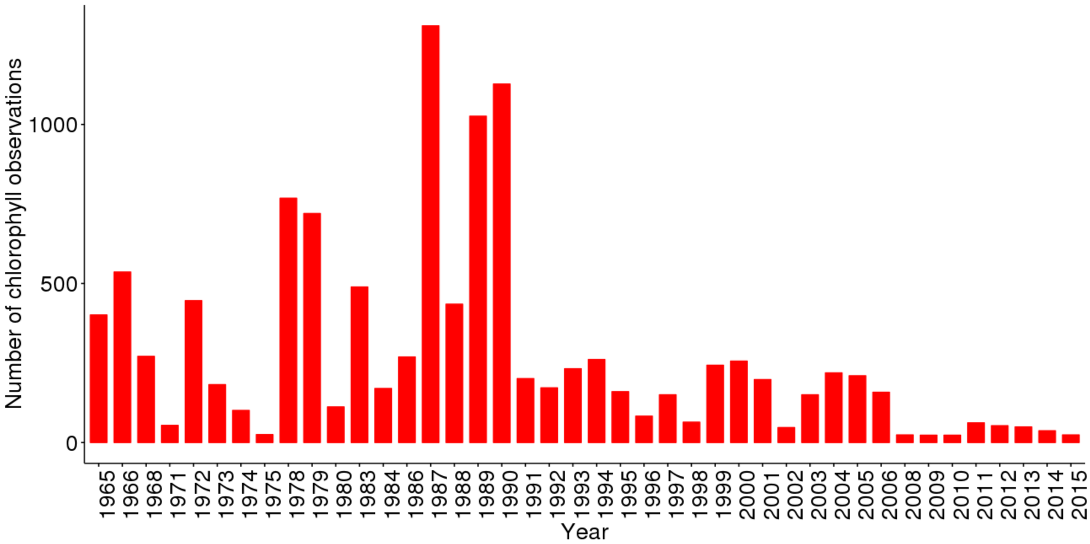


Figure 5 - Total number of observations over the whole period (A), clustered by research vessel (B), and by biotic (orange line) and abiotic (blue line) parameters (C).

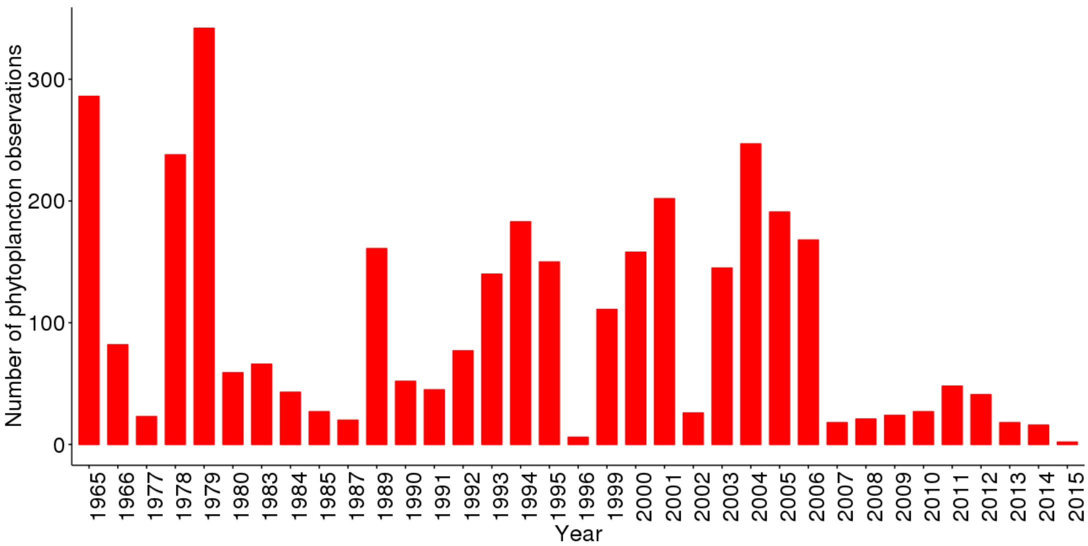
The database presents a heterogeneous number of observations for each parameter, mainly due to: (i) parameter priority for the specific research conducted, (ii) the instruments and analytical efforts required, and (iii) the specific funding programs and resources.



