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REVIEW

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Biologging intelligent Platform (BiP): an integrated and standardized platform for sharing, visualizing, and analyzing biologging data

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Abstract

Sharing biologging data can facilitate collaborative research and biological conservation by providing maps showing animals' distribution and movements. It is a critical social mission to preserve not only horizontal position data, but also behavioral data such as diving depth, flight altitude, speed, and acceleration, as well as physiological data such as body temperature, along with related metadata, ensuring their preservation for future generation. Moreover, although biologging was initially developed in the field of biology, it now contributes to diverse fields such as meteorology and oceanography, leading to expanded opportunities for secondary data utilization. In light of social and academic requirements, we developed "Biologging intelligent Platform (BiP)", which adheres to internationally recognized standards for sensor data and metadata storage. As a result, BiP not only stores sensor data along with metadata but also standardizes this information to facilitate secondary data analysis, facilitating broader applications of biologging data across various disciplines. By visiting the website (https://www.bip-earth.com) and completing the user registration, data owners can interactively upload sensor data, input metadata associated with individual animals, devices, and deployments, standardize data formats, and choose between open and private settings for sharing data. Anyone interested in utilizing the data can access metadata and visualized route maps, irrespective of the data's open or private status. Users can freely download open datasets that are available under the CC BY 4.0 license, which permits copying, redistribution, and modification while adhering to the metadata's credit requirements. To use private datasets, users can contact the data owner to request permission. A unique feature of BiP is the Online Analytical Processing (OLAP) tools that calculate environmental parameters, such as surface currents, ocean winds, and waves from data collected by animals. Algorithms published in some previous studies are integrated into the OLAP which can estimate the environmental and behavioral parameters. To enhance data accessibility, BiP allows users to search for datasets using the DOI of the paper in which the data was used. We believe that linking with other databases for data exchange and multi-repository storage could enhance the sustainability of the data itself.

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Introduction

Before the term *biologging* was coined, a method was developed to attach small recorders to marine animals in order to monitor their behavior and physiological conditions in the wild; data that are otherwise difficult to collect through direct observation. Initially, the method targeted seals and penguins in Antarctica, species that are less sensitive to researchers due to the absence of land or ice-based predators [14, 21]. This made them ideal candidates for biologging, in which a recorder is attached to the animal, and the device is later retrieved after the animal is recaptured. As technology advanced, devices became smaller, reducing the impact on the animals. Furthermore, the development of satellite technology enabled data to be transmitted remotely, eliminating the need for animal recapture. This progress allowed biologging to expand to include fish, marine reptiles, terrestrial animals and flying animals, with study areas extending beyond Antarctica to temperate and tropical regions (reviewed by [13, 29, 30]). The term *Bio-Logging* was officially proposed by the organizing committee at the first international symposium held in Tokyo in 2003 [20], where it was accepted by around 150 participants. Since then, the International Bio-Logging Symposium has been held approximately every three years in various locations around the world, and the term has become widely recognized within the scientific community. The 8th International Bio-Logging Symposium was again hosted in Tokyo in March 2024.

Subsequently, biologging has been recognized as an effective tool for monitoring the environment surrounding animals and has made significant contributions to related fields such as oceanography, meteorology, and environmental science. Currently, meteorological satellites and Argo floats are the primary tools used to observe the physical environment of the globe. Meteorological satellites can measure parameters such as sea surface temperature, ocean currents, and ocean winds over large areas, but their observation frequency is limited. Additionally, radio waves cannot penetrate saltwater, meaning that meteorological satellites can only monitor surface ocean and the atmospheric conditions. To address this limitation, Argo floats are widely used, which measure temperature and salinity below the ocean surface by automatically ascending and descending, transmitting the collected data via satellite [24]. However, Argo floats are not suitable for shallow waters, as they commute between depths of 2000 m and the surface. Furthermore, they ascend and descend once every 10 days, making it difficult to obtain data with a temporal resolution of less than a few days. In this context, biologging data obtained from animals are expected to complement existing observation systems, providing additional insight into the environment with higher temporal resolution and broader spatial coverage.

At the First International Biologging Symposium in 2003, Mike Fedak from the Sea Mammal Research Unit at the University of St Andrews proposed using Satellite Relay Data Loggers (SRDL) on diving animals to observe the physical ocean environment [10]. The SRDLs store essential data, such as dive profiles and depth-temperature profiles, and transmit the compressed data via satellite. The data transmission can continue for more than one year. By deploying SRDLs on white whales *Delphinapterus leucas* that live in the Arctic region, researchers could observe the regions with floating sea ice that are difficult to measure with ships or Argo floats [15]. The frontal structure associated with the Antarctic Circumpolar Current has been successfully observed through water temperature and salinity data collected from both Argo floats and southern elephant seals *Mirounga leonina* [4]. Since then, the amount of water temperature and salinity data collected by instruments on animals (phocid seals mainly) has become comparable to that collected by Argo floats, however, data from seals are abundant only in the Antarctic, Arctic, and the eastern Pacific Ocean (see Fig. 2 in [17]). In the other regions where pinnipeds are absent, sea turtles, sharks and other large-bodied fish were used to obtain oceanographic data in the temperate to tropical regions [1, 6, 8, 16, 19, 27]. The water temperature data from SRDLs on turtles was highly correlated with measurements from existing observation instruments such as Argo floats [19].