(A)



(B)



(C)

Figure 6 - Distribution over the years of the temperature (A), chlorophyll-*a* (B) and phytoplankton (C) observations

In Figure 6 we compare the total number of observations of one physical (temperature) and two biological (chlorophyll-*a* and phytoplankton abundance) parameters. All the three parameters were measured each year, although with different frequency. Temperature attains up to ~15000 records, while chlorophyll-*a* ~1200 records at most and phytoplankton ~300. The number of temperature data has a temporal distribution similar to the general one described in Figure 5a, where 89% of the observations occurred in the last 17 years, due to the adoption of CTD probes. Chlorophyll-*a* observations show instead peaks during the years 1987-1990, due to intense regional monitoring activities occurring in those years. The lowest number of phytoplankton observations is mainly due to the complex and time-consuming analytical procedure, which do not allow processing too many samples, and to the reduction of extensive monitoring activities since 2006.

5. Data visualization

The data management activities of the national flagship project RITMARE (Fugazza et al. 2014) allowed to develop two tools to enhance the deployment of a distributed Spatial Data Infrastructure (SDI) for Italian marine researchers community. SDI is an interoperable technological infrastructure for preservation, publication,and discovery of geospatial, modeled on standard (Open Geospatial Consortium - OGC, World Wide Web Consortium - W3C, and INSPIRE Directive 2007/2/EC) web services. In order to strengthen the RITMARE infrastructure, the Open Source software suite GET-IT (~~Geoinformation Enabling ToolkIT starterkit®;~~ Oggioni et al., 2017; Menegon et al., 2017) and the customizable, template-driven metadata editor EDI (Pavesi et al. 2016; Tagliolato et al. 2016; https://github.com/SP7-Ritmare/EDI-NG_client) have been developed and released as Open Source code. One of the nodes of the distributed SDI provides geospatial data collected by CNR-ISMAR marine researchers (http://vesk.ve.ismar.cnr.it).
Following the OGC Sensor Web Enablement (SWE) web service, each instrument or procedure has to be filled out as a "sensor", then observations can be provided, for a specific parameter, as OGC O&M (Observations and Measurements) web standards. Through the EDI interface, integrated within GET-IT software suite, a first core of sensors was already tested and uploaded in 2015 (Bastianini et al. 2015). A number of buoys (e.g. ABATE - Seabird SBE 19 Plus V2), laboratory instruments (e.g. Spettrophotometer Perkin Elmer), methods (e.g. Titration Winkler) and sensors, have been described for this study by using XML SensorML v2.0 language and their metadata, including manufacturer (provided as RDF, which stays for Resource Description Framework, Friends Of A Friends FOAF in Oggioni, 2019), owner and operator contacts, measured parameters, position, documentation, and history, can be easily visualized in separate dedicated landing pages (Figure 7). Currently, in the CNR-ISMAR GET-IT data node, 35 sensors have been described (http://vesk.ve.ismar.cnr.it/sensors/), for which it is possible to upload observations, collected from different stations in the NAS.

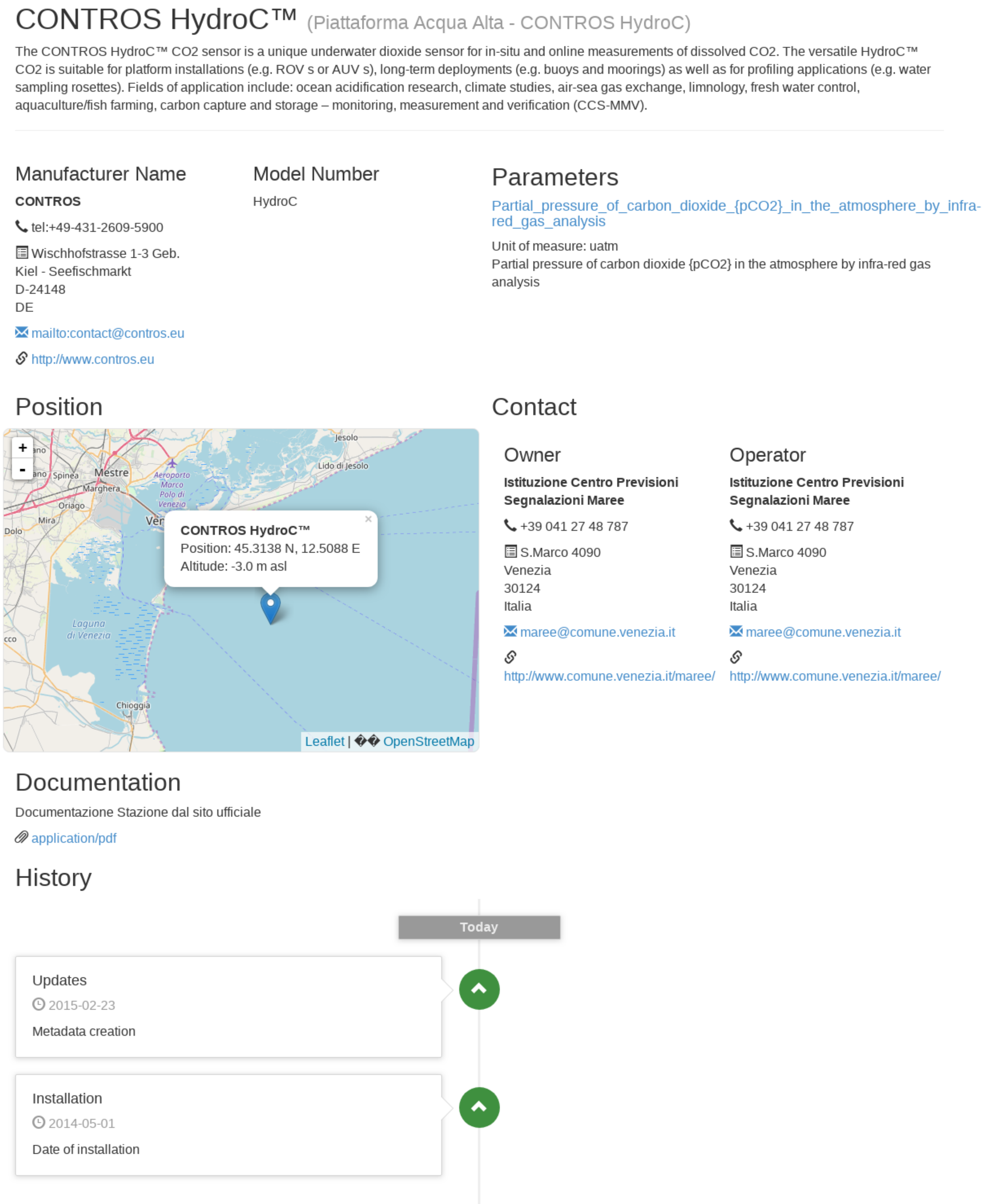


Figure 7 - Example of the sensor description provided by GET-IT. Information about manufacturer, owner and operator contacts, measured parameters, position, documentation, and history are displayed. Base map credits: © OpenStreetMap contributors 2019. Distributed under a Creative Commons BY-SA License.