When using seals and sea turtles for oceanographic observations, the animals carry the instruments to target areas. Additionally, some studies have used instrumented seabirds to estimate physical environmental parameters, such as ocean currents, ocean winds, and waves, at the ocean–atmosphere boundary by analyzing their movements [11, 28, 32, 33]. More recently, the AniBOS (Animal Borne Ocean Sensors) project (https://anibos.com/) was launched to establish a global ocean observation system that leverages animal-borne sensors to gather various physical environmental data worldwide [17].

Biologging field surveys are being conducted worldwide, leading to a growing accumulation of data. Recently, the practice of sharing biologging data held by individual researchers and research institutions has become more common. For example, in addition to meta-analyses of seabird behavior [5] and distribution mapping for conservation purposes [2], several studies have utilized large-scale datasets contributed by dozens of co-authors (e.g., [3, 12, 23]). To facilitate such international collaborations and interdisciplinary analyses, multiple databases have been developed. Campbell et al. [7] introduced 12 web-based databases that manage biologging data collected from wild animals. Among them, Movebank, operated by the Max Planck Institute of Animal Behavior in Germany, is the largest database containing 7.5 billion location points and 7.4 billion other sensor data across 1478 taxa as of January 2025 (https://www.movebank.org/cms/movebank-content/about-movebank).

Biologging technology currently enables the measurement of a wide range of parameters, including depth, speed, atmospheric pressure, water temperature, salinity, acceleration, angular velocity, geomagnetism, light intensity, and horizontal position. Most of the data stored in existing databases is location data, such as latitude and longitude [7], but the use of various data formats limits collaborative research and the secondary use of biologging data in fields beyond biology, such as meteorology, oceanography, and environmental science. For example, inconsistencies such as different column names for the same sensor data (e.g., "Latitude" vs. "lat"), variations in date-time formats (e.g., ISO8601 vs. non-standard formats, separate columns for date and time, "DD/MM/YY" instead of "YYYY-MM-DD," or using two-digit instead of four-digit years), differences in file types (e.g., CSV vs. TXT), and differing numbers of header lines before the data begins further complicate data integration and reuse. These discrepancies often vary depending on the sensor type, manufacturer, device, or even the version of the software or application being used. To facilitate collaborative research using biologging data and to encourage its secondary use in various fields, a standardized database was needed that could store diverse data types. To establish interoperable biologging data formats across all fields in animal ecology, a standardization framework was proposed [25]. In response, a new database, “Biologging intelligent Platform (BiP)” (https://www.bip-earth.com) was developed to store standardized sensor data along with the associated metadata. The system was designed to deal with data from not only aquatic animals but also terrestrial animals. In this paper, we introduce unique features of BiP, explain how to use it, outline its future expansion plans, and discuss its ultimate goals.

Unique features of Biologging intelligent Platform (BiP)

BiP offers functions such as: (1) sensor data standardization along with detailed metadata, (2) support for a wide variety of parameters, and (3) Online Analytical Processing (OLAP) to estimate environmental parameters.

Sensor data standardization along with detailed metadata

The primary content of biologging data consists of large volumes of sensor data (e.g., date, latitude and longitude) obtained by recorders attached to animals. However, sensor data alone are not sufficient to understand their behavior, physiology, and ecology. When sensor data are linked to various individual traits (e.g., sex, body size), they become a meaningful data set. BiP can store related metadata including information about animal traits (Table 1), details about the attached instrument (Table 2), and deployment information (Table 3), such as who conducted the deployment, when and where it occurred, and how it was carried out. The metadata items and formats stored in BiP conform to international standard formats, including the Integrated Taxonomic Information System (ITIS), Climate and Forecast Metadata Conventions (CF), Attribute Conventions for Data Discovery (ACDD), and International Organization for Standardization (ISO) [25]. For users uploading and standardizing data, entering these metadata is time-consuming and laborious, but integrating these traits with sensor data enables researchers to explore various research questions. For example, researchers could examine the influence of body size, sex, and breeding history of each individual on migration range and distance. To reduce user workload and minimize errors caused by typos or spelling inconsistencies, BiP provides pull-down menus for many metadata fields. For example, when a user selects an organism category in the “Basic Info” section (Table 1), the scientific names of relevant animals are displayed, and upon selection, the common name is automatically filled in (Table S1). If data are collected from multiple animals in a single survey, organism information can be easily duplicated from an initial entry, with only specific details (e.g., individual ID and body size) modified as needed. Additionally, metadata for multiple individuals can be prepared in advance in a CSV file, which can then be uploaded to create individual organism records automatically. Metadata can be downloaded in JSON format for use in meta-analysis. Internally, Apache Parquet files (https://parquet.apache.org/) are utilized to centrally manage both metadata and sensor data, providing a structure well-suited for big data analysis of time-series columnar data. Apache Parquet