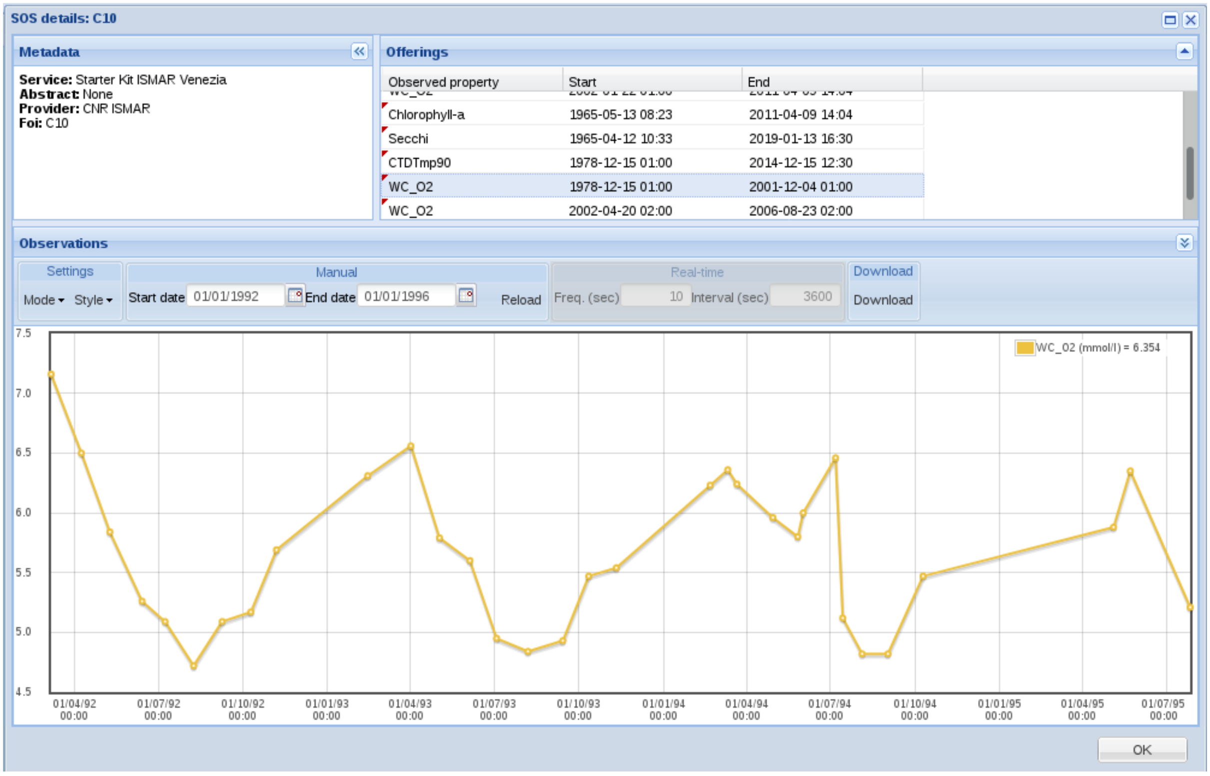
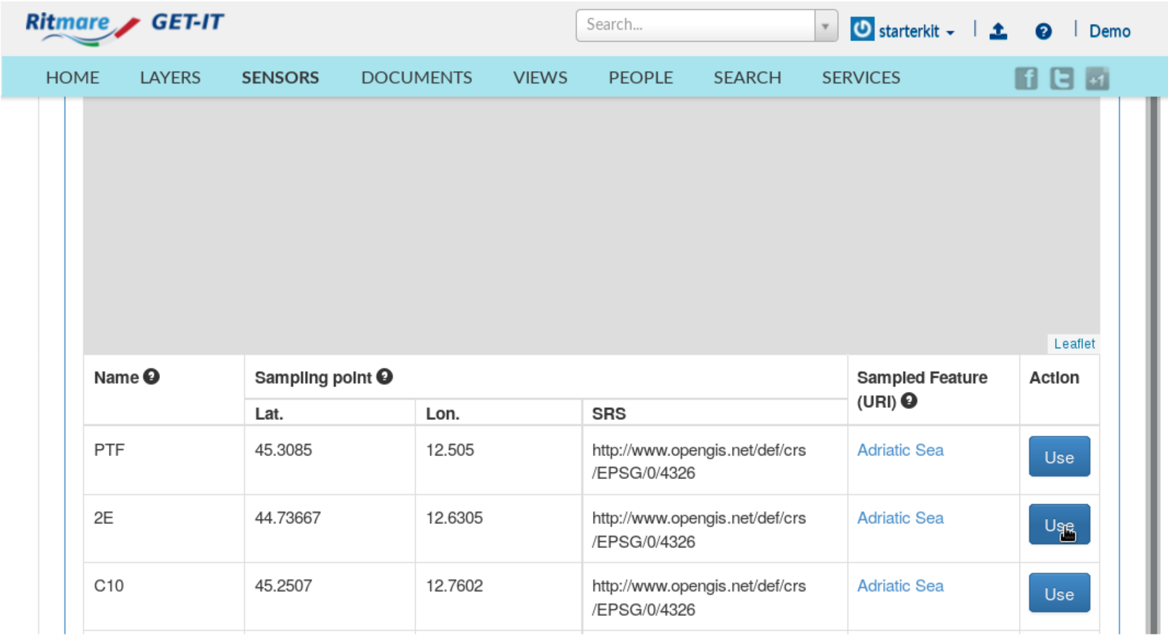