Table 1 Metadata input fields for tagged individual traits "Organism"

Input field		Description
Basic Info	Individual Name*	Individual name assigned by the provider
	Organism Category	Select taxonomic group (Bird, Fish, Turtle, Pinniped, Whale)
	Scientific Name*	Scientific name
	Common Name	Standard English name
Additional Info	Sex	Select sex (Male, Female, Unknown)
	Reproductive class	Select reproductive stage (Adult, SubAdult, Juvenile, Newborn, Unknown)
	Age	
	Origin	Select origin (Wild, Cultured, Unknown)
	Capture Location Name	Name of capture location
	Capture Location	Latitude and longitude of capture location
	Capture Datetime	Date and time of capture
	TimeZone	Select time zone for capture date and time
Size and Mass	Mass	Body mass (kg)
	DateTime	Date and time of body mass measurement
	TimeZone	Select time zone for body mass measurement
	Comment	Special notes on mass measurement methods
	Size	Body length (m)
	Size Category	Select measurement site
	Comment	Special notes on body length measurement methods
Others	Capture Method	Description of capture method
	Other tag ID	Identification number of other individual tags, such as bird leg rings
	Comment	Other special notes

*Required field

offers flexibility in data manipulation through Apache Arrow (https://arrow.apache.org/) and supports conversion to the Network Common Data Form (NetCDF) format via xarray (https://docs.xarray.dev/en/stable/index.html), a Python library designed for working with labeled multi-dimensional arrays. This enables a highly extensible and portable file storage solution. Through these various efforts, BiP has successfully stored biologging data in a manner guided by international standards [25], though certain adaptations or omissions have been made.

Support for a wide variety of parameters

There are multiple data formats, even for positional data. To accommodate data from commonly used models, we have created instrument files tailored to each model. When BiP receives sensor data, it automatically standardizes the data using the corresponding instrument file for each manufacturer and product model, ensuring that diverse sensor data can be stored and accessed in a standardized format. BiP can handle a total of 44 types of sensor data, including Global Positioning System (GPS) and satellite transmitter data (such as latitude, longitude, and location accuracy), as well as measurements recorded by different data loggers, such as depth, speed, atmospheric pressure, water temperature, salinity, acceleration, angular velocity, geomagnetism, light intensity, etc. (Table S2). If the required data format is not available, users can request the creation of a new instrument file through the BiP website (https://help.bip-earth.com/en/contact/), or they can create the file themselves.

Online analytical processing (OLAP) function

A unique feature of BiP is the OLAP function to estimate ocean currents, ocean winds and waves (Table 4). Users can access all data analyzed using OLAP and download data in CSV format. They can also download data integrated with metadata in NetCDF format. For example, aggregated oceanographic data (ocean wind, current, and wave) collected from streaked shearwaters (*Calonectris leucomelas*) along the Sanriku coast, Japan, during the chick-rearing period (September) from 2015 to 2022 are available (https://help.bip-earth.com/en/open-dataset/). This dataset will be updated annually as long as field surveys continue. In addition, as data from other seabird species in different ocean regions accumulate, environmental data derived from seabirds are expected to become even more comprehensive. In the future, we plan to enhance the functionality of OLAP, for example, by adding a function to extract feeding points from GPS and acceleration data obtained from seabirds.

Table 2 Metadata input fields for "Instrument"

Input fields		Description
Instrument Info	Instrument Manufacturer*	Select instrument manufacturer
	Instrument Model*	Instrument model
	Instrument Type*	Select instrument type (GPS, Argos, GLS, TDR, VHF, Acoustic)
	Instrument Name*	Assign a device name recognizable by the registrant
Data Info	Upload File Extension*	Select RawFile extension (csv, txt)
	Data Separator*	Select delimiter (Comma, Space, Tab, SemiColon, Colon)
	Decimal*	Select decimal separator (Period, Comma)
Sensor Info	Sensor Type*,**	Select from (Latitude, Longitude, Pressure, Internal Temperature, External Temperature, Illumination, Acceleration X, Acceleration Y, Acceleration Z, etc.)
	Sensor Manufacturer	Manufacturer
	Sensor Model Name	Instrument model
	Units Reported*	Select units of measurement
	lowerSensorDetectionLimit	Measurement lower limit
	upperSensorDetectionLimit	Measurement upper limit
	sensorPrecision	Accuracy
	sensorResolution	Resolution
	SensorColumnName*	Column name for the target sensor data
	SensorColumnRowNumber*	Row number containing column names (default is 1)
	SensorDataRowNumber*	Row number where sensor data begins (default is 2)
	DateTime	If data is not recorded at equal intervals (Equal sampling), specify the column containing the recorded timestamps and select the datetime format
	TimeZone	Select the time zone for sensor data
	Edge Processing	If edge processing is performed within the device, provide details
	Additional Note	Special notes about the sensor
Other Info		Special notes about the instrument in general

*Required field

**See Table S1 for more detail

"cal_oceancurrent": This function estimates surface currents with a time resolution of 1 min using GPS position data from seabirds resting on the sea surface, recorded at intervals of 1 min or less. According to a previous study [26], the speed distribution of streaked shearwaters was bimodal, with higher speeds interpreted as flight and lower speeds (below 15 km/h) as drifting on the sea surface. Yoda et al. [32] confirmed that currents deduced from these drift movements aligned well with ocean surface currents derived from in situ and satellite data.

"cal_wind1": This function estimates ocean wind with a time resolution of 5 min using GPS position data from soaring seabirds measured at intervals of 1 s or less. The algorithm was developed by Yonehara et al. [33] for streaked shearwater, Laysan albatross *Phoebastria immutabilis*, and wandering albatross *Diomedea exulans*. These soaring seabirds flew in tortuous paths, and their ground speeds fluctuated, presumably due to tailwinds and headwinds. By comparing variations in ground speed relative to flight direction, the wind speed and direction experienced by the birds were estimated. A comparison of wind direction estimates from bird-based and satellite-based measurements showed good agreement; however, the absolute difference between these measurements increased in weaker winds. Bird-based wind speed was strongly correlated with satellite-based wind speed but tended to be underestimated. Satellite-based wind speed is extrapolated to a reference height of 10 m, while the average flight height of the studied birds is below 10 m. This height difference is thought to be one of the causes of the underestimation of bird-based wind speed due to the wind speed shear effect near the ocean surface [33].

"cal_wind2": This function estimates ocean wind with a time resolution of 50 min using GPS position data from seabirds, measured at intervals of 1 min or less. The algorithm, developed by Goto et al. [11], applies a novel animal movement model to the track vectors derived from the tracking data of streaked shearwaters, allowing for the estimation of wind speed and direction. The wind

Table 3 Metadata input fields for "Deployment"

Input fields		Description
Instrument	InstrumentSerial*	Instrument serial number
Deployment	deploymentDateTime	Deployment date and time
	TimeZone	Select time zone for deployment date and time
Data Info	deploymentLocationLat	Latitude of deployment location
	deploymentLocationLon	Longitude of deployment location
	Attachment Place	Select from (External, Internal)
	Attachment Details	Details of deployment method
Release	releaseDateTime*	Release date and time
	TimeZone*	Select time zone for release date and time
	releaseLocationLat*	Latitude of release location
	releaseLocationLon*	Longitude of release location
	Release details	Details of release
Detachment or Recovery	detachmentDateTime	Recovery date and time
	TimeZone	Select time zone for recovery date and time
	releaseLocationLat	Latitude of recovery location
	releaseLocationLon	Longitude of recovery location
	deploymentEndType*	Select from (Recapture, Drop)
	detachmentDetails	Details of recovery
Other Info		Other special notes

*Required field

estimates from this model were consistent with the spatiotemporally coarse wind data provided by an atmospheric simulation model. Although bird-based wind speeds were strongly correlated with reanalyzed wind data, they were 37% lower on average [11]. The discrepancy between bird-based wind direction and reanalyzed data was more pronounced in low wind speed conditions [11].

"cal_waveheight": This function estimates wave height, period and direction with a time resolution of 15 min based on the movements of seabirds floating on the sea surface. The algorithm was developed by Uesaka et al. [28] using 3D GPS position and Doppler velocity (5 Hz) measured by "Ninja-scan" motion recorders deployed on streaked shearwaters and wandering albatrosses. The ocean wave parameters estimated from streaked shearwaters showed strong correspondence with buoy observation results. Additionally, significant wave height estimated from streaked shearwaters and wandering albatrosses correlated well with hindcast model values. However, the smaller body size and lighter masses of streaked shearwaters (0.6 kg) and wandering albatrosses (10 kg), compared to standard observation buoys (90 kg), likely result in the detection of smaller wave components and consequent underestimation of wave height [28]. In contrast to wave height, bird-based wave periods were underestimated; however, the moderate correlation between bird- and model-based wave periods supports the reliability of bird-based wave period observations [28]. The same applies to wave direction, where there is a moderate correlation between bird-based significant wave direction and model-based primary wave direction [28].