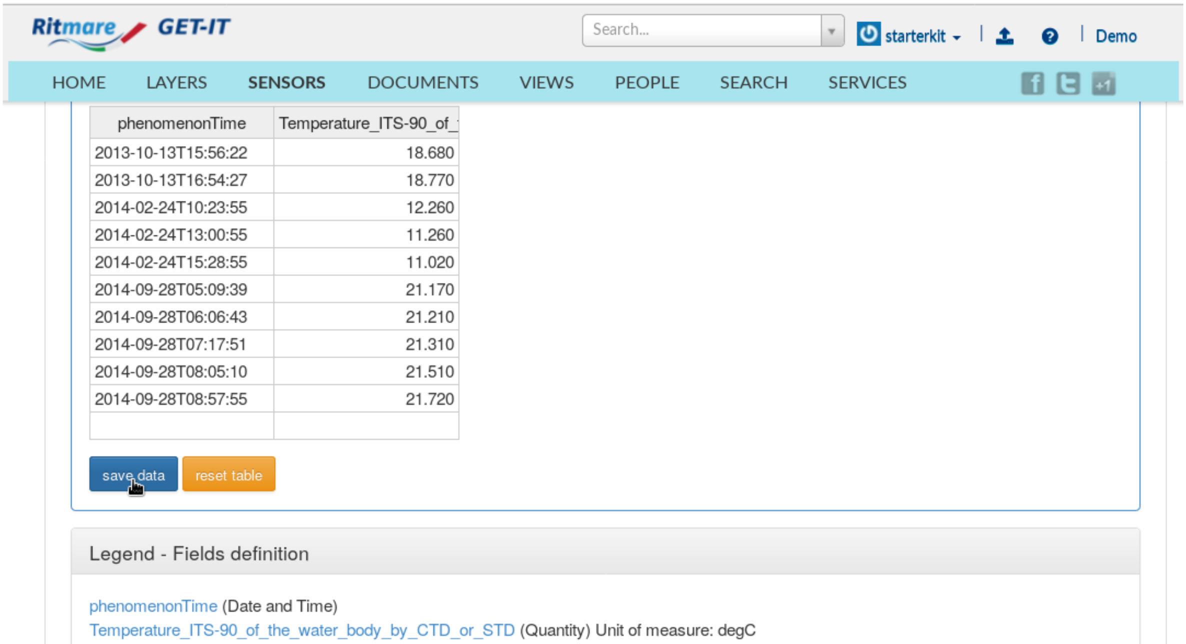
Figure 8 - Example of the graph in output from a query into the database. Oxygen data at station C10 for the period 01/01/1992-01/01/1996 are displayed.

Since v1.3.17 GET-IT still does not allow the three-dimensional representation of data, we decided to upload into the software suite only surface values of each parameter and sampling operation. This part of the database can be queried and graphed, directly into GET-IT using developed tool, in order to showtime series of selected parameters (Figure 8). A total of 16017 observations have been uploaded.

Observations can upload using the graphical interface or, for the skilled people, using an XML language directly into SOS (Sensor Observation Service) web service. For the upload from the interface, data have to be formatted in a table with datetime and parameter value (Figure 9). Since the speed of the process largely depends on the browser used to upload data, most of the data have been uploaded, through a Python script, by formatting specific .xml files, containing information about the sensor's ID, sampling station, and date time and following SWE standard. In both cases, the data upload begins with the selection of the sensor we want to upload data from and, then, with the selection of the sampling station from the map, if already available, or by creating a new one.



(A)



(B)

Figure 9 - Data upload from the graphic interface. Selection of the sampling station for the specific sensor (A) and format of data to be uploaded into the SDI (B).