How BiP works

To use BiP, (1) users are required to log in to upload and standardize data, as well as enable real-time viewing on the LIVE MAP page, whereas (2) users do not need to log in to search, view, and download data.

Upload and standardize data, and LIVE MAP

In BiP, data is standardized and saved with each logger as the basic unit. Users can register and log in from the top page to upload their data. After logging in, users can upload sensor data as RawFile, which is then stored in the system as raw, unprocessed Level 0 data (Fig. 1). Users then enter animal trait information into an "Organism" file (Table 1) and proceed with standardization in the "Data Management" menu. During the standardization process, users first select the target file from the "Raw File" list. Next, they select the equipment used from the "Instrument" list (Table 2), followed by the target individual file from the "Organism" list. After that, they enter information about deployment (Table 3) and, finally additional information under "Other Information". In the "Reference" field, users can enter multiple Digital

Table 4 Analysis tools for extracting oceanographic information integrated in the Online Analytical Processing (OLAP) function of BiP

Analysis name	Input data		Output data	
	Parameter	**Interval**	**Parameter**	**Interval**
cal_oceancurrent	Time Latitude Longitude	≦1 min	time latitude longitude current_direction current_speed ocean_current_straightness	1 min
cal_wind1	Time Latitude Longitude	≦1 s	time latitude longitude wind_direction wind_speed	5 min
cal_wind2	Time Latitude Longitude	≦60 s	time latitude longitude wind_direction wind_speed	5 (50) min*
cal_waveheight	Time Latitude Longitude horizontal_speed_north horizontal_speed_east height_above_mean_sea_level	≦0.4 s	time latitude longitude sg_wave_height sg_wave_period sg_wave_direction number_of_waves	15 min

*In cal_wind2, ocean wind is estimated based on data from 25 min before and after each point (a total of 50 min), and a 5-min sliding window is used to output data at 5-min intervals

Object Identifiers (DOI) of papers that utilize the data. Basic information from the logged-in account is automatically entered under “Owner Information”, though users can modify these details and add multiple individuals as needed. Once all the information is entered, Level 1 data is automatically created in a standard format, with any unnecessary data removed before the release of the animals and after equipment retrieval (Fig. 1). This standardized data is saved in formats such as CSV or NetCDF, ensuring consistency across data fields. For example, column names are unified (e.g., "Latitude" standardized to "latitude"), date-time formats are converted to ISO8601, and data structures are optimized to eliminate redundancies. These standardized files facilitate seamless integration and compatibility for advanced analyses across various applications and disciplines. Standardized files are initially registered as “Private” (not publicly available) and cannot be downloaded. However, users can change the status from “Private” to “Open” to make the data publicly available, for instance, after a related paper is published.

BiP also provides a feature for users who want to publish real-time tracking routes of individual animals. On the “LIVE MAP” page, routes received via satellite or cellular network can be displayed (Fig. 2). If the data owner logs in and registers the account name and password to access, data from the currently tracked individual will appear in the “Live Data” list. This function could be used in educational programs, enabling schoolchildren and the general public to observe the daily movements of their favorite animals.

Search, view and download data

A route map or time series figure of Level 1 data standardized and registered in BiP can be viewed by anyone, whether marked as open or private (Fig. 3). Users do not need to register to view figures or download open data. Via “View Data” function on the top page and selecting “Standardized data”, users can display a list of all data stored in BiP. This list can be filtered by various attributes, such as species names. When readers are interested in the data used in a published paper, they can easily locate the sensor data and metadata by entering the