6. Data availability

The dataset is available at http://doi.org/10.5281/zenodo.3465097[4]~~http://doi.org/10.5281/zenodo.3266246~~ (Acri et al., 2019). It was also uploaded in the DEIMS-SDR repository (Dynamic Ecological Information Management System - Site and Dataset Registry, https://deims.org/dataset/38d604ef-decb-4d67-8ac3-cc843d10d3ef~~https://deims.org/~~), which is the official sites and data registry for LTER International network. The aim of DEIMS-SDR is to be a catalogue of in-situ observation or experimentation facilities; it is implemented as a web-based information portal for integrated ecological information which~~that~~ comprises detailed descriptions of sites where research is carried out, including the technical infrastructure, ecosystem properties and research activities (see Wohner et al., 2019 for a full description). DEIMS-SDR provides a service which~~that~~

allows to associate a PID (Persistent IDentifier) to the uploaded dataset. Thanks to an agreement between the eLTER Research Infrastructure and the EUDAT Collaborative Data Infrastructure (CDI), the dataset is automatically available also in the B2Share catalogue (https://b2share.fz-juelich.de/records/e8d57102fd194bde957407ca290ad06a~~https://b2share.fz-juelich.de/~~) and, through this, in the EOSC (European Open Science Cloud) and GEOSS (Global Earth Observation System of Systems) catalogues. Since we opted for CC-BY license our data are immediately fully available for download and reuse upon citation, without embargo rules or any further limitations.

Table 3 collects the list of columns, short name and extended name of each parameter and ancillary field composing the database.

~~Data described here can be also accessed through the following link: http://hdl.handle.net/21.11125/4672def7-4aeb-47e0-a325-311d02860967. The list of columns composing the database corresponds to the list of parameters reported in Table 2.~~

Column number	**Parameter short name (database)**	**Parameter extended name**
1	Long	Longitude [decimal degrees]
1	Long	Longitude [decimal degrees]
2	Lat	Latitude [decimal degrees]
3	Depth	Depth [m]
4	Station	Name of sampled station
5	Station_updated_name	Updated name of sampling station, if present
6	Cruise	Cruise
7	Ship	Ship
8	YYYY-MM-DD	Date
9	hh:mm:ss	Time
10	Bot. Depth [m]	Water column depth [m]
11	Secchi [m]	Transparency [m]
12	Temp_sensor	Temperature sensor
13	Temp	Temperature [°C]

14	Sal_sensor	Salinity sensor
15	Sal	Salinity [dimensionless]
16	Dens	Density Anomaly [kg m^{-3}]
17	pH_sensor	pH sensor
18	pH	pH [pH Units]
19	Oxyg_sensor	Oxygen sensor
20	Oxyg (ml/l)	Dissolved Oxygen concentration [ml l^{-1}]
21	Ox%	Dissolved Oxygen saturation [%]
22	NH3_sensor	Ammonia sensor
23	NH3 (microMol)	Ammonia [µm dm^{-3}]
24	NO2_sensor	Nitrite sensor
25	NO2 (microMol)	Nitrite [µm dm^{-3}]
26	NO3_sensor	Nitrate sensor
27	NO3 (microMol)	Nitrate [µm dm^{-3}]
28	Din (microMol)	Total Dissolved inorganic Nitrogen [µm dm^{-3}]
29	PO4_sensor	Phosphate sensor
30	PO4 (microMol)	Phosphate [µm dm^{-3}]
31	Si_sensor	Silicate sensor
32	Si (microMol)	Silicate [µm dm^{-3}]
33	Chla_sensor	Chlorophyll-*a* sensor

34	Chla (ug/l)	Chlorophyll-*a* concentration [µg l^{-1}]
35	Pheo (ug/l)	Phaeopigments concentration [µg l^{-1}]
36	Alky	Alkalinity
37	Diato (cell/ml)	Diatoms abundance [cell ml^{-1}]
38	Dino (cell/ml)	Dinoflagellates abundance [cell ml^{-1}]
39	Flag (cell/ml)	Other Flagellates abundance [cell ml^{-1}]
40	Cocco (cell/ml)	coccolithophorids abundance [cell ml^{-1}]
41	Phyto TOT (cell/ml)	Total phytoplankton abundance [cell ml^{-1}]
42	Zoo (ind/m^3)	Total mesozooplankton organisms [ind m^{-3}]

Table 3 - Correspondence between column number, short name and extended name of each parameter reported into the database.