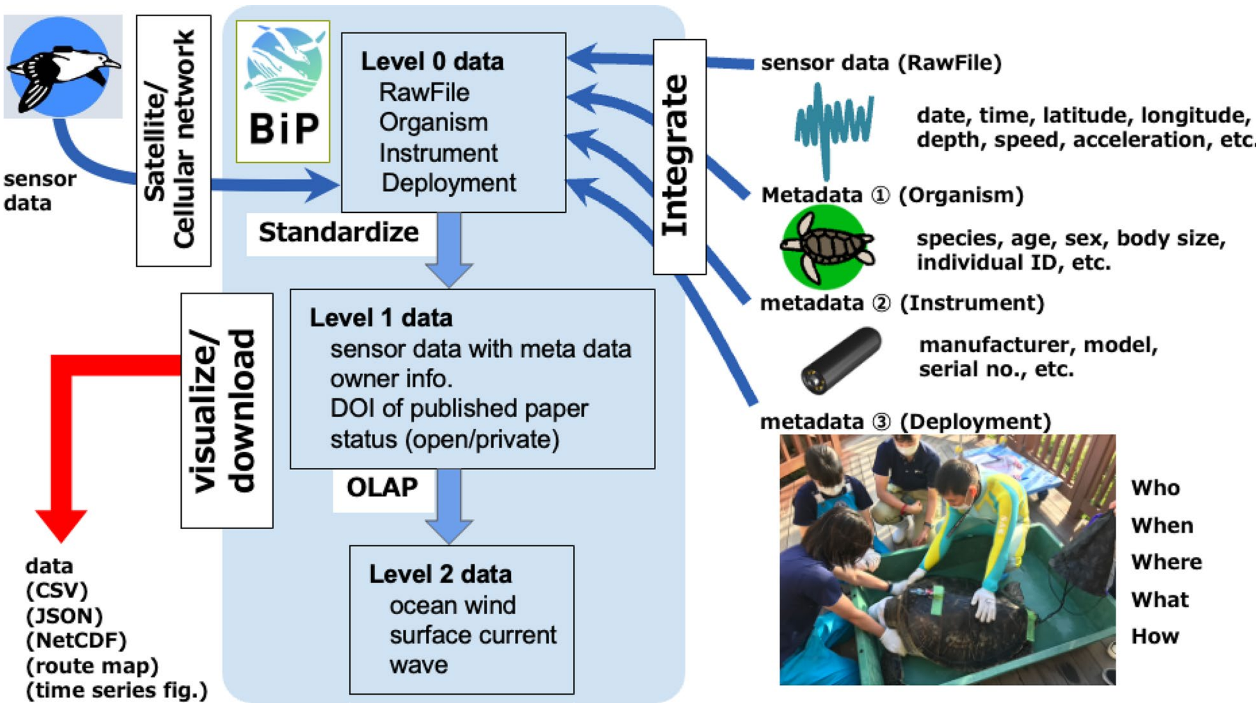

Fig. 1 Outline of BiP. Level 0 data obtained through biologging, which are raw sensor data collected from recorders, are integrated with metadata related to the organism, instrument, and deployment to generate standardized Level 1 data. Level 1 data consist of sensor data fully equipped with metadata, including ownership information, and are available either as open data under a CC-BY license (with all sensor data and metadata downloadable) or as restricted data (with metadata/route map publicly available but sensor data kept private). DOI information for publications utilizing these data can be linked, enabling proper citation by third parties. On BiP, Level 1 data can be visualized through maps and time-series graphs. Additionally, compatible Level 1 data can be processed through OLAP (Online Analytical Processing) to calculate environmental parameters such as ocean wind, surface currents, and wave conditions, promoting secondary usage as Level 2 data

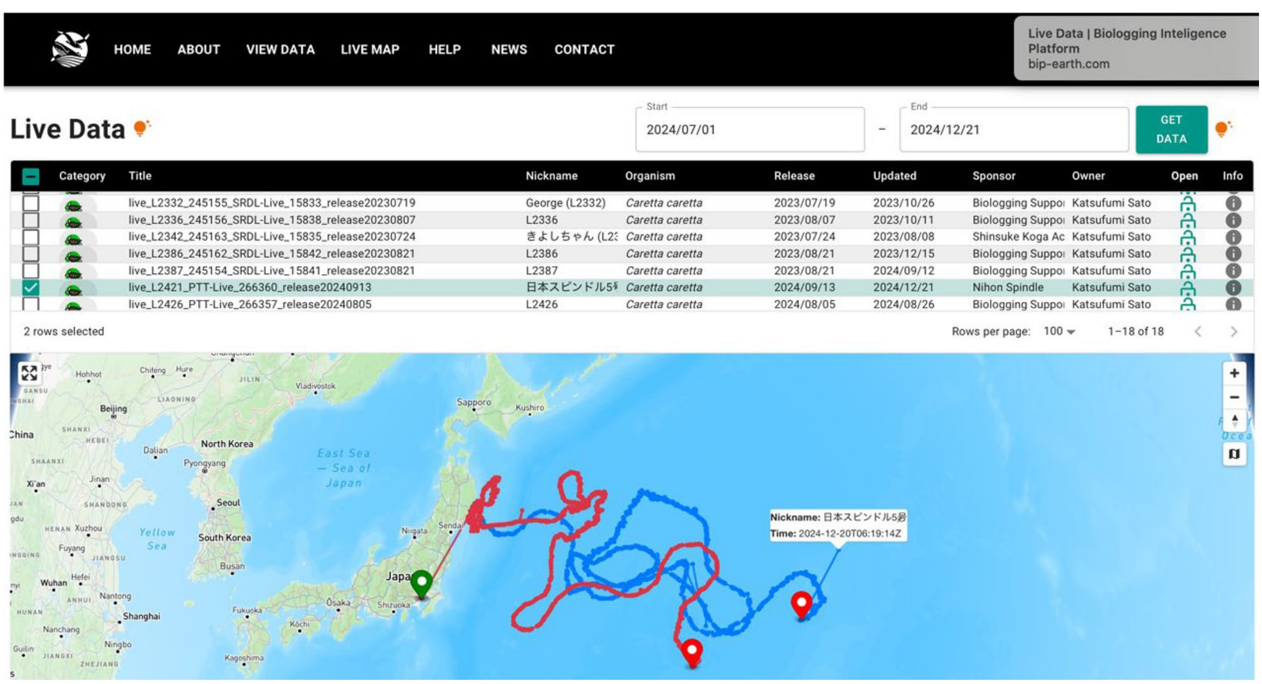

Fig. 2 LIVE MAP page of BiP. To see the migration routes of the currently tracked individuals, users can select individuals, and click the "Get Data" button. Above routes are two examples of loggerhead turtles released from Iwate Prefecture Japan

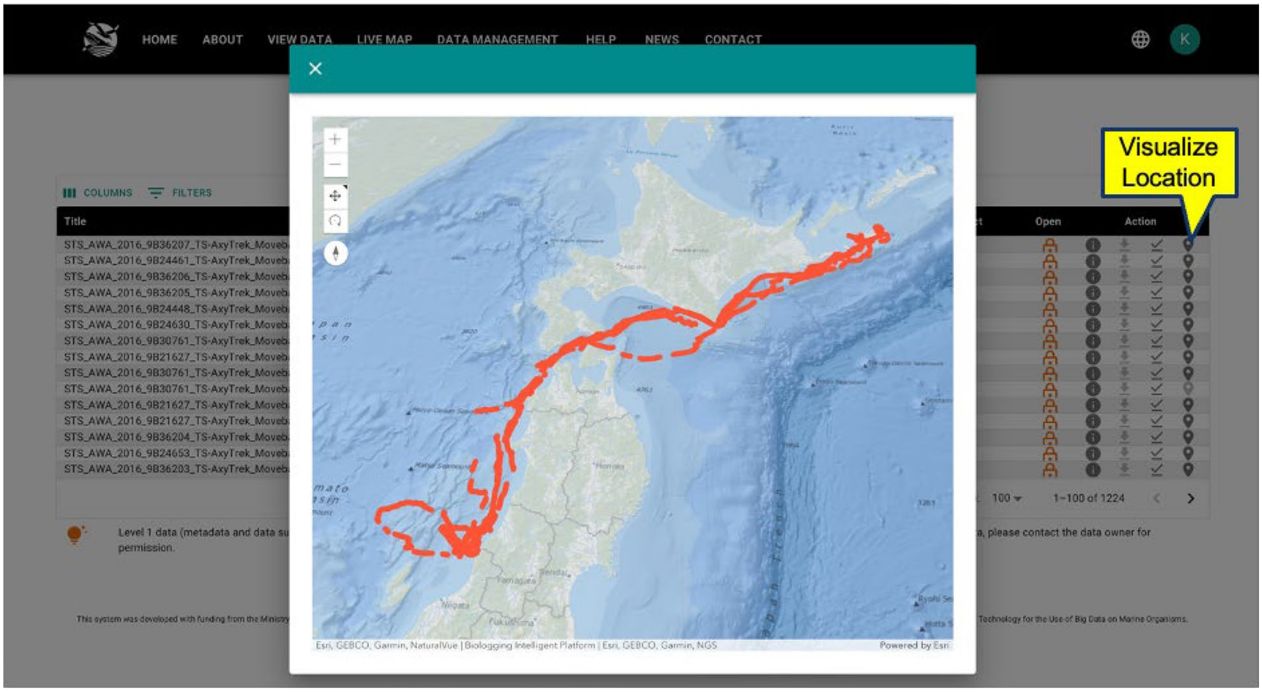

Fig. 3 VIEW DATA page of BiP. Users can overview of specific data, whether marked as open or private, by clicking the "Visualize location" button on the right side of the table. Above map is an example of a streaked shearwater *Calonectris leucomelas*

paper's DOI. Downloaded open data can be freely copied, redistributed, modified, and used by anyone, as long as the credits listed in the metadata are provided, in accordance with the Creative Commons Attribution 4.0 International license (CC BY 4.0, https://creativecommons.org/licenses/by/4.0/). Users interested in accessing private data can contact the data owner to request permission. Metadata can be downloaded in JSON format, while sensor data is available in CSV format. Additionally, integrated datasets that combine sensor data with metadata can be downloaded in NetCDF, a widely used format for managing large-scale, multidimensional scientific data. Users can see the migration routes of the currently tracked individuals on the LIVE MAP page without logging in (Fig. 2).