7. Conclusions

The 50-year database of plankton and abiotic parametersfactors in the NAS may contribute to an in-depth comprehension of plankton dynamics required not only to manage aquatic resources but also to predict and tackle future environmental changes. Long-term site-based studies on plankton may provide an invaluable opportunity to assess common or contrasting patterns of variability, to understand how those patterns change at different scales and to hypothesize about causes and consequences. Wide availability of the data on long-term variations of the planktonic system allows large scale studies that obviously go beyond the local use, representing a source of information for cross-system analysis, allowing comparison among ecosystems as well as new approaches in data analysis and in the development of water quality indicators.

However, these potential uses appear constrained by issues that are intrinsic to long-term series and that are related to the obvious variations, across the years, of sampling coverage and frequency and of analytical methodologies. In this respect, it is crucial to appropriately document the data, collecting and making available most ancillary information as possible on the changes occurred in time for each parameter measurement. This process was thoroughly carried for the 50 years NAS dataset so that the potential users might know which could be the proper application and the limitations of the dataset.

The open access to the 50-year dataset of abiotic data and plankton in the NAS was framed in a wider open science life-cycle approach undertaken in the EcoNAOS project (Minelli et al., 2018), with the purpose to develop a practical case study which could root the high and inspiring principles of Open Science into the scientific community, fostering as well a cultural shift. In EcoNAOS we involved, since its start, both LTER and data management researchers in a joint partnership. In particular, the elaboration of the 50-year datasets has been worked out by a small group of plankton ecologists and data management experts, with the aim of sharing and harmonizing as well the different experiences, needs and points of view. This participatory process is recognized to be crucial to contribute overcoming cultural differences, barriers and fragmentation that might represent an obstacle for Open Science (Björk, 2004; Janssen et al., 2012; Barry & Bannister, 2014). The constant interactions of oceanographers and ecologists with experts on data management and analysis, geospatial standards and web services interoperability, creating a rich and multi-domain research group, has been necessary to make available and understandable the very detailed knowledge behind environmental surveys, samplings, analyses, methodologies, through the sound and fit-for-purpose technical solutions for data management and interoperability.

Accessibility and interoperability concepts and practices are crucial elements for LTER networks because the more the time series are consistent, coherent and available, the more it is possible to reconstruct trends and dynamics and to identify and compare reliable trends. The consistency and the coherence of the dataset require careful efforts in supplying the proper metadata, which could document the methodological changes that occurred through the years, thus allowing the potential users to evaluate the restrictions as well as the most suitable uses of the dataset. The activity described in this data paper is fully in line with the data management plan of the LTER networks, at the national, European and global level, since one of the LTER mandates is actually to foster open sharing of LTER data (Mirtl 2010; Mirtl et al., 2018). The national LTER networks are fostered to adopt the aspects of open science that are currently feasible in the different research groups.
Currently, a dynamic update and integration of the published dataset is not yet supported by specific tools nor integrated in automatic procedures; anyway, it is foreseen to go on with the promotion of a full open science approach to LTER also in the coming years and extend the dataset through the publication of updates and possibly through the integration of different long-term datasets. ~~The future perspective of our activities are linked as well to the development ongoing in the wider context of LTER, in particular about the citation of a dynamic dataset and about the qualitative and quantitative integration of the different long-term datasets.~~

Author contribution

Minelli A. led the whole process of dataset recovery, metadatation and publication. Oggioni A., Pugnetti A. and Sarretta A. were the reference persons for the entire activity. Acri F., Bastianini M., Bernardi Aubry F., Camatti E., Bergami C., Minelli A., Oggioni A., Sarretta A., Pugnetti A. contributed to the writing of this paper: drafting of the text and of the figures and tables, revisions and suggestions.
Acri F., Bastianini M., Bernardi Aubry F., Camatti E., Boldrin A., Cassin D., De Lazzari A., Pansera M., Finotto S., Socal G. collected and analysed data over time, providing statistics and material (graphs and tables) for the paper.

Competing interests

Authors declare that there are no competing interests that might have influenced the performance or presentation of the work described in this manuscript.

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