Expected outcomes and further perspective

Enhancing cyber ocean through data assimilation

Seals survey the waters beneath the sea ice in polar regions [4], while sea turtles help collect data in shallow tropical waters [8]. In the Kuroshio-Oyashio Confluence region off the coast of Sanriku in Japan—where the warm southern current and the cold northern current mix in a complex manner—subadult loggerhead turtles migrate and remain in the area without moving downstream, allowing for observations of this biologically productive region for several months [22]. These characteristics of animal-based measurements provide unique insights compared with conventional profiling floats like ARGO. Miyazawa et al. [19] demonstrated that assimilating vertical water temperature profiles from loggerhead turtles into the JCOPE2M ocean data assimilation system improved the reproducibility of the three-dimensional structure of mesoscale eddies, leading to effects that expanded over a wider area and to deeper layers than the turtles' observation point. Another example is the assimilation of surface current data from seabirds into JCOPE2 ocean nowcast/forecast system, which enhanced the accuracy of the model output, making them more consistent with actual measurements from surface-drifting buoys [18]. Similarly, Doi et al. [8] reported that assimilating vertical water temperature profiles collected by five olive ridley turtles *Lepidochelys olivacea* migrating in the Arafura Sea into the SINTEX-F2 operational seasonal prediction system altered the ocean mixed layer structure, leading to improved sea surface temperature predictions up to three months in advance. In the future, if more environmental data can be gathered from animals through biologging, organized, and made publicly available—such as by creating Level 3 data that grids oceanographic information—the "cyber ocean" could increasingly resemble the real ocean. Assimilating these data into physical models on supercomputers could enhance the accuracy of future weather and ocean forecasts.

Enhancing animal conservation

Understanding how animals respond to climate change across different spatial and temporal scales, such as global warming over decades, annual climate fluctuations driven by El Niño and La Niña, and short-term meteorological events like typhoons, is a key research focus in the natural sciences. Additionally, in the field of conservation biology, it is crucial to examine the impacts of human economic activities on wildlife, including pollution, anthropogenic noise, bycatch, and plastic debris. At the same time, human society relies on natural environments for various purposes, such as food production through farming and fishing, the construction of solar panels and wind farms, the development of airports and ports, oil and mineral exploration, and transportation by aircraft and ships. To minimize the impact of these activities on wildlife, it is essential to establish protected areas. Areas that are important to animals should be prioritized for protection, and biologging, which enables detailed, long-term tracking of animal movements as well as the measurement of environmental conditions, offers valuable insights for identifying and managing these areas effectively [31].

Long-term data is essential to address these challenges. It is crucial to preserve the accumulated data in an accessible format and ensure its availability for future generations. While the term biologging was coined in 2003, data collection by explorers in this field dates back to the 1960s, and many of the first-generation researchers are nearing retirement without making their data publicly available. There is also a risk of data loss due to disasters, such as tsunamis, fires, and floods, which can destroy hard drives and computers storing valuable information. Therefore, it is imperative to recover and archive past data stored on individual-owned hard drives and computers, as well as to upload current data to the cloud. Making this data publicly accessible, along with individual-level traits, will enable researchers, decades or even centuries from now, to perform comparative analyses. BiP stores not only two-dimensional movement data of animals but also detailed behavioral data, such as depth (or altitude), speed, acceleration, and geomagnetism. If future researchers can recreate the behaviors of extinct species by studying past data on movement ranges, three-dimensional paths, and even flipper (or wing) stroking frequency, this could contribute significantly to evolutionary and comparative research.

Ensuring data longevity

While many journals now require open data access and assign DOIs to datasets used in publications, we believe that BiP's functionality, which allows users to locate data via a paper's DOI, enhances data accessibility. Although DOIs serve as persistent identifiers, they do not guarantee the indefinite availability of data [9]. Thus, maintaining data in an accessible form requires a continuous funding source to support database operations and maintenance. The funding we currently receive from the Ministry of Education, Culture, Sports, Science, and Technology can continue until 2030 at the latest; however, we are actively exploring options for sustainable database management beyond this period. Another way to mitigate the risk of data loss is to establish data exchange agreements between databases. Currently, several databases exist for storing biologging data. In the near future, consolidating all biologging data into a single, large database might be convenient for users who wish to utilize data for secondary analyses. However, we have not yet reached a conclusion on the ideal final form of such a database. Moreover, predicting which databases will remain operational in the long term is extremely difficult.

As biologists, we understand that diversity reduces the extinction risk of species and populations. Following this principle, it seems optimal, at least for the time being, to standardize the vocabulary and data formats to ensure compatibility across multiple databases, while maintaining diversity in aspects such as data entry methods and analytical functionalities. This approach enables multiple databases to coexist while supporting flexible and sustainable data management.

Abbreviations

BiP	Biologging intelligent platform
OLAP	Online analytical processing

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40462-025-00551-8.

Additional file 1.

Author contributions

KS, SW, MAY, TN and TK are members of Working Group to develop and improve the database BiP. The details of the database specifications proposed by the Working Group were reviewed and finalized by other authors. KS was a major contributor in writing the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interest
The authors declare that they have no competing interests.

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